

DEVELOPING OF A MICROPROCESSOR SYSTEM FOR  
AUTOMATING A THERMAL ABSORPTION CALORIMETER.

By

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A Thesis submitted in part fulfillment for the degree of  
Master of Science at the University of Nairobi.

1991

This work is my own work and has not been submitted in any other University.

A handwritten signature in black ink, appearing to read 'William George K. Mulwa', written in a cursive style.

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This Thesis has been submitted for examination with my approval as a University supervisor.



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TO FLORENCE AND ALEX



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## ABSTRACT

A microprocessor-based system for automating the Thermal Absorption Calorimeter has been developed. The system is based on the Z-80 microprocessor and runs at a speed of 2MHz.

It features an in-built Read Only Memory (ROM) for storing the monitor program and a Random Access Memory (RAM) for storing the captured data. The system is successfully interfaced to the Calorimeter, controlling the opening and closing of the shutter window and sampling data from four different material plate.

Sample plates of steel, copper, aluminium and brass materials, both paint-coated and uncoated are prepared and data of the variation of temperature with time of the plate sampled using the system. The sampled data is uploaded to a fully developed system using a data upload port developed to support communication between the system and a microcomputer via an In-Circuit-Emulator.

The data is subjected to calibration equations using a Micro-soft MSWORKS software. The temperature/time distribution curves are obtained, from which the thermal absorption coefficients of the black coating material on the sample plates are derived.

## INTRODUCTION

Computer technology has gone through the most revolutionary change recorded during the last two decades. Of particular interest has been the beneficial impact of advances in the field of semiconductor technology. A recent innovation in the computer area is the development of the microprocessor using very large scale integrated (V.L.S.I) circuit as well as the programmable logic arrays' technology.

Most of these advancements of the microprocessor has led to the development of electronic appliances which are either computer controlled or microprocessor controlled, for use in laboratories, industrial process control or business management systems.

Portable computers available are normally designed for use in friendly environments. In research where data sought are obtainable from areas of high temperature and humidity, the means of data acquisition requires special selection of 'hardened' portable data logging systems. Morgan(1986) has described a typical research and development field application system, which is a climate resistant data logger for collecting data basically based on anthropologically work. Giulghiarell(1986) et al , reports a microcomputer interface for an electron paramagnetic

resonance spectrometer which acquires data from the instrument, processes it and displays it on the computer screen via an IEEE 488 standard bus.

Most of these developed systems are tailored to suit specific application. However for interaction between the physical quantity and the interfacing systems, there must be some type of device to convert one form of energy to another. These input devices available to measure quantities in the real world such as temperature probes, acceleration transducers and the likes, often require a link between them and a computer system. The computer according to it's program, can then react to the incoming information and produce a suitable output as demonstrated by Yager(1987) et al. A data logger based on the RS7581LN CMOS chip for interfacing onto an Apple II computer has been designed as described by Blunden(1986) et al. It uses a similar approach in data acquisition.

Alternatively, dedicated systems based on microprocessors may be used. In these type of systems, information received from the physical quantity being measured is converted into an electrical signal by use of Analogue to Digital (A to D) converters. Besides their ease to be moved around, and direct application without involving a computer to co-ordinate the events under automation, such data loggers offer a direct means of monitoring physical quantities over extended periods in areas remote from supply of mains electricity. University of Reading(1984)

cites the development and use of the COMBINE logger system in a similar manner to investigate plant growth under various tropical weather conditions. It provides a complete simulator of the daily and seasonal thermal profiles of a tropical location and also provides irrigation and humidity control. A battery powered sampling frequency meter developed by Lockerbie(1984) applies similar techniques, to collect data based on humidity at a preset interval in remote locations over a period of twelve months. The data is stored in an organised format for the same period in a battery powered semiconductor memory. The aim of this work is to develop a microprocessor based system, which automates a thermal absorption calorimeter for measurement of solar radiation absorptance of selected surfaces used in solar collectors. The verification of the system is then carried out determining the absorption coefficient of four types of metal surfaces both coated and uncoated.

The prime purpose of the collector plate is to absorb incident radiation from the sun. It's coated surface should have as high absorptivity (emisivity) as possible in the near infrared parts of the spectrum where most of the solar energy is concentrated. Meinal(1976) et al has reported that although a selective surface greatly reduces radiative losses, it may have a lower overall absorption coefficient for solar radiation than black paint. To analyse such details of the selected surfaces, precise-

methods for data acquisition and analysis which have to be taken under the real environmental conditions normally poses a challenge.

This work addresses such challenges by taking into account the fact that when sampling data in the field, a computer based system is not well suited due to climatic related problems such as excessive heat and extreme humidity or aridity which can be quite unfriendly to the computer.

The system is enclosed in a portable casing, providing connection ports for interfacing to the thermal absorption calorimeter. It acquires data and stores it on semiconductor memory chips. The data is uploaded onto a fully developed system for analysis using a data upload port also provided in this system.

The instrument was developed to establish a cheap and suitable method of finding the most effective materials used in solar collectors. Rapp(1981) has established that the effect of selective surface on collector performance is manifested in terms of lower heat loss due to radiation from the collector plates. The effectiveness of these radiant heat loss reduction depends on the fraction of heat loss due to radiation from the system which are predominant. Use of selective surfaces can therefore be very effective.

Although a selective surface may greatly reduce radiative losses, it may also have a lower overall absorption coefficient for solar radiation than a black painted collector. This could be due to the infrared region where the absorptivity of the selective surface falls off with increase in wavelength as reported by Miniel(1976) et al. Chapter one introduces the reader to the Absorption Calorimeter, giving the general overview of it's function and operational details. Chapter two describes the system design, reviewing the different circuit units and justifying the tools used.

Chapter three deals with the system block function and their operational modes. Chapter four is on the system operation, discussing the operational details of the various circuit units. Chapter five gives the reader an insight on the system development and emulation, by describing the system hardware and software development procedures. System application which gives the processes before and after data collection is presented in chapter six. Chapter seven is the conclusion with a discussion on the additional work that can be done on and with the system.

# CHAPTER 1: THE ABSORPTION CALORIMETER

## 1.1 INTRODUCTION.

The absorption calorimeter developed by Mate(1980) is a BBC microcomputer based system for acquiring data on radiation absorption. It records the temperature change produced on samples of materials used in solar collectors and comprises of the functional units listed and shown in figure 1.1.

Interface board

Signal conditioning unit

Window shutter mechanism

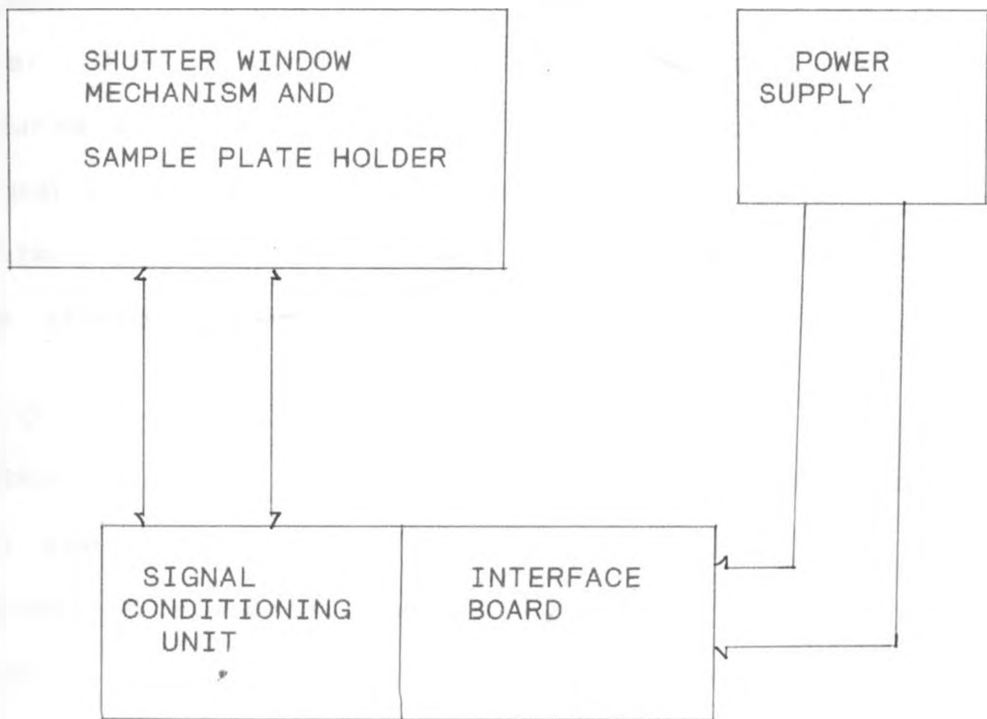


Figure 1.1

*The Calorimeter Block Diagram*



## 1.2 FUNCTIONAL UNITS

### 1.2.1 INTERFACE BOARD

This comprises of the address decoder, the A/D converter and the motor interface unit. In the address decoder section two addresses &FCC0 and &FCC1 of the page &FC of the BBC 1MHz bus are decoded for accessing the A/D converter and the stepper motor drive circuit. This is implemented by linking all the buffered address line which are low when the setting on them corresponds to C1(1100 0001) and C0 (1100 0000) through a 74LS30 8-input NAND gate, to obtain a unique low output line. These line is further gated together with the  $\overline{R/W}$  and the NPGFC line to produce the device select line. The address bus decoding circuit is built around the 74LS138 line decoder. The data bus in this interface board is configured to have two input ports and one output port. The input port being assigned to the A/D converter inputs and detection inputs while the output ports are assigned to the stepper motor.

The A/D converter unit is based on the multichannel AD7828KN chip with 8 -analogue inputs and an inbuilt sample and hold function. It employs the successive approximation conversion method by use of the half flush conversion technique. This means that there is no need to generate a clock signal for the A/D converter. It's inputs are connected to the thermocouples to convert data from the collector plate samples, each channel being selected-

uniquely by a software code.

The stepper motor interface circuit is based on the RS standard circuit using the SAA1027 stepper motor driver IC. The circuit is interfaced with the rest of the system using 741 comparators. It's operational functions consist of starting and stopping of the stepper motor rotation. This forms the shutter rack and pinion system to transform the rotational motion of the pinion to a linear motion of the shutter window.

### 1.2.2 SIGNAL CONDITIONING UNIT

The signal from the thermocouples is increased in magnitude and processed to a specific level for digital recording purpose. This process of preparing the signal before display or recording is what is called signal conditioning.

The thermocouples output emf which is in the order of millivolts is amplified by 5532 operational amplifiers operating in a non-inverting configuration. It has an internal compensation for unit gain operation and no offset null adjustment. Since the thermocouples are essentially wires and exhibit electrical noise owing to the thermal agitation of the electrons, the noise is minimized by encasing the wires in an aluminium foil to screen them from external interferences.

### 1.2.3 SHUTTER WINDOW MECHANISM

The shutter mechanism consists of an opaque flat plate which slides inside guiding vee-ways. A rack which is in constant mesh with a gear driven by the stepper motor is attached to the window to transmit the rotational motion of the motor into a linear motion. A speed control knob is provided to adjust the rotational speed of the motor hence the time taken for the shutter to close or open.

The stepper motor used in this set-up is a RS size 2 type of stepper motor which rotates in step angles of 7.5 degrees. It is directly compatible with the SAA1027 motor driver IC, although it utilizes 12V power supply which is not within the TTL level. The stepwise form of rotation permit it to stop promptly and also suddenly change direction.

### 1.3 SYSTEM-CALORIMETER INTERFACE

The system is interfaced to the calorimeter as shown in the schematic block diagram Figure 1.2. A 34 way ribbon cable which is 35mm long and terminated on both ends with 34 way dual-in-line low profile sockets is used as the communication bus for data and address transmission between the two systems. The standard recommended length so as not to have signal losses is a maximum of 50mm.

The connector cable is slotted onto the 1MHz ports of the Thermal Absorption Calorimeter system and that of the microprocessor system.

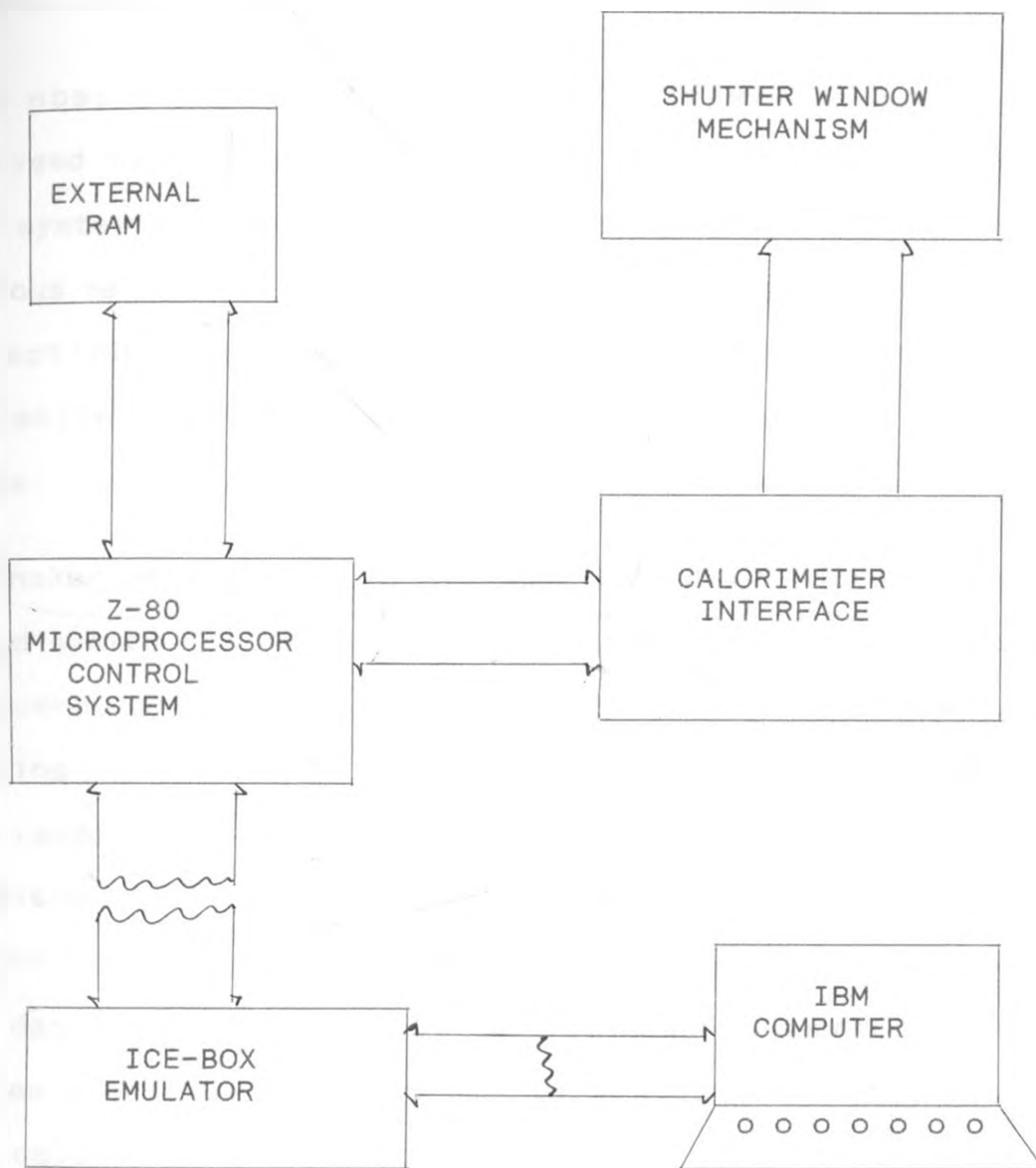


Figure 1.2  
*The System-Calorimeter Interface*

## 1.4 CONCLUSION

Mate(1980) has developed a thermal absorption calorimeter which is controlled by a BBC microcomputer and used to sample data of some coated and uncoated plates.

The absorption coefficients of different materials analysed using the computer controlled system show that the system can be used to sample thermophysical data for various materials. This is a factor which can be useful in selecting a coating/material combination for solar radiation absorption application such as a collector plate.

El-Dhaker et al(1986) in his development of microcomputer based system for measurement of conductivity in atmospheric semiconductors found that, in order to verify the exact working conditions of materials to be used in the field, the research work should be done under the real field conditions. Likewise for real field data on the behaviour of the radiant heat from the sun on the collector plates, the data must be sampled at the field where such collector plates are to be used. The use of the computer to control the calorimeter thus becomes limited. For this reason and others cited in the introductory chapter, this project is undertaken to develop a microprocessor system to automate the calorimeter thus making it more flexible for use in field data sampling.

## CHAPTER 2: SYSTEM DESIGN AND JUSTIFICATION

### 2.1 INTRODUCTION

Systems designed around microprocessors are conceptually unique in that they are bus structured with data being transferred around the system in parallel formats. In general, input data is read and processed in the central processing unit (CPU) to produce the output under the control of the system software. When debugging or fault finding on this type of systems, many lines need to be monitored simultaneously and in synchronism with some derivatives of the system's clock.

The complexity of some systems aggravates the problem of fault location. Techniques of hardware debugging include the use of special Test equipment and the ability of the processor to diagnose itself.

Various design techniques can be used, some requiring special equipments, but the choice of each equipment should be to help overcome the problems of fault diagnosis. In this chapter the author looks at the reasons of choice of such equipment used in this system and their justification.

## 2.2 SYSTEM DESIGN

### 2.2.1 THE MICROPROCESSOR

The choice of the microprocessor used in the system, which is supposed to control the operation and flow of instruction from the system to the calorimeter, is mainly dependent on the mode of communication between the Thermal absorption calorimeter and the control system.

Two 8 bit processors were available in the department at the time the system was being designed. These were the 6502 on which the calorimeter was designed and the Z-80 CPU. Unlike the 6502 processor which has only two usable registers, the Z-80 processor has 6 secondary registers which are easily accessed for data storage, thus influencing it's choice as the system processor besides the fact that the only In-Circuit-Emulator in the Department was for the Z80.

Other features that make it suitable for it's application are;

- The two index registers which simplify the memory location accessing during data storage operation.
- The 16 bit stack pointer which allows a stack to be implemented anywhere in addressable memory.
- The different interrupt mode of the Z-80 processor that provide a means of setting the interval between data collection. This is done by the BBC internal clock when the calorimeter is controlled by the microcomputer.

### 2.2.2 BUS BUFFERING

The data are collected from the calorimeter and the coded instructions communicated to it for control purpose are maintained at TTL level. This is done by a bus buffering section which utilizes four 74LS244 TTL chips. This sustains all the signals communicated through the data and address bus to and from the absorption calorimeter at the required level apart from providing a bi-directional address bus and a uni-directional data bus.

### 2.2.3 DECODING AND DATA STORAGE

The configuration of the data memory is mainly depended on the amount of data collected. These data is stored temporarily in some semi-conductor memory before being transfered into a fully developed system for analysis. The system is designed to have the buffered address and data lines from the processor being linked to four HM6116 static rams and two HN2732A Eproms.

The HM6116 rams are more compact than the slightly cheaper equivalent of four HM4114's, simplifying the design layout and consuming only 20 micro-amp current in standby mode. It does not require a refresh signal like the cheaper dynamic rams which have a bigger storage capacity per chip, and require eight of such to provide an eight bit address storage. The TC5516 static RAM's can be used in place of the HM6116 but these require an extra chip-enable line and a common read/not write input which are not readily available in the processor used.



Nicholls(1982) has developed an eprom emulator using the HM6116 static rams and found that on stand-by mode, they can be powered by a nickel cadmium battery with a VA rating of 20, for a period of 200 days. This is a useful feature in the project since data has to be stored in the rams for some time before being dedicated into a disk storage facility for analysis.

#### 2.2.4 CONTROL LINES

The calorimeter requires some control line which are not directly obtained from the Z-80 processor. Special control lines the  $\overline{\text{NPGFC}}$ , 1MHz and  $\overline{\text{INT}}$  lines are generated.

The page FC which lies within the  $\overline{\text{NPGFC}}$  signal range is used by the two main input /output devices of the calorimeter system namely, the A/D converter from which the data is read and the stepper motor driver circuit to which data is written to control the calorimeter shutter. This control line NPGFC is obtained by gating the upper six address lines through a NAND gate the 74LS30. Its output is gated through a three to four line decoder the 74LS139 together with address lines A8 and A9 to obtain the control signal from pin 4 of the 74LS139 line decoder.

A 1MHz signal which is a 50% duty-cycle square wave with a 1MHz frequency is used by the calorimeter system to generate a CNPGFC signal which is later used to enable the address decoder Ics within the calorimeter system.

## 2.3 TOOLS JUSTIFICATION

### 2.3.1 THE MICROCOMPUTER FOR SYSTEM DEVELOPMENT

Any standard microcomputer having a keyboard and a disc operating system with a Z-80 In-Circuit Emulator could be used in this project for the system development. At the time when this project was started, three such computers; the NasCom-II, the BBC and the IBM PS/2 microcomputers were available in the department. From both hardware and software point of view only the IBM computers could be utilised, due to the fact that the only In-Circuit-Emulator system available in the Department was that of the Z-80 microprocessor for the IBM PS/2 model 50 .

Although the BBC microcomputer was the main development computer for the calorimeter, it could not be used for the above reasons. The IBM computers have advanced software for running the emulator which was available in the department. This include the ICE-BOX1 and ICE-BOX2 softwares which control the Z-80 In-Circuit Emulator.

### 2.3.2 THE EMULATOR

Developing object codes software for a target system presents problems. However one solution is to use an emulator as a debugging tool for both hardware and software. Different types of emulators which are based on different microprocessors have been made and are available in the market. The portal emulator developed by-

Green(1987) is one such device which runs under the Meta Assembler package on the user port of a BBC microcomputer with no extra hardware.

The Hewlett Parkard's 64000 is also another development emulator which offers a variety of options ranging from a standalone portable station to a hard-disc based network capable of supporting a wide spectrum of microprocessor families. Similarly the Microtek's Micro-In-Circuit-Emulator (MICE) developed by Ferguson(1984) is a low cost emulator which offers emulation for most industrial standard microprocessors, including the 8088/8086, 68000, 8085, 6809 and the popular domestic processor, the 6502. Practically in most of this emulators a port is provided in which the host computer is plugged onto and another for plugging in the target system under development.

In these project the ICE-BOX Emulator, developed by Noral Micrologic Ltd. and based on the Z-80 microprocessor is used. It's attributes include:-

- Allowing the host development computer to get between the target system and it's processor, hence enabling it to monitor bus activities or to inject signal codes onto the target system.
- It's extra RAM proves useful during program development, providing workspace for software before it is finally committed to the ROM.
- Ability to display and modify memory/registers

during program execution.

- Use of single stepping through software under development for error trace.

The emulator also offer's a separate power unit, from which power for the system can be drawn without affecting the performance of the emulator. This means that when using the emulator one has the option of not using external power supply where only TTL level voltages are required.

### 2.3.3 THE LOGIC ANALYSER

Logic analysers are basic tools for the development of microprocessor applications. A typical analyser may have 8 or 16 channels with a specified sampling rate and with some memory designated for timing analysis, and more channels and memory for state analysis.

The Tektronix 1200 logic analyser for instance, can display 16 channels at a time with a sample rate of up to 100MHz. It has many trigger options, a non-volatile set up memory, real-time clock and glitch detection unit. A similar analyser is the Thandar TA3000 which can interactively combine 8 or 16 channels or 100MHz timings with 32, 64 or 96 channels of 20MHz state analysis. It has a cross trigger of the state timing channels which allows 'snapshot' to be taken of the hardware activity at a specific point during the operation of the circuit under test. It also has a full CP/M+ computing software facilities.

Other types of analysers exist with varying types of functions. The Thandar TA-2000 analyser developed by Thander electronic company is used in this project due to its availability in the department. It offers 32 channels of 25 MHz or eight channels at 100 MHz. It features multi-level triggering, 5nS glitch capture and trigger. It has three external clocks with independent thresholds. RS-232, GPIB and centronics links are provided, for communicating with other compatible set-ups. Its main operation and user ports are described in chapter 3. Its speed of 100MHz is also adequate as the system under development runs at 2MHz, a speed which is fifty times lower than the maximum speed of the analyser. Besides this, its operation convenience are also on its quantitative properties such as the number of channels, clock rate and memory depth which can not be achieved by use of a double beam oscilloscope. Other operating concepts such as display of the timing diagrams of the signal under test contribute much to its usefulness over the oscilloscope.

#### 2.3.4 UNITEX WELDER

During the sample preparation, the thermal-couples have to be joined onto the metal plates to form the best joint between the plates and them. Various techniques can be used, with some giving semi-homogeneous joints. Such methods include the use of special glues like the 'Super Glue', or the use of normal soldering which may not work for some types of metals like aluminium.

For this project the Unitex Welder from the Unitex Corporation is used for joining the thermocouples to the plates. With the principle of stored-energy resistance, it is possible to join two or more similar or dissimilar metals by forging the parts together while simultaneously passing a millisecond pulse of high amperage/low-voltage energy through a common point.

The use of the unit is preferred to the other modes of joining the thermocouples in that it utilises an easy technique which does not require extra bonding materials or flux, as in soldering and other welding techniques. It also provides a complete line of precision welding heads which enhances the welding process by confining the heat to the weld zone only from the millisecond discharge.

### CHAPTER 3: THE DEVELOPMENT COMPONENTS

The system development components are interconnected to one another as shown in the block diagram figure 3.1. The function of each unit is discussed in this chapter.

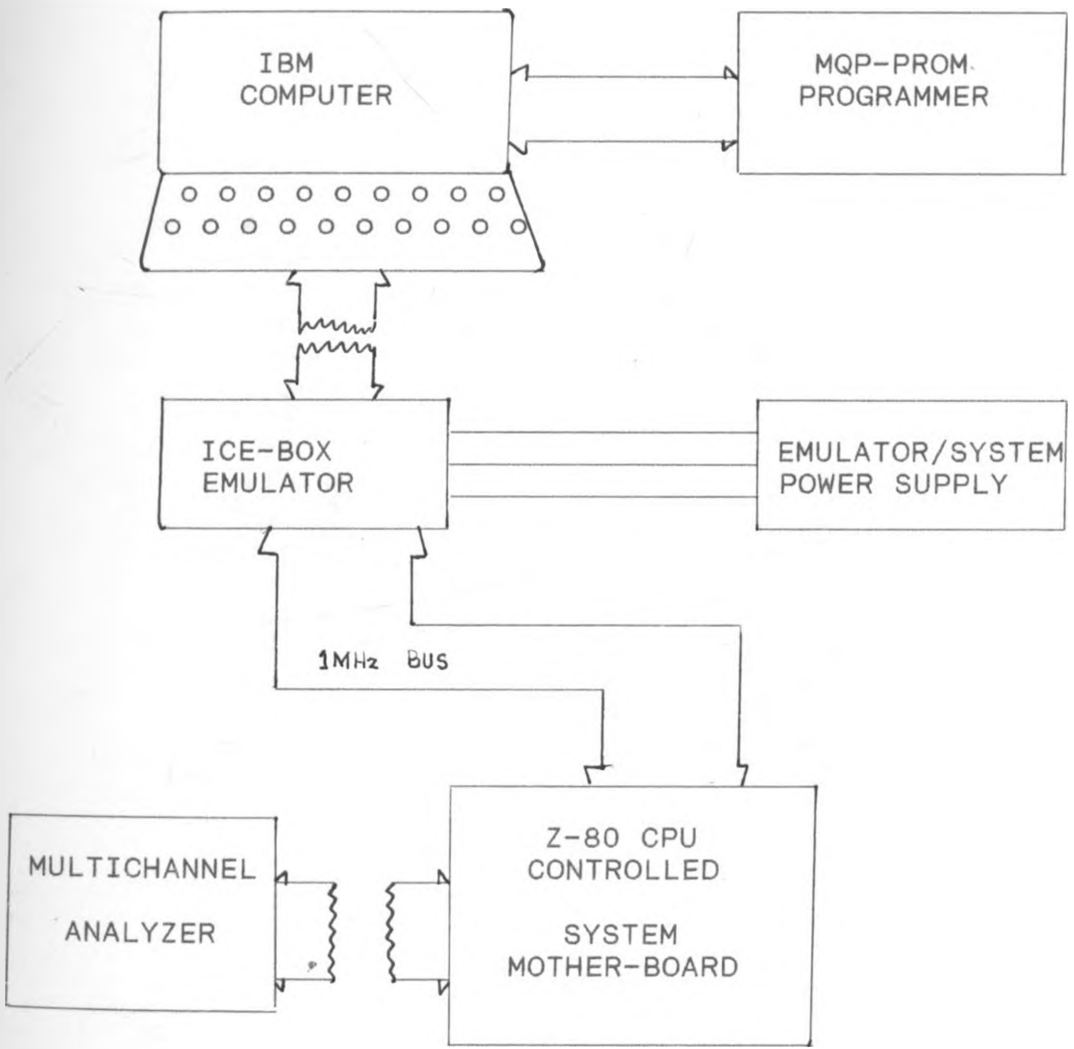


Figure 3.1 System Development Components Interconnection Block Diagram

### 3.1 THE Z-80 CPU

As earlier mentioned the heart of this system is the Z-80 microprocessor, which is an 8-bit CPU in a 40-pin package. It has 158 instructions and can address 64KBytes of contiguous memory. These CPU has 16 address lines , 8 data lines, 13 control lines, power, ground and clock inputs as shown in figure 3.2. Both the address lines and the data lines are asserted high, but all the control signals are asserted low.

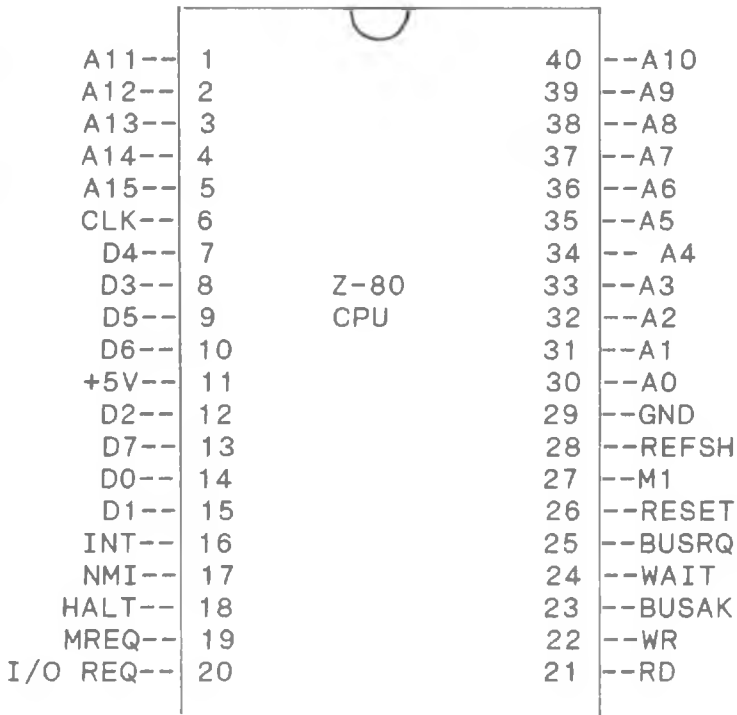


Figure 3.2 The Z-80 CPU



The  $\overline{\text{MREQ}}$ ,  $\overline{\text{IORQ}}$ ,  $\overline{\text{RD}}$ ,  $\overline{\text{WR}}$  and  $\overline{\text{WAIT}}$  lines are for reading and writing onto memory and input output devices. The Z-80 puts the desired address on the address lines and asserts both  $\overline{\text{MREQ}}$  and  $\overline{\text{RD}}$  in order to read from memory. After waiting for a certain period of time in the range of nano-seconds for the memory to respond, the Z-80 then loads the byte in from the address and data lines asserting both the  $\overline{\text{MREQ}}$  and  $\overline{\text{WR}}$ .

The lines used in the system are the  $\overline{\text{MREQ}}$ ,  $\overline{\text{RD}}$ ,  $\overline{\text{WR}}$ ,  $\overline{\text{RESET}}$ ,  $\overline{\text{INT}}$ , the clock, ground, power, all the address lines and all the data lines. The rest of the lines are held high by 10K pull-up resistors to prevent them from being active in case of any signal glitches. The function of the control lines used are briefly described.

$\overline{\text{MREQ}}$  (pin 19) - Memory request. Goes low to indicate a valid address on the address bus or memory read or write operation.

$\overline{\text{RD}}$  (pin 21) - This line indicates that the CPU wants to read a memory location or an I/O device. The line is ORed with a  $\overline{\text{MREQ}}$  to give a synchronised  $\overline{\text{RD}}$  line for use in the system since no input output operation are done.

$\overline{\text{WR}}$  (pin 22) - This line indicates a memory or I/O write operation. Like the  $\overline{\text{RD}}$  line the line is also ORed with the  $\overline{\text{MREQ}}$  to give a

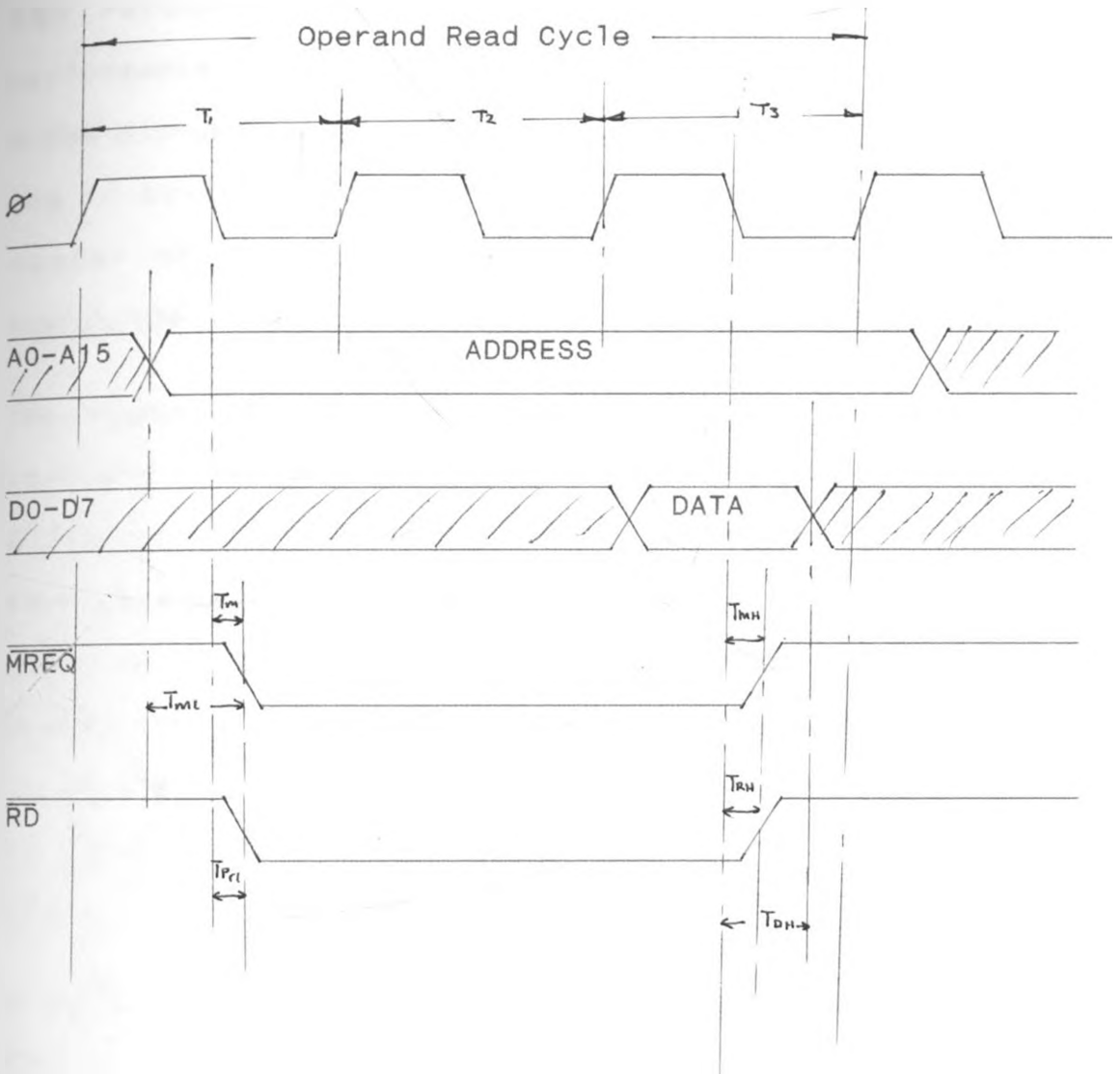
synchronised  $\overline{\text{WR}}$  line for use in the system as no input output operation are performed.

