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# Central Receiver Test Facility Experiment Manual

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# Central Receiver Test Facility Experiment Manual

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## Abstract

This manual provides potential users with detailed information about the Central Receiver Test Facility operated by Sandia National Laboratories for the US Department of Energy. This installation is the primary solar test facility for component and subsystem evaluations within the Department of Energy's Solar Central Receiver development program, and can also be used for thermal effects testing. Administrative procedures, facility capabilities and interfaces, and the information required from potential experimenters by site personnel are described.

# Acknowledgments

The authors acknowledge the following people for the information they provided: Kenneth Boldt, heliostat control system and distributed digital process control system; Lindsey Evans, steam/water heat rejection system; Richard Houser, heliostat and beam characterization systems; J. Milt Stomp, tower utilities and data systems; and Jay Holton, tower equipment specifications.

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# Central Receiver Test Facility Experiment Manual

## Chapter 1. Introduction

The Central Receiver Test Facility (CRTF) is the primary solar test facility for component and subsystem evaluations within the US Department of Energy (DOE) Solar Central Receiver development program.

The CRTF (Figure 1.1) has a thermal capability greater than 5 MW and is designed to perform a variety of functions including, but not limited to

- Evaluating prototype solar receivers to convert the concentrated sunlight from a field of heliostats into usable heat in a heat-transport fluid such as water, molten salt, air, or sodium
- Evaluating prototype solar collectors (heliostats) for future solar central receiver plants
- Testing components and subsystems for advanced solar thermal systems, including heat or other energy storage systems
- Evaluating direct-energy-conversion cycles (such as photovoltaics or thermionics) that utilize concentrated sunlight
- Developing and testing instrumentation and process control systems
- Training personnel to operate solar central receiver facilities
- Developing high-temperature solar chemical and metallurgical processes, and determining high-intensity solar radiation effects on materials
- Performing thermal-effects testing of materials and devices not related to solar energy development programs such as
  - Simulation of chemical reaction or nuclear weapon heating
  - Simulation of aerodynamic or reentry heating
  - Simulation of nuclear reactor fault and accident events.

Correspondence from potential experimenters should be addressed to

CRTF Supervisor and Test Engineer (name)
Division 6222
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PO Box 5800
Albuquerque, NM 87185
Commercial: (505) 844-2280
FTS: 844-2280

**Figure 1-1.** Aerial Veiw of CRTF

# Chapter 2. Administrative Processes

DOE-sponsored programs are given top priority for CRTF testing and resource schedules. Priorities are set by the DOE and the CRTF. In general, the priority order is as follows:

- DOE-sponsored solar central receiver development programs
- Programs sponsored by others that complement the DOE central receiver program
- Other DOE solar programs
- DOE-sponsored non–solar-energy development programs
- Other US-government-sponsored programs
- Programs not sponsored by US government
  - US corporations or individuals
  - Foreign governments or private programs
- Others

Test programs are approved and priorities assigned by DOE's Solar Thermal Program Office. Scheduling of test operations by the CRTF depends on the priority, workload, available resources, and other factors.

## 2.1 Experiment Implementation

Experimental programs at the CRTF require strong, direct interaction between the experimenters and the CRTF staff to ensure that the work is carried out systematically and on time. The experimenters must supply detailed information to the CRTF so that the experiment can be installed and operated safely and reliably to obtain results under desired test conditions. Figure 2-1 illustrates this process.

For each series of tests at the CRTF, the experimenter must provide documentation. Table 2-1 summarizes the elements. The Experiment Application (sample presented in Appendix A) is used to determine the priority and secure approval to perform the tests; its submittal formally initiates a potential experiment. The details of the Contract Agreement, required only of non–DOE-funded users, are determined by the experimenter and the DOE Albuquerque Operations Office (AL). This document is prepared after the detailed scope of work has been reviewed by the CRTF and a cost estimate made for the proposed work. The scope of work is submitted to DOE/AL by the experimenter after it is developed jointly by the experimenter and the CRTF staff.

Information that must be included in the Data Package, Test Plan, QA Records and As-Built Drawings, and Detailed Procedures is described in Chapter 4 of this report. These documents are combined with CRTF system procedures into the Integrated Test Procedures (ITP). The ITP (the final authority for performing the experiment) must be approved by the user, the CRTF supervisor, and Sandia's Safety and Environmental Health organizations. After the experiment is completed, a CRTF test engineer will prepare a final Data Report that will include conditions for all tests, operational details, and the data required by the user and not provided in another format (i.e., magnetic tape, computer printout, etc.). The experimenter is responsible for data analysis and publication of the test program results.

**Table 2-1. Required Test Documentation**

| Item of Documentation | Prepared By | Approved By | Lead Time (days) |
|---|---|---|---|
| Experiment Application | User | CRTF supervisor, DOE/HQ | — |
| Scope of Work* | User and CRTF | DOE/AL | — |
| Contract Agreement* | User and DOE/AL | User and DOE/AL | — |
| Data Package | User | CRTF | 60 prior to hardware delivery |
| Test Plan | User | CRTF | 90 prior to test |
| Detailed Procedures | User | CRTF and user | 60 prior to test |
| QA Records and As-Built Drawings† | User | CRTF | With hardware |
| Integrated Test Procedure | User and CRTF | User, CRTF and SNLA Safety | 10 prior to test |
| Data Report | CRTF | CRTF supervisor | 60 after test completion |

*For non–DOE-funded users only.

†The QA package requirement may be waived in some cases, depending on the nature of the experiment.

## 2.2 CRTF Test Engineers

The CRTF provides the following engineering services to experimenters through the assigned test engineer, who

- Assists with obtaining approvals for the experiment (see Figure 2-1 for details)
- Expedites user access; indicates priorities and develops implementation schedules
- Provides information on CRTF capabilities, controls, data systems, interfaces, and safety requirements
- Consults with experimenters on their designs for mounting and interface hardware; experimenters normally provide all connections to existing CRTF systems and utilities
- Provides detailed test planning to ensure that test conditions and data requirements are met
- Works with the experimenter to transform the experimenter's detailed procedural input into actual test operating procedures and sequences (ITP)
- Provides special safety equipment and procedures as required to ensure personnel, facility, and test hardware safety
- Provides data reports including test data, local weather data, and a limited amount of on-line data processing and analysis
- Provides summary reports on the operation and control of the experiment.

## 2.3 Experiment Operation

Many types of experiments are possible at the CRTF. Some are complex, requiring strong interfaces with the CRTF systems. These experiments must be closely coordinated between the CRTF staff and the resident experimenter. In general, the CRTF staff operates the CRTF heliostats, utility systems, and diagnostic tools, and is responsible for personnel and facility safety. Less complex experiments may be operated by the resident experimenter. The exact role of the experimenter in test operations is defined during the review of the Data Package and Test Plan.

The solar flux and other system-operating conditions can be changed and tailored in real time. Allowable flux patterns and sequences are related to facility safety and to the capability of the heliostat control system. These are defined during the detailed test planning and procedure development by the experimenter and the CRTF staff. Deviations from the Test Plan during actual operation require the approval of the CRTF test engineer and the operations/safety engineer.

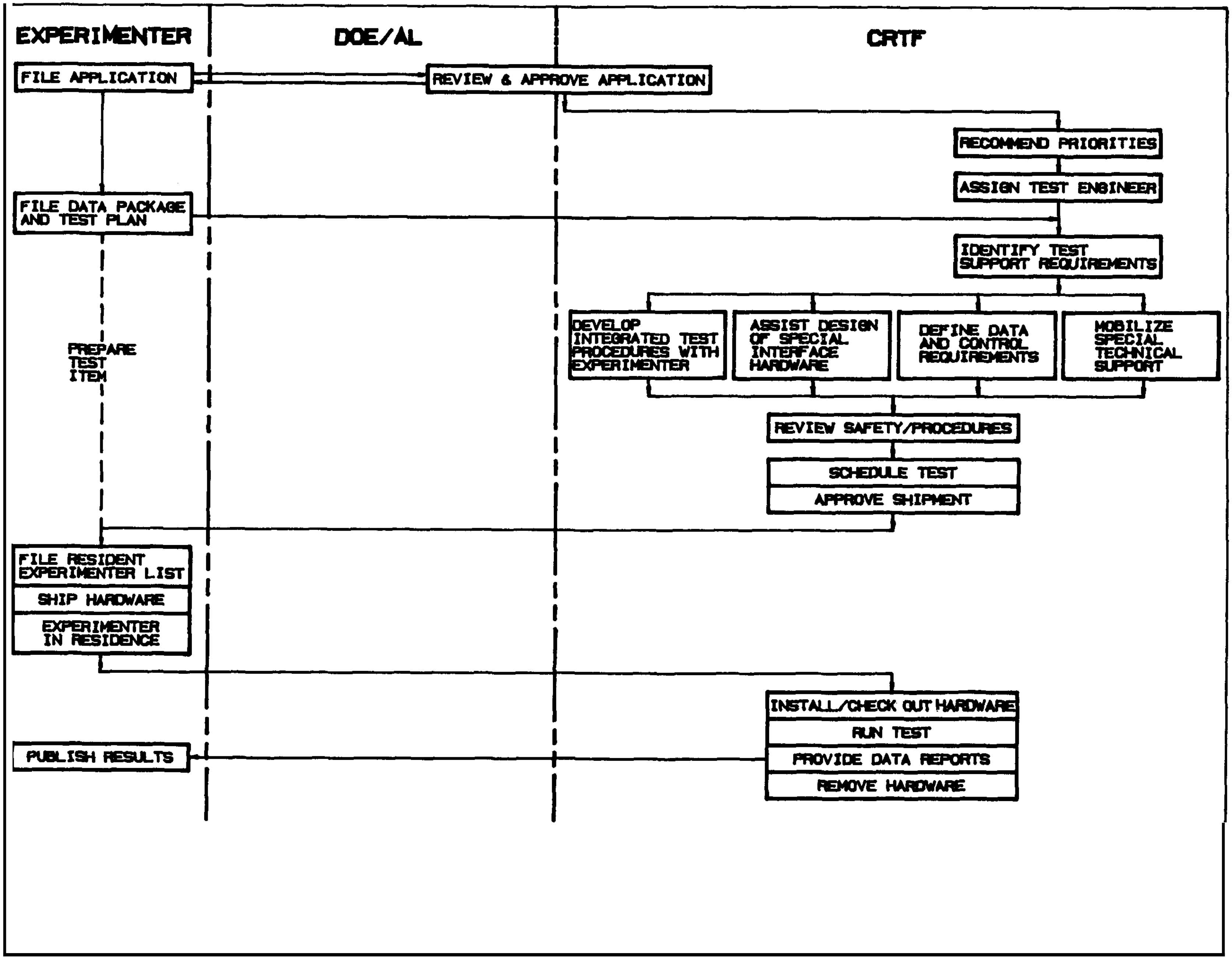


**Figure 2-1.** CRTF Experiment Implementation

## 2.4 Scheduling

The CRTF supervisor is responsible for scheduling test activities. Input from the experimenter, advice from the CRTF staff, and guidance from DOE is considered when scheduling experiments. The experimenter is notified of the tentative schedule for experiment when the Experiment Application or Contract Agreement (for non-DOE experimenters) is approved. The detailed test schedule will be worked out during the review of the experimenter's Data Package and Test Plan.

Weather conditions affect testing schedules. Some tests may require clear days only, others partly cloudy days. Table 2-2 is a 38-year summary of the US Weather Bureau data for Albuquerque, New Mexico. Our experience to date is that about half the days in the year have weather adequate for most test programs.

## 2.5 Access to KAFB and the CRTF

The CRTF is located on the Kirtland Air Force Base (KAFB). Visitors must inform the CRTF of their expected arrival time, and when they arrive at the entrance to KAFB, they must provide the Security police with the name and phone number of the CRTF contact. Figure 2-2 shows the location of the CRTF relative to other prominent features at Sandia National Laboratories and KAFB. Visitors need not stop at any other Sandia location before proceeding to the CRTF.

A visitor to the CRTF normally is not required to have a security clearance; however, a visitor who is not a US citizen must secure DOE approval to visit or reside at the CRTF. This approval is secured by the visitor's embassy, the US State Department, or the DOE Office of International Affairs.

The following items are not permitted on the CRTF site:

- Firearms, ammunition, or other dangerous weapons
- Alcoholic beverages or other intoxicants
- Illegal drugs, stimulants, or depressants
- Explosives or incendiaries
- Radioactive or toxic materials (without special permission of the CRTF supervisor).

**Table 2-2. Typical Albuquerque Weather**

(Compiled from 38-year record)

| Month | Clear | Partly Cloudy | Cloudy | Percent Sun | Average Wind Velocity (mph) | Wind Direction |
|---|---|---|---|---|---|---|
| January | 13 | 8 | 10 | 72 | 8.0 | N |
| February | 12 | 7 | 9 | 73 | 8.8 | N |
| March | 12 | 10 | 9 | 73 | 10.1 | SE |
| April | 13 | 9 | 8 | 77 | 11.0 | S |
| May | 15 | 10 | 6 | 79 | 10.5 | S |
| June | 18 | 8 | 4 | 83 | 10.0 | S |
| July | 12 | 14 | 5 | 76 | 9.1 | SE |
| August | 14 | 12 | 5 | 76 | 8.2 | SE |
| September | 17 | 8 | 5 | 80 | 8.6 | SE |
| October | 18 | 7 | 6 | 80 | 8.3 | SE |
| November | 16 | 7 | 7 | 77 | 7.9 | N |
| December | 14 | 8 | 9 | 72 | 7.7 | N |
| | 174 | 108 | 83 | | | |

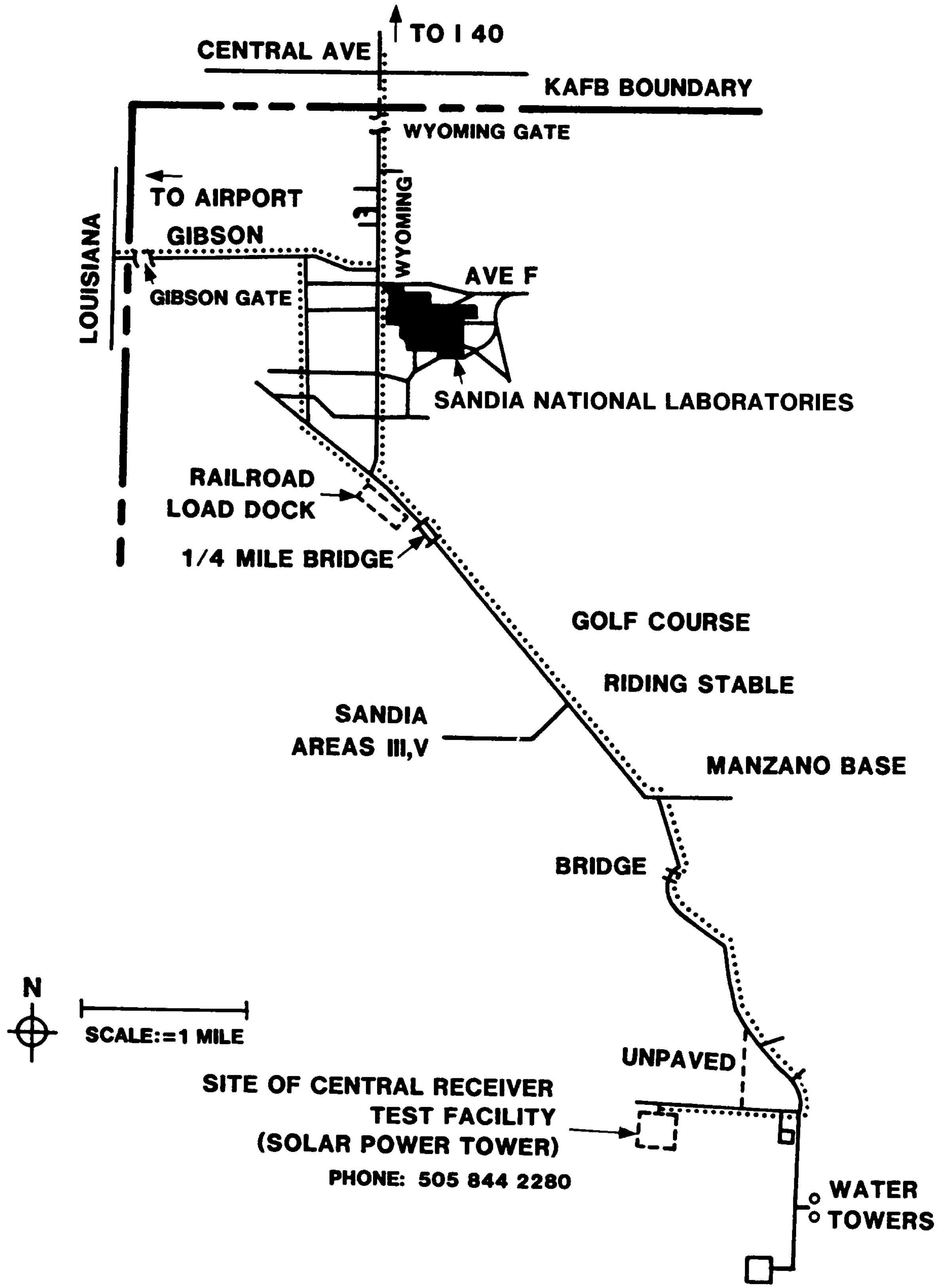


**Figure 2-2.** Location of the Solar Thermal Test Facility on Kirtland Air Force Base

# Chapter 3. Description of CRTF Capabilities and Interfaces

## 3.1 Heliostat Array Subsystem

The CRTF energy collection field consists of 221 heliostats (Figure 3-1). The total heliostat field can concentrate sunlight equal to >5 MW of thermal power under optimal sun, heliostat, and target conditions. For test flexibility, heliostats may be located on either of two foundation arrays that form a northern or a circular distribution with respect to the tower's center. To date, only the northern location has been used.

