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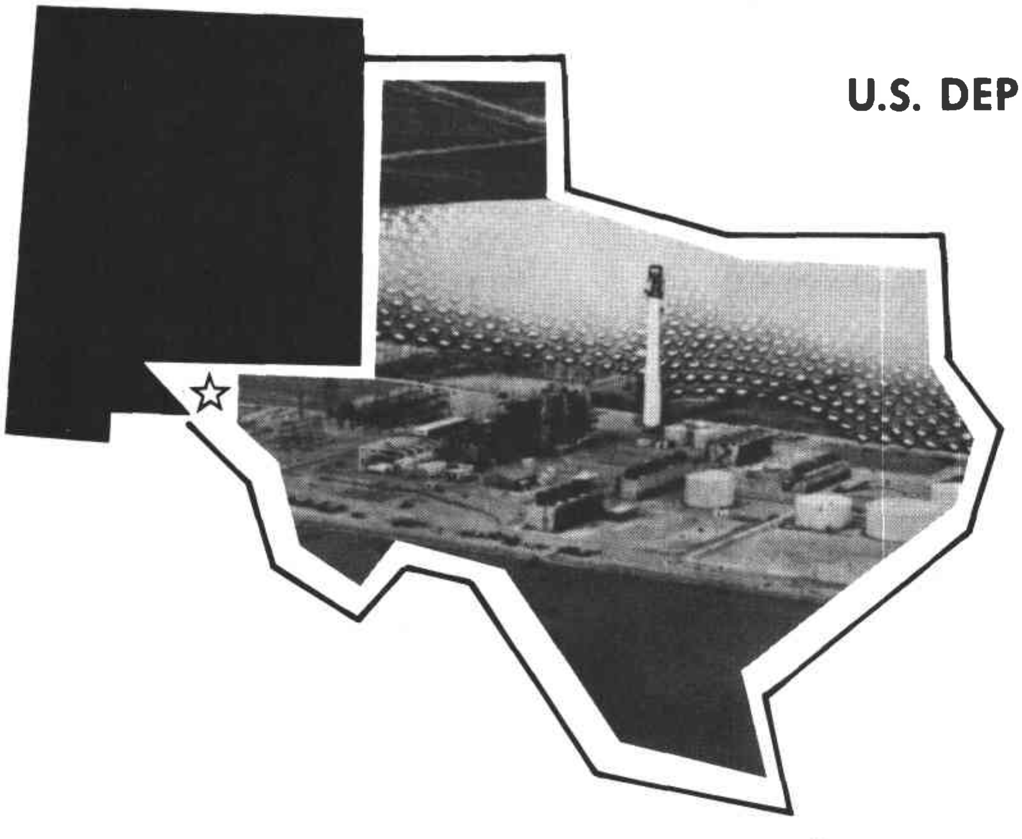
NEWMAN UNIT 1 SOLAR REPOWERING PRELIMINARY DESIGN

FINAL REPORT

Volume 2

prepared for:
U.S. DEPARTMENT OF ENERGY

NOVEMBER 1983



The Electric Company

EL PASO ELECTRIC COMPANY

Volume 2

NEWMAN UNIT 1
SOLAR REPOWERING
PRELIMINARY DESIGN

1248

FINAL REPORT

EL PASO ELECTRIC COMPANY
NEWMAN UNIT 1 SOLAR REPOWERING
PRELIMINARY DESIGN

NOVEMBER 1983

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Prepared for
U.S. Department of Energy
Contract No. SF11677-2

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LIST OF ABBREVIATIONS AND ACRONYMS

*NOTE - Abbreviations used for equipment mark numbers and plant systems have not been included in this table

A

A	- ampere
ac	- alternating current
AFI	- allowance for indeterminates
AFUDC	- allowance for funds used during construction
AISC	- American Institute of Steel Construction
ANSI	- American National Standards Institute
APS	- Arizona Public Service
ASME	- American Society of Mechanical Engineers
Attemp	- attemperator

B

B&W	- Babcock & Wilcox
BCS	- beam characterization system
BOP	- balance of plant
Btu	- British thermal unit

C

°C	- degree Celsius
c-c	- combined cycle
cl	- class
cm	- centimeter
CPU	- computer processing unit
CRT	- cathode ray tube
c-t	- combustion turbine plant
C/V	- cost/value

D

dc	- direct current
DDC	- direct digital control
DEH	- digital electrohydraulic control
DNB	- departure from nucleate boiling
DOE	- Department of Energy
DOE-SAN	- Department of Energy-San Francisco Operations Office

E

EHL	-	extreme high level
el	-	elevation
EPE	-	El Paso Electric Company
EPGS	-	electric power generating system
EPRI	-	Electric Power Research Institute

F

°F	-	degree Fahrenheit
FAA	-	Federal Aviation Administration
FMEA	-	failure mode and effects analysis
ft	-	foot
ft^2	-	square foot
FTA	-	fault tree analysis

G

gpm	-	gallons per minute
GWh	-	gigawatt hour
GWhe	-	gigawatt hour electric

H

HAC	-	heliostat array controller
HC	-	heliostat controller
HFC	-	heliostat field controller
Hg	-	mercury
hp	-	horsepower
hr	-	hour
HVAC	-	heating, ventilating, and air conditioning
HWL	-	high water level
Hz	-	hertz

I

ID	-	inside diameter
IEEE	-	Institute of Electrical and Electronic Engineers
in.	-	inch
IIE	-	Instituto de Investigacionas Electricas
I/O	-	input/ouput
IP	-	intermediate pressure
I/P	-	current to pneumatic converter

J

K

kg/h - kilograms per hour
kJ/kWh - kilojoules per kilowatt hour
km - kilometer
km^2 - square kilometer
kPa - kilopascal
kV - kilovolt
kVA - kilovolt ampere
kW - kilowatt
kWh - kilowatt hour

L

lb/hr - pounds per hour
ldc - load duration curve
lp - low pressure

M

m meter
m^2 square meter
MBtu million British thermal units
MCC motor control center
MCR maximum continuous rating
MCS master control system
m^3/h cubic meters per hour
MJ mega joules
mm millimeter
MOV motor operated valve
MPa mega pascals
mph miles per hour
m/s meters per second
MVA megavolt amperes
MW megawatt
MWe megawatt electric

N

NEMA - National Electric Manufacturers Association
NERC - National Energy Reliability Council
NFPA - National Fire Protection Association
Nm - Newton meter
NPDES - National Pollution Discharge Elimination System
NPRD - nonelectric parts reliability data
NPSH - net positive suction head
NRC - Nuclear Regulatory Commission
NRV - nonreturn valves
NSRM - Newman Solar Repowering Model
NUREG - Nuclear Regulatory Commission Report
NWL - normal water level

O

OA/FA	- oil air/forced air
OD	- outside diameter
O&M	- operation and maintenance
OSHA	- Occupational Safety and Health Administration

P

lb/ft^3	- pounds per cubic foot
pf	- power factor
P&I	- piping and instrumentation
PID	- piping and instrumentation diagram
ppb	- parts per billion
lb/ft^2	- pounds per square foot
psi	- pounds per square inch
psia	- pounds per square inch absolute
psig	- pounds per square inch gage

Q

R

R&D	- research and development
RH	- reheat
ROE	- return on equity
ROW	- right-of-way
RV	- relief valve

S

SEC SH	- secondary superheater
SH	- superheater
Solar One	- DOE 10MWe Solar Thermal Central Receiver Pilot Plant - Barstow, California
SWEC	- Stone & Webster Engineering Corporation

T

TDH	- total dynamic head
TEMA	- Tubular Exchanger Manufacturers' Association
T-G	- turbine-generator
thk	- thick
TMY	- typical meteorological year
TX	- Texas

U

UBC	- Uniform Building Code
UAC	- Utility Advisory Council
USGS	- United States Geodetic Survey

V

V	- volt
VWO	- valves wide open

W

WEC	- Westinghouse Electric Corporation
W/m^2	- Watts per square meter

X

Y

Z

APPENDIX A

APPENDIX A

SUMMARY OF PREVIOUS DOCUMENTATION

Results of the Conceptual Design Phase of the Newman Unit 1 Solar Repowering Program were documented in "Newman Unit 1 Solar Repowering Final Report" (El Paso Electric Company, Volumes I and II, No. DOE/SG-10740-1/I,II. July 1980).

These results were superseded by the Advanced Conceptual Design effort reported in "Newman Unit 1 Advanced Solar Repowering Final Report" (El Paso Electric Company, Volumes I and II, No. DOE/DF 11566-2. April 1982). The Table of Contents, List of Tables, and List of Figures for the April 1982 report are provided in Tables A-1, A-2, and A-3, respectively.

In addition, the following articles were published relating to this program:

- "Solar Repowering an 82 MW Reheat Steam Turbine," presented at the 8th Energy Technology Conference, Washington, D.C. March 10, 1981
- "Solar Repowering: The Next Step to Commercial Solar Power Generation," Modern Power Systems, pp. 51-55. August 1982
- "Solar Repowering - A Step Forward," Right of Way, pp. 18-20. August 1982
- "Preliminary Design of a Solar Repowered Gas-Fired Generating Station," ASME Joint Power Conference, Indianapolis, Indiana. September 28, 1983
- "Newman Unit 1 Solar Repowering Project," presented at the IEEE MEXICON 83, Cuernavaca, Mexico. November 23, 1983

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APPENDIX B

APPENDIX B

DESIGN REQUIREMENT DOCUMENT

SOLAR REPOWERING NEWMAN UNIT 1
EL PASO ELECTRIC CO.

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SECTION 1

PURPOSE

The purpose of the Design Requirement Document is to define design requirements and system environmental requirements for solar repowering Newman Unit 1.

General and specific system and subsystem design requirements are presented in Section 2. These requirements are primarily functional and based on a system configuration selected in January 1983.

Environmental criteria are provided in Section 3. These criteria will assist in proper selection of materials and sizing of structures to support operational, survival and lifetime requirements.

Applicable standards, codes, regulations and other published documents that may constrain plant design are identified in Section 4.

SECTION 2

DESIGN REQUIREMENTS

The Solar Repowered Newman Unit 1 shall be designed to meet the requirements of this section. Section 2.1 describes overall system design requirements; Sections 2.2-2.6 provide specific design requirements for each subsystem.

2.1 OVERALL SYSTEM REQUIREMENTS

General requirements applicable to all subsystems are presented as follows:

2.1.1 System Design Point Performance

The system design point shall achieve 50 percent repowering fraction, a nominal 41 MWe (net), at solar noon, winter solstice with a direct normal insolation level of 1000 watts/m^2. The solar multiple at the design point is 1.0 which means that essentially all energy received is used immediately; no thermal storage is provided beyond the inherent thermal mass of the system. At the design point, 112 MW of thermal power is absorbed by the water/steam flow in the solar receiver. The thermal power incident on the receiver surface shall be sufficient to offset the losses due to reradiation and convection from the receiver, and the loss due to the reflectivity of the receiver surface, while still providing required thermal input to the water/steam flow.

The repowering system shall supply 10.1 MPa/538°C (1465 psia/1000°F) steam to the high pressure turbine inlet and 1.52 MPa/533°C (220 psia/992°F) reheat steam to the intermediate stage turbine.

2.1.2 Unit Fundamental Flow Diagram

The concept for solar repowering Newman Unit 1 is summarized in Figure 2.1-1, "Unit Fundamental Flow Diagram." This configuration allows for operation of the combined unit in either fossil/solar, fossil-only or solar only mode.

During fossil/solar operation, main steam generated by the receiver is mixed with the steam provided by the existing fossil steam generator prior to admission to the high pressure (HP) turbine. The cold reheat steam (HP turbine exhaust) is split between the fossil boiler reheater section and the solar reheat heat exchanger. The resulting hot reheat steam is mixed prior to entering the intermediate pressure (IP) turbine. Attemperation of the solar and fossil generated steam ensures that the temperature is maintained within turbine design limits.

Fossil-only unit operation requires isolation of the solar portion of the combined unit. Isolation is accomplished at the piping tie-in-points for feedwater, main steam and reheat steam.

The fossil steam generator and first and second point heaters are isolated during solar-only operation.

2.1.3 Existing Plant Arrangement

Newman Station consists of four electric power generating units rated at a combined total of 477 MWe. Newman Unit 1, the unit selected for solar repowering is an 82 MWe (net) unit built in 1960. Unit 1 represents an ideal repowering situation for a water/steam cycle configuration. The plant arrangement minimizes feedwater, reheat steam and main steam piping runs by locating the receiver tower adjacent to the turbine building, which offers a simple repowering design. The placement of the receiver tower reduces piping costs, pressure drop, and thermal losses associated with long piping runs, and decreases the likelihood and extent of maintenance problems.

The heliostat field is to be located on available land north of the tower. Figure 2.1-2 is a site arrangement showing the approximate location of the tower and heliostat field relative to the existing unit.

2.1.4 Economic Criteria

The following nominal economic factors are used to support component tradeoff evaluations:

1. Incremental plant capital cost: $2,000/kW (1983)

2. Annual solar plant output: 70 GWh

3. Incremental energy cost: $0.10/kWh

2.1.5 Unit Availability and Reliability

Consideration in the design shall be given to achieving high reliability, by providing design and operating margins and by utilizing sound engineering design practices.

Special consideration shall be given to protecting receiver and tower external surfaces in the event of loss of heliostat tracking capability, and to protect heliostats from extreme weather conditions. This protection manifests itself primarily in careful design of a reliable power supply and control systems.

2.1.6 Maintainability

Unit modifications and new installations shall be designed to be compatible with existing unit maintainability characteristics and practices. Potential maintenance locations shall be easily reached and components, such as electronic units, motors, drivers, etc., readily replaced. Elements subject to wear and damage shall be easily serviced or replaced. The combined unit shall be capable of being serviced with a minimum of specialized equipment or tools.

2.2 SITE

The heliostat field and other facilities associated with solar repowering Newman Unit 1 will require approximately 1.1 km^2 (224 acres) of land north of the unit. Site preparation will include minor grading and surface preparation. An existing state highway, Farm-to-Market Road 2529, will be rerouted. Existing transmission lines currently located along a right-of-way north of the Newman Station switchyard will be rerouted to the west of the heliostat field. A new access road to the Newman Station and a perimeter road around the heliostat field will be provided to support vehicular traffic.

Heliostats shall be excluded from portions of the land where existing equipment and piping rights-of-way (ROWs) are required, and where future transmission line ROWs will be located.

Existing underground natural gas and other pipelines which transect the northern portion of the field will remain, with an exclusion area provided along their 55 m (180 foot) ROW. ROW for pipelines currently along Farm-to-Market Road 2529 will be maintained.

Drainage ditches are required to channel rain run-off away from the heliostat field to minimize erosion of the graded surfaces and protect foundation integrity. The solar repowering site shall include fences to protect against unauthorized entry to portions of the site.

2.3 SITE FACILITIES

New site facilities will include a new solar equipment building and new tower equipment rooms, as well as additions to the existing control room and maintenance building.

The control room will require a second level to house the new electronic equipment. The second level shall be air condition to maintain the correct ambient temperature for the new computers and associated equipment.

Suitable space will be located in the tower to house receiver control cabinet equipment and motor control centers.

An addition to the maintenance building will be required to enable plant personnel to repair and test complete heliostat assemblies. Additional evaporative coolers will be required to circulate fresh air through the maintenance area.

A solar equipment building will be required to house the solar feed pumps, the solar repowering secondary unit substation and motor control center, condensate polishing equipment, and feedwater heaters.

The existing fire protection system will be extended to protect the new site facilities.

Outdoor lighting shall be provided along the heliostat field perimeter road and at the base and upper levels of the tower.

2.4 COLLECTOR SUBSYSTEM

The Collector Subsystem shall reflect solar radiation onto the Receiver Subsystem in a manner which satisfies receiver incident heat flux requirements specified in Section 2.4.2. In addition, the Collector Subsystem shall respond to commands from the Master Control System (MCS) for unit control integration, emergency defocusing of the reflected energy, or to protect the heliostat field against environmental extremes. The heliostats shall be properly positioned for repair or maintenance in response to either MCS or manual commands. Heliostat design shall provide for stored or safe positions for use at night, during periodic maintenance, and during adverse weather conditions. The Collector Subsystem shall be designed to provide energy in accordance with the requirements of the receiver. The Collector Subsystem shall include a Beam Characterization System (BCS) to provide periodic evaluation and correction of individual heliostat optical performance.

2.4.1 Heliostat Field

The heliostat field shall be designed so that 134 MWt of the redirected solar energy will impinge on the receiver absorber surfaces at solar noon, winter solstice, assuming a direct normal insolation value of 1000 W/m^2, clean mirrors, and two percent of the heliostats unavailable.

