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A Modular Data Acquisition and Display Software System for a Laboratory Environment

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A Modular Data Acquisition and Display Software System for a Laboratory Environment

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ABSTRACT

This report describes the processes involved in acquiring and analyzing experimental laboratory data using a medium sized computer in a multi-programming environment with a modular software system. Research involving Phase Change Materials and Calorimetric Performance measurements in building research are used as case studies to describe the functional capabilities and operational procedures of the system. The software system consists of computer programs which allow the researcher to collect, store, and analyze data graphically.

Key words: experimental data processing; graphical data analysis; interactive processing; laboratory data collection; modular computer software.

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1. INTRODUCTION

An automated system, Modular Acquisition and Display Software System (MADS) has been designed and implemented for a multi-tasking computer environment. MADS comprises many computer programming modules and allows a researcher to design an experimental process (with regard to computer interaction), acquire, validate, store, and analyze data in an efficient manner thus reducing the start-up time needed to accomplish these tasks. Another benefit realized by MADS is the instrumentation facility staff are provided the resources to monitor and manage data among several research projects operating in a concurrent mode on a single computing system.

This report describes the computing environment as related to projects involving the research and testing of building materials and components. It addresses the conceptual aspects essential in acquiring and processing scientific data in an unattended and automatic mode of operation. Programming modules are defined by function as well as their operating procedures.

A Perkin-Elmer[1] Model 7/32 minicomputer system was used in the development and implementation of the system with it's associated peripherals and computer software resources. Other minicomputer systems can be used to implement the system, although modifications will undoubtedly be necessary to achieve similar results.

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[1]The reference of equipment manufacturers in this document does not constitute an endorsement by NBS.

2. SCOPE OF THE MADS

The scope of the automated system can be logically divided into component parts which represent the steps necessary to acquire and process data. The first of these components is the acquisition phase. During this process, the parameters of the experiment are established. These parameters direct the computer to collect and store the data at specified intervals using predetermined digital signals (data channels) and identifies each experimental session by allowing the researcher to assign a unique name. Malfunctions which may occur during the progress of the experiment are reported to the operator through the use of the operator command device installed in the laboratory.

The second component is the preparatory phase. During this process, data previously stored during the acquisition phase is verified as to format and proper data ranges. This process is normally performed at a pre-determined time which is optionally built into the acquisition module. In the case of a continuous experiment for example, this process is automatically started by the computer at the end of the day. Another important function performed during this phase is to compress the data by eliminating non-essential characters which may be stored in the raw data file. This allows for maximum storage capacity on the computing system as well as increased efficiency during data analysis.

Lastly, data analysis phase. During this phase, data is analyzed using a variety of methods, including report generation, statistical and numerical analysis, and graphical analysis, both interactive and batch.

3. EXPERIMENTAL PROCEDURES

The applicability of MADS to the automation of long-term laboratory experiments was demonstrated in the context of evaluating the response of a Phase Change Material (PCM) to repeated thermal cycling. Phase change materials represent one class of materials used to store thermal energy. These compounds store or deliver energy, as latent heat, when they undergo a phase transition such as melting or freezing. A typical example of a phase change materials is sodium borate and clay. Sodium borate is a nucleating agent which is added to promote the phase change in a suitable temperature range, and a thickening agent, clay, is added to minimize segregation. The material is encapsulated in polyetheylene containers, and is approximately 50 calories of energy per gram of material are stored or delivered at a temperature near 30 degrees centigrade according to the following reaction:

$$\underset{\text{(solid)}}{Na_2SO_4 \cdot 10H_2O} = \underset{\text{(solid)}}{Na_2SO_4} + \text{saturated solution}$$

The energy storage capacities of phase change storage systems, however, tend to decrease with thermal cycling.

Monitoring the variations in the energy storage capacities of PCM's and elucidating the mechanisms leading to them requires the development of an accelerated thermal cycling device and a calorimeter. The thermal cycling device is used to simulate the thermal cycling of PCM's which occurs in service and the calorimeter is used to determine the variations in storage capacity with cycling.

To monitor the specific responses to thermal cycling, selected specimens were instrumented with thermocouples as shown in Figure 1. In addition, the time and temperature dependence of conductance changes were measured in other instrumented specimens (Figure 2). The acquisition and reduction of this data, acquired at a rate of one point per minute over a period of several months, required automation of the acquisition system, (as is subsequently discussed).

Periodically, specimens were removed from the cycling device and their thermal storage capacities determined using isoperibolic calorimetry. This technique required the establishment of the calorimetric baseline, the measurement of the rate of change in temperature in the calorimeter and the establishment of a second baseline after the PCM specimen had delivered the energy stored. These measurements required the accumulation of digital data at the rate of 6 points every 10 seconds over a period of 4 hours.

4. COMPUTING ENVIRONMENT

4.1 LABORATORY INSTRUMENTATION

Major equipment components of laboratory experimentation include devices which measure analog signals, control experimental processes, and convert analog signals to digital data representation. The MADS system is designed to operate in a laboratory environment where the primary responsibility for these functions is performed by devices called data loggers. These data loggers provide the link between laboratory instruments which include calorimeters, spectrophotometers, chromatographs, thermocouples, and pressure transducers.

Connecting the instruments and the data logger is performed by electrical cable. Each laboratory measurement, commonly referred to as a channel of data, requires an individual wire to transmit the analog signal. The cables are connected to terminal points located on the data logger. Signal sampling is performed at predetermined time intervals set by controls also installed in the data logger. Data loggers can record many of these signals collectively representing a scan of data. The researcher can suppress or skip the reading of data channels through switches.

Analog to digital converters transform the electronic voltage readings (channels) into digital representations and stores them temporarily in small amounts of local memory. Predetermined quantities of this data are then transmitted through a communications port to a remote device such as the CBT Instrumentation Facility computer where it is collected, validated and processed. Figure 3 illustrates the components used in the Phase Change Materials experiment and the Calorimetric Performance experiment.

4.2 DATA COMMUNICATIONS METHODS

The transmission of data between the CBT Instrumentation Facility and the laboratory environment is accomplished using the EIA RS-232 standard for asynchronous data communications interfaces. Since the data logging devices, operational command consoles, and the computer are located in the same building, direct cable and short haul modems are used to interface the PCM and Calorimetric experiments. In Figures 4, 5, and 6, the communications components and their connections are illustrated.

4.3 CBT INSTRUMENTATION FACILITY

One of the main missions of the Center For Building Technology's, Central Instrumentation Facility is to interface laboratory experimentation (such as the PCM and Calorimetric research) and provide the researcher with computing resources to process the data. A Perkin-Elmer, Model 7/32 computer system (hereafter referred to as the "computer") and several peripheral devices were installed during the mid 1970's to accomplish this task. Several major enhancements have been added to the facility to include; installation of large capacity disk storage devices, interactive graphics capabilities and statistical tools. This section describes the elements of the facility which are used by the MADS software system and the research described in this report. Up to five experimental processes have been supported on the computer simultaneously, along with additional data processing applications such as graphical and statistical data analysis, modelling and its related program development functions.

4.3.1 Computer System Hardware Configuration

The computer system used is classified as a minicomputer system. A configuration of the computer is presented in Figure 7. Its central processing unit processes data and computer instructions in 32-bit word lengths. Double precision (64-bit) scientific notation using a Fortran Language processor is also available on the computer. These computations are processed using software programs which are slower than the hardware 32-bit processing. The ratio of the two modes of computation is approximately 14 to 1.

The memory capacity of the computer is one million bytes of storage. The computer supports ferrite core memory which is characteristic of computer memory implementations of its time period. Unlike virtual memory systems, this computer allows running programs to utilize the entire memory complement, though in a central computing environment this method would not be practical.

Storage of data is accomplished using 3 different types of magnetic media; one-half inch magnetic tape drives, rotating magnetic disk cartridge drives, and eight inch floppy diskette drives. Collectively, this provides 462 million characters of on-line disk storage, and 3 magnetic tape drives; both for 9 track and 7 track recording.

As stated in section 4.2, RS-232 asynchronous communications protocols are used to communicate with the computer. This method provides the only access to the computer for terminals, other computers, and instruments. The capacity of the computer is currently thirty-eight ports. Although the hardware design allows for additional port capacity, saturation of memory and the central processor would occur if they were installed.

4.3.2 Software Components

The software components of the computer include those which are supplied by the computer's manufacturer (sections 4.3.2.1 and 4.3.2.2), and custom software such as the MADS system which was designed and implemented by the CBT programming staff. In developing the MADS application software, careful consideration was given to the overall impact on all running programs. Design considerations for memory management and priority scheduling were implemented to allow the MADS system to perform within the contraints of the computer system.

4.3.2.1 Operating System

The Operating System is the nucleus of all software which runs on the computer system. It supports a multi-programming computer environment. Major software components of the operating system are identified in Table 1. Operator communications with the computer are accomplished using two methods. The first is the Multi-Terminal Manager. It provides access to the computer through the use of accounts and passwords, similar to large time shared systems. The second method utilized by the MADS software system, is through application software control. All device communications are accomplished through application programs.

4.3.2.2 Utilities

Several programs are available on the computer to allow for the creation and manipulation of data sets and text. These programs are supplied by the computer manufacturer and greatly assist the programmer and researcher in editing, copying and archiving computerized files. Table 2 lists the utilities which are used in the PCM and Calorimetric experiments.

4.3.2.3 Applications Software

The MADS software system was programmed in the Fortran programming language using the Perkin-Elmer ANSI Standard X3.9, Fortran compiler, compatible with the 1978 standard. Several auxiliary sub-programs and compiler features were also invoked in order to gain optimum performance and control over the loading of programs and to insure an efficient data processing environment. These added features do not conform to the ANSI standard and would require replacement or modification if it is desirable to transport the MADS software to another computer system. The application software currently involves over 27 major program entities which acquire and process data for PCM and Calorimetric experiments. A significant advantage resulting from the modular design of the system is that additional experiments can be integrated into the system by including modules such as the acquisition and processing modules. In Chapters 5 and 6, a detailed description of the programming modules and their operating procedure is presented.

5. MODULAR ACQUISITION AND DISPLAY SOFTWARE SYSTEM DESCRIPTION

This section describes the functional capabilities of the MADS software system as related to the PCM and Calorimetric experiments. The structure of the software system is discussed along with modes of operation.

5.1 SOFTWARE SYSTEM DESCRIPTION

The software system can be described as one which has a supervisor program and many sub-programs under it. These sub-programs perform many functions relating to the acquisition and processing of laboratory data. Performing these tasks also requires supporting utilities such as graphics and statistical libraries. These utilities will not be discussed in detail in this paper. A list of references has been provided which the user may consult for detailed descriptions of the resources. Figure 8 illustrates the hierarchical structure of the MADS system. This will help the reader understand the relationship of the programming modules.

5.2 OPERATING MODES

Operation of the MADS software system requires two distinct modes. The first mode utilizes the computer system through the use of the programming modules in a real-time environment. In this mode priority is given to the MADS system which allows operator commands and program instructions to be executed before other tasks which are currently operating in the computer. Only those commands which are directed by the operator in the laboratory are processed. The user resides in a "shell-like" system, interacting with the operating system directly. The second of the two modes requires the operator to gain access to the computer using a terminal which is installed as a port to the Perkin-Elmer Multi-Terminal Manager sub-system. In this mode the operator competes for various computer resources such as memory, processor time and disk access. Requests for these resources are honored on a first-in, first-out basis according to priority. All terminals under the Multi-Terminal Manager operate at the same priority. Therefore, many users could be requesting similar resources which could lengthen response time. Design of the MADS system allows its processing programs to operate in this mode. All data acquisition programs must operate in real-time.

5.3 USER INTERFACE

Operator interaction with the computer is provided through the use of Cathode Ray Tube (CRT) devices installed in the laboratory. These CRTs provide command input to the MADS software programs and act as a display device for responses from the computer. They are non-intelligent in nature, and provide alphanumeric keyboard entry and display only. An exception to the CRTs are various graphical display units which are installed in the CBT Instrumentation Facility and in other parts of CBT. They are used by the software programs which are described in Section 5.4.8. These units are intelligent and have local programming capabilities. Transmission speed is set at 960 characters per second to provide maximum response and interaction with the system.

