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TRI-SERVICE THERMAL FLASH TEST FACILITY.(U)

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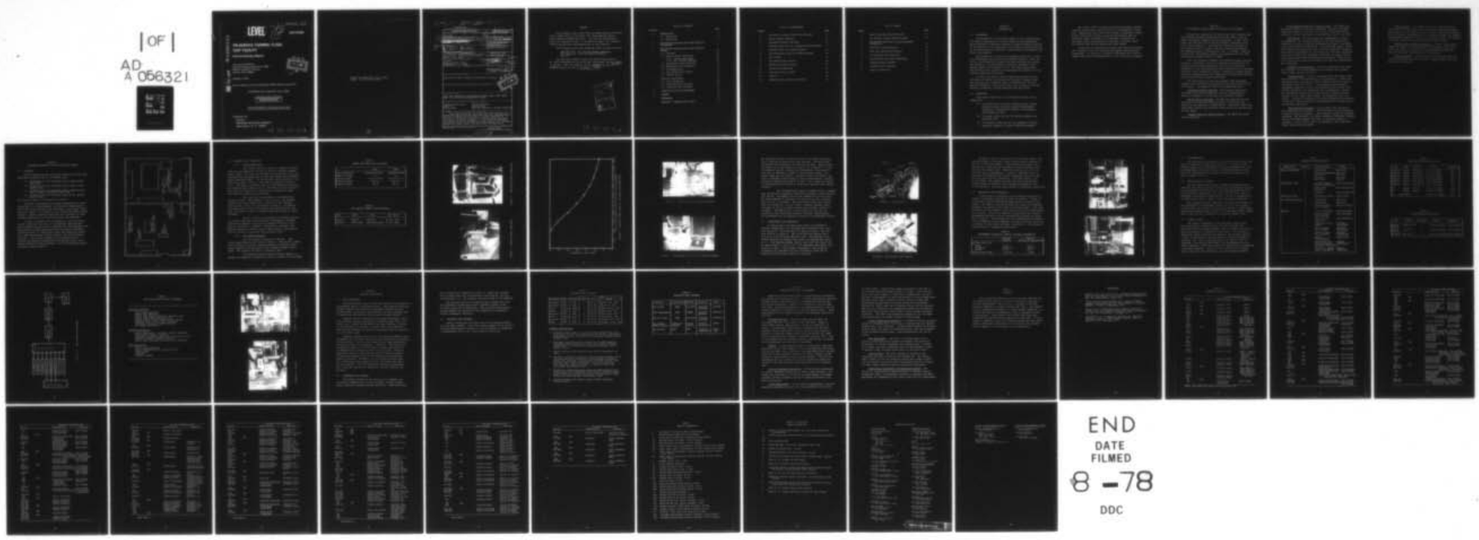

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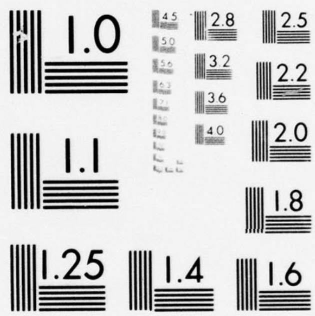

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TRI-SERVICE THERMAL FLASH TEST FACILITY

Interim Summary Report

University of Dayton
Industrial Security Super KL-505
300 College Park Avenue
Dayton, Ohio 45409

29 March 1978

Interim Report for Period 6 August 1976—5 November 1977

CONTRACT No. DNA 001-76-C-0339

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Prepared for
Director
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This report describes the status and capabilities of the Tri-Service Thermal Nuclear Flash Test Facility. The Facility is used for investigating the effects of thermal radiation on materials. The Facility consists of several quartz lamp banks for simulating thermal radiation, a wind tunnel for simulating aerodynamic loads, and a mechanical loading device for simulating tension and binding loads, and associated instrumentation.

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PREFACE

This summary report covers work performed during the period from 6 August 1976 to 5 November 1977 under Defense Nuclear Agency contract DNA001-76-C-0339. The work was administered under the direction of Maj. D. Garrison and Capt. J.M. Rafferty, Contracting Officer's Representatives on this contract.

The following report was generated under the same contract:

> UDRI-TR-77-28, "Tri Service Thermal Radiation Test Facility: Test Procedures Handbook," May 1977.

The work was conducted under the general supervision of Mr. Dennis Gerdeman and the principle investigator was Dr. Ronald A. Servais. The test engineer was Mr. Benjamin H. Wilt and the research technician was Mr. Nicholas J. Olson.

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

The degradation of materials exposed to the intense radiation heating generated by a nuclear blast can vary enormously. The performance of materials exposed to intense radiation heating can be observed in the laboratory; the results of these tests can be utilized by design engineers to match material performance with design requirements.

The University of Dayton has extensive experience in materials development and materials performance testing. Since the 1950's, the University of Dayton has been involved with testing and evaluating the performance of materials exposed to high thermal inputs, particularly for U.S. Air Force applications. These efforts have included the development and operation of the required laboratory facilities.

In 1976, the Defense Nuclear Agency contracted with the University of Dayton to establish and operate a thermal flash test facility for conducting tests on materials for the Tri-Services community. The facility was to be located at the USAF Materials Laboratory, Wright-Patterson AFB, Ohio 45433.

1.2 OBJECTIVES

The primary objectives of the research activity can be summarized:

(1) To provide the Tri-Service community with a quick-response intense radiation heating experimental capability, including the effects of aerodynamic and mechanical loads;

(2) To conduct tests for the Tri-Service community as required; and

(3) To generate a data base of the response of typical materials exposed to nuclear flash environments.

The initial effort included identifying available intense radiation sources and related control and instrumentation hardware. Appropriate data acquisition system, a mechanical loading device, and various thermal monitoring instruments were not available; these items had to be purchased or constructed. Laboratory space and appropriate high power utilities, water for cooling, and venting systems were also needed.

A plan for the laboratory operation and testing procedures and a priority list for laboratory development also had to be established. In addition, information describing the facility capabilities had to be disseminated to the Tri-Service community.

SECTION 2

TRI-SERVICE NUCLEAR FLASH TEST FACILITY DEVELOPMENT

Through the cooperation of several Air Force divisions and laboratories located at Wright-Patterson AFB, much of the required laboratory equipment was made available. A small wind tunnel was obtained from the Flight Dynamics Laboratory along with a solar simulator. The Materials Laboratory provided an arc imaging furnace, a quartz lamp bank, several radiometers, and laboratory space in Building 56, Bay 7, at WPAFB. These activities were coordinated primarily by personnel from the USAF Aeronautical Systems Division of WPAFB.

After the available hardware and laboratory space had been obtained, a laboratory layout was developed and priorities for installing the various simulation devices were established. Components of the laboratory which were required but not available including a data acquisition system, a mechanical loading device, and other instrumentation were identified and purchased following normal Defense Nuclear Agency procedures.

The installation of the basic thermal flash simulation hardware was the primary activity during the initial portion of the contract. The specific efforts are summarized below.

Stationary Quartz Lamp Bank - The SQLB was operational initially; this unit is primarily used for instrumentation check-out although it is available for materials testing.

Mobile Quartz Lamp Bank - The MQLB was designed and constructed as the primary radiation source for both the wind tunnel and the mechanical loading device. Electrical power with associated controls was installed along with an air cooling unit for the lamps.

Gaussian Beam Arc Imaging Furnace - The GBAIF was operational initially.

One-Dimensional Beam Arc Imaging Furnace - The ODBAIF was obtained but power has not been installed. Bringing the ODBAIF (sometimes referred to as the solar furnace) up to operational status has not been considered a high-priority item at this time.

Wind Tunnel - The wind tunnel was disassembled, cleaned, and repainted. The internal surfaces in the test section were remachined in order to provide aerodynamically smooth interfaces. A new quartz window was installed. A new specimen support system was designed and constructed; new ports for access and instrumentation were incorporated; an exit screen was installed; electrical power and controls were installed, along with an exhaust system in accordance with WPAFB environmental procedures. The two wind tunnel flow conditions were determined and some flow improvements were completed.

Mechanical Loading Device - Since no mechanical load frame was available, a unit was purchased from Applied Test Systems (Series 2450) and was installed.

Instrumentation - Several radiometers were available; these were returned to the manufacturer for recalibration. Additional radiometers were purchased in order to monitor the full range of anticipated heat flux levels. A discrepancy between several radiometers required a trip to the manufacturer to clarify calibration procedures; the problem was due to improperly locating the radiometers (which have various incident radiation angles) relative to the radiant heat source; the problem has been resolved. A pressure transducer and related hardware were purchased. In addition, jigs for mounting instrumentation for various applications were fabricated.

Data Acquisition System - A high speed, high resolution data system was not available. With the advice of the University of Dayton computing analysts, a data handling system was designed, purchased, and installed; the system includes a dedicated telephone line to the WPAFB computer facility, an accoustic coupler, a teletype, a clock, and an LSI-11 microcomputer, with associated signal conditioning equipment.

Control System - A portable console for controlling the lamp banks, the wind tunnel, other peripheral laboratory systems and housing the data acquisition system was designed and assembled. It also includes instrumentation for monitoring tests (for example, thermocouple temperature output and lamp bank voltage and current) and safety controls for quick shutdown of the facility.

Pre-Test and Post-Test Information - A still photographic capability (both 35 mm and Polaroid) is available, along with scales and measuring devices for measuring and recording pre-test and post-test characteristics of materials.

