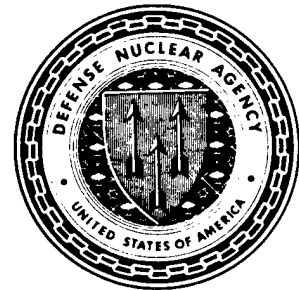




**Defense Nuclear Agency
Alexandria, VA 22310-3398**



DNA-TR-96-34

Tri-Service Thermal Radiation Test Facility Xenon Flashlamp Operators Manual

**Michael Sweeney
University of Dayton Rsch Inst
300 College Park Avenue
Dayton, OH 45469-0135**

June 1997

DTIC QUALITY ASSURED

Technical Report

CONTRACT No. DNA 001-90-C-0081

Approved for public release;
distribution is unlimited.

19970805 055

DESTRUCTION NOTICE:

Destroy this report when it is no longer needed.
Do not return to sender.

PLEASE NOTIFY THE DEFENSE SPECIAL WEAPONS
AGENCY, ATTN: CSTI, 6801 TELEGRAPH ROAD,
ALEXANDRIA, VA 22310-3398, IF YOUR ADDRESS IS
INCORRECT, IF YOU WISH IT DELETED FROM THE
DISTRIBUTION LIST, OR IF THE ADDRESSEE IS NO
LONGER EMPLOYED BY YOUR ORGANIZATION.



DISTRIBUTION LIST UPDATE

This mailer is provided to enable DSWA to maintain current distribution lists for reports. (We would appreciate your providing the requested information.)

- ☐ Add the individual listed to your distribution list.
- ☐ Delete the cited organization/individual.
- ☐ Change of address.

NOTE:

Please return the mailing label from the document so that any additions, changes, corrections or deletions can be made easily. For distribution cancellation or more information call DSWA/IMAS (703) 325-1036.

NAME: _____

ORGANIZATION: _____

OLD ADDRESS

CURRENT ADDRESS

TELEPHONE NUMBER: () _____

DSWA PUBLICATION NUMBER/TITLE

CHANGES/DELETIONS/ADDITIONS, etc.) (Attach Sheet if more Space is Required)

DSWA OR OTHER GOVERNMENT CONTRACT NUMBER: _____

CERTIFICATION OF NEED-TO-KNOW BY GOVERNMENT SPONSOR (if other than DSWA):

SPONSORING ORGANIZATION: _____

CONTRACTING OFFICER OR REPRESENTATIVE: _____

SIGNATURE: _____

CUT HERE AND RETURN



DEFENSE SPECIAL WEAPONS AGENCY
ATTN: IMAS
6801 TELEGRAPH ROAD
ALEXANDRIA, VA 22310-3398

DEFENSE SPECIAL WEAPONS AGENCY
ATTN: IMAS
6801 TELEGRAPH ROAD
ALEXANDRIA, VA 22310-3398

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 970601		3. REPORT TYPE AND DATES COVERED Technical 910426 – 940717
4. TITLE AND SUBTITLE Tri-Service Thermal Radiation Test Facility Xenon Flashlamp Operators Manual			5. FUNDING NUMBERS C - DNA 001-90-C-0081 PE - 62715H PR - RG TA - RR WU - DH307290	
6. AUTHOR(S) Michael Sweeney				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Dayton Rsch Inst 300 College Park Avenue Dayton, OH 45469-0135			8. PERFORMING ORGANIZATION REPORT NUMBER UDR-TR-94-66	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Defense Special Weapons Agency 6801 Telegraph Road Alexandria, VA 22310-3398 EST\Chivers			10. SPONSORING/MONITORING AGENCY REPORT NUMBER DNA-TR-96-34	
11. SUPPLEMENTARY NOTES This work was sponsored by the Defense Special Weapons Agency under RDT&E RMC Code B4662D RG RR 00034 TDTR 5200A AB 25904D.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Safe operating and servicing test procedures for the Flashlamp Thermal Simulator, the Flashlamp Thermal Simulator Voltage Monitor, and the Vortek Stabilized Arc Lamp are described in this document. The manual guides test technicians operating a Bentley 286/8 microcomputer through proper safety and operational procedures while operating the Flashlamp Thermal Simulator and the Vortek Stabilized Arc Lamp. A (pre and post) safety checklist to be followed during equipment utilization is provided. A description of the instrumentation used in support of testing and procedures for servicing are also provided.				
14. SUBJECT TERMS Safety Checklist Vortek Stabilized Arc Lamp Operation and Servicing Flashlamp Thermal Simulator Operation and Servicing Instrumentation			15. NUMBER OF PAGES 58	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR	

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

CLASSIFIED BY:

N/A since Unclassified.

DECLASSIFY ON:

N/A since Unclassified.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) (Continued)

Science Applications Intl Corp
P.O. Box 1303
McLean, VA 22102

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

PREFACE

This document incorporates the Flashlamp Controller Operator's Manual developed under Contract No. DNA001-88-C-0083 by Science Applications International Corporation, developers of the Xenon flashlamp system. The operator's manual, written by N. Convers Syeth of SAIC, is still used as the basic manual for facility operation.

In developing a training guide for the safe operation of the Flashlamp Thermal Simulator (FTS), sections regarding safety and additional operating parameters developed since publication of the original SAIC operator's manual have been added.

TABLE OF CONTENTS

Section		Page
1	SAFETY	1
2	SAIC FLASHLAMP CONTROLLER OPERATORS MANUAL.....	4
3	AUTOMATIC 3-PARAMETER PULSE SHAPING	45
4	SYSTEM DATA SET-UP AND VOLTAGE MONITORING	47
5	SERVICING.....	48

SECTION 1

SAFETY

All procedures in the operation of test equipment within the Tri-Service Thermal Radiation Test Facility will be in accordance with the UDR-TR-94-70, "Standard Safety Operating Procedures Manual" which governs all activities within the TRTF.

General

Ear protection should be worn whenever occupying the Data-Acquisition Room 710C (Figure 1.1) or the FTS/VSAL Control Room 701B (Figure 1.1) during operation of Wind Tunnels or when cooling the Flashlamp Thermal Simulator during a test.

Eye protection with a minimum #10 welding filter is used to observe a test but the energy source should never be viewed directly regardless of protection.

No personnel will occupy the Flashlamp Thermal Simulator/Vortek Stabilized Arc Lamp (FTS/VSAL) Room 711 (Figure 1.1) or the Nitrogen Cooling Bank Room 711B (Figure 1.1) when either the FTS or VSAL is being operated. There is the danger of flying glass from a ruptured lamp, high-pressure water from a ruptured hose, exposed high-voltage connections, corrosive chemical from a ruptured capacitor or hot metal sparks from an overheated component or test specimen. The FTS/VSAL Control Room 710B and the Data-Acquisition Room 710C may be occupied by a limited number of personnel during testing. The test may be observed through the smoked acrylic window between Room 710B and 711 but only with adequate filtered eye protection. The doorway between Room 710B and 711 must be kept clear of personnel during FTS/VSAL operation. The doorway between the FTS/VSAL Test Room 711 and the main hallway is interlocked preventing access to 711 from the hall whenever either the FTS or VSAL is energized. The doorway between 711 and the General Storage area Room 712 (Figure 1.1) is kept locked from the 711 side preventing access to 711 from 712 at any time.

The emergency eye wash and emergency laboratory full-body shower (Figure 1.1) are located in the main hallway at the West end near the exit doors that have no windows. The eye wash is activated by a palm-press handle located below and to the right of the bowl and must be held down to cause the water to flow. The full-body shower is a flush

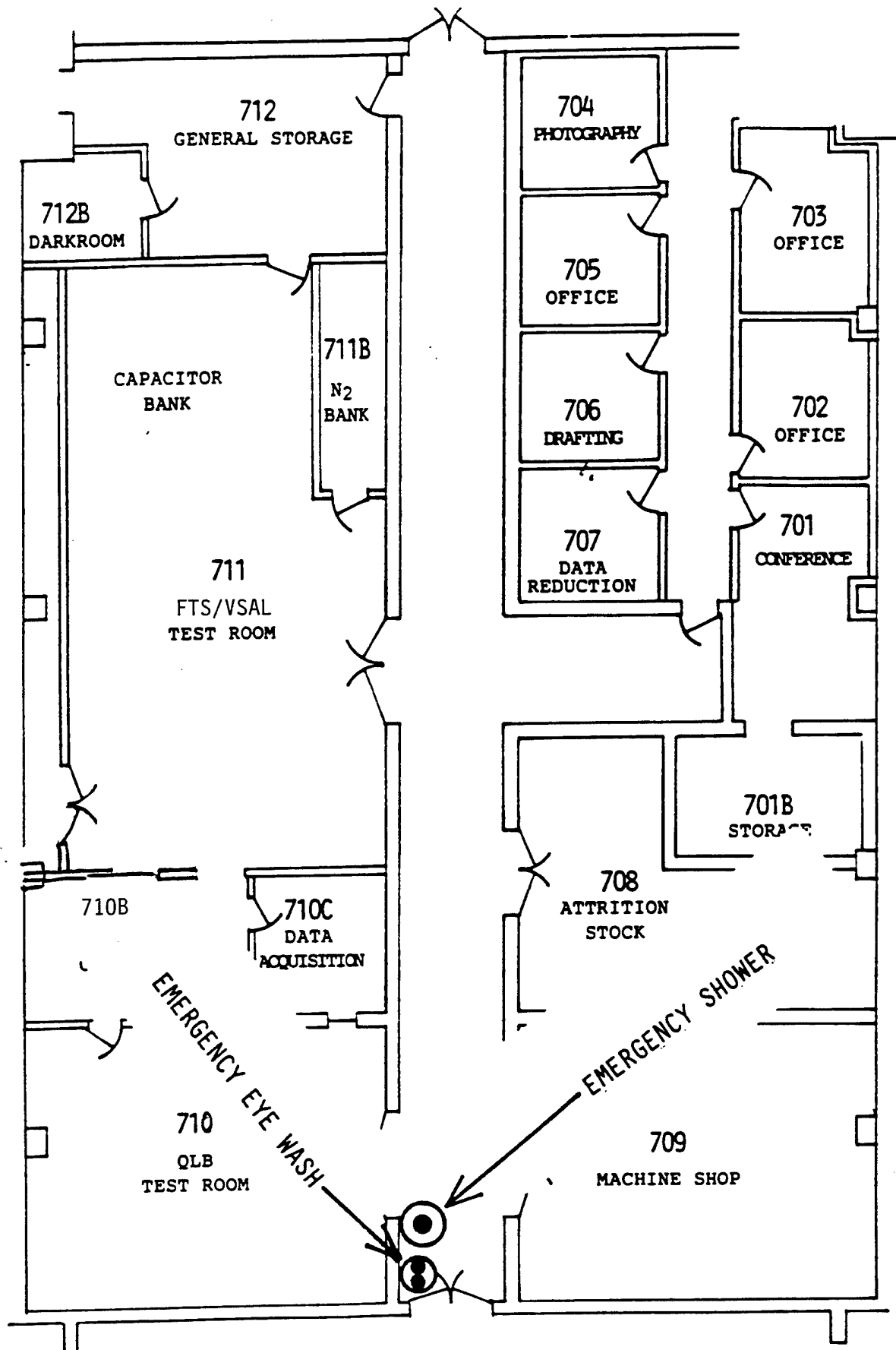


Figure 1.1. Emergency Eye Wash and Shower.

Signs have been posted on the Facility Attic access ladders in the West hall. Authorized personnel assessing the attic area are warned on the possible noise and light that could pass through the ceiling material causing distraction and possible balance loss to personnel in the attic area.

All full-time University of Dayton Research Institute personnel working at or assigned to the Tri-Service Thermal Flash Test Facility shall be trained in the technique of Cardiopulmonary resuscitation (CPR).

SECTION 2

SAIC FLASHLAMP CONTROLLER OPERATOR'S MANUAL

FLASHLAMP CONTROLLER OPERATOR'S MANUAL

N. Convers Wyeth

December 1988

Supported by:

Defense Nuclear Agency
6801 Telegraph Road
Alexandria, VA 22310-3398

Contract No.: DNA001-88-C-0083

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

1710 Goodridge Drive, P.O. Box 1303, McLean, VA 22102
(703) 821-4300

LIST OF FIGURES & DRAWINGS

<u>Figure</u>	<u>Page</u>
2.1 Main menu of the FTS controller operating code	9
3.1 Sequence of menu choices to produce thermal flux curves using the MORE program	11
3.2 Display of flux file selection list	14
3.3 Example of the printed record of a flux curve and its calculated FTS synthesis	19
4.1 Window for entry of calibration shot parameters: number of cycles and firing time interval	24
4.2 VSAL-only prefiring procedure check list	25
4.3 VSAL (only) firing sequence	27
4.4 VSAL-only postfiring procedure check list	28
4.5 Prefiring procedure check list	30
4.6 Pre-fire sequence	31
4.7 Screen display during lamp simmering	32
4.8 Shut down sequence	34
4.9 Flashlamps and VSAL sequence	35
4.10 Postfiring procedure check list	37
Drawing 1 FTS Controller Board - circuit diagram	41
Drawing 2 FTS Controller Board - circuit diagram (cont.) . .	42
Drawing 3 FTS Controller Board - circuit diagram (cont.) . .	43

1. INTRODUCTION

The Flashlamp Thermal Simulator (FTS) Controller Upgrade consists of a Bentley 286/8 microcomputer (IBM-AT compatible), keyboard, color display, printer, custom interface board, desk, and software. It replaces the old FTS controller unit and handheld controller. Improvements over the old system include the use of off-the-shelf components throughout (except for the custom interface board which uses replaceable, off-the-shelf chips), automatic sequencing and keyboard control of some functions which were previously manual (e.g., high gas, ignitron power, etc.), and the ability to calculate nuclear waveforms and lamp firing times on the controller computer itself. The software is menu-driven and operator-prompting and therefore virtually self-explanatory.