5.4 MADS SOFTWARE MODULES

5.4.1 Supervisor Program Module

The Supervisor Program Module is named MADSUP. The function of MADSUP is to provide command traffic control between the computer and the laboratory. When the MADS software system is activated at the main computer console, it is the first program which is loaded. Each command device configured in the MADS system receives a message indicating that the system is available (PCM and Calorimetric Experiments require only one operator CRT). Program MADSUP idles until an operator in the laboratory issues a command to load another program module for processing. Upon completion of the called program, control is returned to the MADSUP program where it waits for the next command. The user selects from a displayed directory of available modules. As additional modules are needed, their names are included in the directory by modifying MADSUP.

The result of MADSUP's design allows maximum use of computer memory by requiring only one module to be loaded per operator CRT at any given time with the exception of the data acquisition modules which are loaded and executed independently of other modules in the system. The determined size of computer memory requirements can be calculated by summing the size of program MADSUP and the size of the largest sub-program which is part of the MADS system. To clarify the operating sequence of the MADS software system, Figure 9 illustrates a sample session involving a Calorimetric experiment.

5.4.2 Project Select Program Module

The Project Select Program module is named MADSEL. The function of MADSEL is to allow the operator to select a project name which directs the MADS system to call the appropriate sub-programs for processing. The project name entered by the operator is retained until another project is specified or until the system is restarted. Project identities are recorded within the MADSEL program and may be modified by changing the program.

5.4.3 Monitor Program Module

The Monitor Program module is named MADMON. The function of MADMON is to display the current status of the MADS software system. MADMON may be called by the operator from the laboratory, or from the main computer console which resides in the CBT Instrumentation Facility. Information relating to the status of the acquisition tasks controlled by the MADS system is stored in a data file. This file is catalogued under the name "MADMON.AQU", and is updated by MADS sub-program MADSET and the MADS acquisition modules (PCMACQ and CALACQ). Figure 10 identifies the elements contained in the MADMON monitor file.

5.4.4 Acquisition Setup Program Module

The Acquisition Setup Programs are named according to the project and related to data collection and processing. The project identifier selected in the MADSEL module is used to concatenate the appropriate acquisition name to be loaded. For example, selecting the PCM experiment (project PCM), would result in the loading of program PCMSET and the Calorimetric experiment (project CAL), would result in the loading of the program CALSET. During the process of the setup programs, parameters for collecting data are specified through a series of question and answers. These parameters are stored in a temporary command file which is utilized in the subsequent acquisition mode processing. Information such as number of channels per scan and a unique name for the experimental session is specified. In Section 6.4.2, detailed instructions are given for the execution of the setup program modules.

5.4.5 Data Acquisition Program Module

The Data Acquisition Program modules are named in the same manner described in the MADSET Section (5.4.4). The function performed by the acquisition programs is to collect data from the laboratory and store it on the computer's mass storage system.

5.4.5.1 Phase Change Materials Acquisition

Program PCMACQ is unique because it operates on a 24 hour per day basis. Data is collect from 31 different channels at 1 minute intervals, resulting in 1440 individual channel observations per day. The raw data (see Appendix A) is stored in a holding file which is named PCMRAW.XXX, where XXX is the current Julian day. A list of the channel identities is provided in Appendix B. These identities are stored in a file named PCMDATA.LEG and are used by the MADS PCM processing programs to index channel information for report generation and plotting.

Very little operator intervention is required except for restarting and reconfiguring the instrumentation. Since the PCM process is cyclic, it was desirable to provide for automatic processing of data at a predetermined time. Hence, automatic loading and execution of data prepping, report generation and Versatec plotting is performed daily at 12:00 midnight. This process is initiated by the acquisition program which looks at the computer clock and takes the necessary actions to load the processing programs in a completely unattended mode. The result is a processing mode which allows for the collection and processing of data simultaneously. Errors detected during the acquisition process are reported to the main computer console as well and to the monitor acquisition file MADMON.AQU.

5.4.5.2 Calorimetric Acquisition

Program CALACQ collects data for the Calorimetric experiment. Acquisition sessions involving this experiment normally last approximately 4 hours. Data is collected from 4 to 12 channels (see Appendix A for format, and Appendix B for channel identities) at intervals determined by the researcher at start time. Typical intervals between readings range from one scan every ten seconds to one scan every 2 minutes. Storage of the data is maintained through a holding file named CALRAW.XXX, where XXX is a unique file extension given the experimental session by the operator during CALSET program execution. Information is continually collected until the operator terminates the acquisition program through program MADCAN. Subsequent processing is performed through operator control at the laboratory command console. This processing involves prepping the data file, the generation of graphical presentations of the data and optional printed reports. Errors detected during the acquisition process are reported to the main computer console as well as the monitor acquisition file MADMON.AQU.

5.4.6 Data Prepping Program Module

The Data Prepping Program modules are named in the same manner as the setup and acquisition programs. The function provided by the prepping modules is to validate the data and compress it by eliminating unnecessary characters which are transmitted by the data loggers. A characteristic of data loggers is to format the raw data into lines of several channels. This process introduces spaces between the individual channel numbers and their values in addition to formatting characters which are often appended to the beginning and end of each line transmitted. The result of this procedure is increased readability for humans but significant amounts of unnecessary mass storage are required to store the data in this format. An important function of the prepping modules is to generate a new and compressed data file containing only the information needed by the computer to process the data. In the case of the PCM experiment a data file is processed in the format as shown in Appendix C. It is renamed to PCMDATA.XXX, where XXX is the current Julian day. For Calorimetric experiments a similar process takes place, CALRAW.XXX is renamed to CALDATA.XXX. Appendix D illustrates the format. Savings of up to two-thirds of disk storage is common. Another file is produced by the prepping modules. This file contains the information found to be in error during the process of validating the data. The operator may wish to view this file if there is reason to believe that serious problems occurred during the acquisition of the data. To assist the operator, a message indicating the number of raw data records found in error is displayed.

5.4.7 Report Generating Program Module

The Report Generating Program Modules are named PCMLST and CALLST. The function provided by these programs is to generate a report of the data collected during the acquisition process. The format of the report is illustrated in Appendices E & F. When the operator starts the programs, parameters are requested from the operator command device. Responding to the questions allows the operator to generate a portion of the data file. An example would be to extract all data collected between the hours of 09:00 and 12:00. No calculations are performed on the data, it is displayed just as it is stored. Each observation (scan) of data would correlate to a physical data record stored in the magnetic disk file. The operator may optionally direct the report to be printed on the command device or the line printer in the computer facility. These programs provide the utility for displaying data stored on disk. This utility is often found in a text editor program. However, the format of the stored data and the physical record size prohibits the use of text editing programs.

5.4.8 Graphics Generating Program Modules

This section describes the graphical methods of analyzing data for the PCM and Calorimetric experiments. The volume of data involved in these research projects required such methods which frees the researcher from "poring" through large printed listings. The use of graphical display devices allows the researcher to analyze changes in the experimental processes. These changes can occur on a daily basis or span the length of the project. The ability to compare curve plots of related measurements greatly reduces the amount of time required to form a hypothesis and helps the researcher make required changes in laboratory measurement techniques.

5.4.8.1 Versatec Batch Plotting

The Versatec Batch Plotting program for the PCM project is named PCMPLT. The function provided by PCMPLT is to generate a plot of Time (X axis) versus Engineering Unit (Y axis) for each measurement collected during each day in which the project runs. There are several sub-programs which support PCMPLT. These programs are identified in Table 3 along with their supporting function. The main output from PCMPLT is provided on a Versatec Electrostatic Plotting Device. Additionally, sub-files are produced which are used by the sub-programs to produce summary data reports and graphics. Appendix G illustrates a PCM daily plot for one channel of data. Thirty-one frames are normally produced for each day. A file containing the channel designations is used during the processing. Section 5.5.1.3 describes the format of this file.

There are two additional processes which result from the execution of program PCMPLT. The first process requires the use of a set of sub-files which are for several selected channel measurements. These files are called worker files, that is they are regenerated each time program PCMPLT is run. They contain Time (X axis) and Measurement values (Y axis) for selected data collection times occurring during an experimental day. This segment of data is referred to as the "phase change segment" and provides important information to the researcher by identifying the exact time and value for the phase change. A statistical utility available on the CBT computer called Minitab was utilized to generate the plot. Appendix H illustrates a sample Phase Change segment plot.

The second process involves the plotting of maximum and minimum peak values for selected measurements. These values and their time of occurrence are stored in a data file which is updated during the course of executing program PCMPLT. An entire year of peak information is kept in the file for future processing. Two programs are available which allow graphing of measurement values. They are described in Section 5.4.8.3.

The program to plot Calorimetric experimental data is named CALPLT. The function of CALPLT is much less extensive than that of PCMPLT. CALPLT simply graphs each channel of measurement data collected during a specific experimental session. The session is identified by the name given by the operator during the execution of CALSET. A data file containing the channel identification is utilized to generate each plotting frame. Appendix I illustrates a sample Calorimetric Versatec plot.

5.4.8.2 Easygraphing Interactive Graphics Module

Two programs are used to generate Easygraphing graphics, PCMPEAK and PCMPEAKA. The function of PCMPEAK and PCMPEAKA is to allow the researcher to plot peak values from the data file generated using program PCMPLT. Easygraphing is a graphics utility produced by Tektronix, Inc. It has a easy to use command structure and is used to generate graphics on Tektronix Model 4014 and 4027 computer graphics terminals.

PCMPEAK and PCMPEAKA are very similar in the graphics they provide. PCMPEAK produces a plot of one cycle of information for a specified channel. PCMPEAKA produces all three cycles of information for a specified channel. The operator specifies the starting and ending measurement days to be plotted. A single day or an entire year of information may be displayed using the programs. Appendix J and K illustrate sample Easygraphing frames. A significant advantage of using this plotting method is that the process of rescaling the data can be done quickly.

5.5 DATABASE STORAGE

Storage of data collected during the PCM and Calorimetric projects involves the use of a large 300 million character storage magnetic disk drive. All data is stored in a compressed format as discussed in Section 5.4.5. Once the data has been processed it is archived to magnetic tape for permanent storage and later processing if needed. The following sections briefly describe the purpose of each file of the database. Appendices illustrating database record formats are provided.

5.5.1 Data File and Record Formats

A data file as defined by the MADS system is one with which a unique name is associated. PCM data files are named PCMDATA.XXX where XXX is the Julian day for the data being collected. Calorimetric data files are named CALDATA.XXX, where XXX is a unique sequence number given by the operator at the beginning of the experimental session. Other data files are given preassigned names and are never changed.

A data file record is a group of information contained in a data file. A record is synonomous with a scan. Many records make up a data file. For example, there are a maximum of 1440 data records contained in a PCM data file. Calorimetric data files vary in length depending on the length of the experiment.

Within each data record there are a number of record elements. These elements are the smallest pieces of a data file record which are accessed through program control. Examples of record elements are measurement values and time of occurrence.

5.5.1.1 Raw Data File

Raw data files contain information in the format as it is transmitted from the laboratory to the computer facility. As stated in Section 5.4.5, much of the contents of the raw data files serves no purpose except for readability. Once the prepping process has been completed, raw data files are erased from the disk. PCM raw data files are named PCMRAW.XXX, where XXX is the Julian day for the data being collected. Calorimetric raw data files are named CALRAW.XXX, where XXX is the unique sequence number given to the experimental session. Appendix A illustrates examples of raw data file records.

5.5.1.2 Compressed Data File

Compressed data files are generated from raw data files using the prepping program modules. They contain the information used to generate all report and graphical output for the PCM and Calorimetric experiments. Compressed data files are designed to accommodate a maximum number of channels per data scan. For example, the PCM data file can store up to 100 channels of PCM data per record. By indexing within a record using the channel number to store or retrieve the measurement value, it is not necessary to include the channel number as part of the data file record contents. This method reduces the size of the record significantly. Appendices C and D illustrate compressed data file records.