Each heliostat (Figure 3-2) contains 25 individual mirror facets, totaling 37.2 $m^2$ (400 $ft^2$) of reflective surface. Each facet is adjusted so that its reflected beam merges with the reflected beams from the other 24 heliostat facets, to form a single image at the target. The ideal reflected energy concentration ratio per heliostat is 25:1. In addition, each facet is contoured so that it gives a concentration ratio of 1.5 to 2.0:1 at its focal length. The facets are mounted on a structure with azimuth and elevation gimbals; the gimbals allow the reflected energy to be aimed at any target.

Each heliostat gimbal can be driven at angular rates of 5.6 mrad/s for the fast (or slew) mode and 0.3 mrad/s for the slow (or sun-tracking) mode. While tracking the sun, the gimbals can be directed to $2^{13}$ (8192) discrete, angular, switch-position increments ($7.7\times10^{-4}$ rad/increment) that are provided by position sensors. During slew, used for startup, shutdown, and emergency maneuvers, the control system uses only $2^{10}$ (1024) increments ($6\times10^{-3}$ rad/increment).

### 3.1.1 Heliostat Control System

The heliostat control system and experiment interface are shown in Figure 3-3. This system is based on an HP-1000 A-900 computer that is dedicated to controlling the heliostat field. For automated control of the experiment, it is necessary to inform the heliostat control computer of the status of the experiment, either directly or through a distributed link. The types of data that can be passed to the heliostat control computer are temperatures, experiment power profiles, or simply the power demand.

Each major control and data acquisition system shown in Figure 3-3 transfers data to an HP-1000F computer for database manipulation, storage, display, and printing. These systems share peripheral equipment through a distributed system link.

Commands and data transmitted to the individual heliostats are received and executed by the Heliostat Control Electronics (HCE). The HCE provides the proper drive-motor power until the gimbal axis encoders indicate appropriate heliostat attitude has been attained. The HCE and heliostat motors then await the next command.

When not in use, the heliostats are stored with the mirror surface facing the ground. As beams of energy are moved above the horizon, they are controlled so that "the light intensity in the airspace near the CRTF is one-sun (or less) at twice the focal length of the heliostat, and that no intensities over one-sun extend above twice the height of the standby point."[1] Additional details of this procedure are found in Reference 1. The heliostats can be moved individually or in groups to specific target points. Returning the heliostats to the stow position is done in a safe manner, also described in Reference 1.

### 3.1.2 Solar Power Transients

To date, the CRTF heliostats have been used to produce a variety of transient heating conditions and thermal pulses. For pulsing, a shutter is used to provide a rapid rise in flux and a timed sequence of the flux reduction is achieved with the heliostats. Figure 3-4 shows examples of pulses that have been generated using this approach. Figure 3-5 shows the power transient generated using special heliostat control strategies. Heliostats can be brought onto the target at a much slower rate than shown in this figure if desired.

The heliostats can be removed from the target in one of three ways: (1) by issuing commands; (2) by issuing a scram; and (3) by using manual switches to the elevation drives. Using the first option, groups or individual heliostats can be commanded off target following almost any timing sequence desired. The scram causes *all* the heliostats at the on-target position to go to a standby position. The resulting flux transient is shown in Figure 3-6. The third option, manual switching, is a last resort and is normally used only in an emergency case. The heliostats travel down in elevation with no movement in azimuth. Recovering from this action is very time consuming.

