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10 MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT OPERATIONAL TESTING PLAN

DECEMBER 23, 1981

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Energy Technology Engineering Center

Operated for the U.S. Department of Energy
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FOREWARD

This Operational Testing Plan for the Solar Ten Megawatt Pilot Plant (STMPP) was prepared by ETEC in accordance with the Test Requirements Document (SAND 79-8037) published by Sandia-Livermore in June 1981. The essentially complete Plan is being submitted to Sandia for their retention and use. At Sandia's request, this Plan will not be published to general distribution.

The guidelines in the Test Requirements Document and in this Testing Plan are comprehensive and are structured to meet the overall STMPP project objectives. Assumptions made in the Sandia document and herein were that all plant subsystems and associated hardware would be functional at the conclusion of start-up and acceptance testing. However, recent budgetary limitations have delayed completion of the following:

1. Thermal storage activation
2. Plant-level operational status displays software development
3. Coordinated and automatic control software development

The above activities will not be available at the onset of operational testing in early 1982, but eventually will be incorporated into the system. Total implementation of the proposed Operational Testing Plan cannot be accomplished until the deferred activities have been completed.

The schedule and preferred test sequence in this draft do not reflect the recent decision to defer the key activities delineated above and should therefore be revised when completion of the deferred items have been scheduled.

Questions pertaining to the test plan should be directed to R. W. Wiese at (213) 700-5516 or J. J. Droher at (213) 700-5517.

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Figures

Tables

TEST PLAN NOMENCLATURE

BCS	Beam Characterization System
C&SB	Charging & Storage Boosted (Operating Mode 7)
CRT	Cathode Ray Tube
CRTF	Central Receiver Test Facility (Albuquerque, N.M.)
CS	Collector System
DAS	Data Acquisition System
DOE	Department of Energy
EPGS	Electric Power Generation System
HAC	Heliostat Array Controller
HC	Heliostat Controller
HFC	Heliostat Field Controller
I	Inactive (Operating Mode 8)
ILF	In-Line Flow (Operating Mode 4)
ILS	Interface Logic System (includes interlocks)
IO	Initial Operation (Operating Mode)
MCS	Master Control System
MW_e	Megawatt-electric
MW_t	Megawatt-thermal
OCS	Operating Control System
PSS	Plant Support System
RADL	Report and Deliverables List
RLU	Red Line Unit (includes alarms)
RMU	Remote Multiplexing Unit
RS	Receiver System
SAN	San Francisco Operations Office
SB	Storage-Boosted (Operating Mode 3)
SC	Storage Charging (Operating Mode 5)
SCE	Southern California Edison
SD	Storage Discharging (Operating Mode 6)
SFDI	Solar Facilities Design Integrator
SHIMMS	Special Heliostat Instrumentation and Meteorological Measurements System
STMPO	Solar Ten Megawatt Project Office
STMPP	Solar Ten Megawatt Pilot Plant
TBD	To be determined
TD	Turbine Direct (Operating Mode 1)
TD&C	Turbine Direct and Charging (Operating Mode 2)
T-GF	Turbine-Generator Facilities
TSS	Thermal Storage System
TSU	Thermal Storage Unit (Storage vessel itself)
UMU	Ullage Maintenance Unit
WU	Warmup (Operating Mode)

Note: For instrument and equipment identification letters see Appendix C, pages C-1 thru C-6.

I. SCOPE

This document delineates the plan for operational testing of the 10 MWe Solar Thermal Central Receiver Pilot Plant at Barstow, CA. The plan has been structured to meet the DOE objectives for the pilot plant, as defined in the Overall Plant Design Description (OPDD 40-0-800-IDD) which are:

- To establish the technical feasibility of solar thermal power plant of the central receiver type, including collection of data for repowering/retrofit applications of solar boilers to existing power plants fueled by oil or natural gas.
- To obtain sufficient development, production, and operating and maintenance data to identify the potential economic operation of commercial solar plants of similar design including repowering and retrofit applications on a comparable scale.
- To determine the environmental impact of solar thermal central receiver plants.
- To gather operational data that can be analyzed to determine system operating and safety characteristics.
- To develop both utility and commercial acceptance of solar thermal central receiver systems.
- To stimulate industry to develop and manufacture solar energy systems.
- To enhance public acceptance and familiarity with solar energy systems.

To meet these objectives, a five-year test and evaluation program is presented. This program will commence immediately after acceptance of the pilot plant (anticipated date is March 1982) by DOE and the Associates. The test and evaluation program has been designed to fulfill the Operational Test Requirements identified by Sandia-Livermore in SAND 79-8037 (June 1981).

During an initial two-year experimental period, a wide variety of tests will be conducted to accumulate data on performance of the plant and its subsystems and components. By the end of this period it is expected that a reasonably complete engineering evaluation of the plant will have been completed. In addition, plant operating modes and control configurations will have been optimized for various combinations of clear and cloudy scenarios.

Based upon this knowledge, the test program can then proceed to a follow-on three-year power production period to demonstrate the capability of the pilot plant to supply electrical power to the SCE grid at capacity factors expected for a solar thermal plant. During this power-production phase, operating and maintenance data will be acquired which should be representative of steam-cooled solar thermal central receivers.

In addition to delineating the complete test program, this test plan includes pertinent system descriptions and provides information on test management, test schedules, measurement requirements, data management, and technology transfer. Test specifications for individual tests involving the entire plant are given in Appendix A. These tests comprise the basic structure of the entire operational test program. A test matrix summarizing these tests appears on pages through . Appendix B lists the requirements for component performance evaluation tests. These are tests which involve individual aspects of the overall plant (e.g., the heliostat mirrors) for which data must be obtained at repetitive intervals throughout the operational test phase. Appendix C provides information on the computations needed for in-test and post-test data reduction. Appendix D discusses test precautions and operational considerations which influenced the choice of test parameters and the sequencing selection for pilot plant testing.

II. SYSTEM DESCRIPTION

The 10 MWe Central Receiver Solar Thermal Pilot Plant at Barstow, California, is a joint venture between DOE and the Associates (Southern California Edison, Los Angeles Department of Water and Power, and California Energy Commission). The pilot plant is designed to deliver 10 MWe of electric power to the Southern California Edison Co. distribution grid. This power level will be the net output of the plant after subtracting all plant operating requirements, excluding storage, when operating solely from insolation for a period of:

1) at least 4 hours on the least favorable clear day of the year, or

2) at least 8 hours on the most favorable clear day of the year.

The storage charging rate is sized to accept all the energy available in excess of the rated 10 MWe net for 8 hours on the most favorable day. When operating solely from a fully charged thermal storage subsystem, the plant will deliver a minimum of 28 MWe-hr of electrical energy to the grid. The net power will be 7 MWe when operating solely from a fully charged thermal storage system.

The pilot plant consists of solar, non-solar, and common use facilities. A brief description of each solar facility subsystem follows. For a more detailed description, refer to Sections I and II of the Overall Plant Design Description, OPDD-40-0-800-IDD, dated March 1978 (RADL 2-1).

Collector Subsystem (CS). The collector subsystem is an array of individually controlled reflectors (heliostats) that direct the available solar insolation onto an elevated receiver. The heliostat field array surrounds the receiver tower (see Figure 1).

Receiver Subsystem (RS). The receiver subsystem pumps water to the top of a tower where an array of preheat and boiler panels comprising a once-through cylindrical steam boiler is located. Solar energy is focused by the heliostats onto the external surface of the boiler. The dry superheated steam from the boiler is then returned to the ground level for delivery to other subsystems.

SOLAR 10-MWe PILOT PLANT

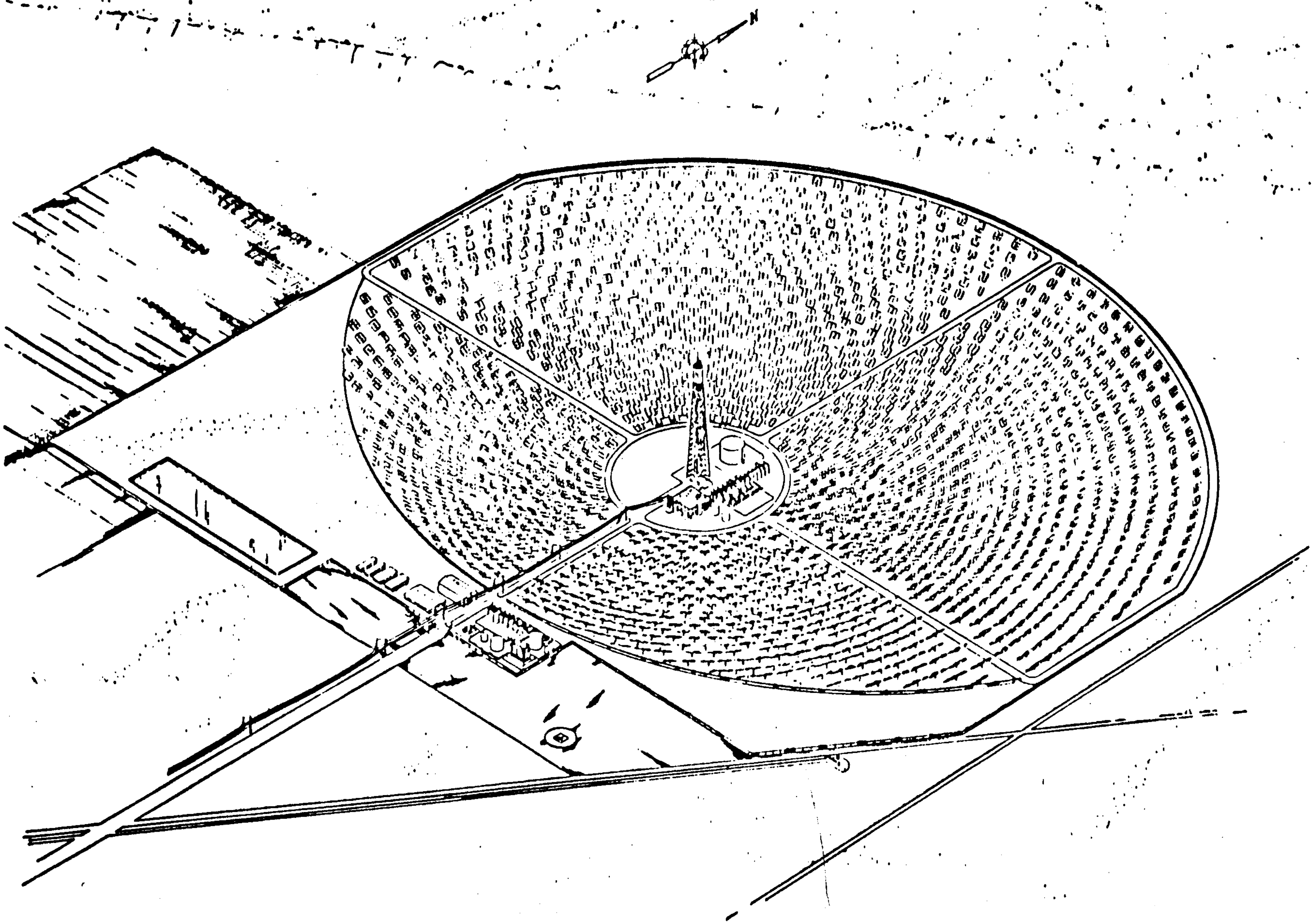

FIGURE 1

Thermal Storage Subsystem (TSS). This subsystem consists of an oil-rock thermal storage unit, a charging train, a steam-generator discharge train, and an ullage maintenance unit. When charging the system, energy from receiver steam is transferred to oil for sensible heat storage in the oil-rock containment vessel. When discharging, transfer of thermal energy from oil back to steam will be accomplished within this subsystem. The thermal storage subsystem is capable of performing both charging and discharging operations simultaneously. The subsystem is sized to include the auxiliary energy needed by other subsystems as well as the energy stored for reconversion to power.

Beam Characterization Subsystem (BCS). The beam characterization subsystem is that equipment permitting rapid and automatic measurement and characterization of flux delivered by any single heliostat.

Electric Power Generation Subsystem (EPGS). The non-solar facilities consist of the electric power generation subsystem (EPGS). The major subsets of the EPGS are:

Turbine-Generator (T-G). The turbine is an automatic admission, condensing unit. High-pressure steam from the receiver subsystem (950F, 1465 psia nominal) for 10 MWe net, is supplied to the high-pressure inlet valves, and low-pressure steam from the thermal storage subsystem (525F, 385 psia nominal) for 7 MWe net, is supplied to the low-pressure automatic admission port.

Circulating Water Subset. This subset includes makeup water supply, pumps, and the equipment that provides coolant for the condenser and the mechanical draft wet cooling tower.

Condensate and Feedwater Subset. This subset includes the condenser, feedwater heaters, deaerater, pumps, and full-flow polishing demineralizer.

Electrical Distribution Subset. The electrical distribution subset connects the generator through the facility main power transformer to the transmission system for distribution of the generated power to the utility grid.

The common use facilities provide the overall plant control, interconnection, and utilities for plant integration. A brief description of each subsystem of the common use facilities follows:

Master Control Sybsystem (MCS). The master control subsystem is a computerized supervisory system which responds to operator or automatic direction to provide integrated plant control. The MCS controls the functions of plant start-up, shutdown, operation, mode changes, and contains capability for emergency actions on a plant basis. The MCS consists of the plant operational control subsystem (OCS) and the data acquisition subsystem (DAS). The DAS will accomplish the data collection required by this test plan. Figure 2 shows the interconnection of the master control subsystem with the other subsystems.

Plant Support Subsystem (PSS). The plant support subsystem provides for inter-connection of the major subsystems, utility distribution throughout the plant, and the necessary facilities such as roads, lighting, buildings, security, and communications.

Raw water, emergency electrical power for the collector field, and maintenance support are supplied from SCE's Cool Water station located adjacent to the pilot plant.

The test configuration is not expected to change during the five-year test and evaluation period. A simplified schematic diagram of the present pilot plant configuration is shown in Figure 3.

PILOT PLANT SUBSYSTEMS (Reference 3)

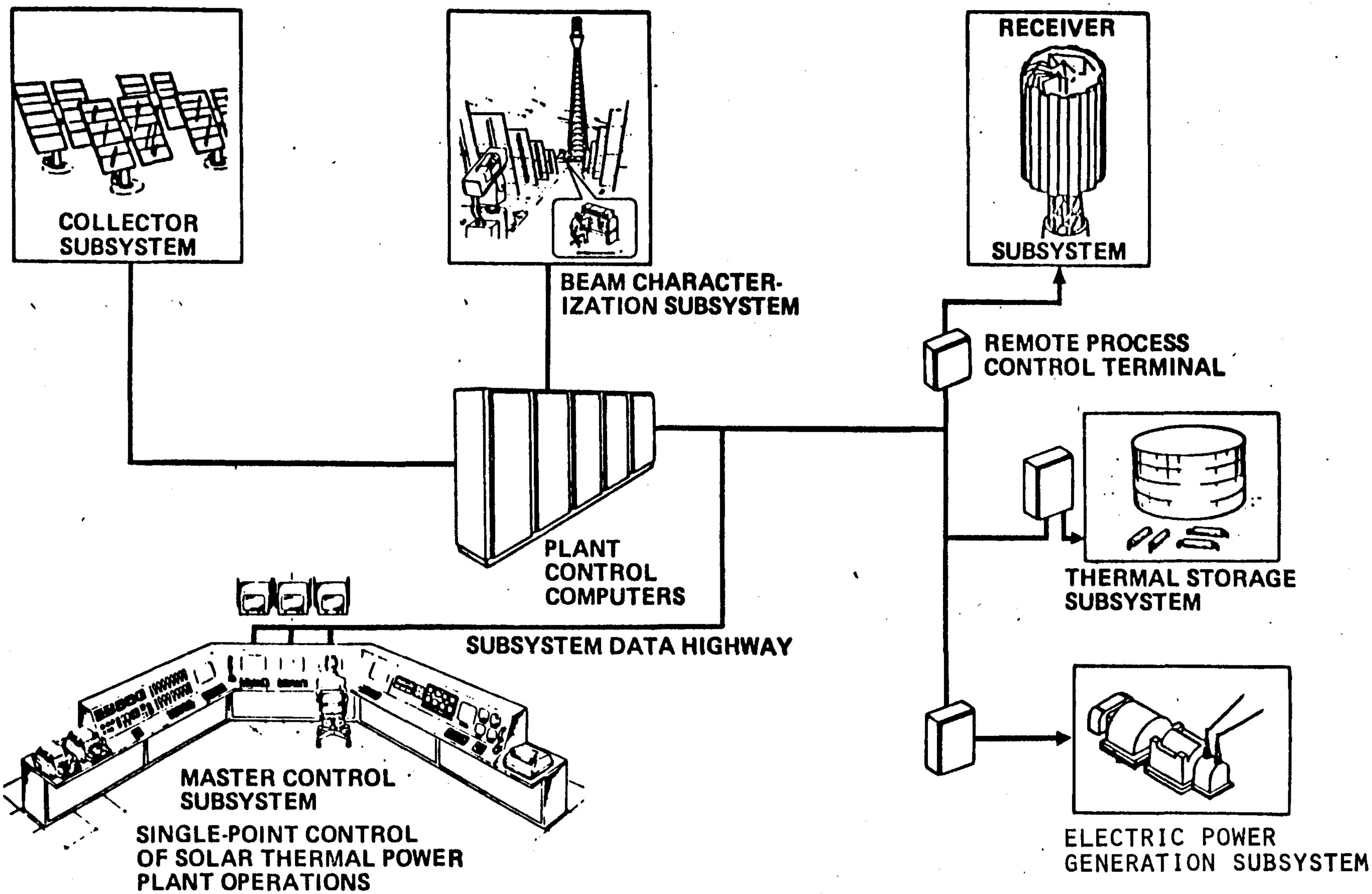

FIGURE 2

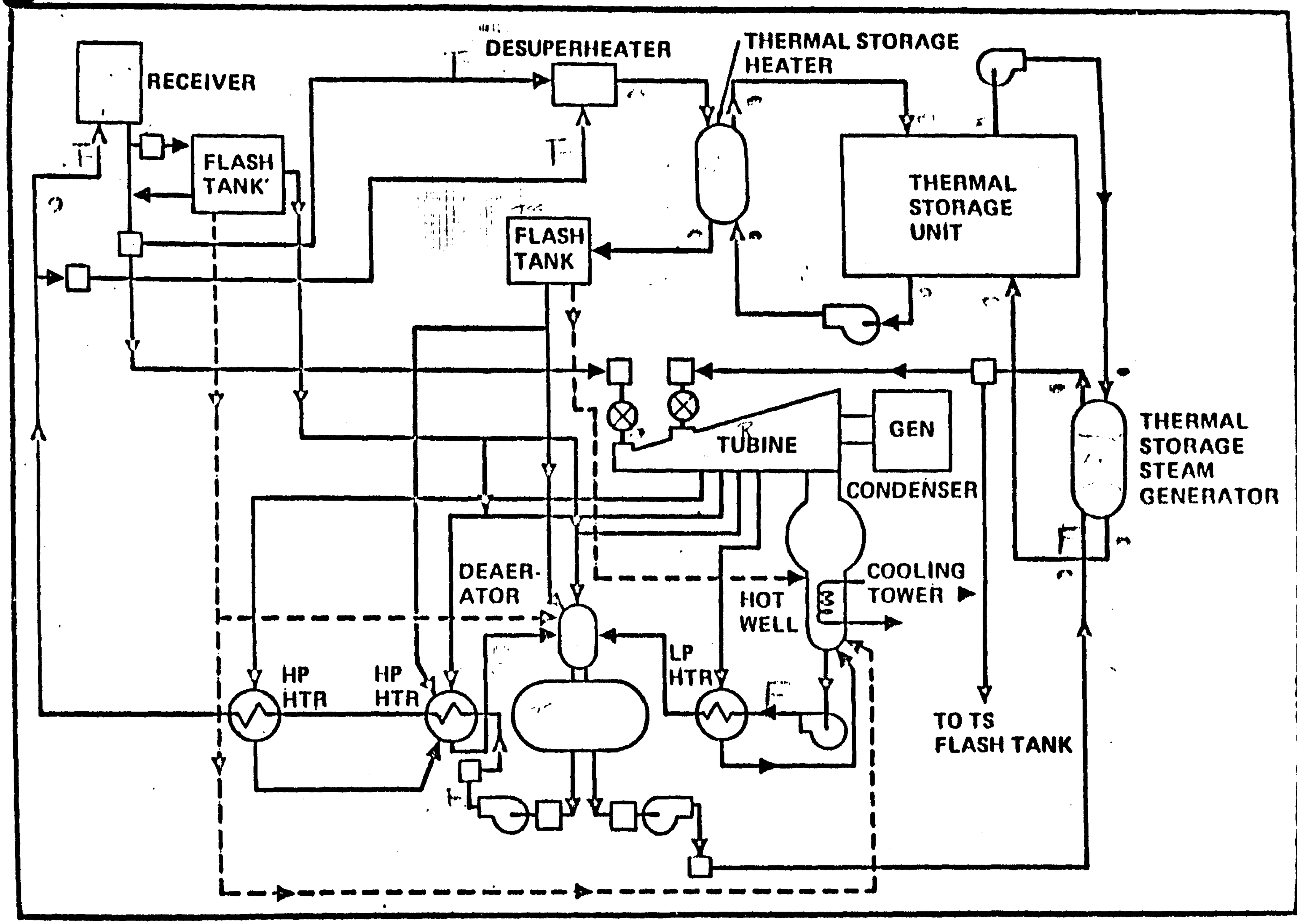

Figure 3. Pilot Plant Simplified Schematic (Reference 3)

III. TEST MANAGEMENT

A number of organizations are involved in the Test and Evaluation Program from inception to conclusion. Department of Energy Headquarters responsibility for the project has been assigned to the Division of Solar Thermal Energy Systems within the Office of Solar Heat Technologies. A Solar Ten Megawatt Project Office (STMPO) has been established by SAN with responsibility for the day-to-day planning, direction, execution and control of the prcject through the design, construction, startup, and acceptance test phases.

The project is a joint utility and government funded project. The utility partners, collectively referred to as the Associates, are comprised of Southern California Edison Company, the Los Angeles Department of Water and Power, and the California Energy Commission. The Associates are participating in the engineering management, construction, operations, testing, and technology transfer aspects of the project, in accordance with a Cooperative Agreement between DOE and the Associates.

Upon acceptance of the plant, the Operational Test Phase will begin. The organizational responsibility for this phase of activity is shown in Figure 4.

Responsibility for coordinating the preparation of key documents for the Operational Test Phase is shown in Figure 5.

A more detailed explanation of test management activities may be found in the Management Plan prepared by DOE-SAN (Ref. 12) with inputs from all key participants.

PILOT PLANT OPERATIONAL PHASE ORGANIZATION

(Reference 4)

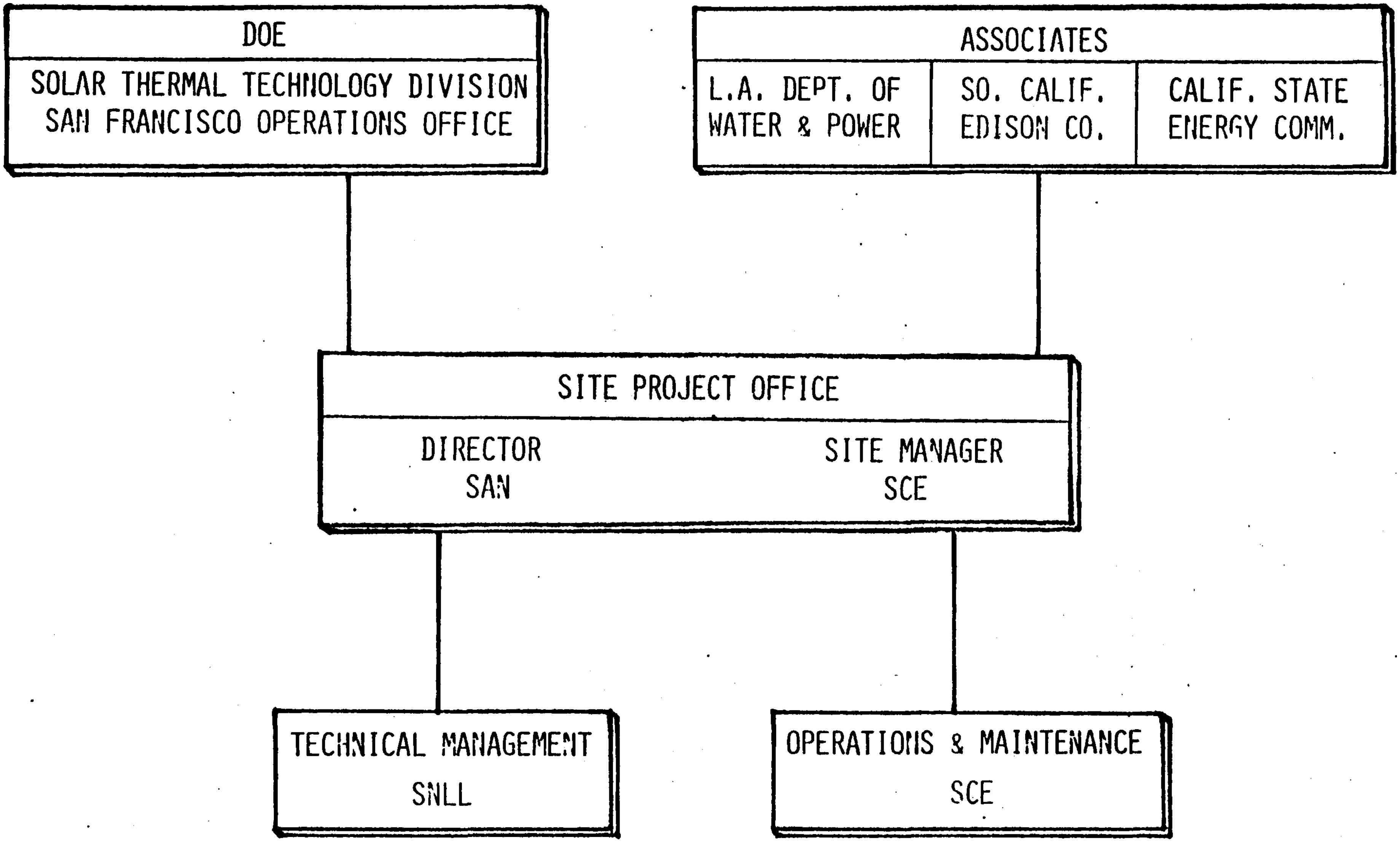

Figure 4

PILOT PLANT OPERATIONS CONTROL DOCUMENTS

(Reference 4)

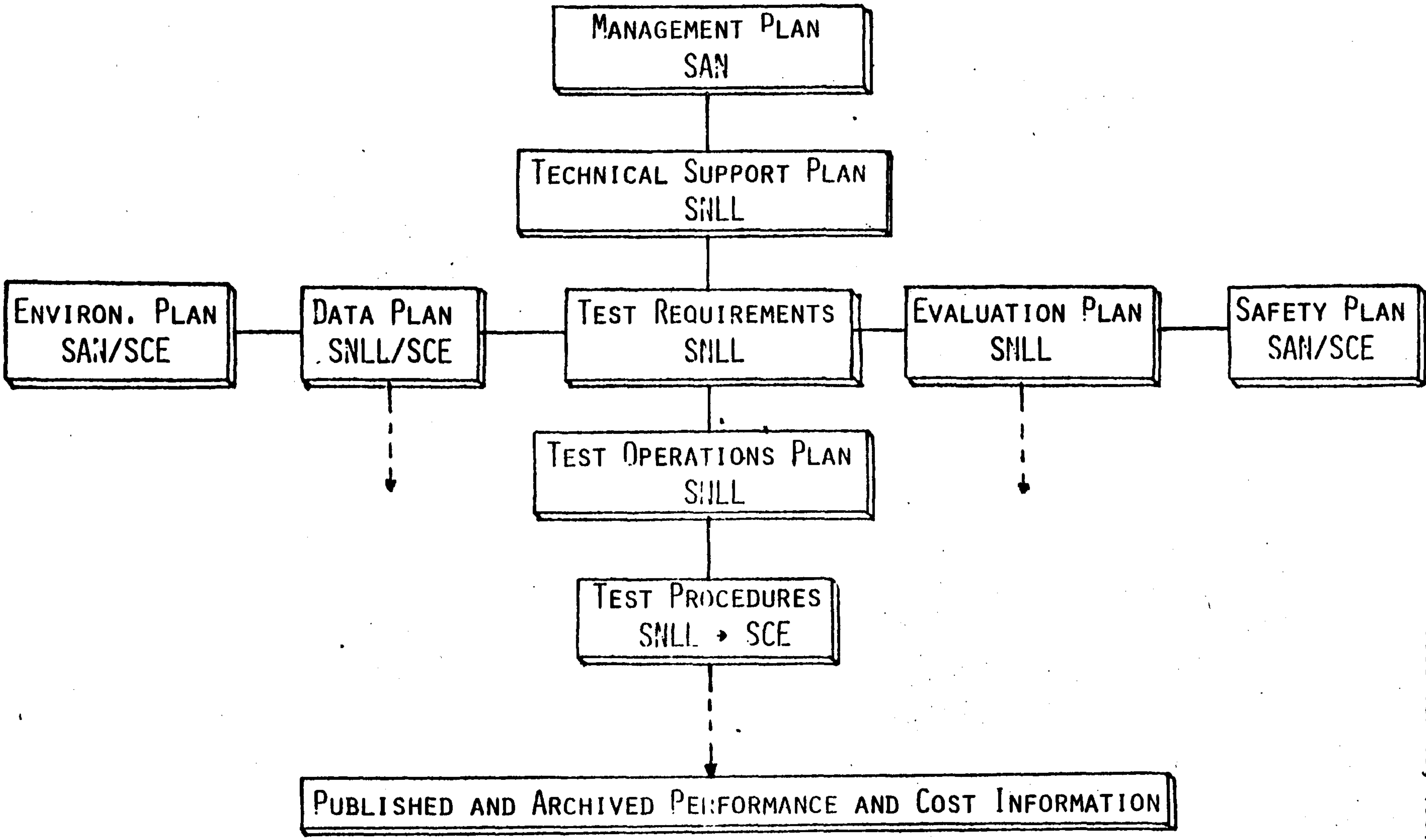

Figure 5

IV. OPERATIONAL TESTING

This section of the test plan includes a listing of tests, the performance of which is considered necessary to satify the objectives of the test program as previously stated in Section 1, "Scope."

The program consists of three major divisions, namely, Experimental Phase, Power Production Phase, and Programmatic Support Activities. A test schedule is also included for all three phases of Operational Testing.

A. Initial Experimental Phase

The tests listed are all those to be done during the two-year experimental period and have been grouped into the following categories:

1. Steady State Tests
2. Safety Assessment Tests
3. Preliminary Power Production Tests
4. Normal Transition Tests
5. Failure Transition Tests
6. Transition Timing Tests
7. Engineering Tests
8. Plant and Control Optimization Tests
9. Associates Tests

A general guideline followed in arranging these tests was to perform the simplest operating function (MODE) at low power first, increase power level in that mode and then move to the more complex operation. This approach minimizes the possibility of inadvertent plant damage.* A listing of tests in the recommended sequence is shown in Table I. Fluid flow rates and power levels shown in the chart are included to indicate the magnitude and range of variables to be tested. Power levels for simultaneous operation with Receiver and Thermal Storage Steam are derived from Figure 6. The sequence of tests is to be considered as a guideline; weather conditions, equipment outages and/or state of conditioning, and other operating constraints will impact the decision as to which particular tests will be conducted on a given day.

The duration of each test is given in the individual test specifications. Factors affecting test duration include: 1) the minimum time required to optimize

* see also Appendix D, "Precautions and Operating Considerations for Pilot Plant Testing"

TABLE 1. TEXT MATRIX FOR EXPERIMENTAL PHASE

Test No.	Spec. No.	Operating Mode	Control Configuration	RS Stm to TGF lb/hr	RS Stm to TSS lb/hr	TSS Stm to TGF lb/hr	TGF (Gross MWe)	Notes and Comments
			STEADY-STATE TESTS					
SS-1	SS 1-4	SC (5)	Sun Following		30,000			
SS-2	SS 1-4	SC (5)	Sun Following		60,000			
SS-3	SS 1-4	SC (5)	Sun Following		114,300			
SS-4	SS 1-4	SC (5)	Sun Following		130,400			Max. charge flow; max. charge rate to be experimentally determined
SS-5	SS 5-8	SD (6)	Sun Following			30,000	1.7	Min. TSS discharge rate as governed by turbine.
SS-6	SS 5-8	SD (6)	Load Following			55,000	3.7	
SS-7	SS 5-8	SD (6)	Load Following			85,000	6.3	
SS-8	SS 5-8	SD (6)	Load Following			110,000	8.4	Capacity test of TSS at max. discharge rate, starting with fully charged TSS.
SS-9	SS9-12	ILF (4)	Sun Following or Load Following		65,000	43,000	2.7	Low charge rate with min. discharge rate.
SS-10	SS 9-12	ILF (4)	" "		130,000	45,000	2.9	Max. charge rate, low discharge rate.
SS-11	SS 9-12	ILF (4)	" "		130,000	108,600	7.9	Tests 10 & 11 require Htr 2 drains to condenser.
SS-12	SS 9-12	ILF (4)	" "		130,000	108,600	7.4	Max. charge and max. discharge rate.
SS-13	SS 13-16	TD (1)	Sun Following	30,000			2.3	Minimum load.
SS-14	SS 13-16	TD (1)	Sun Following	56,150			5.9	50% load
SS-15	SS 13-16	TD (1)	Sun Following	105,150			10.0	10 Mwe design.
SS-16	SS 13-16	TD (1)	Sun Following	112,300			12.5	100% load.
SS-17	SS 17-20	TD&C (1)	Sun Following and Load Following	30,000	105,000		2.3	Min. throttle flow, max. TSS charge.
SS-18	SS 17-20	TD&C (1)	" "	60,000	60,000		6.3	Equal TGF and TSS charge flows.
SS-19	SS 17-20	TD&C (1)	" "	90,000	26,000		10.0	
SS-20	SS 17-20	TD&C (2)	" "	114,300	20,000		12.8	Max. RS flow.
SS-21	SS 21-24	SB (3)	Load Following	105,100		5,500	10.4	Design throttle flow, min. one loop TSS discharge flow.

TABLE 1. TEXT MATRIX FOR EXPERIMENTAL PHASE

Test No.	Spec. No.	Operating Mode	Control Configuration	RS Stm to TGF lb/hr	RS Stm to TSS lb/hr	TSS Stm to TGF lb/hr	TGF (Gross MWe)	Notes and Comments
			STEADY-STATE TESTS (continued)					
SS-22	SS 21-24	SB (3)	Load Following	90,000		25,000	11.9	
SS-23	SS 21-24	SB (3)	Load Following	60,000		60,000	9.9	
SS-24	SS 21-24	SB (3)	Load Following	30,000		85,000	12.0	Max. discharge flow, min. throttle flow.
SS-25	SS 25-28	C&SB (7)	Load Following	60,000	40,000	54,000	9.9	50% turbine flow with moderate TSS output.
SS-26	SS 25-28	C&SB (7)	Load Following	30,000	20,000	85,000	9.0	
SS-27	SS 25-28	C&SB (7)	Load Following	30,000	100,000	85,000	9.0	Max. TSS output combined with turbine throttle flow;balance to TSS; 4 hr duration required.
SS-28	SS 25-28	C&SB (7)	Load Following	30,000	130,000	40,000	5.2	
			PRELIMINARY POWER PRODUCTION					
PP-1	PP-1	TD	Sun Following	112,300			12.5	Operate at full power for an extended run.
PP-2	PP-2	TD&C and SB	Load Following				12.0	Choice of mode using TSS; max. power output.
			SAFETY ASSESSMENT TESTS					
ST-1	ST-1	TD&C to IA	Sun Following or Load Following to Manual	60,000	60,000		6.6	Safety assessment test No. 1; loss of primary elec. power.
ST-2	ST-2	" "	" "	50,000	60,000		5.0	Safety assessment test No. 2; turbine trip.
ST-3	ST-3	TD to IA	Sun Following to Manual	30,000			2.7	Safety assessment test No. 3; valve(s) failure
ST-4	ST-4	SB to IA	Load Following to Manual	30,000		30,000	4.4	Safety assessment test No. 4; feedwater pump trip.
ST-5	ST-5	TD to IA	Sun Following to Manual	49,000			5.0	Safety assessment test No. 5; receiver panel leak.
ST-6	ST-6	TD to IA	Sun Following to Manual	50,000			5.0	Safety assessment test No. 6; receiver panel stoppage.

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TABLE 1. TEST MATRIX FOR EXPERIMENTAL PHASE

Test No.	Spec. No.	Operating Mode	Control Configuration	RS Stm to TGF lb/hr		RS Stm to TSS lb/hr		TSS Stm to TGF lb/hr		TGF (Gross MWe)		Notes and Comments
						NORMAL TRANSITION TESTS						
NT-1	NT-1	SC to TD&C	Sun Following to Load Following	0	56,000	30,000	30,000			0	5.9	Normal transition
NT-2	NT-2	TD&C to SC	Load Following to Sun Following	56,000	0	30,000	30,000			5.9	0	Normal transition
NT-3	NT-3	SC to ILF	Sun Following to Load Following			30,000	30,000	0	45,000	0	2.9	Normal transition
NT-4	NT-4	ILF to SC	Load Following to Sun Following			30,000	30,000	45,000	0	2.9	0	Normal transition
NT-5	NT-5	SD to SB	Load Following in Both Modes	0	56,000			30,000	30,000	1.7	7.3	Normal transition
NT-6	NT-6	SB to SD	" "	56,000	0			30,000	30,000	7.3	1.7	Normal transition
NT-7	NT-7	SD to ILF	" "			0	30,000	45,000	45,000	2.9	2.9	Normal transition
NT-8	NT-8	ILF to SD	" "			30,000	0	45,000	45,000	2.9	2.9	Normal transition
NT-9	NT-9	TD to TD&C	Sun Following to Load Following	56,000	56,000	0	30,000			5.9	5.9	Normal transition
NT-10	NT-10	TD&C to TD	Load Following to Sun Following	56,000	56,000	30,000	0			5.9	5.9	Normal transition
NT-11	NT-11	TD to SB	Sun Following to Load Following	56,000	56,000			0	30,000	5.9	7.6	Normal transition
NT-12	NT-12	SB to TD	Load Following to Sun Following	56,000	56,000			30,000	0	7.6	5.9	Normal transition
NT-13	NT-13	C&SB to TD&C	Load Following in Both Modes	56,000	56,000	30,000	30,000	40,000	0	8.3	5.9	Normal transition
NT-14	NT-14	TD&C to C&SB	" "	56,000	56,000	30,000	30,000	0	40,000	5.9	8.3	Normal transition
NT15	NT-15	C&SB to SB	" "	56,000	56,000	30,000	0	40,000	40,000	8.3	8.3	Normal transition
NT-16	NT-16	SB to C&SB	" "	56,000	56,000	0	30,000	40,000	40,000	8.3	8.3	Normal Transition
NT-17	NT-17	ILF to C&SB	" "	0	56,000	30,000	30,000	45,000	45,000	2.9	8.8	Normal Transition
NT-18	NT-18	C&SB to ILF	" "	56,000	0	30,000	30,000	45,000	45,000	8.8	2.9	Normal Transition

TABLE 1. TEST MATRIX FOR EXPERIMENTAL PHASE

Test No.	Spec. No.	Operating Mode	Control Configuration	RS Stm to TGF lb/hr	RS Stm to TSS lb/hr	TSS Stm to TGF lb/hr	TGF (Gross MWe)	Notes and Comments
			FAILURE TRANSITION TESTS					
FT-1	FT-1	TD to IA	Sun Following to Manual	56,000 0			5.9 0	Turbine trip
FT-2	FT-2	TD&C to IA	Load Following to Manual	60,000 0	60,000 0		6.4 0	Receiver trip
FT-3	FT-3	SB to IA	" "	90,000 0		25,000 0	11.9 0	Turbine trip
FT-4	FT-4	C&SB to SC	Load Following to Sun Following	30,000 0	40,000 40,000	30,000 0	4.4 0	Turbine trip
FT-5	FT-5	C&SB to SD	Load Following to Manual	56,000 0	40,000 0	40,000 40,000	8.3 2.4	Receiver trip
FT-6	FT-6	SD to IA	" "			30,000 0	1.7 0	Turbine trip
FT-7	FT-7	SB to SD	Load Following in Both Modes	90,000 0		30,000 30,000	11.4 1.7	Receiver trip
FT-8	FT-8	ILF to SD	" "		60,000 0	60,000 60,000	4.2 4.2	Receiver trip
FT-9	FT-9	ILF to SC to IA	Load Following to Sun Following to Manual		65,000 65,000 0	45,000 0 0	2.9 0 0	Turbine trip followed by receiver trip.
FT-10	FT-10	ILF to SD to IA	Load following to Manual		65,000 0 0	45,000 45,000 0	2.9 2.9 0	Receiver trip followed by turbine trip.
			TRANSITION TIMING TESTS					
TT-1	TT-1	I IA to SC to ILF	Manual to Load Following		0 0 105,000	0 30,000 110,000	0 1.7 7.0 (net)	
TT-2	TT-2	I IA to TD	Manual to Sun Following	0 105,150			0 10.0 (net)	
TT-3	TT-3	I IA to TD to TD&C	Manual to Sun Following to Load Following	0 30,000 114,600	0 0 20,000		0 2.7 10.8	Max. receiver flow
TT-4	TT-4	TD to SB to SD to IA	Sun Following to Load Following to Manual	105,150/85,000/ 0/0		0/30,000/110/000/0	10 (net) 10 (net) 8.4 0	Simulates latter portion of "clear day scenario"
TT-5	TT-5	C&SB to ILF to SD	Load Following in all modes	60,000 0 0	40,000 105,000 0	45,000 110,000 110,000	10.7 7.0 (net) 7.0 (net)	

TABLE 1. TEXT MATRIX FOR EXPERIMENTAL PHASE

Test No.	Spec. No.	Operating Mode	Control Configuration	RS Stm to TGF lb/hr	RS Stm to TSS lb/hr	TSS Stm to TGF lb/hr	TGF (Gross MWe)	Notes and Comments
				ENGINEERING TESTS				
ET-1	ET-1	IA to TD to TD&C to SB to SD	Manual to Sun Following to Load Following	30,000/105,150/ 90,000/0	0 20,000 0 0	0 0 110,000/ 110,000	2.7 11.7 8.4 8.4	Most favorable day, design point.
ET-2	ET-2	IA to TD to TD&C to SB to SD	" "	30,000/105,150/ 90/000/0	20,000	0 0 25,000/ 105,000	2.7 11.7 11.9 8.4	Least favorable day, design point
ET-3	ET-3	IA to TD IA	Manual to Sun Following to Manual	0 105,150 0			0 11.9 0	Sun Following control strategy for re-powering.
ET-4	ET-4	IA to TD SB	Manual to Sun Following to Load Following	0 30,000 Variable		0 30,000 Variable	6.0 (net)	Load following control strategy for repowering; constant load.
ET-5	ET-5	Clear-Day Scenario	Manual to Fully Automatic	Variable	Variable	Variable	Variable	Demonstrate OCS control in following clear-day scenario.

Notes:
1. Based on performance curves provided by SCE for the G.E. turbine-generator. (Plot labelled LSTD-4159D-2).
2. The performance curve includes the effects of Feedheating. Receiver feedwater is heated in 4 stages while Thermal storage feedwater is heated in 2 stages.
3. Refer to LTSD-4159D-11, 12, 13, & 14 for typical heat balances.
4. At throttle flows below approx. 15000 lb/hr., close main stop valve and open by-pass cooling line.

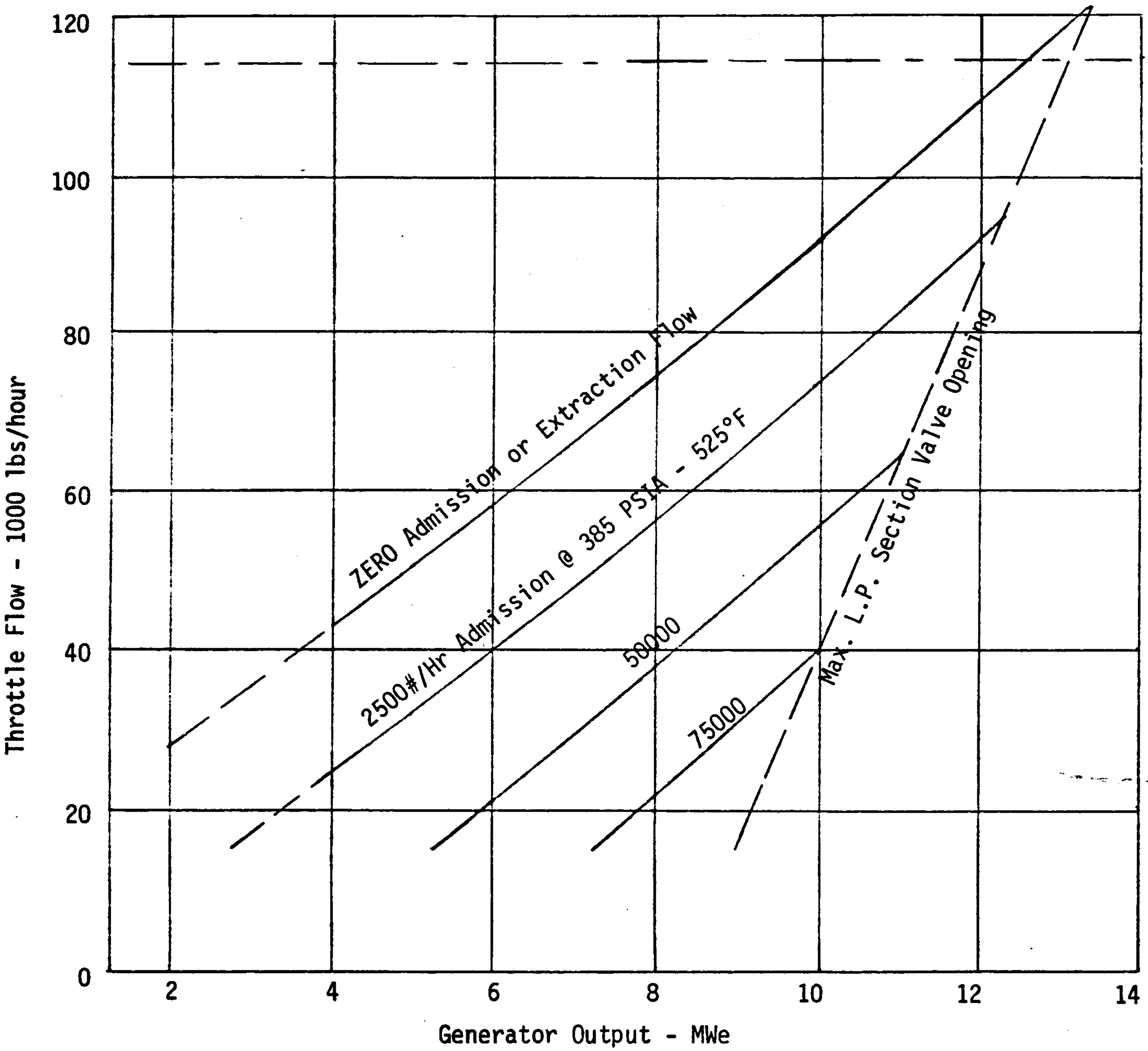


Figure 6

gathering of data; 2) minimum time to demonstrate capability; and 3) stated operating goals which are a part of the program plan, e.g., stable electrical output in the turbine direct mode at 10 MWe for 4 hours.

It must be recognized that in the course of test performance, data will be progressively obtained which may permit elimination of some tests called for in the listing. Appendix A contains a detailed description of each test in the Experimental Phase.

1. Steady-State Tests

This portion of the testing is aimed at gathering steady-state data in the basic operational modes. The operating modes and their descriptors are shown in Figure 7. A mode that does not show is the receiver startup mode with collector subsystem heating the receiver until usable steam is available. This mode has been designated as Initial Operation (IO). Another mode is the Warm Up (WU) mode with both receiver and turbine warm up.

The initial evaluation will include operation at partial power levels, gradually building to fully rated conditions. Figure 8 shows the operational ranges of power transfer between subsystems. The listing of tests to be performed during the assessment phase is shown in Table 1. It is to be noted that these tests start with the Storage Charging (SC) mode followed by Storage Discharging (SD). Depending on the condition of the TSU at the end of the acceptance test program, and weather conditions at the time, tests SS 1-4 and SS 5-8 may be done in any reasonable sequence, or interleaved. This series continues into the ILF, TD, TD&C, SB modes and finally to the C&SB mode.

2. Safety Assessment Tests

The major safety events which require testing during this initial evaluation period are:

a) Loss of Electrical Primary Power
b) Turbine-Generator Trip
c) Valve Failures
d) Feedwater Pump Failure
e) Receiver Panel Leak
f) Plugged Boiler Panel

Tests of these six events are considered analogoud to the setting of boiler safety valves, and are to be accomplished early in the test program in

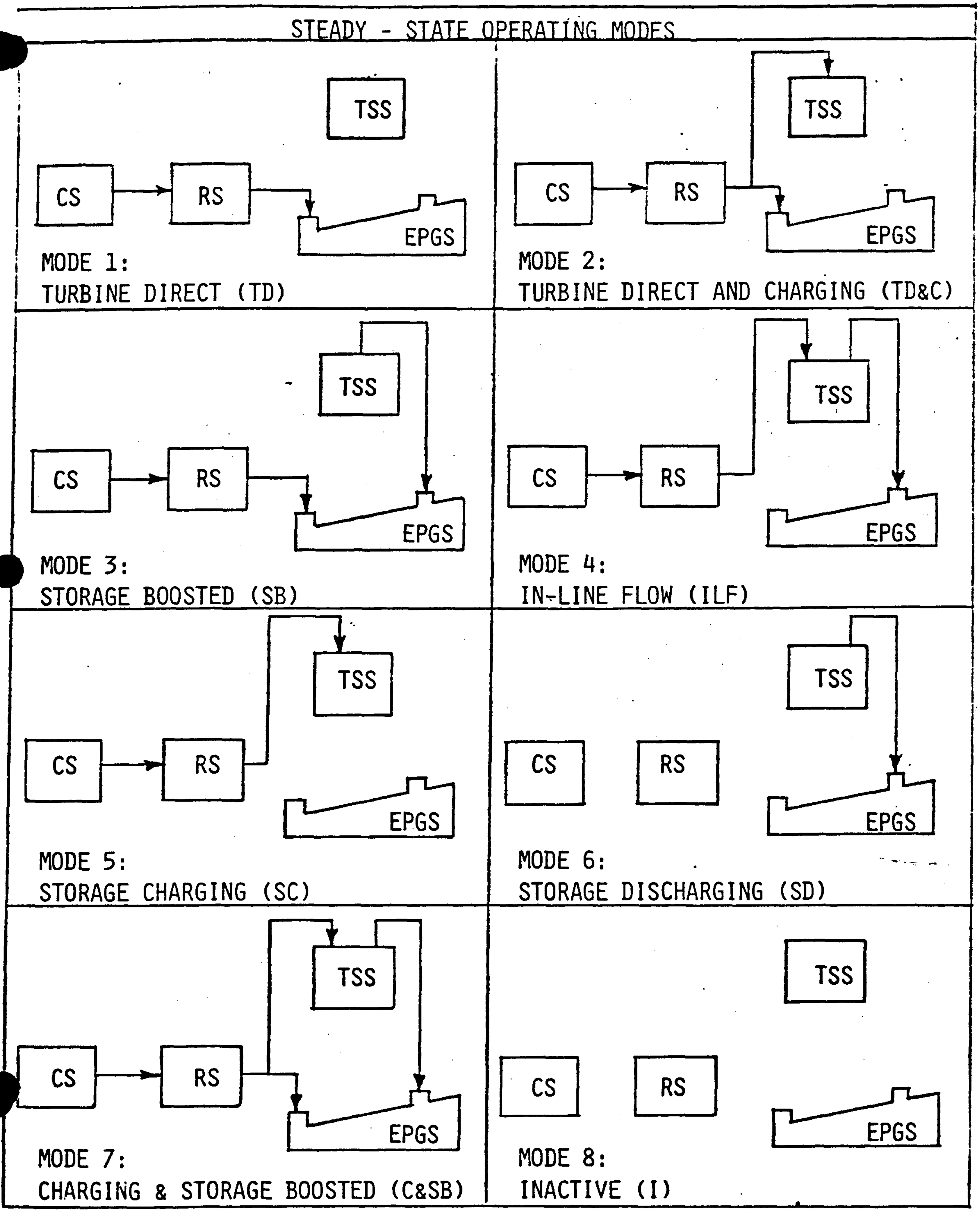
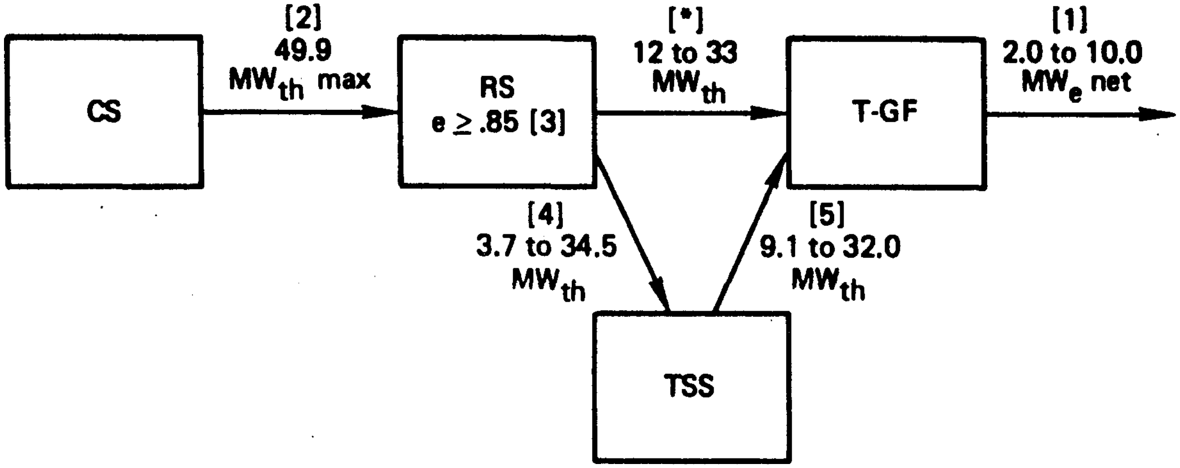

STEADY - STATE OPERATING MODES
TSS
CS
RS
EPGS
MODE 1:
TURBINE DIRECT (TD)
TSS
CS
RS
EPGS
MODE 2:
TURBINE DIRECT AND CHARGING (TD&C)
TSS
CS
RS
EPGS
MODE 3:
STORAGE BOOSTED (SB)
TSS
CS
RS
EPGS
MODE 4:
IN-LINE FLOW (ILF)
TSS
CS
RS
EPGS
MODE 5:
STORAGE CHARGING (SC)
TSS
CS
RS
EPGS
MODE 6:
STORAGE DISCHARGING (SD)
TSS
CS
RS
EPGS
MODE 7:
CHARGING & STORAGE BOOSTED (C&SB)
TSS
CS
RS
EPGS
MODE 8:
INACTIVE (I)

Figure 7



PILOT PLANT SPECIFICATIONS:
[1] NET ELECTRICAL POWER OUT
[2] MAXIMUM INCIDENT POWER ON RECEIVER
[3] MINIMUM RECEIVER EFFICIENCY
[4] STORAGE CHARGING RATE
[5] STORAGE DISCHARGING RATE
[*] RATED POWER TO T-GF (ESTIMATE ONLY)

Figure 8. Pilot Plant Subsystem Ratings (Reference 3)

order to validate safety protection of the plant. There is a high probability that some or all of these events will have occurred during the plant acceptance period. Performance tests of these events are required here to assure documentation of all requisite data, and will not be repeated if adequate data have been obtained from prior testing.

3. Preliminary Power Production

There are many electric utility and industrial process heat plants in existence with thermal energy requirements suitable for solar central receiver system application and with sufficient sunshine and available land for the required heliostat field. Such plants are candidates for "repowering" with solar central receiver systems to reduce the use of fossil fuels. The existing fossil-fueled boiler or fluid heating system can be used as a back-up to the solar sustem for weather interruptions and for night-time dispatch when it is economic. Such applications could incorporate thermal energy storage if it is found to be cost-effective or required for short-term buffering.

Two series of tests have been specified to provide for an early demonstration of routine sustained power production capability of the plant in support of the re-powering aspects of the central solar thermal power program. One of the test series utilizes thermal storage as part of the hybrid solar-thermal plant application; the second does not utilize thermal storage. The objectives for these tests are to obtain operation, performance, and maintenance data with the plant running at maximum power output - consistent with safety and equipment capabilities. Each of the test series is to run for 30 tests days, as nearly consecutive as weather will permit.

