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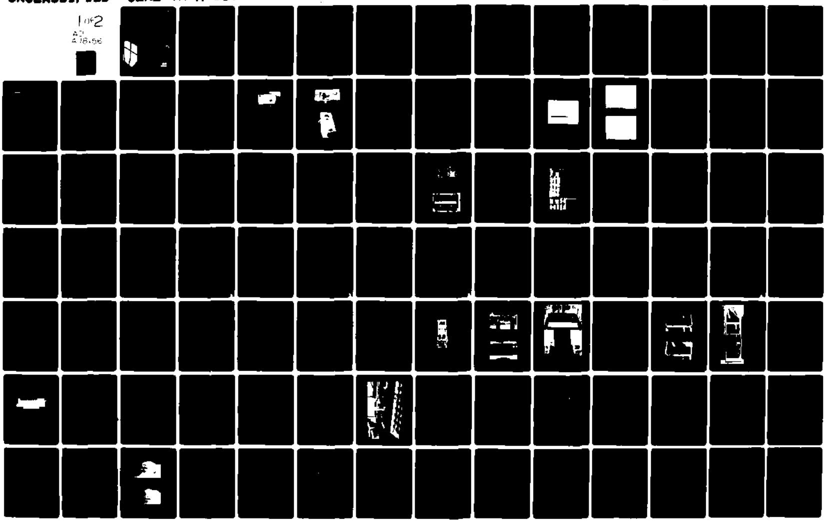

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TECHNICAL MANUSCRIPT M-317
June 1982
NDT Weld Quality Monitor/Semi-Automatic Welding

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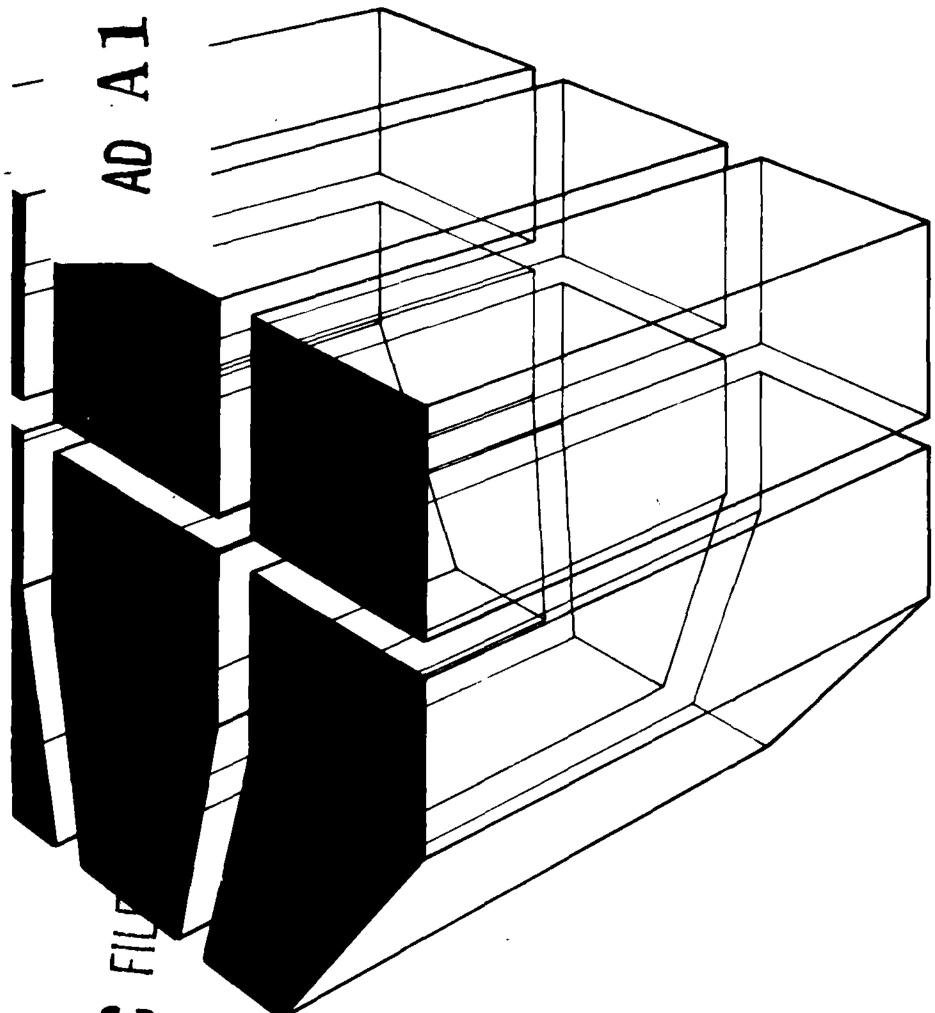
MICROPROCESSOR CONTROLLED WELD ARC SPECTRUM ANALYZER FOR QUALITY CONTROL AND ANALYSIS



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This thesis describes the components and operation of a system designed to analyze parameters associated with a weld arc. In particular, the spectrum, voltage, current, and travel speed of the weld arc are sampled by a microprocessor for analysis.

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The system is broken down into hardware and software components, which are described in detail, and an operating procedure for the system is provided. Experimental results are given which correlate changes in the weld parameters with the occurrence of defects. Changes in the voltage and current of the arc are correlated with spectral changes of the arc. A correlation between the spectral energy and weld heat input is also presented.

FOREWORD

This research was conducted in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering at the University of Illinois at Urbana-Champaign. The work was conducted at the University of Illinois, Radio Research Lab (RRL). The work was funded by the U.S. Army Construction Engineering Research Laboratory (CERL) under Project 4A762731AT41, "Military Facilities Engineering Technology," Technical Area B, "Construction Management and Technology," and Work Unit 030, "NDT Weld Quality Monitor/Semi-Automatic Welding." COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

I would like to thank Dr. C. S. Gardner for his guidance and assistance in my pursuit of a Master of Science. I would also like to thank Frank Kearney of CERL, whose advice was instrumental in completing this project and Rich Davis, a fellow graduate student, for his assistance in compiling data.

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1. INTRODUCTION

During the welding process, changes in arc voltage, travel speed, heat input and shielding gas content can cause defects which seriously decrease the service life of the welded joint. The cost of locating and repairing these defects can be a major portion of the construction costs. During the past decade, the Construction Engineering Research Laboratory (CERL) has been developing a real-time weld quality monitor to detect flaws as they occur [1] - [3]. Recent work at CERL has indicated that it may be possible to detect weld flaws using electrooptical techniques. This paper describes a microprocessor controlled spectrograph for use with the CERL weld quality monitor.

Construction Engineering Research Laboratory engineers developed a low-resolution arc spectrum analyzer [2]. Photographic filters were used to divide the arc spectrum into five bands spanning the range from 400 to 1000 nanometers. With this device it was possible to separate and quantify segments of the weld spectrum and correlate the energy distribution among these segments to specific weld parameters. The results indicate that it may be possible to classify weld flaws based upon the energy distribution in the arc spectrum.

To supplement and extend this work, a high-resolution microprocessor-controlled spectrograph was developed. A block diagram of the system is illustrated in Figure 1. The optical radiation emitted by the weld arc in the region from 300 to 1200 nanometers is collected by a fiber optic bundle. The bundle, which is designed to withstand the higher temperatures surrounding the weld arc, is terminated at the spectrograph entrance slit. The light passing through the slit is reflected by a mirror to a concave holographic

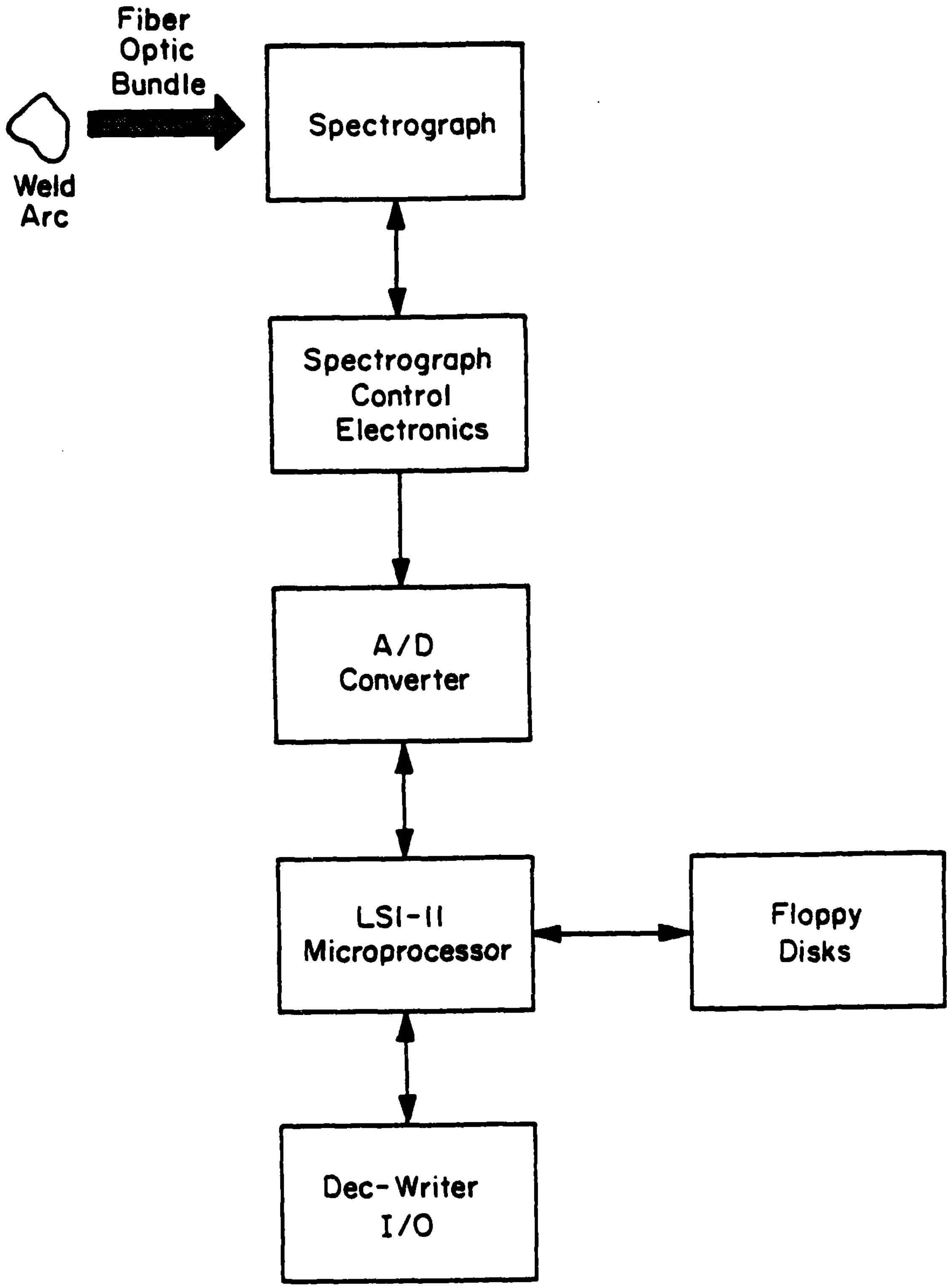


Figure 1. Block diagram of microprocessor controlled spectrograph.

grating which images the spectral range from 300 to 1200 nanometers onto a 1024 element linear photodiode array. The spectrograph resolution is on the order of 1 nanometer. The photodiode array is interfaced to a high-speed analog-to-digital converter and LSI 11/23 microprocessor. The spectral data along with measurements of the arc voltage, urrent, and travel speed can be processed or stored on floppy disks for later analysis.

With this system, important features of the weld arc can be observed in real time and correlated with weld flaws. This report describes in detail the system design and operation.

2. AN OVERVIEW OF THE WELD QUALITY MONITOR SYSTEM

The Weld Quality Monitor (WQM) is comprised of three parts: the optical and electronic hardware to measure the weld arc spectrum, the Digital Equipment Corporation (DEC) LSI-11 microcomputer for data acquisition and storage, and the software to control the WQM. The optical hardware is composed of a lens and fiber optic bundle that gathers the optical radiation from the weld and guides it to the spectrograph. The spectrograph uses a holographic grating to image the spectrum on a photodiode array that is controlled by scanning and synchronization circuitry. Data are acquired by an analog-to-digital (A/D) converter that is controlled by Direct Memory Access (DMA) electronics. The user interface, data transfer, and WQM control are maintained by either Fortran IV or the DEC machine language, Macro-11. The device initialization, synchronization, and data acquisition programs are written in Macro-11. The user interface programs that are necessary for data specification and display are written in Fortran IV.

3. THE WELD QUALITY MONITOR SYSTEM

3.1 Spectrograph and Fiber Optics

3.1.1 Fiber optic bundle

The Dolan-Jenner fiber optic bundle is a steel clad industrial cable capable of withstanding 260 degrees centigrade (500 degrees Fahrenheit) temperatures (see Figure 2). It has an acceptance cone of 68 degrees and a numerical aperture of 0.55. Figure 3 [4] shows the transmittance curve for different lengths of cable. It is easily seen that the ultraviolet and middle infrared regions are severely attenuated. Fortunately, due to the high intensity of radiation emitted from the weld arc, signal strength can compensate for some of the losses.

3.1.2 Spectrograph

The spectrographs shown in Figures 4a and 4b have three different slit widths of 50, 100, and 250 μm. Light passes from the fiber bundle through the slit and strikes an ISA holographic grating. Either a 200-1200 nm or 200-800 nm range grating may be used. Using these slit widths and gratings produces the variation in resolution shown in Table 1. These are somewhat idealized results in that they neglect spillover into other diodes, parallax in alignment, and defocusing errors. Actual resolution may be as much as one nanometer worse than the values given.

TABLE 1

RESOLUTION OF SPECTROGRAPH

Grating \ Slit Widths	50 μm	100 μm	250 μm
200-1200 nm	1.95 nm	3.91 nm	9.76 nm
400-900 nm	1.17 nm	2.34 nm	5.86 nm

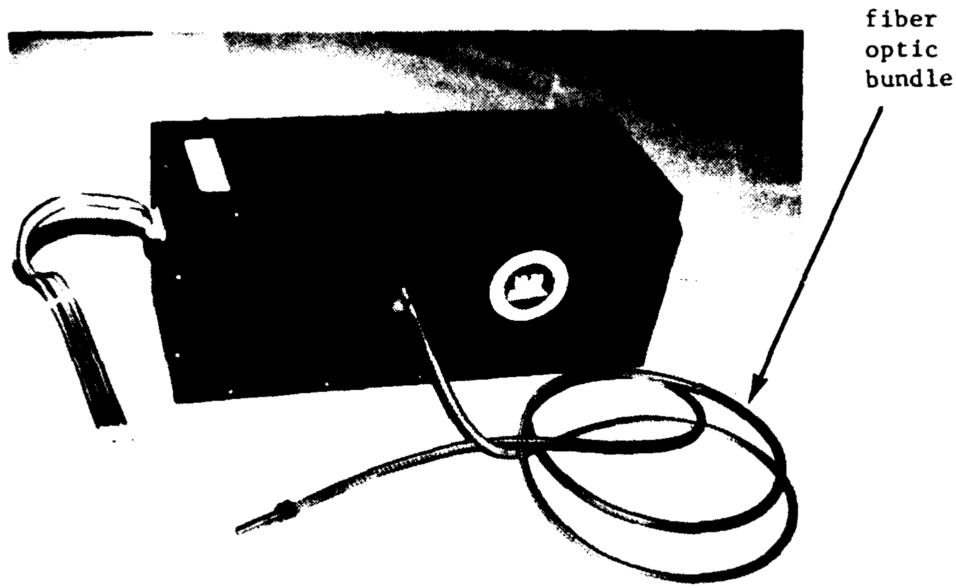


Figure 2. Fiber optic bundle to spectrograph.

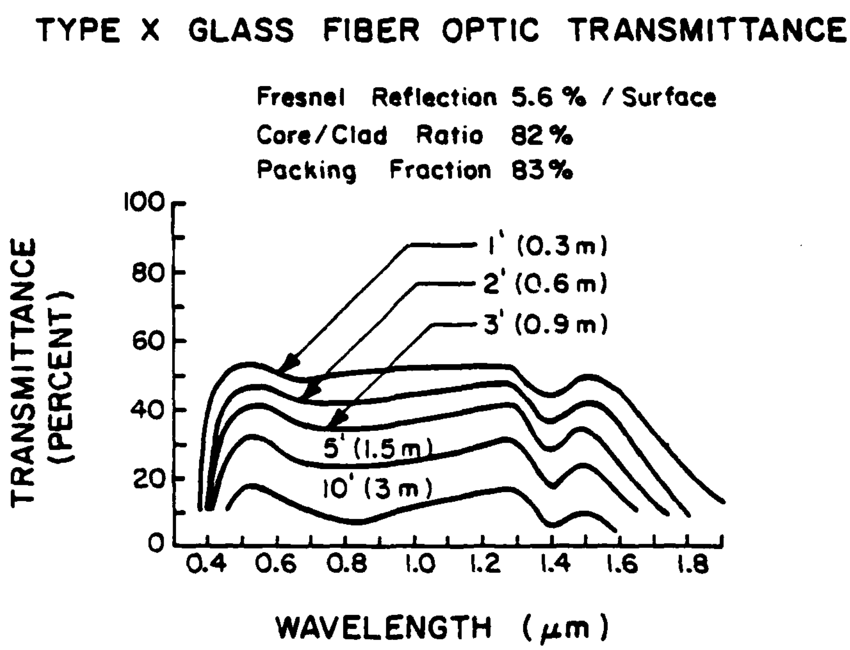


Figure 3. Transmittance curve for fiber bundle.

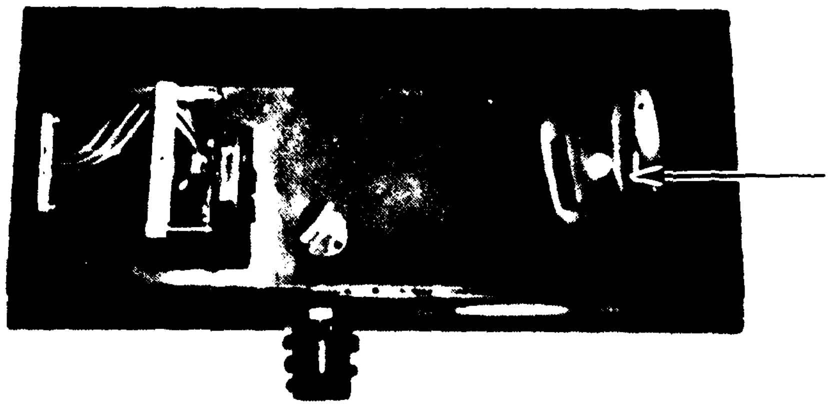


Figure 4a. Spectrograph (top view).

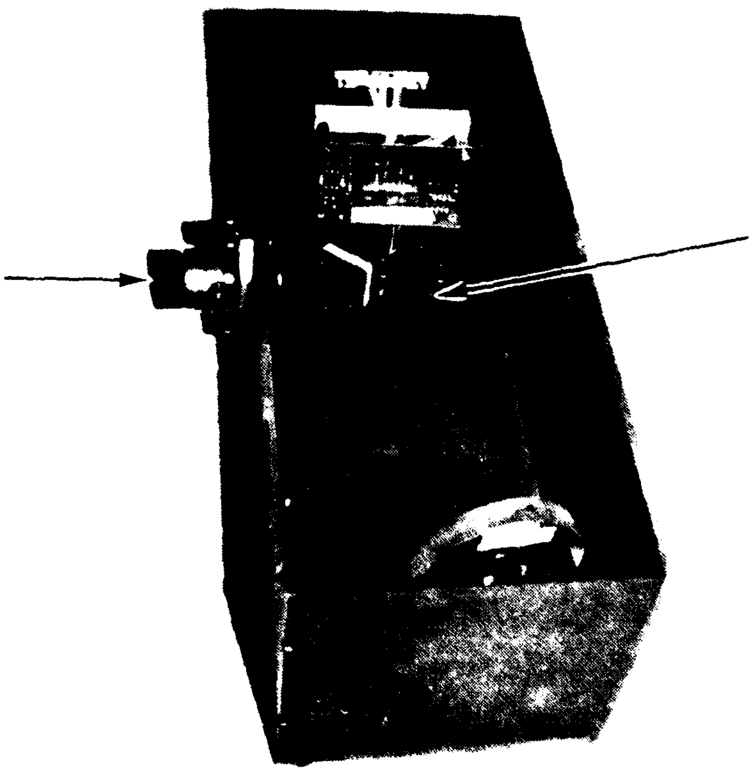


Figure 4b. Spectrograph.

3.2 Photodiode Array and Electronics

The optical sensor consists of a 1.008-inch linear array of 1024 silicon photodiodes, 15 μm high, and 25 μm spacing. These dimensions are illustrated in Figure 5. Spectral responsivity, governed by the quartz window covering the array, the aperture response, and the quantum nature of the diodes themselves, decreases to about 20% at 250 and 1000 nm (see Figure 6).

Each diode has a storage capacitor for integration of the photo current. The charge on the storage capacitor is gradually removed by the reverse current generated by the photodiodes. Each capacitor is sequentially sampled by multiplex switches turned on and off by a shift register driven by a two-phase clock. At the end of each sample, the capacitor is recharged to +5 V. The clock sequence is initiated by a start pulse (see Figure 7).

The support electronics consist of sample and hold circuitry. The video line is set to ground prior to each diode sample. When a multiplex switch is closed, charge is divided between the photodiodes and the video line. This line is sampled and held, giving the display shown in Figure 8. The start pulse and clock (see Figure 9) are set by the user. Further details on this and other aspects of the array are contained in Appendix A.

Figures 10 and 11 show the oscilloscope displays of the spectral output of the electronics box in response to a Helium-Neon laser. Figure 10 shows the spectrum from 200 to 1200 nm. The wavelength of the radiation from a Helium-Neon laser is 632.8 nm. The display in Figure 10 verifies this. Figure 11 is an expanded display of the spectral line of the Helium-Neon laser. It shows that approximately three diodes are illuminated by the laser radiation. This corresponds to about 3 nm, which is as might be expected using the 50-micrometer slit on the spectrograph.

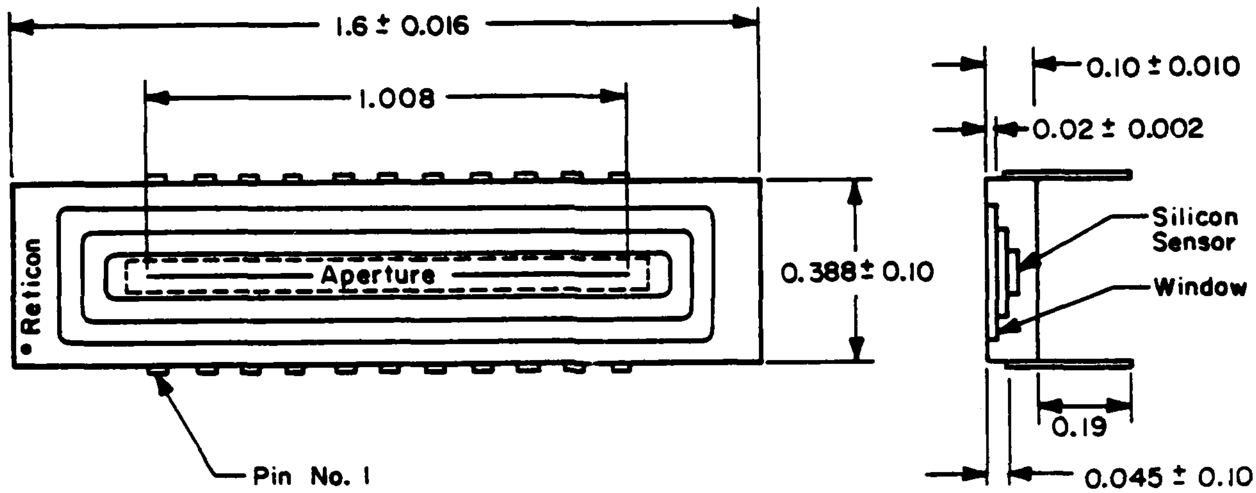
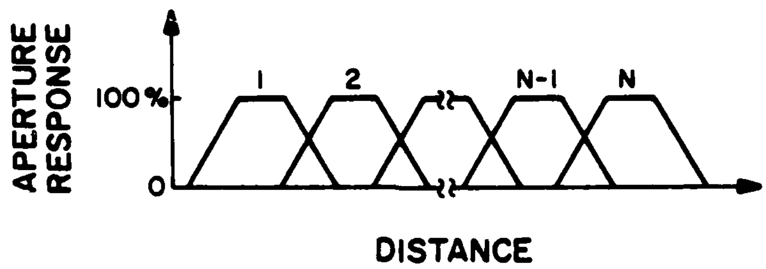


Figure 5. Photodiode array.



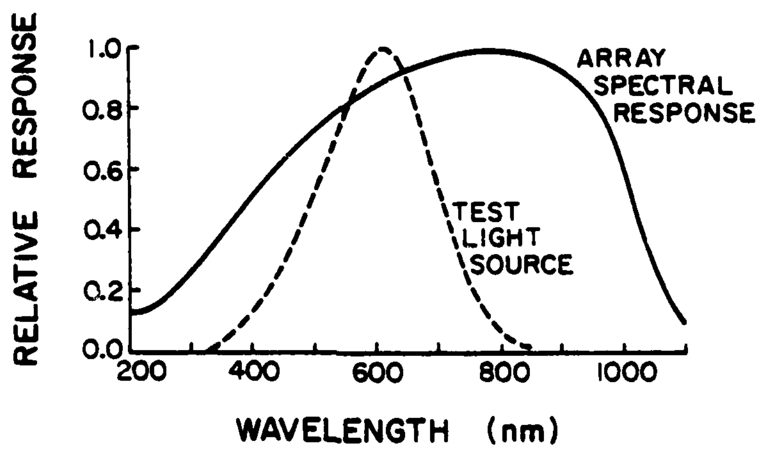


Figure 6. Optical response of photodiode array.

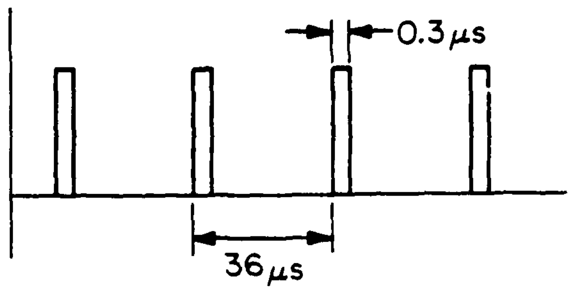


Figure 7. Start pulses.

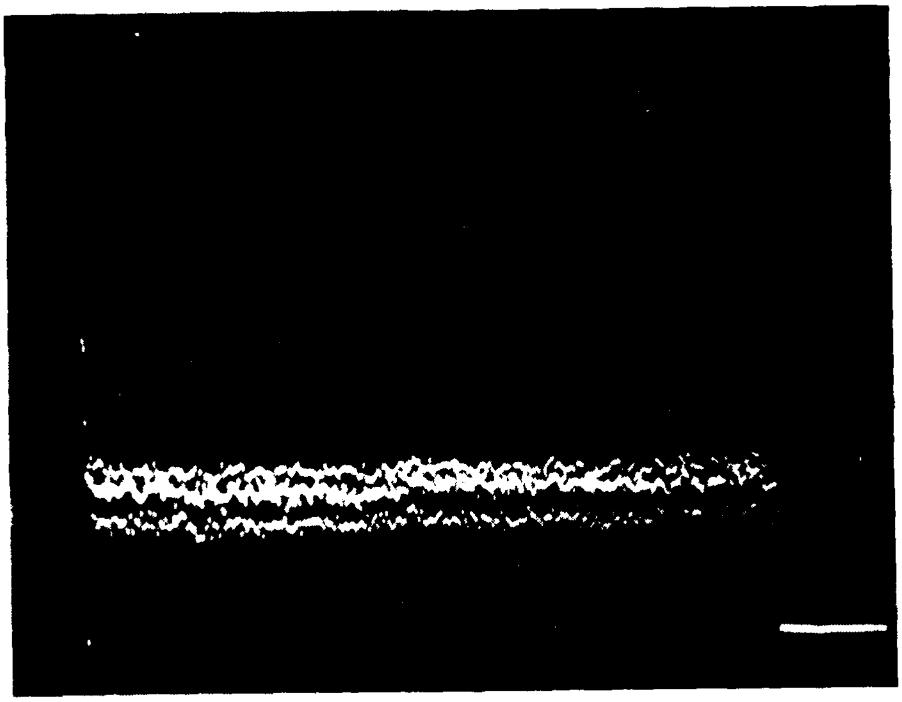


Figure 8. Video output.

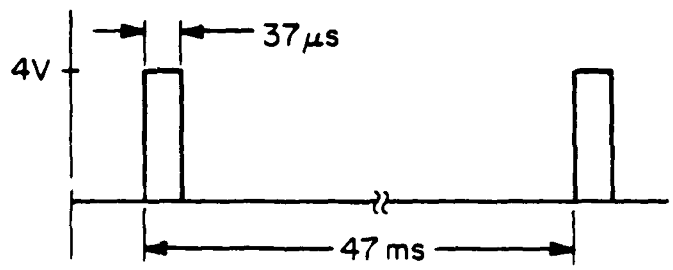


Figure 9. Clock pulses.

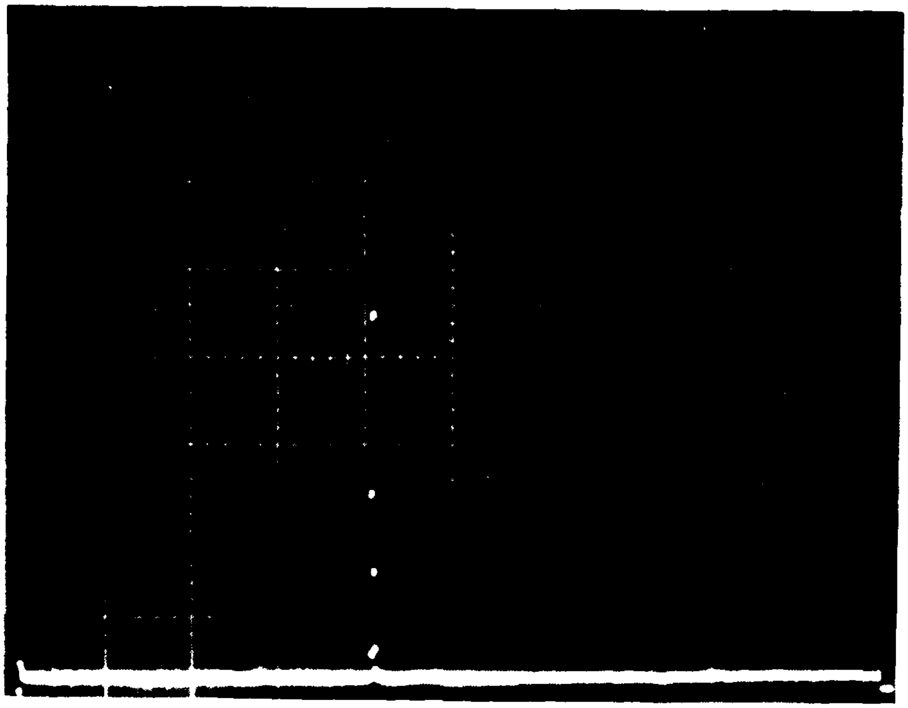


Figure 10. Spectrum with Helium-Neon laser.