Exhaust Systems - Exhaust systems for the wind tunnel and a hood for testing with the Mechanical Loading Device have been designed and installed.

SECTION 3

TRI-SERVICE NUCLEAR FLASH TEST FACILITY STATUS

3.1 OVERVIEW

The Tri-Service Nuclear Flash Test Facility has four basic experimental capabilities at the present time:

(1) Irradiation of test specimens using a Quartz Lamp Bank (QLB);

(2) Irradiation of test specimens using a QLB in aerodynamic flow;

(3) Irradiation of test specimens using a QLB with tension or bending mechanical loads; and

(4) Irradiation of test specimens using an Arc Imaging Furnace (AIF).

The Facility layout is illustrated in Figure 1.

Available instrumentation includes radiometers for determining heat flux, thermocouples for monitoring temperatures, a pitot tube for determining flow velocities, strain gages, still and movie cameras, x-y recorders, and various electronic control devices. Limited machining facilities are available for minor specimen modification or alteration during test programs.

In order to maximize the utilization of the Tri-Service Nuclear Flash Test Facility, two coordination meetings were held at Wright-Patterson AFB in November 1976 and September 1977. The meetings included representatives from various projected industrial users, as identified by DNA, USAF Materials Laboratory, USAF Aeronautical Systems Division, and the University of Dayton. The primary purposes of the meetings were to identify anticipated requirements for projected tests, to establish tentative testing schedules, and to provide preliminary materials response results.

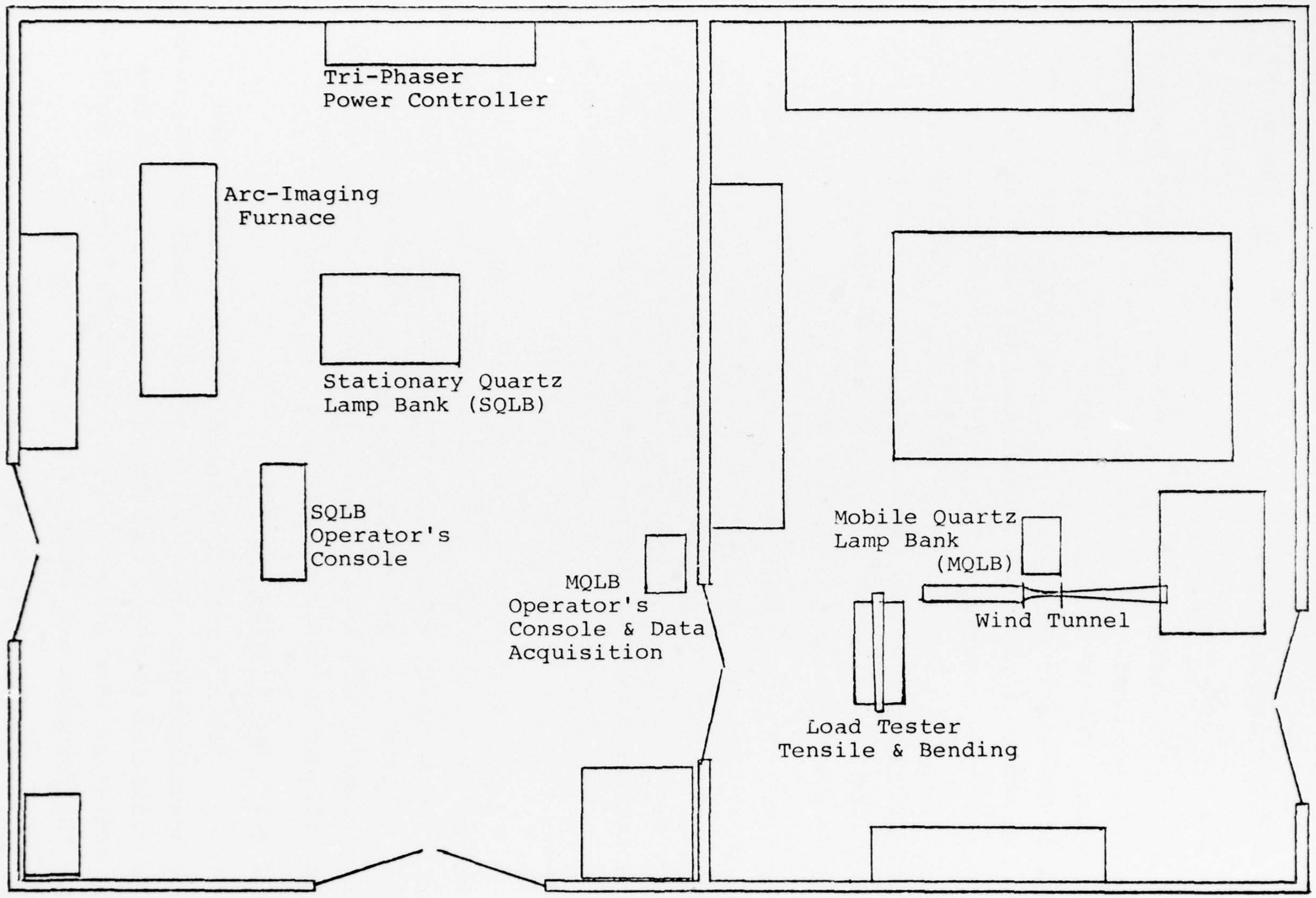

Figure 1. Tri-Service Nuclear Flash Test Facility.

3.2 NUCLEAR FLASH SIMULATION

3.2.1 Quartz Lamp Banks

The intense radiation needed to simulate a nuclear flash can be produced by a series or bank of tungsten filament, quartz lamps. Two banks are available in the Facility; they are designated the Stationary Quartz Lamp Bank (SQLB) and the Mobile Quartz Lamp Bank (MQLB). The operational characteristics of the banks are listed in Table 1; the banks are shown in Figures 2 and 3. The SQLB is primarily used for instrumentation check-out and radiation-only exposure tests. The MQLB is used in conjunction with the simulation of aerodynamic or mechanical loads. Both banks are completely operational.

The large bank area produces a one-dimensional radiation source, approximately 15 cm by 12 cm. The incident radiation on a test specimen is a function of the distance from the bank source, as illustrated in Figure 4. No physical constraints are placed on the maximum test specimen size; however, care must be taken to minimize edge heat losses on larger specimens.

Several options for increasing the radiant heating of a quartz lamp bank array have been investigated, including visiting the Rockwell International Research Facility in Los Angeles, California. Rockwell's approach for increasing the heating primarily involves a denser lamp packing; this approach will be utilized in designing new lamp bank arrays.

3.2.2 Arc Imaging Furnaces

Two arc imaging furnaces are available. The furnace specifications are given in Table 2. Both utilize carbon arcs as radiation sources, thereby producing a different wavelength radiation than produced by the tungsten filament quartz lamps. The furnaces are shown in Figures 5 and 6.

The Gaussian Beam Arc Imaging Furnace (GBAIF) is capable of producing a radiant heat flux up to about 140 $cal/cm^2 sec$.

TABLE 1

QUARTZ LAMP BANK SPECIFICATIONS

	SQLB	MQLB
Lamp Designation	GE/Q6M/T3/CL/HT	GE/Q6M/T3/CL/HT
Number of Lamps	24	24
Lamp Bank Area	22 cm x 25 cm	22 cm x 25 cm
Maximum Voltage	460 vac	460 vac
Maximum Current	300 a	300 a

TABLE 2

ARC IMAGING FURNACE SPECIFICATIONS

Mfgr	Model	Beam	Arc Power
Strong	66000-2	Gaussian	72 vdc, 160a
Genarco	T-ME 6-CWM	One-dimensional	75 vdc, 420a

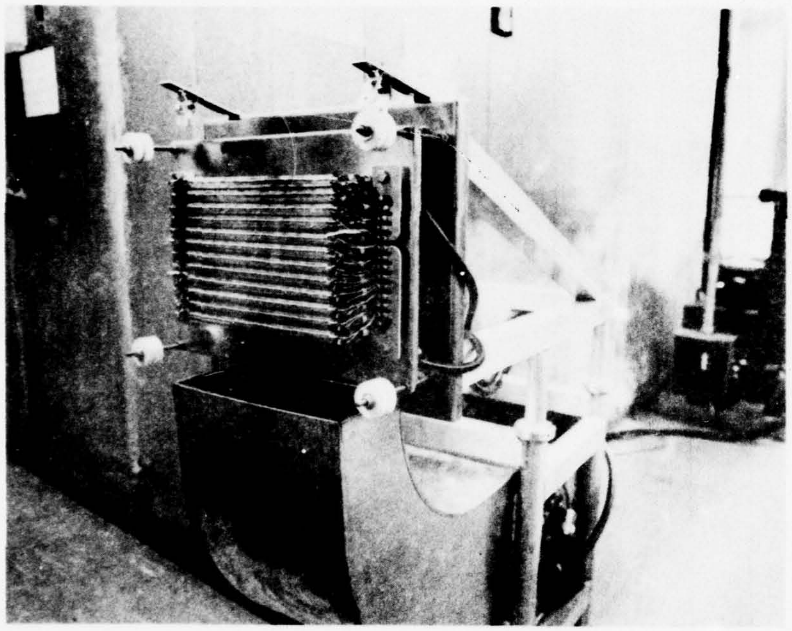

Figure 2. Mobile Quartz Lamp Bank.

