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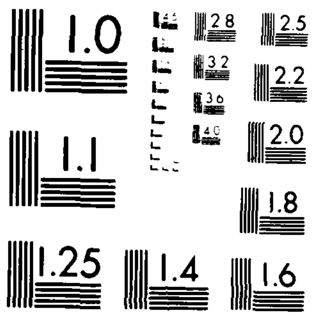
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DEPARTMENT OF DEFENCE SUPPORT

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

WEAPONS SYSTEMS RESEARCH LABORATORY

DEFENCE RESEARCH CENTRE SALISBURY
SOUTH AUSTRALIA

TECHNICAL REPORT
WSRL-0281-TR

A DATA ACQUISITION AND PROCESSING SYSTEM FOR GUN INTERIOR BALLISTIC STUDIES (PART 2)

A.R. RYE

Approved for Public Release

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A DATA ACQUISITION AND PROCESSING SYSTEM FOR GUN INTERIOR BALLISTIC STUDIES (Part 2)

A.R. Rye

S U M M A R Y

A data acquisition and processing system controlled by a Hewlett-Packard 85 desktop computer and designed for use in small calibre gun ballistic ranges is described. A digital transient recorder is interfaced to the computer using a specially developed timing control circuit. Software is written in Hewlett-Packard's extended BASIC language and full details are given to allow users to develop their own special-purpose versions.

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F O R E W O R D

This report is the second of a series describing the use of small computers to perform the acquisition and processing of gun ballistic range data. The first report described the use of a Hewlett-Packard 9825A Desktop Computer in this role. The software described in this report is unique to the Hewlett-Packard 85 computer, although similar capabilities are displayed by machines from other manufacturers.

The use of manufacturers' or trade names in this report does not constitute endorsement of any commercial product.

No warranty, expressed or implied, is made by Weapons Systems Research Laboratory as to the accuracy and functioning of programs and no responsibility is assumed by Weapons Systems Research Laboratory in connection herewith. Furthermore, Weapons Systems Research Laboratory will not accept any responsibility to undertake a software supporting role.

1. INTRODUCTION

A key element of the operation of experimental gun ballistic ranges is the gathering of information relating to the performance of the ammunition under test. Typically, this might include such items as internal pressure (at one or more locations in the gun), muzzle blast overpressure and barrel hoop and/or axial strain. At WSRL, it has been the practice in the Gun Propulsion Research Group to acquire these data in real time using digital transient waveform recorders. The data stored within the internal memory of the transient recorder is then processed by a dedicated computer, which may draw from other sources additional data such as muzzle velocity and ballistic cycle times. During the last two years, considerable experience has been gained by WSRL personnel in the handling of gun interior ballistic data by small computers. Initial efforts(ref.1) utilised a Hewlett-Packard 9825A computer. Another computer, the Hewlett-Packard 85, has recently been brought into service at a small calibre range. It is considerably cheaper than the HP9825A. The HP-85 has demonstrated comparable performance to the HP9825A, and in addition offers the capability for on-screen graphics and hard-copy, plus a more useful internal line printer. The use of this computer for data handling in the small-calibre range is described in this report.

2. SYSTEM CONFIGURATION

2.1 General comments

Details of instrumentation for a small-calibre ballistic range at WSRL have recently been published(ref.2). A schematic diagram of a typical configuration is shown in figure 1, which illustrates the data acquisition components relevant to this report. The primary concern is the gathering of data from the transient recorder and associated devices and its subsequent processing. In the normal operating mode printed and plotted information is readily obtained between firings, without the need to transfer data to secondary magnetic media. In this report this is referred to as "on-line" processing. In the past, and at other laboratories (see, for example, reference 3) it has been the practice to store the raw data on magnetic tape and process it at the conclusion of a firing program. While a capability for such "off-line" processing has been included in the present system, it has proved to be an infrequent user requirement.

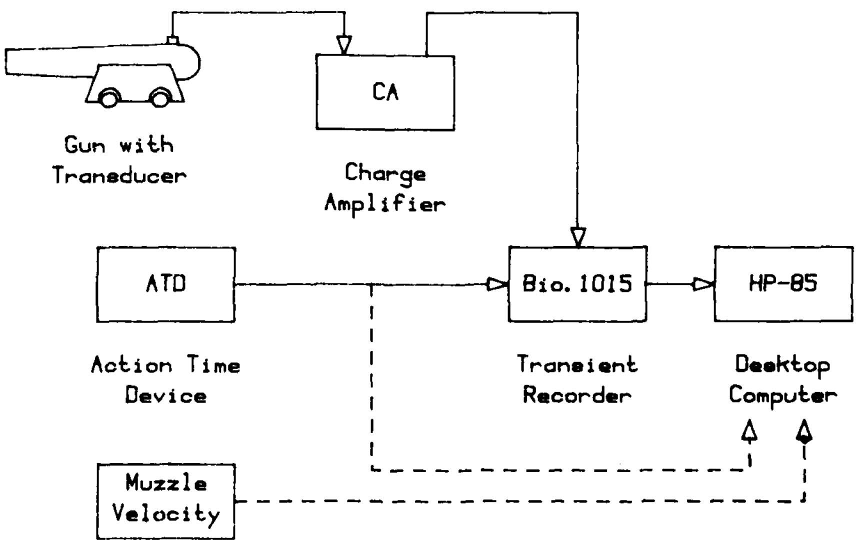

Figure 1. Schematic diagram of data acquisition equipment

2.2 System control and data processing

A Hewlett-Packard 85 Desktop Computer is used to control the gun data acquisition system. This computer (figure 2) is capable of "stand-alone" operation in that it has its own internal printer and tape-drive unit as well as a full screen graphics capability. In addition, it is able to control a range of peripheral devices through appropriate digital interfaces. Software is written in Hewlett-Packard's Enhanced BASIC computer language, an extended version of ANSI BASIC(ref.4). The principal extensions relate to printer control, mass storage operations, graphics, and memory allocation(ref.5). The computer used in this system has 32K bytes of random-access memory (RAM) and has read-only memories (ROMs) which control Input/Output and Printing and Plotting(ref.6,7). The source coding for the software is stored in a tokenised form(ref.8) which is essentially a partial compilation. This effects considerable economy in the storage of programs in comparison with many similar machines(ref.9). Eight "soft-key" allocations can be made, which are used to allow user-controlled program branching. These keys are similar to those of the HP9825, except they are "live" - which means they are dynamically allocated under software control. The HP9825's "soft" keys are essentially static in their allocations. A "Key Label" area on the internal CRT of the computer is available to remind the operator of current key functions.

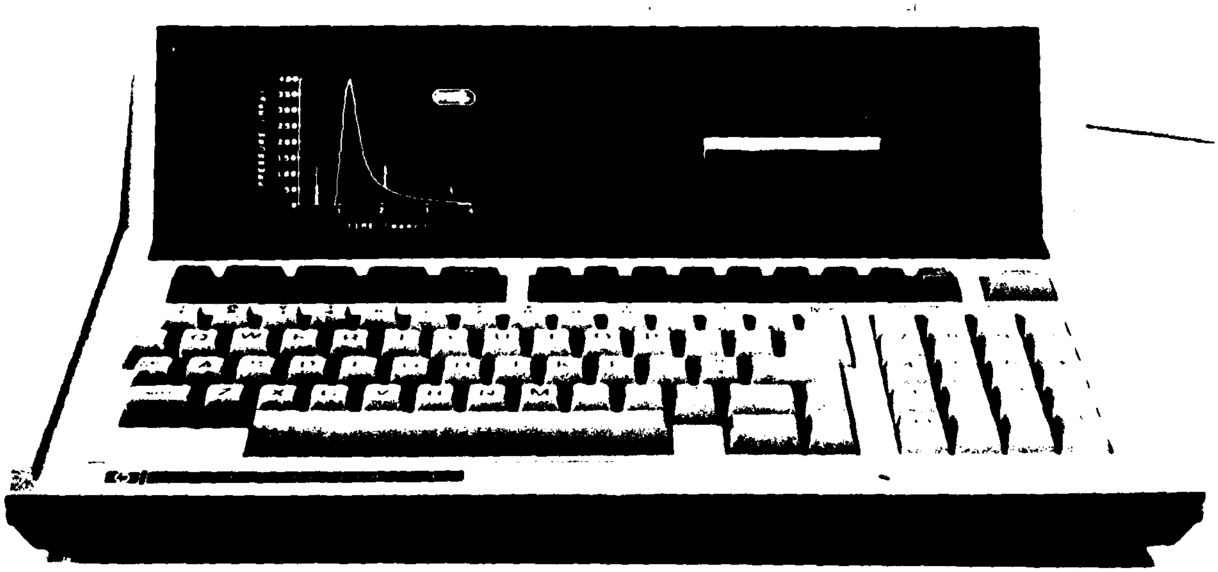

Figure 2. Hewlett-Packard 85 Desktop Computer

2.3 Graphic display

A Hewlett-Packard 9872B Plotter is connected to the computer using the HP82937A Interface. This interface is Hewlett-Packard's implementation of the IEEE-488 standard(ref.10) for the HP-85. The plotter is a four-pen device which is compatible with many kinds of computer. It responds to a special language called HP-GL (Hewlett-Packard Graphics Language) which can be either directly input or generated by ROMs which implement high-level language commands. The computer has a useful on-screen graphics capability which can be used for "quick-look" records and for firings which do not require high-quality plots. The resolution of this device is limited by the relatively small screen (192×255 dots). The screen image can be quickly transferred to the internal thermal printer.