The heliostat field design shall provide minimum capital cost for the solar plant considering at least the following:

- The power requirement given above
- Limitations on the solar energy flux incident on receiver as specified by the receiver manufacturer
- Installed cost of the heliostats

- Field wiring cost
- Land availability
- Height of center of the receiver above ground level
- Cost of piping in the tower
- Cost of foundations

The Collector Subsystem shall function as appropriate for all steady-state modes of plant operation. This shall include the capability of controlling the number of heliostats in the tracking mode to vary the redirected flux to the receiver when necessary to maintain control of steam temepráture.

Drive systems must be capable of positioning a heliostat to stowage, standby, cleaning, or maintenance orientation from any operational orientation in response to a command signal.

Elevation and azimuth drives shall not drift from last commanded positions due to environmental conditions.

The drive system shall provide for cost effective stowage of the reflective surface to minimize reflected beam safety hazards and dust or dirt build-up on the mirrors. Heliostat orientation shall be available to the MCS at all times.

Heliostat control shall be by computer hierarchy. Control functions shall be accomplished as follows or in a comparable manner:

Heliostat Array Controller (HAC) shall:

- Initiate operational mode commands to heliostat field controller (HFC)
- Address commands to HFC groups or individual heliostat controller (HC)
- Respond to MCS commands and requests
- Interface with BCS
- Provide time base

Heliostat Field Controller (HFC) shall:

- Determine sun vector
- Transmit sun vector to HC
- Transmit status and data to HAC

- Initiate safe stowage command
- Control groups of HCs

Heliostat Controller (HC) shall:

- Determine heliostat azimuth and elevation position requirements
- Control drive motors
- Provide heliostat axis position data to HFC

The Collector Subsystem shall be capable of emergency defocusing upon command to reduce peak incident radiation on the receiver to less than 3 percent of initial value within 120 seconds.

Heat fluxes on the tower and on normally unheated portions of the Receiver Subsystem are limited to 25 kW/m^2 (7,880 $Btu/hr\text{-}ft^2$).

Heat fluxes on the receiver will satisfy flux distribution requirements specified by receiver design.

Beam control strategy and equipment will protect personnel and property within and outside the plant facility, including air space.

The Collector Subsystem will be designed to satisfy the environmental conditions specified in Section 3.

2.4.2 Heliostats

Detailed heliostat design requirements are provided in the heliostat field technical specification.

2.5 RECEIVER SUBSYSTEM

The Receiver Subsystem shall include a receiver mounted on a single tower and shall provide a means of transferring the incident radiant flux energy from the Collector Subsystem into water/steam flow and transport the main steam to the HP turbine (at throttle condition) 10.1 MPa/538°C (1,450 psig/1,000°F) and primary steam at 12.6 MPa/549°C (1,825 psia/1,020°F) to the reheat heat exchanger.

2.5.1 Structural Design

The receiver and tower shall be designed to provide access for maintenance and inspection of the tower structure, receiver, working fluid, instruments and controls, hydraulic equipment, etc. Consideration shall be given to ease of maintenance. Adequate provisions shall be made to ensure crew safety at all times for required operations, inspection, maintenance, and repair. The receiver design shall be consistent with Section 1 of the ASME Boiler Codes and appropriate sections of the construction codes. The design lifetime shall be 30 years. The tower and receiver will be designed to satisfy the environmental conditions specified in Section 3.

2.5.2 Receiver

The receiver shall have an external panel configuration with a forced recirculation boiler and shall face a north field of heliostats. The receiver shall be capable of operating safely and reliably for 30 years with heat flux levels not exceeding a skewed flux profile with a peak heat flux on the bottom half not to exceed 400 kW/m^2 at solar noon, winter solstice with an incident power level of 134 MWt.

At solar noon, winter solstice (design point), the receiver shall be capable of absorbing 112 MWt with a receiver incident power of 134 MWt and shall at least generate, in the first (primary) superheater pass, steam at the rate of 119,000 kg/hr (262,000 lb/hr) with outlet conditions of 12.58 MPa/549°C (1,825 psia/1,020°F) and, in the second (final) superheater pass, generate main steam at the rate of 131,000 kg/hr (289,000 lb/hr) with outlet conditions of 10.41 MPa/540.5°C (1,510 psia/1,005°F). The maximum allowable pressure drop in the two pass superheater shall not exceed 1.79 MPa (260 psi) in the first pass and 1.59 MPa (230 psi) in the second pass.

The receiver shall be designed for stable operation at all possible sun angles and for most expected partial cloud cover conditions.

2.5.3 Working Fluid

The receiver working fluid shall be water/steam for the first superheater pass and superheated steam for the second superheater pass.

2.5.4 Receiver Tower

The receiver tower must support the receiver, piping, other elements of the Receiver Subsystem, and the targets for the BCS. Tower design will be based on Section 3 and the following:

- Tower height - 136 m (447 ft)
- Elevation of receiver centerline - 155 m (509 ft)
- Weight of receiver including support structure - 725,600 kg (1,600 kips)

The tower will be required to support receiver feedwater, steam, and auxiliary piping and associated controls and provide access for maintenance and repair. Two equipment rooms are provided near the top of the tower to house receiver instrumentation and control equipment. In addition to internal ladders, platforms, and walkways, the design of the tower shall include an internal elevator having a capacity of approximately 1225 kg (2,700 lb).

2.6 MASTER CONTROL SYSTEM (MCS)

The MCS provides overall supervisory plant control, integrating all major plant control functions.

2.6.1 General Design Requirements

The Newman Unit 1 control system and existing plant equipment shall be modified to provide daily cycling of the unit and utilize fossil and solar energy for generation of electrical power. The MCS shall control the solar steam supply system and the existing unit equipment in a safe and reliable condition for all modes of operation.

The MCS shall permit the operator to select one of three unit operating modes: fossil-only, solar-only, or combined solar/fossil.

The MCS shall operate the unit for all conditions including startup, shutdown, transient, steady state, and emergency operation.

2.6.2 Design Criteria

To satisfy the general design requirements the MCS shall meet the following design criteria:

a. High Availability

- High component/circuit reliability employing the latest solid state technology and conservative designs.
- Major control systems and components shall have full redundant backup with automatic fail-over.
- Modular architecture to enhance fault detection and maintenance.
- Self-diagnostic capability wherever possible.

b. Redundancy

The MCS will include full system redundancy where feasible. A failure of one computer processing unit (CPU) will not cause a reduction in control, monitoring, display recording, or other required plant control functions.

c. Comprehensive Operator/Plant Interface

- Adequate CRT displays shall be provided to support the following:
  - Process monitoring
  - Trouble identification
  - Operator guidance
  - Interactive communications
  - Status information
  - Historical review
- Main control board with conventional analog displays, control stations, alarms, etc, providing the operator with a familiar operation/process interface for those unit portions unaffected by the repowering.

d. Flexibility

All control logic functions and control algorithms are implemented in comprehensive direct digital control software. The system is programmed in a manner which allows changes to be made simply and quickly.

e. System Modifications

Existing control systems will be modified only where necessary. The following criteria will determine which controls are changed:

- Direct interface with MCS.
- Significant enhancement of the repowered unit's ability to meet the design requirements.
- Ability of the equipment to function properly for the required 30-year lifetime.

In general, all instrumentation replaced satisfies two or more of the above criteria.

2.6.3 Operating Modes

Through the MCS, the operator shall select the unit operating mode.

2.6.3.1 Fossil Mode

When the fossil mode has been selected, the solar steam supply system is isolated from the existing fossil fueled plant. In this mode, the MCS allows the unit to be placed in either a boiler-following control, turbine-following control, or coordinated boiler/turbine control.

2.6.3.2 Solar-Only Mode

With clear day insolation available, the operator may select the solar-only mode of operation. The fossil boiler is isolated from the balance of plant (BOP) equipment and the solar steam supply system and the BOP is placed in a turbine following control. The solar receiver, and the Collector Subsystem will be automatically controlled to maximize thermal energy output from the solar steam supply system. The turbine inlet control valves will be automatically positioned to maintain stable steam conditions to the turbine inlets.

2.6.3.3 Combined Solar/Fossil Mode

When meteorological conditions are unstable or when it is economical to operate the unit at high load, the Master Control System will control the plant in a solar/fossil mode. The main steam from the solar receiver and the fossil boiler shall be combined prior to being admitted to the turbine. The control system will operate the solar steam supply system to maximize solar thermal output and use the fossil boiler to supplement steam to meet the unit's load demand.

2.7 FOSSIL BOILER SUBSYSTEM

The Fossil Boiler Subsystem of Newman Unit 1 shall interface with the solar steam supply system according to the following boiler performance requirements:

- Minimum automatic operation - 28 percent load (36 percent rated steam flow)
- Maximum boiler ramp rate - 10-20 percent/min (change in boiler thermal output) above 28 percent load.
- Energy required from cold startup to 28 percent load - 1.06×10^{11} J (100 MBtu) over 4 hours
- Energy required from hot standby to 28 percent load - 1.58×10^{10} J (15 MBtu)

- Boiler efficiency - 84.4 percent
- Ability to maintain superheat and reheat temperature of 538°C (1,000°F) to minimum load

2.8 ELECTRIC POWER GENERATING SUBSYSTEM (EPGS)

The EPGS will be required to accept steam from either or both the solar or fossil steam supply systems.

Operating constraints imposed by the existing EPGS are as follows:

a.	Maximum gross electric output	85.8 MWe
b.	Rated main steam flow for guaranteed output	257,000 kg/hr (567,000 lb/hr)
c.	Main steam rated temperature	538°C (1000°F)
d.	Reheat steam rated temperature (May be revised pending detailed reheat heat exchanger design)	538°C (1000°F)
e.	Main steam rated pressure	10.1 MPa (1,450 psig)
f.	Rated reheat pressure drop	255 kPa (37 psi)

g. Steam temperature limitations (at turbine main stop valve)

1. Average over 12 months not to exceed 538°C (1,000°F)
2. 552°C (1,025°F) for not more than 400 hours for 12 months
3. 566°C (1,050°F) for up to 15 minutes: not more than 80 hours/year

h. Steam pressure limitations

1. 10.1 MPa (1,450 psig) at rated output
2. 10.6 MPa (1,523 psig) as turbine approaches zero output
3. 13.0 MPa (1,885 psig) momentarily, not exceeding 12 hours/year

i. Load limitations

Rate of load change is limited by metal temperatures in critical areas of turbine. Normal turbine load change rates are limited to about 5 MWe/min. Faster load

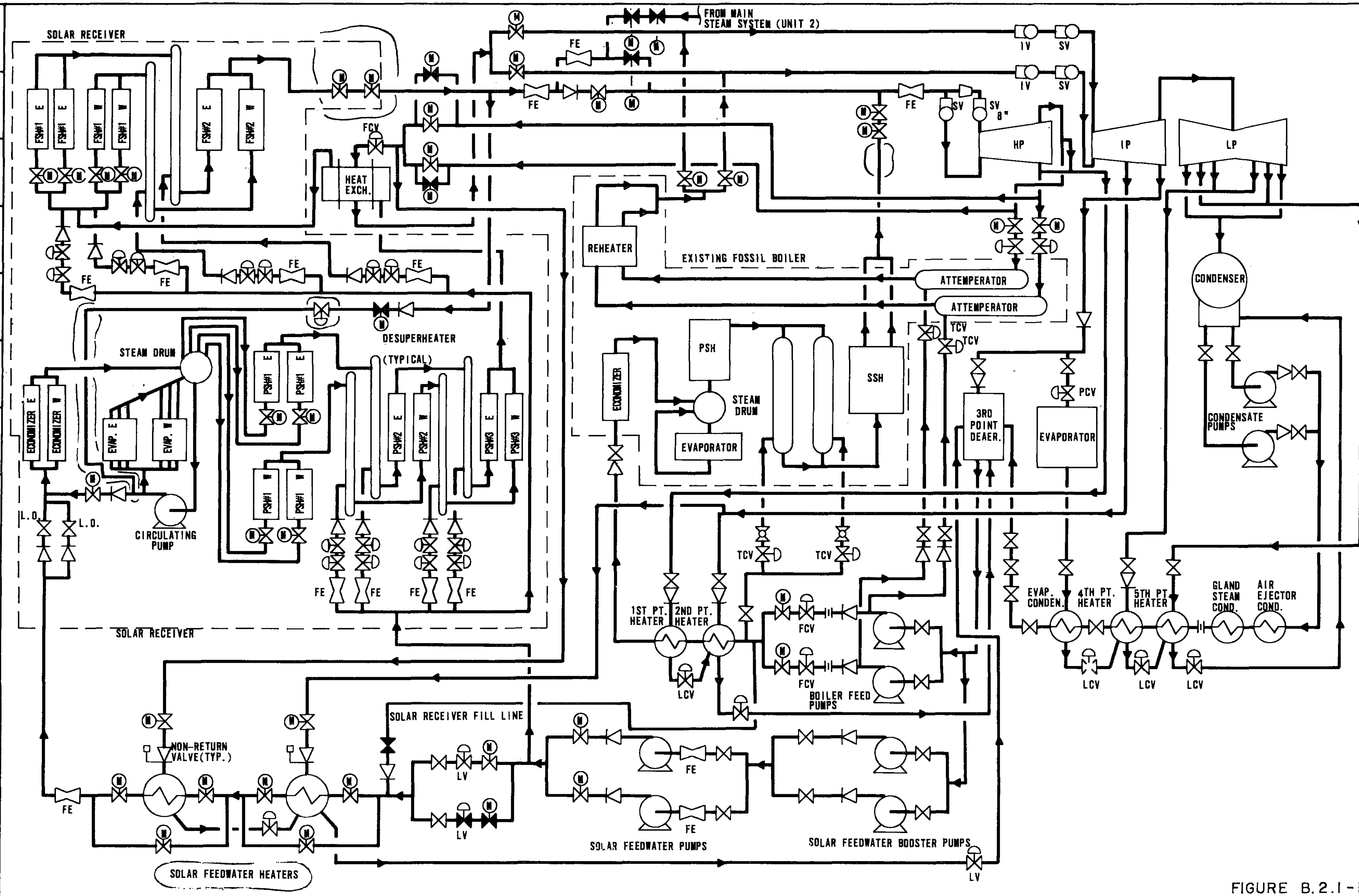

FIGURE B.2.1-1

GEN. REV.

4	3	2	1	ISSUE
SC BPJ	SC BPJ		WHM GMS	PREP
RR BW	RR RWJ	BMJ	DPL MAS	REVIEW
BMJ	BMJ	RWK	RWK	APP
9-27-83	7-22-83	3/14/83	4/15/82	DATE

FLOW DIAGRAM - SOLAR REPOWERING
STATION FUNDAMENTAL
UNIT NO. 1 - NEWMAN POWER STATION
EL PASO ELECTRIC COMPANY
STONE & WEBSTER ENGINEERING CORPORATION

14380-PID-1-1-SR

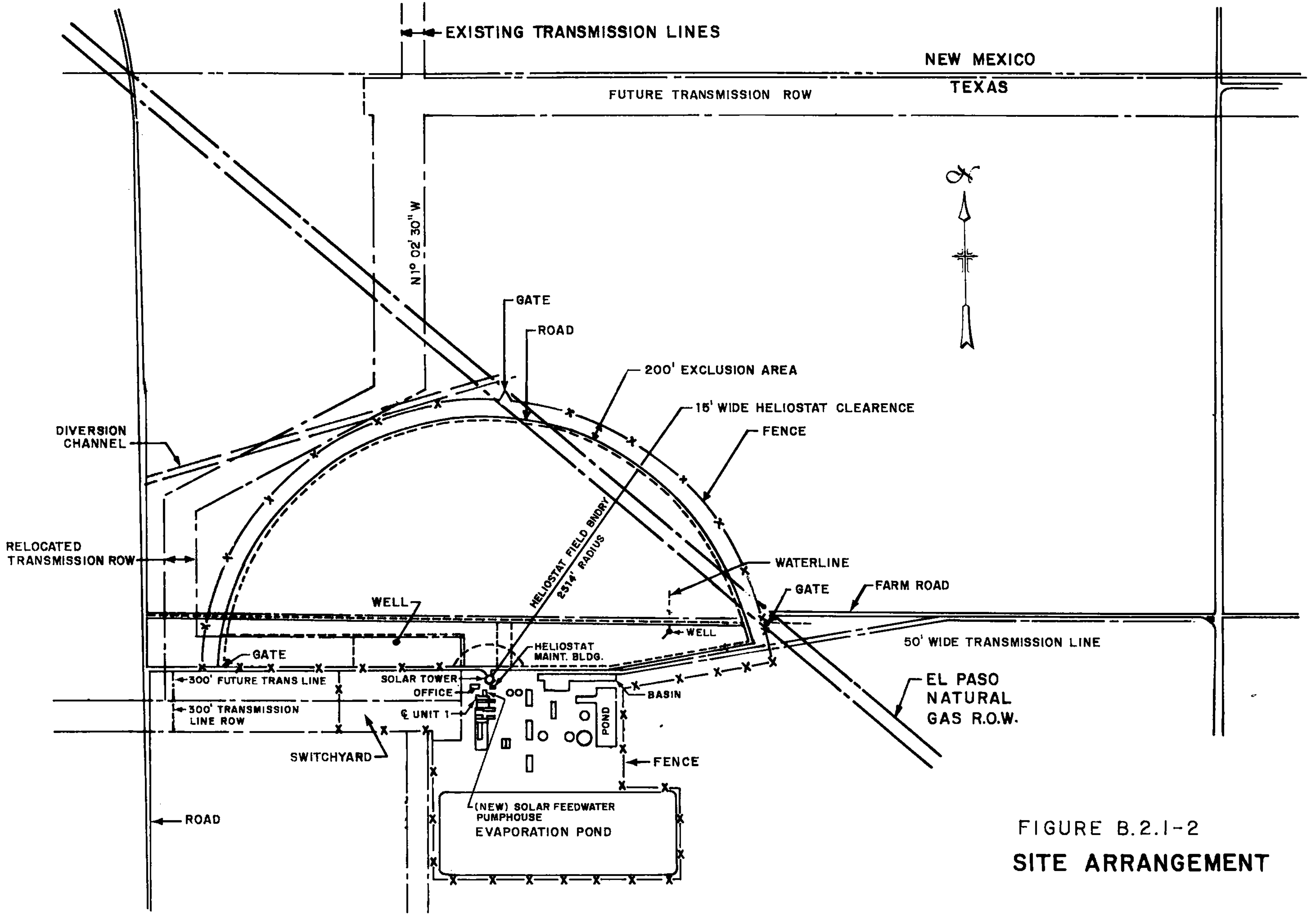

FIGURE B.2.1-2

SITE ARRANGEMENT

SECTION 3

ENVIRONMENTAL CRITERIA

This section addresses plant environmental design requirements and environmental standards.