5.5.1.3 Peak Summary Data File

The peak summary data file is generated from the PCMPLT program. It contains summary information used to generate graphical outputs for program PCMPEAK and PCMPEAKA as described in Section 5.4.8.3. A record exists for each day in which PCM data was collected. The position of the record identifies the Julian day for the year collected. The file is 365 records long and is named PCMPEAK.DTA. Appendix L illustrates the format of a record.

5.6 ARCHIVAL STORAGE

Storing data on backup or archival magnetic media is important for file security and eliminates the need to keep unnecessary data files stored on resident disk volumes. The process of storing data for archival purposes involves the use of a Perkin-Elmer utility known as OSCOPY/32. This utility allows the operator to copy a file from disk to tape or tape to disk. It is not performed through MADS and must be executed from an MTM terminal. The reader should refer to the Perkin-Elmer OSCOPY/32 user manual for detailed instructions on its operation and commands.

6. MODULAR ACQUISITION AND DISPLAY SYSTEM OPERATING REFERENCE

This section describes the operational procedures for the MADS software system as related to the PCM and Calorimetric experiments. The format of this section is presented in a "cookbook" approach. Each program's environment, starting parameters and operator queries and responses are presented. A sample session of a MADS system startup and program run sequence is presented in Appendix M.

A terminal device which acts as the main operator command console for the computer system is installed in the CBT Instrumentation Facility. This device is unique because it is used to issue commands not privileged by the Multi-Terminal Manager terminals. These commands direct the computer to perform executive tasks such as loading the MADS software system and monitoring the system activity. For a detailed description of the operator commands which are not part of the MADS system, the reader should consult the Perkin-Elmer "OS32MT Operator Reference Manual".

6.1 INSTRUMENTATION FACILITY EXPERIMENTAL PROCESS STARTUP & MONITORING

Established operating procedures of the computer system require that the MADS software system be operating at all times. Since it not possible to predict when experimental processes are scheduled and in order to relieve the researcher from computer facility operation, the MADS system is started automatically when the computer is turned on from an outage or restarted from a failure. A single command which activates a procedural file has been developed to perform this function. By typing the command "MADSUP" at the main computer console, the MADS system is activated.

It is important for the computer facility staff to be aware of certain computer system activity in order to maintain a responsive and efficient computer system. Since the data acquisition activities of the computer are given priority status, a means for checking the individual acquisitions status is important to ensure that the MADS system is not adversely affecting other running tasks. A procedure has been developed to allow the operator to issue single commands to start-up and check the status of the MADS software system. By typing the command "MADSMON", the computer operator can determine the currently running MADS acquisition tasks.

6.2 COMPUTER SYSTEM RECOVERY PROCEDURES

Occasionally, it is necessary to restart the computer system due to failures which may occur in the hardware or software components of the system, or a failure may occur in the physical facilities of the computer room (such as air conditioning or power). A process known as rebooting is performed by the computer facility staff to bring the computer back to normal operating mode. During this time the data collection activities of the computer cease. A procedural file named "BOOT.CSS" is stored on the computer's boot diskette which has stored in it the command to restart the MADS system. This allows the MADS system to be restarted automatically.

This completes the activities which are required at the main computer console. The following procedures involve the use of the laboratory command device or a Multi-Terminal Manager device.

6.3 PROGRAM MODULE OPERATION

6.3.1 Supervisor Program Module (MADSUP)

Program MADSUP is started from the main computer console (See section 6.1). When activated a message will appear on the researchers terminal in the laboratory which identifies the MADS system and displays a menu of available modules. Commands are issued to MADSUP from the researchers terminal in the laboratory. Enter the number corresponding to the module you desire to be loaded. An incorrect response triggers the message "Incorrect Select Code...Re-Enter". Stopping the MADSUP program module is performed at the main computer console in the computer facility. Enter the command "CANCEL MADSUP". This command should only be entered if there is no activity in the MADS system.

6.3.2 Project Select Module (MADSEL)

The Project Select Module is activated by selecting code 12 from the MADSUP menu. A message is displayed identifying the MADSEL module and a list of valid projects is also displayed. Enter the 3 character project code from the list. The project code is stored and control is returned automatically to the MADSUP menu.

6.3.3 Monitor Module (MADMON)

The Monitor Module is available from the researcher's terminal is activated by entering code 1 from the MADSUP menu. A message indicating the status of the currently selected project is displayed. It will show whether the acquisition is active or inactive, time of last scan and the file name which is currently active or last used.

6.3.4 Acquisition Setup Module (MADSET)

The PCM acquisition setup module PCMSET is activated by entering a code 2 from the MADSUP menu. The Calorimetric setup module CALSET is also activated by entering a code 2 from the MADSUP menu. When selected, a message requesting the name of the data file is issued. Respond by entering:

PCMRAW (for PCM project) or CALRAW.XXX (For Calorimetric Project)

where XXX is a unique extension assigned by the researcher.

The program requests the number of channels being collected. Respond by entering number of lines corresponding to the total channels being collected. The program then requests whether a continuous or interval collection mode is needed. Respond by entering:

"C" for continuous (useful for testing)
or
"D" for delayed (normal collection)

The program then returns to the MADSUP menu.

6.3.5 Data Acquisition Module (PCMACQ & CALACQ)

The PCM and Calorimetric acquisition modules PCMACQ and CALACQ are activated by entering a code 4 from the MADSUP menu. No operator commands are required for these modules. The necessary commands are created during the MADSET program process. The programs wait 30 seconds and then start the listening mode of operation.

To cancel the acquisition programs at any time, enter a code 3 from the MADSUP menu.

6.3.6 Data Prepping Module (PCMPREP & CALPREP)

The data prepping modules are activated by entering a code

8 from the MADSUP menu. The file name to be prepped is requested. Enter the appropriate file name in the format as specified in the setup program modules (Section 6.3.4). No additional commands are necessary for the prepping modules. When completed, control is returned to the MADSUP menu.

An exception to this process is the normal prepping which occurs for the PCM data files. PCM data is prepped automatically at midnight each day. This is performed by the automatic loading of the module PCMPREP by the acquisition module PCMACQ. In this case, the program looks for the previous days data file. The result is a new data file represented in the compressed format.

6.3.7 Graphics Generating Modules

6.3.7.1 Versatec Batch Plotting (PCMPLT & CALPLT)

The PCMPLT and CALPLT program modules are activated by entering code 11 from the MADSUP menu. When activated, a message requesting the data file to be plotted is displayed on the researcher's console. Respond by entering the appropriate file name in the format described above. This will result in a series of frames being produced on the Versatec printer/plotter. When completed, control is returned to the MADSUP menu.

6.3.7.2 Minitab Batch Plotting

The Minitab batch plotting program involves only PCM data files. This process is activated from a Multi-Terminal Manager terminal. Enter the following commands to accomplish this process.

```
SIGNON PCM,ACCT,PASSW      (allows access to the computer)
MINITAB.BCH                (starts the plotting process)
SIGNOFF                    (sign off of the computer)
```

A list of the commands found in the procedural file "MINITAB.BCH" is presented in Appendix N.

6.3.6.3 Easygraphing Graphics (PCMPEAK & PCMPEAKA)

The programs required to generate the Easygraphing plots are activated by using a Tektronix Model 4014 or 4027 terminal assigned to the Multi-Terminal Manager. Enter the following commands to accomplish these procedures:

SIGNON PCM,ACCT,PASSW	(allows access to the computer)
PCMPEAK	(requests program PCMPEAK)
CHANNEL #	(identifies channel number to be plotted)
STARTING JULIAN DAY	(identifies starting day for plotting)
ENDING JULIAN DAY	(identifies ending day for plotting)

OMIT THE NEXT COMMAND FOR PROGRAM PCMPEAKA

CYCLE NUMBER	(identifies PCM daily cycle number-1,2,3)
HEAT OR COOL PEAK	(identifies heating or cooling peak- 1 for heat and 2 for cool)

This will result in a search of the data file PCMPEAK.DTA, and sub-files being written to disk. Upon completion, the Easygraphing program is automatically loaded. Enter the command "RUN PEAK" to generate the plot on the graphics terminal screen. When completed, type "BYE" and "SIGNOFF" to exit from the computer system.

6.4 REPORT GENERATING MODULES (PCMLST AND CALLST)

The report generating modules are activated using a Multi-Terminal Manager terminal. Enter the commands below to accomplish the procedures:

SIGNON MADS,ACCT,PASSW	(allows access to the computer)
CALLST FILENAME and	(load the Calorimetric program names a file to be used)
or	
PCMLST FILENAME	(loads the PCM program and names a file to be used)
# DATA BLOCKS blocks	(identifies the number of data to be printed)

A report of the data blocks identified is printed on the line printer in the computer facility.

6.5 PROGRAM DEVELOPMENT AND ENHANCEMENTS

Program development and enhancements are processed using the Perkin-Elmer Text Editor, Fortran Compiler and Link programs. This process requires extensive knowledge beyond the scope of this paper and will not be covered. For a detailed description of the utilities and their operating procedures, consult the reference list found in Section 9.

7. FILE SECURITY

The issue of file security is handled using two methods. The first method involves the normal operating procedures of the CBT Instrumentation Facility. A Perkin-Elmer file utility known as BACKUP is used to copy newly created and modified disk files to magnetic tape at three time intervals; daily, weekly and monthly. If for some reason a file should be destroyed or lost. The copy stored on magnetic tape can be retrieved to disk through operator control at the main computer console.

The second method involves the OSCOPY/32 utility described in 5.6 entitled Archival Storage. Periodically, PCM and Calorimetric data files are copied to magnetic tape reels which are used to store permanent copies of the compressed data. These files may also be retrieved from tape and copied back onto disk for further processing. The methods just described are independent of the MADS software system.

Additional security measures exist within the CBT Instrumentation Facility to insure the safety of data. These include limited access to the computer facility and password identities for accessing the computer in a terminal mode.

8. CONCLUSIONS

A generalized description of a computerized software system for the collection and processing of laboratory data developed to analyze phase change storage materials has been developed. This system makes it possible for the researcher to devote more time to the processes related directly to the experiment by allowing the computer facility staff to monitor computer system activity.

The MADS system also provides for efficient data base storage through compressed file formats. This feature allows for rapid and efficient data analysis methods, especially when interactive computer graphics modules are utilized.

The design and implementation of a software system such as MADS increases the productivity of the research staff and computer staff by eliminating the need to write computer programs which have the same or similar functions. Additional research projects can be added to the system with a minimal amount of computer program coding by including the project identity and customized acquisition and processing modules into the MADS software system environment.

9. REFERENCES

Perkin-Elmer
Computer Systems Division
2 Crescent Place
Oceanport, NJ 07757

OS/32 Multi-Terminal Monitor Reference Manual

OS/32 Edit User Guide

OS/32 Link Reference Manual

Fortran VII Reference Manual

Fortran VII User Guide

System Mathematical Run Time Library Reference Manual

Copy/32 Reference Manual

Tektronix, Inc.
2 Research Court
Rockville, MD

Plot 10 Easy Graphing User's Manual

The Pennsylvania State University
Statistics Department
215 Pond Laboratory
University Park, PA 16802

Minitab Reference Manual

Minitab Student Handbook

Table 1 Major Operating System Software Components

Software	Function
OS32MT Executive Operating System	Controls all software activity of the computer (scheduling,execution)
Device Drivers	Controls communications between devices (remote ports, peripherals) and the central processing unit
Utilities (Edit, Backup, Copy, Language Processors)	Provide facilities for developing programs and manipulating files
MADS System	Provides user interface and processing functions for laboratory data

Table 2 Utilities Used By the MADS Software System

Utility Name	Function
OS/32 Multi-Terminal Manager	Provides terminal access for interactive users.
OS/32 Edit	Provides text manipulation facilities.
OS/32 Link	Generates executable program code from Fortran object code.
Disk Backup	Provides the facility backup of data and program files.
Fortran Compiler	Provides application program language facilities.