2.4 Data storage for future reference

Experience has shown that data storage is not often required for small calibre firings. However, this capability is available using the HP-85's internal cartridge tape drive. A particularly useful feature of the HP-85 is that only one additional line of programming is required to adapt tape mass-storage functions to diskette functions, should this be a future requirement. A special program variant has been developed to allow "off-line" (ie remote from the range) processing of data recorded on tape or diskette.

2.5 Printed output

The 32-column thermal printer of the HP-85 has proved quite adequate for all operations at the small calibre range. As is shown later in this report, the extra width (in comparison to the HP9825) allows compact tabulation of firing data in a typical muliple-shot small-calibre experiment.

2.6 Data acquisition

A Biomation 1015 Waveform Recorder(ref.11) (figure 3) is used to acquire the gun firing data. This device embodies four input channels. Each channel comprises, in essence, a 10-bit analog-to-digital converter and 1024-word storage with associated processing electronics. Separate controls exist for timebase, triggering and analog output functions. The four 1024-word channels can be linked if required. The minimum acquisition interval is 0.01 ms. Several operating modes are available; usually the "pre-trigger, single shot" mode is selected. In this mode, arming the recorder causes it to continually sample the signal lines. On receipt of a suitable trigger signal an additional (switch-selectable) number of points is taken, then sampling is terminated. This allows relatively high trigger voltage levels to be set and makes pre-trigger information available.

2.7 Interfacing

The HP-85 computer is connected to the plotter, and other available peripheral devices described in reference 1, using the HP82937A interface which conforms to the IEEE-488 standard(ref.10). As many as fourteen devices may be controlled using this interface, including other computers and mass-storage devices. The Biomation 1015 Waveform Recorder is connected to the computer using the HP82940A GPIO interface, a 16-bit parallel interface which is the equivalent (for the HP-85) to the HP98032A interface described in reference 1. The electrical connections are roughly comparable and are tabulated in reference 12. The most important electrical requirements are those which relate to the synchronisation and polarity of the data exchange. Data exchange protocol is maintained by

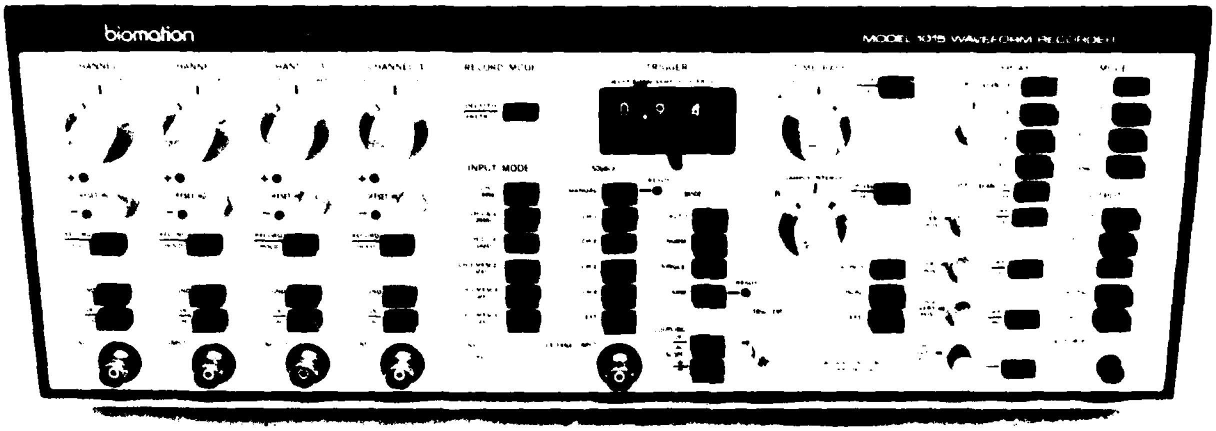

Figure 3. Biomation 1015 Waveform Recorder

pairs of "handshake" lines. These lines, in this application, are called "FLGA" (flag A) and "CTLA" (control A) respectively. FLGA is a line from the peripheral device through which it indicates its readiness to transmit data. CTLA is asserted by the interface to synchronise the exchange. FLGA has the logic states "BUSY" and "READY"; CTLA can be "TRUE" or "FALSE". The electrical specifications of the Biomation 1015 require certain settings of the interface:

(a) full handshake (see below) for data exchange.
(b) inverted logic sense on CTLA and FLGA control lines.
(c) data valid with ready-to-busy transition of FLGA.
(d) inverted logic sense on data lines.
(e) interface set for 16-bit parallel operation.

The correct sequence of operations for full-handshake data input is shown in figure 4. The mandatory requirements are:

(1) interface checks FLGA to ensure "ready" state.
(1) interface sets CTLA "true".
(3) peripheral responds by placing data on the data lines.
(4) peripheral sets FLGA "busy".
(5) data word is read.
(6) interface sets CTLA "false".
(7) peripheral sets FLGA "ready".

However, when the proper wiring allocations were made, it was found that a timing incompatibility existed between the HP82940A interface and the

Biomation 1015 recorder. The response of the Biomation 1015 gave rise to the situation illustrated in figure 5. The premature FLGA response caused the interface to "hang up" and the transfer was interrupted. A simple circuit (figure 6) was developed by to resolve this situation and allow coherent data exchange. This circuit is incorporated in a small connector box which draws its power requirements from the Biomation 1015. Effectively, this circuit uses a sequence of logic gates to prevent the premature presentation of FLGA in the "ready" state to the interface or CTLA in the "true" state to the peripheral. This second condition should not arise in the "full-handshake" mode, but can occur with other timing protocols. This problem did not occur when the HP98032A interface was configured(ref.1) as its CTL response follows the dotted line in figure 5.

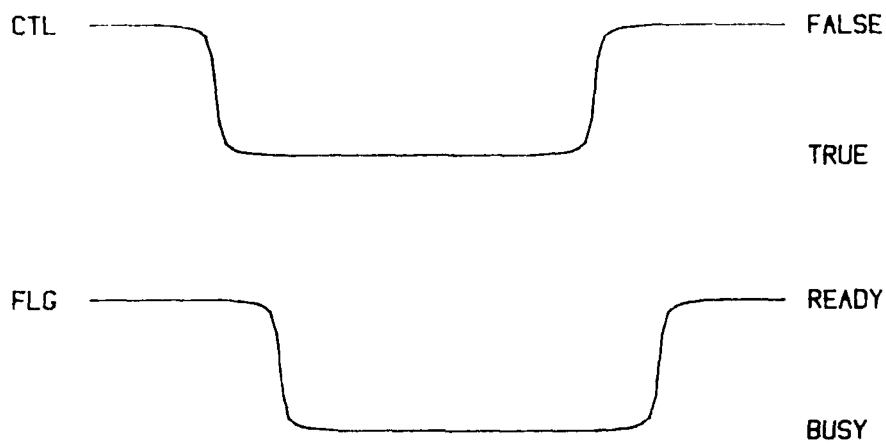

Figure 4. Ideal full-handshake timing diagram

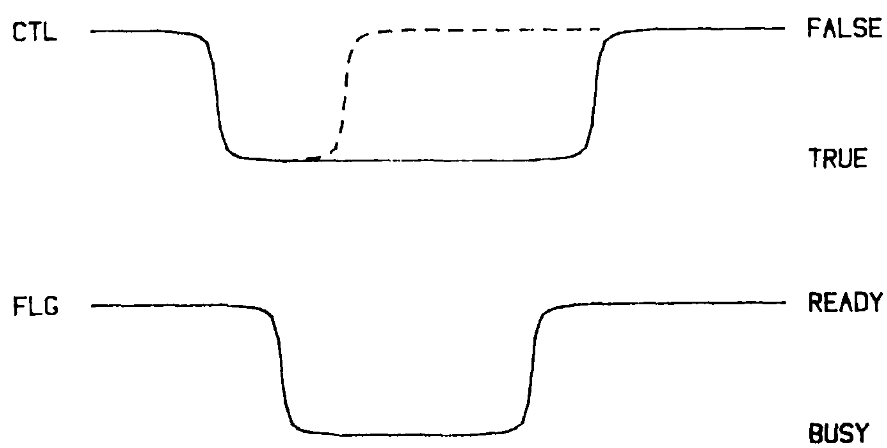

Figure 5. Timing diagram before synchronisation

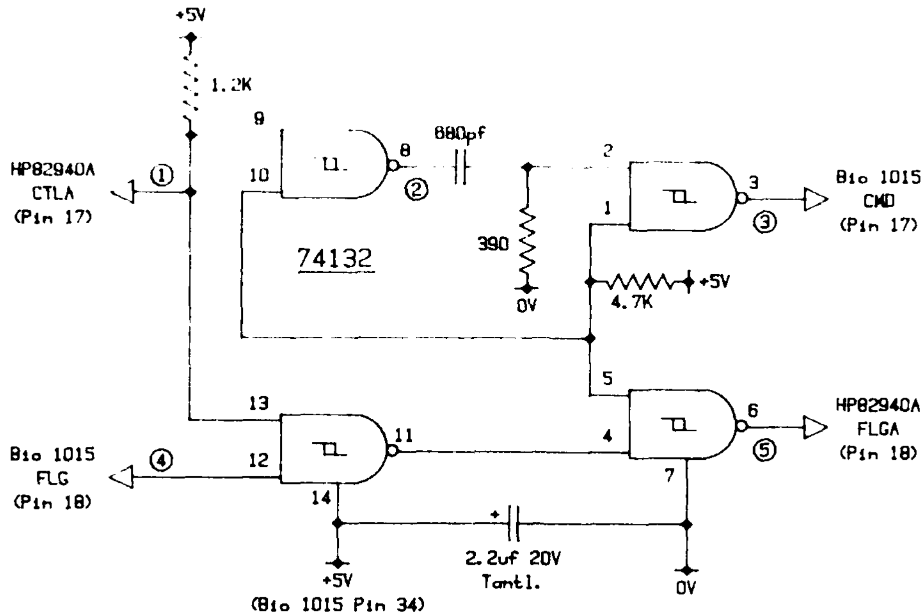

Figure 6. Timing synchronisation circuit

2.8 Program security

Recent experience has shown that special precautions to secure tapes are not required. Occasionally tapes reach the end of their useful life, a problem easily resolved by the existence of an adequate current library of master programs.