3.1 DESIGN REQUIREMENTS

The system shall be capable of operating in appropriate combinations of the following environments.

a. Temperature: The plant shall be able to operate in the ambient air temperature range from -22° to +50°C (-8° to 122°F). Performance requirements shall be met throughout an ambient air temperature range of 0°C to 50°C (32°F to 122°F).

b. Wind: Performance requirements shall be met for a wind speed, including gusts of 12 m/s (27 mph) at a height of 10 m (33 ft). The plant shall be capable of operating using a wind speed, including gusts of 16 m/s (36 mph) at a height of 10 m (33 ft.) for the operating condition (Degraded performance allowed). Wind analyses shall satisfy the requirements of ANSI A58.1-1982.

The system shall be capable of surviving appropriate combinations of the environments specified below.

a. Wind: The plant shall survive winds with a maximum speed, including gusts of 40.3 m/s (90 mph), at a height of 10 m (33 ft), without damage. Heliostats shall be designed to survive the 40.3 m/s (90 mph) winds when stowed in the horizontal position. In addition, the heliostats, in any orientation, shall survive winds with a maximum speed, including gusts of 22 m/s (50 MPH), without damage. A local wind vector variation of ±10 degrees from the horizontal shall be assumed. Wind analyses shall satisfy the requirements of ANSI A58.1-1982.

b. Snow: The plant shall survive a static snow load of 250 Pa (5 lb/ft^2) and a snow deposition rate of 0.3 m (1 ft) in 24 hours.

c. Rain: The plant shall survive the following rainfall conditions at a maximum 24-hr rate of 75 mm (3 in).

d. Ice: The plant shall survive freezing rain and ice deposits in a layer 50 mm (2 in) thick.

e. Earthquake: The receiver tower shall withstand loading consistent with a peak horizontal ground acceleration of 0.05g. The response spectrum shall be developed based upon the procedures outlined in NRC Regulatory Guide 1.60. Since wind load governs for the heliostats, seismic analysis is not required.

f. Hail: The plant shall survive hail impact up to the following limits:

Diameter	25 mm (1 in)
Specific Gravity	0.9
Terminal Velocity	23 m/s (75 fps)
Temperature	-6.7°C (22°F)

g. Sandstorm Environment: The plant shall survive after being exposed to flowing dust comparable to the conditions described by Methods 510 of MIL-STD-810B.

h. Lightning: The plant shall be provided with a lightning protection system for the tower and receiver to protect against direct strikes.

3.2 ENVIRONMENTAL STANDARDS

Federal, state, and local regulations applicable to solar repowering Newman Unit 1 are presented in Section 4.

SECTION 4

DESIGN DOCUMENTS

4.1 APPLICABLE DOCUMENTS

Various codes, standards, and other documents identified below will provide the guidelines for development of designs that are presented in this document. These applicable documents will influence the design and selection of vessels, heat-transfer equipment, mechanical equipment, structures, civil work, piping, instrumentation, and electrical items that are used in the utility industry.

4.1.1 Standards And Codes

The latest revisions of each of the following standards and codes in effect during final design will be used.

American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code

- ASME I - Power Boilers, including: ANSI B31.1-1977 Power Piping
- ASME II - Materials Specifications
- ASME VIII - Pressure Vessels

Instrument Society of America

- ASME TDP-1-1980, Part 1 Instrumentation and Controls

Occupational Safety and Health Administration (OSHA), Code of Federal Regulations

- OSHA Title 29, Part 1910 Occupational Safety and Health Standard

NRC Regulatory Guides 1.60

Institute of Electrical and Electronic Engineers (IEEE) Code

- IEEE 112 - 1978 Test Procedures for Polyphase Induction Motors and Generators.

National Electrical Manufacturers Association (NEMA)

- NEMA ICS 1 - 1980 General Standards for Industrial Control and Systems

- NEMA ICS 2 - 1980 Industrial Control Devices, Controllers, and Assemblies

- NEMA ICS 6 - 1980 Enclosures for Industrial Control Systems

- NEMA MG 1 - 1978 Motors and Generators

National Fire Protection Association (NFPA) National Fire Codes
Human Engineering Design Criteria

- MIL-STD-801C

- MIL-STD-1472

Design, Construction, and Fabrication Standards

- Manual of Steel Construction, 8th edition, 1980, American Institute of Steel Construction (AISC)

- ACI 318-77 Building Code Requirement for Reinforced Concrete-American Concrete Institute

- Standards of TEMA (Tubular Exchanger Manufacturer's Association)

- ANSI A58.1 - 1982 Minimum Design Loads for Buildings and Other Structures - American National Standards Institute

- Uniform Building Code, 1979 Edition, by International Conference of Building Officials.

4.1.2 Other Publications And Documents

Newman Station Spill Prevention Containment Countermeasure (SPCC) Plan

4.1.3 Permits and Licenses Required

Construction Permit

Waste Water Discharge Permit National Pollutant Discharge Elimination System (NPDES)

Air Navigation Approval Federal Aviation Administration (FAA)

Elevator Permit/Certificate

State (Highway Connector)

Local (land use, general construction, private road construction and use)

4.1.4 Applicable Laws and Regulations

Texas Clean Air Act of 1973 (Air Control Board)

Texas Water Quality Act of 1977 (Dept. of Water Resources) t)

Federal Aviation Regulation, Part 77 (FAA)

El Paso Building Laws

El Paso Zoning Laws

Department of Transportation, State Highway Dept Reg

Texas Regulation, Control of Air Pollution from Visible Emissions of 1975

APPENDIX C

APPENDIX C

Appendix C consists of the following components:

C.1 Description of Work - Includes Direct Cost Items and Owners Costs

C.2 Capital Cost Estimate

C.3 Detail of Solar Receiver Costs

APPENDIX C.1

DESCRIPTION OF WORK
NEWMAN UNIT 1 - SOLAR REPOWERING
EL PASO ELECTRIC COMPANY

This Description of Work discusses or provides references to the individual items identified and included in the capital cost estimate, detailed in Appendix C.2. The same account numbers are used for the Description of Work and cost estimate for easy cross reference. Metric units are not shown since they were not used to derive cost information.

5100 SITE IMPROVEMENTS $1,700,000*

5100.101 Clearing and Grading

An approximate 275-acre portion of the site will be cleared of vegetative growth and graded to provide a reasonably smooth working surface and to control drainage. The natural configuration of the ground will be retained, as much as practicable, in order to minimize earthwork.

*Stem account estimated costs shown in 1983 dollars.

5100.102 Diversion Channel and Drainage - Heliostat Field

A diversion channel, approximately 5,000 ft long, will be constructed from the southwest corner of the heliostat field around the north side of the field. This channel will intercept several arroyos which enter the site area from the west. These arroyos carry significant flows after intense storms in nearby mountains. The diversion channel and ditches will have side slopes of approximately 2.5 horizontal to 1 vertical. The first 1,000 ft will be about 3 ft deep with a 5-ft bottom width. The remainder will be about 5-ft deep with a 10-ft bottom width. No special allowances for unusual design of the pipeline crossing for the diversion channel have been included pending detailed design.

Site drainage ditches will be designed to utilize the existing contours as much as practicable. The diversion channel and drainage ditches will be lined with riprap or gravel or asphalt pavement where necessary to prevent erosion.

5100.103 Crushed Rock Surface - Heliostat Field

Heavily traveled areas in the heliostat field will be provided with a crushed stone surface for added trafficability and dust prevention.

5100.104 Roads

A paved perimeter road around the heliostat field, approximately 10,200-ft long x 30-ft wide for access to service the heliostats, will be constructed. A new paved access road to the existing plant, approximately 3,200-ft long x 30-ft wide, will be provided.

5100.105 Fences and Gates

A new 8-ft high chain link fence, approximately 12,500 ft in length, will be installed around the perimeter of the heliostat field and will connect with the existing fence. Gates will be provided at roadways and for access to the El Paso Natural Gas Company and Southern Pacific Pipelines ROWs.

5100.201 Waste Disposal System

Existing liquid and solid waste disposal facilities at the Newman Station will be utilized.

5100.202 Yard Fire Protection

The existing yard fire protection will be extended and fire hydrants added as required to protect the added buildings. Fire protection for the heliostat field will be in the form of wheeled, dry, chemical units.

5100.401 Electrical Structures

New duct lines will be provided to the receiver tower, solar equipment building, and heliostat field. New structures will be tied into the station grounding system.

5100.402 Wire and Cable

Control and power cable and ground wire will be provided for operation and protection of the heliostats.

Power to the 2,400 V bus in the Solar Equipment Building will be supplied by a cable, in underground duct, connected to the auxiliary solar transformer secondary.

The 2,400 V transfer bus will provide startup and backup power for the solar auxiliaries. This bus is accessible in a junction box located on Reserve Station Service Transformer No. 1. A feeder will be run in underground duct from this junction box to the 2,400 V solar bus.

A source of 480 V, 3-phase, 60 Hz, power will be supplied to the Maintenance Building from the motor control center (MCC) in the Solar Equipment Building. This feeder will be run in underground duct.

Drawings

General Arrangement Heliostat Field	14380-EE-S1
Main One-Line Diagram Solar Repowering System	14380-EW-1A
One-Line Diagram 480 V Motor Control Centers	14380-EW-3A

5100.403 Electrical Equipment

An auxiliary solar transformer, 5,000 kVA, 13.8/2.4 kV, 3-phase, 60 Hz, will be located adjacent to Unit 1 generator step-up (GSU) transformer and tied to the GSU transformer 13,800 V bus. This transformer secondary will supply power to the solar 2,400 V bus in the Solar Equipment Building.

A 480 V feeder fed from the motor control center in the Solar Equipment Building will supply power to the uninterruptible power supply (UPS) which serves the control room, solar equipment building, and receiver tower.

Additional yard lighting will be provided by El Paso Electric Company.

5100.601 Yard Piping and Supports

Drainage from the new structures will be tied into the existing drainage system in the yard. Any fire protection water required in the new structures will be supplied from the existing yard fire protection system.

Service water return lines will be rerouted in the area of the new Solar Equipment Building.

5200 SITE FACILITIES $1,700,000

5210 Control Room Extension (Results Center)

5210.101 Substructure

The substructure for the building extension will consist of a concrete floor slab with concrete grade beams and footings to support the structural steel framing.

5210.102 Superstructure

A second floor approximately 1,650 sq ft will be added to the existing control room for solar repowering electronic equipment. All new structural and architectural materials such as steel framing, siding, roofing, and interior finishes will be selected on the basis of compatibility with the existing construction.

5210.201 Fire Protection and Facilities

The computer room and the relay room will each have a separate, self-contained Halon fire protection system. Portable fire extinguishers will be provided for the other areas of the control room.

Heating, ventilating, and air conditioning will be provided in all areas of the control room extension. The men and ladies rooms will have separate exhaust systems.

5210.402 Wire and Cable

A separate 480 V, 3-phase, 60 Hz, power feeder, taken from the existing Unit 1 station service load center, will supply power for the electrical loads in the control room extension.

5210.403 Electrical Equipment

One lighting transformer and one distribution panel will be provided for the 120 V ac loads. An uninterruptible power supply (UPS), including a 125 V dc battery, battery charger, inverter, and UPS bypass transformer will be provided to power the computer complex and instrumentation. This battery will be sized to power the UPS for 15 minutes upon loss of ac power. Emergency lighting will consist of an emergency fluorescent battery pack in selected normal fluorescent lighting fixtures.

The 125 V dc battery for the UPS will be caged in a metal mesh enclosure on the Unit 1 turbine building mezzanine floor.

5210.601 Piping and Supports

The existing plumbing will be extended to provide drinking water and water for new sanitary facilities (men's and ladies' rooms). Sanitary drainage from the new sanitary facility will be added and tied into the existing yard piping. New roof drains will collect and transfer the rain water to the existing yard storm drainage piping.

5220 Solar Equipment Building

5220.101 Substructure

The substructure for the building will consist of a concrete floor slab with concrete grade beams and footings to support the structural steel framing and mechanical equipment.

5220.102 Superstructure

The Solar Equipment Building will be a two-level steel framed building with insulated metal siding. The ground level will be approximately 3,125 sq ft and the second level will be approximately 1,743 sq ft.

5220.201 Fire Protection and Facilities

Fire protection will be provided by the installation of interior hose stations fed from the existing yard loop. Ventilation and cooling will be provided by evaporative coolers and exhaust fans. Heating will be provided by gas or electric unit heaters. Floor and equipment drainage piping will also be provided.

5220.402 Wire and Cable

Control wire and cable will be provided for control and instrumentation associated with the various loads and power sources. Power cable will be provided for connection of the pump and MOV motors to the 2,400 V and 480 V buses.

<u>Drawings</u>

Main One-line Diagram Solar Repowering System	14380-EW-1A
One-Line Diagram 480 V Motor Control Centers	14380-EW-3A

5220.403 Electrical Equipment

The solar 2,400 V switchgear; solar secondary unit substation comprised of one 750 kVA, 2,400/480 V, 3-phase, 60 Hz transformer and one 480 V bus; backup 750 kVA, 2,400/480 V 3-phase, 60 Hz transformer; and one 480 V motor control center will be housed in the Solar Equipment Building. These will supply power to the heliostat field power centers, solar feed and recirculation pumps, service water pumps, fire pump, motor-operated valves, HVAC system, uninterruptible power system, lighting, and other miscellaneous electrical accessories in the Solar Equipment Building, and all loads in the receiver and tower. The 2,400 V bus will consist of Bus Sections A and B with a bus tie breaker inbetween. The backup 750 kVA transformer will be connected to solar 2,400 V Bus A. Station solar Bus A will be connected to the station 2,400 V transfer bus through a 2,400 V ACB and disconnect switch. The connection to the transfer bus will be made in a junction box on Unit 1 Reserve Station Service Transformer.

A 240 kW, 0.8 p.f. (300 kVA), 2,400 V, 3-phase, 60 Hz emergency diesel engine generator (housed in an outdoor enclosure) will supply power to the heliostats upon loss of system and station power.

<u>Drawings</u>

Main One-Line Diagram Solar Repower System	14380-EW-1A
One-Line Diagram 480 V Motor Control Centers	14380-EW-3A

5220.601 Piping and Supports

Steel framing will be provided above the electrical equipment area for pipe support.

<u>Drawings</u>

General Arrangement-Solar Equipment Building, Solar Reheat Exchanger	Plan EM-232A-SR-1 Sect. EM-232B-SR-1

5230 Maintenance Building Extension

5230.101 Substructure

The substructure for the building extension will consist of a concrete floor slab with concrete grade beams and footings to support the structural steel framing.