4. Normal Transition Tests

Transitions are described as the sum and sequence of functions required to change the Pilot Plant operation from one mode to another. Transitions fall into three categories: safety or emergency shutdown transitions, failure transitions, and normal fully-controlled modal changes. In normal operation, transitions can be initiated manually by the operator or automatically either by signal from safety instrumentation or by pre-programmed computer routines. The first time transitions are performed, test initiation shall be done manually by the operator unless especially designated otherwise. Subsequently, when the OCS is available, automatically initiated runs will be made. Safety transitions may be done by either simulation or by actual equipment stripping; failure events are to be simulated.

Several factors influence the selection of transitions to be performed. In addition to the seven operating modes, there are eleven different control configurations (as shown in Figure 9) which were under development during plant design. Ultimately all of these combinations must be tested and optimized.

One constraint that has been placed upon the MCS design is that power flow between subsystems can be added or deleted with only one change at a time. Using this as a guide, there is a practical limit to the number of mode-to-mode changes that must be evaluated. Figure 10 identifies the possibilities for a normal day of plant operation. Using it as a guide, a series of transitions is graphically shown in Figure 11 as either transitions from normal day operations or those resulting from failures. Additionally, Figure 12 shows, in a matrix form, all of the transitions that must be performed experimentally; the chart includes the source of signal to initiate the action.

Transition tests shown in the test matrix (Table I)* include all those required for normal Pilot Plant operation. Specific power levels have been shown in Table I. However, the final test levels specified will be a function of the final system design and will be tempered by experience gained during plant operation. Individual steps in all possible transitions will be evaluated.

Transition test specifications here have been numbered in a preferred sequence. However, the sequence is not considered crucial, and is subject to change because of weather, prior test conditions, or special operating requirements. Included here are all those transitions specified by Sandia those proposed (by SFDI) for performance during acceptance testing, plus a few more considered desirable by ETEC.

Data requirements for the entire set of transition tests are essentially identical. Minor differences have been called out in the individual specifications. It is recommended that all instrument points available for fast scanning be monitored during all transition tests. The duration of fast scanning must be determined at the time of each given test; however, fast scanning should start at least 30 seconds before and continue for one minute after each transition.

During the course of acceptance testing and the steady state operational tests, many transitions will have been performed. However, complete data may not have been recorded. Any specific test included here, for which adequate data have been recorded, may be eliminated from the test program. (Such deletion must be agreed to by the DOE site Test Director.)

*[illegible]

PLANT CONTROL CONFIGURATIONS

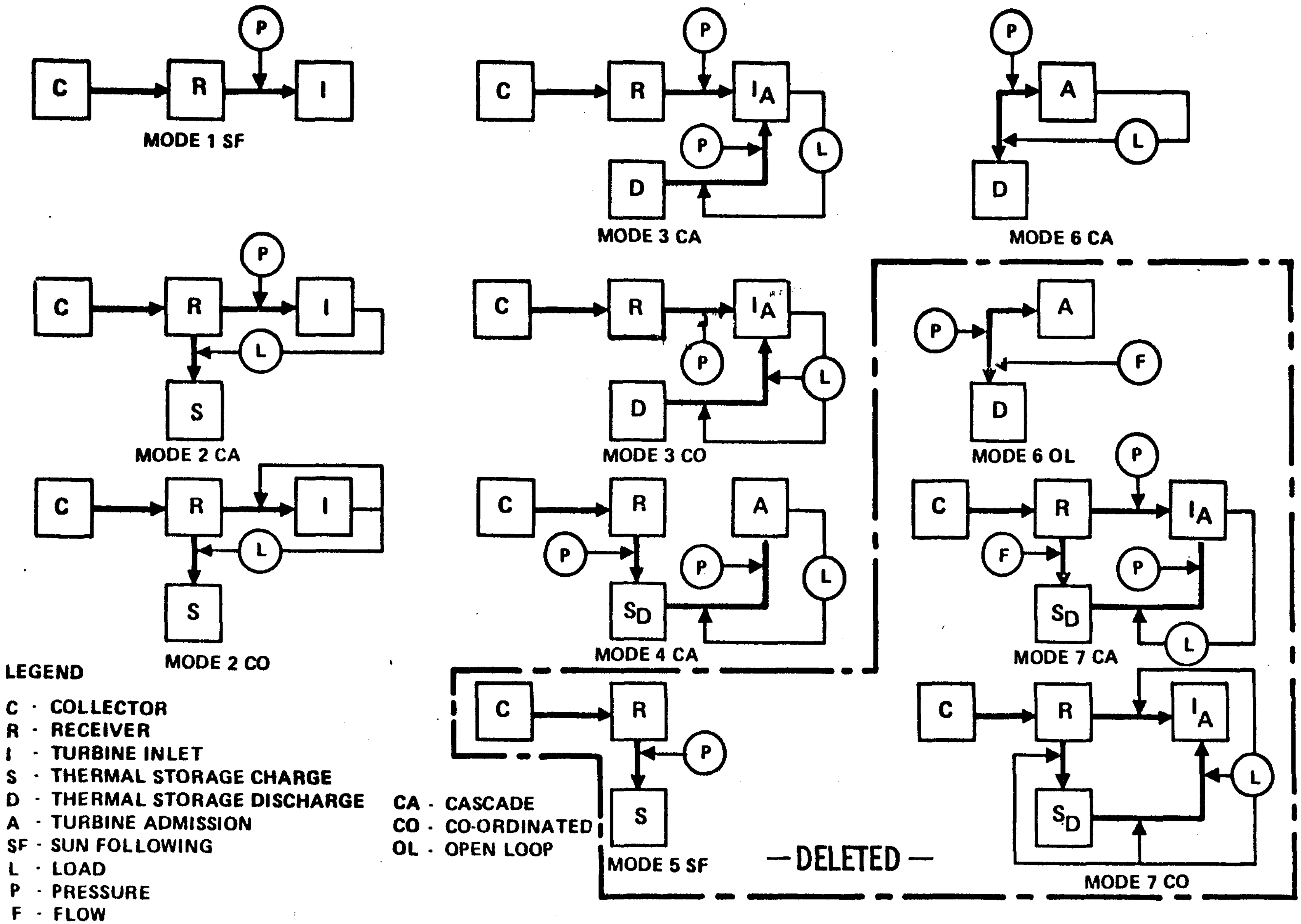
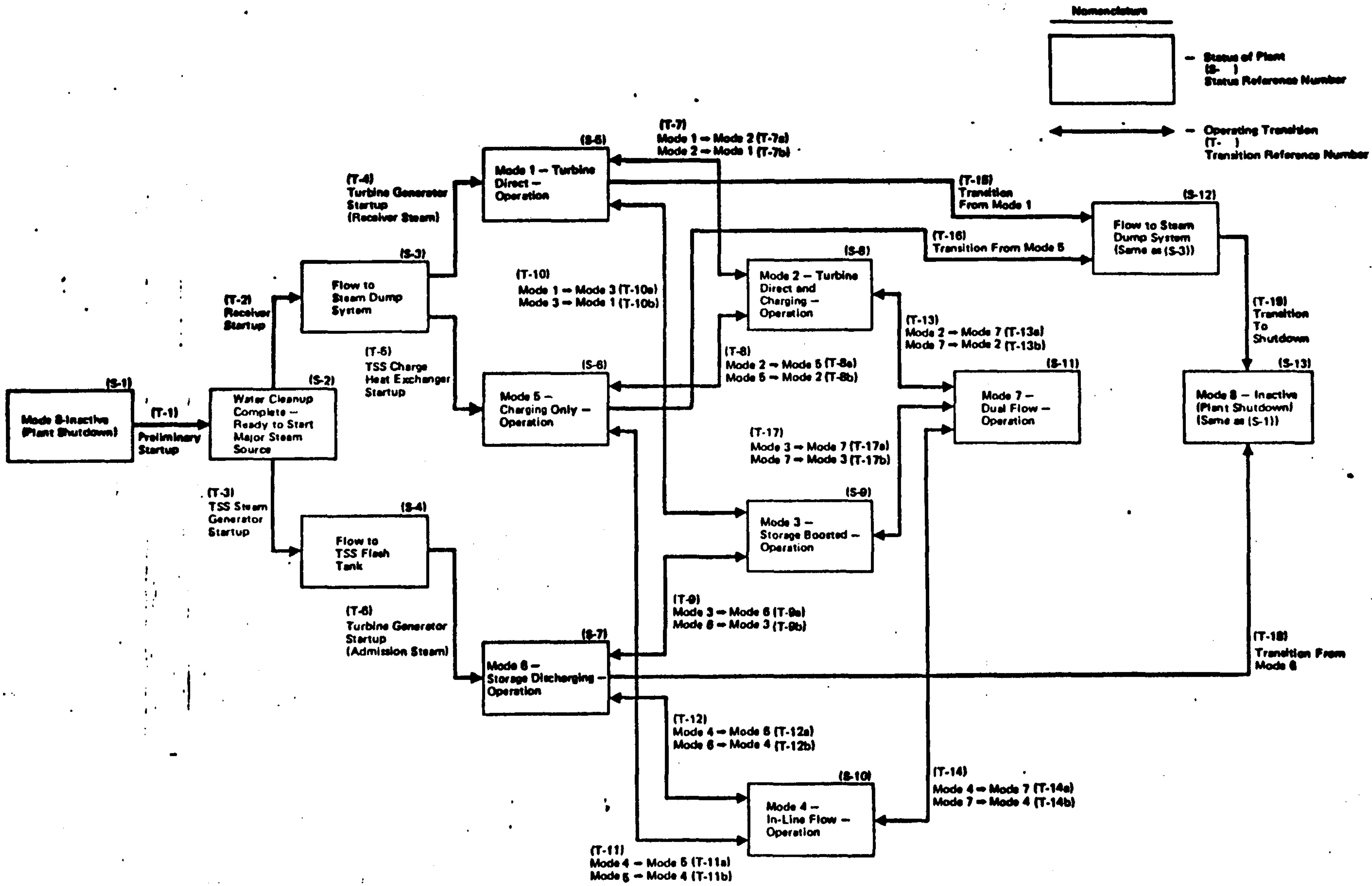


Figure 9 (Reference 3)



Operational Flow Diagram (Reference 5)

Figure 10

Pilot Plant Normal Operating Day

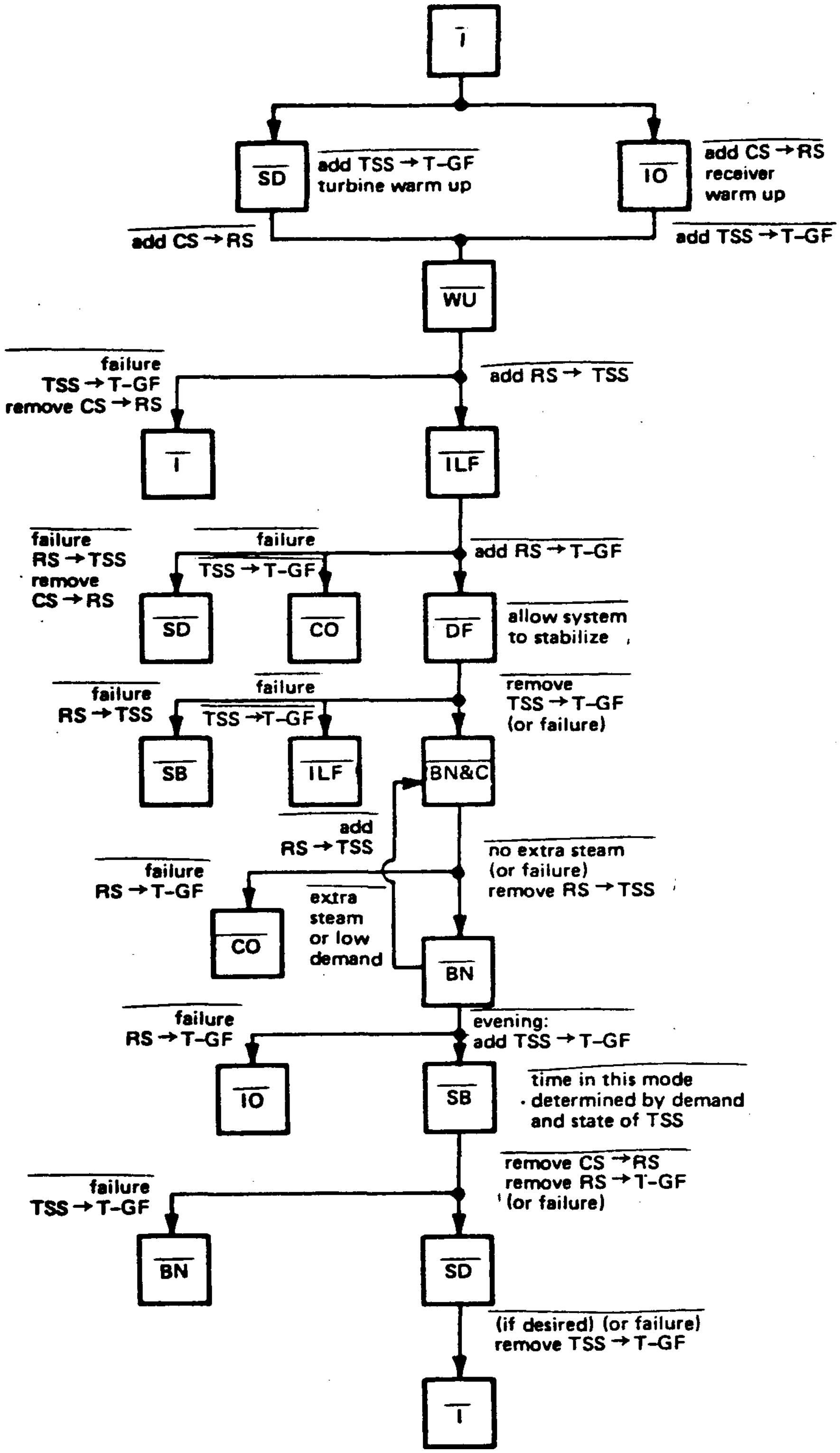


Figure 11*. Transitions to Evaluate (Reference 3)

*This figure includes pages 28 through 30.

A. NORMAL DAY OPERATIONS

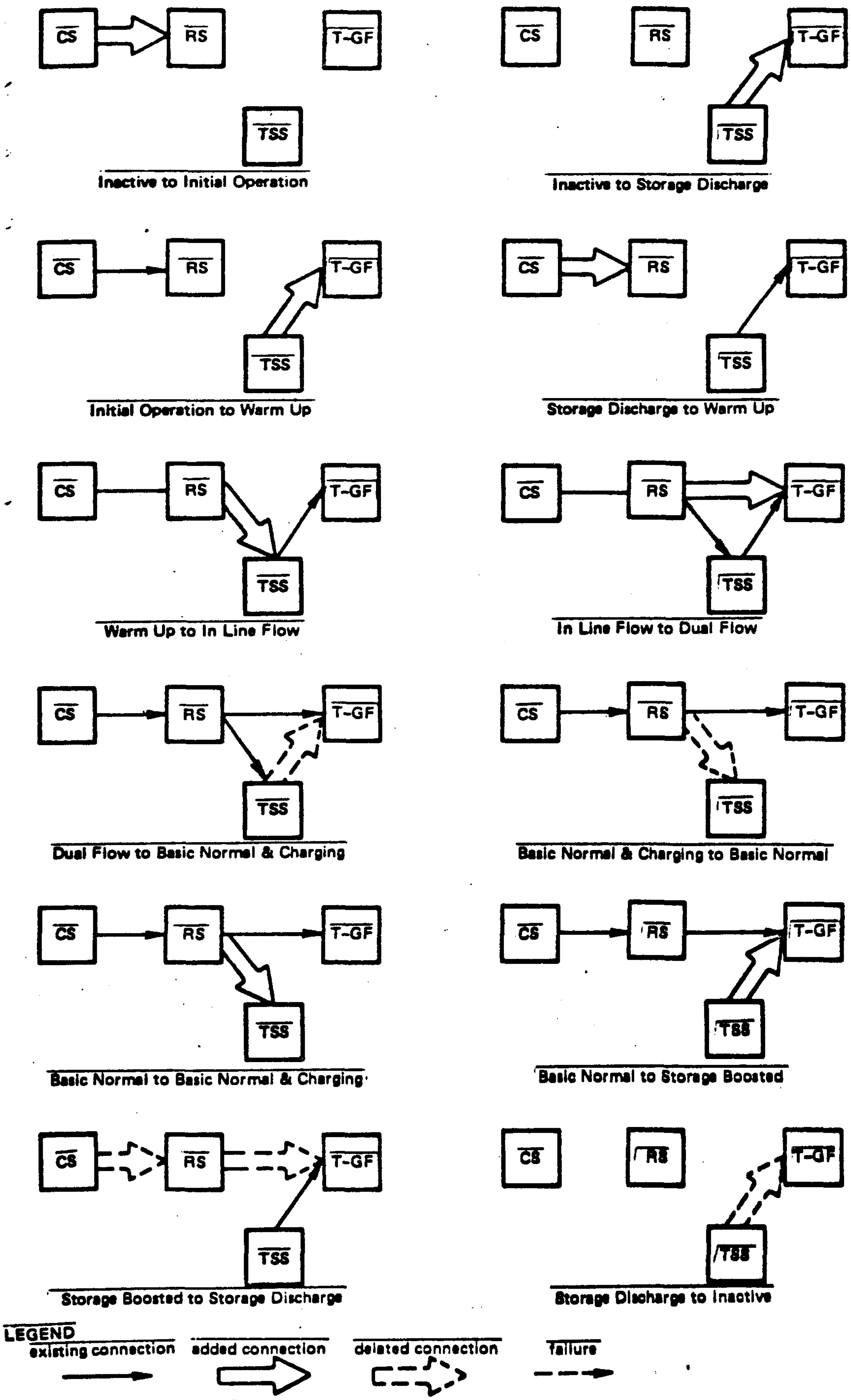


Figure 11* **Transitions to Evaluate** (Reference 3)
*This figure includes pages 28 through 30.

B. RESULTING ONLY FROM FAILURES

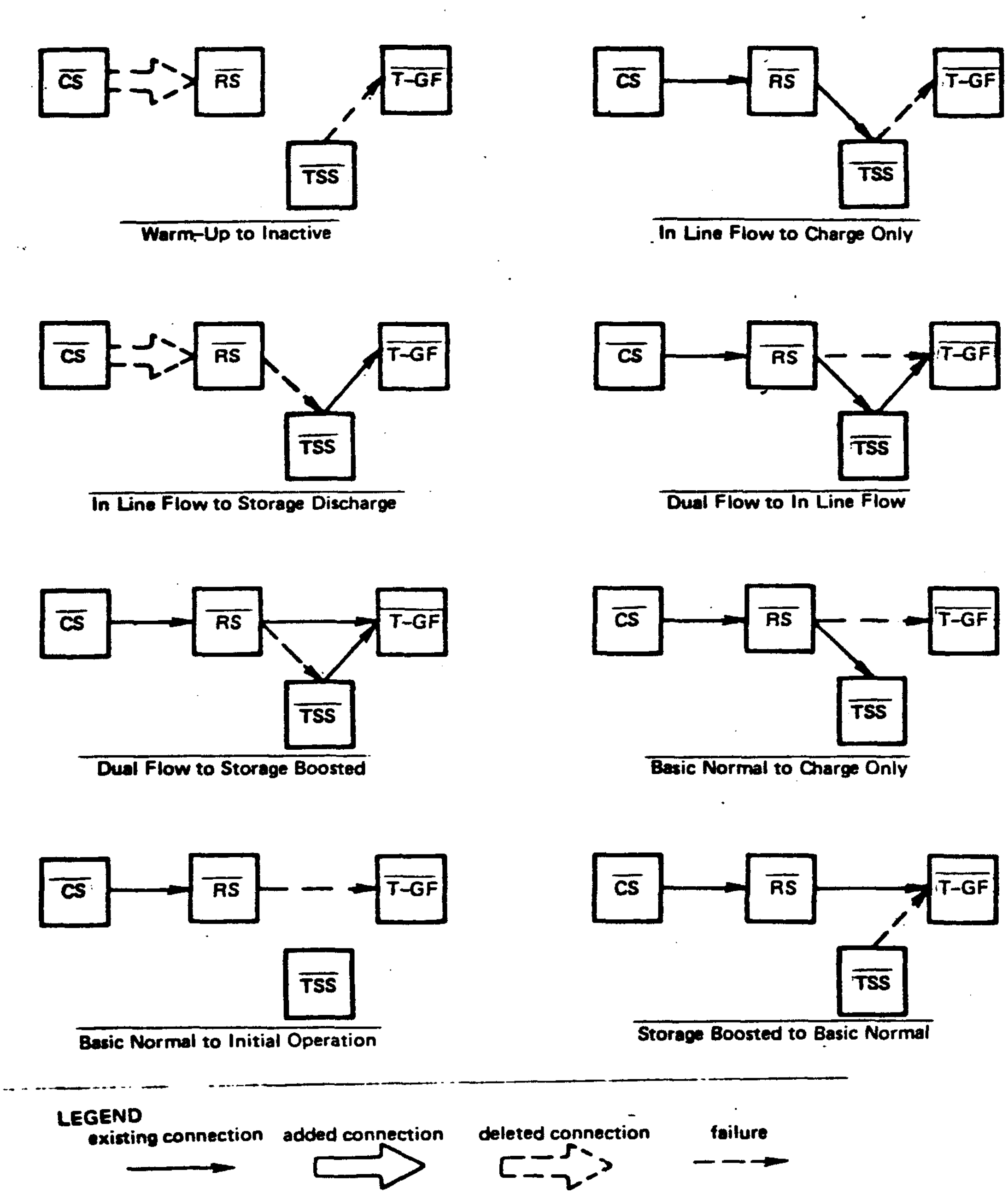


Figure 11.* Transitions to Evaluate (Reference 3)
*This figure includes pages 28 through 30.

To Mode

	1	2CA	2CO	3CA	3CO	4	5	6	7	8	SD	WC	FT
1	-	A M		A M							T		
2CA	A M	-	M				M		M				
2CO		M	-										
3CA	A M			-	M			A M	M				
3CO				M	-								
4						-	M	M	M				
5		M				M	-				M		
6				M		M		-		M			
7		M		M		M			-				
8										-		M	
SD	M						M			M	-		
WC											M	-	M
FT	M							M					-

A Automatic Detection and Transition
M Manually Initiated by Operator
CA Cascade Control
CO C-ordinated Control
SD Flow to Steam Dump System
WC Water Cleanup
FT Flow to TSS Flash Tank

Figure 12 . System Mode Transition Matrix

The normal transition tests concentrate on expanding the mode-to-mode transition knowledge and determining the subsystem response or lag times. Attention is called to the fact that the specifications included here provide for manual initiation only. When the OCS has been made fully operative, those transitions which require manual-OCS or OCS fully automatic initiation (as shown on Figure 11) will need to be repeated.

5. Failure Transition Tests

A series of ten failure transition tests were selected to thoroughly investigate plant response to the failure modes. Two of the mode transitions are also listed under group 4, Normal Transition Tests. The difference is that under group 4 conditions the transition will be done relatively slowly with careful control, whereas in a failure transition the action will be very rapid and in some cases proceed to a shut-down condition.

6. Transition Timing Tests

In order to gain necessary experience in scheduling power production, it is necessary to establish minimum start-up, transition, and orderly shut-down cycle times. A series of five tests are included here to facilitate obtaining these data.

7. Engineering Tests

A group of five tests have been specified which provide for evaluation of Pilot Plant operation in terms of verifying its design on both the most favorable and least favorable solar days. Also included here are two tests intended to obtain repowering information. It is anticipated that the need for additional tests in this category will become apparent as the result of analysis and evaluation of completed tests. The final engineering test (ET-5) is for the clear-day scenario (Figure 13) and is to be performed under fully automatic control after suitable software has been developed and each automatic transition has been individually demonstrated.

8. Plant and Control System Optimization

By the time that the plant optimization part of testing begins, considerable operating experience will have been gained. This experience will guide the determination of the optimum sequence of operating modes for various weather conditions. The plant will be evaluated for ease of operation and automatic control. Further experimentation on and analysis of the various control modes are planned and better data will be collected. Much of the optimization will have

CLEAR-DAY SCENARIO

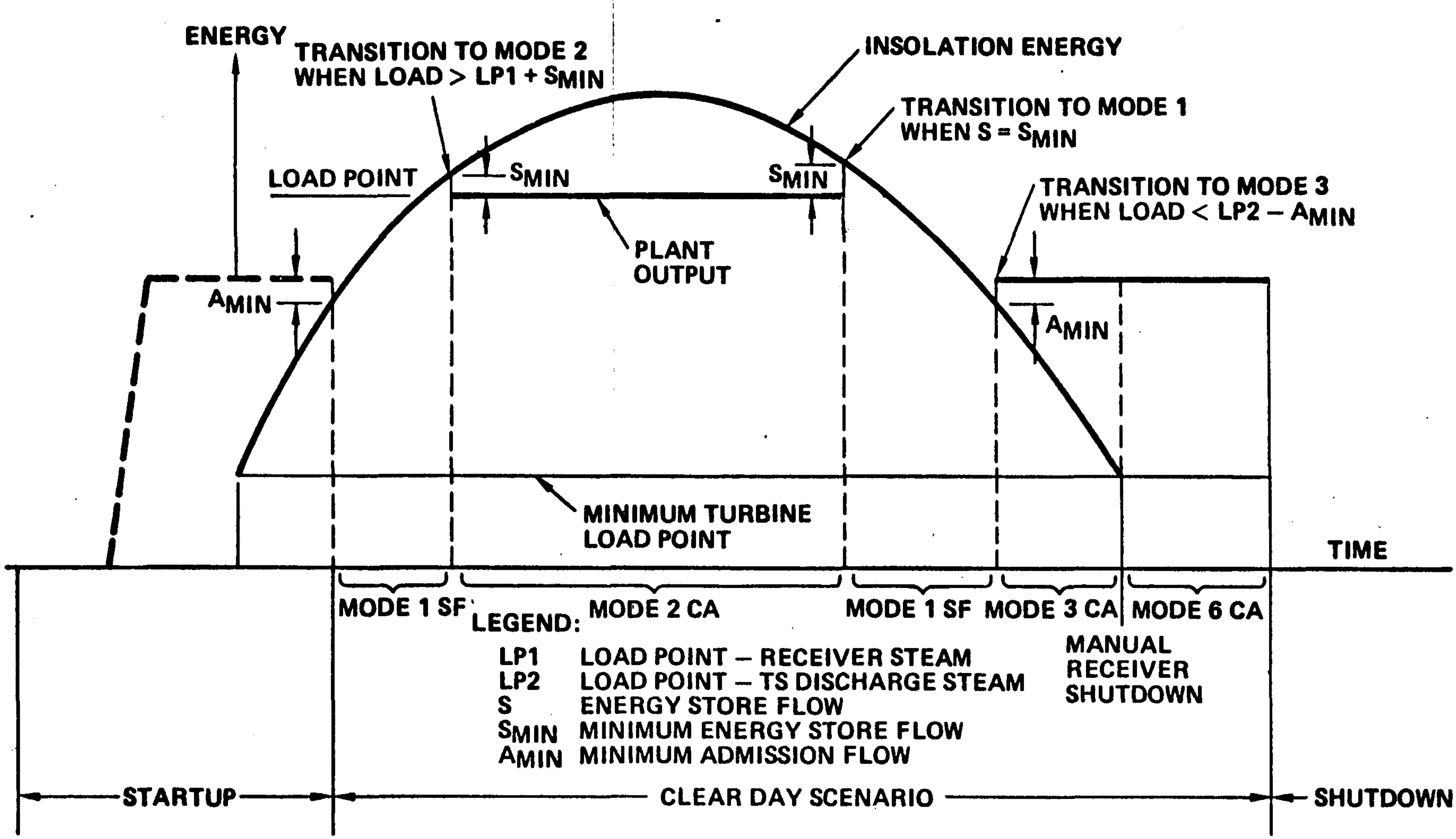


Figure 13 (Reference 3)

occurred in the preview seven test categories. Additional specific tests cannot be defined but will become apparent after prior tests are performed.

9. Associates Testing

A block of test time has been allocated to the Associates. The specific test plan during this testing period will be generated by the Associates. Hoever, the collection of engineering data will continue as will the evaluation of the plant.

B. Follow-on Power-Production Phase

It should be noted that during the initial experimental phase, continuous power production is not the plant goal; instead, the primary goal is to obtain data that allows a complete engineering evaluation of the pilot plant. However, the follow-on power-production phase will be devoted to demonstrating that the pilot plant can supply electrical power to a utility grid effectively using thermal energy from the receiver and from thermal storage. By the time that the power production phase of testing begins, sufficient performance data and operating experience will be available to permit selection of optimum operating modes and control configuration. The plant will be operated in the selected optimum modes and configurations during the first part of the power production phase. After an intermediate down period for inspection and evaluation, special tests applicable to retrofit and commercial plant evaluation will be conducted.

1. Performance Evaluation

This portion of the test program is aimed at gathering information on the behavior of a solar thermal central receiver plant during long-term production of power and at determining the associated operation and maintenance requirements. By the start of this phase of the program, considerable operating experience will have been accumulated by conducting the experimental-phase tests which span the gamut of useful options. Based upon these test results and the associated operating experience, a selection will be made of specific operating modes, control configuration, and operating procedures.

The plant then will be operated in these optimized modes, configurations, and procedures for sufficiently long periods of time to assess the probable desirability for use during a 20-to-30-year plant life. Data will be obtained during this period on plant performance, and on operation and maintenance requirements. The plant will be evaluated for ease of operation and control under the full range of weather conditions and operating conditions encountered. At the conclusion of this portion of the testing, an intermediate inspection of the plant, its subsystems and components will be performed.

2. Retrofit Evaluation

Tests identified as applicable to fossil-fuel retrofit plants will be performed. Of particular importance will be the critical control parameters applicable to repowering. Various ways of reconfiguring the plant also will be explored to most expeditiously obtain data desired at this point in time by the designers for plants then being considered for or undergoing retrofitting. If reconfiguring is feasible and costs are not excessive, the most attractive approach will be implemented.

3. Commercial Plant Evaluation

Tests will be conducted to collect data applicable to commercial plants of similar design. In addition, tests will be performed to obtain data requested by designers of advanced solar thermal central receiver plants, if pertinent data can be obtained with little or no modifications.

C. Programmatic Support Activities

Test activities described in the preceding section A will occur during the first two years of the test program, while activities in Section B will occur during the final three years. In addition, there will be other activities spanning the entire five-year time frame of the test program. Such activities have been designated as programmatic support effort and they fall into three categories, of environmental impact, equipment performance, and plant economies. Detailed descriptions of each category follows.

1. Environmental Impact Evaluation

Utilization of solar energy is generally regarded as a benign technology. However, solar central power stations require large heliostat fields which function to concentrate considerable quantities of energy in a relatively small geometric space. These requirements give rise to several environmental concerns which are addressed in the following paragraphs together with tests required to substantiate or alleviate the concerns.

Misdirected and Reflected Solar Radiation

One environmental concern relates to the potential for accidental eye or skin damage to personnel in or near the pilot plant. A series of experimental measurements will be made of the intensity of concentrated light from various arrays of heliostats when not at their aim point and of reflected light from the receiver. These measurements will be made at locations likely to be occupied by personnel during pilot-plant operation and will include regions surrounding and over the pilot plant. Data obtained will be utilized to check exposure levels, to verify access limitations under all planned operating modes, and to confirm analytical models. Because it is undesirable and impractical to make direct measurements of irradiance on the retina, indirect techniques will be utilized involving photographs, photometers, radiometers, calorimeters, and movie or video cameras.

Initial measurements will be made of a single heliostat at various distances expressed as fractions and multiples of the focal length. Other measurements will be made of groups of heliostats while aimed at the receiver and also at standby aim points.

Helicopter flyover measurements, similar to those performed at CRTF, will be made to obtain 1) indirect information on quantitative retinal exposure, 2) photographic and moving picture records giving the overall impression of the field as it would appear to the pilot of an overflying aircraft, 3) qualitative information on the distractive and flash-blindness effects of the field, and 4) recovery-time for an observer to be able to read indicators on the helicopter instrument panel after glancing at the heliostat field and/or receiver tower at safe distances (from the standpoint of retinal damage).

Heliostat Field Ground Surface Effects

Construction and maintenance of heliostat fields can potentially modify native plant and animal communities and impact surface water and groundwater conditions. The nature of these effects depends on the details of the heliostat field. The heliostat field at the Barstow Pilot Plant will not be paved, nor will a soil stabilizer be used to minimize dust generation.

Local patterns will be monitored to detect any significant changes in groundwater flow or wash area formation. Using standard community analysis techniques, flora and fauna will be characterized at the facility site. The results of this analysis will then be compared to the results of an analysis for an adjacent, "similiar" site. This will indicate the degree of ecological disturbance resulting from the facility heliostat field, as well as the characteristics of the replacement community.

Under a contract with DOE, the Laboratory of Biomedical and Environmental Sciences at the University of California, Los Angeles, is performing environmental monitoring at the pilot plant site. This work addresses not only the construction phase, but also ensuing periods of testing and operation. UCLA will issue quarterly, and annual status reports and topical reports (Reference 7).

In addition, the ground reflectivity of the treated portion of the field will be compared with that where regrowth has been permitted. Any other dissimilarities affecting dust control and access to heliostats for maintenance and washing will be noted.

Air Quality

Compared to conventional power generating systems, solar thermal power systems should produce minimal effects on air quality. There is a possibility that the high temperatures and light intensities produced at the receiver panels may initiate chemical reactions in the atmosphere to generate harmful pollutants such as the nitrogen oxides. Accordingly, using portable instrumentation, air monitoring surveys will be conducted periodically to determine the magnitude and type of undesirable constituents.

Fugitive dust may be a problem during construction, and will need to be controlled after plant commissioning to prevent deterioration of heliostat surfaces. For this reason, atmospheric dust content will be periodically measured.

Accidental release of oil vapor from the thermal storage subsystem could influence air quality. This is discussed in the following section.

Hydrocarbon Oil Release

Environmental effects of any spills of the Caloria HT 43 used as heat transfer fluid in the thermal storage subsystem will be observed and recorded. The effects of hydrocarbon vapor emitted from the Ullage Maintenance Unit also will be observed. The planned procedure is to burn this gas as it is emitted. However, for various reasons (e.g., malfunction, high proportion of nitrogen) combustion may not be complete and some oil particles may be released. The extent, if any, of oil particle release and subsequent pattern of deposition will be monitored. Release of oil mist also could affect heliostat reflectivity.

Alteration of the Microclimate

Alteration of the microclimate by solar central power system operation may adversely affect indigenous wildlife and vegetation. Although for a single facility of the pilot plant size, these effects may not be severe, microclimate impacts may be of some concern for larger size plants. Because of the lack of adequate observational data, appropriate monitoring activities are planned.

When the pilot plant begins operations, various climatological parameters will be measured at the facility, including air and surface temperatures, wind speed and direction, and net reflectivity. Data will be obtained as a function of power level and heliostat mirror orientation (stow, standby, on target, etc.). Such data will be used for comparison with pre-existing conditions at the site and with normal conditions in surrounding areas.

Land and Water Usage

Site selection for future solar thermal power plants will involve finding relatively low-cost land areas of suitable size, with adequate supplies of cooling water, located in regions of good insolation. The need for a large heliostat field makes solar thermal systems more land intensive than a conventional fossil-fired plant. Cooling water requirements become particularly important in desert regions where there are many potential low-cost sites of high insolation. For these reasons, the land and water requirements for a solar thermal plant are of great interest, and data related to these requirements will be obtained during the pilot plant program.

During the five years of pilot plant tests, periodic surveys will be made to determine the minimum exclusion area required from the standpoint of reducing the production of fugutive dust to reduce risk and nuisance to the public by misdirected reflections. This information on land requirements, along with water availability, will permit a better determination of the number of suitable sites for solar thermal power plants.

Solar thermal power plants may require more water than conventional systems because of their lower thermal energy conversion efficiency and their heliostat cleaning requirement. In the case of "wet" cooling towers and evaporation ponds, the water is evaporated and thus represents a greater net loss to the local water supply than if the water is returned to the ground. Water availability and use can represent a significant siting problem in arid regions of the southwestern United States. Records will be maintained of water consumption in cooling towers and in cleaning heliostat mirrors. An attempt will be made to reduce water consumption by trying different water management schemes, including recycling of heliostat wash water.

2. Plant and Equipment Performance Monitoring (see also Appendix B)

Throughout the test and evaluation period, the performance of the overall system, the seven subsystems, and individual components will be periodically monitored to detect any significant change in performance. These checks will be made at four different power levels and at three different receiver outlet temperatures during each of the seven operating modes. By compensating for the effects on performance of operating mode, power level, and temperature level, it will then be possible to detect if there is any significant degradation or improvement in equipment performance.

Measurements and calculations which will be periodically performed in this connection are as follows:

a) Heliostat Reflectivity
b) Heliostat Aiming Accuracy
c) Heliostat Tracking Capability
d) Heliostat Shadowing and Blocking*
e) Atmospheric Attenuation**

*Shadowing and blocking of heliostats will vary with the time of day and the day of the year. However, effects should repeat under similar conditions. Measurements of the Collector Subsystem cutput also will be needed to verify computer codes such as HELIOS.

**Atmospheric attenuation will vary with weather conditions. Measurements will be made at various slant ranges to determine values typical for clear days, overcast days, cloudy days, etc.

f) Receiver Absorbtance and Emittance
g) Receiver Heat Losses
h) Receiver Steam-Side Heat Transfer Coefficient
i) Receiver Flash Tank Moisture Trapping Capability
j) Thermal Storage Charging and Discharging Heat Exchangers Heat Transfer Coefficients
k) Thermal Storage Unit Heat Capacity
l) Thermal Storage Unit Heat Losses
m) Thermal Storage Heat Transfer Fluid Degradation
n) Riser and Downcomer Heat Losses
o) Pump Power Requirements
p) System Parasitic Power Consumption
q) Turbine-Generator Performance
r) Collector Subsystem Efficiency
s) Receiver Subsystem Efficiency
t) Thermal Storage Subsystem Efficiency
u) Turbine-Generator Efficiency
v) Plant Efficiency***

Concurrently with monitoring the performance of components, instrument sensors will be periodically recalibrated to detect any significant changes in output.

Performance evaluation of pilot plant subsystems and components also will include a comparison of performance data obtained during the five-year test and evaluation period with applicable data obtained during related developmental test programs conducted previously. These test programs include, but are not limited to, those involving: the five-tube and seventy-tube receiver panel tests conducted at Sandia-Albuquerque; the thermal storage tests conducted at Rocketdyne-Santa Susana; the heliostat tests conducted by Martin-Marietta; and the heliostat shine-off tests at CRTF.

***The term Plant Efficiency refers to a calculated value for plant heat rate, which in this instance considers the heat input as the total incident insolation at the heliostats and the output as the net electricity generated, reduced to the conventional BTU/Kwhr.

3. Plant Economic Evaluation

One of the three principal objectives of the Pilot Plant Program is to obtain sufficient development, production, and operating and maintenance data to identify the potential for economic operation of commercial solar plants. This objective will be met by a three-pronged approach of (1) collecting pertinent cost data separated into capital and operating categories, (2) measuring the performance factors (such as plant capacity factor) which are needed to assess economic feasibility, and (3) exploring approaches offering potential for improved performance and cost effectiveness.

The important cost data for economics-related calculations for conventional electrical generating plants fall into three general categories: (1) capital costs, (2) operating costs, and (3) fuel costs. Fuel costs for a stand-alone solar electric plant are negligible and hence this category can be omitted. Cost accounting for the pilot plant will be arranged under the headings shown in Table 2 & 3.This figure has been prepared following the basic guidelines of "Uniform System of Accounts for Public Utilities and Licensees, Part 101" published by the Federal Power Commission in 1973. Modifications have been made to include solar-related subsystems and also to account for the experimental nature of the plant. This means that costs directly related to the testing program should be accounted separately, as they would not be accrued in a plant entirely dedicated to power production. Additionally, all costs are to be recorded by the date incurred to permit normalizing into constant dollars.

A primary economic parameter required as a result of the program is the levelized cost of electricity. This levelized cost is defined as the cost of producing one Kwhr of electricity over the expected life of the plant. Calculation of the levelized costs requires as input data: capital costs, capital financing charges, fuel costs, operations and maintenance costs, and plant capacity factor. All of these items will be documented as previously stated.

In reference to the plant capacity factor, it should be noted that during the initial assessment period the plant capacity factor will be lower than would be expected for a plant totally committed to power generation. Appropriate corrections will need to be applied to the capacity factor so as to yield a realistic calculation of levelized cost.

TABLE 2

COST AND TECHNICAL DATA CATEGORIES

CAPITAL INVESTMENT RELATED

Project Management

Permits and Related Studies

Steam Plant

- Land and Land Rights
- Structures and Improvements
- Solar Facility
    - Collector Subsystem
    - Receiver Subsystem
    - Master Control System
    - Thermal Storage Subsystem
    - Beam Characterization System
    - Plant Support Subsystem

Turbogenerator Plant Equipment

- Turbine Generator
- Turbine Generator Auxiliaries and Service Systems

Transmission Plant

- Substation Equipment

General Plant

Distributables

OPERATION RELATED

Project Management

Data Requirements and Planning

- Acceptance Tests
- Operational Tests
- Power Generation Operations

Plant Operation and Maintenance

- Operator Training
- O&M Costs

Data Management

Special Studies

Reports, Information Dissemination and Public Interface

TABLE 3

SCE O & M COST ACCOUNTS (REFERENCE 8)

		PUC Acct.	Solar One
A.	Overhead		
	1. Supervision	184.560	905.00X
	2. Administration	184.560	.01X
	3. Engineering	184.560	.02X
	4. Accounting and Clerical	184.560	.03X
	5. Stationery and Office Supplies	184.560	.04X
	6. Miscellaneous Overhead Costs	184.560	.05X
	7. Grievance Under Labor Contract	184.560	.06X
	8. Automotive Expense	184.560	.07X
B.	Operations		
	1. Operation Supervisor	546.000	910.10X
	2. Air Pollution/Beam Safety	548.000	.11X
	3. Operation Steam Generation Equipment	548.000	.12X
	a. Receiver	548.000	.13X
	b. Thermal Storage	548.000	.14X
	c. Heliostat	548.000	.15X
	4. Operating Turbine/Generator	548.000	.16X
	5. Operating Auxilaries Switchgear/Transformer, etc.	548.000	.17X
	6. Water and Chemical Analysis	548.000	.18X
C.	Miscellaneous Non-Production Costs		
	1. Station Supplies	549.000	915.20X
	2. Safety Meetings	549.000	.21X
	3. Security Officers/Janitors etc.	549.000	.22X
	4. Expendable Small Hand Tools	549.000	.23X
	5. Job Training Meetings	549.000	.24X
	6. Station Ground Keeping	549.000	.25X
	7. Station Rentals	549.000	.26X
D.	Maintenance		
	1. Maintenance Supervision - * Engineer	551.000	920.30X
	2. Warehousing and Store Keeping	551.010	.31X
	3. Maintenance Indirect Costs	551.010	.32X
	4. Miscellaneous Maintenance Material	551.010	.33X
	5. Buildings and Grounds	552.000	.34X
	6. Control Systems - General	553.000	.40X
	a. Beckman - Remote Station	553.000	.41X
	b. Beckman - Control Room	553.000	.42X
	c. Modcom - Heliostat Array Control	553.000	.43X
	d. Modcom - Non HAC	553.000	.44X
	e. Modicon - Interlocking Logic System	553.000	.45X
	f. Modicon - Red Line Unit	553.000	.46X
	g. Cyber	553.000	.47X
	h. Intelligent System Corp.	553.000	.48X
	I. HFCs, HCs and 1/os	553.000	.49X

TABLE 3 (continued)

	PUC Acct.	Solar One
7. Steam Generation Facility Receiver (General)	553.00	920.50X
a. Preheat Panel	553.00	.51X
b. Boiler Panel	553.00	.52X
c. Temperature Control Valves	553.00	.53X
d. Receiver Steam Dump Equipment	553.00	.54X
e. Valves	553.00	.55X
f. Controls Primary Elements and Transmitters	553.00	.56X
g. Chemical Cleaning	553.00	.57X
h. Electrical	553.00	.58X
8. Steam Generation Facility, Thermal Storage (Gen)	553.00	.60X
a. Thermal Storage Tank	553.00	.61X
b. TSS Charging System (Steam)	553.00	.62X
c. TSS Extraction System (Steam)	553.00	.63X
d. TSS Charging System (Caloria)	553.00	.64X
e. TSS Extraction System (Caloria)	553.00	.65X
f. Strainers and Filters	553.00	.66X
g. Attemperator	553.00	.67X
h. Valves	553.00	.68X
i. Ulleage Maintenance System	553.00	.69X
(1) Ullage Pump	553.00	.69X
(2) Ullage Blower	553.00	.69X
(3) Burner Assembly	553.00	.69X
(4) Valves	553.00	.69X
(5) Controls	553.00	.69X
(6) Pilot Gas Supply	553.00	.69X
j. Electrical	553.00	.69X
9. Steam Generation Facility, Collector System (Gen)	553.00	.70X
a. Heliostat	553.00	.71X
b. Azimuth Motor	553.00	.72X
c. Elevation Motor	553.00	.73X
d. Collector Field Electrical	553.00	.74X
e. Encoder	553.00	.75X
f. Rectifier	553.00	.76X
g. Gear Drive	553.00	.77X
h. Electrical	553.00	.78X
i. Heliostat Wash	553.00	.79X
10. Steam Generation Facility, Start-Up	553.00	.80X
a. Flash Tank	553.00	.80X
b. Valves	553.00	.80X
c. Controls	553.00	.80X
d. Desuperheater/Attemperators	553.00	.80X
11. Secondary Steam Production (Gen)	553.00	.81X
a. Auxilary Boiler	553.00	.81X
b. Heater Elements	553.00	.81X
c. Valves	553.00	.81X
d. Controls	553.00	.81X

TABLE 3 (continued)

	PUC Acct.	Solar One
12. Condensate System (General)	553.00	920.82X
a. Condensate Pump	553.00	.82X
b. Condensate Pump Motor	553.00	.82X
(1) Low Pressure Heater	553.00	.82X
(2) Deareator	553.00	.82X
(3) Valves	553.00	.82X
(4) Traps	553.00	.82X
c. Inline Polish Demineralizer	553.00	.8 X
13. Feedwater System	553.00	.84X
a. Receive	553.00	.84X
b. High Pressure Heaters	553.00	.84X
c. Hydraulic Coupling	553.00	.84X
d. Receiver Feedwater Pump Motor	553.00	.84X
e. Valves	553.00	.84X
f. Controls	553.00	.84X
g. Chemical Control	553.00	.84X
14. Steam Turbine	553.00	.85X
a. Control Valves/Stop and Admission Valve	553.00	.85X
b. Hydraulic Oil/EH System	553.00	.85X
c. Lube Oil System	553.00	.85X
d. Turning Gear	553.00	.85X
e. Bearings	553.00	.85X
f. Valves	553.00	.85X
g. Motors	553.00	.85X
h. Oil Pumps		
	553.00	.86X
15. Generator	553.00	.86X
a. Rotor	553.00	.86X
b. Stator	553.00	.86X
c. Air Coolers - Filter	553.00	.86X
d. Bearings	553.00	.86X
16. Cooling Water System	553.00	.90X
17. Fire Water/Service Water System	553.00	.91X
18. Repairing Shop and Miscellaneous Equipment	553.00	.92X

Note: The least significant digit represents the following activities:

Activities:

0. Steam Division Labor
1. Materials
2. Contract Services
3. R & O
4. Construction
5. Start-Up
6. T.B.D.
7. T.B.D.
8. T.B.D.
9. Miscellaneous

The cost effectiveness of any power plant can be improved by such familiar measures as reducing costs, improving efficiency, and increasing capacity factor (e.g., increasing reliability to decrease down time). These avenues will be explored during the five year test period to determine the potential for improvement of cost effectiveness of the pilot plant and of later generations of solar thermal power plants.

Because the pilot plant is a first-of-a-kind installation, potential for certain cost reductions are rather predictable. Experience has shown that production costs of newly developed components can be reduced in a fairly predictable way by a learning curve. For example, subsequent plants should anticipate lower costs than the first generation plant for the heliostat field and for the thermal storage system.

The heliostat array comprises about 40% of the total cost of a solar thermal power plant. If the field can be optimized to either reduce the number of heliostats or increase their effectiveness, cost reduction can be made. In addition to the geometric arrangement of heliostats (which influences shadowing and blocking), other factors are applicable. Among the most significant are heliostat beam quality, accuracy, reflectivity, mirror breakage/degradation, spillage losses and thermal losses. Such data will be gathered throughout the five year test program and will be used to optimize the performance of the collector and receiver subsystems.

The cost effectiveness of the thermal storage subsystem will be reviewed as data are accumulated on the capacity displacement credit of varying degrees of storage. The cost effectiveness of the plant operating with modes involving thermal storage (e.g., in-line flow and dual flow) will be determined and compared with the cost effectiveness without thermal storage.

D. Test Schedule

Figure 14 shows the anticipated schedule for the 5-year Test and Evaluation Program. According to present plans, the Test and Evaluation Program will start in early 1982, immediately after completion of Acceptance Testing for the 10 MWe Pilot Plant.

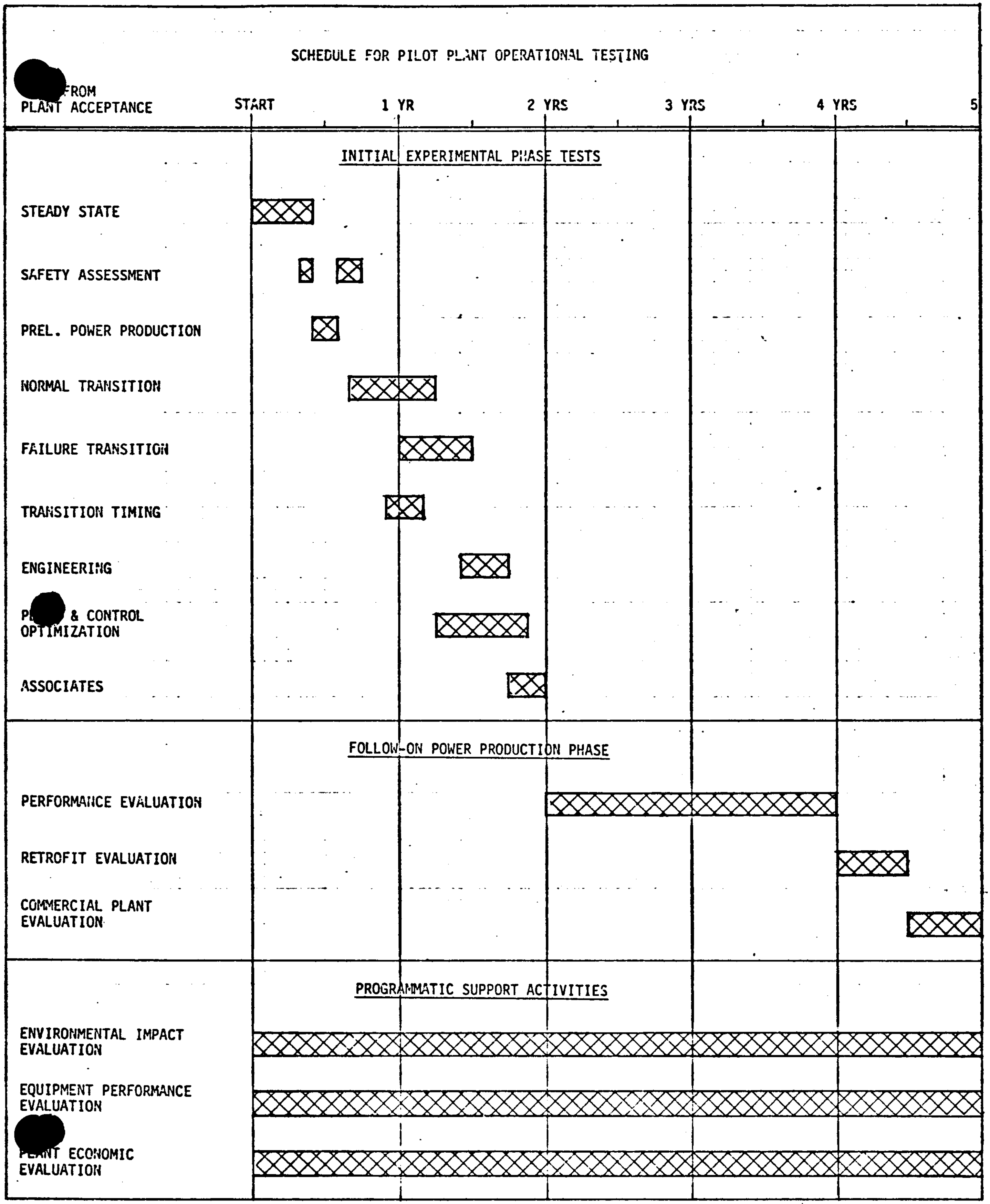

SCHEDULE FOR PILOT PLANT OPERATIONAL TESTING
FROM
PLANT ACCEPTANCE
START
1 YR
2 YRS
3 YRS
4 YRS
5
INITIAL EXPERIMENTAL PHASE TESTS
STEADY STATE
SAFETY ASSESSMENT
PREL. POWER PRODUCTION
NORMAL TRANSITION
FAILURE TRANSITION
TRANSITION TIMING
ENGINEERING
& CONTROL
OPTIMIZATION
ASSOCIATES
FOLLOW-ON POWER PRODUCTION PHASE
PERFORMANCE EVALUATION
RETROFIT EVALUATION
COMMERCIAL PLANT
EVALUATION
PROGRAMMATIC SUPPORT ACTIVITIES
ENVIRONMENTAL IMPACT
EVALUATION
EQUIPMENT PERFORMANCE
EVALUATION
ECONOMIC
EVALUATION

Figure 14

V. MEASUREMENT REQUIREMENTS

Measurement requirements for the Pilot Plant will be met primarily by utilizing data inputs to the Master Control System (MCS) which includes two primary computer systems: Operational Control System (OCS) and Data Acquisition System (DAS). The DAS is dedicated to acquisition of data for test and evaluation of the plant while the OCS is dedicated to operational control. Data points in the listings below which are called out for DAS are those needed for the test program that are not specified for operation and/or control. Those points noted as OCS/DAS are those for which test and evaluation requirements can be met by transferring the information from the OCS to the DAS, thus eliminating the need for duplicate sensors in the process systems.

Major Subsystem	Acquisition Methods				
	OCS/DAS	DAS	Local	Spares	Total
Collector Subsystem*	16	155	1	-	172
Meteorological Station*	3	62	3	-	68
Receiver Subsystem	235	301	4	16	556
Elec. Power Gen. Subsystem	477	94	120	-	691
Thermal Storage Subsystem	199	85	32	115	431
Plant Support Subsystem	30	8	12	-	50
	960	705	172	131	1968

It may be seen that a total of 1968 instrument sensors will be available to meet the data requirements for the test and evaluation program. Of these, 960 sensors also are required for plant operation and control, and information from those sensors will be recorded by the DAS. A group of 705 sensors are dedicated to providing inputs solely to the DAS. In addition to the instrumentation sensors, other pameters which may be recorded include control-system internal signals such as controller set-points and outputs.

*Of the 191 instrument sensors in Special Heliostat Instrumentation and Meteorological Measurement Systems (SHIMMS), 126 are load cells mounted on selected heliostats. Consequently, the 126 load cells are included under collector systems. The remaining 65 are included under Meteorological Station (62 DAS and 3 Local).

The distribution of the 1968 instrument sensors for the test program by type of measurement is as follows:

Temperature(1)	632	Meteorlogical (SHIMMS)	65
Pressure	212	Heat Flux	75
Pressure Differential	38	BCS Flux Sensors	16
Flow	58	Strain	128
Position(2)	339	Vibration	12
Displacement	11	Load Cells (SHIMMS)	126
Pump Speed	31	Fluid Level	69
Electrical(3)	125	Miscellaneous	10
Chemical Analysis	21	Total	1968

(1) TW (Thermowells) were not included as only sensors were counted.
(2) Position includes valve and circuit breakers position.
(3) Electrical includes voltage, current, power, frequency, etc. It does not include trips, which are counted under Position.

The above tabulated summary was derived from an "Instrumentation List" printout prepared by MDAC on Oct. 12, 1981. Because of its length (226 pages) the detailed listing by individual tag numbers is not included as part of this test plan. MDAC has delivered copies of the printout to the plant site, and these copies are available to test and operating personnel (Reference 9).