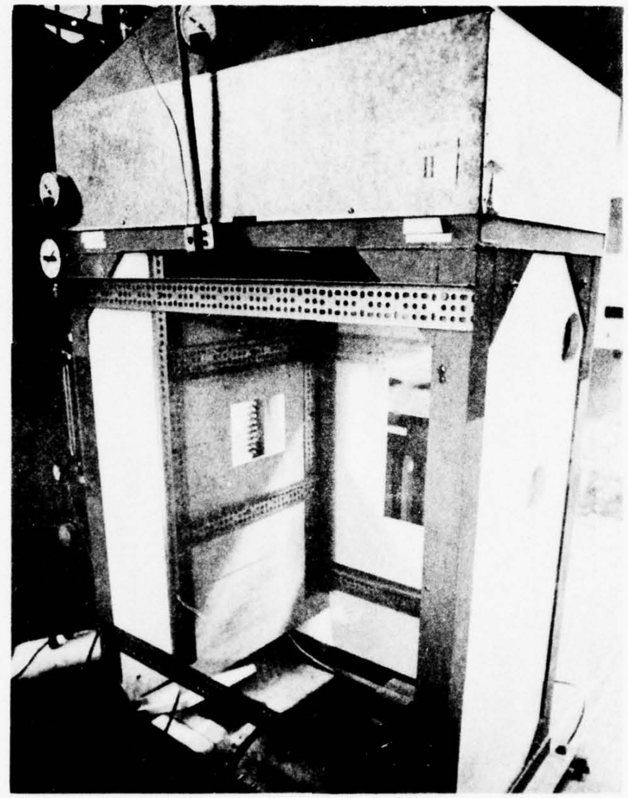

Figure 3. Stationary Quartz Lamp Bank.

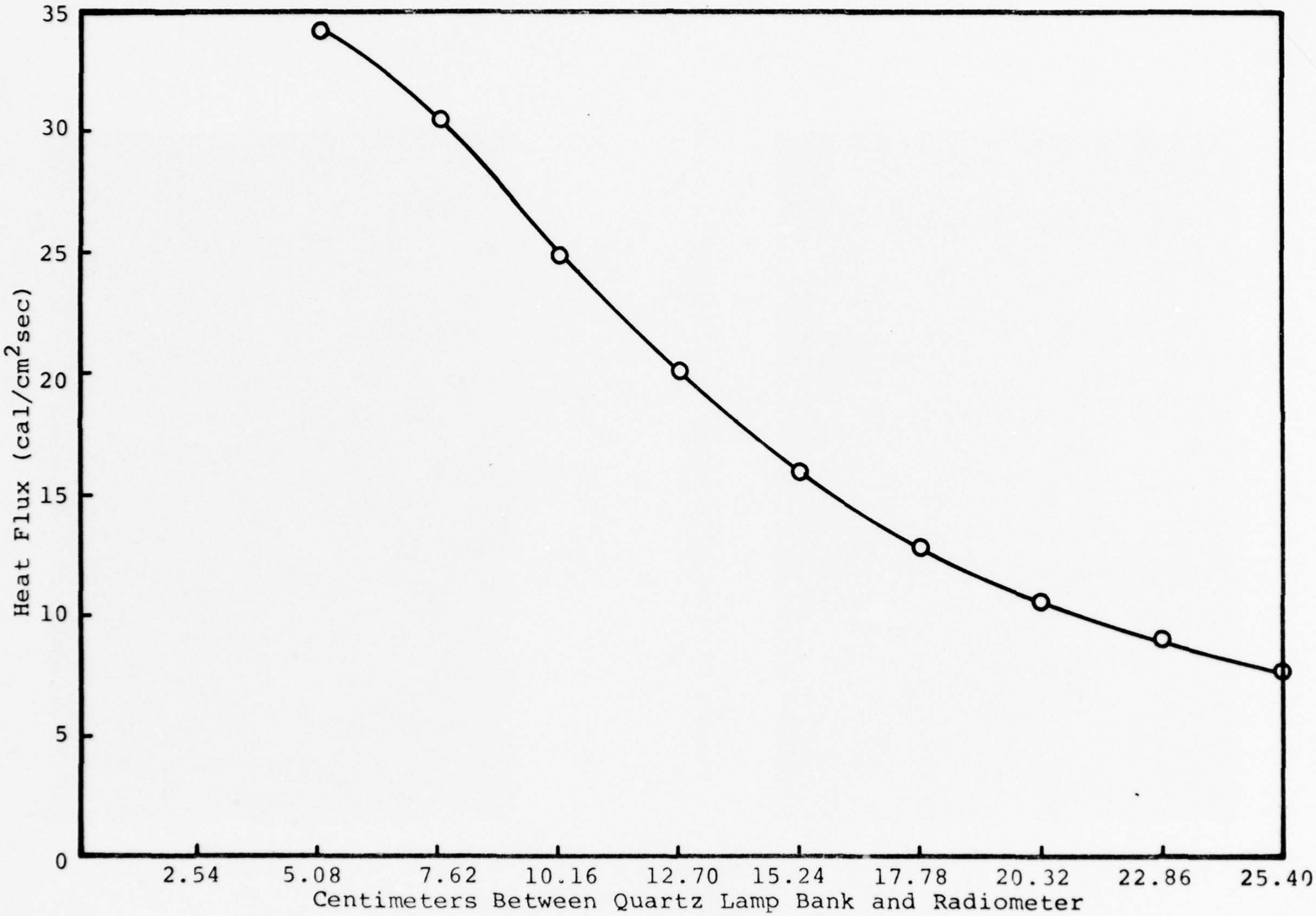

Figure 4. Radiation Heat Flux vs. Distance From Lamp Bank.

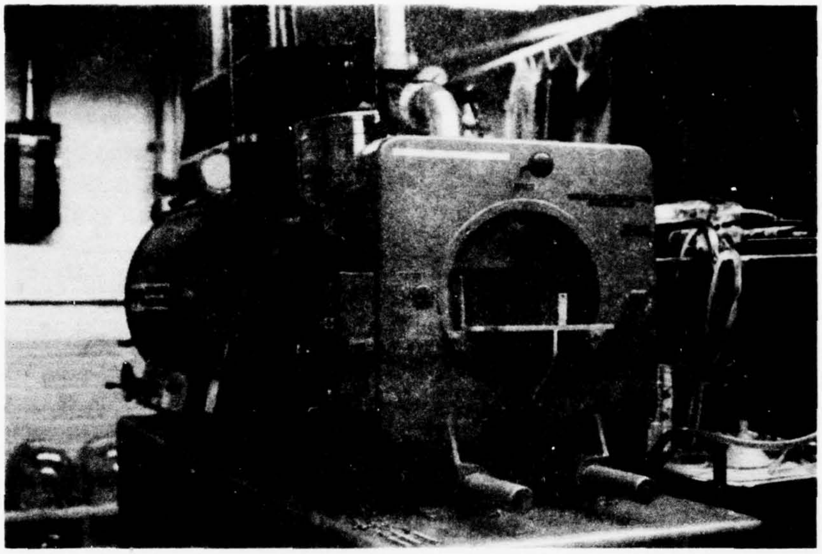

Figure 5. Gaussian Beam Arc Imaging Furnace.

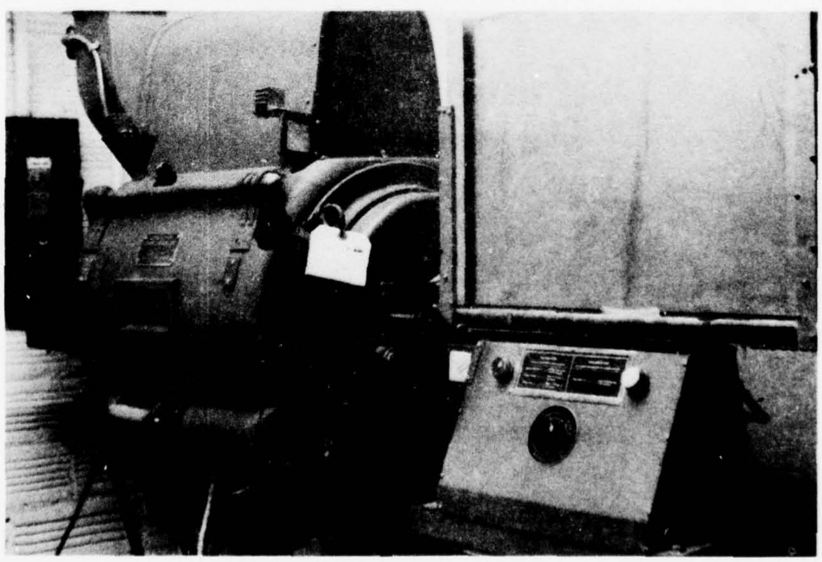

Figure 6. One-Dimensional Beam Arc Imaging Furnace.

Two parabolic mirrors are used to reflect the beam from the arc and to refocus the beam on the test specimen. Different peak intensities are achieved by de-focusing the beam. Typical specimen sizes are on the order of 2.5 cm by 2.5 cm square or 2.5 cm in diameter; usually a special mounting bracket is designed for each type of specimen in order to minimize heat losses. Exposure times may vary from 0.1 seconds to about 20 seconds; the time is accurately controlled by a water-cooled shutter, thereby producing a square wave profile in time. Arc voltage and current are monitored during testing to insure that the heat flux remains constant.

The One-Dimensional Beam Arc Imaging Furnace (ODBAIF) uses one mirror to produce an essentially parallel light radiation test device. The ODBAIF has not been checked out at this time. The beam diameter is expected to be about 30 cm with a constant heat flux of 1 cal/cm^2sec. The heat flux-to-area ratio can be used to estimate the flux for smaller diameter exposure areas. A shutter is used to produce a square wave profile, similar to the GBAIF. The ODBAIF will not be brought on-line until an appropriate test requirement becomes available; approximately two man-months will be required to bring it to operational status.