5230.102 Superstructure

The existing maintenance building will be extended to provide space for assembly and testing of heliostats prior to field installation. The new maintenance area, 40 ft x 60 ft, will be enclosed by a steel framed building with insulated metal siding.

5230.201 Fire Protection and Facilities

New interior hose stations will be provided. These stations will be fed from the existing yard fire protection loop.

Ventilation and cooling will be provided by evaporative coolers and exhaust fans. Heating will be provided by gas or electric unit heaters. Floor and equipment drainage piping will also be provided.

5230.402 Wire and Cable

Wire and cable will be provided for lighting and the distribution circuits to miscellaneous 120 V, 1-phase loads.

5230.403 Electrical Equipment

One 480 V, 3-phase, distribution panel and lighting transformer with one 120 V, 1-phase, distribution panel will be provided for electrical loads in the building, including the HVAC system lighting, and other miscellaneous loads.

Drawings

One-Line Diagram 480 V Motor Control Centers	14380-EW-3A

5230.601 Piping and Supports

Covered in account 5230.201.

5300 COLLECTOR SUBSYSTEM $56,600,000

5300.101 Heliostat Foundations

Foundations for heliostats will consist of a cast-in-place reinforced concrete pier installed in an augered hole approximately 2 ft-6 in. in dia, using selected depths of 15 and 20 ft.

Sketches

Heliostat Foundation No. 14380-SSK-1A

5300.201 Heliostat Assemblies

The collector field will consist of 1,875 heliostat assemblies which will include modules, structural support, drive units, control sensors, pedestal and mounting interface to foundations, and heliostat cabling and termination boxes.

5300.301 Heliostat Controls

Heliostat controls consist of a heliostat field controller, redundant heliostat array controller, heliostat controllers, and peripherals. Heliostat controls are provided by the heliostat vendor.

5300.302 Beam Characterization System

The beam characterization system will be provided by the heliostat vendor and includes the beam characterization computer, specification for the beam targets, television cameras, and peripherals. Three BCS targets will be provided.

5300.402 Heliostat Field Wiring

The heliostat field and the three beam characterization installations will utilize armored direct burial power and control cable or cables in PVC conduit. The cable will be buried in a trench system designed for optimum use of the cable. A No. 4/0 bare copper ground cable will also be run in the trench to each heliostat and power supply transformer. Four 200-ft deep uncased grounding wells will be driven in the heliostat field. No. 4/0 bare copper cable connected to the heliostat field ground grid will be dropped to the bottom of each well.

Drawings

General Arrg't Heliostat Field 14380-EE-S1

5300.403 Electrical Equipment

Fifteen 75 kVA, 2,400/208/120 V, 3-phase, 60 Hz, transformers with a low voltage distribution cabinet will be located throughout the heliostat field for powering the heliostats and heliostat field controllers.

5400 RECEIVER SYSTEM $22,700,000

5400.101 Tower Foundation

The foundation for the receiver tower will consist of a circular reinforced concrete mat 85 ft in dia. Excavation for the foundation will include removal of unsuitable soils and replacement with compacted backfill to a depth of approximately 25 ft.

Drawings

Receiver Tower and Foundation	EC-601A-SR EC-601B-SR

5400.102 Tower Superstructure including Platforms, Stairs, Instrument and Control Equipment Rooms.

The solar central receiver will be supported on a reinforced concretre tower 447 ft high. The tower will support feedwater, steam and auxiliary piping, and associated controls with access for maintenance and repairs provided by internal stairs, ladders, platforms, and walkways. Two equipment rooms will be located near the top of the tower to house receiver instrumentation and control equipment.

Drawings

Receiver Tower and Foundation	EC-601A-SR EC-601B-SR

5400.103 Elevator

A 2,700 lb capacity rack and pinion type electric elevator will be furnished. The elevator will provide access to the equipment rooms, receiver, and pipe support platforms. The elevator speed will be 105 fpm.

5400.201 Receiver

The solar receiver will supply main steam at approximately 310,000 lb/hr at 1,000°F and 1,450 psig to the existing Newman Unit 1 Turbine-Generator. The receiver absorber surface will be made up of 18 panels, supported by structural steel, consisting of economizers, evaporators, and multiple stages of superheaters. Details of receiver cost scope are presented in Appendix C.3.

5400.202 Heat Exchanger (Reheater)

The heat exchanger (reheater) is located near the base of the tower. It receives reheating steam from the primary superheater of the solar receiver. Cold reheating steam is returned to the solar receiver. The reheat heat exchanger will be a single pass shell and tube design, approximately 4 ft in dia by 50 ft long. The shell side design pressure and temperature are 500 psig and 1,005°F, respectively. The tube side design pressure and temperature are 2,250 psig and 1,045°F, using type 304 SS tubes. The exchanger will contain 13,125 ft^2 of heating surface.

5400.203 Recirculation Drain Tank, Pump, and Driver

The recirculation drain tank, located at the base of the receiver tower, will provide storage capability for the receiver water inventory for maintenance and for overnight storage when freeze-up is likely. The tank will be designed to 50 psig and 300°F. Capacity will be 8,000 gal. The tank will be fabricated in accordance with ASME Section VIII. A return pump will be provided to return the water in the drain tank to the receiver before daily plant operation begins if water chemistry permits. The pump would be a horizontal centrifugal pump with a design point of 200 gpm and 800 ft tdh. The pump driver will be a 50 hp, 480 V odp electric motor.

5400.204 Fire Protection and Facilities

Fire protection will be provided for the tower equipment room by a high pressure carbon dioxide system with automatic detection and activation. Each control equipment room will have a separate, self-contained fire protection system. The upper equipment room will be cooled by a single air conditioning unit. The lower equipment room will be cooled by a vent fan. Each area will be heated by an electric unit heater. A floor and equipment drainage system will be provided to serve the equipment at the top of the tower.

5400.205 Boiler Blowoff Tank

The boiler blowoff tank, located near the base of the receiver tower, will provide storage capability of emergency drain from the receiver steam drum during cloud transients. The tank will be designed to 50 psig and 655°F. Capacity will be 4,000 gallons.

5400.301 Receiver Instrumentation and Controls (Local)

The receiver controls are a microprocessor-based distributed system provided by the receiver manufacturer and interface with other plant controls via a "data highway" brought to the upper equipment room.

5400.402 Wire and Cable

The output signals from the solar receiver control system provided by the receiver manufacturer will be routed to the control interface in the upper equipment control room. A new motor control center (MCC) and one MCC provided by the receiver manufacturer, located in the same tower equipment room, will be powered by a 480 V feeder from the load center in the solar equipment building.

Wire and cable will be provided for tower aircraft obstruction lighting, tower lightning protection, tower grounding, internal tower lighting below the receiver level, tower elevator and hoist, and tower equipment rooms, vent and HVAC systems. Lighting in the receiver area and all wire and cable in the upper equipment room directly below the receiver, except as listed above, will be provided by the receiver manufacturer.

<u>Drawings</u>

One-Line Diagram 480 V Motor Control Centers	14380-EW-3A

5400.403 Electrical Equipment

The following electrical equipment will be provided and installed in the tower:

- One 480 V, 3-phase, 60 Hz MCC
- Aircraft Obstruction Lighting
- Tower Lightning Protection and Grounding
- Internal Tower Lighting below the receiver area

The following electrical equipment will be provided and installed in the solar tower by the receiver manufacturer:

- One 480 V, 3-phase, 60 Hz MCC
- All receiver controls in the equipment room immediately below the solar boiler area
- All equipment including lighting in the receiver area

Drawings

One-Line Diagram 480V Motor Control Centers	14380-EW-3A

5500 CONTROL SYSTEM

5510 Solar System

5510.101 Miscellaneous Foundations

Concrete pad foundations will be provided for heliostat field controller. Power supply boxes to be provided by the heliostat manufacturer.

5510.301 Master Control System Including Computer and Control Board (Solar and Fossil)

The master control system includes all hardware and software required to integrate the operation of the solar collector, solar receiver, fossil boiler control and burner management subsystems. The system includes sequence recording, data logging annunciation, sequential control hardware and software, algorithms software and operator/system interface console. Also included are input/output cabinets for field interfaces, trend recorders, printers, and engineers programming and analysis console. Dedicated controls for safety oriented functions are included on the operator/system interface main control board console.

5510.302 Miscellaneous Instruments and Controls

Miscellaneous instruments and controls includes field mounted transmitters, process sensing elements, indicators, switches and local controllers associated with the solar receiver and its support subsystems.

5520 Existing Fossil Control System

5520.301 Modifications to Existing Fossil Unit Control System and Miscellaneous Instruments and Controls

Existing fossil unit modifications include a new burner management system, new boiler control system, and modified turbine-generator control system.

Instrumentation and control equipment located in the field is provided to monitor and control equipment from the MCS. Included are transmitters, switches, analyzers, valves, etc.

5800 <u>ELECTRICAL POWER GENERATION SYSTEM</u> 10,400,000

5800.101 Miscellaneous Foundations

Foundations will be provided for additional small pumps such as feed pumps, seal water pumps, and high pressure auxiliary service water pumps. Foundation dimensions will be 2 ft x 4 ft x 12 in.

5800.102 Pipe Support Structures

Steel structures will be provided to support pipes from the solar equipment building and the receiver tower.

5800.201 Solar Feedwater Pumps and Drivers

Two half-size, six-stage horizontal centrifugal motor-driven feedwater pumps, rated at 450 gpm and 6,300 ft tdh, will be provided. Each pump will be driven by an 1,250 hp, 2,400 V, odp electric motor.

5800.202 Solar Feedwater Booster Pumps Drivers

Two full-size horizontal, end suction, tap discharge centrifugal, single-stage motor-driven solar feedwater booster pumps, rated at 900 gpm and 100 ft tdh, will be provided. Each pump will be driven by a 40 hp, 480 V, odp electric motor.

5800.203 Solar Feedwater Heaters

Two new shell and tube horizontal heat exchangers, "A" and "B", will be provided to heat the solar feedwater. Both the "A" and "B" heaters will be approximately 2.5 ft in dia x 31 ft long with total surface areas of 1,800 sq ft each. The "A" heater shell side design pressure and temperature will be

510 psig and 770°F while the tube side will be designed for 3,000 psig and 510°F. The "B" heater shell side will have a design pressure and temperature of 190 psig and 850°F while the tube side will be designed to 3,000 psig and 420°F.

5800.204 Condensate Polishing System

The polishing system shall be a powdered resin type of unit. The system shall consist of one equipment skid measuring 8 ft x 20 ft x 15 ft high, a NEMA ICS Type 12 control panel measuring 4 ft-6 in. x 10 ft-6 in. x 7 ft-6 in. high, and a freestanding sample sink measuring 48 in. x 10 in.

The equipment skid shall contain the following major components:

- Three - 50 percent unlined carbon steel polishing filter vessels constructed in accordance with the VIII ASME code.
- One - 100 percent three-coat epoxy lined carbon steel precoat tank (atmospheric).
- Two - 100 percent capacity precoat pumps with stainless steel wetted parts construction.
- Two - 100 percent capacity backwash pumps with stainless steel wetted parts construction.
- One - stainless steel precoat tank agitation.
- Internal (skid boundary) interconnecting piping and instrumentation.
- Resin strainers utilizing a carbon steel body and a 24 x 110 mesh stainless steel basket.

5800.205 Chemical Feed Equipment

With the exception of a new coordinated phosphate feed system (skid mounted), chemical control using all volatile treatment (AVT) may be accomplished with existing chemical feed equipment.

A new coordinated phosphate feed system shall be provided for protection of the receiver in the event of a condensate polishing system upset. The system consists of a 316L stainless steel mixing tank (150 gal capacity), mixer, one metering pump and associated controls, valves, and piping, all mounted on a skid. The approximate dimensions of the skid are 7 ft x 4 ft x 6 ft high. The discharge line from the skid shall feed directly into the receiver drum.

5800.206 High Pressure Auxiliary Service Water Pumps and Drivers

Two full-size single stage centrifugal motor-driven pumps rated at 30 gpm, 430 ft tdh, shall be provided. Each pump will be driven by a 7.5 hp, 480 V, TEFC motor.

5800.207 High Pressure Auxiliary Service Water Tank

Provided by receiver manufacturer.

5800.208 HVAC Equipment

Covered in accounts 5210.201, 5220.201, and 5230.201.

5800.209 Relocated Equipment

No allowance included

5800.301 New Control System for Existing Turbine-Generator

The existing turbine-generator mechanical hydraulic control system will be modified to include a throttle pressure control which will interface with the MCS. Additional turbine monitoring instrumentation will be added to provide closed loop control for an automatic turbine startup.

5800.402 Wire and Cable

The control wiring for the fossil boiler and turbine-generator modifications will be routed to the addition to the control room.

5800.403 Electrical Equipment

Supplied by others, see controls.

5800.404 Heat Tracing

Electric heat tracing will be provided for freeze protection of piping as described below:

Inside Receiver Tower

Feedwater Line - Top to base of tower, Boiler Blowdown Vent and Drain Lines - Top to base of tower, Main and High Pressure Steam Drain Lines - Top to base of tower, Main Stream Valves - Top of Tower

Outside on Open Pipe Rack

Feedwater Line

Main and High Pressure Steam Drain Lines

Cold and Hot Reheat Motor Operator and Air Operated Valves

Hot Reheat Steam Drain Lines

The equipment/material will consist of distribution transformers, centralized power distribution controllers, sensors (RTDs), heat tracing cable (MI), and supporting hardware. Isometric drawings will be provided as required.

The power source for heat tracing inside the tower will be from the MCC in the lower equipment room beneath the boiler. The power source for heat tracing outside will be from the MCC in the Solar Equipment Building.

5800.405 Relocated Electrical Equipment, Wire and Cable, and Cable Trays

No allowance included

5800.406 Communications

The communications system will be an extension to the present Gai Tronics voice-paging system in the plant. A handset station with speakers will be provided in the following locations:

Solar Equipment Building
Tower Upper Equipment Room
Base of Tower
Maintenance Building Extension

5800.601 Piping and Supports

Piping shall be provided for each of the following systems:

A. Solar Feedwater

Drawings

Solar Feedwater Booster Piping - Existing Turbine Building	Plan EP-660A-SR-1 Sect. EP-660B-SR-1
Boiler Feed Suction Piping - Existing Turbine Building	Plan and Sect. EP-605A-SR-1

P&IDs

Feedwater System	14380-PID-6-1A-SR 14380-PID-6-1B-SR 14380-PID-6-1C-SR

B. New 1st and 2nd Point Extraction Steam

Drawings

2nd Point Extraction - Steam System	Plan EP-607-A-SR-1

P&IDs

Extraction Steam System	14380-PID-3-4-SR-1

C. Attemperation piping will be as shown on 14380-PID-6-1-SR

D. Solar Steam

A chromium coating will be applied to the steam side surface of the main, high pressure and hot reheat steam piping to alleviate scale exfoliation. The solar steam systems will include the piping for the following systems:

High Pressure Steam

Drawings

Area Piping - Existing Turbine Building Tower	Plan EP-659A-SR-1 Plan EP-659B-SR-1 Sect. EP-659C-SR-1

P&IDs

Main and High Pressure Steam Systems	14380-PID-3-1A-SR
Steam Systems	14380-PID-3-1B-SR

Main Steam

Drawings

Main Steam Piping -	Plan EP-601A-SR-1
Existing Turbine Building	Sect. EP-601B-SR-1

P&IDs

Main and High Pressure Steam Systems	14380-PID-3-1A-SR
	14380-PID-3-1B-SR

Cold Reheat Steam

Drawings

Low Temp. Reheat Steam Piping	Plan EP-603A-SR-1
Existing Turbine Building	Sect. EP-603B-SR-1

P&IDs

Cold and Hot Reheat System 14380-PID-3-2-SR

Hot Reheat Steam

Drawings

High Temp. Reheat Steam Piping -	Plan EP-602A-SR-1
Existing Turbine Building	Sect. EP-602B-SR-1

All the steam piping will be provided with vents and drain piping.

Safety relief valves vent piping will be provided for safety valves on the solar steam lines.

P&IDs

Solar Heater Drain, Vent Relief System	14380-PID-6-6-SR

E. Receiver Blowdown, Vents, and Drains System piping is shown on 14380-PID-11-3-SR.

F. Condensate Polishing System is shown on Sketch 14380-WT-1.

The turbine plant sampling system will include water quality analyzers, pressure reducers, a sample cooker, main sample conditioning panel, and a recording and monitoring panel.

5800.602 Valves and Specialties

All necessary gear operated and manual isolation valves, check valves, motor-operated stop valves, feedwater regulator valves, nonreturn valves, bypass valves, air operated and solenoid control valves, safety valves, vent and drain valves are provided.