Collector Subsystem items which must be monitored include: (1) meteorological factors which might affect the performance of either individual heliostats or the entire collector field; (2) heliostat status, which should yield statistical data on the availability or unavailability of heliostats for plant service; (3) heliostat performance showing energy requirements and the influence of environmental factors on aim point, and (4) measurement of the reflected-beam "quality" as determined by the Beam Characterization Subsystem.

Meteorological factors can greatly influence the output of the collector field. The total direct insolation on the collector field represents the atmospherically attenuated solar input. The reflected beam will be further diminished by atmospheric attenuation between the heliostat and the receiver, and wind loads which influence aim point. Also, environmental factors such as rain and dust can alter the mirror reflectivity. Because meteorological factors influence other subsystems as well as the collector subsystem, they have been grouped into a separate category under the title of "Meteorological Station."

Performance of heliostats in the Collector System will be monitored in a number of ways:

(1) A status overview of the entire collector field will be recorded in DAS. This overview will indicate the number of heliostats in each possible heliostat operating mode (e.g., tracking, standby, stow, stow-Alt. 2).

(2) Heliostat position (azimuth and elevation) as a function of time can be recorded in DAS for as many as 20 heliostats.

(3) The backup HAC has a tape drive and this HAC can be commanded to write selected heliostat information for the entire collector field or specified portions thereof.

(4) Data from the Special Heliostat Instrumentation and Meteorological Measurement Systems (SHIMMS) can be recorded in DAS. This consists of meteorological information in the field and load cells on six selected heliostats.

(5) BCS data is acquired under control of the OCS and recorded on disk. However, at least every three operating days the disk data will be transferred to tape. The data recorded on tape will be available to test evaluators.

For test and evaluation of the Receiver Subsystem, a total of 540 data points are required, of which 301 are assignable to the DAS. The Receiver Subsystem is comprised of the Preheat Panels (6), Boiler Panels (18), Moisture Accumulator, and the Receiver Flash Tank. A large number of the DAS data points are accounted for in the instrumented receiver panels. Each receiver panel has three heat flux gages (to measure incident solar energy) and seven thermocouples. Four of the 18 boiler panels have an additional 33 thermocouples. All panels have a displacement gage to measure axial elongation and selected panels have gages to measure panel lateral movement and panel bending for a total of 56 gages.

In addition, a portable infra-red device will be utilized to scan all receiver panels and monitor them for hot spots attributable to either excessive power density or tube blockage. This device will not be dependent upon the DAS for processing the infra-red data.

Data points selected within the Electric Power Generation Subsystem mainly were limited to those data sources required to permit calculation of plant heat balances and mass balances and to determine in-plant electrical loads. This basis is consistent with the ground rule that the steam/electric plant equipment is all standard, state-of-the-art equipment and will be evaluated on a gross plant basis.

For test and evaluation of the Thermal Storage Subsystem, there are 414 instrument sensors. This includes 143 thermocouples to monitor the thermocline within the Thermal Storage Unit, and the temperature distribution along the tank wall. Instrumentation sensors are positioned at inlets and outlets to each heat exchanger used in the "Charging Mode" and the "Storage Discharging Mode." Included under the TSS are instrumentation requirements for the Fluid Maintenance System and the Ullage Maintenance Unit.

All operator commands to the OCS computer will be recorded and will be available on hard copy at the end of each day. This hard copy can be used later for evaluation, with the result that no DAS channels will be needed for command signals. Alarms and trips will be handled in a similar manner to provide plant reliability data and to permit correlation of any such events with their effects on the plant.

No data points have been included at this time which apply uniquely to repowering requirements. The mass of data to be obtained for evaluation of the Pilot Plant will provide reasonable coverage of potential requirements for general repowering studies based on the present plant configuration. Repowering studies suggest several test configuration options which would involve the use of special piping assemblies. Installation of any such piping assembly during the segment of testing devoted to repowering during the follow-on power-production phase would require special instrumentation which can be specified at the time the added system is designed.

Four categories of sampling intervals will be used for recording DAS data on tape, namely: 1 second, 10 seconds, 1 minute, and 10 minutes. The disk sampling rate should be five times faster to permit retaining data at faster sampling rates when required on infrequent occasions such as a transient or an unexpected event. In this case, data covering the time span of interest could be transcribed from the disk to tape at the faster sampling rate before writeover occurs.

INSTRUMENT CALIBRATION

The calibration of the instrument sensors will generally follow normal plant practices, with manufacturers data providing the basic calibration. The manufacturer's calibration will be confirmed to a varying extent, depending on the type of sensor, during the Acceptance Test Phase. These field calibrations, listed below, are not traceable to NBS standards but are considered adequate for the majority of the plant measurements.

INSTRUMENT TYPE	FIELD CALIBRATION
Thermocouples and Heat Flux Transducers	Sensor Resistance Measurement Ambient Measurement 80% of Full-Scale Circuit Test
Resistance Thermometers (RTD)	RTD Resistance Measurement Span & Zero Circuit Test
Pressure, Differential Pressure, and Level Transmitters; Linear Potentiometers	Span & Zero Calibration, Linearity Test Using Simulated Process Input
Linear Displacement Transducers	0 & 100% Position Test, Linearity Test, Symmetric Voltage Test
Flowmeters	Span & Zero Circuit Test
Pressure Switches	Setpoint Check Using Gas Pressure & Test Gauge

While these field calibrations are considered adequate for most of the instrument sensors, there are 52 plant measurements which are critical for plant process evaluation. These measurements must be accurate if the evaluation of the plant processes are to be valid. Therefore, special calibration techniques should be applied to these sensors. The critical plant measurements are shown in Table 4, while the recommended calibration procedures are shown in Table 5.

TABLE 4

CRITICAL PLANT MEASUREMENTS

TAG NO.	LOCATION-FUNCTION	LINE NO.	DWG.
PT-937	Admission Steam to Turbine	8"-ST-19-HEA	P3-1902
TE-1025	Admission Steam to Turbine	8"-ST-19-HAE	P3-1902
TEX-1102	HP Heater #1	CCS-303-2"-T	P3-1903
PT-2002	Feedwater to Receiver	4"-TW-200-MBX	P3-1201
TE-2001	↓	↓	↓
FT-2230	↓	2 1/2"-FW-201-MBX	↓
FT-2231	↓	2 1/2"-FW-202-MBX	↓
FT-2232	↓	2 1/2"-FW-203-MBX	↓
TE-3108	TSS Water to Desuperheater	2"-FW-9-MBA	P3-1300 P3-1302
PT-3109	↓	1 1/2"-FW-4-MBA	↓
TT-3105	↓	↓	↓
TE-2005	Preheater Outlet	3"-TW-228-MBX	P3-1201
PT-2006	↓	↓	↓
PT-2902	Receiver Outlet	6"-MS-201-QEX	P3-1208
TT-2904	↓	↓	↓
TEX-2950	Receiver Regulator Outlet	6"-MS-2-QEB	↓
TE-1022	Turbine Inlet	6"-MS-2-QEB	P3-1900 - 1902
PIT-1001	↓	6"-MS-6-QEB	P3-1901
FT-3102	TSS Steam to Desuperheater	6"-MS-3-QEB	P3-1300 - 1302
TE-3103	↓	↓	↓
PT-3104	↓	↓	↓
FT-3205	Steam to Feedwater Heater #1	6"-MS-4-KBA	P3-1303
TE-3204	↓	↓	↓
PT-3203	↓	↓	↓
TEX-3251	Steam Condenser Outlet	6"-CO-306-KBA	↓
PTX-3252	↓	↓	↓
LT-3213	Steam-TS Surge Tank Level	3/4"-MS-301-KBA	↓
TEX-3253	Steam-TS Subcooler	4"-CO-301-KBA	↓
TE-3214	Oil-Charging Oil Inlet	8"TO-4-BBA	P3-1301
PT-3211	↓	↓	↓
FT-3211	↓	↓	↓
TE-3211A	Oil Charging Oil Outlet	8"-TO-9-BBA	↓
PT-3208	↓	↓	
TE-3254	Oil Charging Oil Inlet to Condenser	6"-ST-303-FBA	P3-1305
FT-3504	Steam -TSS Feedwater Inlet	2 1/2"-FW-10-FBA	P3-1305
TE-3503	↓	↓	↓
PT-3502	↓	↓	↓
TEX-3754	Steam - Boiler Inlet	2 1/2"-FW-301-FBA	↓
PT-3702A	Steam - Superheater Inlet	6"-ST-303-FBA	↓
TEX-3753	↓	↓	↓
TE-3710A	Steam - Superheater Outlet	6"-ST-5-FBA	↓
PT-3714	↓	↓	
TE-3711	Oil - Superheater Inlet	8"-TO-12-BBA	P3-1304
FT-3712	↓	↓	↓
PT-3713	↓	↓	↓
TEX-3755	Oil - Superheater Outlet	8"-TO-303-BBA	↓
PT-3703	Oil - Boiler Inlet	8"-TO-25-BBA	↓
TE-3704	↓	↓	↓
FT-3706	↓	↓	↓
TEX-3750	Oil - Boiler Inlet	↓	↓
TEX-3752	Oil - Boiler Outlet	8"-TO-305-BBA	↓
TEX-3351	Oil - Preheater Outlet	8"-TO-21-BBA	↓

TABLE 5

RECOMMENDED CALIBRATION FOR CRITICAL PARAMETERS

SENSOR TYPE	RECOMMENDED CALIBRATION BEFORE OPERATIONAL TESTING	ROUTINE RECALIBRATION	IN-SITU CHECKS
Thermocouples	Remove and calibrate, simulate output for circuit calibration	Repeat yearly	Compare with equivalent temps when iso-thermal
Resistance Thermometers (RTD)	Remove and calibrate, simulate resistance for circuit calibration	Repeat yearly	Compare with equivalent temps when iso-thermal
Rosemount Pressure Transmitters	Remove and calibrate transmitter, simulate output for circuit calibration	Repeat yearly	Pressurize system with no flow
Viatran Pressure Transmitters	Remove and calibrate transmitter, simulate output for circuit calibration	Repeat every 6 months plus local R-Cal monthly	Pressurize system with no flow
Level Transmitters	Remove and calibrate transmitter, simulate output for circuit calibration	Repeat yearly plus monthly zero check by opening by-pass valve.	Compare with sight glass when available
Turbine Flowmeters (for oil)	Remove and calibrate flow-meter, simulate flowmeter pulse output for circuit calibration	Recalibrate flow-meter every two years, simulate flowmeter output for yearly cir-cuit calibration.	Heat balance or pump characteristics
Ramapo Flowmeters* (for water and steam)	Remove and calibrate flow-meter, simulate millivolt output for circuit cali-bration	Recalibrate flowmeter every two years, simu-late flowmeter output for yearly circuit calibration.	Heat balance or pump characteristics

*Force propotional to V^2 ($W_{correct} = W_{actual} \frac{\rho\ actual}{\rho\ nominal}$). Calibrate by adjusting for density. Electrical output proportional to square of the velocity. Flow is proportional to the square root.

VI. DATA MANAGEMENT

A. Data Acquisition

Data which is required for evaluation of plant systems and components will be acquired either by the Operational Control System (OCS) or the Data Acquisition System (DAS). Those data which are required for plant operation, in addition to being required for plant evaluation, will be acquired by the OCS and provided in digital form to the DAS. Those data required solely for plant evaluation will be acquired directly by the the DAS. Overall configuration is shown in Figure 15.

Data acquisition by both the DAS and OCS will be accomplished utilizing remote stations, for each of the major plant subsystems. The analog signals from each sensor will be connected to these remote stations, with signal conditioning being provided as necessary. These analog signals will then be multiplexed, converted to digital signals, and transmitted to the DAS or OCS.

Examples of data which are required for both plant operation and evaluation are:

Total Solar Insolation
Receiver Subsystem Inlet and Outlet Temperatures
Receiver Panel Inlet and Outlet Temperatures
Receiver Subsystem Flow Rates
Turbine Throttle Steam Flow, Pressure, and Temperature
Turbine Admission Steam Flow, Pressure, and Temperature
Feedwater Chemistry
TSS Charging Loop Oil Heaters Steam Flow, Pressure, and Temperature
TSS Charging Loop Oil Heaters Oil Inlet and Outlet Temperatures
TSS Extraction Loop Oil Flows and Inlet and Outlet Temperatures
TSS Extraction Loop Steam/Feedwater Inlet and Outlet Temperatures

Examples of data which are required only for evaluation are:

Ambient Wet and Dry Bulb Temperatures
Active Cavity Radiometer and Circumsolar Telescope
Receiver Panel Water Flow Rates
Specially Instrumented Panel Temperatures, Stresses, and Heat Fluxes
TSS Oil Pumps Power
TSS Storage Tank Temperature Rakes (Some)

BASELINE CONTROL/MONITOR AND EVALUATION ARCHITECTURE

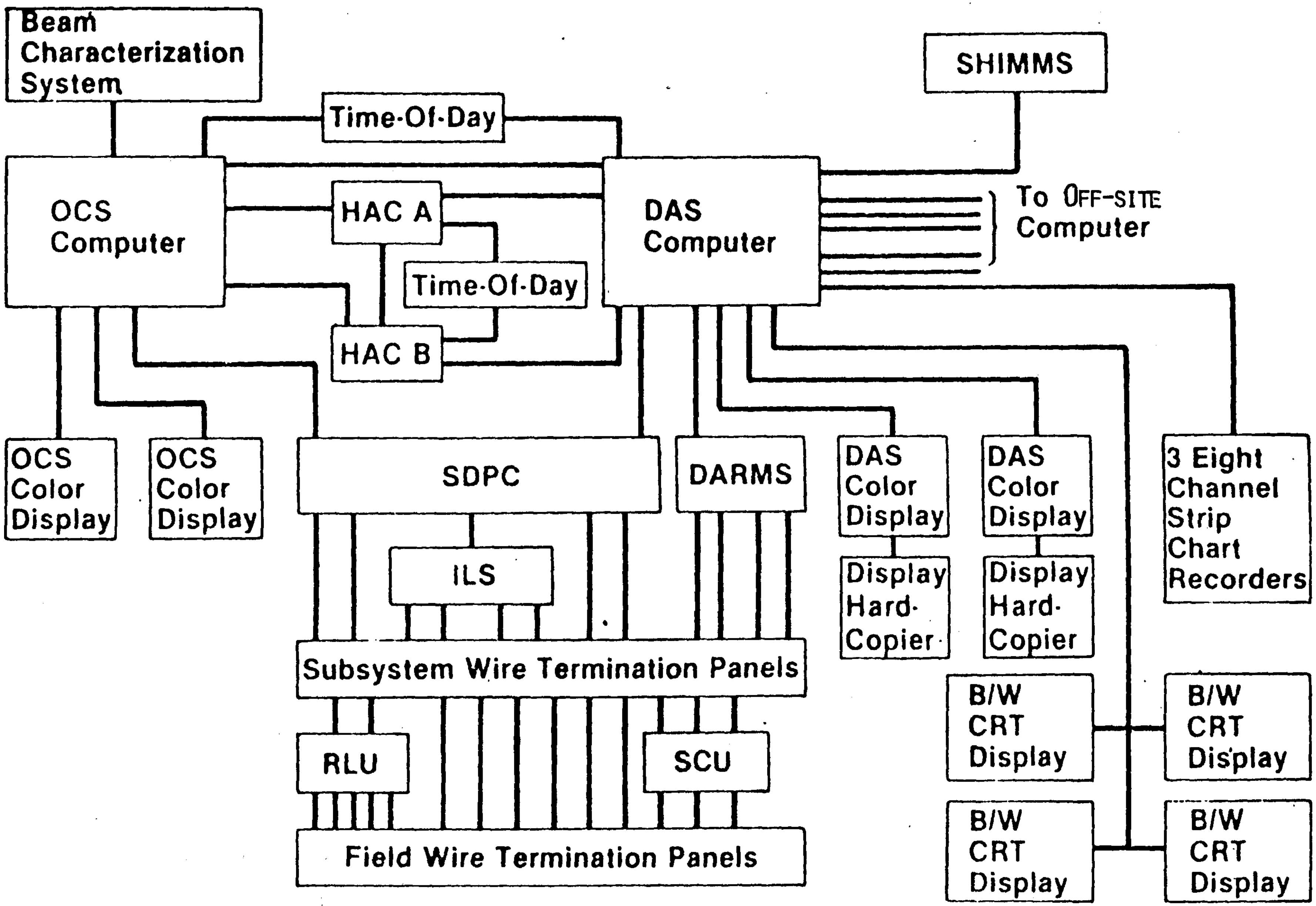


FIGURE 15

N-072E-A00-TS019
December 23, 1981

B. Data Reduction

Data reduction will fall into two time frames, on-line and off-line. On-line or real-time data reduction must be performed for all data which is displayed on the DAS graphic displays. This on-line data reduction will range from simple conversions to engineering units to more complex calculations such as receiver efficiency.

Off-line data reduction is that accomplished some time after the data is acquired. Off-line data reduction generally will be more thorough and complex than that performed on-line. Off-line data reduction may be performed utilizing the DAS computer either during plant operation, depending upon the demands on the DAS computer for other functions, or during times when the plant is shut-down, such as each night. Off-line data reduction can also be accomplished off-site where appropriate computer facilities are available.

C. Data Display and Recording

Data is available from numerous sources at the pilot plant and can be displayed in various formats and time frames. Figure 16 shows the floor plan for equipment layout at the plant control building. Essentially all of the real-time evaluation of test data will take place in either the Engineering Evaluation Room or at an off-site computer room, as the Control Room generally will be restricted to SCE operating personnel.

Figure 17 lists the on-site display and recording equipment according to its location in the plant control building. The following paragraphs describe the display and recording capability of each room in more detail.

Control Room Display and Recording

There are four different sources of display within the Control Room: the System Distributed Process Controllers (SDPC), the Operational Control System (OCS), the Collector System (CS), and the Beam Characterization System (BCS).

The SDPC terminals provide three types of displays: trend plots, tabular listings, and plant graphics. The trend plots consists of one to four process variables plotted versus time, with selectable time bases of 10, 100, or 500 minutes and 25 hours. These trend plots display the data for the time base period prior to display request and are then updated for the period that the display remains on the terminal. The tabular listings consist of hourly averages for the previous 24 hours for up to eight process variables. The plant graphic displays are schematic representations of portions of the plant process (under control of that particular SDPC) which include dynamic displays of preselected process variables in the appropriate location within the graphic. The SDPC Loggers provide permanent records of alarms and operator commands. They can also provide hard copies of the terminal displays. The SDPC trend recorders can record a total of 18 SDPC parameters, with a maximum of 12 parameters from any one of the three SDPC systems.

The Operating Control System (OCS) will provide displays similar to those provided by the SDPC terminals and loggers except that the displays will

PLANT CONTROL BUILDING: SECOND FLOOR PLAN
MCS EQUIPMENT LAYOUT

(Reference 3)

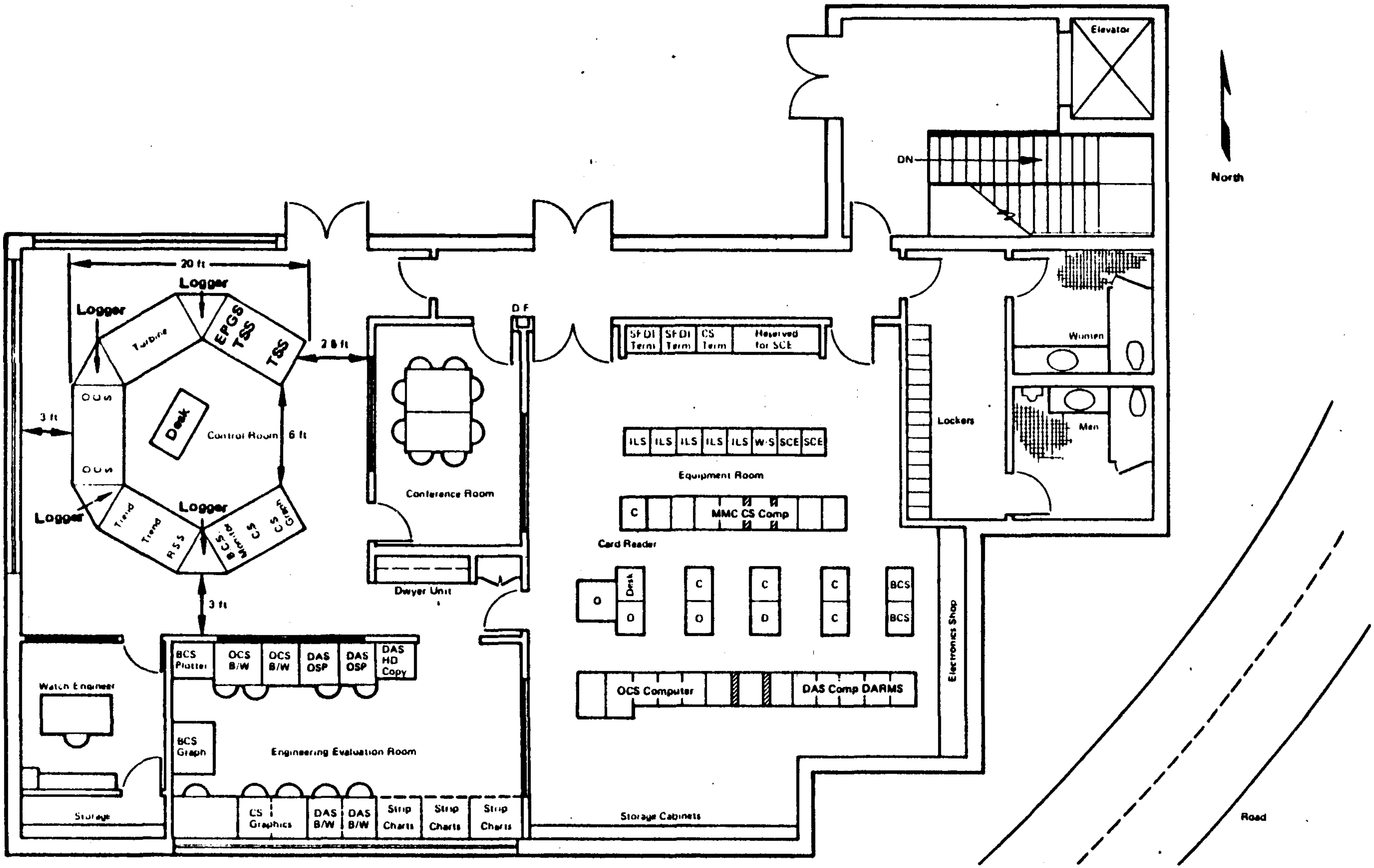


Figure 16

Control Room

- SDPC
  - RS Color CRT CON-700-12
  - TSS Color CRT CON-700-44
  - EPGS Color CRT CON-700-46
  - Loggers (3) CON-706, -707, -708
  - Trend Recorders (3) CON-700-9, -10, -11
- OCS
  - Color CRT (2) CON-700-29, -30
  - Logger OCS-701
- CS
  - Color CRT CS-701
  - Color Graphics CRT CS-702
  - Logger CS-703
- BCS
  - Video Monitor Panel CON 700-8
  - Video Monitor BCS-702-1

Equipment Room

- DAS
  - Keyboard Printer DAS 608
  - Line Printer DAS 609
- OCS
  - Keyboard Printer OCS 606
- CS
  - Keyboard Printer (2) CS-603, -604
  - Line Printer (2) CS-606, -611

Evaluation Room

- DAS
  - Color CRT (2) DAS-801, -802
  - B/W CRT (2) DAS-803, -804
  - Strip Chart Recorders (3) DAS-805, -806, -807
  - Hard Copy Unit (2) DAS-808, 809
  - Data Logger DAS-810
- OCS
  - B/W CRT (2) OCS-801, -802
- CS
  - Color Graphics CRT CS-801
- BCS
  - B/W CRT BCS-801
  - Line Printer BCS-801
- MDAC Data Base
  - B/W CRT
  - Hard Copy Unit

Miscellaneous

- TSU Strain Gauge Recorder Located At
  TSS Remote Station
- Circumsolar Telescope
  Magnetic Tape Recorder Located At
  South Meteorological Station

Figure 17

On-Site Data Display and Recording Equipment (Reference 10) include data from all three SDPC's and the Data Acquisition System (DAS). The OCS trend plots will have time bases of 3, 6, 12, or 24 hours with one to three parameters per plot. The trend plots and tabular listings may include process variables or calculated values. The graphics presentations will include types similar to those on the SDPC terminals (but which can cover any part of the total facility), bar charts, X/Y plots, and electrical single-line diagrams.

The Collector System (CS) displays include graphics displays of the status of all or part of the heliostat field and tabular listings of collector system status and messages. A logger records CS commands and alarms.

The BCS display is a video monitor which provides an image of one of the four BCS targets as selected by the operator. The CS logger can also log BCS alarms of errors in beam centroid or total beam power.

Evaluation Room Display and Recording

There are five sources of displays in the Evaluation Room: the DAS, CS, OCS, BCS, and the terminal connected by a data link to an off-site computer.

The DAS displays (which have access to SDPC, OCS, DAS, and HAC data) include black and white (B&W) terminals, color terminals (with hard copy on request),a logger, and strip chart recorders. The B&W terminals display only tabular listings, either a scrollable listing of one to five parameters or fixed listings of 48 parameters which are updated every five seconds. The color terminals can provide these same tabular listings and can also display trend plots of one to four parameters which start at the time of plot selection--historical recall is not provided. The 24 channels of strip chart recording can be software-assigned to any parameter.

The CS display in the Evaluation Room provides the same graphics displays as those in the Control Room.

The black and white CRTs located in the Evaluation Room will display OCS system information related to software development, system diagnosis, and maintenance. As such, the black and white CRT's will not be a primary source of preoperational and acceptance test data.

The BCS logging function in the Data Evaluation Room provides the record of all BCS related activities. It documents such information as centroid error, power error, and beam power profiles on a heliostat-by-heliostat basis as the BCS functions are being carried out. It also time tags all measurement data for future reference. The related Data Evaluation Room BCS CRT displays routine machine related information and time-tagged data which is subsequently diverted to the logger.

Miscellaneous Data Display and Recording

Strain gauge data from the thermal storage unit are recorded on four dedicated 8-channel strip chart recorders located in the thermal storage remote station. These recorders provide a continuous readout of tank strain during tank operation, starting with the initial tank fill. These data supplement dedicated DAS tank strain-gauge data that can be recorded.

The circumsolar telescope unit contains dedicated magnetic tape recording equipment which time tags and records the telescope measurements. The data rate will be every 2 or 15 minutes depending on the telescope configuration provided by Lawrence Berkeley Laboratory. The data will provide the calibration standard against which the normal incident pyroheliometer data (recorded by DAS through the SHIMMS buffer) can be calibrated. At present, no interface exists between the circumsolar telescope and the DAS recording equipment. As a result, the insolation calibration data tape must be shipped to Lawrence Berkeley Laboratory or to Sandia National Laboratory for reading and data reduction activities with a turn-around time of one to two weeks.

Additional manually prepared data and information are available in the form of the operating and maintenance logs maintained by SCE operating personnel. Standard plant information as well as unique factors involving the solar portion of the plant will be recorded as part of operating and maintenance personnel functions. The types and quantity of information to be logged by these personnel will be as specified by SCE Operations organization. Any manual logging functions for the purpose of plant evaluation required of the SCE operations and maintenance personnel must be carried out with the prior approval of SCE. The manual logs should be viewed as a secondary source of information since any additional plant evaluation related logging functions must not interfere with the job responsibilities of the SCE personnel.

Off-Site Computer

Terminals linked to an off-site computer center* could provide trend plots, plots of one or more parameters versus another, and tabular listings of measured or calculated parameters either in near-real-time or on historical recall from the magnetic disc memory or archived magnetic tapes.

Summary of Data Display Capability

Table 6 is a matrix which summarizes the types of displays at the three primary locations, based upon the system or systems from which the display is derived and the time frame in which the display data are available. For example, in the Control Room there are real-time plots, tabulations, or graphics displays available on an SDPC. However, the SDPC will provide post-test (historical) displays only in the plot format.

D. Data Evaluation and Storage

Data evaluation will consist primarily of comparison of actual system and component performance to expected performance. These comparisons will lead to:

1) Verification of predicted performance
2) Improved design basis for plant components
3) Improved basis for economic projections
4) Improvements in the plant simulation model
5) Refinements in plant control modes and mode transitions.

Data will be stored on both the DAS magnetic disc memory and on the DAS digital magnetic tapes. Storage on the disc memory will be for periods of 1, 6, or 24 hours depending upon the nature of the data. The magnetic tapes provide long-term storage of all data acquired by the DAS. These magnetic tapes will be used for the off-line data reduction and will also provide archival storage of the data as deemed appropriate.

*During the Startup and Acceptance Test Phase the data links to an off-site computer consisting of five 9600-Baud lines to a PDP-10 computer at MDAC-Huntington Beach. The location of the off-site computer during the Operational Test Phase had not been determined at the time this Test Plan was prepared.

Table 6

Solar One Data Display Capability

Location	Source	Time Frame: Real Time	Time Frame: Post Test	Type of Data Display: Plot	Type of Data Display: Tabular	Type of Data Display: Graphics
Control Room	SDPC	X		X	X	X
	SDPC		X	X		
	OCS	X		X	X	X
	HAC	X			X	X
	BCS	X			X	
Evaluation Room	SDPC	X		X	X	X
	DAS	X		X	X	X
	OCS	X		X	X	X
	HAC	X		X	X	X
	BCS	X		X	X	X
Off-Site Computer	TBD*	X	X	X	X	X

*To be determined.

VIII. TECHNOLOGY TRANSFER

Technology transfer objectives for the pilot plant are:

- To develop both utility and commercial acceptance of the solar thermal central receiver systems;
- To stimulate industry to develop and manufacture solar energy systems;
- To enhance public acceptance and familiarity with solar energy systems.

These objectives will be met by establishing a technology transfer program to disseminate pertinent information to appropriate user groups. Information to be transferred falls into two broad categories of technical data and cost data. Technical data will come from all phases of the five year Test and Evaluation program, as well as preliminary data acquired during the Design, Construction, and Acceptance phases of the Pilot Plant Program. Similarly, cost data and any performance data significantly influencing costs will be collected as described in Section IV-C-3 on "Plant Economic Evaluation."

Central solar power system technology will be transferred to the audience of data users as shown in Table 7. This table shows the organizations needing and using the technical and cost data, decisions to be influenced, and information required to influence these decisions.

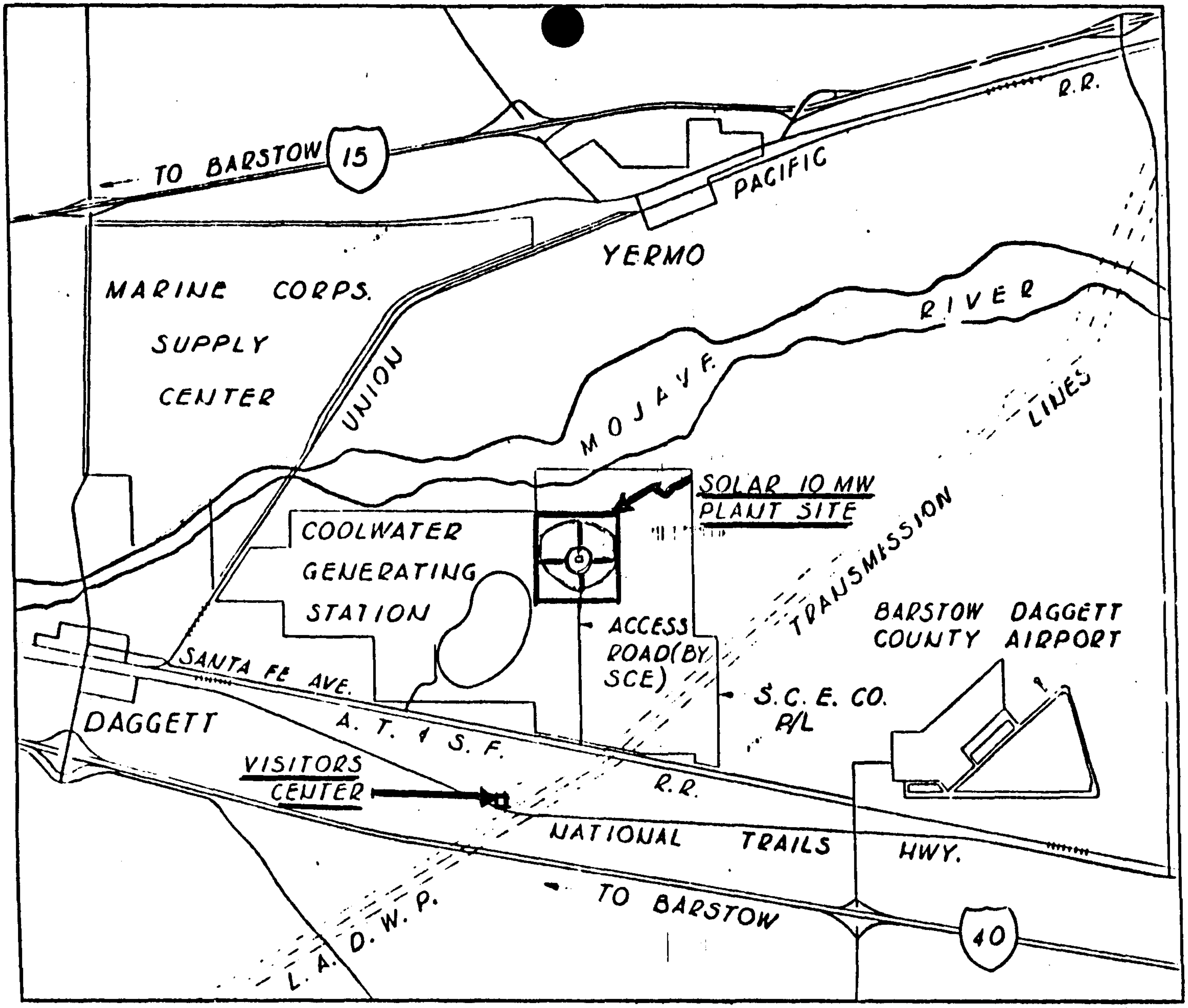
Portions of the technology transfer program have already been implemented by DOE & SCE; namely, formation of several committees, holding of an Annual Technology Review, construction of a Visitors Center (Figure 18) and dissemination of reports covering progress to date.

A Project Advisory Committee and a Project Review Committee (listed in Figure 19, have been established to disseminate solar thermal technology. These committees provide for design and operating reviews with such potential users as utilities, equipment manufacturers, and architect-engineer firms. The Project Advisory Committee has been meeting semiannually, but will meet quarterly during construction and operational testing. Each year one of these meetings will be designated the Annual Technology Review Meeting and will have the combined attendance of the Project Advisory Committee and the Project Review Committee. This annual meeting will provide members with a full project examination including site tours as appropriate. Comprehensive project reports will be published.

Table 7

PILOT PLANT TECHNOLOGY TRANSFER

ORGANIZATIONAL DATA NEEDS	AUDIENCE OR DATA USERS	DECISIONS TO BE INFLUENCED	INFORMATION REQUIRED IN ORDER TO INFLUENCE DECISION
[illegible]ES: COST, TECH. Turbine Generator Facility Solar Facility Financial-Proj.,Corp. Environmental	Corporate Officers, Boards of Directors and Project Managers of investor-owned utilities, Managers of municipal and coop type utility firms.	Addition of a solar-based unit to total generating capacity. Debt versus equity financing of same. Individual firm versus joint venture undertaking.	Magnitude of capital investment in collector field, receiver system, plant, and transmission systems. Historical operational costs of same. Solar-based versus other fuels' return-on-investment. Statistical appraisal of productivity over proposed plant lifetime. Cash flow projection over plant lifetime (including utility's power demand projection).
DEVELOPERS: COST, TECH. Solar Facility Environmental Financial - Proj., Corp.	Corporate Officers, Boards of Directors and Project Managers of resource development firms. Same audience individuals for equipment vending firms servicing the developers.	Delineation of a Solar Facility with commercially viable productivity and longevity characteristics. operations-generated versus debt/equity financing, individual firm versus joint venture undertaking.	Capital investment required for commercialization, including environmental considerations. Historical and projected costs of maintaining productivity. Projected utility industry demand for solar-based power generating units.
ARCHI. ENGS: COST, TECH. Turbine Generator Facility Solar Facility Environmental Financial-Proj., Corp.	Corporate Officers, Boards of Directors and Project Managers of architect-engineering firms. Same audience individuals from potential subcontractors to these firms.	To bid on design and construction of solar-based facilities. Special focus of marketing strategy on solar element of power generation industry.	Historical and projected plant capital costs with special emphasis on solar aspects. Projected utility industry demand for solar-based power generation units.
FINAN. COMMUN: COST Financial-Proj.,Corp. Turbine Generator Facility Solar Facility Environmental	Investment bankers, pension fund trustees, principals of life insurance firms, venture capitalists, bankers, brokerage firm principals, labor union officials, financial and management consultants and consulting firms.	Justification of capital investment through perception of an acceptable level of risk. Debt versus equity financing. Suitability of intermediate term loans. Extent of available trade credit.	Potential borrower's financial integrity, capital investment requirements. Historical operating data. Project cash flow over plant lieftime. Solar-based versus other fuels return-on-investment.
SCIEN. COMMUN: TECH. Solar Facility Environmental	Technical consultants and principals of consulting firms. Educators, academic researchers, government laboratory scientists.	Justification of extensions of basic and applied research programs. Development of new items of commerce.	Scientific analyses of technical data. Extent of financial resources available for research and development activities.
EQUIPMENT MFGRS: COST, TECH Turbine Generator Facility Solar Facility Environmental Financial - Proj., Corp.	Corporate Officers, Boards of Directors and Project Managers of equipment manufacturing firms. Same audience from potential subcontractors to these firms.	Revised marketing strategies for established products. New product development. Established product improvement programs. Desire to bid on fabrication & installation of equipment.	Projected utility industry demand for solar-based power generation units. Historical and projected equipment costs with special emphasis on solar aspects. Profitability of equipment sales as determined by power plant energy base.
DOE-HQ: COST, TECH Environmental Financial - Proj.	S&C personnel CO personnel EV personnel	Evaluation of the DOE/industry team approach. Viability and success of a commercially-oriented demonstration project. Program planning.	Variances from projected project cost, schedule and technical parameters. Scientific analyses of technical data. Extent of utilization of project data by industrial firms to influence investment in solar-based power generating capacity.
DOE-STMPO/PO: COST, TECH Financial-Proj. Turbine Generator Facility Solar Facility Environmental	SAN/MO personnel SAN/PRO personnel SAN/BUD personnel SAN/EV personnel SAN/AMPRJ personnel	Viability of the DOE/industry team approach to technical, financial and commercialization aspects of a solar-based power plant.	Extent of the effect of the indirect profit motive of a DOE/industry team on project completion and commercialization, variances from projected cost, schedule, and technical parameters. Degree of establishment of DOE credibility as a working partner with industrial firms. Extent of utilization of project data by industrial firms to influence investment in solar-based power generation capacity. Scientific analyses of technical data.
TRADE ORGANS: COST, TECH Turbine Generator Facility Solar Facility Financial-Proj.,Corp. Environmental	Individual and corporate members representing technical and commercial solar interests.	Degree of emphasis on commercialization of solar resources.	Variances from projected project cost. Schedule and technical parameters. Scientific analyses of technical data. Extent of utilization of project data by industrial firms to influence investment in solar-based power generation capacity.
GOVT.-ST&FED: COST, TECH Environmental Financial - Proj.	Local officials including those representing minority groups such as Indians. State officials, federal & federal agency officials.	Degree of endorsement and support of commercial development of solar resources.	Scientific analyses of technical data (particularly environmental). Extent of enhancement of local employement opportunities during plant construction and operation phases.
NO[illegible]RIC APPLICATIONS: CO[illegible]CH Prod. System Financial - Proj., Corp. Environmental	Corporate Officers, Boards of Directors and Project Managers of firms interested in non-electric applications. Individual members of commercial firms' new product development departments.	Assessment of the commercial viability of solar resource development. Improvement of established non-electric applications. Development of new non-electric applications.	Capital investment required for commercialization to include environmental considerations. Projection of demand for customer products and services derivable at least in part from solar resources.



VICINITY MAP

NO SCALE

Figure 18

A building to house a Visitors Information Center has been constructed at the Barstow site. During the test program, the Center will serve to disseminate information about the pilot plant and solar thermal power systems to the general public.

The most important modes of technology transfer during the Test and Evaluation period will be (1) the publication of articles and topical reports, and (2) the presentation of papers to various groups, committees, and societies. These publications and presentations will be aimed at the various user audiences delineated in Table 7.

A. Project Advisory Committee

1. Tucson Gas and Electric Company
2. Colorado-Ute Electric Association, Inc.
3. Nevada Power Company
4. Bonneville Power Administration
5. Johnson Controls, Inc.
6. Bechtel Power Corporation

B. Project Review Committee

1. Sacramento Municipal Utility District
2. Pacific Gas and Electric Company
3. Public Service Company of Colorado
4. Hawaiian Electric Company, Inc.
5. The Washington Water Power Company
6. City of Tacoma, Department of Public Utilities
7. Bureau of Reclamation, Lower Colorado Regional Office
8. Public Service Company of New Mexico
9. Stone and Webster Engineering Corporation

Figure 19 Technology Review Committees

Reference Documents

1. "Overall Plant Design Description," OPDD 40-0-800-IDD, March 1979

2. "10 Mwe Solar Thermal Central Receiver Pilot Plant - Operational Test Requirements," SAND 79-8037, June 1981

3. Briefings at McDonnell Douglas - Huntington Beach, primarily:
   a) "Fourth Project Design Review (RADL Item 1-5)," March 25-27, 1981
   b) "Solar One Plant Control Seminar," Feb. 25-26, 1981

4. S. D. Elliott, Jr., "10-MWe Pilot Plant Operational Plans," Paper presented at Solar Central Receiver Annual Meeting, held at Claremont, Ca., October 13-15, 1981

5. "Plant Operating/Training Manual (RADL Item 2-36), Book 1 - Operating Instructions," SAN/0499-83 (MDAC G9707), July 1981

6. Heat and Mass Balance Design Analysis (RADL Item 2-15), SAN/0499-47 (MDAC G8255), Revised February 1980

7. F. Turner, R. Woodhouse and R. Lindberg, "Environmental Monitoring at the 10 Mwe Pilot Solar Thermal Power Plant at Barstow, California," draft copy dated May 1981

8. C. Lopez, "Solar One Operation & Maintenance," pass-out material presented at joint meeting of DOE/SCE/Sandia/Aerospace/ETEC, held on May 13, 1981

9. "Instrument List," computerized printout dated Oct. 21, 1981 of Solar One instruments, compiled by Wilson Wong and R. Miller, MDAC-HB

10. "10 MWe Solar Thermal Central Receiver Pilot Plant - Pilot Plant Startup and Acceptance Test Plan (RADL Item 2-46)," SAN/0499-78 (MDAC-G9330), June 1981

11. R. N. Schweinberg and J. N. Reeves, "10 Mwe Solar Thermal Central Receiver Pilot Plant," Paper presented at Solar Central Receiver Annual Meeting, held at Claremont, Ca., October 13-15, 1981.

12. "Operational Test Management Plan - 10 Mwe Solar Thermal Central Receiver Pilot Plant," U.S. Department of Energy, to be published

13. "10 Mwe Solar Thermal Central Receiver Pilot Plant, Pilot Plant System Description (RADL Item 2-1)," SAN/0499-57 (MDC-G8544), December 1980

14. "Instrumentation Requirements for Test and Evaluation of the Solar 10 MW Pilot Plant, Rev. 2" ETEC Letter (79ETEC-DRF-2886) to DOE-STMPO, dated September 12, 1979

15. DOE/SCE Workshop Meeting of Program Participants and Interested Utilities to Discuss Barstow Repowering Options, held at Southern California Edison, Rosemead, California, Dec. 3-4, 1980.

16. "Information Exchange Meeting on Pilot Plant Data Requirements for Operational Test Phase," Joint meetings between Sandia-Livermore and ETEC on April 28, 1981, June 16, 1981 and July 13, 1981

17. Discussions with D. L. King at CRTF - SNLA, July 1981

18. "Environmental Reflectance Degradation of CRTF Heliostats," by D. L. King and J. E. Meyers, Proceeding of SPIE Symposium, Optics in Adverse Environment, Los Angeles, California, February 4, 1980

19. The Development of a Portable Specular Reflectometer for Field Measurement of Solar Mirror Materials," by J. M. Freese, SAND-1918, October 1978

20. "Water Treatment Practices for Cyclic Operation of Utility Boilers" by F. Gabrielli and W. R. Sylvester, presented at International Water Conference of Engineers Society of Western Pennsylvania, Oct. 31-Nov. 2, 1978, Pittsburgh, Pa.

21. Discussions with Duncan Tanner, October 28, 1981, on heliostat data recording.

APPENDIX A

APPENDIX A

TEST SPECIFICATIONS

FOR

INITIAL TWO-YEAR

EXPERIMENTAL PHASE

OF

PILOT PLANT OPERATIONAL TESTING

APPENDIX A

Introduction to Test Specifications

A number of requirements of the test program are common to all tests. Therefore, several paragraphs follow which discuss some of these common factors.

1) Definition of "Stable Operation"

   Stable operation is defined in terms of acceptable variation in process variables over a stated period of time. For all steady state-tests, process variables shall indicate proper values - at the given conditions for individual tests - within ±2% for at least one hour. In the event of a cloud transient, the one-hour time period need not be continuous _if_ the process variables return to 95% of their pre-transient values within 10 minutes and continue within the tolerance given. This definition applies regardless of the mode of control used during testing. However, the tolerance on variables may have to be revised under the various control configurations.

2) Heliostat Requirements History

   Several of the test specifications request determination of the number* of heliostats needed to supply enough heat to satisfy power generation requirements and system losses. These data are to be recorded and must include time-of-day, day-of-year, and solar insolation intensity. This action is to result in compilation (over an extended period) of a tabular matrix of heliostat requirements for each mode of operation, over the full range of power levels, and as affected by day-of-the-year. These data will be useful to plant operators in helping to permit more accurate pre-scheduling of mode and power level for each days operation, and will also provide information to evaluators in comparing predicted with actual heliostat count.

*Also include the individual heliostat identification numbers so that location of the active heliostats in the heliostat field can be inferred.

3) Transition Timing Requirements

Most of the normal transition tests require determination of minimum time to accomplish the transition. This minimum time is to be reckoned in terms of an orderly, deliberate, and completely controlled transition. Different operators will chose to effect transitions in slightly different ways - with the result that these times will vary, acceptably. Five tests, the "Transition-Timing" series, however, are to be done on an expedited, rapid-fire action basis. This information is needed to evaluate means of minimizing start-up and shut-down times.

4) Boiler Feedwater Quality Records

Many of the test specifications request recording of feedwater quality at certain times. It is recognized that SCE will constantly monitor and record feedwater quality without respect to the test program. When test specifications request such data, it means simply that the chief operator on duty during test performance must assure the appropriate transfer of the data from the SDPC's to the DAS.

5) General Data Requirements

The data requirements for the test matrix vary, but a substantial body of data is common to all tests. In order to minimize data listings with the individual tests, common requirements have been identified for three of the plant systems in the following paragraphs:

A. Receiver System (RS)

All times during which the RS is in operation, data are to be recorded in the DAS in order to permit both near-real-time and post-test evaluation of plant and component performance. In general, all RS data points connected to the DAS and those OCS points available to the DAS will be recorded continuously during test operation. The paragraphs below identify either data or calculated values that are required from the RS. Because different tests have varying requirements, not all of these statements apply to all tests; individual test specifications call out the applicable paragraphs by number.

Data and calculated values required during operation of the RS are as follows:

1) Determine axial thermal gradients along receiver panels.

2) Determine total insolation impinging on receiver panels; consider preheater and boiler panels separately.

3) Measure expansion and, if any, distortion of panels.

4) Determine maximum and minimum heat flux on receiver; correlate with portion of heliostat field in service and also with aiming strategy, if appropriate.

5) Determine heat losses from receiver assembly. (For this calculation, include panels and piping between inlet and outlet valves.)

6) Determine heat losses for downcomer.

7) Determine heat losses from feedwater piping at tower; i.e.: riser, ring header, and connections.

8) Determine mass-energy balance for preheat panels and boiler panels under steady-state (or nearly steady-state) conditions. This calculation should be made for overall receiver performance, for sections of 3 panels, and for the two highly isntrumented panels. One set of calculations should be done for each discrete power level called for in the individual tests.

9) Monitor the temperature of the receiver support structure. Review after each test for maximum values occurring during operation at stated conditions for each test.

10) Monitor pressure drop across the panels:

    a) for preheater panels PI-2002 less PI-2006

    b) for boiler panels (in parallel) PI-2006 less PI-2902

    c) for entire receiver assembly, PDT-2008

B. Electrical Power Generating System (EPGS)

All times during which the EPGS is in operation, data are to be recorded in the DAS in order to permit both near-real-time and post-test evaluation of plant and component performance. In general, all EPGS data points connected to the DAS, and those of OCS available to the DAS, will be recorded continuously during system operation. The paragraphs below identify both data and calculated values that are required from the EPGS.

Data requirements for the EPGS are as follows:

1) Generator gross output
2) Auxiliary power (in EPGS)
3) Condenser duty
4) T-G set efficiency (intermittent checks)
5) Plant heat rate - using for the input energy the calculated value of heat transferred into the receivers.

C. Thermal Storage System (TSS)

Data are to be obtained to satisfy the following objectives any time that the TSS is in service. Applicable paragraphs are called out in the individual test specifications.

1) Charging Loop

   a) Determine the number of heliostats required to provide for losses and energy transfer to the TSS to accomplish minimum, maximum and at least three other charging rates under CO operation.

   b) Obtain heat balance on TSS charging heat exchangers (E301, E302, E311, E312).

      Calculate heat transfer coefficients (both U and h) for each exchanger.

      Maintain record of heat transfer characteristics as a function of both load and time.

      Cross check results against parallel units.

c) Determine stability of steam temperature control and pressure regulation when

1) desuperheat is in operation with rated steam from RS; and
2) when de-rated steam is supplied from RS.
(Sensor points PIX3311, TEX3350, FIX3305.)

d) Obtain oil-side pressure-drop values across each heat exchanger in the charging loop. (Initially, these data are to be evaluated every two hours of TSS operation. Frequency of evaluation may be stretched out after stable operations have been demonstrated; that is, after Caloria decomposition rates are established.)

e) Verify stable operation of the TSS charging loop under both minimum and maximum flow conditions (charge rates) as given in Reference 4, page 9 and page 23.

f) Determine heat losses for entire charging loop.

2) Extraction Loop

a) Obtain heat balances on extraction loop heat exchangers E305, E306, E307 and E308.

Calculate heat transfer coefficients (both U and h) for each unit Maintain record of heat transfer characteristics as a function of load and time.

Cross check results against parallel units.

b) Obtain oil-side pressure drops across each heat exchanger in the extraction loop. (Initially, these data are to be evaluated every two hours of TSS extraction loop operation. Frequency of evaluation may be stretched out after degredation effects on the Caloria are established.)

c) Obtain water/steam side pressure drop on boiler units (E305, E306).

d) Verify stable operation of the extraction loop under maximum and minimum design flow conditions as given in Reference 4, page 27 and page 75.

e) Determine heat losses for the extraction loop.

3) TSU and Common

a) Determine the thermocline interval to the TSU and the temperature gradient on the tank surface during operation of both Modes 5 and 6. Thermocline data is also to be recorded during periods when heat is being stored and Caloria is not flowing.

b) 1) Obtain chemical analyses of TSS heat transfer fluid ("Caloria" oil), reporting both normal constituents, decomposition products and contaminants. Determine rate of Caloria decomposition as a function of time, temperature and load/duty factors.

2) Determine Caloria make-up rates.

c) Determine heat losses, both earth and air, from the TSU during charging and discharging operations and during heat storage periods.

d) Determine thermal storage capacity of the TSU.

Test Specification SS 1-4
Steady-State
Tests SS-1, -2, -3, -4

Description

Operate the Pilot Plant in Mode 5, Storage Charging, (SC), at four different power levels (heat transfer rates):

Test SS-1	30,000 lb/hr TSS steam flow
Test SS-2	60,000 lb/hr TSS steam flow
Test SS-3	114,000 lb/hr TSS steam flow
Test SS-4	130,000 lb/hr TSS steam flow

Objectives

1. Demonstrate stable operation* of the Pilot Plant during SC operation at the four stated power levels.

2. Determine the number of heliostats required to provide for energy transfer to the TSS and losses to accomplish each of the four charging rates.**

3. Obtain heat balances on TSS charging heat exchangers (E301, E302, E311, E312) and determine the heat transfer characteristics of these units in the "new and clean" condition.

4. Observe the behavior of the TSU thermocline as a function of charge rate, time, and initial condition.

5. Determine stability of steam temperature control and pressure regulation when 1) desuperheater is in operation with rated steam from RS; and 2) when derated steam is supplied from RS. (Sensor points PIX3311, TEX3350, FIX3305).

6. Observe detailed performance of the UMU including monitoring of the composition of TSU cover gas.

7. Obtain operating data from the CS & RS during Mode 5 operation as specified under "General Objectives" paragraph numbers RS 1 thru 10.

8. Obtain initial baseline data on heat losses from the TSS system under Mode 5 operation.

9. Demonstrate capability to fully charge the TSU. Verify maximum charge rate (Test SS-4) to confirm design sizing of equipment at rated conditions.

* See definition under the "Introduction to Test Specifications".

** Refer to comments on this requirement under "Introduction to Test Specifications."

10. Verify reduced flow requirements as "cold oil" temperature rises above 425°F.

11. Verify proper operation of control system components involved in Mode 5 operation.

Initial Conditions & Prerequisites

1. Entire plant inoperative (Mode 8).

2. All equipment required to permit "Storage Charging (SC-Mode 5) operation in either manual or semiautomatic control modes is operative and available.

3. The TSU is thermally charged to no more than 10% of its design thermal capacity.

Test Conditions

Clear weather.

EPGS not involved.

Test Sequence

Starting from Mode 8 (inactive) establish Mode 5 operation.

SC operation with steam to TSS at 1465 psia, 650°F and flow of 30,000 lb/hr (Test SS-1) to either one of the two condensers (E311 or E312). Remain at steady state conditions for 1 hour minimum, and obtain data.

. SC to inactive.

NOTE: Performance of this test series will result in progressive charging of the TSU. When the TSU becomes fully charged, it will be necessary to do some portion of test series SS 5-8, operating in Mode 6, Storage Discharge (SD). Tests SS-1 and SS-5 must be done first in their respective series, but the sequence of the rest of these two series may be ordered as required to store heat in or reject heat from the TSU.

Completion Criteria

Stable operation in Mode 5 has been demonstrated at the four power levels shown under "Description".

Data requirements have been satisfied.

Primary Data Requirements

1. All T's, P's, and F's in the TSS charging loop (including the TSU and desuperheater).

2. Identity of heliostats used during each test.

3. Normal CS operating data.

4. All UMU operating data.

5. Chemical analysis of Caloria before and after test series.

6. Water analysis of condensate, using sample point at #1 FWH outlet; sample to be obtained just prior to starting each test.

7. Parasitic power consumption, determined during operation at the four full stated test conditions.

8. Calculated values required

   a. Heat rate into TSS loop.

   b. Heat rate into Caloria.

   c. Log mean Δ T across charging heaters.

   d. Heat balance of charging heaters.

   e. Overall U and shell-side & tube-side h values.

   f. Heat losses from TSS piping and vessels; TSU earth and air losses separately identified.

   g. Maximum heat capacity of TSU (as experimentally determined).

Special Requirements

Initially, in Test SS-1, steam flow should be directed through one of the two parallel condenser/subcooler paths. Tests SS-1 and SS-2 should be repeated using the alternate flow path to that initally used. Evaluation of equipment performance includes comparing results of the two flow paths.

Test Specification SS 5-8
Steady State
Tests SS-5, -6, -7, -8

Description

Operate the Pilot Plant in Mode 6, Storage Discharge (SD) at four different power levels:

Test SS-5 30,000 lb.hr Turbine Admission Steam

Test SS-6 55,000 lb/hr Turbine Admission Steam

Test SS-7 85,000 lb/hr Turbine Admission Steam

Test SS-8 110,000 lb/hr Turbine Admission Steam

Objectives

1. Demonstrate stable operation* of the Pilot Plant during Mode 6 (SD) at the four stated power levels.

2. Obtain heat balances on TSS extraction heat exchangers (E305, E306, E307, and E308) and determine their heat transfer characteristics in the "new and clean" condition.

3. Obtain oil-side pressure drop on the heat exchangers during each test in order to establish a long-term record of any degradation of operation.