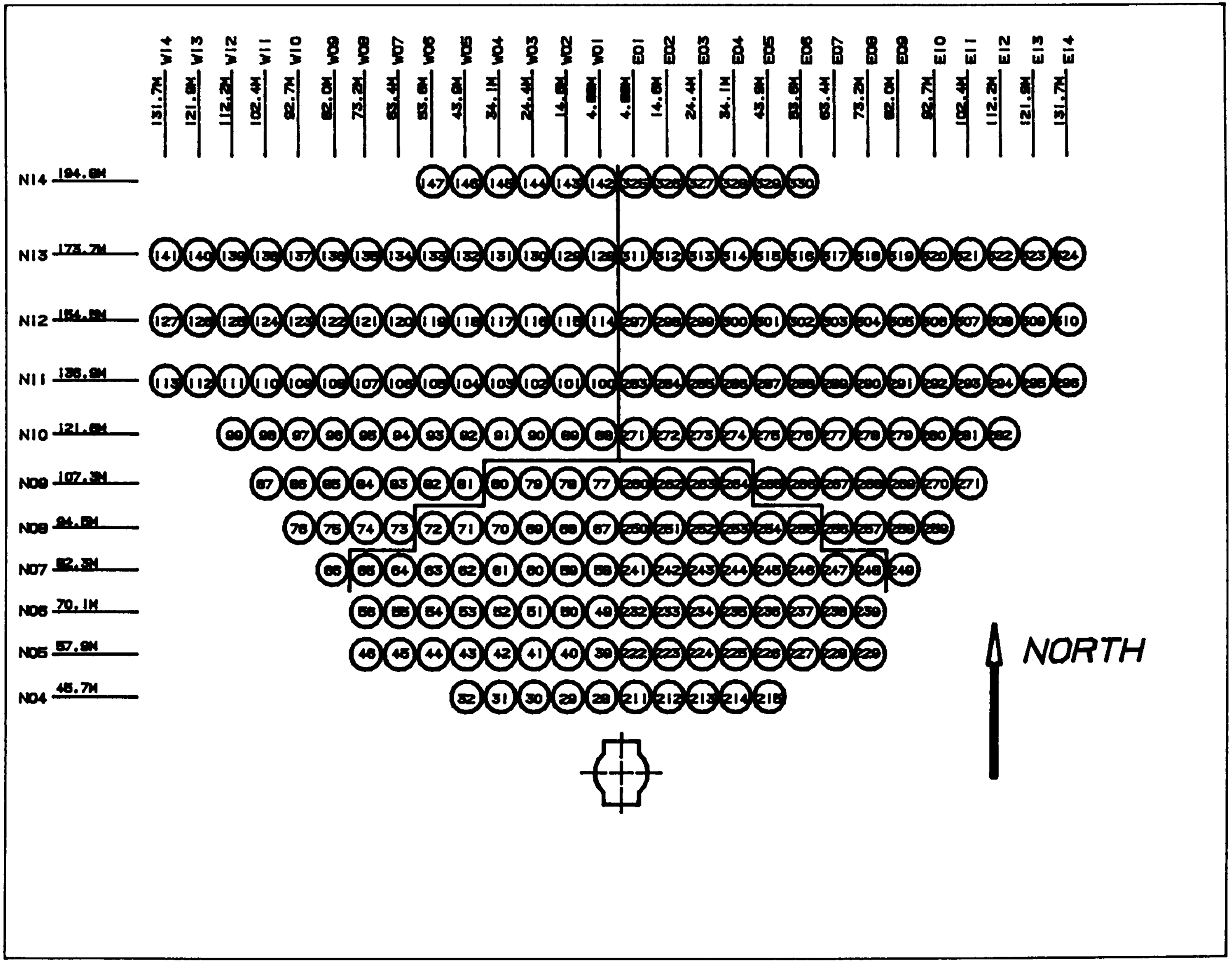


Figure 3-1. CRTF HELIOS Number System

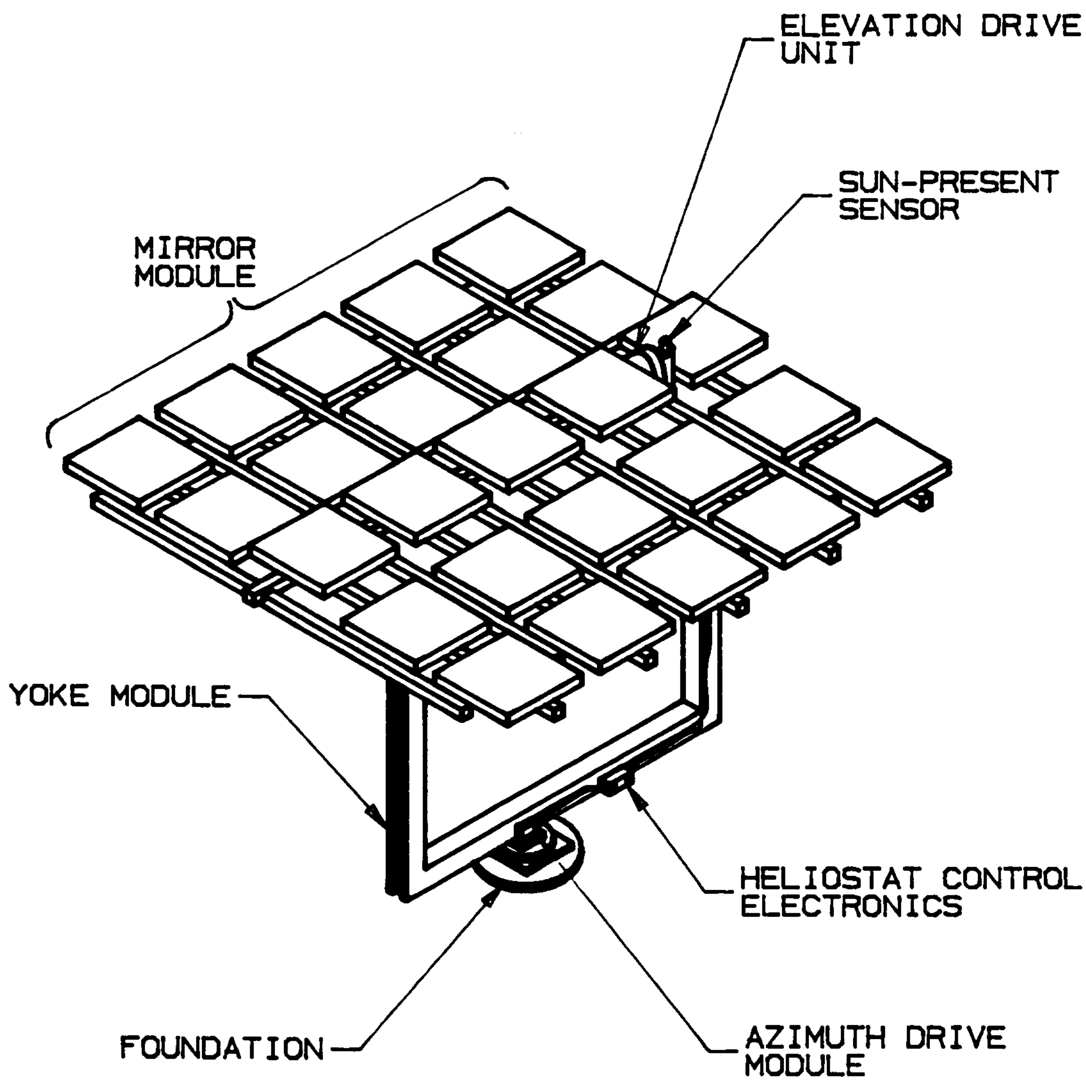


**Figure 3-2.** CRTF Heliostat

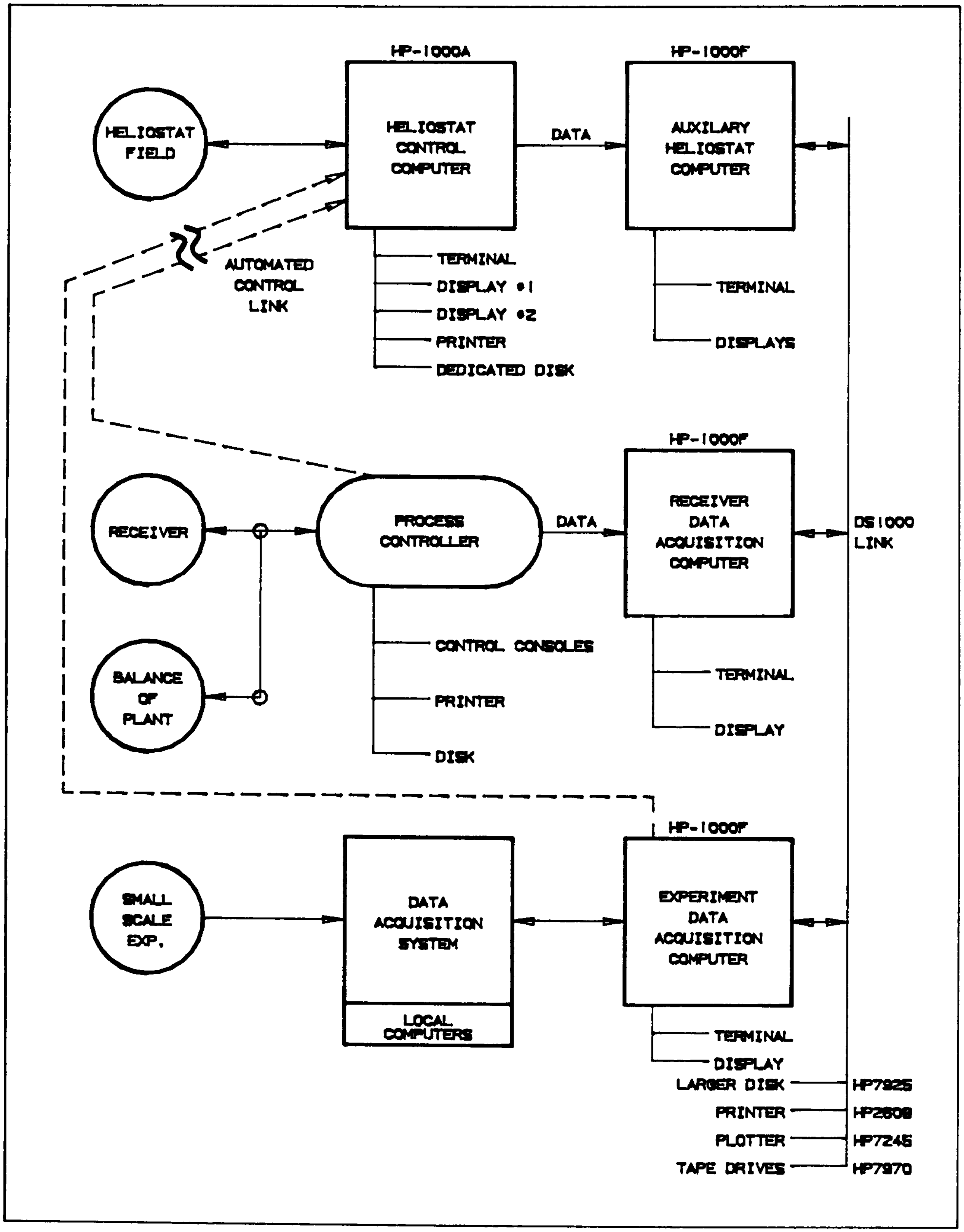


**Figure 3-3.** Heliostat Control System and Experiment Interface

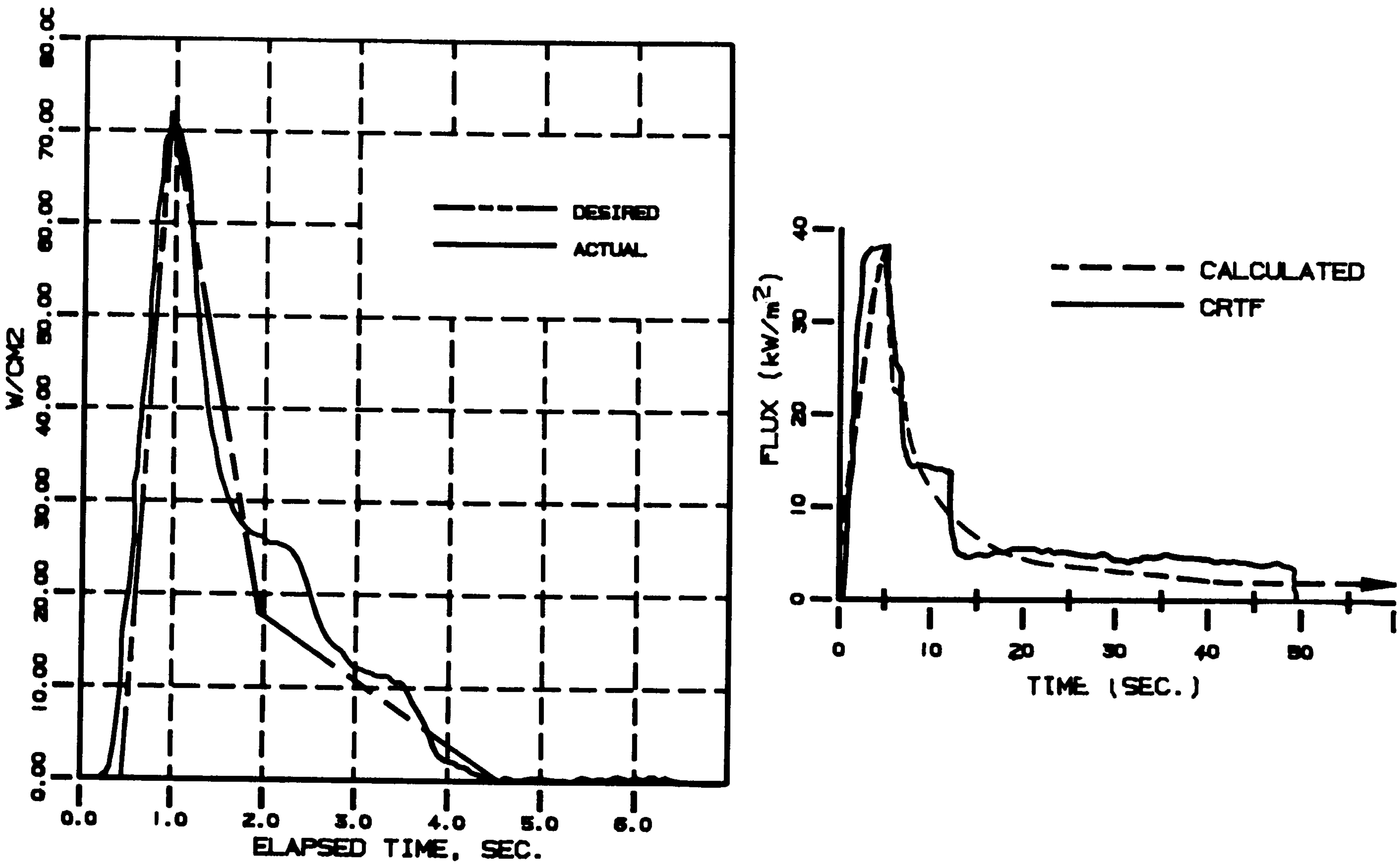


**Figure 3-4.** Pulses Generated Using the Water-Cooled Shutter

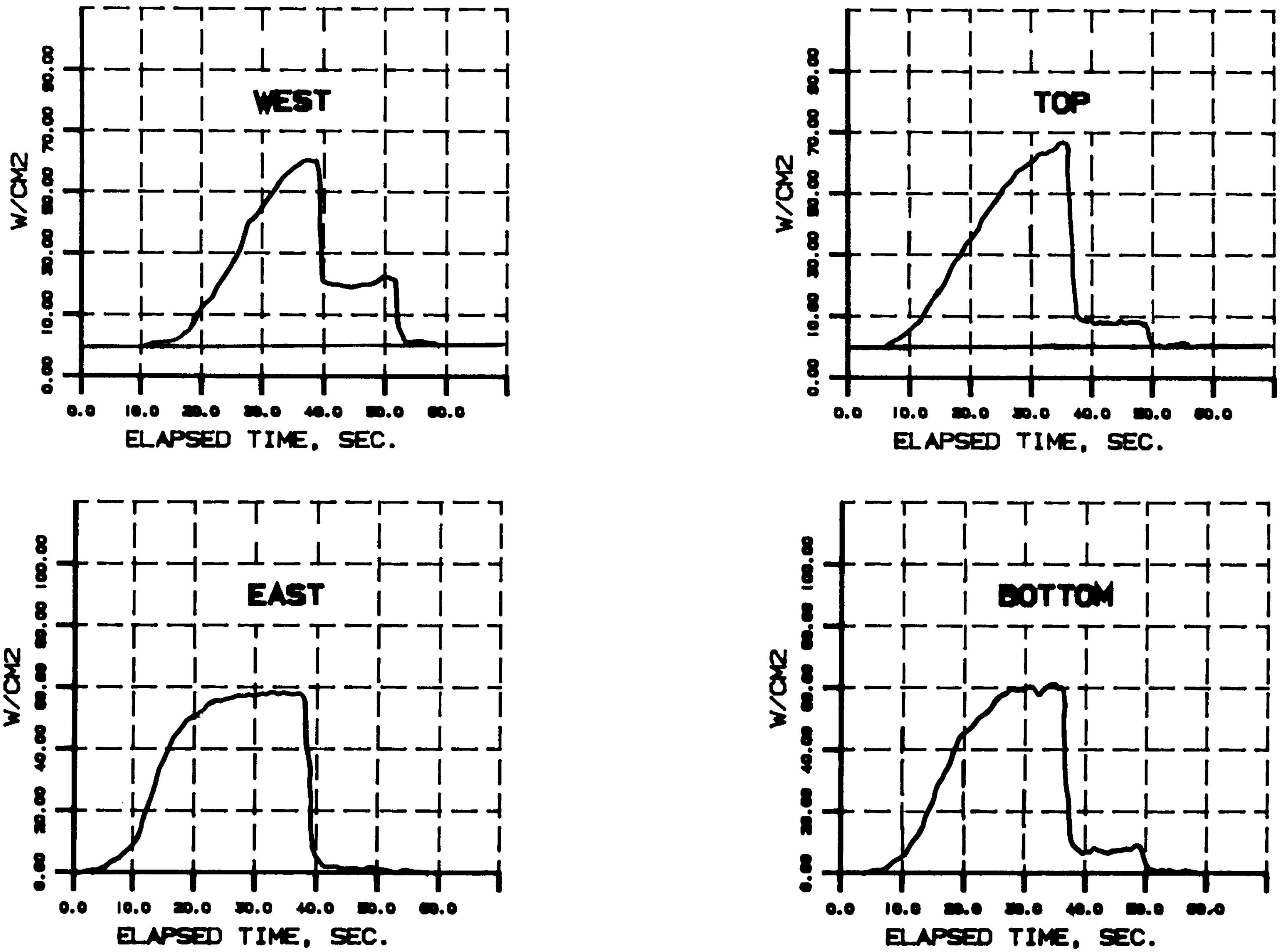


**Figure 3-5.** Reentry Vehicle Thermal Pulses

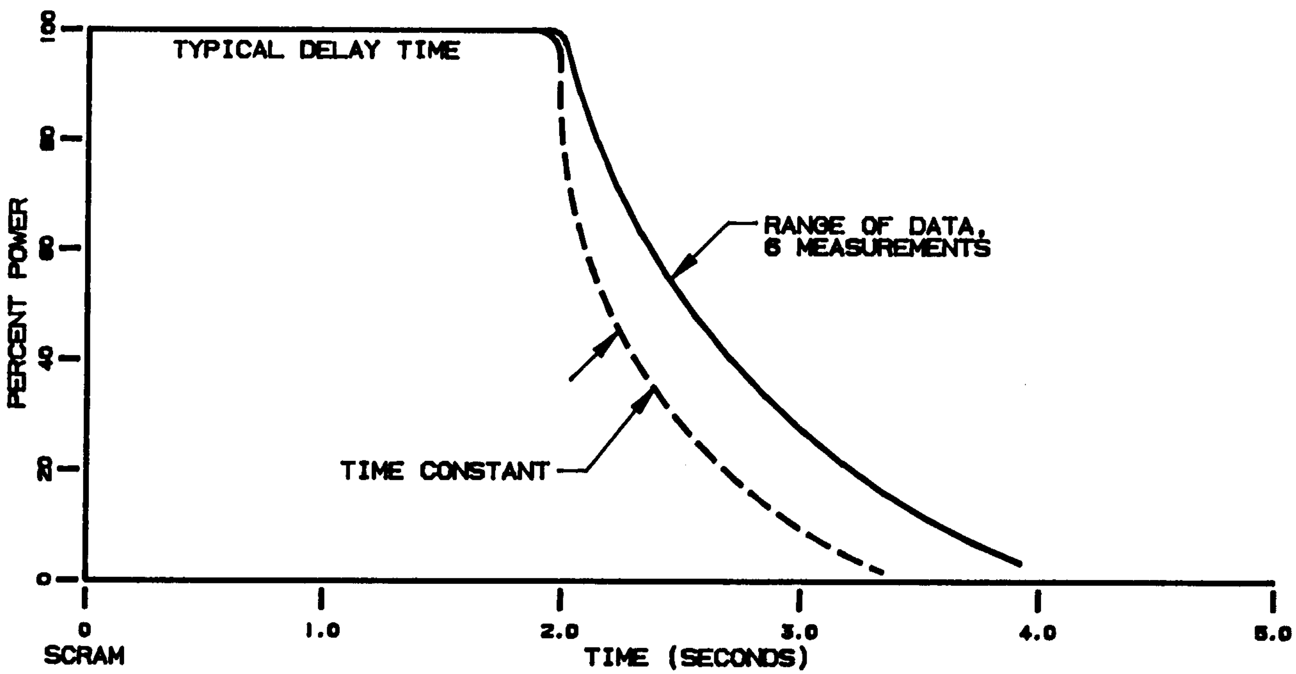


**Figure 3-6.** Solar Power Transient Caused by Scram

One of every 10 heliostats can be equipped with a detector to determine if the sun is shadowed by a cloud. Tests sensitive to rapid applications of thermal power such as would likely follow passage of a cloud can be protected by moving the heliostats off the target when the sun is interrupted. When the sun is again detected, the heliostats are returned slowly to the target. (This system has not been used to date.)

## 3.2 Heliostat and Beam Characterization Systems

The CRTF can characterize the optical performance and tracking accuracy of heliostats using the Beam Characterization System (BCS). We can also characterize the contour accuracy and alignment of heliostat facets with the Heliostat Characterization System (HCS). Potential users of either system should contact the CRTF liaison for additional details.

### 3.2.1 Beam Characterization System

The BCS is used to characterize the optical performance and tracking accuracy of heliostats used in central receiver solar power plants. Figure 3-7 is a schematic of the basic components of the system.

A heliostat beam is reflected onto a flat target having lambertian reflectance characteristics. A video camera is used to measure the reflected light coming from the target. This video image is digitized in an array (480H×512V) by 8 bits to get 256 shades of grey. A pyrheliometer located at the center of the target is used to measure and correlate the incident flux density with the video image intensity levels.

Typically, the BCS is used in one of two basic operational modes, the beam quality mode or the tracking accuracy mode. In the beam quality mode, a full system calibration is performed, and then the flux density distribution and total power are measured. These data, in conjuction with an optical model, are used to assess the performance of the heliostat. The optical model used is the computer code HELIOS (Section 3.3). In the tracking accuracy mode of operation, a rapid sampling of the beam centroid location is obtained. (A beam centroid is analogous to a mass centroid in solid mechanics except that the calculation is weighted by flux density instead of mass.) The centroid location is calculated and updated twice a second. The centroid data is then used to compute daylong root-mean-square (rms) tracking errors. Codes are available to unfold error parameters (azimuth axis tilt, azimuth to elevation axis nonorthogonality, angular encoder bias, etc.).

### 3.2.2 Heliostat Characterization System

The HCS is used to characterize the contour accuracy and alignment of heliostat mirror facets. Figure 3-8 is a schematic of the system.

The video camera is located at the center of the target (heliostat aim point) and looks back down the beam at the modified image of the sun in the heliostat. A perfectly aligned and focused heliostat presents a complete picture of the heliostat with all facets uniformly bright (i.e., the center of the sun would be visible at every point on the mirror surface). A poorly aligned heliostat presents an incomplete picture with some facets missing or only partially bright. To attain both qualitative and quantitative information, the system makes use of the limb-darkening phenomenon of the sun (the variation of intensity as a function of the sun's radius) to determine the contour accuracy and alignment of the mirror surfaces. This is accomplished by correlating the brightness of each elemental area of the mirror with the corresponding region of the sun's diameter, and that region's angular deviation from the center of the sun. As a qualitative system, the HCS can be used to quickly assess the performance of each heliostat facet and allow realignment.

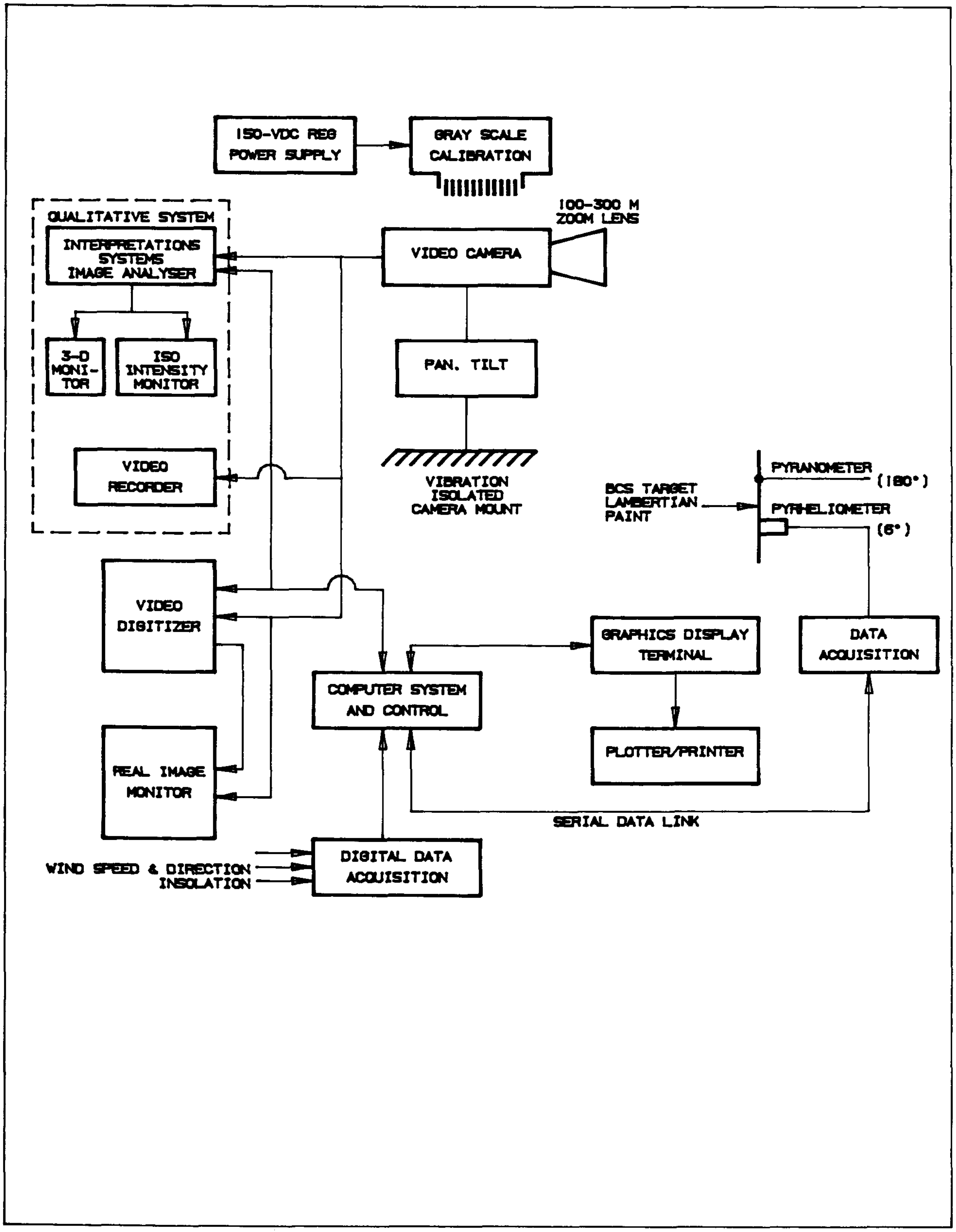


**Figure 3-7.** Beam Characterization System Schematic

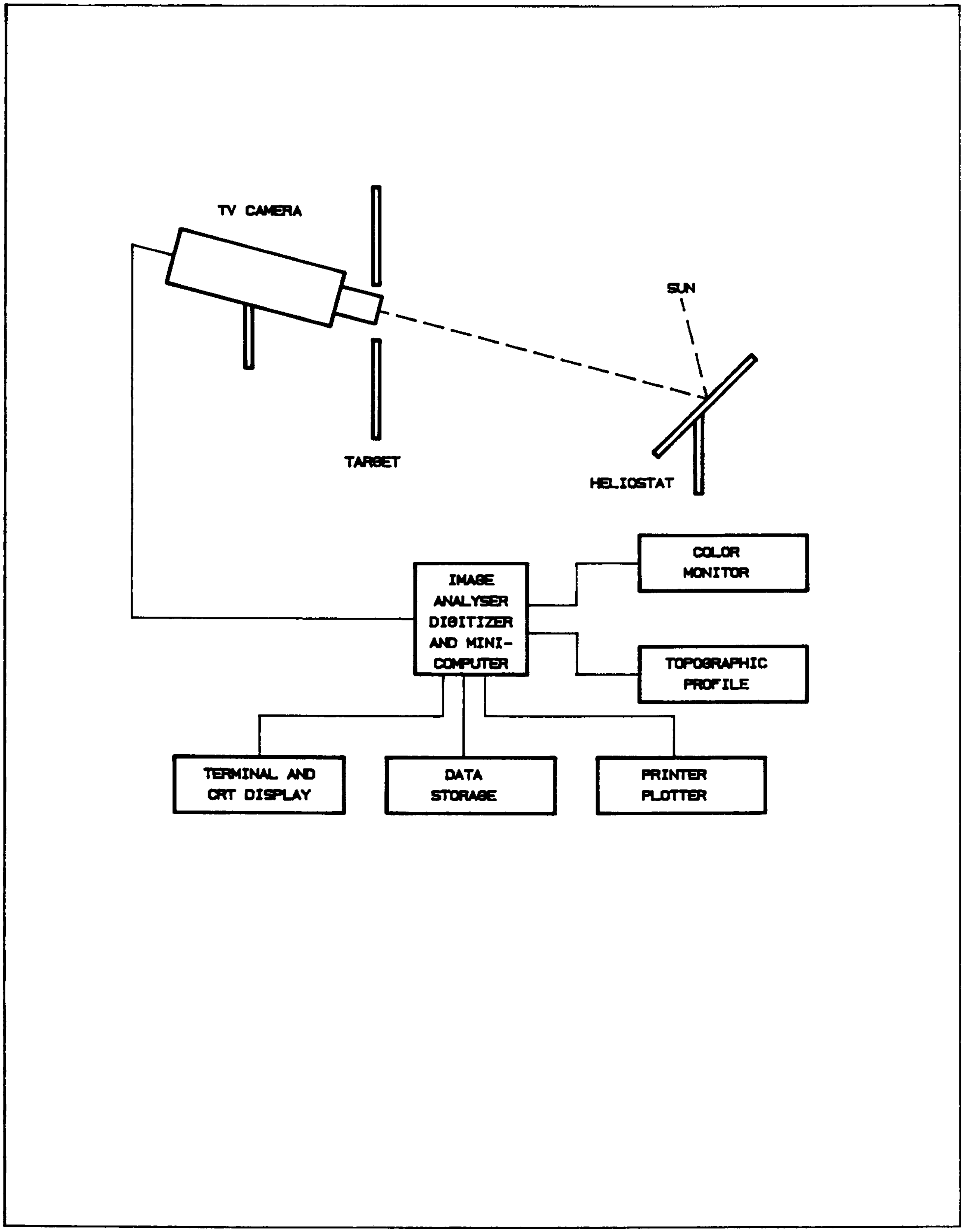


**Figure 3-8.** Heliostat Characterization System

## 3.3 Computerized Heliostat Beam Model

The CRTF heliostat field has been modeled to allow the user to study many different operating and safety conditions. HELIOS, a Sandia-developed heliostat cone optics computer model, is used to calculate the solar intensity reflected from the heliostats to any target location. The code can calculate the flux density on a surface (receiver or other experiment) or it can be used to develop aiming strategies that give unique flux distributions to meet the needs of a particular experimenter. The capabilities of the HELIOS model are described in Reference 2.