Both the software and hardware of the Controller Upgrade were built with components and designs allowing for later improvements and/or additions such as data acquisition, diagnostics/exercises, etc.

2. START UP: THE MAIN MENU

When the controller computer is turned on, the boot-up sequence includes the automatic loading and running of the controller operating code. With the monitor turned on, the main menu of seven choices appears as shown in Figure 2.1. The shaded selector bar is moved to the desired choice using either set of arrow keys; when using the number pad arrow keys, be sure the number lock ("num loc") function is off. Press the <Enter> key to activate the menu choice. Note that the No. 3 choice (Diagnostics/Exercisers) is not available on this version. No. 7 (Exit to DOS) allows the user to enter the computer's MS/DOS operating system for file management, editing, etc. (see Sections 3.3 and 3.4 below). After exiting to DOS, the controller operating code can be restarted by rebooting the computer or (when in the DNA directory) by typing "dna" (without the quotation marks) and hitting <Enter>.

Starting the operating program causes all of the control outputs to be initialized to their proper settings. However, if the interface board is turned on (power switch on right desk front) with the computer off or the operating program not running, certain of the output control lines (e.g., DAS trigger, ignitron triggers 1-93) may be in the "on" state. This should not cause any serious problems because all the important power controls are locked "off" (see Section 5).

DNA FLASHLAMP THERMAL SIMULATOR

**** MAIN MENU ****

- 1 - Calculate nuclear waveform
- 2 - Synthesize pulse shape
- 3 - Diagnostics/Exercisers
- 4 - Calibration shot
- 5 - Fire VSAL only
- 6 - Fire pulse
- 7 - Exit to DOS

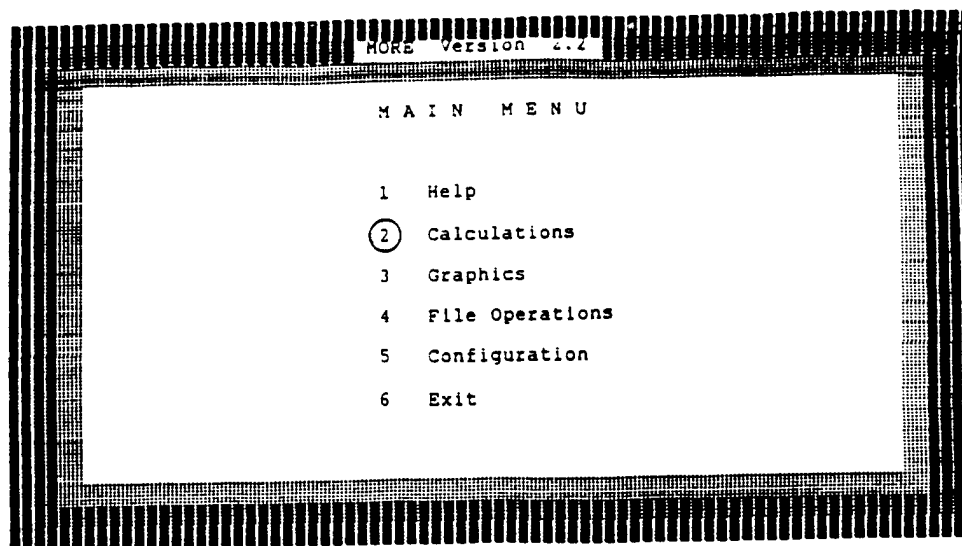
Figure 2.1. Main menu of the FTS controller operating code.

3. COMPUTATIONAL FUNCTIONS

3.1 Calculate Nuclear Waveform

When this option from the main menu is chosen, a DNA-supplied program called "MORE" is activated. Use of this code is self-explanatory with an extensive "HELP" file. While this program can perform a number of useful calculations concerning nuclear weapons effects, its primary reason for inclusion here is to calculate thermal flux versus time curves from a set of input parameters such as height of burst, yield, distance, atmospheric conditions, etc. The user chooses a name for the data output from a calculation, and when the thermal time history plot data file for the specified parameters is generated, it will use the chosen name with the file extension ".hot". The sequence of menu choices to produce thermal flux data files is as follows (see Figure 3.1). Choose No. 2 (calculations) from the main MORE menu and enter the input parameters called for. When the next calculation selection menu appears, choose No. 6 (Generate plot data files), and from the succeeding plot option menu, choose No. 2 (Thermal time history plots).

The user can view (and print) a graph of this flux versus time curve before exiting "MORE". Several thermal flux data files can be created in one session on "MORE", each with a different name and all with the extension ".hot". The names should be noted by the user so that they can be recalled for simulation by the FTS after



Parameter input, etc.

Default MENU option is 1

Select a number from the MENU below:

- 1 - Calculate environments using specified input
- 2 - Find range for a given peak overpressure or dynamic pressure
- 3 - Find range for a given peak material velocity
- 4 - Find range for a given thermal flux or fluence
- 5 - Find range for a given radiation level
- 6 - Generate plot data files
- 7 - Change input
- 8 - Quit

Enter selection

Default plot option is 0

- 0 - All plots
- 1 - Blast time history plots
- 2 - Thermal time history/spectral distribution plots
- 3 - Burst/target encounter simulation
- 4 - Abort back to option MENU

Enter selection or hit carriage return

Figure 3.1. Sequence of menu choices to produce thermal flux curves using the MORE program.

returning to the main menu.

3.2 Synthesize Pulse Shape

This main menu option is used to activate a sub-program in the controller code which accepts a flux versus time file as input and calculates the optimum flashlamp firing times, bank voltage, and flux multiplier to simulate the flux curve. The firing times will be stored for later use in operating the FTS (see below), the bank voltage is set by the operator, and the flux multiplier is the factor (≤ 1.0) by which the standard (reflector exit plane) output of the FTS must be reduced in order to reproduce the desired flux curve (this reduction is usually achieved by moving the sample away from the exit plane).

The flux data file must meet the following criteria:

- Number of lines: 1-250
- On each line: time in seconds, flux in $\text{cal/cm}^2\text{-sec}$ with both values in floating point format, no other format requirements
- Range: time - begin with 0, no greater than 10
flux - no greater than 2000
- Increments: the increment between successive time values must be constant
- File Name and Location: must have extension ".dat" and be stored in subdirectory C:\DNA\DAT, or can be ".hot" file created in "MORE" (see Sections 3.1 and 3.3).

The "Synthesize Pulse Shape" routine starts by displaying a list (with dates) of all files in the DNA/DAT subdirectory and the ".hot" files in "MORE" (see Figure 3.2). When an acceptable file name is chosen from the displayed list, a graph of the flux-time curve contained in the file is displayed (including the calculated total fluence, peak flux, and time of peak), and the operator is asked if this is the correct curve to be simulated. A negative response causes a return to the main menu, while a positive response evokes a second query regarding changing the maximum flux multiplier setting to a value less than one (the default value). If the nature of the test requires that the thermal flux be used (or the test object be placed) at some distance from the FTS reflector exit plane, a maximum value less than one can be specified for the flux multiplier, where this maximum value corresponds to the minimum distance allowed.

Once the flux multiplier has been set (or the default value chosen), the code begins to calculate the lamp firing times, bank voltage, and flux multiplier value needed to best simulate the flux curve. This calculation cannot proceed unless a file listing the lamp efficiency factors is stored properly in the computer.

DNA FLASHLAMP THERMAL SIMULATOR

Flux Files	
SQUAREPU.DAT	9-15-88
MAXF.DAT	11- 7-88
SAMPLE2.HOT	7-22-87
SAMPLE4.HOT	7-22-87
SAMPLE3.HOT	7-22-87
SAMPLE1.HOT	7-22-87
NUC9.HOT	9-21-88
NUC1.HOT	9-20-88
NUC2.HOT	9-21-88
NUC3.HOT	9-21-88

Use 'Home' and 'End' keys to move selection
bar to desired file name, then hit 'Enter'.

Figure 3.2. Display of flux file selection list.

The following is a general description of how this pulse synthesizing algorithm works. The guiding criteria for the calculation are:

- The bank voltage is as low as possible - this reduces lamp wear and allows more pulses to be used which can make for a smoother output curve.
- The flux multiplier is as low as possible (subject to the bank voltage being minimized) - this also allows more pulses to be used.
- Refire limitation - a given lamp cannot be fired again until the refire time has elapsed since its last firing, with the refire time given by:

$$\tau_r(\text{sec}) = (3.33 \times 10^{-5})V^2 + 0.159$$

where V is the firing (bank) voltage.

- Adjacency limitation - a given lamp cannot be fired if any of its nearest neighbors were fired within the previous 40 msec. This is to prevent induction effects from an operating lamp on one that is being started.
- The lamps are fired no faster than one per millisecond in a fixed order (up to three times) with the starting point in the sequence chosen to put a particular section of the firing order around the flux curve maximum (the latter approach is used because the nearest neighbor firing spacing varies throughout the sequence).

The algorithm procedure begins by using the total fluence of the desired pulse shape to calculate first-cut values for the bank voltage, flux multiplier, and number of lamp pulses. This is done by using the total fluence contribution for each lamp and finding the minimum voltage and minimum flux multiplier (the former having

precedence over the latter) for which up to 93 pulses can supply all of the required fluence. If the total fluence demand exceeds the simulator maximum, the algorithm proceeds anyway using the maximum voltage and maximum flux multiplier values. With the initial values for voltage and flux multiplier now set, the total fluence of the first lamp in the firing order is calculated, and integration of the desired pulse shape (flux curve) is begun at time zero and steps forward in one millisecond intervals. When the integrated fluence under the curve reaches one half the fluence of the first lamp, the firing time of this lamp is set at 20 msec before that time to which the integration of the curve had proceeded. The standard FTS lamp pulse shape has produced one half of its fluence approximately 20 msec after pulse initiation (firing). Thus this procedure matches the midpoint of a lamp pulse fluence contribution with the fluence midpoint of the flux curve segment which it is simulating. The total fluence of the next lamp in the firing order is calculated, and the flux curve integration is continued until the integrated fluence minus the total fluence of all lamps already fired equals one half of the next lamp's fluence and so on. After each lamp firing time is set and before the calculation proceeds, the refire and adjacency limitation criteria (see above) are checked for the lamp just fired. If either criterion is violated (i.e., the lamp is to be fired too soon), the algorithm halts the flux curve integration process and attempts to raise the fluence output per lamp in order to increase the time between lamp firings and remove the criterion violation.

The first choice for increasing lamp fluence is to increase the flux multiplier (in practice, this means moving closer to the FTS reflector exit plane). If the flux multiplier value is not already set at its specified maximum, it is increased by a factor roughly proportional to the firing time lengthening required, and the integration through the flux curve pulse shape to determine firing times is begun again starting at time zero. If the flux multiplier is already at its specified maximum, the second choice for increasing lamp fluence is to increase the bank voltage. Although increasing the bank voltage increases the refire time (τ_r), the increase in lamp fluence (proportional to the voltage squared) is proportionally greater than the increase in τ_r because of the constant term in the equation for τ_r (see above). Therefore, increasing the bank voltage does increase the fluence available from one lamp with multiple firings (at the shortest refire time) over a given time interval. If the bank voltage value is not already set at its specified maximum, it is increased by a factor roughly proportional to the firing time lengthening required (taking account of the quadratic dependencies involved), and the integration through the pulse shape is begun again at time zero.

If the algorithm is unable, due to either a lamp firing time limitation violation or running out of fluence (i.e., more than 93 pulses required), to integrate through the entire pulse shape with both the flux multiplier and the bank voltage at their maximum values, the truncated simulation is presented (see below). For

certain fast-rising, very high peak flux pulse shapes, the simulation may truncate after fewer than eleven lamp firings due to the adjacency limitation. This occurs because the flux curve requires that the lamps be fired very rapidly, one after another, and the standard firing order comes back to an adjacent lamp after about 8 lamp firings on average and has several places where only 6 firings separate adjacent lamps. For these special cases, the algorithm switches to a different firing order which allows at least 11 lamps to be fired in rapid succession while sacrificing any chance of proceeding much further along the pulse shape.

When the pulse synthesis is finished, the lamp output flux curve is displayed with the flux curve for comparison, and the operator is asked whether the synthesis is acceptable. If accepted, the generated lamp firing order table (FOT) is stored as a file with the extension ".FOT" in the subdirectory C:\DNA\FOT. The FOT file contains the bank voltage, flux multiplier, and lamp firing times needed to synthesize the pulse. It also contains a coded checksum which the pulse firing function (see Section 4.3 below) will detect. This is to prevent firing order tables not generated by this code (with its restrictions on adjacency and refire times) from being used to operate the FTS.

The operator can also produce a printed record of the flux curve and FTS synthesis as shown in Figure 3.3.