4. Observe the behavior of the TSU thermocline as a function of extraction rate, time, and initial condition.

5. Determine stability of steam conditions, i.e., temperature, pressure, and flow at the Turbine Admission valve supply.

6. Observe detailed performance of the UMU including monitoring of the composition of TSU cover gas.

7. Obtain operating data from EPGS during Mode 6 operation as specified under General Objectives paragraph for the EPGS.

8. Obtain initial data on heat losses from the TSS during Mode 6 operation.

9. Verify the maximum design-heat-extraction rate to confirm design sizing of equipment at rated conditions.

10. Verify proper operation of control system and computer components involved in Mode 6 operation.

* See definition under the "Introduction to Test Specification."

Initial Conditions & Prerequisites

1. Entire plant inoperative (Mode 8).
2. All equipment required to permit "Storage Discharge" (Mode 6) operation is operative and available. Control components required for either manual or semiautomatic control modes are also operative and available.
3. The TSU is thermally charged to a minimum of 50% of its design capacity.

Test Conditions

Only TSS extraction loop and EPGS active.
CS, RS, and TSS charging loop inactive.
Weather not involved.

Test Sequence

Starting from Mode 8 establish Mode 6 operation.

Mode 6 operation with steam to turbine admission valve at 385 psia and 525^{o}F with a flow of 30,000 lb/hr (for Test SS-5) from one of the two flow paths.

Remain at steady state conditions for 1 hour minimum and obtain required data.

Mode 6 to Inactive.

NOTE: Performance of this test series will result in progressive discharging of the TSU. It will become necessary to shift to Mode 5 operation to recharge the unit. Test SS-5 must be done first; thereafter the sequence of runs may be interspersed with series SS 1-4 tests to reject or store heat as required.

Completion Criteria

Stable operation in Mode 6 has been demonstrated at the four power levels shown under "Description".

Data requirements have been satisfied.

Primary Data Requirements

1. All T's, P's, and F's in the TSS extraction loop (including the TSU), and in the EPGS.
2. All UMU operating data.
3. Chemical analysis of the caloria after each test.
4. Analysis of feedwater to extraction boiler taken just before each test and once during full operating conditions of each test.
5. Parasitic power consumption, obtained during operation at the four stated test conditions.

6. Calculated values required:

   a. Heat rate out of TSU.

   b. Cycle heat rate.

   c. Heat balances for the extraction preheater, boiler, and superheater.

   d. Overall U and shell-side and tube-side h values.

   e. Heat losses from TSS extraction loop piping and vessels; TSU earth and air heat losses.

Special Requirements

Initially in Test SS-5 steam will be generated in only one flow path of the extraction loop. Tests SS-5 and SS-6 should be repeated using the alternate flow path to the one used the first time. Evaluation of equipment performance includes comparing results of the two flow paths.

Test Specification SS-9-12
Steady State
Tests SS-9, -10, -11, -12

Description

Operate the Pilot Plant in Mode 4, In-Line Flow (ILF) at the four different flow rate combinations shown below:

Test	TS Charge Flow, lb/hr	Turbine Admission Flow, lb/hr	Gross Power Output, Mwe
SS-9	65,000	43,000	2.7
SS-10*	130,000	45,000	2.9
SS-11*	130,000	109,000	7.4
SS-12	130,000	109,000	7.4

Objectives

1. Demonstrate stable operation**of the Pilot Plant during Mode 4 In-Line Flow (ILF) operation at the four stated power level combinations under both steady state and cloud transient conditions.

2. Determine the number of heliostats required to provide energy transfer in Mode 4 operation at each of the four tests listed above.

3. Obtain heat balances on TSS charging heat exchangers (E301, E302, E311, and E312) and determine the heat transfer characteristics of these units.

4. Obtain heat balances on TSS extraction heat exchangers (E305, E306, E307 and E308) and determine their heat transfer characteristics.

5. Obtain oil-side pressure drop on the heat exchangers during each test in order to establish a long-term record of any degradation of operation.

6. Observe the behavior of the TSU thermocline as a function of the combined charge/extraction rate, time, and initial condition.

7. Determine stability of steam temperature control and pressure regulation when 1) desuperheater is in operation with rated steam from RS; and 2) when derated steam is supplied from RS. (Sensor points PIX3311, TEX3350, FIX3305).

* Tests 10 and 11 require all drains from Feedwater Heater #2 to be routed to the condenser (see H&MB 4-2 and 4-3 in Ref. 4)

** See definition under the "Introduction to Test Specifications".

8. Determine stability of steam conditions, i.d., temperature, pressure, and flow, at the Turbine Admission valve supply.

9. Observe detailed performance of the UMU including monitoring of the composition of TSU cover gas.

10. Obtain complete operating data from the CS, RS, EPGS, and TSS during Mode 4 operation as specified under General Data Requirements for those systems.

11. Obtain heat-loss data for all operating systems.

12. Verify proper operation of control system and computer components during Mode 4 operation; particular attention is to be given to response of the MCS during cloud transients.

13. Evaluate time requirements for each modal transition that is executed during performance of this test series.

Initial Condition

Plant to be inoperative in any shutdown status (as defined in Operating Instruction S-1).

Entire plant must be operable and available.

All SS 1-8 tests should have been completed utilizing the semiautomatic control mode.

· TSU charged to the range of 50-70% of capacity.

Test Conditions

Partially cloudy or clear weather.

Test Sequence

Starting from inactive status take necessary steps to attain Mode 4 operation.

Establish Mode 4 conditions of 43,000 lb/hr admission steam and 65,000 lb/hr TSU charging flow (Test -9) and maintain for two hours of stable operation, then complete tests SS 9-12 in any order. It would be desirable for test SS-9 to be done on a clear day and be repeated on a cloudy day to assess cloud transient operation.

NOTE: This test series requires two sequential transitions.* Special attention is to be given to performing required transitions by both manual and semiautomatic control modes. By properly recording data during these transitions, the need to perform equivalent tests in the NT series may be satisfied.

Completion Criteria

Stable operation in Mode 4 has been demonstrated in all four power level combinations shown under "Description" above.

* See Figure 2 in Book I of the Plant Operating/Training Manual (RADL 2-36) for alternative paths.

Modal transitions required for this test shall have been demonstrated to be properly controlled and result in smooth transfer from one mode to the next.

Primary Data Requirements

1. All T's, P's, and F's in the TSS charging loop, the TSS extraction loop, the TSU, the EPGS, and the RS.

2. Normal CS operating data.

3. Chemical analysis of the Caloria before the first and after the last test of this series.

4. Analysis of feedwater to the RS (sample station at #1 Heater outlet) taken just before each test and, once during full operating conditions of each test.

5. Parasitic power consumption, obtained during operation at the four stated test conditions.

6. Calculated values required:

   a. Heat rate CS to RS.

   b. Heat rate RS to TSS

   c. Heat rate out of TSS.

   d. Heat rate into turbine.

   e. Cycle heat rate

   f. Heat balances for TS charging heaters and extraction preheater, boiler, and superheater; overall U and shell side and tube side h values.

   g. Heat losses for entire plant, calculated by system.

7. Prepare an "energy staircase" for the full rated conditions of test SS-12.

Special Requirements

None

Test Specification SS-13-16
Steady State
Tests SS-13, -14, -15, -16

Description

Operate the Pilot Plant in Mode 1, Turbine Direct (TD) at four different power levels:

Test	Turbine Throttle Flow, lb/hr	Gross Electrical Output, Mwe
SS-13	30,000	2.7
SS-14	56.00	5.9
SS-15	105,000	10.0 (net)
SS-16	112,000	12.5

Objectives

1. Demonstrate stable operation* of the Pilot Plant during Mode 1 (TD) at each of the four stated power levels under sun-following control.

   On test SS-15, the objective is the 10 Mwe net power output; the steam flow is to be adjusted as necessary to obtain the required power output.

2. Demonstrate proper operation of the MCS in the three control modes - manual, semi-automatic and fully automatic, under the sun-following control strategy.

3. Determine the number of heliostats required to operate the plant at the four power levels required (also includes identity).

4. Obtain heat loss values for the RS & EPGS.

5. Obtain heat balances on the RS and EPGS for each of the four tests.

6. Determine cycle heat rate for all four cases.

7. Obtain operating data from the RS during Mode 1 operation as specified under General Data Requirements.

8. Obtain operating data from the EPGS during Mode 1 operation as specified under General Data Requirements.

Initial Conditions & Prerequisites

Plant inactive
Heliostat field, the RS, and EPGS must be operative and available.

Test Conditions

Clear weather.
TSS not involved.

* See definition under "Introduction to Test Specifications".

Test Sequence

Inactive to Mode 1 operation.

Mode 1 operation with 30,000 lb/hr of steam at 1465 psia and 960°F to the turbine throttle (Test SS-13).

Continued Mode 1 test operation.

Return to inactive.

Success Criteria

Stable, steady-state operation of the plant in Mode 1 at the four power levels specified above.

Data requirements have been satisfied.

Primary Data Requirements

1. All T's, P's, and F's in the RS and EPGS; all normal CS operating data.
2. Parasitic power consumption, obtained during operation at the four stated test conditions.
3. Analysis of feedwater to the receivers taken just prior to each test and one during full test conditions. Sample to be obtained from outlet of #1 Heater.
4. All items called out in General Data Requirements for the RS and EPGS.
5. Calculated values
   - a. Total system heat losses.
   - b. Cycle heat rate.

Special Requirements

Performance of this series of tests is mandatory. If weather conditions, season of the year, or other factors prevent proper conduct of these tests at the time of initial scheduling, they should be rescheduled in order to assure satisfactory completion. This is the basic normal way of operating a central-receiver plant.

Test Specification SS-17-20
Steady State
Tests SS-17, -18, -19, -20

Description

Operate the Pilot Plant in Mode 2, Turbine Direct and Charging at four different power levels:

Test	Turbine Throttle Flow, lb/hr	TS Charge Flow lb/hr	Gross Electrical Output, Mwe
SS-17	30,000	105,000	2.7
SS-18	60,000	60,000	6.3
SS-19	90,000	26,000	10.0
SS-20	114,000	20,000	12.8

Objectives

1. Demonstrate stable operation of the Pilot Plant during Mode 2 Turbine Direct and Charging Operation at the four stated power level combinations during both steady-state conditions and during cloud transients. Initially, the tests are to be manually controlled under both sun-following and load-following control strategies. At a later time these tests should be repeated with fully-automatic control.

2. Determine the number of heliostats required to operate the plant at the four steady-state power levels required.

3. Obtain heat balances on TSS charging heat exchangers (E301, E302, E-311 and E312) and determine the heat-transfer characteristics of these units at the four steady-state conditions listed.

4. Observe the behavior of the TSU thermocline as a function of the charge rate, time, and initial condition.

5. Determine stability of steam temperature control and pressure regulation when 1) desuperheater is in operation with rated steam from RS; and 2) when derated steam is supplied from RS. (Sensor points PIX3311, TEX3350, FEX3305).

6. Observe detailed performance of the UMU including monitoring of the composition of TSU cover gas.

7. Obtain complete operating data from the CS, RS, EPGS, and TSS during Mode 2 operation as specified under General Data Requirements.

8. Obtain heat loss-data for all operating systems.

Initial Conditions

1. The plant inoperative.
2. The TSS charged to less than 25% of design capacity.

Test Conditions

Both clear days and partially cloudy days are required.

Test Sequence

Starting from inactive status or from either Modes 1 or 5, make transition to Mode 2.

In Mode 2, adjust steam flow to the turbine throttle at 30,000 lb/hr and admission flow to 105,000 lb/hr (for Test SS-17). Continue for 2 hours of steady-state conditions.

Effect transition to Mode 5 (storage charging) and then to inactive.

Tests in this series may be done in any order; however, operational test data must be obtained under both clear and partially cloudy weather conditions.

Completion Criteria

Stable operation in Mode 2 has been demonstrated at the four power levels shown under "Description". Data requirements have been satisfied.

Primary Data Requirements

1. All T's, P's, and F's in the RS, EPGS, and in the TSS Charging Loop (including the TSU).
2. Normal CS and SHIMMS data.
3. All UMU operating data.
4. Chemical analysis of the caloria before the first and after the last test of this series.
5. Parastic power consumption, obtained during operation at the four stated test conditions.
6. Obtain oil side pressure drop on the heat exchangers during each test in order to establish a long-term record of any degradation of operation (refer to Paragraph IV, C.2).
7. Calculated value required:
   a. Heat rate CS to RS.
   b. Heat rate RS to TSS.
   c. Heat rate into turbine.
   d. Cycle heat rate.
   e. Heat balance for TS charging heaters; overall heat transfer coefficient, U, and shell and tube side film coefficients, h.

f. Heat losses from TSS charging-loop piping and vessels; TSU earth and air heat losses.

g. Determine thermal storage capacity of the TSU.

h. Prepare an energy staircase for the steady-state condition for Test SS-20 only.

Special Requirements	None

Test Specification SS-21-24
Steady State
Tests SS-21, -22, -23, -24

Description

Operate the Pilot Plant in Mode 3, Storage Boosted, at four different power levels:

Test	Turbine Throttle Flow, lb/hr	Turbine Admission Flow, lb/hr	Gross Electrical Output, Mwe
SS-21	105,000	5,500*	12.2
SS-22	90,000	25,000	11.9
SS-23	60,000	60,000	10.8
SS-24	30,000	85,000**	9.6

Objectives

1. Demonstrate stable operation of the Pilot Plant during Mode 3 Storage Boosted operation at the four stated power levels both in steady-state and cloud transients under a "Load-Following" control strategy.

2. Determine the number of heliostats required to operate the plant at steady-state at the four power level combinations required. Also include identity of heliostats.

3. Obtain heat balances on TSS extration preheater, boiler, and superheater and determine the heat transfer characteristics of these units.

4. Observe the behavior of the TSU thermocline as a function of the extration rate, time, and initial conditions.

5. Determine stability of steam conditions; i.e., temperature, pressure, and flow, at the turbine admission valve.

6. Observe detailed performance of the UMU including monitoring of the composition of TSU cover gas.

7. Obtain heat loss data for all operating systems.

* Design throttle flow combined with minimum flow through one TSS discharging loop.

** Turbine admission flow is to be maximized with the minimum throttle flow.

Initial Conditions

1. The plant inoperative - in Mode 8 status S-1.3.

2. The TSU is thermally-charged to a minimum of 75% of its design capacity.

Test Conditions Both clear days and partially cloudy days are required for these tests.

Test Sequence Starting from inactive status, Mode 8, or either Modes 1 or 6, make the transition to Mode 3. Perform the tests in any order while holding each test for a minimum of one hour at stable conditions. Upon test completion, effect the transition to Mode 6 and then to inactive status. Performance of the plant is to be evaluated on both clear and partially cloudy days.

Completion Criteria Stable operation in Mode 3 has been demonstrated at the four power levels shown under "Description". Data requirements have been satisfied.

Primary Data Requirements

1. All T's, P's and F's in the RS, EPGS, and in the TSS extration loops (including the TSU).
2. All normal CS and SHIMMS operating data.
3. All UMU operating data.
4. Chemical analysis of the Caloria before the first and after the last test in this series.*
5. Parastic power consumption, obtained during operation at the four stated test conditions.
6. Calculated values required:
   a. Heat rate CS to RS.
   b. Heat rate out of TSU.
   c. Heat rate RS to turbine throttle.
   d. Heat rate TSS to turbine admission.
   e. Cycle heat rate.
   f. Heat balances for the extration preheater, boiler, and superheater (all six).
   g. Overall heat transfer coefficient, U, and shell-side and tube-side film coefficients, h, for each of the extraction heat exchangers.
   h. Heat losses from TSS extration loop piping and vessels; TSU earth and air heat losses.
   i. Prepare an energy staircase for steady-state conditions for Test SS-24 only.

Special Requirements None

* This requirement may be waived, or samples taken less frequently as data indicates a stable caloria condition.

Test Specification SS-25-28
Steady State
Tests SS-25, -26, -27, -28

Description

Operate the Pilot Plant in Mode 7, Dual Flow, at four different power levels:

Test	Turbine Throttle, Flow, lb/hr	TS Charge Flow, lb/hr	Turbine Admission Flow, lb/hr
SS-25	60,000	40,000	55,000
SS-26	30,000	20,000	85,000
SS-27	30,000	100,000	85,000
SS-28	30,000	130,000	40,000

Objectives

1. Demonstrate stable operation of the Pilot Plant during Mode 7, Dual Flow, at the stated power levels during steady-state conditions and cloud transients. The tests are to be operated in two load-following control strategies (see comments under Special Requirements).
2. Determine the number of heliostats required to operate the plant at the four power levels required; also heliostat identity.
3. Obtain heat balances on TSS extraction preheater, boiler, and superheater and the charging heat exchangers and determine the heat transfer characteristics of these units.
4. Obtain oil-side pressure drop on the heat exchangers during each test in order to establish a long-term record of any degradation of operation.
5. Observe the behavior of the TSU thermocline as a function of the combined extraction and charge rate, time, and initial condition.
6. Determine stability of steam temperature control and pressure regulation when 1) desuperheater is in operation with rated steam from RS; and 2) when derated steam is supplied from RS. (Sensor points PIX3311, TEX3350, TIX3305.)
7. Determine stability of steam conditions; i.e., temperature, pressure, and flow, at the Turbine Admission valve supply.
8. Observe detailed performance of the UMU including monitoring of the composition of TSU cover gas.

9. Verify proper operation of control system and computer components during Mode 7 operation.

10. Evaluate time requirements for each modal transition that is executed during performance of this test series.

Initial Conditions

1. The plant inoperative.
2. The TSU charged to a range of 50-70% of design capacity.

Test Conditions

Clear weather and partially cloudy.

Test Sequence

Starting from inactive status, or from either of Modes 2, 3, or 4, make the transition to Mode 7. Perform the tests in any order while holding each test for a minimum one hour at stable conditions. Tests are to be performed on both clear days and partially cloudy days.

Completion Criteria

Stable operation in Mode 3 has been demonstrated at the four power levels shown under "Description". Data requirements have been satisfied.

Primary Data Requirements

1. All T's, P's, and F's in the RS, EPGS, and TSS.
2. Normal CS and SHIMMS operating data.
3. Chemical analysis of the Caloria before the first and after the last test in this series.
4. Parastic power consumption, obtained during operation at the four stated test conditions.
5. Obtain heat loss data for all operating systems.
6. Calculated value required:
   a. Heat rate CS to RS.
   b. Heat rate RS to EPGS.
   c. Heat rate RS to TSS.
   d. Heat rate out of TSU.
   e. Heat rate TSU to EPGS.
   f. Cycle heat rate.
   g. Heat balance for both the charging and extraction heat exchangers.
   h. Overall U and shell-side and tube-side h values.

i. Heat losses from TSS extraction and charging loop piping and vessels; TSU earth and air heat losses.

Special Requirements

1. Mode 7 tests are to be conducted in two variations of load following control strategies. The description of these strategies is repeated here from Plant Operating Training Manual (RADL 2-36):

   In the first approach to "load following" (similar to Mode 2 -- "load following"), load control is maintained by controlling the thermal storage charging steam flow while the turbine main steam control valves pass excess receiver steam. At the same time, the admission steam control valve pass a fixed admission steam flow. In the second approach to "load following" (similar to Mode 6 -- "Load following"), load control is maintained by controlling the admission steam flow to the turbine while the receiver steam is divided between the thermal storage charging equipment (fixed flow) and the turbine main steam control valves (excess receiver flow).

2. The gross electrical output was not included in the table of test conditions because that parameter is not a governing factor in this series of tests. The flow rates shown are governing. The operator's attention is called to the fact that three of these tests require a total combined flow through the turbine of the maximum value 115,000 lb/hr. It is recommended that the throttle flow be the governing factor, with admission flow adjusted to maximize turbine through-put, and TSS charge flow varying to strike a balance between total receiver flow and TSS discharging flow. Although Mode 7 is considered a transitional mode, it is necessary to evaluate plant operation in steady state in this mode.

Test Specification PP-1
Preliminary Power Production
Test No. PP-1

Description

Operate the plant to demonstrate sustained electrical power production for 30 test days (as nearly consecutive days as circumstances permit) when operating in the turbine-direct mode under the sun-following control configuration. This series of tests is designed to provide preliminary information in direct support of the repowering program on sustained clear-day operation of a hybrid solar-thermal power plant without any thermal storage capability.

Objectives

1. Provide performance data for sustained power production of a solar-thermal plant operating without a thermal storage system. Operation will be in the turbine-direct mode under the sun-following control configuration, utilizing the maximum number of heliostats for each operating day within equipment performance limitations.

2. Provide preliminary data as early as possible in support of the repowering program relative to sustained power production by the solar-portion of a hybrid solar-thermal power plant without thermal storage capability.

Initial Conditions

1. The plant is inoperative - in Mode 8 status S-1.3.
2. The TSU is not involved in these tests.
3. Required number of heliostats at "Standby."

Test Conditions

1. Clear weather.

Test Sequence

Starting from inactive status, Mode 8, go through startup to Mode 1. Perform startup as quickly as possible to bring plant on line as soon as possible during the operating day.

Prior to the start of the test select the number of heliostats required to maximize the electrical output at solar noon when operating in the Turbine Direct Mode. Bring these heliostats from "Standby" to their respective receiver aim points as required during startup. When all heliostats required have been brought on target leave them on target throught the operating day. During the operating day, remove heliostats from their respective aim points only if dictated by plant safety or by malfunction of individual heliostats or the associated heliostat field controller (HFC). In case of malfunction of only a small number of heliostats during the operating day, attempt to substitute other heliostats at equivalent locations in the collector field so that the number of targeted heliostats remains constant throughout the operating day. Continue Mode 1 operation for as long as possible as the end of the daylight period is approached; then take the plant to Inactive Mode, Mode 8, status S-1.3.

Completion Criteria

Stable operation has been demonstrated for 30 test days. Interruptions for significant time periods (more than one hour) caused by weather conditions or facility problems will be recorded and any such test days will not be counted as contributing towards the total number required for completion.

Primary Data Requirements

1. Electrical power output, net and gross throughout each operating day.
2. Cumulative electrical output, net and gross, in kilowatt-hours at the end of each test day.
3. Plant availability and capacity factor for the time period involved in this particular test.
4. Complete plant operating data is required each test day; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

Complete plant operating data should be collected and stored on magnetic tape in fulfillment of Item 4 under Primary Data Requirements. However, reduction and evaluation of <u>all</u> data for <u>each</u> operating day will not be required. Instead, upon completing the 30 test days specified, the Test Management Team will convene and select the particular items and test days for reduction and evaluation.

Test Specification PP-2
Preliminary Power Production
Test No. PP-2

Description

Operate the plant to demonstrate sustained electrical power production for 30 test days (in as short a period as possible) when operating in accordance with the clear-day scenario. Details of the clear-day scenario are shown in Figures A-1 and A-2. This series of tests is designed to provide preliminary information in direct support of the repowering program on sustained clear-day operation of a hybrid solar-thermal power plant with thermal storage capability.

Objectives

1. Provide performance data for sustained power production of a solar-thermal plant operating with a thermal storage system. Operation will be in accordance with the clear-day scenario (Figure A-1) utilizing the maximum number of heliostats for each operating day within equipment performance limitations.

2. Obtain data on plant operation in accordance with the clear-day scenario using the Beckman System Distributed Process Controller (SDPC). Compare the relative advantages and disadvantages of the SDPC with those of the OCS in making the transitions involved in the clear-day scenario.

3. Provide preliminary data as early as possible in support of the repowering program relative to sustained power production by the solar portion of a hybrid solar-thermal power plant with thermal storage capability.

Initial Conditions

1. The plant is inoperative - Mode 8, status S-1.3.

2. The TSU is operable and capable each test day of accepting all excess energy input over and above that required to deliver the maximum turbine output.

3. Required number of heliostats at "Standby."

Test Conditions

Clear weather.

Test Sequence

Start from Inactive Status, Mode 8.0 through the sequence of opreating modes and transitions indicated in Table 1.

When operating in Mode 6 in the evening, extract thermal energy from the TSU equivalent to that input during the preceeding hours of daylight. However, be sure to leave enough thermal energy for seal and blanket steam during the night and for startup the following day.

CLEAR-DAY SCENARIO

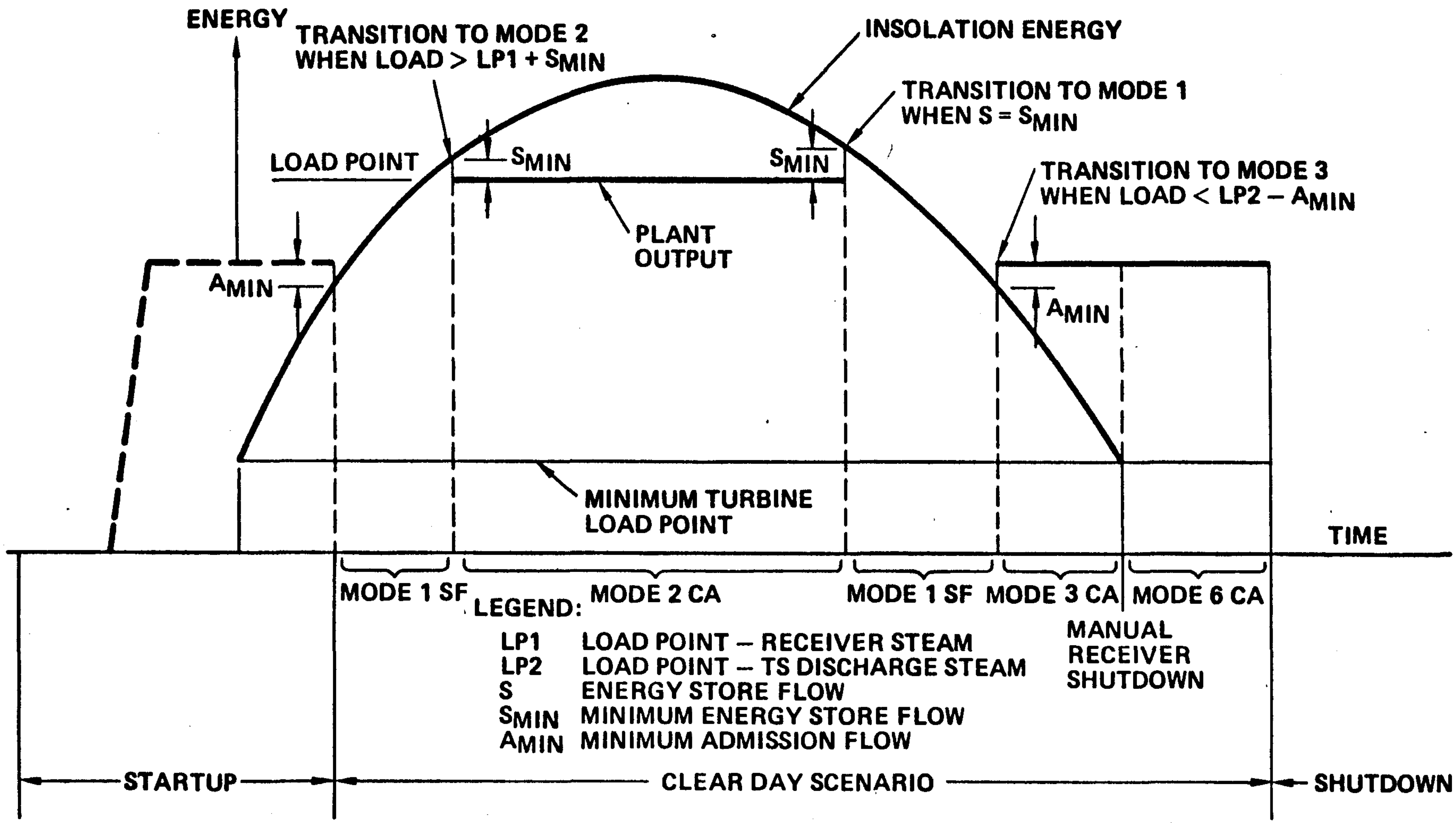


FIGURE A-1*

*From SAN/049-79 MDC G9362
"Solar One Plant Control Seminar," Feb. 25-26 1981

Figure A-2 Test No. ST-30 Operational Sequence

Operating Instructions Number for Status (S) or Transition (T)	Description of Plant Status Or Transition Between Operating Modes	Time During Test Day
S-1	Plant Shutdown in Mode 8, Inactive	Pervious Night
T-1	Preliminary Startup	Pre-dawn
S-2	Water Cleanup Complete and Ready to Start Major Steam Source	Pre-dawn
T-2	Transition to Receive Startup	Early Morning
S-3	Flow to Steam Dump System	Early Morning
T-4	Startup of Turbine Generator Using Receiver Steam	
S-5	Operation in Mode 1, Turbine Direct	Morning
T-7A	Transition from Mode 1 to Mode 2	Morning
S-8	Operation in Mode 2, Turbine Direct and Charging	Mid-day
T-7B	Transition from Mode 2 to Mode 1	Afternoon
S-5	Operation in Mode 1, Turbine Direct	Afternoon
T-10A	Transition from Mode 1 to Mode 3	Late Afternoon
S-9	Operation in Mode 3, Storage Boosted	Late Afternoon
T-9A	Transition from Mode 3 to Mode 6	Prior to Sunset
S-7	Operation in Mode 6, Storage Discharging	Early Evening
T-18	Transition to Mode 8, Inactive	Late Evening

Completion Criteria

Stable operation has been demonstrated for 30 test days. Interruption for significant time periods (more than one hour) caused by weather conditions or facility problems will be recorded and any such test days will not be counted as contributing towards the total number required for completion.

Primary Date Requirements

1. Electrical power output, net and gross throughout each operating day.

2. Cumulative electrical output, net and gross in kilowatt-hours at the end of each test day for each operation mode (Mode 1, 3, and 6).

3. Plant availability and capacity factor for the time period involved in this particular test.

4. Complete plant operation data is required each test day; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

Complete plant operating data should be collected and stored on magnetic tape in fulfillment of Item 4 under Primary Data Requirements. However, reduction and evaluation of all data for each operating day will not be required. Instead, upon completing the 30 test days specified, the Test Management Team will convene and select the particular items and test days for reduction and evaluation.

Test Specification SA-1

Safety Assessment

Test No. SA-1

Description	Safety Assessment Test No. 1--Loss of primary plant-electrical power with the plant operating in the Turbine Direct and Charging mode.
Objectives	Demonstrate the safe shutdown of the plant with emergency backup power following the loss of plant primary electrical power.
Initial Conditions	Plant operating in Turbine Direct and Charging mode, No. 2. The operating conditions from which this transition is to occur are:

Gross electrical output	6.6 Mwe
Turbine throttle flow	60,000 lb/hr
Steam flow to TSS (charge)	60,000 lb/hr

Test Conditions	Clear weather.
Test Sequence	Plant operating in the turbine direct and charging mode; Trip the plant main breakers; Shut down the plant on emergency power.
Completion Criteria	The plant safely shut down with no abnormal condition or incurred damage in any subsystem. Operating data during transient is properly recorded.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	This test is to be performed by an actual tripping of the plant main circuit breakers. Data points available for fast scanning shall be recorded for 30 seconds before and 2 minutes after the trip is effected. After two minutes, continue at normal scan rate for an additional hour.

Test Specification SA-2

Safety Assessment

Test No. SA-2

Description	Safety Assessment Test No. 2 involves a turbine generator trip while the plant is operating in Mode 2, Turbine Direct and Charging.
Objectives	Demonstrate the safe transition from Mode 2 to Mode 5, Charging Only, as a result of a turbine trip.
Initial Conditions	Plant operating in Mode 2 with these conditions: Gross electrical output 5.0 Mwe Turbine throttle flow 50,000 lb/hr TSS charging steam flow 60,000 lb/hr TSU charged to 80% of capacity.
Test Conditions	Clear weather.
Test Sequence	Plant operating in Mode 2; Turbine generator tripped; Transition to Mode 5.
Completion Criteria	Satisfactory and safe performance of the transition from Mode 2 to Mode 5 with no abnormal conditions resulting nor any system or equipment. Operating data have been properly recorded.
Primary Data Required	Complete plant operating data are to be recorded; this includes CS, RS, EPGS, TSS, and SHIMMS. Those instrument points available to fast scanning are to be recorded for at least 30 seconds before the trip and until 1 minute after completion of the transition, then 1 hour normal scan.
Special Requirements	This test is to be performed by an actual tripping of the turbine. It is to be noted that this test will result in a sudden surge in steam flow to the TSS charging loops. Special attention is to be given to determining whether system time constants are short enough to permit the TSS to pick up the additional steam input without causing the RS to trip.

Test Specification SA-3
Safety Assessment

Test No. SA-3

Description	Safety Assessment Test No. 3--Failure of control valve PV-1001 while plant is operating in Turbine Direct, Mode 1.
Objective	Demonstrate the safety shutdown of the plant following the failure (to fully closed) of the steam dump control valve.
Initial Conditions	Plant operating in Mode 1, at a power level of 2.7 MWe gross (minimum TG output) and under a "sun-following" control strategy.
Test Conditions	Clear weather.
Test Sequence	Plant operating in Mode 1; Valve failure initiated (see "Special Requirements" below); Automatic transition to shut down.
Completion Criteria	The safe shutdown of the plant following the valve failure with no damage incurred to any of the plant's systems. Operating data have been properly recorded.
Primary Data Required	Complete plant operating data are to be recorded; this includes CS, RS, EPGS, TSS, and SHIMMS. Those instrument points available to fast scanning are to be recorded for at least 30 seconds before the trip and until 1 minute after completion of the transition.
Special Requirements	This test is to be performed in several steps to permit observation of plant behavior. Under the initial conditions and with "sun-following" control, valve PV-1001 will be controlling steam pressure. The first test run should be made when a near-steady-state condition is established with PV-1001 in a 10-30% open position; the operator would then initiate the functional test by manually tripping the steam dump system, using HS-1001A, which will in turn result in RS trip, TG trip, and plant shutdown. A second run to be accomplished with the same power level but with PV-1001 in a 30-70% open position before trip. If the system responds properly, a third run should be made at a load of 6.0 MWe gross and valve PV-1001 at 60-80% open. At this point evaluation of results should permit the Test Manager to decide whether or not to perform an additional run at full power. The Chief Operator is requested to review Operating Instruction S-5 just prior to running this test.

Test Specification SA-4
Safety Assessment
Test No. SA-4

Description	Safety Assessment Test No. 4--Feedwater pump (P-917) trip with the plant operating in the Storage-Boosted mode, No. 3.
Objectives	Demonstrate the safe shutdown of the receiver following the trip of the feedwater pump while the TSS continues to supply turbine steam.
Initial Conditions	Plant operating in storage-boosted mode at: Gross turbine output ≈ 4.4 Mwe Steam flow to turbine throttle 30,000 lb/hr Steam flow to turbine admission 30,000 lb/hr TSU charged to 60-70% of capacity.
Test Conditions	Clear weather.
Test Sequence	Plant operating in the storage-boosted mode; Trip pump; Receiver shutdown transition from storage-boosted mode to storage-discharge mode (manual control).
Completion Criteria	Safe shutdown of the receiver and transition from Storage-Boosted mode to Storage-Discharge mode with no damage incurred in any plant system. Operating data have been properly recorded.
Primary Data Required	Complete plant operating data are to be recorded; this includes CS, RS, EPGS, TSS, and SHIMMS. Those instrument points available to fast scanning are to be recorded for at least 30 seconds before the trip and until 1 minute after completion of the transition, then 1 hour normal scan.
Special Requirements	Because of the potential for damage to the receiver panels if feedwater is cut off, this test is to be simulated rather than actual. A dummy signal is to be generated to cause the ILS to function - but without actually interrupting power flow to the pump P-917. Subsequent to performing this simulated test, a decision can be made whether or not to perform a similar run by actually tripping the pump. The flow rates shown above are the independent minimums for the two steam sources; the resulting power level should be accepted as experimentally produced - and is not a controlling factor.

Test Specification SA-5
Safety Assessment
Test No. SA-5

Description	Safety Asscessment Test No. 5--Receiver Panel leak while the plant is operating in the Turbine Direct mode, No. 1.
Objectives	Demonstrate the safe shutdown of the receiver and EPGS following a major leak in one of the boiler panels while the plant is operating in the Turbine Direct mode, No. 1.
Initial Conditions	Plant operating in the turbine direct mode at 5 MW_e, gross.
Test Conditions	Clear weather.
Test Sequence	Turbine direct mode at 5 MW_e gross; Initiate leak; Shut down plant.
Completion Criteria	Safe shutdown of the plant with no damage to any plant system. Operating data during transient is properly recorded.
Primary Data Required	Complete plant operating data is required; this includes the CS, RS, TSS, EPGS, and SHIMMS. Data points available for fast scanning shall be recorded from 30 seconds before leak initiation signal until 1 minute after shut down is accomplished. Thereafter, record 1 hour normal scan.
Special Requirements	Modify one north boiler panel over-pressure relief valve such that it may be manually remote-opened to simulate a panel leak.

Test Specification SA-6

Safety Assessment

Test No. SA-6

Description	Safety Assessment Test No. 6--Receiver Panel Flow Stoppage while the plant is operating in the Turbine Direct mode, No. 1.
Objectives	Demonstrate the safe shutdown of the receiver and EPGS following an abrupt flow stoppage in one boiler panel while the plant is operating in the Turbine Direct mode, No. 1.
Initial Conditions	Plant operating in the turbine direct mode at 5 MW_e gross.
Test Conditions	Clear weather.
Test Sequence	Turbine direct mode at 5 MW_e gross; initiate north boiler panel flow stoppage; shut down plant.
Completion Criteria	Safe shutdown of the plant with no damage to any plant system. Satisfactory recording of operating data during the transient.
Primary Data Required	Complete plant operating data is required; this includes the CS, RS, TSS, EPGS, and SHIMMS. Data points available for fast scanning shall be recorded for 30 seconds before flow stoppage is initiated and until 1 minute after shutdown is accomplished; 1 hour normal scan thereafter.
Special Requirements	Modify the receiver system controller such that one north panel inlet control valve can be commanded closed to simulate a complete panel flow stoppage.

Test Specification NT-1
Normal Transition
Test No. NT-1

Description	Normal Transition from Mode 5, Storage Charging, to Mode 2, Turbine Direct and Charging.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 5 to Mode 2 at the stated conditions. c) Gather data for system and equipment performance evaluation.
Initial Conditions	Plant operating in Mode 5. The operating condition from which this transition is to occur is a TSS charge steam flow of 30,000 lb/hr.
Test Conditions	Clear weather
Test Sequence	a) Establish Mode 5 at conditions stated. b) Effect transition to Mode 2 and establish a turbine throttle steam flow of 56,000 lb/hr and a TSS charging steam flow of 30,000 lb/hr. The resulting gross electrical output should be 5.9 Mwe.
Completion Criteria	A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.
Primary Data Required	Complete plant operating data is required; that includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	The procedure used to perform this test transition should be the same as Operating Instruction T-8b.

Test Specification NT-2
Normal Transition
Test No. NT-2

Description	Normal Transition from Mode 2, Turbine Direct and Charging, to Mode 5, Storage Charging.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 2 to Mode 5 at the stated conditions. c) Gather data for system and equipment performance evaluation.
Initial Conditions	Plant operating in Mode 2. The operating conditions from which this transition is to occur are: a) Gross electrical output: 5.9 Mwe b) Turbine throttle steam flow of 56,000 lb/hr. c) TSS charge steam flow of 30,000 lb/hr.
Test Conditions	Clear weather
Test Sequence	a) Establish Mode 2 at the conditions stated. b) Effect transition to mode 5 maintaining the charge steam flow of 30,000 lb/hr.
Completion Criteria	A smooth transition between Modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	The procedure used to perform this test transition should be the same as Operating Instruction T-8a.

Test Specification NT-3
Normal Transition
Test No. NT-3

Description	Normal Transition from Mode 5, Charge Only, to Mode 4, In-Line Flow.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 5 to Mode 4. c) Gather data for system and equipment performance evaluation.
Initial Conditions	Plant operating in Mode 5. The operating condition from which this transition is to occur is a TSS charge steam flow of 30,000 lb/hr.
Test Conditions	Clear weather.
Test Sequence	a) Establish Mode 5 operation at the condition stated. b) Effect the transition to Mode 4 and establish a turbine admission steam flow of 45,000 lb/hr while maintaining the TSS charge steam flow at 30,000 lb/hr. The resulting gross electrical output will be about 2.9 Mwe.
Completion Criteria	A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data has been properly recorded.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	Heater #2 drains should be routed to the condenser during Mode 4 Operation. The procedure used to perform the test transition should be the same as Operating Instruction T-11b.

Test Specification NT-4
Normal Transition
Test No. NT-4

Description

Normal transition from Mode 4, In-Line Flow, to Mode 5, Storage Charge.

Objectives

a) Demonstrate stable and smooth plant operation in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 4 to Mode 5 at the specified power levels.

c) Gather data for system and equipment performance evaluation.

Initial Conditions

Plant operating in Mode 4. Operating conditions from which this transition is to occur are:

a) Gross electrical output $\approx$ 2.9 Mwe

b) TSS charge steam flow of 30,000 lb/hr.

c) Turbine admission steam flow of 45,000 lb/hr.

d) TSU is charged to $<$ 60% of capacity.

Test Conditions

Clear weather.

Test Sequence

a) Establish Mode 4 at the conditions stated.

b) Effect transition to Mode 5 with the TSS charge steam flow remaining at 30,000 lb/hr.

Completion Criteria

A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.

Primary Data Required

Complete plant operating data are required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

The procedure used to perform this test transition should be the same as Operating Instruction T-11a. Heater #2 drains should be routed to the condenser during Mode 4 operation.

Test Specification NT-5
Normal Transition
Test No. NT-5

Description

Normal transition from Mode 6, Storage Discharging, to Mode 3, Storage Boosted.

Objectives

a) Demonstrate stable and smooth plant operation in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 6 to Mode 3 at the specified power levels.

c) Gather data for system and equipment performance evaluation.

Initial Conditions

Plant operating in Mode 6. Operating conditions from which this transition is to occur are:

a) Gross electrical output 1.7 Mwe

b) Turbine admission steam flow of 30,000 lb/hr.

c) TSU charged to >75% of capacity.

Test Conditions

Clear weather.

Test Sequence

a) Establish Mode 6 at the conditions stated.

b) Effect the transition to Mode 3 and establish the following flow rates:

Turbine throttle:	56,000 lb/hr
Turbine admission:	30,000 lb/hr
Gross Electrical Output:	7.3 MWe

Completion Criteria

A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.

Primary Data Required

Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

The procedure used to perform this test transition should be the same as Operating Instruction T-9B.

Test Specification NT-6
Normal Transition
Test No. NT-6

Description
Normal transition from Mode 3, Storage Boosted, to Mode 6, Storage Discharging.

Objectives

a) Demonstrate stable and smooth operation of the plant in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 3 to Mode 6, at the specified power levels.

c) Gather data for system and equipment performance evaluation.

Initial Conditions
Plant operating in Mode 3. Operating conditions from which this transition is to occur are:

a) Gross electrical output ≈7.3 Mwe

b) Turbine throttle steam flow of 56,000 lb/hr.

c) Turbine admission steam flow of 30,000 lb/hr.

d) TSU charge to >75% of capacity.

Test Conditions
Clear weather.

Test Sequence

a) Establish Mode 3 at the conditions stated.

b) Effect transition to Mode 6 with the turbine admission steam flow remaining at 30,000 lb/hr.

Completion Criteria
A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.

Primary Data Required
Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements
The procedure used to perform this test transition should be the same as Operating Instruction T-9A.

Test Specification NT-7
Normal Transition
Test No. NT-7

Description

Normal transition from Mode 6, Storage Discharging, to Mode 4, In-Line Flow.

Objectives

a) Demonstrate stable and smooth plant operation in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 6 to Mode 4, at the specified power levels.

c) Gather data for system and equipment performance evaluation.

Initial Conditions

Plant operating in Mode 6. Operating conditions from which this transition is to occur are:

a) Gross electrical output $\approx$2.9 Mwe

b) Turbine admission steam flow of 45,000 lb/hr.

c) TSU charged to >75% of capacity.

Test Conditions

Clear weather.

Test Sequence

a) Establish Mode 6 at the conditions stated.

b) Effect transition to Mode 4 retaining the turbine admission flow at 45,000 lbs/hr (and power output at 2.9 Mwe) and establish a TSS charging flow of 30,000 lb/hr.

Completion Criteria

A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager.

Primary Data Required

Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

The procedure used to perform this test transition should be the same as Operating Instruction T-12b.

Test Specification NT-8
Normal Transition
Test No. NT-8

Description	Normal transition from Mode 4, In-Line Flow, to Mode 6, Storage Discharging.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 4 to Mode 6 at the specified power levels. c) Gather data for system and equipment performance evaluation.
Initial Conditions	Plant operating in Mode 4. Operating conditions from which this transition is to occur are: a) Gross electrical output $\approx$ 2.9 Mwe b) Steam flow to TSS charge at 30,000 lb/hr. c) Turbine admission steam flow of 45,000 lb/hr.
Test Conditions	Clear weather.
Test Sequence	a) Establish Mode 4 at the conditions stated. b) Effect the transition to Mode 6 with the turbine admission steam flow remaining at 45,000 lb/hr.
Completion Criteria	A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	The procedure used to perform this test transition should be the same as Operating Instruction T-12a. Heater #2 drains should be routed to the condenser during Mode 4.

Test Specification NT-9
Normal Transition
Test No. NT-9

Description	Normal transition from Mode 1, Turbine Direct, to Mode 2, Turbine Direct and Charging.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 1 to Mode 2 at the specified power levels. c) Gather data for system and equipment performance evaluation.
Initial Conditions	Plant operating in Mode 1. Operating conditions from which this transition is to occur are: a) Gross electrical output $\approx$5.9 Mwe b) Turbine throttle steam flow of 56,000 lb/hr. c) TSU is charged to $>$75% of rating.
Test Conditions	Clear weather.
Test Sequence	a) Establish Mode 1 at the conditions stated. b) Effect the transition to Mode 2 and establish the following flow rates: Turbine throttle 56,000 lb/hr. TSS charging steam 30,000 lb/hr.
Completion Criteria	A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	The procedure used to perform this test transition should be the same as Operating Instruction T-7a.

Test Specification NT-10
Normal Transition
Test No. NT-10

Description	Normal transition from Mode 2, Turbine Direct and Charging, to Mode 1, Turbine Direct.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 2 to Mode 1 at the specified power levels. c) Gather data for system and equipment performance evaluation.
Initial Conditions	Plant operating in Mode 2. Operating conditions from which this transition is to occur are: a) Gross electrical output: 5.9 Mwe b) Turbine throttle steam flow of 56,000 lb/hr. c) TSS charge steam flow of 30,000 lb/hr.
Test Conditions	Clear weather
Test Sequence	a) Establish Mode 2 at the conditions stated. b) Effect the transition to Mode 1 with the turbine throttle steam flow remaining at 56,000 lb/hr.
Completion Criteria	A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.
Primary Data Required	Complete plant operating data is required that includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	The procedure used to perform this test transition should be the same as Operating Instruction T-7b.

Test Specification NT-11
Normal Transition
Test No. NT-11

Description

Normal transition from Mode 1, Turbine Direct, to Mode 3, Storage Boosted.

Objectives

a) Demonstrate stable and smoother plant operation in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 1 to Mode 3 at the specified power levels.

c) Gather data for system and equipment performance evaluation.

Initial Conditions

Plant Operating in Mode 1. Operating conditions from which this transition is to occur are:

a) Gross electrical output: 5.9 Mwe

b) Turbine throttle steam flow of 56,000 lb/hr.

c) TSU charged to 75% of capacity.

Test Conditions

Clear weather.

Test Sequence

a) Establish Mode 1 at the conditions stated.

b) Effect the transition to Mode 3 with the turbine throttle steam flow remaining at 56,000 lb/hr and establish a turbine admission steam flow of 30,000 lb/hr.

Completion Criteria

A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.

Primary Data Required

Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

The procedure used to perform this test transition should be the same as Operating Instruction T-10a.

Test Specification NT-12
Normal Transition
Test No. NT-12

Description	Normal transition from Mode 3, Storage Boosted, to Mode 1, Turbine Direct.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 3 to Mode 1 at the stated power levels. c) Gather data for system and equipment performance evaluation.
Initial Conditions	Plant operating in Mode 3. Operating conditions from which this transition is to occur are: a) Gross electrical output: 7.6 Mwe b) Turbine throttle steam flow of 56,000 lb/hr. c) Turbine admission steam flow of 30,000 lb/hr.
Test Conditions	Clear weather.
Test Sequence	a) Establish Mode 3 at the conditions stated. b) Effect the transition to Mode 1 with a turbine throttle steam flow of 56,000 lb/hr, with the corresponding gross electrical output of 5.9 Mwe.
Completion Criteria	A smooth transition between modes has been demosntrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data has been properly recorded.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	The procedure used to perform this test transition should be the same as Operating Instruction T-10b.

Test Specification NT-13
Normal Transition
Test No. NT-13

Description

Normal transition from Mode 7, Charging and Storage Boosted, to Mode 2, Turbine Direct and Charging.

Objectives

a) Demonstrate stable and smooth plant operation in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 7 to Mode 2 at the stated power levels.

c) Gather data for system and equipment performance evaluation.

Initial Condition

Plant operating in Mode 7. Operating conditions from which this transition is to occur are:

a) Gross electrical output: 8.3 Mwe

b) Turbine throttle steam flow of 56,000 lb/hr.

c) TSS charge steam flow of 30,000 lb/hr.

d) Turbine admission steam flow of 40,000 lb/hr.

Test Conditions

Clear weather

Test Sequence

a) Establish Mode 7 operation at the conditions stated.

b) Effect the transition to Mode 2 with the turbine throttle steam flow remaining at 56,000 lb/hr and the TSS charge steam flow remaining at 30,000 lb/hr.

Completion Criteria

A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data has been properly recorded.

Primary Data Required:

Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

The procedure used to perform this test transition should be the same as Operating Instruction T-13b.

Test Specification NT-14
Normal Transition
Test No. NT-14

Description	Normal transition from Mode 2, Turbine Direct and Charging, to Mode 7, Charging and Storage Boosted.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 2 to Mode 7 at the stated power levels. c) Gather data for system and equipment performance evaluation.
Initial Conditions	Plant operating in Mode 2. Operating conditions from which this transition is to occur are: a) Gross electrical output: 5.9 Mwe b) Turbine throttle steam flow of 56,000 lb/hr. c) TSS charge steam flow of 30,000 lb/hr.
Test Conditions	Clear weather
Test Sequence	a) Establish Mode 2 operation at the conditions stated. b) Effect the transition to Mode 7, maintaining the turbine throttle steam flow of 56,000 lb/hr, the TSS charge steam flow at 30,000 lb/hr, and establish a turbine admission steam flow of 40,000 lb/hr. The associated gross electrical output should remain unchanged (net power obviously will change).
Completion Criteria	A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data has been properly recorded.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	The procedure used to perform this test transition should be the same as Operating Instruction T-13a.

Test Specification NT-15
Normal Transition
Test No. NT-15

Description

Normal transition from Mode 7, Charging and Storage Boosted, to Mode 3, Storage Boosted.

Objectives

a) Demonstrate stable and smooth plant operation in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 7 to Mode 3 at the stated power levels.

c) Gather data for system and equipment performance evaluation.

Initial Conditions

Plant operating in Mode 7. Operating conditions from which this transition is to occur are:

a) Gross electrical power: 8.3 Mwe

b) Turbine throttle steam flow of 56,000 lb/hr.

c) TSS charge steam flow of 30,000 lb/hr.

d) Turbine admission steam flow of 40,000 lb/hr.

Test Conditions

Clear weather

Test Sequence

a) Establish Mode 7 operation at the conditions stated.

b) Effect the transition to Mode 3 with the turbine throttle flow remaining at 56,000 lb/hr and the admission flow remaining at 40,000 lb/hr. Gross electrical output should also remain the same.

Completion Criteria

A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been properly recorded.

Primary Data Required

Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

The procedure used to perform this test transition should be the same as Operating Instruction T-17b.

Test Specification NT-16
Normal Transition
Test No. NT-16

Description

Normal transition from Mode 3, Storage Boosted, to Mode 7, Charging and Storage Boosted.

Objectives

a) Demonstrate stable and smooth plant operation in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 3 to Mode 7 at the stated power levels.

c) Gather data for system and equipment performance evaluation.

Initial Conditions

Plant operating in Mode 3. Operating conditions from which this transition is to occur are:

a) Gross electrical output: 8.3 Mwe

b) Turbine throttle steam flow of 56,000 lb/hr.

c) Turbine admission steam flow of 40,000 lb/hr.

Test Conditions

Clear weather

Test Sequence

a) Establish Mode 3 operation at the conditions stated.

b) Effect the transition to Mode 7 maintaining the turbine throttle flow at 56,000 lb/hr, the admission flow at 40,000 lb/hr and establish a TSS charging steam flow of 30,000 lb/hr. The gross electrical output is to remain unchanged.

Completion Criteria

A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data has been properly recorded.

Primary Data Required

Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements

The procedure used to perform this test transition should be the same as Operating Instruction T-17a.

Test Specification NT-17
Test Transition
Test No. NT-17

Description — Normal transition from Mode 4, In-Line Flow, to Mode 7, Charging and Storage Boosted.

Objectives

a) Demonstrate stable and smooth plant operation in accomplishing this transition.

b) Determine the minimum time necessary for the plant to perform a transition from Mode 4 to Mode 7 at the stated power levels.

c) Gather data for system and equipment performance evaluation.

Initial Condition — Plant operating in Mode 4. Operating conditions from which this transition is to occur are:

a) Gross electrical output: 2.9 Mwe

b) TSS charge steam flow of 30,000 lb/hr.

c) Turbine admission steam flow of 45,000 lb/hr.

Test Conditions — Clear weather

Test Sequence

a) Establish Mode 5 operation at the conditions stated.

b) Effect the transition to Mode 7 maintaining the turbine admission steam flow at 45,000 lb/hr, TSS charging flow at 30,000 lb/hr, and establish a turbine throttle flow of 56,000 lb/hr. The gross electrical output should increase to 8.8 Mwe.

Completion Criteria — A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data have been correctly recorded.

Primary Data Required — Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements — The procedure used to perform this test transition should be the same as Operating Instruction T-14a. Heater #2 drains should be routed to the condenser during Mode 4 operation.

Test Specification NT-18
Normal Transition
Test No. NT-18

Description	Normal transition from Mode 7, Charging and Storage Boosted, to Mode 4, In-Line Flow.
Objectives	a) Demonstrate stable and smooth plant operation in accomplishing this transition. b) Determine the minimum time necessary for the plant to perform a transition from Mode 7 to Mode 4 at the stated power levels. c) Gather data for system and equipment performance evaluation.
Initial Condition	Plant operating in Mode 7. Operating conditions from which this transition is to occur are: a) Gross electrical output: 8.8 Mwe b) Turbine throttle steam flow of 56,000 lb/hr. c) TSS charge steam flow of 30,000 lb/hr. d) Turbine admission steam flow of 45,000 lb/hr.
Test Conditions	Clear weather
Test Sequence	a) Establish Mode 7 operation at the conditions stated. b) Effect the transition to Mode 4 maintaining the TSS charge steam flow at 30,000 lb/hr and the turbine admission steam flow at 45,000 lb/hr. The gross electrical output will drop to about 2.9 Mwe.
Completion Criteria	A smooth transition between modes has been demonstrated with no adverse effects on equipment or controls. The time requirements are determined satisfactory to the DOE Test Manager. Operating data has been properly recorded.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	The procedure used to perform this test transition should be the same as Operating Instruction T-14b. Heater #2 drains should be routed to the condenser during Mode 4 operation.

Test Specification FT-1
Failure Transition
Test No. FT-1

Description	Failure Transition Test No. 1, Mode 1, Turbine Direct, to Mode 8, Inactive, Following a Turbine Trip.
Objective	Demonstrate the emergency transition from Mode 1 to Mode 8 following an actual turbine trip.
Initial Conditions	The plant operating in Mode 1. The operating conditions from which this failure transition is to occur are: Gross electrical output — 5.9 MWe Turbine throttle steam flow — 56,000 lb/hr
Test Conditions	Clear weather
Test Sequence	a) Plant operating in Mode 1. b) Initiate an actual turbine trip. c) Plant shutdown Mode 8, preferably in Status S2*.
Completion Criteria	The plant safely transitions to Mode 8 following the turbine trip with no abnormal condition or incurred damage to any subsystem. Operating data is properly recorded during the transition.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by initiating an actual turbine trip. Follow fast scanning with 1 hour of scanning at the normal rate.

*As defined in the Plant Operating/Training Manual, RADL 2-36, Book 1. If plant is to go down for the night, go to Status S1.3.