2.9 Special peripheral devices

Two other special peripherals are used at the small-calibre range. Although not strictly part of the data acquisition network, it is appropriate to mention them at this stage.

(a) Oehler Model 33 Chronotach system

Modifications have been made to this commercial velocity measuring system(ref.2) to provide improved reliability and accuracy. Three separate units are used, which display projectile velocity directly on individual LED read-outs.

(b) Ballistic signal generator

This device (figure 7) (ref.14) generates a characteristic square-pulse voltage of short duration when triggered by the impact of the firing pin on the cartridge base or by an ionisation detector at the muzzle of the test gun. This allows estimates to be made of ignition delays and ballistic cycle time. This device presents its output on a separate channel of the Biomation 1015. The signal is then synthesised into the primary pressure-time trace with software. This situation has the disadvantage of using a quarter of the available channels for a relatively trivial signal but has certain electrical and processing advantages. Alternative approaches to the timing of events in the ballistic cycle are being investigated.

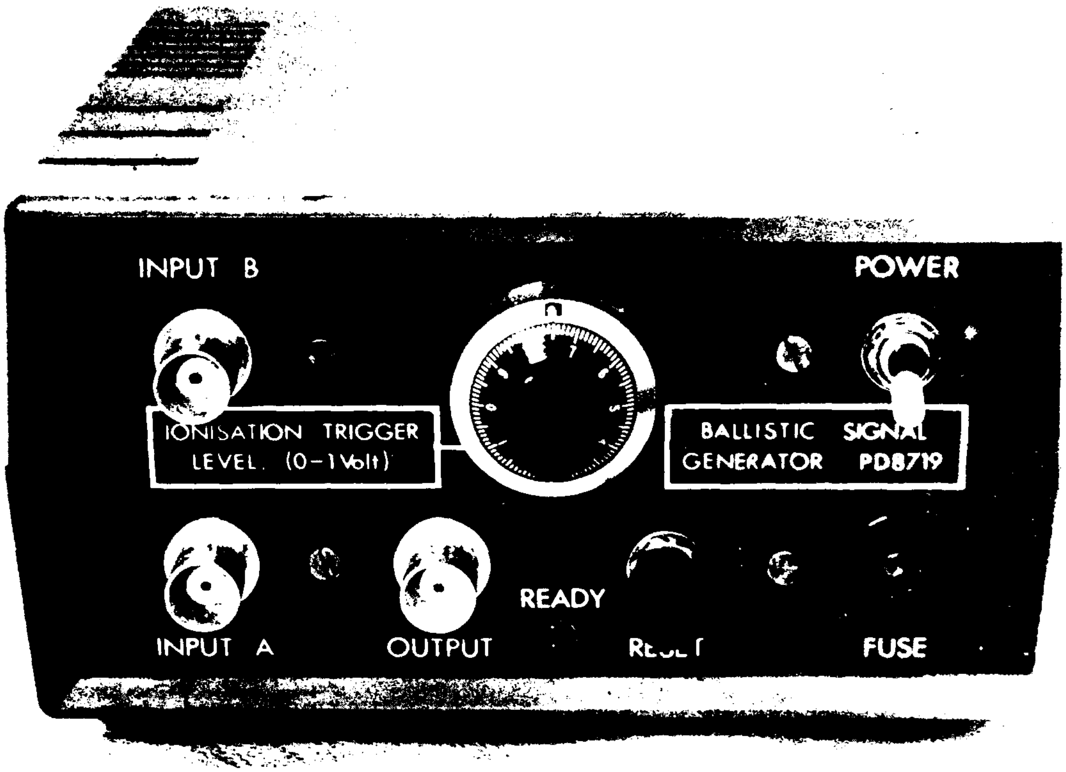

Figure 7. Ballistic signal generator

3. SYSTEM OPERATION

This section gives an overview of the capabilities of the system and the general manner in which it is used. The actual operating methods are determined by the firing program being undertaken, but they are usually very similar to those used for the alternative HP9825-driven system described in reference 1.

3.1 System connections

The Biomation transient recorder is connected to the computer via the modified HP82940A GPIO interface described in section 2.7. The plotter is connected using the HP82937A interface. Connections between the unit and the Ballistic Signal Generator are made. The projectile velocity *measurement* system is activated. Transducers and charge amplifiers are set up using the manufacturers' recommendations.

3.2 Data acquisition

The front panel controls of the Biomation 1015 are set to suitable values. Once all other preliminaries have been concluded, the firing is initiated, which triggers the transient recorder. The data are now held within the memory of the Biomation 1015 and are available to the computer. Preparations for the next firing can now be undertaken while the data are processed.

3.3 Data processing

The operator loads a program tape cartridge into the HP-85 and turns on the power to the computer. The computer automatically loads a start-up program called "Autost". This program will, if required, produce a listing on the internal printer which informs the user of the various program capabilities. Such a listing is illustrated in figure 8.

At present, the standard program tape uses four similar programs for data acquisition and processing:

(a) 85BIO - General purpose program which gives a similar output to figure 2 of reference 1. Useful for "one-off" firings.
(b) 85BIOa - Normal small-calibre program which yields data in a compact tabular form suitable for multiple firing programs.
(c) 85BIOb - As for 85BIOa with Ballistic Signal Generator output on Channel 2 of the transient recorder.
(d) BLANK - A variant of 85BIOb tailored for the special needs of blank ammunition.

A program suitable for the type of firing being conducted is loaded and run. Certain information regarding titles, instrument settings and projectile velocity is entered by the operator in response to prompting by the computer. The computer then acquires the raw digital data from the transient recorder and performs preliminary calculations to determine voltage offsets, maximum values, and conversion factors. A firing summary is printed. Typical summaries from the four standard programs are illustrated in figure 9. The operator is then prompted to select one of several output options which include:

(a) printing parts of the acquired data
(b) plotting the data on a digital plotter in one of four available formats
(c) plotting the data on the internal CRT of the computer
(d) copying the CRT plot on the printer
(e) storing the data for later reference.

A typical data printout is illustrated in figure 10. Plots of firing data on an external plotter and on the internal CRT are shown in figures 11 and 12 respectively.

```
********************************

These programs acquire their
data from a Biomation 1015, and
are designed for convenient
repetitive operation.

Data entries are only required
once, but can be entered or
changed at will.  Calculations
within input lines are not
permitted.

On successive runs, data keyed
in earlier is retained by use of
the [END LINE] key without data
entry.

Use of the [END LINE] key in
this way when the Firing Serial
Number is requested will raise
that number by one.

Keyboard data is limited to 32
characters per input line.

********************************

      NORMAL OUTPUT OPTIONS

These options will be displayed
at appropriate times in the 'KEY
LABEL' window.

START - Finished with processing
      - Acquire next channel.
PRINT - Print data summary of
        current channel.
STORE - Record data on tape
        cartridge.
PLOT  - Start Plot Option Menu.
MENU  - Return to normal Option
        Menu after plotting.
SUM'Y - Reprint titles and main
        ballistic data.

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          PLOT OPTIONS

PLOT1 - Single Plot (A4 Paper)
PLOT2 - Double Plot (A4 Paper)
PLOT3 - Single Plot (A3 Paper)
PLOT4 - Four Plots  (A3 Paper)
CPLOT - Plot on CRT screen
CCOPY - Copy CRT plot on
        thermal paper.
RESET - Reset plot position
        indicators
MENU  - Return to normal options

********************************

      MULTI-CHANNEL OPTIONS

NEXT  - Acquire next channel.
SKIP  - Ignore next channel.

********************************

       MULTI-CHANNEL INPUT

This program can draw data from
up to four channels of the
BIOMATION 1015 recorder.

An extra output option ('NEXT')
starts acquisition of data from
the next channel.  Data in the
next channel may also be disreg-
arded by the use of 'SKIP'.

Print and plot output of multi-
channel data is done in terms of
pressure units, using the common
timebase of the recorder.
'PRINT' may be used with any
channel to produce a summary.

If the 'PLOTn' options have been
used, the new data will also be
plotted, using the last plotting
device and plot format.  A new
pen colour will be used, if
appropriate to that device.

In multi-channel usage, once you
record data on tape, you will be
cautioned if you omit to record
later data from other channels.

********************************
```

Figure 8. Operator instruction listing

****

7.62mm BALL - Test Firing

FIRING NUMBER
239

Channel No. 1

Propellant - AR2206
26th November, 1981

****

Max. Pressure....	393.6 MPa
Muzzle Velocity..	863.7 m/s

****

****

7.62mm BALL - Test Firing

Propellant - AR2206
26th November, 1981

****

Serial Number	Channel Number	Maximum Pressure (MPa)	Muzzle Velocity (m/s)
1	1	393.6	863.7
	2	86.2	
2	1	387.2	860.1
	2	88.4	
3	1	397.7	865.8
	2	89.1	
4	1	389.1	860.6
	2	85.9	
5	1	385.3	870.0
	2	87.7	

****

7.62mm BALL - Test Firing

Propellant - AR2206
26th November, 1981

****

Ser. No.	Chan. No.	Max. Press. (MPa)	Muzzle Vel. (m/s)	Action Time (msec)
1	1	393.6	863.7	1.64
	2	86.2		
2	1	387.2	860.1	1.58
	2	88.4		
3	1	397.7	865.8	1.67
	2	89.1		
4	1	389.1	860.6	1.55
	2	85.9		
5	1	385.3	870.0	1.69
	2	87.7		