Table 3 PCM Plotting Support Programs

Program Name	Purpose
PCMPLT	Generates several outputs from daily PCM data files. These are: individual frame plots PCM peak cycle plots PCM segment blowup Summary peak report
PEAKMAX	Finds maximum peak point for heat-cool cycles for each channel.
PEAKMIN	Finds minimum peak point for heat-cool cycles for each channel.
PEAKRPT	Generates report of peak points for each day.
PCRPT	Finds phase change segment for each cooling cycle and produces plotting worker files.
PUTPEAKS	Writes heat cycle peak points to PCMPEAK data file for subsequent interactive plotting.

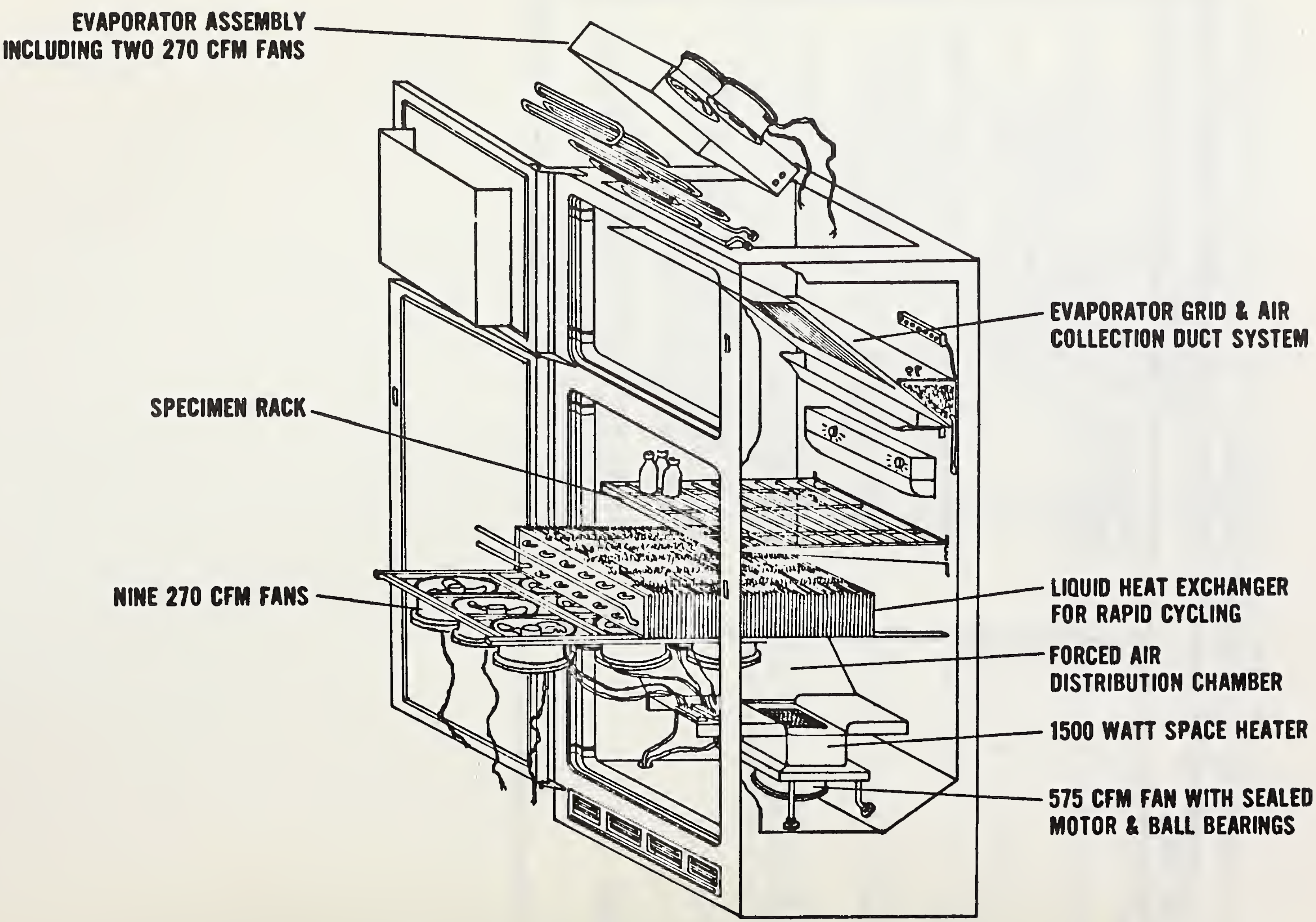


Figure 1 Thermal Cycle Thermocouple Diagram

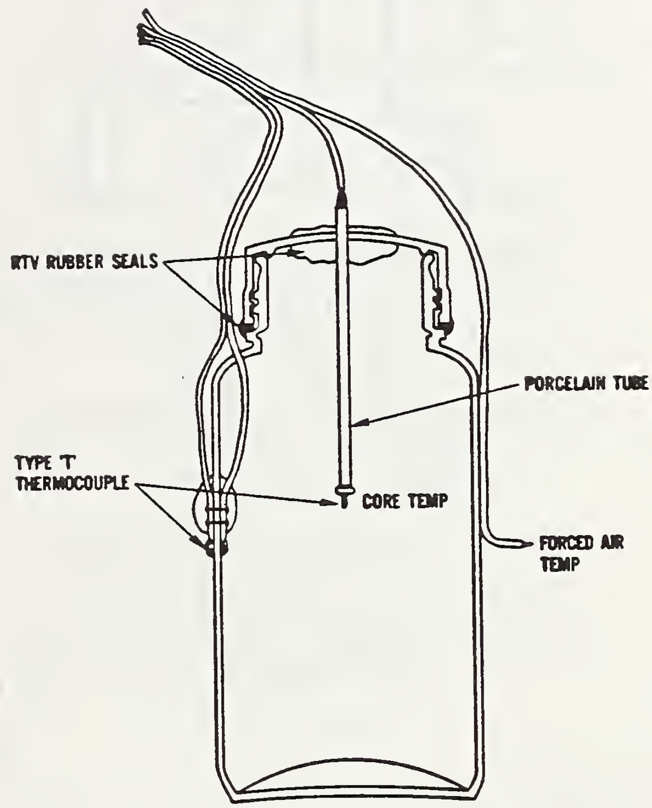


Figure 2 Time and Conductance Specimen Diagram

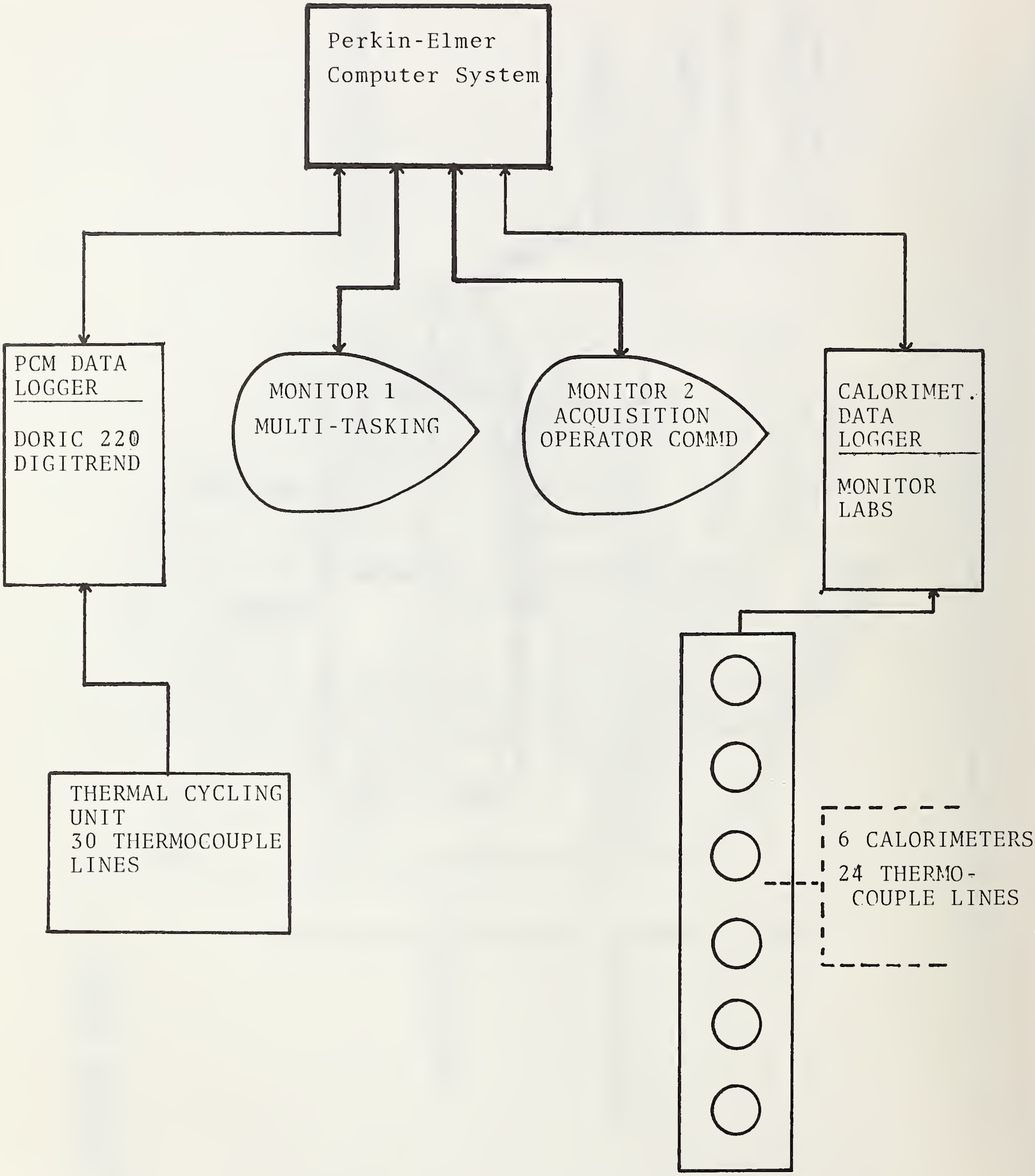


Figure 3 PCM & Calorimetric Instrument Components

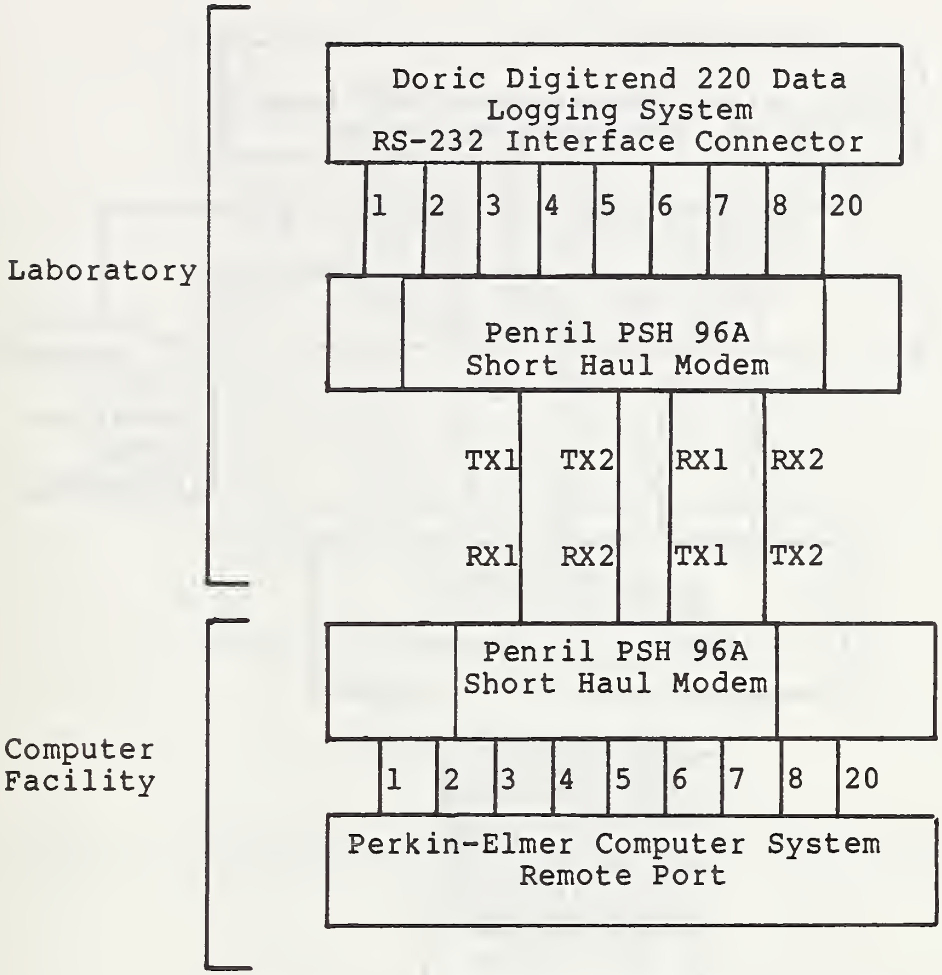


Figure 4 PCM Communications Configuration

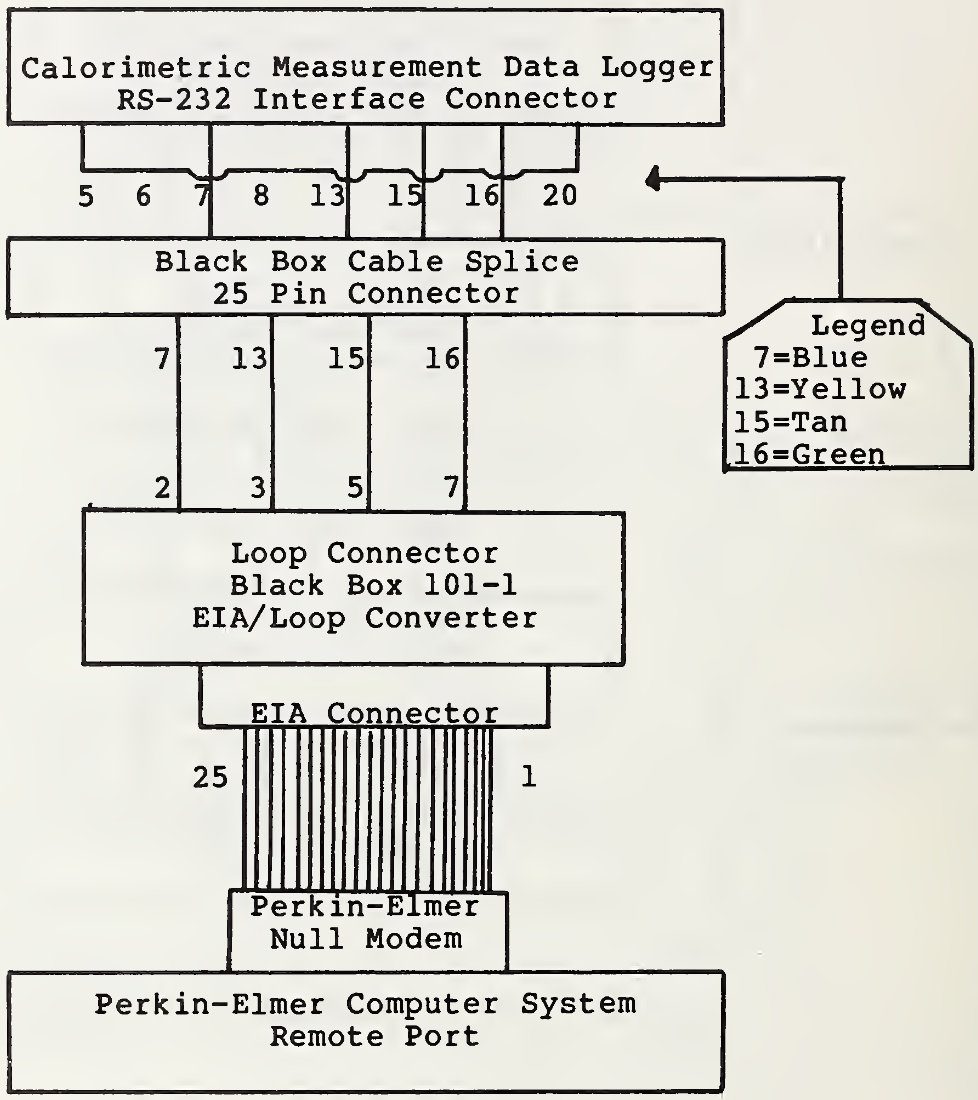


Figure 5 Calorimetric Communications Configuration

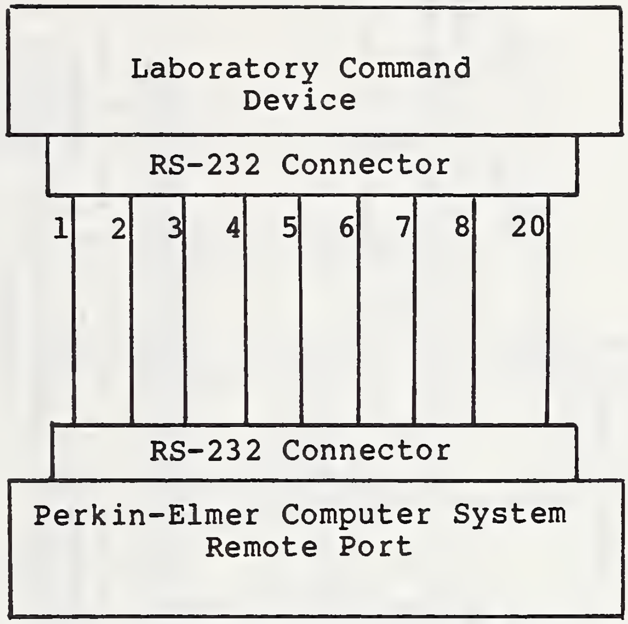


Figure 6 Command Device Communication Configuration

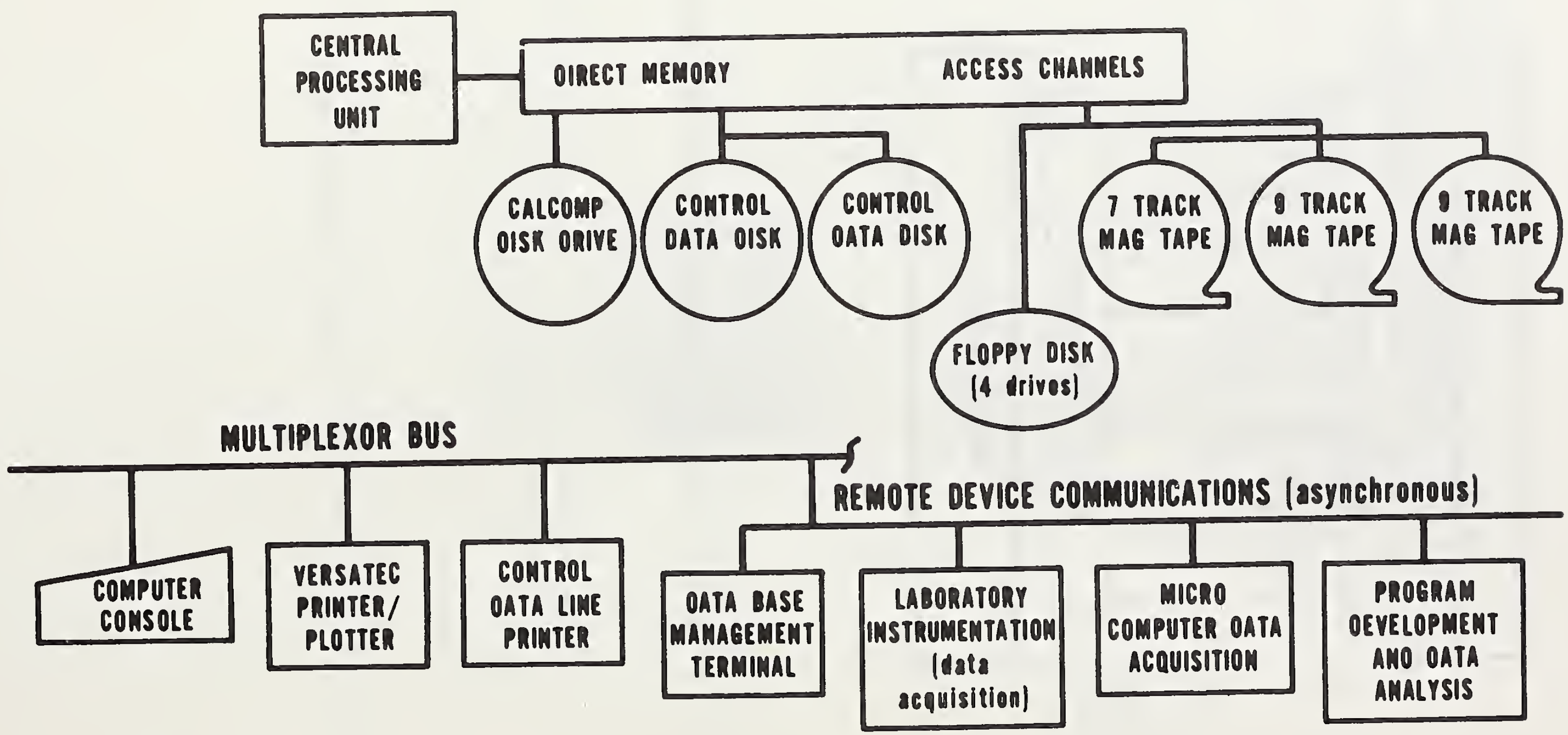


Figure 7 CBT Perkin-Elmer 7/32 Computer System Configuration

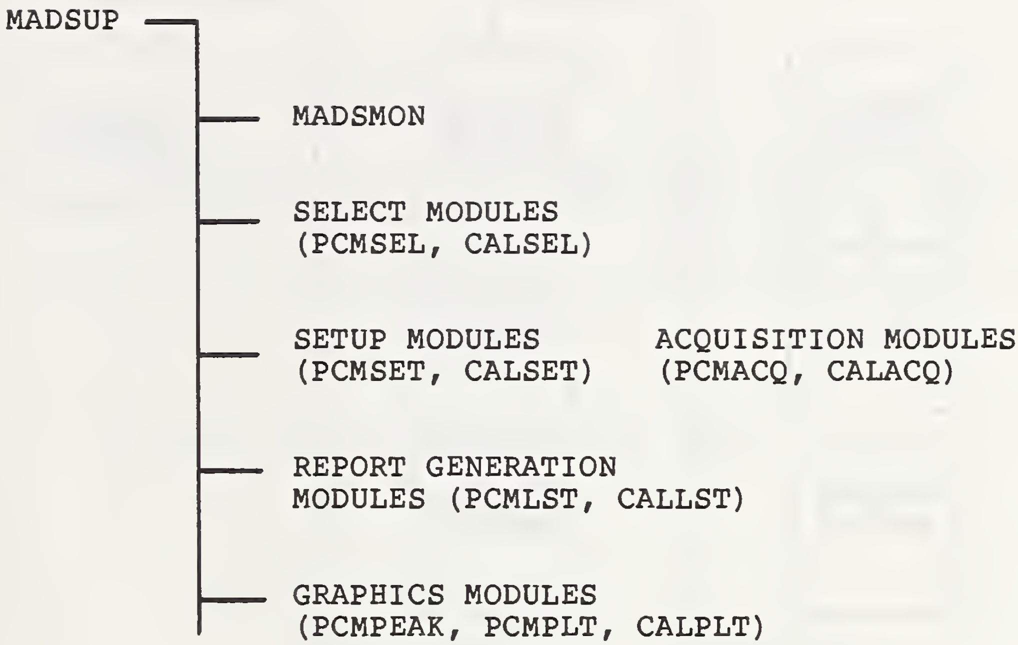


Figure 8 Hierarchial Structure of MADS Software System

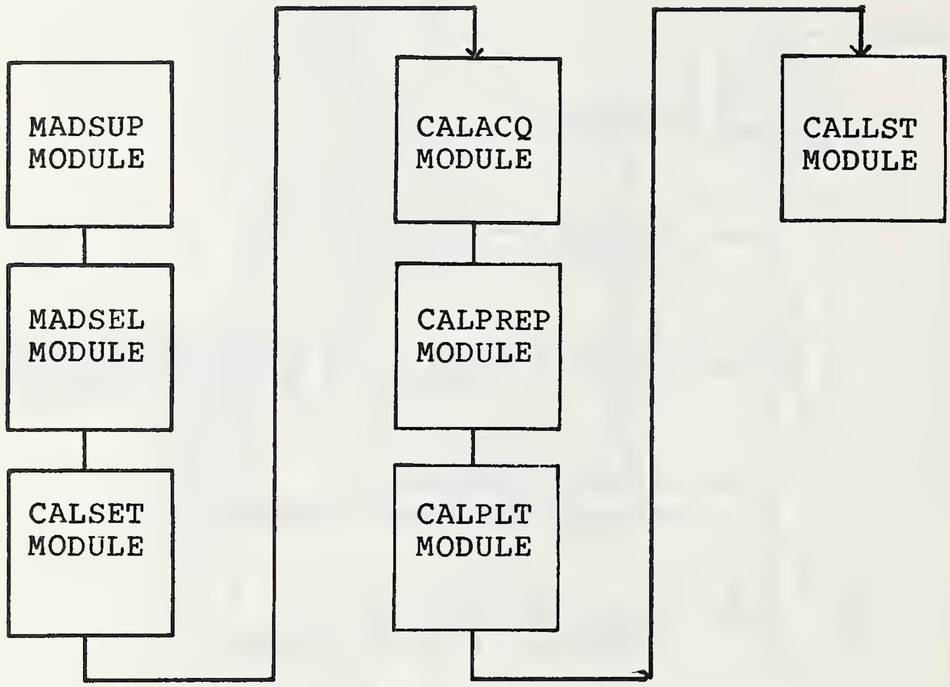


Figure 9 Sample Program Sequence of Calorimetric Experiment

Acquisition	Status Flag	Start Date	Start Time	End Time	End Date	Last Scan Date	Last Scan Time	Current Data File

Figure 10 MADS Monitor File Format

Appendix A Raw Data File Illustrations

Phase Change Materials

Scan Time

```
01983  273      16 03 59 H

001  0061.7F   002  0058.1F   003  0053.1F   004  0055.7F    005  0057.7F
006  0050.2F   007  0052.5F   008  0072.4F   009  0061.8F    010  0052.6F
011  0048.7F   012  0072.8F   013  0053.0F   014  0055.5F    015  0058.0F
016  0063.9F   017  0057.5F   018  0058.9F   019  0054.8F   *020 -9999.9F
021  0062.8F   022  0076.5F   023  0076.6F   024  0069.2F    025  0063.2F