Figure 3-9 lists examples of HELIOS calculations. The calculations are for day 80 (vernal equinox) at two hours before solar noon, at solar noon, and at four hours after solar noon. The solar insolation used was 0.1 $W/cm^2$. Shown in the figure is the predicted flux distribution (in $W/cm^2$) at 121 points ($11 \times 11$ matrix) on the target surface and the total power on the target (watts). The hypothetical flat target was located on top of the tower, oriented vertically, and faced north.

The alignment coordinates for the heliostats are those of the HCS (Section 3.3.2) camera. The predictions were made using day 80 at solar noon as the prealignment day and time for all heliostats.

In this example, the total power is <5 MW because of the small target ($3 \times 3$ m). Similar results are available for each facet and heliostat and can be generated for any target size, shape, location, or number of heliostats. Experimenters are encouraged to contact the CRTF in the early design stages of their experiments to ensure that the solar beam will perform as expected. Specific HELIOS calculations will be made by the CRTF staff.

The calculated total power and peak intensity as a function of time of day and day of year are shown in Figures 3-10 and 3-11. The total power on a $3 \times 3$-m target varies from 5.4 MWth at noon on the day for which the heliostats are aligned, to a low of 3.4 MWth near the winter solstice. Between 10:00 and 14:00 the total power within the $3 \times 3$-m target exceeds 4.9 MWth throughout the year. The peak flux is a maximum of ~240 $W/cm^2$ at noon on the equinoxes and a minimum of ~100 $W/cm^2$ at 8:00 and 4:00 at the winter solstice. Figure 3-12 shows CRTF flux density contours. These contours are valid for any day of the year at any time of the day on any flat target.

## 3.4 Solar Tower

The CRTF tower rises 200 ft above ground and extends 50 ft below ground. The tower cross section is circular with rectangular projections on the north and south (Figure 3-13).

The tower cross section begins to taper at 185 ft and is smallest at 200 ft. The taper minimizes flux blockage for targets above 200 ft. At ground level the tower cross section is circular (Figure 3-14). The outermost area, which is one story high, houses mechanical and electrical equipment.

### 3.4.1 Test Locations on the Tower

The CRTF tower has four major test locations: three are located on the north side and the fourth is the tower top. The test bay locations are shown schematically in Figure 3-15. The test bays are referred to as the 220-ft level, the 240-ft level, and the 260-ft level. (This nomenclature is a result of the designation on the architectural drawings.) Table 3-1 lists the height of the test bay floors (as measured from ground level in the tower), bay dimensions, and rollup door dimensions.

***220-ft Test Bay.*** The 220-ft test bay dimensions are given in Table 3-1. The south side of the bay has no wall and opens into the tower interior. Experiments (depending on size and weight) can be lifted to the test bay either by using the passenger elevator, the elevating module (Section 3.4.2), or the work platform (Section 3.4.3), or from the north side by using the jib crane located at the 260-ft bay (Section 3.4.3).

Cooling water can be supplied to this bay through the 250-ft level 400 gpm pump (see Section 3.4.6 for details). An electrical junction box is installed on the west wall of the bay. It has plug-in jack panels for 48 Type K and 48 Type T thermocouples, and 96 data/control connections that can be made on terminal strips. The numbered cables terminate at an identical box at the 200 level where the signals can be connected to the experimenter's or the CRTF data/control equipment (see Section 3.5 for details).

***240-ft Test Bay.*** The dimensions of the 240-ft test bay are the same as those of the 220-ft bay. Currently, a high-speed shutter with a $1 \times 1$-m aperture is located at this level. Cooling water is supplied to this test bay from the 250-ft level pump. The coolant is supplied through a 6-in. header that has four 2-in., nine 1-1/2-in., and six 1-in. ball valves. All valves have flow switch indicators and positions where thermocouples can be installed, and all coolant supply and return lines have quick disconnects on both ends. The instrumentation patch panel at this level is identical to that at the 220-ft test bay.

***260-ft Test Bay.*** The test bay at the 260-ft level is an exposed platform (dimensions noted in Table 3-2). Personnel protection panels can be installed along the north edge of the bay so that experimental setup can continue while solar tests are conducted at other levels on the tower.

W/SQ CM ON TARGET SURFACE FOR DAY 80. AND TIME -2.0000 HOURS.

| Z METERS / X(I)= | 1.5000 | 1.2000 | .9000 | .6000 | .3000 | 0.0000 | -.3000 | -.6000 | -.9000 | -1.2000 | -1.5000 M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5000 | .211E+01 | .394E+01 | .643E+01 | .901E+01 | .108E+02 | .111E+02 | .980E+01 | .753E+01 | .508E+01 | .305E+01 | .165E+01 |
| 1.2000 | .411E+01 | .838E+01 | .151E+02 | .233E+02 | .304E+02 | .325E+02 | .283E+02 | .208E+02 | .133E+02 | .751E+01 | .381E+01 |
| .9000 | .673E+01 | .148E+02 | .291E+02 | .502E+02 | .725E+02 | .815E+02 | .694E+02 | .477E+02 | .281E+02 | .147E+02 | .701E+01 |
| .6000 | .938E+01 | .218E+02 | .461E+02 | .874E+02 | .139E+03 | .164E+03 | .137E+03 | .881E+02 | .480E+02 | .235E+02 | .105E+02 |
| .3000 | .113E+02 | .270E+02 | .600E+02 | .121E+03 | .205E+03 | .252E+03 | .211E+03 | .130E+03 | .664E+02 | .309E+02 | .133E+02 |
| 0.0000 | .118E+02 | .285E+02 | .643E+02 | .133E+03 | .230E+03 | .290E+03 | .247E+03 | .150E+03 | .751E+02 | .341E+02 | .145E+02 |
| -.3000 | .107E+02 | .257E+02 | .570E+02 | .115E+03 | .197E+03 | .250E+03 | .218E+03 | .136E+03 | .694E+02 | .320E+02 | .136E+02 |
| -.6000 | .849E+01 | .197E+02 | .417E+02 | .791E+02 | .128E+03 | .162E+03 | .145E+03 | .962E+02 | .523E+02 | .252E+02 | .111E+02 |
| -.9000 | .572E+01 | .126E+02 | .250E+02 | .436E+02 | .653E+02 | .795E+02 | .742E+02 | .535E+02 | .319E+02 | .166E+02 | .768E+01 |
| -1.2000 | .318E+01 | .659E+01 | .121E+02 | .195E+02 | .269E+02 | .313E+02 | .302E+02 | .236E+02 | .158E+02 | .896E+01 | .446E+01 |
| -1.5000 | .143E+01 | .277E+01 | .475E+01 | .713E+01 | .933E+01 | .106E+02 | .105E+02 | .884E+01 | .641E+01 | .398E+01 | .214E+01 |

TOWER COORDINATES OF TARGET POINTS 1, 11, 111, AND 121

| | | | |
|---|---|---|---|
| .150E+01 | .800E+01 | .655E+02 | UPPER LEFT CORNER |
| -.150E+01 | .600E+01 | .655E+02 | UPPER RIGHT CORNER |
| .150E+01 | .800E+01 | .625E+02 | LOWER LEFT CORNER |
| -.150E+01 | .800E+01 | .625E+02 | LOWER RIGHT CORNER |

POWER MATRIX (INTEGRATIONS OF EACH SET OF 3 X 3 ARRAYS ABOVE)

| | | | | |
|---|---|---|---|---|
| .3300E+05 | .9104E+05 | .1287E+06 | .8333E+05 | .3017E+05 |
| .8444E+05 | .3189E+06 | .5616E+06 | .3236E+06 | .9067E+05 |
| .1111E+06 | .4766E+06 | .9393E+06 | .5315E+06 | .1319E+06 |
| .7672E+05 | .2924E+06 | .5556E+06 | .3482E+06 | .9740E+05 |
| .2651E+05 | .7754E+05 | .1249E+06 | .9373E+05 | .3547E+05 |

TOTAL POWER ON TARGET SURFACE IS .56641E+07 WATTS.

CHECK OF POWER MATRIX

| | | | | |
|---|---|---|---|---|
| .3295E+05 | .9097E+05 | .1290E+06 | .8327E+05 | .3012E+05 |
| .8446E+05 | .3188E+06 | .5617E+06 | .3235E+06 | .9065E+05 |
| .1112E+06 | .4769E+06 | .9385E+06 | .5317E+06 | .1320E+06 |
| .7672E+05 | .2923E+06 | .5557E+06 | .3481E+06 | .9741E+05 |
| .2646E+05 | .7747E+05 | .1252E+06 | .9369E+05 | .3541E+05 |

TOTAL POWER ON TARGET SURFACE IS .56641E+07 WATTS.

FACET AREA = 8223.4 M**2
REDUCED BY COS GIVES 7563.4 M**2
FURTHER REDUCED BY SHBL GIVES 7540.1 M**2
POWER INTERCEPTED BY MIRRORS = .7563E+07 WATTS.
NO SHBL EFFECTS INCLUDED.
SOLAR INSOLATION = .10000 W/CM**2

ERROR ESTIMATE FOR POWER MATRIX

| | | | | |
|---|---|---|---|---|
| .6294E+03 | .8459E+03 | .3039E+04 | .6414E+03 | .6261E+03 |
| .1258E+03 | .1141E+04 | .1611E+04 | .6824E+03 | .1442E+03 |
| .1372E+04 | .3633E+04 | .1006E+05 | .2896E+04 | .1634E+04 |
| .6107E+02 | .9576E+03 | .1971E+04 | .1216E+04 | .8070E+02 |
| .5602E+03 | .8218E+03 | .2903E+04 | .5131E+03 | .7211E+03 |

**Figure 3-9.** Sample HELIOS Calculations

W/SQ CM ON TARGET SURFACE FOR DAY 80. AND TIME 0.0000 HOURS.

| Z METERS | X(I)= 1.5000 | 1.2000 | .9000 | .6000 | .3000 | 0.0000 | -.3000 | -.6000 | -.9000 | -1.2000 | -1.5000 M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5000 | .114E+01 | .239E+01 | .438E+01 | .683E+01 | .897E+01 | .981E+01 | .889E+01 | .671E+01 | .427E+01 | .233E+01 | .111E+01 |
| 1.2000 | .271E+01 | .606E+01 | .119E+02 | .199E+02 | .274E+02 | .305E+02 | .273E+02 | .197E+02 | .118E+02 | .601E+01 | .269E+01 |
| .9000 | .519E+01 | .123E+02 | .260E+02 | .477E+02 | .716E+02 | .829E+02 | .716E+02 | .477E+02 | .260E+02 | .123E+02 | .519E+01 |
| .6000 | .804E+01 | .199E+02 | .450E+02 | .903E+02 | .149E+03 | .180E+03 | .150E+03 | .908E+02 | .453E+02 | .200E+02 | .805E+01 |
| .3000 | .103E+02 | .262E+02 | .619E+02 | .133E+03 | .235E+03 | .291E+03 | .235E+03 | .134E+03 | .623E+02 | .263E+02 | .103E+02 |
| 0.0000 | .111E+02 | .286E+02 | .689E+02 | .152E+03 | .274E+03 | .343E+03 | .274E+03 | .152E+03 | .689E+02 | .266E+02 | .111E+02 |
| -.3000 | .102E+02 | .261E+02 | .621E+02 | .134E+03 | .236E+03 | .293E+03 | .236E+03 | .133E+03 | .617E+02 | .260E+02 | .102E+02 |
| -.6000 | .787E+01 | .197E+02 | .448E+02 | .904E+02 | .149E+03 | .180E+03 | .149E+03 | .899E+02 | .445E+02 | .196E+02 | .786E+01 |
| -.9000 | .498E+01 | .119E+02 | .254E+02 | .468E+02 | .704E+02 | .815E+02 | .704E+02 | .468E+02 | .254E+02 | .119E+02 | .498E+01 |
| -1.2000 | .251E+01 | .567E+01 | .112E+02 | .189E+02 | .263E+02 | .294E+02 | .264E+02 | .191E+02 | .114E+02 | .572E+01 | .253E+01 |
| -1.5000 | .998E+00 | .213E+01 | .398E+01 | .633E+01 | .646E+01 | .936E+01 | .851E+01 | .643E+01 | .407E+01 | .219E+01 | .102E+01 |

TOWER COORDINATES OF TARGET POINTS 1, 11, 111, AND 121

| | | | |
|---|---|---|---|
| .150E+01 | .800E+01 | .655E+02 | UPPER LEFT CORNER |
| -.150E+01 | .800E+01 | .655E+02 | UPPER RIGHT CORNER |
| .150E+01 | .800E+01 | .625E+02 | LOWER LEFT CORNER |
| -.150E+01 | .800E+01 | .625E+02 | LOWER RIGHT CORNER |

POWER MATRIX (INTEGRATIONS OF EACH SET OF 3 X 3 ARRAYS ABOVE)

| | | | | |
|---|---|---|---|---|
| .2509E+05 | .8047E+05 | .1239E+06 | .7996E+05 | .2491E+05 |
| .7870E+05 | .3339E+06 | .6184E+06 | .3353E+06 | .7909E+05 |
| .1132E+06 | .5461E+06 | .1096E+07 | .5459E+06 | .1132E+06 |
| .7808E+05 | .3339E+06 | .6187E+06 | .3323E+06 | .7763E+05 |
| .2374E+05 | .7733E+05 | .1203E+06 | .7779E+05 | .2388E+05 |

TOTAL POWER ON TARGET SURFACE IS .59577E+07 WATTS.

CHECK OF POWER MATRIX

| | | | | |
|---|---|---|---|---|
| .2503E+05 | .8040E+05 | .1242E+06 | .7989E+05 | .2485E+05 |
| .7870E+05 | .3337E+06 | .6187E+06 | .3351E+06 | .7909E+05 |
| .1134E+06 | .5465E+06 | .1095E+07 | .5463E+06 | .1133E+06 |
| .7808E+05 | .3337E+06 | .6190E+06 | .3322E+06 | .7763E+05 |
| .2367E+05 | .7726E+05 | .1206E+06 | .7772E+05 | .2382E+05 |

TOTAL POWER ON TARGET SURFACE IS .59577E+07 WATTS.