FLUX CURVE FROM FILE:'NEWNUC.HOT'
LAMP FIRING ORDER FILE:'NEWNUC.FOT'

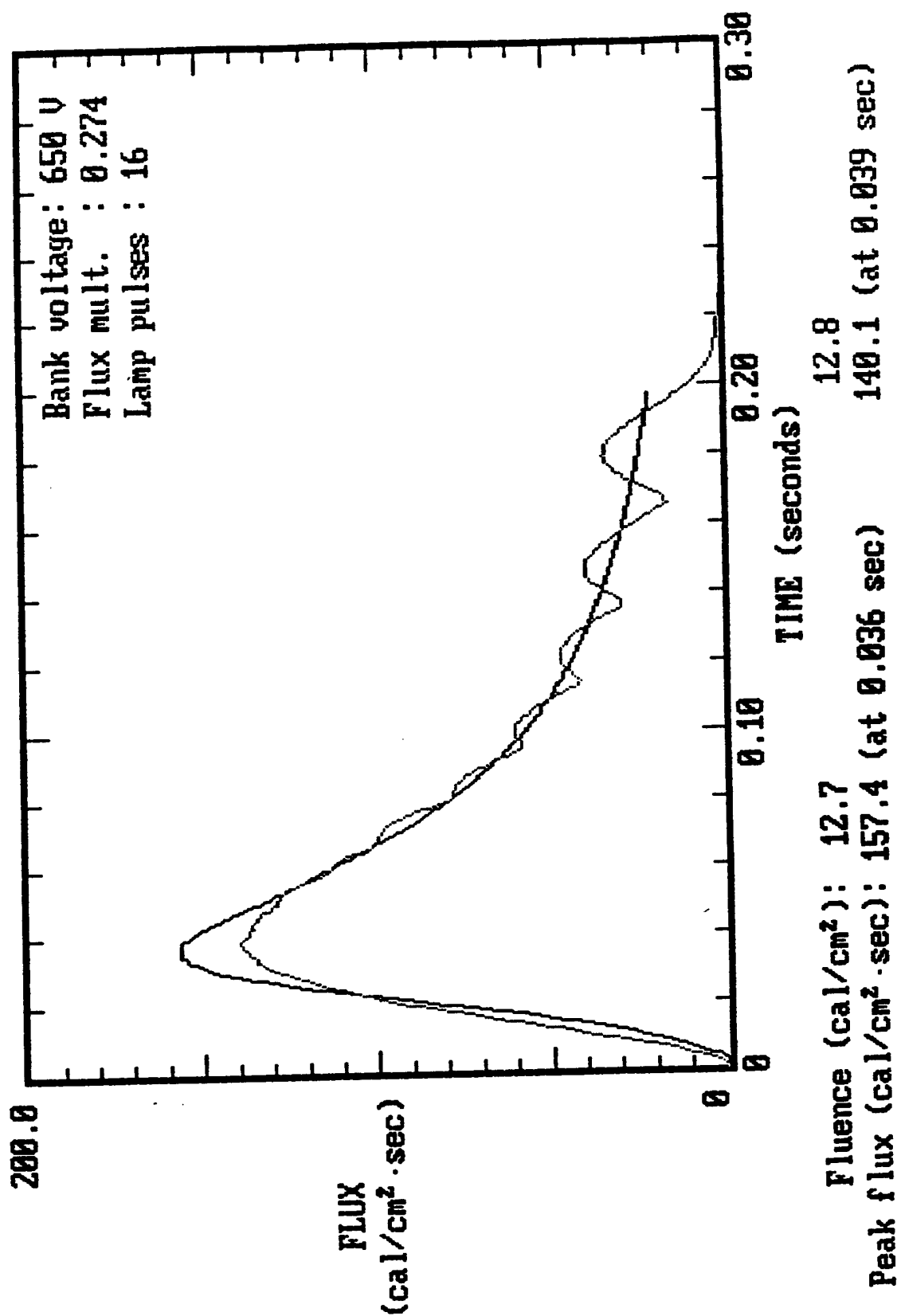


Figure 3.3. Example of the printed record of a flux curve and its calculated FTS synthesis.

3.3 Other Flux Files

User generated flux files may be used with the FTS controller provided they meet the criteria listed at the beginning of Section 3.2 above. They can be created using a text editor such as "Program Editor 4.1" from WordPerfect Corp. (supplied with the controller; see next section) or read from a floppy disk and then stored in the subdirectory C:\DNA\DAT. Flux files not satisfying the criteria will be rejected by the pulse synthesis sub-program.

3.4 Lamp Efficiency File

In order for the pulse synthesis routine to calculate how much fluence each lamp will contribute when fired, a table of lamp efficiencies must be available. The efficiency value for a given lamp is a decimal fraction between 0 and 1 which indicates how much of its theoretical thermal output flux reaches the exit plane of the reflector. Typical values usually range from 0.15 to 0.40 depending on lamp position, lamp age, and condition of the reflector surface. Because the last two quantities change with time, the lamp efficiencies must be remeasured periodically (see Section 4.1 below) and the table updated.

The table is stored as the file "lamp.eff" in the DNA subdirectory (the working directory for the main program, dna.exe). It contains 31 lines, each line consisting of an integer representing the lamp number and a decimal fraction (floating

point) giving the corresponding efficiency. The file can be updated as follows. Exit the main program to DOS (Option No. 7 on the main menu). Then type "PE lamp.eff" and hit the <Enter> key. This will call up the Program Editor (Version 4.1 from WordPerfect Corp.) to edit the "lamp.eff" file. After the editor program loads, the file itself appears. The function key F3 can be used for help in using the Program Editor, but updating this file is relatively simple. Simply use the arrow keys to move the cursor through the file lines, and typeover (or delete and add) the new efficiency values for each of the 31 lamp numbers. When this is completed, hit the function key F7 to exit the editor, and answer the editor's exit questions (bottom line on the screen) so as to replace the old efficiency file with the new version just created.

After exiting the editor, type "dna", and hit the <Enter> key to restart the main controller program.

4. OPERATIONAL FUNCTIONS

The "Control-Break" key combination can be used to abort the controller program at any point. It will initiate an abort sequence which should shut off all systems. However since the controller has little direct feedback, observe all controls with care during any such abort and be prepared to manually correct any problems.

4.1 Calibration Shot

To measure the individual lamp efficiencies (see Section 3.4 above), the peak flux of each lamp when fired at a known voltage must be measured at the reflector exit plane. The formula for the peak flux ($\dot{Q}_{\text{peak}}$) in cal/cm²-sec is

$$\dot{Q}_{\text{peak}} = (1.11 \times 10^{-3}) V^2 f \eta_L$$

where V is the lamp firing (bank) voltage, f is the flux multiplier, and η_L is the lamp efficiency. Since f is unity at the exit plane (by definition), the lamp efficiency is found from the measured peak flux and voltage as

$$\eta_L = \dot{Q}_{\text{peak}} / (1.11 \times 10^{-3}) V^2.$$

To routinely measure the peak flux of each lamp individually,

the Calibration Shot function causes the lamps to be fired in the order of their numbered positions (note: this is not the firing order during a pulse synthesis shot) at a specified time interval. The 31 lamps can be fired up to 3 times (3 cycles) in a calibration shot in order to use all of the capacitor banks and obtain an average efficiency for each lamp. A calorimeter is placed at the reflector exit plane, and the peak flux for each of the conveniently spaced lamp pulses is recorded.

The controller procedure used to fire the lamps for a calibration shot is very similar to that used in a pulse synthesis shot which is discussed in Section 4.3. The main difference is that instead of choosing a pulse synthesis firing order table (FOT), the operator enters the number of cycles desired (1, 2, or 3) and the lamp firing time interval (50-500 ms) in the window which appears (Figure 4.1).

4.2 Fire VSAL Only

The FTS Controller Upgrade provides the capacity to operate the vortex stabilized arc lamp (VSAL) from the controller keyboard. After choosing this option, the operator is asked for the VSAL pulse duration (up to 60 sec) and the VSAL current level (300-1200 amps). These values are then shown in the upper left corner of the screen for reference, while the operator goes through a prefiring check list (Figure 4.2).

DNA FLASHLAMP THERMAL SIMULATOR

CALIBRATION

Enter the number of cycles...(1,2 or 3) 1
Enter the lamp firing time interval in ms 100
minimum 1 cycle, maximum 3 cycles
minimum 50 ms, maximum 500 ms

Figure 4.1. Window for entry of calibration shot parameters: number of cycles and firing time interval.

DNA FLASHLAMP THERMAL SIMULATOR

VSAL-ONLY PREFIRING PROCEDURE CHECK LIST

As each item is completed, hit space bar

Inspect VSAL quartz tube, electrodes, & reflector

Check water levels of VSAL cooling systems

Turn on FTS controller board & VSAL main power

Remove VSAL shorting bar

Figure 4.2. VSAL-only prefiring procedure check list.

After these preparations, the operator is prompted to send the standard sequence of commands to the VSAL by using the keyboard spacebar (Figure 4.3). After the initial STANDBY command is sent, the controller pauses for approximately 18 seconds allowing the VSAL to achieve the standby condition. Note that there is no direct feedback to the controller telling it that the VSAL is indeed ready to proceed. When the RUN command is sent, the controller waits to receive a signal from the VSAL that it has gone to full current before displaying "VSAL FIRING". After the specified pulse duration time has elapsed, the controller sends the STOP command to the VSAL. There is no feedback to the controller that the VSAL has actually stopped. Therefore the operator must always be prepared to have the pulse manually terminated from the VSAL control panel.

After the VSAL run is completed, the operator goes through a postfiring check list (Figure 4.4). During the firing sequence, a graphic representation of the VORTEK control panel is shown to inform the operator of the assumed state of the VSAL.

4.3 Fire Pulse

After choosing this function, the operator is shown a list of the stored lamp firing order tables (FOT files) and asked to select one. This collection of files (which is stored in C:\DNA\FOT) should periodically be cleansed of all files older than the present

DNA FLASHLAMP THERMAL SIMULATOR

VSAL Secs: 5.00
VSAL Amps: 500

*** VSAL FIRING SEQUENCE ***

✓ STANDBY command sent

✓ RUN command sent

VSAL FIRING

VSAL AUTOMATIC SEQUENCE

VORTEK CONTROL PANEL

STOP

STBY

RUN

Figure 4.3. VSAL (only) firing sequence.

DNA FLASHLAMP THERMAL SIMULATOR

VSAL Secs: 5.00

VSAL Amps: 500

VSAL-ONLY POSTFIRING PROCEDURE CHECK LIST

As each item is completed, hit space bar

- ✓ Turn off VSAL main power & replace VSAL shorting bar
- Inspect VSAL quartz tube & electrodes for damage
- Inspect VSAL reflector for damage
- Check VSAL cooling system

Figure 4.4. VSAL-only postfiring procedure check list.

lamp efficiency file (see Section 3.4 above) because they will only produce the intended pulse syntheses if the lamp efficiencies have not changed since the FOT files were created.

Next, the operator indicates whether the VSAL is to be operated with the flashlamps. If so, the VSAL pulse duration and current level will be entered after the prefiring check list. Next, the data acquisition time is requested. This time value specifies how long the data acquisition system (DAS) will run after the start of the pulse. If no entry is made, the DAS will never be turned on at the start of the pulse. Next, the operator steps through a prefiring check list (Figure 4.5) which varies slightly depending on whether the run is a calibration shot, a flashlamps-only pulse, or a flashlamps-with-VSAL pulse.

After these preparations, the prefiring sequence (Figure 4.6) of simmering the flashlamps and turning on various power supplies and gas flows is begun. The name of the FOT file, bank voltage, flux multiplier, and VSAL pulse length and current (if needed) are shown in the upper left corner for reference. When the lamps are being started, a schematic diagram of the FTS reflector head appears with the 31 lamp positions shown. The start/simmer process is followed in real time, and the non-starting lamps are listed by number (see Figure 4.7). At this point the operator can proceed and fire the pulse or stop the sequence to replace the faulty lamps. In the latter case, a list of the bad lamps can be printed

(a)

DNA FLASHLAMP THERMAL SIMULATOR
CALIBRATION PREFIRING PROCEDURE CHECK LIST

Inspect flashlamps & reflector

Check water levels of FTS cooling system

Open nitrogen cylinder valves - check cylinder pressure

Make sure FTS controller board is on

Turn on FTS water pump

Charge capacitor banks

As each item is completed, hit space bar

(b)

DNA FLASHLAMP THERMAL SIMULATOR
PREFIRING PROCEDURE CHECK LIST

As each item is completed, hit space bar

✓ Inspect flashlamps & reflector

✓ Check water level of FTS cooling systems

✓ Open nitrogen cylinder valves - check cylinder pressure

Make sure FTS controller board is on

Turn on FTS water pump

Note that flux multiplier is 0.372 for this pulse

Charge capacitor banks to 650 volts for firing

(c)

DNA FLASHLAMP THERMAL SIMULATOR
PREFIRING PROCEDURE CHECK LIST

As each item is completed, hit space bar

✓ Inspect VSAL tube, electrodes, seals & water level

✓ Remove VSAL shorting bar & turn on VSAL power

Inspect flashlamps & reflector

Check water level of FTS cooling systems

Open nitrogen cylinder valves - check cylinder pressure

Make sure FTS controller board is on

Turn on FTS water pump

Note that flux multiplier is 1.000 for this pulse

Charge capacitor banks to 705 volts for firing

Figure 4.5. Prefiring procedure check list: (a) calibration shot; (b) flashlamps-only pulse; (c) flashlamps-with-VSAL.

DNA FLASHLAMP THERMAL SIMULATOR

File: NUC5.FOT
Bank Volt 705
Flux Mult 1.000

*** PRE-FIRE SEQUENCE ***

- ✓ Simmer sequence complete
- ✓ Stepper switch homed
- ✓ Low Gas turned on
- ✓ High Voltage turned on
- ✓ Ignitron Power turned on
- ✓ High Gas turned on

PULSE FIRING CONTROL

Hit fire key to begin firing sequence

Figure 4.6. Pre-fire sequence.