$\overline{\text{RESET}}$  (pin 26) - If this input signal is activated for a minimum time of three clock periods, the contents of the program counter will be set to zero. When the reset goes low, the processor begins operation at address zero. This signal is obtained from the reset circuit.

$\overline{\text{INT}}$  (pin 17) - Interrupt request. It is active when low. The processor responds to this asynchronous input at the end of the current instruction cycle. This signal is derived from the interrupt circuit.

$\text{O}$  (clock pin 6)- The clock input should be a 5 volt square wave at any frequency upto some maximum (2.5, 4 or 6 MHz) depending on the chip version. Because each instruction takes a specific number of clock cycles, the CPU speed is directly proportional to the clock frequency, which is 2MHz in this system.

The Z-80 operand timing and specification of some critical times are shown in Figure 3.3.



- $T_{AD}$  - Address output delay 110nSec max.
- $T_{M}^{\downarrow}$  -  $\overline{MREQ}$  delay from falling edge of  $\phi$  in  $T_1$ , 85nSec max.
- $T_{P1}^{\downarrow}$  - Address stable prior to  $\overline{MREQ}$  60nSec min.
- $T_{P_{r1}}^{\downarrow}$  -  $\overline{RD}$  delay from falling edge of  $\phi$  in  $T_1$ , 85nSec max.
- $T_{DS}^{\downarrow}$  - Data setup time prior to falling edge of  $\phi$  50nSec min.

Figure 3.3 The Z-80 Operand Timing Diagram.

## 3.2 THE IBM MICROCOMPUTER

### 3.2.1 INTRODUCTION

The host computer used for the system development is an IBM Personal System/2 model 50, which is a high performance bench-top computer. It is centered on the 80286 microprocessor and has a 20 megabyte hard disk with one in-built and one external disk drive. It offers a number of advanced hardware design features and is compatible with a large selection of software programs.

The computer consists of a keyboard and a system unit. The keyboard can be configured to correspond to several different international languages and formats. Any of several displays can be used, but this particular system uses an IBM P/S colour display, using the Enhanced Graphics Adapter (EGA). The system unit has several built-in connectors so that any accessory piece of hardware can be installed inside the system unit to expand its capabilities with ease.

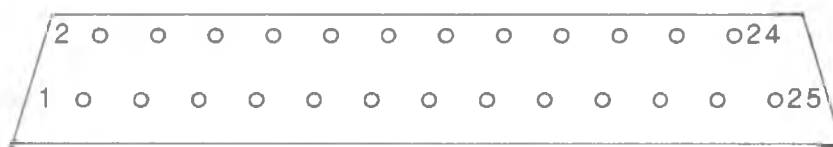
### 3.2.2 CONNECTION PORTS

Several connector ports are provided at the rear panel of the system unit whose features include.

- A power cord for connecting the system power
- Keyboard connector port where the keyboard plugs in.
- Mouse or pointing device connector, where a mouse or other pointing device cables like the joy-stick

plug in.

- Parallel connector where a printer signal cable is usually plugged in.
- Serial connector where a modem or serial printer signal cables plug in. See figure 3.4.
- Display connector where the display signals are communicated through.
- Expansion slots which are three in number and allow the installation of three adapters inside the system unit so that it's capabilities can be expanded. The slots are numbered 1 through 3 and corresponds with the slot number listed in the configuration menu. A fixed disk drive adapter is installed in slot 2. for an external disk drive.



PIN No.	ASSIGNMENT	PIN No.	ASSIGNMENT
1	-----PG Protective Ground	2	----TD Transmit Data
3	-----RD Receive Data	4	----RTS Request To Send
5	-----CTS Clear To Send	6	----DSR Data Set Ready
7	-----SG Signal Ground	8	--DCD Data Carrier Detect
9	-----Data Set Test	10	---- Data Set Test
11	----- Unassigned	12	----SDSD Secondary DCD
13	-----SCTS Secondary DCD	14	----STD Secondary TD
15	-----Transmit Clock	16	----SRD Secondary DR
17	-----Receive Clock	18	----Unassigned
19	-----SRTS Secondary RTS	20	-DTR Data Terminal Detect
21	-----Signal Quality Detect	22	----RI Ring Indicator
23	--Data Signal Rate Select	24	----Transmit Clock
25	----- Unassigned		

Figure 3.4

### *Serial Port Connector Pin Assignment*

### 3.3 THE EMULATOR

#### 3.3.1 INTRODUCTION

The ICEBOX emulator is used as the debug/test equipment for developing system software and hardware. Unlike other emulators it utilises two microprocessors, an internal control processor which resides on the emulator hardware and an emulation processor which resides on the emulation interface board and whose sole function is that of emulation. It is designed for the Z-80 microprocessor family. Besides being used as a debugging/test tool it acts as the link between the host computer and the microprocessors of the target system. This provides a means of entering data by writing onto the system memory as well as capturing and displaying the contents of the address bus while indicating the type of operation being carried out as the programs are executed. It operates on four different modes giving a wide scope of hardware and software test approach.

#### 3.3.2 POWER SUPPLY

A separate unit provides a line operated triple rail switched mode power supply for the Icebox and any other devices. This power supply unit is used to provide the system power. It supplies +5v at 4A, +12v at 40mA and -12v at 40mA.

### 3.3.3 OPERATIONAL MODES

The emulator can operate on four different types of modes namely;

- i) Local/stand alone mode
- ii) Terminal mode
- iii) Computer mode
- iv) A.T.E. mode

In the local/stand alone mode the inbuilt keyboard and hexadecimal display are used. Error message are transmitted to the display as a two digit code. In this mode uploading and downloading of programs is not possible and no data is output in this mode.

In the Terminal mode a serial terminal can be used, being connected via an RS232 port. Downloading and uploading is possible with the local keyboard and display on the emulator being functional. Some DIP switches on the rear panel give the user an option of disabling the local keyboard and the display. This mode is mainly used when the host computer is busy with other users, even though no action is taken in the transmission of errors.

When using the computer mode the emulator is connected to the host computer via a RS232 link. These mode is similar to the terminal mode but a handshake software is operated during uploading and downloading of programs, to ensure correct transmission and reception of data. This is the mode basically used in the system development. It provides a facility for disassembling programs for editing

purpose, and a means of visualising address locations when single stepping of the programs.

In the A.T.E.(Automatic Test Equipment) mode, the emulator is used as a programmable test tool, which executes sequences of commands, simulating the target hardware in a known way hence providing a hardware test facility. It provides a good testing approach of the system memory by being able to diagonalise faulty memory locations or inaccessible areas.

### 3.3.4 RS232C SERIAL PORT

The serial port is a 9 way D-type socket which provides the link between the Icebox emulator and the host computer. The pin configuration of the serial port are shown in Figure 3.5.

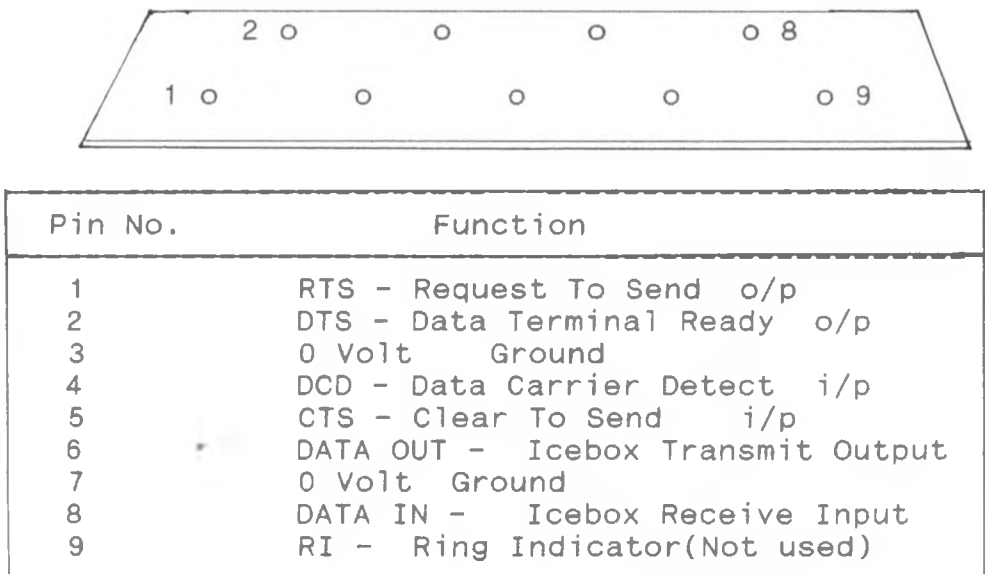


Figure 3.5 9-Way RS232C Serial Port Pin Assignment



## 3.4 THE MULTICHANNEL ANALYSER

### 3.4.1 INTRODUCTION

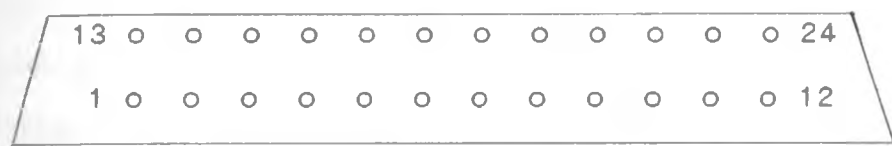
The TA2000 is a high performance, portable analyser for system development, production and field-service application. It can capture data across 32 channels (at 25 MHz) at up to 100 MHz (8 channels) and display data in both timing and list formats on it's seven inch Cathode Ray Tube (CRT).

The analyser features multi-level triggering, 5nS glitch capture and glitch trigger. It's high impedance input pods (8 channel per pod) minimise circuit loading and feature independent software controls for selecting the various operating levels. All functions are accessed through easy to follow soft-key controlled displays. The use of soft-keys minimise the number of keystrokes required to achieve the desired function. All the acquisition parameters can be set up using only two menus.

### 3.4.2 USER PORTS

The front panel of the analyser has 4 data pods each having 8 channels per pod. Three clock input pods are provided each independently qualified from the other. The rear panel connection comprises the standard IEEE-488, RS-232 and centronics interface connectors together with BNC( Bayonet Coupling ) sockets for composite video out, Trigger out and Restart out. The GPIB ( General Port Interface Bus) control facilities allow for transfer of

complete set-ups of data in either direction between the analyser and the controller (or another device on the bus), as well as a configuration and control of the instrument by simulating key presses with remote commands. The pin assignment of the GPIB connector is shown in figure 3.6.



PIN No.	SIGNAL
1 to 4	DI/O 1 to DI/O 4
5	EOI
6	DAV
7	NRFD
8	NDAC
9	IFC
10	SRQ
11	ATN
12	0V
13 to 16	DI/O 5 to DI/O 8
17	REN
18 to 24	0V

Figure 3.6 GPIB Pin assignment

### 3.4.3 OPERATIONAL MODE

The operational modes can be selected by 6 keys to give direct access to the 6 menus and data displays through which the instrument is controlled and results presented.

A brief feature of the modes of operation is listed below.

**CONFIG** - This is a CONFIGuration mode which selects the target instrument configuration, clock parameters, acquisition mode, trigger/restart filter setting and display brightness.

**TRIGGER** - In this mode the data pod thresholds, the trigger word and the trigger sequence can be selected.

**TIMING** - The timing mode presents the acquired data as a waveform display with magnify and find features. In this mode difference between data reference memories can be highlighted and a search made for any word and any difference.

**LIST** - The LIST display presents the acquired data as a state list display in the selected bases ( binary, octal, hex, decimal, ASCII and microprocessor mnemonics) with a find and compare option.

**UTILITIES** - Utilities mode primarily saves the data and set-up to a non-volatile memory and is also used to specify the communication interfaces.

**OPTION** - This option mode is used to call up the installed option, such as microprocessor disassembly software.

## 3.5 THE EPROM PROGRAMMER

### 3.5.1 INTRODUCTION

The microprocessor system design requires some facility to transfer the already developed control software from paper onto a permanent storage semiconductor memory. This is achieved by use of an EPROM programmer MQP model 18 whose reason of choice is cited in chapter 2.

### 3.5.2 MODES OF OPERATION

The MQP18 EPROM programmer operates on any host computer or terminal having a RS232C port and can program upto 51 types of Eproms, which can be extended to other families of Eproms and programmable microprocessors by use of optional socket adapters. The microprocessor controlled programmer automatically selects the correct voltage and programs timing and sequences for the EPROM selected. It communicates with the host computer via a serial RS232C link with data rate between 300b/s and 19200 b/s. The programmer adapts to the rate of the host computer automatically. It has two types of operating protocols namely;

i) Host computer protocol

ii) Terminal protocol

The host computer protocol is used in the project since it enables reliable communication with the host computer for interaction of the software package 'PROM DRIVER' on the computer with the PROM programmer. The software which is

menu driven, allows the display and printing of PROM files. PROM security functions, byte splitting, data polarity control and also the possibility of editing the software program as it is being loaded into the Eproms.

The terminal protocol can be used together with a VDU or computer running a terminal emulation program connected to the programmer. The ICEBOX emulation software program in the computer working together with the programmer can be utilised here, but the former protocol of operation is preferred as it offers more flexible utilities.

### 3.5.3 THE RS232C CONNECTOR

The programmer is equipped with a female 25 way D type connector with only pin 2,3,5,6,7,8,20 and 23 being connected. When using an IBM pc as the host computer as is the case in these project the pin configuration of the male and female connectors is as shown in the table 3.1.

IBM PC(25 pin male)	MQP18(25 pin female)
1 Ground .....	N/C
2 TXD o/p .....	2 TDX i/p
3 RXD i/p .....	3 RXD o/p
4 RTS o/p .....	N/C
5 CTS i/p .....	5 CTS o/p
6 DSR i/p .....	6 DSR o/p
7 Ground .....	7 Ground
8 DCD i/p .....	8 DCD o/p
20 DTR o/p .....	20 DTR i/p
22 (RI) i/p .....	23 (DSRS) i/p

Table 3.1 IBM/MQP18 25 Pin Connector. Pin Interconnection

## CHAPTER 4: SYSTEM OPERATION

### 4.1 INTRODUCTION

This chapter describes the system circuits and operational sequences for the control of the calorimeter data acquisition and processing. The automation unit developed has its in-built memory besides the interfacing circuits.

### 4.2 SYSTEM MOTHERBOARD

The system motherboard comprises of the functional block diagram shown in figure 4.1. Its components can be grouped into different units namely:-

- Z-80 CPU
- System clocks
- Buffer circuit
- Address decoder
- System memory (RAM and ROM)
- Control signal generator
- Interrupt circuit
- Reset and start-up circuit
- 1MHz port
- Memory expansion port
- Data acquisition port

The operational details of the units are as described in subsequent sections.

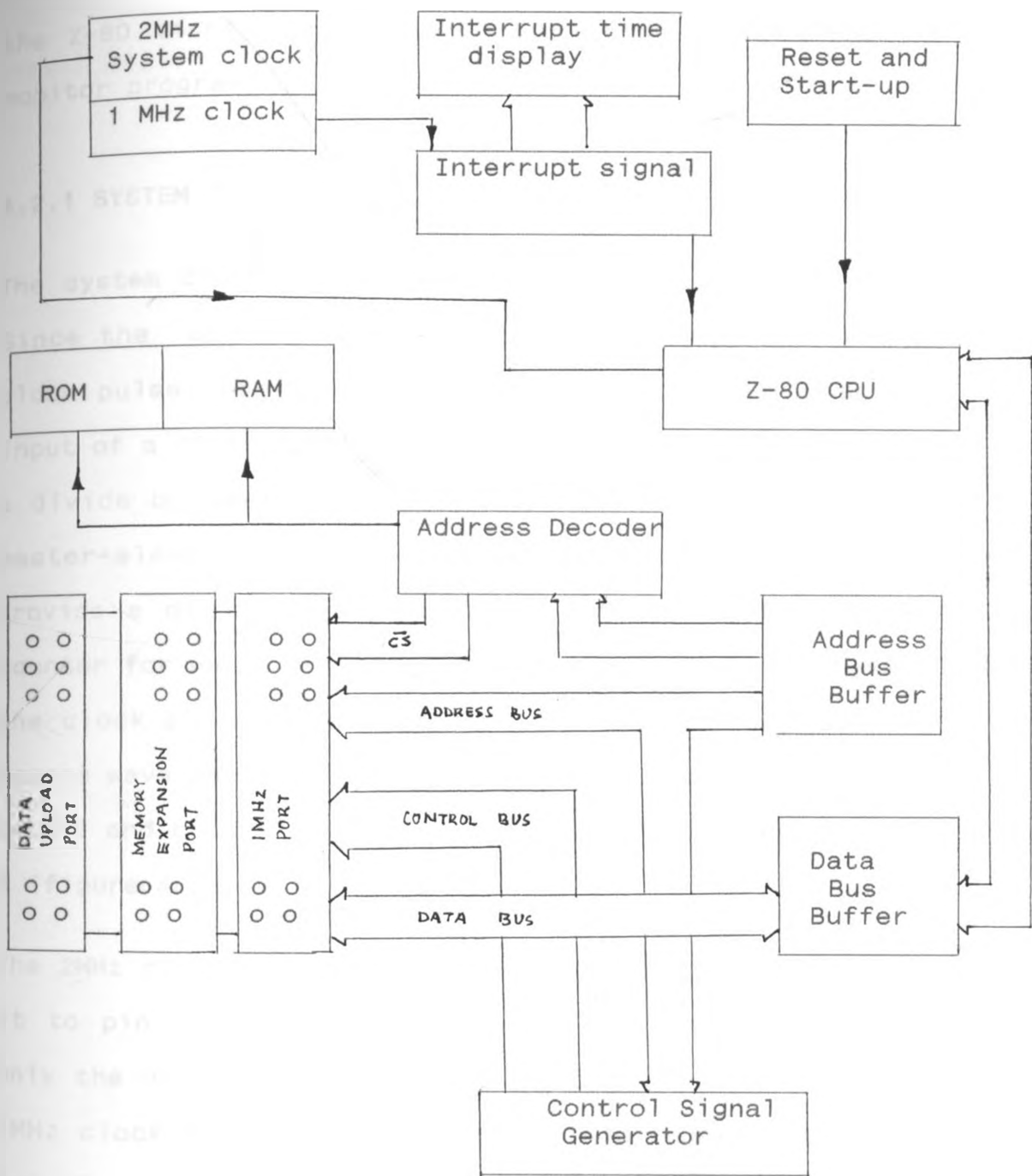


Figure 4.1

The Mother-board Block Diagram

On power-up or system reset, the clock and start-up circuit (figure 4.2) generate the 2MHz clock signal to run the Z-80 microprocessor which then starts executing the monitor program.

#### 4.2.1 SYSTEM CLOCKS

The system clock is derived from a 24MHz quartz crystal. Since the operating speed of the system is 2MHz, the clock pulse from the crystal clock is cascaded to the input of a TTL chip. The chip used is the 74LS92, which is a divide by twelve monolithic counter containing four master-slave flip flops. It has additional gating to provide a divide-by-two counter and a three-stage binary counter for which the count cycle length is divide-by-six. The clock pulse is decremented by the counter to 2MHz square wave which is tapped from the output (pin 8) of the 74LS92 and connected to the clock pin of the Z-80 CPU pin 6 (figure 4.2).

The 2MHz clock pulse is further divided by two by gating it to pin 14 of a similar 74LS92 chip, this time using only the divide by two section of the counter to give a 1MHz clock signal for the 1MHz bus of the Calorimeter interface.

The RST (Reset) signal is obtained for a D-Type flip-flop the 74LS74. Its clock input is driven by the system clock at a speed of 2MHz. The circuit is designed such that on



pressing the debounce switch, the flip-flop resets to zero giving a LOW reset signal ( $\overline{\text{RST}}$ ) from pin 9 and a HIGH reset signal (RST) from pin 8.

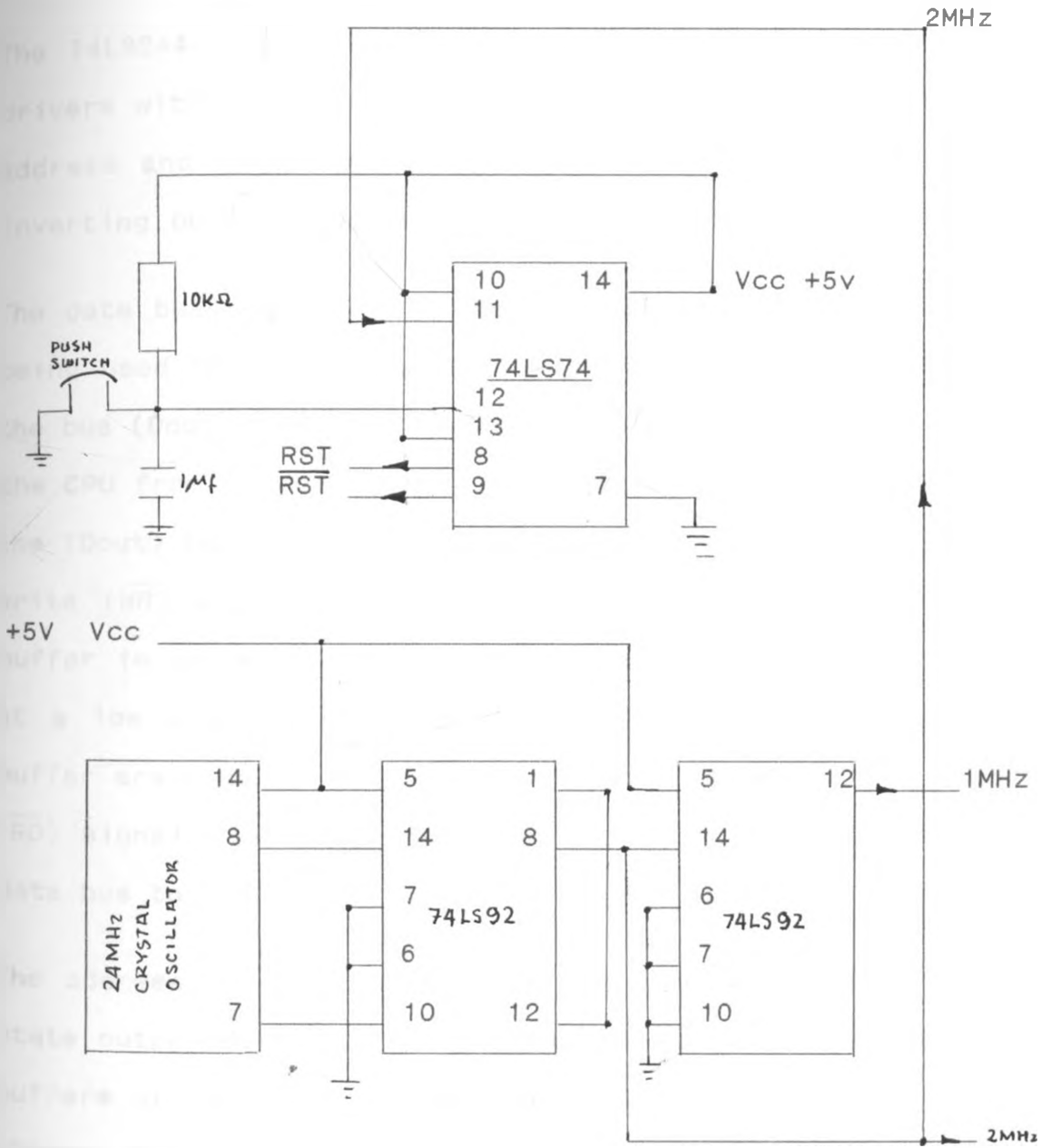


Figure 4.2

*System Clocks and Start-up/Reset Circuits*

#### 4.2.2 SYSTEM BUS BUFFERS

The address and data lines in the system are used to drive many inputs simultaneously and therefore require buffering to amplify the currents and isolate the lines from other devices.

The 74LS244 IC's which are TTL octal buffers and line drivers with tri-state outputs are used to buffer all the address and data lines. They are uni-directional non-inverting buffers. Reference to fig 4.3.

The data bus requires two of these buffers, one of them being used for buffering data flowing in from the CPU to the bus (Dout) and the other for buffering data flowing to the CPU from the bus (Din). The enable pins (1 and 19) of the (Dout) buffer are enabled by the out-put of ORing the write ( $\overline{WR}$ ) signal and the  $\overline{MREQ}$  signal. The data in the buffer is released when the enable pins of the buffer are at a low state. Similarly the enable pins of the (Din) buffer are enabled by the output signal of ORing the read ( $\overline{RD}$ ) signal and the  $\overline{MREQ}$  to allow data to flow from the data bus to the CPU.

The address line buffering uses two similar 74LS244 tri-state output buffers, for all the 16 address lines. These buffers are enabled by the output of ORing the  $\overline{MREQ}$  and GROUND, as the address signals are uni-directional. Figure 4.3 shows the schematic diagram of the system bus buffering circuit.

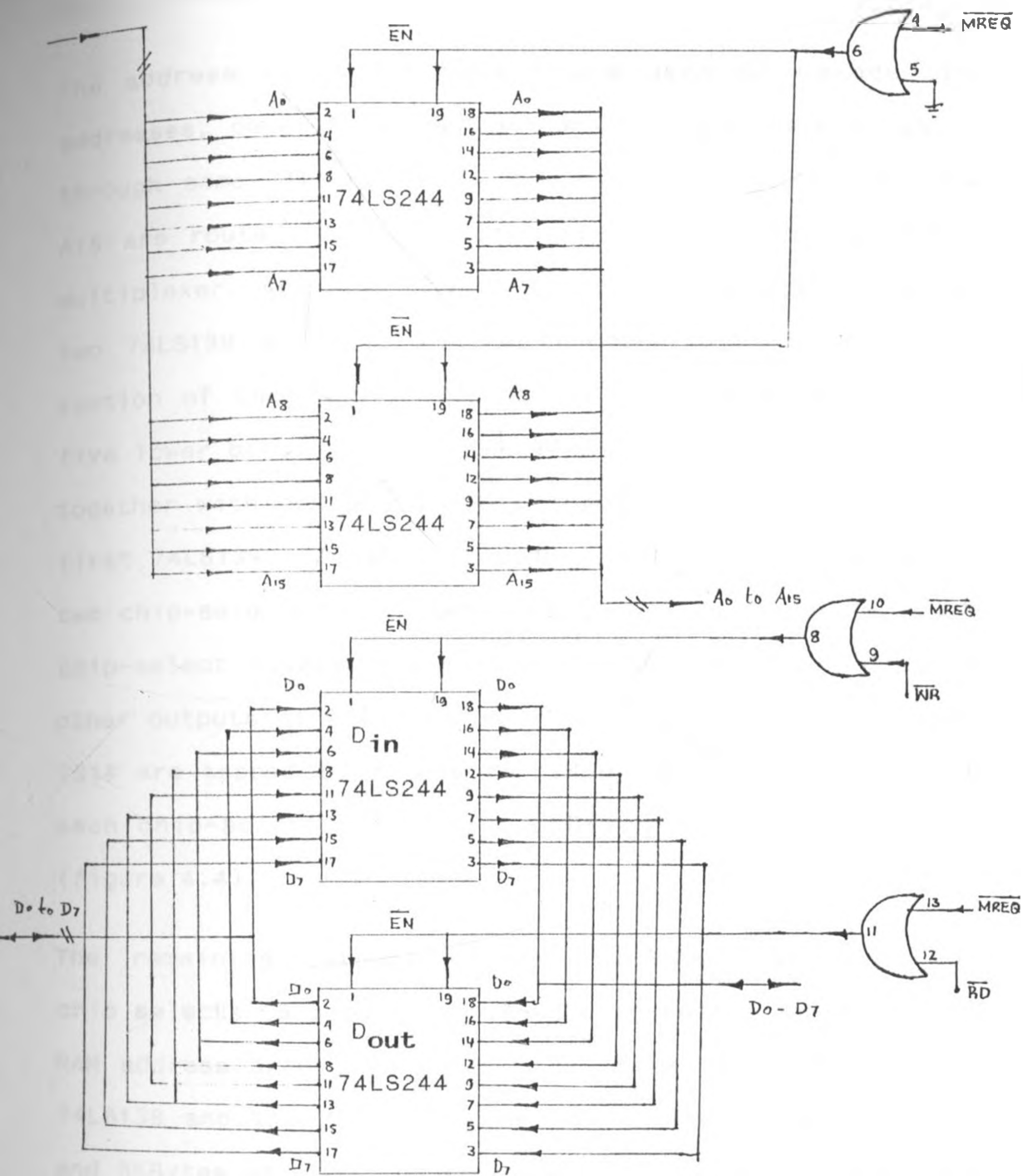


Figure 4.3 System Bus Buffering

### 4.2.3 ADDRESS DECODER

The address lines A11 to A15 are used to decode the addresses, generating the various chip-selects when gated through some TTL decoders. Buffered address line A13 to A15 are routed to (IC11) 74LS138 a 3 to 8-line decoder/multiplexer. Address lines A11 and A12 are used to drive two 74LS139 and 2-to-4 line decoders/multiplexers. Each section of the 74LS139 decoder is enabled by one of the five lower bit outputs of the 74LS138 decoder, while pin 4 together with pin 5 and pin 6 together with pin 7 of the first 74LS139 are gated through an AND gate to give the two chip-selects lines used for selecting the ROMs. Each chip-select covers a memory area of 4KBytes. From the other outputs of the 74LS139 IC, chip-selects CS3 through CS14 are tapped to decode for 24KBytes of RAM area, with each chip-select covering a 2KBytes RAM address range (figure 4.4).

The remaining outputs of the 74LS138 IC provides, the chip selects CS15 to CS18. Each chip-select decodes for a RAM address area of 4KBytes. The three TTL IC's 74LS139, 74LS138 and the 74LS08 decode the entire 56KBytes of RAM and 8KBytes of ROM. The functional tables of the decoders used is given in table 4.1a and table 4.1b.

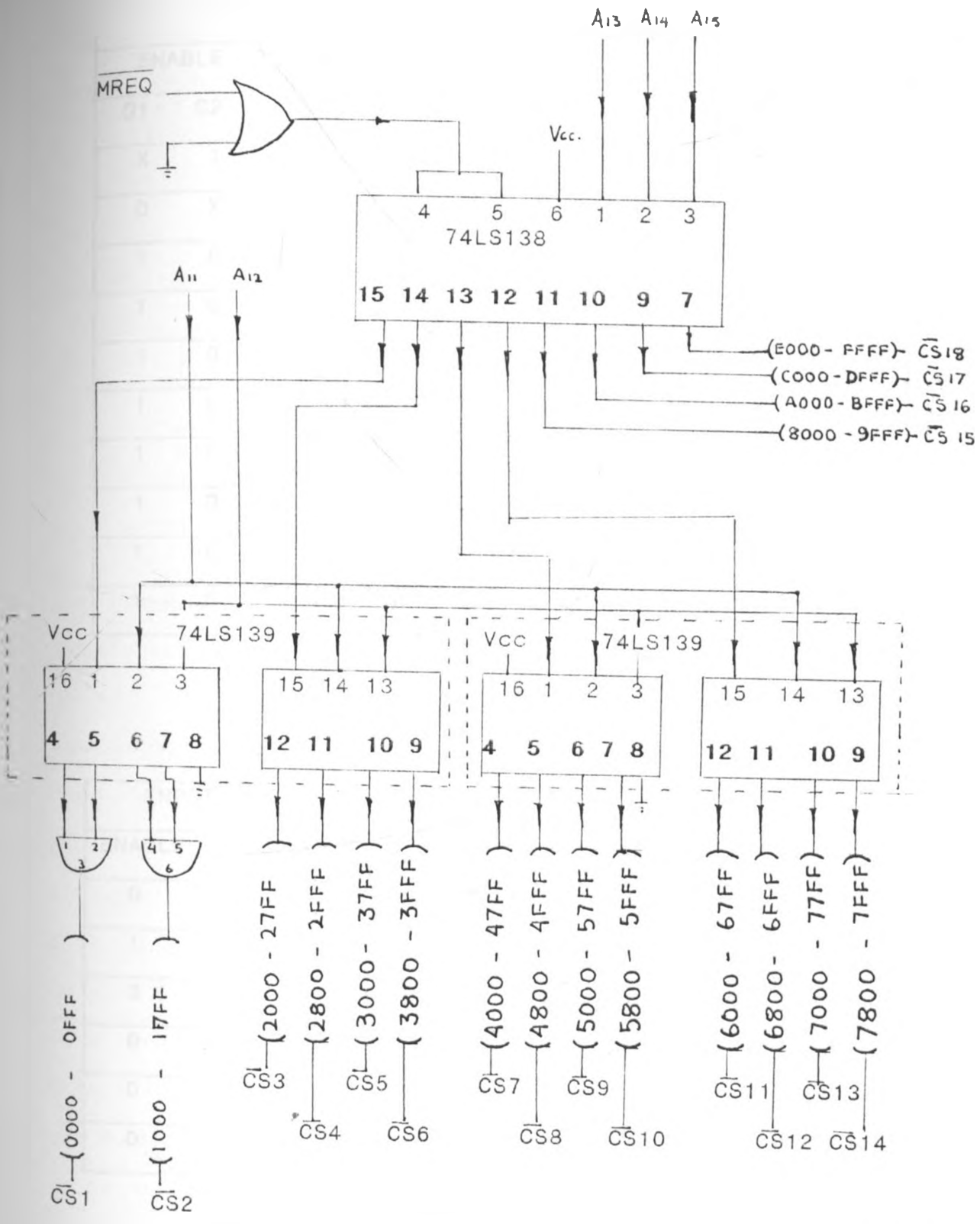


Figure 4.4  
Memory Address Decoding Circuit

INPUTS					OUTPUTS							
ENABLE		SELECT										
G1	G2	C	B	A	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7
X	1	X	X	X	1	1	1	1	1	1	1	1
0	X	X	X	X	1	1	1	1	1	1	1	1
1	0	0	0	0	0	1	1	1	1	1	1	1
1	0	0	0	1	1	0	1	1	1	1	1	1
1	0	0	1	0	1	1	0	1	1	1	1	1
1	0	0	1	1	1	1	1	0	1	1	1	1
1	0	1	0	0	1	1	1	1	0	1	1	1
1	0	1	0	1	1	1	1	1	1	0	1	1
1	0	1	1	0	1	1	1	1	1	1	0	1
1	0	1	1	1	1	1	1	1	1	1	1	0

Table 4.1(a)

INPUTS			OUTPUTS			
ENABLE	SELECT					
G	B	A	Y0	Y1	Y2	Y3
1	X	X	1	1	1	1
0	0	0	0	1	1	1
0	0	1	1	0	1	1
0	1	0	1	1	0	1
0	1	1	1	1	1	0

Table 4.1(b)

Functional tables (a) for 74LS138 and (b) for 74LS139

#### 4.2.4 SYSTEM MEMORY (ROM AND RAM)

The microprocessor-based system requires memory to store programs and data. Two distinct types of memory are used:

i) Random Access Memory (RAM)

ii) Erasable Programmable Read Only Memory (EPROM)

Four HM6116 which are 2048-word by 8-bit CMOS Static RAM's and featuring:-

- High speed access time of 120ns
- Low-power (standby) of 100mW
- Low- power (operation) of 180mW
- Storage capacity of 2KBytes
- TTL compatibility

are used to provide a total RAM storage capacity of 8KBytes on the mother-board. The buffered address lines A0 to A10 and data lines D0 to D7 are connected to the respective address and data line inputs of the HM6116 rams, with each chip connected in parallel to each other. Similarly two HN2732A ICs which are 4096-word by 8-bit ultraviolet erasable (EPROM's), are used to provide the storage area for the monitor program. It's pins connection is in parallel to that of the RAM's with an extra address line A11 and no write line connected. A separate chip-select from the address decoding unit is routed to each of the RAM's and EPROM's chip selects, selecting each of the chips uniquely any time that address area is accessed (figure 4.5). The pin configuration of the EPROMs and RAM's used are shown in figure 4.6.