3.3 AERODYNAMIC LOAD SIMULATION

An open-circuit pull-down wind tunnel is available to simulate aerodynamic flow over specimens exposed to high intensity radiation. The wind tunnel is shown in Figure 7 and the test section in Figure 8. The 30 cm long test section has a 2.38 cm by 11.43 cm cross-sectional area. The constant free-stream velocity is nominally 240 m/sec; the nominal Mach number is 0.7. The Reynolds number based on the inlet wall length can be varied from 2×10^6 to 18×10^6, depending upon which inlet section is used. A pitot probe, manometers, and a pressure transducer are available for flow calibration, which can be supplied with each test program, as required.

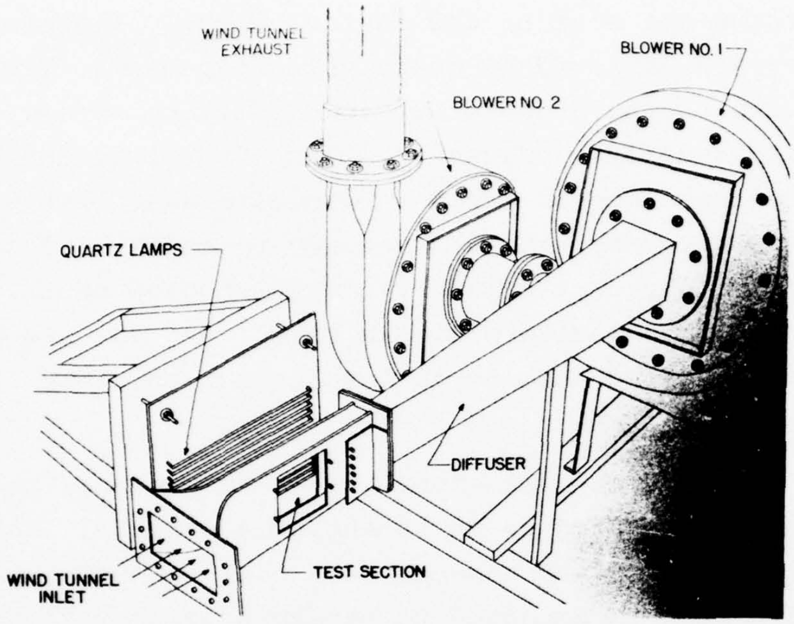

Figure 7. Wind Tunnel.

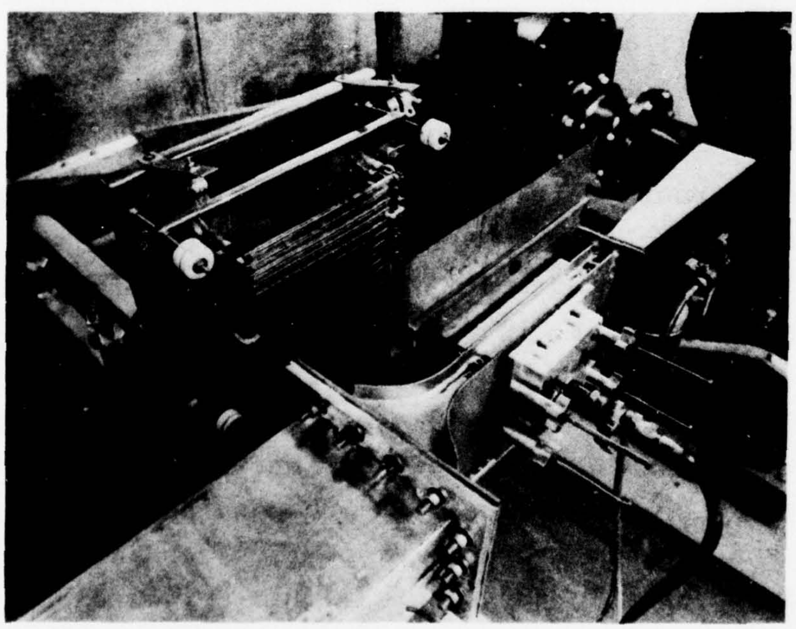

Figure 8. Wind Tunnel Test Section.

The MQLB is used in conjunction with the wind tunnel; the beam is brought in through a quartz window which is mounted in one wall of the test section. The opposite wind tunnel test section wall holds the test specimens, which is mounted flush with the wind tunnel wall. Specimen sizes up to 11.43 cm by 10.08 cm can be accommodated. A special "specimen plate" is available for mounting the various radiometers and pitot tube for heat flux and flow calibration. Heat flux levels up to 40 cal/cm^2sec, are readily achieved with this configuration. Exhaust gases are vented to the atmosphere through the roof of the building. The wind tunnel system is completely operational.

3.4 MECHANICAL LOAD SIMULATION

A creep frame is available for dead weight simulation of tensile and bending loads and is shown in Figure 9. Figure 10 illustrates a typical mounted specimen prior to radiation exposure. The MQLB is used as the radiation source; the exposure procedure is similar to that used in the wind tunnel. Note that mechanical and aerodynamic loads cannot be applied simultaneously at this time. Tension and bending configurations are possible. Recommended specimen sizes and maximum applied loads are specified in Table 3. Strain gages and other appropriate instrumentation are mounted on test specimens in order to monitor strain as a function of time during exposure to radiation. The mechanical loading device is completely operational.

TABLE 3

RECOMMENDED MECHANICAL LOADING SPECIMEN INFORMATION

	Uniaxial Tension	Bending Tension or Compression
Specimen Size (cm)		
Width	5-7.5	5-7.5
Thickness	0.02-1.25	0.6-2.5
Length	25-60	50-75
Stress Levels (MPa)	3.5-1700	7-1400

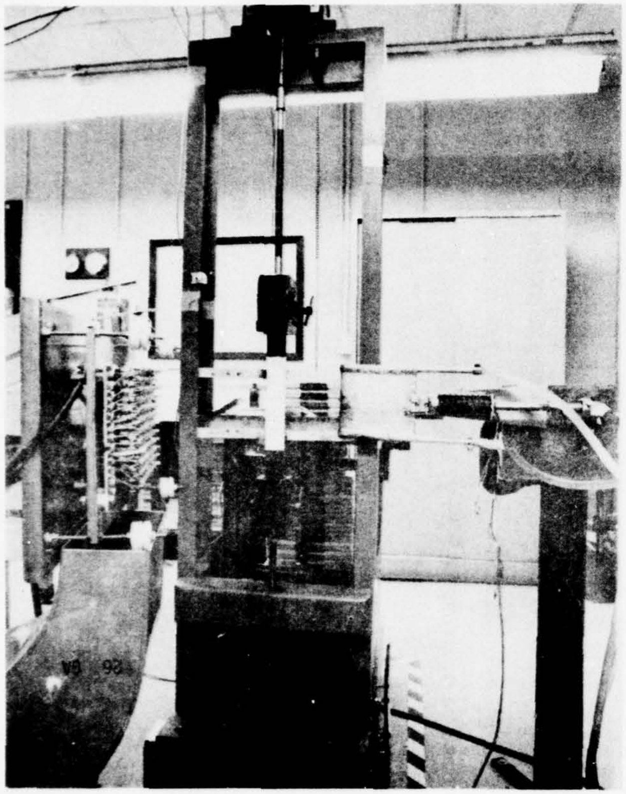

Figure 9. Mechanical Loading Device.

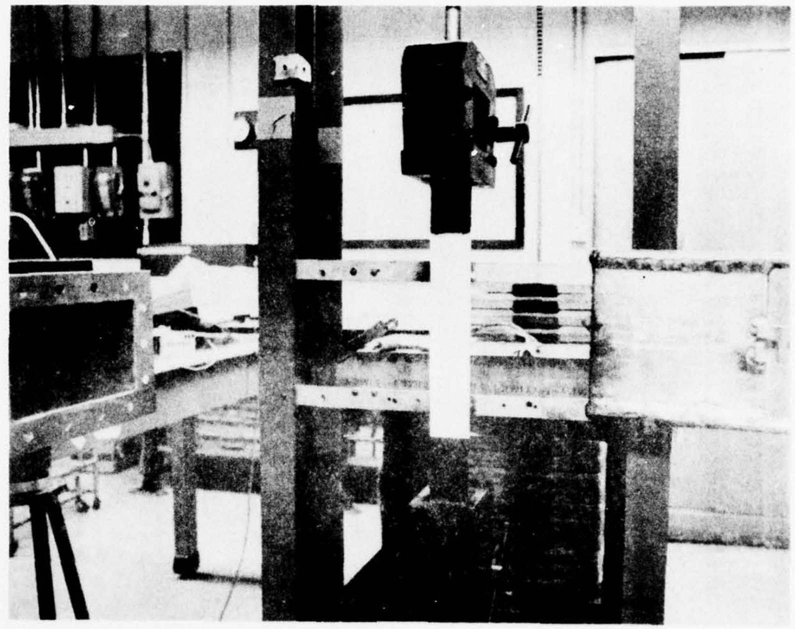

Figure 10. Tensile Test Specimen.

3.5 INSTRUMENTATION

The instrumentation required for operating the facility and which is available is summarized in Table 4. Facility users normally supply their own specimen-mounted instrumentation, such as thermocouples and strain gages. Additional details on the heat flux instrumentation and plotters which are available are given in Tables 5 and 6.