Test Specification FT-2

Test No. FT-2

Description	Failure Transition Test No. 2, Mode 2, Turbine Direct and Charging, to Mode 8, Inactive, following a receiver trip.
Objective	Demonstrate the emergency transition from Mode 2 to Mode 8 following a simulated receiver trip.
Initial Conditions	Plant operating in Mode 2. The operating conditions from which this failure transition is to occur are:

Gross electrical output	6.4 MWe
Turbine throttle steam flow	60,000 lb/hr
TSS charge steam flow	60,000 lb/hr

Test Conditions	Clear weather
Test Sequence	a) Plant operating in Mode 2. b) Initiate a receiver trip. c) Plant inactive in Mode 8, Status S2.
Completion Criteria	The plant safely transitions to Mode 8 following the receiver trip with no abnormal condition or incurred damage to any subsystem. Operating data is properly recorded during the transition.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by simulating a receiver trip. Follow fast scanning with 1 hour of scanning at the narmal rate.

Test Specification FT-3
Failure Transition
Test No. FT-3

Description	Failure Transition Test No. 3, Mode 3, Storage Boosted, to Mode 8, Inactive, Following a Turbine Trip.
Objective	Demonstrate the emergency transition from Mode 3 to Mode 8 following an actual turbine trip.
Initial Conditions	The Plant operating in Mode 3. Operating conditions from which this test is to occur are:

Gross electrical output	11.9 MWe
Turbine throttle steam flow	90,000 lb/hr
Turbine admission steam flow	25,000 lb/hr

Test Conditions	Clear weather
Test Sequence	a) Plant operating in Mode 3. b) Initiate an actual turbine trip. c) Plant shutdown to Mode 8, Status S2.
Completion Criteria	The plant safely transitions to Mode 8 following the turbine trip with no abnormal conditions or incurred damage to any subsystem. Operating data are properly recorded during the transition.
Primary Data Required	Complete plant operating data are required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by initiating an actual turbine trip. Follow fast scanning with 1 hour of scanning at the normal rate.

Test Specification FT-4
Failure Transition
Test No. FT-4

Description	Failure Transition Test No. 4, Mode 7, Charging and Storage Boosted, to Mode 5, Storage Charging, following a Turbine Trip.
Objective	Demonstrate the emergency transition from Mode 7 to Mode 5 following an actual turbine trip.
Initial Conditions	Plant operating in Mode 7. The operating conditions for which this failure transition is to occur are:

Gross electrical putput	4.4 MWe
Turbine throttle steam flow	30,000 lb/hr
TSS charge steam flow	40,000 lb/hr
Turbine Admission flow	30,000 lb/hr

Test Conditions: Clear weather

Test Sequence

a) Plant operating in Mode 7

b) Initiate a turbine trip

c) Plant to automatically transition to Mode 5,maintaining the TSS charging flow of 40,000 lb/hr.

d) Continue in steady state operation in Mode 5 for at least one hour, then effect transition to any other mode.

Completion Criteria: The plant safely transitions to Mode 8 following the turbine trip with no abnormal condition or incurred damage to any subsystem. Operating data is properly recorded during the transition.

Primary Data Required: Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements: Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by an actual turbine trip. Follow fast scanning with 1 hour of scanning at the normal rate.

Test Specification FT-5
Failure Transition
Test No. FT-5

Description	Failure Transition Test No. 5, Mode 7, Charging and Storage Bossted, to Mode 6, Storage Discharging, Following a Receiver Trip.
Objective	Demonstrate the emergency transition from Mode 7 to Mode 6 following a simulated receiver trip. Determine plant response time to these conditions.
Initial Conditions	The plant operating in Mode 7. Operating conditions from which this test is to occur are:

Gross electrical output	8.3 MWe
Turbine throttle steam flow	56,000 lb/hr
TSS Charge steam flow	40,000 lb/hr
Turbine admission steam flow	40,000 lb/hr

Test Conditions	Clear weather
Test Sequence	a) Plant operating in Mode 7. b) Initiate a receiver trip. c) Plant to automatically change to Mode 6 and stabilize in that mode.
Completion Criteria	The plant safely transitions to Mode 6 and stabilizes following the receiver trip with no abnormal condition or incurred damage to any subsystem. Operating data are properly recorded during transition.
Primary Data Required	Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by simulating a receiver trip. Follow fast scanning with 1 hour of scanning at the normal rate.

Test Specification FT-6
Failure Transition
Test No. FT-6

Description
Failure transition Test No. 6. Mode 6, Storage Discharging, to Mode 8, Inactive, following a turbine trip.

Objectives
Demonstrate the emergency transition from Mode 6 to Mode 8 following a turbine trip.

Initial Conditions
The plant operating in Mode 6. The operating conditions from which this test is to occur are:

Gross electrical output	1.7 Mwe
Turbine admission steam flow	30,000 lb/hr

Test Conditions
Clear weather

Test Sequence

a) Plant operating in Mode 6

b) Initiate an actual turbine trip

c) Plant to automatically shut down to Mode 8, Status S2.

Completion Criteria
The plant safety transition to Mode 8 following the turbine trip with no abnormal condition or incurred damage to any subsystem. Operating data properly recorded.

Primary Data Required
Complete plant operating data are required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements
Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by initiating an actual turbine trip. Follow fast scanning with 1 hour of scanning at the normal rate.

Test Specification FT-7
Failure Transition
Test No. FT-7

Description	Failure transition Test No. 7. Mode 3, Storage Boosted, to Mode 6, Storage Discharging, following a receiver trip.
Objectives	Demonstrate the emergency transition from Mode 3 to Mode 6 following a receiver trip.
Initial Conditions	The plant operating in Mode 3. The operating conditions from which this test is to occur are:

Gross electrical output	11.4 Mwe
Turbine throttle steam flow	90,000 lb/hr
Turbine admission steam flow	30,000 lb/hr

Test Conditions Clear weather

Test Sequence

a) Plant operating in Mode 3.

b) Initiate a receiver trip.

c) Plant to automatically change to Mode 6, maintaining the turbine admission flow at 30,000 lb/hr.

d) Continue in stable operation in Mode 6 at about 1.7 Mwe, for a minimum of 1 hour.

e) Transition to any other desired mode.

Completion Criteria The plant safely transitions to Mode 6 following the turbine trip with no abnormal conditions or incurred damage to any subsystem. Operating data during transition is properly recorded.

Primary Data Required Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The trip is to be performed by simulating a receiver trip. Follow fast scanning with 1 hour of scanning at the normal rate.

Test Specification FT-8
Failure Transition
Test No. FT-8

Description	Failure Transition Test No. 8, Mode 4, In-line Flow, to Mode 6, Storage Discharging, following a Receiver Trip.
Objective	Demonstrate the failure transition from Mode 4 to Mode 6 following a simulated receiver trip.
Initial Conditions	Plant operating in Mode 4. The operating conditions for which this failure transition is to occur are:

Gross electrical output	4.2 MWe
Turbine admission steam flow	60,000 lb/hr
TSS charge steam flow	60,000 lb/hr

Test Conditions: Clear weather

Test Sequence:

a) Plant operating in Mode 4.

b) Initiate a receiver trip.

c) Plant to automatically transition to Mode 6 maintaining the turbine admission flow of 60,000 lb/hr.

d) Continue in steady state operation in Mode 6 for one hour minimum.

e) Transition to any other desired mode.

Completion Criteria: The plant safely transitions to Mode 6 following the receiver trip with no abnormal condition or incurred damage to any subsystem. Operating data during transition is properly recorded.

Primary Data Required: Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements: Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by simulating a receiver trip. Follow fast scanning with 1 hour of scanning at the normal rate.

Test Specification FT-9
Failure Transition
Test FT-9

Description — Failure transition test No. 9, Mode 4, In-line Flow, to Mode 5, Storage Charge, to Mode 8, Inactive subsequent to sequential turbine trip and receiver trip.

Objective — Demonstrate and observe the emergency response of the plant in changing from Mode 4 to Mode 5 to Mode 8 subsequent to an actual turbine trip, followed immediately by a simulated receiver trip.

Initial Conditions — The plant operating in Mode 4. Operating conditions for which this failure transition is to occur are:

Gross electrical output	2.9 MWe
TSS charge steam flow	65,000 lb/hr
Turbine admission steam flow	45,000 lb/hr

Test Conditions — Clear weather

Test Sequence

a) Plant operating in Mode 4

b) Initiate an actual turbine trip

c) Plant to automatically transition to Mode 5 and the systems to stabilize for no more than five minutes

d) Initiate a simulated receiver trip

e) Transition to Mode 8

Completion Criteria — The plant safely transitions to Mode 5 and then to Mode 8 with no abnormal condition or incurred damage to any subsystem. Operating data during transitions are properly recorded.

Primary Data Required — Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements — Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by initiating an actual turbine trip and a simulated receiver trip. Heater #2 drains should be routed to the condenser during Mode 4 operations. Follow fast scanning with 1 hour of scanning at normal rate.

Test Specification FT-10
Failure Transition
Test FT-10

Description	Failure transition test No. 10, Mode 4, In-line Flow, to Mode 6, Storage Discharging, to Mode 8, Inactive following the respective receiver trip and turbine trip.
Objective	Demonstrate and observe the emergency response of the plant in changing from Mode 4 to Mode 6 following a simulated receiver trip, followed immediately by a turbine trip resulting in total plant shutdown.
Initial Conditions	The plant operating in Mode 4. Operating conditions for which this failure transition is to occur are:

Gross electrical output	2.9 MWe
TSS charge steam flow	65,000 lb/hr
Turbine Admission steam flow	45,000 lb/hr

Test Conditions: Clear weather

Test Sequence

a) Plant operating in Mode 4

b) Initiate a simulated receiver trip

c) Plant to automatically transition to Mode 6 and systems to stabilize for no more than 5 minutes

d) Initiate an actual turbine trip

e) Transition to Mode 8

Completion Criteria: The plant safety transition to Mode 6 and then to Mode 8 with no abnormal condition or incurred damage to any subsystem. Operating data during transitions are properly recorded.

Primary Data Required: Complete plant operating data is required; this includes CS, RS, TSS, EPGS, and SHIMMS.

Special Requirements: Data points available for fast scanning shall be recorded for 15 seconds before and 1 minute after the trip is effected. The test is to be performed by initiating a simulated receiver trip and an actual turbine trip. Heater #2 drains should be routed to the condenser during Mode 4 operations.

Test Specification TT-1
Transition Timing
Test No. TT-1

Description	Transition Timing test No. 1; Inactive Mode 8 to Mode 6, storage discharging, to Mode 4, In-line Flow and to full rated conditions in Mode 4.
Objectives	Determine the minimum time required to start up the plant from a cold shutdown condition and pass through the required steps to attain full load conditions under Mode 4 operation.
Initial Conditions	Plant in inactive, cold shutdown status. The TSU is charged to at least 50% of capacity.
Test Conditions	Clear weather.
Test Sequence	Inactive S-1.3 Mode 8, then to warm-up status S-2; Start TSS steam generator to status S-4, and transition into Mode 6 operation at minimum TFG load (1.7 Mwe gross); Transition from Mode 6 to Mode 4 at constant power; Increase TGF load to 7 Mwe net; Increase TSS charging flow to full design charging rate. The concurrent flow conditions are: Admission steam flow 110,000 lb/hr TSS charging steam 105,000 lb/hr (max)* Continue in these conditions for 2 hours minimum Transition to any other operational mode.
Completion Criteria	Results of the test are reasonable and acceptable with no evidence of wasted time or any obvious means of reducing time requirements. Time requirements to accomplish this test compare favorably with values predicted by simulation models (this is a success criteria, not a completion criteria).
Primary Data Required	Complete plant operating data is required; CS, RS, TSS, EPGS, and SHIMMS are all included.
Special Requirements	This test is to be started by initiating Mode 6 operation at dawn of the test day. The time of completion shall be the earliest time of attaining steady-state operation at the rated flow conditions. The steady-state conditions are to be extended for the two-hour period specified. Because of the day-of-the-year effect on this test, it is required that this be repeated at least 3 times during a year. This test is specifically intended to demonstrate a minimum time to attain full power in Mode 4. Rates of power increase with steam to the turbine admission valve must be restricted to those given in G.E. turbine operating limits.

*Refer to Operating Instruction S-6 and Fig. S-6-1 for limitations on charging steam flow as a function of temperature.

Test Specification TT-2
Transition Timing
Test No. TT-2

Description	Transition Timing test No. 2; Inactive Mode 8, Cold Shutdown, to Mode 1, Turbine Direct.
Objectives	Determine the minimum time to start up the plant from a cold shutdown and pass through the required steps to start the turbine with RS steam and attain a power level of 10 Mwe net.
Initial Conditions	Plant in Mode 8, cold shutdown.
Test Conditions	Clear weather.
Test Sequence	Inactive Mode 8, then to warm-up status, S-2; Start RS flow to steam dump system, status S-3; Start up turbine generator and establish Mode 1 at minimum power; Increase load to 10 Mwe net and continue for at least 2 hours at steady state; Continue, or transition, to some other mode.
Completion Criteria	The time to reach 10 Mwe net in the turbine direct mode from cold shutdown condition is shown to be within the time range predicted by the dynamic plant simulation models or is acceptable to the Test Director.
Primary Data Required	Complete plant operating data is required; that includes CS, RS, TSS, EPGS, and SHIMMS.
Special Requirements	None

Note: This test is specifically intended to demonstrate a minimum time to attain rated power in Mode 1. Rates of rise must be restricted to those given by G. E. in the turbine operating limits.

Test Specification TT-3
Transition Timing
Test No. TT-3

Description	Transition Timing test No. 3; Inactive Mode 8 to Mode 1, Turbine Direct, and then to rated conditions in Mode 2, Turbine Direct and Charging, with maximum receiver flow.
Objectives	Determine the minimum time required to start up the plant from cold shutdown condition and pass through the required steps to attain full-load conditions in Mode 2 operation.
Initial Conditions	Plant in Mode 8, cold shutdown. The TSU is charged to less than 60% capacity.
Test Conditions	Clear weather.
Test Sequence	Inactive Mode 8, to warm-up status S-2; start RS flow to steam dump system, status S-3; start turbine generator and establish Mode 1 at minimum power; transition to Mode 2 (Op Instruction T-7a); increase power level to 10.8 Mwe net and increase TSS charging steam flow to a value of 20,000 lb/hr; continue at steady state for 1 hour minimum; transition to any other operational mode.
Completion Criteria	The time to reach 10.8 Mwe and TSS charge flow of 20,000 lb/hr from shutdown is shown to be within the range predicted by the dynamic plant simulation model or is acceptable to the Test Director.
Primary Data Required	Complete plant operating data for all systems are to be recorded during this test.
Special Requirements	None

Note: This test is specifically intended to demonstrate a minimum time to obtain rated conditions in Mode 2, via the specified steps. Rates of rise must be restricted to those given by G.E. in the turbine operating limits.

Also, this test could be conducted as a follow-on sequence to the previous test, TT-2. Alternatively, by properly choosing start-stop times, this test could provide the data required for both TT-2 and TT-3.

Test Specification TT-4
Transition Timing
Test No. TT-4

Description

Transition Timing test No. 4; Turbine Direct, Mode 1 to Storage Boosted Mode 3, to Storage Discharge Mode 6, to Inactive Mode 8.

Objectives

Determine minimum time requirements for the plant to transition from steady state Mode 1 operation to Modes 3 to 6 to 8, representing a controlled power reduction and shutdown representative of the latter third of the "clear day scenario".

Initial Conditions

Plant in Mode 1 operation at 10 Mwe net. The TSS is charged to more than 85% of capacity.

Test Conditions

Clear weather.

Test Sequence

Mode 1 operation at 10 Mwe net;
Effect transition T-10a and attain a condition of approximately 10 Mwe net with the turbine throttle flow of 85,000 lb/hr and admission flow of 30,000 lb/hr;
Reduce throttle flow and increase admission flow in proper proportion to retain approximately 10 Mwe net but increasing admission flow to design maximum of 110,000 lb/hr;
Effect transition T-9a to Mode 6 with 110,000 lb/hr admission flow which will produce approximately 8.4 Mwe gross;
Effect transition T-18 to shutdown (preferably to status S-1.3).

Completion Criteria

Measured transition times are shown to be within the ranges predicted by dynamic plant simulation models or are acceptable to the Test Director.

Primary Data Required

Complete plant operating data for all systems are to be recorded during this test.

Special Requirements

None

Test Specification TT-5
Transition Timing
Test No. TT-5

Description	Transition Timing test No. 5; Mode 7 Charging and Storage Boosted to Mode 4, In-line Flow, to Mode 6, Storage Discharging.
Objectives	Determine minimum times required to effect the sequence of transitions from Mode 7 to Modes 4 and 6, representative of operational changes required due to changes in weather conditions.
Initial Condition	Steady state operation in Mode 7. The TSU is charged to a range of 70-80% of capacity.
Test Conditions	Clear weather*
Test Sequence	Plant operation in Mode 7 in the following conditions: Turbine throttle flow 60,000 lb/hr Turbine admission flow 54,000 lb/hr TSS charge flow 40,000 lb/hr Gross electrical output 10.7 Mwe Effect transition to Mode 4, and gradually adjust flows to attain full design conditions in this mode (which will result in approximately 7.0 Mwe net): Turbine admission flow 110,000 lb/hr TSS charging flow 105,000 lb/hr Continue in Mode 4 for a minimum of 1 hour; Effect transition to Mode 6 and maintain power output at 7.0 Mwe net for a minimum of one hour.
Completion Criteria	The results of the test are reasonable and acceptable with no evidence of wasted time or obvious means of reducing time requirements. Comparison of data with predictions in the dynamic simulation models are acceptable.
Primary Data Required	Complete operating data for all systems are to be recorded during this test.
Special Requirements	None

*This test is done in anticipation of operations on a day in which weather conditions deteriorate; however, the test itself should be done on a clear day.

Test Specification ET- 1

Engineering Test

Test No. ET- 1

Description

Operate the plant on the most favorable design-point day to obtain data to bracket the ability of the plant to produce electricity and to store excess thermal energy using all operable heliostats.

Operate in Turbine Direct when generator net electrical output is below 10 Mwe and operate in Turbine Direct and Charge when net electrical output equals 10 Mwe. After sundown, operate in Storage Discharge using thermal energy stored during the day.

Objectives

1. On the most favorable design-point day determine the total number of Kw-hours generated using all operable heliostats.
2. On the most favorable design-point day determine the number of hours the plant can operate while producing 10 Mwe from receiver steam.
3. On the most favorable design-point day determine the amount of excess thermal energy which can be collected while producing 10 Mwe from receiver steam.
4. On the most favorable design-point day determine the amount of electrical energy which can be extracted from the Thermal Storage Unit subsequent to a full day's operation wherein the plant was operated in Turbine Direct and Charging at all times when net electrical output from receiver steam reached 10 Mwe.

Initial Conditions

1. The plant inoperative - in Mode 8, State S 1.3
2. The TSU is discharged to its minimum effective capacity.

Test Conditions

1. Test shall occur within $\pm$ one day of the most favorable design-point day (weather permitting).
2. Clear weather.
3. All operable heliostats are used in this test and they constitute at least 98% of the full complement of 1818 heliostats.

Test Sequence

Starting from inactive status, make the transition to Mode 1, (Turbine Direct).

When net electrical output reaches 10 Mwe make the transition to Mode 2 (Turbine Direct and Charging).

Continue to operate in Mode 2 for as long as the 10 Mwe net output can be sustained.

When net electrical output falls below 10 Mwe, or when excess thermal energy is insufficient to operate in Mode 2 (whichever comes first), make the transition back to Mode 1.

Continue to operate in Mode 1 for as long as possible. Then make the transition to Mode 8.

From Mode 8 make the transition to Mode 6 (Storage Discharging) and operate in Mode 6 until the TSU is discharged to it minimum.effective capacity.

Completion Criteria

Data have been obtained to meet the four objectives described above.

Primary Data Requirements

1. Number of Kw-hours of electricity produced from receiver steam.
2. Number of Kw-hours of electricity produced from admission steam.
3. Number of hours (to nearest tenth of an hour) plant produced 10 Mwe net while operating in the Turbine Direct and Charging Mode.
4. Number of hours (to nearest tenth of an hour) plant produced 7 Mwe net while operating in the Storage Discharging Mode.

Special Requirements

A design requirement for the plant is to produce 10 Mwe for 7.8 hours at summer solstice day. Verification of the ability to meet this requirement is one of the purposes of this test.

Test Specification ET- 2

Engineering Test

Test No. ET- 2

Description

Operate the plant on the least favorable design-point day to obtain data to bracket the ability of the plant to produce electricity and to store excess thermal energy using all operable heliostats.

Operate in Turbine Direct when generator net electrical output is below 10 Mwe and operate in Turbine Direct and Charge when net electrical output equals 10 Mwe. After sundown, operate in Storage Discharge using thermal energy stored during the day.

Objectives

1. On the least favorable design-point day determine the total number of Kw-hours generated using all operable heliostats.
2. On the least favorable design-point day determine the number of hours the plant can operate while producing 10 Mwe from receiver steam.
3. On the least favorable design-point day determine the amount of excess thermal energy which can be collected while producing 10 Mwe from receiver steam.
4. On the least favorable design-point day determine the amount of electrical energy which can be extracted from the Thermal Storage Unit subsequent to a full day's operation wherein the plant was operated in Turbine Direct and Charging at all times when net electrical output from receiver steam reached 10 Mwe.

Initial Conditions

1. The plant inoperative - in Mode 8, State S 1.3
2. The TSU is discharged to its minimum effective capacity.

Test Conditions

1. Test shall occur within ± one day of the least favorable design-point day (weather permitting).
2. Clear weather.
3. All operable heliostats are used in this test and they constitute at least 98% of the full complement of 1818 heliostats.

Test Sequence

Starting from inactive status, make the transition to Mode 1, (Turbine Direct).

When net electrical output reaches 10 Mwe make the transition to Mode 2 (Turbine Direct and Charging).

Continue to operate in Mode 2 for as long as the 10 Mwe net output can be sustained.

When net electrical output falls below 10 Mwe, or when excess thermal energy is insufficient to operate in Mode 2 (whichever comes first), make the transition back to Mode 1.

Continue to operate in Mode 1 for as long as possible. Then make the transition to Mode 8.

From Mode 8 make the transition to Mode 6 (Storage Discharging) and operate in Mode 6 until the TSU is discharged to it minimum.effective capacity.

Completion Criteria

Data have been obtained to meet the four objectives described above.

Primary Data Requirements

1. Number of Kw-hours of electricity produced from receiver steam.
2. Number of Kw-hours of electricity produced from admission steam.
3. Number of hours (to nearest tenth of an hour) plant produced 10 Mwe net while operating in the Turbine Direct and Charging Mode.
4. Number of hours (to nearest tenth of an hour) plant produced 7 Mwe net while operating in the Storage Discharging Mode.

Special Requirements

A design requirement for the plant is to produce 10 Mwe for 4.0 hours at winter solstice day. Verification of the ability to meet this requirement is one of the purposes of this test.

Test Specification ET-3
Engineering Test
Test No. ET-3

Description	Engineering test No. 3; Sun-following control strategy for repowering.
Objectives	Demonstrate the power production of the plant while operating with a solar multiple of 1.0 and a sun-following control stategy; Gather data on system performance for application to other DOE programs.
Initial Conditions	Plant shutdown in Mode 8, status 1.5; TSU should be charged at least to 25% of capacity; TSS is to be supplying sealing and blanketing steam.
Test Conditions	Clear weather.
Test Sequence	Plant shutdown in Mode 8, status S-1.5; Establish Turbine Direct operation (Mode 1) when RS steam flow is enough to sustain minimum load; Remain in Mode 1, sun-following control strategy with load consistent with receiver power until a solar multiple of 1.0 is attained momentarily at solar noon of the test day at a net power output of 10 Mwe; Continue in Mode 1 until quantity and quality of RS steam requires shutdown; Plant inactive in Mode 8, status S-1.3.
Completion Criteria	Satisfactory demonstration of the specified run. (This test is not a design requirement of the plant, but does fulfill part of project objectives.)
Primary Data Required	Complete plant operating data for all systems are to be recorded during this test. Particular attention is to be given to recording the number of heliostats used, the date, details of the weather/atmospheric conditions as a part of being able to correlate the results with those of other sites; also identify helistats used.
Special Requirements	The collector field controls must be modified to permit the use of only those heliostats consistent with a solar multiple of 1.0 with the test day as the most favorable design point day.

Test Specification ET-4
Engineering Test
Test No. ET-4

Description	Engineering test No. 4; load-following control strategy for repowering with the TSS simulating a non-solar steam supply.
Objectives	Demonstrate the ability of the plant to supplement, in a repowering or hybrid mode, a non-solar steam supply to provide constant power production.
Initial Conditions	Plant shutdown in Mode 8, status 1.5; TSS fully charged.
Test Conditions	Clear or partially cloudy weather.
Test Sequence	Establish Turbine Direct operation (Mode 1) when RS steam flow is enough to sustain minimum load; Immediately effect transition to Storage Boosted (Mode 3) operation and establish load-following control strategy at 6.0 Mwe net. All RS steam available to go to Turbine and TSS supplying varying flow to maintain constant power output; Remain in Mode 3 for 10 hours minimum; Shut down plant at end of run.
Completion Criteria	Satisfactory demonstration of specified run. (This test is not a design requirement of the plant, but does fulfill a part of project objectives.)
Primary Data Required	Complete plant operating data for all systems are to be recorded during this test. Particular attention is to be given to recording the number of heliostats used, the date, details of the weather/atmospheric conditions as a part of being able to correlate the results with those of other sites; include heliostat identities.
Special Requirements	The collector field controls must be modified to permit the use of only those heliostats consistent with a solar multiple of 1.0 occurring momentarily at solar noon, at 6.0 Mwe net, and with the test day as the most favorable design point day.

Test Specification ET-5

Engineering Test

Test No. ET-5

Description

Operate the plant according to the clear-day scenario completely under computerized control (except for warmup and shutdown) including a period at mid-day when excess thermal energy from the receiver is diverted into storage charging.

Objective

Demonstrate that the OCS can properly control the plant throught a typical clear-day scenario (see Figure A-1)* by performing all indicated transitions except start up and shutdown.

Initial Conditions

Warmup has been conpleted and the transition to Mode 1, Turbine Direct, under OCS automatic control has been completed.

Test Conditions

Clear Weather

Test Sequence

With the plant in Mode 8, Inactive Status, go through the following transitions and operating modes under operator control.

T-1	Preliminary Startup
S-2	Water Cleanup
T-2	Transition to Receiver Startup
S-3	Flow to Steam Dump System
T-4	Startup of T-G with Receiver Steam
S-5	Operation in Mode 1, Turbine Direct.

Immediately after going to Mode 1 operation, place the plant under fully automatic control and go through the following portions of the clear-day scenario.

S-5	Operation in Mode 1, Turbine Direct
T-7A	Transition from Mode 1 to Mode 2
S-8	Operation in Mode 2, Turbine Direct and Charging
T-7B	Transition from Mode 2 to Mode 1
S-5	Operation in Mode 1, Turbine Direct
T-10A	Transition from Mode 1 to Mode 3
S-9	Operation in Mode 3, Storage Boosted
T-9A	Transition from Mode 3 to Mode 6
S-7	Operation in Mode 6, Storage Discharging

*Figure A-1 is on Page A-29

When the thermal storage unit has discharged sufficiently, change from fully automatic operation and make transition T-18 from Mode 6 to shutdown, and perform the shutdown procedure under operator control to Mode 8, Inactive.

Completion Criteria

The plant safely and automatically makes all of the required transitions at the proper time when operating under full automatic control.

Primary Data Required

1. Steady-state operating data while in Modes 1, 5, 3, and 6. (Operating instructions S-5, S-8, S-9, and S-7).
2. Transition data for Transitions T-7A, T-7B, T-10A, and T-9A.
3. Compare the above steady-state and transition data with similar data obtained with the pilot plant under fully-automatic control with similar data while under manual and semi-automatic control (portions of Steady-state Test Number 5-8 and 13-24, and of Normal Transition Test Numbers 6, 9, 10, and 11).

Special Requirements

1. OCS is available and in good working order.
2. Software for clear-day scenario under fully-automatic control has been developed and de-bugged.
3. All of the required transitions in the clear-day scenario have been demonstrated under semi-automatic operation.

APPENDIX B

APPENDIX B

COMPONENT PERFORMANCE EVALUATION TESTS

FOR

INITIAL TWO-YEAR

EXPERIMENTAL PHASE

OF

PILOT PLANT OPERATIONAL TESTING

STMPP Operational Test Specification

Reflectivity Changes in Heliostat Mirrors

Description

Measurements of beam power and mirror reflectance of heliostats at selected positions in the heliostat field are needed to monitor changes due to environmental degradation (such as buildup of dust) and cleaning (such as periodic washing and occasional rainfall). These tests must be made at a shorter time interval than that permitted by routine Beam Characterization Measurements, which are repeated at approximately three- or four-month intervals. In addition, some mirror reflectance measurements are needed to provide a cross-correlation with BCS measurements. Ultimately data from these tests will provide data on the degradation of mirror reflectance and performance with time as a function of stow position and of position in the heliostat field. In addition, data will be obtained on improvement in mirror reflectance and performance caused by manual washing and by rainfall, non-recoverable reflectance due to build up of plaque coatings which are not removed by routine washing or occasional rainfall, and the nature of the coat or plaque which forms on mirrors.

Objectives:

1) Determine environmental degradation effects with time of heliostat mirror reflectivity as a function of location within the heliostat field and of stow position. Of particular interest here are detecting any effects due to (a) the prevailing wind direction at STMPP, (b) proximity to moisture spray from the cooling tower, (c) proximity to dust from the spoke and perimeter roads, and (d) stow orientation at night.

2) Quantify the effectiveness of washing procedures used periodically to clean the heliostat mirrors.

3) Quantify the effects of rain cleaning on the STMPP heliostat mirrors.

4) Determine the non-recoverable fraction of initial reflectance due to buildup of plaque coatings on the mirror which are not completely removed by routine washing and occasional rain.

5) Determine the nature of the plaque coatings which build up on the mirrors (usually due to a combination of dust and moisture).

Initial Conditions and Prerequisites:

1) Heliostat mirrors selected for this test are clean and have specular reflectivity approximately equal to that of the as-delivered condition.

2) Beam Characterization System is operational and yielding consistent results with a standard reference mirror.

3) A portable specular reflectometer (Freese type or equivalent) for field measurements of reflectance is available and in good working order.

4) Special identifying bands have been painted on the heliostats selected for this test.

Test Conditions

Selected heliostats will consistently be stowed in a face-up, or face-down position, or vertical position as designated in the procedure.

BCS measurements on given heliostats will be repeated at the designated time intervals under reasonably consistent insolation conditions (approximately similar insolation values and relative sun position).

Portable specular reflectometer measurements will be made at night if possible. If night measurements are not possible, orient heliostats so that mirrored surface being measured is in the shade.

Test Sequence

See the Procedure section for details.

Completion Criteria

Data will be obtained throughout the two-year period of operational testing. A final evaluation will be made at the end of that time period.

Primary Data Requirements

1) Total beam power for each selected heliostat will be obtained as a function of time. Total beam power should be normalized for an insolation level of 1 kilowatt per square meter, for solar noon at the spring equinox, and for a heliostat orientation with mirror modules perpendicular to the BCS target.

2) Fraction of original specular reflectance will be plotted as a function of time. Original specular reflectance refers to the clean as-received mirrors just after fabrication.

3) The effect of each scheduled wash on total beam power and spectral reflectance of the elected heliostats will be determined.

4) The effect of rainfall cleaning on total beam power and spectral reflectance of the selected heliostats will be determined after each rain.

Special Requirements

The heliostats selected for this test must be stored in their designated stow positions. Exceptions will be made whenever necessary to protect against mirror damage due to hail, sandstorms, etc.

The heliostats selected for this test must be specially marked by red rings on the pedestal at the 4-foot and 6-foot level so that they will not be cleaned inadvertently during routine washing operations. They will be washed according to the schedule given in this procedure.

Procedure

A. Verification of Selected Heliostats

1. Verify that special identifying bands have been painted on the heliostats selected for this test (SNLL will do selection). Once verified this step need not be repeated in later operations.

B. Special Beam Characterization System Measurements

1. Using standard operating procedures for the Beam Characterization System obtain measurements of total beam power, centroid, and distributed flux for each selected heliostat according to the schedule selected by SNLL.

2. Normalize the total beam power for an insulation level of 1 Kw/m^2 at solar noon on the spring equinox day, and for a heliostat orientation with mirror modules perpendicular to the BCS target.

3. Plot beam power for each selected heliostat as a function of time for the BCS measurements made according to the SNLL schedule.

4. Examine the plots to see if decreases in total beam power with time can be correlated with (a) the prevailing wind direction at STMPP, (b) proximity to moisture spray from the cooling tower, (c) proximity of heliostats to dust from the spoke and perimeter roads, and (d) stow orientation at night and other times when heliostat is not in use.

C. Portable Specular Reflectometer Measurements

(Note: Only a few of the selected heliostats are cross-checked with portable specular reflectometer measurements. See SNLL for listing.)

1. Turn on the portable specular reflectometer (Freese type or equivalent) for at least 15 minutes prior to use to allow sufficient instrument warmup time.

2. Set the angle of incidence between the collimating and the collecting optics at 10 degrees.

3. Obtain reflectance measurements once each week on the upper left-hand mirror (Mirror module #1) and then repeat for the lower right hand mirror (Mirror module #12) of the selected heliostats. Selected heliostats and their stow positions will be picked by SNLL.

4. Orient the heliostat so that the mirror module is at a convenient height for using the portable reflectometer at ground level. The most desirable time for making specular reflectance measurements is at night. If it is necessary to make reflectance measurements during the day, prior to doing this step first rotate mirrors to the vertical plane and then rotate azimuthly so that mirror faces are on the shady side. This prevents excessive buildup of heat in the reflectometer, which is very temperature sensitive.

5. Place small reference mirror in the sample position and align the reflectometer. To accomplish the alignment, the beam apertures are placed in the collimation and collection beam paths. With the viewing optics in position, adjust the vertical height and x-y tilt to provide maximum radiation and to center the beam in the collection aperture. The viewing optics are then replaced with a silicon detector and final adjustments are made to maximize the signal.

6. Record the reference mirror reading and a black offset reading on a data sheet (see Table I for data sheet).

7. Adjust the heliostat mirrors so that the Mirror Module #1 (upper left-hand mirror module, when facing the mirror module) is, in a convenient position to make specular reflectance measurements. Use the string to divide this mirror facet into eleven approximaely-equal vertical sections.

8. Take two measurements near the center of each of the 11 divisions of the facet except for the extreme right (11th division). Before taking the last two measurements, wash the extreme right (11th) section with deionized water using a clean sponge and squeegee. Measurements in the 11th section will provide a clean reference section for each data set. A total of 22 measurements will be recorded on the data sheet (see Table I) for each lower right-hand facet.

9. The 20 readings taken on the ten divisions are then averaged to determine an overall average. Likewise, the two readings in the 11th section are averaged to determine the reference value of the washed region.

10. Repeat steps 4 through 9 for Mirror Module #12 (the lower right-hand mirror module when facing the mirror module).

References for Preparation of this Procedure:

1. Discussions with D. L. King at CRTF-SNLA.

2. "Environmental Reflectance Degradation of CRTF Heliostats" by D. L. King and J. E. Meyers, Proceedings of SPIE Symposium, Optics in Adverse Environment, Los Angeles, California, February 4, 1980

3. "The Development of A Portable Specular Reflectometer for Field Measurements of Solar Mirror Materials," by J. M. Freese, SAND-1918, October 1978.

DATE ____________

SEMI-WEEKLY BARSTOW FIELD REFLECTIVITY MEASUREMENTS

MEASUREMENT No	HELO #	1357		1358		1512		2735		1257		1514	
	MOD #	1	# 12	# 1	# 12	# 1	# 12	# 1	# 12	# 1	# 12	# 1	# 12
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
AVE													
STD DEVIATION.													
CLEAN 1													
2													

ALL DATA PLOT (DRF 3314)

Recommendations for Caloria Testing

The purpose of Caloria sample testing is:

1. To determine the physical composition and properties of the oil and to record changes due to operation of the TSS.
2. To determine the amount of trace elements in the oil and to record changes due to operation of the TSS.

The sampling schedule should be commensurate with the changes encountered during the test. It is suggested oil samples be taken from the fresh oil in the tank cars at the completion of the TSS acceptance test, and initially once a month during the operational test period.

Following four to six months of test operation (depending upon TSS operation), the sample frequency should be modified depending upon laboratory test results.

The following tests should be performed on each oil sample:

1. Infrared Scan Gross Characterization

   This test determines the infrared absorption characteristics of the oil. Using the fresh oil fingerprint, subsequent changes are compared with the original. The location in the spectrum of the changes then give an indication of molecular changes in the oil.

2. Infrared Scan for Oxygen Inhibitor Amount

   The oxygen inhibitor is an additive to the oil. This organic compound can be identified in the infrared scan by its absorption band. Using the fresh oil sample as a base, subsequent oil samples are compared with the fresh oil sample and changes are semi-quantified as a percent of the original amount in the base sample.

3. Viscosity

   The viscosity of the oil is an index of its physical properties. The test is inexpensive and simple. A correlation between the oil's performance and a simple viscosity test might lend itself to being used at the pilot plant as an operating test.

4. Investigate the Amounts of the Following Elements:

   Iron: The TSS system is principally composed of iron components. Corrosion in the system would be indicated by an increase of iron

   Chlorine: The incidence of chlorine in the TSS would also indicate corrosion. Chlorine is associated with corrosion and the transfer of iron from a cold place to a hot place. The chlorine is released by heat allowing it to return to the cold area to attack the iron.

   Silicon: The TSS bed, made up of rock and sand, is in contact with the oil. It is expected the oil will carry fines and suspended particles. This amount should stabilize after startup.

   Water: The amount of moisture in the oil is expected to be low. However, if a leak in a heat exchanger should occur the amount of water should increase giving a warning of trouble.

5. The Patch Test

   As the heat transfer oil ages it is anticipated that some degradation of the oil will occur. Aliquots of the oil may be diluted with hexane and passed through 0.45 um pore size Millipore filters (type HA) forming a "patch" on each filter. The darkened area, or patch on the filter is due primarily to the adsorption of colloidal sized particles on the filter surfaces. Particles in the colloidal size range, because of their relatively large size and surface activity, are the most likely species to deposit on heat transfer surfaces and cause their fouling. The patch test is a rapid and relatively simple test that may relate to the fouling potential of the oil. The test should be conducted regularly, and correlated with other aspects of operation of the system.

6. Vapor Pressure Test

   This test is important for plant operation. Changes in the vapor pressure of the oil could cause valve or pump cavitation requiring costly repairs or plant modifications.

7. Flash Point Test (ASTM D92)

The flash point of the oil is related to plant safety. Should oil samples be taken at temperatures greater than their flash point, it is imperative that necessary precautions (absence of ignition sources) be taken in their handling.

Recommendation for Heptane Testing

The Ullage Maintenance Unit utilities heptane as a means of providing a recoverable cover gas for the thermal storage unit (see Figure B-1). With continued operation of the TSU, light hydrocarbons and other gases may result. These gases will enter the Ullage Maintenance Unit resulting in compositional change of the ehptane. Change in heptane composition should be monitored with time by periodically removing samples for analysis by mass spectrometry.

Recommendation on Effects of Cyclic Operation

The potential for boiler internal corrosion and overheating from deposition of corrosion products is greatly increased during cyclic operation. The large number of startup, shutdowns, and idle periods provide conditions when air "inleakage" is most likely to occur, especially in the condensate and low pressure feedwater system. This results in oxygen corrosion of feedwater heaters, extraction piping, etc. The corrosion by-products, such as iron oxide and copper, are then transported to the boiler where they will deposit on heat transfer surfaces. High oxygen concentrations in the feedwater/boiler-water can also lead to corrosion pitting, which can directly promote tube failures.*

In future revisions of this test plan, tests should be delineated to: (1) present methods for monitoring the effects of cyclic operation on heat-transfer capability of the receiver, (2) present a schedule for examining selected portions of the water-steam circuit for corrosion, particularly oxygen-related corrosion pitting, and (3) monitor the effects of cyclic operation on water treatment requirements.

*Reference:

"Water Treatment Practices for Cyclic Operation of Utility Boilers" by F. Gabrielli and W. R. Sylvester, presented at International Water Conference of Engineers Society of Western Pennsylvania, Oct. 31-Nov. 2, 1978, Pittsburgh, Pa.

APPENDIX C

N-072E-A00-TS019
December 23, 1981

APPENDIX C

IN-TEST AND POST-TEST DATA REDUCTION

FOR

INITIAL TWO-YEAR

EXPERIMENTAL PHASE

OF

PILOT PLANT OPERATIONAL TESTING

APPENDIX C

IN-TEST AND POST-TEST DATA REDUCTION

INTRODUCTION

This appendix was developed to provide the computations necessary for evaluating plant performance using test data. Input data will come from the various instrument sensors associated with specific items of equipment and from controller set points and output signals. The output signals from the instrument sensors will be converted into engineering units. Computations will then be made using the equations shown in this appendix, with each computed quantity identified by a computation label. Thus using these equations, software will then be prepared for in-test and post-test data reduction. Data displays.in the form of tabulations and plots for evaluating pilot-plant performance will then be used to show reduced data as well as selected sensor outputs.

INSTRUMENTATION IDENTIFICATION

Each instrument sensor has been assigned an alpha-numeric tag number for identification. The alphabetical component designator preceeding the tag number is assigned according to the identification table shown in Table C-1. and in the numerical component according to the identification table shown in Table C-2.

EQUIPMENT IDENTIFICATION

Each piece of equipment has been assigned an alpha-numerical tag number for identification. The alphabetical component designator preceeding the tag number is assigned according to the identification table shown in Table C-3. and the numerical component according to the identification table shown in Table C-4. Thus P-905 is the fith pump in the EPGS area.

COMPUTATION LABEL IDENTIFICATION

A computational label had been developed as a convenient shorthand method to quickly identify a computed quantity. Table C-5 shows the convention utilized for identifying computed values. For example, DCXS is used to label the total energy exchanged by steam in the thermal storage charging systems wherein:

D = Delta Energy
C = Thermal Storage Charging
X = Total
S = Steam

The various computational labels are shown in Table C-6 (pages C-9 to C-22).

COMPUTATION LABEL LOCATION

System flow diagrams showing the location of the various computed quantities are shown in Table C-7 (pages C-24 to C-27). The purpose of these diagrams is to show the relationship between the various heat and mass flow calculated values. For example, the feedwater mass flow (WRPWT) and the total power in the feedwater stream (RPW) are calculated at the same point in the system; the panels (ERBST) less the total power in the feedwater (ERPW) equals the Btu's/hr absorbed by the solar panels. The system flow diagrams in this appendix are for the reciever, thermal storage charging, thermal storage extraction, and the thermal storage tank.

EQUATIONS FOR COMPUTATION

The equations for computing performance of the Solar One Plant are shown in Table C-8 (pages C-29 to C-58). The units involved are indicated for each computation.

DATA DISPLAYS

Real-time CRT Data Displays from the DAS will be utilized by Solar One test personnel to evaluate pilot-plant performance. This will provide quick-look capability while a test is in progress via plots and tabulations. Data displays developed for this purpose are shown in Table C-9 (pages C-60 to C-96).

TABLE C-1

INSTRUMENT IDENTIFICATION LETTERS

ALPHABETICAL COMPONENT DESIGNATOR

	FIRST LETTER		SUCCEEDING LETTERS		
	MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS		ALARM		
B	BURNER FLAME				
C	CONDUCTIVITY			CONTROL	
D	DENSITY OR SPECIFIC GRAVITY	DIFFERENTIAL			
E	VOLTAGE		PRIMARY ELEMENT		
F	FLOW RATE	RATIO			
G	GAGING		GLASS		
H	HAND				HIGH
I	CURRENT		INDICATE		
J	POWER	SCAN			
K	TIME OR TIME SCHEDULE			CONTROL STATION	
L	LEVEL		LIGHT		LOW
M	MOISTURE OR HUMIDITY				MIDDLE OR INTERMEDIATE
N	NON RETURN		NOZZLE		
O	DELFECTION		ORIFICE		MALFUNCTION
P	PRESSURE OR VACUUM		POINT		
Q	QUANTITY OR EVENT	INTEGRATE OR TOTALIZE			
R	RADIOACTIVITY		RECORD OR PRINT		
S	SPEED OR FREQUENCY	SAFETY		SWITCH	
T	TEMPERATURE			TRANSMIT/TRANSMITTER	
U	MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	MULTIFUNCTION
V	VISCOSITY			VALVE,DAMPER OR LOUVER	
W	WEIGHT OR FORCE		WELL		
X	VIBRATION				DAS
Y	HEAT			RELAY OR COMPUTE	
Z	POSITION			DRIVE OR ACTUATE	

Notes: (1) From SAN/0499-80 (MDCG9704), "Integrated (Operational) Piping and Instrumentation Diagrams (RADL Item 2-38)," issued June 1981 by MDAC

(2) Conforms to ISA-S5.1 dated 1972

TABLE C-2

INSTRUMENT IDENTIFICATION NUMBERS

NUMERICAL COMPONENT DESIGNATOR

0-999 ELECTRICAL POWER GENERATING SYSTEM (EPGS)

- 0-199 EPGS FEEDWATER & CONDENSATE
- 200-299 EPGS CIRCULATING WATER
- 300-399 EPGS COOLING WATER
- 400-499 EPGS DEMINERALIZER AND FIRE PROTECTION
- 500-599 EPGS COMPRESSED AIR
- 600-699 EPGS STEAM
- 700-799 EPGS SAMPLING
- 800-899 EPGS DRAIN AND SUMP
- 900-999 EPGS TURBINE-GENERATOR PROCESS SYSTEM

1000-1999 PLANT SUPPORT SYSTEM (PSS)

- 1000-1099 PSS STEAM
- 1100-1199 PSS FEEDWATER
- 1200-1299 PSS WATER TREATMENT
- 1300-1399 PSS UNASSIGNED
- 1400-1459 PSS COLLECTOR FIELD INSTRUMENTAITON
- 1460-1499 PSS MISC. INSTRUMENTATION
- 1500-1599 PSS FIRE PROTECTION
- 1600-1699 PSS LIQUID WASTE AND DRAINS
- 1700-1799 PSS SERVICE WATER
- 1800-1899 PSS UNASSIGNED
- 1900-1999 PSS MISCELLANEOUS

2000-2999 RECEIVER SYSTEM (RS)

- 2000-2099 RS INLET AND GASEOUS NITROGEN
- 2100-2199 RS PREHEAT PANELS 22, 23, 24
- 2200-2299 RS PREHEAT PANELS 1, 2, 3
- 2300-2399 RS BOILER PANELS 4, 5, 6
- 2400-2499 RS BOILER PANELS 7, 8, 9
- 2500-2599 RS BOILER PANELS 10, 11, 12
- 2600-2699 RS BOILDER PANELS 13, 14, 15
- 2700-2799 RS BOILER PANELS 16, 17, 18
- 2800-2899 RS BOILER PANELS 19, 20, 21
- 2900-2999 RS OUTLET AND FLASH TANK

3000-4099 THERMAL STORAGE SYSTEM (TSS)

- 3000-3099 TSS THERMAL STORAGE TANK
- 3100-3199 TSS DESUPERHEATER & FLASH TANK SKID-SA301
- 3200-3299 TSS HEATER SKID-SA302
- 3300-3399 TSS HEATER SKID-SA303
- 3400-3499 TSS CHARGING OIL PUMP SKID-SA304
- 3500-3599 TSS PREHEATER SKID-SA305
- 3600-3699 TSS PREHEATER SKID-SA306
- 3700-3799 TSS BOILER AND SUPERHEATER SKID-SA307
- 3800-3899 TSS BOILER AND SUPERHEATER SKID-SA308
- 3900-3999 TSS EXTRACTION PUMP SKID-SA309
- 4000-4099 TSS ULLEAGE MAINTENANCE UNIT

5000-9999 CONTINGENCY USE (ALL SYSTEMS)

- 5000-5200 EPSG ELECTRICAL
- 9000-9019 SPECIAL HELIOSTAT INSTRUMENTATION AND METEROLOGICAL MEASUREMENTS SYSTEMS (SHIMMS)

TABLE C-3

EQUIPMENT IDENTIFICATION LETTERS

ALPHABETICAL COMPONENT DESIGNATOR

AG - Agitator
B - Boiler
BL - Buildings and Structures
CF - Chemical Feeder
CL - Chlorinator
CP - Compressor
CR - Cooling Equipment (Cooling Towers, After-Coolers & Evaporative Coolers, Lube Oil Cooler)
DA - Deaerator
DE - Demineralizer Equipment
DR - Dryer
DS - Desuperheater
E - Exchanger
F - Filter
FA - Fans
H - Heater
HC - Heliostat Area Controller
HE - Heliostat
HS - Hoist
IO - Ion Exchange Equipment
MC - Motor Control Center
MT - Moisture Trap
P - Pump
PR - Purifier
RB - Receiver Boiler
RO - Deleted
RP - Receiver Panel
S - Sample Panel
SA - Skid
SE - Separator
SF - Softener
SP - Sewage Treatment Equipment
TG - Turbine Generator
TK - Tanks
TR - Transformer
V - Vessel
VP - Vaporizer

TABLE C-4

EQUIPMENT IDENTIFICATION NUMBER
NUMERICAL COMPONENT DESIGNATOR

100 - Not Required
200 - Receiver System (RS)
300 - Thermal Storage System (TSS)
400 - Master Control System (MCS)
500 - Collector System (CS)
600 - Beam Characterization System (BCS)
700 - Plant Support System (PSS)
800 - Not Required
900 - Electric Power Generation System (EPGS)

TABLE C-5

DATA ANALYSIS

COMPUTATION LABLE NAMING CONVENTION

Letter	First Position	Second Position	Third Position	Fourth/Fifth Positions
A	Area			
B	Heat Flux		Boiler	
C	Comparator	TS Charging	Condenser	Condensate
D	Delta Energy		Desuperheater	
E	Power Btu/Hr	TS Extraction	Turbine	
F	Efficiency	Farenheit		
G				Gross
H	Enthalpy		High Manifold	
I			Intermediate Manifold	
J	Power Watt-Hr			
K				
L	Log Mean Δt		Low Manifold	
M	Mass			
N				Net
O				Oil
P	Pressure	Power Gen.	Preheater	
Q	Sum of Energy			
R	Density	Receiver	Return	Rock
S	Sum of Flow	Saturation	Superheater	Steam
T	Temperature	Thermal Storage	Tank	
U	Overall Heat Transfer Coef.		Subcooler	
V	Volume			
W	Mass Flow			Water
X	Heat Loss		Total	Total
Y				
Z	Position			

TABLE C-6

COMPUTATION LABELS

(Pages C-9 to C-22)

Computation Lable	Description
Heat Flux	
BRBWA	Total Solar Flux Boiler Panel RB204
BRBWB	Total Solar Flux Boiler Panel RB205
BRBWC	Total Solar Flux Boiler Panel RB206
BRBWD	Total Solar Flux Boiler Panel RB207
BRBWE	Total Solar Flux Boiler Panel RB208
BRBWF	Total Solar Flux Boiler Panel RB209
BRBWG	Total Solar Flux Boiler Panel RB210
BRBWH	Total Solar Flux Boiler Panel RB211
BRBWI	Total Solar Flux Boiler Panel RB212
BRBWJ	Total Solar Flux Boiler Panel RB213
BRBWK	Total Solar Flux Boiler Panel RB214
BRBWL	Total Solar Flux Boiler Panel RB215
BRBWM	Total Solar Flux Boiler Panel RB216
BRBWN	Total Solar Flux Boiler Panel RB217
BRBWO	Total Solar Flux Boiler Panel RB218
BRBWP	Total Solar Flux Boiler Panel RB219
BRBWQ	Total Solar Flux Boiler Panel RB220
BRBWR	Total Solar Flux Boiler Panel RB221
BRPW1	Total Solar Flux Preheat Panel RB201
BRPW2	Total Solar Flux Preheat Panel RB202
BRPW3	Total Solar Flux Preheat Panel RB203
BRPW4	Total Solar Flux Preheat Panel RB222
BRPW5	Total Solar Flux Preheat Panel RB223
BRPW6	Total Solar Flux Preheat Panel RB224
BRBX	Total Solar Flux On Boiler Panels
BRPX	Total Solar Flux On Preheater Panels
BRX	Total Solar Flux On Receiver

Computation Lable	Description
Delta Energy	
DRBSA	Btu/Hr Received in Panel 204
DRBSB	Btu/Hr Received in Panel 205
DRBSC	Btu/Hr Received in Panel 206
DRBSD	Btu/Hr Received in Panel 207
DRBSE	Btu/Hr Received in Panel 208
DRBSF	Btu/Hr Received in Panel 209
DRBSG	Btu/Hr Received in Panel 210
DRBSH	Btu/Hr Received in Panel 211
DRBSI	Btu/Hr Received in Panel 212
DRBSJ	Btu/Hr Received in Panel 213
DRBSK	Btu/Hr Received in Panel 214
DRBSL	Btu/Hr Received in Panel 215
DRBSM	Btu/Hr Received in Panel 216
DRBSN	Btu/Hr Received in Panel 217
DRBSO	Btu/Hr Received in Panel 218
DRBSP	Btu/Hr Received in Panel 219
DRBSQ	Btu/Hr Received in Panel 220
DRBSR	Btu/Hr Received in Panel 221
DRPW1	Btu/Hr Received in Panel 201
DRPW2	Btu/Hr Received in Panel 202
DRPW3	Btu/Hr Received in Panel 203
DRPW4	Btu/Hr Received in Panel 222
DRPW5	Btu/Hr Received in Panel 223
DRPW6	Btu/Hr Received in Panel 224
DRPW	Total Btu/Hr Received in Preheat Panels
DRBS	Total Btu/Hr Received in Boiler Panels
DRT	Total Btu/Hr Received in Receiver Stream
DETG	Total Btu/Hr Equivalent Power Generated by Turbine (Gross, Turbine Output)
DETN	Total Btu/Hr Equivalent Power Generated by EPGS (Net Plant Output)
DCCS2	Btu/Hr Released by Steam in 301
DCCS3	Btu/Hr Released by Steam in 302
DCUW2	Btu/Hr Released by Condensate in 311
DCUW3	Btu/Hr Released by Condensate in 312
DCCO2	Btu/Hr Received by Oil in 301
DCCO3	Btu/Hr Received by Oil in 302
DCUO2	Btu/Hr Received by Oil in 311
DCUO3	Btu/Hr Received by Oil in 312
DCCS	Total Btu/Hr Released by Charging Steam
DCCO	Total Btu/Hr Received by Charging Oil

Computation Lable	Description
DESS5	Btu/Hr Received by Steam in Superheater 107
DESS6	Btu/Hr Received by Steam in Superheater 108
DEBS5	Btu/Hr Received by Steam in Boiler 105
DEBS6	Btu/Hr Received by Steam in Boiler 106
DEPW5	Btu/Hr Received by Feedwater in Preheater 103
DEPW6	Btu/Hr Received by Feedwater in Preheater 104
DETS5	Btu/Hr Received in Loop 5
DETS6	Btu/Hr Received in Loop 6
DESO5	Btu/Hr Released by Oil in Superheater 107
DESO6	Btu/Hr Released by Oil in Superheater 108
DEBO5	Btu/Hr Released in Oil in Boiler 105
DEBO6	Btu/Hr Released by Oil in Boiler 106
DEPO5	Btu/Hr Released by Oil in Preheater 103
DEPO6	Btu/Hr Released by Oil in Preheater 104
DETO5	Btu/Hr Released by Oil in Loop 5
DETO6	Btu/Hr Released by Oil in Loop 6
DEBS	Total Btu/Hr Received by Extract System Steam
DEBO	Total Btu/Hr Released by Extraction Oil System
DTTO	Net Instantaneous Energy Entering or Leaving the TS (Btu/Hr)