FACET AREA = 8223.4 M**2
REDUCED BY COS GIVES 7822.0 M**2
FURTHER REDUCED BY SHBL GIVES 7820.6 M**2
POWER INTERCEPTED BY MIRRORS = .7822E+07 WATTS.
NO SHBL EFFECTS INCLUDED.
SOLAR INSOLATION = .10000 W/CM**2

ERROR ESTIMATE FOR POWER MATRIX

| | | | | |
|---|---|---|---|---|
| .7219E+03 | .8576E+03 | .3451E+04 | .8183E+03 | .7356E+03 |
| .2159E+01 | .1898E+04 | .3613E+04 | .1942E+04 | .1773E+02 |
| .1682E+04 | .5446E+04 | .1449E+05 | .5449E+04 | .1680E+04 |
| .2374E+02 | .1928E+04 | .3523E+04 | .1890E+04 | .8951E+01 |
| .7467E+03 | .8184E+03 | .3474E+04 | .8555E+03 | .7311E+03 |

**Figure 3-9.** Sample HELIOS Calculations (continued)

W/SQ CM ON TARGET SURFACE FOR DAY 80. AND TIME 4.0000 HOURS.

| Z METERS \ X(I)= | 1.5000 | 1.2000 | .9000 | .6000 | .3000 | 0.0000 | -.3000 | -.6000 | -.9000 | -1.2000 | -1.5000 M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5000 | .457E+01 | .642E+01 | .855E+01 | .107E+02 | .125E+02 | .134E+02 | .128E+02 | .107E+02 | .772E+01 | .481E+01 | .266E+01 |
| 1.2000 | .754E+01 | .114E+02 | .165E+02 | .222E+02 | .277E+02 | .308E+02 | .297E+02 | .240E+02 | .163E+02 | .954E+01 | .499E+01 |
| .9000 | .108E+02 | .176E+02 | .274E+02 | .399E+02 | .532E+02 | .618E+02 | .591E+02 | .454E+02 | .287E+02 | .158E+02 | .789E+01 |
| .6000 | .139E+02 | .242E+02 | .404E+02 | .631E+02 | .888E+02 | .105E+03 | .972E+02 | .702E+02 | .416E+02 | .219E+02 | .106E+02 |
| .3000 | .162E+02 | .301E+02 | .532E+02 | .875E+02 | .126E+03 | .145E+03 | .128E+03 | .874E+02 | .498E+02 | .258E+02 | .125E+02 |
| 0.0000 | .174E+02 | .336E+02 | .617E+02 | .103E+03 | .146E+03 | .161E+03 | .135E+03 | .886E+02 | .502E+02 | .264E+02 | .131E+02 |
| -.3000 | .167E+02 | .330E+02 | .610E+02 | .100E+03 | .136E+03 | .142E+03 | .114E+03 | .749E+02 | .439E+02 | .240E+02 | .125E+02 |
| -.6000 | .142E+02 | .278E+02 | .500E+02 | .786E+02 | .100E+03 | .100E+03 | .803E+02 | .549E+02 | .341E+02 | .159E+02 | .109E+02 |
| -.9000 | .103E+02 | .195E+02 | .333E+02 | .491E+02 | .595E+02 | .587E+02 | .487E+02 | .356E+02 | .239E+02 | .149E+02 | .876E+01 |
| -1.2000 | .627E+01 | .113E+02 | .182E+02 | .250E+02 | .293E+02 | .294E+02 | .259E+02 | .205E+02 | .149E+02 | .100E+02 | .634E+01 |
| -1.5000 | .321E+01 | .550E+01 | .830E+01 | .109E+02 | .124E+02 | .128E+02 | .119E+02 | .102E+02 | .806E+01 | .591E+01 | .403E+01 |

TOWER COORDINATES OF TARGET POINTS 1, 11, 111, AND 121

| | | | |
|---|---|---|---|
| .150E+01 | .800E+01 | .655E+02 | UPPER LEFT CORNER |
| -.150E+01 | .800E+01 | .655E+02 | UPPER RIGHT CORNER |
| .150E+01 | .800E+01 | .625E+02 | LOWER LEFT CORNER |
| -.150E+01 | .800E+01 | .625E+02 | LOWER RIGHT CORNER |

POWER MATRIX (INTEGRATIONS OF EACH SET OF 3 X 3 ARRAYS ABOVE)

| | | | | |
|---|---|---|---|---|
| .4267E+05 | .8365E+05 | .1161E+06 | .9011E+05 | .3671E+05 |
| .9024E+05 | .2295E+06 | .3614E+06 | .2475E+06 | .8245E+05 |
| .1253E+06 | .3609E+06 | .5346E+06 | .3141E+06 | .9926E+05 |
| .1032E+06 | .2746E+06 | .3487E+06 | .2008E+06 | .7426E+05 |
| .4341E+05 | .9436E+05 | .1108E+06 | .7666E+05 | .3735E+05 |

TOTAL POWER ON TARGET SURFACE IS .41787E+07 WATTS.

CHECK OF POWER MATRIX

| | | | | |
|---|---|---|---|---|
| .4264E+05 | .8362E+05 | .1162E+06 | .9010E+05 | .3668E+05 |
| .9023E+05 | .2295E+06 | .3614E+06 | .2474E+06 | .8248E+05 |
| .1254E+06 | .3610E+06 | .5343E+06 | .3142E+06 | .9932E+05 |
| .1033E+06 | .2745E+06 | .3488E+06 | .2008E+06 | .7425E+05 |
| .4337E+05 | .9439E+05 | .1109E+06 | .7662E+05 | .3733E+05 |

TOTAL POWER ON TARGET SURFACE IS .41787E+07 WATTS.

FACET AREA = 8223.4 M**2
REDUCED BY COS GIVES 6836.7 M**2
FURTHER REDUCED BY SHBL GIVES 5899.4 M**2
POWER INTERCEPTED BY MIRRORS = .6837E+07 WATTS.
NO SHBL EFFECTS INCLUDED.
SOLAR INSOLATION = .10000 W/CM**2

ERROR ESTIMATE FOR POWER MATRIX

| | | | | |
|---|---|---|---|---|
| .2808E+03 | .3174E+03 | .1222E+04 | .5305E+02 | .4063E+03 |
| .1815E+03 | .3705E+03 | .2355E+03 | .9565E+03 | .3472E+03 |
| .8126E+03 | .6464E+03 | .3749E+04 | .1236E+04 | .6294E+03 |
| .2966E+03 | .1211E+04 | .8146E+03 | .7356E+01 | .1369E+03 |
| .4815E+03 | .3200E+03 | .9796E+03 | .4035E+03 | .2404E+03 |