Specialties such as temporary strainers, traps, restricting orifices, expansion joints, blowoff pots, orifices, desuperheaters, and other miscellaneous pipe fittings for pipe and instruments, etc., are included.

5800.603 Insulation

Thermal Insulation (calcium silicate) will be used for equipment and piping whose operating temperature is above 150°F for energy conservation and safety.

5800.604 Relocated Piping and Supports

No allowance included.

5900.050 OWNERS COSTS (Cost shown in 1987 dollars)

A. Land Requirements

A total of 418 acres will be required for the addition of the solar facilities. This includes land for the heliostat field, relocated transmission line ROWs, relocated employee park and the relocated highway. The estimated cost of this land is $1,066,000.

B. Relocation of the State Highway

The estimated cost for relocating Farm-to-Market Road 2529 which borders the existing Newman Station at its northern boundary is $895,000. This estimate is based on relocating the highway to the south as shown on the drawings in Appendix I.

C. Perimeter Lighting

An estimated 28 lighting fixtures spaced every 400 ft around the perimeter of the heliostat field will be installed for security and inspection purposes. The cost of this activity is estimated at $134,000.

D. Relocation of Transmission Lines

Five transmission lines will have to be relocated as a result of solar repowering Newman Unit 1. The cost to perform this relocation is estimated at $551,000. The cost of additional ROWs is included in Subsection A.

E. Distribution Facilities Relocation

The cost of this activity is $130,000. This work includes rerouting existing distribution lines and relocating transformers servicing a pump station and a landfill, relocating existing present overhead lighting in the collector field area and providing underground power to water wells located north of the fossil plant.

F. Environmental Studies

An allowance of $125,000 is included to cover the cost of environmental studies necessary for the licensing of the solar plant and for the relocation of the state highway.

G. Relocation of Irrigation System

Existing wastewater at the Newman Station is used for irrigation of land just north of the plant. The location of the collector field will necessitate relocating the irrigation system. The cost of this activity is estimated at $131,000.

H. Relocation of Employee Park

An allowance of $113,000 is included to cover the cost of rebuilding the existing employee park located north of the plant. The land requirements for the park are included in Subsection A.

I. Public Relations

An allowance of $101,000 is included to cover the cost of the Public Relations' activities associated with the dissemination of

TABLE C.1-1

OWNER'S COSTS FOR EPE

Description	1983 Dollars
Site Land Requirement	1,028,000
Relocating State Highway	852,000
Relocation of Transmission Lines	524,000
Perimeter Lighting	125,000
Relocation of Distribution Facilities	123,000
Environmental Studies	122,000
Relocation of Irrigation System	121,000
Relocating Employee Park	104,000
Public Relations Activities	100,000
Total (1983 dollars)	$3,099,000
Escalation	147,000
Total Owner's Cost in First Quarter 1987 dollars	3,246,000

TABLE C.2-1
CAPITAL COST ESTIMATE

Account	Description	MATERIAL COST	LABOR COST	TOTAL COST
5100	SITE IMPROVEMENTS			
5100.101	Clearing and Grading	0	378,955	378,955
5100.102	Diversion Channel and Drainage - heliostat field	138,000	289,717	427,717
5100.103	Crushed Rock Surface - heliostat field	16,300	10,954	27,254
5100.104	Roads	200,800	137,200	338,000
5100.105	Fences and Gates	48,750	26,250	75,000
5100.201	Waste Disposal System - Existing Facilities	0	0	0
5100.202	Yard Fire Protection	29,600	15,012	44,612
5100.401	Electrical Structure	35,300	81,235	116,535
5100.402	Wire and Cable	63,944	84,870	148,814
5100.403	Electrical Equipment	61,600	17,290	78,890
5100.601	Yard Piping and Supports	5,000	15,012	20,012
TOTAL 5100	SITE IMPROVEMENT	599,294	1,056,495	1,655,789
5200	SITE FACILITIES			
5210	Control Room Extension			
5210.101	Substructure	0	0	0
5210.102	Superstructure	63,756	77,220	140,976
5210.201	Fire Protection	36,760	54,324	91,084
5210.402	Wire and Cable	4,298	28,203	32,501
5210.403	Electrical Equipment	83,400	13,580	96,980
5210.601	Piping and Supports (Incl. in A/C 5210.201)	0	0	0
5220	Solar Equipment Building			
5220.101	Substructure (Incl. in A/C 5220.102)	0	0	0

TABLE C.2-1
CAPITAL COST ESTIMATE (CONT)

Account	Description	MATERIAL COST	LABOR COST	TOTAL COST
5220.102	Superstructure	147,622	164,109	311,731
5220.201	Fire Protection	10,040	13,824	23,864
5220.402	Wire and Cable	9,499	63,101	72,600
5220.403	Electrical Equipment	486,710	87,782	574,492
5220.601	Piping and Supports (Incl. in A/C 5220.201)	0	0	0
5230	Maintenance Building Extension			
5230.101	Substructure (Incl. in A/C 5230.102)	0	0	0
5230.102	Superstructure	129,600	147,888	277,488
5230.201	Fire Protection	12,930	29,304	42,234
5230.402	Wire and Cable	3,690	22,395	26,085
5230.403	Electrical Equipment	8,732	3,780	12,512
5230.601	Piping and Supports (Incl. in A/C 5230.201)	0	0	0
TOTAL 5200	SITE FACILITIES	997,037	705,510	1,702,547
5300	COLLECTOR SUBSYSTEM			
5300.101	Heliostat Foundations	855,575	1,461,360	2,316,935
5300.201	Heliostat Assemblies including drivers	47,000,000	3,000,000	50,000,000
5300.301	Heliostat Controls	300	10,500	10,800
5300.302	Beam Characterization System	197,889	108,092	305,981
5300.402	Heliostat Field Wiring (Power and Control)	1,740,228	2,041,957	3,782,185
5300.403	Electrical Equipment	133,500	63,525	197,025
TOTAL 5300	COLLECTOR SUBSYSTEM	49,927,492	6,685,434	56,612,926
5400	RECEIVER SYSTEM			

TABEL C.2-1
CAPITAL COST ESTIMATE (CONT)

Account	Description	MATERIAL COST	LABOR COST	TOTAL COST
5400.101	Tower Foundation	126,859	462,646	589,505
5400.102	Tower Superstructure (including platforms, stairs, instrument and Control Equipment Room)	1,013,120	1,341,023	2,354,143
5400.103	Elevator	190,532	36,015	226,547
5400.201	Receiver	11,868,000	6,734,000	18,602,000
5400.202	Reheat Heat Exchanger	350,000	23,800	373,800
5400.203	Drain Tank and Return Pump and Driver	28,000	5,950	33,950
5400.204	Fire Protection	52,100	75,960	128,060
5400.205	Boiler Blowoff Tank	14,000	1,750	15,750
5400.301	Receiver Instrumentation and Controls (Local) (Included in A/C 5400.201)	0	0	0
5400.402	Wire and Cable	30,264	153,817	184,081
5400.403	Electrical Equipment	48,650	21,560	70,210
5400.404	Electric Heat Tracing	65,862	55,634	121,496
5400.601	Piping and Supports (Incl. in 5800.601)	0	0	0
5400.602	Valve and Specialties (Incl. in 5800.602)	0	0	0
5400.603	Insulation (Incl. in 5800.603)	0	0	0
TOTAL 5400	RECEIVER SYSTEM	13,787,387	8,912,155	22,699,542
5500	CONTROL SYSTEM			
5510	Solar System			
5510.101	Miscellaneous Foundations	7,075	13,532	20,607
5510.301	Master Control System (Solar and Fossil) including computer and control board	1,348,550	143,500	1,492,050
5510.302	Miscellaneous Instruments and Controls	63,258	59,838	123,096
5520	Existing Fossil Control System			

TABLE C.2-1
CAPITAL COST ESTIMATE (CONT)

Account	Description	MATERIAL COST	LABOR COST	TOTAL COST
5520.301	Modifications to Existing Fossil Unit Control Ststem and Misc. Instruments and Controls	1,320	39,200	40,520
TOTAL 5500	CONTROL SYSTEM	1,420,203	256,070	1,676,273
5800	ELECTRICAL POWER GENERATION SYSTEM			
5800.101	Miscellaneous Foundations	527	1,880	2,407
5800.102	Pipe Support Structure	44,340	36,967	81,307
5800.201	Solar Feedwater Pumps and Drivers	396,000	23,100	419,100
5800.202	Solar Feedwater Booster Pumps and Drivers	34,000	4,900	38,900
5800.203	Solar Feedwater Heaters	180,000	11,900	191,900
5800.204	Condensate Polishing System	260,000	10,500	270,500
5800.205	Chemical Feed Equipment	123,000	43,750	166,750
5800.206	High Prssure Auxiliary Service Water Pumps and Drivers	6,000	3,150	9,150
5800.207	High Pressure Auxiliary Service Water Tank (Included in A/C 5400.201)	0	0	0
5800.208	HVAC Equipment (Incl. in Bldg. Accts.)	0	0	0
5800.209	Relocated Equipment (No Allow. Included)	0	0	0
5800.301	New Control System for Existing Turbine Generator	25,000	2,800	27,800
5800.402	Wire and Cable	1,402	15,981	17,383
5800.403	Electrical Equipment (None Required)	0	0	0
5800.405	Relocated Electrical Equipment, Wire & Cable and Cable Trays (No Allow. Included)	0	0	0
5800.406	Communication System	4,666	12,756	17,422
5800.601	Piping and Supports	3,577,211	3,741,837	7,319,048
5800.602	Valves and Specialties	774,361	168,879	943,240
5800.603	Insulation	444,890	448,427	893,317

TABLE C.2-1
CAPITAL COST ESTIMATE (CONT)

Account	Description	MATERIAL COST	LABOR COST	TOTAL COST
5800.604	Relocated Piping and Supports (No Allow Incl)	0	0	0
TOTAL 5800	ELECTRICAL POWER GENERATION SYSTEM	5,871,397	4,526,827	10,398,224
TOTAL	DIRECT COSTS	72,602,810	22,142,491	94,745,301
5900	OTHER COSTS			
5900.010	Distributable Costs	200,000	1,341,048	1,541,048
TOTAL	CONSTRUCTION COSTS	72,802,810	23,483,539	96,286,349
5900.020	Indirect Costs	1,422,000	6,895,662	8,317,662
TOTAL	CONSTRUCTION & INDIRECTS	74,224,810	30,379,201	104,604,011
5900.030	Allowance for Indeterminates	1,571,000	3,096,274	4,667,274
TOTAL	ESTIMATE - PRESENT DAY, 01 SEPT 83	75,795,810	33,475,475	109,271,285
5900.040	Escalation	9,757,000	3,883,000	13,640,000
TOTAL	EST. EXCL. OWNERS COSTS, AFUDC & SPARE PARTS	85,552,810	37,358,475	122,911,285
5900.050	Owners Costs	3,246,000	0	3,246,000
5900.060	AFUDC	17,158,000	0	17,158,000
TOTAL	ESTIMATE	105,956,810	37,358,475	143,315,285

C.3. RECEIVER COST ESTIMATE DETAIL

This section describes the costs for the receiver subsystem. The scope of work includes engineering, materials, fabrication, erection, checkout and performance evaluation of all the equipment located above the top of the tower. The major components are the receiver, tanks, piping, pump, valves, insulation, instruments, controls, structural steel, enclosure and all auxiliary equipment.

The receiver cost used for the the capital cost estimate is $18,200,000* in 1983 dollars. Table C.3-1 identifies a complete breakdown per the significant items that make up the receiver subsystem cost.

*For the commercially binding estimate required by EPE, a cost of $14,570,000 was provided with a cost tolerance set from +25 percent to-10 percent of this value, resulting in a range from $18,200,000 to $13,100,000.

The approach used to prepare the receiver cost estimates are typical of the methods used to establish a commercially binding quote for a boiler being supplied to the utility industry. Some general information pertaining to the procedures used to obtain the cost estimates are as follows:

- Material and equipment costs include freight and insurance, and are FOB the job site.
- Spare panels and parts are included.
- Competitive bid approach has not been used due to limitation in time and money. However, the quotes have been obtained from organizations selected as being viable suppliers on past utility type boiler contracts.
- A contingency factor has been provided to cover areas where insufficient design information is available, or where the cost database is minimal.
- The methods of cost estimating were vendor quotes, "inhouse" estimating, ratioing based on prior information from other contracts and some judgment applied where impact on cost was considered negligible. Construction costs include all those services normally furnished in the construction of a boiler for the utility industry. Typical items covered are:

- Temporary Housing
- Erection Equipment
- Site Supervision
- Craft Management
- Material Procurement
- Site Supervision Costs
- Clean Up

- Escalation, AFUDC, transaction privilege taxes, etc, have not been included since it is included when the overall plant estimate is prepared.

The impact of having to produce a commercially binding quote has resulted in a sizeable additional uncertainty factor to be considered on top of the $14,570,000 base estimate. The upper limit of this range from +25 percent to -10 percent (or $18,200,000 to $13,100,000) exceeds those used as previous estimates for this and other solar receiver subsystem studies. The implied meaning is that although the estimates are sound and legitimate, the unknowns such as incomplete workscope, time of performance not being well defined, and lack of a positive data point for costs of a solar water/steam receiver, necessitate that one more engineering phase and resulting cost estimate must be provided before a commercial venture of this size can be undertaken.

The final phase of engineering would produce a set of fabrication drawings, erection drawings, hardware specifications and a detailed engineering workscope for the receiver subsystem and a formal cost estimate which would reduce this large uncertainty. It is recommended that for this study, the cost figures given in Table 6.3-1 be used without the uncertainty factor to provide a consistent rationale between this and other solar repowering studies.

It is noted that receiver fabrication, erection, startup, and checkout is the expected critical path of the construction network.

TABLE C.3-1

SOLAR RECEIVER
CAPITAL COST DETAIL

Item	Material	Labor	Total	Remarks
Panel Assemblies	$1,634,600	$1,796,000	$ 3,430,600	(1)
Piping	791,700	443,700	1,235,400	(1)
Steam Drum	61,900	133,300	195,200	(1)
Tooling	509,500		509,500	(1)
Pump	493,600		493,600	(2)
Valves	405,700		405,700	(2)
Instruments/ Controls	946,600		946,600	(1)
Structural Steel/Stairs	448,300		448,300	(2)
Supports, (Piping, Panels)	78,500		78,500	(3)
Water Storage Tank	13,500		13,500	(2)
Engineering		1,690,500	1,690,500	(1)
Erection	1,953,500	2,885,000	4,838,500	(2)
Startup Cost		284,000	284,000	(1)
Subtotal	$7,337,400	$7,232,500	$14,570,000*	
Spare Parts			311,000	
Factor for Commercial Price			3,721,000	
Total			$18,602,000	

* Rounded to nearest thousand dollars

NOTES:

1. By Estimating Department
2. Outside vendor quote
3. Engineering estimate using ratioing methods and other approximating techniques

APPENDIX D

APPENDIX D

RELIABILITY ANALYSIS DETAILED RESULTS

TABLE OF CONTENTS

D.1 Solar Feedwater System

FTSH	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-A	SFWS0011	FEEDWATER SYSTEM PIPING COMMON MODE FAILURE	ANNUNCIATED IN CONTROL ROOM	FAILURE OF SOLAR FEEDWATER SYSTEM PID-1(A-C)-SR	CATEGORY A-B-C
SOLAR-B	SFWS0021	FAILURE OF HEATER FLOW RECEIVER CONTROL SYSTEM	ANNUNCIATED IN CONTROL ROOM	FAILURE OF SOLAR FEEDWATER SYSTEM PID-1(A-C)-SR	CATEGORY C SWITCH TO LIC 31
SOLAR-D	SFWS0032	FDWTR BOOSTR P5A FAILS TO OPERATE LEAKAGE PID-6-1A-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF BOOSTER PUMP LINE A PID-6-1A-SR	CATEGORY C 2-100% CAPACITY PUMPS DUAL FAILURE REQUIRED
SOLAR-D	SFWS0046	PI 56A FAILS TO OPERATE FALSE OUTPUT PID-6-1A-SR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE A PID-6-1A-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-D	SFWS0056	FDWTR BOOSTR PMP LINE A COMMON MODE OPERATOR ERROR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE A PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-E	SFWS0062	FDWTR BOOSTR P5B FAILS TO OPERATE LEAKAGE PID-6-1A-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF BOOSTER PUMP LINE B PID-6-1A-SR	CATEGORY C 2-100% CAPACITY PUMPS DUAL FAILURE REQUIRED
SOLAR-E	SFWS0076	PI 56B FAILS TO OPERATE FALSE OUTPUT PID-6-1A-SR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE B PID-6-1A-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-E	SFWS0086	FDWTR BOOSTR PUMP LINE B COMMON MODE OPERATOR ERROR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE B PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-G	SFWS0092	FE 20A FAILS TO OPERATE FALSE OUTPUT PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-G	SFWS0101	FDWTR PUMP LINE A COMMON MODE OPERATOR ERROR	ANNUNCIATED IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS SOLAR FEEDWATER SYSTEM FMEA-SOLARFWS SH 1