3.6 DATA ACQUISITION SYSTEM

The data acquisition system is capable of producing conventional x-y plots on-line or transmitting the digitized calibration or property data directly to the WPAFB Computing Facility for further data reduction. The output can be in the form of tabulated or plotted and labelled data. Figure 11 schematically illustrates the system. Table 7 lists the system components.

The hardware has been completely installed and checked out. The operational microprocessor program is in the final stages of completion; this effort is being completed by Lt. Randy Rushe, USAF, as his Masters degree thesis in the Computer Science Department of the Air Force Institute of Technology, WPAFB, Ohio.

3.7 CONTROL SYSTEM

The primary components of the laboratory (quartz lamp banks, wind tunnel, exhaust system) can be controlled and monitored from the operator console, which is shown in Figure 12. Only one operator is required for most tests. The console is mobile and located such that the operator can visually observe a test (if appropriate) and also monitor critical voltages and currents, etc. This allows the operator to abort a test if necessary. The console also houses the microcomputer and the other components of the data acquisition system with the exception of the data terminal. Figure 13 is an overview of the mobile quartz lamp bank, the wind tunnel, and the operating console.

TABLE 4

AVAILABLE INSTRUMENTATION

Application	Quantity	Instrumentation	Purpose
Quartz Lamp Banks	6	Radiometers	Heat Flux
	1	Thermac Temperature Controller	Heat Flux Control
	1	Data-Trak Controller	Heat Flux Control
Aerodynamic Load	1	±10 psi Stathem pressure Transducer	Flow Calibration
	1	Pitot Probe Assembly	Flow Calibration
	1	Manometer	Flow Calibration
Mechanical Load	1	Wheatstone Bridge	Strain Gage
Arc Imaging Furnaces	2	Radiometers	Heat Flux
	1	Calorimeter	Heat Flux
	1	Time Controller (0.1 sec min)	Shutter Control
General	3	X-Y-Y' Recorders	Data Recording
	1	Kennedy DS-370 Tape Recorder	Data Recording
	1	LSI-11 Micro-processor	Data Recording
	1	35mm Nikon Still Camera	Specimen Photographs
	1	MP-4 Polaroid Still Camera	Specimen Photographs
	2	8mm Nizo Braun Movie Cameras	Specimen Photographs
	-	Various Thermocouples	Temperature
	1	L&N 8641-S Automatic Recording Pyrometer (760-6000°C)	Surface Temperature
	-	Barometer, Thermometer, Hygrometer	Ambient Conditions

TABLE 5

HEAT FLUX GAGE SPECIFICATIONS

Mfgr	Type	Model	Range	Accuracy
Medtherm	Gardon	64P-20-24	0-5 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-50-24	0-13 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-100-24	0-27 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-100-24	0-27 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-200-24	0-54 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-200-24	0-54 cal/cm^2sec	$\pm 3\%$
RdF	Gardon	CFR-1A	0-400 cal/cm^2sec	$\pm 10\%$
RdF	Gardon	CFR-1A	0-400 cal/cm^2sec	$\pm 10\%$
ADL	Calorimeter	---	50-350 cal/cm^2sec	$\pm 5\%$

TABLE 6

X-Y RECORDER SPECIFICATIONS

Mfgr	Model	Channels	Range	Response
Hewlett-Packard	7046A X-Y-Y'	2	0.2mv/cm-4v/cm	0.025-5cm/sec
Hewlett-Packard	136 X-Y-Y'	2	0.2mv/cm-20v/cm	0.05-5cm/sec
Honeywell	540 X-Y-Y'	2	0.04mv/cm-0.4v/cm	0.025-5cm/sec

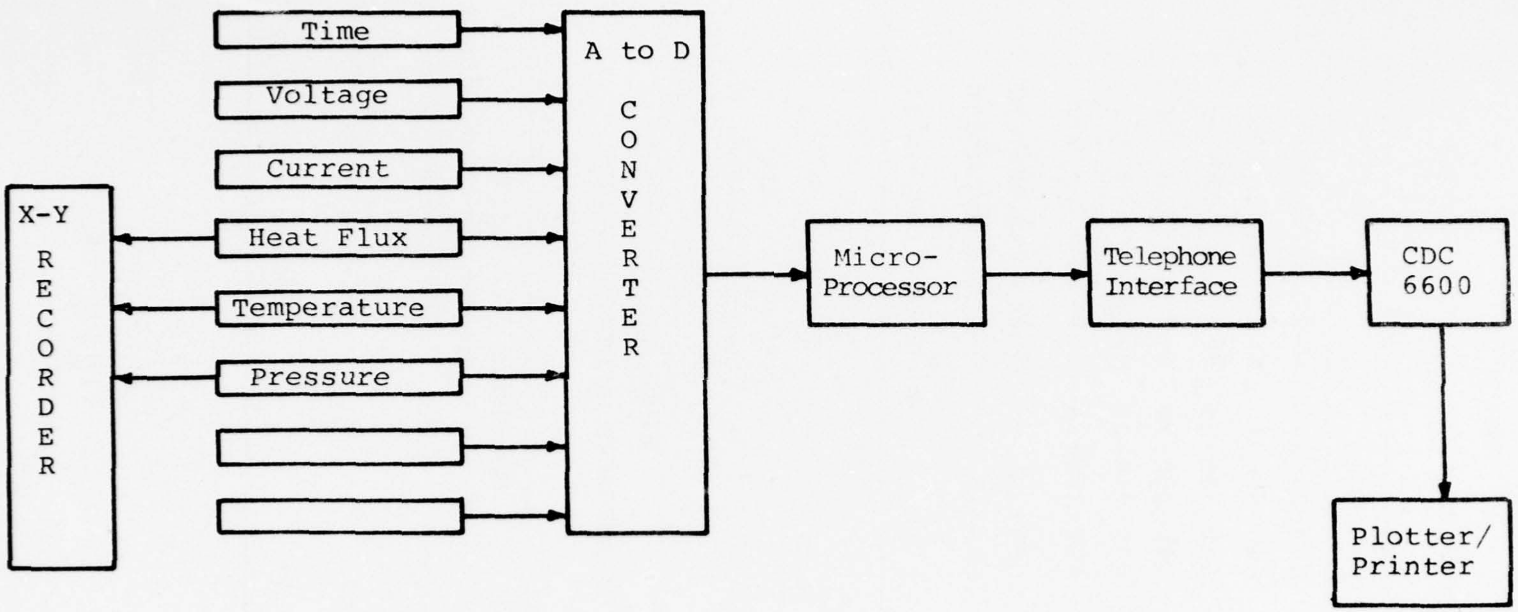

Figure 11. Data Acquisition System.

TABLE 7

DATA ACQUISITION SYSTEM COMPONENTS

Operating Controls	
	Wind tunnel operation
	Quartz lamp operation
	Quartz lamp cooling operation (blower & air)
	Quartz lamp remote operation jack
	Quartz lamp & shutter exposure time control
	Computer reset, clock & hold operation
	Controller set-point remote operation
	Tri-phaser controller
Monitoring Controls	
	Quartz lamp power - voltage & current indicators
	Wind tunnel pressure indicator
	Peripheral equipment temperature indicator (10 pt.)
	Shutter solenoid overheat indicator
	Quartz lamp cumulative operating time indicator
Data Acquisition	
	LSI-11 micro-processor
	Ectron differential D.C. amplifiers (8)
	Power supply
	Teletype
	Acoustic coupler

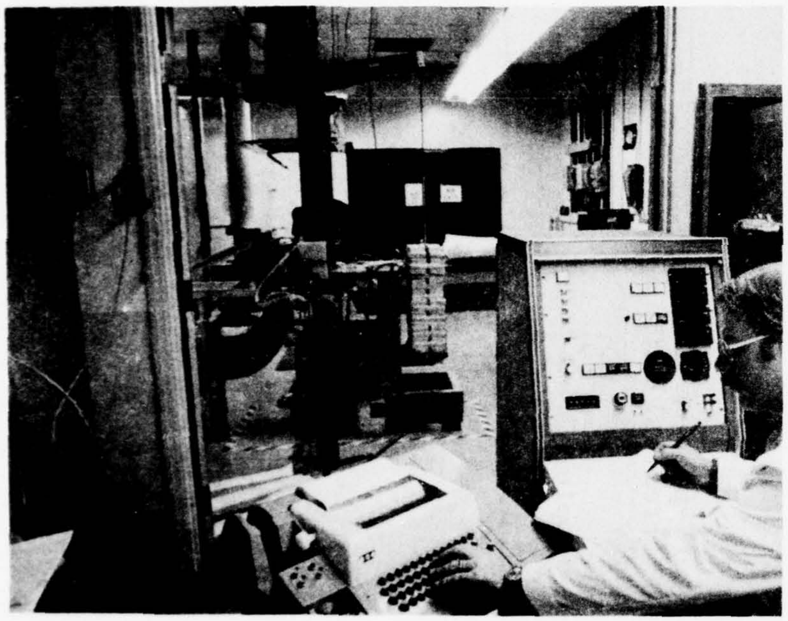

Figure 12. Console.