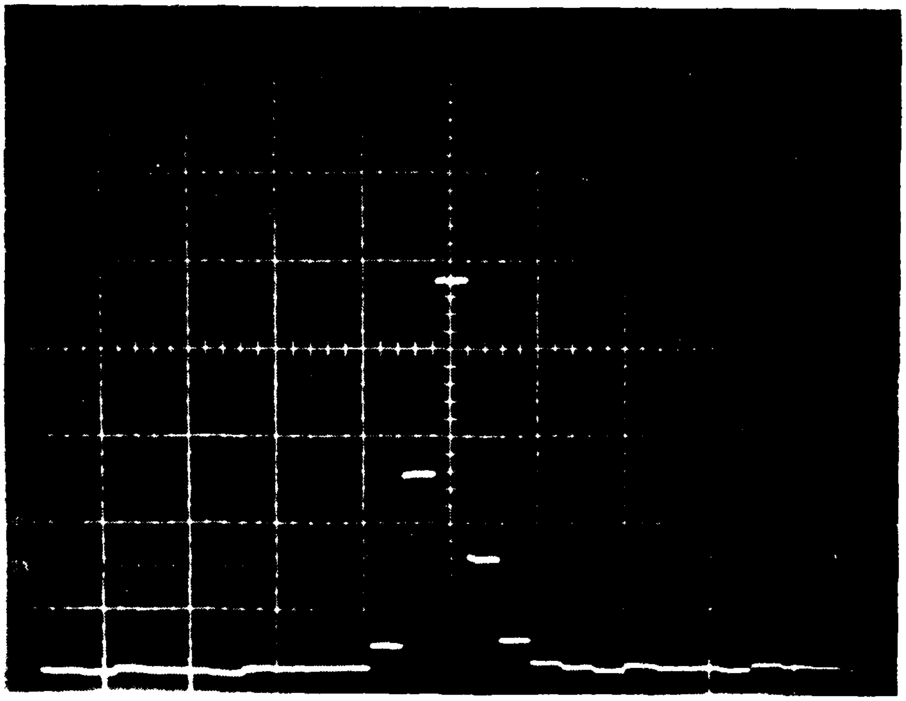


Figure 11. Expansion of spectra showing individual diode levels.

The scanning electronics for the diode array run continuously. Thus, in order for the A/D to sample the diode levels accurately, synchronization circuitry must be provided, which is illustrated in Figure 12. The start pulse used to initiate the video scan sets a D flip flop. The D flip flop in turn opens a gate that allows the same clock pulses to be used by the A/D as an external enable. Thus the A/D is triggered synchronously with the video line out. The DMA has a word counter that is preset to 1024 so that sampling is terminated after all 1024 photodiodes are sampled. Figure 13 gives a timing diagram of the sequence of events.

3.3 LSI-11 Hardware Description

3.3.1 11/23 Central Processing Unit (CPU) description

The Digital Equipment Corporation (DEC) LSI 11/23 is a 16-bit word or 8-bit byte-oriented microprocessor. It is capable of executing over 400 machine language instructions. With the proper system software, it is further capable of handling Fortran, Pascal, APL, and Basic. The machine language utilized (Macro-11) is a stack-oriented language with eight general-purpose registers. Without extended software this language will directly access 64K words of memory. The lower 376 locations are reserved for interrupt vectors and traps. The top 8K works are reserved for peripheral device addressing. Further details on both the hardware and software associated with the 11/23 can be found in the DEC Microcomputer Processor Handbook [4].

3.3.2 Input/output description

3.3.2.1 Serial interface description. The serial interface for the LSI 11/23 is a DEC DLV11-J. It has four independent full duplex asynchronous channels capable of 150 to 9600 baud. Table 2 [5] indicates the jumper

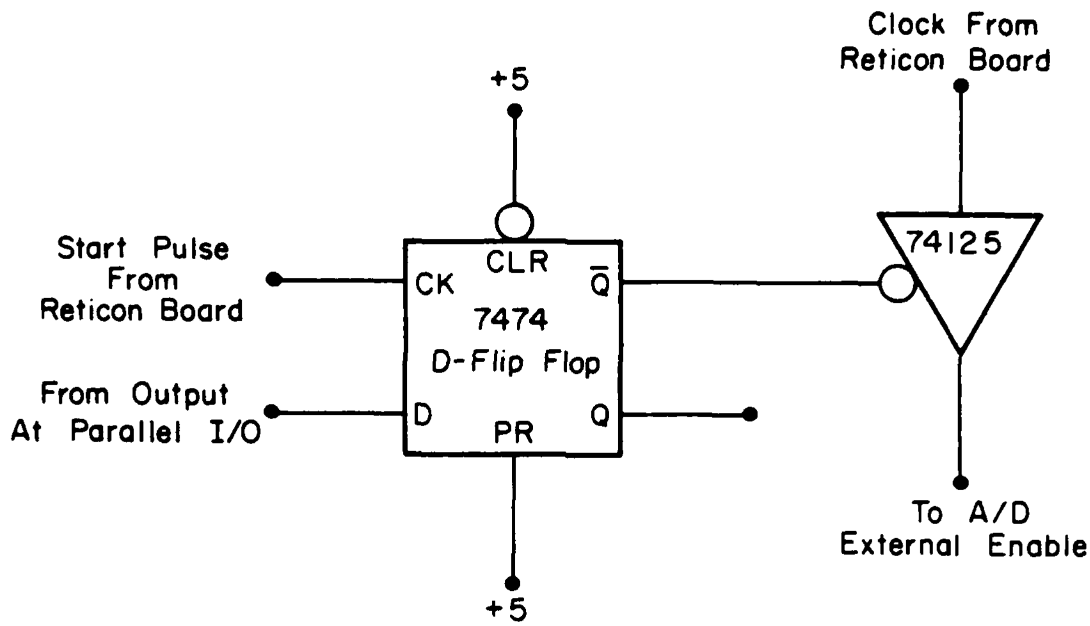


Figure 12. Synchronization circuitry.

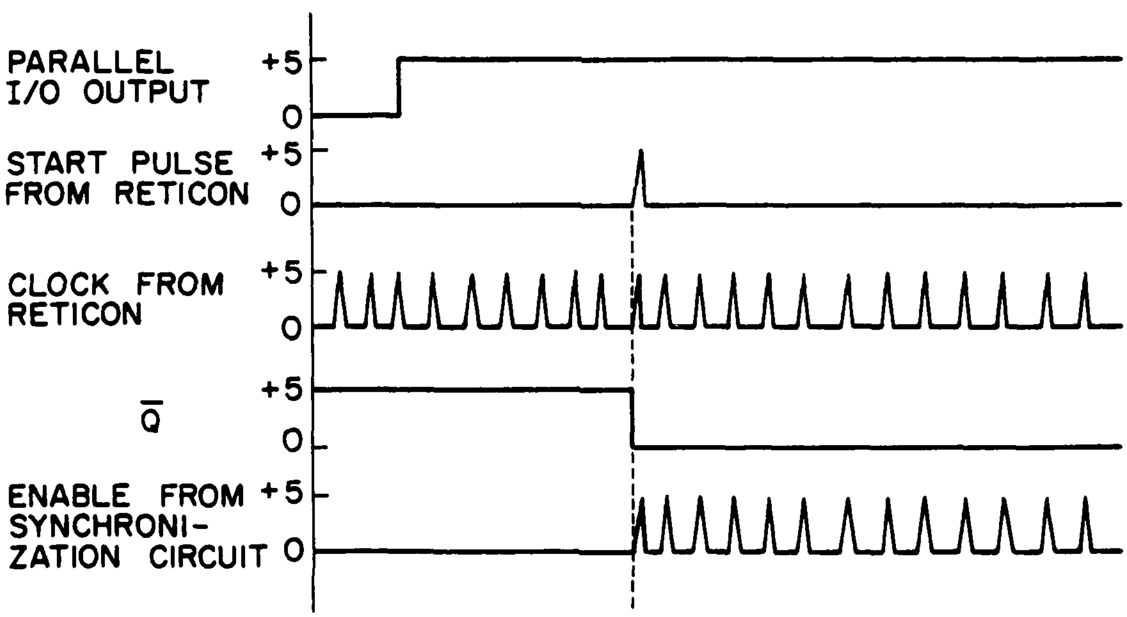


Figure 13. Timing diagram for synchronization.

TABLE 2

BAUD RATE JUMPERS [5]

Wire-Wrap Pin Label	Baud Rate (Bits/Second)
U	150
T	300
V	600
W	1,200
Y	2,400
L	4,800
N	9,600
K	19,200
Z	38,400

When using the DLV11-KA option, 110 bits/sec operation is possible. A 110 baud rate clock generator circuit on the option will supply the DLV11-J module with the proper clock; no baud rate jumper is configured on the module for the desired channel.

selections made on the DLV11-J to select the desired baud rate. Figure 14 [6] shows the location of the jumpers on the board.

Each channel is composed of a receiver control status register (RCSR), receiver buffer (RBUF), transmitter control status register (XCSR), and transmitter buffer (XBUF). The factory jumpered addresses for these channels are shown in Table 3 [6]. Further information on the DEC DLV11-J can be obtained in the DEC Microcomputer Interfaces Handbook, pp. 221-249 [6].

3.3.2.2 Parallel interface description. The parallel interface is an MDB MLSI-DRV11-C. It has sixteen TTL and DTL logic compatible input and output lines with four control lines for a peripheral device: NEW DATA READ, DATA TRANSMITTED, REQUEST A, and REQUEST B. Tables 4 [7] and 5 show the interface pin assignments and the addressing structure, respectively. Device address locations can be changed by utilizing the jumper selections shown in Table 6 [7]. Table 7 [7] shows the jumpers for selection of Interrupt Vectors. Figure 15 [7] shows the location of the jumpers on the module.

The Control Status Register (CSR) is a 16-bit word that is used to control the parallel I/O board. The bits in the CSR have the following functions:

BIT	NAME	DESCRIPTION
15	REQUEST B	A read only bit that is cleared by system initialization. This bit is set by a peripheral device and may be used as a flag for device status. It may also be used as an interrupt request if bit 5 is also set.
14-8	Unused	
7	REQUEST A	It has the same function as REQUEST B except the interrupt is generated only if bit 6 is set.

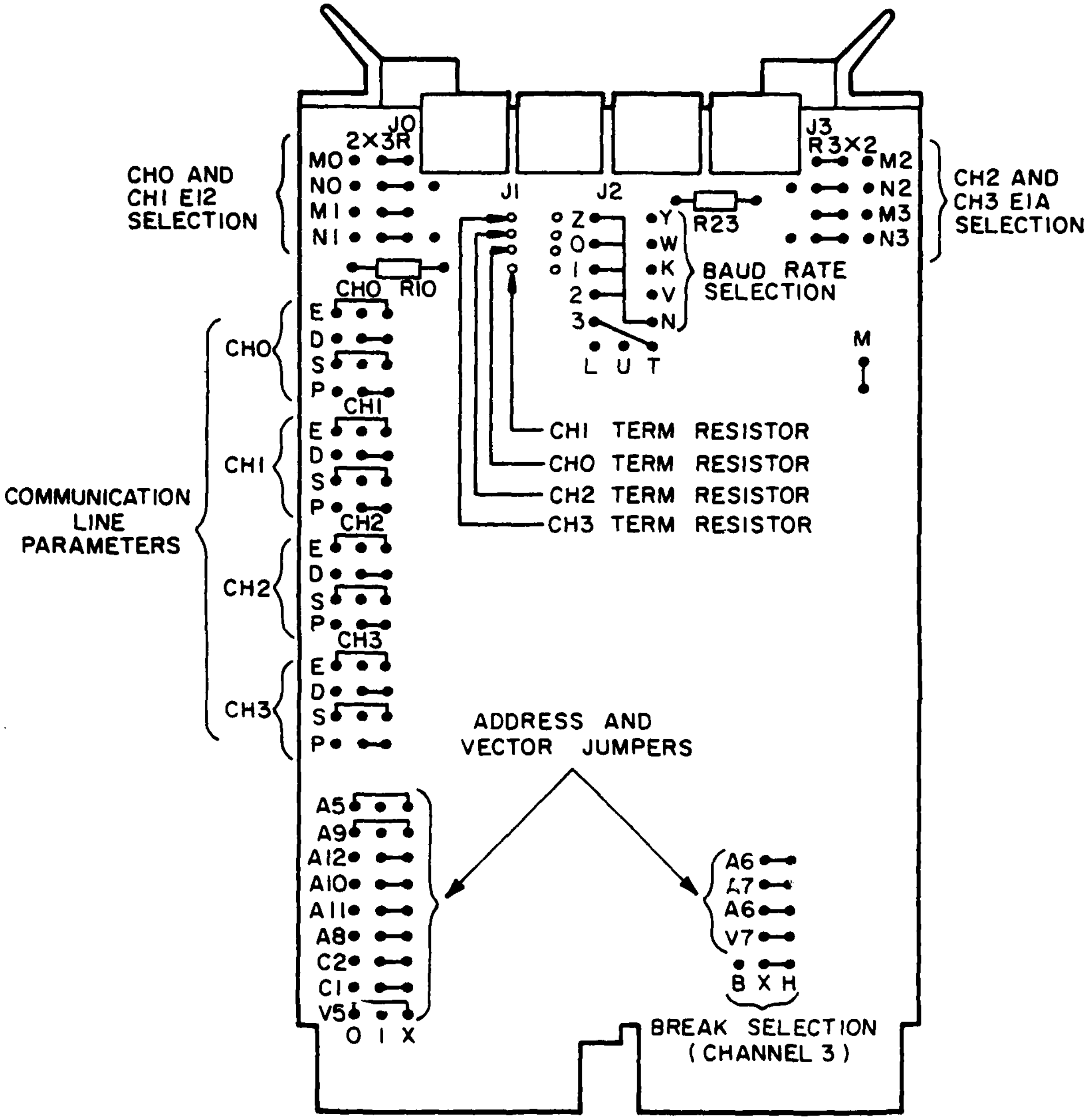


Figure 14. Jumper locations on serial I/O board [6].

TABLE 3

CHANNEL ADDRESSES FOR SERIAL I/O BOARD [6]

Address	Register	Vector	
176500	RCSR		
176502	RBUF	300	
176504	XCSR		Channel 0
176506	XBUF	304	
176510	RCSR		
176512	RBUF	310	
176514	XCSR		Channel 1
176516	XBUF	314	
176520	RCSR		
176522	RBUF	320	
176524	XCSR		Channel 2
176526	XBUF	324	
177560	RCSR		
177562	RBUF	60	
177564	XCSR		Channel 3
177566	XBUF	64	

TABLE 4

INTERFACE PIN ASSIGNMENTS FOR PARALLEL I/O BOARD [7]

J1		J2	
Signal	**Pin**	**Signal**	**Pin**
OUT00	C	IN00	TT
OUT01	K	IN01	LL
OUT02	NN, RR	IN02	H, E
OUT03	u	IN03	BB
OUT04	L	IN04	KK
OUT05	N	IN05	HH
OUT06	R	IN06	EE
OUT07	T	IN07	CC
OUT08	W	IN08	Z
OUT09	X	IN09	Y
OUT10	Z	IN10	W
OUT11	AA	IN11	V
OUT12	BB	IN12	u
OUT13	FF	IN13	P
OUT14	HH	IN14	N
OUT15	JJ	IN15	M
INIT	P	INIT	RR, NN
NEW DATA READY	VV	DATA TRANSMITTED	C
CSR1	DD	CSRO	K
REQUEST A	LL	REQUEST B	S
GND	J, M, S, V, CC, FF, KK, MM, PP, SS, UU	GND	J, L, R, T, X, AA, DD, JJ, MM, PP, SS, UU

TABLE 5

ADDRESSING STRUCTURE FOR PARALLEL I/O BOARD

Address Name	Mnemonic	Address
Control Status Register	CSR	167770
Output Buffer	OUTBUF	167772
Input Buffer	INBUF	167774

TABLE 6

DEVICE ADDRESS JUMPERS FOR PARALLEL I/O BOARD [7]

Address Bit	Jumper Location	Connect for "1"	Connect for "0"
12	4	K-J	H-J
11	5	N-M	L-M
10	5	H-J	K-J
09	3	N-M	L-M
08	2	L-M	N-M
07	1	H-J	K-J
06	4	L-M	N-M
05	3	K-J	H-J
04	2	H-J	K-J
03	1	L-M	N-M
02	Bits 00, 01, and 02 are hardwired and program-controlled.		
01			
00			

TABLE 7

INTERRUPT VECTOR ADDRESS JUMPERS FOR PARALLEL I/O BOARD [7]

Address Bit	Jumper Location	Connect for "0"	Omit for "1"
07	6	H-J	H-J
06	8	H-J	H-J
05	9	H-J	H-J
04	10	H-J	H-J
03	7	H-J	H-J
02	none	hardwired	

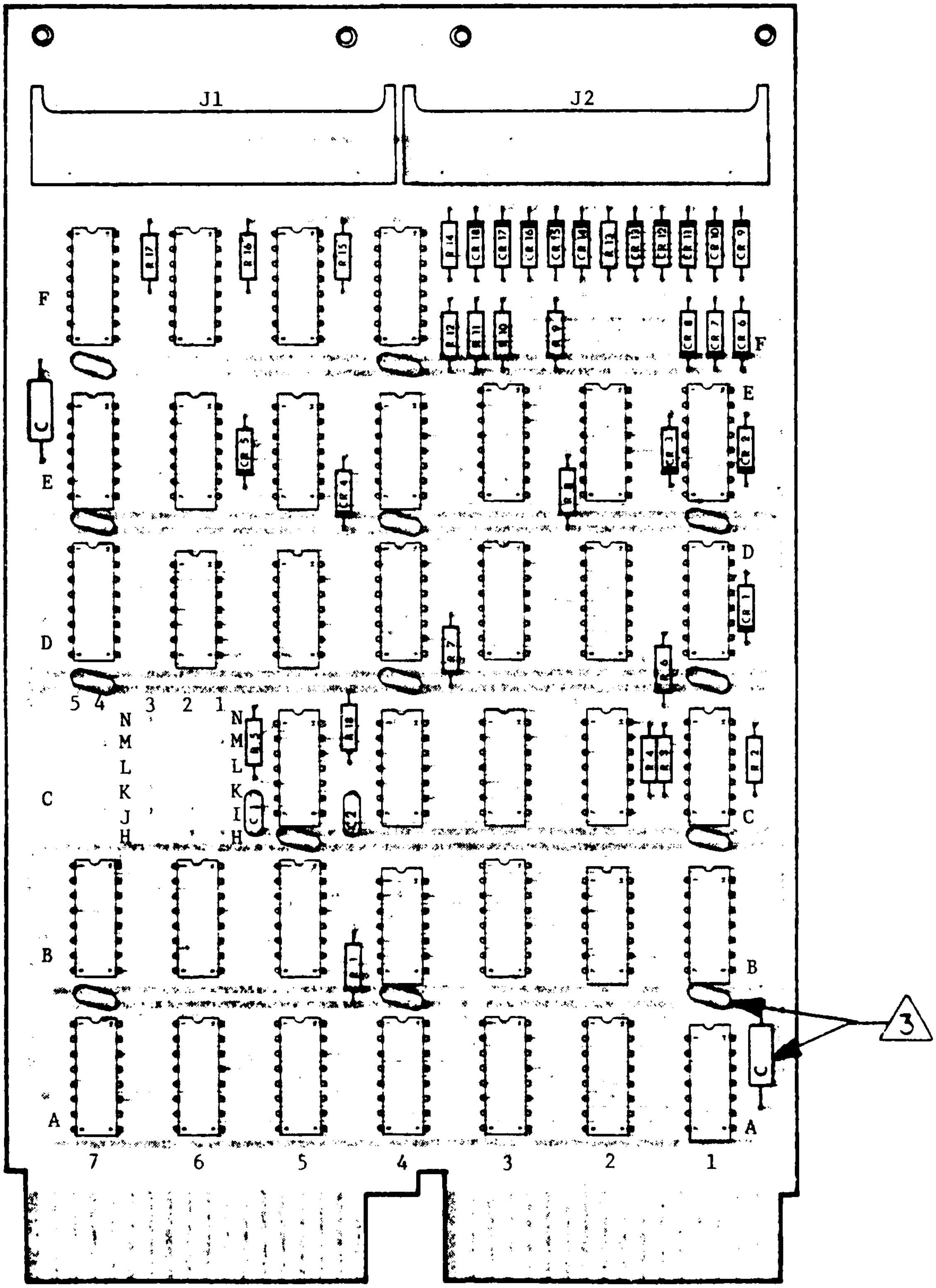


Figure 15. Jumper locations on DRV11-C [7].

BIT	NAME	DESCRIPTION
6	ENTENBA	A read/write bit cleared by system initialization. When set, it will enable an interrupt to occur upon the setting of bit 7.
5	INTENBB	It has the same function as bit 6 except it applies to bit 15. Cleared by system initialization.
4-2	Unused	
1	CSR 1	A read/write bit cleared by system initialization. It can be used to flag a device.
0	CSR 0	Same as bit 1.

More information can be obtained from the MDB MLSI-DRV11C Parallel Line Interface Module Instruction Manual [6].

The DRV11C is used to synchronize the A/D converter with the video line from the Reticon scanning electronics. By moving a 1 into the output buffer, pin C is set on the output cable. This line is then tied to the input of a D flip flop that opens a gate at the occurrence of a start signal from the array scanning electronics that initiate scanning. When the gate opens, it allows the video clock signal to trigger the A/D converter.

3.3.3 Floppy disk description

The floppy disk control module is a DEC RXV21 (see Figure 16) board that controls a dual density RX02 floppy disk drive (see Figure 17). Each floppy disk is capable of storing 512,512 eight-bit bytes per diskette. The average access time (composed of seek, settle, and rotate time) is 262 msec. Additional details on the operation of the RXV21 with the RX02 drive can be found in the DEC Microcomputer Interfaces Handbook, pp. 608-628 [6].

Floppy disk files can be accessed for reading or writing either manually or under program control. The system provides two methods for user interactive editing of disk files. The RT-11 editor provides a simple but

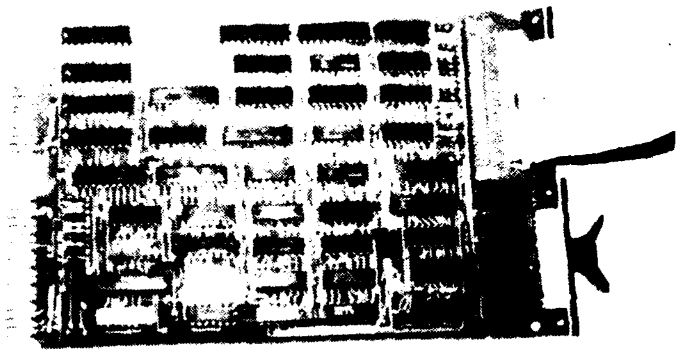


Figure 16. RXV21 floppy disk board.

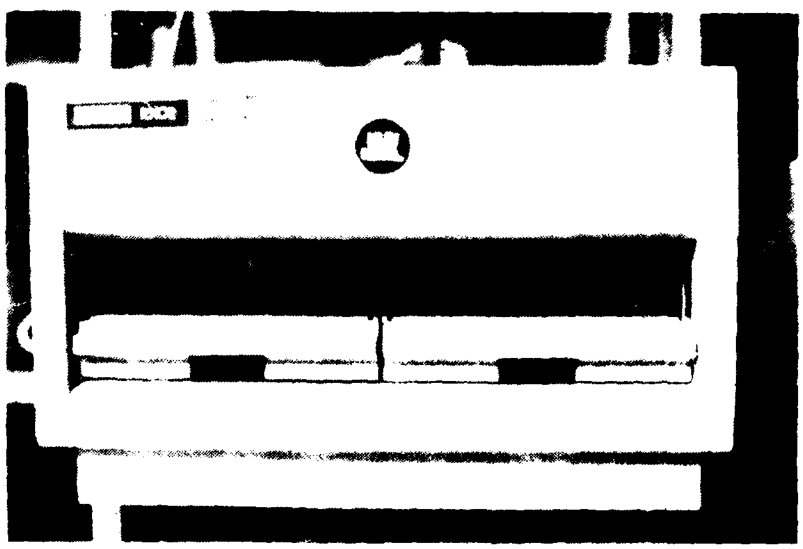


Figure 17. RX02 floppy disk drive.

unsophisticated means for editing disk files. An easy-to-read, step-by-step introduction is provided in volume 1B, "Introduction to RT-11," Chapter 5, "Creating and Editing Text Files," of the RT-11 Operator Manuals [8]. A more sophisticated method of editing files is provided by using TECO (Text Editor and Corrector). Unlike the RT-11 editor, TECO is character-oriented rather than line. Thus, it provides the user with better scanning software. A complete guide to TECO is provided in the "TECO Users Guide," volume 2 of the RT-11 Operator Manuals [8].

There are three other methods of writing and reading files on floppy disks. The crudest of these three is done using macros. It has, however, the advantage of using less space for program storage and of being faster. Chapter 2 of the "Advanced Programmer's Guide," volume 3 of the RT-11 Operator Manuals [8], describes the program requests available. The other two methods are accessed as RT-11 Fortran subroutines. Unfortunately, in order to understand the subroutine available, a good understanding of the macro program request is essential. The Fortran system subroutine library contains the necessary routines needed to allocate channels, name devices, etc. A combination of all these subroutines is contained in two subroutines called OPEN and ASSIGN. They are very sophisticated and require a good understanding of the Fortran system subroutines from which they are built. A description of these two commands can be found in Appendix B of the "Fortran User's Guide," volume 4 of the RT-11 Operator Manuals [8].

3.3.4 Analog to digital converter

The A/D converter is an ADAC Model 1012 (see Figure 18) [9]. It has 16 single-ended, pseudo difference, or differential inputs. Each line has programmable gain, 100 KHz throughput (10 microsecond settling and conversion

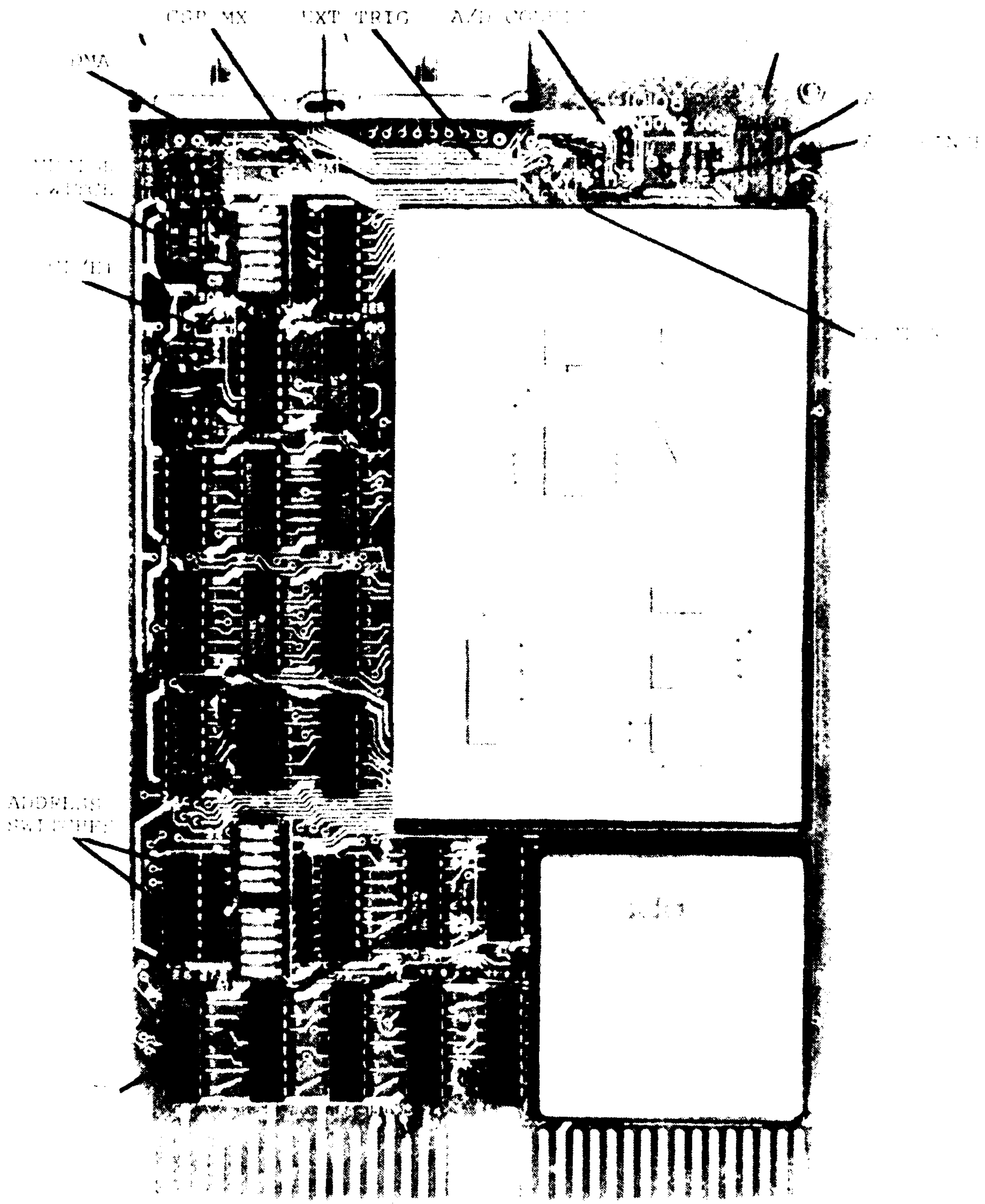


Figure 18. Jumper and adjustment locations on A/D [9].

time), and 12-bit resolution. Nine optional hard jumpered features on the A/D are the input range, type of input configuration, trigger, status register, external enable, vector, external trigger, DMA, and external power. All of these jumpered options are discussed in the ADAC Instruction Manuals, pp. 27-28 [9]. Presently, the board is configured for a -10 to +10 voltage input range, single-ended input, external triggering, bit 1 as the external enable in the CSR, DMA control disabled (so triggering is done externally), and no external power.

Switch jumpers are provided for selection of the control status register and vector interrupt location. These switches are set up as illustrated in Figure 19 with an off setting as a one and an on setting as a zero. The current control status register and vector address are 177000 and 130, respectively.

Input and output are done over a 20 conductor shielded ribbon cable. Pin assignments for the ribbon cable's connector are given in Figure 20. Currently, channel 0 is used for the video signal, channel 1 for the voltage, channel 2 for the current, and channel 3 for the travel speed. The external trigger is supplied by the synchronization circuitry and Reticon electronics. Further details on cabling can be found in the ADAC Instruction Manuals, pp. 14-15 [9].

Control of the A/D is maintained through the status register. It is set up as follows:

ADDRESS SWITCHES

S1

1	ON	D7
2	ON	D6
3	ON	D5
4	ON	D4
5	ON	D3

S2

1	OFF	D12
2	OFF	D11
3	OFF	D10
4	OFF	D9
5	ON	D8

VECTOR SWITCH

S3

1	ON	D7
2	OFF	D6
3	ON	D5
4	OFF	D4
5	OFF	D3
6	ON	D2

Figure 19. Jumper switches for addressing for 1012 A/D.