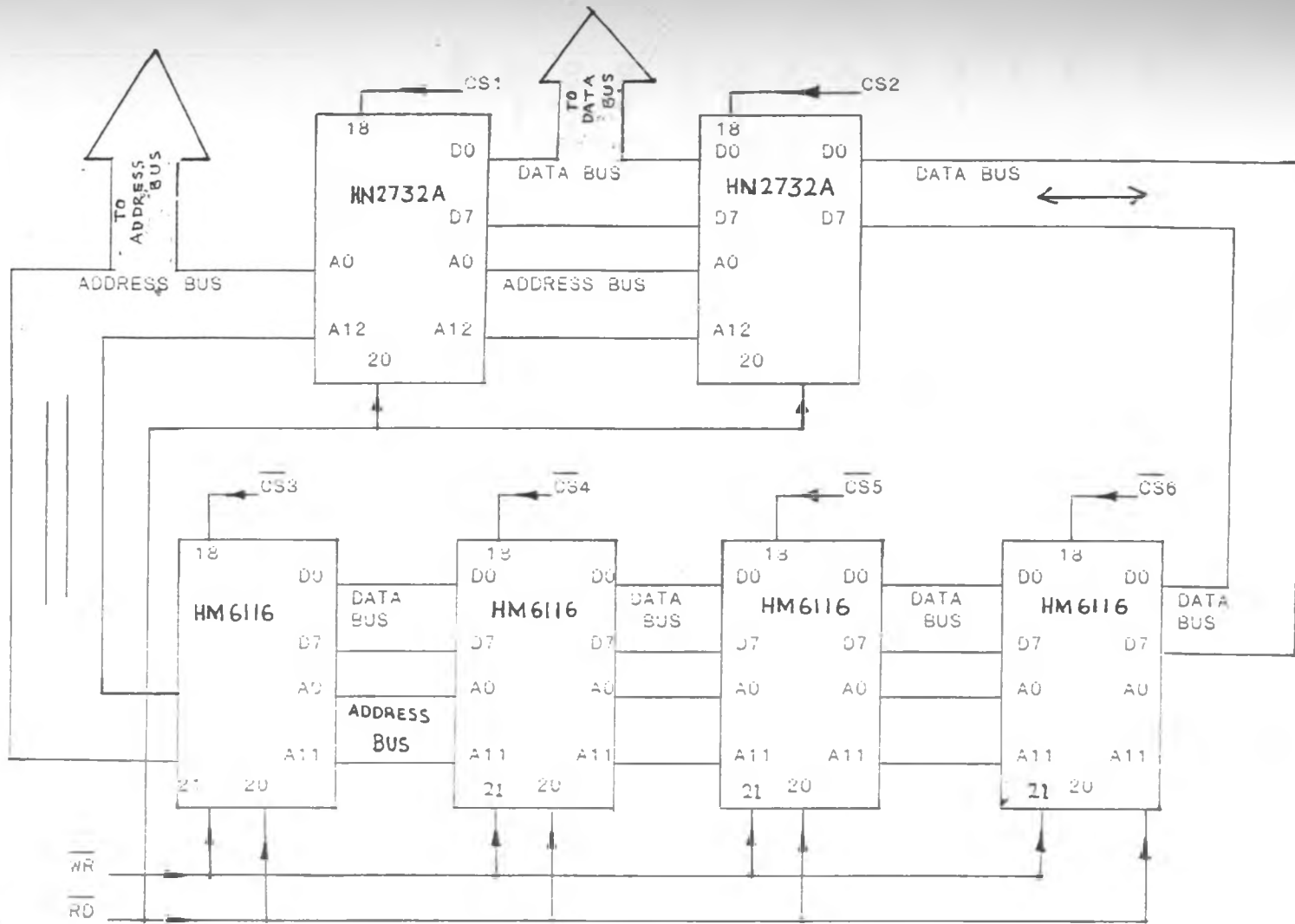


Figure 4.5 System Memory Layout



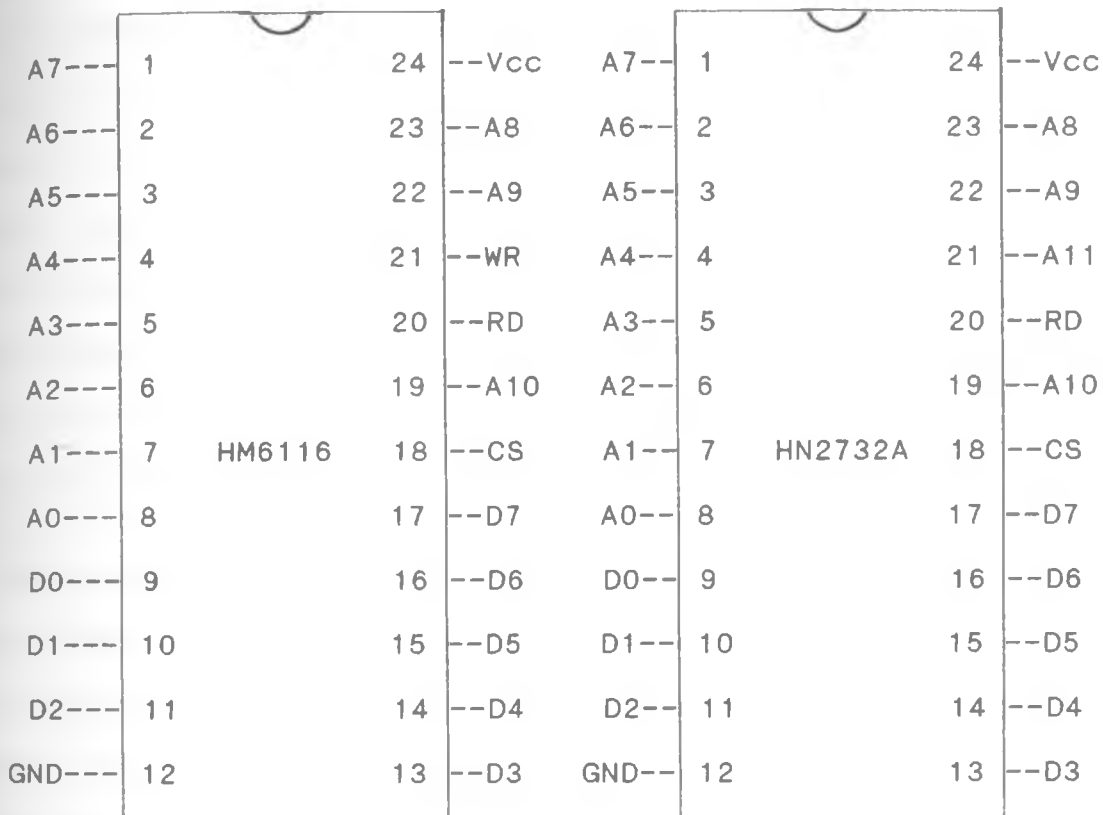


Figure 4.6  
*Pin Configuration of the RAM and EPROM*

#### 4.2.5 CONTROL SIGNAL GENERATOR

To generate the NPGFC equivalent signal for use in the 1MHz bus, a 74LS30 IC which is a 8-input positive NAND gate and a 74LS137 which is a dual 2-to-4 line decoder/multiplexer, are used. The upper six buffered address lines A15 to A10 are routed to the six input pins of the NAND-gate while the other two input pins are held high permanently. The output pin 8 of the NAND-gate are connected to the enable pin 1 of the 74LS139 decoder. The other two inputs, pin 2 and pin 3, are linked to the buffered address lines A9 and A8 respectively. A NPGFC equivalent signal is then tapped from pin 4 of the 74LS139 decoder, which is asserted low whenever the address FC00H to FCFFH is accessed.

A Read Not-Write signal for use in the 1MHz bus, is obtained by inverting the RD line of the Z-80 microprocessor with a 74LS04 inverter, which is further ANDed with the WR signal by a 74LS32 AND gate to give a R/W line (figure 4.7). The timing diagram of the control signals shown in Figure 4.8.

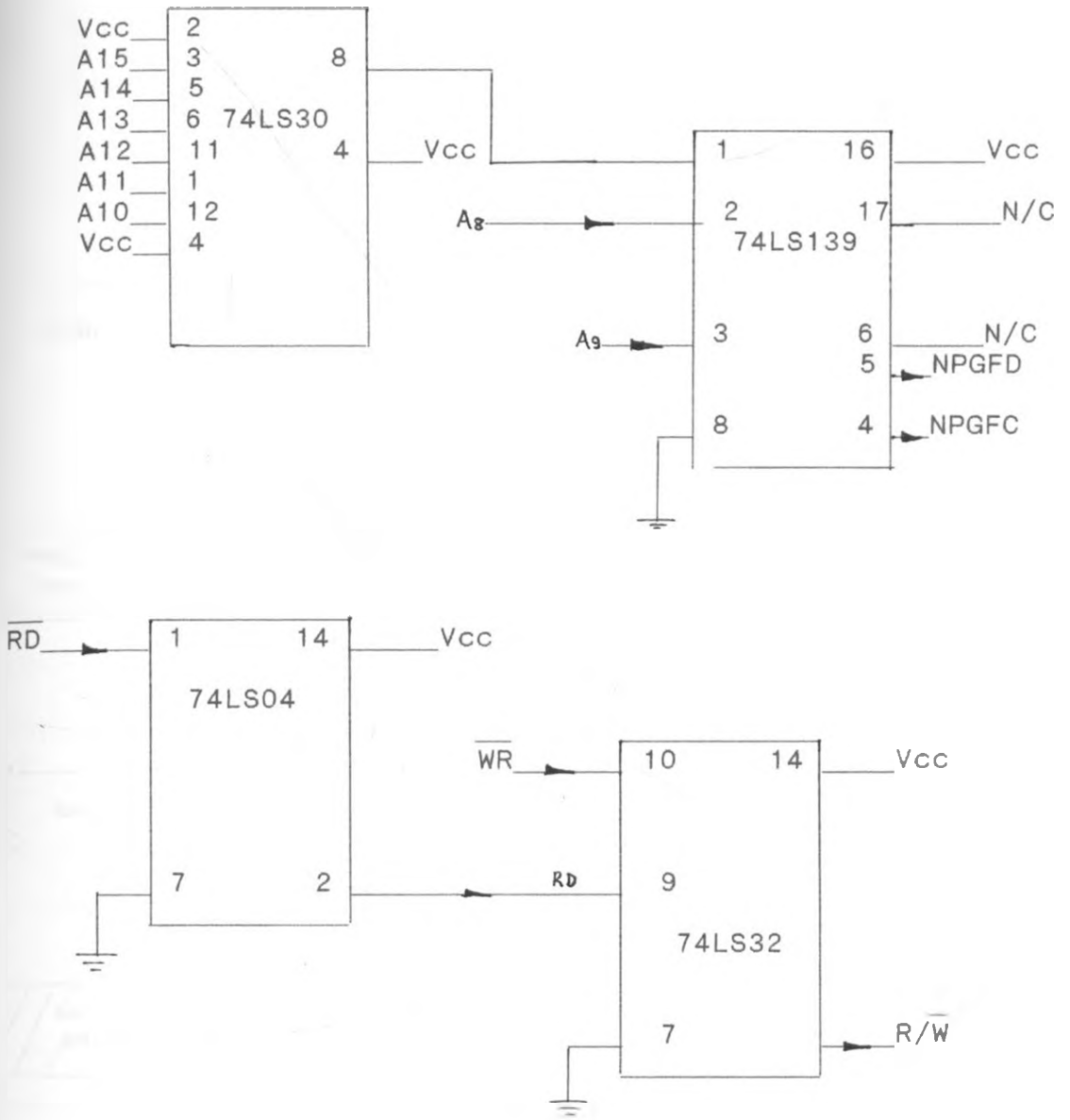


Figure 4.7  
*R/W and NPGFC Control Signal Circuit*

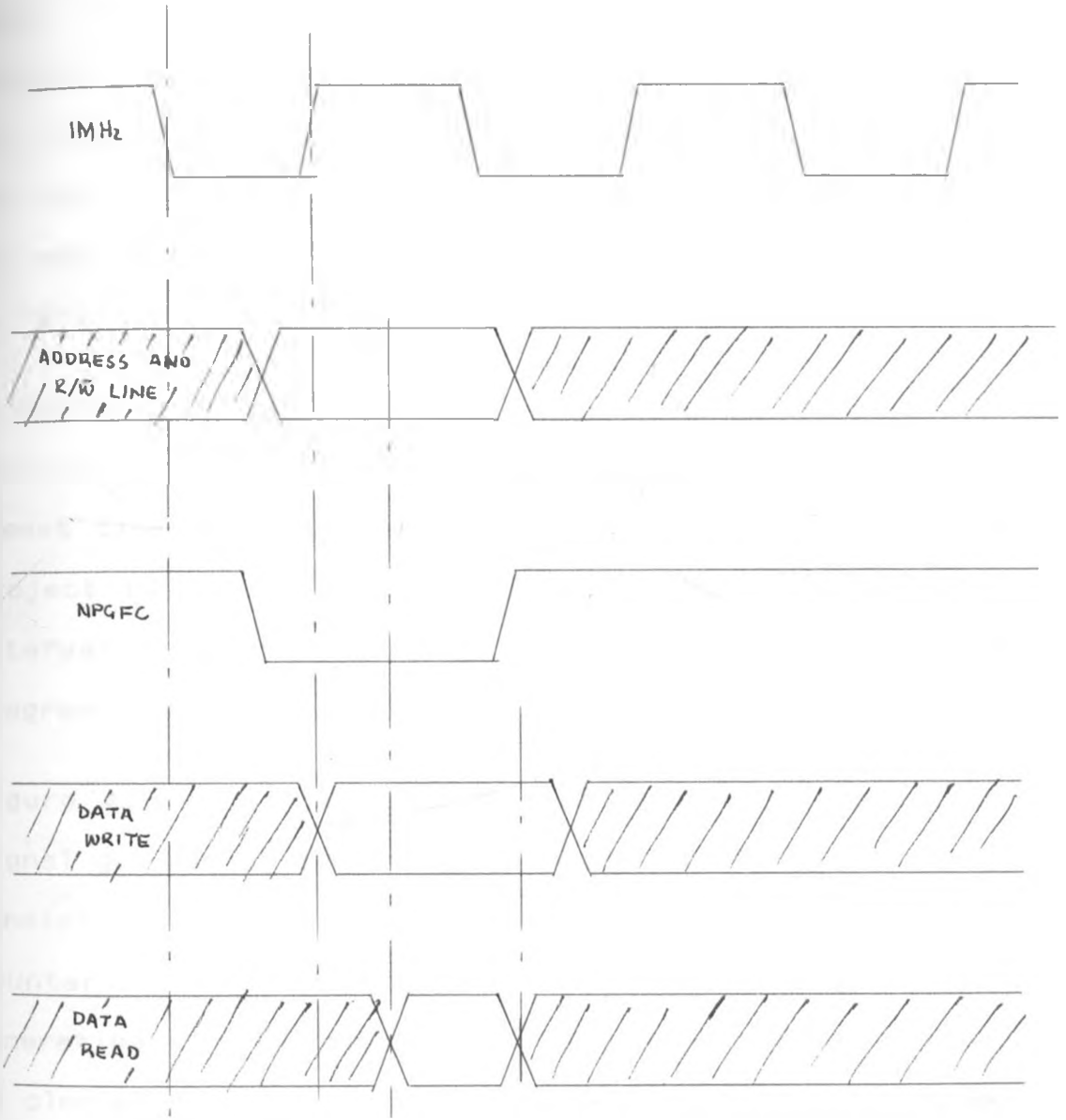


Figure 4.8  
Control Lines Timing Diagram

#### 4.2.6 THE INTERRUPT CIRCUIT

During data collection by the thermal absorption calorimeter, the interval between which data is collected plays a major role in the manipulation of the collected data. Precise software delay loops can be used which on program execution move the program pointer within a loop of a specified time depending on the number of loops. At the end of the delay loop the program pointer can be set by means of a software command to move to the data collection routine.

Alternatively, an intelligent hardware technique which sends signals to interrupt the processor every after a preset time, can be used. This approach is used in the project as it provides a means of changing the time interval between data collection outside the monitor program, without having to alter the control software.

Figure 4.9 is the schematic diagram of the interrupt signal generation circuit. Two 74LS90 BCD counters, which consist of a toggling flip flop and a 3-stage modula 5 counter, are cascaded together to perform the task of generating an interrupt signal. The first 74LS90 counter is clocked by a one second pulse derived from a 555 timer circuit set to give a pulse duration of one second. The upper bit output of the counter is used to clock a second 74LS90 counter. The counters are reset after 16 Seconds by linking the outputs 'A' of the first counter and the 'B' of the

and 'C' outputs of the second counter through a triple input AND gate, whose output gives the reset and clear signal to the two counters. Similarly the same outputs 'A' 'B' and 'C' are linked via a triple input NAND gate (74LS11) to give the required interrupt signal.

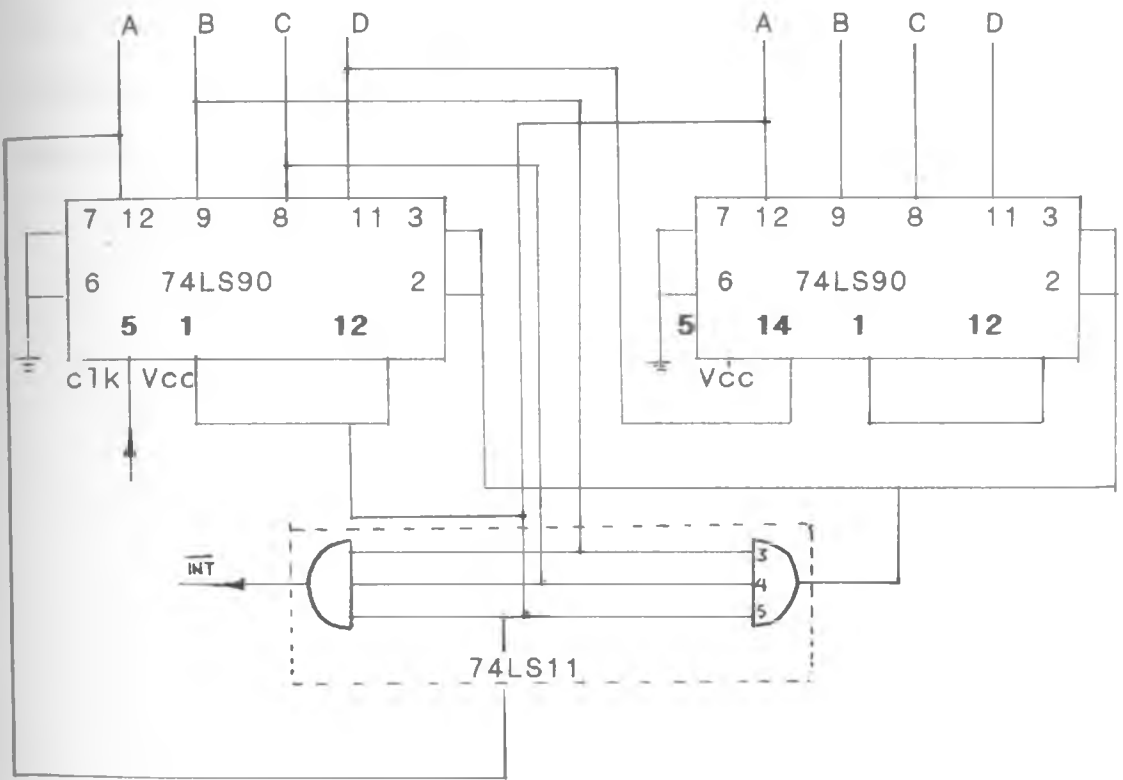


Figure 4.9

*Interrupt Signal Generation Circuit*

#### 4.2.7 INTERRUPT TIME DISPLAY MODULE

To display the time interval between data collection, two seven segment displays are used. The outputs of the two 74LS90 BCD counters represented the number to be displayed. This code is converted to seven output lines using a 74LS47 BCD-to-seven-segment decoder. Figure 4.10 shows the display module circuit, with the inputs (A,B,C and D) of the 74LS47 chip connected to the corresponding outputs (A,B,C and D) of the 74LS90 counters of the interrupt circuit. The outputs of these BCD to seven segment converter are linked to the inputs of the seven segment displays.

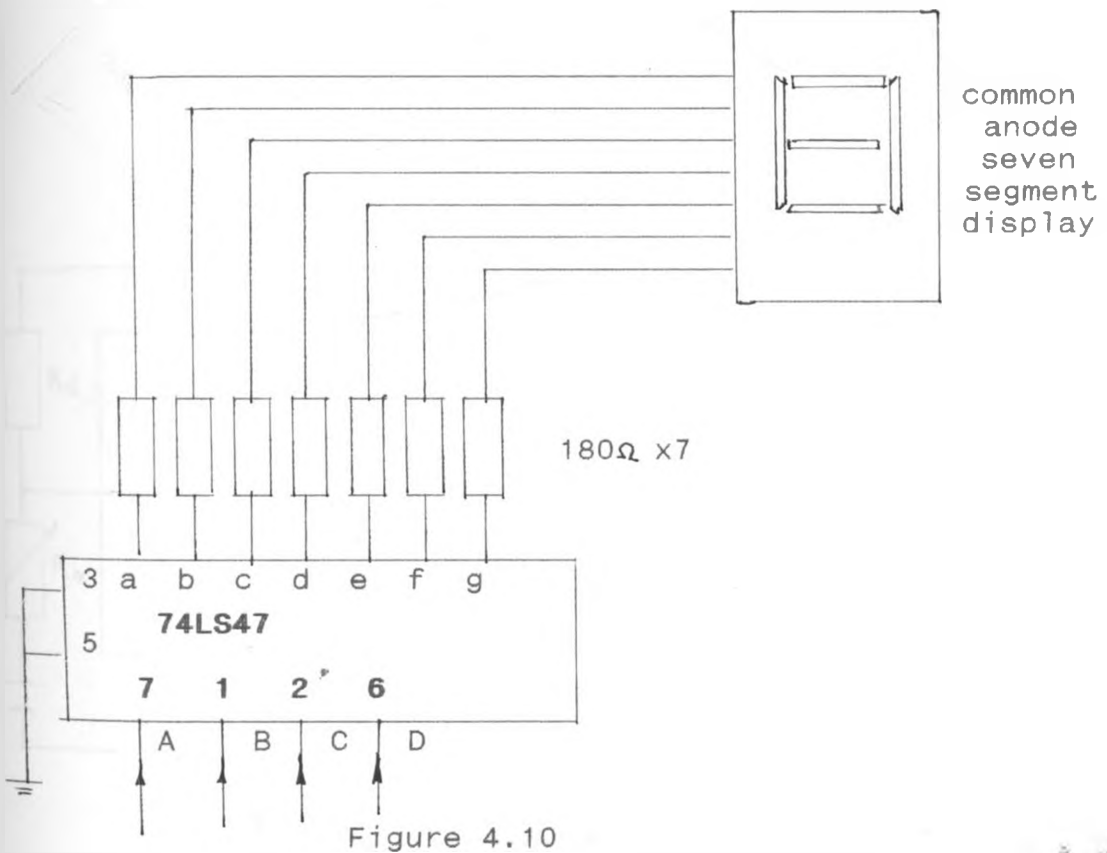


Figure 4.10  
*Interrupt Time Display Circuit Diagram*

#### 4.2.8 THE 555 TIMER CIRCUIT

A 555 timer IC which is a TTL device is used to generate the 1 second pulse for use in the interrupt circuit. The values of the connecting resistors and capacitors is arrived at by the calculation shown below. Figure 4.11 shows the timer circuit using the NE555E timer to generate a one second pulse.

$$\text{Charging rise time } t_1 = 0.7(R_a + R_b)C$$

$$\text{Discharging fall time } t_2 = 0.7(R_b)C$$

$$\text{But Total Period time } T = t_1 + t_2 = 1 \text{ Sec.}$$

$$\text{Frequency} = \frac{1}{T} = \frac{1.43}{(R_a + 2R_b)C} = 1$$

$$\text{If } R_a = 1K \text{ and } C = 1 \times 10^{-6} \text{ Then } 2R_b = (1.43 \times 10^6) - 1.0 \times 10^3$$

$$R_b = 719.5 \text{ M}\Omega$$

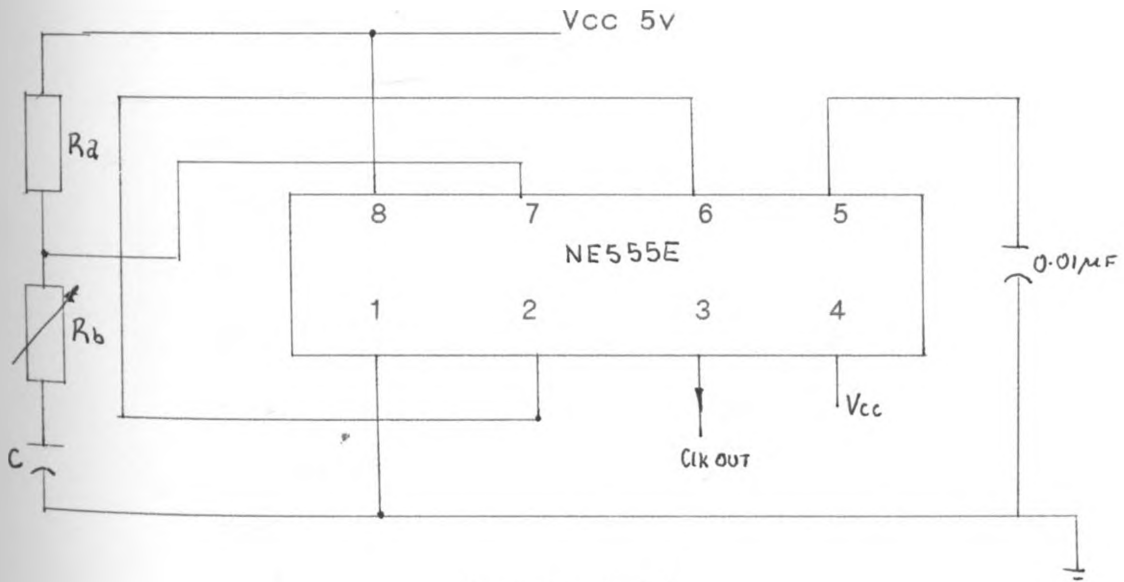


Figure 4.11

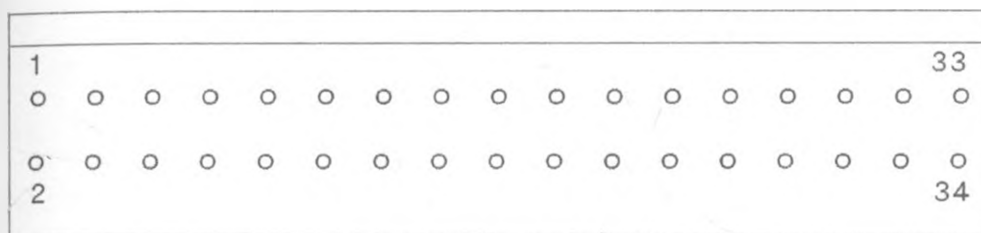
555 Timer Circuit



#### 4.2.9 THE 1MHZ. PORT.

The communication between the calorimeter and the microprocessor control system is via the 1MHz bus as described in Chapter 1, Section 5.3.3 and by Mate(1980). A standard port with 34 pins and configured to meet the BBC specification is wired on the system to be the main interface port between the system and the calorimeter. The pin configuration of the port are shown in Figure 4.12. A ribbon cable of 46cm length and terminated in the usual way is used to connect the two systems together.

Viewed from front



Odd Numbered PIN 1 to PIN 17 --- 0 volts

PIN 2 ----- Read Not-Write Line

PIN 4 ----- 1MHZ. Line

PIN 6 ----- Not Connected

PIN 8 ----- Not Connected

PIN 10 ----- NPGFC (FRED) Line

PIN 12 ----- NPGFD (JIM) Line

PIN 14 ----- Not Connected

PIN 16 ----- Not Connected

PIN 18 to PIN 25 --- D0 to D7

PIN 26 ----- 0 volts

PIN 27 to 34 ----- A0 to A7

Figure 4.12 1MHz Port Pin Configuration

#### 4.2.10 THE MEMORY EXPANSION PORT

This port is used to interface the expansion memory RAM-card onto the main system. It carries the various chip-selects lines, the data lines, address lines, control lines and the power line. Figure 4.13 shows the pin assignment of the port.

CLS--	1	o	o	26	--A0
GND--	2	o	o	27	--A1
N/C--	3	o	o	28	--A2
D0--	4	o	o	29	--A3
D1--	5	o	o	30	--A4
D2--	6	o	o	31	--A5
D3--	7	o	o	32	--A6
D4--	8	o	o	33	--A7
D5--	9	o	o	34	--A8
D6--	10	o	o	35	--A9
D7--	11	o	o	36	--A10
N/C--	12	o	o	37	--A11
IORQ--	13	o	o	38	--A12
CS18--	14	o	o	39	--A13
RD--	15	o	o	40	--A14
INT--	16	o	o	41	--A15
WR--	17	o	o	42	--CS7
NMI--	18	o	o	43	--CS8
MREQ--	19	o	o	44	--CS9
WAIT--	20	o	o	45	--CS10
BUSRQ--	21	o	o	46	--CS11
CS17--	22	o	o	47	--CS12
CS16--	23	o	o	48	--CS13
CS15--	24	o	o	49	--Vcc
CS14--	25	o	o	50	--GND

Figure 4.13

*Pin Configuration Of The Memory Expansion Port.*

### 4.3 SYSTEM MEMORY MAP

Several considerations arose with regard to the location of the main program, subroutines, RAM variables and data storage area, as the development of the system software for the instrument proceeded. The Z-80 microprocessor imposes some memory constraints such as that of the program counter moving to address 0000H when power is turned ON or on RESET and expect to find the first instruction there. It is therefore necessary to have a memory block starting from this address reserved for ROM. By being able to specify where variables and different parts of the program are to be located in the RAM and ROM, it is possible to provide the memory map of the system designed as shown in figure 4.14.

The memory location 0000H to 0040H is left for the interrupt jumps to monitor program and constant storage. The monitor program starts at address 0200H and ends at address 0330H. Since the ROM area is reserved upto address 1FFFH, the rest of the area is left for future work as shall be explained in chapter 7. Address FCDAH to FFFFH is left for the stack pointer storage. Location 2800H to 3FFFH is the on-board data storage area which is used to store the data obtained from the Calorimeter.

For the system control program, the used data storage area is sub-divided into four regions. The first region which

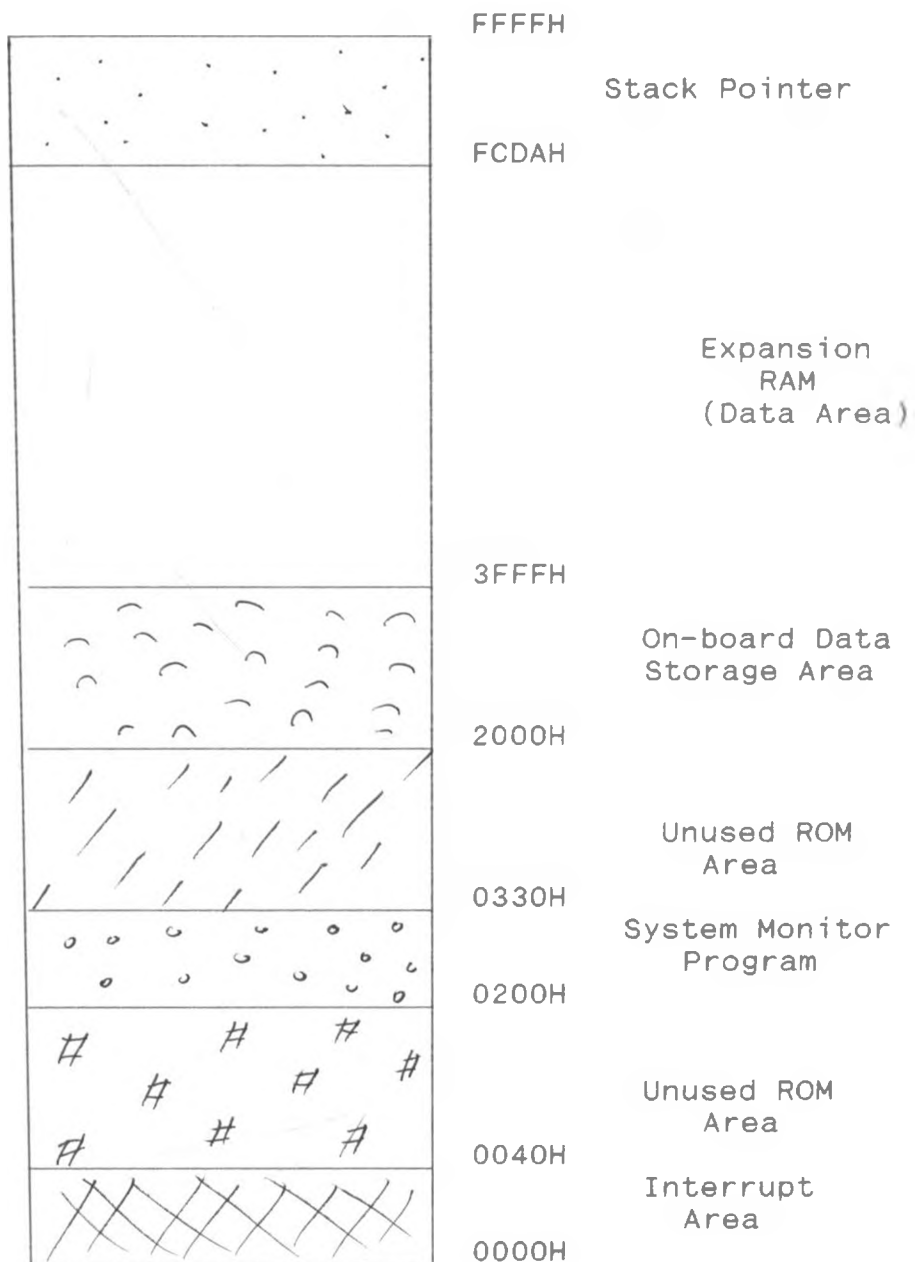


Figure 4.14  
System Memory Map

occupies memory location 3100H to 31FFH is used to store the material temperature data during the cooling cycle. The second region which runs from memory location 3200H to 32FFH is used to store the cumulative time taken for each data sampled in the cooling cycle. The third region which runs from location 3500H to 35FFH, holds the sampled temperature data of the material during the heating cycle. The final region running from location 3600H to 36FFH is used to hold the cumulative time taken for each sampled data in the heating cycle.

Location 4000H to FFFFH is the user 'scratch pad' memory area and is on the expansion RAM card, out of the main motherboard. Some of these locations can be used for storage of multiple data sets.

#### 4.4 THE DATA ACKNOWLEDGMENT DISPLAY CIRCUIT

Figure 4.15 shows the data acknowledgment display circuit using two 74LS04 ICs to drive eight LEDs. The inputs to the circuit are connected to the buffered data bus of the calorimeter. When any of the eight data lines of the calorimeter goes HIGH the corresponding LED lights up indicating that the particular data line is active HIGH. The LEDs are OFF when the data lines are inactive. The digital data can thus be traced by coding the sequence displayed by the LEDs. This circuit is used as a visual display to ascertain the transmission of data between the calorimeter and the developed system.