****

7.62mm BLANK - Lot MF11/6/81

Horizontal Firing - Ambient
25th November, 1981

****

Serial Number	Channel Number	Maximum Press. (MPa)	Primer Delay (msec)
1	1	77.0	0.45
	2	23.5	
2	1	118.1	0.47
	2	23.5	
3	1	72.9	0.46
	2	24.2	
4	1	90.3	0.45
	2	25.4	
5	1	81.7	0.47
	2	25.2	

Figure 9. Typical firing summaries

****

7.62mm BALL   Test Firing

FIRING NUMBER
239

Channel No. 1

TIME (uSEC)	PRESSURE (MPa)
900	14.2
950	72.3
1000	143.6
1050	230.5
1100	309.1
1150	368.2
1200	393.6
1250	381.8
1300	348.6
1350	308.6
1400	267.6
1450	229.5
1500	195.8
1550	166.5
1600	144.0
1650	124.5
1700	109.9
1750	97.7
1800	86.9
1850	78.1
1900	70.3
1950	64.0
2000	58.1

****

Figure 10. Typical single-channel data summary

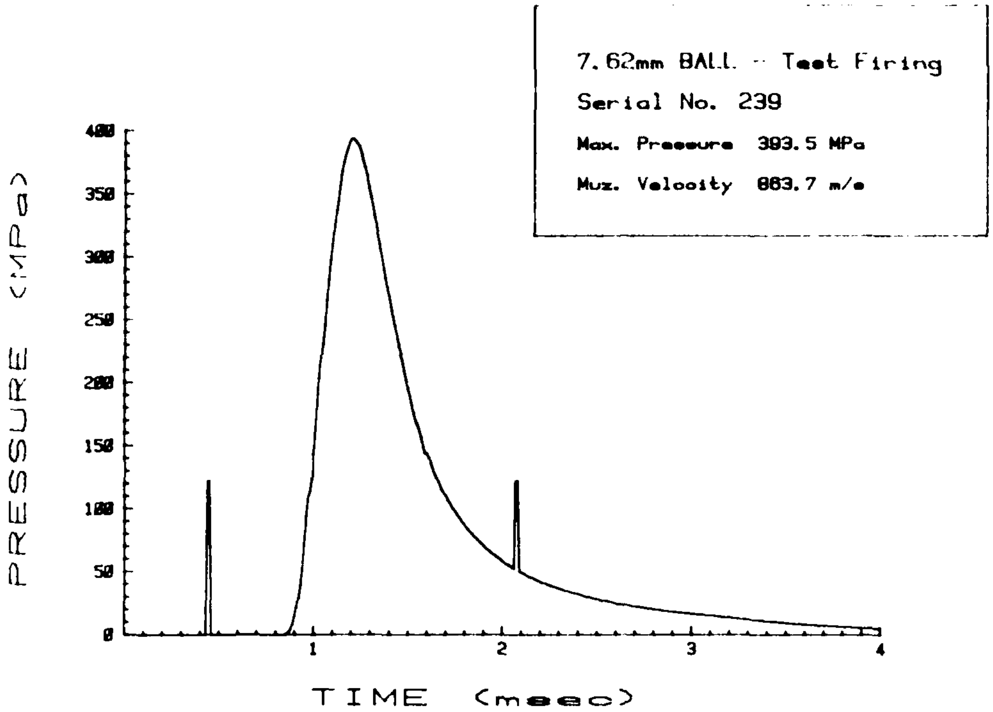

Figure 11. Typical record on external plotter

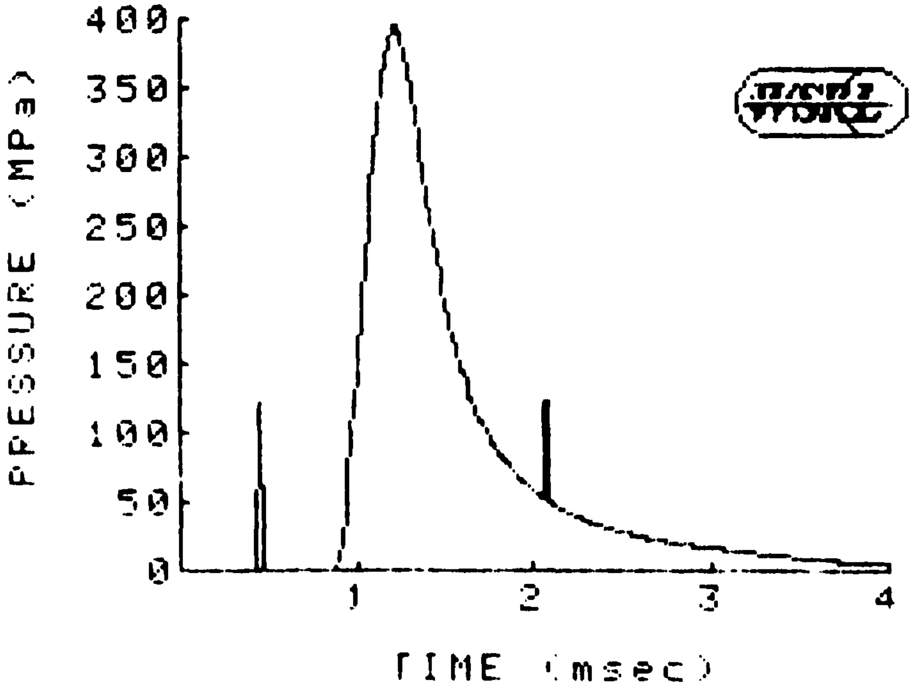

Figure 12. Typical record on HP-85 internal CRT

4. PROGRAM STRUCTURE

Much effort has been devoted to ensure a substantial degree of similarity to the programs described in reference 1. Although there is little in common in the appearance of the HPL language used by the HP9825A and the BASIC language of the HP-85, the languages are functionally alike, and it has been possible to maintain a common overall structure with the earlier programs.

The appendices to this report include complete program documentation. Appendix I gives information relating to the structure of the programs, including subroutine functions, variable allocations, test status and a schematic flow chart. Appendix II includes a complete source listing of the program "85BIOa". Partial listings of the programs "85BIOb" and "BLANK" are illustrated in Appendix III. These partial listings cover areas of significant divergence from "85BIOa". The programs contain remarks in areas where the source language is not explicit, and Appendices II and III include additional notes for user guidance.

5. COMPARATIVE PERFORMANCE

A recent report(ref.15) compared the speeds of a number of small computers in a computation-intensive task. The HP9825 was about 150% faster than the HP-85. Therefore, measurements were made of the performance of the software in this report for comparison with that of reference 1. All programs displayed identical numerical accuracy. Performance data (time/channel) are included in Table 1. Three representative tasks were chosen and timed manually with a stopwatch. Task 1 involves the acquisition of data from one Biomation channel (1024 samples), examination of the record for baseline offset, a search for the maximum value, and the printing of a data summary. This task is the minimum that will be asked of any system. Task 2 involves the production of a complete single-channel plot on A4 chart paper, including framing, axis drawing and labelling, plotting the data and labelling of a data summary window. This is the most demanding and time-consuming task commonly required. Task 3 is only relevant to the HP-85 and is included for comparison purposes only.

TABLE 1. RELATIVE PERFORMANCE FIGURES

Task	HP9825 Time (sec)	HP-85 Time (sec)
Task 1: Acquire/maximise/ print summary	19	19
Task 2: Channel 1 plot on A4 chart paper	105	115
Task 3: Channel 1 plot on internal CRT	n.a.	40

These figures show that the HP-85 has very similar capabilities to the HP9825 in the handling of small-calibre ballistic range data. Clearly, the HP-85's language flexibility and its faster printing capability lead to similar overall performance to the HP9825 despite the latter machine's advantage in computational speed.

In a recent experiment, large numbers of rounds of blank ammunition were required to be fired each day. Firings were plotted as required, and several overhead transparencies were made (using special pens for the plotter). A comfortable throughput of 20 rounds per hour was maintained. This is a very satisfactory figure, allowing statistically relevant numbers of rounds to be fired in a short time. In addition, comparison between several different types of ammunition can be made on the same day under the same firing conditions.

6. CONCLUSIONS

6.1 General comments

A data acquisition and processing system based on the Hewlett-Packard HP-85 desktop computer can process small-calibre gun ballistic data reliably and efficiently at low cost compared with some systems used overseas. The computer has features which allow flexible options such as hard copy on internal or external printers, plotting on the its internal CRT, plotting on an external plotter, and the use of tape cartridges as flexible mass storage devices. System software is written in a BASIC variant which is readily learnt and understood, and users may develop software, based on the listings in this report, to suit their individual needs.

6.2 Future developments

The HP-85 has excellent expansion capabilities to cope with future requirements. The most complicated current software leaves over 50% of the RAM memory intact after all data storage requirements have been met. It is anticipated that the Biomation 1015 recorder will eventually be replaced with a more modern device which transmits data over the IEEE-488 digital interface. The HP-85 has data transfer capabilities in this environment which make it especially suitable for operation with such a device.

7. ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance given by Mr F.A. Rousseau in the resolution of several electronic problems during the development of this system. Mr R.T. Hammond assisted in the conduct of the firing trials during which the inevitable software "bugs" were eliminated.

System documentation provided by the Hewlett-Packard company has been valuable source material during the production of this report.