026  0068.9F   027  0053.2F   028  0054.8F   029  0076.2F    030  032.64M
031  10.509M   032  1.0573V   033  0.8088V
```

Channel Number (032)   Channel Reading (0.8088V)

Calorimetric Performance Measurement

Scan Time

```
350:11:18:20
 4   20.9'C    7   21.2'C    10   20.8'C    13   21.1'C
16   20.7'C   19   20.8'C

350:11:18:30
 4   21.0'C    7   21.2'C    10   20.7'C    13   21.1'C
16   20.7'C   19   20.7'C

350:11:18:41
 4   21.0'C    7   21.3'C    10   20.8'C    13   21.2'C
16   20.7'C   19   20.7'C
```

Channel Number (19)   Channel Reading (20.7'C)

Appendix B Channel Legend File

Channel #	Channel Description	Field Engr. Unit
001	1ST PCM#57-TEMP OUTSIDE SPEC. CONTAINER FLO	DEGREES C
002	1ST PCM#57-OUTSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
003	1ST PCM#57-INSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
004	1ST PCM#57-CORE TEMP. OF PCM	DEGREES C
005	2ND PCM#3-OUTSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
006	2ND PCM#3-INSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
007	2ND PCM#3-CORE TEMP. OF PCM	DEGREES C
008	2ND PCM#3-TEMP. OUTSIDE SPEC. CONTAINER LC	DEGREES C
009	3RD PCM#22-OUTSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
010	3RD PCM#22-INSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
011	3RD PCM#22-CORE TEMP. OF PCM	DEGREES C
012	3RD PCM#22-TEMP. OUTSIDE SPEC. CONTAINER C	DEGREES C
013	4TH PCM#43-CORE TEMP. OF PCM	DEGREES C
014	4TH PCM#43-INSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
015	4TH PCM#43-OUTSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
016	4TH PCM#43-TEMP. OUTSIDE SPEC. CONTAINER FRC	DEGREES C
017	5TH PCM#61-OUTSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
018	5TH PCM#61-INSIDE WALL TEMP. OF PCM CONTAINER	DEGREES C
019	5TH PCM#61-CORE TEMP. OF PCM	DEGREES C
020	5TH PCM#61-TEMP. OUTSIDE SPEC. CONTAINER RC	DEGREES C
021	UNIT TEMP.-UNIT TEMP. OVER SPECIMEN AREA FC	DEGREES C
022	UNIT TEMP.-UNIT TEMP. OVER SPECIMEN AREA BR	DEGREES C
023	UNIT TEMP.-UNIT TEMP. OVER SPECIMEN AREA BC	DEGREES C
024	UNIT TEMP.-UNIT TEMP. OVER SPECIMEN AREA BL	DEGREES C