CANON PIN NUMBER	3M PIN NUMBER		CANON PIN NUMBER	3M PIN NUMBER	
1	1	CH0-0A IN	20	2	CH8-0B IN
2	3	CH1-1A	19	4	CH9-1B
3	5	CH2-2A	18	6	CH10-2B
4	7	CH3-3A	17	8	CH11-3B
5	9	CH4-4A	16	10	CH12-4B
6	11	CH5-5A	15	12	CH13-5B
7	13	CH6-6A	14	14	CH14-6B
8	15	CH7-7A	13	16	CH15-7B
9	17	EXT TRIG IN	12	19	POWER RETURN
10	19	AMP LO IN	11	20	SIGNAL RETURN

Figure 20. Pin assignments for I/O on ADAC 1012 A/D.

BIT	DESCRIPTION
D15	ERROR (Read Only). Set if a conversion is started before a previous conversion is completed or before data are removed from the data buffer.
D14	ERROR INTERRUPT ENABLE (Read/Write). When set, allows an interrupt at selected vector upon setting of D15.
D13, D12	Unused.
D11-D8	MUX CHANNEL (Read/Write). 4-bit channel number corresponding to the channel to be converted.
D7	DONE (Read Only). Set at end of conversion. Cleared by system initialization or reading of data buffer.
D6	DONE INTERRUPT ENABLE (Read/Write). When set, allows DONE to generate an interrupt at chosen vector.
D5	OPTIONAL ENABLE (Read/Write). Optional external enable.
D4, D3	PROGRAMMABLE GAIN (Read/Write). Two-bit gain code.

Gain Code	Gain
0	8
1	4
2	2
3	1

BIT	DESCRIPTION
D2	SEQUENTIAL ENABLE (Read/Write). Will allow the mux channel register to be incremented after a conversion for each channel.
D1	EXTERNAL ENABLE (Read/Write). Allows an external signal to start a conversion.
D0	START CONVERSION (WRITE ONLY). Starts a conversion.

Thus, a simple move instruction can be used to initialize the A/D board. The data buffer for the A/D is located 2 bytes after the CSR or at 177002 in this case. It is a read-only register.

Appendix B provides complete schematics for the ADAC 1012 and a calibration procedure. Complete details on the board can be found in the ADAC Instruction Manuals, pp. 9-41 [9].

3.3.5 Direct Memory Access description

The ADAC Model 1620 Direct Memory Access (DMA) is a DEC compatible board that provides a means of transferring digitized data directly from the ADAC A/D to memory, without CPU intervention. It has an 18-bit memory address counter, a 6-bit final channel register and comparator, a 16-bit word counter, and interrupt enable capability. The DMA is composed of four registers which are described as follows (addressing is described in Table 8):

1) Bus Address Register (BAR): an 18-bit read/write register that is loaded under program control. The BAR is incremented by two after each DMA transfer. This address is used to specify the address in memory to which the data are to be moved. It is word addressable only.

2) Word Count Register (WC): a 16-bit read/write register that contains the 2's complement of the total number of cycles to be completed before DMA termination. It is also loaded under program control. WC is incremented after each DMA transfer, and upon overflow, resets READY FF in the Control Status Register and causes an interrupt request. It is word addressable only.

3) Multiplex Comparator Register (MCR): a six-bit write only register that is loaded under program control. It is used for last channel addressing when used in conjunction with the 1012 A/D. It is word addressable only.

4) Control and Status Register: a 16-bit register that is used to control the DMA. It is broken down as follows:

TABLE 8

ADDRESSING STRUCTURE OF DMA

Register Name	Mnemonics	Address
Word Count Register	WC	172410
Bus Address Register	BAR	172412
Control and Status Register	CSR	172414
Multiple Comparator Register	MCR	172416

BIT	DESCRIPTION
D15	ERRORS (Read Only). Set by addressing nonexistent memory or by grounding of external ATTN line. Cleared by system initialization, the clearing of D14, or clearing ATTN line.
D14	NEX (Read/Write). Nonexistent memory (NEX) is set by addressing nonexistent memory.
D13	ATTN (Read Only). Indicates status of ATTN line.
D12-8	Not used.
D7	READY (Read Only): Indicates DMA is ready to start a new set of data transfers. Set by system initialization, word count overflow, and clearing of ERROR (D15).
D6	INTERRUPT ENABLE (Read/Write). Enables interrupts when READY (D7) is set. Cleared by system initialization.
D5, D6	Extended Address Bits-17,16 (Read/Write).
D1-3	Not used
D0	GO (Write). Starts DMA operation. Forces READY (D7) to go low.

Complete schematics for the ADAC 1620 DMA are given in Appendix C. Further documentation for the DMA can be found in the ADAC Instruction Manuals, pp. 42-50 [9].

3.4 LSI-11 Software Description for the WQM

3.4.1 Fortran program

The Fortran program, AQSPEC (see Appendix E), is an operator interface that leads the Weld Quality Monitor operator through a sequence of questions to qualify and quantify the nature of the data desired. It also allows the operator the opportunity to examine acquired data. A flowchart of the program and a flowchart of the program as the user sees it are given in Figures 21 and 22, respectively. The user is queried whether a single or average set of scans is to be taken. If a single scan is desired for

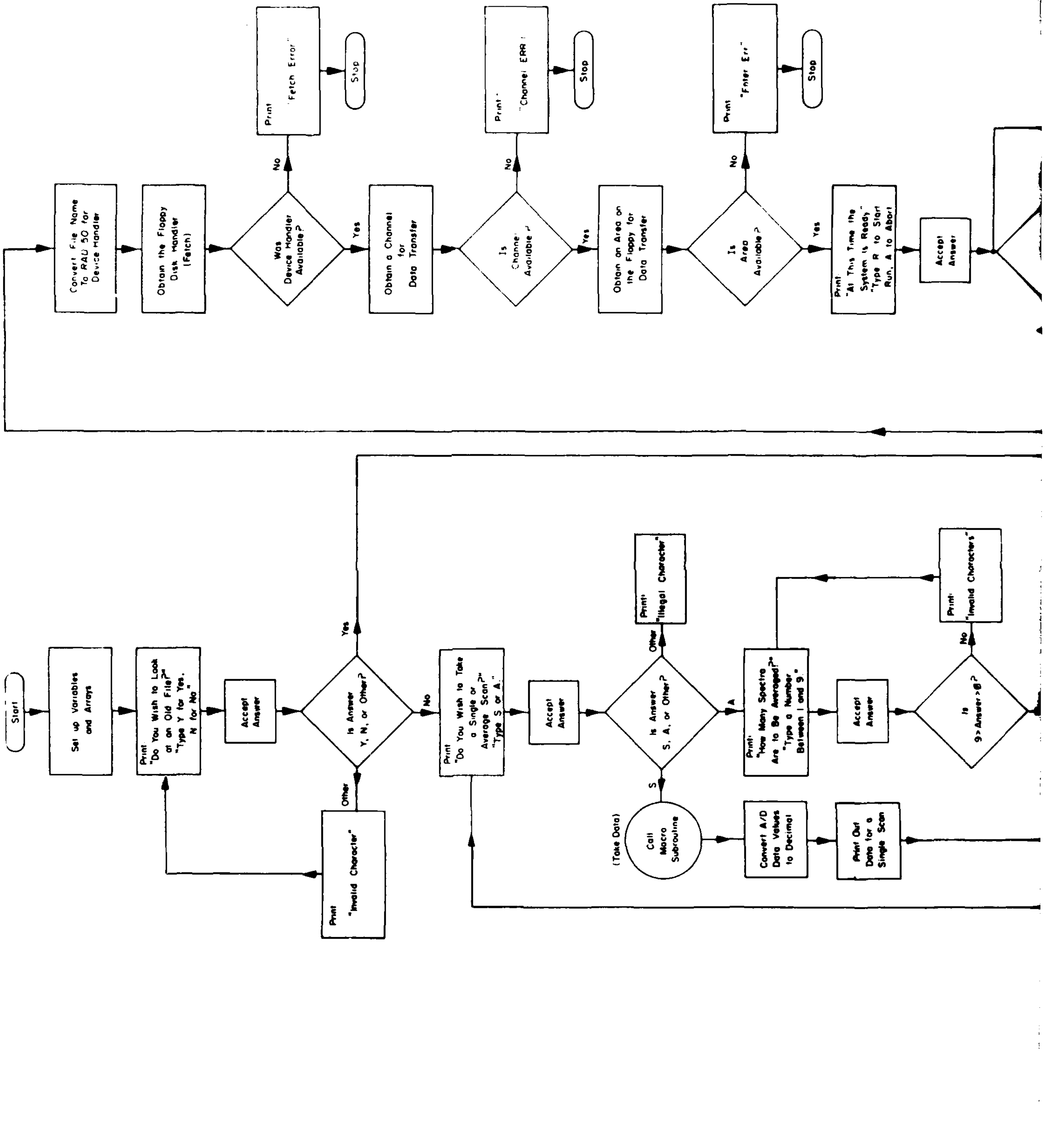
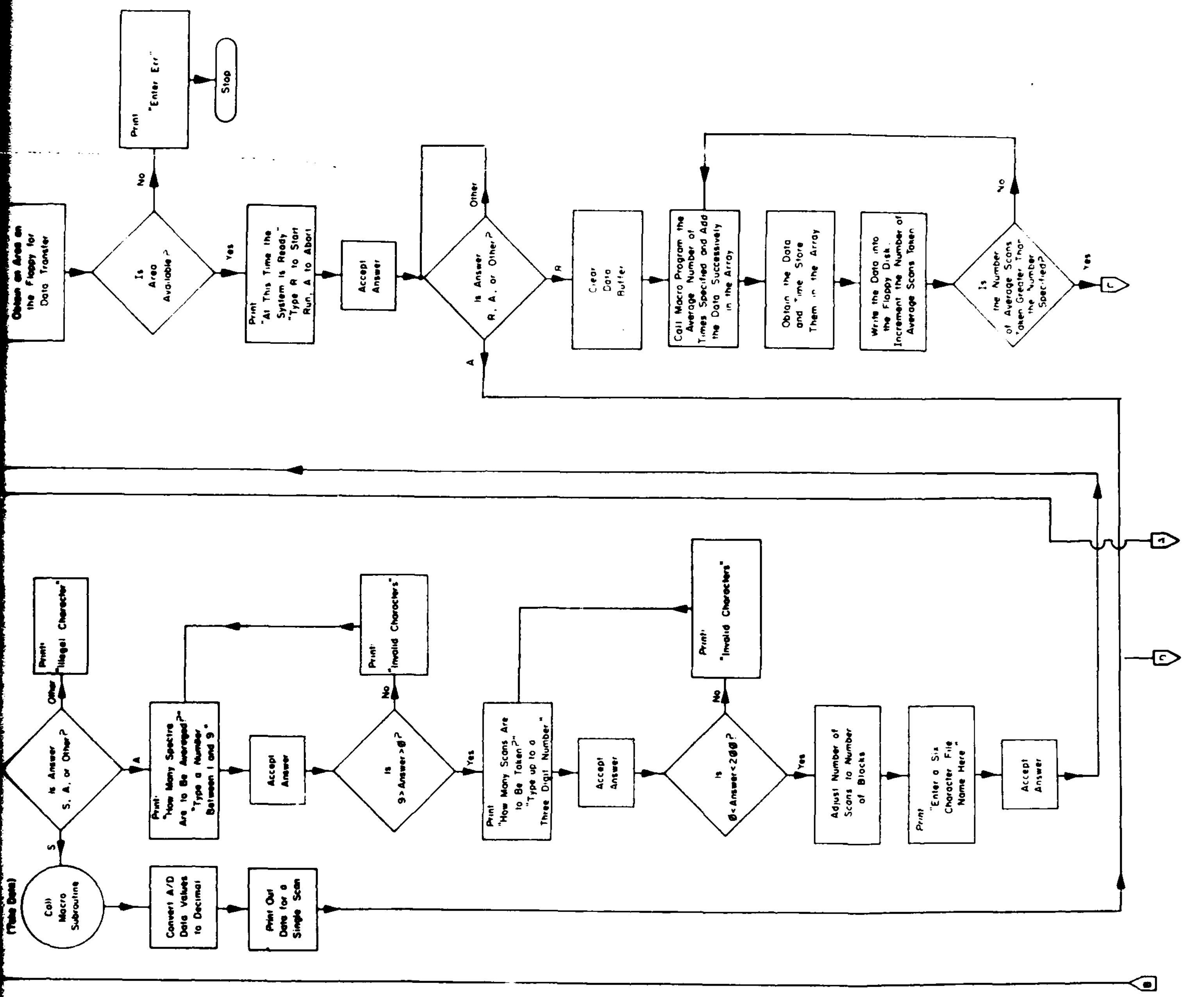


Figure 21. Flowchart of FORTRAN program.



lowchart of FORTRAN program.

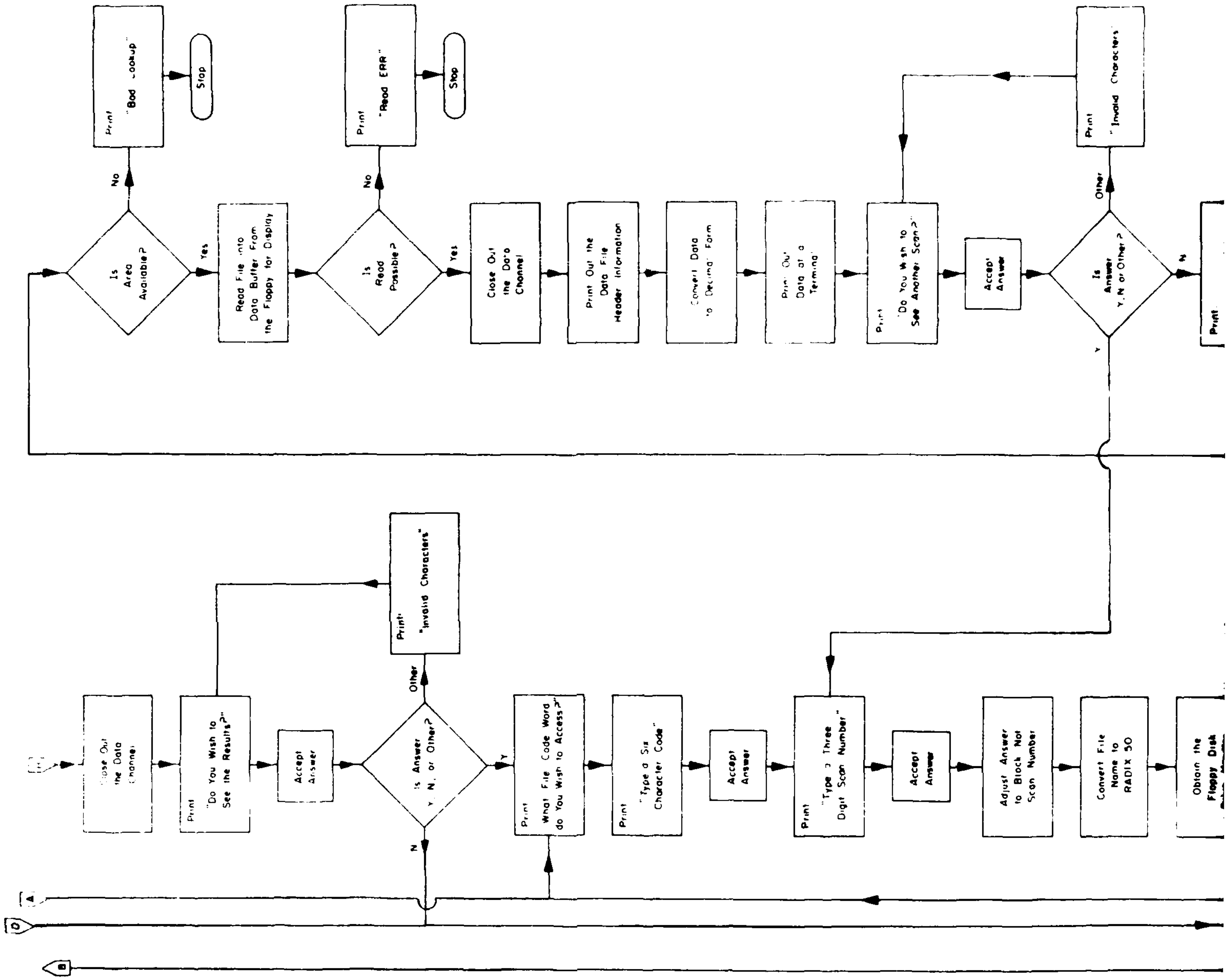
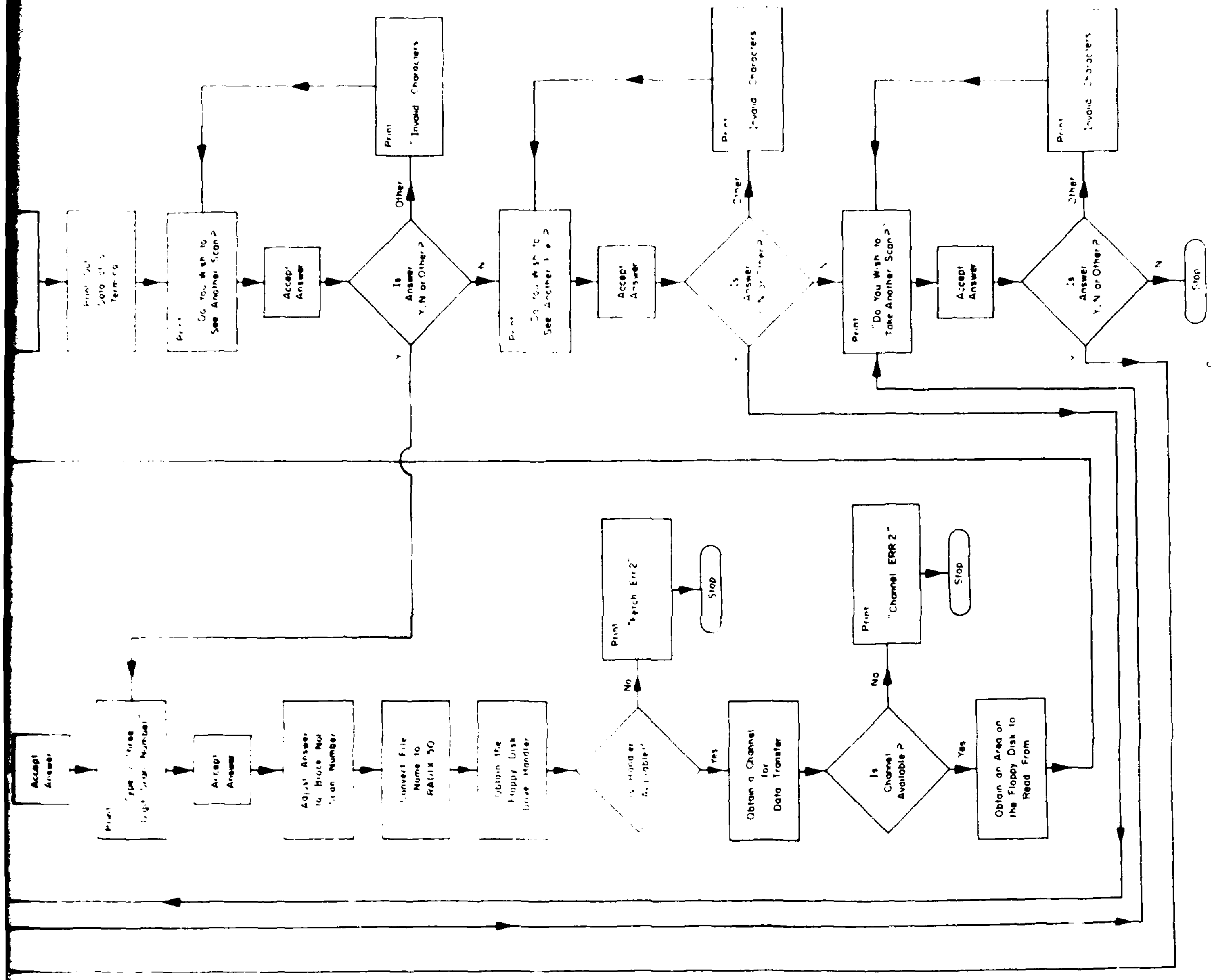


Figure 21. Continued.


Print "Do You Wish to See Another Scan?"
Accept Answer
Is Answer Y, N or Other ?
Other
Print "Invalid Characters"
N
Y
Accept Answer
Other
Print "Invalid Characters"
Print "Do You Wish to Take Another Scan?"
Accept Answer
Is Answer Y, N or Other ?
Other
Print "Invalid Characters"
N
Stop
Y
Accept Answer
Accept Answer
Adjust Answer to Block Not Scan Number
Convert File Name to RAD50
Obtain the Floppy Disk Drive Handler
No
Print "Fetch Err2"
Stop
Yes
Obtain a Channel for Data Transfer
Is Channel Available ?
No
Print "Channel ERR 2"
Stop
Yes
Obtain an Area on the Floppy Disk to Read From

Continued.

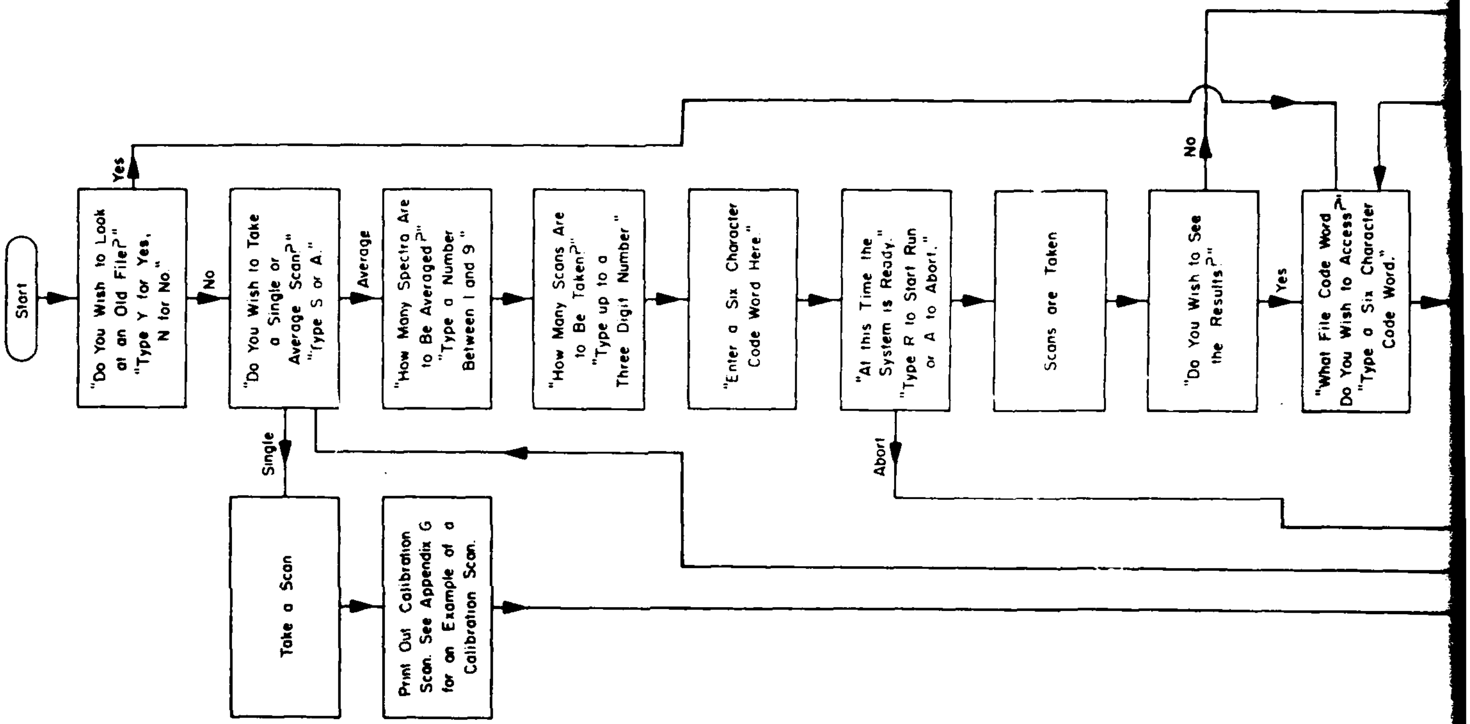
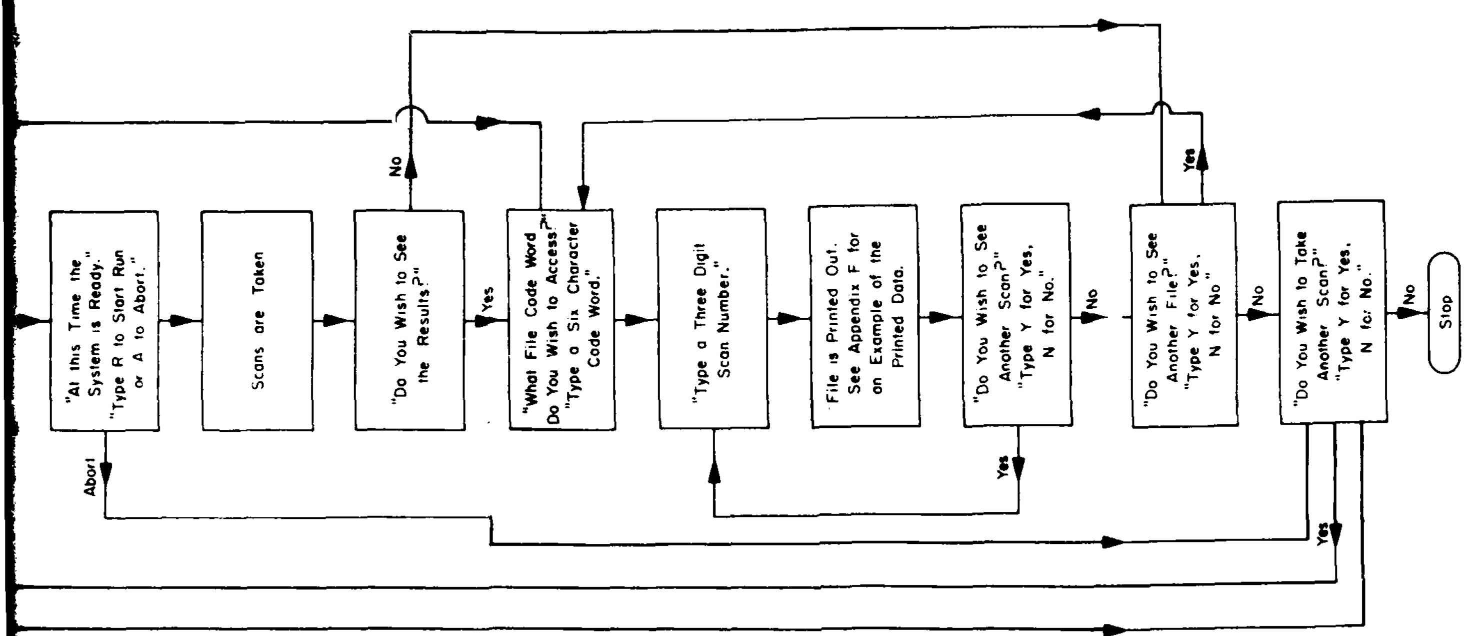


Figure 22. User flowchart of FORTRAN program.



User flowchart of FORTRAN program.

calibration, a call to DMAIT (the Macro-11 subroutine for data collection, see next section) is made. If actual data are to be taken, then an average scan is selected. The user must select the number of spectral scans that the user wishes to have averaged together. Then, the user specifies the total number of these averages that the user wishes to store and thereby sets the amount of time used for data acquisition. It takes, on the average, 0.26 second for the head on the floppy disk drive to search and settle on the floppy disk and 0.15 second to acquire, add, and write a spectral scan. Thus, it takes about 1 second to acquire 5 scans, add them, and store them on the disk. For the sake of expediting data acquisition, the voltage levels taken from the A/D are added together and stored as a sum. Division by the number of scans is done when the data are outputted onto a peripheral device.

Data storage on floppy disks is accomplished through a set of Fortran subroutines available with the RT-11 Fortran Library. These routines are described extensively in the RT-11 Operator Manuals, vol. 3, "Advanced Programmer's Guide" [8]. Each file that is created on a floppy disk under the RT-11 system is catalogued with a user-defined file name and its subsequent creation date. The file, as it is created in AQSPEC, is subdivided into sets of 1024 words. The first 11 words are used to store the date the data were taken, approximate time the data were taken, number of scans averaged, arc voltage, arc current, and travel speed. Thus, the first 11 photodiode voltage levels are overwritten. However, the next 1013 are intact.

Values stored directly from the A/D are not equal to the actual voltages at the A/D input channel ports. The voltage conversion specified by ADAC is given as follows.

If the range is unipolar, look up the proper conversion factor from Table 9 [9] and utilize the formula (1) shown below.

$$\text{Voltage(decimal)} = \text{Conversion Factor(decimal)} \times \text{A/D Output(decimal)} \quad (1)$$

If the range is bipolar, there are two separate procedures for negative and positive voltages. For negative voltages, or decimal A/D values less than 4095 and greater than 2046, find the proper conversion factor from Table 9 [9] and utilize formula (2) shown below.

$$\text{Voltage(decimal)} = -\text{Conversion Factor(decimal)} \times [4095 \text{ A/D Output(decimal)} + 1] \quad (2)$$

For positive bipolar voltages or decimal values less than 2046 and greater than zero, find the proper conversion factor and utilize formula (3).

$$\text{Voltage(decimal)} = \text{Conversion Factor(decimal)} \times [\text{A/D Output(decimal)} + 1] \quad (3)$$

Individual arc spectra with the accompanying time, date, arc voltage, current, and travel speed can be displayed on the LA120 if desired. The operator is also given the option of looking at other old files, or scans, taking more data, or terminating the program. When the program has been terminated, the terminal will respond with a ".". At this time, the power bus can be shut off to power down all of the equipment.