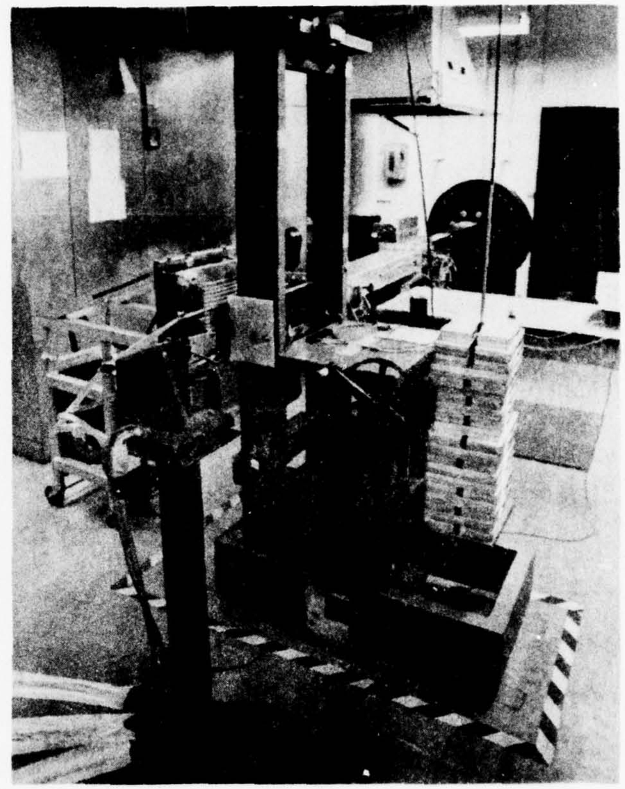

Figure 13. Thermal Flash Laboratory Overview.

SECTION 4
FACILITY UTILIZATION

4.1 TEST SCHEDULING

The Tri-Services Nuclear Flash Test Facility is available to governmental users on a no-charge basis. Test programs involving nuclear thermal flash materials performance receive priority although other tests may be accommodated; all test programs must be approved by the Defense Nuclear Agency contract monitor.

Specific details regarding test program procedures, scheduling, special testing requirements, specimen sizes, heat flux levels, etc., should be directed to the Test Director in charge of the Facility, Mr. Ben Wilt (513-255-4795 or 513-229-2517). Note that the analysis of material performance must be conducted by the Facility user.

Material response tests for the Tri-Service community take precedence over all other activities associated with the operation of the Facility. That is, test requests have been scheduled at the test initiator's convenience if possible. Since most test programs are about one to five days in length, few conflicts in scheduling have arisen and few are anticipated. Based on experience, each new test program typically requires special planning and hardware (such as instrumentation and specimen mounting brackets); therefore, the more advance notice given for a particular test program the more efficiently the tests can be conducted. All test scheduling, special requirements, etc., have been and will be handled by the Test Director, Mr. Ben Wilt.

4.2 COMPLETED TEST PROGRAMS

The primary purpose of the Facility is to support the Tri-Service community with a quick-response, thermal nuclear flash, materials response testing capability. Tests which have been conducted are summarized in Table 8. Additional information on these tests can be obtained by contacting Mr. Ben Wilt and References 1-4. The specific runs are listed in the Appendix.

The facility was also utilized by Major Joseph Hurst for his mechanical engineering doctoral research program at the Air Force Institute of Technology. This involved investigating optical methods for determining the temperature distribution through transparent materials.

4.3 PROJECTED TEST PROGRAMS

Table 9 identifies the known tests to be conducted during the next twelve months. Since the primary purpose of the Facility involves quick-response testing, it is not possible to establish a comprehensive list of all future tests at this time.

TABLE 8

COMPLETED TEST PROGRAMS

Initiator	Org.	Project	Test Matl.	Test No.	Test Dates
Alexander	AVCO	DNA	1	001-073	March 7-10, 1977
Alexander	AVCO	DNA	1	074-086	March 15, 1977
Collis	Boeing	AWACS	2	087-316	March 21-24, 1977
Graham	AVCO	DNA	3	359-416	June 6-16, 1977
Alexander	AVCO	DNA	4	419-574	June 20-24, 1977
Collis	Boeing	ALCM	5	576-677	July 19-22, 1977
Alexander	AVCO	DNA	4	678-772	October 5-7, 1977
Grady	AVCO	DNA	6	773-870	October 12-22, 1977

MATERIAL DESCRIPTIONS

1. Aluminum, glass epoxy, or graphite epoxy substructure with multilayer coatings including primer MIL-P-2337, unpigmented polyurethane resin and pigmented polyurethane topcoat (aerodynamic load).

2. Aluminum, epoxy-fiberglass, magnesium, or epoxy-graphite honeycomb substructures with enamel MIL-C-8326, astrocoat black/white, or fluorocarbon black/white coatings (aerodynamic load).

3. Quartz polyimide and graphite epoxy tensile specimens (no load).

4. Two-layer antistatic aluminized polyurethane coatings, white silicone coatings, three-layer fluoroelastomer coatings, copper foil coatings, flame-sprayed aluminum, teflon, cork silicone, white epoxy polyimides, Grafoil coating over 6061 aluminum, quartz polyimide, or graphite epoxy substructures (aerodynamic load).

5. Aluminum or epoxy-fiberglass honeycomb substructures with primer MIL-P-23377 and enamel MIL-C-83286, astrocoat-primer plus erosion coating 8001 plus white topcoat 8004 or combinations of those coatings (aerodynamic load).

6. Quartz polyimide and graphite epoxy tensile specimens (tensile load).

TABLE 9

PROJECTED TEST PROGRAMS

Initiator	Organization	Project	Material	Date
Sid Litvak	AFML	aircraft	Aircraft coatings	January
John Rhodehamel	AFML	ILAAMT	Graphite epoxies	February
Bob Van Vliet	AFML	aircraft	Aircraft coatings	February
Don Schmidt (AFML Contact)	McDonnell-Douglas	cruise missile	Missile protection	March
Jan Patrick	AVCO	DNA	Aircraft composites	April/ May

SECTION 5

PROJECTED FACILITY DEVELOPMENT

Keeping the Tri-Services Thermal Flash Facility operational and current is an ongoing activity. Periodic maintenance typically includes quartz lamp replacement, instrumentation calibration, and related activities. Updating the Facility is also an important task. Projected improvements are summarized below, with the primary emphasis on increasing the radiant heating levels. These improvements will be conducted between test programs during FY78 and FY79.

Increased Heating - Several methods are available for increasing the heat flux levels of the lamp bank. These include higher density lamp packing, the use of reflectors, or lenses. A preliminary investigation indicates that the best approach for our application involves using a water-cooled reflector to focus the radiant energy from the back of the lamps onto the test specimen, thereby, increasing the heat flux. Each of the methods will be evaluated further, and one will be chosen for incorporation into the quartz lamp banks.

Shutter - A water-cooled shutter for the quartz lamp bank which will allow "pulse shaping" will be designed and fabricated. The initial sharp rise in the heat flux associated with a nuclear flash can be more properly simulated by using a shutter, which produces a step-function initial heating profile. The tail-off associated with the nuclear flash can be handled by taking advantage of the lamp cool-down characteristics, as is currently done.

Surface Phenomena Photography - Motion picture photography of surface degradation would be an asset to data analysis. Although this procedure is relatively straightforward, the proper placement of the equipment, choice of lenses and filters, etc., must be perfected.

Strain Measurement - In the current configuration, the only method for measuring strain in the test specimen is by the use of strain gages. These strain gages are placed on the back of the specimen directly behind the heated surface. Since the output of the strain gages is a function of temperature, the data reduction requirements for this configuration is quite complicated. For many of the tests in this facility, the use of LVDT type deflectometers would meet the strain measuring requirements. Because the LVDT's need not be mounted directly on the specimen, they are not affected by the temperature change during exposure. The LVDT's also provide a much larger range of strain measuring capability. The LVDT strain measuring capability will be added while maintaining the present system of strain gages.

Surface Temperature Pyrometry - A recording optical pyrometer system is available which can be used to measure the high surface temperature of test specimens. Although the procedure is straightforward, there are physical constraints which limit the placement of the pyrometer sensing head. Some modifications will be required.

Flow Improvement - The flow in the wind tunnel is not uniform, complicating the analysis of materials for which the performance is strongly dependent upon surface shear. Screens, inlet shape, and other approaches will be investigated in order to achieve a more uniform surface shear in the wind tunnel.

Solar Furnace - The solar furnace is located in the laboratory but must be wired up and checked out. The furnace uses a carbon arc for the radiation source more closely simulating the nuclear flash black body temperatures and also allowing for wave length variation effects on material performance.

Simultaneous Aerodynamic and Mechanical Loading - The ability to simultaneously expose materials to radiant heating, aerodynamic shear, and mechanical loading is obviously desirable. Approaches for implementing this type of test will be investigated.

SECTION 6

SUMMARY

The Tri-Services Thermal Nuclear Flash Test Facility for investigating the effects of thermal radiation on materials has been established. The Facility is located at the USAF Materials Laboratory, Wright-Patterson AFB, Ohio. The capability for irradiating specimens to intense thermal radiation, including the effects of aerodynamic loads or mechanical loads is operational. Eight hundred and seventy tests have been conducted for the Tri-Service community at this time. A large number of additional tests are scheduled during the next twelve months; additional improvements to the Facility are planned, with an emphasis on an increased heating capability.

REFERENCES

1. Scherer, W.R. and Collis, S.E., "Nuclear Thermal Survivability/Vulnerability of the E-4B," Boeing Aerospace Co. Rpt. No. D226-20380-1, March 1977.

2. "Skin Friction Drag Increase Due to Nuclear Thermal Damage," Boeing Aerospace Co. Final Report on Contract DNA001-77-C-0090, 30 September 1977.