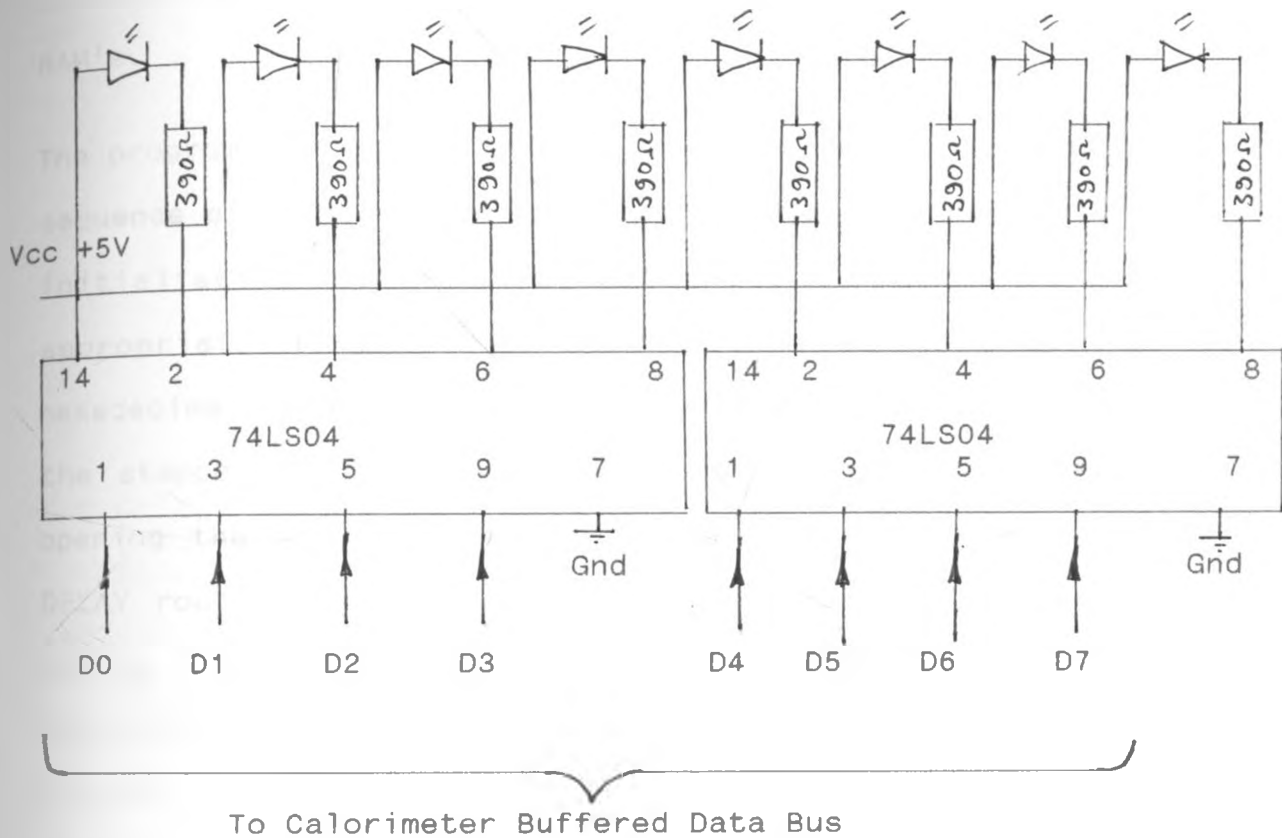


FIGURE 4.15

*Data acknowledgment display circuit*

#### 4.5 THE SYSTEM MONITOR PROGRAM

The system monitor program is developed to control the operations of the thermal absorption calorimeter, which include the opening and closing of the shutter window, collecting of data and storing it in the data storage RAM's.

The program is written in Z-80 assembler object codes as a sequence of routines. On power ON the program moves to the initialisation routine, which transfers control to the appropriate routine. The OPENwindow routine sends the hexadecimal code C1 to memory location FCD2H. This sets the stepper motor moving in a clockwise direction hence opening the shutter window for the heating process. The DELAY routine is used to hold the program for some time before invoking the next routine, providing the window enough time to open fully. The HOLDwindow routine once invoked sends a hexadecimal code 00 to address FCD2H which stops the stepper motor and holds the window in one position.

The INTERRUPT routine loops the program in a hold state as it waits for the CPU to be interrupted. These provide the intervals between data collection. The program counter is then set to the interrupt service routine which enables the transfer of data from the calorimeter to the data storage area once the CPU has been interrupted.

during the cooling cycle, the CLOSEwindow routine is initiated sending the hexadecimal number C0 to memory location FCD2H to set the stepper motor moving in an anti-clockwise direction thereby closing the window. The other routines are then executed in the same order as during the heating cycle. Routine BLINK is invoked once all the data has been collected. Hexadecimal codes AA and 00 separated with an interval delay of one second, are transmitted through the data bus, causing the LED's(Light Emitting Diodes) of the data acknowledgment circuit (section 4.4) to blink. This forms a visual indicator to show that data transfer has been completed.

#### 4.6 DATA ACQUISITION PROCEDURE

The data collected from the calorimeter is stored in some semi-conductor RAM's for uploading onto a fully developed system (the host computer). These data is in ASCII hexadecimal format which includes the memory address onto which it is stored and the end of line and beginning of line character codes.

A pascal program (Appendix D) comprising of sequences of procedures, is written in a user friendly format using some special pascal statements as explained by Webster(1985). The system automation is enhanced by use of the program, since data uploaded from the system RAM does not need to be entered manually in its refined format for data analysis.



procedure DOCHAR removes the memory addresses and the end of line characters within the raw data. Procedure SEPR groups the data into a four bit format with a gap between them. Procedure LOOKUP is used to look for the numerical equivalence of the hexadecimal data before it is acted on by procedure CONV which converts the hexadecimal four bit data into decimal numbers and rearranges them into a continuous row form. The program finally stores the converted data as a data file, which can be imported onto a spreadsheet package.

In this project a MSWORKS (Micro-Soft WORKS) package comprising of a DataBase, a Wordprocessor and a Spreadsheet facilities is used for the data manipulation and analysis. This is done by fitting the data into a calibration equation to obtain corresponding graphs (Chapter 6), from which different results can be derived.

## CHAPTER 5: SYSTEM DEVELOPMENT

### 5.1 INTRODUCTION

Development of the system was done in steps which involved building of each interface section of the motherboard. The interface is connected to the host computer via an In-circuit-Emulator (ICE-BOX). Each unit was firstly developed on an experimental breadboard and later transferred to the prototyping high-density boards, forming one complete unit.

Once the units were developed, test program which were developed simultaneously with the units, were executed from the IBM micro-computer through the emulator to the unit, for debugging purposes. Using the THANDAR 2000 multi-channel analyser together with the 60MHz TEKTRONIX Oscilloscope, the signals were tested at various test points.

The circuits developed on the Mother-board include the bus buffers, address decoder, storage memory array, system clocks, reset and start-up circuit, the various control signals generators which include the interrupt signal, the interrupt time display and the required interfacing ports. Section 5.2 covers the hardware units development with the software development discussed in section 5.3.

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## 5.2 HARDWARE DEVELOPMENT AND TESTING

### 5.2.1 ADDRESS BUS DECODING AND BUFFERING

Address lines A11 to A15 gated through some TTL gates are used to decode locations for the various memory chips, by generating the required chip-select signal. This is implemented by linking address lines A13, A14 and A15 to the inputs of a 74LS139 a 3-to-8 decoder/multiplexer (section 4.3.3). Two 74LS139 3-to-4 decoder/multiplexer are driven by the outputs of a 74LS138 IC to generate the required signals. A  $\overline{\text{MREQ}}$  and Ground signals ORed together through a 74LS32 OR gate was used to produce the enable signal to the decoders. Test program 1 (Appendix C2) was used to confirm that the  $\overline{\text{CS}}$  signal pulses are asserted when-ever that address is accessed, but this is done later after the storage memory array to provide a scratch memory area, is already developed.

Each of the 18  $\overline{\text{CS}}$  outputs of the memory decoding circuit are connected to an independent input of the multichannel analyser. Test program 1 is executed, and the duration of the  $\overline{\text{CS}}$  signal (Figure 5.1) monitored to confirm the validity of the signals. Once this is confirmed the  $\overline{\text{CS}}$  are routed to the respective memory ICs.

### 5.2.2 STORAGE MEMORY ARRAY

The on-board storage memory (RAM) was developed using the HM6116 static RAMs, to provide a user RAM area of 8KBytes as described in section 4.3.4. All of the RAM Ics are connected in parallel but accessed differently depending on whether the CS line of that particular RAM chip is active.

Target diagnostic tests which are run via the emulator, are then used to test the memory access hardware. A diagnostic test which does a RAM memory read/write test is used for this purpose. It includes (a) a walking one's test and (b) memory data test. In the walking one's test a defined pattern is written into the specific block of memory by writing into successive locations throughout the entire block and then reading from the block to verify the contents. The memory data test is invoked automatically upon completion of the walking one's test, and consists of writing the sequence 00, 55, AA and FF to each memory location, verifying after each individual byte that it has been successfully written before repeating the test on the next address.

### 5.2.3 BUFFERED DATA/ADDRESS BUS TESTING

With the multi-channel analyser configured to run at 100MHz for easy data capture, all the data lines and address lines are connected to its inputs. Program 2 for data line test and Program 3 for address lines test.

Appendix C2 are then executed and the output signals analysed from the screen of the analyser both as waveforms and as binary digits to confirm that the buses are wired correctly.

#### 5.2.4 CONTROL LINES GENERATION AND TESTING

Some explicit specification for the control signals are required by the microprocessor used and the Absorption calorimeter, which include:

- Minimum and maximum allowable frequencies
- Tolerance on the high and low voltage levels
- Maximum rise and fall times of the waveforms.

Various control lines were generated and tested to confirm that they match the specification and requirement mentioned above.

The control lines specially generated include the  $\overline{\text{NPGFC}}$  (Not Page FC) control line, the Read/Not Write line, the interrupt line and the 1MHz line ( Chapter 4 ) which are used to interface the microprocessor system to the Absorption Calorimeter.

Verification of the timing relationship of the  $\overline{\text{NPGFC}}$  signal relative to the other signals (Figure 4.8), was done by using program 4 Appendix C2.

The interrupt signal was tested by connecting it's signal output pin to one of the inputs of the multi-channel analyser. Resistor Rb of the timer circuit (figure 4.11) was then varied so that the time interval between the

interrupt pulses is set to 16 seconds. The pulse duration was kept at 16 Seconds since it was found by calculation that in order to cover the entire heating or cooling curves and at the same time sample one hundred data samples, the most suitable time interval between data samples was 16 seconds. Once the signals were verified they were linked to their respective interfacing ports for actual system interfacing.

## 5.3 SOFTWARE DEVELOPMENT

### 5.3.1 INTRODUCTION

The development of the software was done in three stages. The first stage involved the writing of the test programs, which was done in phase with the hardware development for debugging purposes. These are discussed in section 5.3.2. The second stage involved the development of a system monitor program which controls the Absorption Calorimeter and is presented in section 5.3.3. The third stage involved the writing of data analysis programs, used in sorting and formatting the collected data for further importation to a spreadsheet package for analysis. These are discussed in section 5.3.4.

### 5.3.2 TEST PROGRAMS

Four sets of test programs were written for various hardware testing and debugging, with each being executed separately for the unit under test. These have been referred to in section 5.3.1 and are discussed below. The program listing of the test programs are given in appendix C2.

#### Program 1

This program was written to access different memory blocks, by generating a chip-select ( $\overline{CS}$ ) signal. When an address is loaded onto the bus, the upper five address lines A15, A14, A13, A12 and A11 are asserted high or low depending on the address loaded. This enables the inputs of the decoder circuit (section 4.3.3), which in turn decodes the address and asserts the corresponding  $\overline{CS}$  pin low.

#### Program 2

Program 2 was used for testing the efficiency of data transfer within the data lines and confirm the correctness of the data bus wiring. Suitable hexadecimal numbers are loaded onto the accumulator, with all the data line being monitored using the display screen of the multi-channel analyser. The digital output is then compared to that of the data loaded. For a successful test the loaded data and the digital output should match as in table 5.1.

DATA LOADED	DATA LINE OUTPUT							
	D7	D6	D5	D4	D3	D2	D1	D0
00H	0	0	0	0	0	0	0	0
FFH	1	1	1	1	1	1	1	1
AAH	1	0	1	0	1	0	1	0
55H	0	1	0	1	0	1	0	1

Table 5.1 *Data Loaded And Expected Data Line Outputs*

### Program 3

Program 3 is similar to program 2, but tests the efficiency of the address transfer on the address bus. By writing to or reading from a memory location, all the address lines are monitored from the analyser to confirm that the digital output corresponds to the address of the particular memory location being accessed.

Some of the addresses used for the test and the corresponding digital output are shown in table 5.2.



ADDRESS LOADED	ADDRESS LINE OUTPUT			
	A15-A12	A11- A8	A7 - A4	A3 - A0
2555H	0 0 1 0	0 1 0 1	0 1 0 1	0 1 0 1
26AAH	0 0 1 0	0 1 1 0	1 0 1 0	1 0 1 0
1555H	0 0 0 1	0 1 0 1	0 1 0 1	0 1 0 1
0555H	0 0 0 0	0 1 0 1	0 1 0 1	0 1 0 1
ED55H	1 1 1 0	1 1 0 1	0 1 0 1	0 1 0 1
FDFDH	1 1 1 1	1 1 0 1	1 1 1 1	1 1 0 1
3555H	0 0 1 1	0 1 0 1	0 1 0 1	0 1 0 1
FCD2H	1 1 1 1	1 1 0 0	1 1 0 1	0 0 1 0

Table 5.2 *Address Loaded And Expected Address Line Outputs*

#### Program 4

Running this program causes the NPGFC signal generator circuit (section 4.3.5) to output a low pulse signal when the hexadecimal numbers FC00 to FCFF are valid on the address bus. In the event of a malfunction the signal is not sensed at the NPGFC pin of the 1MHz bus. This program also sets the R/W signals active depending on whether it is a read or write operation. The program is written such that it scans the entire address block FC00H to FCFFH with an interval of one second between scans.

## 5.4 EPROM PROGRAMMING

The EPROMs are programmed using a MQP model 18 eprom programmer. This is a high performance versatile PROM programmer which is controlled by a resident software package the PROM-DRIVER in the IBM host computer. Programming is done by fitting the EPROMs on a zero insertion (ZIF) socket. Using a menu, the MQP18 programmer is configured by selecting the type of EPROM to be programmed, file type, baud rate, data polarity and the file to read from. An automatic blankcheck is performed before the EPROM is programmed followed by checksum after programming. This verifies the program transfer to the EPROM relative to that on the file copied from.

The procedure involved to invoke the PROM software on the IBM computer using the hard carriage return represented as (CR) in order to activate the PROM programmer are as follows;

```
>cd applicat (CR)
c:\APPLICAT>cd prom (CR)
c:\APPLICAT\PROM>pd (CR)
```

A menu appears on the screen which by selecting the number representing the option required can activate that procedure.

## 5.5 PROGRAM OPERATION PROCEDURE

### 5.5.1 INVOKING ICEBOX SOFTWARE

ICEBOX is a Z-80 microprocessor series Assembler language program package developed by Noral micrologic systems with the IBM microcomputer as the host, using the following invocation procedures with a hard carriage return represented as (CR).

To invoke the test programs, the system is interfaced to the IBM computer via the In-Circuit Emulator then powered up. The Ice-Box Emulator LEDs turn on and both the system and emulator are ready for use. The screen of the IBM computer displays a menu from which the DOS (Disk Operating System ) option is selected. At this stage the emulator is activated by using the entries below;

```
>cd applicat (CR)
```

```
C:\APPLICAT>icebox (CR)
```

```
C:\APPLICAT\ICEBOX>icebox1 (CR)
```

The IBM computer will respond with the message;

```
Noral ICEbox> IBM-PC Interface version 2.0
```

```
(c) Copyright Noral Micrologics Ltd. 1987.
```

Entering a carriage return a menu appears on the screen from which the commands supported are;

```
Term [F1] Terminal emulation mode
```

```
DL [F2] Download (Tx) hex file
```

```
U Upload (Rx) hex file
```

```
QUIT Quit to operating system.
```

These are the emulator versions used during the period of

this work. At this stage the function key F1 is pressed choosing the Terminal emulation mode which in response the following message is displayed on the screen;

Enter Command>

The system and the emulator at this stage are ready for any communication. The program is then entered to the required memory area by typing;

M(address area) (CR)

The program is entered as hexadecimal object codes with a carriage return after each command.

Execution of the test programs is invoked by entering the command;

E (address area)

Downloading is done by typing;

D (CR)

File name:> (file name of data to be downloaded).

To Upload a file one has to specify the format in which the file is to be uploaded. By entering the following commands the data is uploaded in tektronics hexadecimal format;

U0 (CR)

U (starting address) (ending address) (CR)

Function key F1 (CR)

(name of file to be stored as) (CR)

### 5.5.2 INVOKING MS-WORKS

To invoke the data processing programs, the user executes the MSWORKS package within the IBM computer. This is done by using the following commands;

```
cd msworks (CR)
```

```
c:\MSWORKS>works (CR)
```

At these stage a menu appears on the screen which can be controlled with the microsoft mouse or the directional keys of the computer. Selecting O (CR) moves to the FILE EDIT menu with the following message displayed.

```
File to be opened [ *.* ..... ]
```

```
(file to be opened and the directory/ drive) (CR)
```

Selecting the file brings a sub-menu from which either the the option of word-processing, spreadsheet or database can be selected. The spreadsheet option is selected with the cursor pointed at the FORMAT sub-option. At this point the data is formatted for the type of graph to be drawn. The title fonts together with the graph labeling are set at this stage.

To invoke Chart drawing the direction key is directed to the View option, and Newchart sub-option selected the formatted data is then put to the chart as a piechart, x-y graph, barchart etc. which can be printed or saved in a floppy diskette for later use.

## CHAPTER 6: SYSTEM APPLICATION AND DATA ANALYSIS

### 6.1 INTRODUCTION

The system is designed to control the calorimeter and store collected data on its data storage RAM, before the data is transferred to a microcomputer system for analysis. Test measurements are performed using the system for verification purpose. The theoretical heating and cooling curves are as shown in figure 6.1.

This section discusses the process followed before and during data acquisition, whereby the system is used to control the operation of the calorimeter by sampling data on the variation of temperature with time for selected sample materials.

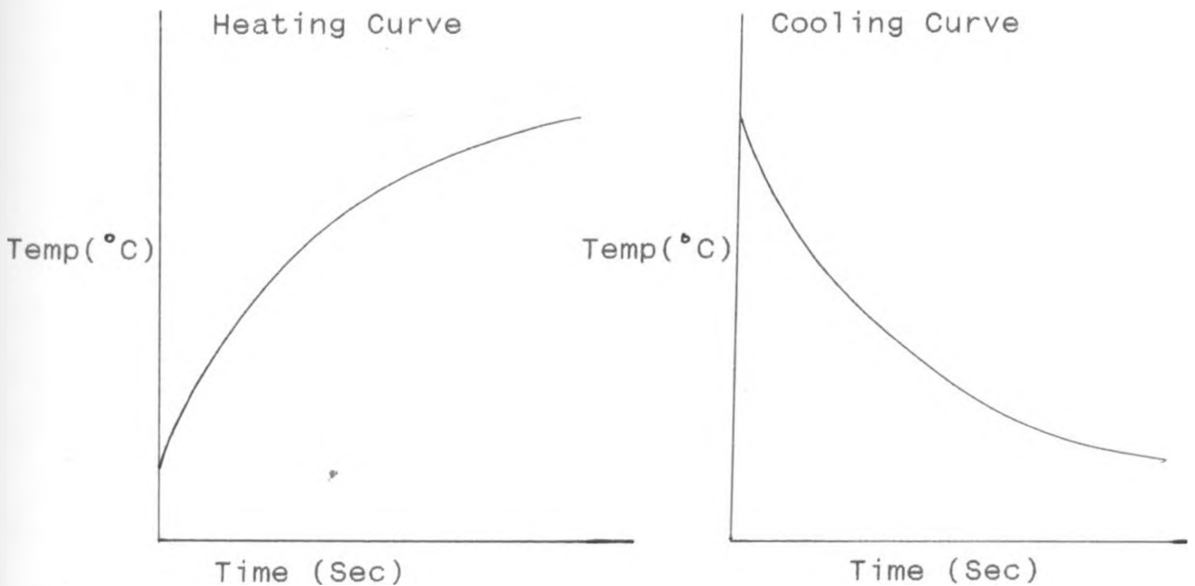


Figure 6.1  
Generalized Heating And Cooling Curves

## 6.2 SAMPLE PREPARATION

The samples on which data measurements are done are prepared from four different types of metals; Copper, steel, Brass and Aluminium. Each of these samples being cut into a square metal plate of sides measuring 50mm and of thickness 1.5mm. Two of each type of metal are prepared, one of which is coated with a black paint while the other is left uncoated.

To determine the temperature distribution of the metal plate, two thermocouple are embedded near the center of the surface of each plate. A dent punched on the plate forms a seat for the thermocouple junction as shown in figure 6.2

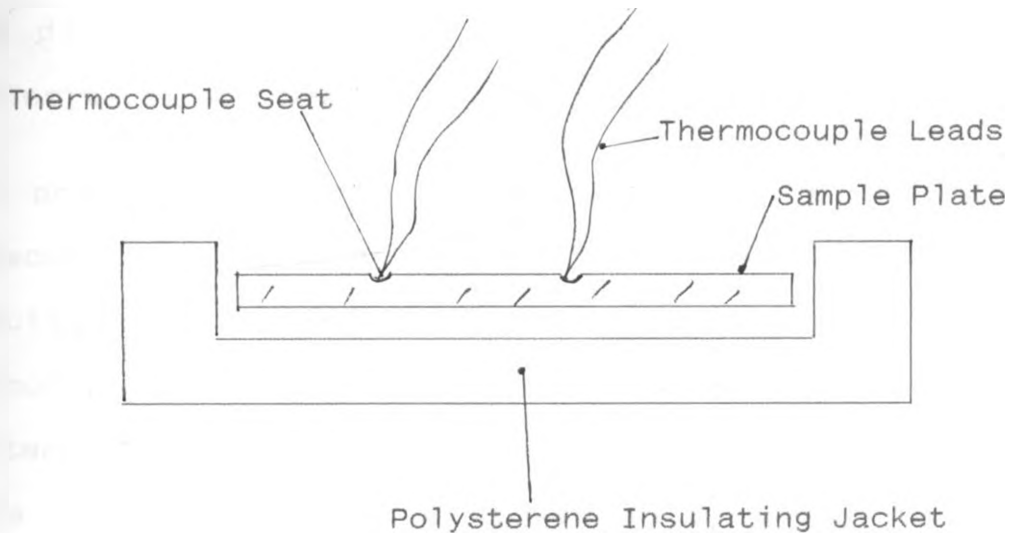


Figure 6.2 Thermocouples/Plate Junction

The thermocouples are fixed onto the plates by means of welding, using the UNITEX WELDER (section 2.3.4) to provide a good thermal contact between the thermocouple junction and the sample surface. This thermocouple/plate junction however causes a joint resistant which is not uniform in all plates by varies depending on the material of the plate used. Their outputs are connected to the signal amplifier of the calorimeter before being linked to the A/D converter.

### 6.3 DATA ACQUISITION

The sample under investigation is loaded on the expanded polystyrene insulating jacket on the sample holder of the calorimeter, then the microprocessor system is interfaced to the calorimeter via the 1MHz port. A table lamp light is directed on top of the shutter window of the calorimeter to simulate the sun rays for heating purposes.

On power ON the monitor program on the RAM starts execution and sends an open-window command which opens the shutter window. The interrupt circuit becomes active simultaneously, sending a signal after every 16 seconds to interrupt the CPU for data capture from the sample plate. The temperature data is stored in an array of memory locations.

The LEDs on the data acknowledge display unit blink every time data is captured and transmitted for storage. The process continues after every 16 seconds until one hundred



data samples have been acquired during the heating cycle. The close-window command is transmitted immediately after this, with the shutter window closing and sampling of data commencing for the cooling cycle.

On completion of data sampling for both heating and cooling cycle, the program sends a code that makes the LEDs on the data acknowledgment display circuit (Fig 4.15) to blink continuously, providing a visual indicator for the completion of data capture. The data collected is uploaded to a microcomputer system and stored on disk for analysis.

#### 6.4 DATA ANALYSIS

The equation derived and used by Mate(1980) to manipulate the collected data is used in this work for data analysis. This equation which governs the absorption of a quantity  $Q$  of heat energy from a radiating source whose intensity is  $I$  for a period of time  $\Delta t$  is given by:

$$Q = mc \frac{\Delta T}{\Delta t} + L(t) \dots \dots \dots (6.1)$$

Where  $m$  is the total mass of the sample

$c$  is the total heat capacity

$\Delta T$  is the temperature change produced

$L(t)$  is the loss temperature given by

$$L(t) = K(T - T_{\alpha}) \text{ where}$$

$T$  is the maximum temperature reached

$T_{\alpha}$  is the ambient temperature

$K$  is a constant

The total area of the sample capturing the radiation is give by  $A_m^2$  from which we can arrive at:

$$Q = IA\tau\alpha \dots \dots \dots (6.2)$$

where  $\alpha$  is the film absorptance

$\tau$  is the transmittance

Applying similar principals as those used by Kola(1990) et al, the absorption coefficient of the coated material can be obtained using equation 6.3 below.

$$\alpha_s = \alpha_r \left[ \frac{\left[ \left( \frac{\Delta T}{\Delta t_1} \right) - \left( \frac{\Delta T}{\Delta t_2} \right) \right]_s}{\left[ \left( \frac{\Delta T}{\Delta t_1} \right) - \left( \frac{\Delta T}{\Delta t_2} \right) \right]_r} \right] \dots \dots \dots (6.3)$$

$\alpha_s$  is the absorption coefficient of the coated sample  
 $\alpha_r$  is the absorption coefficient of the uncoated sample  
 $\Delta t_1$  is the time taken for the sample material to attain a temperature difference  $\Delta T$  during the heating cycle.  
 $\Delta t_2$  is the time taken for the sample material to attain a temperature difference  $\Delta T$  during the cooling cycle.

The respective heating and cooling curves obtained are shown in figure 6.3 to 6.10. The actual curves obtained using the system together with the corresponding tabulation are shown in appendix A and B.

To obtain the absorption of the samples material, each graph is plotted to have both the heating and cooling curves together, for each sample material. Two graphs, one for uncoated material and the other for the coated material sample are shown.

For Aluminium the graph for the uncoated sample (Figure 6.3) gives  $\Delta T=24.5^{\circ}\text{C}$ ,  $\Delta t_1=1300$  Seconds and  $\Delta t_2=1800$  Sec. While that of the black coated aluminium sample (Figure 6.4) gives  $\Delta T=27.5^{\circ}\text{C}$ ,  $\Delta t_1=1560$  Seconds and  $\Delta t_2=1800$  Seconds. Using  $\alpha_r$  (absorption coefficient) for pure aluminium to be 0.09 and applying equation 6.3,  $\alpha_s$  (absorption coefficient) for the black coated sample becomes 0.2006 which is a 123% increment.

The graph for uncoated Brass sample (Figure 6.5) gives  $\Delta T=23.7^{\circ}\text{C}$ ,  $\Delta t_1=1380$  Seconds and  $\Delta t_2=1800$  Seconds. For the black coated brass sample (figure 6.6)  $\Delta T=30.3^{\circ}\text{C}$ ,  $\Delta t_1=1400$  Seconds and  $\Delta t_2=1720$  Seconds. Fitting the variables in equation 6.3,  $\alpha_s$  for the coated brass sample is 0.243 which is an increment of 10.5% from  $\alpha_r=0.22$ .

Figure 6.7, the graph of the uncoated copper sample gives  $\Delta T=30^{\circ}\text{C}$ ,  $\Delta t_1=1400$  Seconds and  $\Delta t_2=1700$  Seconds. For the coated sample (figure 6.8)  $\Delta T=30^{\circ}\text{C}$ ,  $\Delta t_1=1440$  seconds and  $\Delta t_2=1600$  seconds. Similarly using equation 6.3,  $\alpha_s$  for the coated sample is 0.27 from 0.15 in it's pure state. This is a 80% increment to the absorptance due to the coating applied on the sample.

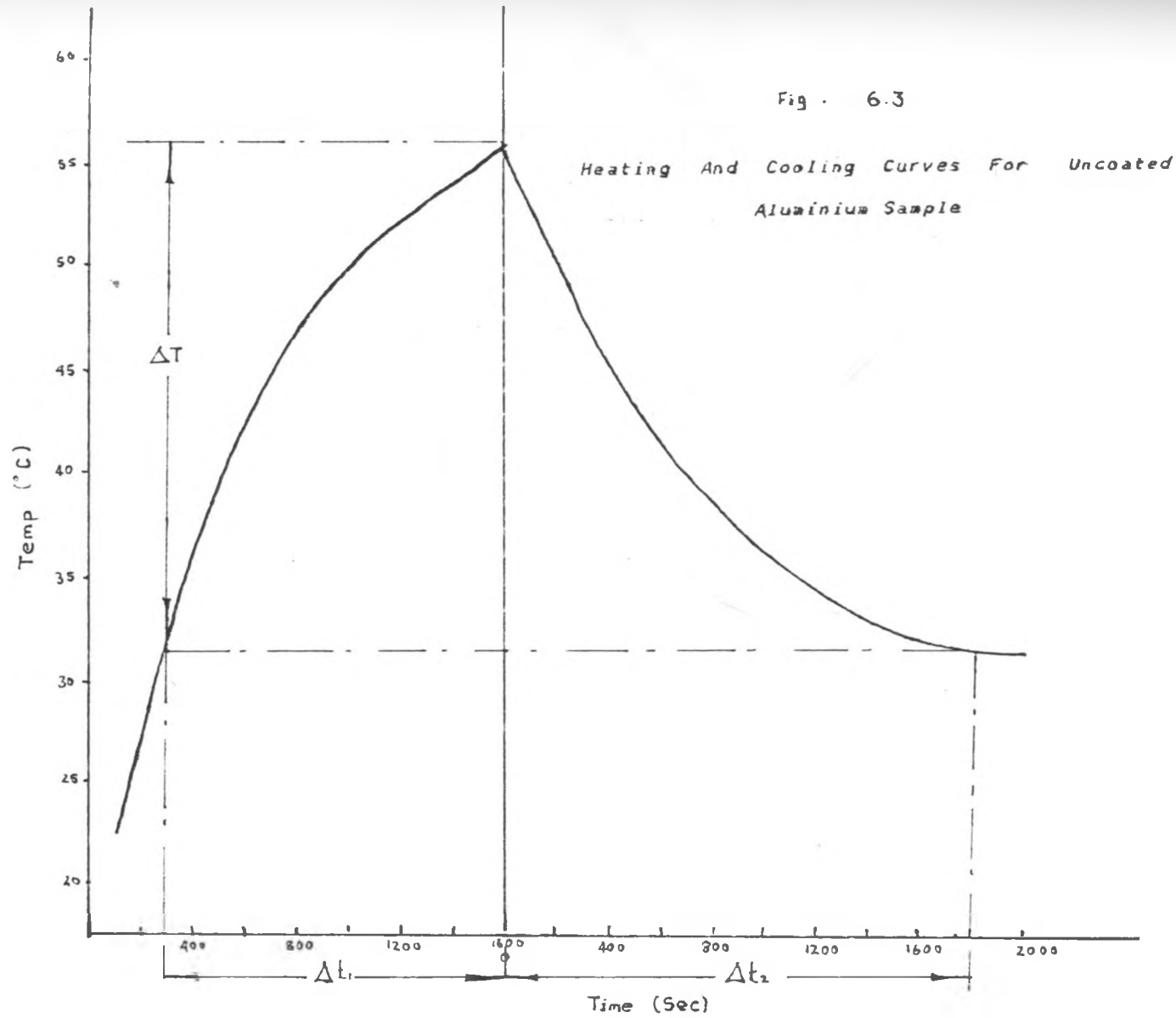
A similar treatment on the graphs of the uncoated and coated steel samples (Figure 6.9 and 6.10) gives the absorptance of the coated steel sample  $\alpha_s$  to be 0.67 from 0.66 of the pure unpolished steel. This in effect is an increment of 1.5% to the absorptance of the material, due

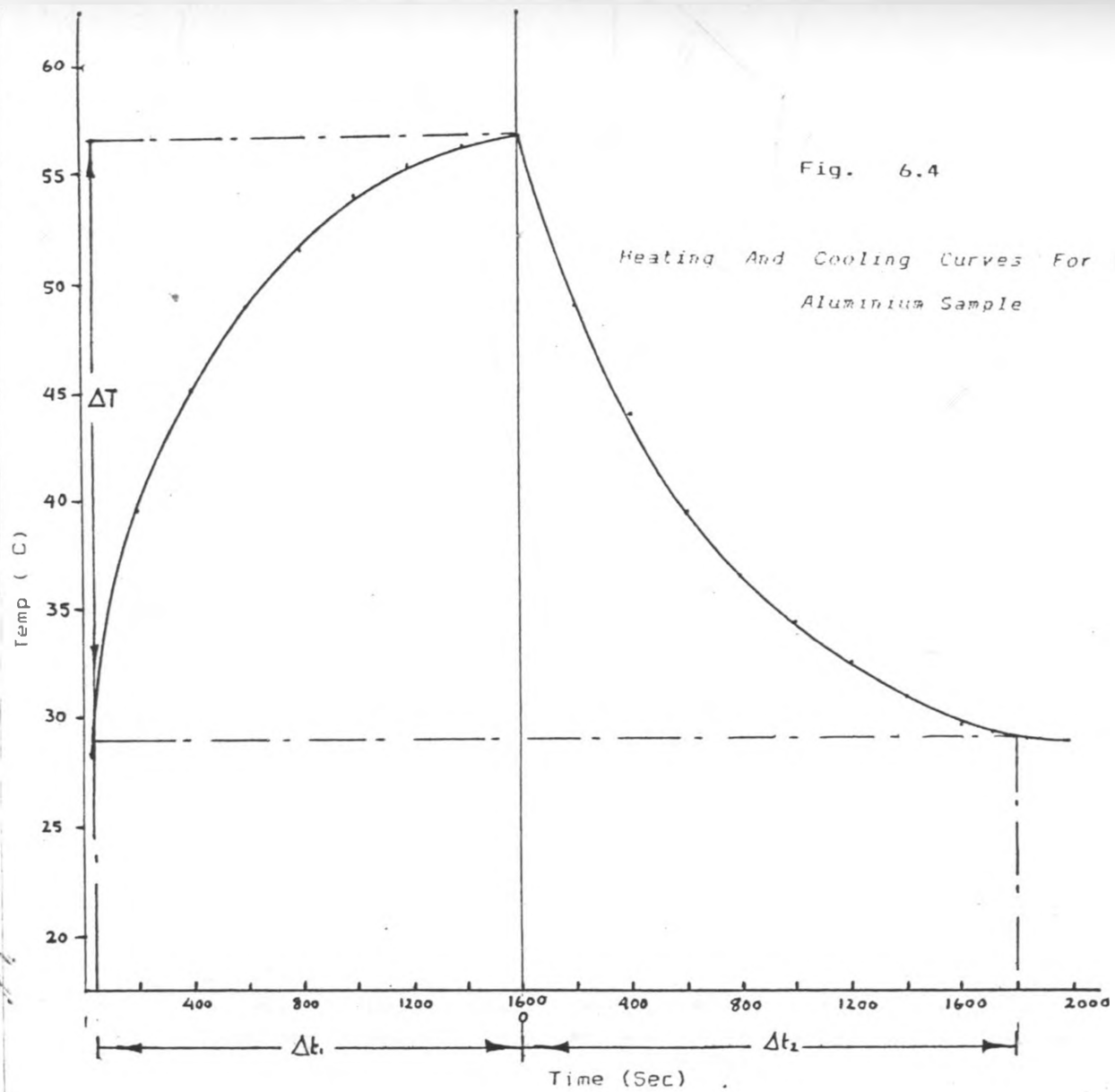
to the coating applied.