DNA FLASHLAMP THERMAL SIMULATOR

*** LAMP SIMMERING IN PROGRESS ***

12 LAMPS DID NOT LIGHT

**3 5 6 11 13
14 19 21 22 27
29 30**

**The lamps listed above failed to start
Proceed & fire pulse with them missing ?
(y/n)**

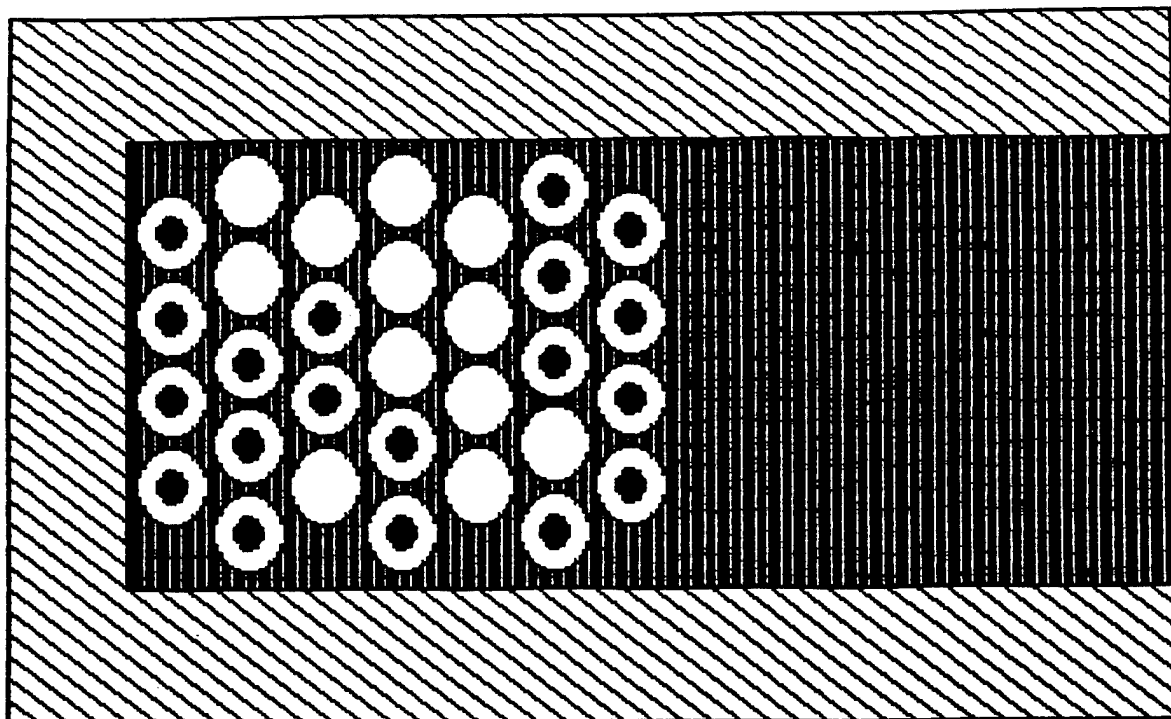


Figure 4.7. Screen display during lamp simmering.

for reference. Toward the end of the prefire sequence, the controller operation takes one of two paths depending on whether the VSAL is included.

For flashlamps only (no VSAL), the prefire sequence is followed by a request for the operator to hit the "fire key" to begin the pulse (Figure 4.6). The fire key is the letter "f" (lower case), and its identity is not revealed by the screen display so that persons who have not read this manual or who are not familiar with the FTS will not know how to initiate a pulse. After the last flashlamp is fired, a shutdown sequence is called for, allowing the operator to turn off the cooling gas flows as the need for them abates (Figure 4.8).

For flashlamps and VSAL, the same fire key hit is requested, but in this case it initiates the VSAL preparation sequence (i.e., STANDBY, delay, RUN) as described in Section 4.2. Here, however, the VSAL sequence proceeds automatically to ensure coordination with the flashlamp firing. The command sequence is shown to the operator as it takes place along with the VORTEK Control Panel graphic (Figure 4.9). Up until just after the RUN command is sent, the operator has a special abort option (compare with Section 4.4 below) available by hitting the space bar. Six seconds after the RUN command is sent, the high gas flow is turned on to just precede the VSAL going to full current. When the VSAL goes to full current (i.e., the beginning of the VSAL pulse), it sends a signal to the

DNA FLASHLAMP THERMAL SIMULATOR

File: NUC5.FOT
Bank Volt 705
Flux Mult 1.000

*** SHUT DOWN SEQUENCE ***

- ✓ High Voltage turned off
- ✓ Ignitron Power turned off
- ✓ High Gas turned off

Turn off Low Gas

HIT SPACE BAR TO EXECUTE

Figure 4.8. Shut down sequence.

DNA FLASHLAMP THERMAL SIMULATOR

File: NUC3.FOT
Bank Volt 733
Flux Mult 1.000
VSAL Secs 5.00
VSAL Amps 300

VORTEK CONTROL PANEL

STOP

STBY

RUN

** FLASHLAMPS & VSAL SEQUENCE **

VSAL RUN command sent

High Gas turned on

VSAL FIRING

FLASHLAMPS FIRING

Figure 4.9. Flashlamps and VSAL sequence.

controller which causes the flashlamp pulse sequence to start. The two pulses (flashlamp and VSAL) must be coordinated in this way because the time interval between when the VSAL receives the RUN command and when it goes to full current is indeterminate but at least 6 seconds.

After the last flashlamp is fired or the VSAL pulse ends (whichever is later), the shutdown sequence appears (Figure 4.8). This sequence is followed by a postfiring check list (Figure 4.10). If the DAS time has not elapsed by the time the shutdown sequence is completed, a message appears and the system does not proceed to the postfiring check list until the DAS time has elapsed. Before returning to the main menu, the operator has the option of printing the pulse data window (including the date).

4.4 Manual Overrides

The FTS Controller has only a few direct feedback signals from the system it is controlling. Besides sensing the flashlamp simmer currents, it reads the stepper home signal and the VSAL full-current signal. Thus it has no direct information about the state of the VSAL or the state of the various switches controlled electrically (e.g., high gas, ignitron power, etc.). Several of these controls are toggled, so if the controller loses track of the state (on/off) of a control due to manual operation of that control, it may send a signal to turn off the control which will

(a)

DNA FLASHLAMP THERMAL SIMULATOR

CALIBRATION POSTFIRING PROCEDURE CHECK LIST

- ✓ Inspect flashlamps & reflector for damage
- ✓ Close nitrogen cylinder valves
- Turn off FTS water pump
- Take DVM reading - hold is released after next list item
- Hit space bar to initiate second MacSym trigger
- Check that capacitor banks are discharged

As each item is completed, hit space bar

(b)

DNA FLASHLAMP THERMAL SIMULATOR

POSTFIRING PROCEDURE CHECK LIST

As each item is completed, hit space bar

- ✓ Inspect flashlamps & reflector for damage
- ✓ Close nitrogen cylinder valves
- Turn off FTS water pump
- Take DVM reading - hold is released after next list item
- Hit space bar to initiate second MacSym trigger
- Check that capacitor banks are discharged

(c)

DNA FLASHLAMP THERMAL SIMULATOR

POSTFIRING PROCEDURE CHECK LIST

As each item is completed, hit space bar

- ✓ Inspect VSAL quartz tube & electrodes for damage
- ✓ Inspect flashlamps & reflector for damage
- Close nitrogen cylinder valves
- Turn off FTS water pump
- Take DVM reading - hold is released after next list item
- Hit space bar to initiate second MacSym trigger
- Check that capacitor banks are discharged

Figure 4.10. Postfiring procedure check list: (a) calibration shot; (b) flashlamps-only pulse; (c) flashlamps-with-VSAL.

in fact turn it on. Therefore, where manual overrides are used, the control program should probably be aborted and restarted.

The "Control-Break" key combination can be used to abort the controller program at any point. It will initiate an abort sequence which should shut off all systems. However since the controller has little direct feedback, observe all controls with care during any such abort and be prepared to manually correct any problems.

5. HARDWARE

5.1 Computer, Internal Boards, and Peripherals

The microcomputer used in the Controller Upgrade is a Bentley 286/8 (IBM-AT compatible) with 40 Mb miniscribe hard disk, 80287-8 coprocessor, 4800 I/O board, EGA card, and color monitor. Also installed in the computer are a DIO216 interface board and a DCC5 timer board from Industrial Computer Source. An Epson FX-86 printer is also included for hardcopy records.

5.2 Custom Interface Board

The computer I/O boards communicate with the FTS by sending and receiving TTL signals from an SAIC-designed custom interface board housed in a slide-out drawer in the controller desk. On this board, the FTS Controller Board (DNA-001-88-C-0083), all signals to and from the computer are buffered through enable-controlled IC's. All signals to and from the FTS pass through opto-isolators to prevent EMI from the high-current, high-voltage FTS system from reaching the controller.

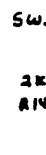
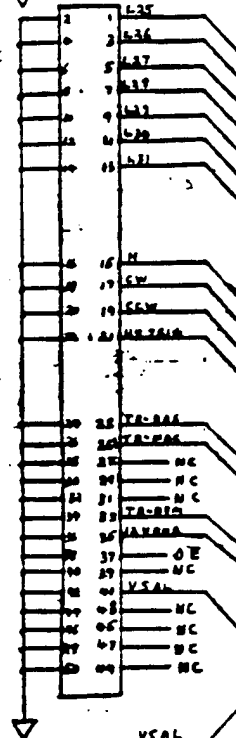
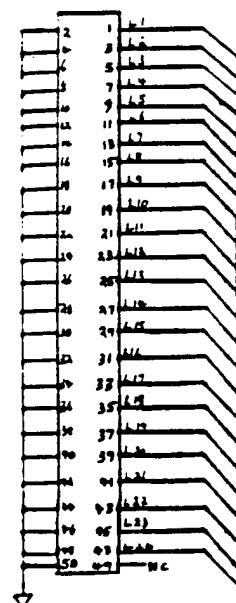
Board mounted reed relays are included to control the high and low gas, high voltage, and ignitron power. Three spare relays were included to allow for future expansion of automated control functions. Three toggle switches were also included in the FTS Controller Board to allow board diagnostics. However, the software

to use these functions is not yet part of the FTS Controller; for normal operation, these switches should remain in the "on" position.

The circuit diagram of the FTS Controller Board is shown in the following three drawings. For further information on the commercial hardware, refer to the individual manufacturers' literature.

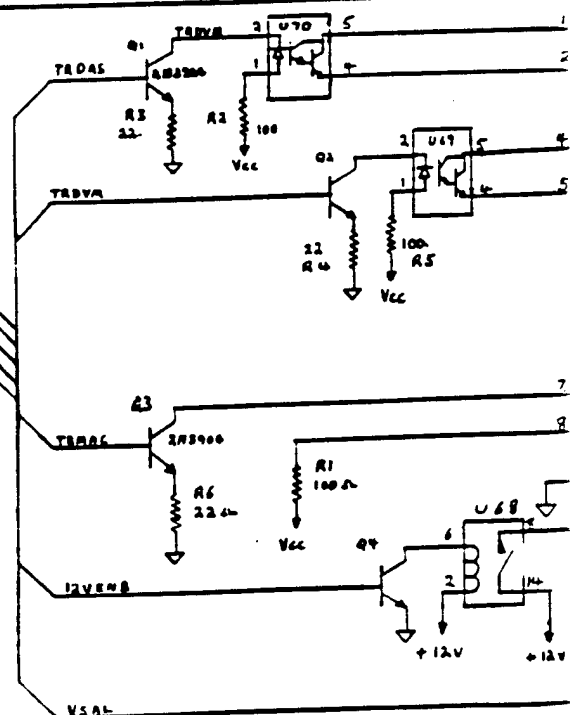
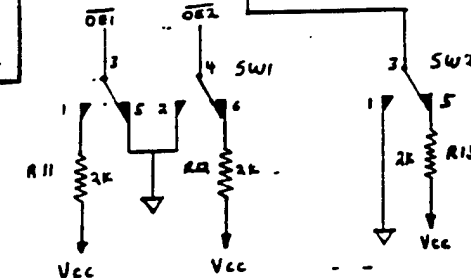
P5