D.1 Solar Feedwater System (Cont)

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-F	SFWS0112	FE 20B-FT-FIC FAILS TO OPERATE FALSE OUTPUT PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-F	SFWS0121	FDWTR PUMP LINE B COMMON MODE OPERATOR ERROR	ANNUNCIATED IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-C	SFWS0136	BLOCK LV 31 FAILS TO REMAIN OPEN OR LEAKS PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF MAIN LINE FDWTR CONTROL PID-6-1B-SR	CATEGORY B STARTUP-BYPASS LINE AVAILABLE
SOLAR-C	SFWS0141	FDWTR CONTROL MAIN LINE COMMON MODE OPERATOR ERROR	ANNUNCIATED IN CONTROL ROOM	LOSS OF MAIN LINE FDWTR CONTROL PID-6-1B-SR	CATEGORY B STARTUP-BYPASS LINE AVAILABLE
SOLAR-H	SFWS0156	BLOCK LV 32 FAILS TO REMAIN OPEN OR LEAKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF STRTUP-BYPSS FDWTR CONTROL PID-6-1B-SR	CATEGORY C LINE REQUIRED FOR STARTUP-BYPASS ONLY
SOLAR-H	SFWS0161	FDWTR CONTROL STRTUP-BYPSS LN COMMON MODE OPERATOR ERROR	ANNUNCIATED IN CONTROL ROOM	LOSS OF STRTUP-BYPSS FDWTR CONTROL PID-6-1B-SR	CATEGORY C LINE REQUIRED FOR STARTUP-BYPASS ONLY
SOLAR-D	SFWS0176	LOCKED OPEN VALVE FAILS TO REMAIN OPEN OR LEAKAGE PID-6-1A-SR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE A PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-D	SFWS0186	RV 51A INADVERT OPENING MECH FAILURE LEAK PID-6-1A-SR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE A PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-D	SFWS0196	CHECK VALVE FAILS TO REMAIN OPEN OR CHECK LEAK PID-6-1A-SR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE A PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-D	SFWS0201	START-STOP VALVE POSITION ZS 57A INADVERT CLOSURE LEAK PID-6-1	ANNUNCIATED IN CONTROL ROOM	LOSS OF BOOSTER PUMP LINE A PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS SOLAR FEEDWATER SYSTEM FMEA-SOLARFWS SH 2

D.1 Solar Feedwater System (Cont)

FTSM	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-E	SFWS0216	LOCKED OPEN VALVE FAILS TO REMAIN OPEN OR LEAKS PID-6-1A-SR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE B PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-E	SFWS0226	DRAIN RV 51B INADVERT OPENING MECH FAILURE LEAK PID-6-1A-SR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE B PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-E	SFWS0236	CHECK VALVE FAILS TO REMAIN OPEN OR CHECK LEAK PID-6-1A-SR	PERIODIC INSPECTION	LOSS OF BOOSTER PUMP LINE B PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-E	SFWS0241	START-STOP VALVE POSITION ZS 57B INADVERT CLOSURE LEAK PID-6-1	ANNUNCIATED IN CONTROL ROOM	LOSS OF BOOSTER PUMP LINE B PID-6-1A-SR	CATEGORY C 2-100% CAPACITY LINES DUAL FAILURE REQUIRED
SOLAR-G	SFWS0251	LOCKED OPEN VALVE FAILS TO REMAIN OPEN OR LEAKS PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-G	SFWS0266	RV 21A INADVERT OPENING LEAKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-G	SFWS0276	CHECK VALVE FAILS TO REMAIN OPEN OR CHECK LEAK PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-K	SFWS0281	FDWTR PMP CONTRL FS 23A-PS 22A FAILS TO OPERATE PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY B SWITCH TO FV 26A AND MOV 28A
SOLAR-K	SFWS0292	PRESS TRANSM 24A FAILS TO OPERATE FALSE OUTPUT PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-J	SFWS0306	ORIFICE RO 27A LEAKAGE OR BLOCKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS SOLAR FEEDWATER SYSTEM FMEA-SOLARFWS SH 3

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-J	SFWS0316	SHUTOFF VALVE FAILS TO OPERATE LEAKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-J	SFWS0326	CHECK VALVE FAILS TO REMAIN OPEN OR CHECK LEAK PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-F	SFWS0331	LOCKED OPEN VALVE FAILS TO REMAIN OPEN OR LEAKS PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-F	SFWS0346	RV 21B INADVERT OPENING LEAKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-F	SFWS0356	CHECK VALVE FAILS TO REMAIN OPEN OR CHECK LEAK PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-M	SFWS0361	FDWTR PMP CONTRL FS 23B-PS 22B FAILS TO OPERATE PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY B SWITCH TO FV 26B AND MOV 28B
SOLAR-M	SFWS0372	PRESS TRANSM 24B FAILS TO OPERATE FALSE OUTPUT PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-L	SFWS0386	ORIFICE RO 27B LEAKAGE OR BLOCKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-L	SFWS0396	SHUTOFF VALVE FAILS TO OPERATE LEAKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-L	SFWS0406	CHECK VALVE FAILS TO REMAIN OPEN OR CHECK LEAK PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*

				FAILURE MODES AND EFFECTS ANALYSIS
				SOLAR FEEDWATER SYSTEM
4	3	2	1	
				FMEA-SOLARFWS SH 4

D.1 Solar Feedwater System (Cont)

FTSM	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-C	SFWS0412	MOV 29 FAILS CLOSED LEAKAGE PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF MAIN LINE FDWTR CONTROL PID-6-1B-SR	CATEGORY B BYPASS-STARTUP LINE AVAILABLE
SOLAR-C	SFWS0422	MOTOR FAILURE SPURIOUS SIGNAL MOV 29 PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF MAIN LINE FDWTR CONTROL PID-6-1B-SR	CATEGORY B BYPASS-STARTUP LINE AVAILABLE
SOLAR-C	SFWS0432	SRCS FAILURE MOV 29 PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF MAIN LINE FDWTR CONTROL PID-6-1B-SR	CATEGORY B
SOLAR-C	SFWS0441	LV 31 (AIR OPERATED) FAILS TO OPERATE PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF MAIN LINE FDWTR CONTROL PID-6-1B-SR	CATEGORY B BYPASS-STARTUP LINE AVAILABLE
SOLAR-C	SFWS0451	LVL TRANSD LV 31 FAILURE SPURIOUS SIGNAL PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF MAIN LINE FDWTR CONTROL PID-6-1B-SR	CATEGORY B-C SPURIOUS SIGNAL CLOSES LV 31
SOLAR-H	SFWS0462	MOV 30 FAILS TO REMAIN CLOSED LEAK PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF STRTUP-BYPSS FDWTR CONTROL PID-6-1B-SR	CATEGORY C LINE NOT REQUIRED FOR NORMAL OPERATION
SOLAR-H	SFWS0472	MOTOR FAILURE MOV 30 PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF STRTUP-BYPSS FDWTR CONTROL PID-6-1B-SR	CATEGORY C LINE NOT REQUIRED FOR NORMAL OPERATION
SOLAR-H	SFWS0482	SRCS FAILURE MOV 30 PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF STRTUP-BYPSS FDWTR CONTROL PID-6-1B-SR	CATEGORY C LINE NOT REQUIRED FOR NORMAL OPERATION
SOLAR-H	SFWS0491	LV 32 (AIR OPERATED) FAILS TO OPERATE PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF STRTUP-BYPSS FDWTR CONTROL PID-6-1B-SR	CATEGORY C LINE NOT REQUIRED FOR NORMAL OPERATION
SOLAR-H	SFWS0501	LVL TRANSD LV 32 FAILURE SPURIOUS SIGNAL PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF STRTUP-BYPSS FDWTR CONTROL PID-6-1B-SR	CATEGORY C LINE NOT REQUIRED FOR NORMAL OPERATION
SOLAR-P	SFWS0516	ISOLATION MOV 63 FAILS TO REMAIN CLOSED OR LEAKS PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDWTR HTR "A" ISOL MOV 63 PID-6-1C-SR	CATEGORY C BYPASS VALVE FOR "B" SOLAR HEATER

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-N	SFWS0526	ISOLATION MOV 66 FAILS TO REMAIN CLOSED OR LEAKS PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDWTR HTR "B" ISOL MOV 66 PID-6-1C-SR	CATEGORY C BYPASS VALVE FOR "A" SOLAR HEATER
SOLAR-G	SFWS0536	MOV 28A FAILS CLOSED LEAKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-G	SFWS0542	MOTOR FAILURE MOV 28A PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-G	SFWS0552	LOGIC FAILURE SPURIOUS SIGNAL MOV 28A PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE A PID-6-1B-SR	CATEGORY B-C SPURIOUS SIGNAL CLOSES MOV 28A
SOLAR-F	SFWS0566	MOV 28B FAILS CLOSED LEAKAGE PID-6-1B-SR	PERIODIC INSPECTION	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-F	SFWS0572	MOTOR FAILURE MOV 28B PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-F	SFWS0582	LOGIC FAILURE SPURIOUS SIGNAL MOV 28B PID-6-1B-SR	INDICATING LIGHT IN CONTROL ROOM	LOSS OF FDWTR PUMP LINE B PID-6-1B-SR	CATEGORY B-C SPURIOUS SIGNAL CLOSES MOV 28B
SOLAR-P	SFWS0592	PT 35-PE-PI FAILS TO OPERATE FALSE OUTPUT PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDWTR HEATER PATH A PID-6-1C-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-P	SFWS0601	"A" HEATER E3 FAILS OR LEAKS BLOCKAGE PID-6-1C-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF FDWTR HEATER PATH A PID-6-1C-SR	CATEGORY C HEATER CAN BE BYPASSED
SOLAR-P	SFWS0611	FDWTR HTR PATH A COMMON MODE OPERATOR ERROR PID-6-1C-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF FDWTR HEATER PATH A PID-6-1C-SR	CATEGORY C

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS SOLAR FEEDWATER SYSTEM FMEA-SOLARFWS SH 6

FTSM	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-N	SFHS0622	TH 40-TE-TI FAILS TO OPERATE FALSE OUTPUT PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDHTR HEATER PATH B PID-6-1C-SR	CATEGORY C
SOLAR-N	SFHS0631	"B" HEATER E4 FAILS OR LEAKS BLOCKAGE PID-6-1C-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF FDHTR HEATER PATH B PID-6-1C-SR	CATEGORY C HEATER CAN BE BYPASSED
SOLAR-N	SFHS0641	FDHTR HTR PATH B COMMON MODE OPERATOR ERROR PID-6-1C-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF FDHTR HEATER PATH B PID-6-1C-SR	CATEGORY C
SOLAR-P	SFHS0656	TH 33 FAILS TO OPERATE PID-6-1C-SR	PERIODIC INSPECTION	NONE	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-P	SFHS0666	TH 34-TE-TI FAILS TO OPERATE FALSE OUTPUT PID-6-1C-SR	PERIODIC INSPECTION	NONE	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-Q	SFHS0676	RV 37 INADVERT OPENING LEAKAGE PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDHTR HEATER PATH A PID-6-1C-SR	CATEGORY C HEATER CAN BE BYPASSED
SOLAR-Q	SFHS0682	LOGIC INTEGRAL CS FAILURE FDHTR HTR PATH A PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDHTR HEATER PATH A PID-6-1C-SR	CATEGORY C INCREASES PROBABILITY OF SYSTEM FAILURE
SOLAR-R	SFHS0696	RV 42 INADVERT OPENING LEAKAGE PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDHTR HEATER PATH B PID-6-1C-SR	CATEGORY C HEATER CAN BE BYPASSED
SOLAR-R	SFHS0702	LOGIC INTEGRAL CS FAILURE FDHTR HTR PATH B PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDHTR HEATER PATH B PID-6-1C-SR	CATEGORY C INCREASES PROBABILITY OF SYSTEM FAILURE
SOLAR-N	SFHS0716	TH 46-TE-TI FAILS TO OPERATE FALSE OUTPUT PID-6-1C-SR	PERIODIC INSPECTION	NONE	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS SOLAR FEEDWATER SYSTEM FMEA-SOLARFWS SH 7

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-N	SFHS0726	TH 47 FAILS TO OPERATE PID-6-1C-SR	PERIODIC INSPECTION	NONE	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-Q	SFHS0736	FDHTR HTR PATH A BLOCK MOV 62 FAILS CLOSED LEAK PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDHTR HEATER PATH A PID-6-1C-SR	CATEGORY C DOWNSTREAM BLOCK VALVE & BYPASS VALVE AVAILABLE
SOLAR-Q	SFHS0746	FDHTR HTR PATH A BYPASS VALVE FAILS OPEN LEAK PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDHTR HEATER PATH A PID-6-1C-SR	CATEGORY C VALVE USED FOR BYPASS ONLY
SOLAR-R	SFHS0756	FDHTR HTR PATH B BLOCK MOV 65 FAILS TO CLOSE LEAK PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDHTR HEATER PATH B PID-6-1C-SR	CATEGORY C DOWNSTREAM BLOCK VALVE & BYPASS VALVE AVAILABLE
SOLAR-R	SFHS0766	FDHTR HTR PATH B BYPASS VALVE FAILS OPEN LEAK PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDHTR HEATER PATH B PID-6-1C-SR	CATEGORY C USED FOR STARTUP-BYPASS ONLY
SOLAR-G	SFHS0771	50% CAPACITY SOLAR FDHTR P2A FAILS TO OPERATE LEAK PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF FDHTR PUMP LINE A PID-6-1B-SR	CATEGORY B 2-50% CAPACITY PUMPS
SOLAR-F	SFHS0781	50% CAPACITY SOLAR FDHTR P2B FAILS TO OPERATE LEAK PID-6-1B-SR	ANNUNCIATED IN CONTROL ROOM	LOSS OF FDHTR PUMP LINE B PID-6-1B-SR	CATEGORY B 2-50% CAPACITY PUMPS
SOLAR-Q	SFHS0796	FDHTR HTR PATH A BLOCK MOV 61 FAILS CLOSED LEAK PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDHTR HEATER PATH A PID-6-1C-SR	CATEGORY C HEATER CAN BE BYPASSED
SOLAR-Q	SFHS0802	FDHTR HTR PATH A MOTOR FAILURE BLOCK MOV 61 PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDHTR HEATER PATH A PID-6-1C-SR	CATEGORY C HEATER CAN BE BYPASSED
SOLAR-R	SFHS0816	FDHTR HTR PATH B BLOCK MOV 64 FAILS CLOSED LEAK PID-6-1C-SR	PERIODIC INSPECTION	FAILURE OF FDHTR HEATER PATH B PID-6-1C-SR	CATEGORY C HEATER CAN BE BYPASSED

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS SOLAR FEEDWATER SYSTEM FMEA-SOLARFWS SH 8

FTSM	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-R	SFWS0822	FDWTR HTR PATH B MOTOR FAILURE BLOCK MOV 64 PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDWTR HEATER PATH B PID-6-1C-SR	CATEGORY C HEATER CAN BE BYPASSED
SOLAR-P	SFWS1512	MOTOR FAILURE ISOLATION MOV 63 PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDWTR HTR "A" ISOL MOV 63 PID-6-1C-SR	CATEGORY C BYPASS VALVE FOR "B" SOLAR HEATER
SOLAR-N	SFWS1522	MOTOR FAILURE ISOLATION MOV 66 PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDWTR HTR "B" ISOL MOV 66 PID-6-1C-SR	CATEGORY C BYPASS VALVE FOR "A" SOLAR HEATER
SOLAR-Q	SFWS1732	FDWTR HTR PATH A MOTOR FAILURE BLOCK MOV 62 PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDWTR HEATER PATH A PID-6-1C-SR	CATEGORY C DOWNSTREAM BLOCK VALVE & BYPASS VALVE AVAILABLE
SOLAR-R	SFWS1752	FDWTR HTR PATH B MOTOR FAILURE BLOCK MOV 65 PID-6-1C-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF FDWTR HEATER PATH B PID-6-1C-SR	CATEGORY C DOWNSTREAM BLOCK VALVE & BYPASS VALVE AVAILABLE