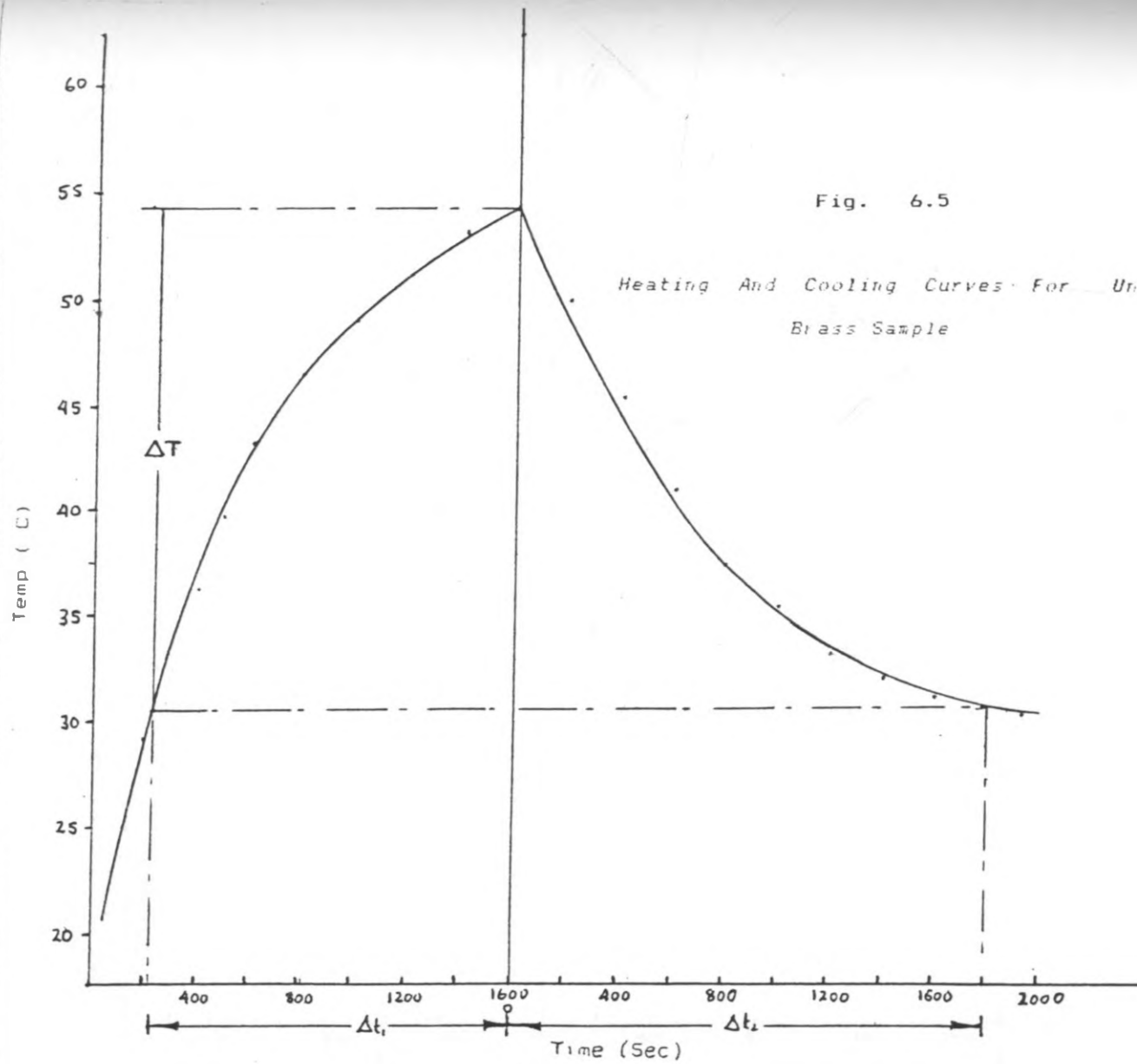
In general the black coating surface applied on the sample materials increases their absorptance. The steel sample is found to have a relatively low increment in its absorptance after the black coating is applied, due to the fact that the steel sample in its pure unpolished state has a natural gray/black coating on its surface hence the additional coating on its surface has a little effect on its absorptance as explained by Whitaker(1977).

In general the verification of the system is found to be successful, since the data obtained for the temperature profile as the thermocouple is exposed to thermal radiation shows a raise in temperature recorded as stored in the memory storage area of the system. A drop in temperature recorded is also observed as the sample plate cools during the cooling cycle.

The various absorption coefficients of the coated sample plates obtained vary depending on the material used. The absorption coefficient of the Aluminium sample is found to increase by a factor of 123% when coated, while that of copper increases by 80% followed by brass with 10.5% then steel with 1.5% . This variation of absorption coefficients as recorded by the system verify that it can be used to determine the most suitable coated material for use in solar collectors.







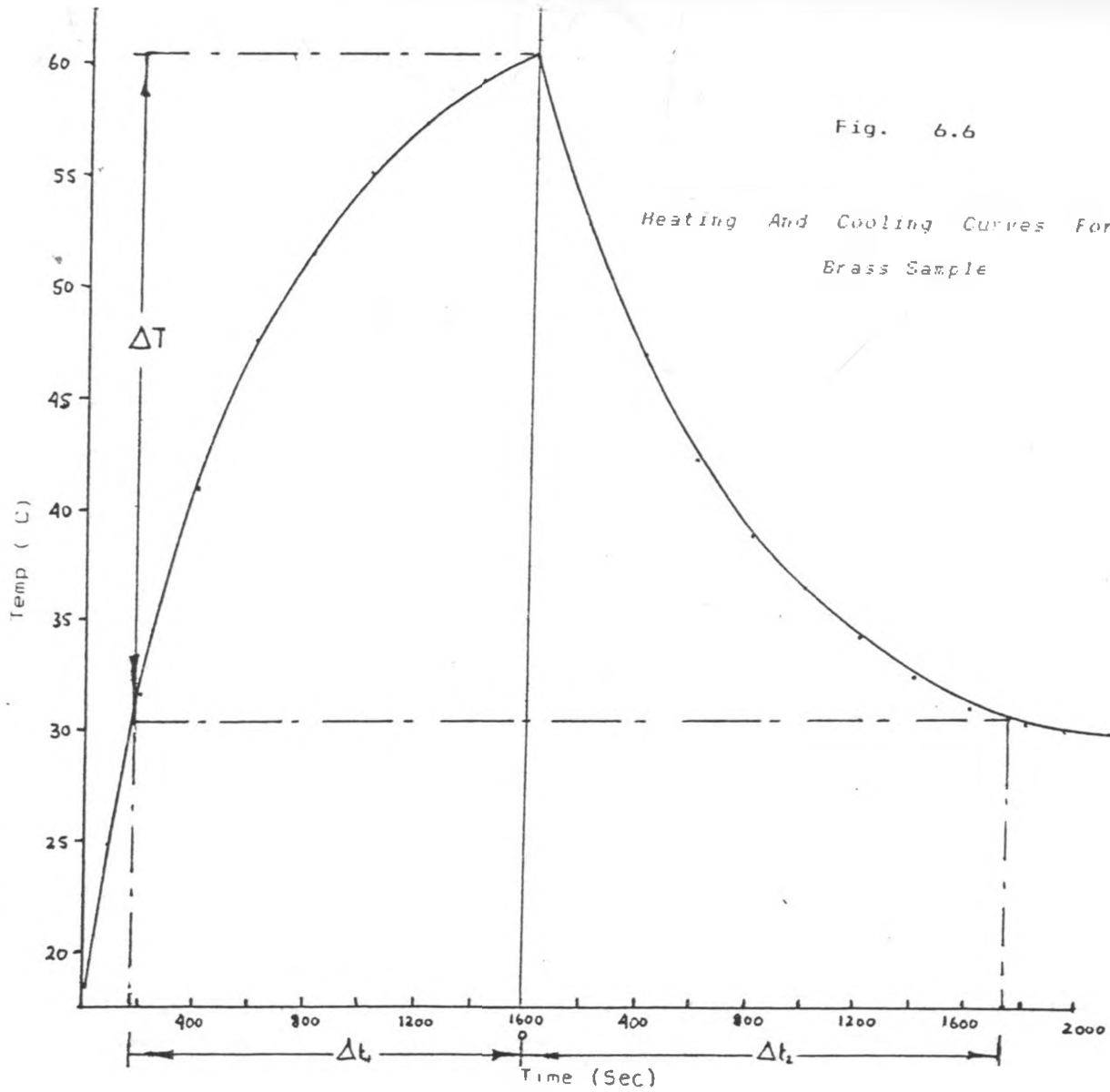
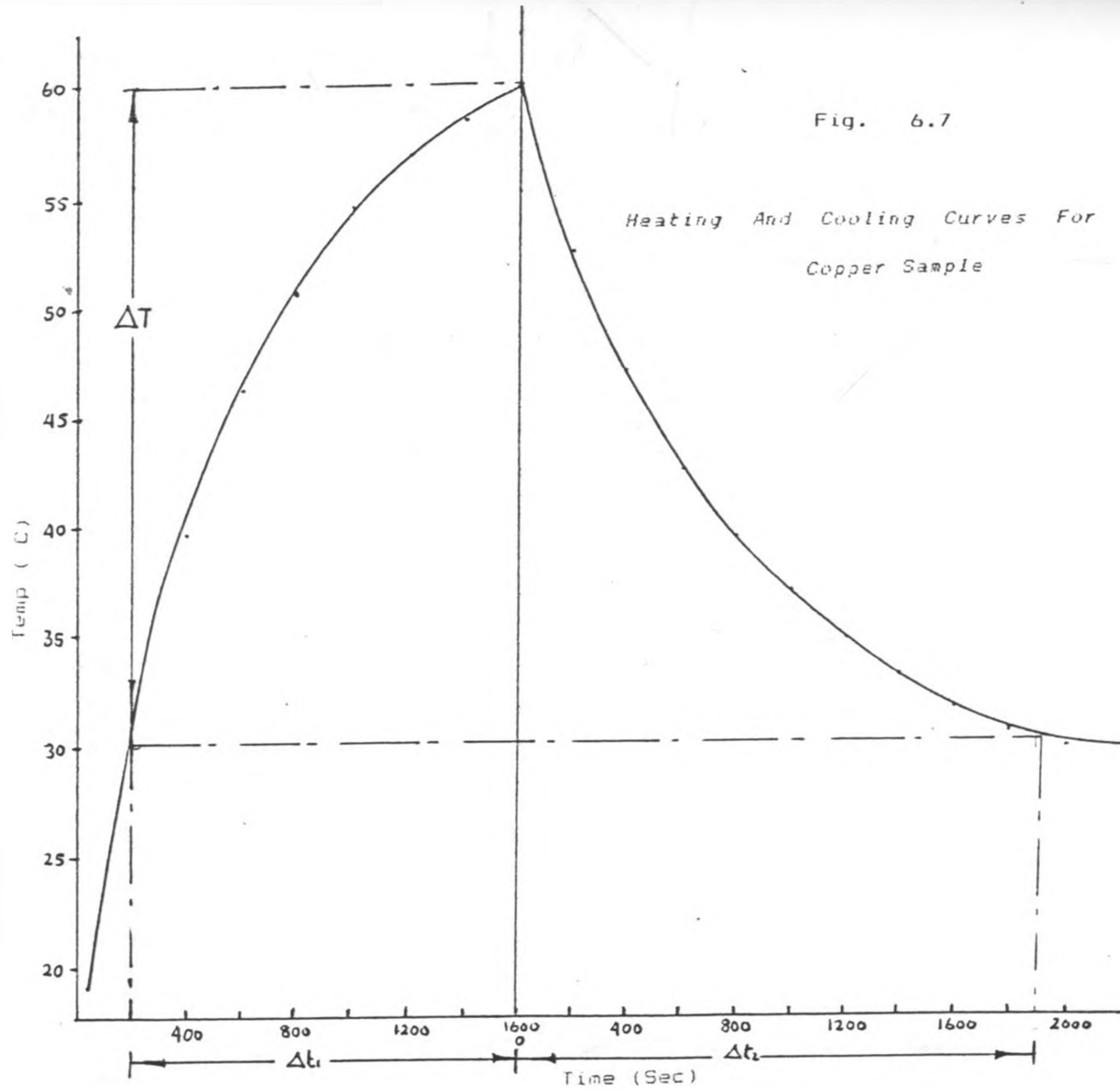


Fig. 6.6

Heating And Cooling Curves For Coated Brass Sample





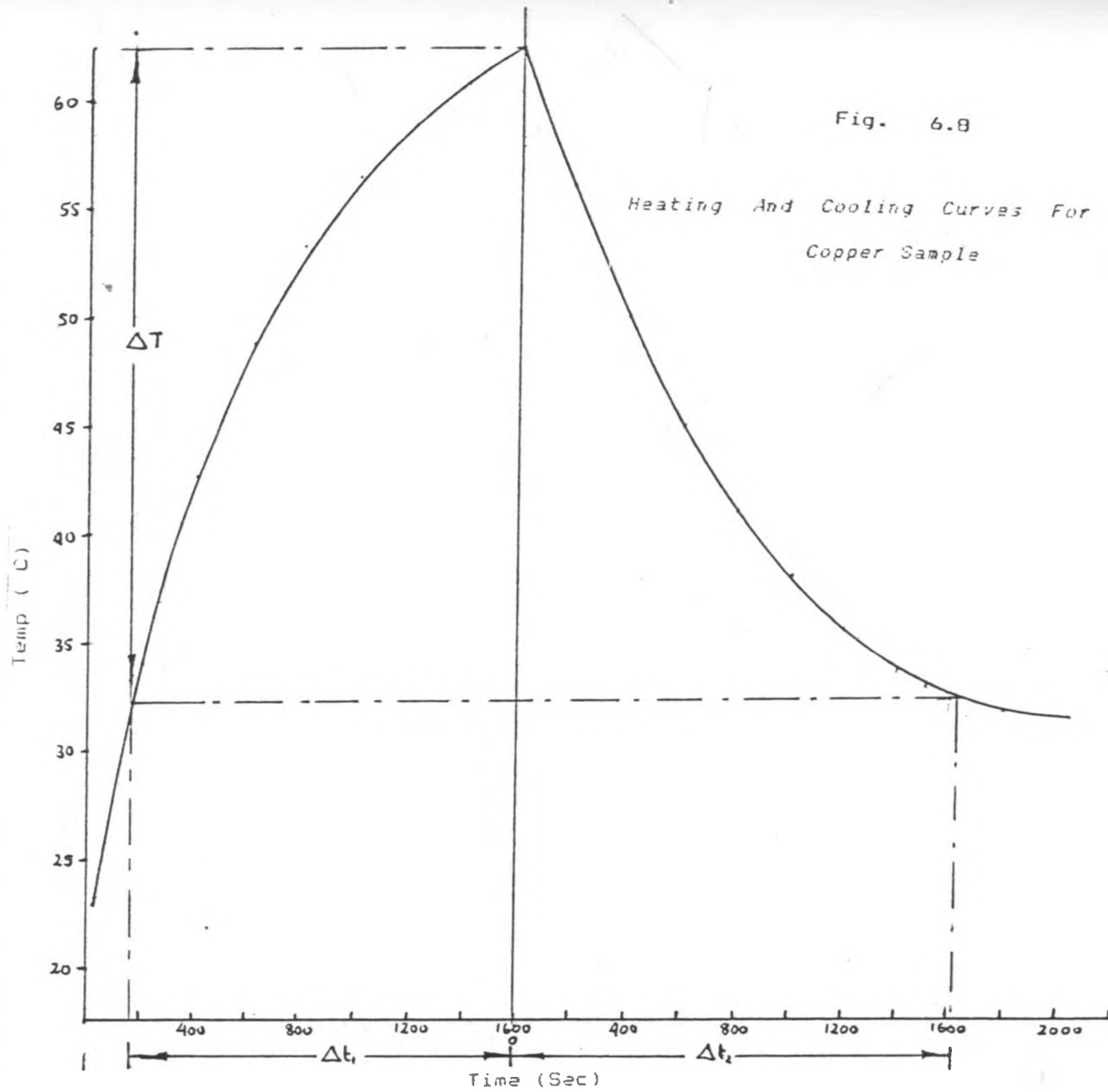


Fig. 6.8

Heating And Cooling Curves For Coated Copper Sample

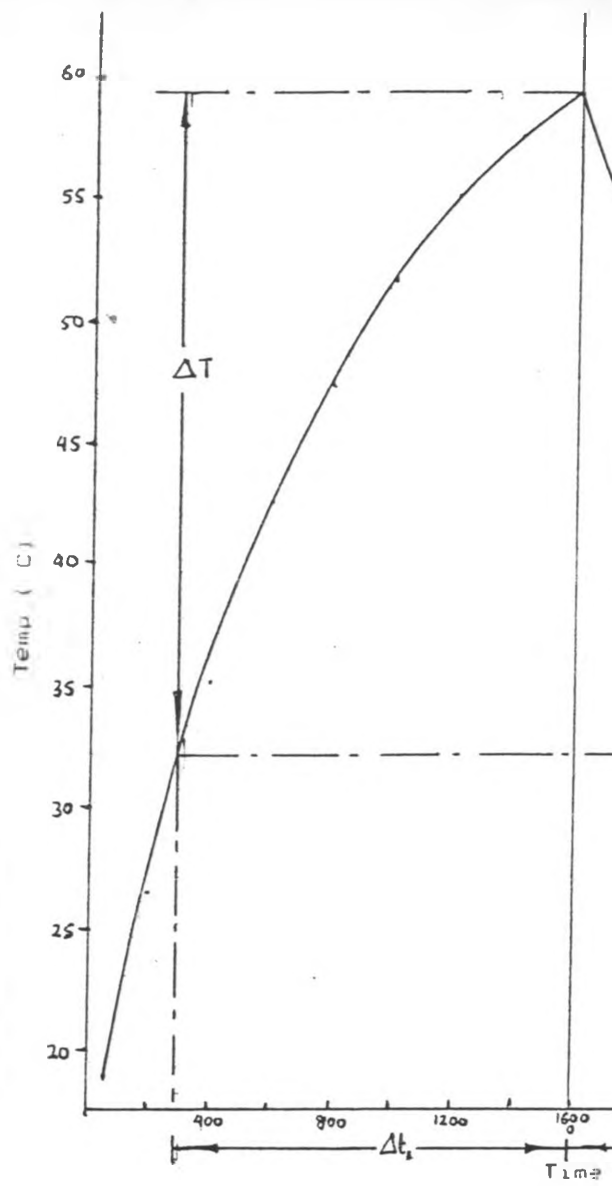
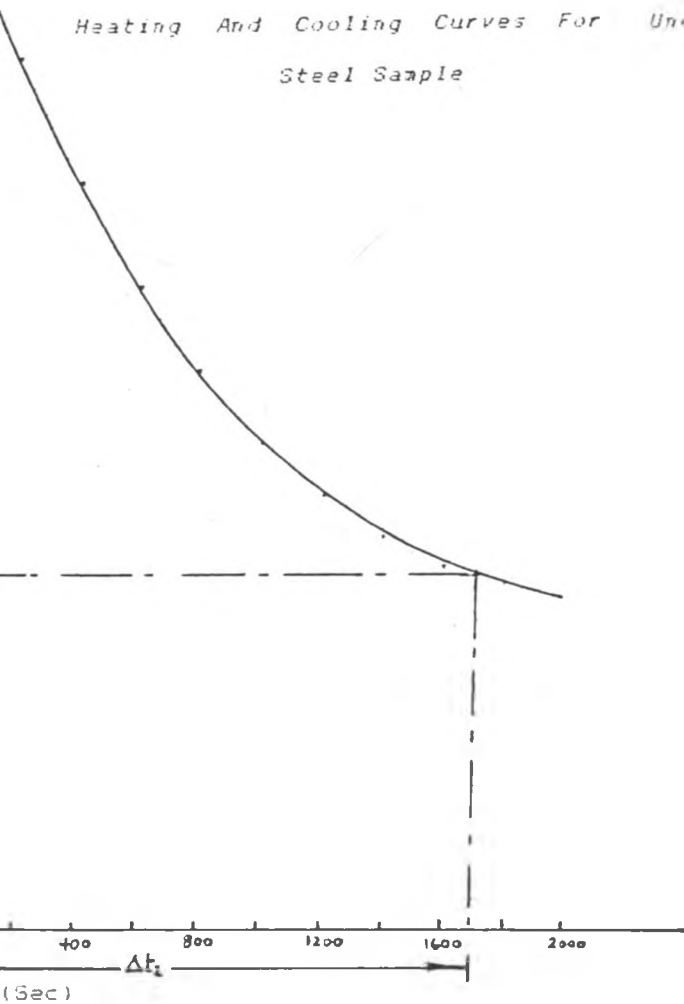


Fig. 6.9

Heating And Cooling Curves For Uncoated  
Steel Sample



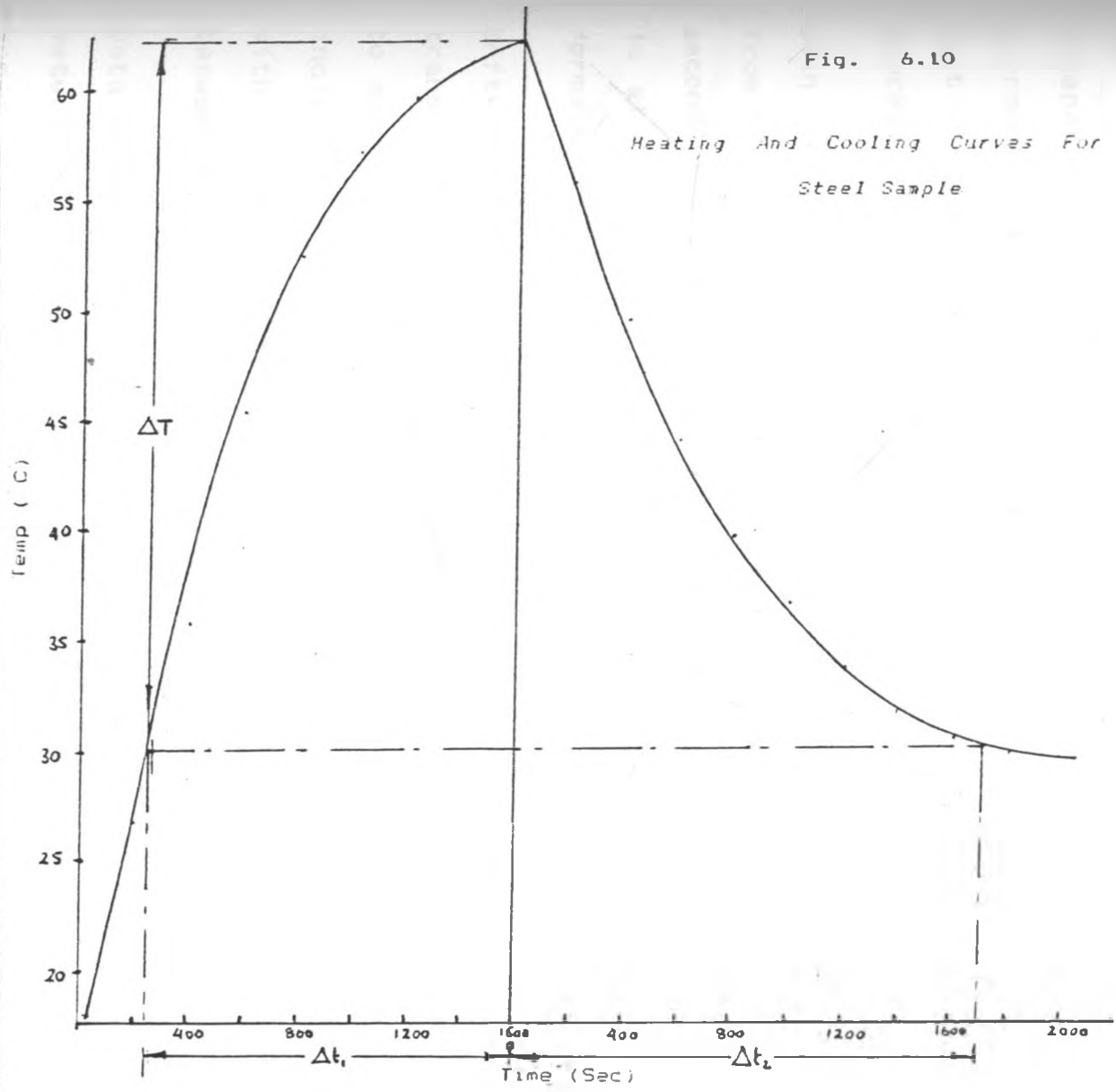


Fig. 6.10

Heating And Cooling Curves For Coated Steel Sample

## CHAPTER 7: CONCLUSION AND FUTURE WORK

### 7.1 CONCLUSION

A microprocessor system has been developed which utilizes the Z-80A CPU to meet the requirements of controlling the thermal Absorption Calorimeter.

The system is designed to work effectively either as an independent system or as an interface to the IBM PS/2 microcomputer via an In-Circuit Emulator. It incorporates most of the Z-80 CPU features and static RAMs for data storage.

With the system clock running at 2MHz, data is captured from the sample plates linked to the calorimeter every 16 seconds and transmitted to the data storage area where it is stored in different memory locations in an array format.

Software control procedures have been developed which transmit codes to the calorimeter for the shutter window to open and close as required. Additional hardware is included in the calorimeter set-up to provide the user with visual indications of the data transfer processes between the calorimeter and the data storage board.

Data sampling of different uncoated and black painted materials have been attempted to illustrate the system's applicability. The heating and cooling curves of the selected samples have been presented and absorption coefficients of the coated samples determined. Results

obtained by Mate(1980) using a conventional microcomputer to control the Calorimeter for various metal sampling, are found to be within the same limits as obtained by the microprocessor system. For the copper sample, results obtained by Mate(1980) give the absorption coefficient of the coated sample  $s$  to be 0.25 which is a 71% increment as compared to a 80% increment obtained using the microprocessor controlled system.

The aluminium sample results by Mate(1980) give the absorption coefficient of the coated sample  $s$  as 0.24 which is a 140% increment as compared to a 123% increment obtained in this work. Mate(1980) does not however analyse the Brass sample and steel samples.

The resulting differences can be explained as being caused by the different modes of data sampling times. When using the microcomputer to control the Calorimeter, the internal computer clock is used. The timing of an event can be stopped by a software command running at the same computer speed. In this work the time sampling is done by an interrupt circuit which utilizes the 555 timer IC. The circuitry involves passive components whose characteristic vary due to any temperature raise, a change which would also affect the anticipated preset time value.

The other major cause of differences in the results is due to the type of coating used. In this work the sample plates are coated with a G.P Matt Black paint, while

Mate(1980) uses black soot which in comparison to the black paint has lower reflective properties and more uneven surface topography than the brush painted samples.

The thermocouple/sample plate joint resistant can also be described to be a factor which plays a role in the differences of the results obtained. Unlike in Mate's(1980) work where the thermocouples are attached to the sample plate by means of a special glue, in this work the thermocouple is fused onto the sample plate to form a homogeneous joint. These joints are characterized by a joint resistant which varies from plate to plate depending on the material of the sample plate. Due to this, the temperature gradient of a particular sample plate varies on the way the thermocouples are joined onto the sample plates. Increasing or lowering the gradient of the temperature-time profile affects the results of the absorption coefficient. A value which is obtained by using this gradient.

## 7.2 FUTURE WORK

The microprocessor system has a potential of covering the entire 64 Kbytes of ROM/RAM, of which only 0.3 Kbytes of the 8 Kbytes of ROM is used by the system monitor program. An increase in the system applicability can be achieved in expanding the system hardware by adding a alpha-numeric keyboard in which various program routines can be called for execution using the system keypad. This would include writing a keyboard scan program within the system monitor



program. The program would enable the user to set the time duration between data capture and the number of data sampling required depending on the nature of data to be sampled.

The system at present, utilizes a preset time of 16 seconds between each data sampling. This would require the user to change the data storage routine in the system monitor should there be need for the interval to be altered. An on-board keypad would set the time interval between the reset pulses within the software.

To support the storage of the data sampled, a DMA controller can be implemented to facilitate the transfer of data from the system to the host computer memory without the need to use an In-Circuit Emulator. Alternatively, the extra unused ROM area can be used to develop diskdrive control programs enabling an interface of a diskdrive directly to the system. This would also call for the developing of a diskdrive interface circuit for the system.

When sampling data during the heating cycle, the shutter window is normally open and therefore apart from radiative heat energy, there are some conventional heat losses such as due to the air flow on the window opening. Unlike this, the cooling cycle takes place when the shutter window is closed. The already accumulated heat is trapped inside the calorimeter enclosure to restrict the cooling of the

sample plate. There is a need to develop the calorimeter encasement such that there is some ventilation within the enclosure for some air flow to almost counterbalance the air flow when the shutter window is open during the heating cycle. Alternatively there may be need to work out correction procedures to normalize the data.

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APPENDIX A

DATA TABULATION AND GRAPHS FOR  
THE UNCOATED SAMPLES.

TABLE 1  
 DATA OF THE HEATING CURVE FOR  
 UNCOATED ALUMINIUM

CONT/..

TIME (Sec)	TEMP(C)
16.00	21.23
32.00	21.23
48.00	21.23
64.00	23.39
80.00	23.39
96.00	25.12
112.00	25.12
128.00	26.85
144.00	26.85
160.00	28.58
176.00	28.58
192.00	30.31
208.00	30.31
224.00	31.61
240.00	31.61
256.00	32.91
272.00	32.91
288.00	33.78
304.00	34.21
320.00	35.51
336.00	35.51
352.00	36.37
368.00	36.37
384.00	37.24
400.00	37.24
416.00	38.10
432.00	38.10
448.00	39.40
464.00	39.40
480.00	40.27
496.00	40.27
512.00	41.57
528.00	41.57
544.00	42.00
560.00	42.00
576.00	42.86
592.00	42.86
608.00	43.73
624.00	43.73
640.00	44.16
656.00	44.16
672.00	44.16
688.00	44.59
704.00	45.03
720.00	45.46
736.00	45.46
752.00	45.46
768.00	45.89
784.00	45.89
800.00	47.19

TIME (Sec)	TEMP(C)
816.00	49.36
832.00	49.36
848.00	49.36
864.00	49.36
880.00	49.36
896.00	49.79
912.00	49.79
928.00	51.09
944.00	51.09
960.00	51.09
976.00	51.09
992.00	51.09
1008.00	51.09
1024.00	51.95
1040.00	51.95
1056.00	52.38
1072.00	52.38
1088.00	52.38
1104.00	52.38
1120.00	51.95
1136.00	51.95
1152.00	52.38
1168.00	52.82
1184.00	53.68
1200.00	53.68
1216.00	53.68
1232.00	53.68
1248.00	53.68
1264.00	53.68
1280.00	54.55
1296.00	54.55
1312.00	54.55
1328.00	54.55
1344.00	54.98
1360.00	54.98
1376.00	55.41
1392.00	55.85
1408.00	55.41
1424.00	55.41
1440.00	55.85
1456.00	55.85
1472.00	55.85
1488.00	55.85
1504.00	55.85
1520.00	56.28
1536.00	56.28
1552.00	56.28
1568.00	56.28
1584.00	56.28
1600.00	56.71



Heating Curve for Anodized Aluminum

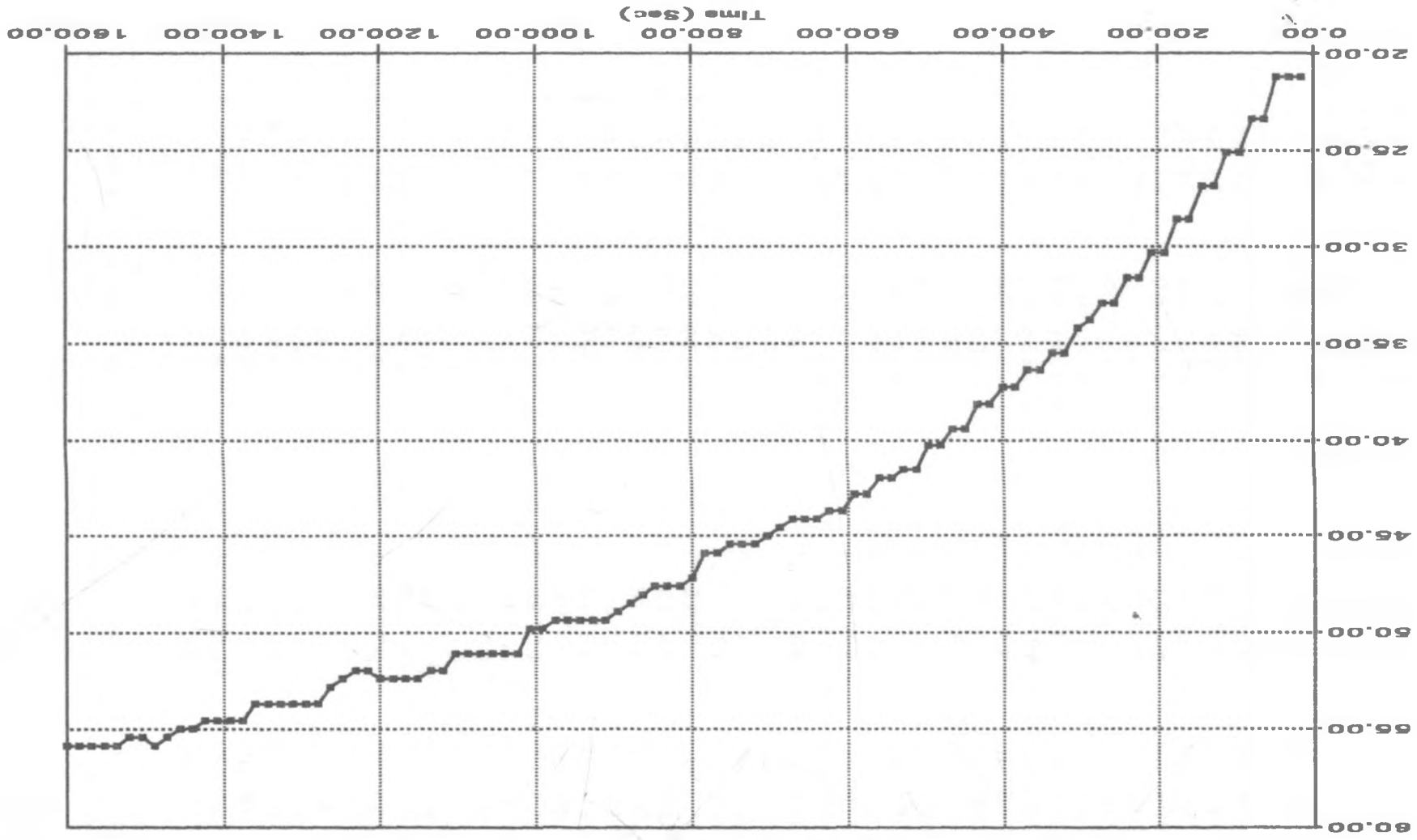


TABLE 2

DATA OF THE COOLING CURVE FOR  
UNCOATED ALUMINIUM

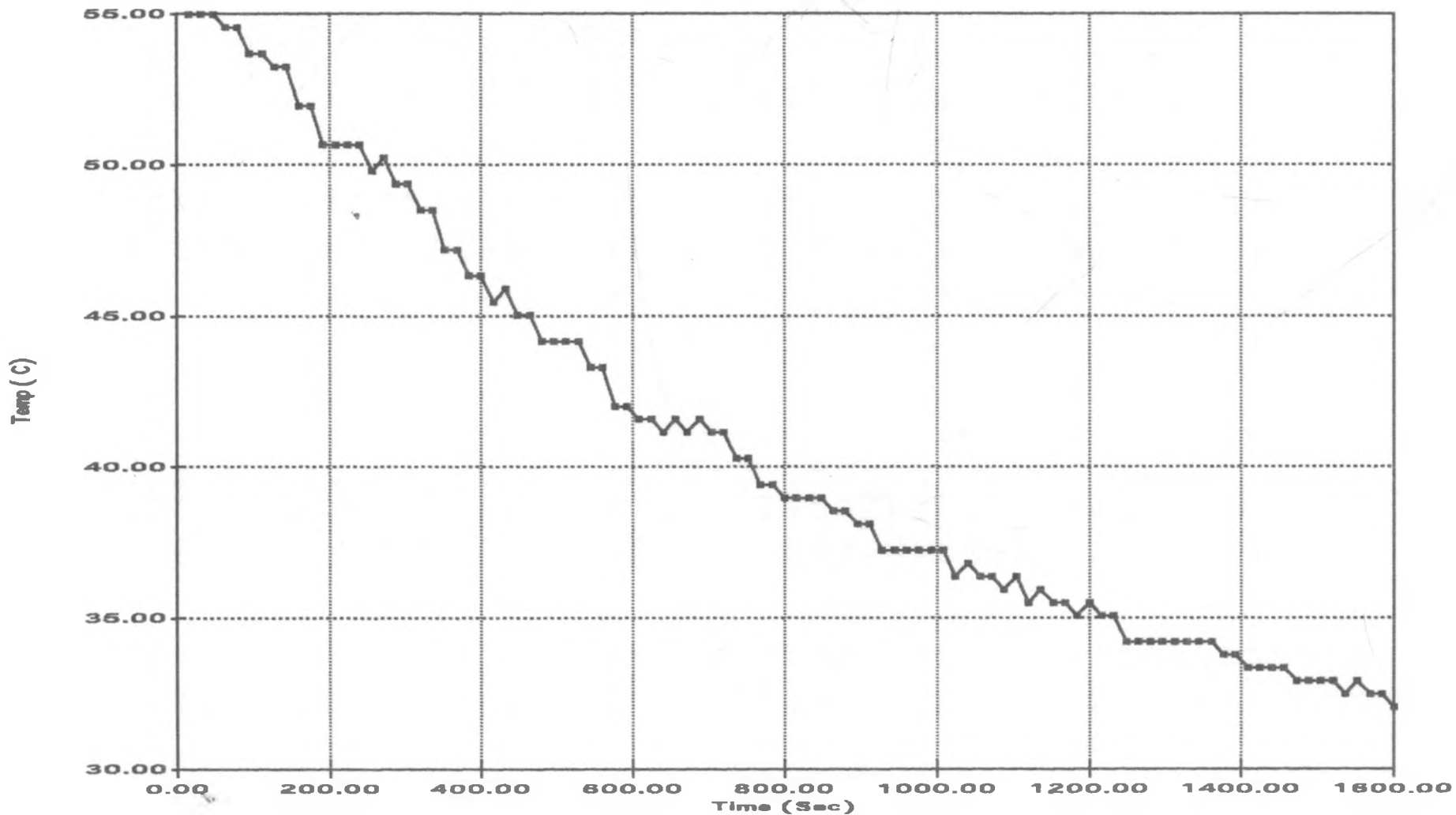
CONT/..