3.4.2 Macro program

All data acquisition, DMA and A/D initialization and activation are done in Macro-11, the DEC machine language. A copy of this program is contained in Appendix D. A flow chart is given in Figure 23. An understanding

TABLE 9

CONVERSION FACTORS

Range	Gain Code			
	0	1	2	3
0 to 10	.244	.488	1.22	2.44
-10 to +10	.488	.976	2.44	4.88
0 to 5	1.221	1.221	1.22	1.22
- 5 to 5	2.442	2.442	2.44	2.44

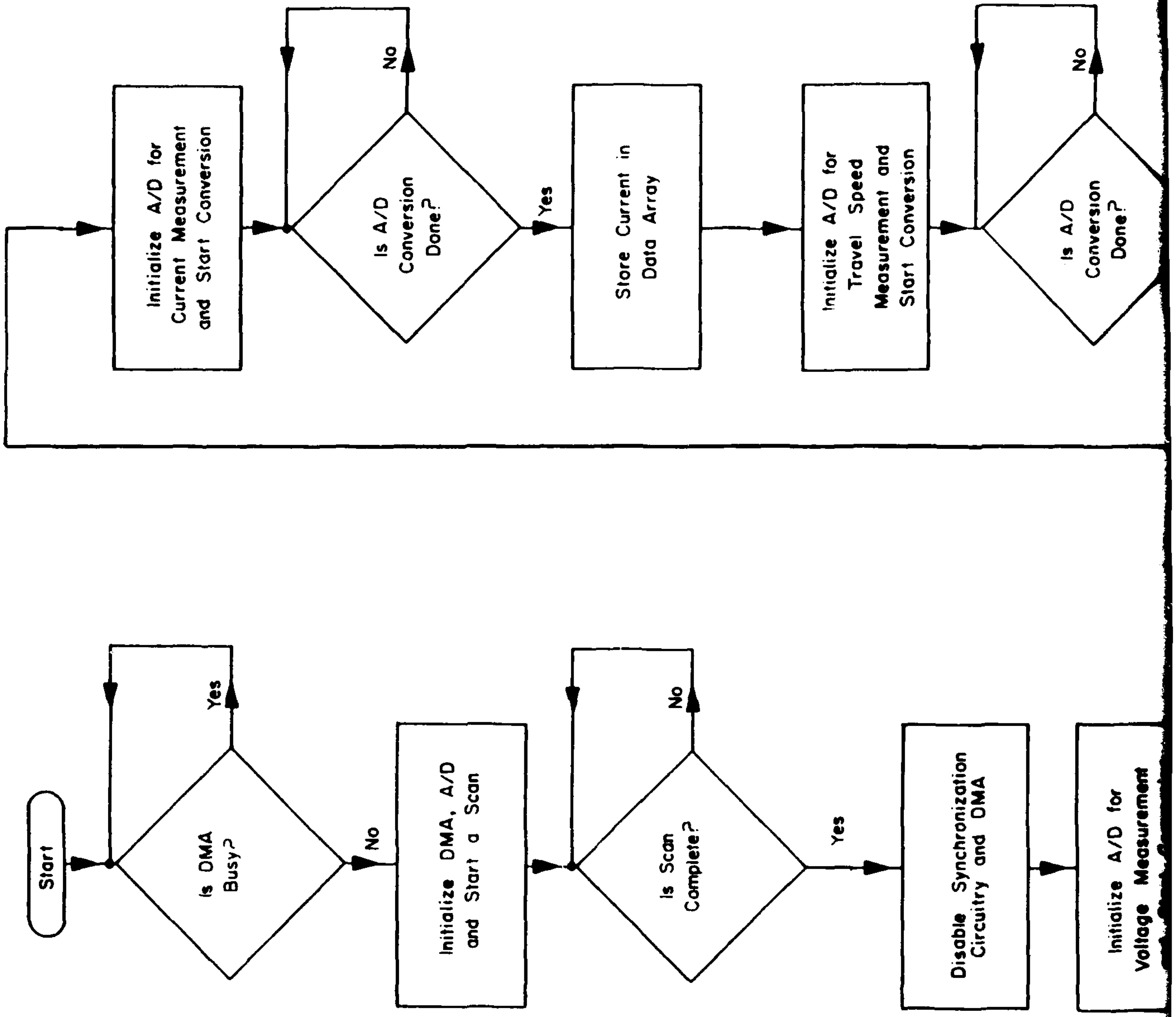
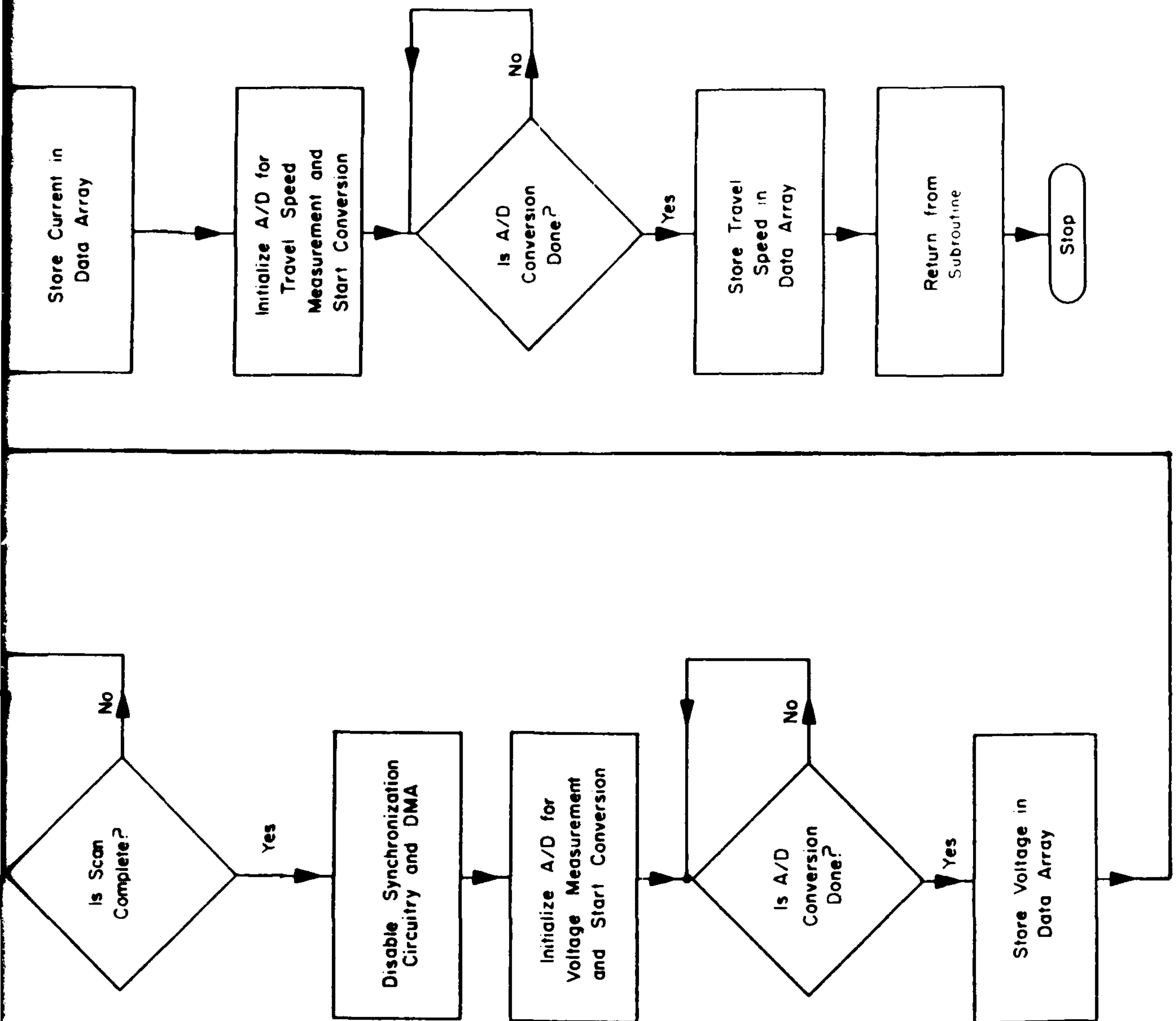


Figure 23. Flowchart of macro program.



Flowchart of macro program.

of the operation of the ADAC A/D and DMA, the synchronization circuitry, and the Macro-11 is needed to truly understand this program. This information can be found in the appropriate section of this report with the exception of information on Macro-11 programming. Two reference sources for this information are the DEC RT-11 Operator Manual [8], vol. 3, "Macro-11 Language Reference" and Minicomputer Systems Organization, Programming, and Applications (PDP-11), by Richard H. Eckhouse, Jr., and L. Robert Morris.

Two features of the program that are not described in the usual Macro-11 documentation are .GLOBL, .TITLE, and .PSECT: RT-11 system macros. .GLOBL is a system macro subroutine that allows the argument of the statement to be accessed globally by other programs of the same or different languages. .TITLE is a means of specifying a title for the program as listed in the floppy directory. The .PSECT directive allows absolute control over the memory allocation of a program at link time, because any program attributes established through this directive are passed to the linker. The directive is formatted as follows: .PSECT name, argl, and 2, ..., argn. Name represents the symbolic name of the program section. Arg represents one or more of the legal symbolic arguments defined for use with the .PSECT directive. The arguments are described in the following manner:

ARGUMENT	DEFAULT	DESCRIPTION
RO/RW	RW	RO = Read-Only Access RW = Read/Write Access defines which type of access is permitted to the program section.
I/D	I	Defines the program section as containing either instructions (I) or data (D).

ARGUMENT	DEFAULT	DESCRIPTION
GBL/LCL	LCL	Defines the scope of the program section, as subsequently interpreted at link time. If an object module contains a local program section, then the storage allocation for that module will occur within the segment in which the module resides. Many modules can reference this same program section. If an object module contains a global program section, the contributions to this program section are collected across segment boundaries, and the allocation of memory for that section will go into the segment nearest the root in which the first contribution to this program section appeared.
ABS/REL	REL	Defines the relocatability attribute of the program section. ABS = Absolute (nonrelocatable). When the ABS argument is specified, the program section is regarded at link time as an absolute module, thus requiring no relocation. REL = Relocatable. When the REL argument is specified, the linker calculates a relocation bias and adds it to all references to locations within the program section.
CON/OVR	CON	Defines the allocation requirements of the program section. CON = Concatenated. All program section contributions are to be concatenated with other references to this same program section in order to determine the total memory allocation requirement for this program section. OVR = Overlaid. All program section contributions are to be overlaid. Thus, the total allocation requirement for the program section is equal to the largest allocation request made by any individual contribution to this program section.

For further information on this directive, see the RT-11 Operator Manuals, "RT-11 Advanced Programmer's Guide," Section 6.8.1, pp. 6-32; 6-36 [8].

The following is a step-by-step description of the Macro program itself.

1) .TITLE INIT.MAC

The .TITLE macro directive is used to place the title of the program at the top of the program li· ·:g. In this case, it is INIT.MAC.

2) .GLOBL DMAIT

The .GLOBL macro directive is used to allow the argument of the directive to name a program section that can be collected across segment boundaries in memory. In this case, DMAIT is made available to the FORTRAN program AQSPEC.

3) DMAIT: TSTB @#172414

DMAIT: is a label used to name this line of code for external reference. TSTB translates to TeST Byte. This command sets the condition codes for the processor status word in the microcomputer. Since the test is performed on the lower byte of the word 172414, the seventh bit will determine the sign of the byte. The seventh bit is the sign bit of a byte in two's complement arithmetic. Bit 7 of word 172414 is the busy bit on the DMA Control Status Register. If it is equal to a 1, it is negative; if it is Ø, it is positive.

4) BPL DMAIT

BPL translates to Branch if PLus. If the BUSY bit is a one (bit seven is a sign bit on a two's complement byte) or negative, go to the argument of this command: DMAIT. If it is not a 1, continue to the next instruction in the program.

5) MOV #176000, @#172410

The MOV command takes the first operand, 176000, and moves it into the second operand, @#172410. The actual number 176000 (i.e., -1024 decimal) is moved into the word at location 172410 in the memory.

172410 is the Word Count Register (WCR) in the DMA. The WCR stops DMA transfers when its content equals zero. After each DMA transfer, the WCR is incremented by one. Thus, 2000 octal transfers or 1024 decimal transfers will be made before the WCR equals zero.

6) MOV_TOT,@#172412

The effect of this command is to place the memory address associated with the label TOT (TOT is the first word location in a linear array that is 1024 elements long) into the Memory Address Register (MAR) in the DMA. The MAR is used to keep track of the current location for the data storage. It is incremented after each data transfer.

7) MOV #1,@#172414

The effect of this command is to place a 1 in the least significant bit of the word at location 172414. Location 172414 is the DMA Control Status Register (CSR). The bit in question allows the DMA to be enabled.

8) MOV #1,@#172416

Location 172416 is the Multiplex Comparison Register (MCR) in the DMA. The MCR is used if conversions on each channel are to be done sequentially from channel to channel. Since we wish to sample one, a one is placed in the MCR to indicate that only one channel is to be sampled.

9) MOV #32,@#177000

Location 177000 is the Control Status Register for the A/D. The octal value of 32 configures the A/D for an external enable or trigger, unity gain, and conversion on channel 0.

10) MOV #1,@#167772

This command will set the output channel 0 high (+5 V) on the parallel I/O board. This enables the synchronization circuitry to begin triggering of the A/D.

```
11) 1$: TSTB @#172414
        BPL 1$
```

Until 1024 conversions and data transfers have been completed, the BUSY bit in the DMA CSR will be set equal to a 1. When it is set equal to a Ø, the program will continue.

12) MOV #0,@#167772

This command sets the output channel 0 on the parallel I/O board to ground so that the synchronization circuitry is disabled.

13) MOV #0,@#172414

This command will disable the DMA.

14) MOV #431,@#177000

The octal number 431 will force a conversion with unity gain on channel 1 of the A/D. Channel 1 is the weld arc voltage.

```
15) LP1: TSTB @#177000
         BPL LP1
```

When bit 7 of the A/D CSR is set, the A/D has not finished a conversion. When the A/D finishes, the program will continue.

16) MOV #TOT+16.,R1

The memory location TOT plus the decimal value of 16 will equal the ninth word in the linear array following TOT. This word will be used to store the value of the voltage. R1 is a general-purpose register in the LSI-11/23 microprocessor that will be used to point to locations in the array.

17) MOV @#177002,(R1)+

Location 177002 is the data buffer for the A/D. Since step 15 has been completed, the data buffer will contain the converted value for the voltage. (R1)+ has the effect of opening the contents of the location of the address pointed to by the value in R1 for deposit of the converted value for voltage. The + increments the value of R1 by 2 after the completion of the instruction, thus forcing R1 to point to the next word in the array TOT.

18)
```
      MOV #1031,@#177000
LP2:  TSTB @#177000
      BPL LP2
      MOV @#177002,(R1)+
```

The instructions above perform the same function as steps 14, 15, and 17; however, they apply to channel 2 on the A/D which has the weld arc current as an input.

19)
```
MOV #1431,@#177000
BPL LP3
MOV @#177002,(R1)
```

These instructions perform the same function as steps 14, 15, and 17; however, they apply to channel 3 on the A/D which has the weld travel speed as an input.

20) END1: RTS PC

RTS translates to ReTurn from Subroutine. PC is the Program Counter and must be restored to its original value before the subroutine was called so that the computer can start at the right location in the calling program.

21) .PSECT TOT,RW,D,GBL,REL,OVR

A complete description of the macro directive PSECT is given just prior to this section of text.

22) TOT: .BLKW 1024.

.BLKW translates into BLocK of Words. This macro directive has the effect of creating an array of words which is as long as the number following the directive. 1024. forces the number to be considered as a decimal number as opposed to an octal one. Thus, the array is 1024 words long. TOT is a label that will be set equal to the value of the memory location of the first word in the array.

23) .END DMAIT

This macro is used to define the absolute end of the program. Its argument must reference the first executable statement of the program.

It should be noted that Macro-11 code, as in this case, is usually only used when speed and efficiency are required.

4. OPERATING PROCEDURE

Before data acquisition can be accomplished, the following cables must be connected. The numbers circled refer to the corresponding numbers in the figures on pages 68-75 unless otherwise specified.

1) Be sure all power lines from devices on the rack are plugged into the power bus at the top of the rack. At this time, do not plug the power bus into an outlet.

2) All boards should be firmly secured in the back plane of the LSI-11 housing.

3) Six cables that must be in place at this time are: a ribbon cable from the RX02 floppy disk drive to the RXV21 board 1 (Figure 24); a ribbon jumper cable from the A/D to the DMA 2 (Figure 25); a shielded ribbon cable from the A/D to the spectrograph control box 3 (Figures 24, 25, and 26); a cable running from channel 3 of the DLV-J serial interface board to the Decwriter LA-120 4 (Figures 25 and 27); a ribbon cable running from the MDB MISI-DRV11-C parallel interface board to the spectrograph control box 5 (Figures 24, 25, and 26); and a ribbon cable running from the spectrograph control box to the spectrograph 6 (Figures 24 and 26). With the exception of the last cable mentioned, none of these cables should be removed while the computer is powered up.

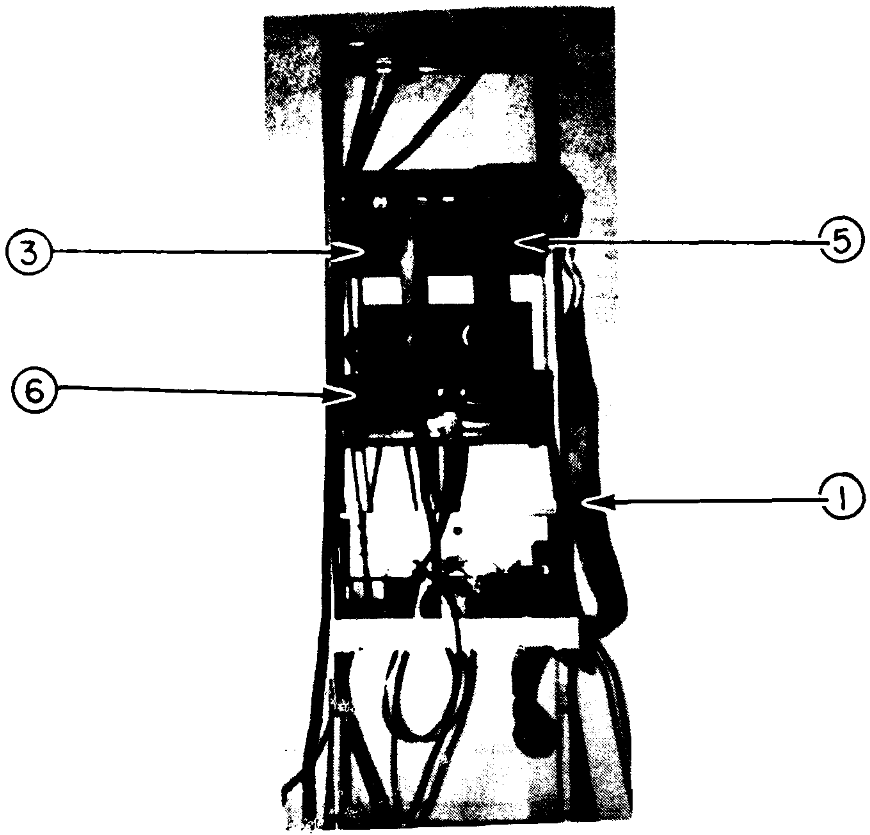


Figure 24. Back view of WQM.

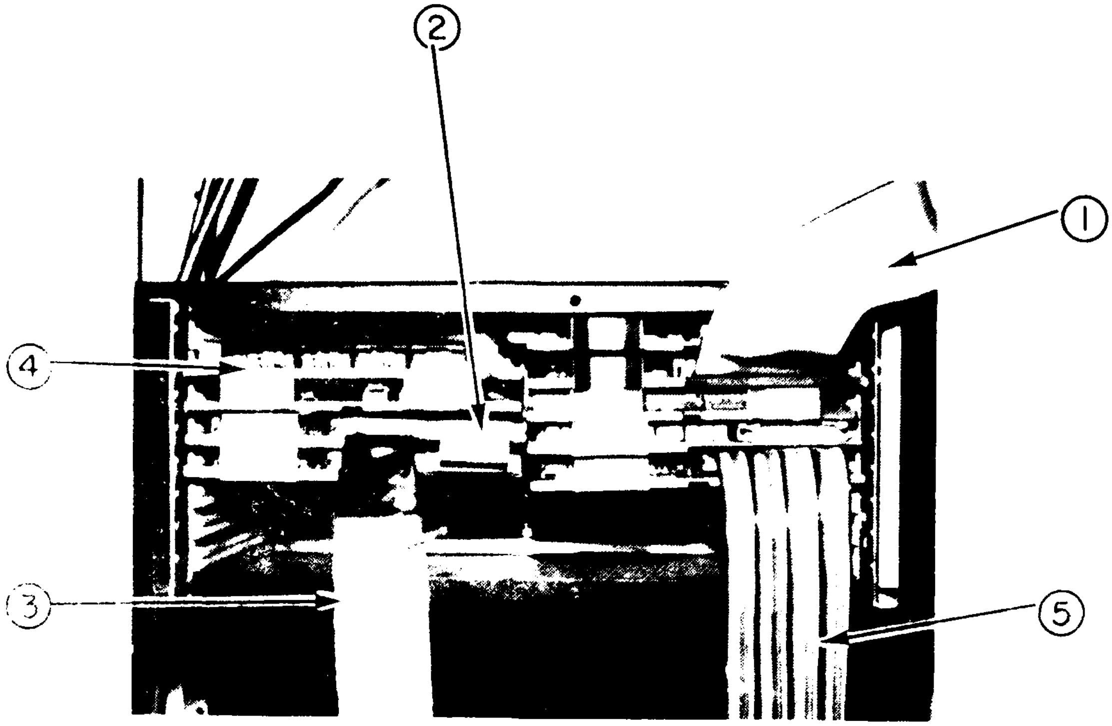


Figure 25. Backplane of DEC minicomputer.

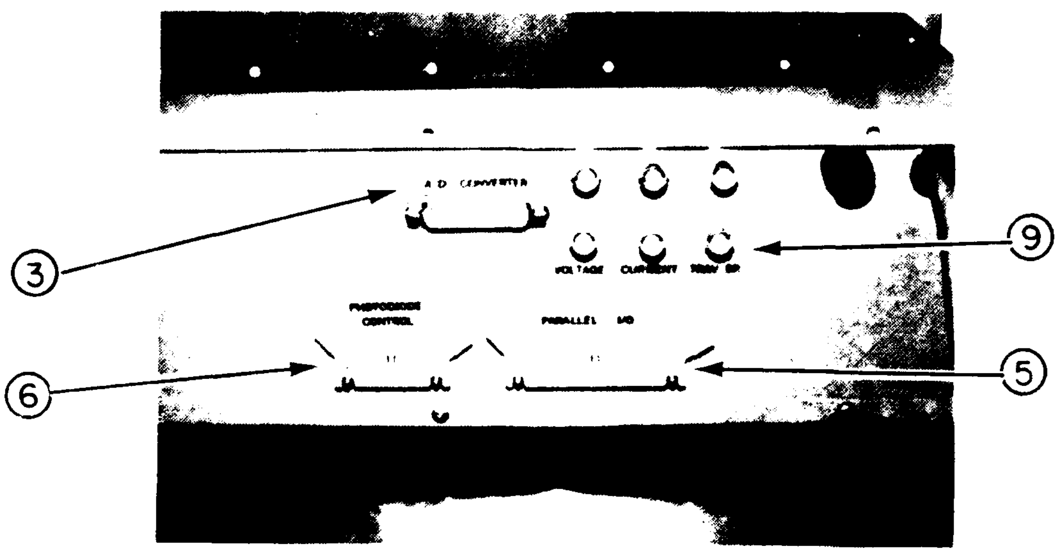


Figure 26. Back of spectrograph control box.

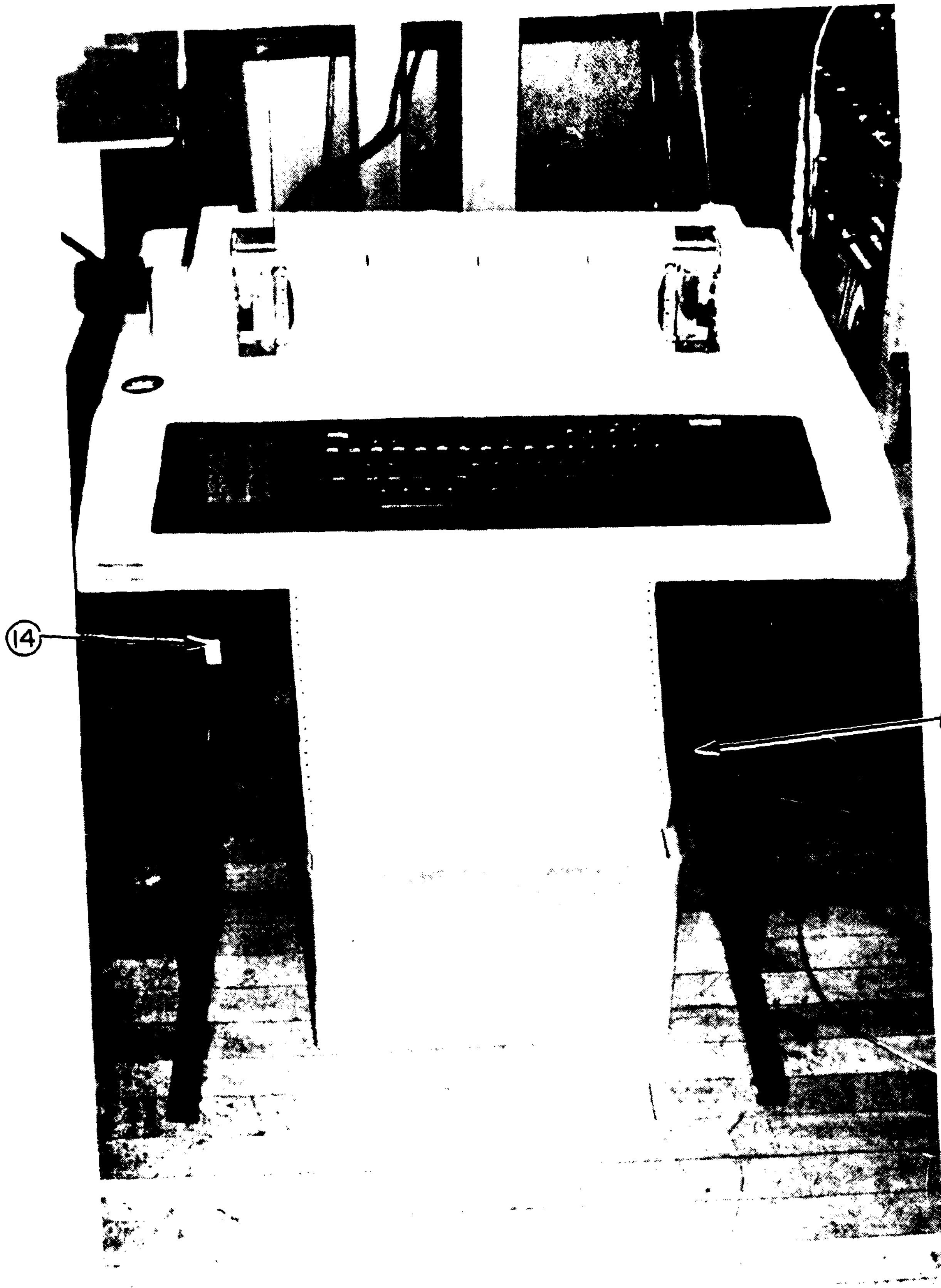


Figure 27. Decwriter LA-120.

4) If a video display of the spectrum is desired, connect one end of an BNC cable to the START OUT (7) (Figure 28) on the spectrograph control box and the other to the oscilloscope trigger. Connect another BNC to the VIDEO OUT (8) (Figure 28) on the spectrograph control box and an inverted channel on the same scope.

5) If voltage, current, and travel speed are desired, connect the appropriate BNC's to the back of the spectrograph control box (9) (Figure 26). The range of these inputs must be restricted to 0-10 V. If these ports are not to be used, they must be shorted for the proper operation of the system.

6) Plug the power cord from the power bus into a 110 V outlet and turn the bus on. The system is now ready for initialization.

After the steps above have been completed, the following procedure can be used to initialize the software for data acquisition.

1) Turn the computer power switch (10) (Figure 29) and the spectrograph control box power switch (11) (Figure 28) on.

2) Take the RT-11 system software and data acquisition floppy disk and slide it into slot 0 (12) (Figure 30) in the RX02 disk drive. Close the door over the slot. (The slot cover is opened by depressing a button under the handle on the slot cover.)

3) Slide a formatted and initialized data floppy disk (see Appendix B) into slot 1 (13) (Figure 30) in the RX02 disk drive and close the door.

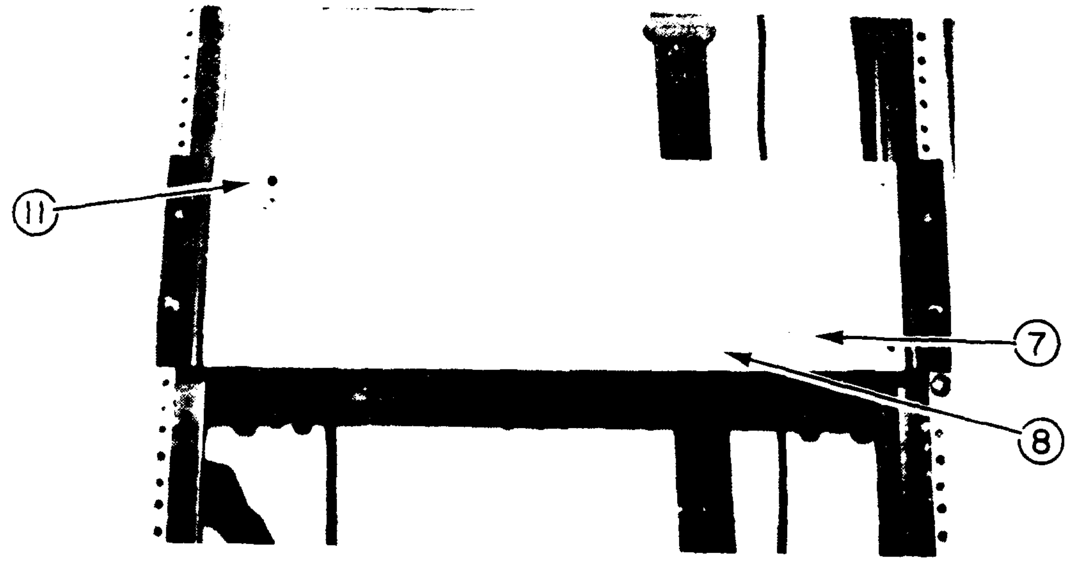
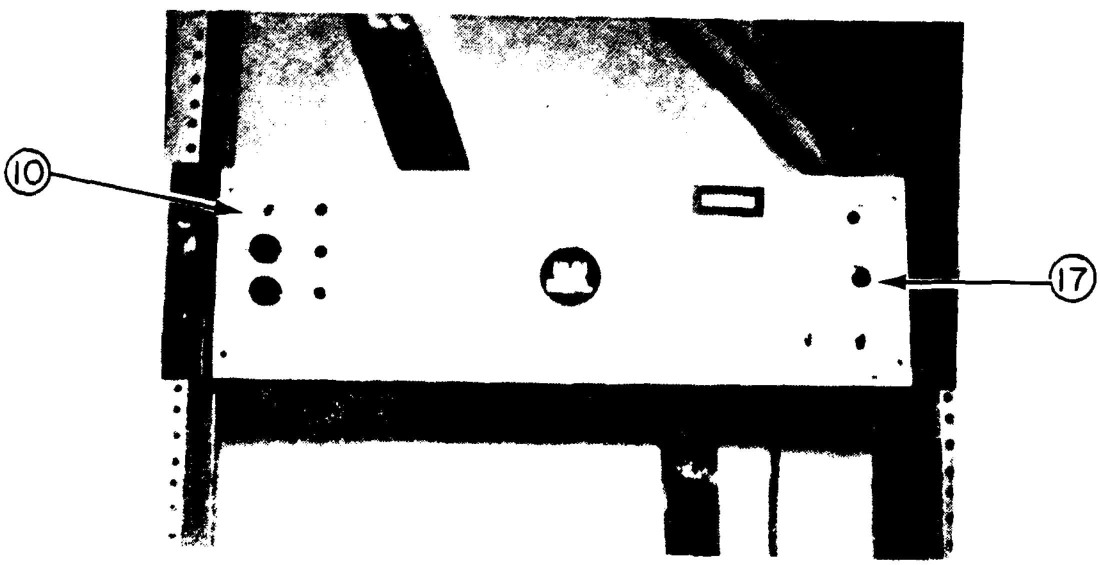


Figure 28. Front of spectrograph control box.