025	UNIT TEMP.-UNIT TEMP. OVER SPECIMEN AREA FL	DEGREES C
026	UNIT TEMP.-UNIT TEMP. OVER SPECIMEN AREA FR	DEGREES C
027	CONDUCTANCE-BLUE CONDUCTIVITY CELL-CORE TEMP	DEGREES C
028	CONDUCTANCE-RED CONDUCTIVITY CELL-CORE TEMP	DEGREES C
029	ROOM TEMP.-ROOM TEMP.	DEGREES C
030	CONDUCTANCE-(BLUE) CONDUCTIVITY	UMHO
031	CONDUCTANCE-(RED) CONDUCTIVITY	UMHO

Appendix C PCM Data File Record Format

File Name Format: PCMDATA.XXX
Where XXX=Julian Day (001-365)

Channel→ 1 Value F7.3	2 F7.3	3 F7.3	4 F7.3	5 F7.3
↓ 6 F7.3	7 F7.3	8 F7.3	9 F7.3	10 F7.3
11 F7.3	12 F7.3	13 F7.3	14 F7.3	15 F7.3
16 F7.3	17 F7.3	18 F7.3	19 F7.3	20 F7.3
- - - - - - - - - - - - - - - -	- - - - - - - - - - - - - - - -	- - - - - - - - - - - - - - - -	- - - - - - - - - - - - - - - -	- - - - - - - - - - - - - -
96 F7.3	97 F7.3	98 F7.3	99 F7.3	100 F7.3
Year 4 digits	Hour 4 Digit	Minute 2 digit	Second 2 digit	Elapsed Seconds Since Midnight 5 digit

Record #1=
Scan #1 for
Day XXX

Channel 1 Value F7.2	2 F7.2	3 F7.2	4 F7.2	5 F7.2
6 F7.2	7 F7.2	8 F7.2	9 F7.2	10 F7.2
11 F7.2	12 F7.2	13 F7.2	14 F7.2	15 F7.2
16 F7.2	17 F7.2	18 F7.2	19 F7.2	20 F7.2
21 F7.2	22 F7.2	23 F7.2	24 F7.2	25 F7.2
26 F7.2	27 F7.2	28 F7.2	29 F7.2	30 F7.2
31 F7.2	32 F7.2	33 F7.2	34 F7.2	35 F7.2
36 F7.2	37 F7.2	38 F7.2	39 F7.2	40 F7.2
41 F7.2				

Appendix E PCMLST Sample Report Format

PCMDATA.273

DATA BLOCK... 937
YR:1982. HR:16. MN:0. SC:59. ELAP TIME:57.59

CHAN	VAL	CHAN	VAL	CHAN	VAL	CHAN	VAL	CHAN	VAL
1	55.20000	2	54.60001	3	57.60001	4	53.0000	5	47.00000
6	51.80000	7	55.10001	8	55.70000	9	52.70000	10	45.70000
11	50.00000	12	57.20000	13	53.20000	14	51.39999	15	47.10001
16	54.89999	17	54.50000	18	51.70000	19	50.49999	20	-99.89800
21	53.30000	22	54.30000	23	51.50000	24	30.20000	25	49.89999
26	61.39999	27	59.50000	28	51.30000	29	70.30000	30	0.03159
31	0.01048	32	1.05740	33	0.80900				

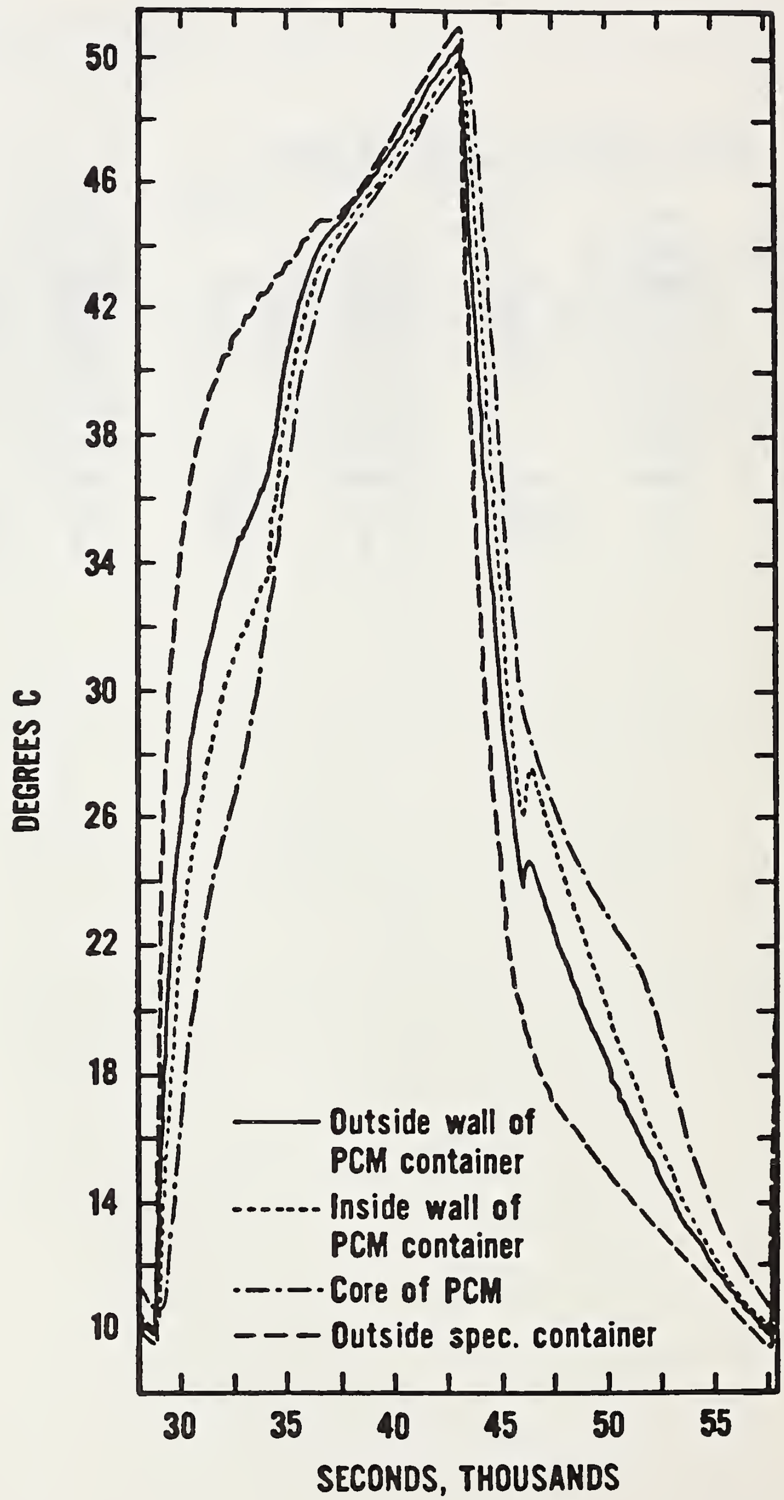
Appendix F Calorimetric Report Format

DATA BLOCK...   0
ELAPSED TIME... 0

CHAN	VAL	CHAN	VAL	CHAN	VAL	CHAN	VAL	CHAN	VAL
4	23.50	7	23.50	10	23.20	13	23.60	16	23.30
19	23.20	0	0.00	0	0.00	0	0.00	0	0.00

DATA BLOCK...   1
ELAPSED TIME...10.