TIME (Sec)	TEMP(C)
16.00	54.98
32.00	54.98
48.00	54.98
64.00	54.55
80.00	54.55
96.00	53.68
112.00	53.68
128.00	53.25
144.00	53.25
160.00	51.95
176.00	51.95
192.00	50.65
208.00	50.65
224.00	50.65
240.00	50.65
256.00	49.79
272.00	50.22
288.00	49.36
304.00	49.36
320.00	48.49
336.00	48.49
352.00	47.19
368.00	47.19
384.00	46.33
400.00	46.33
416.00	45.46
432.00	45.89
448.00	45.03
464.00	45.03
480.00	44.16
496.00	44.16
512.00	44.16
528.00	44.16
544.00	43.30
560.00	43.30
576.00	42.00
592.00	42.00
608.00	41.57
624.00	41.57
640.00	41.13
656.00	41.57
672.00	41.13
688.00	41.57
704.00	41.13
720.00	41.13
736.00	40.27
752.00	40.27
768.00	39.40
784.00	39.40
800.00	38.97

TIME (Sec)	TEMP(C)
816.00	38.97
832.00	38.97
848.00	38.97
864.00	38.54
880.00	38.54
896.00	38.10
912.00	38.10
928.00	37.24
944.00	37.24
960.00	37.24
976.00	37.24
992.00	37.24
1008.00	37.24
1024.00	36.37
1040.00	36.81
1056.00	36.37
1072.00	36.37
1088.00	35.94
1104.00	36.37
1120.00	35.51
1136.00	35.94
1152.00	35.51
1168.00	35.51
1184.00	35.07
1200.00	35.51
1216.00	35.07
1232.00	35.07
1248.00	34.21
1264.00	34.21
1280.00	34.21
1296.00	34.21
1312.00	34.21
1328.00	34.21
1344.00	34.21
1360.00	34.21
1376.00	33.78
1392.00	33.78
1408.00	33.34
1424.00	33.34
1440.00	33.34
1456.00	33.34
1472.00	32.91
1488.00	32.91
1504.00	32.91
1520.00	32.91
1536.00	32.48
1552.00	32.91
1568.00	32.48
1584.00	32.48
1600.00	32.04

# Cooling Curve For Uncoated Aluminium

Temp Vs Time



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TABLE 5  
 DATA OF THE HEATING CYCLE FOR  
 UNCOATED BRASS

CONT/..

TIME (Sec)	TEMP(C)
16.00	21.23
32.00	22.09
48.00	22.52
64.00	23.39
80.00	23.39
96.00	25.12
112.00	25.12
128.00	26.42
144.00	26.85
160.00	28.58
176.00	28.58
192.00	29.45
208.00	29.45
224.00	31.18
240.00	31.18
256.00	32.04
272.00	32.04
288.00	33.34
304.00	33.34
320.00	34.64
336.00	34.64
352.00	35.51
368.00	35.51
384.00	36.37
400.00	36.37
416.00	37.24
432.00	37.24
448.00	37.24
464.00	38.10
480.00	39.40
496.00	39.83
512.00	40.70
528.00	40.70
544.00	42.00
560.00	42.00
576.00	42.43
592.00	42.43
608.00	43.30
624.00	43.30
640.00	44.30
656.00	43.30
672.00	44.16
688.00	44.16
704.00	44.59
720.00	45.03
736.00	45.03
752.00	45.46
768.00	45.89
784.00	45.89
800.00	46.76

TIME (Sec)	TEMP(C)
816.00	46.76
832.00	47.62
848.00	47.62
864.00	48.92
880.00	48.92
896.00	48.92
912.00	48.92
928.00	48.49
944.00	48.49
960.00	49.36
976.00	49.36
992.00	49.36
1008.00	48.92
1024.00	49.79
1040.00	50.22
1056.00	50.22
1072.00	50.22
1088.00	49.79
1104.00	50.22
1120.00	50.22
1136.00	50.65
1152.00	51.09
1168.00	51.09
1184.00	51.09
1200.00	51.09
1216.00	51.52
1232.00	51.95
1248.00	51.95
1264.00	51.52
1280.00	52.38
1296.00	52.38
1312.00	51.95
1328.00	51.95
1344.00	52.38
1360.00	52.38
1376.00	52.82
1392.00	52.82
1408.00	53.25
1424.00	53.68
1440.00	52.82
1456.00	52.82
1472.00	54.12
1488.00	54.12
1504.00	53.68
1520.00	54.12
1536.00	53.68
1552.00	53.68
1568.00	54.55
1584.00	54.55
1600.00	54.12

Temp (C)

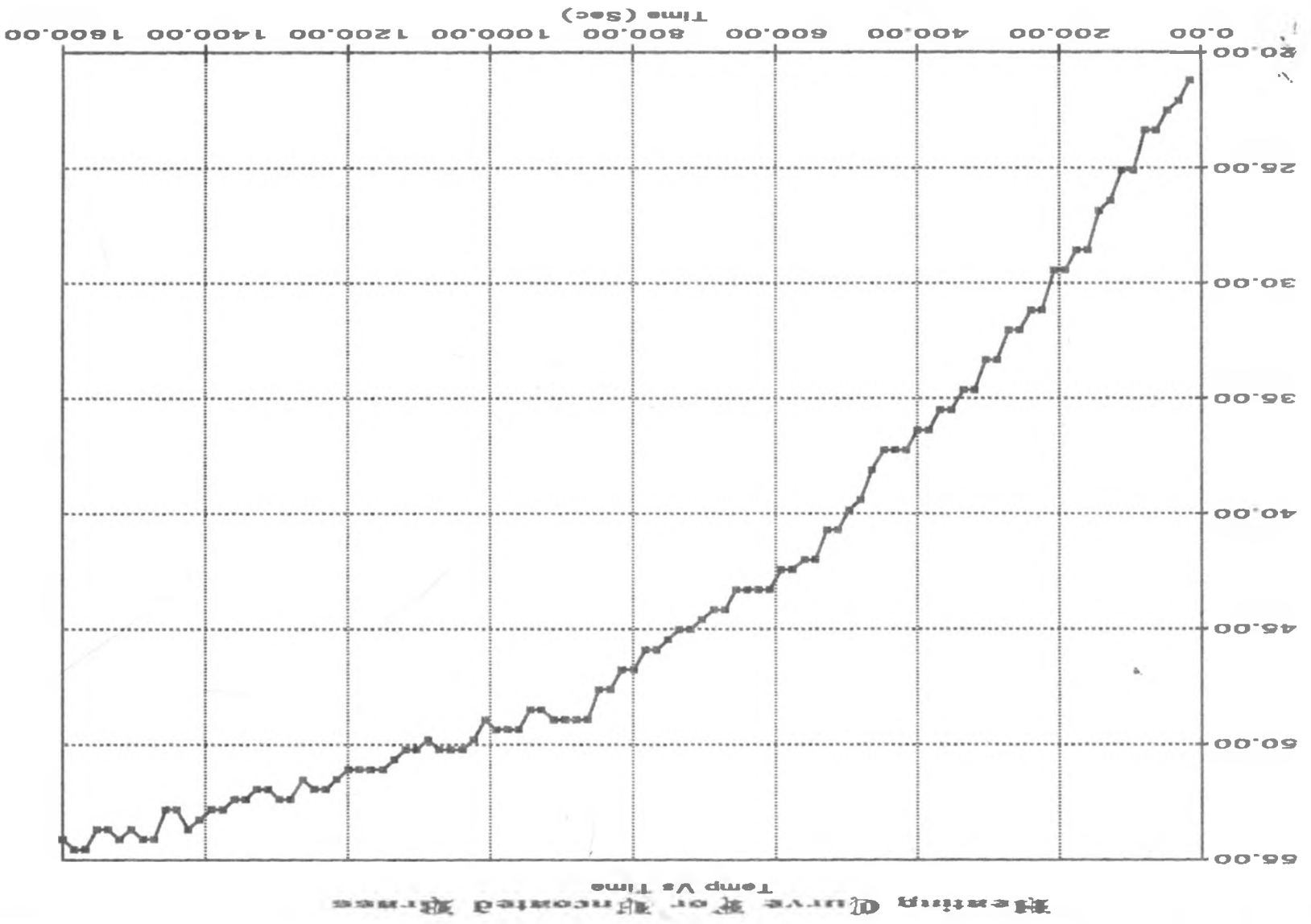


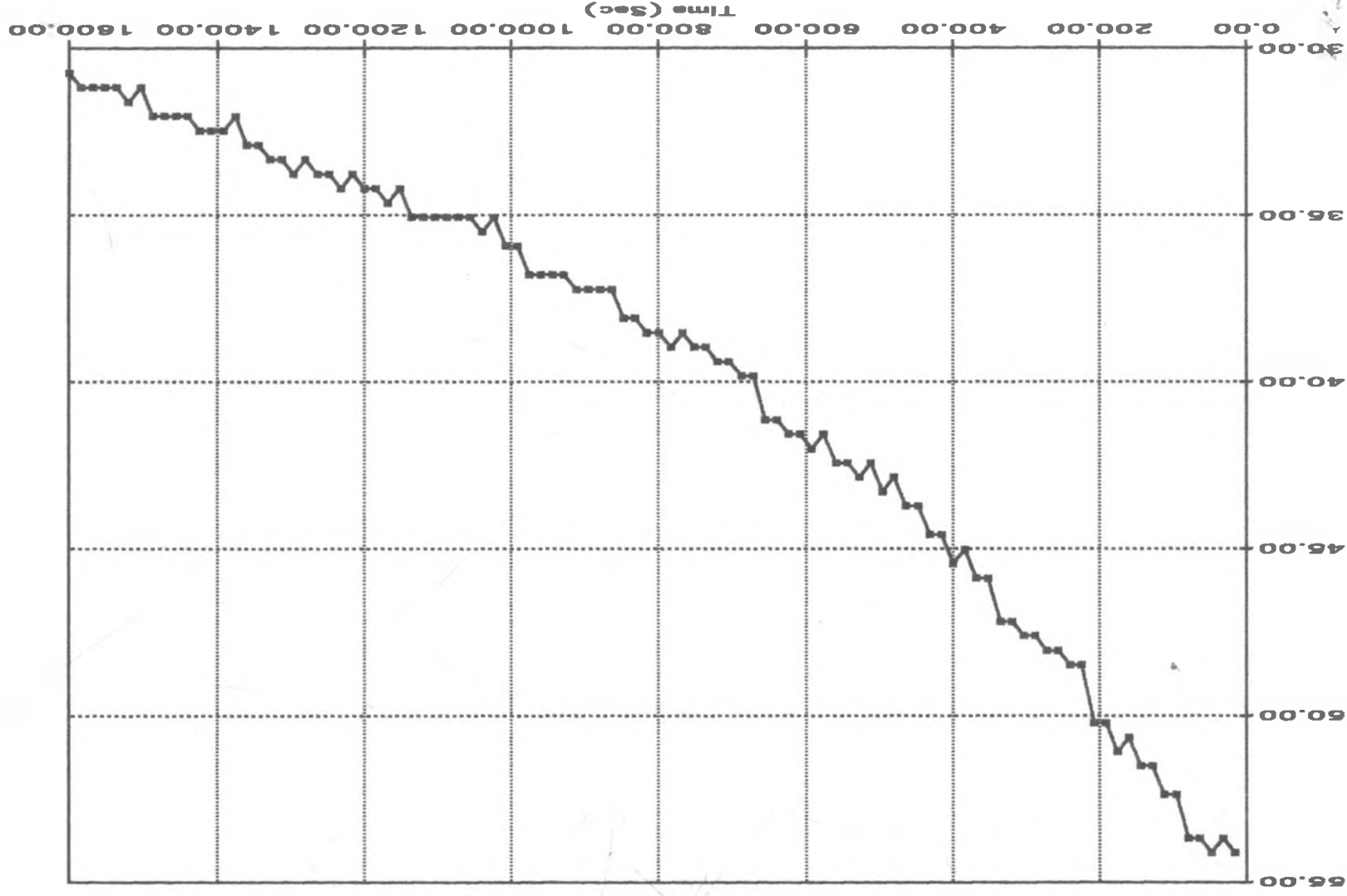
TABLE 6  
 DATA OF THE COOLING CYCLE FOR  
 UNCOATED BRASS

CONT/..

TIME (Sec)	TEMP(C)
16.00	54.12
32.00	53.68
48.00	54.12
64.00	53.68
80.00	53.68
96.00	52.38
112.00	52.38
128.00	51.52
144.00	51.52
160.00	50.65
176.00	51.09
192.00	50.22
208.00	50.22
224.00	48.49
240.00	48.49
256.00	48.06
272.00	48.06
288.00	47.62
304.00	47.62
320.00	47.19
336.00	47.19
352.00	45.89
368.00	45.89
384.00	45.03
400.00	45.46
416.00	44.59
432.00	44.59
448.00	43.73
464.00	43.73
480.00	42.86
496.00	43.30
512.00	42.43
528.00	42.86
544.00	42.43
560.00	42.43
576.00	41.57
592.00	42.00
608.00	41.57
624.00	41.57
640.00	41.13
656.00	41.13
672.00	39.83
688.00	39.83
704.00	39.40
720.00	39.40
736.00	38.97
752.00	38.97
768.00	38.54
784.00	38.97
800.00	38.54

TIME (Sec)	TEMP(C)
816.00	38.54
832.00	38.10
848.00	38.10
864.00	37.24
880.00	37.24
896.00	37.24
912.00	37.24
928.00	36.81
944.00	36.81
960.00	36.81
976.00	36.81
992.00	35.94
1008.00	35.94
1024.00	35.07
1040.00	35.51
1056.00	35.07
1072.00	35.07
1088.00	35.07
1104.00	35.07
1120.00	35.07
1136.00	35.07
1152.00	34.21
1168.00	34.64
1184.00	34.21
1200.00	34.21
1216.00	33.78
1232.00	34.21
1248.00	33.78
1264.00	33.78
1280.00	33.34
1296.00	33.78
1312.00	33.34
1328.00	33.34
1344.00	32.91
1360.00	32.91
1376.00	32.04
1392.00	32.48
1408.00	32.48
1424.00	32.48
1440.00	32.04
1456.00	32.04
1472.00	32.04
1488.00	32.04
1504.00	31.18
1520.00	31.61
1536.00	31.18
1552.00	31.18
1568.00	31.18
1584.00	31.18
1600.00	30.75

Temp (C)



Cooling Curve for Unidentified Brass

TABLE 9  
 DATA OF THE HEATING CYCLE FOR  
 UNCOATED COPPER SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	19.93
32.00	21.66
48.00	21.66
64.00	23.39
80.00	23.39
96.00	25.99
112.00	25.99
128.00	27.72
144.00	27.72
160.00	29.02
176.00	29.45
192.00	30.31
208.00	30.31
224.00	32.48
240.00	32.48
256.00	33.78
272.00	33.78
288.00	35.07
304.00	35.07
320.00	36.81
336.00	36.81
352.00	38.10
368.00	38.10
384.00	39.40
400.00	39.83
416.00	40.27
432.00	40.70
448.00	41.57
464.00	41.57
480.00	42.86
496.00	42.86
512.00	44.16
528.00	44.16
544.00	45.03
560.00	45.03
576.00	45.89
592.00	45.89
608.00	46.33
624.00	46.33
640.00	47.19
656.00	47.19
672.00	48.49
688.00	48.49
704.00	48.92
720.00	48.92
736.00	49.79
752.00	49.79
768.00	50.22
784.00	50.22
800.00	50.65

TIME (Sec)	TEMP(C)
816.00	50.65
832.00	51.09
848.00	51.09
864.00	52.38
880.00	52.82
896.00	53.25
912.00	53.25
928.00	53.25
944.00	53.25
960.00	53.25
976.00	53.68
992.00	54.12
1008.00	54.55
1024.00	54.55
1040.00	54.55
1056.00	54.55
1072.00	54.55
1088.00	54.98
1104.00	54.98
1120.00	56.28
1136.00	56.28
1152.00	56.28
1168.00	56.71
1184.00	57.15
1200.00	57.15
1216.00	57.58
1232.00	57.58
1248.00	57.58
1264.00	57.58
1280.00	58.01
1296.00	58.01
1312.00	58.01
1328.00	58.01
1344.00	58.01
1360.00	58.01
1376.00	58.01
1392.00	58.01
1408.00	58.88
1424.00	58.88
1440.00	59.31
1456.00	59.31
1472.00	58.88
1488.00	58.88
1504.00	58.88
1520.00	59.31
1536.00	59.74
1552.00	59.74
1568.00	59.74
1584.00	60.17
1600.00	60.17



Heating Curve for Uncoated Copper  
Temp Vs Time

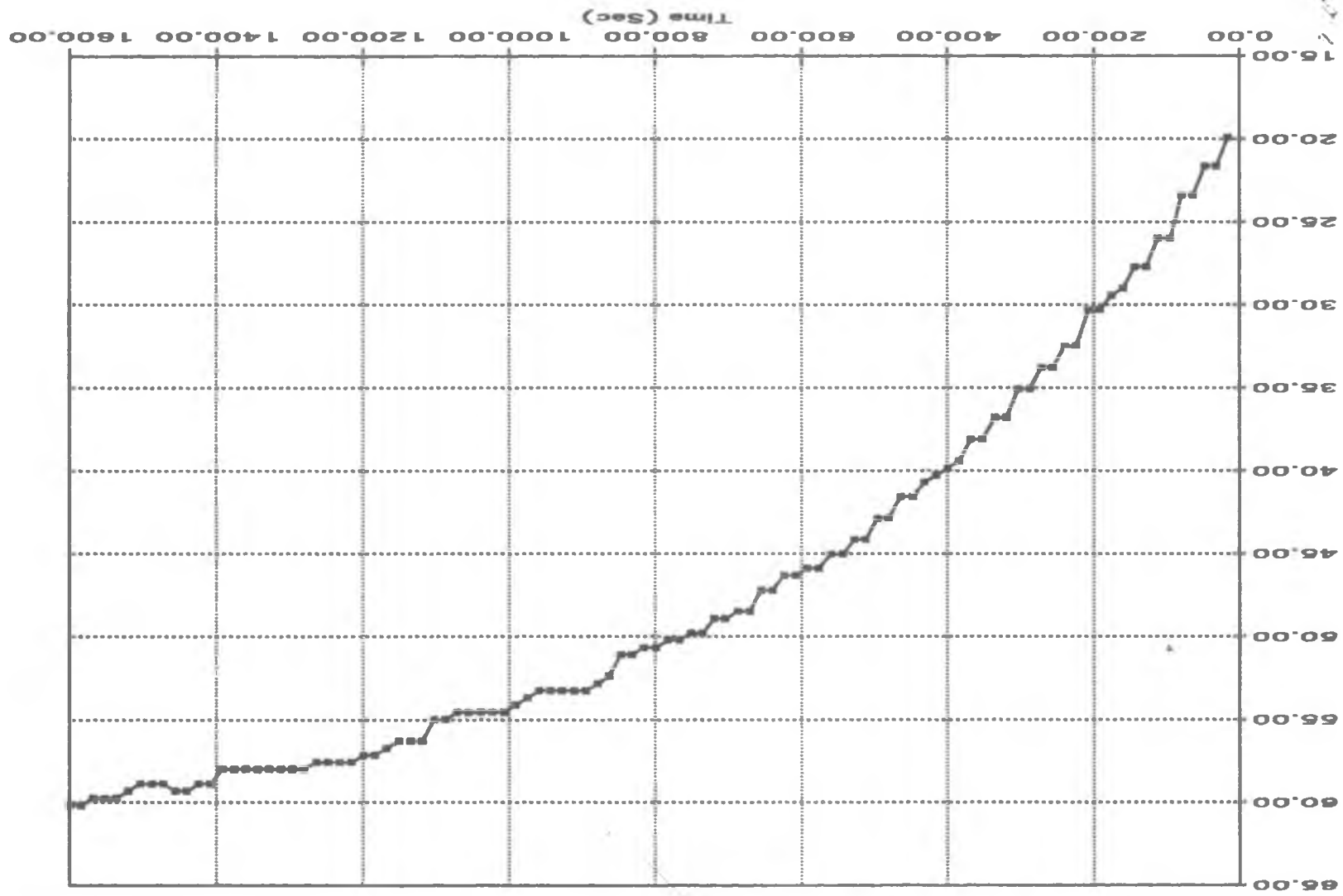


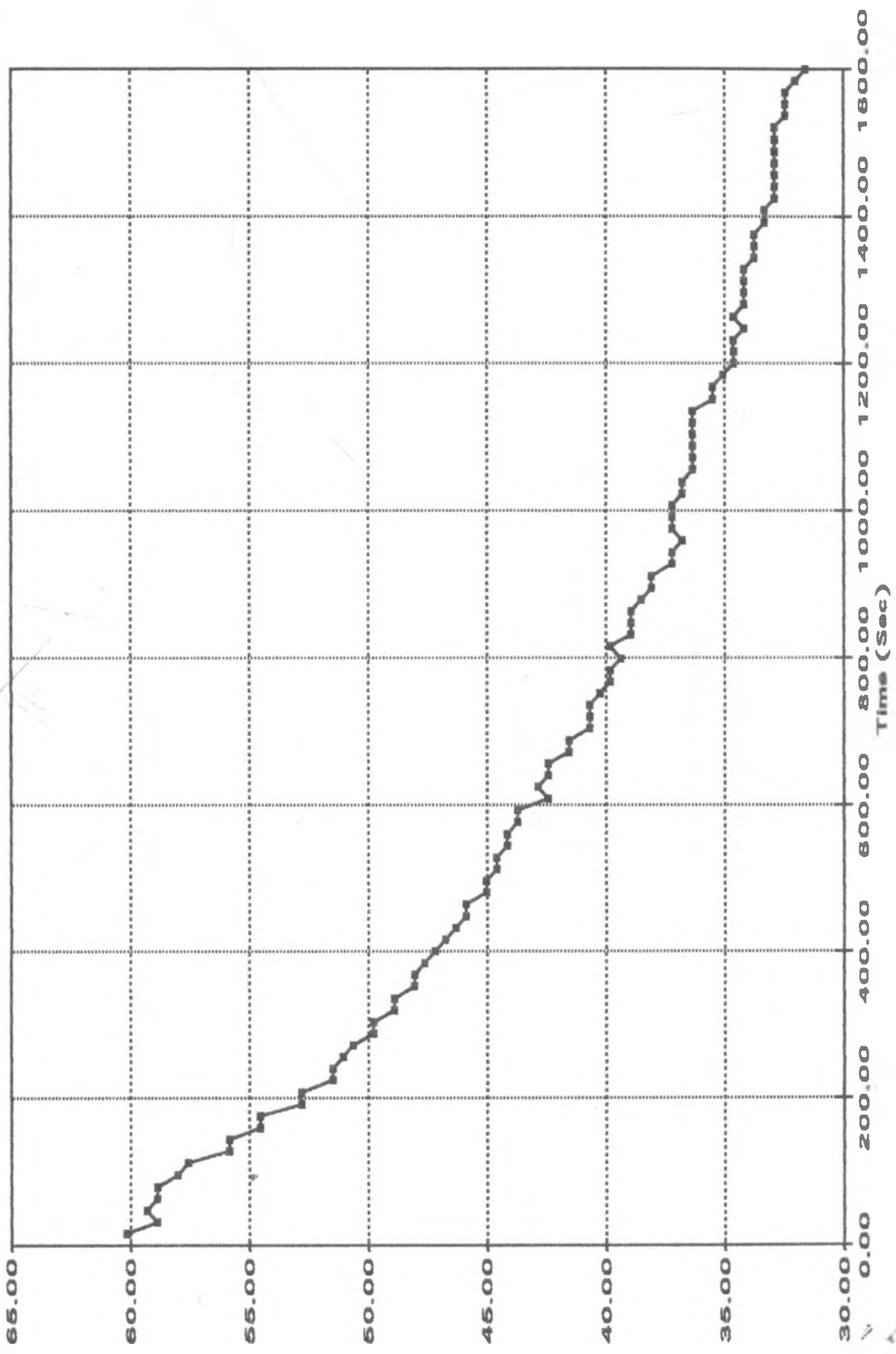
TABLE 10  
 DATA OF THE COOLING CYCLE  
 UNCOATED COPPER SAMPLE

CONT/...

TIME (Sec)	TEMP(C)
16.00	60.17
32.00	58.88
48.00	59.31
64.00	58.88
80.00	58.88
96.00	58.01
112.00	57.58
128.00	55.85
144.00	55.85
160.00	54.55
176.00	54.55
192.00	52.82
208.00	52.82
224.00	51.52
240.00	51.52
256.00	51.09
272.00	50.65
288.00	49.79
304.00	49.79
320.00	48.92
336.00	48.92
352.00	48.06
368.00	48.06
384.00	47.62
400.00	47.19
416.00	46.76
432.00	46.33
448.00	45.89
464.00	45.89
480.00	45.03
496.00	45.03
512.00	44.59
528.00	44.59
544.00	44.16
560.00	44.16
576.00	43.73
592.00	43.73
608.00	42.43
624.00	42.86
640.00	42.43
656.00	42.43
672.00	41.57
688.00	41.57
704.00	40.70
720.00	40.70
736.00	40.70
752.00	40.27
768.00	39.83
784.00	39.83
800.00	39.40

TIME (Sec)	TEMP(C)
816.00	39.83
832.00	38.97
848.00	38.97
864.00	38.97
880.00	38.54
896.00	38.10
912.00	38.10
928.00	37.24
944.00	37.24
960.00	36.81
976.00	37.24
992.00	37.24
1008.00	37.24
1024.00	36.81
1040.00	36.81
1056.00	36.37
1072.00	36.37
1088.00	36.37
1104.00	36.37
1120.00	36.37
1136.00	36.37
1152.00	35.51
1168.00	35.51
1184.00	35.07
1200.00	34.64
1216.00	34.64
1232.00	34.64
1248.00	34.21
1264.00	34.64
1280.00	34.21
1296.00	34.21
1312.00	34.21
1328.00	34.21
1344.00	33.78
1360.00	33.78
1376.00	33.78
1392.00	33.34
1408.00	33.34
1424.00	32.91
1440.00	32.91
1456.00	32.91
1472.00	32.91
1488.00	32.91
1504.00	32.91
1520.00	32.91
1536.00	32.48
1552.00	32.48
1568.00	32.48
1584.00	32.04
1600.00	31.61

Cooling Curve for Platinized Copper  
Temp Vs Time



Temp (c)

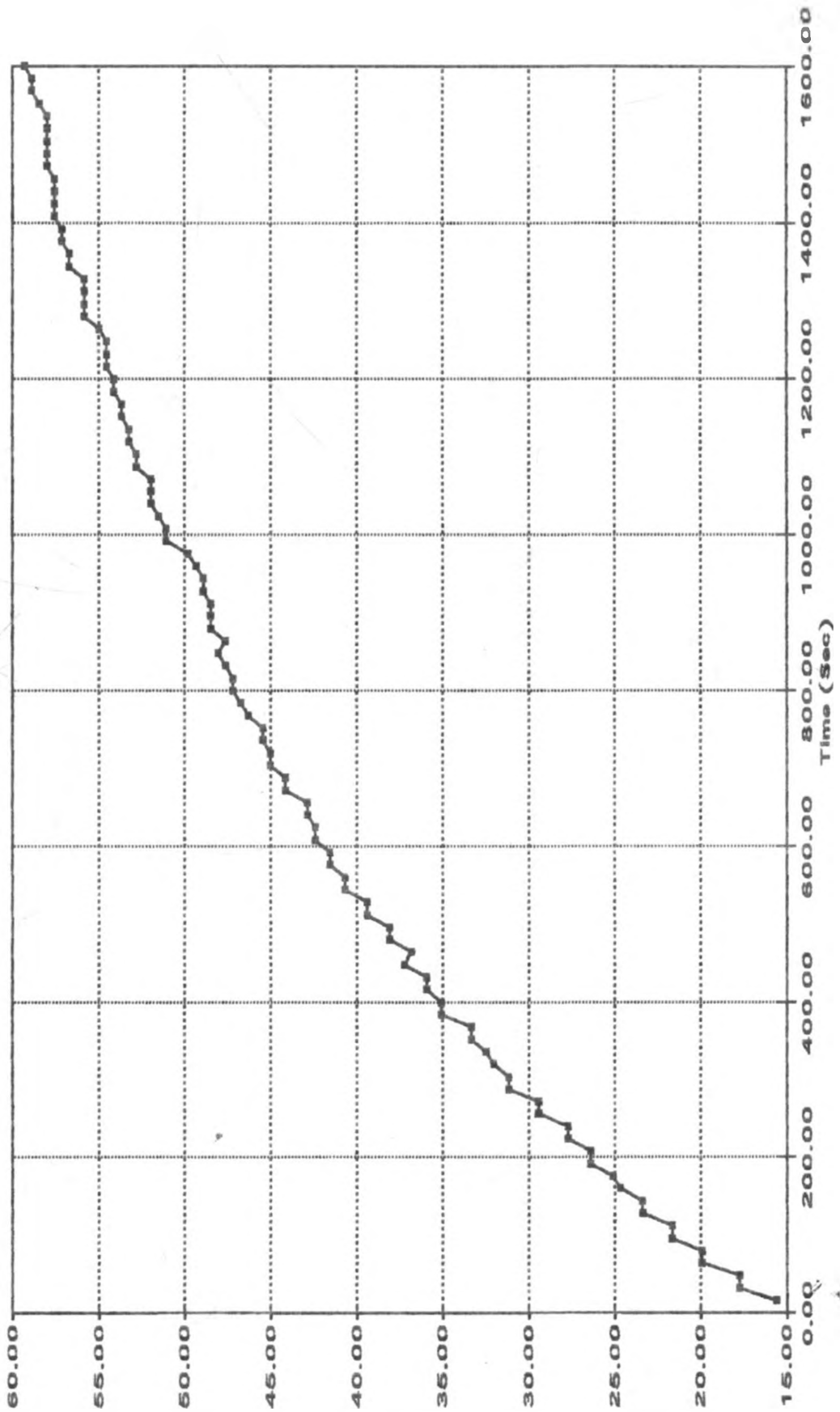
TABLE 13  
 DATA OF THE HEATING CYCLE FOR  
 UNCOATED STEEL SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	15.60
32.00	17.76
48.00	17.76
64.00	19.93
80.00	19.93
96.00	21.66
112.00	21.66
128.00	23.39
144.00	23.39
160.00	24.69
176.00	25.12
192.00	26.42
208.00	26.42
224.00	27.72
240.00	27.72
256.00	29.45
272.00	29.45
288.00	31.18
304.00	31.18
320.00	32.04
336.00	32.48
352.00	33.34
368.00	33.34
384.00	35.07
400.00	35.07
416.00	35.94
432.00	35.94
448.00	37.24
464.00	36.81
480.00	38.10
496.00	38.10
512.00	39.40
528.00	39.40
544.00	40.70
560.00	40.70
576.00	41.57
592.00	41.57
608.00	42.43
624.00	42.43
640.00	42.86
656.00	42.86
672.00	44.16
688.00	44.16
704.00	45.03
720.00	45.03
736.00	45.46
752.00	45.46
768.00	46.33
784.00	46.76
800.00	47.19

TIME (Sec)	TEMP(C)
816.00	47.19
832.00	47.62
848.00	48.06
864.00	47.62
880.00	48.49
896.00	48.49
912.00	48.49
928.00	48.92
944.00	48.92
960.00	49.36
976.00	49.79
992.00	51.09
1008.00	51.09
1024.00	51.52
1040.00	51.95
1056.00	51.95
1072.00	51.95
1088.00	52.82
1104.00	52.82
1120.00	53.25
1136.00	53.25
1152.00	53.68
1168.00	53.68
1184.00	54.12
1200.00	54.12
1216.00	54.55
1232.00	54.55
1248.00	54.55
1264.00	54.98
1280.00	55.85
1296.00	55.85
1312.00	55.85
1328.00	55.85
1344.00	56.71
1360.00	56.71
1376.00	57.15
1392.00	57.15
1408.00	57.58
1424.00	57.58
1440.00	57.58
1456.00	57.58
1472.00	58.01
1488.00	58.01
1504.00	58.01
1520.00	58.01
1536.00	58.01
1552.00	58.44
1568.00	58.88
1584.00	58.88
1600.00	59.31

Heating Curve for Hot-rolled Steel  
Temp Vs Time



Temp (C)

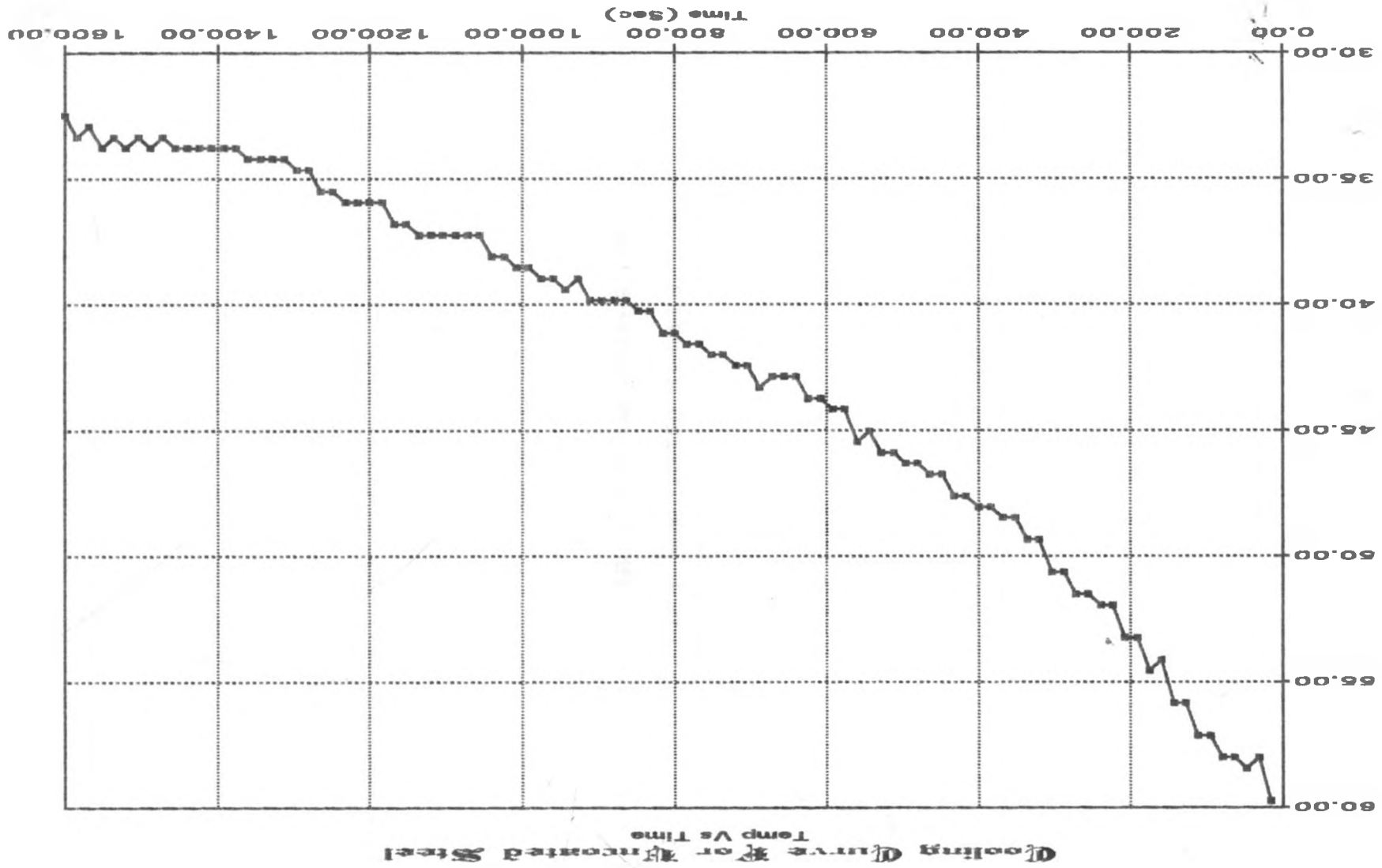
TABLE 14  
 DATA OF THE COOLING CYCLE FOR  
 UNCOATED STEEL SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	59.74
32.00	58.01
48.00	58.44
64.00	58.01
80.00	58.01
96.00	57.15
112.00	57.15
128.00	55.85
144.00	55.85
160.00	54.12
176.00	54.55
192.00	53.25
208.00	53.25
224.00	51.95
240.00	51.95
256.00	51.52
272.00	51.52
288.00	50.65
304.00	50.65
320.00	49.36
336.00	49.36
352.00	48.49
368.00	48.49
384.00	48.06
400.00	48.06
416.00	47.62
432.00	47.62
448.00	46.76
464.00	46.76
480.00	46.33
496.00	46.33
512.00	45.89
528.00	45.89
544.00	45.03
560.00	45.46
576.00	44.16
592.00	44.16
608.00	43.73
624.00	43.73
640.00	42.86
656.00	42.86
672.00	42.86
688.00	43.30
704.00	42.43
720.00	42.43
736.00	42.00
752.00	42.00
768.00	41.57
784.00	41.57
800.00	41.13

TIME (Sec)	TEMP(C)
816.00	41.13
832.00	40.27
848.00	40.27
864.00	39.83
880.00	39.83
896.00	39.83
912.00	39.83
928.00	38.97
944.00	39.40
960.00	38.97
976.00	38.97
992.00	38.54
1008.00	38.54
1024.00	38.10
1040.00	38.10
1056.00	37.24
1072.00	37.24
1088.00	37.24
1104.00	37.24
1120.00	37.24
1136.00	37.24
1152.00	36.81
1168.00	36.81
1184.00	35.94
1200.00	35.94
1216.00	35.94
1232.00	35.94
1248.00	35.51
1264.00	35.51
1280.00	34.64
1296.00	34.64
1312.00	34.21
1328.00	34.21
1344.00	34.21
1360.00	34.21
1376.00	33.78
1392.00	33.78
1408.00	33.78
1424.00	33.78
1440.00	33.78
1456.00	33.78
1472.00	33.34
1488.00	33.78
1504.00	33.34
1520.00	33.78
1536.00	33.34
1552.00	33.78
1568.00	32.91
1584.00	33.34
1600.00	32.48

Temp (c)



APPENDIX B

DATA TABULATION AND GRAPHS FOR  
THE BLACK COATED SAMPLES.