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4	Kemeny, J.G. and Kurtz, T.E.	"Basic Programming". Wiley, New York, 1971
5	Hewlett-Packard Company Corvallis Division	"HP-85 Owner's Manual and Programming Guide". Manual 00085-90002Rev.D1/81, January 1981
6	Hewlett-Packard Company	"HP-85 I/O Programming Guide". Manual 00085-90142Rev.C2/81, February 1981
7	Hewlett-Packard Company	"HP-85 Plotter/Printer ROM Manual". Manual 00085-90140, January 1980
8	Hewlett-Packard Company	"HP 83/85 Assembler ROM and HP-82928A System Monitor Manual". Manual 00085-90444, December 1980
9	Davies, I.	"The HP-85 Revisited". Australian Personal Computer, Vol.2, p19, August/September 1981
10	Institute of Electrical and Electrical Engineers	"Standard Digital Interface for Programmable Instrumentation". IEEE Std.488-1978, 1978
11	Biomation	"Model 1015 Waveform Recorder Operating and Service Manual". Manual 0115-0100, February 1975
12	Weapons Systems Research Laboratory	"Hewlett-Packard 82940A GPIO Interface Cable Connections". Drawing PD8747, April 1981
13	Hewlett-Packard Company	"GPIO Installation and Theory of Operation Manual". Manual 82940-90001, July 1980

No.	Author	Title
14	Weapons Systems Research Laboratory	"Ballistic Signal Generator". Drawing PD8719, October 1981
15	Fox, T.	"Report Card: Benchmark". Interface Age, p75, August 1981

APPENDIX I

PROGRAM DESCRIPTION

I.1 Identification

The programs described in this report belong to the "85BIO" software series. This notation is specific to software used by Gun Propulsion Research Group. The acronym is derived from the explicit association of the Hewlett-Packard 85 Computer with the Biomation 1015 Waveform Recorder.

The current programs in this closely-related series are:

1. 85BIO
2. 85BIOa
3. 85BIOb
4. BLANK

Version date - 19 May 1982

Author - Dr A.R. Rye, Gun Propulsion Research Group,
Weapons Systems Research Laboratory.
Telephone (08) 259 5145

System - Hewlett-Packard 85 Computer

Language - HP extended BASIC
- substantially compatible with other HP computers
- probably incompatible with non-HP computers

I.2 Purpose

These programs perform a straightforward data acquisition and processing task. Ballistic firing data is gathered from a Biomation 1015 Waveform Recorder and associated peripherals. Preliminary processing is performed and a brief summary generated. The software allows flexible user-interaction to determine post-acquisition requirements. Typical options include the printing of detailed data summaries, graphic display on either the computer's internal CRT or an external digital plotter and data transfer to magnetic tape or diskette.

I.3 Method and Output

These topics have been treated in depth in the body of this report.

I.4 Operational requirements and characteristics

Computer - Hewlett-Packard 85 Computer
- 16K memory (minimum)
- 32K memory (desirable)
- HP 82936A ROM Drawer
- HP 00085-15002 Plotter-printer ROM
- HP 00085-15003 Input-output ROM

Interfaces - HP 82937A HP-IB Interface
- HP 82940A GPIO Interface

Acquisition - Biomation 1015 Waveform Recorder

Peripherals - compatible Hewlett-Packard digital plotter
(HP9872 desirable, HP7225 and HP7470 acceptable)
- compatible Hewlett-Packard mass-storage unit
(optional, requires HP 00085-15001 Mass Storage ROM)
- PD8719 Ballistic Signal Generator
- Velocity measurement system (sky screens, etc)

I.5 Structure and coding

The software of the 85BIO program family is similar to that developed earlier for the HP9825(ref.1) in that it contains a "driver" section, a group of "direct-execution" routines, and a number of "service" routines. A schematic flow chart is shown in figure I.1. This chart is included as a guide to the various program options; it is not meant to represent a rigorous flow diagram such as those required for more structured programs. The names and functions of the various program elements have been described in reference 1, but are reproduced here for completeness.

I.5.1 Driver section

This section controls the overall flow of the program up to the data acquisition stage. Program flags are set and cleared as required, and the bulk of the information needed from the operator is gathered in this section.

I.5.2 Direct-execution routines

These routines perform the "workhorse" roles in the program - the acquisition, processing, and output of gun firing data. These routines are:

(a) GETDAT - acquire data from transient recorder
(b) SUMMARY - print data summary
(c) PRINT - print data segments
(d) COMPLOT - shared plotting routine used by all PLOTn routines
(e) CPLOT - plot data on internal CRT
(f) CCOPY - copy CRT to internal printer
(g) STORE - record data on magnetic tape
(h) SKIP - ignore contents of next channel.

I.5.3 Service routines

These routines handle general administrative tasks and defined tasks required by one or more of the direct-execution routines. They include:

(a) PLOTn routines - PLOT1, PLOT2, PLOT3, and PLOT4 initialise the plotting areas for the four available plot formats
(b) SET LIMITS - establishes limits for plot axes
(c) WARNING - signals error conditions
(d) CENTRE - controls print formats

"WARNING" and "CENTRE" have been deleted from the Flow Diagram (figure I.1) for clarity.

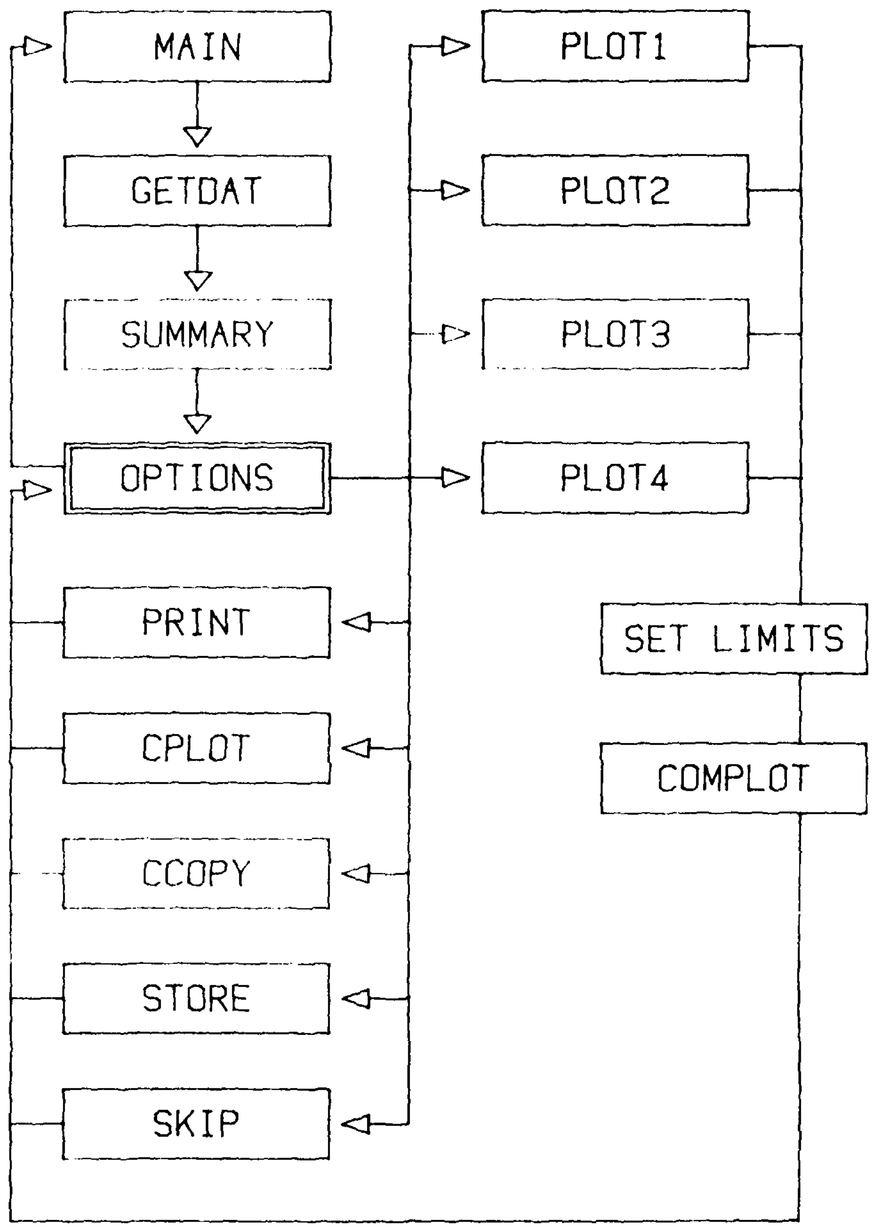

Figure I.1 Flow diagram for 85BIO program series

I.5.4 Program counters

Certain program variables are reserved for internal "housekeeping". These variables include:

(a) D$ - Temporary string, used in many areas of the software.
(b) N - Number of the recorder channel in use. Also designates the plotter pen station associated with that channel.
(c) Q - Number of data files on a data tape.
(d) R - Voltage offset figure (raw data).
(e) Y - Pointer to which of two plots on a double-plot page is current.
(f) Z - Pointer to which of four plots on a four-plot page is current.

I.5.5 Program flags

Variables F1 to F8 are used as flags by the software. Their meanings, when they are non-zero, are:

(a) F1 - Multichannel mode in effect.
(b) F2=1 - Last plot was on external plotter.
    F2=2 - Last plot was on CRT.
(c) F3 - Data has been recorded.
(d) F4 - Current channel to be plotted on external plotter.
(e) F5 - Current channel has been recorded.
(f) F6 - Current channel to be plotted on CRT.
(g) F7 - Headings have been printed.
(h) F8 - Indicates which of the PLOTn formats is in use.