Computation Lable	Description
Power	
ERPWT	Preheater Total Inlet Water Total Power
ERPW1	Preheater Panel 201 Inlet Water Total Power
ERPW2	Preheater Panel 202 Inlet Water Total Power
ERPW3	Preheater Panel 203 Inlet Water Total Power
ERPW4	Preheater Panel 222 Inlet Water Total Power
ERPW5	Preheater Panel 223 Inlet Water Total Power
ERPW6	Preheater Panel 224 Inlet Water Total Power
ERPW7	Preheater Panel 222 Exit Water Total Power
ERPW8	Preheater Panel 223 Exit Water Total Power
ERPW9	Preheater Panel 224 Exit Water Total Power
ERBWT	Boiler Panels Total Inlet Water Total Power
ERBSA	Boiler Panel 204 Exit Steam Total Power
ERBSB	Boiler Panel 205 Exit Steam Total Power
ERBSC	Boiler Panel 206 Exit Steam Total Power
ERBSD	Boiler Panel 207 Exit Steam Total Power
ERBSE	Boiler Panel 208 Exit Steam Total Power
ERBSF	Boiler Panel 209 Exit Steam Total Power
ERBSG	Boiler Panel 210 Exit Steam Total Power
ERBSH	Boiler Panel 211 Exit Steam Total Power
ERBSI	Boiler Panel 212 Exit Steam Total Power
ERBSJ	Boiler Panel 213 Exit Steam Total Power
ERBSK	Boiler Panel 214 Exit Steam Total Power
ERBSL	Boiler Panel 215 Exit Steam Total Power
ERBSM	Boiler Panel 216 Exit Steam Total Power
ERBSN	Boiler Panel 217 Exit Steam Total Power
ERBSO	Boiler Panel 218 Exit Steam Total Power
ERBSP	Boiler Panel 219 Exit Steam Total Power
ERBSQ	Boiler Panel 220 Exit Steam Total Power
ERBSR	Boiler Panel 221 Exit Steam Total Power
ERBST	Receiver Total Steam Total Power
ERBWA	Boiler Panel 204 Entrance Water Total Power
ERBWB	Boiler Panel 205 Entrance Water Total Power
ERBWC	Boiler Panel 206 Entrance Water Total Power
ERBWD	Boiler Panel 207 Entrance Water Total Power
ERBWE	Boiler Panel 208 Entrance Water Total Power
ERBWF	Boiler Panel 209 Entrance Water Total Power
ERBWG	Boiler Panel 210 Entrance Water Total Power
ERBWH	Boiler Panel 211 Entrance Water Total Power
ERBWI	Boiler Panel 212 Entrance Water Total Power
ERBWJ	Boiler Panel 213 Entrance Water Total Power
ERBWK	Boiler Panel 214 Entrance Water Total Power
ERBWL	Boiler Panel 215 Entrance Water Total Power
ERBWM	Boiler Panel 216 Entrance Water Total Power
ERBWN	Boiler Panel 217 Entrance Water Total Power
ERBWO	Boiler Panel 218 Entrance Water Total Power
ERBWP	Boiler Panel 219 Entrance Water Total Power
ERBWQ	Boiler Panel 220 Entrance Water Total Power
ERBWR	Boiler Panel 221 Entrance Water Total Power
EPESA	Total Btu/Hr to Admission Steam Turbine Nozzle
EPESP	Total Btu/Hr to Primary Turbine Nozzle

Computation Lable	Description
ECDW	Charging Desuperheater Water Total Power
ECDS	Charging Desuperheater Steam Total Power
ECCS	TSS Charging Steam Total Power
ECCS2	TSS Charting Steam Total Power to Loop 1
ECCS3	TSS Charging Steam Total Power to Loop 2
ECCW2	TSS Charging Condensate Total Power Loop 1
ECCW3	TSS Charging Condensate Total Power Loop 2
ECUW2	TSS Charging Subcooler Exit Water Total Power Loop 1
ECUW3	TSS Charging Subcooler Exit Water Total Power Loop 2
ECUO2	TSS Charging Oil Inlet Total Power Loop 1
ECUO3	TSS Charging Oil Inlet Total Power Loop 2
ECCO2	TSS Charging Oil Subcooler Out Total Power Loop 1
ECCO3	TSS Charging Oil Subcooler Out Total Power Loop 2
ECRO2	TSS Charging Oil Condenser Out Total Power Loop 1
ECRO3	TSS Charging Oil Condenser Out Total Power Loop 2
EEPW3	TSS Extraction Feedwater Total Power Loop 5
EEPW4	TSS Extraction Feedwater Total Power Loop 6
EEBW5	TSS Extraction Preheat (103) Water Total Power Loop 5
EEBW6	TSS Extraction Preheat (104) Water Total Power Loop 6
EEBS5	TSS Extraction Boiler (105) Steam Total Power Loop 5
EEBS6	TSS Extraction Boiler (106) Steam Total Power Loop 6
EESS7	TSS Extraction Superheater (107) Steam Total Power Loop 5
EESS8	TSS Extraction Superheater (108) Steam Total Power Loop 6
EERO3	TSS Extraction Oil Preheater (103) Outlet Total Power Loop 5
EERO4	TSS Extraction Oil Preheater (104) Outlet Total Power Loop 6
EEPO3	TSS Extraction Oil Boiler (105) Outlet Total Power Loop 5
EEPO4	TSS Extraction Oil Boiler (106) Outlet Total Power Loop 6
EEBO5	TSS Extraction Oil Boiler (105) Inlet Total Power Loop 5
EEBO6	TSS Extraction Oil Boiler (106) Inlet Total Power Loop 6
EESO7	TSS Extraction Oil Superheater (107) Outlet Total Power Loop 5
EESO8	TSS Extraction Oil Superheater (108) Outlet Total Power Loop 6
EETO7	TSS Extraction Oil Superheater (107) Inlet Total Power Loop 5
EETO8	TSS Extraction Oil Superheater (108) Inlet Total Power Loop 6
EETO5	TSS Extraction Oil Superheater (107) Bypass Total Power Loop 5
EETO6	TSS Extraction Oil Superheater (108) Bypass Total Power Loop 6
ETTOS	Energy Stored in Oil, Rock, Sand of TS Tank (Btu)
ETTR	Energy Stored in Rock of TS Tank (Btu)
ETTO	Energy Stored in Oil of TS Tank (Btu)
ETTOD	Calculated Difference (Losses) Between Total Energy Transmitted Via Oil and the Energy in the Rock, Sand, and Oil (Btu)
ETTOR	Ratio of the Total Energy Stored in the TS Tank Oil, Rock, and Sand Divided by the Total Energy Transferred by Oil to the TS Tank

bjm:914

Computation Lable	Description
Efficiency	
FEG	Efficiency of Electrical Generator System (Gross)
FEN	Efficiency of Electrical Generator System (Net)
FCT 23	Heat Transfer Efficiency of Charging Heat Exchanger
FEXO	Heat Transfer Efficiency of Extraction Heat Exchangers
FR	Effiency of Receiver

Computation Lable	Description
Enthalpy	
HW (P_ T_)	Enthalpy of Water at Measured Conditions
HS (P_ T_)	Enthalpy of Saturated Steam at Measured Conditions
HSS (P_ T_)	Enthalpy of Superheated Steam at Measured Conditions
HO (P_ T_)	Enthalpy of Oil at Measured Conditions

Computation Lable	Description
Log Mean Δt	
LCC301	Log Mean Δt of Exchanger 301
LCC302	Log Mean Δt of Exchanger 302
LCU311	Log Mean Δt of Exchanger 311
LCU312	Log Mean Δt of Exchanger 312
LEP303	Log Mean Δt of Exchanger 303
LEP304	Log Mean Δt of Exchanger 304
LEB305	Log Mean Δt of Exchanger 305
LEB306	Log Mean Δt of Exchanger 306
LES307	Log Mean Δt of Exchanger 307
LES308	Log Mean Δt of Exchanger 308

Computation Lable	Description
Mass	
MTTO	Mass of Oil in TS Tank (lb)

Computation Lable	Description
Sum of Energy	
QRBS	Sum of Btu/Hr Received in Individual Boiler Panels
QRPW	Sum of Btu/Hr Received in Individual Preheat Panels
QC2S	Total Charging Steam Energy Released in Exchanger Loop 2
QC3S	Total Charging Steam Energy Released in Exchanger Loop 3
QC2O	Total Charging Oil Energy Released in Exchanger Loop 2
QC3S	Total Charging Oil Energy Released in Exchanger Loop 3
QC23S	Total Charging Loop Steam Energy Released in Exchanger
QC23O	Total Charging Loop Oil Energy Released in Exchanger
QE5S	Total Extraction Steam Energy Released in Exchanger Loop 5
QE6S	Total Extraction Steam Energy Released in Exchanger Loop 6
QE5O	Total Extraction Oil Energy Released in Exchanger Loop 5
QE6O	Total Extraction Oil Energy Released in Exchanger Loop 6
QE56S	Total Extraction Steam Energy Released in Exchangers
QE56O	Total Extraction Oil Energy Released in Exchangers
QTTO	Sum of Incremental Thermal Energy Stored in TS Tank via the Oil Flow (Btu)

Computation Lable	Description
Density	
RO	Caloria Oil Density at Temperature (TF) ^{o}F (lb/cubic ft)

Computation Lable	Description
Overall Heat Transfer Coefficient	
U301	Overall Heat Transfer Coefficient for Exchanger 301
U302	Overall Heat Transfer Coefficient for Exchanger 302
U311	Overall Heat Transfer Coefficient for Exchanger 311
U312	Overall Heat Transfer Coefficient for Exchanger 312
U303	Overall Heat Transfer Coefficient for Exchanger 303
U304	Overall Heat Transfer Coefficient for Exchanger 304
U305	Overall Heat Transfer Coefficient for Exchanger 305
U306	Overall Heat Transfer Coefficient for Exchanger 306
U307	Overall Heat Transfer Coefficient for Exchanger 307
U308	Overall Heat Transfer Coefficient for Exchanger 308

Computation Lable	Description
Mass Flow	
WRPWT	Preheater Total Water Mass Flow (lb/m)
WRPW1	Preheater Panels 201 and 222 Water Mass Flow (lb/m)
WRPW2	Preheater Panels 202 and 223 Water Mass Flow (lb/m)
WRPW3	Preheater Panels 203 and 224 Water Mass Flow (lb/m)
WRBWA	Boiler Panel 204 Water Mass Flow (lb/m)
WRBWB	Boiler Panel 205 Water Mass Flow (lb/m)
WRBWC	Boiler Panel 206 Water Mass Flow (lb/m)
WRBWD	Boiler Panel 207 Water Mass Flow (lb/m)
WRBWE	Boiler Panel 208 Water Mass Flow (lb/m)
WRBWF	Boiler Panel 209 Water Mass Flow (lb/m)
WRBWG	Boiler Panel 210 Water Mass Flow (lb/m)
WRBWH	Boiler Panel 211 Water Mass Flow (lb/m)
WRBWI	Boiler Panel 212 Water Mass Flow (lb/m)
WRBWJ	Boiler Panel 213 Water Mass Flow (lb/m)
WRBWK	Boiler Panel 214 Water Mass Flow (lb/m)
WRBWL	Boiler Panel 215 Water Mass Flow (lb/m)
WRBWM	Boiler Panel 216 Water Mass Flow (lb/m)
WRBWN	Boiler Panel 217 Water Mass Flow (lb/m)
WRBWO	Boiler Panel 218 Water Mass Flow (lb/m)
WRBWP	Boiler Panel 219 Water Mass Flow (lb/m)
WRBWQ	Boiler Panel 220 Water Mass Flow (lb/m)
WRBWR	Boiler Panel 221 Water Mass Flow (lb/m)
WPES	Primary Steam to Turbine Mass Flow (lb/m)
WEPWT	Admission Steam to Turbine Mass Flow (lb/m)
WCDS	TSS Charging Steam Mass Flow Total (lb/m)
WCDS2	TSS Charging Steam Mass Flow to Loop 1 (lb/m)
WCDS3	TSS Charging Steam Mass Flow to Loop 2 (lb/m)
WCUO2	TSS Charging Oil Mass Flow to Loop 1 (lb/m)
WCUO3	TSS Charging Oil Mass Flow to Loop 2 (lb/m)
WEPW5	TSS Extraction Feedwater Mass Flow Loop 5 (lb/m)
WEPW6	TSS Extraction Feedwater Mass Flow Loop 6 (lb/m)
WEXW56	TSS Extraction Feedwater Total Flow Loop (lb/m)
WEBO5	TSS Extraction Oil Mass Flow Loop 5 (lb/m)
WEBO6	TSS Extraction Oil Mass Flow Loop 6 (lb/m)
WETO5	TSS Extraction Oil Superheater Bypass Mass Flow Loop 5 (lb/m)
WETO6	TSS Extraction Oil Superheater Bypass Mass Flow Loop 6 (lb/m)
WETO7	TSS Extraction Oil to Superheater (107) Mass Flow Loop 5 (lb/m)
WETO8	TSS Extraction Oil to Superheater (108) Mass Flow Loop 6 (lb/m)
WTHO	Net Mass Flow In/Out of TS Tank (lb/hr)

Computation Lable	Description
Heat Loss	
XC23	Heat Loss in Charging Heat Exchangers
XE56	Heat Loss in Extraction Heat Exchangers
XTT	Heat Loss from Thermal Storage Tank

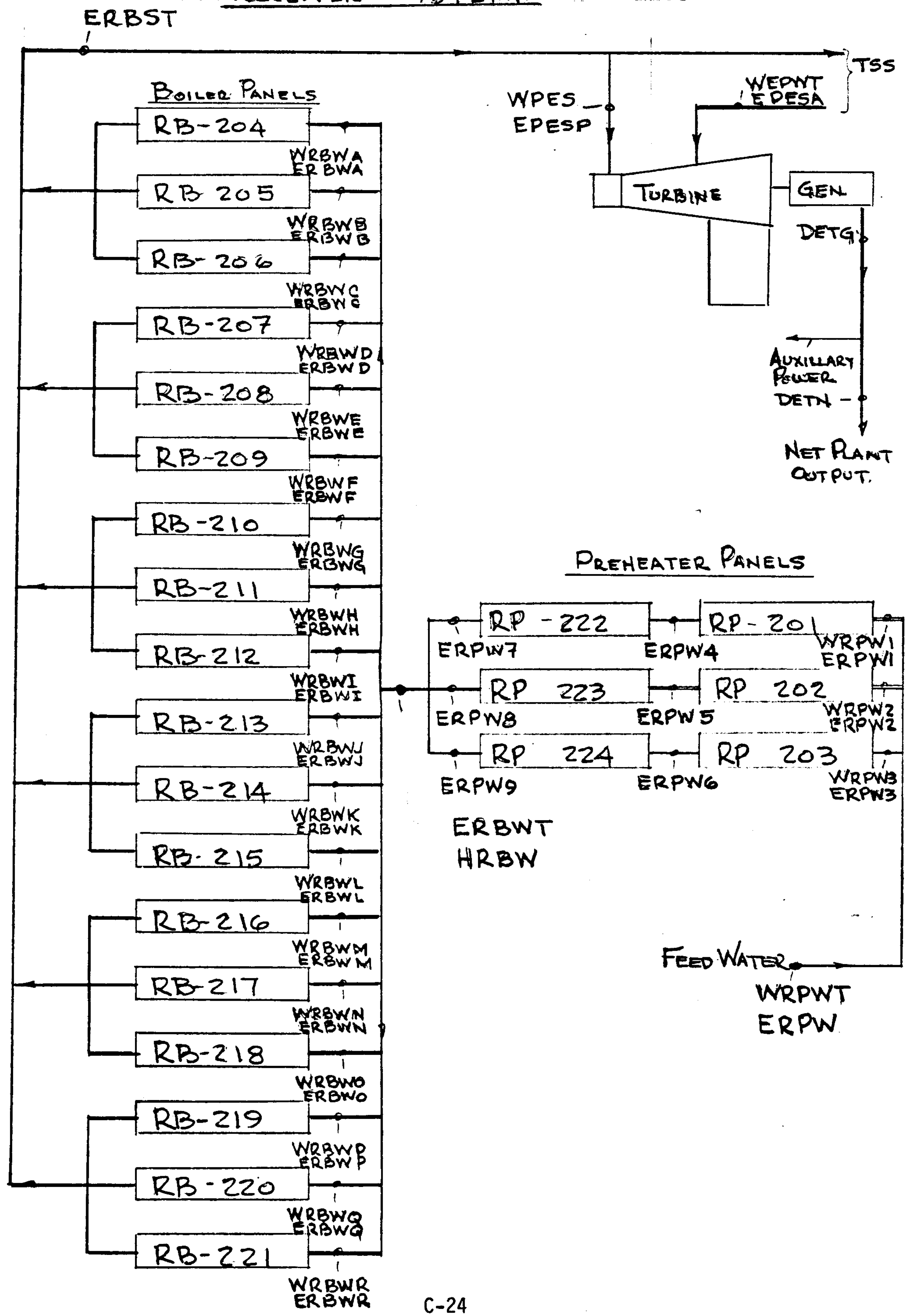
TABLE C-7

LOCATION OF COMPUTED QUANTITIES

(Pages C-24 to C-27)

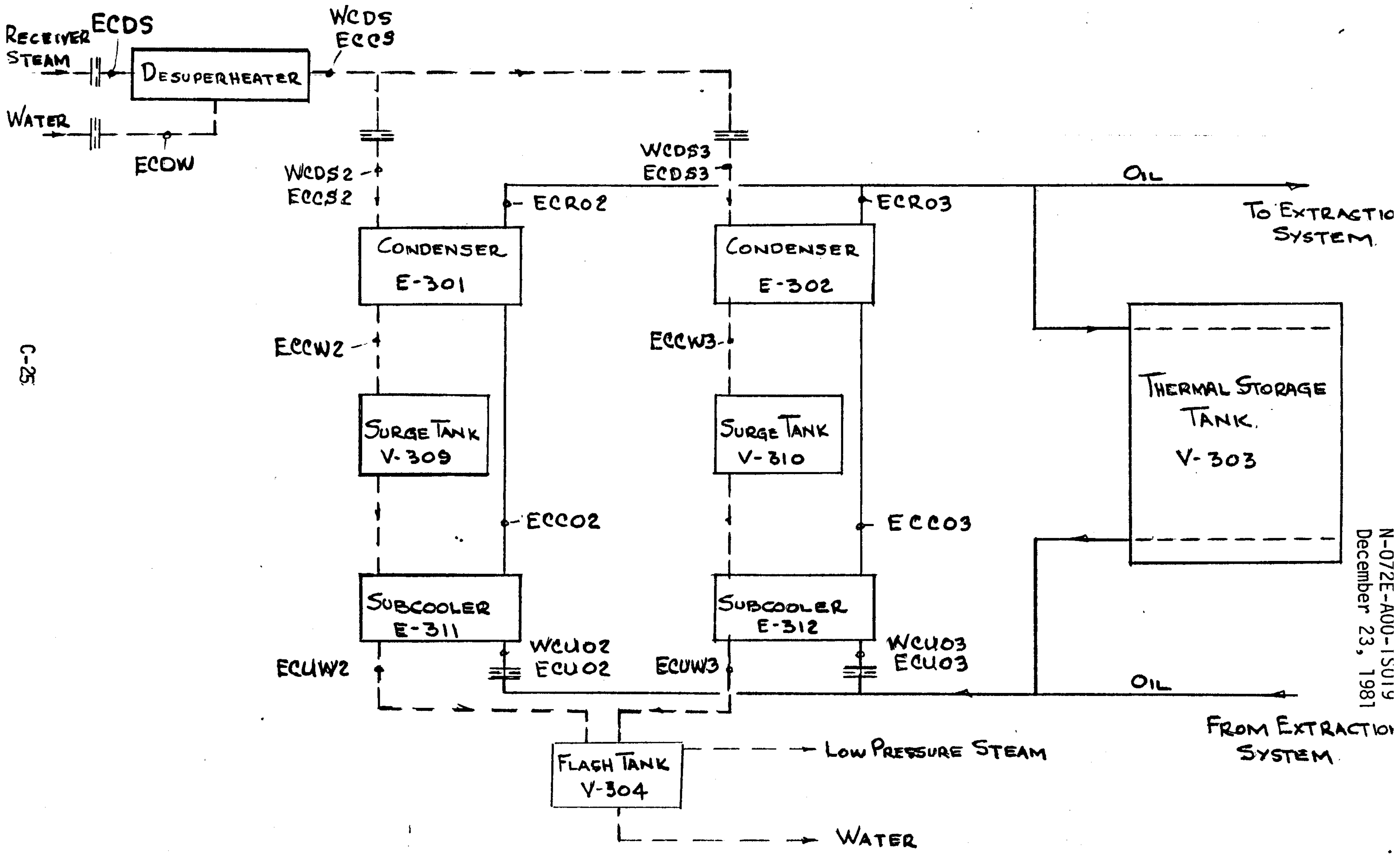
Data Analysis - Computation Lable System Location

Receiver System



DATA ANALYSIS - COMPUTATION LABLE SYSTEM LOCATION.

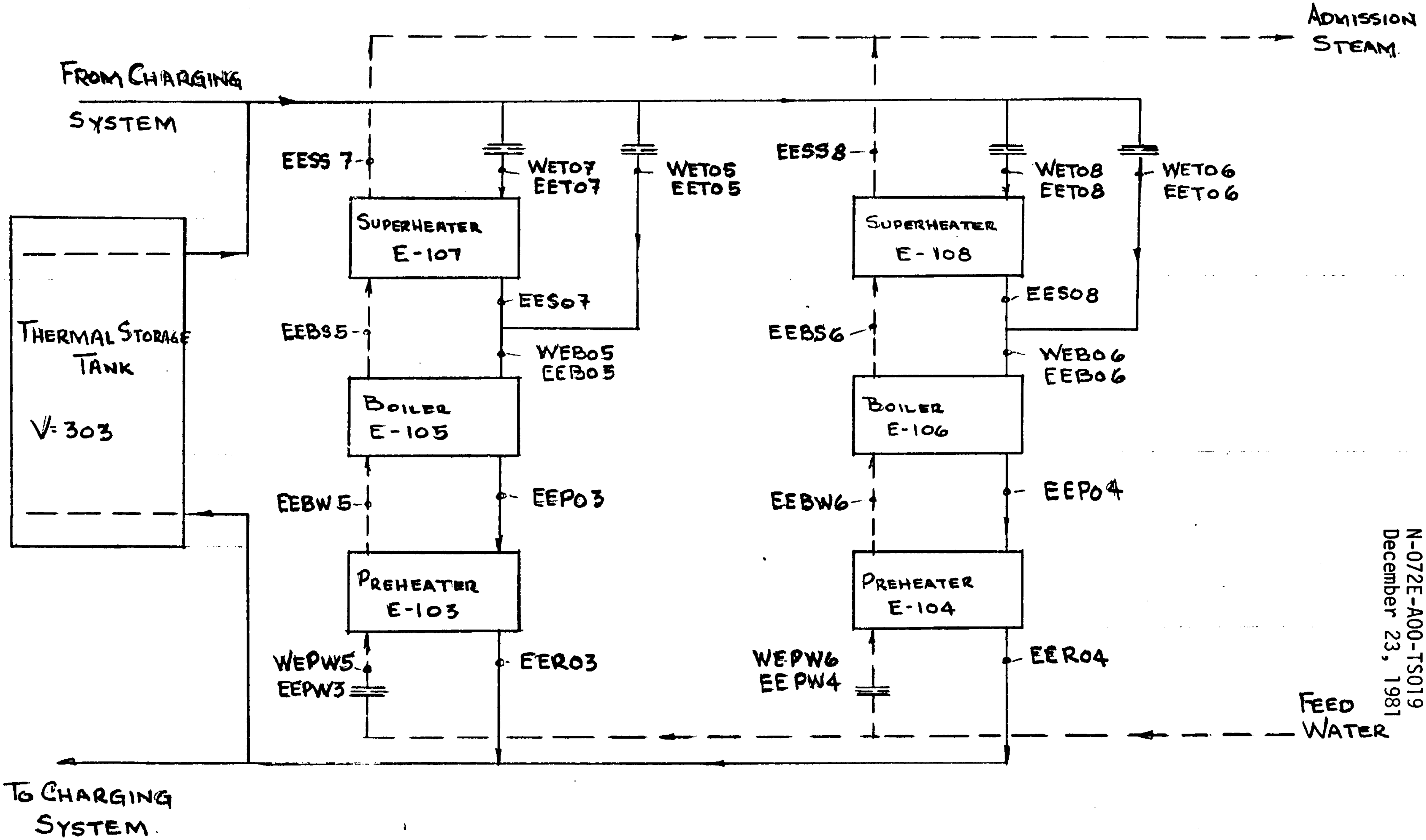
TSS - CHARGING SYSTEM



N-072E-A00-IS019
December 23, 1981

Data Analysis - Computation Lable System Location

TSS - Extraction System (Admission Steam)



N-072E-A00-TS019
December 23, 1981

DATA ANALYSIS - COMPUTATION LABLE SYSTEM LOCATION

TSS - THERMAL STORAGE TANK

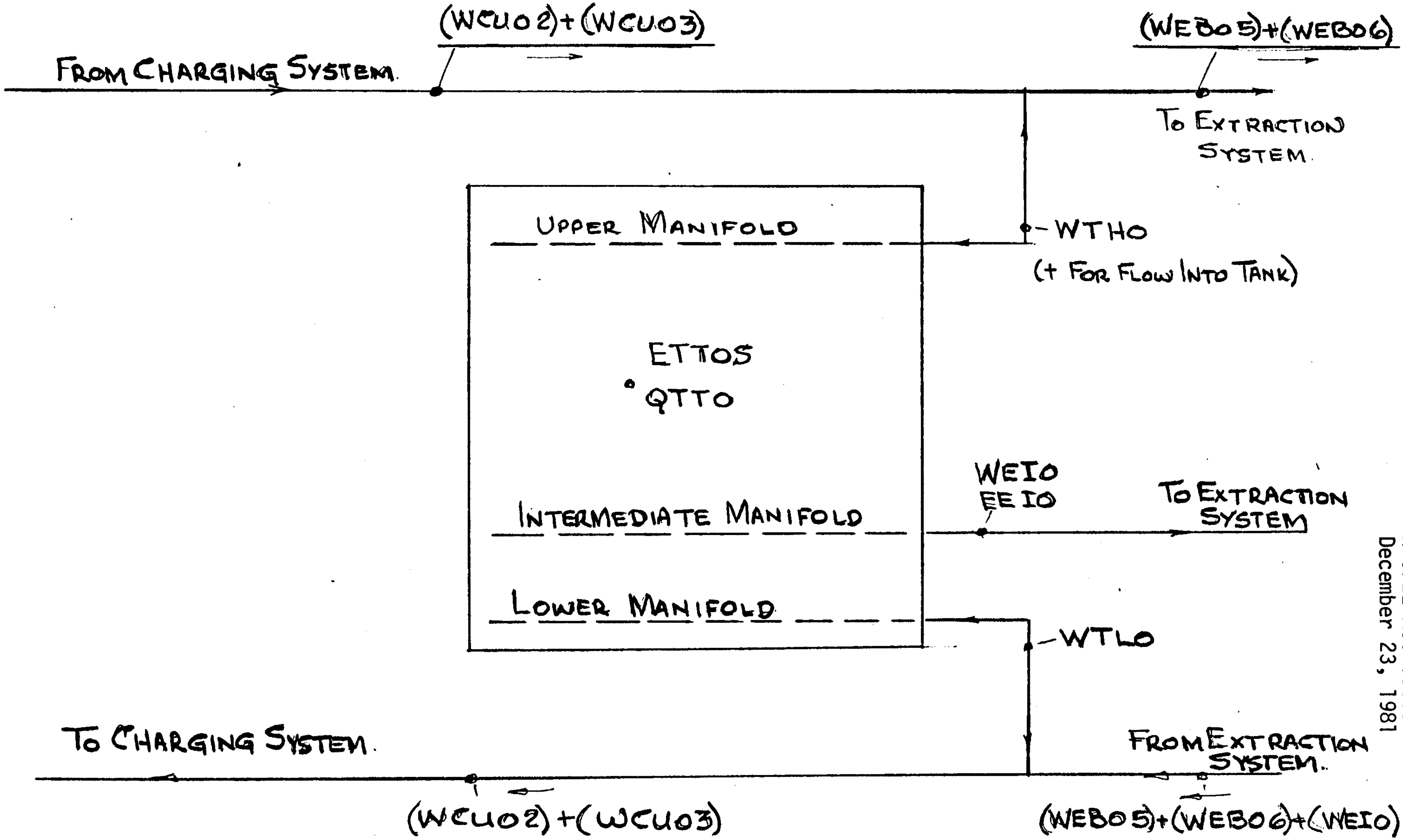


TABLE C-8

COMPUTATION EQUATIONS

(Pages C-29 to C-58)

BRXXX:

Total Solar Heat Flux on Receiver Panels

Equations:

BRXXX = (Average Measured Solar Heat Flux) (Panel Area) Btu/hr
= (Solar Flux Gage Measurements/No Gages) (2.917 ft x 44.0 ft) Btu/hr

BRBWA = 1/3 (YT2307A + YT2307B + YT2307C) (128.35)
BRBWB = 1/3 (YT2308A + YT2308B + YT2308C) (128.35)
BRBWC = 1/3 (YT2309A + YT2309B + YT2309C) (128.35)
BRBWD = 1/3 (YT2407A + YT2407B + YT2407C) (128.35)
BRBWE = 1/3 (YT2408A + YT2408B + YT2408C) (128.35)
BRBWF = 1/3 (YT2409A + YT2409B + YT2409C) (128.35)
BRBWG = 1/3 (YT2507A + YT2507B + YT2507C) (128.35)
BRBWH = 1/3 (YT2508A + YT2508B + YT2508C) (128.35)
BRBWI = 1/3 (YT2509A + YT2509B + YT2509C) (128.35)
BRBWJ = 1/3 (YT2607A + YT2607B + YT2607C) (128.35)
BRBWK = 1/3 (YT2608A + YT2608B + YT2608C) (128.35)
BRBWL = 1/3 (YT2609A + YT2609B + YT2609C) (128.35)
BRBWM = 1/3 (YT2707A + YT2707B + YT2707C) (128.35)
BRBWN = 1/3 (YT2708A + YT2708B + YT2708C) (128.35)
BRBWO = 1/3 (YT2709A + YT2709B + YT2709C) (128.35)
BRBWP = 1/3 (YT2807A + YT2807B + YT2807C) (128.35)
BRBWQ = 1/3 (YT2808A + YT2808B + YT2808C) (128.35)
BRBWR = 1/3 (YT2809A + YT2809B + YT2809C) (128.35)

BRRP1 = 1/3 (YT2210A + YT2210B + YT2210C) (128.35)
BRRP2 = 1/3 (YT2211A + YT2211B + YT2211C) (128.35)
BRRP3 = 1/3 (YT2212A + YT2212B + YT2212C) (128.35)
BRRP4 = 1/3 (YT2110A + YT2110B + YT2110C) (128.35)
BRRP5 = 1/3 (YT2111A + YT2111B + YT2111C) (128.35)
BRRP6 = 1/3 (YT2112A + YT2112B + YT2112C) (128.35)

BRBX:

Equals Sum of Solar Fluxes on Individual Preheater Panels (Total Solar Flux on Preheater Panels) Btu/Hr

Equation:

BRPX = PRPW1 + BRPW2 + BRPW3 + . . . PBPW6

BRBX:

Equals Sum of Solar Fluxes on Individual Boiler Panels (Total Solar Flux on Boiler Panels) Btu/Hr

Equation:

BRPX = BRBWA + BRBWB + BRBWC + . . . BRBWR

BRX:

Equals Sum of Total Preheater Flux and Total Boiler Flux (Total Solar Flux on Receiver) Btu/Hr

Equation:

BRX = BRBX + BRPX

DETN:

Total Btu/Hr Equivalent Power Generated by EPGS (Net Plant Output)

Equation:

DETN = 3413 (JT5102A) Btu/hr

DETG:

Total Btu/hr Equivalent Power Generated by Turbine Generator (Gross Turbine Output)

Equation:

DETG = 3413 (JTX5100) Btu/hr

DXXX:

Delta Energy (Heat Added or Removed)

Equation:

DXXX = (EXXX - EXXX) ± Btu/hr
Total Heat Exit - Total Heat Entrance

DRBSA = (ERBSA) - (ERBWA)
DRBSB = (ERBSB) - (ERBWB)
DRBSC = (ERBSC) - (ERBWC)
DRBSD = (ERBSD) - (ERBWD)
DRBSE = (ERBSE) - (ERBWE)
DRBSF = (ERBSF) - (ERBWF)
DRBSG = (ERBSG) - (ERBWG)
DRBSH = (ERBSH) - (ERBWH)
DRBSI = (ERBSI) - (ERBWI)
DRBSJ = (ERBSJ) - (ERBWJ)
DRBSK = (ERBSK) - (ERBWK)
DRBSL = (ERBSL) - (ERBWL)
DRBSM = (ERBSM) - (ERBWM)
DRBSN = (ERBSN) - (ERBWN)
DRBSO = (ERBSO) - (ERBWO)
DRBSP = (ERBSP) - (ERBWP)
DRBSQ = (ERBSQ) - (ERBWQ)
DRBSR = (ERBSR) - (ERBWR)
DRPW1 = (ERPW4) - (ERPW1)
DRPW2 = (ERPW5) - (ERPW2)
DRWP3 = (ERPW6) - (ERPW3)
DRPW4 = (ERPW7) - (ERPW4)
DRPW5 = (ERPW8) - (ERPW5)
DRPW6 = (ERPW9) - (ERPW6)
DRPW = (ERBWT) - (ERPWT)
DRBS = (ERBST) - (ERBWT)

DCCS2 = (ECCS2) - (ECCW2)
DCCS3 = (ECCS3) - (ECCW3)
DCUW2 = (ECCW2) - (ECUW4)
DCUW3 = (ECCW3) - (ECUW3)

DCCO2 = (ECRO2) - (ECCO2)
DCCO3 = (ECRO3) - (ECCO3)
DCUO2 = (ECCO2) - (ECUO2)
DCUO3 = (ECCO3) - (ECUO3)
DESS5 = (EESS7) - (EEBS5)
DESS6 = (EESS8) - (EEBS6)
DEBS5 = (EESB5) - (EEBW5)
DEBS6 = (EEBS6) - (EEBW6)
DEPW5 = (EEBW5) - (EEPW3)
DEPW6 = (EEBW6) - (EEPW4)
DETS5 = (EESS7) - (EEPW3)
DETS6 = (EESS8) - (EEPW4)
DESO5 = (EESO7) - (EETO7)
DESO6 = (EESO8) - (EETO8)
DEBO5 = (EEBO5) - (EEPO3)
DEBO6 = (EEBO6) - (EEPO4)
DEPO5 = (EEPO3) - (EERO3)

DEP06 = (EEP04) - (EER04)
DET05 = (EET07) + (EET05) - (EER03)
DET06 = (EET08) + (EET06) - (EER04)
DEBS = (EESS7) - (EEPW3) + (EESS8) - (EEPW4)
DEBO = (EET07) - (EER03) + (EET05) + (EET08) - (EER04) + (EET06)

DCCS = (EECS) - (ECUW2) - (ECUW3)
DCCO = (ECR02) + (ECR03) - (ECU02) - (ECU03)

DRT = (ERBST - (ERPW)

DTTO:

The Net Energy Instantaneous Entering or Leaving the Tank, Btu/Hr

Method:

The net mass flow entering or leaving the thermal storage tank (WTHO) multiplied by the difference between the inlet and exit enthalpy minus the delta energy flow removed by the auxillary oil loop flow equals the instantaneous energy flow to or from the thermal storage tank.

Equation:

$$DTTO = (WTHO)\left[HO\ (TE3006) - HO\ (TE3007)\right] - (WEIO)\left[HO\ (TE3086) - HO\ (TE3007)\right]\ \text{Btu/hr}$$

EXXXX:

Total Power in Process Stream

Equations:

EXXXX = (Entrophy at Stream Conditions) (Mass Flow), Btu/hr

ECDW = HW (P 3109, T 3108) (F 3105)
ECDS = HS (P 3104, T 3102) (F 3102)
ECCS = ECDW + ECDS
ECCS2 = HS (P 3203, T 3204) (WCDS2)
ECCS3 = HS (P 3303, T 3304) (WCDS3)

ECCW2 = HW (P 3252, T 3251) (WCDS2)
ECCW3 = HW (P 3352, T 3351) (WCDS3)
ECUW2 = HW (P 3252, T 3253) (WCDS2)
ECUW3 = HW (P 3252, T 3353) (WCDS3)
ECUO2 = HO (T 3214) (WCUO2)
ECUo3 = HO (T 3314) (WCUO3)
ECCO2 = HO (T 3254) (WCUO2)
ECCO3 = HO (T 3354) (WCUO3)
ECRO2 = HO (T 3211) (WCUO2)
ECRO3 = HO (T 3310) (WCUO3)
EEWP3 = HW (P 3502, T 3503) (WEPW5)
EEPW4 = HW (P 3602, T 3603) (WEPW6)
EEBW5 = HW (P 3502, T 3754) (WEPW5)
EEBW6 = HW (P 3602, T 3854) (WEPW6)
EEBS5 = HSS (P 3702A or T 3753) (WEPW5)
EEBS6 = HSS (P 3202A or T 3853) (WEPW6)
EESS7 = HS (P 3714, T 3710A) (WEPW5)
EESS8 = HS (P 3814, T 3810A) (WEPW6)
EERO3 = HO (T 3752) (WEBO5)
EERO4 = HO (T 3651) (WEBO6)
EEPO3 = HO (T 3752) (WEBO5)
EEPO4 = HO (T 3852) (WEBO6)
EEBO5 = HO (T 3750) (WEBO5)
EEBO6 = HO (T 3850) (WEBO6)
EESO7 = HO (T 3755) (WETO7)
EESO8 = HO (T 3855) (WETO5)
EETO7 = HO (T 3711) (WETO7)
EETO8 = HO (T 3811) (WETO8)
EETO5 = HO (T 3704) (WETO5)
EETO6 = HO (T 3804) (WETO6)

ERPWT = HW (P 2002, T 2001) (WRPWT)
ERPW1 = HW (P 2002, T 2001) (WRPW1)
ERPW2 = HW (P 2002, T 2001) (WRPW2)
ERPW3 = HW (P 2002, T 2001) (WRPW3)
ERPW4 = HW (P 2002, T 2007) (WRPW1)
ERPW5 = HW (P 2002, T 2008) (WRPW2)
ERPW6 = HW (P 2002, T 2009) (WRPW3)
ERPW7 = HW (P 2006, T 2107) (WRPW1)
ERPW8 = HW (P 2006, T 2108) (WRPW2)
ERPW9 = HW (P 2006, T 2109) (WRPW3)
ERBWT = HW (P 2006, T 2005) (WRPWT)
ERBWA = HW (P 2006, T 2005) (WRBA)
ERBWB = HW (P 2006, T 2005) (WRBB)
ERBWC = HW (P 2006, T 2005) (WRBC)
ERBWD = HW (P 2006, T 2005) (WRBD)

ERBWE = HW (P 2006, T 2005) (WRBE)
ERBWF = HW (P 2006, T 2005) (WRBF)
ERBWG = HW (P 2006, T 2005) (WRBG)
ERBWH = HW (P 2006, T 2005) (WRBH)
ERBWI = HW (P 2006, T 2005) (WRBI)
ERBWJ = HW (P 2006, T 2005) (WRBJ)
ERBWK = HW (P 2006, T 2005) (WRBK)
ERBWL = HW (P 2006, T 2005) (WRBL)
ERBWM = HW (P 2006, T 2005) (WRBM)
ERBWN = HW (P 2006, T 2005) (WRBN)
ERBWO = HW (P 2006, T 2005) (WRBO)
ERBWP = HW (P 2006, T 2005) (WRBP)
ERBWQ = HW (P 2006, T 2005) (WRBQ)
ERBWR = HE (P 2006, T 2005) (WRBR)
ERBST = HS (PTX2902, TEX2950) (WRPWT)
EPESP = HS (PI-992, TI 945) (WPES)
EPESA = HS (PI-997, TI 946) (WEPWT)

ERBSA = HW (P 2902, T 2345) (WRBWA)
ERBSB = HW (P 2902, T 2345) (WRBWB)
ERBSC = HW (P 2902, T 2345) (WRBWC)
ERBSD = HW (P 2902, T 2345) (WRBWD)
ERBSE = HW (P 2902, T 2345) (WRBWE)
ERBSF = HW (P 2902, T 2345) (WRBWF)
ERBSG = HW (P 2902, T 2345) (WRBWG)
ERBSH = HW (P 2902, T 2345) (WRBWH)
ERBSI = HW (P 2902, T 2345) (WRBWI)
ERBSJ = HW (P 2902, T 2345) (WRBWJ)
ERBSK = HW (P 2902, T 2345) (WRBWK)
ERBSL = HW (P 2902, T 2345) (WRBWL)
ERBSM - HW (P 2902, T 2345) (WRBWM)
ERBSN = HW (P 2902, T 2345) (WRBWN)
ERBSO = HW (P 2902, T 2345) (WRBWO)
ERBSP = HW (P 2902, T 2345) (WRBWP)
ERBSQ = HW (P 2902, T 2345) (WRBWQ)
ERBSR = HW (P 2902, T 2345) (WRBWR)

ETTOR:

Ratio of Total Energy Stored in TS Tank Divided by the Total Energy Transfer to the Tank

Equation:

$$ETTOR = \frac{(ETTOS)}{(QTTO)} \text{ Ratio}$$

ETTOS:

Energy Stored in the Oil, Rock, and Sand

Method:

The instantaneous value of the energy stored in the Thermal Storage Tank is calculated by dividing the rock filled portion of the tank into 20 disks. Each disc has the measured values as shown on the attached table. (Example, Elevation 20: Temp (TE 3010N), disk height — 4 ft, volumetric rock ratio — 0.61).

The energy in each slice is equal to the enthalpy of the rock times the volumetric mass of rock plus the enthalphy of the oil times the volumetric mass of the oil.

The total energy in the tank is the sum of the 20 volumes plus the energy in the oil above the manifold.

Equations:

ETTR:

Energy in the Rock — Btu

$$ETTR = \left[31.4\ (TF_L) + 0.008\ (TF_L)\right] \cdot \left[\frac{\pi}{4}\, 60^2\ \ (HT_L)\ (RR_L)\right]$$

where

(TF_L) = temperature of slice — ^oF
(HT_L) = height of slice — ft
(RR_L) = volumetric rock ratio $\left(\frac{\text{vol of rock}}{\text{vol rock occupies}}\right)$

All above items for one slice of tank per list.

MTTO:

Mass of the Oil in Each Tank Slice - lb

$$MTTO_L = RO\ (TF_L) \left[\frac{\pi}{4}\, 60^2\ (HT_L)\ (1 - RR_L)\right]$$

where

(TF_L), (HT_L), and (RR_L) are same as above

ETTO:

Energy in the Oil of Each Slice — Btu

$$ETTO = (MTTO_L) \left[HO\ (TF_L)\right] - Btu$$

Where

$HO\ (TF_L)$ - enthalpy of oil for temp (TF_L) Btu/lb

ETTOS:

Sum of Energy in the TSS Rock and Oil — Btu

$$ETTOS = \sum(ETTR_{1-20}) + \sum(ETTO_{1-20})\ Btu$$

ENERGY STORED IN OIL, ROCK, AND SAND
LIST OF TANK SLICE PARAMETERS

Slice ID No.	(TF_L)	(HT_L)	(RR_2)
1	(TE3309A)	2	0.15
2	(TE3309C)	2	0.73
3	(TE3309E	2	0.73
4	(TE3309G)	2	0.73
5	(TE3309I)	2	0.73
6	(TE3309K)	2	0.73
7	(TE3309M)	2	0.73
8	(TE3309P)	2	0.73
9	(TE3309R)	2	0.73
10	(TE3309T)	2	0.73
11	(TE3309V)	2	0.73
12	(TE3309X)	2	0.73
13	(TE3009Z)	2	0.73
14	(TE3010B)	2	0.73
15	(TE3010D)	2	0.73
16	(TE3010F)	2	0.73
17	(TE3010H)	2	0.73
18	(TE3101J)	2	0.73
19	(TE3101L)	2	0.73
20	(TE3010N)	4	0.61

FEG:

Efficiency of the Electrical Generator System (Gross)

Equation:

$$FEG = \frac{\text{Total Btu/Hr Gen. Output (Gross)}}{\text{Net Btu/Hr Solar Flux on Receiver}} \times 100\%$$

$$= \frac{DETG}{BRX} \times 100\%$$

FEN:

Efficiency of the Electrical Gen. System (Net)

Equation:

$$FEN = \frac{\text{Total Btu/Hr Plant Output (Net)}}{\text{Net Btu/Hr Solar Flux on Receiver}} \times 100\%$$

$$= \frac{DETN}{BRX} \times 100\%$$

FR:

Efficiency of the Receiver

Equation:

$$FR = \frac{\text{Total Btu/Hr Received in Receiver Stream}}{\text{Net Btu/Hr Solar Flux on Receiver}} \times 100\%$$

$$= \frac{DRT}{BRX} \times 100\%$$

HO:

Enthalphy of Oil

Equation:

$$HO\ (TF) = (TF)\left[(0.40012 + 0.2507^{-3}\ (TF)\right]\ \text{Btu/lb}$$

where

TF = temperature — ^{o}F

HW:

Enthalpy of Water

Equations:

$$HW\ (PG,\ TF) = -38.028 + (TF)\left\{1.08478 + (TF)\left[-0.35584^{-3} + (TF)\left(5.17017^{-7}\right)\right]\right\} + 0.16604^{-3}\ \frac{(PG + 14.7)^2}{TF}\ \text{Btu/lb}$$

where

PG = pressure in psi gage
TF = temperature — ^{o}F

LXX3XX:

Log Mean ΔT of Exhanger No. 3XX

Equation:

$$LXX3XX = \frac{(T_1 - t_1) - (T_2 - t_2)}{\ln \frac{(T_1 - t_1)}{(T_2 - t_2)}}$$

where

T_1 = inlet temperature (^oF) of hot fluid
T_2 = outlet temperature (^oF) of hot fluid
t_1 = outlet temperature of (^oF) cool fluid
t_2 = outlet temperature of (^oF) cool fluid

where:

	T_1	T_2	t_1	t_2
LCC301	(TE3250)	(TE3251)	(TE3211A)	(TE3254)
LCC302	(TE3350)	(TE3351)	(TE3310A)	(TE3354)
LCC311	(TE3251)	(TE3253)	(TE3254)	(TI3214)
LCC312	(TE3751)	(TE3353)	(TE3354)	(TI3314)
LEP303	(TE3752)	(TE3551)	(TE3754)	(TI3503)
LEP304	(TE3852)	(TE3651)	(TE3854)	(TI3603)
LEB305	(TE3750)	(TE3752)	(TE3753)	(TE3754)
LEB306	(TE3850)	(TE3852)	(TE3853)	(TE3854)
LES307	(TI3711)	(TE3755)	(TE3710A)	(TE3753)
LES308	(TI3811)	(TE3855)	(TE3810A)	(TE3853)

QTTO:

Sum of Incremental Thermal Energy Stored in the Thermal Storage Tank Via the Oil Flow

Method:

The net instantaneous energy flow in and out of the thermal storage tank is calculated for every 5-minute inteval of the day. The value is divided by 1/12 to provide the Btu flow for the 5-minute period. The sum of the intevals through the day provides the Btu inventory for the day. This is added to the previous days inventory to obtain the total thermal storage tank Btu inventory at any time of the day.

Every day at 4:00 p.m., when the storage tank should be at a maximum, the tank energy is reset to the value calculated from the temperature measurements (i.e., ETTOS).

Equations:

$$QTTO = ETTOS \pm \sum_{1}^{288} 1/12\ (DTTO)_{5\ min}\ Btu$$

bjm:914

QXXXX:

Total Energy Btu/Hr

Equation:

QXXXX = (individual heat exchanger components Btu/hr released)

QRPW = (DRPW1) + (DRPW2) + (DRPW3) + (DRPW4) + (DRWP5) + (DRPW6)
QRBS = (DRBSA) + (DRBSB) + (DRBSC) . . . (DRBSQ) + (DRBSR)
QC2S = (DCCS2) + (DCUW2)
QC3S = (DCCS3) + (DCUW3)
QC2O = (DCCO2) + (DCUO2)
QC3O = (DCCO3) + (DCUO3)
QC23S = (QC2S) + (QC3S)
QC23O = (QC2O) + (QC3O)
QE5S = (DESS5) + (DEBS5) + (DEPW5)
QE6S = (DESS6) + (DEBS6) + (DEPW6)
QE5O = (DESO5) + (DEBO5) + (DEPO5)
QE6O = (DESO6) + (DEBO6) + (DEPO5)
QE565 = (QE5S) + (QE6S)
QE56O = (QE5O) + (QE6O)

RO:

Caloria Oil Density at Temperature TF (^oF)

Equations:

$$RO\ (TF) = 54.78 - 0.0211\ (TF) - 5.0^{-6}\ (TF)^2\ lb/ft^3$$

Where

TF = temperature — ^oF

UXXX:

Overall Heat Transfer Coefficient $Btu/Hr/Ft^2/^oF$

Equations:

$$UXXX = \frac{\text{DXXX (Total Heat Transferred)}}{\text{A (Area of Heat Trans Surface) (LXX 3XX)}}$$

U301 = (DCCS2) ÷ (7458) (LCC301)
U302 = (DCCS3) ÷ (7458) (LCC302)
U311 = (DCCS2) ÷ (1880) (LCU311)
U312 = (DCUW3) ÷ (1880) (LCU312)

U303 = (DEPW5) ÷ (1433) (LEP303)
U304 = (DEPW6) ÷ (1433) (LEP304)
U305 = (DEBS5) ÷ (7919) (LEB305)
U306 = (DEBS6) ÷ (7919) (LEB306)
U307 = (DESS5) ÷ (670) (LEP307)
U308 = (DESS6) ÷ (670) (LEP307)

WTHO:

Net Mass Flow In/Out of the Thermal Storage Tank Lb/Hr

Equation:

WTHO = (WCU02) + (WCU03) - (WEB05) - (WEB06)

WXXX:

Mass Flow

Method:

The flow sensors are direct reading lb/hr.

WPRWT = (F35A) - (F3105)
WRPW1 = (F 2230)
WRPW2 = (F 2231)
WRPW3 = (F 2232)
WRBWA = (F 2301)
WRBWB = (F 2302)
WRBWC = (F 2303)
WRBWD = (F 2401)
WRBWE = (F 2402)
WRPWF = (F 2403)
WRBWG = (F 2501)
WRBWH = (F 2502)
WRBWI = (F 2503)
WRBWJ = (F 2601)
WRBWK = (F 2602)
WRBWL = (F 2603)
WRBWM = (F 2701)
WRBWN = (F 2702)
WRBWO = (F 2703)
WRBWO = (F 2801)
WRBWQ = (F 2802)
WRBWR = (F 2803)
WPES = WRPWT - (F 3102)
WCDS = (F 3105) + (F 3102)
WCDS2 = (F 3205)
WCDS3 = (F 3305)
WCU02 = (F 3211)
WCU03 = (F 3310)
WEPW5 = (F 3504)
WEPW6 = (F 3604)
WEB05 = (F 3706) + (F 3712)
WEB06 = (F 3806) + (F 3812)
WET05 = (F 3706)
WET06 = (F 3806)
WET07 = (F 3712)
WET08 = (F 3812)
WEPWT = (WEPW5) + (WEPW6)

XC23:

Heat Loss From Charging Heat Exchanger

Equation:

XC23 = (DEB5) - (DEBO) Btu

XE56:

Heat Loss From Extraction Heat Exchanger

Equation:

$$XE56 = (DCCS) - (DCCO) \text{ Btu}$$

XTT:

Calculated Losses Between Total Energy Transmitted to the TSU and the Total Energy Stored in the Rock, Sand, and Oil

Equations:

$$XTT = (QTTO) - (ETTOS) \text{ Btu}$$

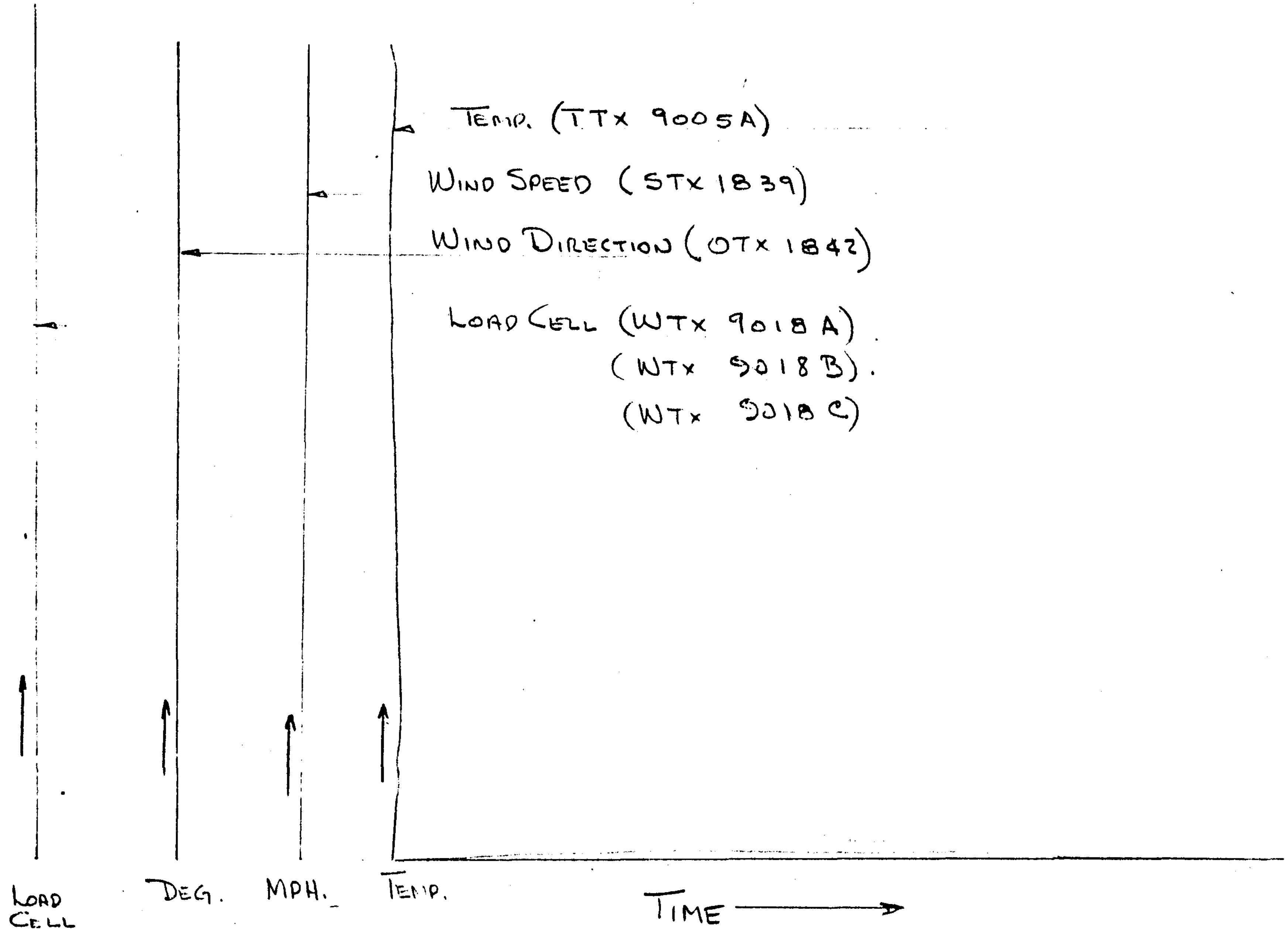
TABLE C-9

DATA DISPLAYS

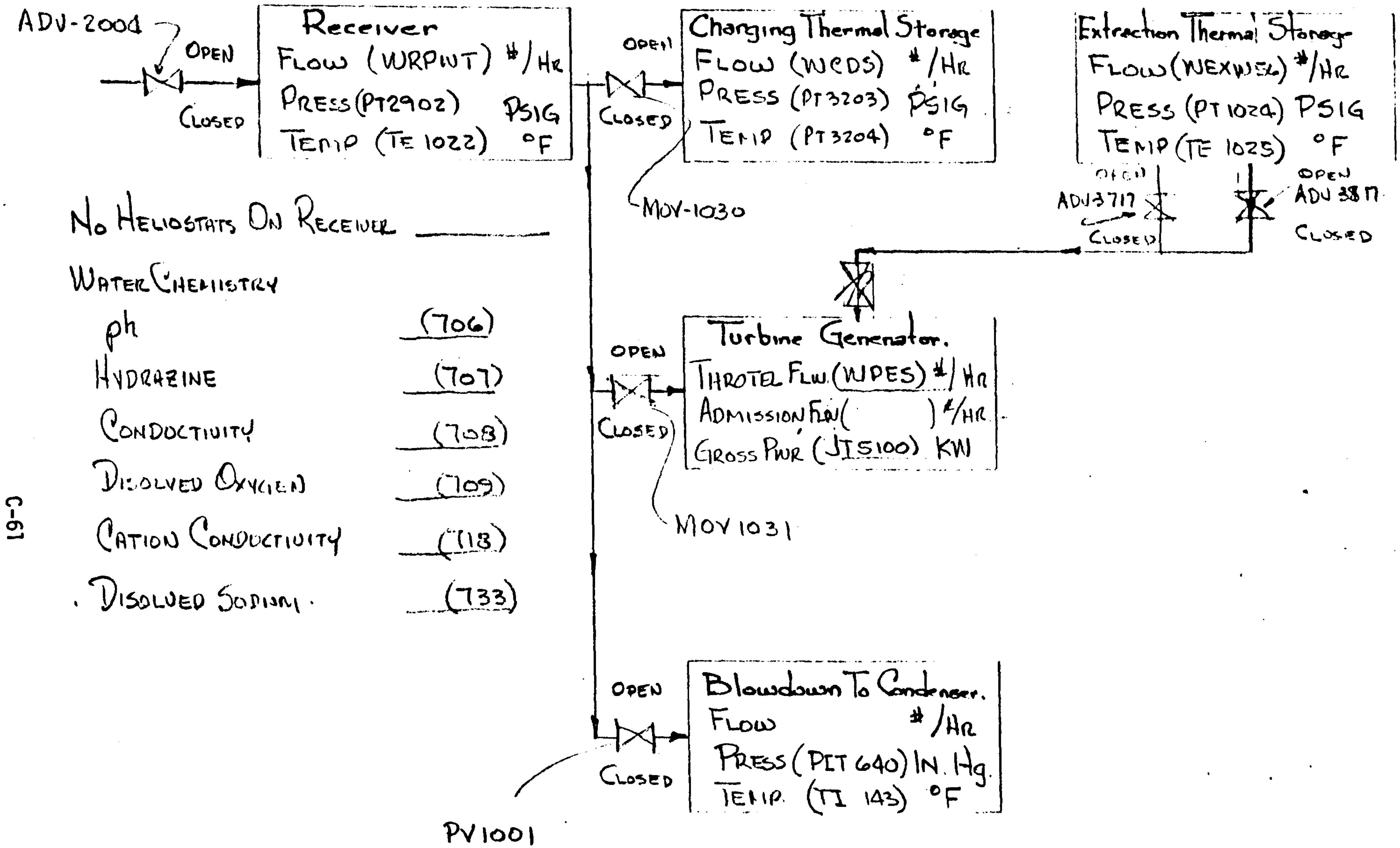
(Pages C-60 to C-96)

DATE ________

HELIOSTAT STRAIN VS WIND SPEED.