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*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                                *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: SOLAR FEEDWATER SYSTEM
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SFWS0756	1.00000D-05	9.00000D+00
2	SFWS1752	2.50000D-05	2.00000D+01
3	SFWS0736	1.00000D-05	9.00000D+00
4	SFWS1732	2.50000D-05	2.00000D+01
5	SFWS0816	1.00000D-05	9.00000D+00
6	SFWS0822	2.50000D-05	2.00000D+01
7	SFWS0796	1.00000D-05	9.00000D+00
8	SFWS0802	2.50000D-05	2.00000D+01
9	SFWS0716	2.00000D-06	8.00000D+00
10	SFWS0726	0.0	0.0
11	SFWS0656	0.0	0.0
12	SFWS0666	2.00000D-06	8.00000D+00
13	SFWS0526	1.00000D-05	9.00000D+00
14	SFWS1522	2.50000D-05	2.00000D+01
15	SFWS0516	1.00000D-05	9.00000D+00
16	SFWS1512	2.50000D-05	2.00000D+01
17	SFWS0566	1.00000D-05	9.00000D+00
18	SFWS0572	2.50000D-05	2.00000D+01
19	SFWS0582	7.00000D-06	1.50000D+01
20	SFWS0536	1.00000D-05	9.00000D+00
21	SFWS0542	2.50000D-05	2.00000D+01
22	SFWS0552	7.00000D-06	1.50000D+01
23	SFWS0491	3.50000D-05	4.00000D+01
24	SFWS0501	2.00000D-06	8.00000D+00
25	SFWS0462	2.00000D-05	1.00000D+01
26	SFWS0472	2.50000D-05	7.00000D+00
27	SFWS0482	7.00000D-06	1.50000D+01
28	SFWS0441	2.00000D-05	4.50000D+01
29	SFWS0451	2.00000D-06	8.00000D+00
30	SFWS0412	1.00000D-05	9.00000D+00
31	SFWS0422	2.50000D-05	2.00000D+01
32	SFWS0432	7.00000D-06	1.50000D+01
33	SFWS0386	1.00000D-07	1.00000D+00
34	SFWS0396	5.00000D-06	8.00000D+00
35	SFWS0406	8.00000D-06	9.00000D+00
36	SFWS0361	1.50000D-05	3.00000D+01
37	SFWS0372	3.00000D-06	1.00000D+01
38	SFWS0306	1.00000D-07	1.00000D+00
39	SFWS0316	5.00000D-06	8.00000D+00
40	SFWS0326	8.00000D-06	9.00000D+00
41	SFWS0281	1.50000D-05	3.00000D+01
42	SFWS0292	3.00000D-06	1.00000D+01
43	SFWS0216	1.30000D-05	9.00000D+00
44	SFWS0226	1.50000D-05	1.00000D+01
45	SFWS0236	2.00000D-05	9.00000D+00

46	SFHS0241	2.200000D-05	1.200000D+01
47	SFHS0176	1.300000D-05	9.000000D+00
48	SFHS0186	1.500000D-05	1.000000D+01
49	SFHS0196	2.000000D-05	9.000000D+00
50	SFHS0201	2.200000D-05	1.200000D+01
51	SFHS0766	1.000000D-05	9.000000D+00
52	SFHS0746	1.000000D-05	9.000000D+00
53	SFHS0696	1.500000D-05	1.000000D+01
54	SFHS0702	7.000000D-06	1.500000D+01
55	SFHS0676	1.500000D-05	1.000000D+01
56	SFHS0682	7.000000D-06	1.500000D+01
57	SFHS0622	2.000000D-06	8.000000D+00
58	SFHS0631	7.600000D-05	1.600000D+01
59	SFHS0641	9.000000D-05	2.000000D+00
60	SFHS0592	3.000000D-06	1.000000D+01
61	SFHS0601	7.600000D-05	1.600000D+01
62	SFHS0611	9.000000D-05	2.000000D+00
63	SFHS0331	1.300000D-05	9.000000D+00
64	SFHS0346	1.500000D-05	1.000000D+01
65	SFHS0356	2.000000D-05	9.000000D+00
66	SFHS0251	1.300000D-05	9.000000D+00
67	SFHS0266	1.500000D-05	1.000000D+01
68	SFHS0276	2.000000D-05	9.000000D+00
69	SFHS0156	1.300000D-05	9.000000D+00
70	SFHS0161	9.000000D-05	2.000000D+00
71	SFHS0136	1.300000D-05	9.000000D+00
72	SFHS0141	9.000000D-05	2.000000D+00
73	SFHS0112	2.000000D-06	4.000000D+00
74	SFHS0121	9.000000D-05	2.000000D+00
75	SFHS0781	1.120000D-04	4.200000D+01
76	SFHS0092	2.000000D-06	4.000000D+00
77	SFHS0101	9.000000D-05	2.000000D+00
78	SFHS0771	1.120000D-04	4.200000D+01
79	SFHS0062	9.200000D-05	8.800000D+01
80	SFHS0076	0.0	0.0
81	SFHS0086	9.000000D-05	2.000000D+00
82	SFHS0032	9.200000D-05	8.800000D+01
83	SFHS0046	0.0	0.0
84	SFHS0056	9.000000D-05	2.000000D+00
85	SFHS0021	4.000000D-06	7.000000D+00
86	SFHS0011	9.000000D-06	2.000000D+01

D.1 Solar Feedwater System (Cont)

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	1.30000000D-05	1.30000000D-05
7.30000000D+02	3.474328899D-04	2.461447180D-05	2.462302660D-05
1.46000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
2.19000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
2.92000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
3.65000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
4.38000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
5.11000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
5.84000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
6.57000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
7.30000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
8.03000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05
8.76000000D+03	3.474328899D-04	2.461447180D-05	2.462302660D-05

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.30000000D+02	1.372928220D-02	1.363854540D-02
1.46000000D+03	3.169784660D-02	3.120981140D-02
2.19000000D+03	4.966641100D-02	4.846805890D-02
2.92000000D+03	6.763497540D-02	6.541886410D-02
3.65000000D+03	8.560353980D-02	8.206770380D-02
4.38000000D+03	1.035721040D-01	9.841995730D-02
5.11000000D+03	1.215406690D-01	1.144809080D-01
5.84000000D+03	1.395092330D-01	1.302557450D-01
6.57000000D+03	1.574777970D-01	1.457495660D-01
7.30000000D+03	1.754463620D-01	1.609673770D-01
8.03000000D+03	1.934149260D-01	1.759140940D-01
8.76000000D+03	2.113834910D-01	1.905945460D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

D.2 SOLAR MAIN STEAM AND HIGH PRESSURE STEAM SYSTEM

FTSM	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-A	SMSS0011	PIPING COMMON MODE FAILURE PID-3-1A-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A-B-C
SOLAR-C	SMSS0021	REHEATER E3 LEAKAGE OR BLOCKAGE PID-3-1A-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A
SOLAR-C	SMSS0031	HI PRESS STEAM COMMON MODE OPERATOR ERROR PID-3-1A-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A-B-C
SOLAR-C	SMSS0042	TM 21-TI-TM 22-TE FAILS TO OPERATE FALSE OUTPUT PID-3-1A-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-C	SMSS0052	PT 23-PI-PI 24 FAILS TO OPERATE FALSE OUTPUT PID-3-1A-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-C	SMSS0062	TM 27-TE-TM 28-TI FAILS TO OPERATE FALSE OUTPUT PID-3-1A-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-C	SMSS0072	PT 26-PI-PI 24 FAILS TO OPERATE FALSE OUTPUT PID-3-1A-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-C	SMSS0082	HI PRESS STEAM BLR BLOWDOWN MOV MOTOR FAILURE PID-3-1A-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C MOV NORMALLY CLOSED
SOLAR-C	SMSS0096	HI PRESS STM MOV FAILS TO REMAIN CLOSED OR LEAKS PID-3-1A-SR	PERIODIC INSPECTION	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY A-B MOV NORMALLY CLOSED
SOLAR-C	SMSS0102	HI PRESS STEAM BLR BLOWDOWN MOV MCS FAILURE PID-3-1A-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A-B-C

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS MAIN AND HIGH PRESSURE STEAM FMEA-SOLARMSS SH 1

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-B	SMSS0111	MAIN STEAM COMMON MODE OPERATOR ERROR PID-3-1B-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A-B-C
SOLAR-B	SMSS0122	TM 32-TM 33-TE 33- FAILS TO OPERATE FALSE OUTPUT PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-B	SMSS0132	FT 29-FE-FI FAILS TO OPERATE FALSE OUTPUT PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-B	SMSS0142	PT 31-PI-PI 30 FAILS TO OPERATE FALSE OUTPUT PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C *NO IMPACT ON* *SYSTEM RELIABILITY*
SOLAR-D	SMSS0151	MN STM CHK VALVE FAILS TO REMAIN OPEN OR CHECK PID-3-1B-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A-B
SOLAR-D	SMSS0162	AUX STEAM STARTUP COMPONENTS FAIL PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C USED FOR STARTUP ONLY
SOLAR-B	SMSS0171	MAIN STM SV 51 INADVERT OPENING LEAKAGE PID-3-1B-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A
SOLAR-B	SMSS0181	MAIN STM SV 52 INADVERT OPENING LEAKAGE PID-3-1B-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A
SOLAR-B	SMSS0191	MAIN STM SV 35 INADVERT OPENING LEAKAGE PID-3-1B-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A
SOLAR-B	SMSS0201	MAIN STM SV 36 INADVERT OPENING LEAKAGE PID-3-1B-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS MAIN AND HIGH PRESSURE STEAM FMEA-SOLARMSS SH 2

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-D	SHSS0212	MAIN STEAM MOV 34 MOTOR FAILURE PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A
SOLAR-D	SHSS0226	MAIN STM MOV 34 FAILS TO REMAIN OPEN OR LEAKS PID-3-1B-SR	PERIODIC INSPECTION	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A VALVE NORMALLY OPEN
SOLAR-D	SHSS0232	MAIN STEAM MOV 34 MCS FAILURE PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A
SOLAR-E	SHSS0242	MAIN STEAM MOV 45 MOTOR FAILURE PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C
SOLAR-E	SHSS0256	MAIN STM MOV 45 FAILS TO REMAIN CLOSED OR LEAKS PID-3-1B-SR	PERIODIC INSPECTION	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY A-B
SOLAR-E	SHSS0262	MAIN STEAM MOV 45 MCS FAILURE PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A-B-C
SOLAR-E	SHSS0272	MAIN STM SOV 46 SOLENOID FAILURE PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY C
SOLAR-E	SHSS0286	MAIN STEAM SOV 46 FAILS TO REMAIN CLOSED OR LEAKS PID-3-1B-SR	PERIODIC INSPECTION	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	CATEGORY A-B
SOLAR-E	SHSS0292	MAIN STEAM SOV 46 MCS FAILURE PID-3-1B-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MAIN STEAM AND HIGH PRESS STEAM PID-3-1(A-B)-SR	***SINGLE FAILURE*** CATEGORY A-B-C

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS MAIN AND HIGH PRESSURE STEAM FMEA-SOLARMSS SH 3

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************************************************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                              *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: MAIN STEAM AND HIGH PRESSURE STEAM
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SMSS0272	6.00000D-06	7.00000D+00
2	SMSS0286	1.00000D-05	9.00000D+00
3	SMSS0292	2.00000D-06	6.00000D+00
4	SMSS0242	1.50000D-05	1.50000D+01
5	SMSS0256	1.00000D-05	9.00000D+00
6	SMSS0262	2.00000D-06	6.00000D+00
7	SMSS0212	2.50000D-05	2.00000D+01
8	SMSS0226	1.00000D-05	9.00000D+00
9	SMSS0232	2.00000D-06	6.00000D+00
10	SMSS0191	2.50000D-05	8.00000D+00
11	SMSS0201	2.50000D-05	8.00000D+00
12	SMSS0171	2.50000D-05	8.00000D+00
13	SMSS0181	2.50000D-05	8.00000D+00
14	SMSS0122	2.00000D-06	8.00000D+00
15	SMSS0132	2.00000D-06	4.00000D+00
16	SMSS0142	3.00000D-06	1.00000D+01
17	SMSS0082	1.50000D-05	1.50000D+01
18	SMSS0096	1.00000D-05	9.00000D+00
19	SMSS0102	2.00000D-06	6.00000D+00
20	SMSS0062	2.00000D-06	8.00000D+00
21	SMSS0072	3.00000D-06	1.00000D+01
22	SMSS0042	2.00000D-06	8.00000D+00
23	SMSS0052	3.00000D-06	1.00000D+01
24	SMSS0151	1.50000D-05	4.80000D+01
25	SMSS0162	9.00000D-06	6.00000D+00
26	SMSS0111	9.00000D-05	2.00000D+00
27	SMSS0021	2.10000D-04	1.50000D+01
28	SMSS0031	9.00000D-05	2.00000D+00
29	SMSS0011	9.00000D-06	2.00000D+01

SYSTEM INFORMATION-UPPER BOUNDS

D.2 SOLAR MAIN STEAM AND HIGH PRESSURE STEAM SYSTEM (CONT)

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	6.49000000D-04	6.49000000D-04
7.30000000D+02	6.78136703D-03	6.48251717D-04	6.52677765D-04
1.46000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
2.19000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
2.92000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
3.65000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
4.38000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
5.11000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
5.84000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
6.57000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
7.30000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
8.03000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04
8.76000000D+03	6.78136703D-03	6.48251717D-04	6.52677765D-04

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.30000000D+02	4.73496877D-01	3.78184830D-01
1.46000000D+03	9.46720630D-01	6.13864584D-01
2.19000000D+03	1.41994438D+00	7.60217237D-01
2.92000000D+03	1.89316814D+00	8.51099456D-01
3.65000000D+03	2.36639189D+00	9.07535589D-01
4.38000000D+03	2.83961564D+00	9.42581356D-01
5.11000000D+03	3.31283940D+00	9.64344112D-01
5.84000000D+03	3.78606315D+00	9.77858371D-01
6.57000000D+03	4.25928691D+00	9.86250469D-01
7.30000000D+03	4.73251066D+00	9.91461802D-01
8.03000000D+03	5.20573441D+00	9.94697941D-01
8.76000000D+03	5.67895817D+00	9.96707522D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

D.3 SOLAR COLD AND HOT REHEAT SYSTEM

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-A	SSRS0011	FV 22 FAILS TO REMAIN OPEN OR OPERATE LEAKS PID-3-2-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF COLD AND HOT REHEAT SYSTEM PID-3-2-SR	***SINGLE FAILURE*** CATEGORY A
SOLAR-A	SSRS0021	RHT FLOW CONTROL FAILS TO OPERATE FALSE OUTPUT PID-3-2-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF COLD AND HOT REHEAT SYSTEM PID-3-2-SR	CATEGORY C INCREASES PROBABILITY OF SYSTEM FAILURE
SOLAR-D	SSRS0031	PRESSURE RV 26 INADVERT OPENING LEAKAGE PID-3-2-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF COLD AND HOT REHEAT SYSTEM PID-3-2-SR	***SINGLE FAILURE*** CATEGORY A-B
SOLAR-D	SSRS0041	RHT HT EXCH MS-E1 FAILS OR LEAKS BLOCKAGE PID-3-2-SR	ANNUNCIATED IN CONTROL ROOM	FAILURE OF COLD AND HOT REHEAT SYSTEM PID-3-2-SR	***SINGLE FAILURE*** CATEGORY A
SOLAR-B	SSRS0051	REHEAT SYSTEM PIPING COMMON MODE FAILURE	ANNUNCIATED IN CONTROL ROOM	FAILURE OF COLD AND HOT REHEAT SYSTEM PID-3-2-SR	***SINGLE FAILURE*** CATEGORY A-B-C
SOLAR-B	SSRS0061	REHEAT SYSTEM OPERATOR ERROR COMMON MODE FAILURE	ANNUNCIATED IN CONTROL ROOM	FAILURE OF COLD AND HOT REHEAT SYSTEM PID-3-2-SR	***SINGLE FAILURE*** CATEGORY A-B-C
SOLAR-A	SSRS0072	MOTOR FAILURE SPURIOUS SIGNAL MOV 20A PID-3-2-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MOVS LTEMP RHT LINE A PID-3-2-SR	CATEGORY B 2-50% CAPACITY LINES (MOV 20A NORMALLY OPEN)
SOLAR-A	SSRS0086	MOV 20A FAILS TO REMAIN OPEN OR OPERATE LEAKS PID-3-2-SR	PERIODIC INSPECTION	FAILURE OF MOVS LTEMP RHT LINE A PID-3-2-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-A	SSRS0092	MOTOR FAILURE SPURIOUS SIGNAL MOV 20B PID-3-2-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MOVS LTEMP RHT LINE B PID-3-2-SR	CATEGORY B 2-50% CAPACITY LINES (MOV 20B NORMALLY OPEN)
SOLAR-A	SSRS0106	MOV 20B FAILS TO REMAIN OPEN OR OPERATE LEAKS PID-3-2-SR	PERIODIC INSPECTION	FAILURE OF MOVS LTEMP RHT LINE B PID-3-2-SR	CATEGORY B 2-50% CAPACITY LINES