I.5.6 Plot formats

Four plotting formats are available on an external HP9872 plotter:

(a) PLOT1 - single plot, A4 size
(b) PLOT2 - dual plot on A4 size paper
(c) PLOT3 - single plot, A3 size
(d) PLOT4 - four plots on A3 paper

Other compatible plotters may be used, but only the PLOT1 format will be useful. A schematic representation of the four plot layouts is illustrated in figure I.2.

I.6 Test status

These programs have been extensively tested in recent months, and are based on eighteen months experience with the system described in reference 1. While it is impossible to guarantee that they are "error free", it can be said that deliberate attempts to generate errors have so far failed. Certainly, no problems have been experienced in the routine exercising of all the current options.

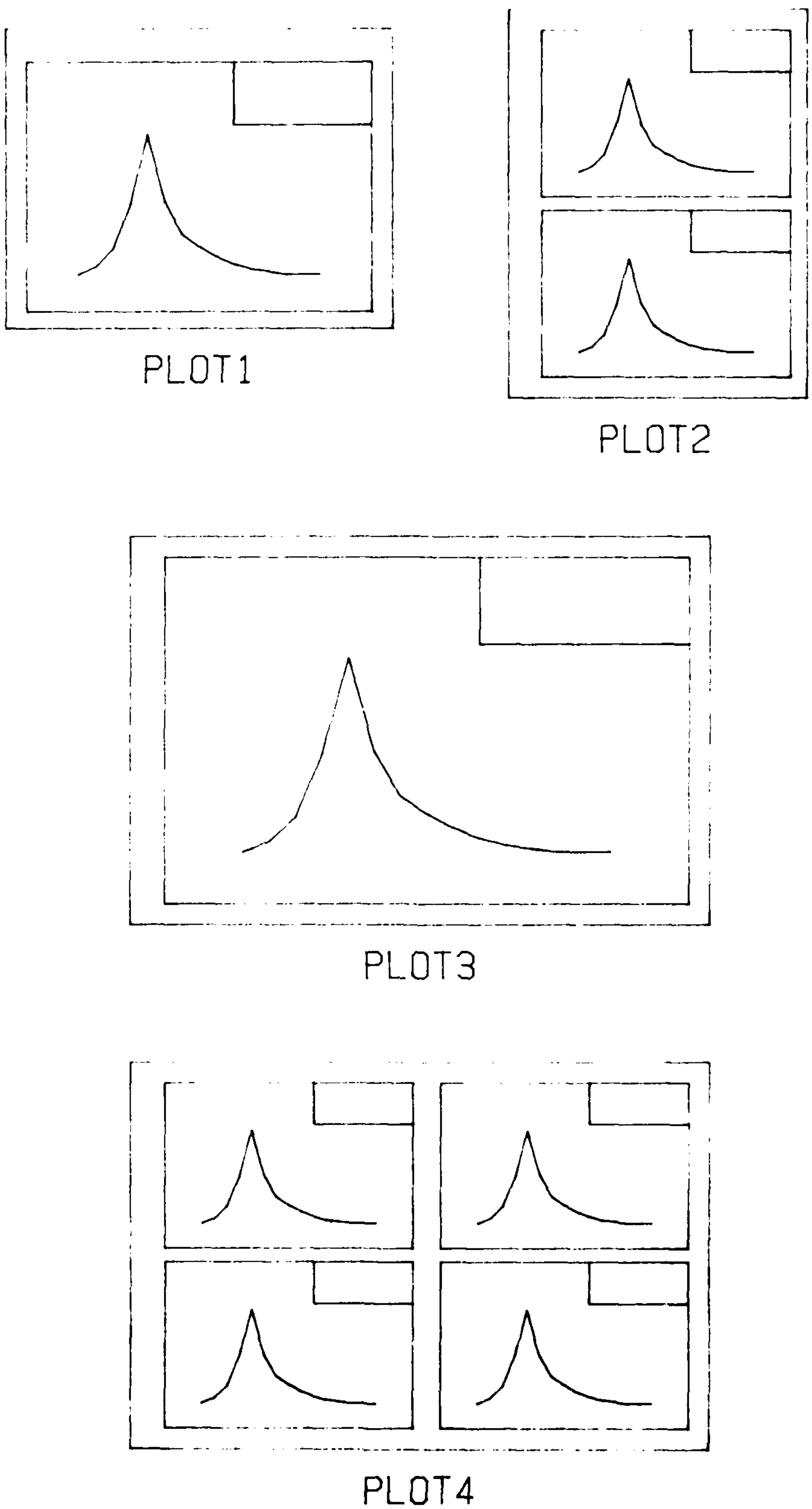

Figure I.2 Available plotting formats

APPENDIX II

PROGRAM LISTING AND USER NOTES FOR PROGRAM "85BIOa"

```
10 REM *  PROGRAM  "85BIOa"  *
20 REM * - USE WHEN FIRING A *
30 REM *   SERIES OF SHOTS   *
40 DEG @ OPTION BASE 1@ Y,Z=1
50 COM Z$[1],Y$[3]
60 DIM T$[32],S$[32],G1$[32],G2$[32]
70 DIM D$[40],L$[108]
80 DIM L1(3,12),L2(3),L3(3)
90 INTEGER F(1024)
100 F3,F5,F7=0 @ L$=""
110 ENABLE KBD 64+32+4+1
120 REM  SET UP GPIO INTERFACE
130 REM   INVERT CTLA & FLGA
140 CONTROL 8,3 : 17
150 REM  START POINT
160 GCLEAR @ CLEAR
170 IF F3 AND NOT F5 THEN GOSUB 2960
180 F1,F2,F3,F4,F5,F6=0 @ N=1
190 IF F7 THEN 510
200 DISP "FIRING PROGRAM TITLE";@ INPUT D$
210 IF LEN(D$)>32 THEN GOSUB 3020 @ GOTO 200
220 IF LEN(D$) THEN T$=D$
230 DISP "FIRING SERIAL NUMBER";@ INPUT D$
240 IF LEN(D$)>32 THEN GOSUB 3020 @ GOTO 230
250 IF LEN(D$)=0 THEN S$=VAL$(VAL(S$)+1) ELSE S$=D$
260 DISP "NUMBER OF CHANNELS";@ INPUT D$
270 IF LEN(D$) THEN M=VAL(D$) ELSE 290
280 IF VAL(D$)>4 THEN 260
290 REM  SECOND START POINT
300 IF F3 AND NOT F5 THEN GOSUB 2960
310 F5=0 @ IF F1 THEN N=N+1
320 IF F1 AND F2=1 THEN F4=1
330 IF F1 AND F2=2 THEN F6=1
340 IF F7 THEN 520
350 DISP "COMMENT # 1";@ INPUT D$
360 IF LEN(D$)>32 THEN GOSUB 3020 @ GOTO 350
370 IF LEN(D$) THEN G1$=D$
380 DISP "COMMENT # 2";@ INPUT D$
390 IF LEN(D$)>32 THEN GOSUB 3020 @ GOTO 380
400 IF LEN(D$) THEN G2$=D$
410 IMAGE //,32("*"),//
420 PRINT USING 410
430 D$=T$ @ GOSUB 2890
440 GOSUB 2930 @ PRINT
450 D$=G1$ @ GOSUB 2890
460 D$=G2$ @ GOSUB 2890
470 PRINT USING 410
480 PRINT "Serial Channel Maximum  Muzzle"
490 PRINT "Number Number  Pressure Velocity"
500 PRINT "                 (MPa)     (m/s)" @ PRINT
510 IF F7 THEN S$=VAL$(VAL(S$)+1)
520 DISP "CHARGE AMP. SETTING (MPa/V)";@ INPUT D$
530 IF LEN(D$) THEN R1=VAL(D$)
540 DISP "VOLTS FULL SCALE";@ INPUT D$
550 IF LEN(D$) THEN F=VAL(D$)
```

```
560 R4=F*R1*10/1023 @ F7=1
570 IF F1 THEN 610
580 DISP "TIMEBASE SETTING (msec)";@ INPUT D$
590 IF LEN(D$) THEN R2=VAL(D$)
600 DISP "MUZZLE VELOCITY";@ INPUT V
610 GOSUB 1030 ! PRESSURES
620 IF M>1 THEN F1=1
630 REM >SUMMARY<
640 IMAGE 4A,6D,8DZ.D,7DZ.D
650 IF N=1 THEN PRINT USING 640 ; S$,1,R3/10,V
660 IF N>1 THEN PRINT USING 640 ; " ",N,R3/10
670 REM >  OPTIONS  <
680 REM >DEFINE KEYS<
690 OFF KEY# 1 @ OFF KEY# 6
700 ON KEY# 2,"STORE" GOTO 1770
710 ON KEY# 3,"PLOT " GOTO 810
720 ON KEY# 4,"MENU " GOTO 690
730 ON KEY# 5,"START" GOTO 150
740 OFF KEY# 7 @ OFF KEY# 8
750 IF F1 THEN ON KEY# 7,"NEXT" GOTO 290
760 IF F1 THEN ON KEY# 8,"SKIP" GOTO 2010
770 CLEAR @ IF F4 THEN ON F8 GOTO 2180,2330,2420,2600
780 IF F6 THEN 1540
790 KEY LABEL
800 GOTO 790
810 ON KEY# 1,"PLOT1" GOTO 2120
820 ON KEY# 2,"PLOT2" GOTO 2210
830 ON KEY# 3,"CPLOT" GOTO 1540
840 ON KEY# 5,"PLOT3" GOTO 2360
850 ON KEY# 6,"PLOT4" GOTO 2450
860 ON KEY# 7,"CCOPY" GOTO 900
870 ON KEY# 8,"RESET" GOTO 890
880 GOTO 770
890 Y,Z=1 @ GOTO 770
900 GRAPH @ COPY @ PRINT USING 410 @ GOTO 770
1000 REM >DIRECT-EXECUTION<
1010 REM >    ROUTINES    <
1020 REM
1030 REM >"GETDAT"<
1040 REM >CONTROL #'S FOR REG.4<
1050 REM > 192 - No Handshake  <
1060 REM > 32  - Full Handshake<
1070 REM > 12  - Inverted Data <
1080 R3,R=0
1090 CONTROL 8,4 ; 12+192
1100 OUTPUT 810 USING "W" ; 226
1110 CONTROL 8,4 ; 12+32
1120 FOR I=1 TO 24
1130 ENTER 810 USING "#,W" ; P(I)
1140 R=P(I)+R @ NEXT I @ R=R/24
1150 IMAGE #,W,W,W,W,W,W,W,W,W,W,W
1160 FOR I=25 TO 1015 STEP 10
1170 ENTER 810 USING 1150 ; P(I),P(I+1),P(I+2),P(I+3),P(I+4),P(I+5),
     P(I+6),P(I+7),P(I+8),P(I+9)
1180 NEXT I @ P6=.3 @ FOR I=25 TO 1024
1190 IF P(I)>R3 THEN R3=P(I)
```

```
1200 IF P(I) R3*P6 THEN 1220
1210 NEXT I
1220 R3=(R3-R)*R4
1230 IF N M THEN RETURN
1240 CONTROL 8,4 ; 12+192
1250 OUTPUT 810 USING "W" ; 228
1260 RETURN
1270 REM  <COMMON PLOTTER>
1280 IF NOT F2 THEN GOSUB 2710
1290 SCALE 0,L3(1),0,L2(1)
1300 PEN N @ IF F2 THEN 1370
1310 LAXES -L3(3),L2(3),0,0,L3(2)/L3(3),L2(2)/L2(3)
1320 MOVE -(L3(1)/(7+6*P1)),L2(1)/10
1330 CSIZE 4,1.5 @ LDIR 90
1340 LABEL "PRESSURE (MPa)"
1350 MOVE L3(1)/4,-(L2(1)/(7+2*P1))
1360 LDIR 0 @ LABEL "TIME (msec)"
1370 REM  "GRAPH"
1380 FOR I=1 TO R7/R2