[illegible]. Front of [illegible] minicomputer.

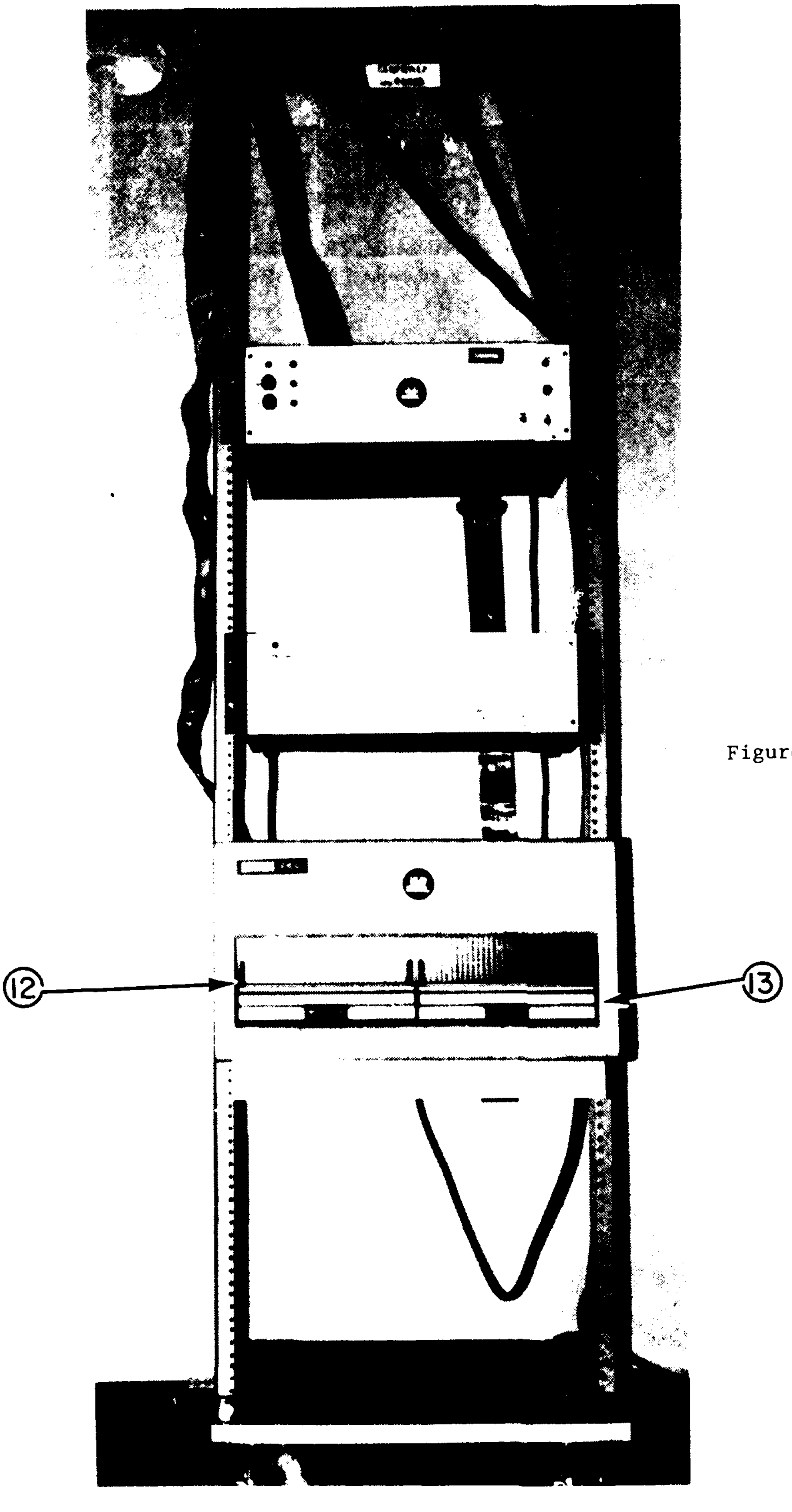


Figure 30. Front of WQM.

4) Turn the LA120 power switch (14) (Figure 27) on.

5) Check to see that the LA120 indicator light is "ON LINE" rather than "LOCAL" (15) (Figure 31) [10]. If it is on "LOCAL," press the ON LINE/LOCAL button (16) (Figure 31) [10].

6) Press the system initialization button (17) (Figure 29) and wait for this response on the LA120:

UI PHYSICS RT-11FB (S)V03B-02

?KMON-F-File not found

The following information will detail the computer interface with the WQM operator and the possible responses. A ●, will precede anything that the computer will type at the terminal. The response by the user is underlined. After the possible user response, there will be a description of the computer action taken and the step number of the next question.

7) ● . ;This is the computer prompt.

<u>DATE 7-JUL-81</u> ;The date shown is representative of the way the date is entered.

8) ● .

<u>TIME 13:48:00</u> ;The value for the time is arbitrary but illustrates the way time is entered into the system.

Note: The date and time must be reset for every system initialization. Also, to erase characters entered, type the delete button until the error is reached. Then, retype the information to correct the mistake.

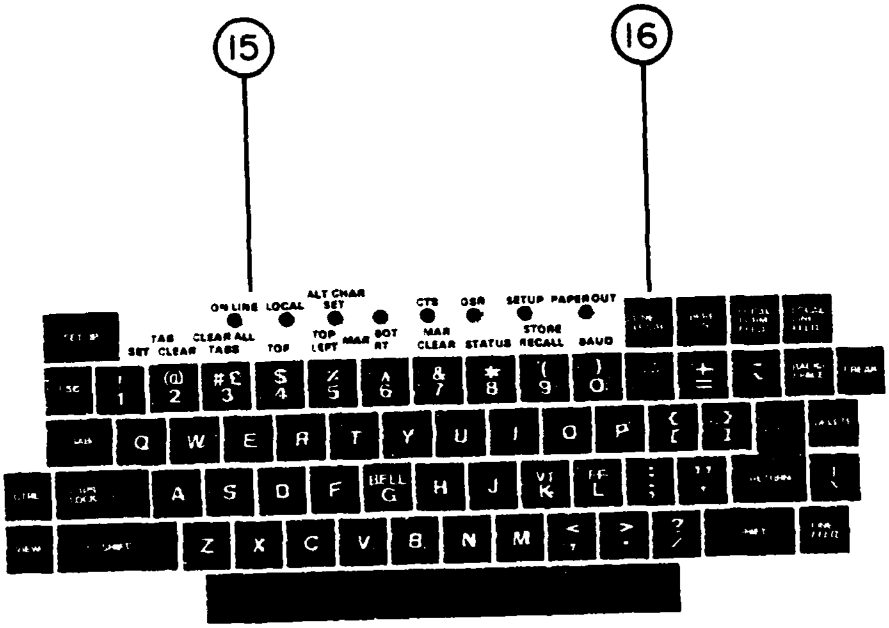


Figure 31. Keyboard for Decwriter LA-120 [10].

9) ● .

<u>RUN AQSPEC</u> ;This will start the data collection program.

10) ● DO YOU WISH TO LOOK AT AN OLD FILE?

● TYPE Y FOR YES, N FOR NO.

<u>Y</u> ;This answer will take the operator to step 17 to specify the file that is to be seen.

<u>N</u> ;Go to step 11.

11) ● DO YOU WISH TO TAKE A SINGLE OR AVERAGE SCAN?

● TYPE S OR A.

<u>S</u> ;This will enable the operator to take a calibration scan with the spectrometer. It will automatically print the scan at the LA 120. An example of a calibration scan can be found in Appendix G. Go to step 14.

<u>A</u> ;Go to step 12.

12) ● HOW MANY SPECTRA ARE TO BE AVERAGED?

● TYPE A NUMBER BETWEEN 1 AND 9.

<u>5</u> ;The number 5 was chosen arbitrarily but it is representative of the way the operator would type in the number of scans the operator would have averaged for data storage. Go to step 13.

13) ● HOW MANY SCANS ARE TO BE TAKEN?

● TYPE UP TO A THREE DIGIT NUMBER.

<u>50</u> ;The number 50 was chosen arbitrarily but it represents the way an operator would enter the number of averaged scans that are to be stored. Go to step 14.

14) ● ENTER A SIX CHARACTER CODE WORD HERE.

<u>TESTOO</u> ;This word can be any combination of six or fewer alphanumeric characters. It will be used on the floppy disk directory to name the file created. All references to this data file must be done with the file name in the future. Go to step 15.

15) ● AT THIS TIME THE SYSTEM IS READY.
● TYPE R TO START A RUN OR A TO ABORT.

<u>A</u> ;This command will terminate the acquisition of data as previously specified. No file will be created and no data will be taken. Go to step 12.

<u>R</u> ;This command will begin the data acquisition and storage. When the computer next responds with a question, the data will have been taken and stored under the code word specified earlier. Go to step 16.

16) ● DO YOU WISH TO SEE THE RESULTS?

<u>N</u> ;Go to step 11.

<u>Y</u> ;This command will allow the operator to view the data on the LA 120. Go to step 17.

17) ● WHAT FILE CODE DO YOU WISH TO ACCESS?
● TYPE A SIX CHARACTER CODE WORD.

<u>TESTOO</u> ;The code word shown is just for purposes of illustration. It can be any six or fewer alphanumeric characters corresponding to an existing file on the floppy disk in slot 1 of the floppy disk drive. Go to step 18.

18) ● TYPE A THREE DIGIT SCAN NUMBER.

28 ;The number shown was arbitrarily selected. It can be any number that corresponds to a set of averaged spectral scans stored in the file specified in step 8. The number must correspond to a number less than or equal to the total number of average scans taken for that file. The scan specified will be printed out automatically. An example of the output is shown in Appendix F. Go to step 19.

19) ● DO YOU WISH TO SEE ANOTHER SCAN?
● TYPE Y FOR YES, N FOR NO.

Y ;This question asks the operator if he would like to see another scan number in the same file that was opened in step 8. With this command, the operator will proceed to step 18.

N ;Go to step 20.

20) ● DO YOU WISH TO SEE ANOTHER FILE?
● TYPE Y FOR YES, N FOR NO.

Y ;This question will allow the user to access any file that exists on the floppy disk in slot 1 of the floppy disk drive. With this answer the operator will proceed to step 17.

N ;Go to step 21.

21) ● DO YOU WISH TO TAKE ANOTHER SCAN?
● TYPE Y FOR YES, N FOR NO.

Y ;This question asks the operator if he wishes to continue taking data. With this answer the operator proceeds to step 11.

N ;This answer will terminate the program. Wait for the computer to respond with its prompt before rerunning the program or starting the power off procedure.

22) To stop operation, turn off the power switch on the LA 120 and the power bus at the top of the rack.

5. EXPERIMENTAL RESULTS

To illustrate the capabilities of the system, results of two experiments are described in this section. Both experiments were bead on plate tests using the shielded metal arc welding process with argon shielding gas, carbon steel base metal, and E70S-3 electrodes (see Figure 32).

In the first experiment, the argon shielding gas was interrupted during the welding process and the resultant changes in the arc spectrum, voltage, and current observed. Complete or partial loss of shielding gas can cause flaws such as porosity and slag in the weld joint. In the past, attempts have been made by other workers to monitor shielding gas flow using pressure transducers; this approach has not been very successful. The experimental procedure was as follows:

With the shielding gas on, the arc was stabilized by adjusting the current to 300 A. Data collection was then initiated by the computer and continued for 50 seconds. Samples of the arc spectrum, voltage, and current were averaged for one-half second and then stored on a disk. Because the access time for the disk is approximately one-half second, data were collected at one-second intervals. Approximately 10 seconds after data collection was initiated, the argon shielding gas was turned off for 10 seconds. Shielding gas was turned on at 20 seconds, off again at approximately 30 seconds, then on at 40 seconds.

Figure 33 is a plot of the arc voltage and current versus time. The times during which the shielding gas was off are clearly evident. When the shielding gas is turned off, the arc current decreases from 300 A to approximately 250 A, and the arc voltage increases from 30 V to approximately

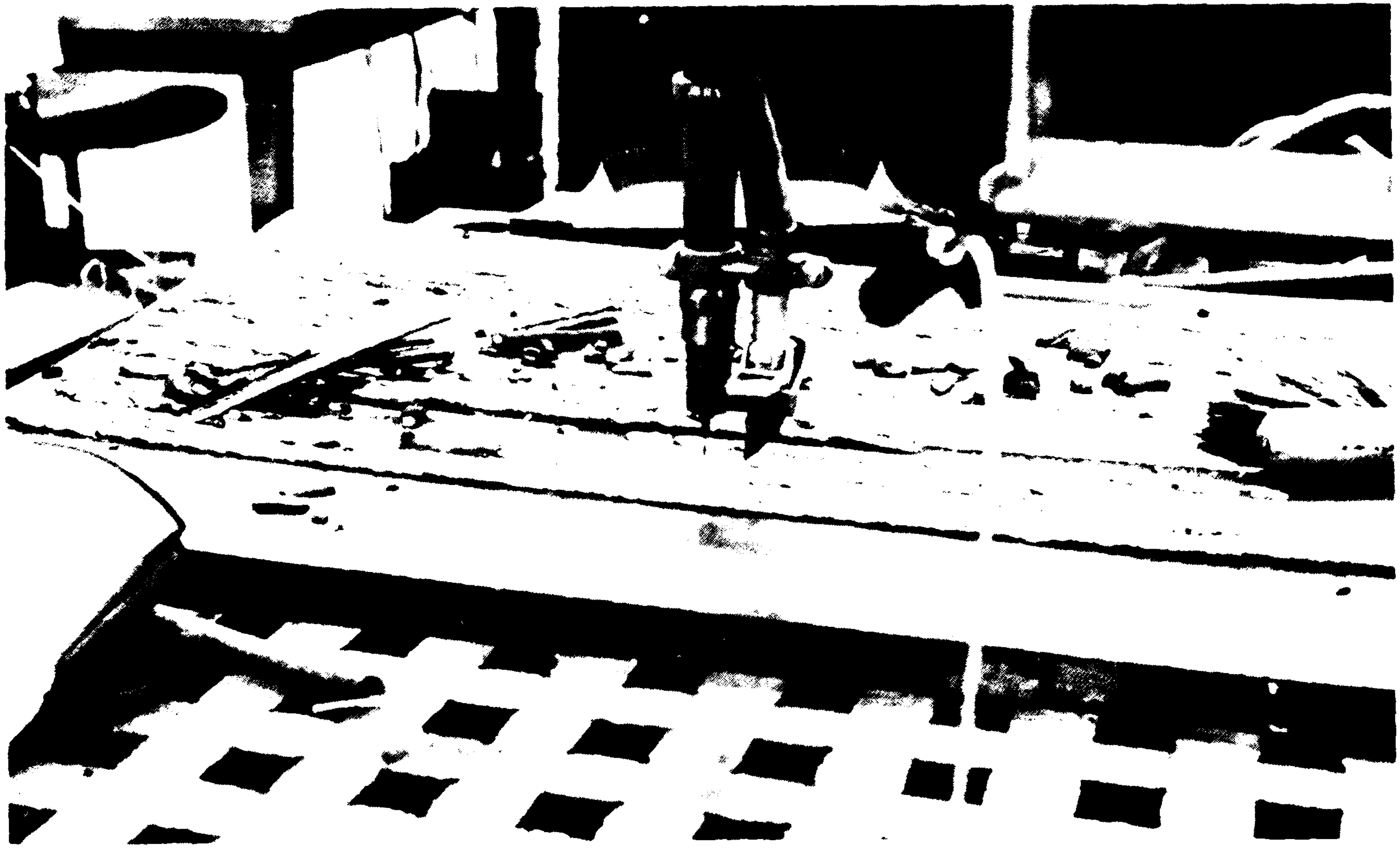


Figure 32. Weld spot and fiber.

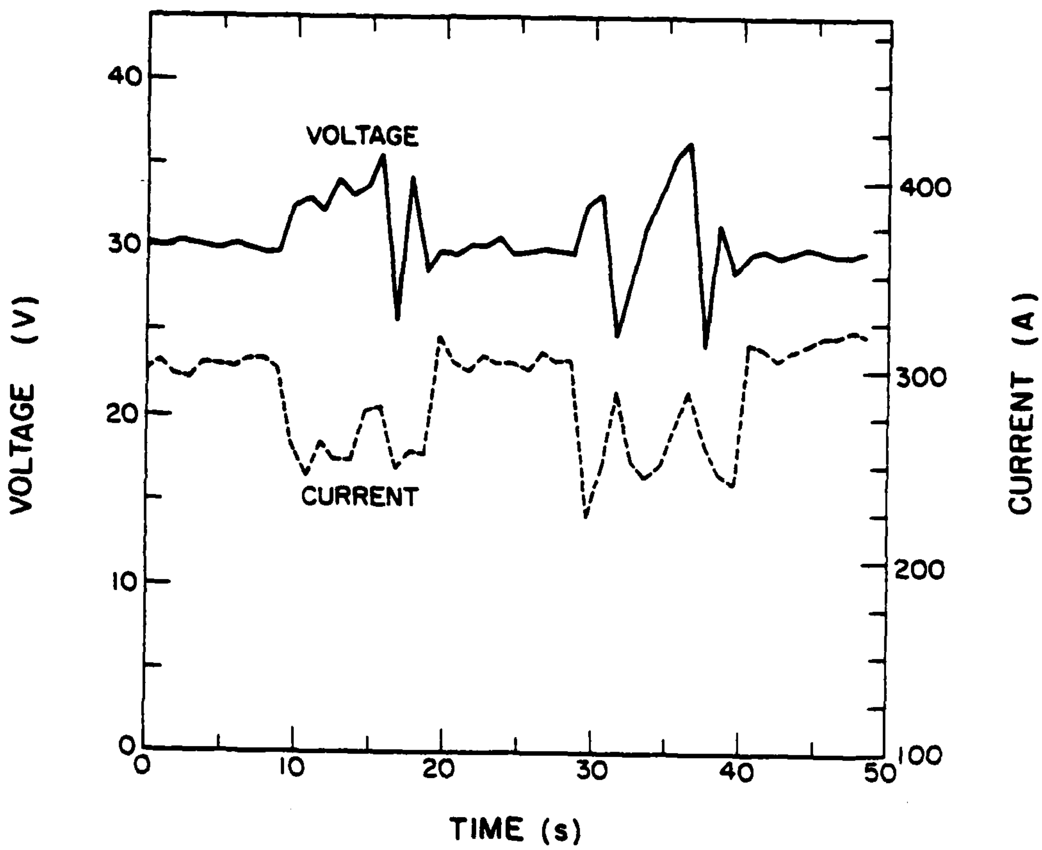


Figure 33. Variation of the arc voltage and current versus time. The argon shielding gas was interrupted twice during this experiment for approximately ten seconds each time. The shielding gas was turned off at approximately 9 seconds and again at approximately 29 seconds.

34 V. Both the voltage and current fluctuate considerably when the shielding gas is off. With the removal of the shielding gas, the arc length decreases and the mode of metal transfer changes from spray to globular. The large globules of weld metal cause some shorting of the arc which in turn causes instability of the current and voltage. Notice that the voltage and current are anticorrelated. The voltage increases when the current decreases and vice versa. The primary parameter WQM, which is presently undergoing field tests at Chrysler and Allis-Chalmers, monitors only arc current and voltage.

Samples of the arc spectrum obtained simultaneously with the current and voltage data are plotted in Figure 34. Figure 34a is a sample of the arc spectrum taken at 28.71 seconds into the experiment. This represents an arc spectrum under normal welding conditions. In Figure 34b the arc spectrum at 29.70 seconds into the experiment is plotted. This represents the spectrum obtained for the flaw inducing condition of loss of shielding gas.

The wavelength range from 400 to 1000 nm corresponds to the spectral region from the near ultraviolet to the near infrared and includes the visible region of the spectrum. The spectral lines with wavelengths longer than 700 nm are due to excitation of the argon shielding gas by the arc. When the shielding gas is removed, these spectral lines disappear. Repeated tests show an unambiguous correlation between the loss of the long wavelength lines and the loss of the argon shielding gas.

To further illustrate this point, the total spectral energy between 700 to 1000 nm is plotted versus time in Figure 35. When the shielding gas is on, the relative energy in this spectral segment is approximately 0.3. When the shielding gas is removed, the relative energy drops to approximately 0.1.

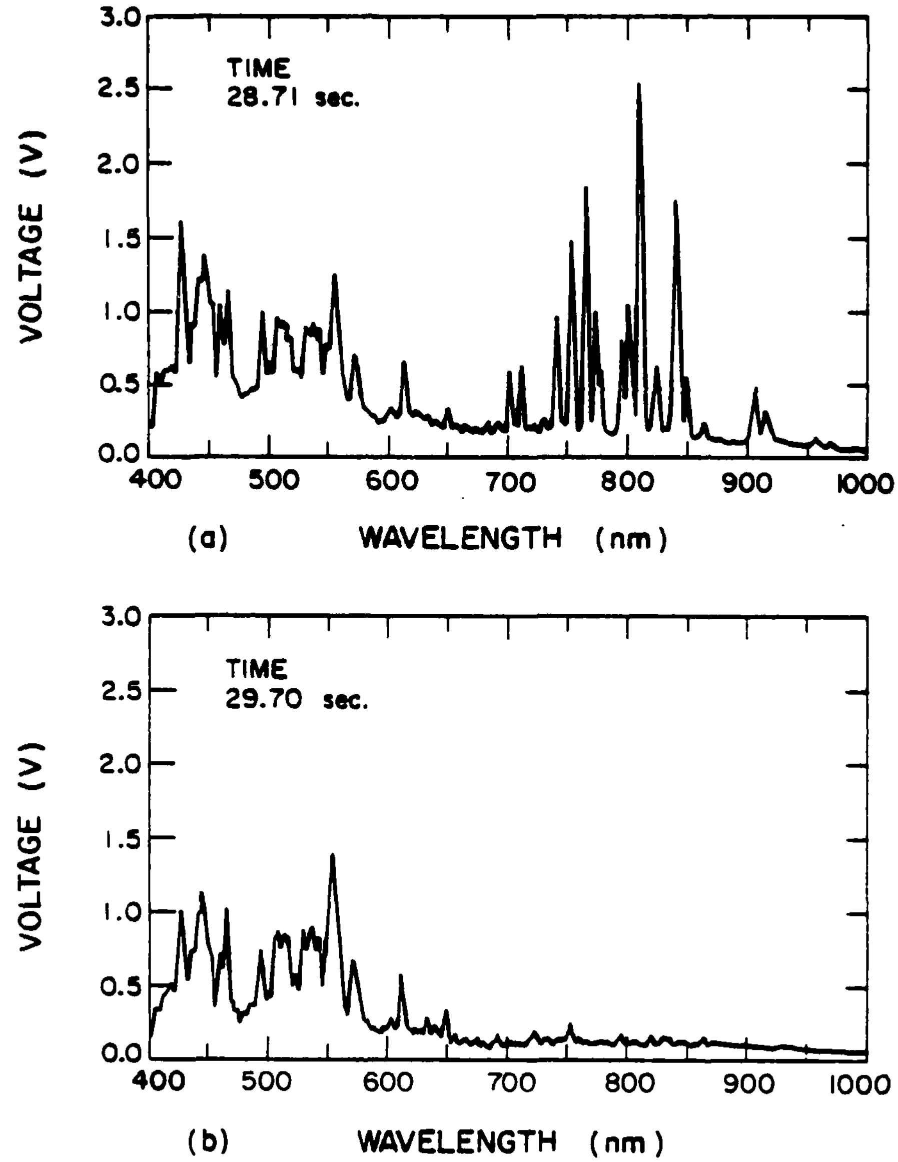


Figure 34. Typical examples of the arc emission spectra. Figure 34a is a spectrum obtained at 28.71 seconds into the experiment and corresponds to normal welding conditions where the argon shielding gas is on. Figure 34b is a spectrum obtained at 29.7 seconds into the experiment and corresponds to abnormal welding conditions when the shielding gas is off.

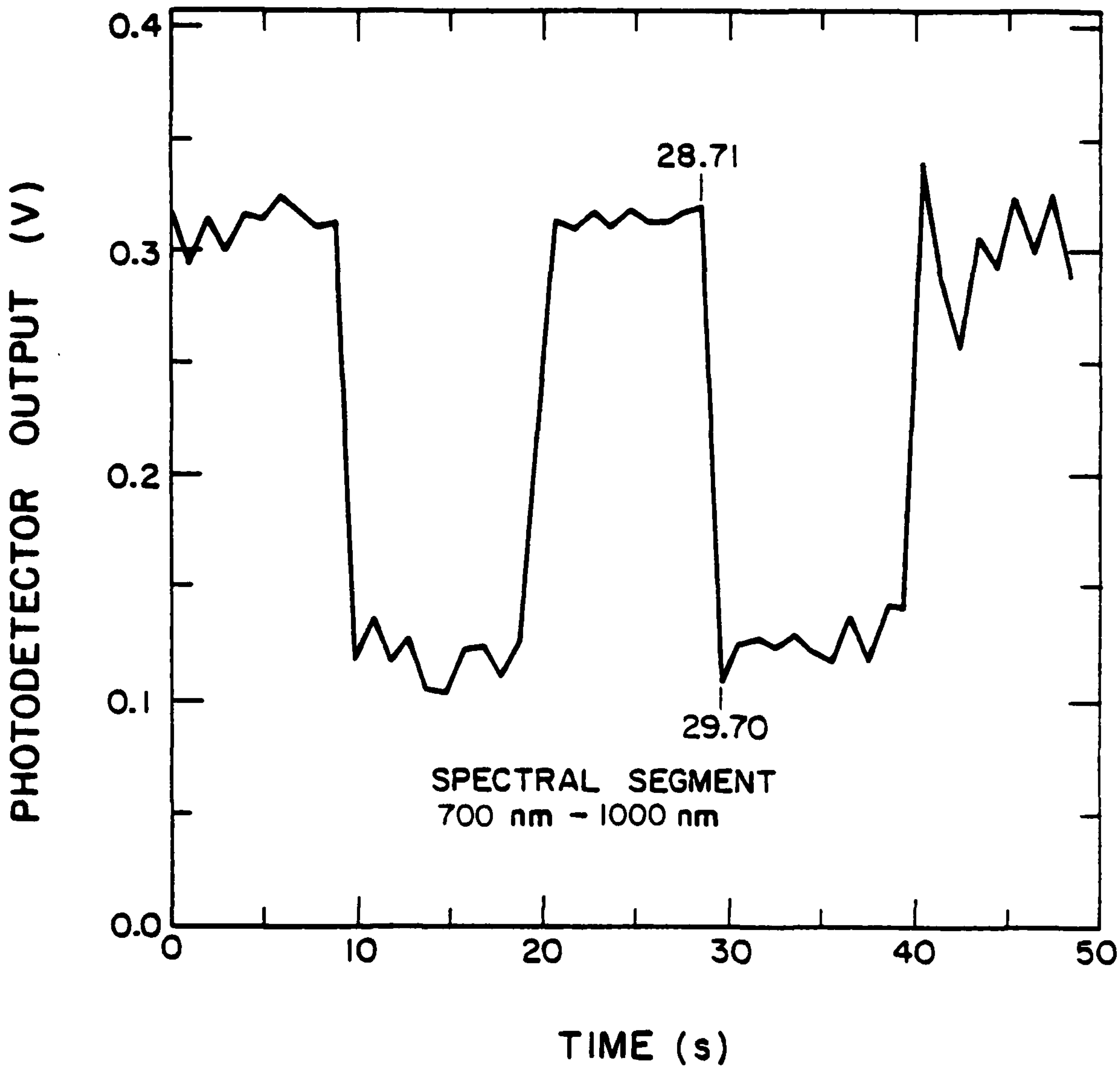


Figure 35. Total energy in the spectral segment from 700 to 1000 nanometers.

The times annotated on Figure 35 correspond to the times at which the spectra in Figure 34 were obtained (28.71 seconds and 29.70 seconds). The data plotted in Figure 35 show that a complete loss of the shielding gas occurs in less than one second. Although the time resolution of our system was one second for this experiment, it can be increased to less than one-tenth of a second, if necessary. Notice that all of the spectral energy was not lost when the shielding gas was off. The residual energy in the 700 to 1000 nm wavelength range is due to black body radiation from the weld arc. It may be possible to determine the temperature of the arc by fitting the background spectral energy to the standard black body curve.

The total energy in the wavelength region between 400 and 700 nm is plotted in Figure 36. Although the energy does decrease in this region when the shielding gas is removed, the decrease is not as abrupt nor as significant as that plotted in Figure 35. We believe the gradual decrease in energy is due to the increase in smoke production when the shielding gas is interrupted. The shorter wavelengths are attenuated by the smoke much more than the longer wavelengths. Consequently, it is smoke that is attenuating the shorter wavelengths rather than loss of argon emissions in this spectral region. When the shielding gas is turned on, the energy does not abruptly increase. It takes awhile for the smoke to be cleared from the welding area. Notice also that when the shielding gas is off, the energy fluctuates considerably more than the energy in the 700 to 1000 nm region. The total energy from 400 to 1000 nm versus time is plotted in Figure 37. This plot shows the combined effect of loss of shielding gas on the near UV, visible, and near IR regions of the arc spectrum.