Da___ Time ___ Hr ___ Min ___ Sec. Op___ Mode ___ Control Config ______ Inso___on ___ kw/



Quick Look   Update   secs

RECEIVER PREHEAT PANELS

DATE __________ MODE _____ INSOLATION _____ KW/M²

HELIOSTATS ON RECEIVER __________

INLET FEED WATER TEMP (TE 2001) °F

TIME HMS	FLOW #/HR (FE 2232)	RP 201 TEMP OUT (TI 2209)	RP 224 TEMP OUT (TI 2109)	FLOW #/HR (FE 2231)	RP 202 TEMP OUT (TI 2208)	RP 223 TEMP OUT (TI 2108)	FLOW #/HR (FE 2230)	RP 203 TEMP OUT (TI 2207)	RP-222 TEMP OUT (TI 2107)

RECEIVER BOILER PANELS.

DATE ______ MODE ________ INSOLATION ____ KW/M²

HELIOSTATS ON RECEIVER ________

FEED WATER PRESS	FEED WATER TEMP	RECEIVER STEAM PRESS	RECEIVER STEAM TEMP
(PI 2006) PSIG	(TI 2005) °F	(PI 2902) PSIG	(TE 2947) °F

PANEL NO	RP 204		RP-205		RP 206		RP-207		RP-208		RP-209		
TIME	FLOW	TOUT	FLOW	TOUT	FLOW	TOUT	FLOW	TOUT	FLOW	TOUT	FLOW	TOUT	Pg 3
	(FT 2301)	(TT 2345)	(FT 2302)	(TT 2346)	(FT 2303)	(TT 2347)	(FT 2401)	(TT 2445)	(FT 2402)	(TT 2446)	(FT 2403)	(TT 2447)	

	RP 210		RP-211		RP 212		RP 213		RP-214		RP-215		
	(FT 2501)	(TT 2545)	(FT 2502)	(TT 2546)	(FT 2503)	(TT 2547)	(FT 2601)	(TT 2645)	(FT 2602)	(TT 2646)	(FT 2603)	(TT 2647)	Pg 4

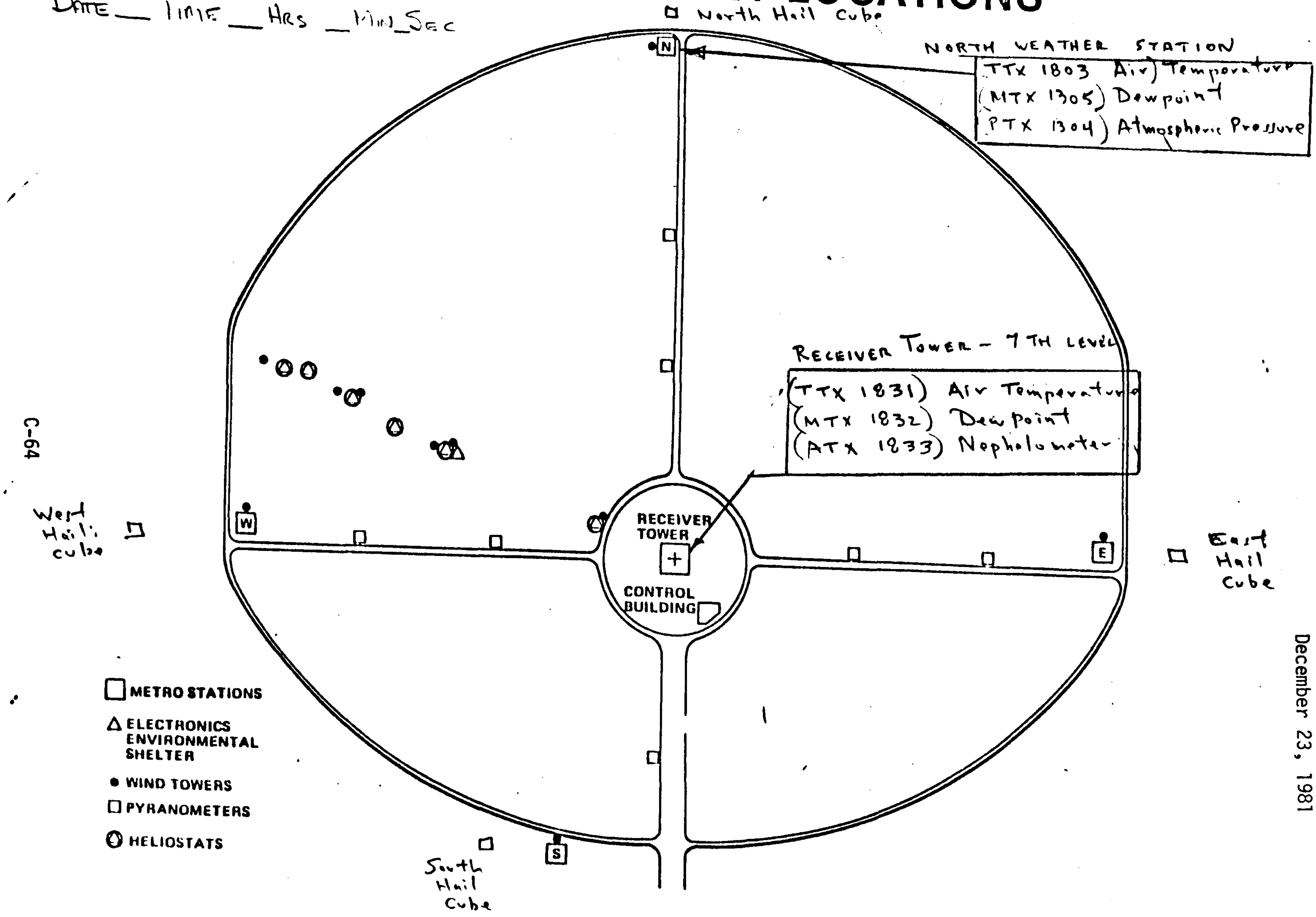
	RP-216		RP-217		RP-218		RP-219		RP-220		RP-221		
	(FT 2701)	(TT 2745)	(FT 2702)	(TT 2746)	(FT 2703)	(TT 2747)	(FT 2801)	(TT 2845)	(FT 2802)	(TT 2846)	(FT 2803)	(TT 2847)	Pg 5

Pg 6

SHIMMS EQUIPMENT LOCATIONS

V[illegible]66N

DATE __ TIME __ HRS __ MIN __ SEC



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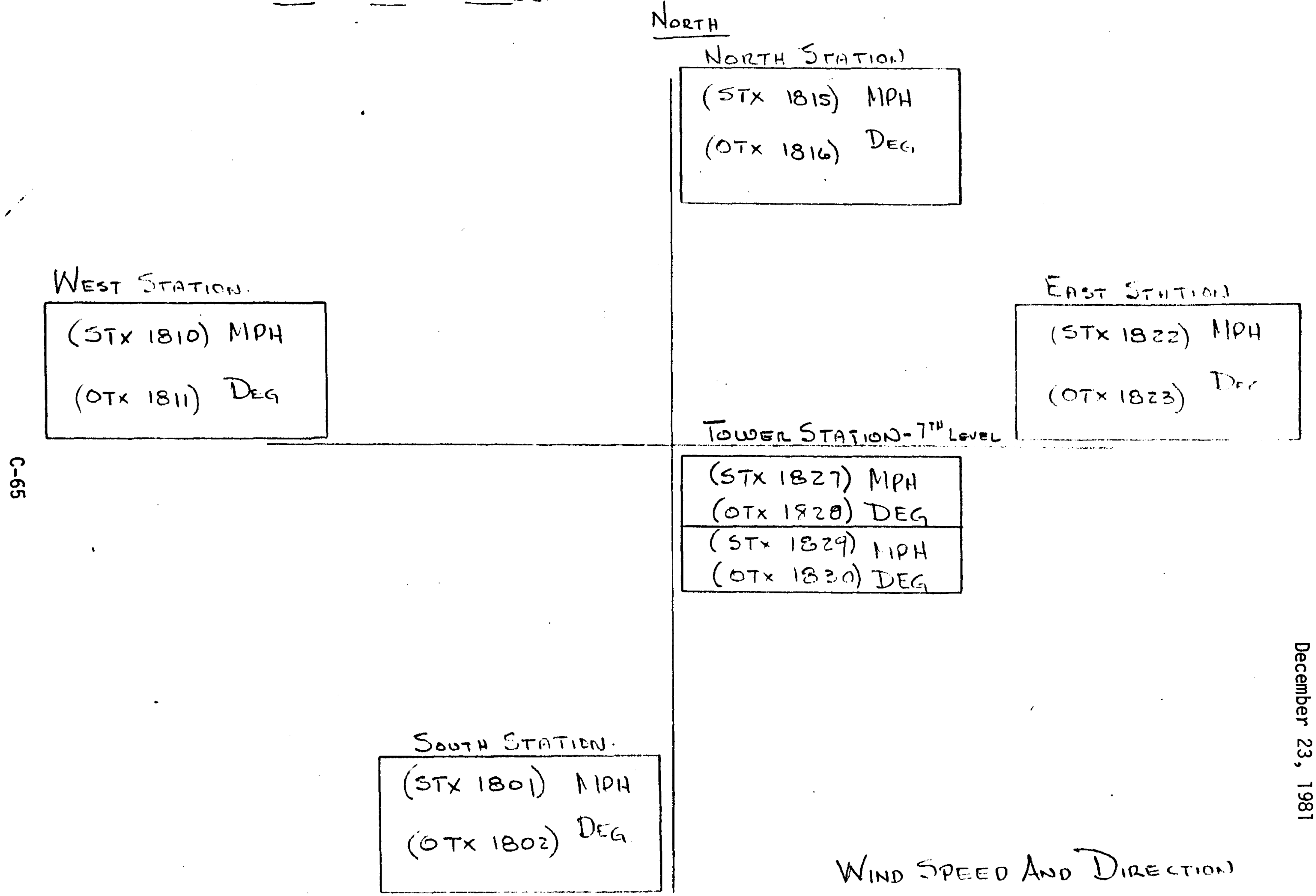
December 23, 1981

Date ____ Time ____ Hrs ____ Min ____ Sec.



Wind Speed And Direction
Field Stations

N-072E-A00-TS019
December 23, 1981

DATE ________ TIME ______ HRS ______ MIN ______ SEC

WIND SPEED AT TOWERS #1 - #6.

MILES PER HOUR

ELEVATION FT	#1	#2	#3	#4	#5	#6
32	(STx 1839)	(STx 1843)	(STx 1847)	(STx 1851)	(STx 1855)	(STx 1859)
20	(STx 1840)	(STx 1844)	(STx 1848)	(STx 1852)	(STx 1856)	(STx 1860)
10	(STx 1841)	(STx 1845)	(STx 1849)	(STx 1853)	(STx 1857)	(STx 1861)

WIND DIRECTION

DEGREES

32	(0Tx 1842)	(0Tx 1846)	(0Tx 1850)	(0Tx 1854)	(0Tx 1858)	(0Tx 1862)

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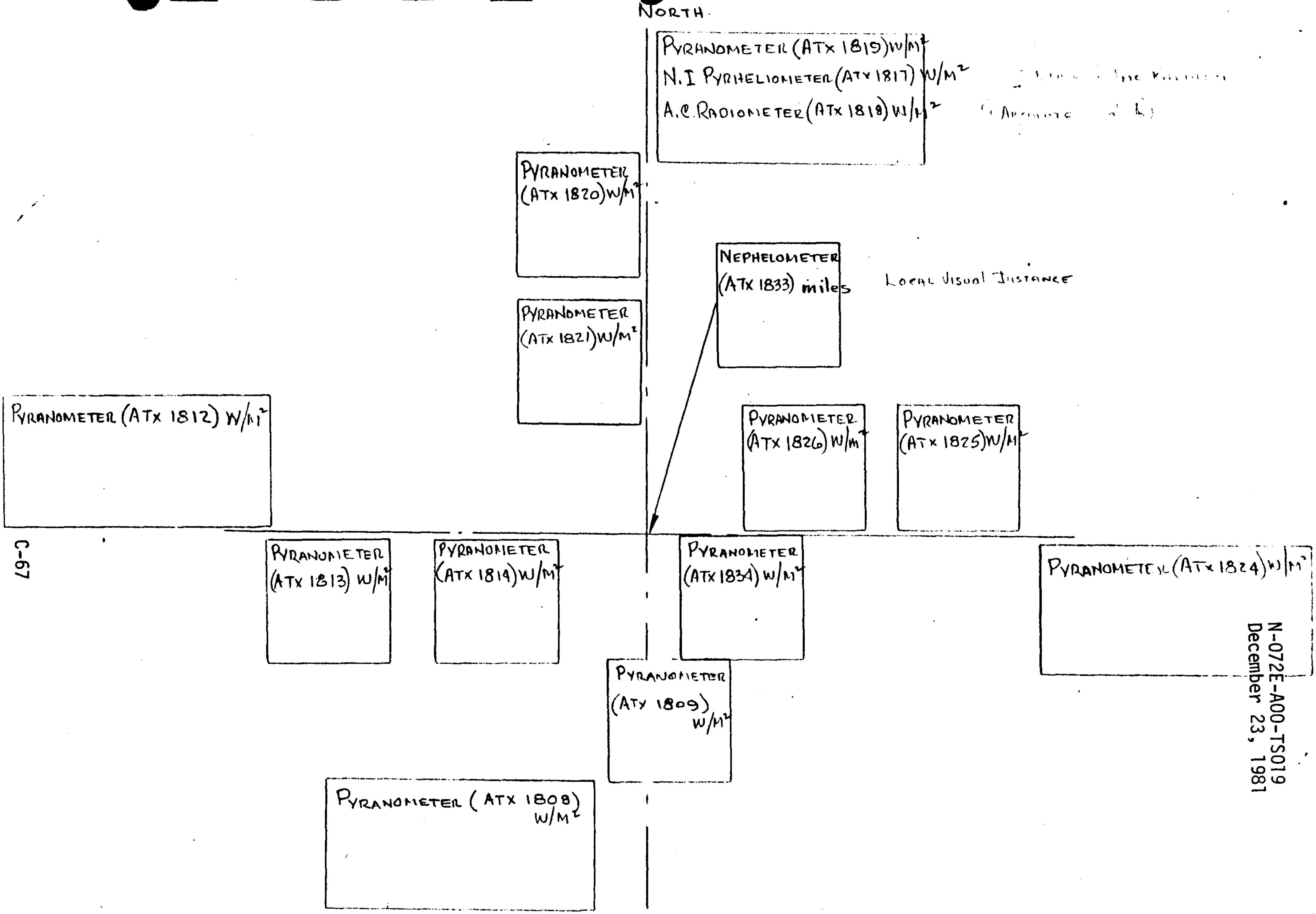
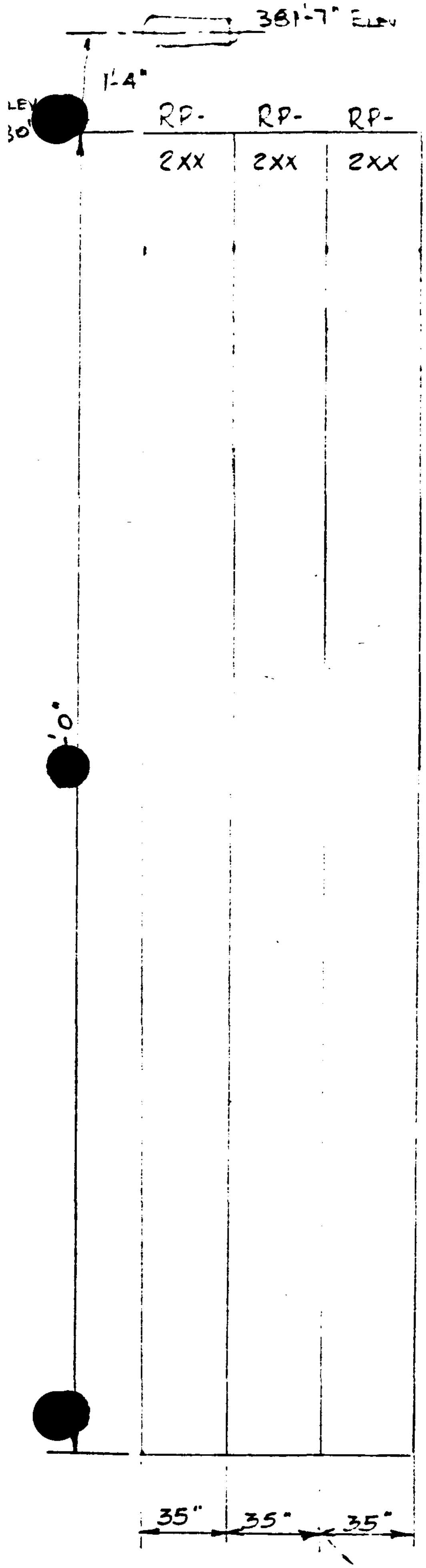
WIND SPEED AND DIRECTION
AT TOWERS IN FIELD

Da___ Time __ hr __ min __ sec



GENERAL



PANEL HEAT FLUX SENSORS
ON PANEL ℄ @ ELEV. 345'-3, 357'-3", 370'-3"
35' 23'- 10'

PANEL TEMPERATURES

PANEL ELONGATION AXIAL

RP-212	TUBE #35	ELEV.	348, 355.25, 367.42, 375.25
ALL PANELS	TUBE #35	ELEV	337.25

PANEL BOWING

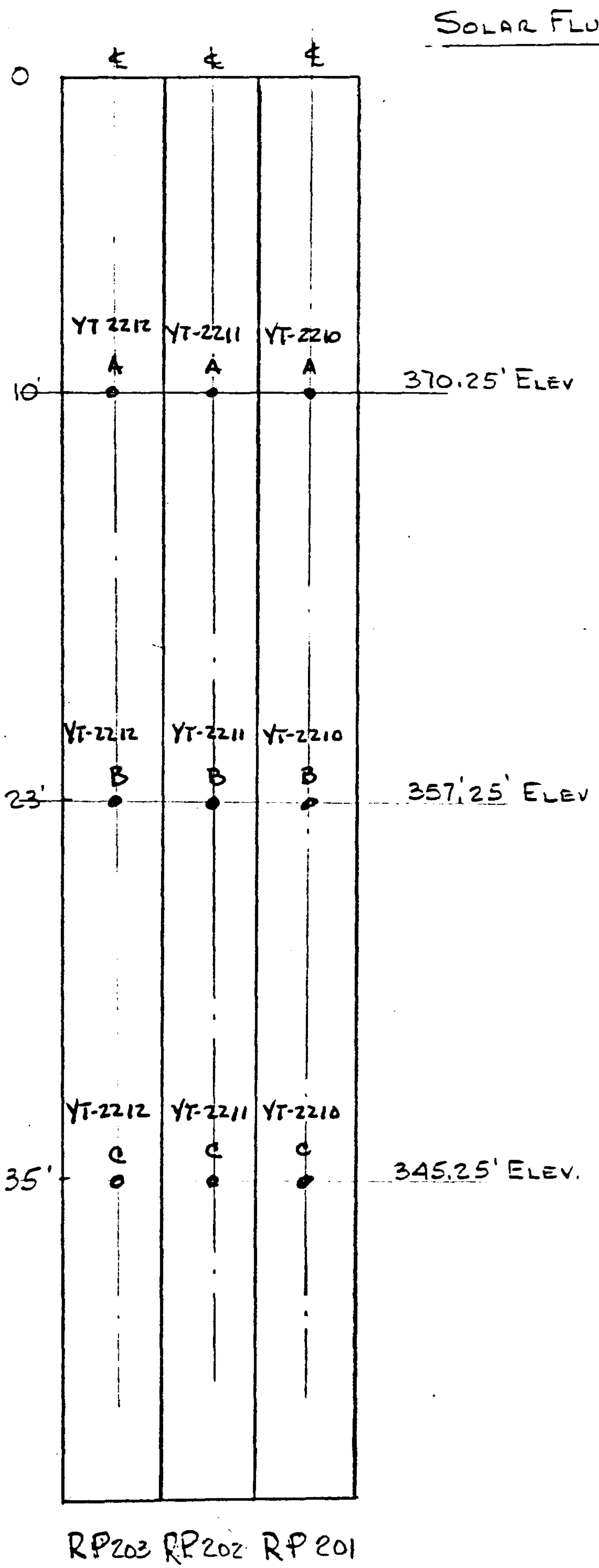
RP-212	TUBE #3 & #35	ELEV.	361.25, 367.42, 375.25
213	3 & 35	ELEV.	
221	#35	ELEV.	
222	#35	ELEV.	

PANEL LATERAL MOVEMENT

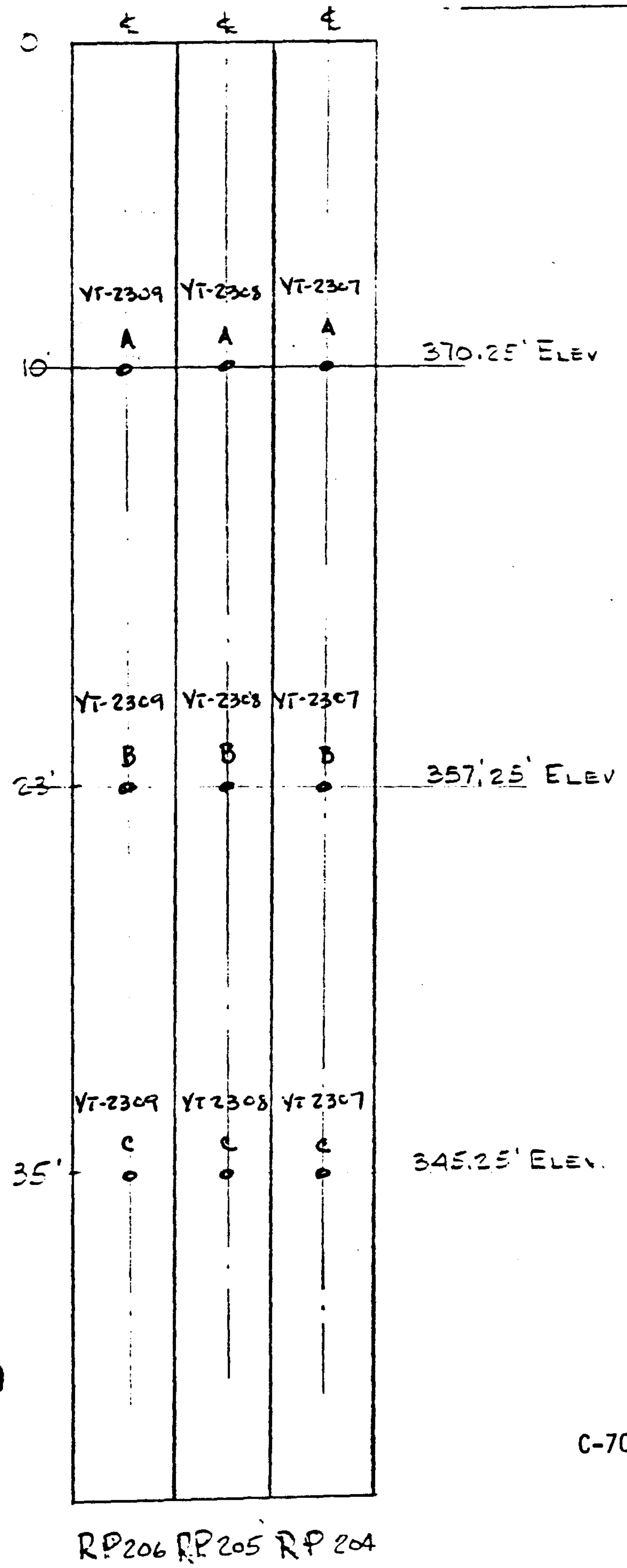
			12'-10"
RP-206	TUBE 36	ELEV	367.42
207	36		367.42
218	36		367.42
219	36		367.42

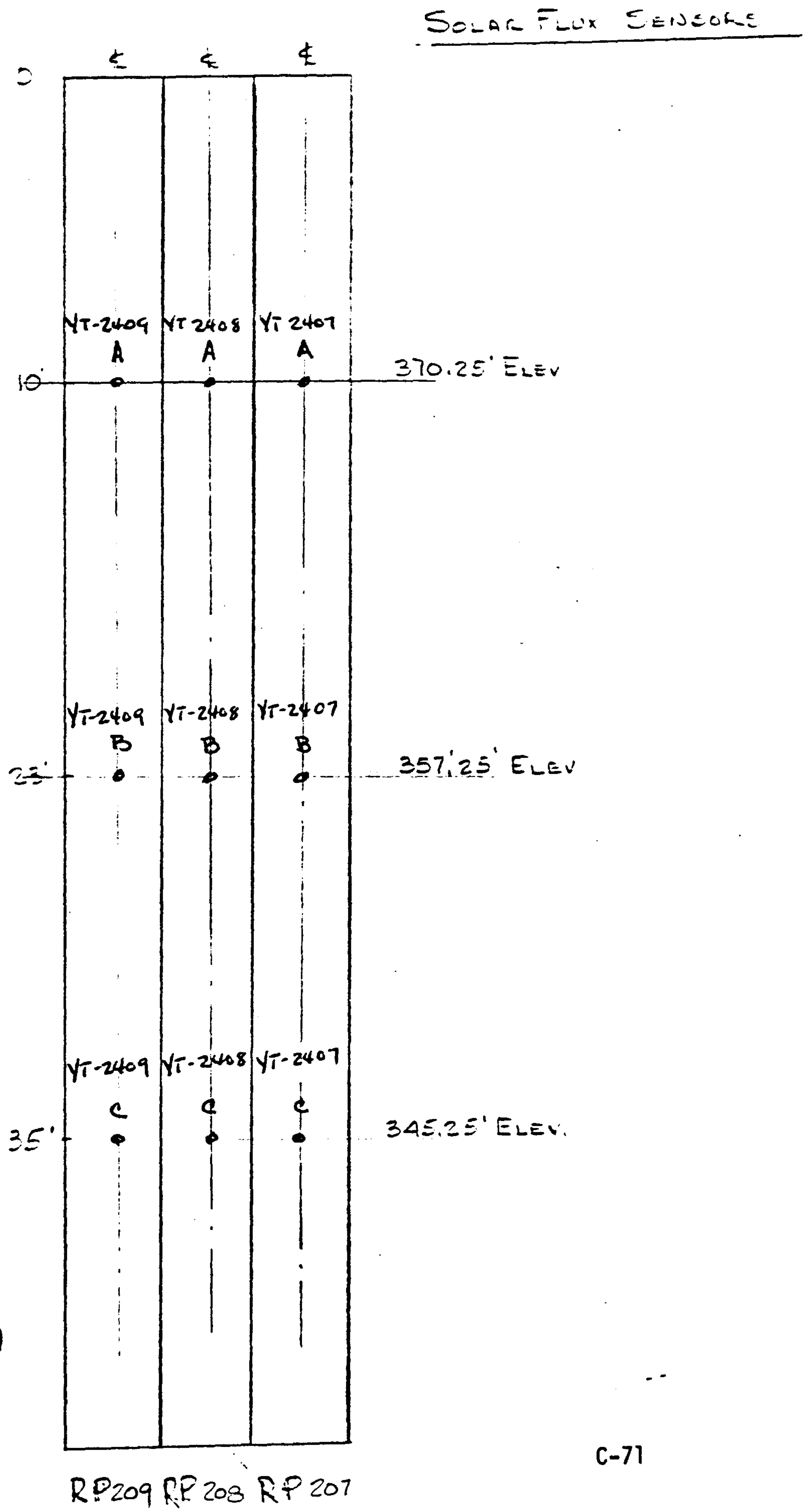
REF. DWGS.

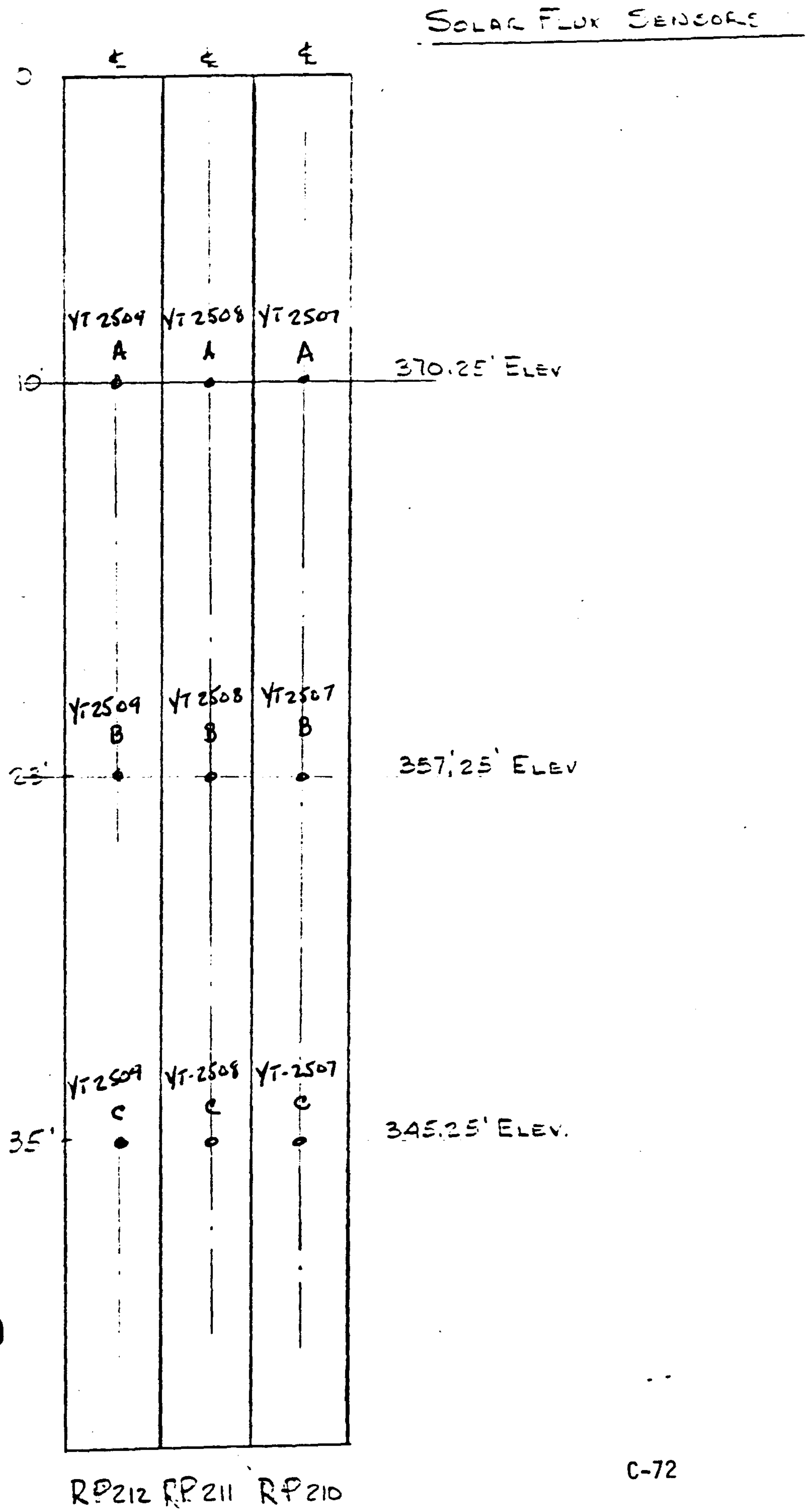
RECEIVER ELECT DWGS - GA-000-90908-EX
RECEIVER PANEL ASSEM. - R0012841 SH 3
RECEIVER TUBE BUNDLE ASSEM - R0012842 SH 1


SOLAR FLUX SENSORS
0
℄
℄
℄
YT 2212
YT-2211
YT-2210
A
A
A
10'
370.25' ELEV
YT-2212
YT-2211
YT-2210
B
B
B
23'
357.25' ELEV
YT-2212
YT-2211
YT-2210
C
C
C
35'
345.25' ELEV.
RP203
RP202
RP201

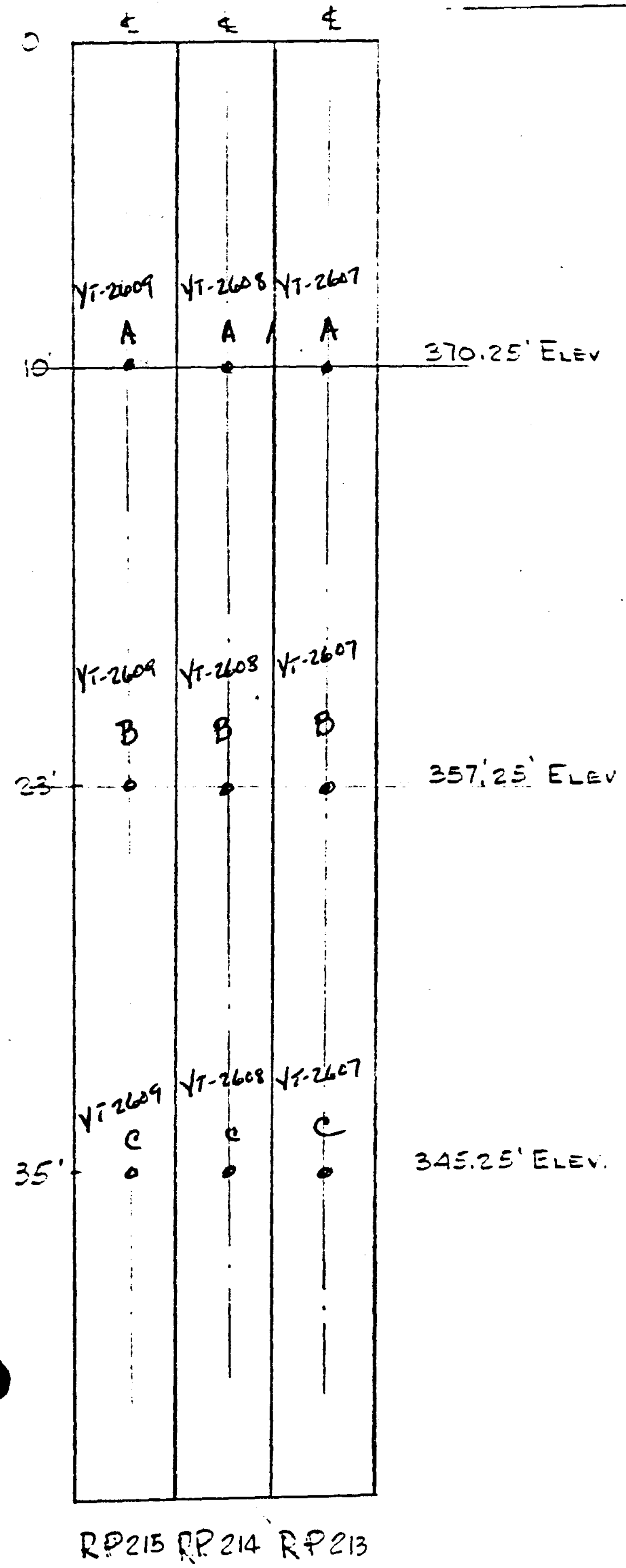
SOLAR FLUX SENSORS



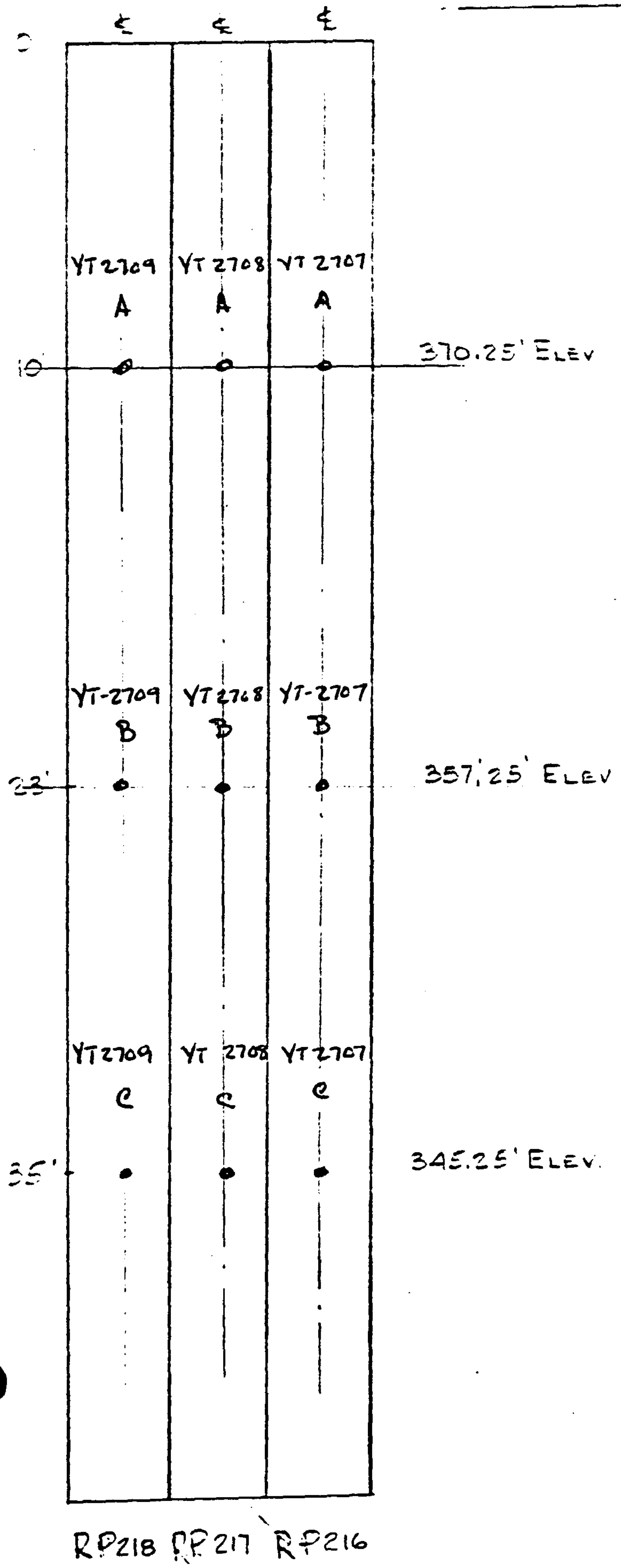

SOLAR FLUX SENSORS
0
10'
25'
35'
YT-2409 A
YT 2408 A
YT 2407 A
370.25' ELEV
YT-2409 B
YT-2408 B
YT-2407 B
357.25' ELEV
YT-2409 C
YT-2408 C
YT-2407 C
345.25' ELEV.
RP209 RP208 RP207


SOLAR FLUX SENSORS
YT 2509
A
YT 2508
A
YT 2507
A
10'
370.25' ELEV
YT 2509
B
YT 2508
B
YT 2507
B
25'
357.25' ELEV
YT 2509
C
YT-2508
C
YT-2507
C
35'
345.25' ELEV.
RP212
RP211
RP210