3. Collis, S.E., "Simulated Nuclear Thermal Testing of AGM-86 Honeycomb Sandwich Structures," Boeing Aerospace Co. Rpt. No. D232-10599-3, November 1977.

4. Alexander, J.G., "Conductive Coatings for Composite Aircraft Surfaces," AVCO Systems Division, Rpt. No. AFML-TR-77-164, September 1977.

APPENDIX

THERMAL FLASH TESTS

Run No.		Specimen Configuration Substructure	Coating
0	CAL		
1-9		Aluminum 6061	WMS-0
10	CAL		
11-14		Aluminum 6061	WMS-0
15	CAL		
16-17		Aluminum 6061	WMS-0
18-19	CAL		
20		Aluminum 6061	WMS-0
21-25		Glass-Epoxy	WMS-0/CMS-905
26		Graphite-Epoxy	WMS-0/CMS-905
27		Glass-Epoxy	WMS-7/CMS-905
28		Graphite-Epoxy	WMS-7/CMS-905
29-31		Glass-Epoxy	CMS-905
32-36	CAL		
37		Glass-Epoxy	WMS-0/CMS-905
38		Graphite-Epoxy	WMS-0/CMS-905
39-40		Glass-Epoxy	WMS-7/CMS-905; CMS-6231
41-42		Graphite-Epoxy	WMS-7/CMS-905
43		Glass-Epoxy	CMS-905
44		Graphite-Epoxy	CMS-905
45-46		Aluminum 6061	WMS-7/CMS-905
47		Graphite-Epoxy	WMS-4/CMS-905
48-49		Aluminum 6061	WMS-0; WMS-4/ CMS-905
50-52	CAL		
53-58		Aluminum 6061	WMS-4; 1224-0; WMS-7; WMS-0/ CMS-905; CMS-6231
59-60		Graphite-Epoxy	1224-0; 1224-4/ CMS-905
61-64		Graphite-Epoxy	WMS-0/CMS-905
65-72		Graphite-Epoxy	WMS-4/CMS-905
73	CAL		
74-78		Graphite-Epoxy	WMS-0;WMS-4; WMS-7/CMS-905
79-83		Graphite-Epoxy	WMS-0;WMS-4; WMS-7/CMS-6231
84-85		Graphite-Epoxy	CMS-6231
86		Graphite-Epoxy	
87	CAL		
88		Glass-Epoxy Honeycomb	MIL-C-8326

NOTE: CAL indicates heat flux calibration run.

Run No.		Specimen Configuration Substructure	Coating
89	CAL		
90		Glass-Epoxy Honeycomb	MIL-C-8326
91	CAL		
92-93		Glass-Epoxy Honeycomb	MIL-C-8326
94	CAL		
95-100		Glass-Epoxy Honeycomb	MIL-C-8326
101-104		Aluminum Honeycomb	MIL-C-8326
105-110		Glass-Epoxy Honeycomb	Astrocoat; Fluorocarbon; MIL-L-81352; Polysulfide; MIL-C-83281
111	CAL		
112-119		Aluminum Honeycomb	MIL-C-83286
120-121		Glass-Epoxy Honeycomb	Astrocoat
122		Graphite-Epoxy TBD Honeycomb	MIL-C-83281
123		Magnesium Sheet	MIL-C-83281
124	CAL		
125		Aluminum	MIL-C-83281
126		Glass-Epoxy Honeycomb	Astrocoat
127-128		Aluminum	MIL-C-83281
129		Glass-Epoxy Honeycomb	MIL-C-83286
130	CAL		
131-135		Glass-Epoxy Honeycomb	MIL-C-83286
136	CAL		
137		Aluminum Honeycomb	MIL-C-83286
138	CAL		
139		Aluminum Honeycomb	MIL-C-83286
140	CAL		
141		Aluminum Honeycomb	MIL-C-83286
142	CAL		
143-148		Aluminum Honeycomb	MIL-C-83286
149-151		Glass-Epoxy Honeycomb	Astrocoat; Fluorocarbon
152		Epoxy-Graphite TBD Honeycomb	MIL-C-83286
153-155		Glass-Epoxy Honeycomb	MIL-L-81352; Polysulfide; Astrocoat
156	CAL		
157-160		Aluminum Honeycomb	MIL-C-83286
161-162		Glass-Epoxy Honeycomb	Astrocoat; MIL-C-83286

		Specimen Configuration	
Run No.		Substructure	Coating
163-166		Aluminum Honeycomb	MIL-C-83286
167	CAL		
168		Aluminum Honeycomb	MIL-C-83286
169	CAL		
170		Aluminum Honeycomb	MIL-C-83286
171		Magnesium Sheet	MIL-C-83286
172-174		Aluminum Sheet	MIL-C-83286
175-177		Aluminum Honeycomb	MIL-C-83286
178-181		Glass-Epoxy Honeycomb	MIL-C-83286
182	CAL		
183-189		Glass-Epoxy Honeycomb	MIL-C-83286; Astrocoat; Fluorocarbon; Polysulfide
190-194		Aluminum Honeycomb	MIL-C-83286
195	CAL		
196-200		Aluminum Honeycomb	MIL-C-83286
201-203		Glass-Epoxy Honeycomb	MIL-C-83286
204	CAL		
205-209		Glass-Epoxy Honeycomb	MIL-C-83286; MIL-L-81352; Polysulfide
210		Graphite-Epoxy TBD Honeycomb	MIL-C-83286
211-212		Glass-Epoxy Honeycomb	Astrocoat, Fluorocarbon
213	CAL		
214-223		Aluminum Honeycomb	MIL-C-83286
224		Glass-Epoxy Honeycomb	MIL-C-83286
225	CAL		
226-239		Glass-Epoxy Honeycomb	MIL-C-83286; Astrocoat; Fluorocarbon; MIL-L-81352; Polysulfide
240-242		Aluminum Sheet	MIL-C-83286
243		Magnesium Sheet	MIL-C-83286
244		Graphite-Epoxy TBD Honeycomb	MIL-C-83286
245	CAL		
246-252		Aluminum Honeycomb	MIL-C-83286
253-257		Glass-Epoxy Honeycomb	MIL-C-83286; Astrocoat; Fluorocarbon
258		Graphite-Epoxy TBD Honeycomb	MIL-C-83286
259		Glass-Epoxy Honeycomb	Fluorocarbon
261-266		Aluminum Honeycomb	MIL-C-83286
267-273		Glass-Epoxy Honeycomb	MIL-C-83286; Astrocoat; Fluorocarbon

Run No.		Specimen Configuration Substructure	Coating
274		Graphite-Epoxy TBD Honeycomb	MIL-C-83286
275	CAL		
276-279		Aluminum Honeycomb	MIL-C-83286
280-282		Glass-Epoxy Honeycomb	MIL-C-83286
283-285		Aluminum Sheet	MIL-C-83286
286		Graphite-Epoxy TBD Honeycomb	MIL-C-83286
287		Glass-Epoxy Honeycomb	Fluorocarbon
288	CAL		
289-291		Aluminum Honeycomb	MIL-C-83286
292-295		Glass-Epoxy Honeycomb	Astrocoat; Fluorocarbon; MIL-C-83286
296-297		Aluminum Sheet	MIL-C-83286
298		Graphite-Epoxy TBD Honeycomb	MIL-C-83286
299	CAL		
300-301		Aluminum Honeycomb	MIL-C-83286
302-303		Glass-Epoxy Honeycomb	Astrocoat; MIL-C-83286
304-305		Aluminum Sheet	MIL-C-83286
306		Graphite-Epoxy TBD Honeycomb	MIL-C-83286
307	CAL		
308		Aluminum Honeycomb	MIL-C-83286
309		Glass-Epoxy Honeycomb	Astrocoat
310		Aluminum Sheet	MIL-C-83286
311-313	CAL		
314		Aluminum Sheet	MIL-C-83286
315-316		Glass-Epoxy Honeycomb	Astrocoat; Fluorocarbon
317-360	CAL		
361		Quartz Polyimide	
362	CAL		
363-366		Quartz Polyimide	
367-369		Graphite-Epoxy	
370-371		Quartz Polyimide	
372-380	CAL		
381-383		Quartz Polyimide	
384-386		Graphite-Epoxy	
387	CAL		
388-390		Graphite-Epoxy	
391-392	CAL		
393-395		Quartz Polyimide	
396-398		Graphite-Epoxy	

Run No.		Specimen Configuration Substructure	Coating
399-401		Quartz Polyimide	
402	CAL		
403-405		Quartz Polyimide	
406	CAL		
407-412		Graphite-Epoxy	
412-429	CAL		
430-434		Glass-Epoxy	Concept* 1;2; 3;4A;4B
435	CAL		
436-440		Glass-Epoxy	Concept* 5A; 5B;5C;5D;6
441-442	CAL		
443-447		Glass-Epoxy	Concept* 6;7
448-451	CAL		
452-468		Glass-Epoxy	Concept* 7;8A; 8B;8C;9;10;11; 12A;12B;13A; 13B;15A;16;17
469	CAL		
470-475		Glass-Epoxy	Concept* 9B;11; 12A;12B;13A;15B
476-478	CAL		
479-483		Graphite-Epoxy	Concept* 1;2; 3;4;5
484		Quartz Polyimide	Concept* 5A
485-491		Graphite-Epoxy	Concept* 5B;5C; 7;8B;10;16;17
492-499		Quartz Polyimide	Concept* 1;2;3; 4A;4B;5B;5C;5E
500		Glass-Epoxy	Concept* 7
501-503		Quartz Polyimide	Concept* 10; 16;17
504		Graphite-Epoxy	Concept* 5B
505-507		Quartz Polyimide	Concept* 5B; 16;17
508-509		Graphite-Epoxy	Concept* 16; 17
510	CAL		
511		Quartz Polyimide	Concept* 2
512-513		Graphite-Epoxy	Concept* 2;4
514-515		Quartz Polyimide	Concept* 4;10
516		Graphite-Epoxy	Concept* 10
517		Glass-Epoxy	Concept* 7
518		Graphite-Epoxy	Concept* 7
519	CAL		

*See Table I.