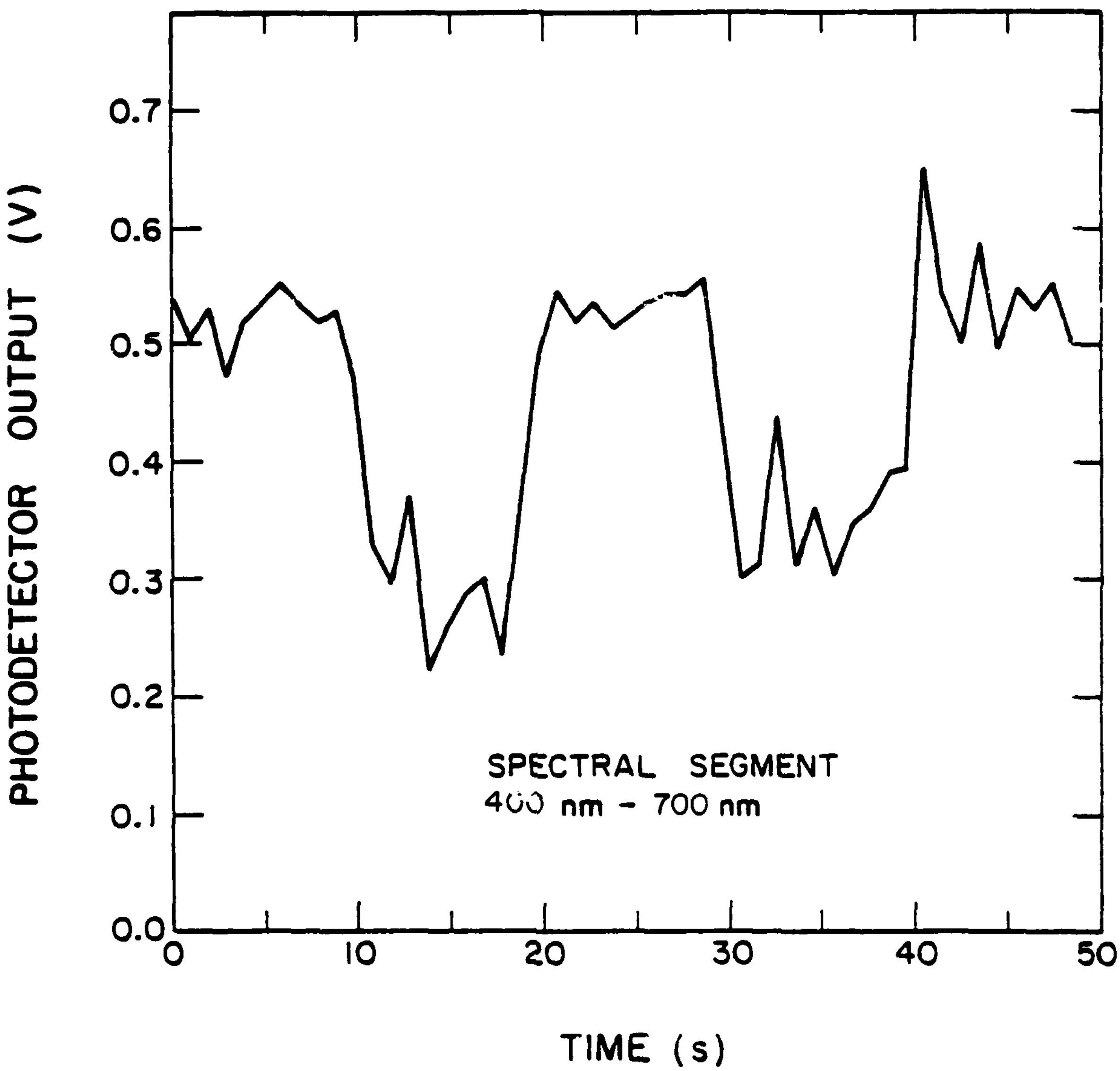


Figure 36. Total energy in the spectral segment from 400-700 nanometers.

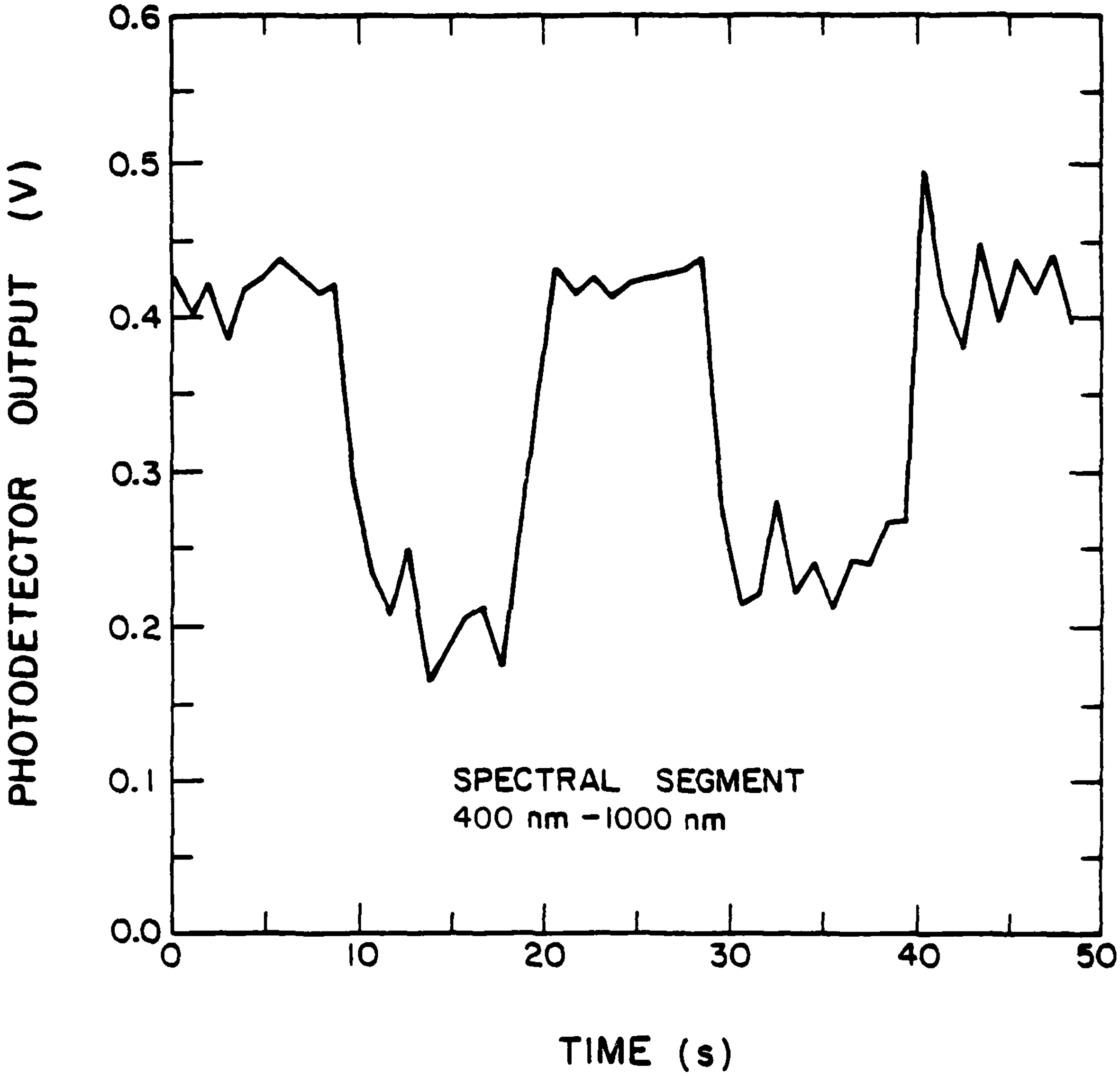


Figure 37. Total energy in the spectral segment from 400 to 1000 nanometers.

Figure 38 is a plot of the energy in the argon line from ̈14 to 816 nm. The energy in this line changes by almost a factor of six when the shielding gas is removed. Obviously, a very simple shielding gas monitor could be constructed by using a narrow-band filter and photodetector to measure the spectral energy in the 814 to 816 nm wavelength region.

The physical results of loss of shielding gas are easily seen in macro etched cross sections of the welds made in this experiment. Figure 39a is the normal weld (shielded), with deep weld metal penetration, a fairly small heat affected zone, and an absence of visible slag inclusions or porosity defects. In Figure 39b the weld made without shielding gas is shown. The weld contains gross porosity, a slag inclusion, and a large heat affected zone. The shape of the weld bead is also flatter and more irregular than that of the sound weld.

The second experiment was designed to determine the correlation between heat input and the arc spectrum. Heat input is defined as the arc current times the arc voltage divided by the travel speed, and is usually given in units of kilojoules per inch. In this experiment the heat input was varied by varying the arc current. Figure 40 is a plot of the current and voltage as a function of time. The current was varied from approximately 200 to 360 amperes. Since the travel speed was constant at ten inches per minute, this corresponds to a variation in the heat input from approximately 36 to 55 kilojoules per inch.

Figure 42 is a plot of the total spectral energy from 400 to 1000 nm as a function of heat input. Figures 42 and 43 are similar plots for the energy in the 400 to 700 nm region and 700 to 1000 nm region, respectively. In all

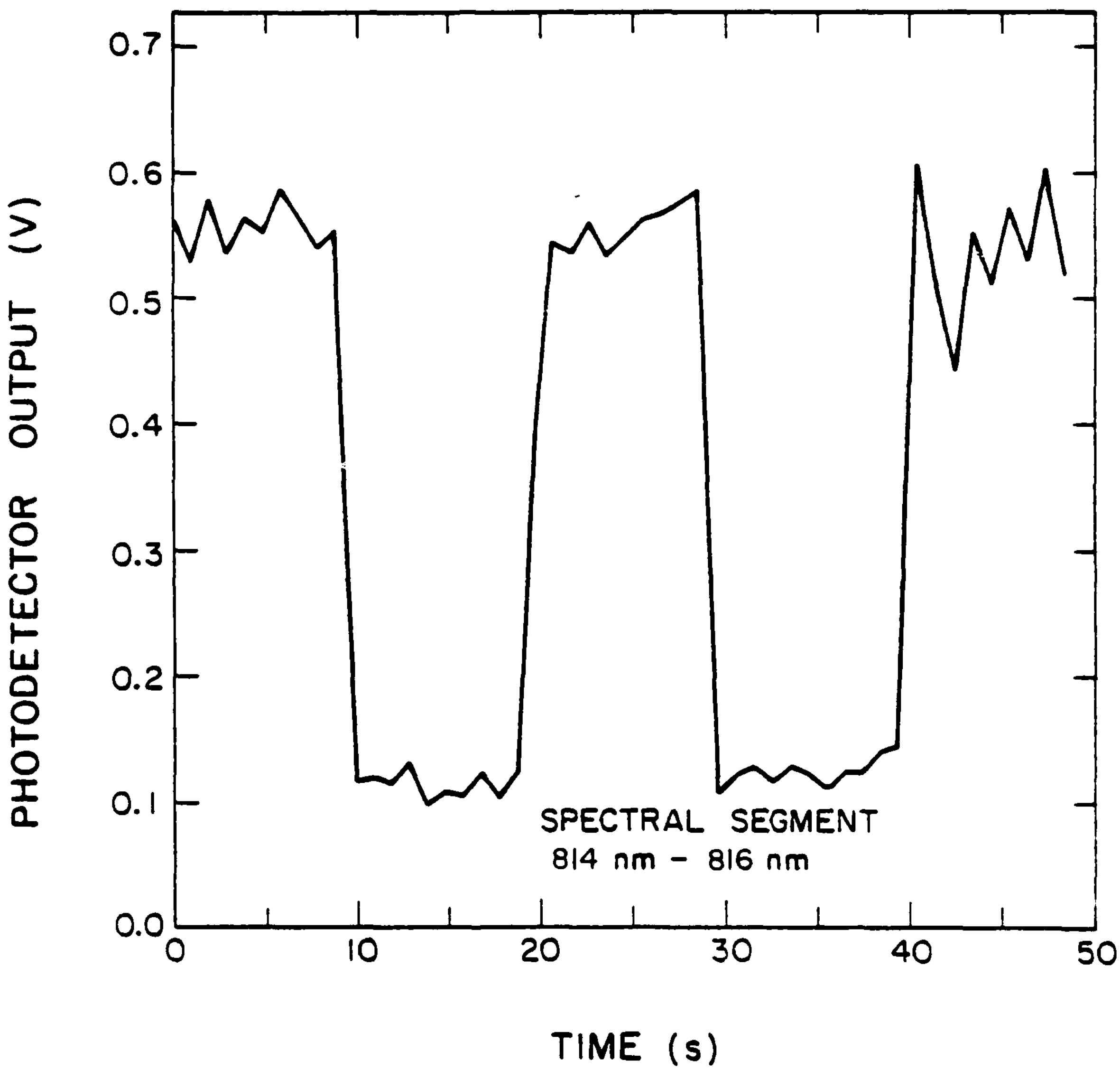


Figure 38. Total energy in the spectral segment from 814 to 816 nanometers.

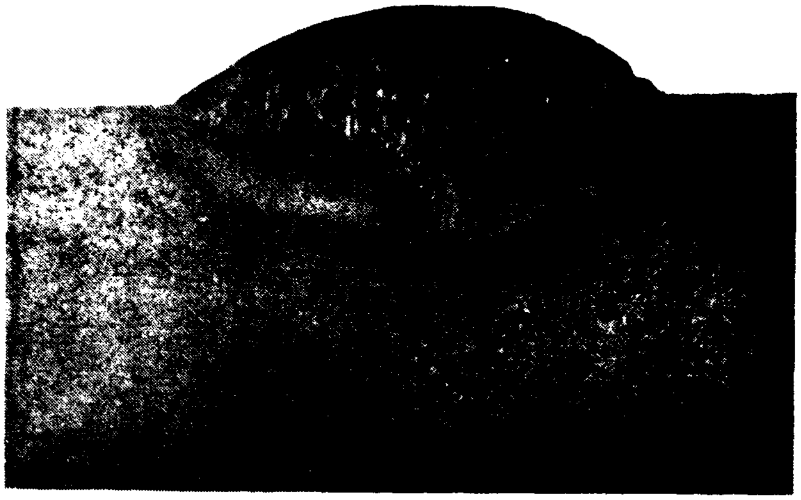


Figure 39. Macro etched across sections of welded joint. Figure 39a is the normal argon shielded weld while Figure 39b is the weld made without shielding gas.

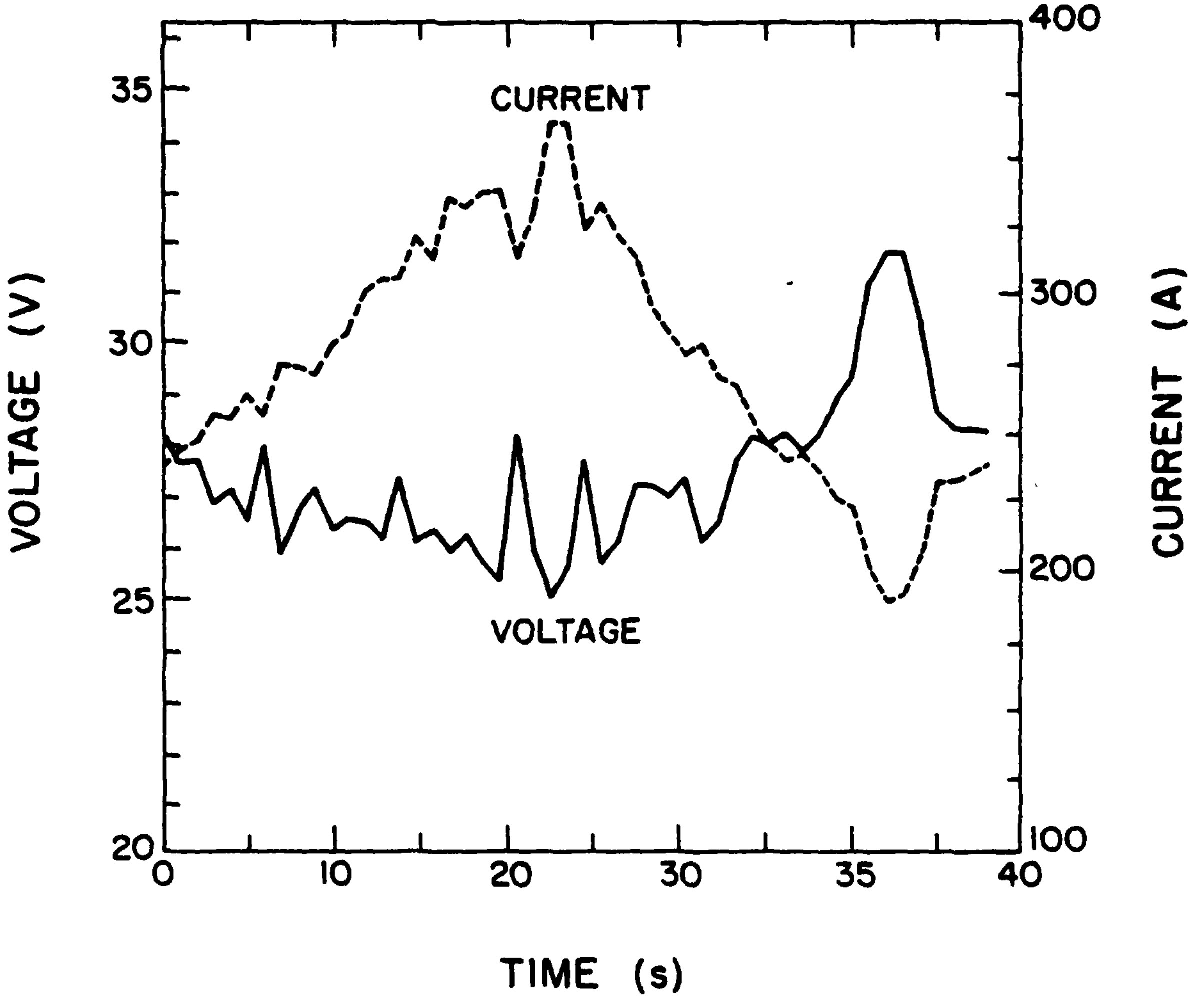


Figure 40. Variation of the arc voltage and current versus time. The arc current was varied between approximately 200 and 360 A.

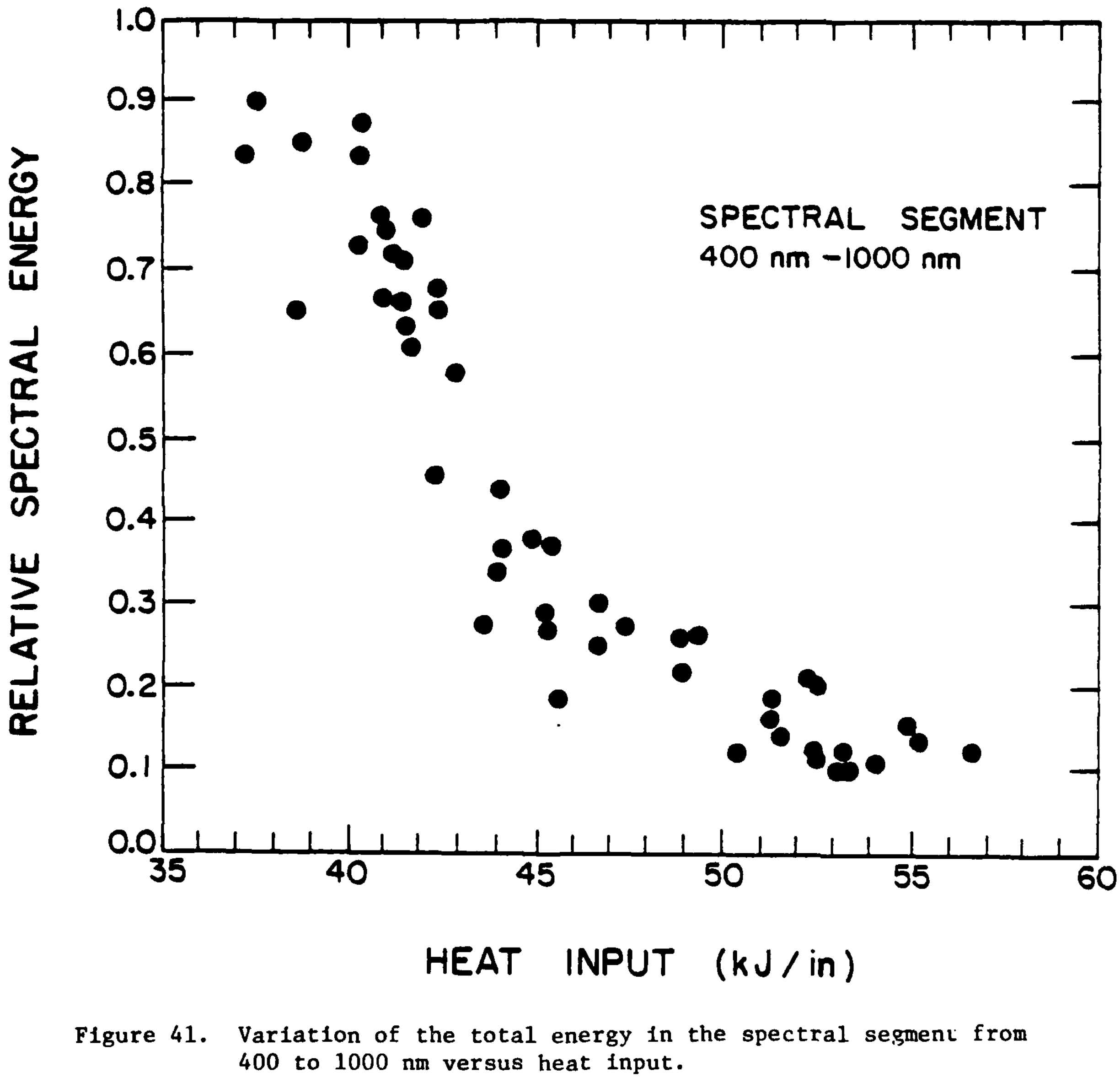


Figure 41. Variation of the total energy in the spectral segment from 400 to 1000 nm versus heat input.

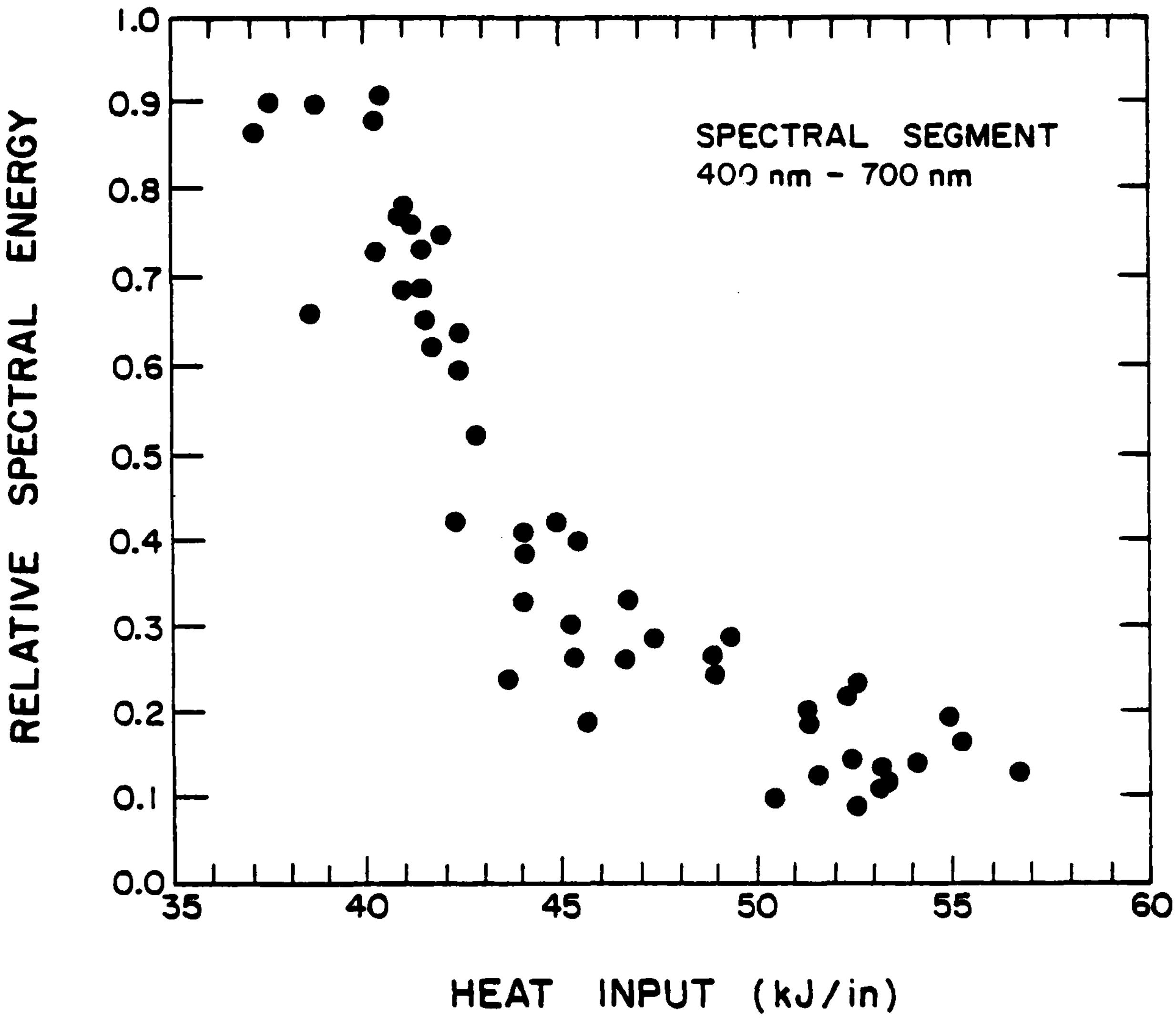


Figure 42. Variation of the total energy in the spectral segment from 400 to 700 nm versus heat input.

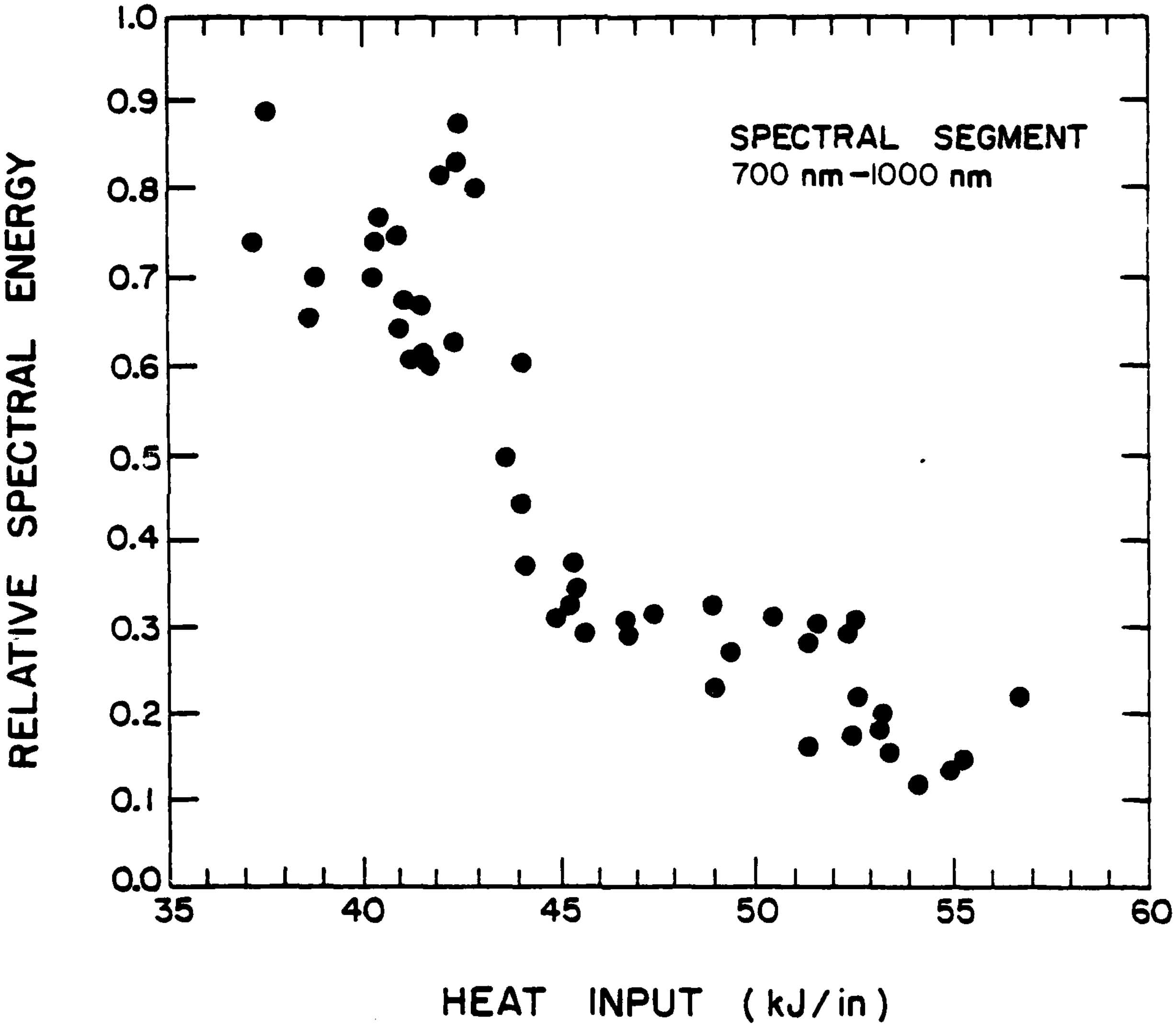


Figure 43. Variation of the total energy in the spectral segment from 700 to 1000 nm versus heat input.

three cases the general trend is for the spectral energy to decrease as the heat input increases. However, the decrease seems to be more pronounced and more systematic for the wavelength region between 400 to 700 nanometers. Because different regions of the spectrum behave differently as the heat input is changed, it may be possible to compute the heat input directly from the spectral data.

Both of the experiments described have been repeated several times at the CERL Welding Laboratory over a six-month period. Excluding hardware anomalies, the same results were obtained.

The real-time weld arc spectrum detection and analysis capabilities of this prototype optoelectronic system are demonstrated by the data presented. The confidence level of the system was established by reproducibility of results during the six-month testing period. An area for future development is resolution. Resolution improvements may prove to give additional weld quality information. In particular, hydrogen and sulfur contaminants may be detectable. Another area of development is the development of heat input/arc spectra correlation. This may be accomplished with a broader data base.

6. CONCLUSIONS

This report has described the software and hardware designs of the electro-optic Weld Quality Monitor. The system was developed to study the spectral and electrical characteristics of the weld arc. Included was a representative sample of data that was collected with the system. It is clear from observing changes in the weld arc spectrum that changes in arc voltage, current, and shielding gas flow are easily discernible in argon gas shielded welds. Additional experiments using different welding techniques are needed to establish the applicability of this system. Currently, weld parameter standards are either nonexistent or crude at best. It is hoped that, with the continued use and refinement of this system, standards will be established that provide improved weld integrity.

APPENDIX A

SPECIFICATIONS AND SCHEMATICS ON RETICON DIODE ARRAY AND SCANNING ELECTRONICS

ALIGNMENT PROCEDURE FOR THE RC-100B MOTHERBOARD WITH RC-104, 105, OR 106 AND "G" SERIES ARRAY

1) Jumper Connections. Split pads are provided to program the RC-100B board for the desired configuration. Refer to p __ (Drawing Number 011-0238) for correct configuration.

2) Monitor . .. Adjust R2 for the desired frequency, 1 MHz maximum. Adjust R11 for a 700 ns negative going pulse width.

3) Monitor P2-b. Set the desired start pulse interval, using rocker switches S1, S2, and S3.

4) Monitor TP2 and adjust R64 for a 100 ns pulse width.

5) Darken the array, monitor J1-1, and adjust R4 (put on the component side of the array board) so that the video signal is approximately centered at -5 V DC. Saturate the array, and readjust R4, if necessary, so no signal or switching spike is more negative than -8 V DC. Do not over-saturate.

6) Monitor P2-N. The video output will be a sample-and-hold boxcar signal.

7) Darken the array and adjust R36 until the video signal is centered around the blanking level. (Blanking is clamped at zero.)

8) Adjust R11 until optimum performance is observed on the video. Optimum adjustment of R11 results in a balance of maximum video output, minimum switching spikes, and fixed pattern tracking from dark to 90% of saturation.

9) With the array in the dark, readjust R36 if necessary to bring the video level with blanking.