**Figure 3-9.** Sample HELIOS Calculations (concluded)

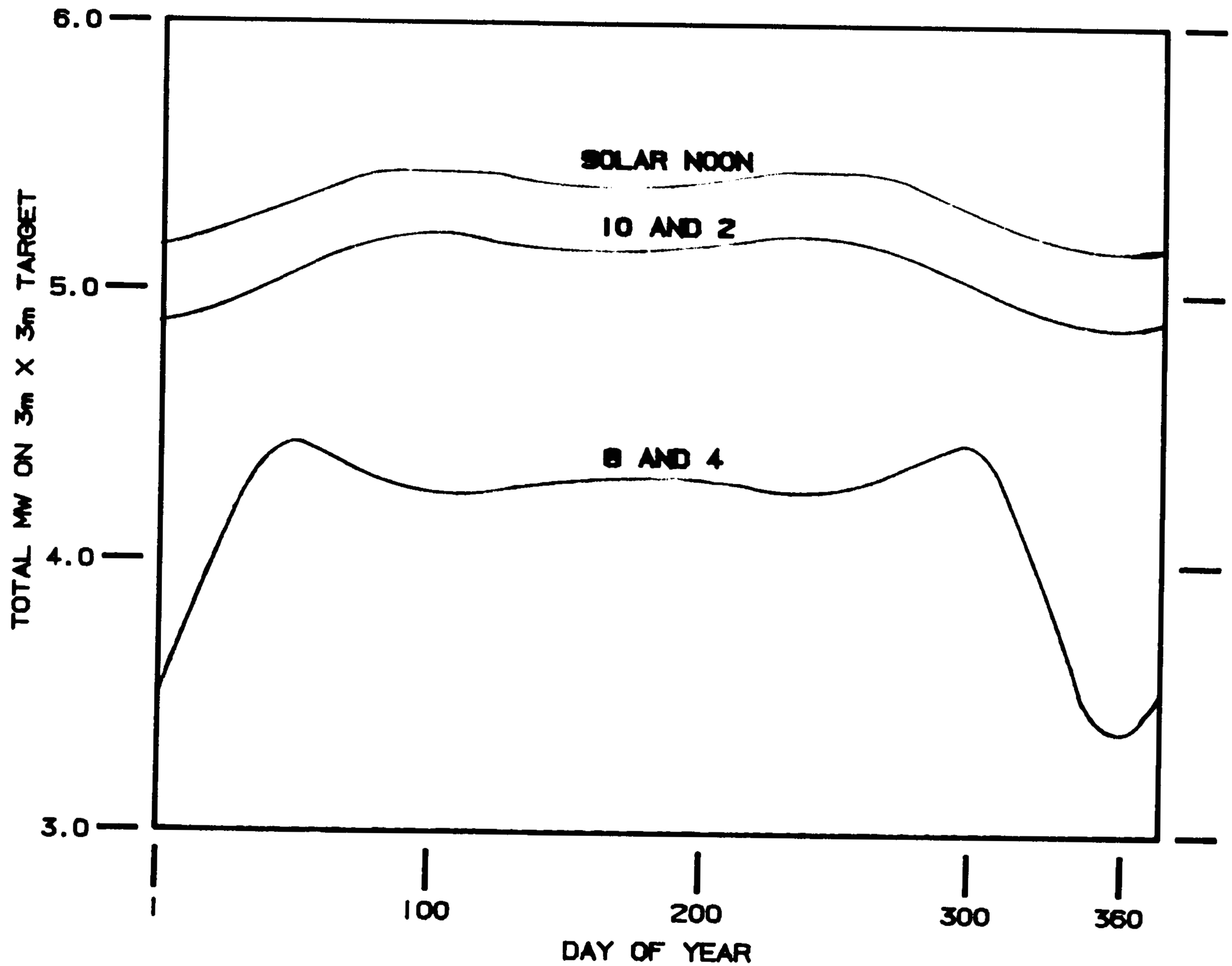


**Figure 3-10.** Power on 3×3-m Tower-Top Target

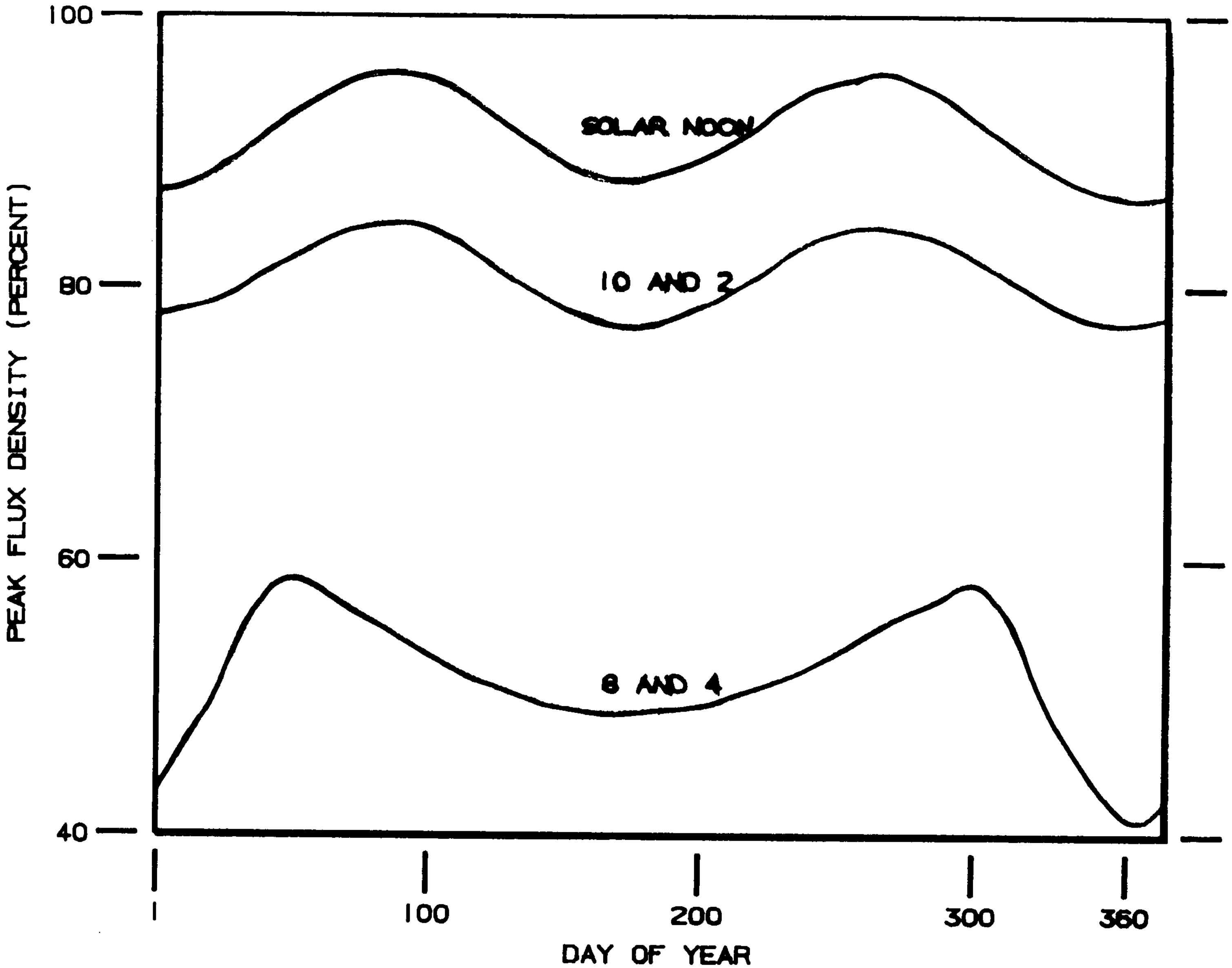


**Figure 3-11.** Peak Flux on Tower-Top Target

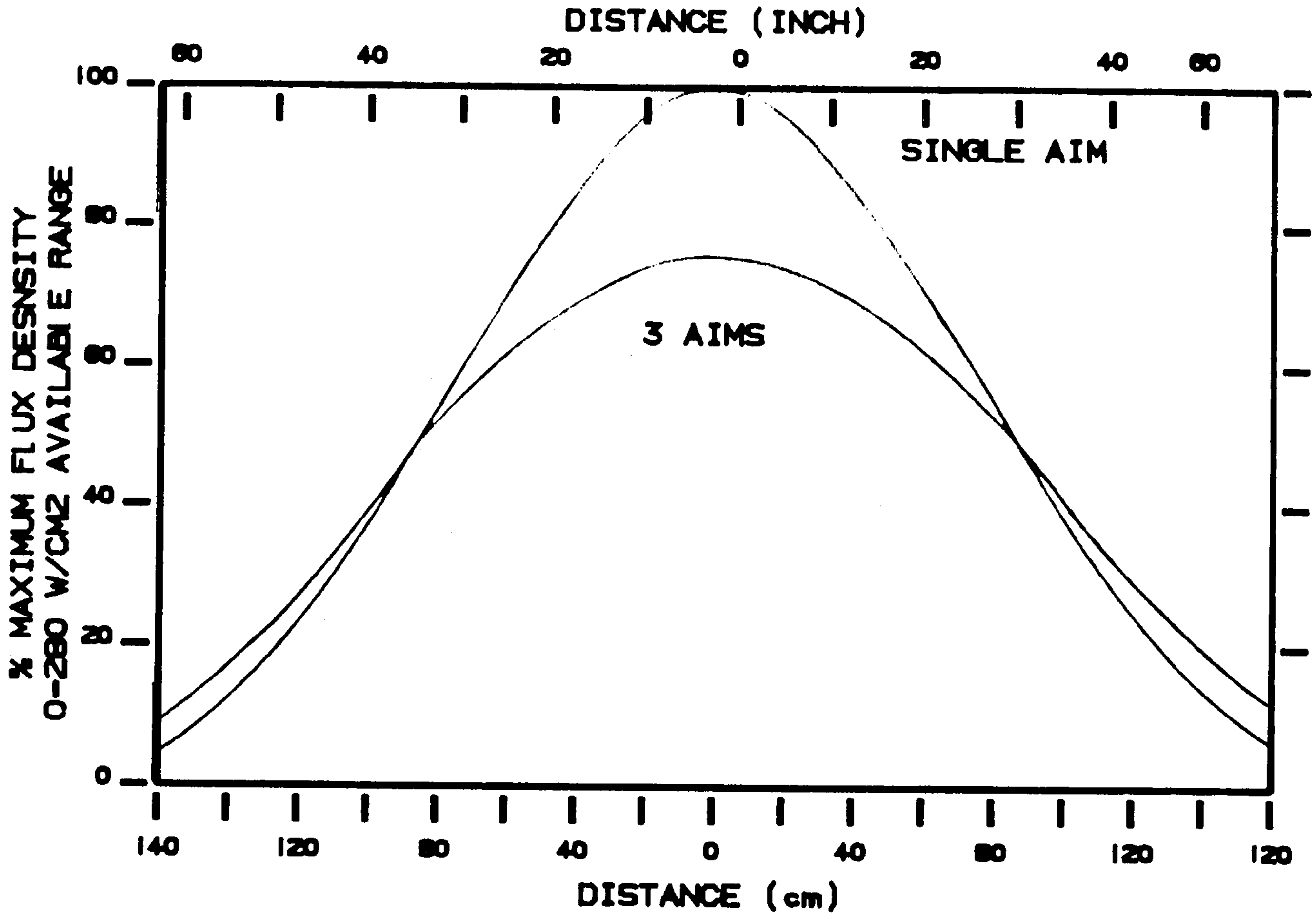


**Figure 3-12.** CRTF Flux Density Contours

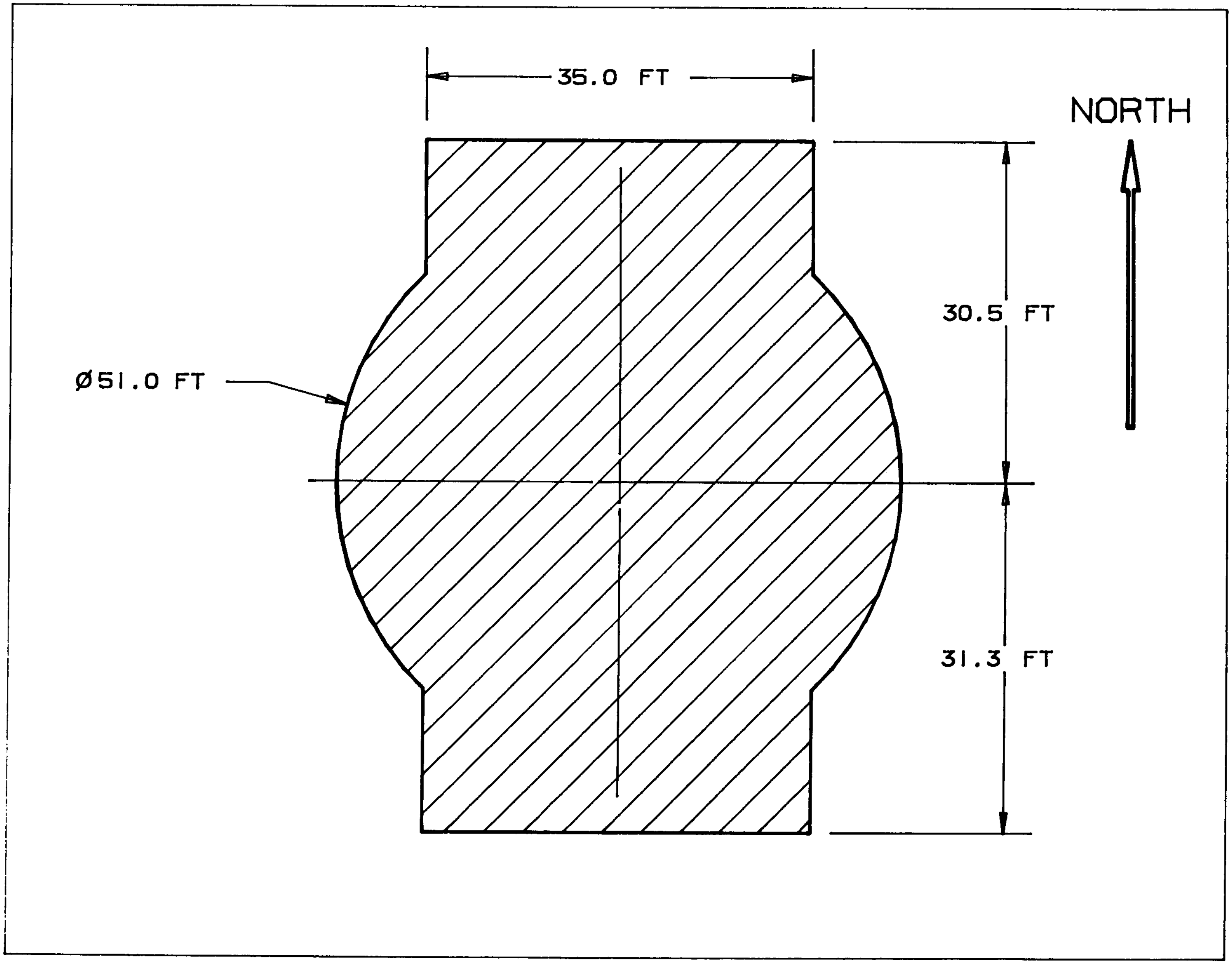


**Figure 3-13.** Tower Cross Section

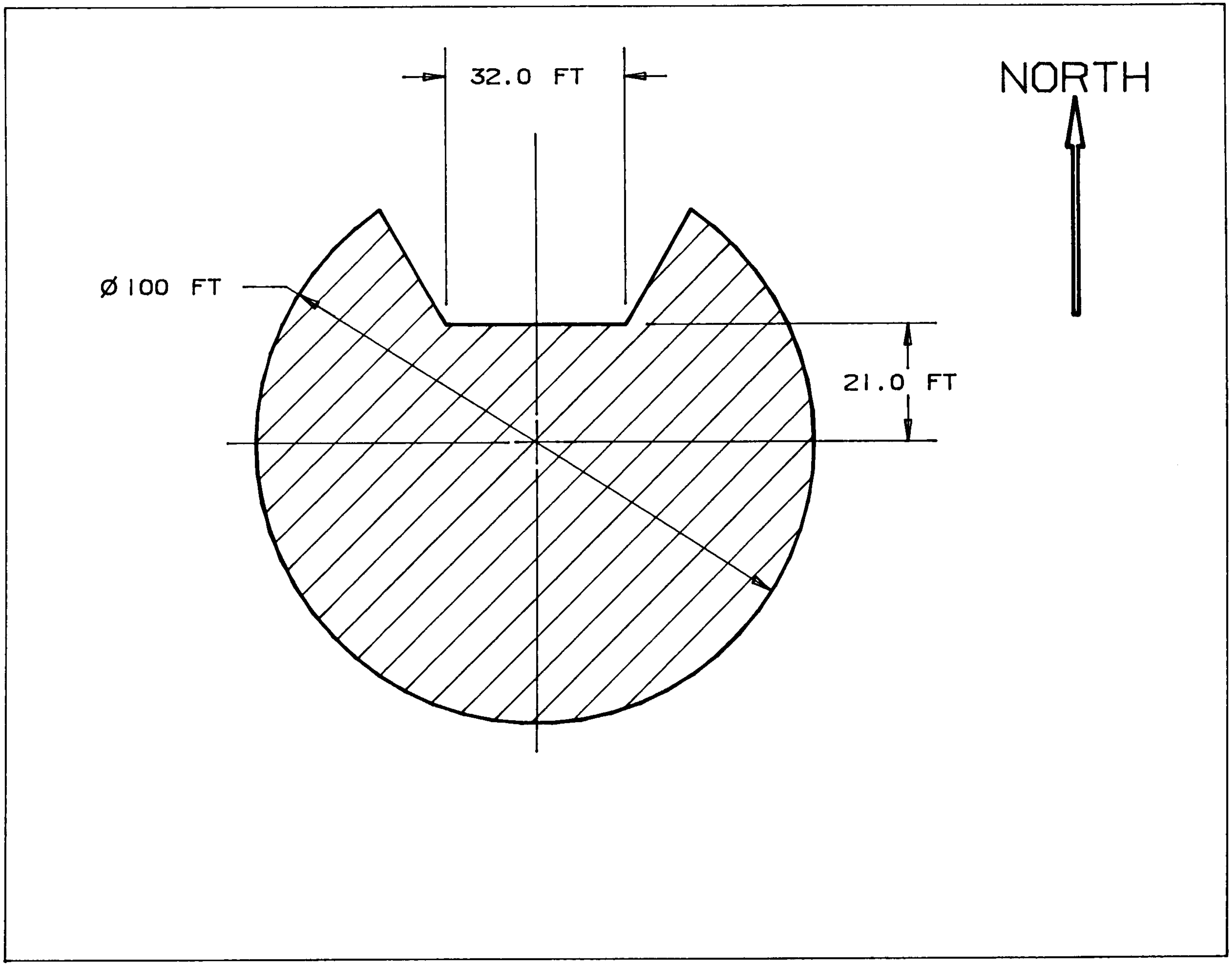


**Figure 3-14.** Tower Cross Section at Ground Level

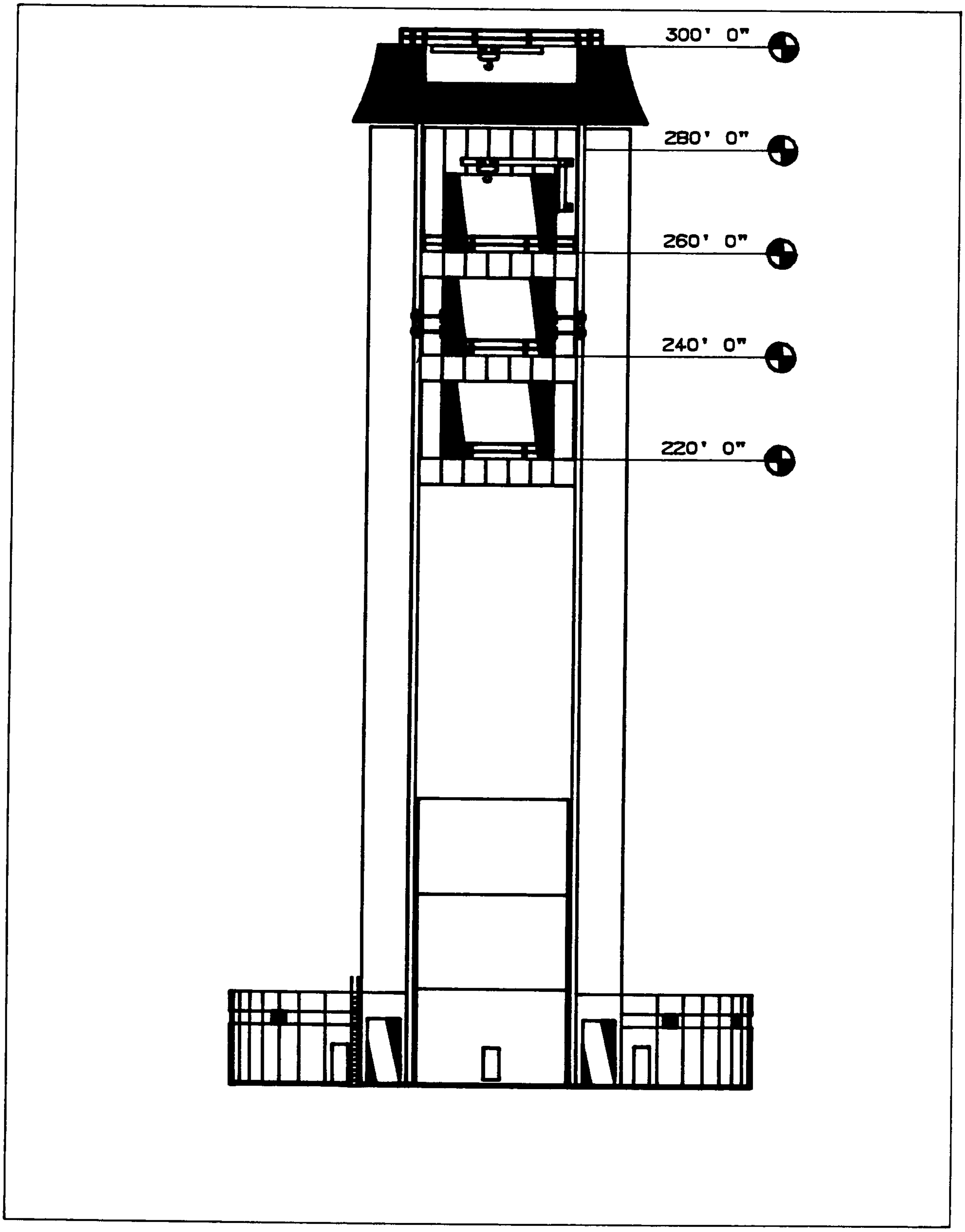


**Figure 3-15.** North Elevation of CRTF Tower Showing Test Bay Locations

**Table 3-1. Dimensions of Test Locations***

| Test Bay | Height Above Ground Level | Bay Dimensions Width (E-W) | Depth (N-S) | Height | Roll-Up Door Dimensions Width (E-W) | Height |
|---|---|---|---|---|---|---|
| 220-ft | 120 (36.6) | 32 (9.8) | 14 (4.3) | 17 (5.2) | 22 (6.7) | 15 (4.6) |
| 240-ft | 140 (42.7) | 32 (9.8) | 14 (4.3) | 17 (5.2) | 22 (6.7) | 15 (4.6) |
| 260-ft | 160 (48.8) | 35 (10.7) | 10 (3) | NA | 22 (6.7) | 15 (4.6) |
| Tower Top | 200 (61.0) | See Module Description | | NA | NA | NA |

*Dimensions are shown in feet (meters)

**Table 3-2. Location, Phase, Quantity, and Breaker Limits of Electrical Outlets in the Tower**

| | 120 V | 208 V | 480 V |
|---|---|---|---|
| Tower Top | 10 ea 20-A Duplex Outlets | 1 ea 60-A, 30<br>3 ea 30-A, 30-5W | 2 ea 300-A, 30-3W |
| 260-ft Level | 4 ea 20-A Duplex Outlets | *1 ea 30-A, 30-5W | 1 ea 30-A, 30-4W |
| 240-ft Level | 4 ea 20-A Duplex Outlets | *1 ea 30-A, 30-5W | 1 ea 30-A, 30-4W |
| 220-ft Level | 4 ea 20-A Duplex Outlets | *1 ea 30-A, 30-5W | 1 ea 30-A, 30-4W |
| Ground Level | 6 ea 20-A Duplex Outlets | — | 1 ea 300-A, 30-3W<br>1 ea 100-A, 30-3W |

*Have the ability to supply additional 208 V using dry transformers

Coolant is supplied via 6-in. headers that have two 2-in., two 1-1/2-in., and one 1-in. ports. Flow indication and temperature instrumentation is the same as that for the 240-ft level. Patch panels identical to those at the other two test bays are also located at this test level.

### 3.4.2 Elevating Module

The elevating module is shown in Figure 3-16. It moves within the rectangular hoistway in the tower interior. The module roof can be positioned anywhere between the ground level and the tower top. Ground level access to the module is provided by a 32×55-ft vertical-lift door on the north side of the tower. It has a 100-ton load capacity.

As shown in Figure 3-16, the module has three separate floors. The upper level contains instrumentation patch panels and cable trays for control and data acquisition cables coming from the experiment mounted on the roof. The middle level contains local control panels and data acquisition computers. The lower level can be used for emergency air or gas supplies and other equipment that supports the experiment on the roof.

The roof of the module is for mounting the largest experiments. The dimensions of the roof are 30 ft (N-S) by 25 ft (E-W). Any experiment mounted on the roof of the module must be attached to the four beams that span the E-W direction (locations shown in Figure 3-17).

When the elevating module is at a level other than the top of the tower, a 30×25-ft steel trap door provides a work/experiment platform at the top of the tower.

### 3.4.3 Methods of Lifting Equipment to the Test Bays

There are several ways to lift hardware to the test bays on the north side of the tower:

***260 Jib Crane.*** A 5-ton-capacity jib crane located at the 260-ft level can be used to lift equipment to the 220-, 240-, and 260-ft levels. The crane is not articulating and therefore cannot extend into the bays at the 220- and 240-ft levels; facility-provided come-alongs can be used to assist in locating equipment in these bays.

***Tower-Top Articulating Crane.*** A 3-ton-capacity articulating crane located on the elevating module roof can be used to lift equipment onto the top of the module from the 260-ft test bay.

***180 Jib Crane.*** Lower levels of the tower interior are serviced by two 5-ton jib cranes, used primarily for support of assembly work on the elevating module when it is at ground level.

***Work Platform.*** A work platform, 30 ft (N-S) by 25 ft (E-W), is located beneath the elevating module. When the elevating module is resting at any location above ground level, the platform can be used to lift loads (weighing up to 100 tons) to any level below. The work platform cannot serve the 260-ft test bay or above.

### 3.4.4 Thermal Protection

All thermal protection for the tower structure is passive. The north face of the tower above the 210-ft level was built with replaceable 3-in.-thick, white, concrete panels or a 2-in.-thick layer of concrete material sprayed on the outer tower walls.

The CRTF has had extensive experience with both active and passive protection used to protect experiment supports, coolant supply, and return lines and instrumentation cabling. Thermal protection recommendations will be made by CRTF personnel depending on the flux levels and experiment size. Active, water-cooled protection is usually required for flux densities above 100 $W/cm^2$.

### 3.4.5 Utilities

A mechanical chase is located along the east interior wall of the tower. Sewer and fire protection lines are also located here. Exact locations of piping and interfacing terminations will be supplied by the CRTF personnel upon request.

The electrical chase on the west side of the tower contains 115-Vac single-phase, 208-Vac three-phase, and 480-Vac three-phase power. The 115 and 208 Vac is distributed throughout the tower. The 480 Vac is available only at the tower top and test bays. Locations of the power lines and their associated current capacities are summarized in Table 3-2. Power lines for tower equipment and data acquisition lines run in separate, isolated conduits in the electrical chase.

### 3.4.6 Steam/Water Heat Rejection System

The heat rejection system supplies impurity-controlled deionized feedwater or water/glycol to experiments and dissipates energy from the returning fluid. The heat rejection system (HRS), shown schematically in Figure 3-18, can supply boiler-quality feedwater at a maximum of 30 gpm, 400°F, and 1250 psi. The feedwater temperature can be increased to 550°F by using the steam-heated preheater, but only if the receiver or steam generator is providing steam. The steam HRS can accommodate 12,000 lb/h of 965°F, 2000-psi steam.