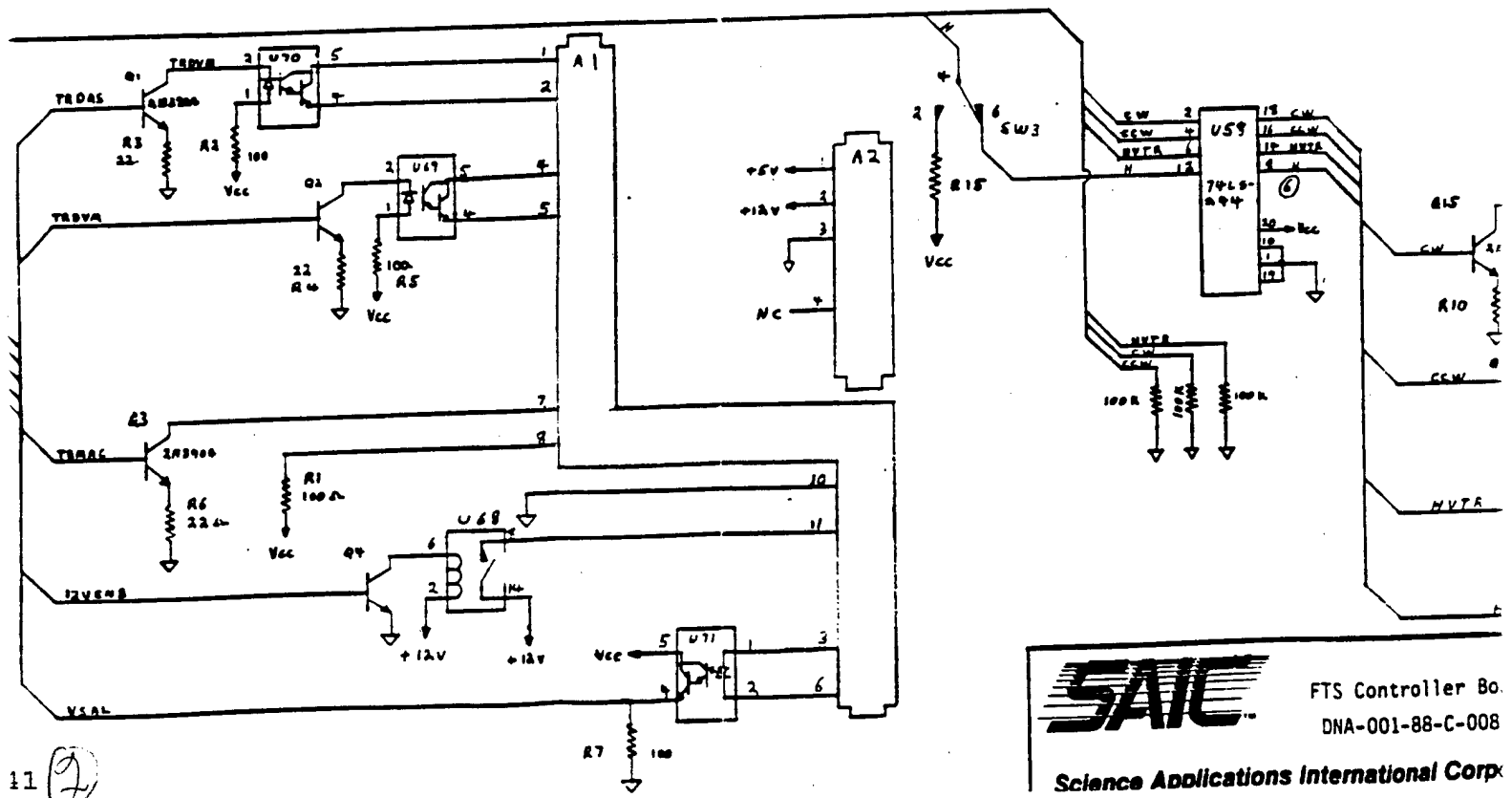
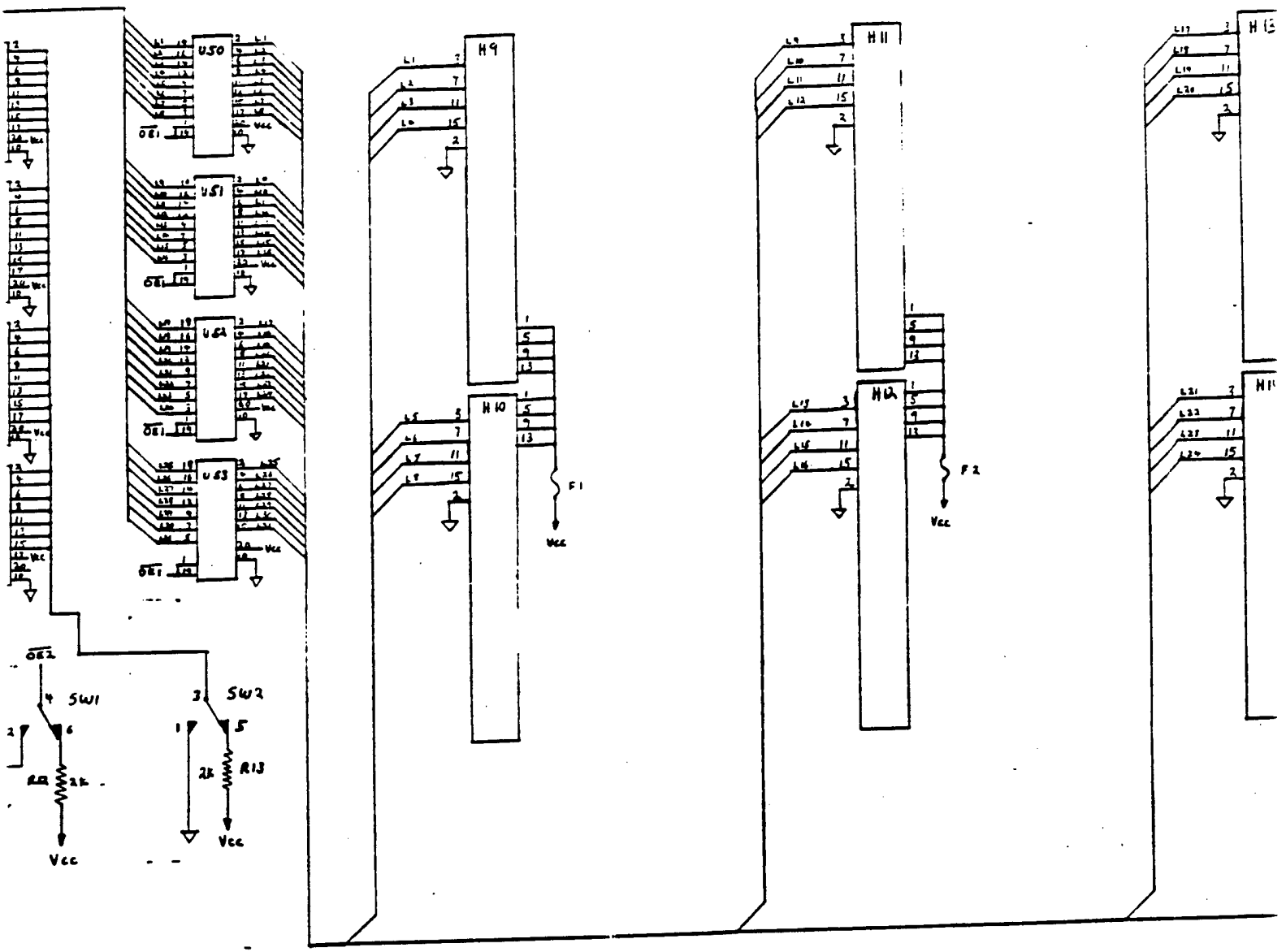
P6

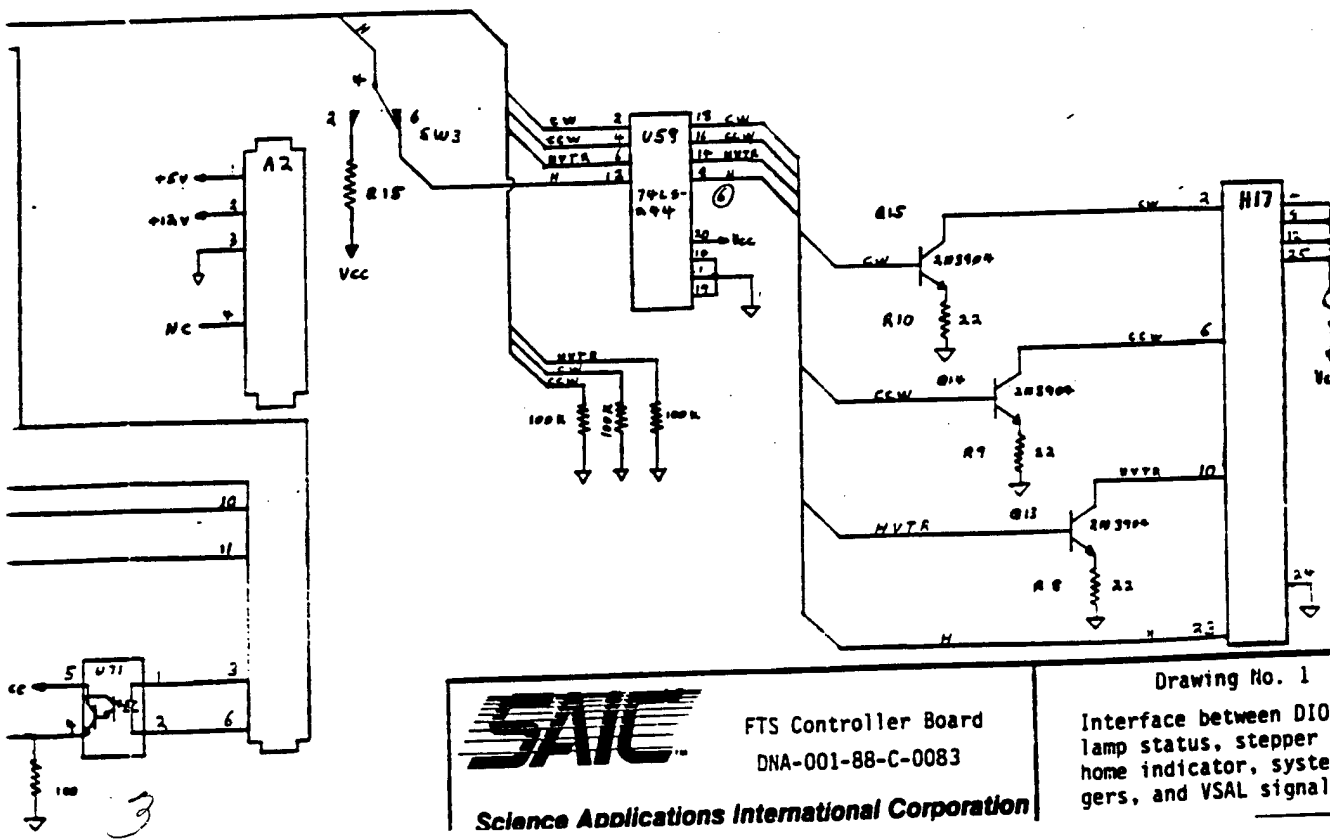
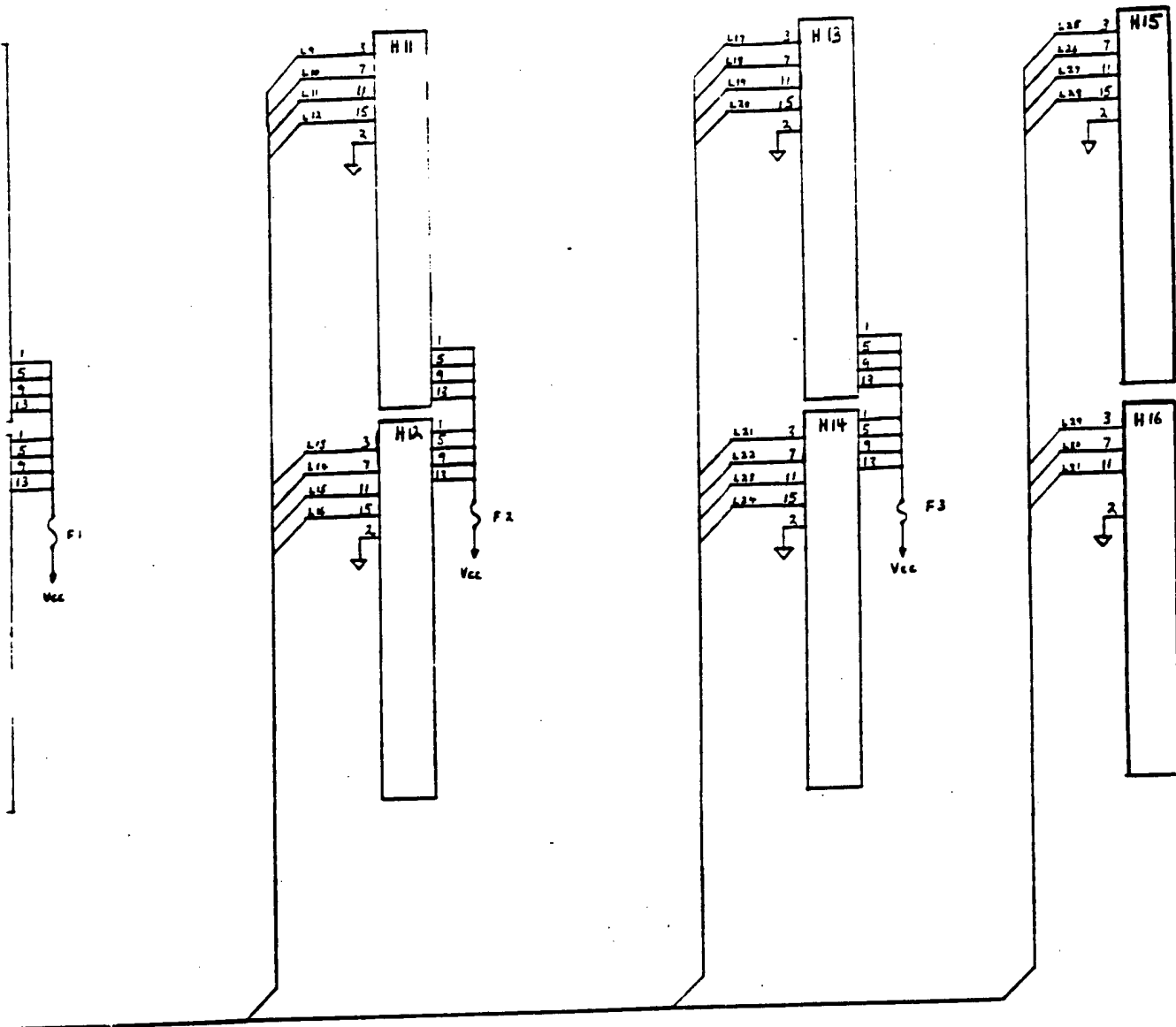


NOTES

- ① Pins not listed are N.C.
- ② A1-A4 are PC board mt. connectors
- ③ U50-U58 are 74LS244N
- ④ U69-U71 are TIL128A; U68 is relay
- ⑤ SW1, SW2, SW3 are PC board mt. DPDT
- ⑥ Data is going in opposite directions for H (Home) and VSAL signals
- ⑦ All unmarked pins H9-H17 are N.C.
- ⑧ All resistance values in ohms
- ⑨ SW1, SW2, SW3 ON for normal operation