SPECIFICATIONS

ELECTRICAL CHARACTERISTICS (25°C)

	Min	Typ	Max	Units
[1]Positive Supply Voltage V_p	+4.5	+5	+5.5	volts
Negative Supply Voltage V_n	-10.5	-10	-9.5	volts
Clock Voltage Low V_{cl}	-10.5	0	+1	volts
Clock Voltage High V_{ch}	V_p -1	+5	V_p	volts
Start Voltage Low V_{sl}	-10.5	0	+1	volts
Start Voltage High V_{sh}	V_p -1	+5	V_p	volts
Clock Pulse Width	0.2	—	—	usec
Start Pulse Width		See Fig. 7		
Clock Frequency f_c	—	—	1	MHz
Integration Time t_i	—	—	30	msec
[2]Clock Input Capacitance C_c	—	5	—	pF
[2]Start Input Capacitance C_s	—	5	—	pF
[2]Video Line Capacitance C_v				
RL-1024G	—	40	—	pF
RL-512G	—	20	—	pF
RL-256G	—	10	—	pF
RL-128G	—	5	—	pF
End-of-Scan Output Resistance	—	5	—	Kohm
D-C Power Dissipation	—	45	—	mwatts

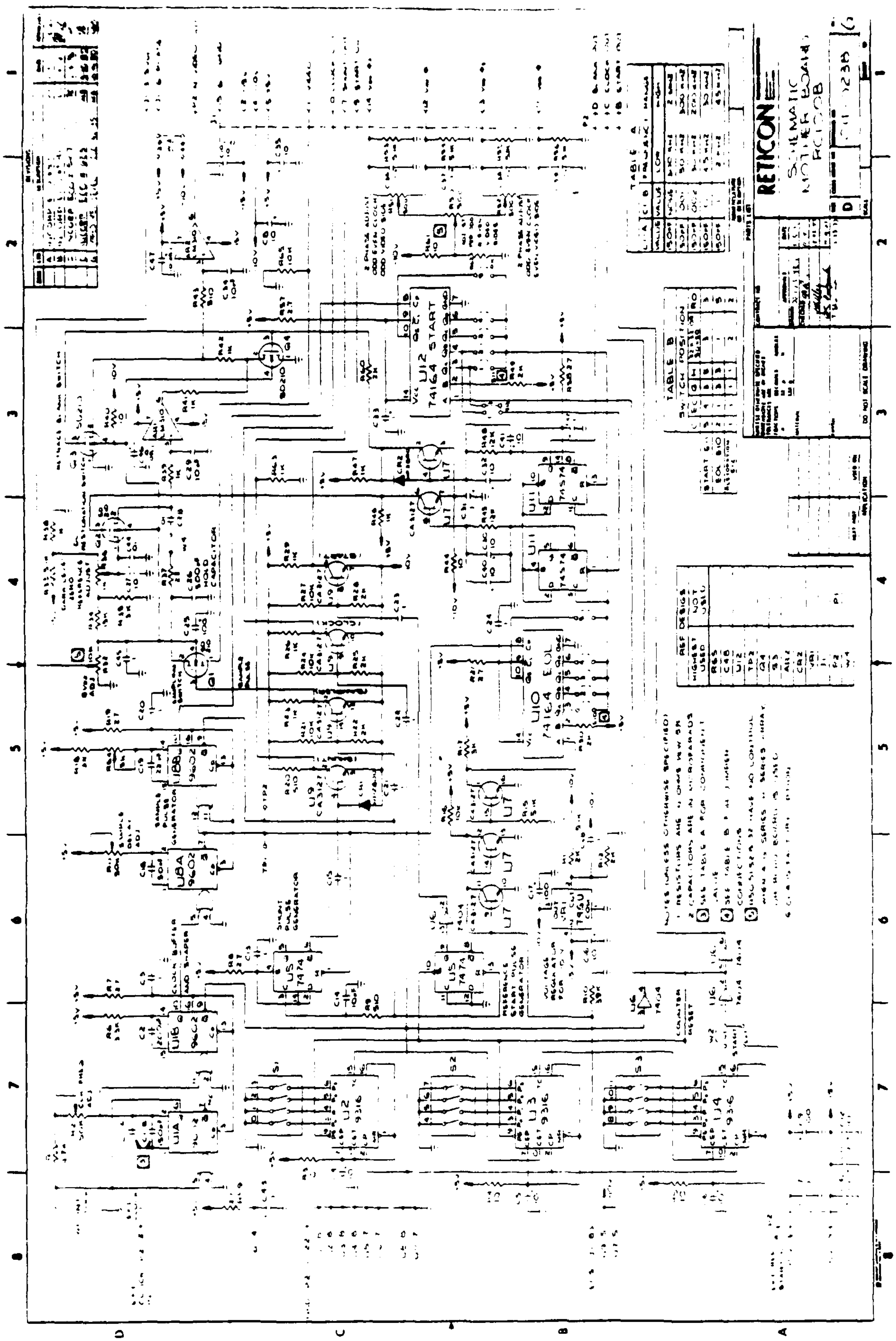
ELECTRO-OPTICAL CHARACTERISTICS (25°C)

	Min	Typ	Max	Units
Diode Center-to-Center Spacing	—	25	—	μm
Diode Aperture Width	—	26	—	μm
[3]Photodiode Sensitivity	—	2.5	—	pA/μwatt/cm²
[3]Non-uniformity of Sensitivity				
RL-128G	—	4	8	±%
RL-256G	—	4	8	±%
RL-512G	—	5	10	±%
RL-1024G	—	7	14	±%
[3]Saturation Exposure	—	1.3	—	μjoules/cm²
Saturation Charge	—	3.2	—	pcoul

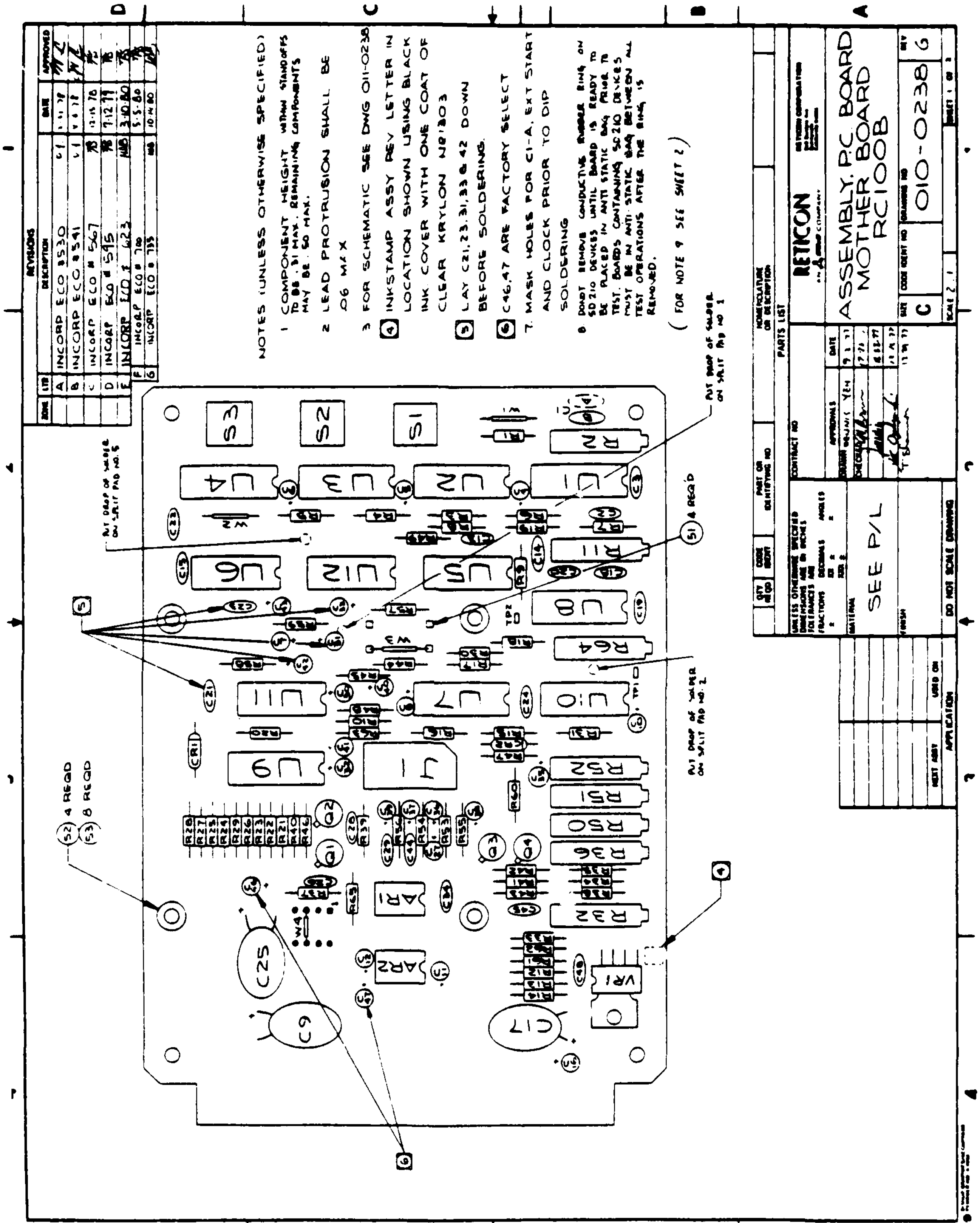
NOTES:

1. No terminal should ever be allowed to go more positive than V_p.
2. Measured with nominal power supply voltages.
3. Measured using light source of Fig. 4.

(From Reticon Corp.)



(From Reticon Corp.)



(From Reticon Corp.)

AD-A118 156 CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL F/G 13/8
MICROPROCESSOR CONTROLLED WELD ARC SPECTRUM ANALYZER FOR QUALIT--ETC(U)
JUN 82 M E NORRIS, C S GARDNER

UNCLASSIFIED CERL-TM-M-317 NL

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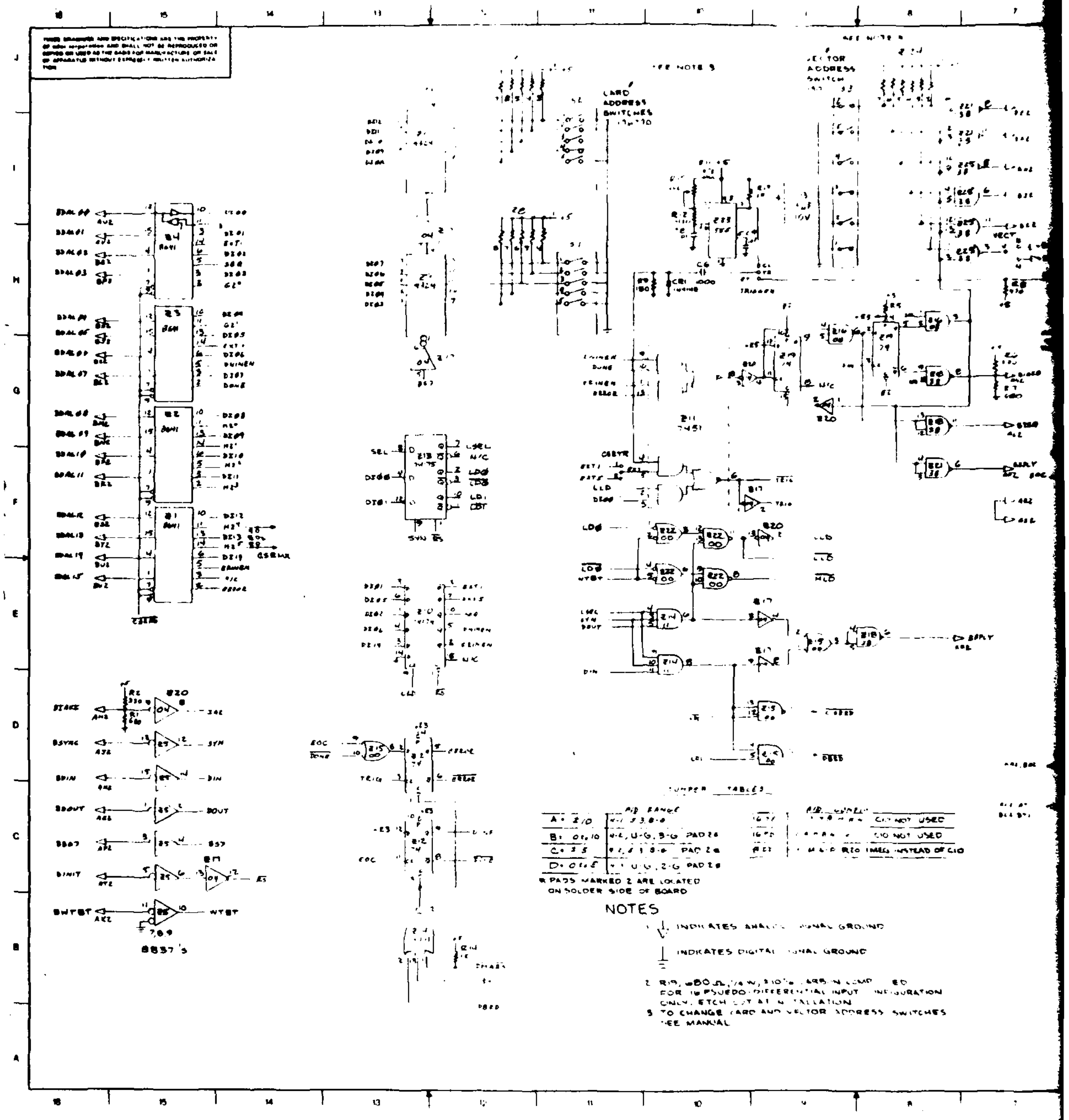
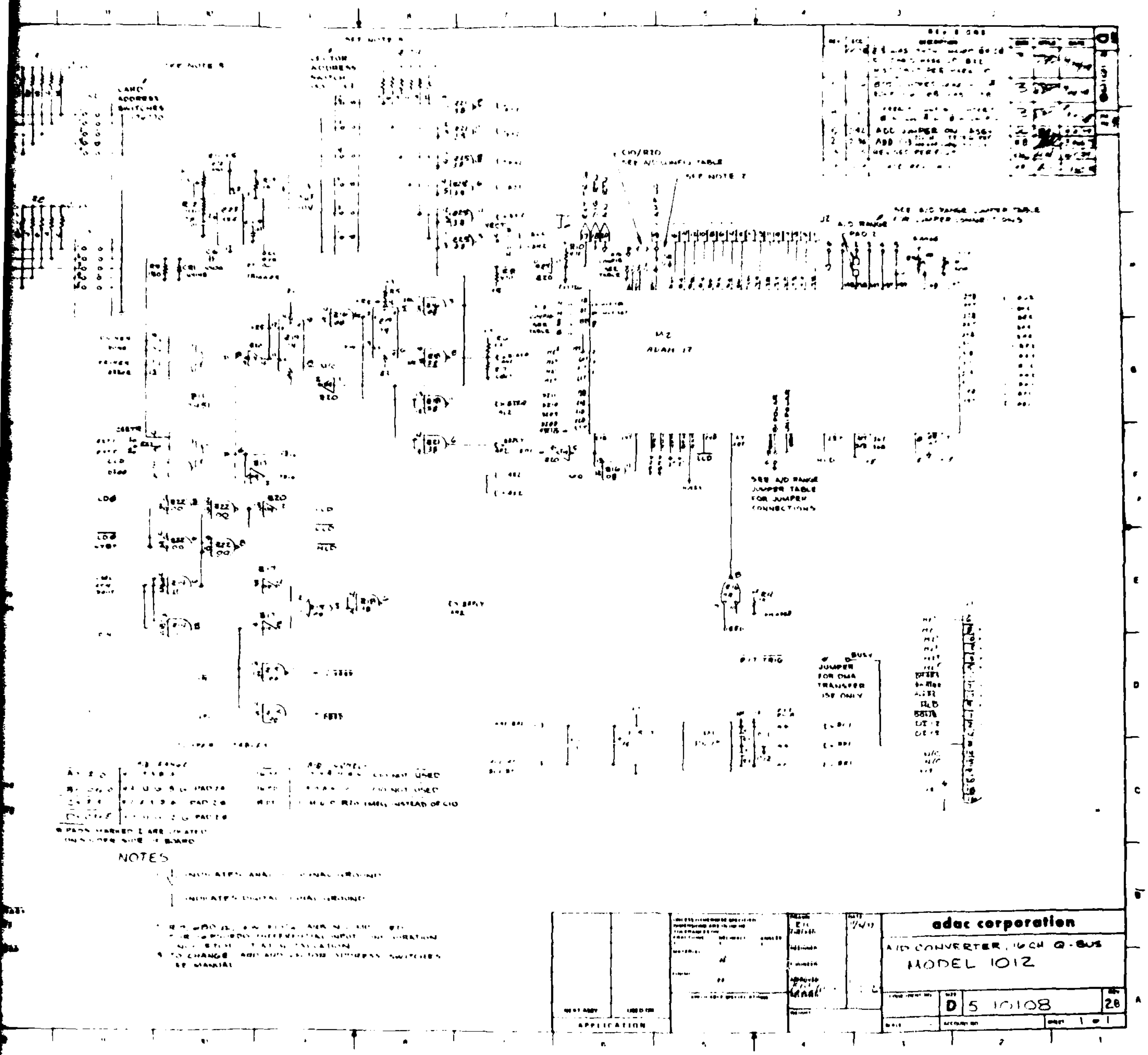
APPENDIX B

SCHEMATIC AND CALIBRATION PROCEDURE FOR THE ADAC 1012 A/D CONVERTER



(From ADAC Corp.)



(From ADAC Corp.)

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CALIBRATION PROCEDURE FOR THE ADAC 1012 A/D CONVERTER

1) Offset Adjustment

With the A/D board in the backplane of the LSI-11, apply the precise voltage shown below to any channel according to the range that has been jumpered on the board. Force a conversion through ODT and open the output buffer. The buffer should contain the code shown below. If not, adjust the Offset until the least significant bit of the code alternates between 1 and 0.

RANGE	INPUT	CODE
-10 V to + 10 V	+9.9976 V	
0 V to + 10 V	+0.0012 V	000000/1 UNIPOLAR
- 5 V to + 5 V	-4.9988 V	004000/1 BIPOLAR
0 V to + 5 V	+0.0006 V	

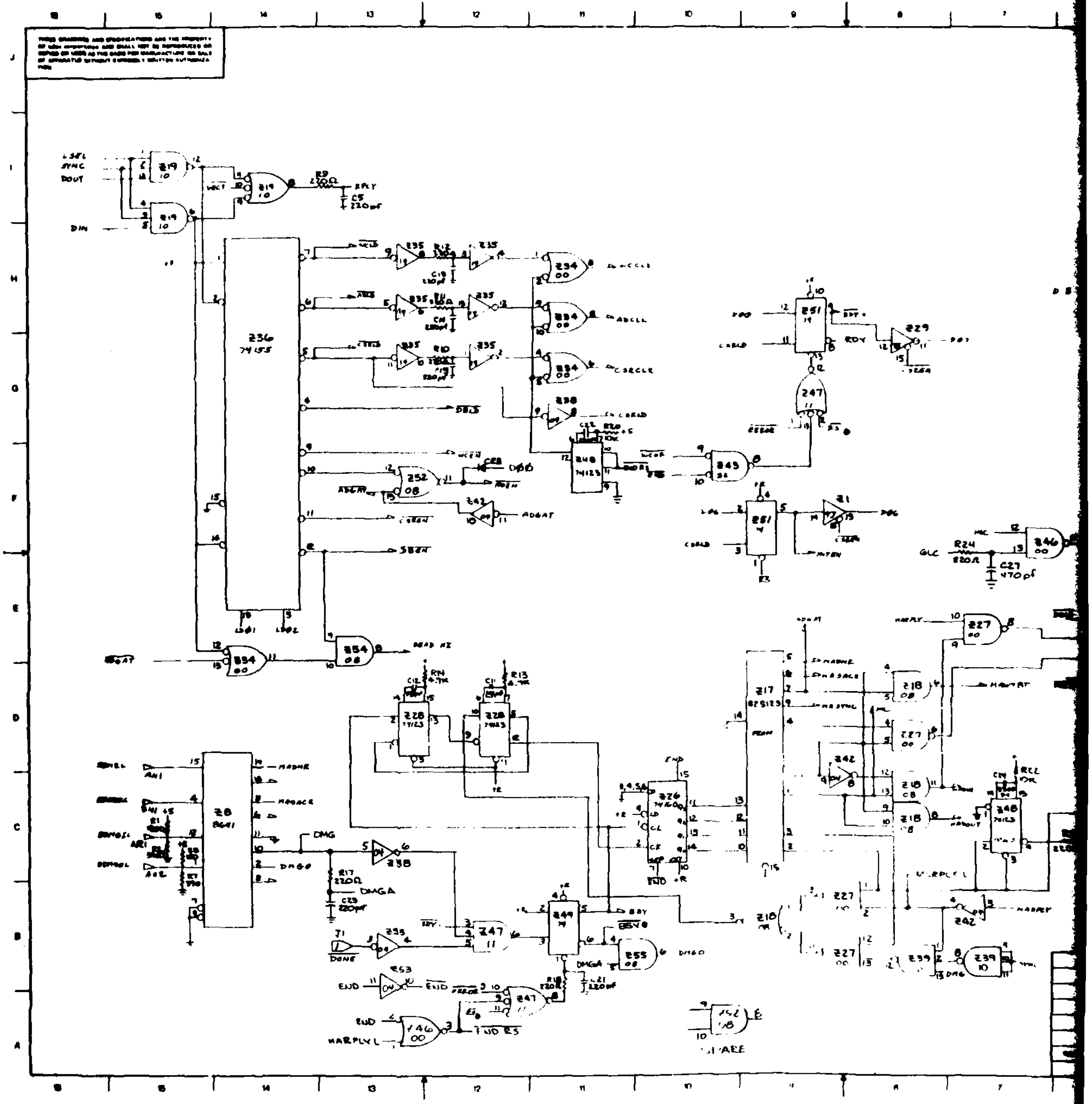
2) Range Adjustment

After the Offset has been adjusted, the range may be adjusted. Follow the same procedure outlined above, except this time use the values given below and make adjustments with the Range pot on the board.

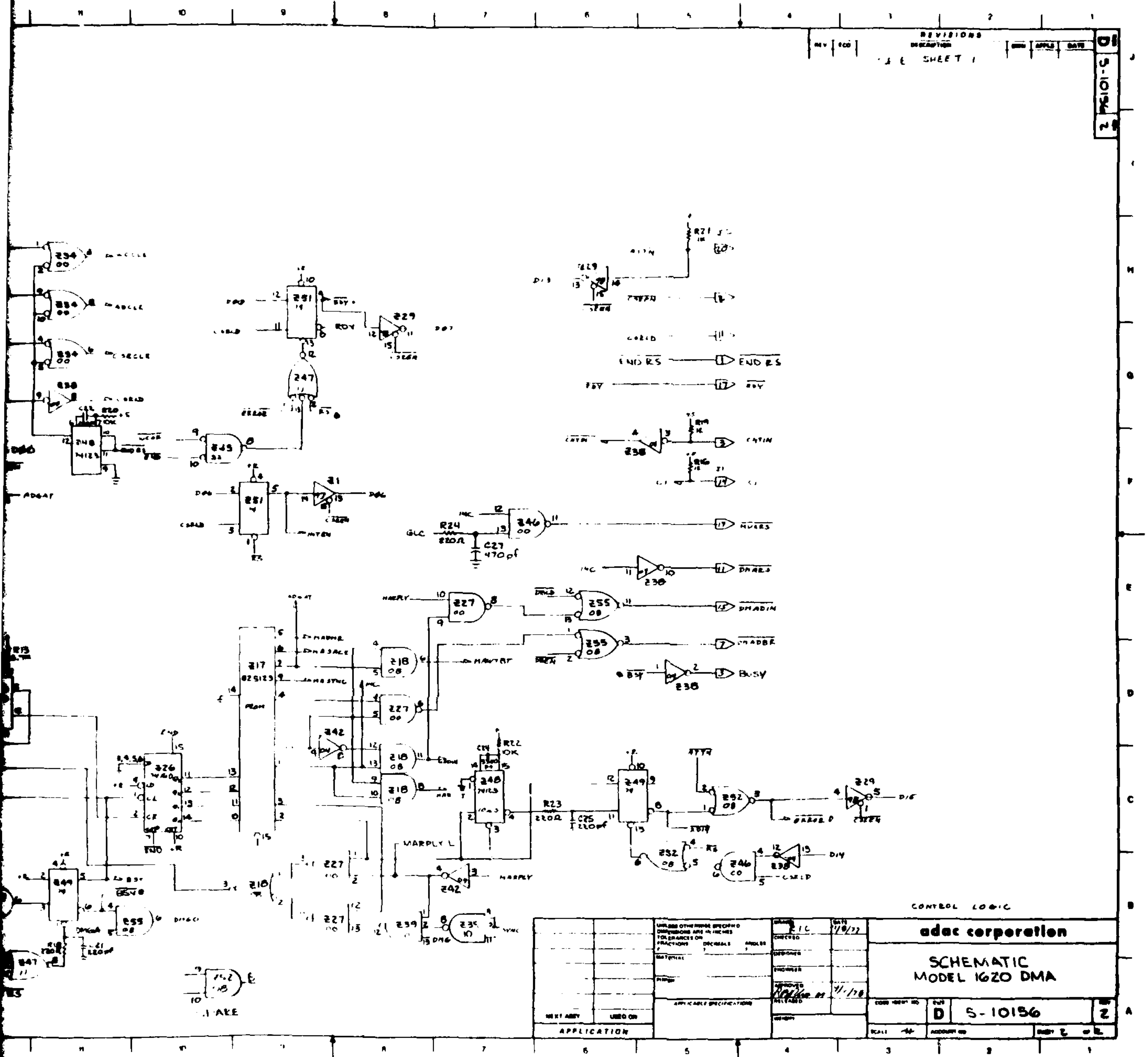
RANGE	INPUT	CODE
-10 V to +10 V	+9.9927 V	
0 V to +10 V	+9.9963 V	7776/7 UNIPOLAR
- 5 V to + 5 V	+4.9963 V	3776/7 BIPOLAR
0 V to + 5 V	+4.9982 V	

APPENDIX C

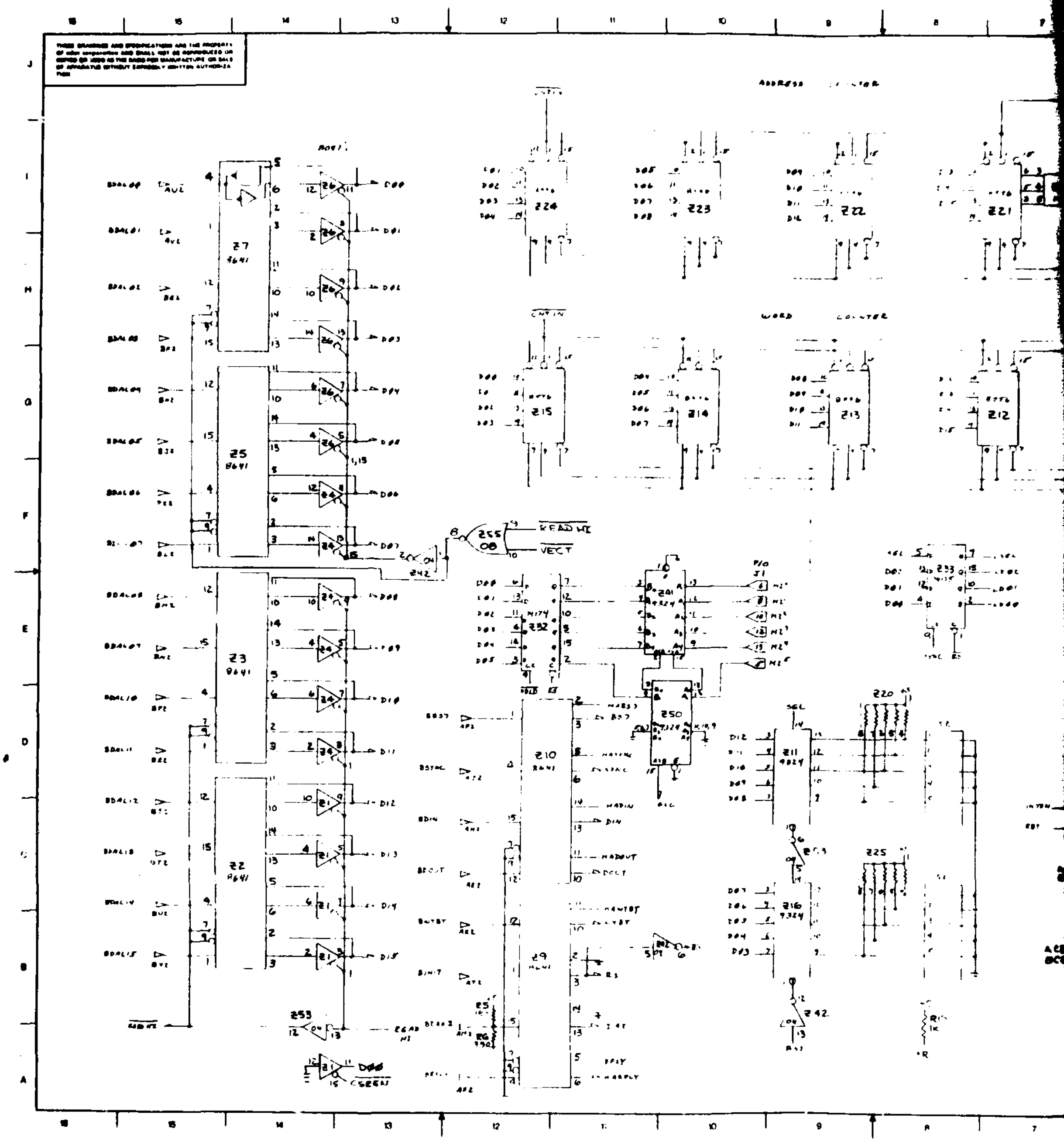
SCHEMATICS FOR THE ADAC 1620 DMA



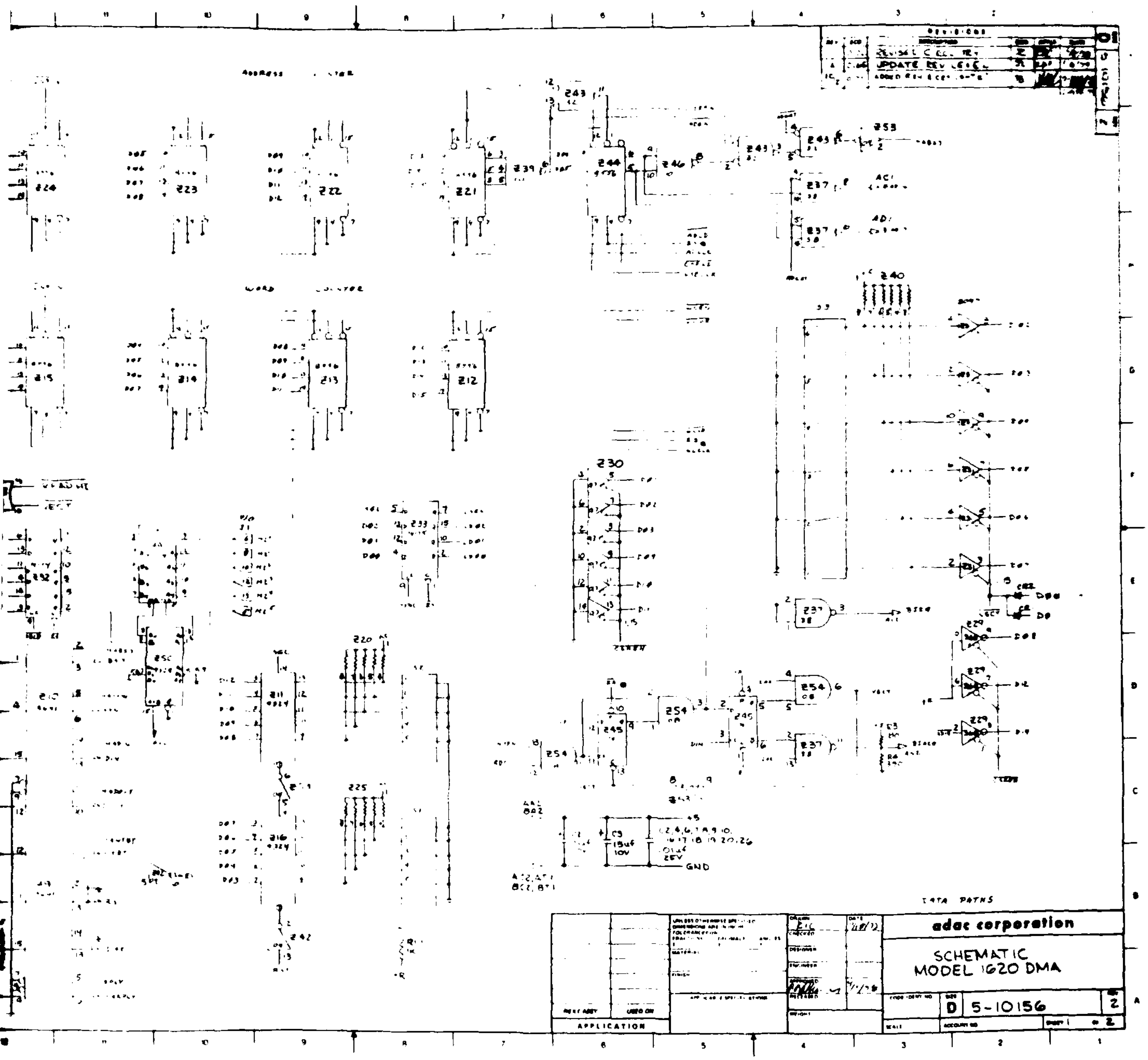
(From ADAC Corp.)