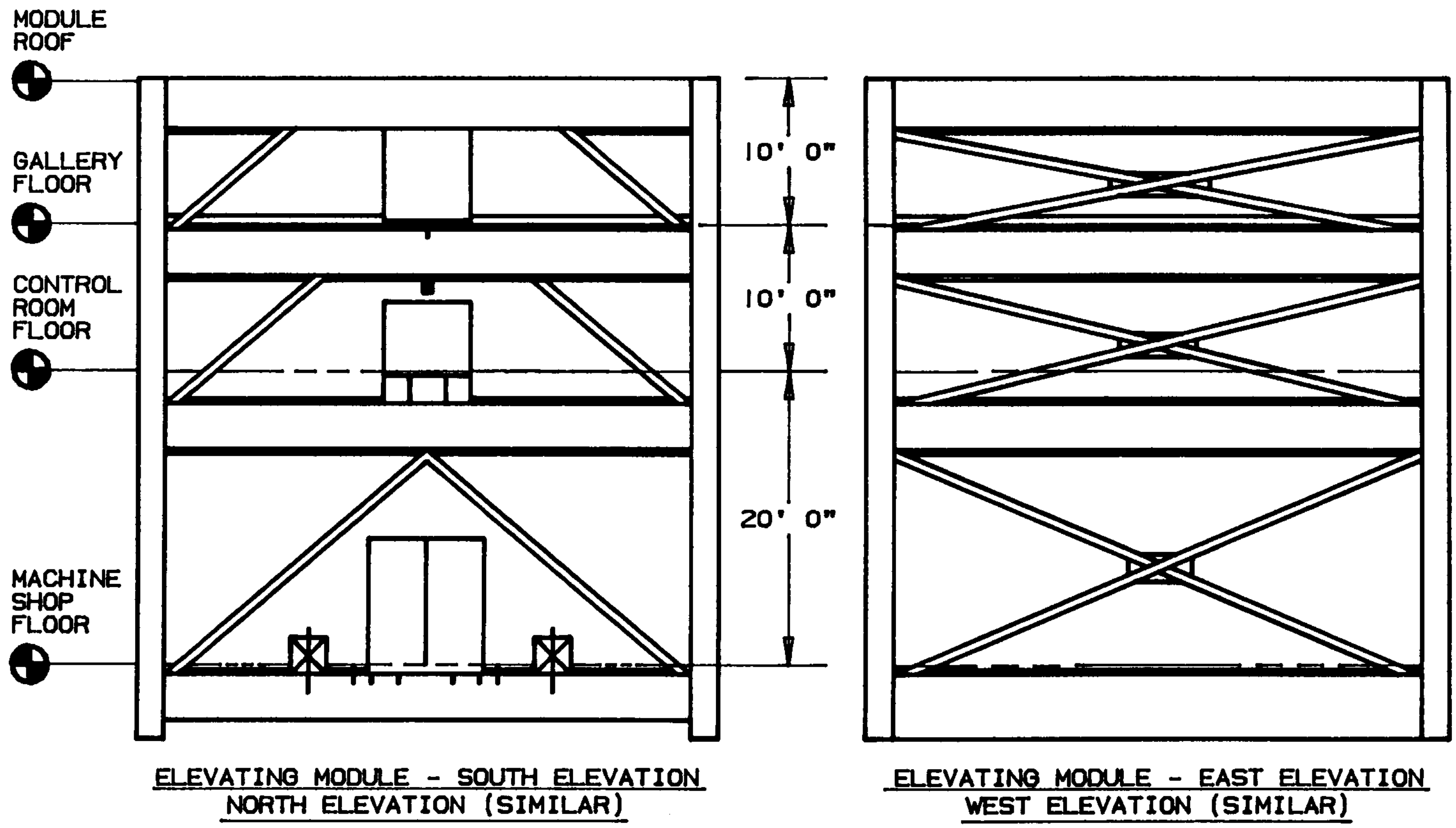


**Figure 3-16.** Elevating Module Schematic

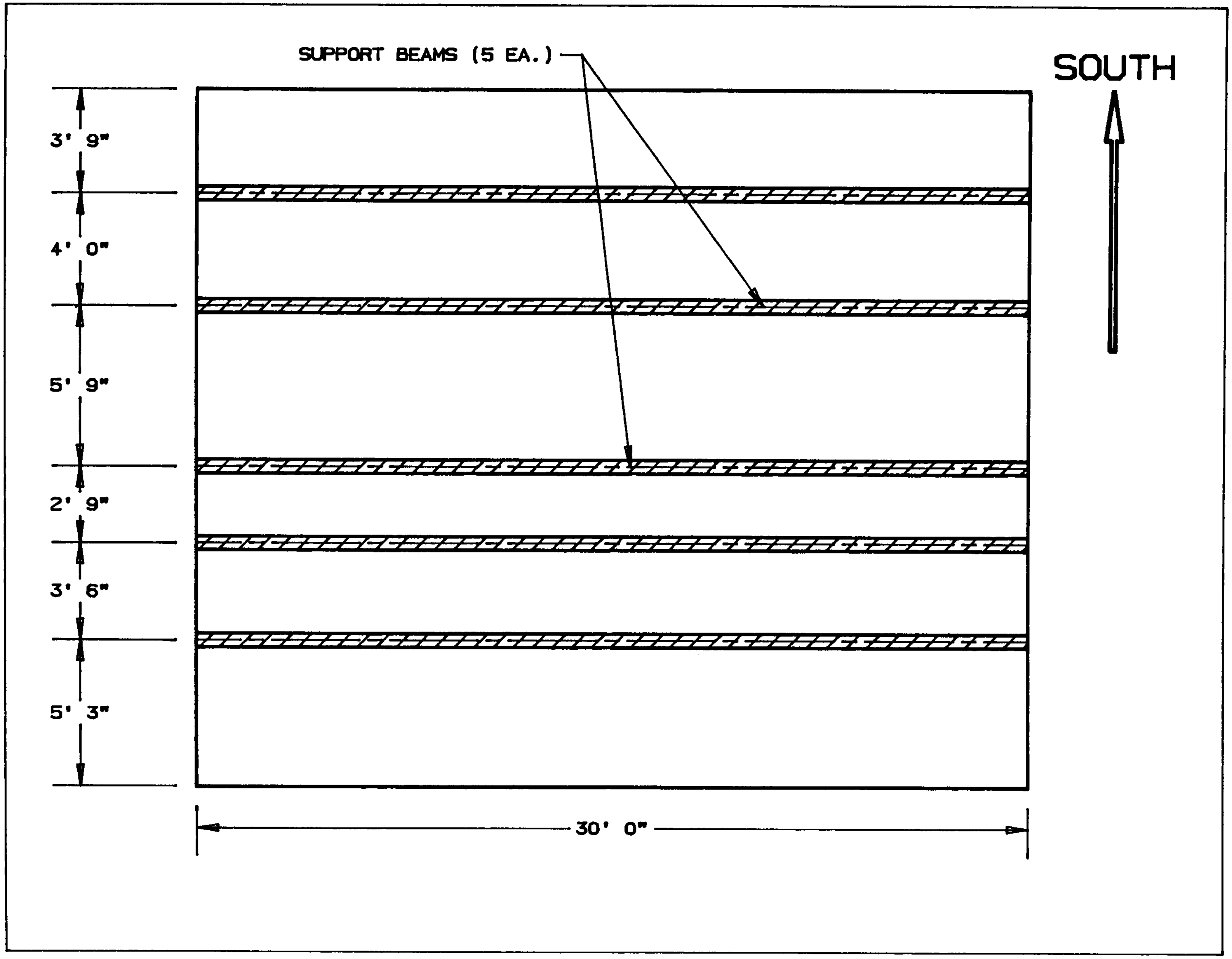


**Figure 3-17.** Location of Support Beams on Module Roof

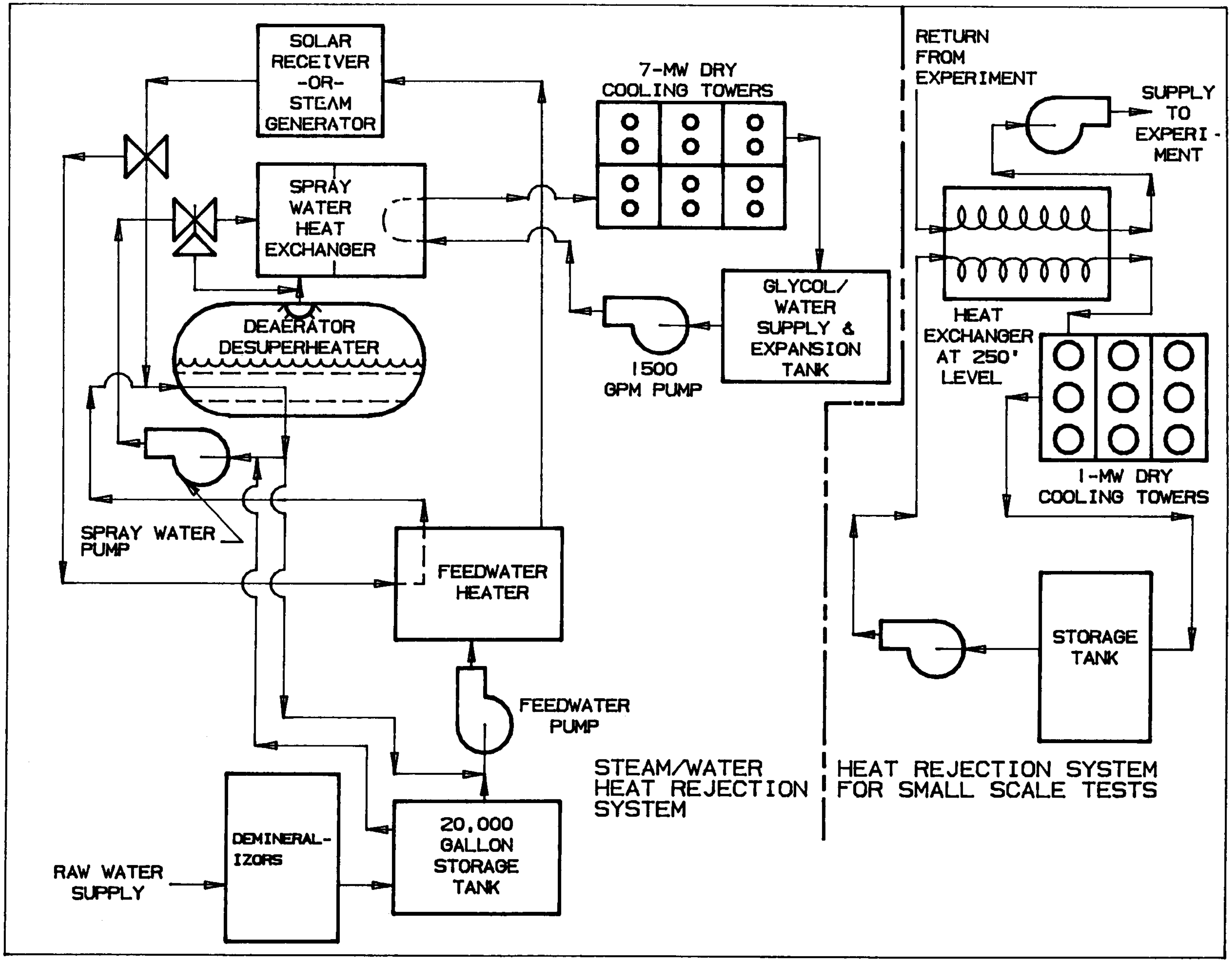


**Figure 3-18.** Heat Rejection System Schematic

The feedwater system starts at the CRTF raw water supply. Water is passed through cation, anion, and mixed demineralizer beds and stored in a 20,000-gal tank. The water is pumped from the tank into the 233-psi spray-water loop that contains a deaerator-desuperheater and heat exchanger where Hydrazine is added for dissolved oxygen control. The feedwater is pumped into high-pressure piping running to an outside boiler. Acidity control chemicals (normally not needed) are added in this high-pressure pipe (condensate polishing is normally not provided).

Water chemistry is monitored at various sample points in the feedwater system. On-line analyzers will be set up as required and can be used to measure

- Cation conductivity
- Specific conductivity
- pH
- Dissolved oxygen
- Hydrazine
- Silica.

A closed-loop, dry-cooling-tower system dissipates energy returned in the feedwater/steam. The cooling-tower loop uses a 50% ethylene glycol/water solution as coolant on the shell side of the heat exchanger in the spray-water loop. Coolant at 1500 gpm is supplied to the heat exchanger.

Two chemical feed mixing tanks and metering pumps are provided for the feedwater pH and $O_2$ control chemicals. A glycol/water mixing tank is provided for glycol water makeup in the dry-cooling-tower loop. A 4000-gal industrial waste water collection tank is provided for system waste.

A separate cooling loop is available for supplying coolant to experiments that require water/glycol only as a coolant. Fifty percent glycol/water is pumped up the tower at 400 gpm to the 250-ft level. Here it passes through a heat exchanger to cool another 400-gpm loop that in turn supplies coolant to the experiment (usually located at the 220-, 240-, or 260-ft test bay). The coolant, which originated from the HRS, rejects its heat as it passes through dry cooling towers located at the base of the tower.

## 3.5 Control and Data Acquisition Systems

### 3.5.1 Distributed Digital Process Control System

The CRTF has an on-line process control system for monitoring and controlling receiver tests. Currently, the system is used for control of HRS, a steam generator, and a solar receiver. The control system has process control units to operate subsystems in a receiver experiment, and control consoles that allow operator monitoring and operation. Each control unit is connected to a central data "highway," which passes information to a data acquisition system.

Experimenters requiring additional information on this control system should contact the CRTF user liaison.

### 3.5.2 Data Systems

The general capabilities of the CRTF data systems are summarized below. All data acquisition systems are continually being improved and potential experimenters must contact the test engineer regarding the capabilities of the facility at the anticipated test period.

| ***Analog System*** | ***Quantity*** | ***Channel*** |
|---|---|---|
| Strip Chart Recorders | 5 | 2 |
| Multipoint Recorders (Temp/MU) | 5 | 16 |
| Oscillograph Recorders | 3 | 18 |
| FM/FM Tape Recorder | 1 | 14 |
| CCTV Beta Tape Recorder | 1 | 1 |

***Digital Microprocessor-Based Data Loggers***

4 Mainframes (Acurex and Doric)
800 Channel (max), Variable Scan Rates
Real Time—
- CRT Displays (3)
- Hard Copy (tables)
- Alarm Features
- Process Control
- Demand Logging

Archive—
- Line Printer
- Floppy Disc Storage
- Magnetic Tape Storage – Cassette

***Digital Minicomputer-Based***

500 Channel, 2-s Scan Rate Nominal

Real Time—
- CRT Displays
- Hard Copy
- Alarm Features
- Process Control
- Disc/Cartridge Storage

Archive—
- Line Printer (tables, graphs)
- Magnetic Tape Storage

## 3.6 Assembly Building

At the CRTF site is a solar passively heated warehouse/assembly building, shown schematically in Figure 3-19. It is currently being used to store spare parts for active CRTF projects and serves as a heliostat maintenance area.

In the high bay of the assembly building is a 5-ton-capacity bridge crane with a 24-ft maximum lift. The building is available for on-site assembly of experiments. Utilities for light welding and machining operations are available.

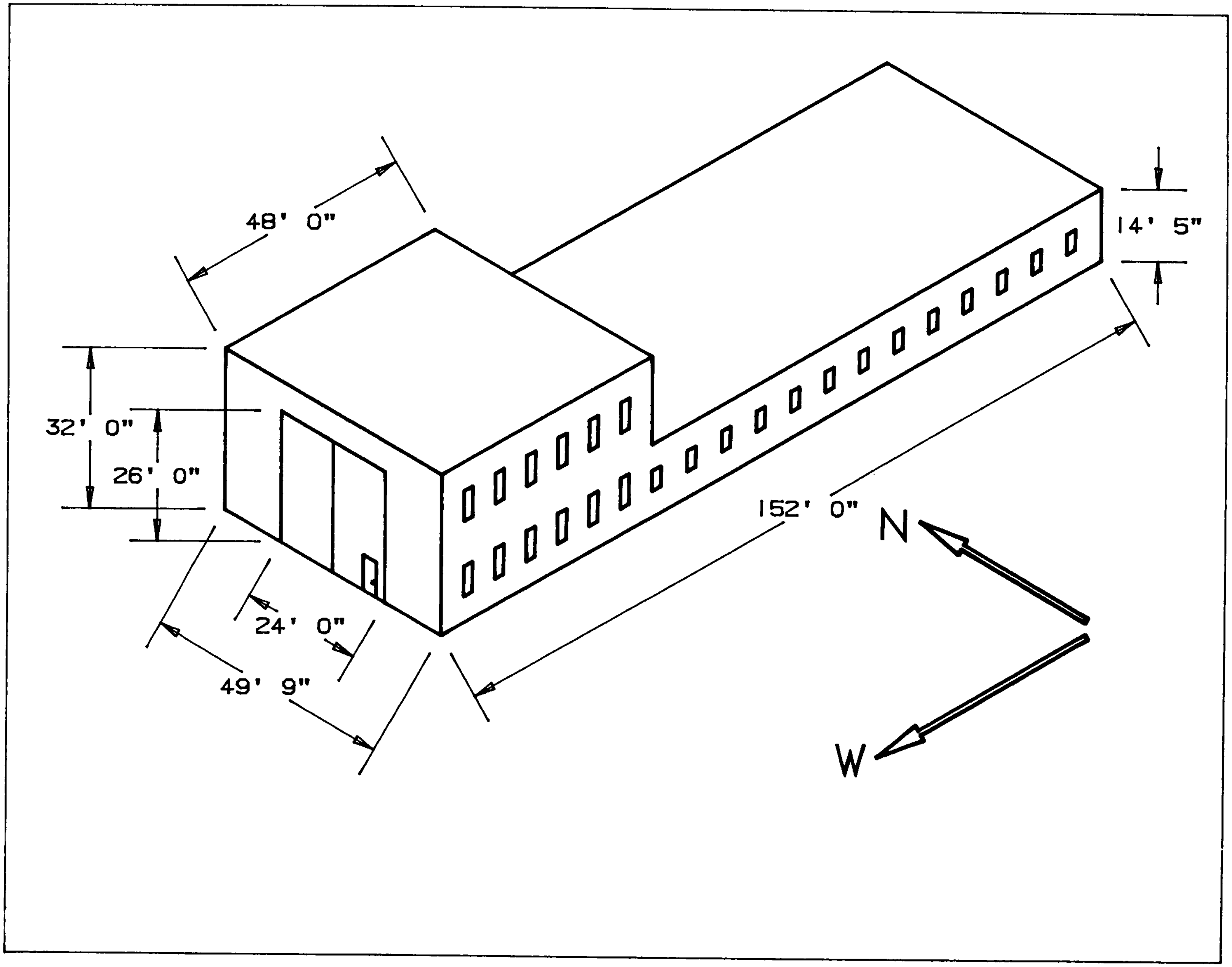


**Figure 3-19.** Isometric View of the Assembly Building

# Chapter 4. Requirements of Experimenters

It is the responsibility of the experimenter to provide detailed information on the experiment as described in this chapter. Table 4-1 summarizes requirements and their lead times. If these lead times are not met, installation and operation schedules may be delayed.

## 4.1 Data Package

The experimenter submits information about the experiment to the CRTF in the form of a Data Package. Five copies are required, including all drawings. Exact contents and amount of detail required depend on the type of experiment and will be determined by the CRTF Test Engineer working with the experimenter. The Data Package should include the following items.