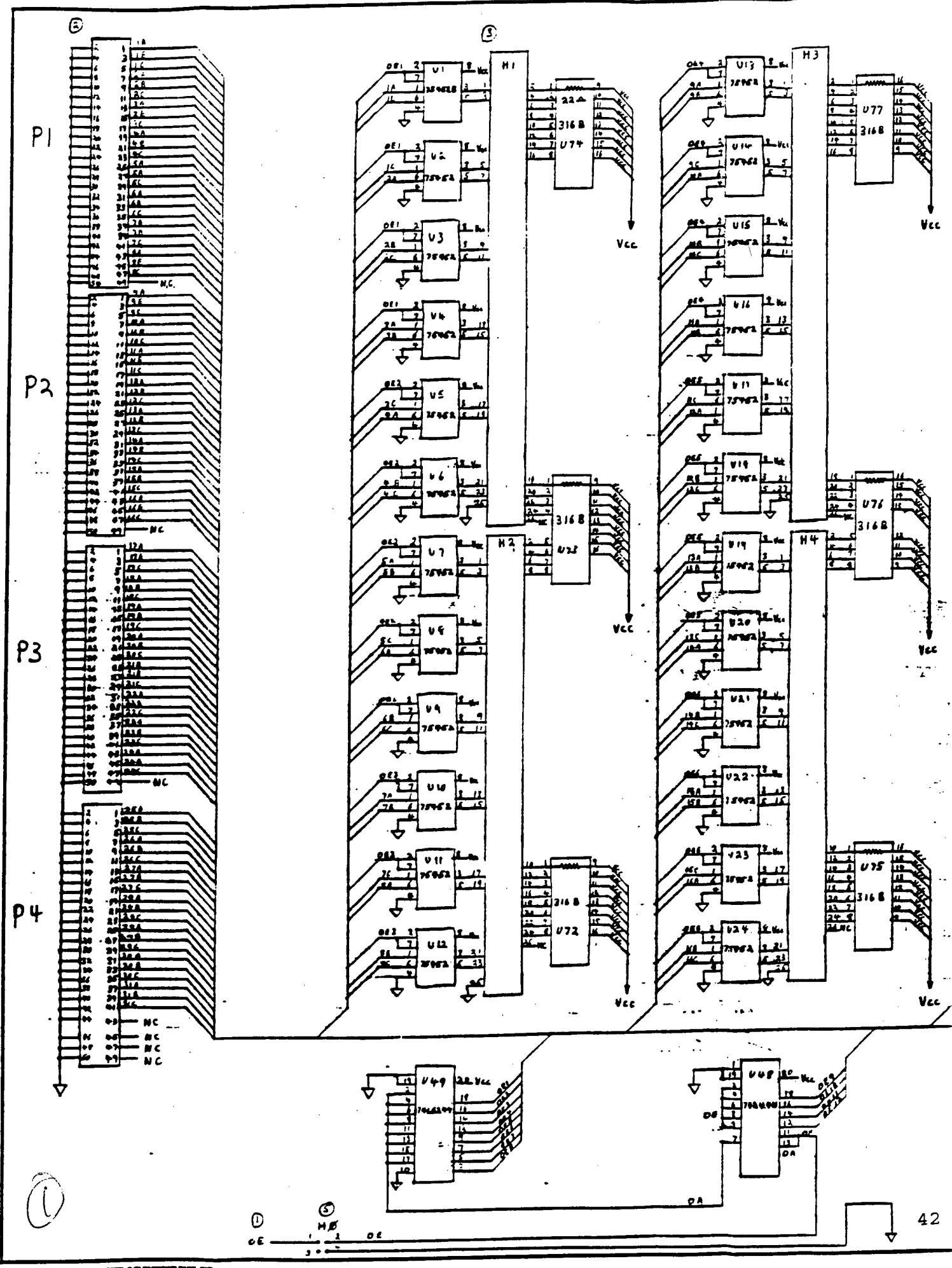


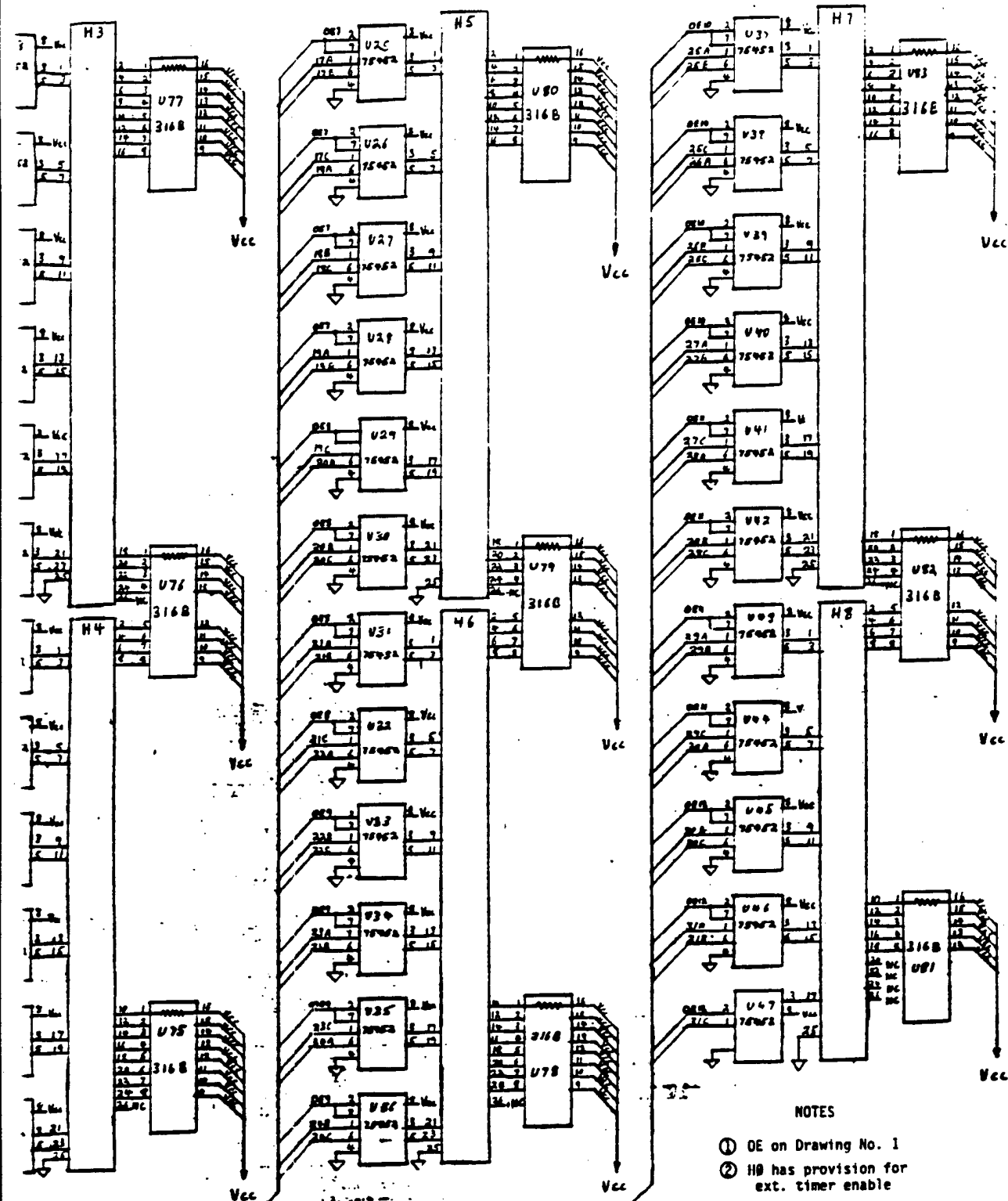
FTS Controller Board
DNA-001-88-C-0083

Science Applications International Corporation

Drawing No. 1

Interface between DIO216 and:
lamp status, stepper control,
home indicator, system trig-
gers, and VSAL signal





NOTES

- ① OE on Drawing No. 1
- ② H8 has provision for ext. timer enable
- ③ H1-H19 are 2-row, 26-pin headers
- ④ 0.1 uF capacitors go next to each IC from Vcc to ground
- ⑤ P1-P7 are 50-pin headers

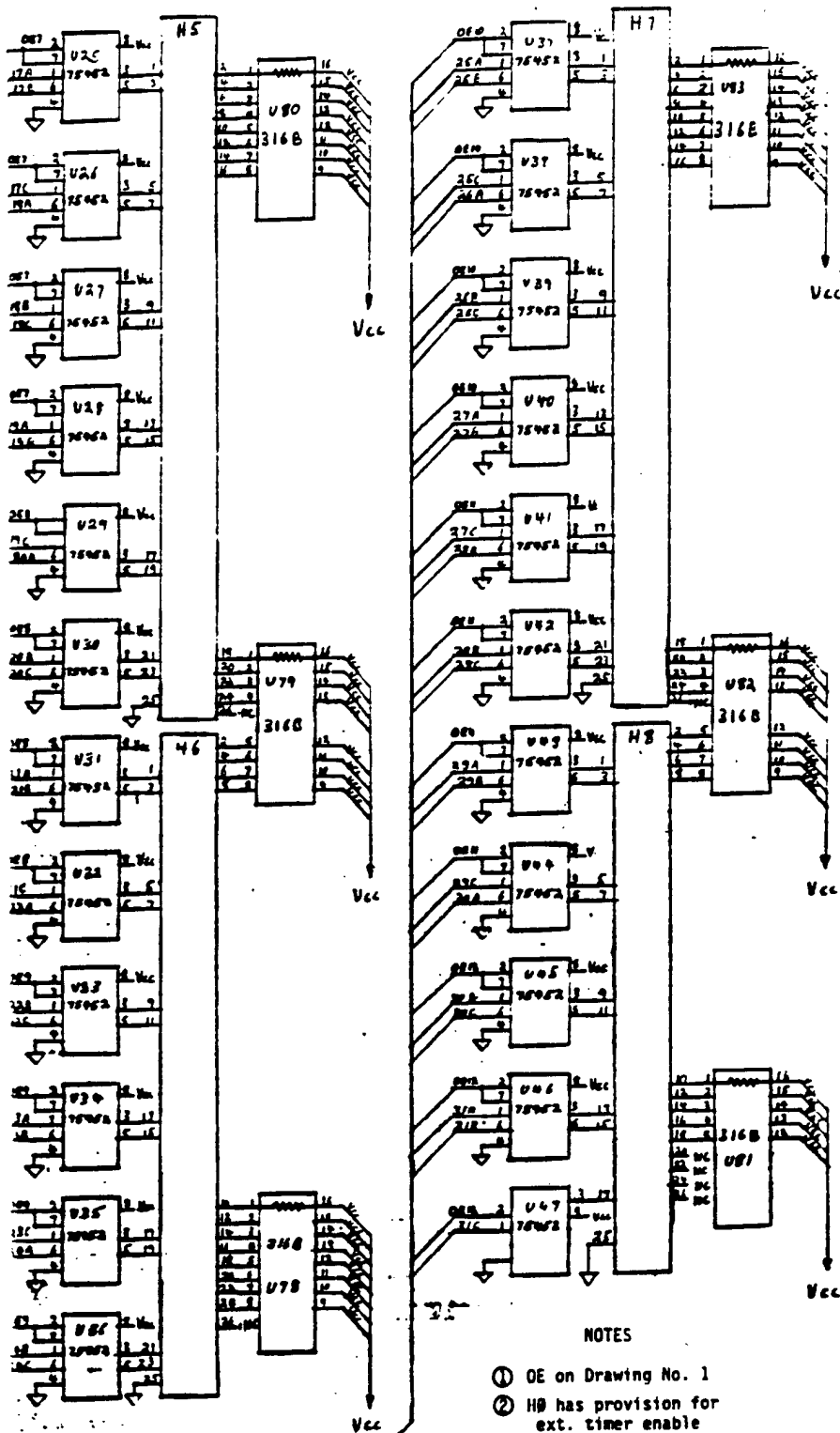


FTS Controller Board
DIA-001-88-C-0083

Science Applications International Corporation

Drawing No. 2

Interface between DIO216 and
ignitron trigger circuits



NOTES

- ① OE on Drawing No. 1
- ② H8 has provision for ext. timer enable
- ③ H1-H19 are 2-row, 26-pin headers
- ④ 0.1 uF capacitors go next to each IC from Vcc to ground
- ⑤ P1-P7 are 50-pin headers