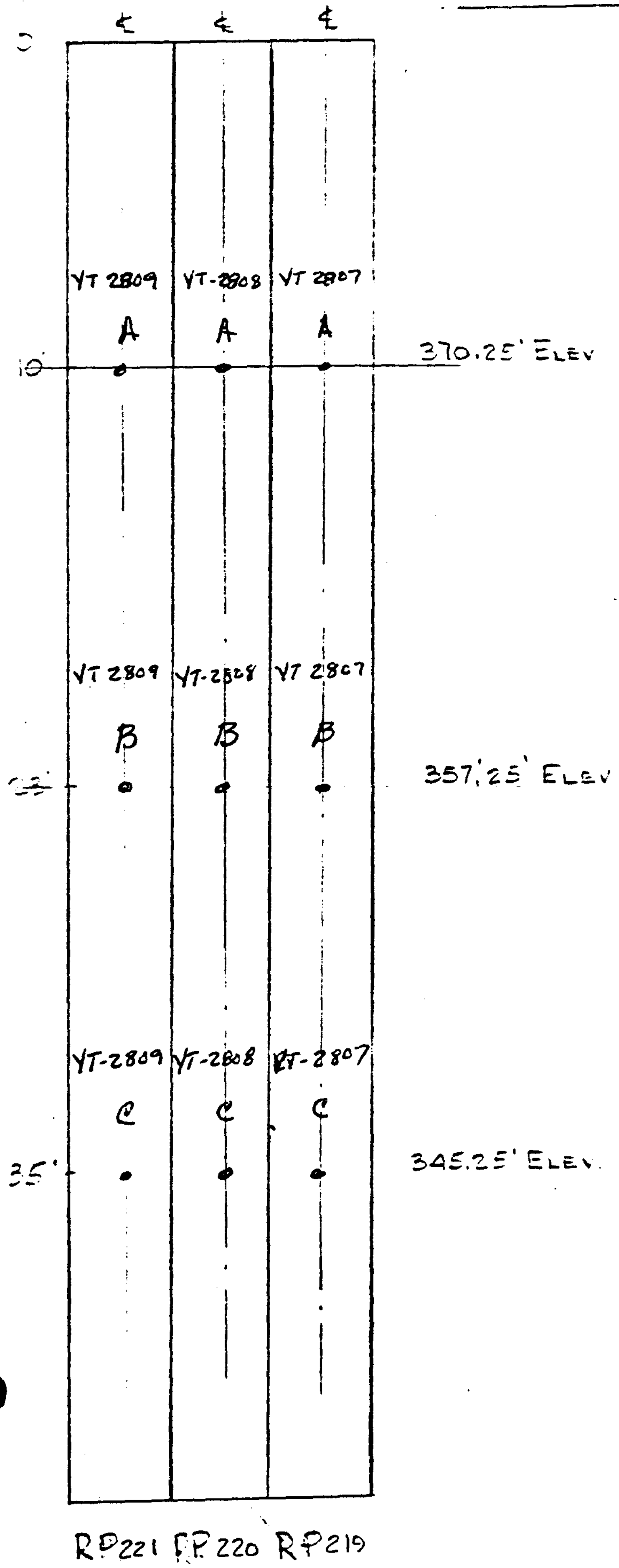
SOLAR FLUX SENSORS



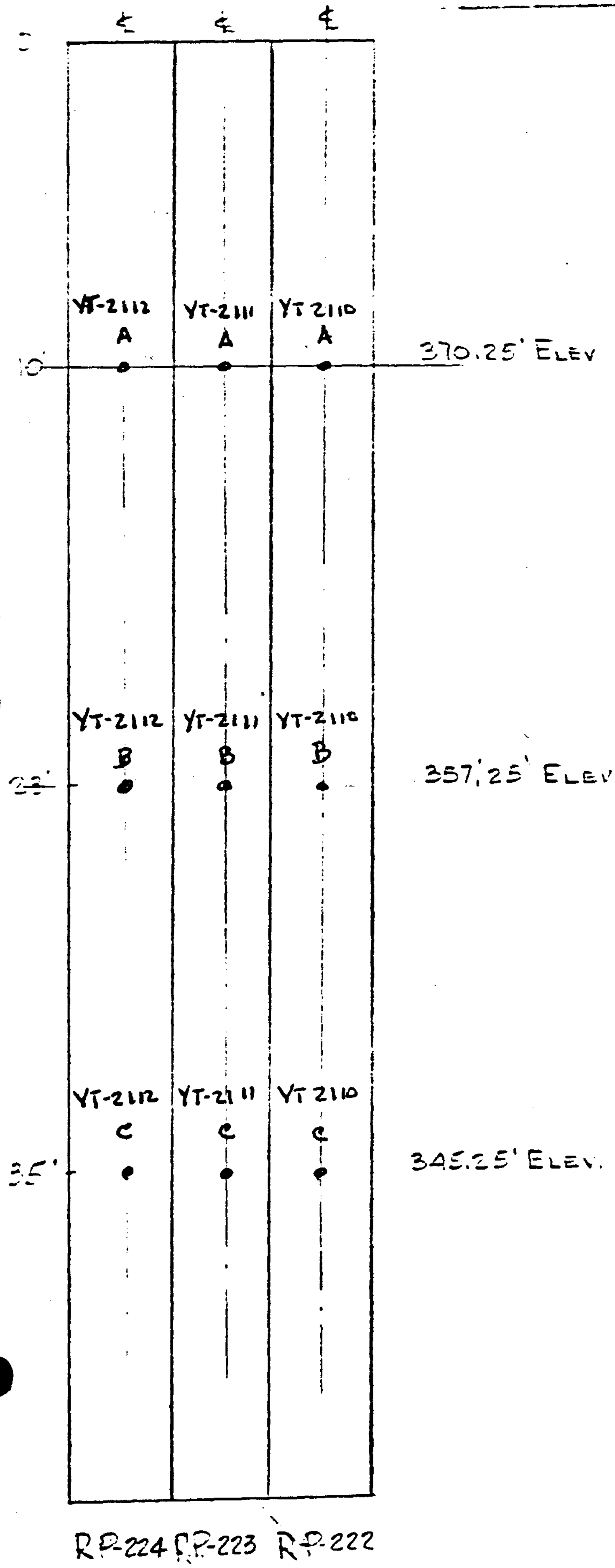
SOLAR FLUX SENSORS



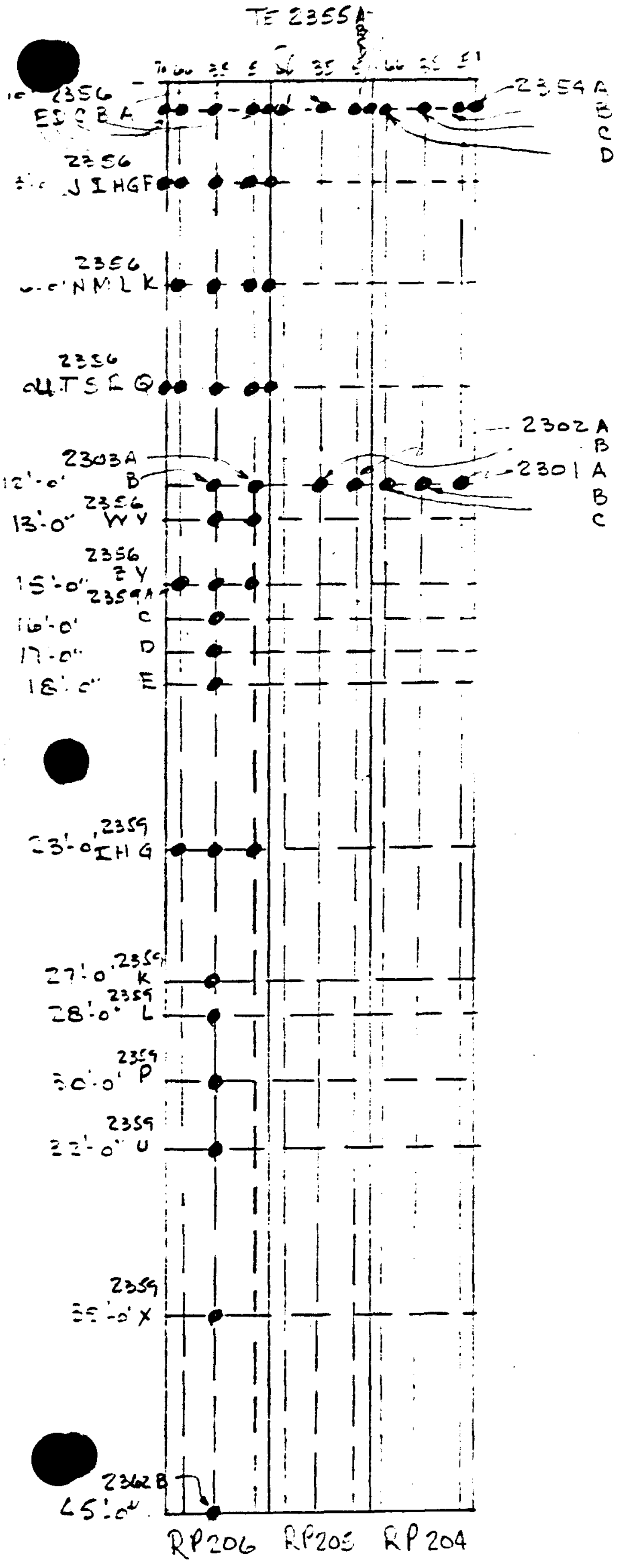
SOLAR FLUX SENSORS



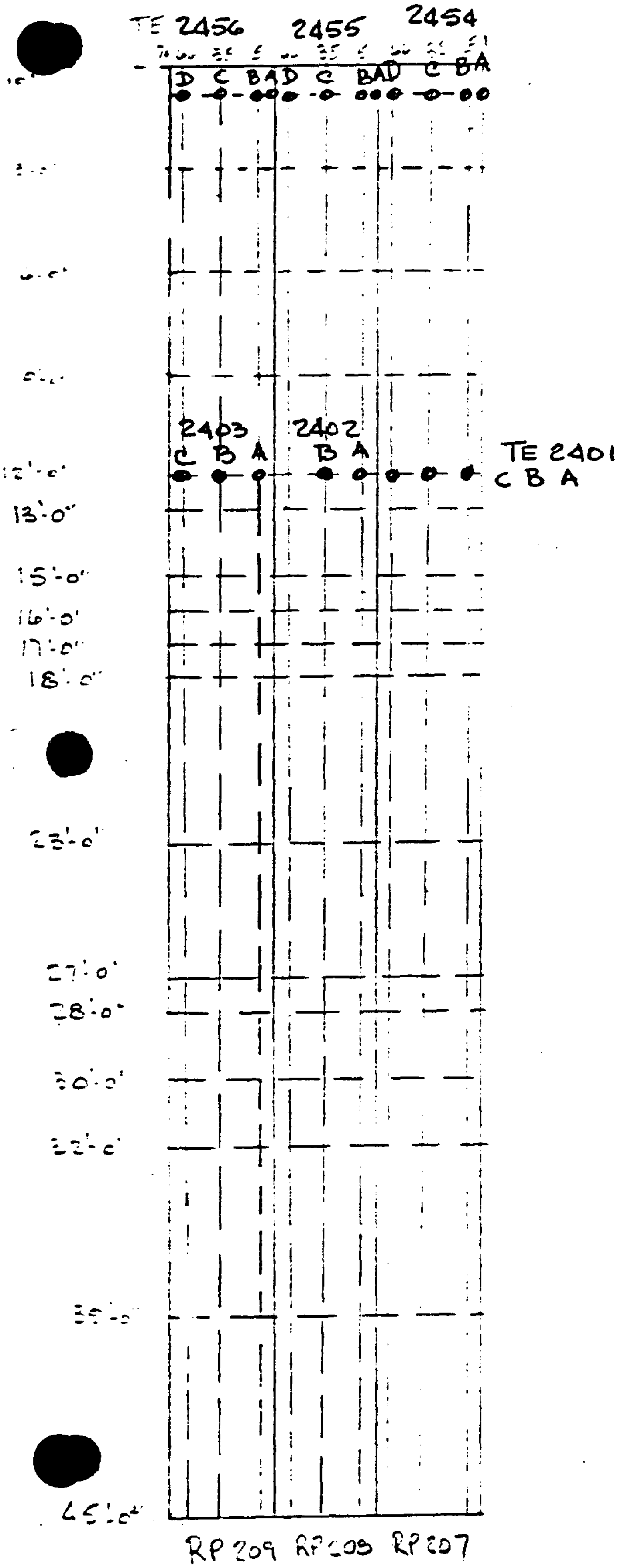
SOLAR FLUX SENSORS



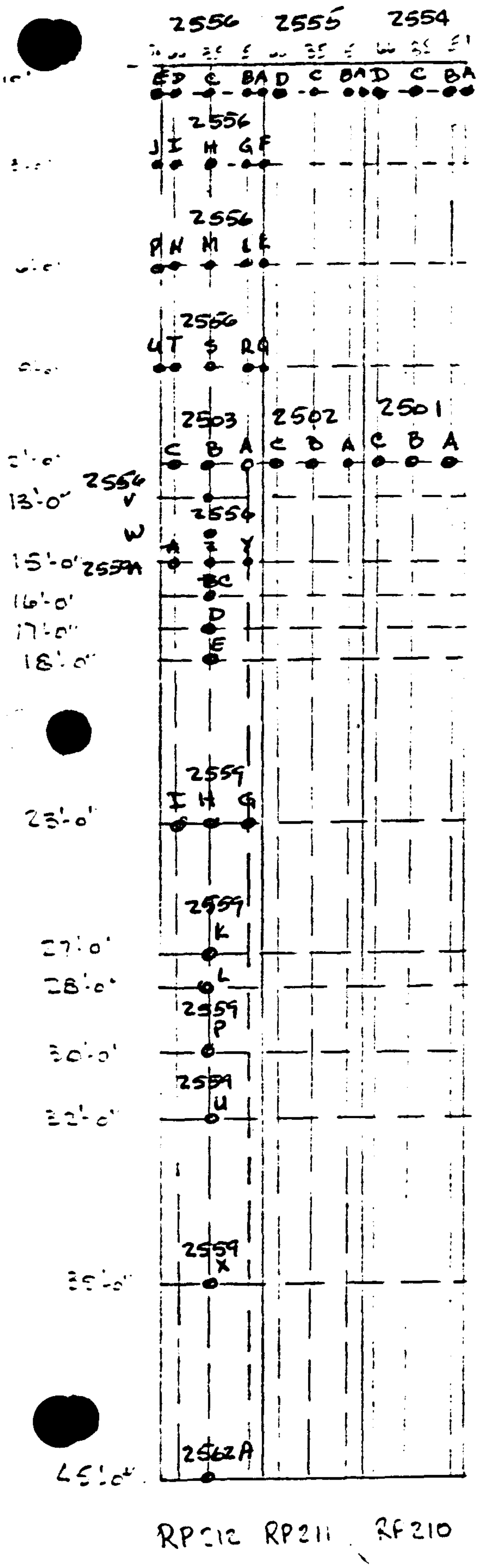
FINAL TUBE TEMPERATURES



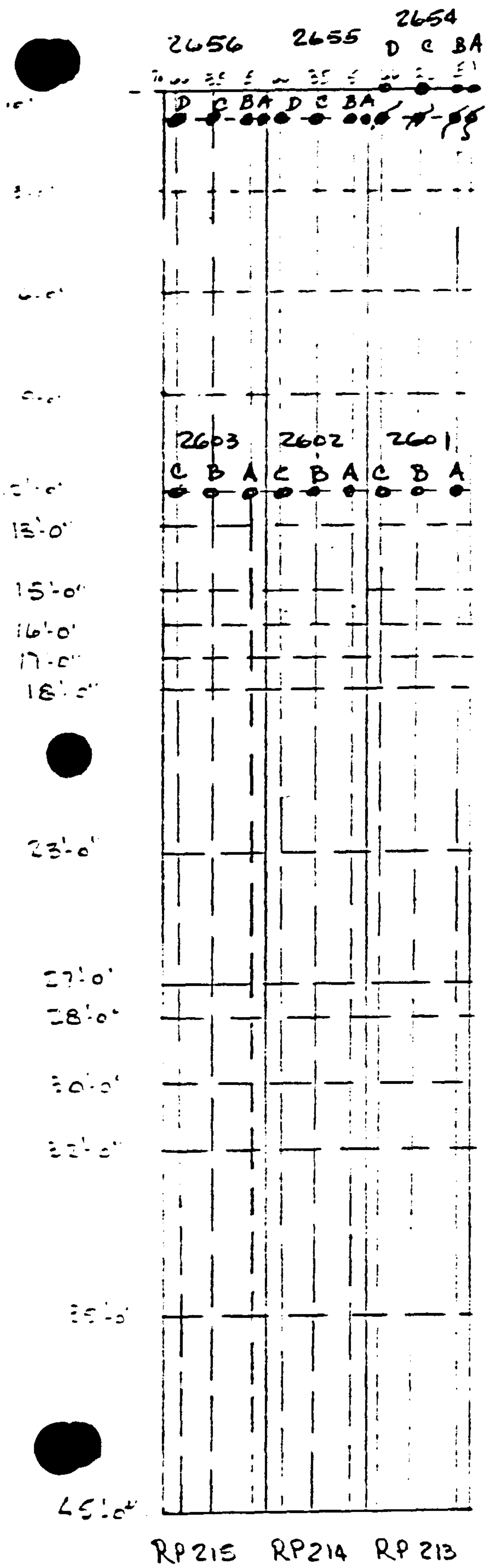
Panel Tube Temperature



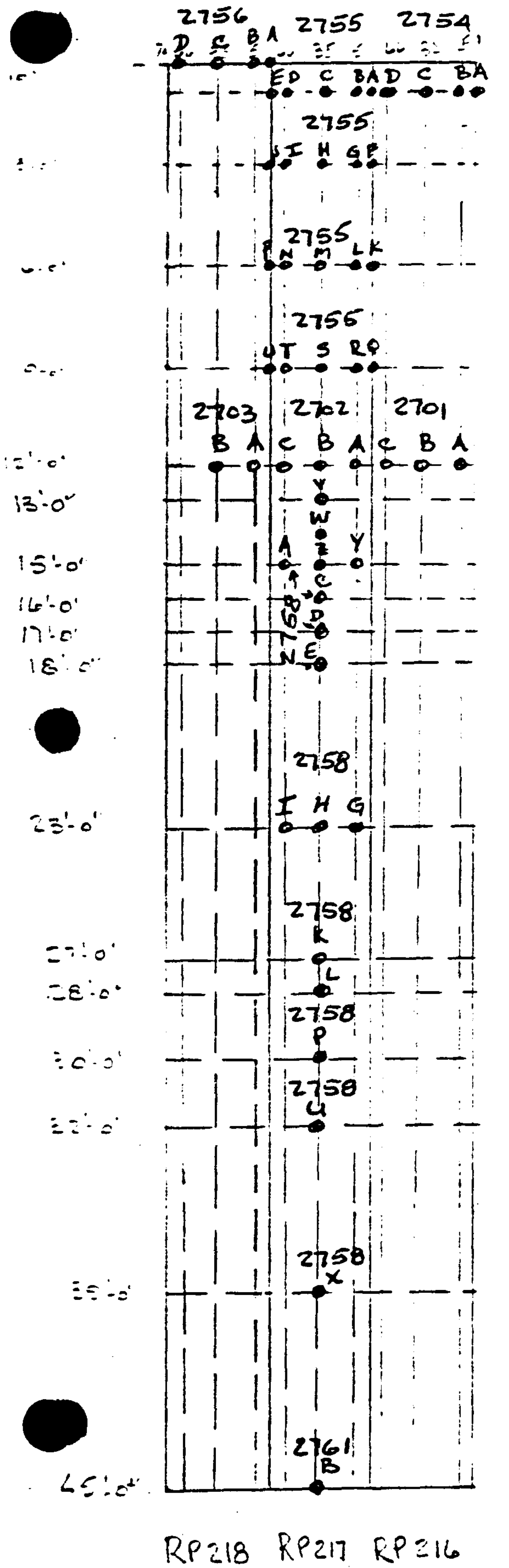
Panel Tube Temperature



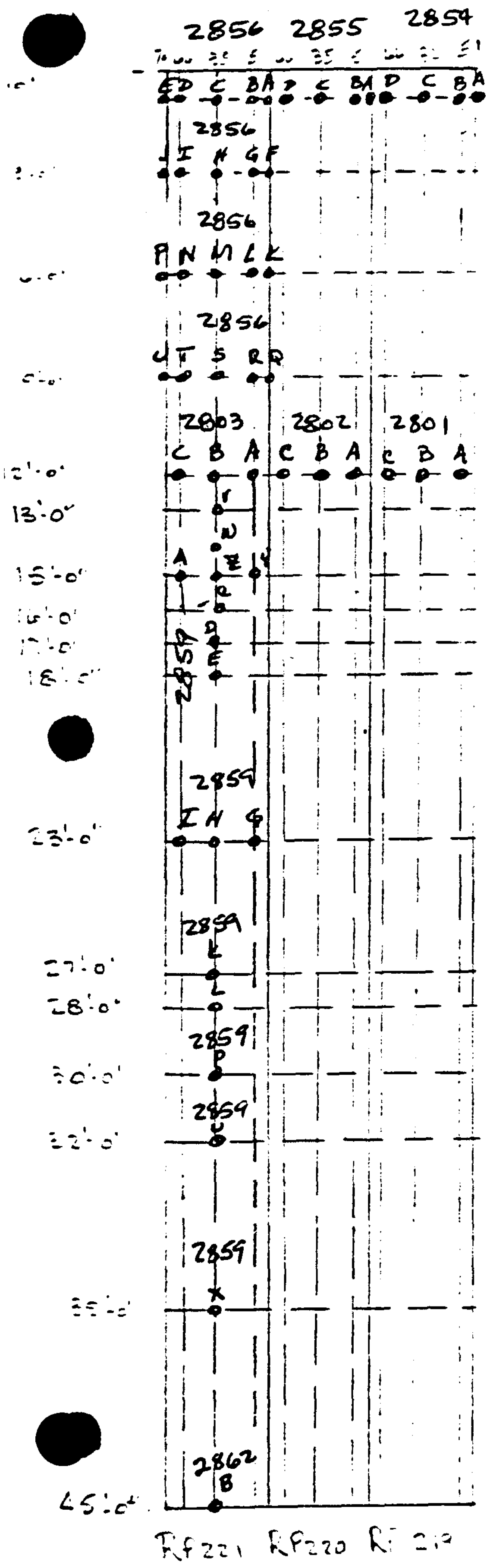
PROBE TUBE TEMPERATURE



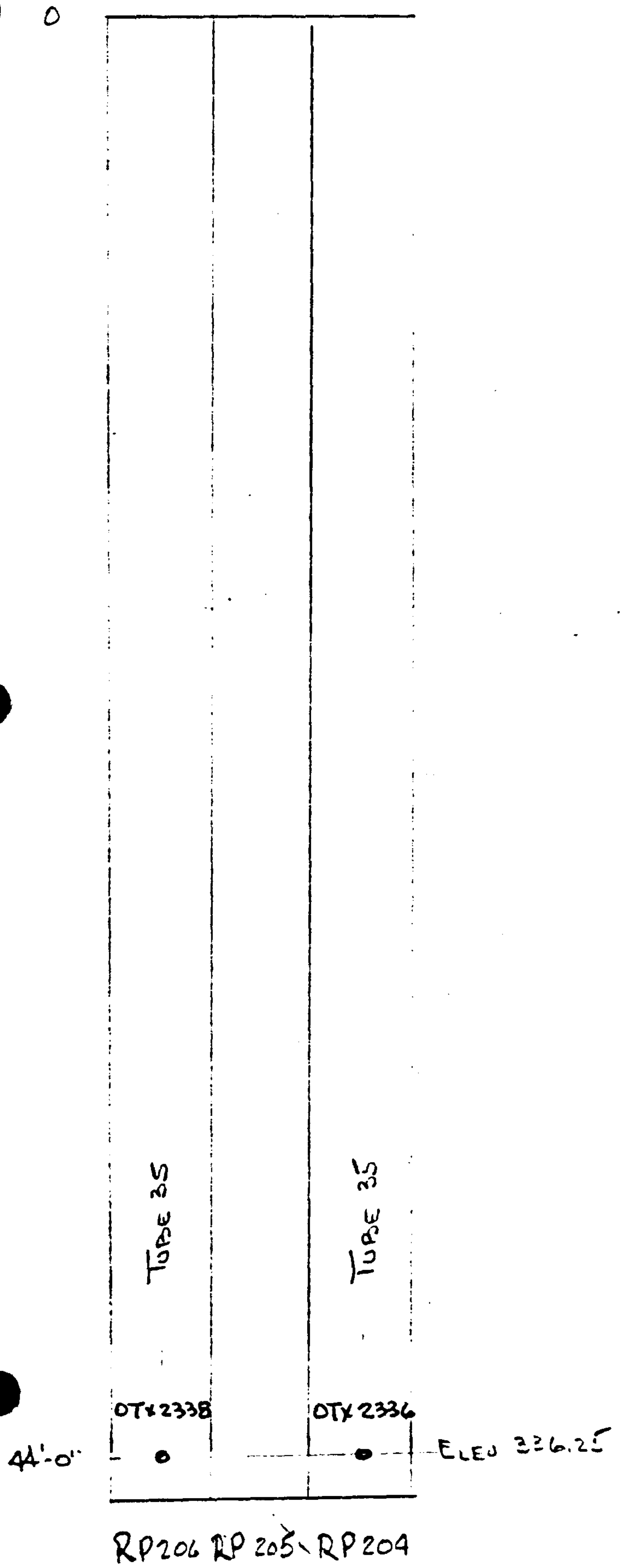
PHASE - TUBE TEMPERATURE



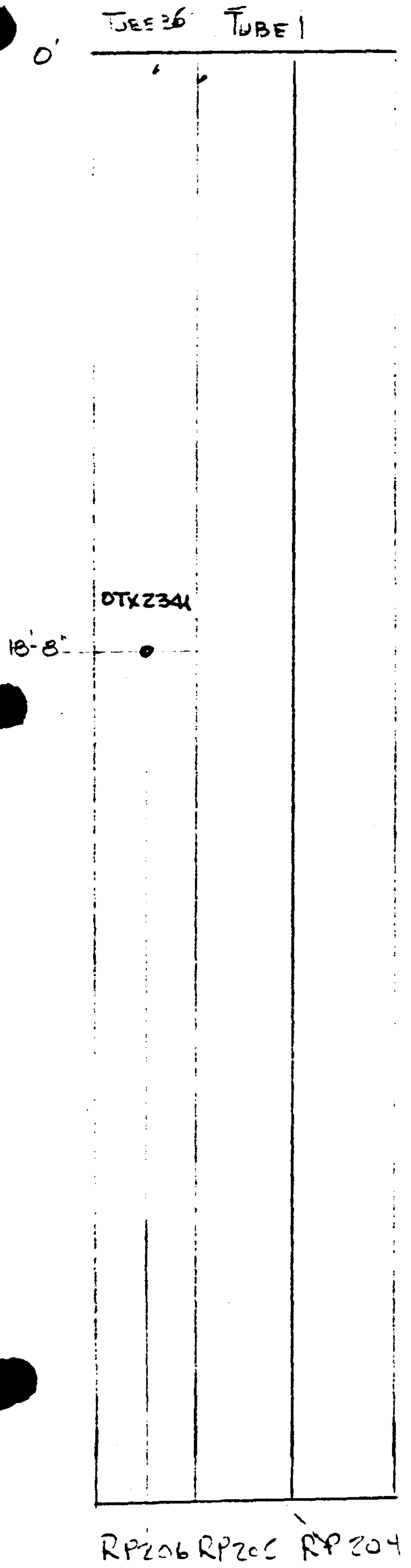
PANEL TUBE TEMPERATURE



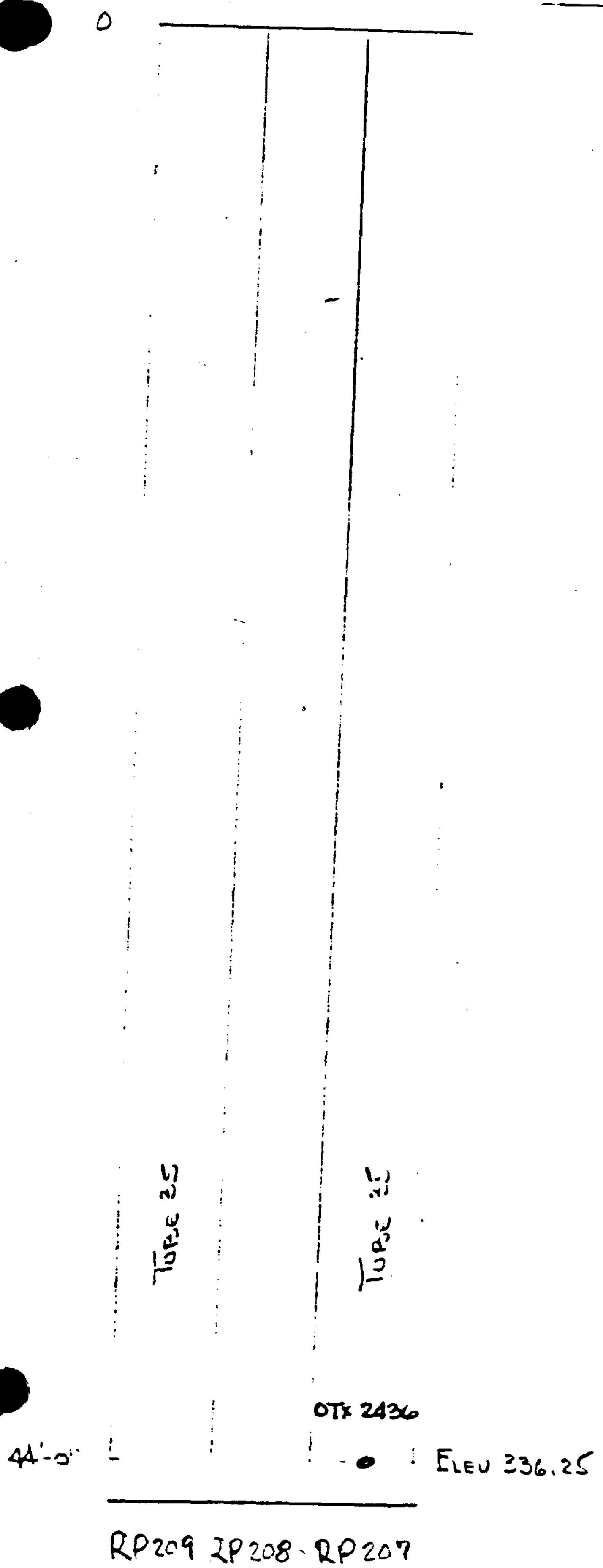
PANEL ELONGATION



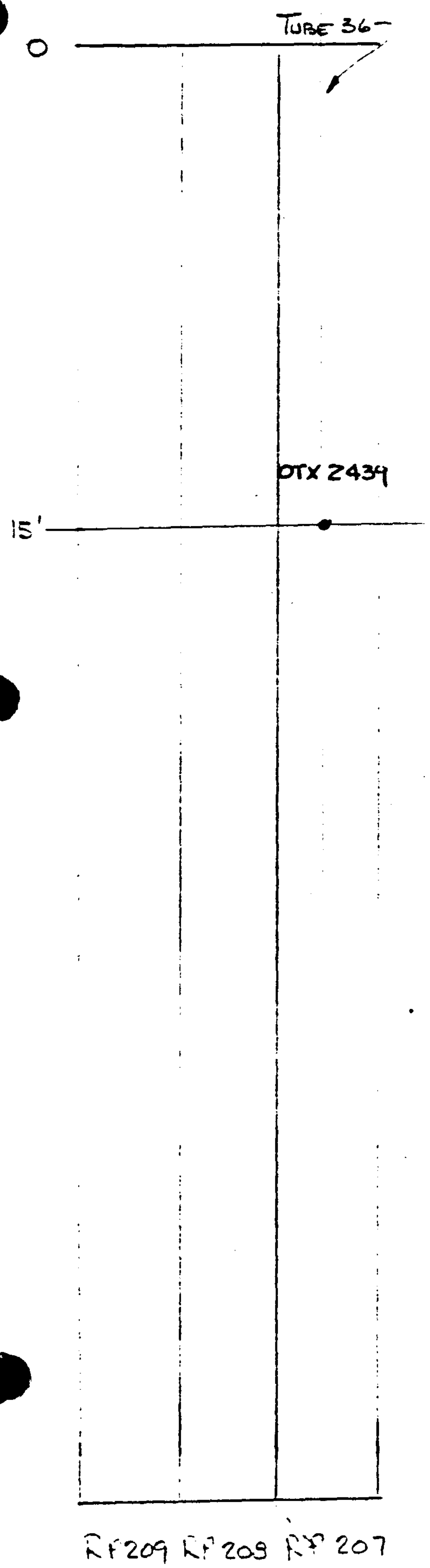
PANEL LATERAL MOVEMENT



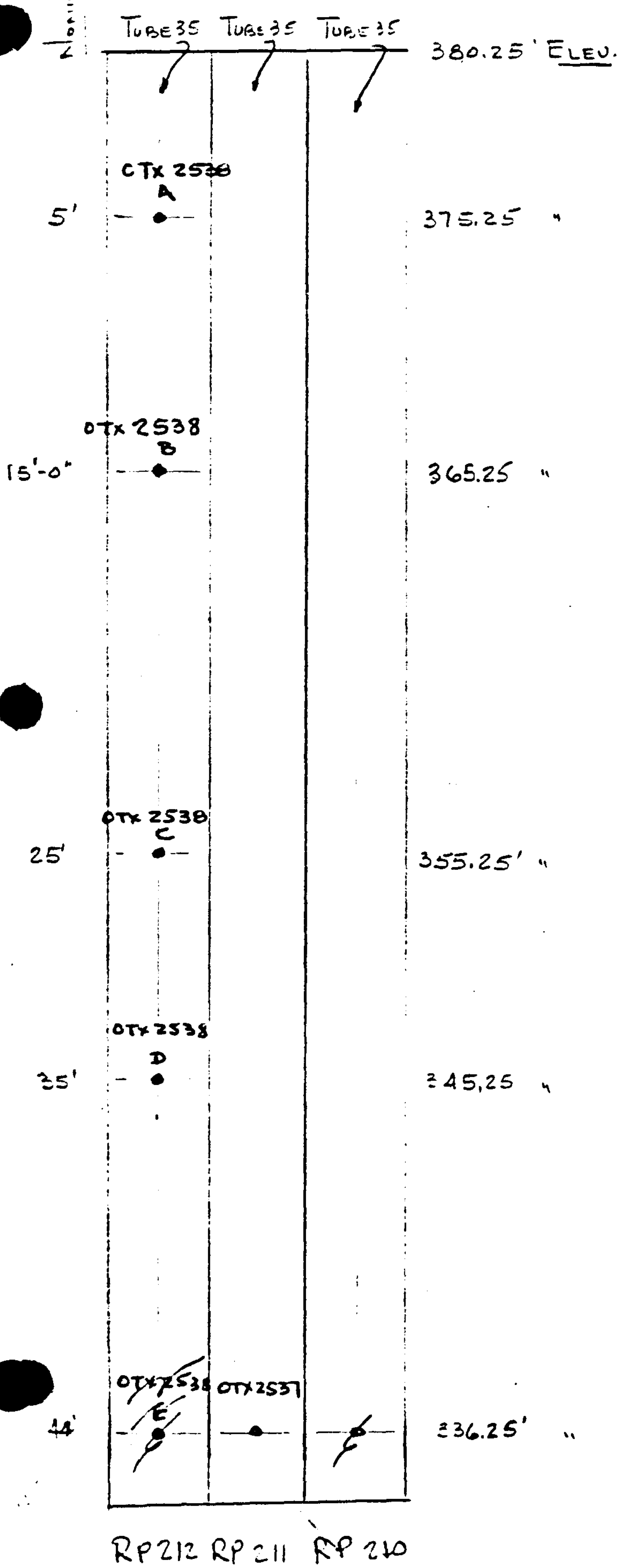
PANEL ELONGATION



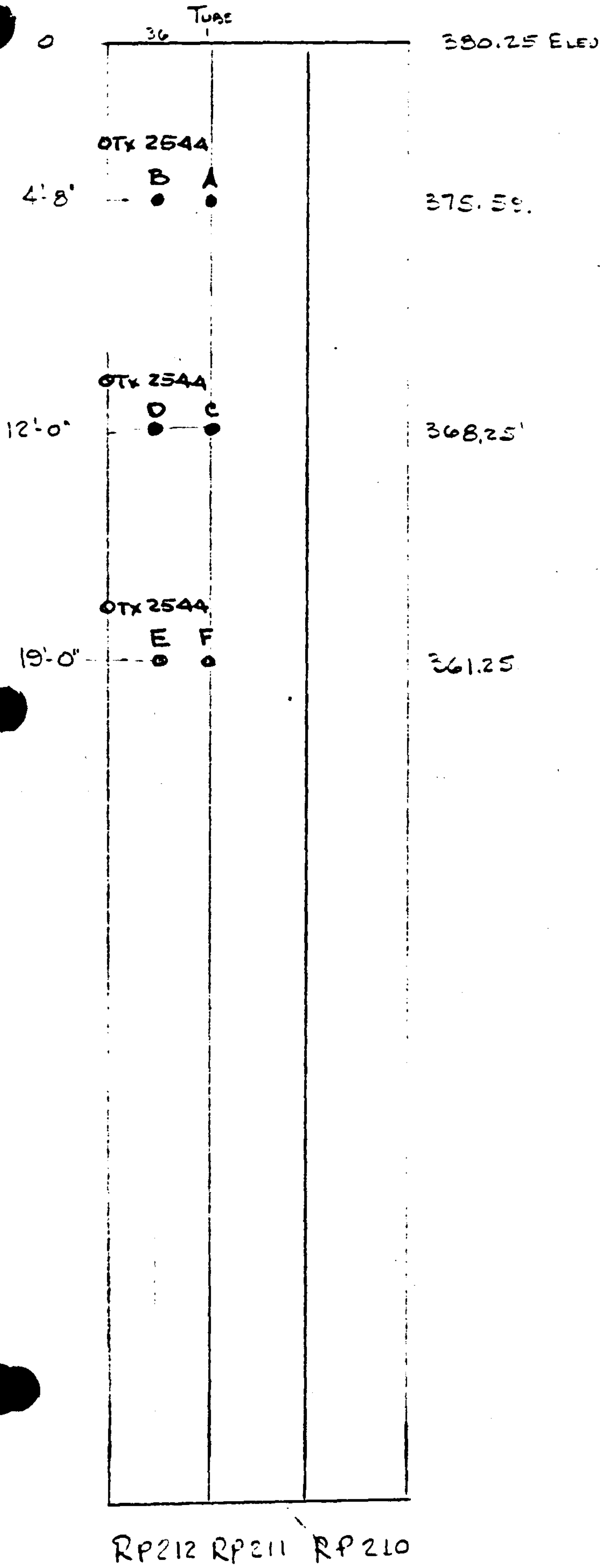
PANEL LATERAL MOVEMENT



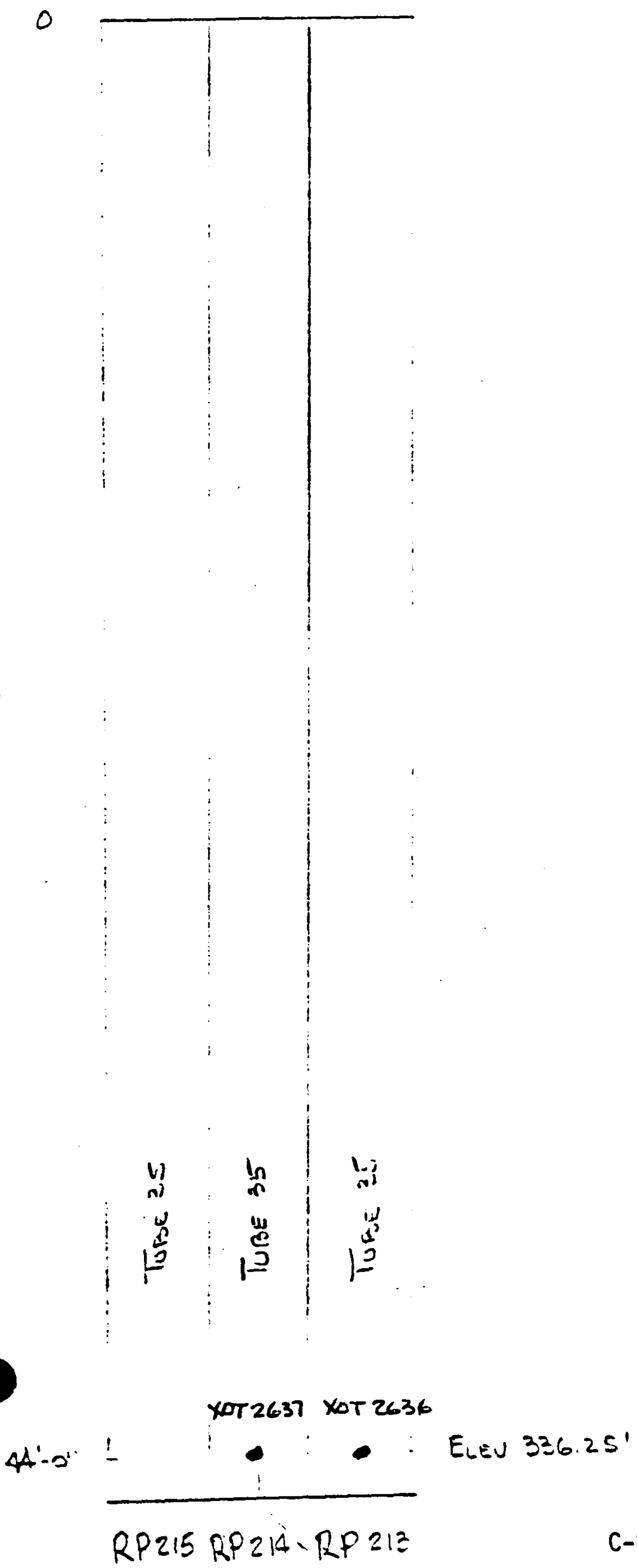
PANEL ELONGATION



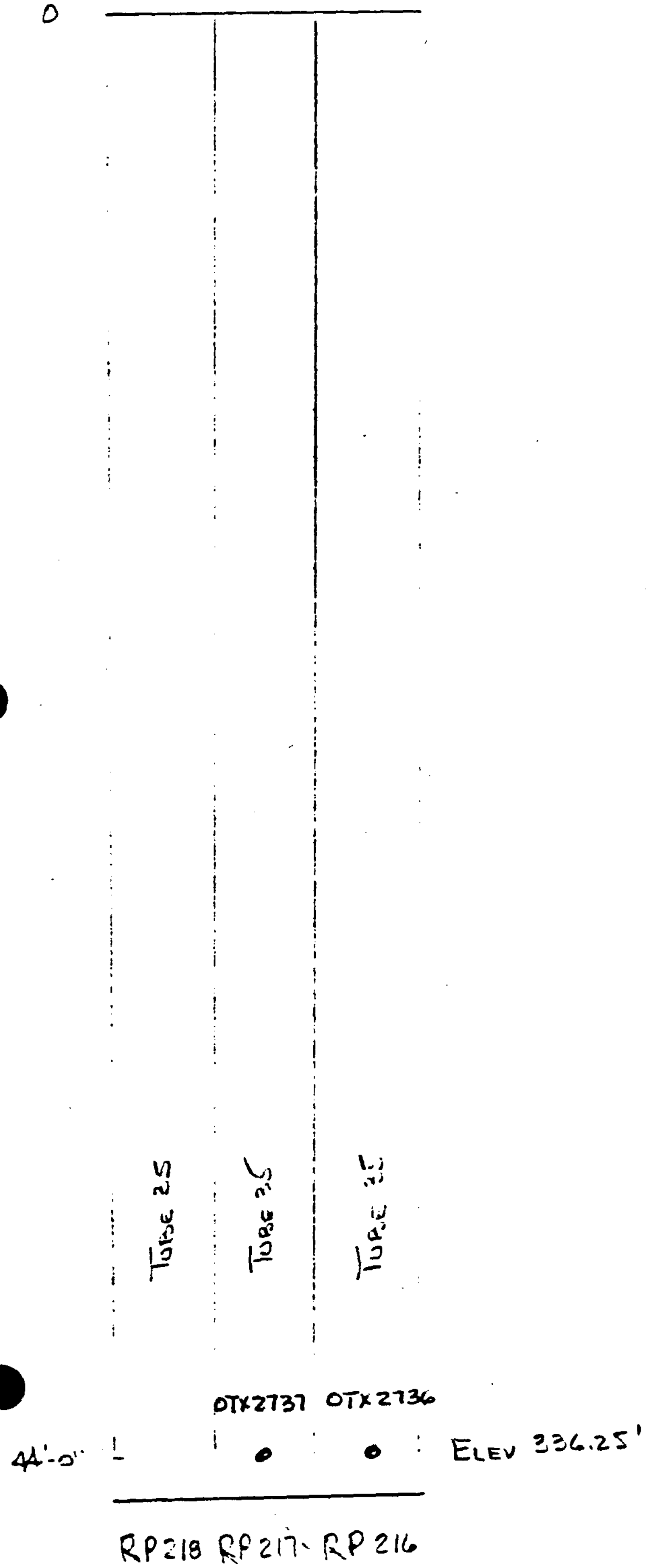
PANEL BOWING



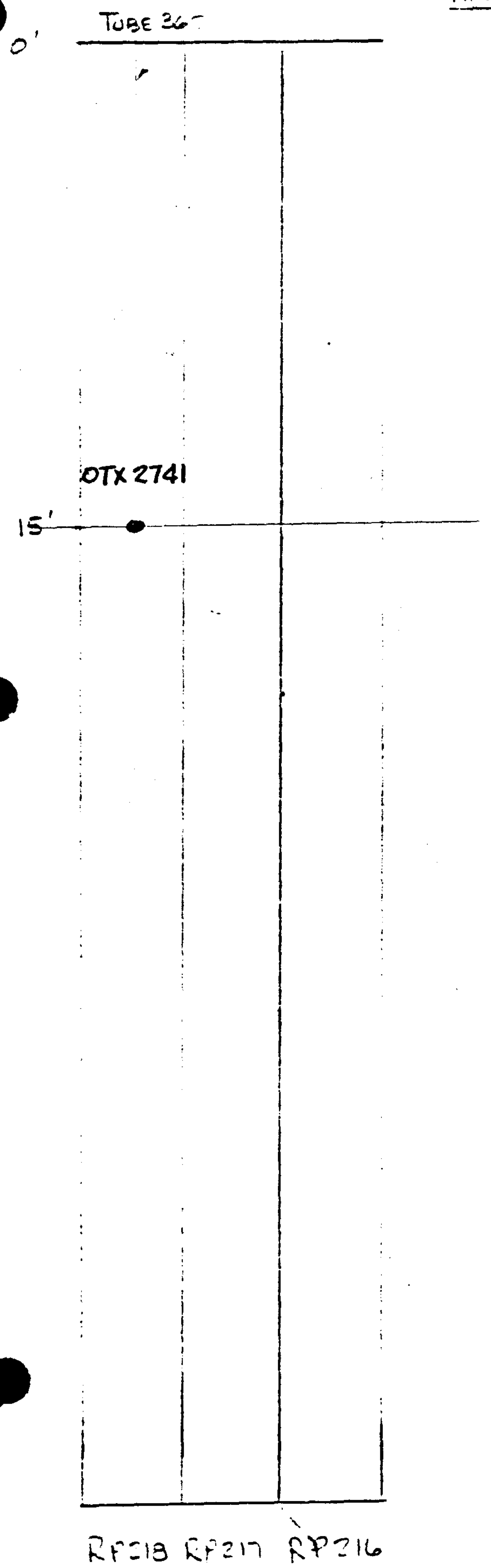
PANEL ELONGATION



PANEL ELONGATION



PANEL LATERAL MOVEMENT



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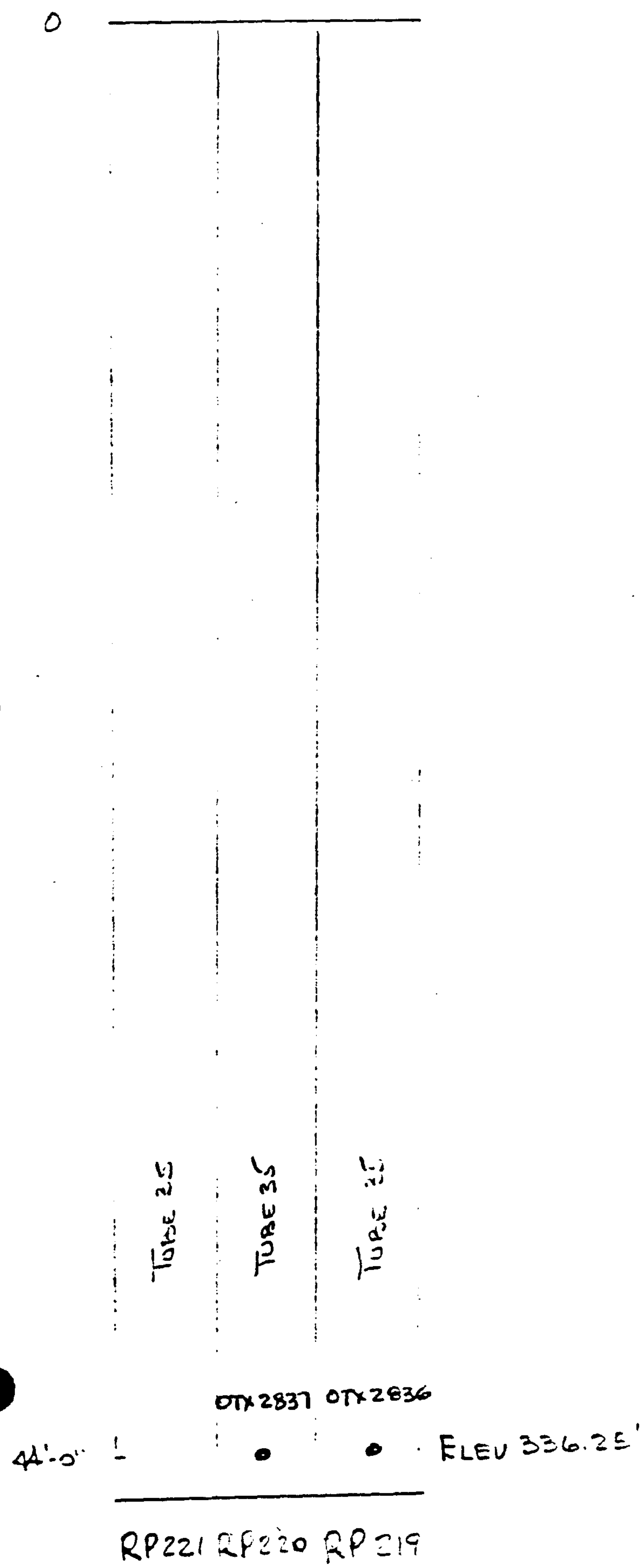
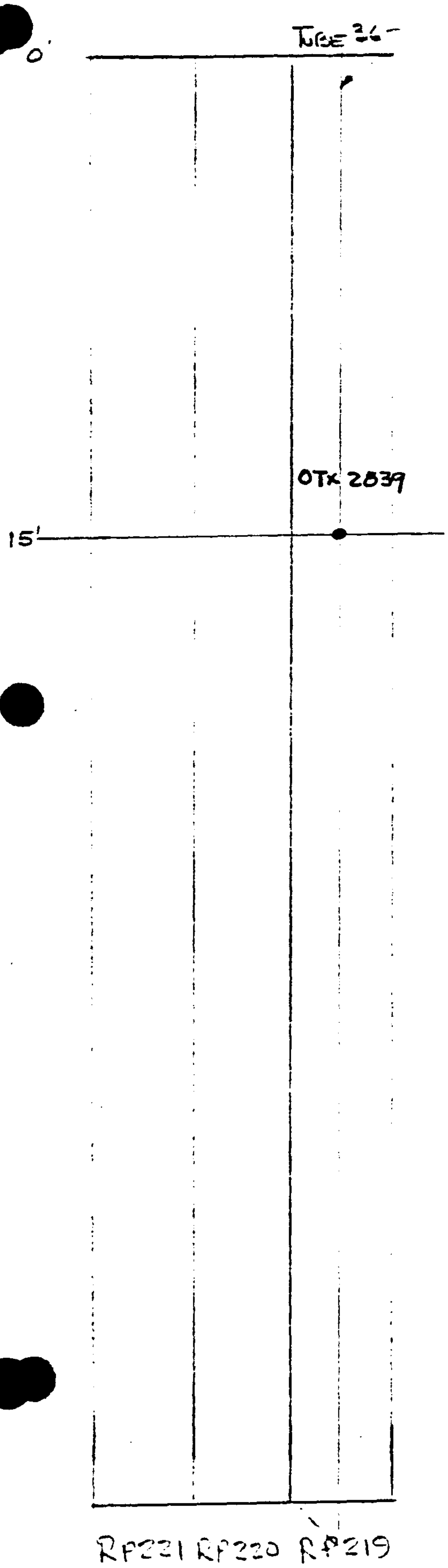
PANEL ELONGATION



PANEL LATERAL MOVEMENT.



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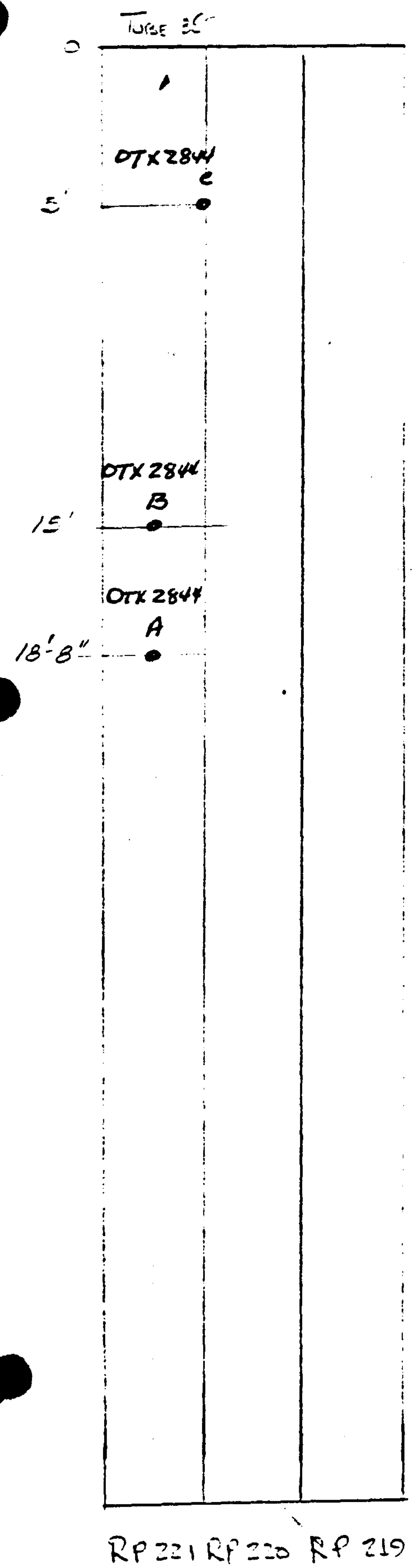

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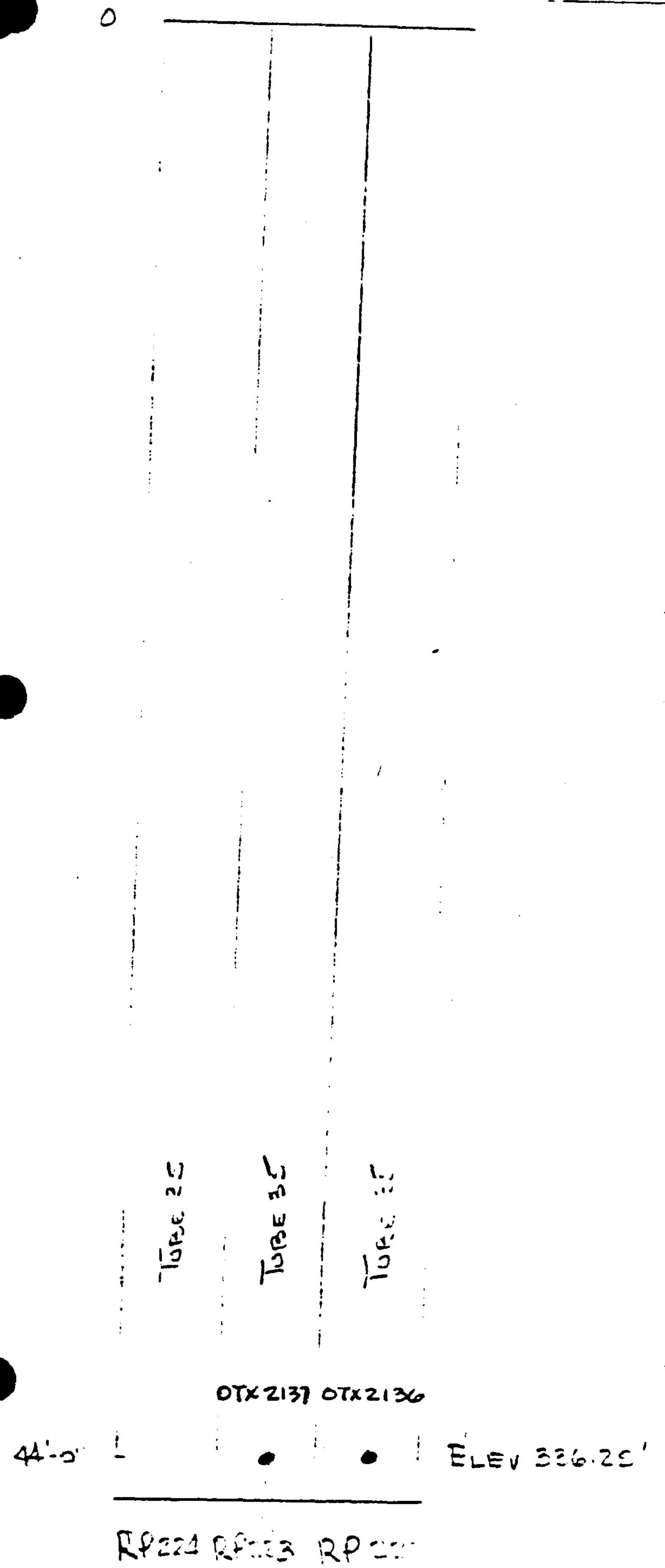

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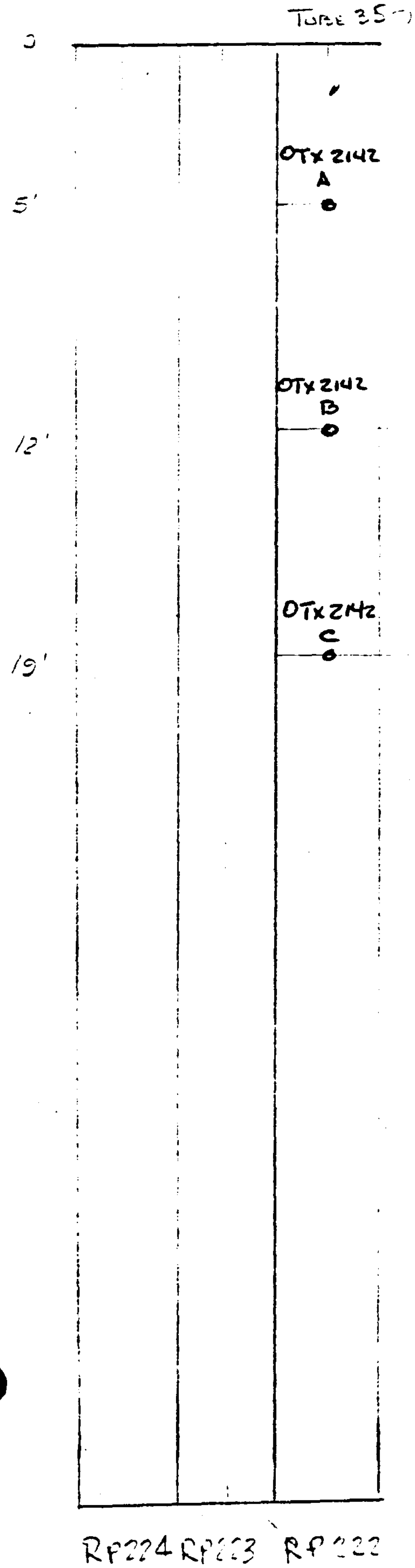

APPENDI

APPENDIX D

PRECAUTIONS AND OPERATING CONSIDERATIONS

FOR

PILOT PLANT TESTING

APPENDIX D

PRECAUTIONS AND OPERATING CONSIDERATIONS FOR PILOT PLANT TESTING

INTRODUCTION

This appendix contains a discussion of some of the operational test considerations which influenced the choice of test parameters and the sequencing of the test matrix in this test plan. These items also should be considered in preparing the test procedures and in conducting the test, particularly during the initial phases of testing. An operational test philosophy is presented first. This is followed by a discussion of a number of precautionary measures to avoid pilot plant damage during testing. Finally, a priority method of deciding upon the response to an unexpected event during testing is described.

BASIC OPERATIONAL PHILOSOPHY

The basic operational philosophy for the early test phases should be to proceed cautiously, beginning with the test that offer the least risk of damage to the Pilot Plant, and then to gradually increase the severity and/or complexity of testing and the associated potential risk as more experience and confidence in operating the plant is acquired. This approach is based upon minimizing the potential for Pilot Plant damage consistent with carrying out an effective test and evaluation program to meet programmatic objectives within a reasonable time frame. Increasing test severity includes increasing power level, increasing temperature, increasing pressure, and increasing heat flux. Increasing complexity means increasing the number of subsystems involved, or the number of control points, and also refers to control method (cascade versus coordinated).

PILOT-PLANT DAMAGE

Each major system within the plant is, of course, susceptible to damage. The discussion which follows is not intended to be a comprehensive listing of all factors which might lead to plant damage. However, it is intended to delineate some of the more significant factors which could lead to damage and to suggest precautionary measures to minimize this potential for damage during testing.

RECEIVER TUBE TEMPERATURE

It is important not to exceed the maximum metal wall temperature of 1150°F because this can lead to undesirable creep-fatigue damage and significantly reduces the receiver life. Since it is not possible to monitor all regions of each receiver panel, initial tests should be done with the lowest possible receiver outlet temperature. Thus, considering the 1150°F tube temperature limit, receiver outlet temperatures of 400 or 500°F permit much more latitude for tube temperature variations than does the 960°F outlet temperature.

Initial receiver outlet temperature should be in the 200-400°F range for conditioning oil in the Thermal Storage Unit. Temperatures should then be gradully increased to supply 660°F de-rated steam to the TSS charging loop, and then gradually increased to supply 950°F steam to the TSS desuperheater and the turbine throttle. Prior to 950°F operation, sufficient analyses and observations should have been performed to provide reasonable assurance that hot-spot tube wall temperatures exceeding 1150°F have not been encountered.

POWER LEVELS DURING STARTUP

Initially, one or two heliostats should be aimed at the receiver. The number of targeted heliostats should be slowly increased in stages for operation at, say, 1/4, 1/2, 3/4, and full power.

Operation should not proceed from one plateau of power to a higher plateau until all the systems involved have been operated long enough to verify satisfactory operation. Alarms and set points should be reviewed for adequacy for operation at each of these stages of power levels.

RECEIVER FLUX DENSITY

The calculated peak incident heat flux for 1818 heliostats is just above 0.3 Mwt per square meter. Until experience is gained with behavior of the receiver and wtih the effectiveness of the aim-point strategy, heat flux densities should be limited to 0.1 Mwt per square meter and then gradually increased to subsequent test to a peak value of 0.3 Mwt per square meter. The effectiveness of the aim point strategy should be based upon: (1) Visual observations with suitable filters for eye protection; (2) measurements including the heat flux gages in the receiver panels, the BCS cameras with filters, and if available, the infra-red optical scanner with filters to remove the longer wave length (greater than 1 micron) radiation emanating from the receiver; and (3) calculated power input to each receiver panel.

RECEIVER DEPRESSURIZATION

The receiver will be depressurized if either the steam outlet pressure exceeds 1600 psi, the steam outlet temperature exceeds 1000 F, or the panel-tube temperature exceeds 1200^{o}F. Depressurization of the receiver will generate additional vapor phase. Since the energy for heat of vaporization will come from the remaining liquid, the sudden cooling of the liquid in the receiver will cause a rather severe down shock, particularly in the lower portion of the receiver. Obviously, thermal shocks of any significant magnitude should be avoided if possible. Early tests should be at low temperatures and pressures to avoid operation limits leading to depressurization.

INITIAL HEATING OF OIL IN THE THERMAL STORAGE UNIT

Initial conditioning of the Caloria HT-43 could involve driving off a fairly large amount of water introduced through previous washing off of the crushed gravel and sand. If the water is driven off at a rate exceeding the capability for release, the thermal storage unit could be overpressurized and the TSU Vessel roof could buckle upward, pulling the vessel walls inward at the top. This could not only deform structural members of the roof and the vessel, but it also could cause failure of the rim weld at the roof-vessel joint. This conditioning phase must be carried out carefully at low input power levels, until sufficient data is acquired on whether there is an upper limit on input power during the initial charge cycle.

IMPAIRMENT OF OIL FLOW IN TSS

Flow of the Caloria HT-43 during conditioning and initial heatup could be somewhat impeded by the low viscosity at ambient temperature and just above. This will result in higher pressure drops through the flow circuit, which conceivably could be high enough to cause capitation in pumps or valves. Initial flow rates at lower temperatures should be low to minimize this possibility.

Likewise, there is some possibility of filters clogging with sand. Here again, low flow rates and careful monitoring of pressure drops are in order. Low flow rate also should minimize the possibility of channeling through the gravel-sand bed in the Thermal Storage Unit.

QUALITY OF INLET STEAM

Avoiding the introduction of condensed droplets of water in the inlet steam to the turbine is a matter of great concern, as the water droplets could cause turbine damage. "Wet" steam could also damage the downcomer pipe in the tower. A sudden sharp decrease in insolation caused by cloud passage, a valve malfunction, or a sluggish valve response are potential factors leading to lower quality steam. The problems associated with "wet" steam can be avoided by having a suitable degree of superheat in the steam. During operation at other than design conditions, it is important to select temperatures and pressures involving several hundred degrees of superheat.

CONTROL OF HELIOSTAT FIELD

There are potential damage and safety problems if control is lost simultaneously on a significant number of active heliostats. The beam from a number of heliostats focused on the tower structure below the receiver could cause damage to sensor and electrical leads, and could even damage the tower structure itself.

Damage could occur within a very short time span when even only a few segments of the 1818 heliostats at the Barstow plant are aimed at passive (uncooled) targets of low reflectivity. Clearly testing of the Barstow heliostats should start by checkout control of the field on less than a segment of 32 heliostats controlled by an NFC, and proceed to check out control of each and every HFC (i.e., each segment), then to gradually increase the number of segments to operate at, say, 1/4, 1/2, 3/4, and full power.

OPERATING MODES

It is possible to rank the operating modes and their associated control configurations in increasing order of complexity, so that tests can be performed initially on the simplest and easiest modal control configurations and then to proceed sequentially through the more complex modal configurations. While ranking is a matter for further discussion, a cursory examination indicates the following sequence for the order of tests:

Test Sequence Ranking	Operating Mode	Control Configuration
1	Storage Charging (SC)	Sun Following
2	Storage Discharging (SD)	Cascade
3	In-Line Flow (ILF)	Cascade
4	Turbine Direct (TD)	Sun Following
5	Turbine Direct and Charging (TD&C)	Cascade
6	Storage Boosted (SB)	Cascade
7	Charging & Storage Boosted (C&SB)	Cascade
8	Storage Discharging (SC)	Open Loop
9	Turbine Direct and Charging (TD&C)	Coordinated
10	Storage Boosted (SB)	Coordinated
11	Charging & Storage Boosted (C&SB)	Coordinated

Mode 5, Storage Charging (SC), was selected for initial operation involving a significant energy input from the heliostat field. This mode can be operated at low power levels and low receiver outlet temperatures. Moreover, it does not involve the turbine generator, so there is no particular need to worry about water in the steam leaving the receiver. As long as temperatures are kept below the point of damaging the oil in the TSU, this mode is probably the most forgiving and can be used to acquire initial experience and data on behavior of the Collector System and Receiver.

To utilize the turbine generator, the simplest way initially is to use the heat stored in the Thermal Storage Unit; so Mode 6, Storage Discharging (SD), is the obvious next choice in the test sequence.

To simultaneously operate the Receiver System and the Electric Power Generating System, a safe approach is to utilize the Thermal Storage System and operate in Mode 4, In-Line Flow (ILF). Here again, there is no need to worry about water in the steam. Having acquired operating experience and data in these three modes, it would now be appropriate to undertake operation in Mode 1, Turbine Direct (TD). Initial operation in this mode should be at low steam pressures and temperatures, choosing the lowest values suitable for running the turbine, but with the temperature high enough to give at least several hundred degrees of superheat. This is done to minimize the possibility of introducing water in the liquid phase into the turbine. Temperatures and pressures would then be increased up to design conditions, but always keeping at least several hundred degrees of superheat.

The next stage in the test sequence might be to attempt Mode 2, Turbine Direct and Charging (TD&C), with various proportions of power going into "charge". Here, there is an opportunity for various power splits. Power to the turbine can be held rather constant and the amount going to charge can be gradually varied, or vice versa.

A logical follow-on to Turbine Direct and Charging is Mode 3, Storage Boosted (SB). Here, the power delivered to EPGS from the Receiver System is augmented by power from the Thermal Storage System. Steam is delivered to both the main valve and the admission valve of the turbine. Again, various power splits are possible.

The final operating mode is the most complex of all, Mode 7, Charging and Storage Boosted (C&SB). Here the flow from the Receiver System is split into two streams to feed EPGS and TSS. Moreover, the TSS feeds the admission valve of the turbine to augment flow to the throttle valve.

To this point, control configurations have utilized cascade control rather than coordinated control when these choices were available. The next step in testing would be to repeat those operating modes for which coordinated control is also planned. Here again, the considerations described above also govern the sequential order in which tests involving coordinated control are performed.

MODE TRANSISTIONS

The philosophy governing planned transitions between operating modes should be to attempt the initial transitions at the lowest temperature and power level feasible. Transitions must be made by adding or deleting one flow stream at a time, and choosing those judged to have the least impact. For example, going from Storage Charging (SC) to Turbine Direct and Charging (TD&C) is a likely early candidate for transition testing. Once a transition is made, it may be possible to reverse the transition on the same day. A tentative list of sequences for normal transitions is as follows:

SC to TD&C	TC&C to SC
SC to ILF	ILF to SC
SD to SB	SB to SD
SD to ILF	ILF to SD
TD to TD&C	TD&C to TD
TD to SB	SB to TD
C&SB to TD&C	TD&C to C&SB
C&SB to SB	SB to C&SB
ILF to C&SB	C&SB to ILF

UNSCHEDULED EVENTS

Alarms are anticipated and plant operators are trained to respond appropriately. However, there are a number of other unscheduled events which can occur during operational testing and these events should be handled in such a manner that they cause minimum impact upon the test program and the plant itself.

The principal decisions in responding to an unscheduled event while a solar test is in progress usually will involve both a collector field action and a decision as to whether testing should be terminated.

Examples of unscheduled events which might occur during the course of testing are; temporary outage of one of the two power lines (33 kva and 4 kva) to the UPS; loss of one HAC; loss of one or several HFC's; loss of control of several active heliostats; temporary problems rendering the DAS inoperative; loss of certain real-time data displays; sudden change in feed-water purity; and loss of signal from a key sensor.

In tests of the EPRI - Boeing Bench Model Solar Receiver at CRTF three alternative courses of action were defined to cover most unscheduled events. These alternative courses, in increasing order of impact upon testing, may be described as follows:

(1) Pause for Evaluation

No change is made in receiver status or in the number of tracking heliostats while the problem is evaluated. Events leading to this action pose no immediate danger of harming the receiver.

(2) Collector Field Standby

All tracking heliostats are quickly moved to standby while the problem is evaluated. Events leading to this action pose an immediate danger of damaging the receiver if solar input is continued. However, the test could be resumed rather quickly by bringing the heliostats back from standby to track if the problem can be resolved satisfactorily without undue delay.

(3) Collector Field to Stow

The entire heliostat field is brought to the stow position. Events leading to this action either make it too risky to even leave the collector field at stanby or make it obviously impossible to continue testing on that particular day until suitable equipment software modifications or corrections can be performed.

Each unscheduled event which can be envisioned and which has a reasonable probability of occurring during testing should be considered and the response should fall into one of the three categories described above. Otherwise, a special more detailed response is required.