(From ADAC Corp.)



(From ADAC Corp.)



(From ADAC Corp.)

APPENDIX D

THE MACRO PROGRAM FOR THE WQM

```
INIT.MAC        MACRO V03.02  00:37:30 PAGE 1

                                                    .TITLE  INIT.MAC
                                                    .GLOBL  DMAIT
  000000  105737  172414                   DMAIT:  TSTB    @#172414
;IS DMA BUSY?
  000004  100375                                   BPL     DMAIT
;IF YES WAIT.
  000006  012737  176000  172410                   MOV     #176000,@#172410
;SET WORD COUNT TO 1024 ON DMA.
  000014  012737  000000' 172412                   MOV     #TOT,@#172412
;SET MEMORY ADDRESS TO DATA ARRAY ON DMA.
  000022  012737  000001  172414                   MOV     #1,@#172414
;ENABLE DMA.
  000030  012737  000001  172416                   MOV     #1,@#172416
;SET MUX COMPARISON REGISTER TO ONE      CHANNEL ON DMA.
  000036  012737  000032  177000                   MOV     #32,@#177000
;SET UNITY GAIN,EXTERNAL ENABLE, AND     CHANNEL 0 ON A/D.
  000044  012737  000001  167772                   MOV     #1,@#167772
;ENABLE SYNCHRONIZATION CIRCUITRY/ START SCAN.
  000052  105737  172414                   1$:     TSTB    @#172414
;IS DMA BUSY?
  000056  100375                                   BPL     1$
;IF YES, WAIT.
  000060  005737  177002                           TST     @#177002
;CLEAR A/D DATA BUFFER.
  000064  012737  000000  167772                   MOV     #0,@#167772
;DISABLE SYNCHRONIZATION CIRCUITRY.
  000072  012737  000000  172414                   MOV     #0,@#172414
;DISABLE DMA.
  000100  012737  000431  177000                   MOV     #431,@#177000
;SET UNITY GAIN, CHANNEL 1, AND START    CONVERSION ON A/D.
  000106  105737  177000                   LP1:    TSTB    @#177000
;IS CONVERSION DONE?
  000112  100375                                   BPL     LP1
;IF NOT WAIT.
  000114  012701  000020'                          MOV     #TOT+16.,R1
;SET R1 TO NINTH WORD IN DATA ARRAY TOT.
  000120  013721  177002                           MOV     @#177002,(R1)+
;STORE VOLTAGE FROM A/D DATA BUFFER     AND INCREMENT LOCATION IN TOT.
  000124  012737  001031  177000                   MOV     #1031,@#177000
;SET UNITY GAIN, CHANNEL 2, AND START    CONVERSION ON A/D.
  000132  105737  177000                   LP2:    TSTB    @#177000
;IS CONVERSION DONE YET?
```

```
     23 000136  100375                                  BPL      LP2
;IF NOT WAIT.
     24 000140  013721  177002                          MOV      @#177002,(R1)+
;STORE CURRENT FROM A/D DATA BUFFER     AND INCREMENT LOCATION IN TOT.
     25 000144  012737  001431  177000                  MOV      #1431,@#177000
;SET UNITY GAIN, CHANNEL 3, AND START     CONVERSION ON A/D.
     26 000152  105737  177000                  LP3:    TSTB     @#177000
;IS CONVERSION DONE YET?
     27 000156  100375                                  BPL      LP3
;IF NOT, WAIT.
     28 000160  013711  177002                          MOV      @#177002,(R1)
;STORE TRAVEL SPEED FROM A/D DATA BUFFER INTO TOT.
     29 000164  000207                          END1:   RTS      PC
;RETURN FROM SUBROUTINE.
     30 000000                                          .PSECT   TOT,RW,D,GBL,REL
,OVR     ;MAKE DATA ARRAY TOT READ/WRITE
     31
;DIRECT ACCESS,GLOBAL
     32
;RELOCATABLE,AND OVERLAYED.
     33 000000                                  TOT:    .BLKW    1024.
;DATA ARRAY.
     34         000000'                                 .END     DMAIT
;END OF PROGRAM




INIT.MAC        MACRO V03.02  00:37:30 PAGE 1-1
SYMBOL TABLE

DMAIT    000000RG         LP1      000106R         LP2      000132R
LP3      000152R          TOT      000000R     002
END1     000164R

. ABS.   000000     000
         000166     001
TOT      004000     002
ERRORS DETECTED:  0

VIRTUAL MEMORY USED:  299 WORDS  ( 2 PAGES)
DYNAMIC MEMORY AVAILABLE FOR  57 PAGES
DK:INIT,DK:INIT=DK:INIT
```

APPENDIX E

THE FORTRAN PROGRAM FOR THE WQM

```
FORTRAN IV      V02.04

        C     PROGRAM AQSPEC
        C     WRITTEN BY: MICHAEL E. NORRIS
        C    300 E.E.R.L.
        C     UNIVERSITY OF ILLINOIS?
        C     URBANA,ILLNOIS  61801
        C
        C
        C
        C     AQSPEC IS A FORTRAN PROGRAM CREATED TO ACQUIRE
        C     PARAMETERS ASSOCIATED WITH WELDS.  USING A
        C     SPECTROMETER AND OTHER HARDWARE IT GATHERS
        C     SPECTRAL AVERAGES, WELD CURRENT, VOLTAGE,
        C     AND TRAVEL SPEED.  IT WAS DEVELOPED UNDER A
        C     CONTRACT WITH THE ARMY CORPS OF ENGINEERS,
        C     CONSTUCTION ENGINEERING RESEARCH LABS,
        C     CHAMPAIGN, ILLINOIS.
        C
        C
        C     DBLK CONTAINS THE RADIX 50 REPRESENTATION OF THE DEVICE
        C     AND FILE SPECIFICATION. AVSCAN IS THE NUMBER OF
        C     SCANS TO BE AVERAGED.
        C
0001          INTEGER*2  DBLK(4),AVSCAN
        C
        C     LBLK CONTAINS THE ASCII REPRESENTATION OF THE FILE
        C     NAME TO BE STORED ON A FLOPPY DISK.
        C
0002          BYTE        LBLK(6)
        C
        C     JTIME WILL BE USED TO STORE THE TIME IN TICKS.
        C
0003          INTEGER*4  JTIME
        C
        C     NA WILL SERVE AS AN ACCUMULATOR FOR AVERAGING SPECTRAL SCANS

        C
0004          DIMENSION NA(1024)
        C
        C     IDNAM CONTAINS THE RADIX 50 REPRESENTATION OF
        C     THE  DISK DEVICE HANDLER.
        C
0005          DATA       IDNAM/2RDY/
        C
        C     SET UP DEVICE AND FILE SPECIFICATION IN RADIX 50.
```

```
C
      DATA       DBLK(1)/3RDY1/,DBLK(4)/3RDAT/
C
C     SET UP DATA FILE AND OVERLAY IT WITH THE MACRO DATA FILE.
C
      COMMON     /TOT/IA(1024)
C
C     QUERY THE USER AS FOLLOWS FOR DATA PARAMETERS
C     GIVEN.
C
44    TYPE 45
```

FORTRAN IV   V02.04

```
45    FORMAT(' DO YOU WISH TO LOOK AT AN OLD FILE?')
      TYPE 46
46    FORMAT(' TYPE Y FOR YES, N FOR NO')
      ACCEPT 47,LKUP
47    FORMAT(A1)
      IF(LKUP.EQ.'Y'.OR.LKUP.EQ.'N') GO TO 49
      TYPE 152
      GO TO 44
49    IF(LKUP.EQ.'Y')GO TO 465
50      TYPE 60
60    FORMAT(' DO YOU WISH TO TAKE A SINGLE OR AVERAGE SCAN?')
      TYPE 80
80      FORMAT(' TYPE S OR A')
      ACCEPT 100,SCAN
100     FORMAT(A1)
      IF(SCAN.EQ.'S') GO TO 180
      IF(SCAN.EQ.'A') GO TO 120
101   TYPE 110
110     FORMAT(' ILLEGAL CHARACTER')
      GO TO 50
120     TYPE 130
130     FORMAT(' HOW MANY SPECTRA ARE TO BE AVERAGED?')
        TYPE 140
140     FORMAT(' TYPE A NUMBER BETWEEN ONE AND NINE')
      ACCEPT 150,AVSCAN
150   FORMAT(I2)
```

```
      IF(AVSCAN.LT.9.AND.AVSCAN.GT.0) GO TO 151
      TYPE 152
152   FORMAT(' INVALID CHARACTERS.')
      GO TO 120
151   TYPE 155
155   FORMAT(' HOW MANY SCANS ARE TO BE TAKEN?')
      TYPE 157
157   FORMAT(' TYPE UP TO A THREE DIGIT NUMBER.')
      ACCEPT 156,IBLONO
      IF(IBLONO.GT.0.AND.IBLONO.LT.200) GO TO 158
      TYPE 152
      GO TO 151
C
C     ADJUST IBLONO TO REFLECT BLOCKS RATHER THAN SCANS.
C
158   IBLONO=IBLONO*4
156   FORMAT(I3)
      TYPE 160
160   FORMAT(' ENTER A SIX CHARACTER FILE NAME HERE:')
      ACCEPT      170,(LBLK(J),J=1,6)
170   FORMAT(6A1)
C
C     CONVERT FILE NAME FROM ASCII TO RADIX 50 AND PLACE IN
C     DEVICE AND FILE SPECIFICATION.
C
      CALL        IRAD50(6,LBLK,DBLK(2))
C
C     OBTAIN FLOPPY DISK HANDLER AND CHECK FOR AN ERROR.

FORTRAN IV      V02.04

C
      IF(IFETCH(IDNAM) .NE. 0) STOP 'FETCH ERROR'
C
C     ALLOCATE A CHANNEL FOR DATA TRANSFER FROM HARD
C     MEMORY TO FLOPPY DISK AND CHECK FOR AN ERROR.
C
      ICHAN=IGETC()
      IF(ICHAN.LT.0) STOP 'CHANNEL ERR1'
C
```

```
C      GET THE FLOPPY DISK AREA, READY IT FOR WRITING,
C      AND CHECK FOR AN ERROR.
C
       IF(IENTER(ICHAN,DBLK,0) .LT. 0) STOP 'ENTER ERR'
174    TYPE 175
175      FORMAT(' AT THIS TIME THE SYSTEM IS READY')
       TYPE 176
176      FORMAT(' TYPE R TO START RUN OR A TO ABORT.')
C
C      DISABLE KEYBOARD INTERRUPT UNTIL DATA TRANSFER
C      HAS BEEN MADE.
C
       CALL IPOKE("44,"10100.OR.IPEEK("44))
C
C      RESET BLOCK COUNTER.
C
201    KLOG=0
202    ACCEPT 177,KEY
177    FORMAT(A1)
178      IF(KEY.EQ.'R') GO TO 300
       IF (KEY .EQ. 'A') GO TO 590
       GO TO 202
C
C      RESET THE DATA BUFFER.
C
300    DO 299 K=1,1024
299    NA(K)=0
C
C      CONDUCT AVSCAN NUMBER OF SCANS SUCCESSIVELY
C      ADDING THE DATA IN ARRAY NA.
C
       DO 302 J=1,AVSCAN
C
C      CALL MACRO SUBROUTINE TO INITIATE SPECTRAL SCAN AND
C      ACQUISITION OF VOLTAGE, CURRENT, AND TRAVEL SPEED.
C
       CALL DMAIT
C
C      ADD SUCCESSIVE SCANS.
C
       DO 301 I=7,1024
301    NA(I)=NA(I)+IA(I)
302    CONTINUE
C
C      GET TIME IN TICKS PAST MIDNIGHT.
```

```
      C
            CALL        GTIM(JTIME)
      C
      C     CONVERT THE TICKS FOUND ABOVE INTO HOURS, MINUTES,
      C     SECONDS, AND TICKS.
      C
            CALL        CVTTIM(JTIME,NA(4),NA(5),NA(6),NA(8))
      C
      C     STORE THREE INTEGER VALUES CORRESPONDING TO THE
      C     MONTH, DAY, AND YEAR.
      C
            CALL        IDATE(NA(1),NA(2),NA(3))
      C
      C     STORE NUMBER OF SCANS AVERAGED.
      C
            NA(7)=AVSCAN
      C
      C     WRITE THE DATA ONTO THE FLOPPY DISK.  IF AN ERROR
      C     OCCURS, REPORT IT.
      C
            IF(IWRITW(1024,NA,KLOG,ICHAN).LT.0)STOP 'WRITE ERR1'
      C
      C     ADVANCE BLOCK NUMBER BY FOUR OR 1024 WORDS.
      C
            KLOG=KLOG+4
      C
      C     CHECK TO SEE IF THE NUMBER OF SCANS TAKEN (KLOG)
      C     EQUALS THE NUMBER DESIRED TO BE AQUIRED (IBLONO).
      C
            IF(KLOG.GE.IBLONO)GO TO 400
            GO TO 300
      C
      C     THE FOLLOWING CODE IS USED FOR CALIBRATION OF A
      C     SINGLE SCAN.
      C
      C     TAKE A SCAN.
      C
      180   CALL' DWAIT
            DO 215  I=1,1024
```

```
      C
      C     CONVERT THE A/D VALUE TO ITS CORRESPONDING DECIMAL
      C     VALUE.
      C
0099  215   IA(I)=((4095-IA(I))+1)*4.88
      C
      C     TYPE OUT A SINGLE SCAN.
      C
0100        DO 220 I=0,1016,8
0101  220     TYPE *,(IA(I+J),J=1,8)
0102        GO TO 590
      C
      C     CLOSE OUT THE CHANNEL AND CLEAR THE BLOCK COUNT
      C
0103  400   CALL        CLOSEC(ICHAN)
```

```
FORTRAN IV      V02.04

      C
      C     RESTORE TERMINAL INTERRUPTS.
      C
0104        CALL        IPOKE("44,"167677 .AND. IPEEK("44))
0105  405         TYPE  410
0106  410     FORMAT(' DO YOU WISH TO SEE THE RESULTS?')
0107        ACCEPT 420,IANS
0108  420     FORMAT(A1)
0109        IF(IANS.EQ.'Y'.OR.IANS.EQ.'N') GO TO 421
0111        TYPE 152
0112        GO TO 405
0113  421   IF(IANS.EQ.'Y')GO TO 465
0115        GO TO 561
0116  465     TYPE 470
0117  470     FORMAT(' WHAT FILE CODE WORD DO YOU YOU WISH TO ACCESS?')
0118        TYPE 480
0119  480     FORMAT(' TYPE SIX CHARACTER CODE')
0120        ACCEPT 490,(LBLK(I),I=1,6)
0121  490   FORMAT(6A1)
0122  485   TYPE 481
0123  481   FORMAT(' TYPE A THREE DIGIT SCAN NUMBER')
0124        ACCEPT 491,KLOG
```

```
0125  491   FORMAT(I3)
      C
      C     ADJUST THE NUMBER OF SCANS TO REFLECT THE CORRESPONDING
      C     BLOCK VALUE.
      C
0126        KLOG=KLOG*4
      C
      C     CONVERT FILE NAME TO RAD50.
      C
0127        CALL        IRAD50(6,LBLK,DBLK(2))
      C
      C     OBTAIN FLOPPY DISK DEVICE HANDLER AND CHECK FOR AN ERROR.
      C
0129        IF(IFETCH(IDNAM).NE.0)STOP'FETCH ERR2'
      C
      C     ALLOCATE A CHANNEL FOR DATA TRANSFER.
      C
0130        ICHAN=IGETC()
      C
      C     CHECK FOR CHANNEL ALLOCATION ERROR.
      C
0131        IF (ICHAN.LT.0)STOP 'CHANNEL ERR2'
      C
      C     LOCATE DESIRED FILE ON FLOPPY DISK AND CHECK FOR AN ERROR.
      C
0133        IF(LOOKUP(ICHAN,DBLK).LT.0)STOP 'BAD LOOKUP'
      C
      C     READ FILE FROM FLOPPY AND STORE IT IN NA AND CHECK FOR AN ER
ROR.
      C
0135        IF(IREADW(1024,NA,KLOG,ICHAN).LT.0)STOP 'READ ERR'
      C
      C     CLOSE OUT THE CHANNEL.



FORTRAN IV      V02.04

      C
0137        CALL CLOSEC(ICHAN)
0138        KLOG=0
      C
```

```
C      PRINT OUT THE DATA READ FROM THE FLOPPY.
C
             TYPE 520,(LBLK(I),I=1,6)
       520     FORMAT(' FILENAME:',6A1)
             TYPE 530,NA(1),NA(2),NA(3)
       530     FORMAT(' DATE:',I2,' -',I2,' -',I2)
             TYPE 540,NA(4),NA(5),NA(6),NA(8)
       540     FORMAT(' TIME=',I2,' :',I2,' :',I2,' :',I2)
C
C      CONVERT SPECTRAL BINARY VALUES TO CORRESPONDING
C      DECIMAL VALUES.
C
             DO 547,I=12,1024
       547   NA(I)=((4095-(NA(I)/NA(7)))+1)*4.88
             DO 548 I=9,11
       548   NA(I)=((NA(I)/NA(7))+1)*4.88
C
C      CONVERT VOLTAGE,CURRENT, AND TRAVEL SPEED
C      BINARY VALUES TO CORRESPONDING DECIMAL VALUES
C      AND PRINT THE DATA.
C
             TYPE        1000,NA(7)
      1000   FORMAT(' AVERAGE NO. OF SCANS=',I2)
             TYPE        1001,NA(9)
      1001   FORMAT(' VOLTAGE=',I5)
             TYPE        1002,NA(10)
      1002   FORMAT(' CURRENT=',I5)
             TYPE        1003,NA(11)
      1003   FORMAT(' TRAVEL SPEED=',I5)
             TYPE        *,(NA(I),I=12,16)
             DO 550 I=16,1016,8
       550     TYPE *, (NA(I+J),J=1,8)
C
C      QUERY THE USER ABOUT THE COURSE OF ACTION
C      TO BE TAKEN AS FOLLOWS:
C
       551   TYPE 555
       555   FORMAT(' DO YOU WISH TO SEE ANOTHER SCAN?')
             TYPE 556
       556   FORMAT(' TYPE Y FOR YES, N FOR NO')
             ACCEPT 557,KANS
       557   FORMAT(A1)
             IF(KANS.EQ.'Y'.OR.KANS.EQ.'N') GO TO 559
             TYPE 152
             GO TO 551
       559   IF(KANS.EQ.'Y')GO TO 485
       561   TYPE 560
```

```
0173  560      FORMAT(' DO YOU WISH TO SEE ANOTHER FILE?')
0174          TYPE 570
0175  570      FORMAT(' TYPE Y FOR YES, N FOR NO')
```

```
FORTRAN IV      V02.04

0176          ACCEPT 580,JANS
0177  580       FORMAT(A1)
0179          IF(JANS.EQ.'Y'.OR.JANS.EQ.'N') GO TO 589
0180          TYPE 152
0181          GO TO 561
0182  589     IF(JANS.EQ.'Y') GO TO 465
0184  590       TYPE 600
0185  600       FORMAT(' DO YOU WISH TO TAKE ANOTHER SCAN?')
0186          TYPE 610
0187  610       FORMAT(' Y FOR YES, N FOR NO')
0188          ACCEPT 620,NANS
0189  620       FORMAT(A1)
0190          IF(NANS.EQ.'Y'.OR.NANS.EQ.'N') GO TO 629
0192          TYPE 152
0193          GO TO 590?
***** I
0194  629     IF(NANS.EQ.'Y') GO TO 50
0196  630     STOP
0197          END
```

```
FORTRAN IV      Storage Map for Program Unit .MAIN.

Local Variables, .PSECT $DATA, Size = 004112 ( 1061. words)
```

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
AVSCAN	I*2	004044	I	I*2	004074	IANS	I*2	004076
IBLONO	I*2	004060	ICHAN	I*2	004064	IDNAM	I*2	004016

```
J       I*2   004062      JANS    I*2   004102      JTIME  I*4   004046
K       I*2   004072      KANS    I*2   004100      KEY    I*2   004070
KLOG    I*2   004066      LKUP    I*2   004052      NANS   I*2   004104
SCAN    R*4   004054

COMMON Block /TOT   /, Size = 004000 ( 1024. words)

Name    Type  Offset      Name    Type  Offset      Name   Type  Offset
IA      I*2   000000

Local and COMMON Arrays:

Name      Type   Section Offset  ------Size----- Dimensions
DBLK    I*2      $DATA   000000  000010 (    4.) (4)
IA      I*2      TOT     000000  004000 ( 1024.) (1024)
LBLK    L*1      $DATA   000010  000006 (    3.) (6)
NA      I*2      $DATA   000016  004000 ( 1024.) (1024)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name    Type    Name    Type    Name    Type    Name    Type    Name    Type
CLOSEC  R*4     CVTTIM  R*4     DWAIT   R*4     GTIM    R*4     IDATE   I*2
IENTER  I*2     IFETCH  I*2     IGETC   I*2     IPEEK   I*2     IPOKE   I*2
IRAD50  I*2     IREADW  I*2     IWRITW  I*2     LOOKUP  I*2
```

APPENDIX F

AN EXAMPLE OF THE DATA OBTAINED FROM THE WQM WHEN DISPLAYED ON THE DECWRITER LA-120

FILENAME:LSRSS2
DATE: 9 -24 -81
TIME=16 :38 : 7 :42
AVERAGE NO. OF SCANS= 2
VOLTAGE=19051
CURRENT= 34
TRAVEL SPEED=19905

297	317	307	292	278			
287	273	263	263	263	258	253	224
268	253	248	239	258	244	234	229
239	224	229	209	234	219	219	204
219	209	209	204	209	214	200	195
214	209	209	200	204	200	190	190
195	190	185	180	185	200	185	170
185	190	180	185	190	170	195	170
200	180	190	161	180	175	175	161
180	170	180	146	175	165	151	151
175	161	165	161	151	170	165	156
165	165	161	141	156	161	146	136
165	146	141	141	146	141	151	146
151	151	146	131	146	136	151	122
156	136	131	126	141	126	141	136
156	141	136	117	136	131	136	126
146	136	122	136	126	141	126	117
141	122	136	122	131	141	126	122
131	122	112	102	117	117	122	112
126	112	117	122	131	117	131	97
122	122	112	92	136	117	126	102
122	117	97	97	117	112	112	102
122	131	122	117	112	126	122	97
126	117	102	107	126	131	112	107
126	102	102	107	122	126	126	112
146	141	141	126	146	141	136	131
151	151	165	156	175	175	200	180
200	200	195	204	268	312	302	292
312	287	244	219	234	248	273	253
268	278	302	317	361	356	341	336
429	458	497	502	497	448	429	390
380	361	370	351	351	341	390	395
395	429	414	400	473	590	697	561
444	424	414	356	409	473	453	390
375	366	390	414	434	444	497	453
536	531	463	409	419	473	546	546
566	610	785	946	795	692	639	468
541	692	580	429	492	600	678	692
683	595	736	732	575	629	771	624

575	561	585	668	624	522	458	419
473	522	497	439	478	497	551	653
727	683	756	751	946	1478	1903	1424
1146	922	834	1029	1302	1171	1117	1156
1000	1146	1224	1093	951	917	1019	985
1098	1293	1185	863	727	653	629	575
585	492	453	448	444	409	463	483
570	717	722	658	590	639	605	478
473	468	468	444	473	507	502	439
405	370	385	395	473	649	805	614
473	414	395	375	414	409	405	390
409	390	409	380	370	331	317	307
351	375	434	683	1044	814	448	351
380	370	351	346	380	375	395	424
419	385	390	356	351	326	322	331
366	385	370	336	331	317	326	336
361	331	336	336	346	317	331	331
405	463	453	385	414	370	351	331
356	375	400	336	336	326	331	302
322	322	331	326	346	322	302	287
317	307	326	326	326	297	292	287
312	312	322	312	326	312	322	292
326	326	341	341	390	390	405	429
434	405	429	463	497	409	390	395
468	473	414	356	370	351	326	302
322	326	317	307	322	317	322	322
361	351	351	361	400	414	400	361
356	346	341	322	351	336	370	361
385	380	385	361	419	453	419	370
458	536	527	395	390	405	463	536
517	400	405	414	434	400	356	312
346	356	361	331	351	326	317	317
317	307	326	322	341	312	322	322
336	326	341	307	356	356	341	307
312	312	302	292	302	263	278	263
283	292	302	312	336	375	375	302
287	287	283	297	317	283	278	283
297	273	283	283	307	292	268	253
258	263	273	244	283	278	273	297
351	322	312	263	287	263	278	253
268	273	287	278	312	278	283	263
292	273	263	244	268	258	258	239
248	263	273	253	278	278	268	268
283	263	248	244	263	258	253	244
258	253	283	283	322	322	297	273
283	253	258	239	258	248	239	224
239	229	224	219	239	229	229	209

229	214	229	214	229	224	204	209
224	224	229	239	283	292	278	244
229	229	214	204	229	214	209	195
209	219	209	195	219	204	200	200
219	195	200	180	209	200	200	185
224	209	195	185	214	204	195	180
204	204	209	195	204	204	204	190
209	190	180	165	190	185	190	175
200	185	190	165	200	190	175	180
190	190	170	170	190	185	170	175
175	175	175	141	180	170	151	156
175	161	165	151	170	175	165	146
170	161	165	146	165	170	161	146
175	151	156	146	146	146	151	122
156	136	131	117	151	126	136	122
136	136	141	141	146	146	141	112
141	126	122	117	141	141	131	126
146	117	131	117	141	136	131	112
141	141	146	117	156	146	131	117
141	97	136	107	131	122	126	107
131	122	131	107	141	122	117	117
126	131	117	117	126	117	117	102
102	117	112	112	122	122	117	97
126	117	122	97	126	107	117	102
131	112	122	102	117	112	107	92
117	97	126	97	126	122	107	102
126	112	126	102	102	107	112	102
122	112	112	107	117	112	107	102
122	117	97	97	117	97	102	107
102	107	107	97	117	117	112	87
117	97	102	97	112	107	107	97
131	97	107	92	102	102	112	87
122	102	97	82	112	112	97	97
117	92	102	92	112	112	107	102
97	97	102	78	107	117	92	87
112	102	107	97	122	97	102	87
102	97	102	97	102	102	102	78
102	97	82	82	112	92	102	92
102	102	102	97	97	97	92	78
112	97	97	73	102	112	78	82
107	87	97	97	92	112	107	87

APPENDIX G

AN EXAMPLE OF CALIBRATION DATA FOR THE SPECTROGRAPH TAKEN USING THE WQM

```
.RUN ADSPEC
DO YOU WISH TO LOOK AT AN OLD FILE?
TYPE Y FOR YES, N FOR NO
N
DO YOU WISH TO TAKE A SINGLE OR AVERAGE SCAN?
TYPE S OR A
S
    39      43     146     161     117      97     112      92
 19573   19602   19637     102     102     102      97      68
   107     112     102      82      97     102     112     102
   102      97      97      92     102     122     102     102
   117      97     112     102     102     107     102     107
   112     112      92      97     107      97     102      92
   102      97     102     102     102     102     122      87
   102      92      92      87      92      97     107      78
   107     107      87      87     112     102      92      82
   102     107     122      82      97      92     102     102
   122      97      87      92     102      87     107      97
    92     102      97      68      87      97      97      78
   107     107      82      87     117      92      97      92
   117      87      97      92     117     112      97      92
   112      97      97     102      97      97     117      82
    97     112     102      87      87     102     112      82
   102      92     107     102     107      97     102      82
   102      97      97      92      97      97     107      97
   122      97      92     102     102      87     107      87
    92     107      92      78      92     102     107      73
   107     112      87      97     112      92     102      87
   112      87      92      87     117     112      97      92
   122     102     102     107     102     102     122      92
   102     112      97      87      87     102     117      82
   102      92     102     107     117     107     102      82
   102      97     102     102     107      97     102     107
   122     102      92     102     112      92     117      92
    97     102     112      82      97     107     112      92
   117     112      92     102     122      92     107      92
   117      87     102      92     117     122     112     102
   122     102     102     107     102      97     112      92
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    87     102      97      73      92      97      97      73
    97     107      87      92     107      82     107      87
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107	102	117	97	107	112	122	87
92	112	97	82	117	97	92	92
112	92	87	92	112	87	107	102

APPENDIX H

FLOPPY DISK FORMATTING AND INITIALIZATION

Inherent in the RT-11 System Software is a utility program called "Format." Any new floppy disk will be unformatted (note: formatting destroys data currently on a disk). To format a floppy disk for this system, type in on the LA-120, "R FORMAT." Then press the return button. The utility program will respond with a prompt that looks like this: *. Then, assuming the unformatted disk is in slot 1 and the system floppy disk is in slot 0, type "DY1:/Y." Then press return.

To initialize the floppy disk for file structuring (this will also destroy all existing files on the floppy disk), type in: "INITIALIZE/BADBLOCKS DY1:." The system will respond with: "DY1: Init are you sure?." Type in "Y." The floppy disk will now be ready for data accumulation. Further information on these commands can be found in the RT-11 operator manuals.

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