SAIC

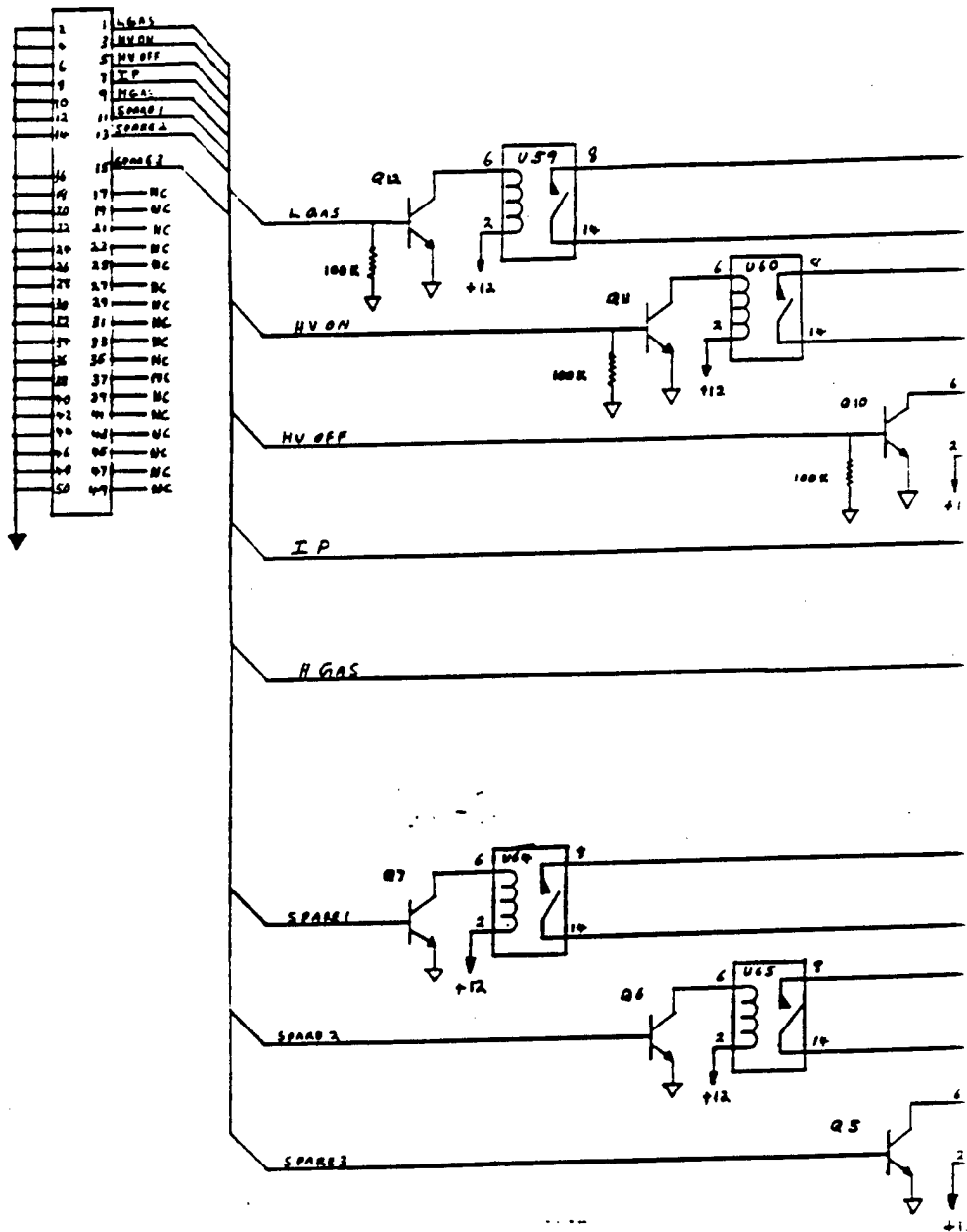
FTS Controller Board
DNA-001-88-C-0083

Science Applications International Corporation

Drawing No. 2

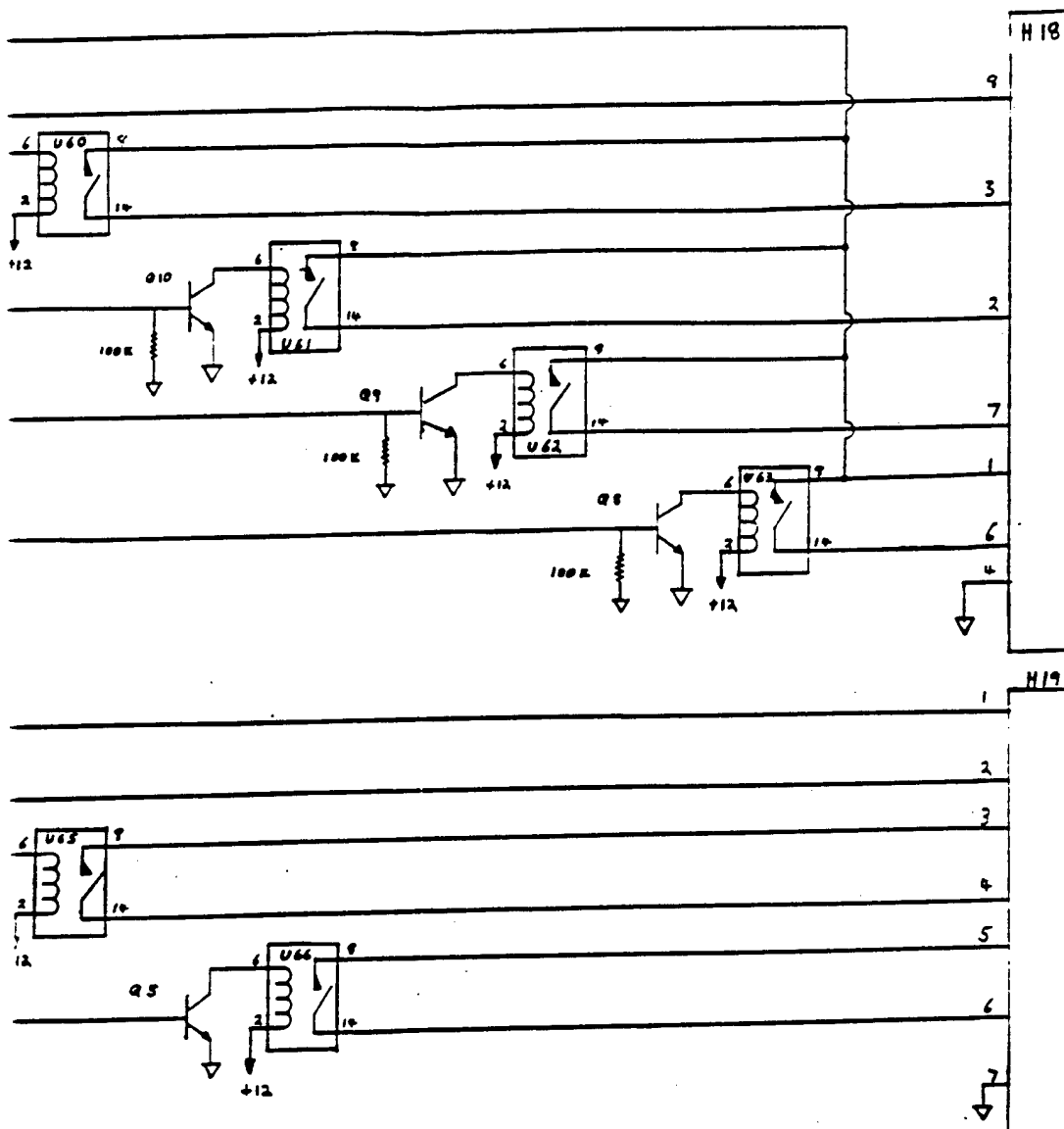
Interface between DI0216 and
ignitron trigger circuits

P7



NOTES

- ① All unmarked pins on H18, H19 are
- ② Q5-Q12 are 2N3904 transistors
- ③ U59-U66 are 17 DIP-9 reed relays with diodes



NOTES

- pins on H18, H19 are N.C.
- 2N3904 transistors
- 7-DIP-9 reed relays

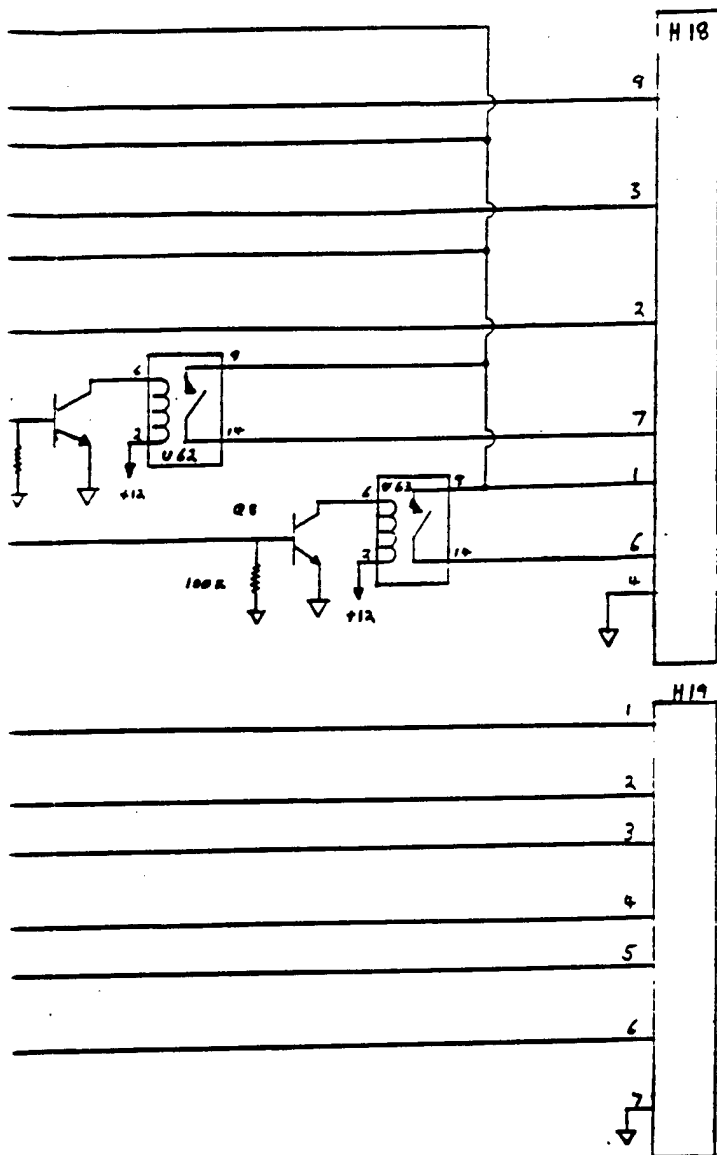


FTS Controller Board
DNA-001-88-C-0083

Science Applications International Corporation

Drawing

Automated relay



FTS Controller Board
DNA-001-88-C-0083

Science Applications International Corporation

Drawing No. 3

Automated relay control circuits

CS

SECTION 3

AUTOMATIC 3-PARAMETER PULSE SHAPING

The automatic 3-parameter waveform can be selected as an alternative to the MORE code operation. When Calculate nuclear waveform is selected from the Main menu, Calculation Choices will be displayed as in Figure 3.1. Select number 2-Automatic 3-parameter waveform and Figure 3.2, Pulse Parameters will be displayed. Peak flux, time to peak flux, and total fluence may be entered.

DNA FLASHLAMP THERMAL SIMULATOR

CALCULATION CHOICES

1 - Direct MORE code operation
② - Automatic 3 - parameter waveform

Type selection number { 1 or 2 }
Hit <Enter> to proceed , <Esc> to go back

Figure 3.1. Calculation Choices.

DNA FLASHLAMP THERMAL SIMULATOR

PULSE PARAMETERS

Enter peak flux: 100 Cal / cm² - sec

Enter time to peak flux: 0.1 seconds

Enter total fluence: 20 Cal / cm²
{ max fluence = 2 * peak flux * tmax }

Choose flux file name: test
{ no extensions }

Figure 3.2. Pulse Parameters.

SECTION 4
SYSTEM DATA SET-UP AND VOLTAGE MONITORING

Setup for voltage monitoring using the Apple IIe:

1. Ensure Macsym 20 in on. (Look for light on its front panel.)
2. Insert ASCII Express for voltage Monitoring into disk drive #1.
3. Turn on Apple IIe monitor and computer.
4. At the "AE: TERM-->" hit space bar then press **ENTER**.
5. At the prompt type **CFG4**; then press **ENTER**.
6. Type **1**; then press **ENTER**.
7. At **01**. press **Control, Q** then **S**.
8. At **Filename** type **PARTONE A.ANALOG**; then **ENTER** 4 times. Wait for prompt!
9. At the prompt type **2**; then press **ENTER**.
10. At **02**. press **Control, Q** then **S**.
11. At **Filename** type **PARTTWO A.ANALOG**; then **ENTER** 4 times. Wait for prompt!
12. At the prompt press **Control, Q** then **R**.
13. At AE: COPY ON
 AE: Term --> type **#1** then press **ENTER**.
14. FOR A HARD COPY OF LAMP BANK VOLTAGES.
 - a. Press **Control, Q** then **R**. (This turns off the copier.)
 - b. Type **Control, Q** then **Y**.
 - c. Type **.O** for a hard copy.
 - d. After you receive a hard copy type **.C** then **ENTER** answer **Y** (yes)
 - e. Type **.X**; at the +> sign type **R**.
 - f. The operator is ready to collect the lamp voltage data again.

SECTION 5

SERVICING

There is no main safety disconnect for the Flashlamp Thermal Simulator (FTS) but power can be cut to the capacitor charging system by opening circuit breakers 37, 39, and 41 on panel LP2 (Figure 5.1) behind the false wall or by pulling the large plug (208V, 30, 50A) on the wall above the control console in the FLS control room. Note that neither of these actions in themselves will render the capacitor bank SAFE.

Access to the capacitor banks for repair or maintenance is limited to authorized, trained Facility personnel. An observer must be present when any work is performed on any part of the capacitor bank system or inside the Flash-Head cabinet. The observer must stand clear of all cabinet, frame, or other structures and must keep the accessing individual in sight at all times. The observer must be trained in the technique of cardiopulmonary resuscitation (CPR) and have available to him a grounded gaff with wooden handle to be used to separate the accessing individual from high voltage if necessary.

When accessing the inside of any capacitor bank or inside the Flash-Head cabinet, the accessing individual will refrain from wearing finger rings, metal watches or bracelets, metal neck adornments, and metal belt buckles. Tools will not be carried in pockets when they protrude from the pocket. Pens or pencils will be removed from breast pockets.

Before accessing the capacitor bank area the bank discharge relays must be activated for a minimum of 10 minutes. Before accessing a capacitor drawer, the output line must be jumpered to ground using a suitable grounding strap and finally the capacitor to be accessed will be shorted using a suitable jumper across its terminals.