### 4.1.1 Scope and Objectives

The scope and objectives summarize the nature of the experiment, including the test sequence and duration, operating conditions, and desired results.

### 4.1.2 Design Description

The *final* design of the experiment must be included. It may also include

a. Specifications and design criteria
b. Drawings—mechanical, electrical, instrumentation, and controls
c. Engineering analysis and calculations to demonstrate the design principles used to ensure the integrity of the equipment during normal, faulted, and emergency conditions. Design calculations and a summary of prior test experience may also be required. Appendix B summarizes the design requirements and the codes and standards that may be applied to the design and construction of an experiment.

### 4.1.3 Safety Analysis

Identification of all potential safety problems and failure modes for the experiment and possible hazards to personnel and equipment must be supplied. The analysis is to include normal and faulted operating conditions and potential problems due to natural occurrences such as earthquakes, high winds, lightning, rain, snow, and hail. It shall list all safety features and demonstrate that fail-safe concepts have been incorporated into the design and operating procedures. The experimenter supplies this safety-related information to the satisfaction of the CRTF and ad hoc review panels organized by the CRTF. The CRTF staff has the final reponsibility for safety during a test.

The CRTF operates with the general safety rules listed below, and the experimenters should incorporate these in their own safety analyses.

a. Personnel is allowed only in restricted parts of the heliostat field during solar operations. The CRTF Safety Engineer rules on all requests for admittance to the field.
b. Personnel is allowed in protected areas of the tower while the experiment is being performed. Access near the experiment is allowed only after special protective equipment and safety policies are established and approved by the CRTF Safety Engineer.
c. Whenever possible, experiments are designed for operation from the CRTF control room or from an area removed from the test item and heliostat beam.

### 4.1.4 Quality Assurance

The quality assurance (QA) plan and procedures provide details about how quality is incorporated into the design and construction of the experimental hardware. Any special QA requirements for installation of the equipment at the CRTF are listed by the experimenter. A completed QA records document may be required at the time hardware is delivered to the CRTF.

### 4.1.5 Supplementary Information

Additional information about the experiment and equipment may be required. This may include, but is not limited to,

a. O&M manuals for commercial components, instruments, and controls
b. Spare parts lists (parts to be supplied by experimenter; the CRTF does not provide spare parts for the experimenter's hardware)
c. Functional wire list for power, instrumentation, and controls

**Table 4-1. Requirements of Experimenters**

| Experimenter Input | Required Lead Time (days) | Copies Required |
|---|---|---|
| Data Package | 60 prior to hardware delivery | 5 |
| Test Plan | 90 prior to test | 5 |
| Procedures | | |
| Installation and QA Requirements | 60 prior to test | 2 |
| Checkout and Presolar Operation | 60 prior to test | 5 |
| Operating and Emergency | 60 prior to test | 5 |
| Training | 60 prior to test | 2 |
| Maintenance | 10 prior to test | 2 |
| Unpacking and Receiving | 10 prior to hardware delivery | 2 |
| Experiment Removal and Disposition | 30 prior to removal | 2 |
| QA Records and As-Built Drawings | With hardware | 2 |

d. Interface drawings for installation of component-to-component and test item-to-CRTF systems

e. List of special tools and equipment provided by the experimenter

f. Description of experimenter's needs for the CRTF assembly building (9982) space and equipment needs, if any.

### 4.1.6 Data Package Changes

Any design or other change to an experiment after the Data Package is approved must be submitted as soon as possible as an addendum. The addendum will be thoroughly reviewed by the CRTF and separately approved. Changes normally lengthen the implementation schedule. Failure to notify the CRTF of changes at an early date may result in delays.

## 4.2 Test Plan

The experimenter's test plan is used to allocate resources and establish the test schedule for the experiment. It is also used to develop operating strategies and procedures for the CRTF during the test. Listed below are some of the items that should be included in the test plan:

1. A test matrix that defines desired test conditions as a function of time for
   - Temperatures
   - Pressures
   - Flow rates
   - Solar flux density distribution and total power requirement
   - Solar flux density transient requirements
   - Coolant purity
   - Environmental and weather conditions
   - Transient operating conditions
   - Other parameters
2. The test schedule and sequence of activities. This schedule should start with the shipment of hardware to the CRTF and continue through removal and final disposition of the experiment. The CRTF Test Engineer works with the experimenter to develop an actual test schedule after receiving the proposed sequence of activities.

3. Data acquisition, on-line computer analysis, and computer control needs. (This must be a *detailed* list of data channel and control requirements developed with the CRTF Test Engineer.) Solar flux monitoring requirements are also to be stated. Data rate and format requirements (tables, plots, units, etc.) must be specified.
4. Special data needs from other CRTF systems.
5. Descriptive procedures indicating the operating or test sequence for checkout, startup, shut down, and emergency or faulted conditions. These descriptive procedures should indicate how and when various parts of the test item and CRTF systems are related, i.e., when cooling must be on or off, when the heliostat beam is required, how long each test event will last, when data systems must operate, etc.

## 4.3 Detailed Procedures and Training Materials

The experimenter must provide detailed operating and maintenance procedures. The CRTF determines the level of detail required based on the nature of the experiment and how it is to be implemented and operated. These procedures shall be step-by-step details of the sequence required to operate or maintain the test item. (The location of each item in the experiment that should be operated or checked should also be listed.) Procedures should be written using functional descriptors of each component as well as tag numbers. The scope of the procedural input required may include the items in Table 4-2.

**Table 4-2. Procedural Inputs**

| Procedure | Lead Time Required (days) | Copies Required |
|---|---|---|
| System installation, and QA requirements for installation | 10 prior to receipt of hardware | 2 |
| Checkout and presolar testing procedures | 10 prior to checkout | 5 |
| Startup, operation, shutdown, and emergency procedures. Emergency procedures shall cover normal and faulted conditions and shall take the experiment and the CRTF from the faulted condition to safe configuration | 60 prior to test | 5 |
| Operator training procedures including procedures for dealing with all unique hazards | 60 prior to test with component delivery | 5 |
| Routine and preventive maintenance procedures | 60 prior to test with component delivery | 2 |
| Unpacking and receiving inspection procedures. Needs for special lifting equipment shall be submitted at least 30 days in advance. | 10 prior to shipment date of hardware | 2 |
| Experiment removal and post experiment handling procedures | 60 prior to removal of hardware | 2 |

The stated lead times are required to assure meeting the installation and operation schedule. An ITP that includes the experiment procedures and CRTF support system procedures are used for the actual test. The CRTF staff, working closely with the experimenter, develops the ITP. The experimenter may need to provide training on the operation of the experiment for the CRTF operators.

## 4.4 As-Built Drawings and QA Records

The experimenter submits QA Records with the hardware. The contents of the QA Records vary depending on specific requirements for quality that are related to potential hazards and the required reliability of equipment used in the experiment. In some cases, formal QA requirements may be waived. The CRTF determines the contents of the QA Records at the time the Data Package is approved. The QA Records in *all* cases will include as-built mechanical drawings (including interfaces) and electrical drawings (including data and control links). The QA Records *may* also include

- Thermal and mechanical design calculations and other documentation
- Nondestructive examination procedures and data
- Certified test reports
- Welder certification records
- Materials certifications
- Archive materials
- Code-stamped certifications.

The CRTF reviews and audits all submitted information. Any serious discrepancies, unexpected design or fabrication changes, or omissions must be resolved prior to the start of the experiment. Normally two weeks are required to review the QA Records.

## 4.5 Shipping and Receiving

The experimenter must ship his experiment prepaid to the CRTF. The shipment should be addressed to:

(Name of Test Engineer)
Central Receiver Test Facility
Division 6222, Building 9982
Sandia National Laboratories
1515 Eubank NE
Albuquerque, NM 87185

The Test Engineer and the resident experimenter, if present, inspects the shipment. The experimenter corrects any shipping damage.

If the test hardware is to be returned at the end of the test program, the experimenter should make the arrangements and pay the shipping costs. Otherwise, the experiment will become DOE property.

# References

[1]John T. Holmes, *Heliostat Operation at the Central Receiver Test Facility (1978 - 1980)*, SAND81-0275 (Albuquerque: Sandia National Laboratories, 1981).

[2]Charles N. Vittitoe, and Frank Biggs, *A User's Guide to HELIOS: Part 1. Introduction and Code Input*, SAND81-1180 (Albuquerque: Sandia National Laboratories, 1981).

# APPENDIX A

## Experiment Application Form

CRTF Application
Control Number ______________________

Date Received ______________________

______________________
(For CRTF Use Only)

CENTRAL RECEIVER TEST FACILITY (CRTF)
EXPERIMENT APPLICATION

EXPERIMENT TITLE:

PRINCIPAL EXPERIMETER: ______________________
(First Name Initial Last Name)

Employer ______________________

Addresss ______________________
(Street) (City)

______________________
(State) (Country) (Zip Code)

Telephone: ______________________ ______________________
(Commercial) (FTS)

U. S. Citizen ___ Yes ___ No ______________________ (Specify Non-US Citizenship)

FUNDING ORGANIZATION:

Organization: ______________________
(Department)

Address ______________________
(Street) (City)

______________________
(State) (Country) (Zip Code)

Program Manager ______________________
(Name) (Title)

Telephone ______________________ ______________________
(Commercial) (FTS)

CRTF EVALUATION OF APPLICATION NO. _____

EXPERIMENT TITLE: ______________________________________________

______________________________________________

1. FEASIBILITY FOR TESTING AT THE CRTF.

2. POTENTIAL CONFLICT WITH DOE PROGRAMMATIC TESTING PLANNED FOR THE REQUESTED TEST PERIOD.

3. ANTICIPATED NON-REIMBURSABLE COST OR EFFORT.

______________________________ ______________________

CRTF EVALUATOR Date

TECHNICAL INFORMATION

CRTF Technical Support Required - Attach a separate summary of the technical support requirements such as beam power and intensity, utilities, data or control systems, heat rejection, etc., and any special requirements that may not be within current CRTF capabilities.

Purpose of Experiment:

Interest of Potential Benefit to the U.S. Department of Energy, if any.

Will the experiment involved any classified information or hardware?

SCHEDULING

Proposed Test Period: From ________________ To ________________

Experimeter Input to the CRTF

| | Date To Be Submitted To CRTF |
|---|---|
| a. Data Package (Detailed Description of Experiment) | ________ |
| b. Test Plan (Details of runs and test procedures) | ________ |
| Total number of solar test days or hours anticipated. | ________ |

Beam exposure time (range) for a single test. ____________________

Time of day or time of year preferred for test. ____________________

AGREEMENT FOR TESTING

When this application is approved, the CRTF-Liaison Engineer will assist in establishing an agreement-for-testing contract with the DOE-Albuquerque Operations Office for all experimenters that do not have a formal agreement with DOE for testing at the CRTF. That contract will define:

1. Scope of work
2. Costs and charges
3. Visits or temporary residence at CRTF
4. Key personnel
5. Coordination and administration
6. Responsibility for damage
7. Security, health, and safety
8. Disputes
9. Reports
10. Patents
11. Data responsibilities
12. Publicity releases

## CRTF EXPERIMENT APPLICATION SIGNATURE PAGE

EXPERIMENT TITLE: ________________________________________________

________________________________________________

PRINCIPAL EXPERIMENTER'S SIGNATURE: (This is an application - not an agreement)

________________________________________________
Signature Date

________________________________________________
Title

________________________________________________
Company

________________________________________________

APPROVALS:

________________________________________________ ______________
U. S. DEPARTMENT OF ENERGY, DIVISION OF SOLAR TECHNOLOGY Date

________________________________________________ ______________
SANDIA LABORATORIES, ALBUQUERQUE - Division 6222 Date

# APPENDIX B

## Design Criteria
## Codes and Standards

# Design Criteria
# Codes and Standards

The CRTF will test equipment and systems that are highly experimental and for which existing codes and standards may not be appropriate. After the feasibility of an experiment is initially established, the CRTF will determine which codes or standards, if any, must be followed. If existing codes or standards cannot be strictly met (due to unconventional design or other reasons), the experimenter must demonstrate by calculations or by test data that the design and fabrication process to be used will provide a safe experiment.

The following detailed mechanical-design documentation may be required with the Data Package, depending on the nature of the experiment. Proprietary designs, design methods, and fabrication methods will be protected.

1. Complete calculations with all assumptions, computer codes, and conclusions reached shall be documented.
2. List the assumed static or dynamic loads, and load factors for normal and faulted conditions. Wind loads for gusts up to 100 mph and earthquake loads* for Zone 2 risk shall be included.
3. Assumed working stress and the factors of safety used shall be listed. Any unique temperature gradients or temperature cycles caused by the solar flux or experiment design must be considered.
4. Any applicable codes, standards, requirements, criteria, references, and sources of test data or other data shall be listed.

The following are potentially applicable codes and standards.

### *Mechanical*

1. ASME Code for Fired and Unfired Pressure Vessels and Relief Valves (applicable sections).
2. ASME (or equivalent ASTM) Materials Specifications.
3. ANSI Code for Pressure Piping (ANSI-B31).
4. Compressed Gas Association Standards.
5. Specification for Architecturally Exposed Structural Steel; AISC.
6. Specification for the Design, Fabrication, and Erection of Steel for Buildings; AISC.
7. OSHA 29CFR1910.

### *Electrical*

1. National Fire Protection Association Standards (includes National Electrical Code).
2. OSHA 29CFR1910.

---

*The CRTF will supply earthquake response data for the appropriate location and test level on the tower.

DISTRIBUTION:

DOE/TIC-4500, Rev. 74, UC—62a (360)

US Department of Energy (6)
Forrestal Building
Attn: H. Coleman
C. Carwile
K. Cherian
C. Mangold
M. Scheve
T. Wilkins
1000 Independence Avenue, SW
Washington, DC 20585

US Department of Energy (3)
Attn: D. L. Krenz
J. Weisiger
D. Graves
PO Box 5400
Albuquerque, NM 87115

US Department of Energy (3)
Attn: R. Hughey
G. Katz
W. Lambert
1333 Broadway
Oakland, CA 94612

New Mexico State University (2)
Department of Mechanical Engineering
Attn: G. P. Mulholland
L. K. Mathews
Las Cruces, NM 88001

University of California
Department of Electrical and
Computer Engineering
Attn: M. Soderstrand
Davis, CA 95616

University of Houston
Solar Energy Laboratory
Attn: A. Hildebrandt
4800 Calhoun
Houston, TX 77704

Aerospace Corporation
Attn: P. Munjal
2350 El Segundo Blvd
El Segundo, CA 90245

ARCO Power Systems (2)
Attn: F. Blake
D. Gorman
7061 S. University, Suite 300
Littleton, CO 80122

Arizona Public Service Company (2)
Attn: J. McGuirk
E. Weber
PO Box 21666
Phoenix, AZ 85036

Babcock and Wilcox (3)
Attn: G. Grant
I. Hicks
D. Smith
91 Stirling Avenue
Barberton, OH 44203

Badger Energy, Inc.
Attn: C. A. Bolthrunis
One Broadway
Cambridge, MA 02142

Bechtel Group, Inc. (3)
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J. Darnell
P. DeLaquil III
PO Box 3965
San Francisco, CA 94119

Black and Veatch Consulting Engineers (2)
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J. E. Harder
PO Box 8405
Kansas City, MO 64114

Boeing Engineering and Construction Compa
Attn: R. B. Gillette
PO Box 3707
Seattle, WA 98124

Burns & McDonnell
Attn: M. Soderstrum
PO Box 173
Kansas City, MO 64141

California Energy Commission
Attn: D. Pierson
1111 Howe Avenue, MS-70
Sacramento, CA 95825

DISTRIBUTION (continued):

Combustion Engineering, Inc.
Attn: C. R. Buzzuto
1000 Prospect Hill Road
Windsor, CT 06095

DFVLR
Attn: M. Becker
Apartado 19, Tabernas
Almeria
SPAIN

El Paso Electric Company
Attn: J. E. Brown
PO Box 982
El Paso, TX 79946

Electric Power Research Institute
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PO Box 10412
Palo Alto, CA 94303

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R. Zoschak
12 Peach Tree Hill Road
Livingston, NJ 07039

Georgia Institute of Technology
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Atlanta, GA 30332

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Attn: J. J. Jimenez
393 Seventh Avenue
New York, NY 10001

Institute of Gas Technology
Suite 218
1825 K Street, NW
Washington, DC 20036

Martin Marietta (2)
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PO Box 179, L#0450
Denver, CO 80201

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L. W. Glover
5301 Bolsa Avenue
Huntington Beach, CA 92647

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Attn: J. Morgan
PO Box 2896
Lake Charles, LA 70624

Olin Chemicals Group (2)
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L. C. Fiorucci
120 Long Ridge Road
Stamford, CT 06904

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Attn: C. Weinberg
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San Ramon, CA 94526

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Richland, WA 99352

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PO Box 2267
Albuquerque, NM 87103

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Canoga Park, CA 91304

Solar Energy Industries Association
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Denver, CO 80217

Stone and Webster Engineering Corporation
Attn: R. W. Kuhr
PO Box 1214
Boston, MA 02107

Westinghouse Electric Corporation
Advanced Energy Systems Division
Attn: J. R. Maxwell
PO Box 10864
Pittsburgh, PA 15236

| | |
|---|---|
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| 6220 | D. G. Schueler |
| 6222 | J. V. Otts |
| 6222 | K. Boldt |
| 6222 | C. P. Cameron |
| 6222 | W. A. Couch |
| 6222 | R. M. Edgar |
| 6222 | D. K. Johnson |
| 6222 | C. W. Matthews |
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| 3151 | W. L. Garner (3) |