TABLE 3  
 DATA OF THE HEATING CURVE FOR  
 BLACK COATED ALUMINIUM

CONT/...

TIME (Sec)	TEMP(C)
16.00	28.58
32.00	29.88
48.00	30.31
64.00	32.04
80.00	32.48
96.00	34.64
112.00	34.64
128.00	36.37
144.00	36.37
160.00	37.67
176.00	38.10
192.00	39.83
208.00	39.83
224.00	41.13
240.00	41.13
256.00	42.00
272.00	42.43
288.00	43.30
304.00	43.30
320.00	44.16
336.00	44.16
352.00	45.03
368.00	45.03
384.00	45.46
400.00	45.46
416.00	46.33
432.00	46.33
448.00	46.76
464.00	46.76
480.00	47.62
496.00	47.62
512.00	48.49
528.00	48.06
544.00	48.49
560.00	48.49
576.00	48.92
592.00	48.92
608.00	49.36
624.00	49.36
640.00	49.79
656.00	49.79
672.00	50.65
688.00	50.65
704.00	50.65
720.00	50.65
736.00	51.09
752.00	51.09
768.00	51.52
784.00	51.95
800.00	51.95

TIME (Sec)	TEMP(C)
816.00	51.95
832.00	51.95
848.00	51.95
864.00	52.82
880.00	52.82
896.00	54.12
912.00	54.12
928.00	54.12
944.00	54.12
960.00	53.68
976.00	53.25
992.00	54.12
1008.00	54.12
1024.00	54.12
1040.00	54.12
1056.00	54.12
1072.00	54.12
1088.00	54.12
1104.00	54.12
1120.00	54.98
1136.00	54.98
1152.00	54.98
1168.00	54.98
1184.00	54.98
1200.00	54.98
1216.00	55.85
1232.00	55.85
1248.00	56.28
1264.00	56.28
1280.00	56.28
1296.00	56.28
1312.00	56.28
1328.00	56.28
1344.00	55.85
1360.00	55.85
1376.00	55.85
1392.00	55.85
1408.00	55.85
1424.00	55.85
1440.00	55.85
1456.00	55.85
1472.00	56.28
1488.00	56.28
1504.00	56.71
1520.00	57.15
1536.00	56.28
1552.00	56.28
1568.00	56.28
1584.00	56.71
1600.00	58.01

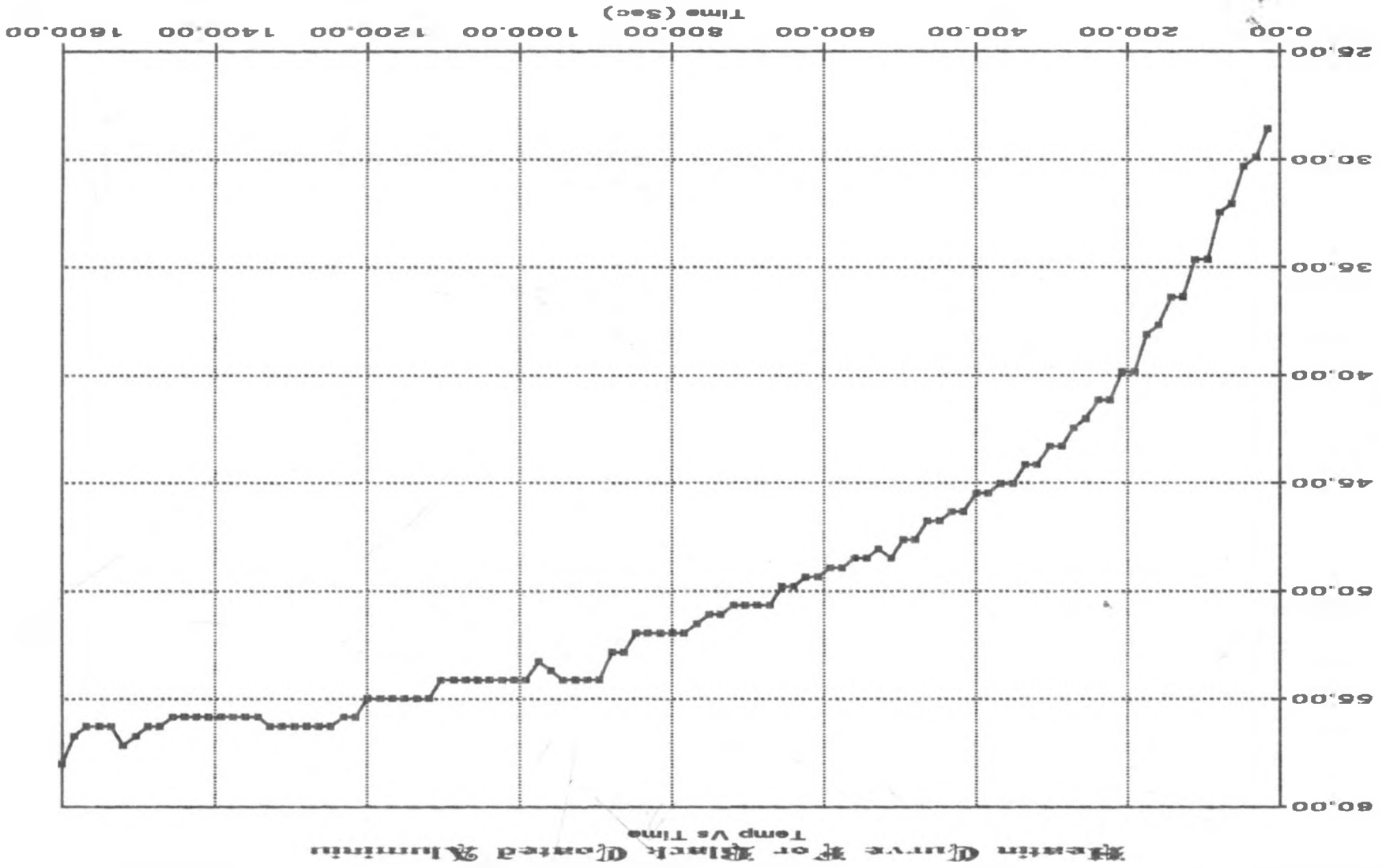


TABLE 4  
 DATA OF THE COOLING CURVE FOR  
 BLACK COATED ALUMINIUM

CONT/..

TIME (Sec)	TEMP(C)
16.00	58.01
32.00	55.85
48.00	55.85
64.00	54.98
80.00	54.98
96.00	53.68
112.00	53.25
128.00	51.52
144.00	51.52
160.00	50.22
176.00	50.22
192.00	49.36
208.00	49.36
224.00	48.49
240.00	48.06
256.00	47.62
272.00	47.62
288.00	46.76
304.00	46.76
320.00	45.89
336.00	45.89
352.00	45.03
368.00	45.03
384.00	44.16
400.00	44.16
416.00	43.30
432.00	42.86
448.00	42.86
464.00	42.86
480.00	42.43
496.00	42.43
512.00	42.00
528.00	41.57
544.00	40.70
560.00	40.70
576.00	39.83
592.00	40.27
608.00	39.83
624.00	39.83
640.00	39.83
656.00	39.83
672.00	38.97
688.00	39.40
704.00	38.54
720.00	38.97
736.00	38.10
752.00	38.10
768.00	37.67
784.00	37.67
800.00	36.81
816.00	36.81

TIME (Sec)	TEMP(C)
816.00	36.81
832.00	36.37
848.00	36.37
864.00	36.37
880.00	36.37
896.00	35.94
912.00	35.94
928.00	35.07
944.00	35.07
960.00	35.51
976.00	35.07
992.00	35.07
1008.00	35.07
1024.00	34.64
1040.00	34.64
1056.00	34.21
1072.00	34.21
1088.00	33.78
1104.00	34.21
1120.00	33.34
1136.00	33.34
1152.00	33.34
1168.00	33.34
1184.00	33.34
1200.00	33.34
1216.00	32.91
1232.00	32.91
1248.00	32.48
1264.00	32.48
1280.00	32.04
1296.00	32.04
1312.00	32.04
1328.00	32.04
1344.00	32.04
1360.00	32.04
1376.00	31.18
1392.00	31.61
1408.00	31.61
1424.00	31.18
1440.00	31.18
1456.00	30.75
1472.00	30.31
1488.00	30.31
1504.00	30.31
1520.00	30.31
1536.00	29.88
1552.00	29.88
1568.00	29.88
1584.00	29.88
1600.00	29.88

Cooling Curve # of Black Coated Alumini  
Temp Vs Time

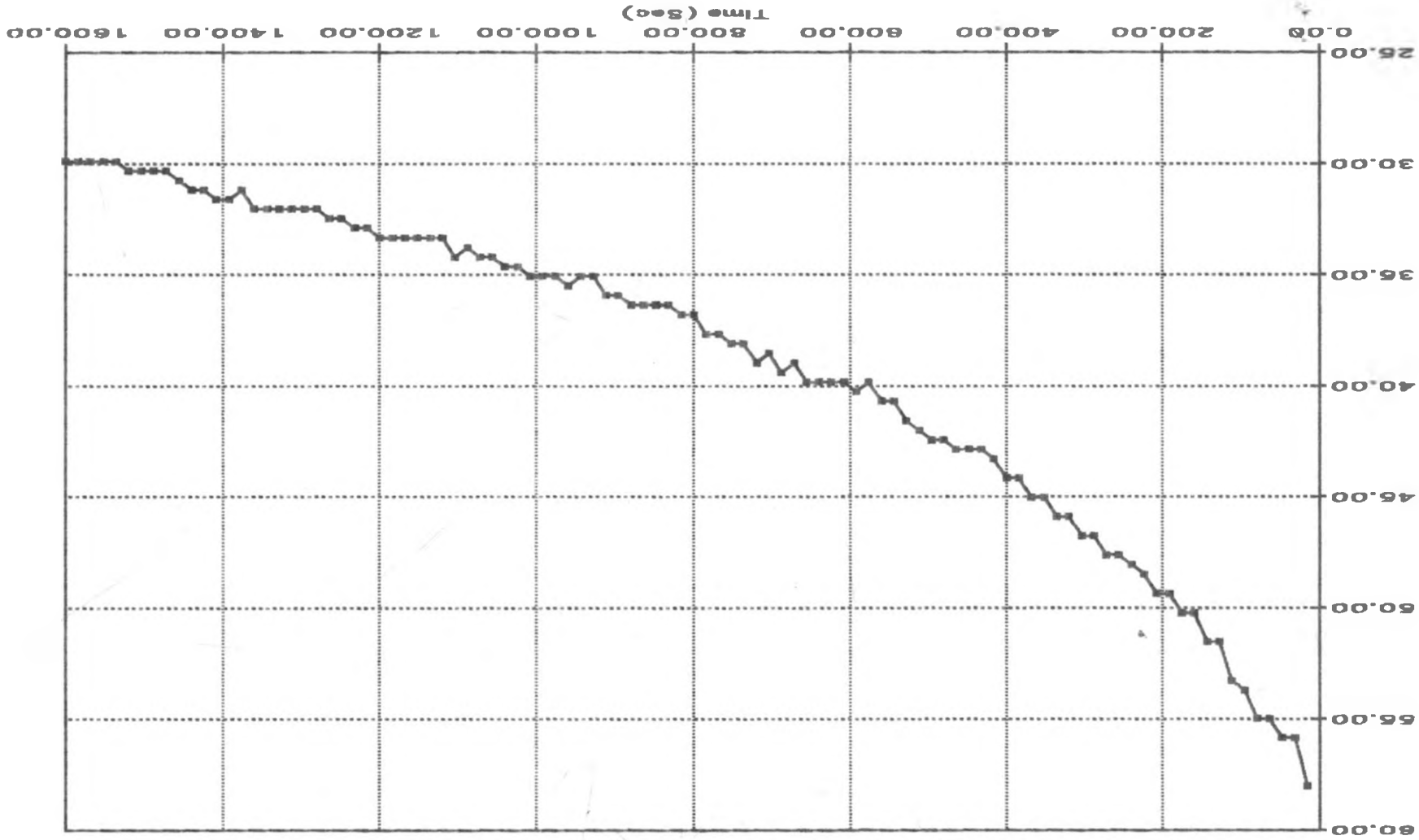


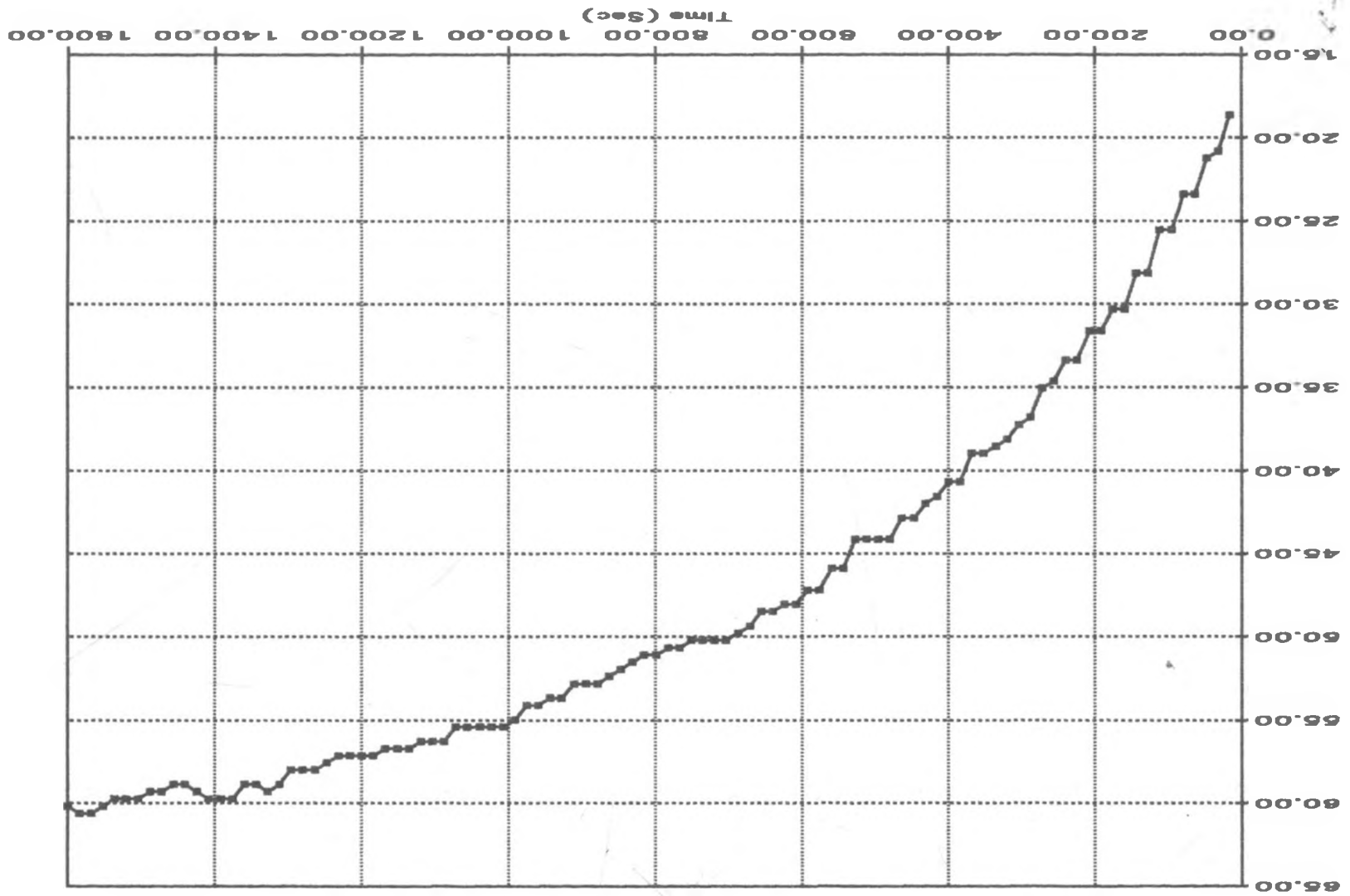
TABLE 7  
 DATA OF THE HEATING CYCLE FOR  
 BLACK COATED BRASS SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	18.63
32.00	20.79
48.00	21.23
64.00	23.39
80.00	23.39
96.00	25.55
112.00	25.55
128.00	28.15
144.00	28.15
160.00	30.31
176.00	30.31
192.00	31.61
208.00	31.61
224.00	33.34
240.00	33.34
256.00	34.64
272.00	35.07
288.00	36.81
304.00	37.24
320.00	38.10
336.00	38.54
352.00	38.97
368.00	38.97
384.00	40.70
400.00	40.70
416.00	41.57
432.00	42.00
448.00	42.86
464.00	42.86
480.00	44.16
496.00	44.16
512.00	44.16
528.00	44.16
544.00	45.89
560.00	45.89
576.00	47.19
592.00	47.19
608.00	48.06
624.00	48.06
640.00	48.49
656.00	48.49
672.00	49.36
688.00	49.79
704.00	50.22
720.00	50.22
736.00	50.22
752.00	50.22
768.00	50.65
784.00	50.65
800.00	51.09

TIME (Sec)	TEMP(C)
816.00	51.09
832.00	51.52
848.00	51.95
864.00	52.38
880.00	52.82
896.00	52.82
912.00	52.82
928.00	53.68
944.00	53.68
960.00	54.12
976.00	54.12
992.00	54.98
1008.00	55.41
1024.00	55.41
1040.00	55.41
1056.00	55.41
1072.00	55.41
1088.00	56.28
1104.00	56.28
1120.00	56.28
1136.00	56.71
1152.00	56.71
1168.00	56.71
1184.00	57.15
1200.00	57.15
1216.00	57.15
1232.00	57.15
1248.00	57.58
1264.00	58.01
1280.00	58.01
1296.00	58.01
1312.00	58.88
1328.00	59.31
1344.00	58.88
1360.00	58.88
1376.00	59.74
1392.00	59.74
1408.00	59.74
1424.00	59.31
1440.00	58.88
1456.00	58.88
1472.00	59.31
1488.00	59.31
1504.00	59.74
1520.00	59.74
1536.00	59.74
1552.00	60.17
1568.00	60.61
1584.00	60.61
1600.00	60.17

Heating Curve for Black United Brass



Temp (°)

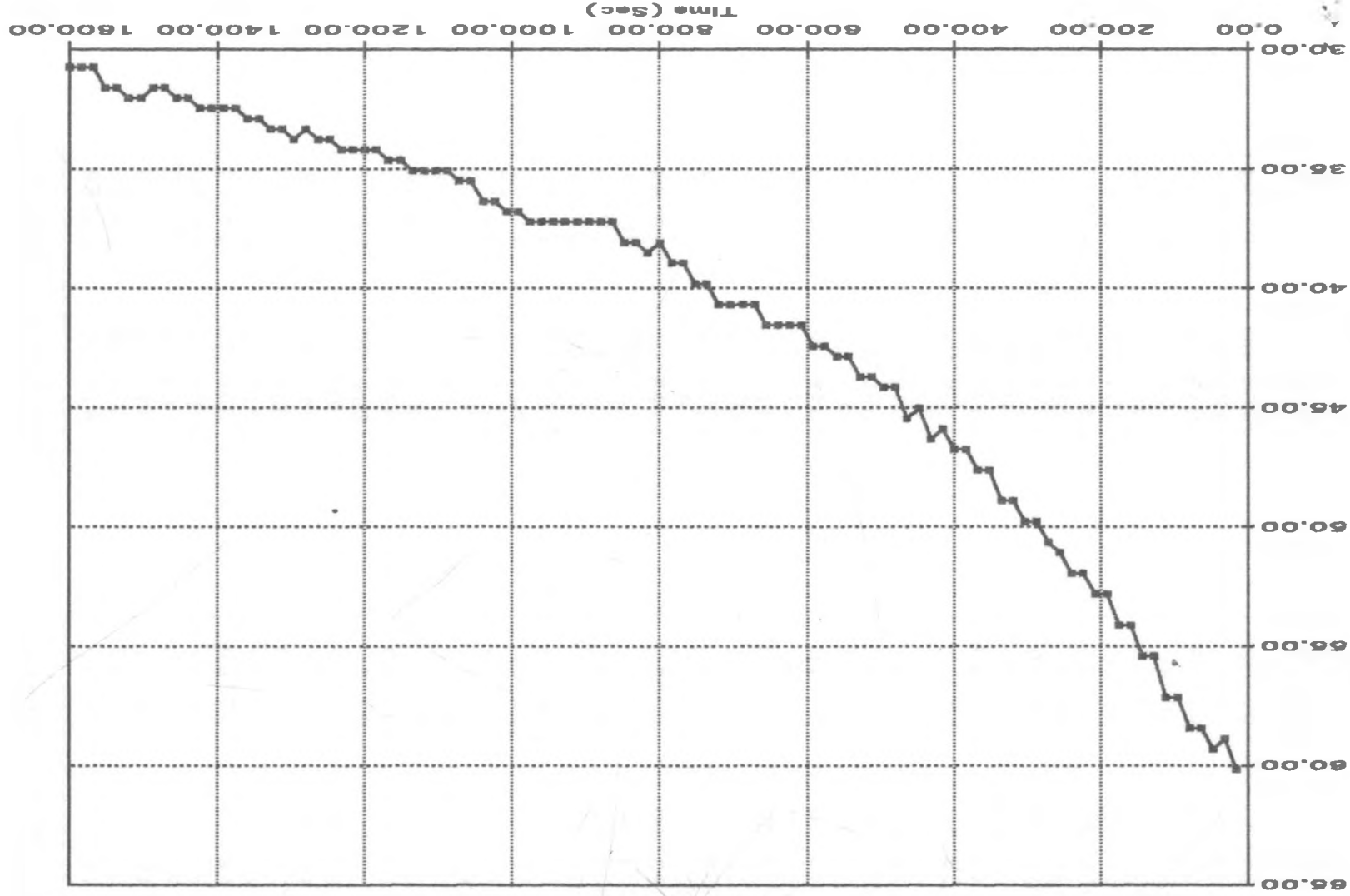
TABLE 8  
 DATA OF THE COOLING CYCLE FOR  
 BLACK COATED BRASS SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	60.17
32.00	58.88
48.00	59.31
64.00	58.44
80.00	58.44
96.00	57.15
112.00	57.15
128.00	55.41
144.00	55.41
160.00	54.12
176.00	54.12
192.00	52.82
208.00	52.82
224.00	51.95
240.00	51.95
256.00	51.09
272.00	50.65
288.00	49.79
304.00	49.79
320.00	48.92
336.00	48.92
352.00	47.62
368.00	47.62
384.00	46.76
400.00	46.76
416.00	45.89
432.00	46.33
448.00	45.03
464.00	45.46
480.00	44.16
496.00	44.16
512.00	43.73
528.00	43.73
544.00	42.86
560.00	42.86
576.00	42.43
592.00	42.43
608.00	41.57
624.00	41.57
640.00	41.57
656.00	41.57
672.00	40.70
688.00	40.70
704.00	40.70
720.00	40.70
736.00	39.83
752.00	39.83
768.00	38.97
784.00	38.97
800.00	38.10

TIME (Sec)	TEMP(C)
816.00	38.54
832.00	38.10
848.00	38.10
864.00	37.24
880.00	37.24
896.00	37.24
912.00	37.24
928.00	37.24
944.00	37.24
960.00	37.24
976.00	37.24
992.00	36.81
1008.00	36.81
1024.00	36.37
1040.00	36.37
1056.00	35.51
1072.00	35.51
1088.00	35.07
1104.00	35.07
1120.00	35.07
1136.00	35.07
1152.00	34.64
1168.00	34.64
1184.00	34.21
1200.00	34.21
1216.00	34.21
1232.00	34.21
1248.00	33.78
1264.00	33.78
1280.00	33.34
1296.00	33.78
1312.00	33.34
1328.00	33.34
1344.00	32.91
1360.00	32.91
1376.00	32.48
1392.00	32.48
1408.00	32.48
1424.00	32.48
1440.00	32.04
1456.00	32.04
1472.00	31.61
1488.00	31.61
1504.00	32.04
1520.00	32.04
1536.00	31.61
1552.00	31.61
1568.00	30.75
1584.00	30.75
1600.00	30.75

Temp (C)



Cooling Curve for Black Dotted brass  
Temp Vs Time



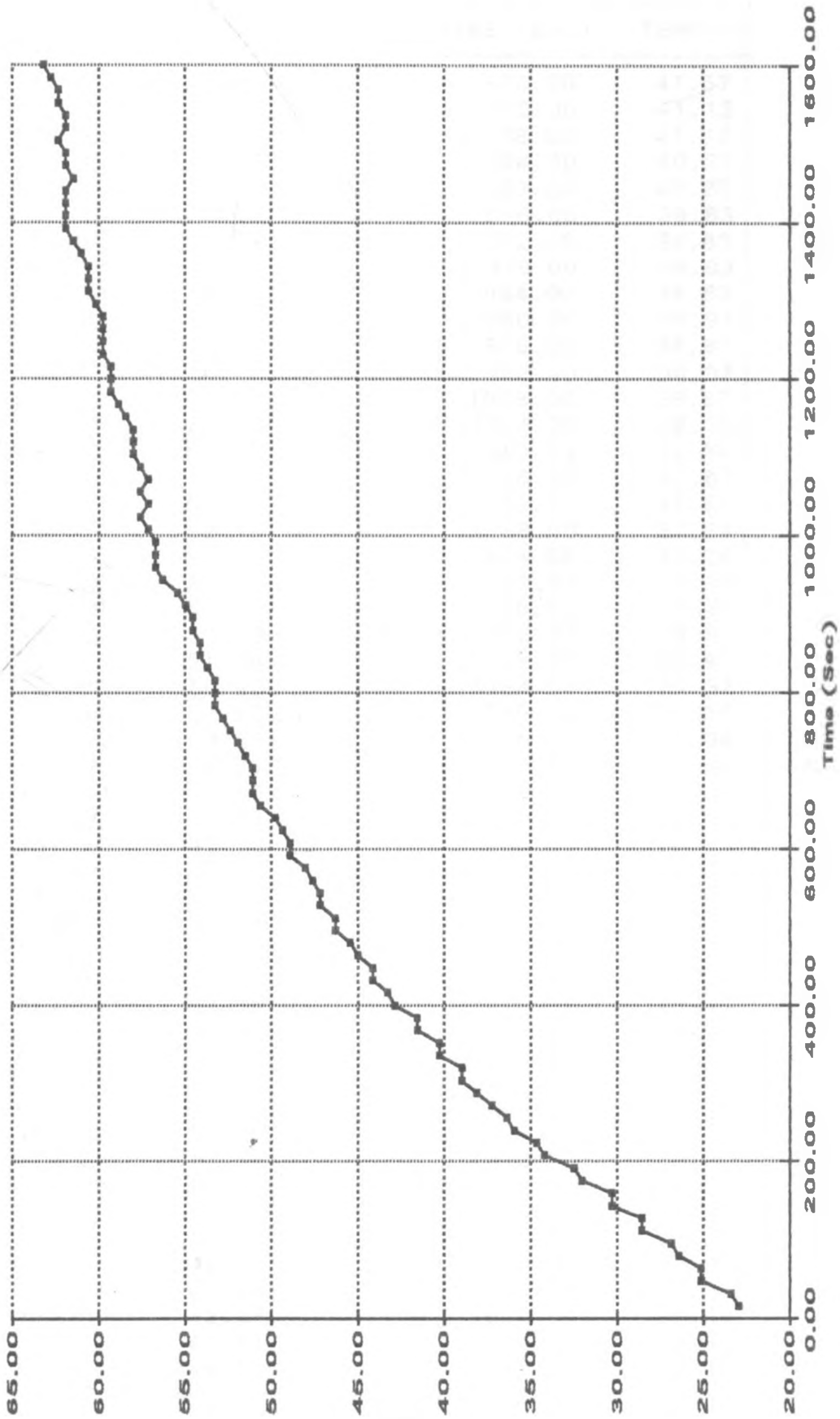
TABLE 11  
 DATA OF THE HEATING CYCLE FOR  
 BLACK COATED COPPER SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	22.96
32.00	23.39
48.00	25.12
64.00	25.12
80.00	26.42
96.00	26.85
112.00	28.58
128.00	28.58
144.00	30.31
160.00	30.31
176.00	32.04
192.00	32.48
208.00	34.21
224.00	34.64
240.00	35.94
256.00	36.37
272.00	37.24
288.00	38.10
304.00	38.97
320.00	38.97
336.00	40.27
352.00	40.27
368.00	41.57
384.00	41.57
400.00	42.86
416.00	43.30
432.00	44.16
448.00	44.16
464.00	45.03
480.00	45.46
496.00	46.33
512.00	46.33
528.00	47.19
544.00	47.19
560.00	47.62
576.00	48.06
592.00	48.92
608.00	48.92
624.00	49.36
640.00	49.79
656.00	50.65
672.00	51.09
688.00	51.09
704.00	51.09
720.00	51.52
736.00	51.95
752.00	52.38
768.00	52.82
784.00	53.25
800.00	53.25

TIME (Sec)	TEMP(C)
816.00	53.25
832.00	53.68
848.00	54.12
864.00	54.12
880.00	54.55
896.00	54.55
912.00	54.98
928.00	55.41
944.00	56.28
960.00	56.71
976.00	56.71
992.00	56.71
1008.00	57.15
1024.00	57.58
1040.00	57.15
1056.00	57.58
1072.00	57.15
1088.00	57.58
1104.00	58.01
1120.00	58.01
1136.00	58.01
1152.00	58.44
1168.00	58.88
1184.00	59.31
1200.00	59.31
1216.00	59.31
1232.00	59.74
1248.00	59.74
1264.00	59.74
1280.00	59.74
1296.00	60.17
1312.00	60.61
1328.00	60.61
1344.00	60.61
1360.00	61.04
1376.00	61.47
1392.00	61.91
1408.00	61.91
1424.00	61.91
1440.00	61.91
1456.00	61.47
1472.00	61.91
1488.00	61.91
1504.00	62.34
1520.00	61.91
1536.00	61.91
1552.00	62.34
1568.00	62.34
1584.00	62.77
1600.00	63.20