CHAN	VAL	CHAN	VAL	CHAN	VAL	CHAN	VAL	CHAN	VAL
4	23.00	7	23.30	10	23.20	13	23.50	16	23.20
19	23.10	0	0.00	0	0.00	0	0.00	0	0.00



50
46
42
38
34
30
26
22
18
14
10
DEGREES C
Outside wall of PCM container
Inside wall of PCM container
Core of PCM
Outside spec. container
30
35
40
45
50
55
SECONDS, THOUSANDS

Appendix H Minitab Plot of Phase Change Segment

Minitab Release 81.1 *** Copyright - Penn State Univ. 1981
Nov. 22, 1982 *** NBS Minitab Ver 81.1-A 810610

READ 'PCHAN4.264' INTO C1 C2 C3 C4 C5 C6

COLUMN	C1	C2	C3	C4	C5	C6
COUNT	100	100	100	100	100	100
	17700.0	29.7500	46320.0	29.8600	75419.9	29.7500
	17760.0	29.4100	46380.0	29.5200	75479.9	29.4700
	17820.0	29.1900	46440.0	29.2500	75639.9	29.2500
	17880.0	28.9100	46500.0	28.9700	75599.9	29.0200

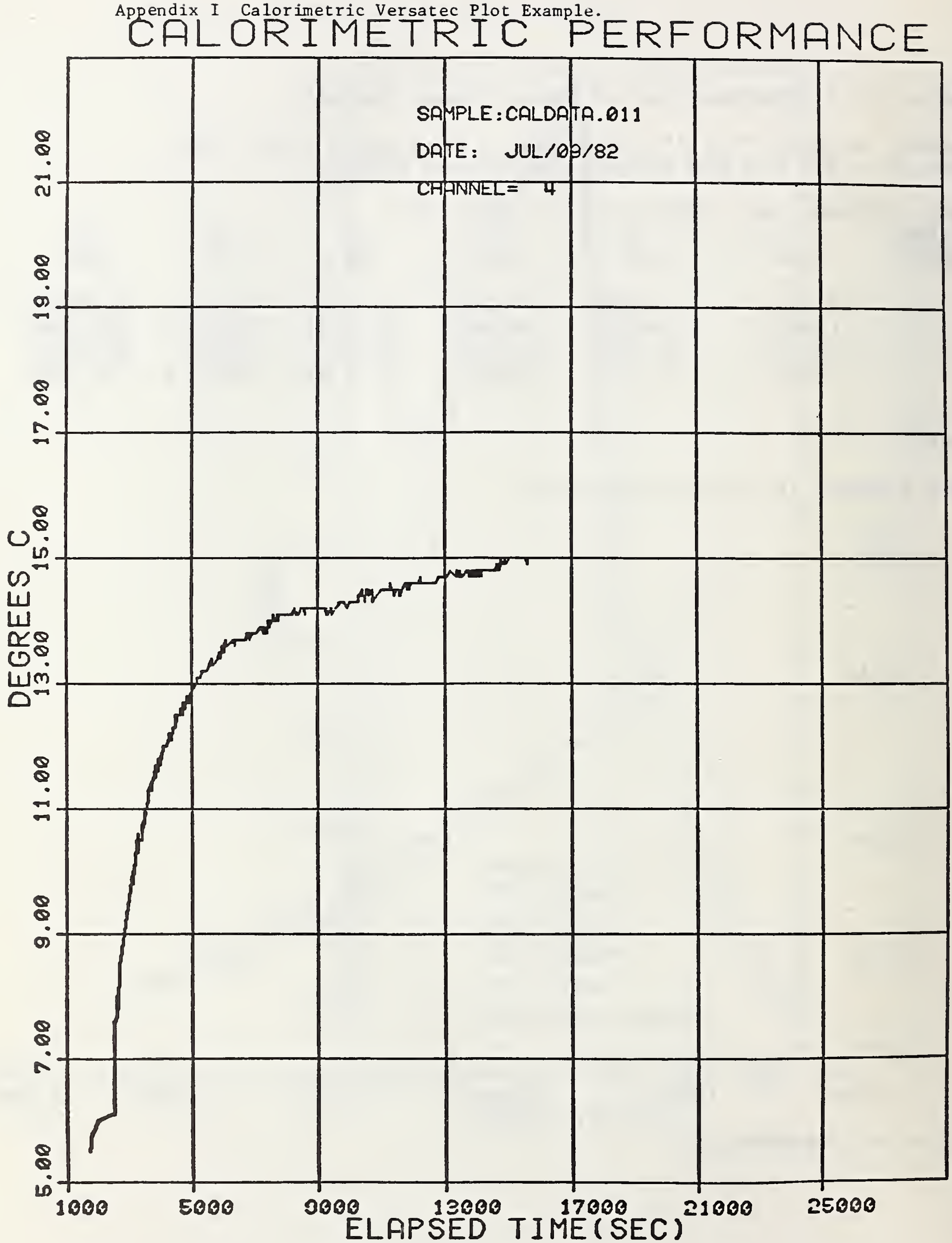
SHARE

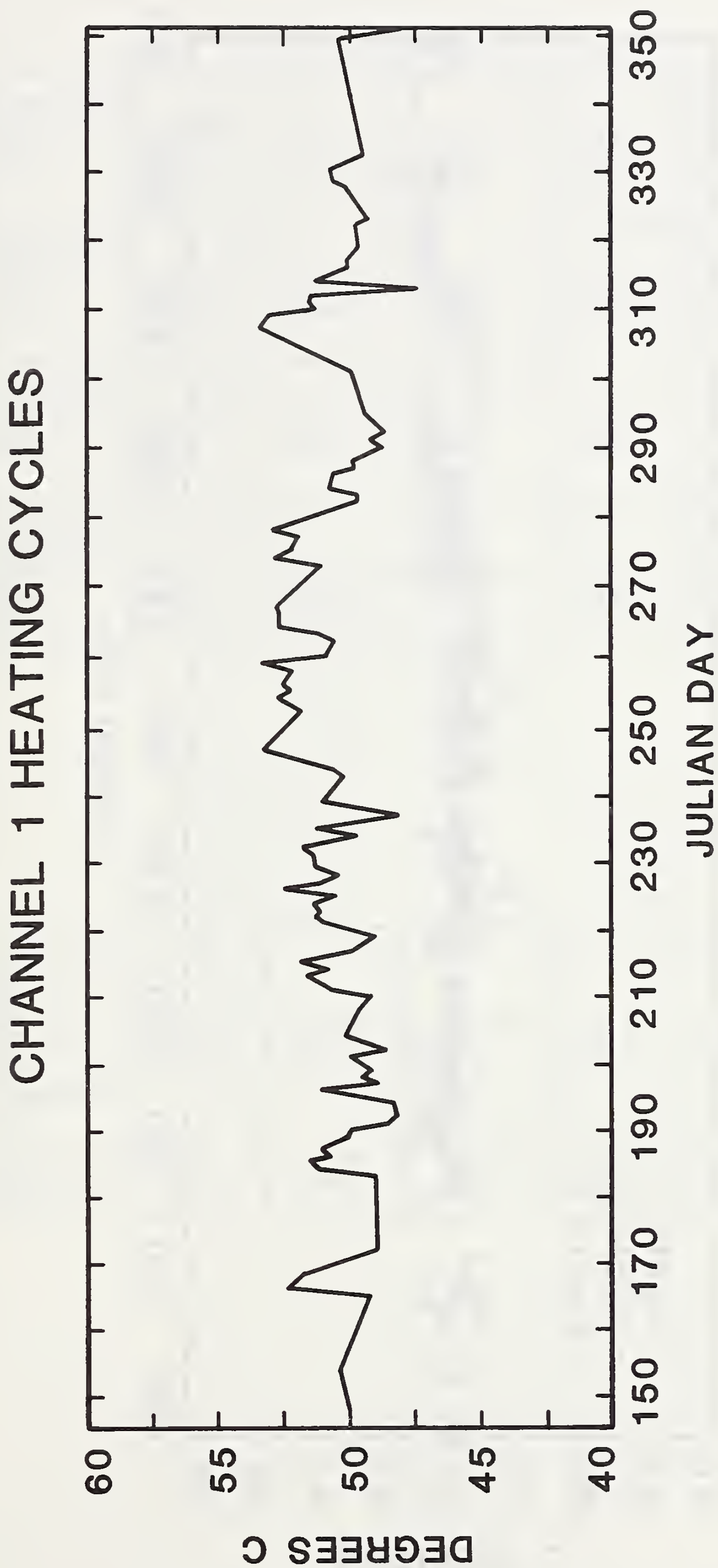
PLOT FOURONE IN C2 VS. TIME IN C1

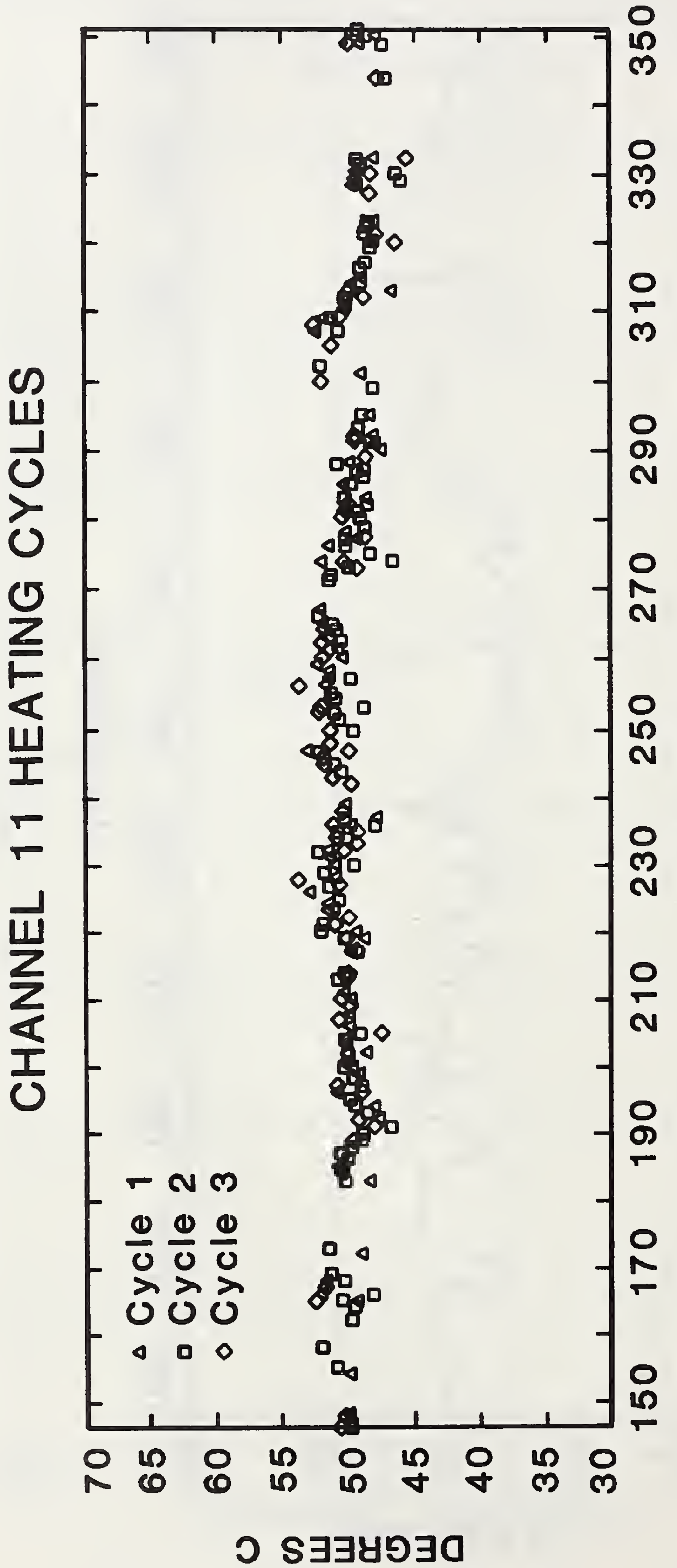
```
     C2
   30.0+
       -          *
       -           *
       -            *
       -             2
   25.5+              **
       -               *2
       -                 *2*
       -                   **2
       -                      2*
       -                        22*
       -                           22
   27.0+                             *2*
       -                               **2*
       -                                  **2
       -                                     2*2*
       -                                        **2*
   25.5+                                           **22*
       -                                                *22*
       -                                                    *
       -
   24.0+
       +------------+-----------+------------+------------+---------+C1
    17000.       18000.      19000.      20000.       21000.    22000.
```

2 MISSING OBSERVATIONS

Appendix I Calorimetric Versatec Plot Example.