Run No.		Specimen Configuration Substructure	Coating
520-521		Graphite-Epoxy	Concept* 2;7
522		Quartz Polyimide	Concept* 2
523-524		Graphite-Epoxy	Concept* 12A;13A
525		Quartz Polyimide	Concept* 12A
526	CAL		
527		Quartz Polyimide	Concept* 2
528-529		Graphite-Epoxy	Concept* 7;2
530		Quartz Polyimide	Concept* 12A
531-535		Graphite-Epoxy	Concept* 6;12A; 11;12B;13B
536-537		Quartz Polyimide	Concept* 15B
538-539		Graphite-Epoxy	Concept* 9A;15A
540-541		Quartz Polyimide	Concept* 9A;15A
542	CAL		
543-544		Graphite-Epoxy	Concept* 9B;12A
545		Quartz Polyimide	Concept* 12A
546-547		Graphite-Epoxy	Concept* 7
548	CAL		
549-551		Graphite-Epoxy	Concept* 5B;3
552		Quartz Polyimide	Concept* 3
553-556		Aluminum 6061	Concept* 18;19; 20;21
557-561	CAL		
562-574		Aluminum 6061	Concept* 6;12; 2;7
575	CAL		
576-582		Aluminum	Concept* A,B,C
583	CAL		
584-595		Aluminum Honeycomb	Concept* A,B,C
596-601		Glass-Epoxy Honeycomb	Concept* A,B,I
602	CAL		
603-608		Glass-Epoxy Honeycomb	Concept* D,E,F
609	CAL		
610-614		Glass-Epoxy Honeycomb	Concept* G,H
615	CAL		
616-623		Aluminum Honeycomb	Concept* A,B,C
624	CAL		
625-628		Aluminum Honeycomb	Concept* B,C
629-634		Glass-Epoxy Honeycomb	Concept* A,B,I
635	CAL		
636-641		Glass-Epoxy Honeycomb	Concept* D,E,F

*See Table I.

Run No.		Specimen Configuration Substructure	Coating
642	CAL		
643-646	CAL		
647	CAL		
648-659		Aluminum Honeycomb	Concept* A,B,C
660-665		Glass-Epoxy Honeycomb	Concept* A,B,I
666	CAL		
667-672		Glass-Epoxy Honeycomb	Concept* D,E,F
673	CAL		
674-677		Glass-Epoxy Honeycomb	Concept* G,H
678-687			
688-692	CAL		
693		Graphite-Epoxy	Concept* 1
694-699		Glass-Epoxy	Concept* 1;2;3; 4B;5A;5B
700-701		Quartz Polyimide	Concept* 5B
702		Glass-Epoxy	Concept* 5C
703		Quartz Polyimide	Concept* 5C
704		Glass-Epoxy	Concept* 5D
705-708		Graphite-Epoxy	Concept* 9A;9C
709-711		Glass-Epoxy	Concept* 10;10B
712		Graphite-Epoxy	Concept* 10
713	CAL		
714		Graphite-Epoxy	Concept* 11A
715		Quartz Polyimide	Concept* 12A
716-721	CAL		
722-726		Quartz Polyimide	Concept* 12A; 12C;12D;14
727-732		Graphite-Epoxy	Concept* 12A; 12C;12D;14;10B; 10C
733-734		Quartz-Polyimide	Concept* 10B;15A
735-736		Graphite-Epoxy	Concept* 22;23
737-738		Quartz Polyimide	Concept* 0
739-741		Glass-Epoxy	Concept* 24;15A
742-743		Quartz Polyimide	Concept* 4B
744		Graphite-Epoxy	Concept* 4B
745	CAL		
746-753		Graphite-Epoxy	Concept* 12C; 12D;14;22;10B; 10C;12A;15B
754-758		Quartz Polyimide	Concept* 12C; 14;15A;10A;5
759		Graphite-Epoxy	Concept* 6
760		Glass-Epoxy	Concept* 7
761		Graphite-Epoxy	Concept* 23

*See Table I.

Run No.		Specimen Configuration Substructure	Coating
762-763	CAL		
764		Glass-Epoxy	Concept* 9A
765	CAL		
766-767		Glass-Epoxy	Concept* 9A
768		Graphite-Epoxy	Concept* 9A
769		Graphite-Epoxy	Concept* 9A (Spec Instru.)
770		Quartz Polyimide	Concept* 9A (Spec Instru.)
771		Graphite-Epoxy	Concept* 9A (Spec Instru.)
772		Quartz Polyimide	Concept* 9A (Spec Instru.)
773-774	CAL		
775-783		Graphite-Epoxy	Tested in tension
784-789		Graphite-Epoxy	White Polyimide tested in tension
790-791	CAL		
792-797		Graphite-Epoxy	Cork Silicone tested in tension
798-801		Graphite-Epoxy	White Polyimide tested in tension
802-803		Quartz Polyimide	Tested in tension
804-805	CAL		
806		Quartz Polyimide	Tested in tension
807	CAL		
808-810		Quartz Polyimide	Tested in tension
811-816		Quartz Polyimide	White Polyimide tested in tension
817-820		Quartz Polyimide	Cork Silicone tested in tension
821-822	CAL		
823-828		Graphite-Epoxy	Tested in tension
829-833		Graphite-Epoxy	White Polyimide tested in tension
834-837		Graphite-Epoxy	Cork Silicone tested in tension
838		Graphite-Epoxy	White Polyimide tested in tension
839	CAL		
840		Graphite-Epoxy	White Polyimide tested in tension
841-845		Quartz Polyimide	Tested in tension
846-852		Quartz Polyimide	White Polyimide tested in tension

*See Table I.

Run No.		Specimen Configuration	
		Substructure	Coating
853-855		Quartz Polyimide	Cork Silicone tested in tension
856	CAL		
857-858		Aluminum	Grey Polymeric Bead
859	CAL		
860-861		Aluminum	Grey Polymeric Bead
862	CAL		
863-864		Aluminum	Grey Polymeric Bead
865	CAL		
866-867		Aluminum	Grey Polymeric Bead
868	CAL		
869-870		Aluminum	Grey Polymeric Bead

TABLE I

TABLE OF MATERIALS

1	Two-layer anti-static white polyurethane
2	Single-layer aluminized polyurethane
3	White MIL-C-83286 over aluminized polyurethane
4A	Dow 808 white silicone, 50 PVC titania
4B	Dow 808 white silicone, 25 PVC titania
5A	Three layer white fluorocarbon, 40 PVC titania plus fibers
5B	Three layer white fluorocarbon, 25 PVC titania plus fibers
5C	Three layer fluorocarbon erosion coating, 25 PVC titania plus fibers
5D	Three layer fluorocarbon erosion coating, 40 PVC titania plus fibers
6	Bonded copper foil, 2 Mil
7	Flame sprayed aluminum
8A	Bonded polyester film, 10 Mil
8B	Bonded TFE teflon film, 10 Mil
8C	Bonded UHMW polyethylene film, 10 Mil
9A	Bonded cork silicone, 20 Mil
9B	Bonded cork silicone, 50 Mil
9C	Cork silicone, 10 Mil
10A	Epoxy-polyimide white ablative paint
10B	Epoxy-polyimide flexible white, 6 Mil
10C	Epoxy-polyimide flexible white, 10 Mil
11	Grafoil stitched package
12A	Bonded RTV 655 silicone, 20 Mil
12B	Bonded RTV 655 silicone, 50 Mil
12C	Modified RTV 655, white, sprayed, 10 Mil
12D	Modified RTV 655, white, sprayed, 3 Mil
13A	Bonded silastic 23510 white silicone, 20 Mil
13B	Bonded silastic 23510 white silicone, 50 Mil
14	RTV-655, 3 Mil over cork silicone, 10 Mil
15A	134/KHDA polyurethane erosion coating, 5 PVC titania
15B	134/KHDA polyurethane erosion coating, 25 PVC titania

TABLE I (Concluded)

TABLE OF MATERIALS

16	Desoto 10A grey polyurethane top coat over aluminized polyurethane
17	Bostic dark grey polyurethane over aluminized polyurethane
18-21	Grey polyurethane
22	White RTV 655, 3 Mil over conductive RTV 3 Mil
23	Bonded aluminum foil, 2.4 Mil
24	Bonded aluminum foil with topcoat, 2.4 Mil
A	MIL-P-23377 primer plus white MIL-C-83286 enamel (Desoto)
B	Same as "A" except thicker enamel
C	Same as "A" except very thick enamel
D	Astrocoat system; primer plus white 8001 erosion coating plus white (non-yellowing) 8004 topcoat
E	Same as "D" but the 8001 coating is thicker
F	Astrocoat system; primer plus white (non-yellowing) 8004 topcoat
G	Astrocoat system; primer plus white 8001 erosion coating plus black 8003 antistatic topcoat
H	Same as "G" except thicker 8001 coating
I	Same as "A" except DEFT white enamel per MIL-C-83286

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