Heating Curve For Black Coated Copper  
Temp Vs Time



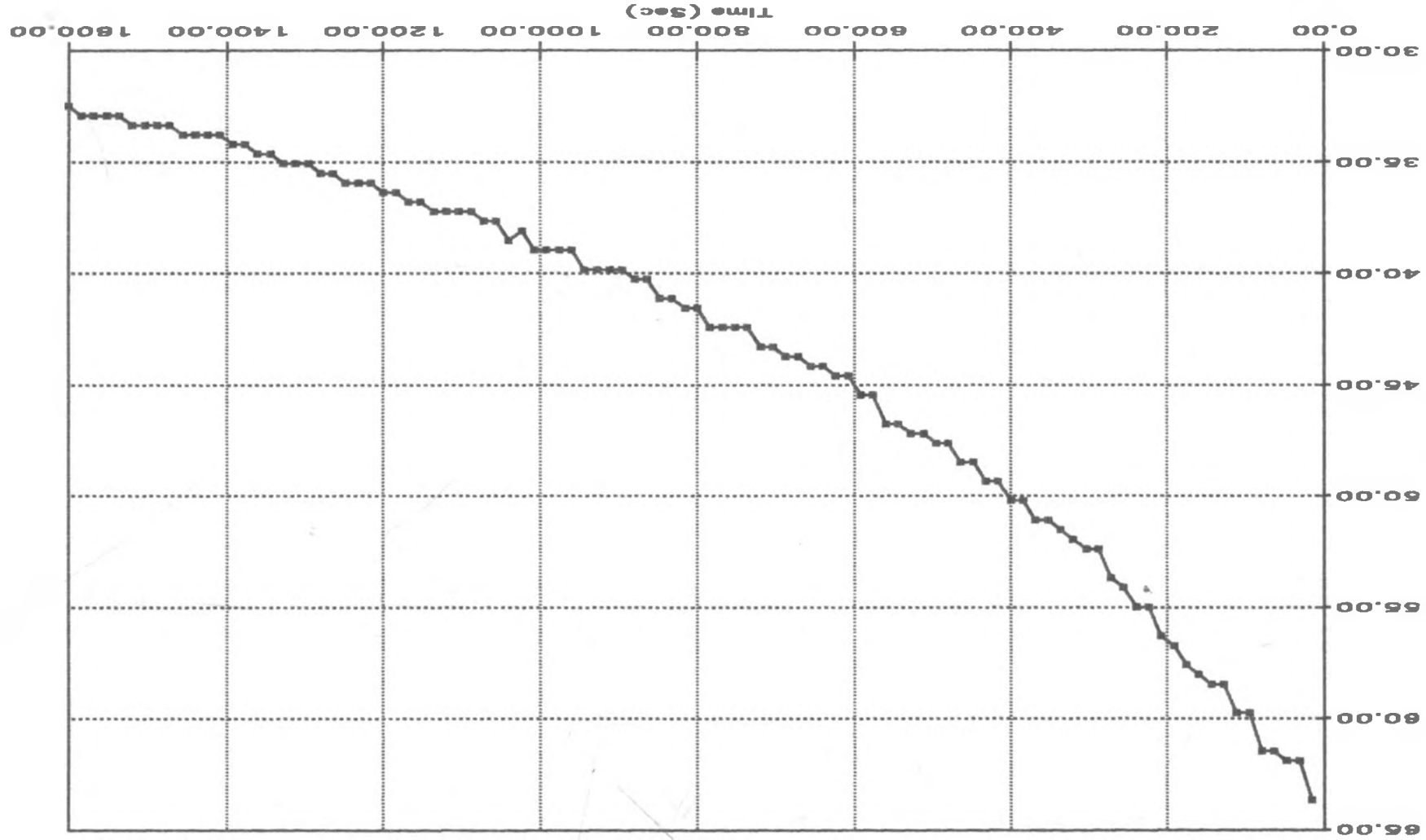
Temp (C)

TABLE 12  
 DATA OF THE COOLING CYCLE FOR  
 BLACK COATED COPPER SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	63.64
32.00	61.91
48.00	61.91
64.00	61.47
80.00	61.47
96.00	59.74
112.00	59.74
128.00	58.44
144.00	58.44
160.00	58.01
176.00	57.58
192.00	56.71
208.00	56.28
224.00	54.98
240.00	54.98
256.00	54.12
272.00	53.68
288.00	52.38
304.00	52.38
320.00	51.95
336.00	51.52
352.00	51.09
368.00	51.09
384.00	50.22
400.00	50.22
416.00	49.36
432.00	49.36
448.00	48.49
464.00	48.49
480.00	47.62
496.00	47.62
512.00	47.19
528.00	47.19
544.00	46.76
560.00	46.76
576.00	45.46
592.00	45.46
608.00	44.59
624.00	44.59
640.00	44.16
656.00	44.16
672.00	43.73
688.00	43.73
704.00	43.30
720.00	43.30
736.00	42.43
752.00	42.43
768.00	42.43
784.00	42.43
800.00	41.57

TIME (Sec)	TEMP(C)
816.00	41.57
832.00	41.13
848.00	41.13
864.00	40.27
880.00	40.27
896.00	39.83
912.00	39.83
928.00	39.83
944.00	39.83
960.00	38.97
976.00	38.97
992.00	38.97
1008.00	38.97
1024.00	38.10
1040.00	38.54
1056.00	37.67
1072.00	37.67
1088.00	37.24
1104.00	37.24
1120.00	37.24
1136.00	37.24
1152.00	36.81
1168.00	36.81
1184.00	36.37
1200.00	36.37
1216.00	35.94
1232.00	35.94
1248.00	35.94
1264.00	35.51
1280.00	35.51
1296.00	35.07
1312.00	35.07
1328.00	35.07
1344.00	34.64
1360.00	34.64
1376.00	34.21
1392.00	34.21
1408.00	33.78
1424.00	33.78
1440.00	33.78
1456.00	33.78
1472.00	33.34
1488.00	33.34
1504.00	33.34
1520.00	33.34
1536.00	32.91
1552.00	32.91
1568.00	32.91
1584.00	32.91
1600.00	32.48



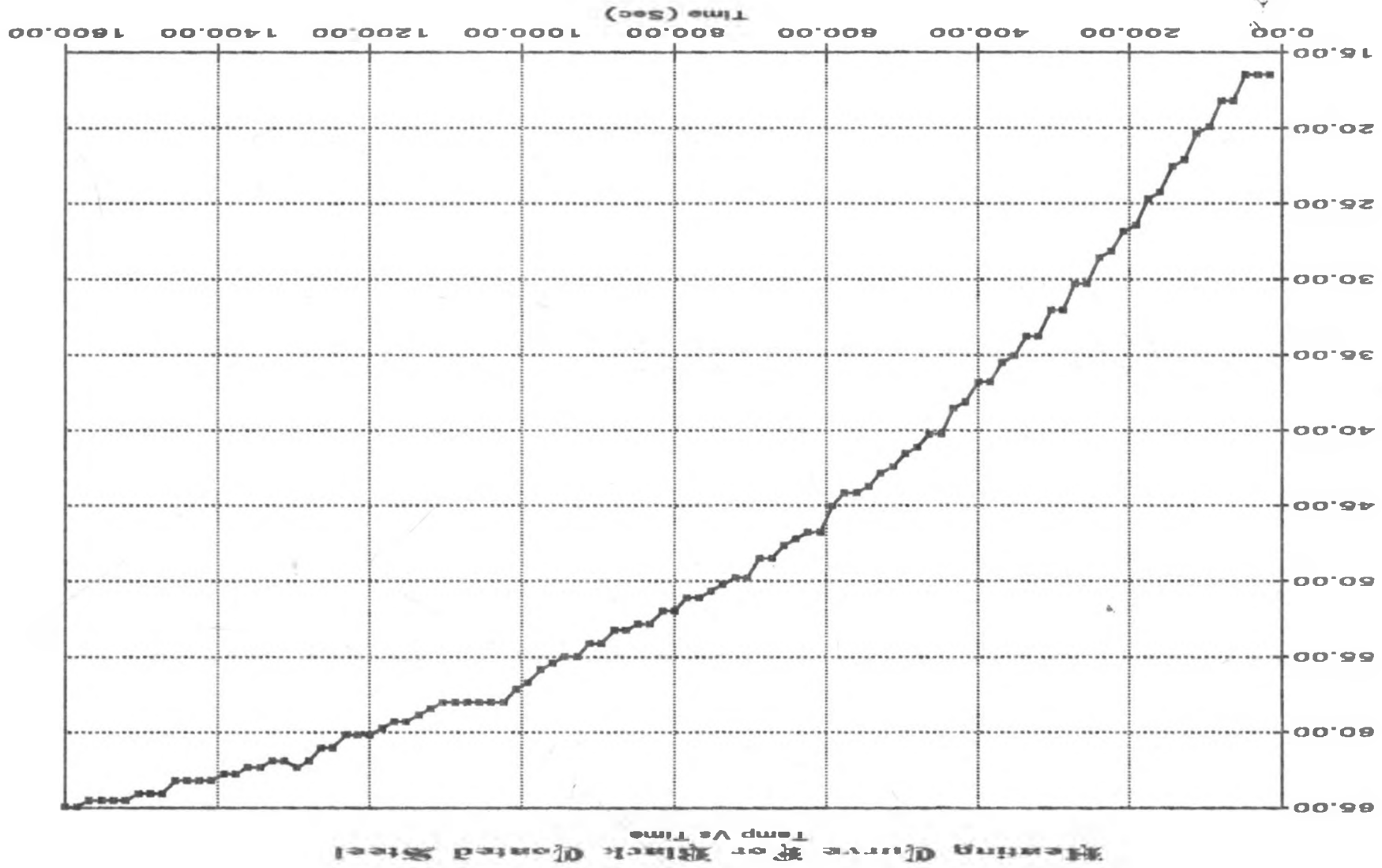
Cooling curve for Black oriented Copper  
Temp Vs Time

TABLE 15  
 DATA OF THE HEATING CYCLE FOR  
 BLACK COATED STEEL SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	16.46
32.00	16.46
48.00	16.46
64.00	18.20
80.00	18.20
96.00	19.93
112.00	20.36
128.00	22.09
144.00	22.52
160.00	24.25
176.00	24.69
192.00	26.42
208.00	26.85
224.00	28.15
240.00	28.58
256.00	30.31
272.00	30.31
288.00	32.04
304.00	32.04
320.00	33.78
336.00	33.78
352.00	35.07
368.00	35.51
384.00	36.81
400.00	36.81
416.00	38.10
432.00	38.54
448.00	40.27
464.00	40.27
480.00	41.13
496.00	41.57
512.00	42.43
528.00	42.86
544.00	43.73
560.00	44.16
576.00	44.16
592.00	45.03
608.00	46.76
624.00	46.76
640.00	47.19
656.00	47.62
672.00	48.49
688.00	48.49
704.00	49.79
720.00	49.79
736.00	50.22
752.00	50.65
768.00	51.09
784.00	51.09
800.00	51.95

TIME (Sec)	TEMP(C)
816.00	51.95
832.00	52.82
848.00	52.82
864.00	53.25
880.00	53.25
896.00	54.12
912.00	54.12
928.00	54.98
944.00	54.98
960.00	55.41
976.00	55.85
992.00	56.71
1008.00	57.15
1024.00	58.01
1040.00	58.01
1056.00	58.01
1072.00	58.01
1088.00	58.01
1104.00	58.01
1120.00	58.44
1136.00	58.88
1152.00	59.31
1168.00	59.31
1184.00	59.74
1200.00	60.17
1216.00	60.17
1232.00	60.17
1248.00	61.04
1264.00	61.04
1280.00	61.91
1296.00	62.34
1312.00	61.91
1328.00	61.91
1344.00	62.34
1360.00	62.34
1376.00	62.77
1392.00	62.77
1408.00	63.20
1424.00	63.20
1440.00	63.20
1456.00	63.20
1472.00	64.07
1488.00	64.07
1504.00	64.07
1520.00	64.50
1536.00	64.50
1552.00	64.50
1568.00	64.50
1584.00	64.94
1600.00	64.94



Temp (C)

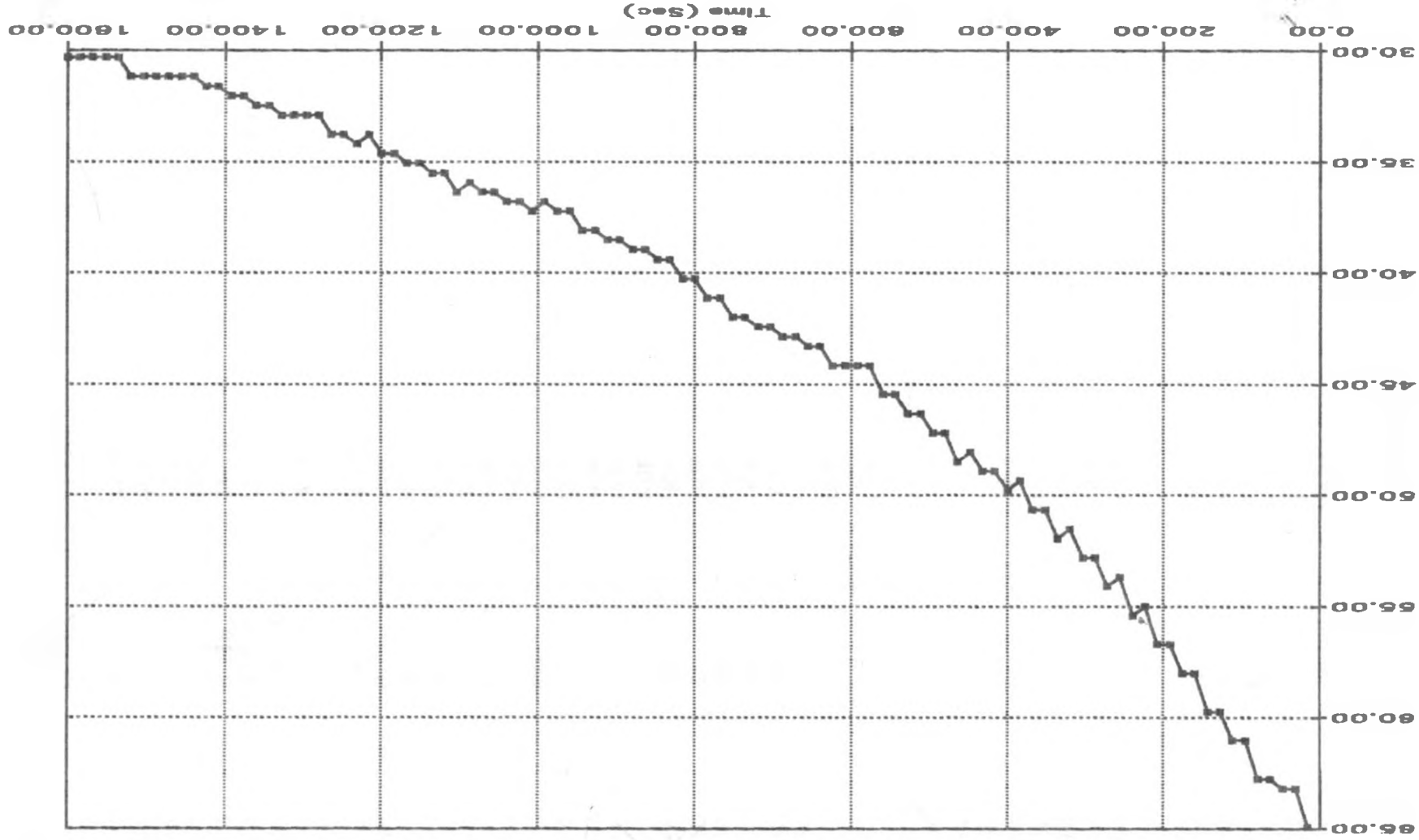
TABLE 16  
 DATA OF THE COOLING CYCLE FOR  
 BLACK COATED STEEL SAMPLE

CONT/..

TIME (Sec)	TEMP(C)
16.00	64.94
32.00	63.20
48.00	63.20
64.00	62.77
80.00	62.77
96.00	61.04
112.00	61.04
128.00	59.74
144.00	59.74
160.00	58.01
176.00	58.01
192.00	56.71
208.00	56.71
224.00	54.98
240.00	55.41
256.00	53.68
272.00	54.12
288.00	52.82
304.00	52.82
320.00	51.52
336.00	51.95
352.00	50.65
368.00	50.65
384.00	49.36
400.00	49.79
416.00	48.92
432.00	48.92
448.00	48.06
464.00	48.49
480.00	47.19
496.00	47.19
512.00	46.33
528.00	46.33
544.00	45.46
560.00	45.46
576.00	44.16
592.00	44.16
608.00	44.16
624.00	44.16
640.00	43.30
656.00	43.30
672.00	42.86
688.00	42.86
704.00	42.43
720.00	42.43
736.00	42.00
752.00	42.00
768.00	41.13
784.00	41.13
800.00	40.27

TIME (Sec)	TEMP(C)
816.00	40.27
832.00	39.40
848.00	39.40
864.00	38.97
880.00	38.97
896.00	38.54
912.00	38.54
928.00	38.10
944.00	38.10
960.00	37.24
976.00	37.24
992.00	36.81
1008.00	37.24
1024.00	36.81
1040.00	36.81
1056.00	36.37
1072.00	36.37
1088.00	35.94
1104.00	36.37
1120.00	35.51
1136.00	35.51
1152.00	35.07
1168.00	35.07
1184.00	34.64
1200.00	34.64
1216.00	33.78
1232.00	34.21
1248.00	33.78
1264.00	33.78
1280.00	32.91
1296.00	32.91
1312.00	32.91
1328.00	32.91
1344.00	32.48
1360.00	32.48
1376.00	32.04
1392.00	32.04
1408.00	31.61
1424.00	31.61
1440.00	31.18
1456.00	31.18
1472.00	31.18
1488.00	31.18
1504.00	31.18
1520.00	31.18
1536.00	30.31
1552.00	30.31
1568.00	30.31
1584.00	30.31
1600.00	30.31

Cooling Curve for Black United Steel





APPENDIX C1

ADDRESS	OBJECT CODE	SOURCE STATEMENT
0000	00	NOP
0001	00	NOP
0002	00	NOP
0003	00	NOP
0004	ED56	IM 1
0006	31E0FF	LD SP,OFFEFH ;Set the stack pointer
0009	C30002	JP 0200H
000C	00	NOP
000D	00	NOP
000E	00	NOP
000F	00	NOP
0001	00	NOP
0011	00	NOP
0012	00	NOP
0013	00	NOP
0014	00	NOP
0015	00	NOP
0016	00	NOP
0017	00	NOP
0018	00	NOP
0019	00	NOP
001A	00	NOP
001B	00	NOP
0030	00	NOP
0031	00	NOP
0032	00	NOP
0034	00	NOP
0035	00	NOP
0036	00	NOP
0037	00	NOP
0038	C34602	JP 0246H ; Jump to interrupt service routine
003B	00	NOP
003C	00	NOP
003D	00	NOP
003E	00	NOP
003F	00	NOP
0040	00	NOP
0041	00	NOP
0042	00	NOP

\*\*\*\* MAIN CONTROL PROGRAM \*\*\*\*

0200	00	NOP
0201	0E02	LD C,02H
0203	00	NOP
0204	00	NOP
0205	00	NOP

```

**** PROCEDURE CLEAR DATA STORAGE AREA ***
0206      DD21FF34      LD IX,34FFH ;Load the memory area to
020A      FD21FF35      LD IY,35FFH ; be cleared
020E      00            NOP
020F      CDC102        CALL 02C1H ;Call a subroutine
**** END PROC.                ***

0212      00            NOP
0213      DD21FF30      LD IX,30FFH ; Load memory area to be
0217      FD21FF31      LD IY,31FFH ; mapped
021B      00            NOP
021C      CDC102        CALL 02C1H
021F      00            NOP
0220      00            NOP

*** PROCEDURE OPEN WINDOW ****
0221      3ECO          LD A, 0C0H ;Load the code required to
0223      32D2FC        LD (0FCD2H),A ; open the window
0226      CDB302        CALL 02B3H ;Call the delay loop
0229      3E00          LD A, 00H ;Load the code required to
022B      32D2FC        LD (0FCD2H),A ; hold the window
**** END PROCEDURE          ****

022E      00            NOP
022F      0665          LD B, 65H
0231      DD21FF34      LD IX,34FFH ;Load data storage array
0235      210036        LD HL, 3600H ;for the heating cycle
0238      00            NOP
0239      00            NOP
023A      CD0403        CALL 0304H
023D      00            NOP
023E      00            NOP
023F      00            NOP
0240      FB            EI
0241      00            NOP
0242      00            NOP
0243      C34102        JP 0241H

**** BEGINNING OF INTERRUPT SERVICE ROUTINE ***
0246      00            NOP
0247      F3            DI ;Disable interrupt
0248      08            EX AF,AF'
0249      D9            EXX
024A      00            NOP
024B      CDD702        CALL 02D7H ; Call the subroutine
024E      00            NOP ; to add up accumulated
; time

```

```

**** PROCEDURE DATA ACKNOWLEDGEMENT ****
**** THIS PROCEDURE SEND A CODE THROUGH ****
**** THE DATA BUS THUS SETTING THE LED's ****
**** ON THE DATA ACKNOWLEDGEMENT CIRCUIT ****
**** TO GO ON WHEN EVER DATA IS TRANSMITTED ****
**** FROM THE CALORIMETER TO THE SYSTEM ****

```

```

024F      3E1E      LD A,1EH      ; Setup the enabling code
0251      32D2FC    LD (0FCD2H),A ; Enable the channel
0254      CDB302    CALL 02B3H    ; Call the delay loop
0257      3E00      LD A,00H      ; Setup disabling code
0259      32D2FC    LD (0FCD2H),A ; Disable the channel
**** END PROC.      ***

```

```

025C      08        EX AF,AF'
025D      D9        EXX
025E      05        DEC B
025F      CA6802    JP Z,0268H    ;Check if 100 data sampling
0262      FB        EI          ;has been done.
0263      ED4D      RETI       ;Return to interrupt loop
0265      00        NOP
0266      00        NOP
0267      00        NOP
0268      00        NOP
0269      F3        DI
026A      00        NOP
026B      0D        DEC C
026C      CA9B02    JP Z, 029BH
026F      00        NOP
0270      0665      LD B,65H
0272      DD21FF30  LD IX,30FFH  ;Load data storage array
0276      210032    LD HL,3200H  ;for the cooling cycle
0279      00        NOP

```

```

*** PROCEDURE CLOSE WINDOW ****
027A      3EC1      LD A,0C1H    ;Load code required to
027C      32D2FC    LD (0FCD2H),A close the window
027F      CDB302    CALL 02B3H    ;Call the delay loop
0282      3E00      LD A,00H      ;Load code to hold the
0284      32D2FC    LD (0FCD2H),A window
*** END PROC.      ***

```

```

0287      00        NOP
0288      00        NOP
0289      00        NOP
028A      00        NOP
028B      00        NOP
028C      CD0403    CALL 0304H
028F      00        NOP
0290      00        NOP
0291      00        NOP
0292      FB        EI
0293      00        NOP
0294      00        NOP

```

```

0295      00      NOP
0296      00      NOP
0297      C39502  JP 0295H
029A      00      NOP

```

```

****  PROCEDURE BLINK  ****
029B      00      NOP
029C      F3      DI
029D      3E0F     LD A,0FH      ;Send code to enable
029F      32D2FC   LD (0FCD2H),A ; the LEDs
02A2      CDB302   CALL 02B3H    ;Call delay loop
02A5      3E00     LD A,00H     ;Disable the LEDs
02A7      32D2FC   LD (0FCD2H),A
02AA      CDB302   CALL 02B3H    ;Call delay loop
****  END PROC.      ****

```

```

02AD      C39B02  JP 029BH
02B0      00      NOP
02B1      00      NOP
02B2      00      NOP

```

```

****  SUBROUTINE DELAY  ****
****  THIS SUBROUTINE IS INVOKED ANY TIME  ****
****  A DELAY OF APPROXIMATELY ONE SECOND  ****
****  IS REQUIRED  ****

```

```

02B3      00      NOP
02B4      11FFFF   LD DE,0FFFFH ;Load the preset value
02B7      1B      DEC DE      ;Decrement it at given
02B8      7A      LD A,D      ;intervals
02B9      B3      OR E
02BA      C2B702  JP NZ,02B7H  ;Continue decrementing
02BD      C9      RET      until the value is zero
02BE      00      NOP
02BF      00      NOP
02C0      00      NOP
02C1      00      NOP
02C2      0665    LD B,65HY   ;Prefix another value
02C4      00      NOP
02C5      97      SUB A      ;Countercheck if the
02C6      DD7701  LD (IX+01H),A ; value has go to zero
02C9      FD7701  LD (IY+01H),A
02CC      DD23    INC IX
02CE      FD23    INC IY
02D0      05      DEC B
02D1      C2C502  JP NZ,02C5H ;Continue decrementing
02D4      00      NOP      value until it is zero
02D5      C9      RET
***  END SUB      ***

```

\*\*\*\* SUBROUTINE ADD TIME \*\*\*\*

\*\*\*\* THIS SUBROUTINE ADDS THE CUMULATIVE \*\*\*\*  
\*\*\*\* TIME TAKEN AND CAPTURES THE TEMPERATURE DATA \*\*\*\*  
\*\*\*\* OF THE THERMOCOUPLES AT THE SAME TIME \*\*\*\*

```
02D6      00      NOP
02D7      00      NOP
02D8      08      EX AF,AF'
02D9      D9      EXX
02DA      3A0030   LD A,(3000H) ;Load the MSB of collected
02DD      57      LD D,A      data into memory
02DE      3A0430   LD A,(3004H) ;Load the LSB of collected
02E1      82      ADD A,D      data to memory
02E2      77      LD (HL),A
02E3      320430   LD (3004H),A
02E6      23      INC HL
02E7      3A0230   LD A, (3002H) ;Check if data is 16 Bit
02EA      57      LD D,A
02EB      3A0530   LD A,(3005H)
02EE      8A      ADC A,D      ;If so combine the MSB
02EF      77      LD (HL),A      with LSB
02F0      320530   LD (3005H),A ; Store data
02F3      23      INC HL
02F4      3AC1FC   LD A,(0FCC1H)
02F7      DD7701   LD (IX+01H),A
02FA      DD23     INC IX
02FC      DD23     INC IX
02FE      00      NOP
02FF      08      EX AF,AF'
0300      D9      EXX
0301      C9      RET ;Return and wait for interupt
**** END SUB ****
```

```
0302      00      NOP
0303      00      NOP
0304      00      NOP
```

\*\*\*\* SUBROUTINE CONSTANTS \*\*\*\*

\*\*\*\* THIS SUBROUTINE STORES THE CONSTANTS \*\*\*\*  
\*\*\*\* REQUIRED TO BE ADDED TOGETHER TO GIVE \*\*\*\*  
\*\*\*\* THE TIME VARIABLE \*\*\*\*

```
0305      3E10     LD A,10H ;Store the required
0307      320030   LD (3000H),A constants into various
030A      3E00     LD A,00H  accessible locations
030C      320230   LD (3002H),A
030F      320430   LD (3004H),A
0312      320530   LD (3005H),A
0315      00      NOP
0316      C9      RET
*** END SUB ****
```

APPENDIX C2

\*\*\*\* PROGRAM 1 \*\*\*

\*\*\*\* THIS PROGRAM ONCE EXECUTED READS AND WRITES           \*\*\*\*  
 \*\*\*\* TO THE ENTIRE DECODED MEMORY AREA THUS GENERATING \*\*\*\*  
 \*\*\*\* ALL THE WIRED CHIP SELECT SIGNALS                   \*\*\*\*

ADDRESS	OBJECT CODE	SOURCE STATEMENT
3000	3E02	LD A,02 ;Load the testing value
3002	32FF07	LD (07FFH),A and load it to memory
3005	2AFF07	LD HL,(07FFH) location
3008	32FF17	LD (17FFH),A
3011	2AFF17	LD HL,(17FFH) ; ''
3014	320025	LD (2500H),A
3017	2A0025	LD HL,(2500H) ; ''
3020	320026	LD (2600H),A
3023	2A0026	LD HL,(2600H)
3026	320035	LD (3500H),A ; ''
3029	2A0035	LD HL,(3500H)
3032	320037	LD (3700H),A ; ''
3035	2A0037	LD HL,(3700H)
3038	320045	LD (4500H),A
3041	2A0045	LD HL,(4500H) ; ''
3044	320049	LD (4900H),A
3047	2A0049	LD HL,(4900H)
3050	320052	LD (5200H),A ; ''
3053	2A0052	LD HL,(5200H)
3056	320059	LD (5900H),A
3059	2A0059	LD HL,(5900H) ; ''
3062	320065	LD (6500H),A
3065	2A0065	LD HL,(6500H)
3068	320069	LD (6900H),A
3071	2A0069	LD HL,(6900H)
3074	320075	LD (7500H),A ; ''
3077	2A0075	LD HL,(7500H)
3080	320079	LD (7900H),A
3083	2A0079	LD HL,(7900H)
3086	320090	LD (9000H),A
3089	2A0090	LD HL,(9000H)
3092	3200B0	LD (B000H),A
3095	2A00B0	LD HL,(B000H) ; ''
3098	3200D0	LD (D000H),A
30A1	2A00D0	LD HL,(D000H)
30A4	3200F0	LD (F000H),A
30A7	2A00F0	LD HL,(F000H)
30AA	C30030	JP 3000H ;Jump to the beginning ;and repeat

\*\*\*\* PROGRAM 2 \*\*\*\*

\*\*\*\* PROGRAM READS AND WRITES A PARTICULAR DATA \*\*\*\*  
 \*\*\*\* CODE ON THE DATA BUS \*\*\*\*

ADDRESS	OBJECT CODE	SOURCE STATEMENT
3000	3E*00*	LD A,*00* ;Load testing value
3002	325525	LD (2555H),A
3005	2A5525	LD HL,(2555H)
3008	C30030	JP 3000H ; Repeat the loop

NOTE: The number \*00\* is varied to suit the data lines being tested.

\*\*\* PROGRAM 3 \*\*\*\*

\*\*\* PROGRAM READS AND WRITES A GIVEN ADDRESS ON THE \*\*\*\*  
 \*\*\* ADDRESS BUS \*\*\*\*

ADDRESS	OBJECT CODE	SOURCE STATEMENT
3000	3EFH	LD A,FFH
3002	32*5525*	LD (*2555H*),A ;Load testing address
3005	2A*5525*	LD HL,(*2555H*)
3008	C30030	JP 3000H ;Repeat the loop

NOTE: The value \*2555H\* changes depending on which address line is to be tested.

\*\*\* PROGRAM 4 \*\*\*\*

\*\*\*\* PROGRAM TRANSMITS THE CODE FC02 THROUGH \*\*\*\*  
 \*\*\*\* THE ADDRESS BUS HENCE GENERATING THE NOT \*\*\*\*  
 \*\*\*\* PAGE FC SIGNAL \*\*\*\*

ADDRESS	OBJECT CODE	SOURCE STATEMENT
3000	3E02	LD A,02H
3002	32FF07	LD (0FC02H),A
3005	2AFF07	LD HL,(0FC02H)
3008	11FFFF	LD DE,0FFFH ;Delay loop of one sec.
3011	1B	DEC DE
3012	7A	LD A,D
3013	B3	OR E
3014	C21130	JP NZ,3011H ;End of delay loop
3017	C30030	JP 3000H ;Repeat the program

APPENDIX D : DATA ANALYSIS PASCAL PROGRAM



## APPENDIX D

```
PROGRAM TEST( INPUT, OUTPUT);

Const
  Blank = ' ' ;

type

  CharFile = File of Char;
  ByteFile = File of Byte;
  ArrFile = File of Array[1..77] of Char;
  AnyFile = Text;
  AnyString = String[25] ;

var
  AluChar : CharFile;
  AluByte : ByteFile;
  AluArr : CharFile;
  AnyAlu, WillChar, WillByte,
  WillArr, AnyWill, AnyChar : AnyFile ;
  I : Integer;
  Item : Char ;
  Filename1, Filename2 : AnyString ;

*/PROCEDURE DOCHAR/*

procedure DoChar( Source, Destination : AnyString );

var
  Item : char ;
  I,J,K : Integer ;

begin
  assign( AluChar, Source );
  assign( WillChar, Destination );
  reset( AluChar);
  rewrite( WillChar );
  I:=0;
  repeat
    I := I + 1 ;
    read( AluChar, Item );
    If (I mod 77 > 9) and ( I mod 77 < 74 ) then
      if I mod 77 = 73 then
        writeln( WillChar, Item )
      else
        write( WillChar, Item );
  until eof( AluChar );
  close( AluChar );
  close( WillChar );
```

```

end ; { Proc DoChar }

*/PROCEDURE SEPR/*

procedure Separate( Source, Destination : AnyString );

var
  Item : Array[1..70] of char ;
  I, J : Integer ;
  A,B,C,D,E,F,G,H,Q,R,K,L,M,N,O,P,Element, Try : String[4]
;

begin
  assign( WillByte, Source );
  Assign( AnyAlu, Destination );
  reset( AnyAlu );
  rewrite( WillByte );
  I := 0 ;
  J := 0 ;
  while not eof( AnyAlu ) do
    begin
      readln( AnyAlu,A,B,C,D,E,F,G,H,Q,R,K,L,M,N,O,P );
      write(
WillByte,A,Blank,B,Blank,C,Blank,D,Blank,E,Blank,F,Blank,
G,Blank
);
      write(
WillByte,H,Blank,Q,Blank,R,Blank,K,Blank,L,Blank,M,Blank,
N,Blank,O,Blank,P);
      writeln( WillByte );
    end ;
  close( AnyAlu );
  close( WillByte );
end ; { Proc Separate }

```

\*/PROCEDURE LOOKUP/\*

```

procedure LookUp( Dummy1 : Char ; var Dummy2 : Integer );

```

```

begin
  Case Dummy1 of
    '1' : Dummy2 := 1 ;
    '2' : Dummy2 := 2 ;
    '3' : Dummy2 := 3 ;
    '4' : Dummy2 := 4 ;
    '5' : Dummy2 := 5 ;
    '6' : Dummy2 := 6 ;
    '7' : Dummy2 := 7 ;
    '8' : Dummy2 := 8 ;
    '9' : Dummy2 := 9 ;
    'A' : Dummy2 := 10 ;
    'B' : Dummy2 := 11 ;

```

```

    'C' : Dummy2 := 12 ;
    'D' : Dummy2 := 13 ;
    'E' : Dummy2 := 14 ;
    'F' : Dummy2 := 15 ;
    '0' : Dummy2 := 0 ;
end; { Case }
end; { Proc LookUp }

```

```

*/PROCEDURE CONV/*

```

```

procedure Convert( Source, Destination : AnyString );

```

```

var
    Temp, One, Two, Three, Four : Char ;
    J, I, Value1, Value2, Value3, Value4, Result : Integer ;
    Title : String[12] ;

```

```

begin

```

```

    assign( AnyAlu, Source );
    {assign( AnyWill, 'a:\Final.Dat' );}
    Assign( AnyChar, Destination );
    reset( AnyAlu );
    {rewrite( AnyWill );}
    rewrite( AnyChar );
    I := 1 ;
    Title := 'Value' ;
    repeat
        for J:= 1 to 15 do
            begin
                Read( AnyAlu, Four, Three, Two, One, Temp );
                I := I + 1 ;
                LookUp( One, Value1 );
                LookUp( Two, Value2 );
                LookUp( Three, Value3 );
                LookUp( Four, Value4 );
                Result := ( Value4 * 16 ) + Value3 + ( Value2 * 4096 )
+ ( Value1 * 256 ) ;
                If ( Result > 9999 ) or ( Result < 0 ) then
                    Result := 0 ;
                {writeln(
I, '.....', Four, '.....', Three, '.....', Two, '.....', One, '.....',
Result
                );}
                write( AnyWill, Result:4, Blank );}
                writeln( AnyChar, Result:4 );
            end;
            Readln( AnyAlu, Four, Three, Two, One, Temp );
            LookUp( One, Value1 );
            LookUp( Two, Value2 );
            LookUp( Three, Value3 );
            LookUp( Four, Value4 );
            Result := ( Value4 * 16 ) + Value3 + ( Value2 * 4096 ) +
( Value1 * 256 ) ;

```

```

    If ( Result > 9999) or ( Result < 0 ) then
        Result := 0 ;
        {writeln(
I, '.....', Four, '.....', Three, '.....', Two, '.....', One, '.....',
Result
);
        writeln( AnyWill, Result:4 );}
        writeln( AnyChar, Result:4 );
until eof( AnyAlu );
close( AnyAlu );
close( AnyWill );
Close( AnyChar );
end; { Proc Convert }

```

```

begin { Main Loop }
    write( 'Enter the File to Be Converted.....' );
    readln( Filename1 );
    writeln;
    write( 'Enter the file to be written to.....' );
    readln( Filename2 );
    DoChar( Filename1, 'Will.dat' );
    Separate( 'Will.dat', 'Temp.dat' );
    convert( 'Temp.Dat', Filename2 );
end.

```

HN2732 ICs