CHANNEL 1 HEATING CYCLES
JULIAN DAY
DEGREES C
150
170
190
210
230
250
270
290
310
330
350
60
55
50
45
40


CHANNEL 11 HEATING CYCLES
Cycle 1
Cycle 2
Cycle 3
JULIAN DAY
150 170 190 210 230 250 270 290 310 330 350
DEGREES C
70 65 60 55 50 45 40 35 30

Channel 1 Cycle 1 Heat	Cycle 2 Heat	Cycle 3 Heat	Cycle 1 Cool	Cycle 2 Cool	Cycle 3 Cool
Channel 2 Cycle 1 Heat	Cycle 2 Heat	Cycle 3 Heat	Cycle 1 Cool	Cycle 2 Cool	Cycle 3 Cool
Channel 3 Cycle 1 Heat	Cycle 2 Heat	Cycle 3 Heat	Cycle 1 Cool	Cycle 2 Cool	Cycle 3 Cool
Channel 4 Cycle 1 Heat	Cycle 2 Heat	Cycle 3 Heat	Cycle 1 Cool	Cycle 2 Cool	Cycle 3 Cool

Channel 30 Cycle 1 Heat	Cycle 2 Heat	Cycle 3 Heat	Cycle 1 Cool	Cycle 2 Cool	Cycle 3 Cool
Channel 31 Cycle 1 Heat	Cycle 2 Heat	Cycle 3 Heat	Cycle 1 Cool	Cycle 2 Cool	Cycle 3 Cool

Appendix M MADSUP STARTUP AND RUN SAMPLE SESSION

```
          CBT PERKIN-ELMER COMPUTER SYSTEM
          MODULAR ACQUISITION & DISPLAY

                   ** M E N U **
                SELECT DESIRED RUN MODE
      01    ACQ MONITOR          09    HELP
      02    ACQ SETUP            10    PEEK
      03    ACQ TERM             11    PLOT
      04    ACQUIRE              12    PROJ SELECT
      05    FILE ARCHIVE         13    REPORT GEN
      07    FILE INDEX           15    TERMINATE
      08    FILE PREP            16    VIEW
                                 17    SEND MESSAGE

ENTER TWO DIGIT CODE
12
** MADS PROJECT SELECT MODULE **
ENTER PROJECT ID FROM TABLE BELOW

    PCM (Phase Change)      CAL (Calorimetric)
    ASP (Autospec)          THM (Thermal Mass)
    NWS (Nike Weather Sta)  ION (Ion Chromatograph)

CAL

                   ** M E N U **
                SELECT DESIRED RUN MODE
      01    ACQ MONITOR          09    HELP
      02    ACQ SETUP            10    PEEK
      03    ACQ TERM             11    PLOT
      04    ACQUIRE              12    PROJ SELECT
      05    FILE ARCHIVE         13    REPORT GEN
      07    FILE INDEX           15    TERMINATE
      08    FILE PREP            16    VIEW
                                 17    SEND MESSAGE

ENTER TWO DIGIT CODE
02

** CALORIMETER CALIBRATION ACQ SETUP **
ENTER FILENAME FOR DATA COLLECTION
CALDATA.099
ENTER NUMBER OF LINES TO BE SCANNED


FOR EXAMPLE: 1-4 CHANNELS = 01 LINES
             5-8 CHANNELS = 02 LINES
            9-12 CHANNELS = 03 LINES
           13-16 CHANNELS = 04 LINES
           17-20 CHANNELS = 05 LINES
           21-24 CHANNELS = 06 LINES
           25-28 CHANNELS = 07 LINES
           29-32 CHANNELS = 08 LINES
           33-36 CHANNELS = 09 LINES
           37-40 CHANNELS = 10 LINES

02
ENTER 'C' FOR CONTINUOUS SCAN
OR 'D' FOR DELAYED SCAN
D
```

Measurement data session

```
                    ** M E N U **
                SELECT DESIRED RUN MODE
    01    ACQ MONITOR            09    HELP
    02    ACQ SETUP              10    PEEK
    03    ACQ TERM               11    PLOT
    04    ACQUIRE                12    PROJ SELECT
    05    FILE ARCHIVE           13    REPORT GEN
    07    FILE INDEX             15    TERMINATE
    08    FILE PREP              16    VIEW
                                 17    SEND MESSAGE

ENTER TWO DIGIT CODE
04
** CALORIMETRIC DATA ACQUISITION MODULE **
Set Instrument and type "GO"

GO

DATA ACQUISITION STARTED


                    ** M E N U **
                SELECT DESIRED RUN MODE
    01    ACQ MONITOR            09    HELP
    02    ACQ SETUP              10    PEEK
    03    ACQ TERM               11    PLOT
    04    ACQUIRE                12    PROJ SELECT
    05    FILE ARCHIVE           13    REPORT GEN
    07    FILE INDEX             15    TERMINATE
    08    FILE PREP              16    VIEW
                                 17    SEND MESSAGE

ENTER TWO DIGIT CODE
15
** MADS SYSTEM NORMAL TERMINATION **
```

```
BATCH
READ 'PCHAN4.351' INTO C1 C2 C3 C4 C5 C6
TSHARE
RECODE VALUES FROM 0.0 TO 0.0 IN C1 INTO '*', STORE IN C1
RECODE VALUES FROM 0.0 TO 0.0 IN C2 INTO '*', STORE IN C2
RECODE VALUES FROM 0.0 TO 0.0 IN C3 INTO '*', STORE IN C3
RECODE VALUES FROM 0.0 TO 0.0 IN C4 INTO '*', STORE IN C4
RECODE VALUES FROM 0.0 TO 0.0 IN C5 INTO '*', STORE IN C5
RECODE VALUES FROM 0.0 TO 0.0 IN C6 INTO '*', STORE IN C6
BATCH
PLOT FOURONE IN C2 VS. TIME IN C1
PLOT FOURTWO IN C4 VS. TIME IN C3
PLOT FOURTHREE IN C6 VS. TIME IN C5
TSHARE
NEWPAGE
ERASE C1 C2 C3 C4 C5 C6
BATCH
READ 'PCHAN7.351' INTO C1 C2 C3 C4 C5 C6
TSHARE
RECODE VALUES FROM 0.0 TO 0.0 IN C1 INTO '*', STORE IN C1
RECODE VALUES FROM 0.0 TO 0.0 IN C2 INTO '*', STORE IN C2
RECODE VALUES FROM 0.0 TO 0.0 IN C3 INTO '*', STORE IN C3
RECODE VALUES FROM 0.0 TO 0.0 IN C4 INTO '*', STORE IN C4
RECODE VALUES FROM 0.0 TO 0.0 IN C5 INTO '*', STORE IN C5
RECODE VALUES FROM 0.0 TO 0.0 IN C6 INTO '*', STORE IN C6
BATCH
PLOT SEVENONE IN C2 VS. TIME IN C1
PLOT SEVENTWO IN C4 VS. TIME IN C3
PLOT SEVENTHREE IN C6 VS. TIME IN C5
TSHARE
NEWPAGE
ERASE C1 C2 C3 C4 C5 C6
BATCH
READ 'PCHA11.351' INTO C1 C2 C3 C4 C5 C6
TSHARE
RECODE VALUES FROM 0.0 TO 0.0 IN C1 INTO '*', STORE IN C1
RECODE VALUES FROM 0.0 TO 0.0 IN C2 INTO '*', STORE IN C2
RECODE VALUES FROM 0.0 TO 0.0 IN C3 INTO '*', STORE IN C3
RECODE VALUES FROM 0.0 TO 0.0 IN C4 INTO '*', STORE IN C4
RECODE VALUES FROM 0.0 TO 0.0 IN C5 INTO '*', STORE IN C5
RECODE VALUES FROM 0.0 TO 0.0 IN C6 INTO '*', STORE IN C6
BATCH
PLOT ELEVENONE IN C2 VS. TIME IN C1
PLOT ELEVENTWO IN C4 VS. TIME IN C3
PLOT ELEVENTHREE IN C6 VS. TIME IN C5
TSHARE
NEWPAGE
ERASE C1 C2 C3 C4 C5 C6
BATCH
READ 'PCHA13.351' INTO C1 C2 C3 C4 C5 C6
TSHARE
RECODE VALUES FROM 0.0 TO 0.0 IN C1 INTO '*', STORE IN C1
RECODE VALUES FROM 0.0 TO 0.0 IN C2 INTO '*', STORE IN C2
RECODE VALUES FROM 0.0 TO 0.0 IN C3 INTO '*', STORE IN C3
RECODE VALUES FROM 0.0 TO 0.0 IN C4 INTO '*', STORE IN C4
RECODE VALUES FROM 0.0 TO 0.0 IN C5 INTO '*', STORE IN C5
```

```
RECODE VALUES FROM 0.0 TO 0.0 IN C6 INTO '*', STORE IN C6
BATCH
PLOT THIRTEENONE IN C2 VS. TIME IN C1
PLOT THIRTEENTWO IN C4 VS. TIME IN C3
PLOT THIRTEENTHREE IN C6 VS. TIME IN C5
TSHARE
NEWPAGE
ERASE C1 C2 C3 C4 C5 C6
BATCH
READ 'PCHA19.351' INTO C1 C2 C3 C4 C5 C6
TSHARE
RECODE VALUES FROM 0.0 TO 0.0 IN C1 INTO '*', STORE IN C1
RECODE VALUES FROM 0.0 TO 0.0 IN C2 INTO '*', STORE IN C2
RECODE VALUES FROM 0.0 TO 0.0 IN C3 INTO '*', STORE IN C3
RECODE VALUES FROM 0.0 TO 0.0 IN C4 INTO '*', STORE IN C4
RECODE VALUES FROM 0.0 TO 0.0 IN C5 INTO '*', STORE IN C5
RECODE VALUES FROM 0.0 TO 0.0 IN C6 INTO '*', STORE IN C6
BATCH
PLOT NINETEENONE IN C2 VS. TIME IN C1
PLOT NINETEENTWO IN C4 VS. TIME IN C3
PLOT NINETEENTHREE IN C6 VS. TIME IN C5
STOP
```

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This report describes the processes involved in acquiring and analyzing experimental laboratory data using a medium sized computer in a multi-programming environment with a modular software system. Research involving Phase Change Materials and Calorimetric Performance measurements in building research are used as case studies to describe the functional capabilities and operational procedures of the system. The software system consists of computer programs which allow the researcher to collect, store, and analyze data graphically.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

experimental data processing; graphical data analysis; interactive processing; laboratory data collection; modular computer software.

13. AVAILABILITY

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