1390 PLOT I*R2,(P(I)-R)*R4/10 @ NEXT I
1400 PENUP @ F4=0 @ IF F2 THEN 770
1410 CSIZE 4-P1,.75
1420 R5=.6*L3(1) @ R6=(1.15-P1/4)*L2(1)
1430 MOVE R5,R6 @ LABEL T$
1440 MOVE R5,R6-.08*L2(1)
1450 LABEL "Serial No. "&S$
1460 MOVE R5,R6-.16*L2(1)
1470 CSIZE 3,.8
1480 LABEL USING 1510 ; "Max. Pressure",R3/10,"MPa"
1490 MOVE R5,R6-.24*L2(1)
1500 LABEL USING 1510 ; "Muz. Velocity",V,"m/s"
1510 IMAGE K,5D.D,X,K
1520 IF F1 THEN F2=1
1530 GOTO 770
1540 REM <PLOT ON CRT>
1550 IF F2=0 THEN GOSUB 2710
1560 PLOTTER IS 1 @ P5=RATIO*100
1570 LOCATE 2 11*P5,10/11*P5,800/53,4800/53
1580 SCALE 0,L3(1),0,L2(1)
1590 IF F2 THEN 1690
1600 GCLEAR @ IF LEN(L$)<1 THEN GOSUB 1740
1610 MOVE L3(1)*.8,L2(1)*.9
1620 BPLOT L$,6
1630 LAXES -L3(2),L2(2),0,0
1640 MOVE L3(1)*.3,-(L2(1)/5)
1650 LABEL "TIME (msec)"
1660 LDIR 90
1670 MOVE -(L3(1)/5),L2(1)*.16
1680 LABEL "PRESSURE (MPa)"
1690 LDIR 0 @ MOVE 0,0 @ F6=0
1700 FOR I=1 TO R7/R2
1710 DRAW I*R2,(P(I)-R)*R4/10
1720 NEXT I @ IF F1 THEN F2=2
1730 GOTO 770
1740 ASSIGN# 1 TO "LDATA2"
```

```
1750 READ# 1 ; L$
1760 ASSIGN# 1 TO * @ RETURN
1770 REM >"STORE"<
1780 D$="" @ IF F5 THEN 3000
1790 IF F3 THEN 1960
1800 DISP "LOAD "&D$&"DATA TAPE; PRESS 'CONT'" @ PAUSE
1810 ON ERROR GOTO 1870 @ D$=""
1820 ASSIGN# 1 TO "INDEX"
1830 READ# 1,1 @ OFF ERROR
1840 IF O+M<25 THEN 1950
1850 BEEP @ DISP "NOT ENOUGH SPACE FOR ALL DATA -"
1860 D$="NEW " @ GOTO 1800
1870 IF ERRN=67 THEN 1890
1880 BEEP @ DISP "Error";ERRN;" in line";ERRL @ PAUSE @ GOTO 1880
1890 BEEP @ DISP "TAPE NOT INITIALISED!"
1900 DISP "INITIALISE IT (7 Minutes)";@ INPUT Y$
1910 IF UPC$(Y$[1,1])#"Y" THEN 1860
1920 ERASETAPE @ CREATE "INDEX",1
1930 CREATE "DATA",25,800
1940 ASSIGN# 1 TO "INDEX" @ O=0
1950 PRINT# 1,1 ; O+M
1960 ASSIGN# 1 TO "DATA"
1970 IF F1 THEN F3=1
1980 PRINT# 1,O+N ; M,T$,S$,G1$,G2$,V,R,R2,R3,R4,P()
1990 ASSIGN# 1 TO *
2000 F5=1 @ GOTO 770
2010 REM >"SKIP"<
2020 IF F3 AND NOT F5 THEN 2960
2030 IF F1 THEN N=N+1
2040 CONTROL 8,4 ; 12+192
2050 OUTPUT 810 USING "W" ; 226
2060 CONTROL 8,4 ; 12+32
2070 FOR I=1 TO 1013 STEP 11
2080 ENTER 810 USING 1150 ; P,P,P,P,P,P,P,P,P,P,P@ NEXT I
2090 IF N=M THEN GOSUB 1240
2100 GOTO 770
2110 REM >SERVICE ROUTINES<
2120 REM >     "PLOT1"      <
2130 PLOTTER IS 705 @ P=100/18
2140 LIMIT 5.4,255.6,5.7,186
2150 SCALE 0,25,0,18 @ MOVE 0,0
2160 P1=14 @ P2=12.5 @ P3=25 @ P4=18
2170 GOSUB 2660 ! BOX ROUTINE
2180 PLOTTER IS 705
2190 LOCATE 4*P,22*P,3*P,15*P
2200 P1=.1 @ F8=1 @ GOTO 1270
2210 REM > "PLOT2" <
2220 PLOTTER IS 705 @ P=100/12
2230 Z=-Z @ IF Z<0 THEN 2260
2240 LIMIT 13.9,194.2,8.8,128.8
2250 GOTO 2340
2260 DISP "LOAD GRAPH PAPER; PRESS 'CONT'" @ PAUSE
2270 LIMIT 13.9,194.2,8.8,258.9
2280 SCALE 0,18,0,25
2290 P1=10 @ P2=8.8 @ P3=18 @ P4=12
```

```
2300 MOVE 0,0 @ GOSUB 2660
2310 MOVE 0,13 @ GOSUB 2660
2320 LIMIT 13.9,194.2,138.9,258.9
2330 PLOTTER IS 705
2340 LOCATE 3*P,15*P,2*P,10*P
2350 P1=0 @ F8=2 @ GOTO 1270
2360 REM > "PLOT3" <
2370 PLOTTER IS 705 @ P=4
2380 LIMIT 15.4,395.9,8.6,258.6
2390 SCALE 0,38,0,25
2400 P1=21 @ P2=17.6 @ P3=38 @ P4=25
2410 MOVE 0,0 @ GOSUB 2660
2420 PLOTTER IS 705
2430 LOCATE 4*P,34*P,3*P,23*P
2440 P1=.5 @ F8=3 @ GOTO 1270
2450 REM > "PLOT4" <
2460 PLOTTER IS 705 @ P=100/12
2470 IF Y=1 THEN Y=2 @ GOTO 2510
2480 IF Y=2 THEN Y=3 @ GOTO 2630
2490 IF Y=3 THEN Y=4 @ GOTO 2640
2500 IF Y=4 THEN Y=1 @ GOTO 2650
2510 DISP "LOAD GRAPH PAPER; PRESS 'CONT'" @ PAUSE
2520 LIMIT 15.4,395.9,8.6,258.6
2530 SCALE 0,38,0,25
2540 P1=10 @ P2=8.8 @ P3=18 @ P4=12
2550 MOVE 0,0 @ GOSUB 2660
2560 MOVE 0,13 @ GOSUB 2660
2570 MOVE 20,0 @ GOSUB 2660
2580 MOVE 20,13 @ GOSUB 2660
2590 LIMIT 15.4,195.7,138.6,258.6
2600 PLOTTER IS 705
2610 LOCATE 3*P,15*P,2*P,10*P
2620 P1=0 @ F8=4 @ GOTO 1270
2630 LIMIT 15.4,195.7,8.6,128.5 @ GOTO 2610
2640 LIMIT 215.6,395.9,138.6,258.6 @ GOTO 2610
2650 LIMIT 215.6,395.9,8.6,128.5 @ GOTO 2610
2660 REM > "BOX" <
2670 IDRAW 0,P4 @ IDRAW P3,0
2680 IDRAW 0,-P4 @ IDRAW -P3,0
2690 IMOVE P1,P4 @ IDRAW 0,P2-P4
2700 IDRAW P3-P1,0 @ RETURN
2710 REM >"SET LIMITS"<
2720 R7=1000*R2
2730 FOR I=1 TO 12 @ FOR J=1 TO 3
2740 READ L1(J,I)@ NEXT J @ NEXT I
2750 DATA 2,1,.1,4,1,.1,5,1,.1,10,1,.2,20,2,.5,40,5,1,50,5,1
2760 DATA 100,10,2,200,20,5,400,50,10,500,50,10,800,100,20
2770 RESTORE
2780 FOR I=1 TO 12 @ J=I
2790 IF L1(1,I)>=R3/10 THEN 2810
2800 NEXT I
2810 IF R2#.01 THEN 2830
2820 DISP "Plot Baseline - 4,5 or 10 msec";@ INPUT R7
2830 FOR I=1 TO 12 @ K=I
2840 IF L1(1,I)>=R7 THEN 2860
```

```
2850 NEXT I
2860 FOR I=1 TO 3 @ L2(I)=L1(I,J)
2870 L3(I)=L1(I,K) @ NEXT I
2880 RETURN
2890 REM >CENTRING ROUTINE<
2900 L=16-LEN(D$)\2
2910 PRINT TAB(L);D$
2920 RETURN
2930 FOR I=1 TO LEN(D$)
2940 D$[I,I]="-" @ NEXT I
2950 GOTO 2910
2960 REM >WARNING ROUTINES<
2970 DISP "LAST CHANNEL NOT STORED" @ BEEP
2980 DISP "ENTER [S] (STORE) OR [C] (CONT)";@ INPUT Y$
2990 IF UPC$(Y$[1,1])="S" THEN 1960 ELSE RETURN
3000 DISP "LAST CHANNEL ALREADY STORED" @ BEEP
3010 GOTO 770
3020 DISP "TOO LARGE, RE-ENTER:"
3030 RETURN
```