When servicing the Vortek Stabilized Arc Lamp (VSAL), the main disconnect (Figure 5.1) must be pulled down to its OFF position. Great caution must be exercised when working on the VSAL and components should always be shorted to ground before touching, because inductors in the system are capable of holding a charge of electricity even though the main disconnect has been pulled OFF. The "Two-Man" system is mandatory, whereby one man is performing the necessary service while a second man, trained in CPR, observes and is prepared to take action to clear the first man of harm by body-block or grounding pole. Eye protection in the form of safety glasses, goggles, or

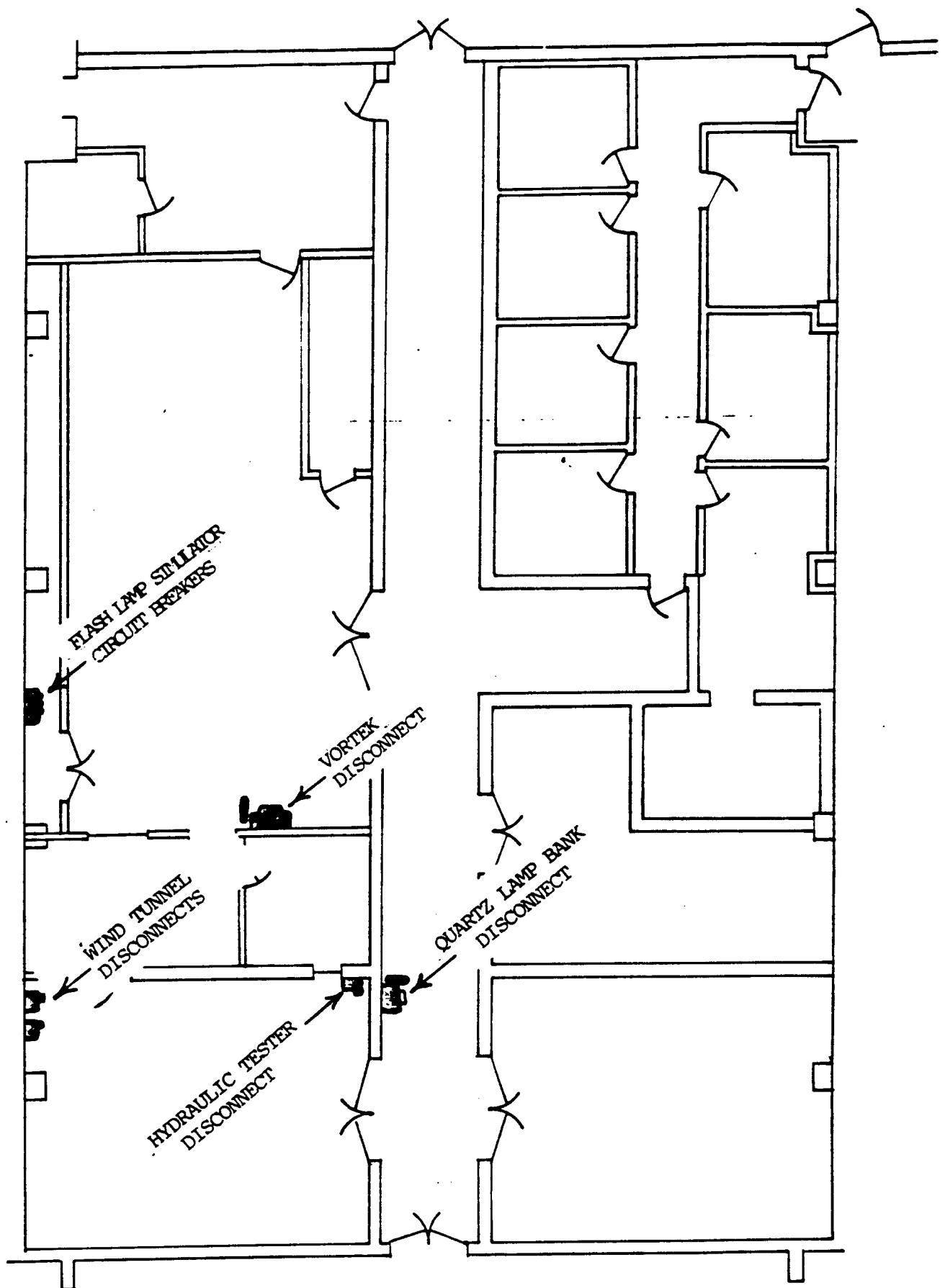


Figure 5.1. Disconnects.

face shields is to be worn by both men. Cooling water could be present on the floor around the VSAL creating a slippery footing condition. Hoses and cables create a possible tripping hazard and caution is advised.

Gas Bottles

Gas bottles will be moved only by trained, authorized Facility personnel and representatives of the supplier. Facility personnel will move only one bottle at a time when no cart is available; two bottles on a two-bottle cart only. Bottles will be stored in a special area where they may be properly secured in an upright position. When in storage, bottles may be grouped without securing each bottle individually but the group must fill the storage area with no open areas into which a bottle could lean or fall. When bottles are put on-line, each bottle will be secured by a chain attached to the wall and wrapping fully around the bottle at a point two-thirds of the bottles height.

Leather palm or other special bottle-handling gloves should be worn when moving gas bottles to improve grip and lessen possible damage to fingers or hands. Leather or safety shoes should be worn when moving gas bottles. Canvas or other soft-sided shoes such as tennis shoes or sneakers are not recommended wear for the manipulation of gas bottles.

Connecting/disconnecting gas bottles will be accomplished only by trained authorized Facility personnel. Eye protection in the form of safety glasses, goggles, or face shield must be worn when changing bottle fittings.

DISTRIBUTION LIST
DSWA-TR-96-34

DEPARTMENT OF DEFENSE

DEFENSE ELECTRONIC SUPPLY CENTER
ATTN: DESC-E

DEFENSE INTELLIGENCE AGENCY
ATTN: OGA-4B2
ATTN: TWJ

DEFENSE SPECIAL WEAPONS AGENCY
4 CYS ATTN: ESA LTC O'SHAUSHNESSY
ATTN: ESA W SUMMA
2 CYS ATTN: TRC
ATTN: WE
ATTN: WEL
ATTN: WEP B PRASAD

DEFENSE TECHNICAL INFORMATION
2 CYS ATTN: DTIC/OCP

FC DEFENSE SPECIAL WEAPONS AGENCY
ATTN: FCT-RSET MAJ SCHLICHER
ATTN: FCTO
ATTN: FCTOS
ATTN: FCTT DR BALADI
ATTN: FCTTS J JABLONSKY
ATTN: FCTTS E MARTINEZ

DEPARTMENT OF THE ARMY

ADVANCED RESEARCH PROJECT AGENCY
ATTN: PMO

ARMY RESEARCH LABORATORIES
ATTN: TECH LIB
ATTN: ANSRL-WT-NB-MARY ABE

NUCLEAR EFFECTS DIVISION
ATTN: B HAMILTON
ATTN: J OKUMA
ATTN: STEWS-NE-A BRIONES
ATTN: STEWS-TE R PENNY

U S ARMY COLD REGION RES & ENG LAB
ATTN: TECHNICAL DIRECTOR

US ARMY ENGINEER DIV HUNTSVILLE
ATTN: HNDED-CS
ATTN: HNDED-SY

U S ARMY ENGR WATERWAYS EXPER STATION
ATTN: D RICKMAN, CEWES-SE-R
ATTN: J WINDHAM, CEWES-SD-R
ATTN: TECHNICAL LIBRARY

U S A NATIONAL GROUND INTELLIGENCE CTR
ATTN: IAFSTC-RMT

U S ARMY NUCLEAR & CHEMICAL AGENCY
ATTN: G LONG

U S ARMY RESEARCH LAB
ATTN: AMSRL-SL-CM E FIORAVANTE
ATTN: AMSRL-WT-NC R LOCKS
ATTN: AMSRL-WT-NC R LOTTERO
ATTN: AMSRL-WT-NC/C MERMAGAN
ATTN: AMSRL-WT-NC/S J SCHRAML
ATTN: SLCBR-SS-T (TECH LIBRARY)
ATTN: SLCBR-TBD-B R PEARSON

U S ARMY SPACE STRATEGIC DEFENSE CMD
ATTN: CSSD-CS
ATTN: CSSD-SA-E

U S ARMY TRADOC ANALYSIS CTR
ATTN: ATRC-WSSR

U S ARMY THAAD PROJECT OFFICE
ATTN: CSSD-H-SA

DEPARTMENT OF THE NAVY

DAVID TAYLOR RESEARCH CENTER
ATTN: P POTTER
ATTN: S BARTON

NAVAL RESEARCH LABORATORY
ATTN: CODE 5227 RESEARCH REPORT
ATTN: CODE 5584 E FRIEBELE
ATTN: CODE 6180
ATTN: J GRUN

NAWC-WD
ATTN: CODE 473320D HERIGSTAD

NRAD ACTIVITY PACIFIC
ATTN: CODE 250

DEPARTMENT OF THE AIR FORCE

HQ 497 IG/INOT
ATTN: INT

DEPARTMENT OF ENERGY

LOS ALAMOS NATIONAL LABORATORY

ATTN: D FRY MS C914
ATTN: D STUPIN, MS C914
ATTN: J FRITT MS P962
ATTN: J ZAHRT MS F669
ATTN: L BRYANT MS C914
ATTN: M THOMPSON MS D410
ATTN: MS P364 REPORT LIBRARY
ATTN:MS218 P WHALEN
ATTN: P GINSBERG
ATTN: S S HECKER
ATTN: W BRUNISH MS-F659

SANDIA NATIONAL LABORATORIES

ATTN: B PLUMMER/S-0175
ATTN: C CAMERON/MS 0153
ATTN: MS 1159/W H BARRETT
ATTN: TECH LIB

OTHER GOVERNMENT

CENTRAL INTELLIGENCE AGENCY

ATTN: OSWR/NED 5S09 NHB

FEDERAL EMERGENCY MANAGEMENT

ATTN: OFC OF CIVIL DEFENSE

DEPARTMENT OF DEFENSE CONTRACTORS

ABERDEEN RESEARCH CENTER

ATTN: N ETHERIDGE

APTEK, INC.

ATTN: S SUTHERLAND

BERKELEY RSCH ASSOCIATES, INC.

ATTN: J ORENS

BOEING TECHNICAL & MANAGEMENT SVCS, INC

ATTN: R BRYAN CARINS

CARPENTER RESEARCH CORP

ATTN: H J CARPENTER

CHARLES NEEDHAM

ATTN: CHARLES NEEDHAM

DAYTON UNIVERSITY

2 CY ATTN: MICHAEL SWEENEY

DAYTON, UNIVERSITY

ATTN: B WILT

ATTN: R SERVAIS

GEO CENTERS, INC.

ATTN: E MARRAM

GEORGIA INSTITUTE OF TECHNOLOGY

ATTN: EES/EMSL/SOLAR SITE C BROWN

H & H CONSULTANTS, INC.

ATTN: W HALL

INFORMATION SCIENCE, INC.

ATTN: W DUDZIAK

JAYCOR

ATTN: J BRYARS

JAYCOR

ATTN: CYRUS P KNOWLES

KAMAN SCIENCES CORP

ATTN: D CAYNE

ATTN: LIBRARY

KAMAN SCIENCES CORP

ATTN: A L PHILLIPS

ATTN: G PADEREWSKI

ATTN: J FANNING

ATTN: T DEUTON

ATTN: Z LAWRENCE

KAMAN SCIENCES CORP

ATTN: D MOFFETT

KAMAN SCIENCES CORP

ATTN: DASIAAC

KARAGOZIAN AND CASE

ATTN: J KARAGOZIAN

LOCKHEED MARTIN CORPORATION

ATTN: S SALISBURY

LOCKHEED MARTIN CORPORATION

ATTN: TECH INFO CTR D/COLL

LOGICON R AND D ASSOCIATES

ATTN: C K B LEE

ATTN: D SIMONS
ATTN: J DRAKE
ATTN: LIBRARY

LOGICON R AND D ASSOCIATES
ATTN: G GANONG

MAXWELL LABORATORIES INC.
ATTN: J BARTHEL
ATTN: T PIERCE

MISSION RESEARCH CORP.
ATTN: TECH LIBRARY

MISSION RESEARCH CORP.
ATTN: D OHARA
ATTN: K WOODS

NICHOLS RESEARCH CORPORATION
ATTN: R BYRN
ATTN: STANLEY R BERRY

PACIFICE-SIERRA RESEARCH CORP
ATTN: H BRODE

PRIMEX PHYSICS INTERNATIONAL
ATTN: E WILLIS

SCIENCE APPLICATIONS INTL CORP
ATTN: TECHNICAL REPORT SYSTEM

SCIENCE APPLICATIONS INTL CORP
ATTN: J GUEST
ATTN: J SIMMONS
ATTN: W SCHAEFER

SCIENCE APPLICATIONS INTL CORP
ATTN: J COCKAYNE
ATTN: W CHADSEY
ATTN: W LAYSON

SCIENCE APPLICATIONS INTL CORP
ATTN: G BINNINGER

SRI INTERNATIONAL
ATTN: DR JIM GRAN
ATTN: G GREENFIELD

TELEDYNE BROWN ENGINEERING
ATTN: J RAVENSCRAFT
ATTN: MS-12 TECH LIB (P SHELTON)

THE AEROSPACE CORP
ATTN: L SELZER M4/925
ATTN: LIBRARY ACQUISITION M1/199

THE BDM CORPORATION OF SAUDIA ARABIA
ATTN: E DORCHAK

TITAN CORPORATION
ATTN: J THOMSEN

TRW SPACE & DEFENSE SECTOR SPACE &
TECH GROUP
ATTN: OUT6/W WAMPLER