USER NOTES FOR PROGRAM "85810a"

Line Number	Comments
60-90	Allocate memory for title, serial number, two comment lines, pressure, and fixed plotting limits.
110	Suppress unintended keyboard interrupts.
140	Inverts the logical sense of the interface control and flag lines.
190	F7 true means headings have already been sought and printed.
410-500	Print headings
560	R4 is conversion factor from 10-bit binary to user units. (A ten-fold scale-up is used so that precision is maintained with integer arithmetic)
590	R2 is timebase per point in msec.
630-660	Print summary
670-760 and 810-880	Establish "soft-key" allocations
770-800	"Options" loop
1030-1260	Acquisition routine - also determines maximum value. (Note - GPIO Interface is set to address "8", port configuration "10". Control register 4 sets handshake and data logic sense. Interface wiring is such data values of 226 and 228 (decimal) initiate and terminate digital output from the Biomation 1015)
1090	Invert data, select "no-handshake" mode (allows direct write to interface).
1010	Invert data, select "full-handshake" mode.
1200	Ceases search for maximum value if current value is less than 30% of maximum value. This line should be modified for records which have unusual waveforms.
1270	Common plotting routine used by "PLOTn" routines.
1280	Routine at line 2710 scales data.
1540	Plotting routine on internal CRT.
1620	Display WSRL logo on screen.
1740	Get data for WSRL logo from tape file.
1770	Store data on tape - initialise if necessary.
2010	Skip one channel of recorder.
2120	PLOT1 sets up framework for single-plot A4 page.

2210	PLOT2 sets up framework for double-plot A4 page.
2360	PLOT3 sets up framework for single-plot A3 page.
2450	PLOT4 sets up framework for four-plot A3 page.
2660	General-purpose framing routine.
2710	Establishes plotting limits.
2890	Centres data on printer.
2960	Various warning routines.

APPENDIX III

PROGRAM LISTING AND NOTES FOR SUPPLEMENTARY PROGRAMS

PARTIAL SOURCE LISTING AND NOTES FOR PROGRAM "85BIOb"

```
1030 REM >"GETDAT"<
1040 REM  CONTROL #'S FOR REG.4<
1050 REM > 192 - No Handshake  <
1060 REM > 32  - Full Handshake<
1070 REM > 12  - Inverted Data <
1080 R3,R=0
1090 CONTROL 8,4 ; 12+192
1100 OUTPUT 810 USING "W" ; 226
1110 CONTROL 8,4 ; 12+32
1120 FOR I=1 TO 24
1130 ENTER 810 USING "#,W" ; P(I)
1140 R=P(I)+R @ NEXT I @ R=R/24
1150 IMAGE #,W,W,W,W,W,W,W,W,W,W,W
1160 FOR I=25 TO 1015 STEP 10
1170 ENTER 810 USING 1150 ; P(I),P(I+1),P(I+2),P(I+3),P(I+4),P(I+5),
     P(I+6),P(I+7),P(I+8),P(I+9)
1180 NEXT I @ P6=.3 @ FOR I=25 TO 1024
1190 IF P(I)>R3 THEN R3=P(I)
1200 IF P(I)<R3*P6 THEN 1220
1210 NEXT I
1220 R3=(R3-R)*R4 @ K=0
1230 IF N#1 THEN 1380
1240 R6=0 @ FOR I=1 TO 11
1250 ENTER 810 USING "#,W" ; R5
1260 R6=R5+R6 @ NEXT I @ R6=R6/11+100
1270 FOR I=12 TO 1013 STEP 11
1280 ENTER 810 USING 1150 ; Q(1),Q(2),Q(3),Q(4),Q(5),Q(6),Q(7),Q(8),
     Q(9),Q(10),Q(11)
1290 IF K=2 THEN 1370
1300 FOR J=1 TO 11
1310 IF K=2 THEN 1360
1320 IF Q(J)<R6 THEN 1360
1330 P(I+J-1)=200+R
1340 IF K=0 THEN K=1 @ T(1)=I+J-1
1350 IF K=1 AND I+J-T(1)>6 THEN K=2 @ T(2)=I+J-1
1360 NEXT J
1370 NEXT I
1380 IF N<M THEN RETURN
1390 CONTROL 8,4 ; 12+192
1400 OUTPUT 810 USING "W" ; 228
1410 RETURN
```

Line Number	Comments
1030-1410	Data gathering routine for "85BIOb"
1270-1370	Examine channel 2, point-by-point. Any that exceed 10% of full-scale (plus offset) are transferred as a 20% of full-scale signal to the channel 1 data already acquired. In addition, the times of peak 1 (primer strike) and peak 2 (muzzle exit) are stored as T(1) and T(2).

PARTIAL SOURCE LISTING AND NOTES FOR PROGRAM "BLANK"

```
1030 REM >"GETDAT"<
1040 REM >CONTROL #'S FOR REG.4<
1050 REM > 192 - No Handshake  <
1060 REM > 32  - Full Handshake<
1070 REM > 12  - Inverted Data <
1080 R3,R=0
1090 CONTROL 8,4 ; 12+192
1100 OUTPUT 810 USING "W" ; 226
1110 CONTROL 8,4 ; 12+32
1120 FOR I=1 TO 24
1130 ENTER 810 USING "#,W" ; P(I)
1140 R=P(I)+R @ NEXT I @ R=R/24
1150 IMAGE #,W,W,W,W,W,W,W,W,W,W,W
1160 FOR I=25 TO 1015 STEP 10
1170 ENTER 810 USING 1150 ; P(I),P(I+1),P(I+2),P(I+3),P(I+4),P(I+5),
     P(I+6),P(I+7),P(I+8),P(I+9)
1180 NEXT I @ FOR I=25 TO 1024
1190 IF P(I)>R3 THEN R3=P(I)
1200 NEXT I
1210 R3=(R3-R)*R4 @ K=0
1220 IF N#1 THEN 1360
1230 R6=0 @ FOR I=1 TO 11
1240 ENTER 810 USING "#,W" ; R5
1250 R6=R5+R6 @ NEXT I @ R6=R6/11+100
1260 FOR I=12 TO 1013 STEP 11
1270 ENTER 810 USING 1150 ; Q(1),Q(2),Q(3),Q(4),Q(5),Q(6),Q(7),Q(8),
     Q(9),Q(10),Q(11)
1280 IF K>0 THEN 1320
1290 FOR J=1 TO 11
1300 IF Q(J)>R6 THEN P(I+J-1)=200+R @ K=K+1 @ T(K)=I+J-1
1310 NEXT J
1320 NEXT I
1330 R5=R3/(10*R4)+R @ FOR I=T(1)+4 TO 1024
1340 IF P(I)>R5 THEN T(2)=I @ GOTO 1360
1350 NEXT I
1360 IF N<M THEN RETURN
1370 CONTROL 8,4 ; 12+192
1380 OUTPUT 810 USING "W" ; 228
1390 RETURN
```

Line Number	Comments
1030-1390	Data gathering routine for "BLANK"
1260-1350	Examine channel 2, point-by-point. Any that exceed 10% of full-scale (plus offset) are transferred as a 20% of full-scale signal to the channel 1 data already acquired. T(1) is the first of these. T(2) is the time when the pressure is 10% of its maximum. T(2)-T(1) is the usual definition of ignition delay time.

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16 SUMMARY OR ABSTRACT
(if this is security classified, the announcement of this report will be similarly classified)

(U) A data acquisition and processing system controlled by a Hewlett-Packard 85 desktop computer and designed for use in small calibre gun ballistic ranges is described. A digital transient recorder is interfaced to the computer using a specially developed timing control circuit. Software is written in Hewlett-Packard's extended BASIC language and full details are given to allow users to develop their own special-purpose versions.

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