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS COLD AND HOT REHEAT SYSTEM FMEA-SOLARSRS SH 1

FTSH	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOLAR-A	SSRS0116	STARTUP MOV 32A FAILS TO REMAIN CLOSED OR LEAKS PID-3-2-SR	PERIODIC INSPECTION	FAILURE OF MOVS LTEMP RHT LINE A PID-3-2-SR	CATEGORY C VALVE USED FOR STARTUP-WARMUP ONLY
SOLAR-A	SSRS0126	STARTUP MOV 32B FAILS TO REMAIN CLOSED OR LEAKS PID-3-2-SR	PERIODIC INSPECTION	FAILURE OF MOVS LTEMP RHT LINE B PID-3-2-SR	CATEGORY C VALVE USED FOR STARTUP-WARMUP ONLY
SOLAR-C	SSRS0132	MOTOR FAILURE SPURIOUS SIGNAL MOV 21A PID-3-2-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MOV 21A HTEMP RHT LINE A PID-3-2-SR	CATEGORY B 2-50% CAPACITY LINES (MOV 21A NORMALLY OPEN)
SOLAR-C	SSRS0146	MOV 21A FAILS TO REMAIN OPEN OR OPERATE LEAKS PID-3-2-SR	PERIODIC INSPECTION	FAILURE OF MOV 21A HTEMP RHT LINE A PID-3-2-SR	CATEGORY B 2-50% CAPACITY LINES
SOLAR-C	SSRS0152	MOTOR FAILURE SPURIOUS SIGNAL MOV 21B PID-3-2-SR	INDICATING LIGHT IN CONTROL ROOM	FAILURE OF MOV 21B HTEMP RHT LINE B PID-3-2-SR	CATEGORY B 2-50% CAPACITY LINES (MOV 21B NORMALLY OPEN)
SOLAR-C	SSRS0166	MOV 21B FAILS TO REMAIN OPEN OR OPERATE LEAKS PID-3-2-SR	PERIODIC INSPECTION	FAILURE OF MOV 21B HTEMP RHT LINE B PID-3-2-SR	CATEGORY B 2-50% CAPACITY LINES

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS COLD AND HOT REHEAT SYSTEM FMEA-SOLARSRS SH 2

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*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                                *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: COLD AND HOT REHEAT SYSTEM
* OPERATING MODE
ENDOPM
* RATES
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COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SSRS0152	2.50000D-05	7.00000D+00
2	SSRS0166	1.00000D-05	9.00000D+00
3	SSRS0132	2.50000D-05	2.00000D+01
4	SSRS0146	1.00000D-05	9.00000D+00
5	SSRS0092	2.50000D-05	2.00000D+01
6	SSRS0106	1.00000D-05	9.00000D+00
7	SSRS0126	1.00000D-06	1.00000D-01
8	SSRS0072	2.50000D-05	2.00000D+01
9	SSRS0086	1.00000D-05	9.00000D+00
10	SSRS0116	1.00000D-06	1.00000D-01
11	SSRS0051	9.00000D-06	2.00000D+01
12	SSRS0061	9.00000D-05	2.00000D+00
13	SSRS0031	1.50000D-05	1.00000D+01
14	SSRS0041	1.00000D-04	9.00000D+00
15	SSRS0011	1.50000D-05	4.30000D+01
16	SSRS0021	7.00000D-06	8.00000D+00

SYSTEM INFORMATION-UPPER BOUNDS

D.3 SOLAR COLD AND HOT REHEAT SYSTEM (CONT)

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	2.360000000D-04	2.360000000D-04
7.300000000D+02	2.10862001D-03	2.359523150D-04	2.364509000D-04
1.460000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
2.190000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
2.920000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
3.650000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
4.380000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
5.110000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
5.840000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
6.570000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
7.300000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
8.030000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04
8.760000000D+03	2.10862001D-03	2.359523150D-04	2.364509000D-04

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.300000000D+02	1.722625950D-01	1.583950690D-01
1.460000000D+03	3.445077840D-01	2.918177020D-01
2.190000000D+03	5.167529740D-01	4.040883680D-01
2.920000000D+03	6.889981640D-01	4.985603650D-01
3.650000000D+03	8.612433530D-01	5.780553000D-01
4.380000000D+03	1.033488540D+00	6.449477660D-01
5.110000000D+03	1.205733730D+00	7.012354630D-01
5.840000000D+03	1.377978920D+00	7.485996710D-01
6.570000000D+03	1.550224110D+00	7.884550620D-01
7.300000000D+03	1.722469300D+00	8.219920360D-01
8.030000000D+03	1.894714490D+00	8.502122740D-01
8.760000000D+03	2.066959680D+00	8.739586560D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

D.4 POWER SUPPLY TO THE HELIOSTAT FIELD

FTSM	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
HELIO-A	SEPS0011	ELECTRIC SYSTEM CABLE OPEN CIRCUIT SHORT CIRCUIT	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER TO HELIOSTAT FIELD	***SINGLE FAILURE*** CATEGORY A-B-C POSSIBLE PLANT FAILURE
HELIO-A	SEPS0021	ELECTRIC SYSTEM COMMON MODE OPERATOR ERROR	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER TO HELIOSTAT FIELD	***SINGLE FAILURE*** CATEGORY A-B-C POSSIBLE PLANT FAILURE
HELIO-A	SEPS21	LOSS OF SOLAR 115-2.4 KV POWER LINE		LOSS OF POWER TO HELIOSTAT FIELD	***SINGLE FAILURE*** CATEGORY A REVIEW APPROPRIATE FMEA
HELIO-A	SEPS22	LOSS OF SOLAR 2400V BUSES A AND B		LOSS OF POWER TO HELIOSTAT FIELD	***SINGLE FAILURE*** CATEGORY A REVIEW APPROPRIATE FMEA
HELIO-A	SEPS5111	LOSS OF HELIOSTAT LOOP 2 BUS A	ANNUNCIATED IN CONTROL ROOM	NONE	CATEGORY B REDUNDANCY PROVIDED BY BUS B-LOOP 1
HELIO-A	SEPS5121	LOSS OF HELIOSTAT LOOP 1 BUS B	ANNUNCIATED IN CONTROL ROOM	NONE	CATEGORY B REDUNDANCY PROVIDED BY BUS A-LOOP 2
HELIO-A	SEPS5131	LOSS OF HELIOSTAT LOOP 1 BUS A	ANNUNCIATED IN CONTROL ROOM	NONE	CATEGORY B REDUNDANCY PROVIDED BY BUS B-LOOP 2
HELIO-A	SEPS5141	LOSS OF HELIOSTAT LOOP 2 BUS B	ANNUNCIATED IN CONTROL ROOM	NONE	CATEGORY B REDUNDANCY PROVIDED BY BUS A-LOOP 1

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS POWER TO HELIOSTAT FIELD FMEA-HELIO SH 1

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*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                    *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: LOSS OF POWER TO HELIOSTAT FIELD
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SEPS5131	1.00000D-07	1.13000D+01
2	SEPS5141	1.00000D-07	1.13000D+01
3	SEPS5111	1.00000D-07	1.13000D+01
4	SEPS5121	1.00000D-07	1.13000D+01
5	SEPS0011	1.50000D-05	2.00000D+00
6	SEPS0021	1.20000D-05	8.00000D+00
7	SEPS21	1.83000D-05	4.10000D+00
8	SEPS22	2.34000D-05	1.21000D+01

SYSTEM INFORMATION-UPPER BOUNDS

D.4 POWER SUPPLY TO THE HELIOSTAT FIELD (CONT)

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	6.87000000D-05	6.87000000D-05
7.30000000D+02	4.840048850D-04	6.869040200D-05	6.872366460D-05
1.46000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
2.19000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
2.92000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
3.65000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
4.38000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
5.11000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
5.84000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
6.57000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
7.30000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
8.03000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05
8.76000000D+03	4.840048850D-04	6.869040200D-05	6.872366460D-05

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.30000000D+02	5.014749670D-02	4.892241530D-02
1.46000000D+03	1.002914900D-01	9.545924110D-02
2.19000000D+03	1.504354840D-01	1.397189910D-01
2.92000000D+03	2.005794770D-01	1.818130830D-01
3.65000000D+03	2.507234710D-01	2.218474840D-01
4.38000000D+03	3.008674640D-01	2.599229770D-01
5.11000000D+03	3.510114580D-01	2.961354120D-01
5.84000000D+03	4.011554510D-01	3.305759500D-01
6.57000000D+03	4.512994450D-01	3.633312910D-01
7.30000000D+03	5.014434380D-01	3.944838920D-01
8.03000000D+03	5.515874320D-01	4.241121770D-01
8.76000000D+03	6.017314250D-01	4.522907310D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

D.5 POWER SUPPLY TO THE HELIOSTAT LOOPS

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
LOOP-A	SEPS0161	LOOP SECTION 1 TRANSFORMER FAILS	ANNUNCIATED IN CONTROL ROOM	FAILURE OF LOOP SECTION 1 TRANSFORMER OR SWITCHES	CATEGORY B 1 OF 4 XFMRS IN LOOP
LOOP-A	SEPS0171	LOOP SECTION 1 1 OF 2 SWITCHES FAILS	ANNUNCIATED IN CONTROL ROOM	FAILURE OF LOOP SECTION 1 TRANSFORMER OR SWITCHES	CATEGORY B 1 OF 4 SECTIONS IN LOOP
LOOP-A	SEPS0181	LOOP SECTION 2 TRANSFORMER FAILS	ANNUNCIATED IN CONTROL ROOM	FAILURE OF LOOP SECTION 2 TRANSFORMER OR SWITCHES	CATEGORY B 1 OF 4 XFMRS IN LOOP
LOOP-A	SEPS0191	LOOP SECTION 2 1 OF 2 SWITCHES FAILS	ANNUNCIATED IN CONTROL ROOM	FAILURE OF LOOP SECTION 2 TRANSFORMER OR SWITCHES	CATEGORY B 1 OF 4 SECTIONS IN LOOP
LOOP-A	SEPS0201	LOOP SECTION 3 TRANSFORMER FAILS	ANNUNCIATED IN CONTROL ROOM	FAILURE OF LOOP SECTION 3 TRANSFORMER OR SWITCHES	CATEGORY B 1 OF 4 XFMRS IN LOOP
LOOP-A	SEPS0211	LOOP SECTION 3 1 OF 2 SWITCHES FAILS	ANNUNCIATED IN CONTROL ROOM	FAILURE OF LOOP SECTION 3 TRANSFORMER OR SWITCHES	CATEGORY B 1 OF 4 SECTIONS IN LOOP
LOOP-A	SEPS0221	LOOP SECTION 4 TRANSFORMER FAILS	ANNUNCIATED IN CONTROL ROOM	FAILURE OF LOOP SECTION 4 TRANSFORMER OR SWITCHES	CATEGORY B 1 OF 4 XFMRS IN LOOP
LOOP-A	SEPS0231	LOOP SECTION 4 1 OF 2 SWITCHES FAILS	ANNUNCIATED IN CONTROL ROOM	FAILURE OF LOOP SECTION 4 TRANSFORMER OR SWITCHES	CATEGORY B 1 OF 4 SECTIONS IN LOOP

				FAILURE MODES AND EFFECTS ANALYSIS HELIOSTAT FIELD LOOP
4	3	2	1	NEWMAN UNIT FMEA-LOOP SH 1

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***********************************************************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                                         *
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EL PASO SOLAR NEWMAN UNIT 1:FAILURE OF HELIOSTAT FIELD LOOP
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SEPS0221	1.00000D-05	6.00000D+01
2	SEPS0231	4.00000D-06	8.00000D+00
3	SEPS0201	1.00000D-05	6.00000D+01
4	SEPS0211	4.00000D-06	8.00000D+00
5	SEPS0181	1.00000D-05	6.00000D+01
6	SEPS0191	4.00000D-06	8.00000D+00
7	SEPS0161	1.00000D-05	6.00000D+01
8	SEPS0171	4.00000D-06	8.00000D+00

SYSTEM INFORMATION-UPPER BOUNDS

D.5 POWER SUPPLY TO THE HELIOSTAT LOOPS (CONT)

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	0.0	0.0
7.30000000D+02	1.59094959D-13	1.41060431D-14	1.41060431D-14
1.46000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
2.19000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
2.92000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
3.65000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
4.38000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
5.11000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
5.84000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
6.57000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
7.30000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
8.03000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14
8.76000000D+03	1.59094959D-13	1.41060431D-14	1.41060431D-14

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.30000000D+02	5.14870575D-12	5.14870575D-12
1.46000000D+03	1.54461172D-11	1.54461172D-11
2.19000000D+03	2.57435287D-11	2.57435287D-11
2.92000000D+03	3.60409402D-11	3.60409402D-11
3.65000000D+03	4.63383517D-11	4.63383517D-11
4.38000000D+03	5.66357632D-11	5.66357632D-11
5.11000000D+03	6.69331747D-11	6.69331747D-11
5.84000000D+03	7.72305862D-11	7.72305862D-11
6.57000000D+03	8.75279977D-11	8.75279977D-11
7.30000000D+03	9.78254092D-11	9.78254092D-11
8.03000000D+03	1.08122821D-10	1.08122816D-10
8.76000000D+03	1.18420232D-10	1.18420232D-10

*****CONCLUSION OF OUTPUT FROM KITT-1*****

D.6 POWER SUPPLY TO THE 1500 HP FEED PUMP MOTORS

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOL48-A	SEPS0011	ELECTRIC SYSTEM CABLE OPEN CIRCUIT SHORT CIRCUIT	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER TO 2400V BUSES AND 1500HP MOTORS	***SINGLE FAILURE*** CATEGORY A-B-C POSSIBLE PLANT FAILURE
SOL48-A	SEPS0021	ELECTRIC SYSTEM COMMON MODE OPERATOR ERROR	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER TO 2400V BUSES AND 1500HP MOTORS	***SINGLE FAILURE*** CATEGORY A-B-C POSSIBLE PLANT FAILURE
SOL48-A	SEPS21	LOSS OF SOLAR 115-2.4 KV POWER LINE		LOSS OF POWER TO 2400V BUSES AND 1500HP MOTORS	***SINGLE FAILURE*** CATEGORY A REVIEW APPROPRIATE FMEA
SOL48-A	SEPS22	LOSS OF SOLAR 2400V BUSES A AND B		LOSS OF POWER TO 2400V BUSES AND 1500HP MOTORS	***SINGLE FAILURE*** CATEGORY A REVIEW APPROPRIATE FMEA

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS POWER TO SOLAR 2400V BUSES FMEA-SOL480V SH 1

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**********************************************************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                                        *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: LOSS OF POWER TO SOLAR FDPUMP MOTORS
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SEPS0011	1.50000D-05	2.00000D+00
2	SEPS0021	5.50000D-06	8.00000D+00
3	SEPS21	1.83000D-05	4.10000D+00
4	SEPS22	2.07000D-05	1.21000D+01

SYSTEM INFORMATION-UPPER BOUNDS

D.6 POWER SUPPLY TO THE 1500 HP FEED PUMP MOTORS (CONT)

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	W	L
0.0	0.0	5.95000000D-05	5.95000000D-05
7.30000000D+02	3.99384630D-04	5.94927516D-05	5.95165216D-05
1.46000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
2.19000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
2.92000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
3.65000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
4.38000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
5.11000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
5.84000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
6.57000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
7.30000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
8.03000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05
8.76000000D+03	3.99384630D-04	5.94927516D-05	5.95165216D-05

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	WSUM	FSUM
7.30000000D+02	4.34323544D-02	4.25109848D-02
1.46000000D+03	8.68620631D-02	8.32203144D-02
2.19000000D+03	1.30291772D-01	1.22198815D-01
2.92000000D+03	1.73721480D-01	1.59520076D-01
3.65000000D+03	2.17151189D-01	1.95254559D-01
4.38000000D+03	2.60580898D-01	2.29469727D-01
5.11000000D+03	3.04010607D-01	2.62230176D-01
5.84000000D+03	3.47440315D-01	2.93597758D-01
6.57000000D+03	3.90870024D-01	3.23631692D-01
7.30000000D+03	4.34299733D-01	3.52388680D-01
8.03000000D+03	4.77729441D-01	3.79923014D-01
8.76000000D+03	5.21159150D-01	4.06286678D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

D.7 POWER SUPPLY TO SOLAR 480V BUS

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOL48-A	SEPS0011	ELECTRIC SYSTEM CABLE OPEN CIRCUIT SHORT CIRCUIT	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A-B-C POSSIBLE PLANT FAILURE
SOL48-A	SEPS0021	ELECTRIC SYSTEM COMMON MODE OPERATOR ERROR	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A-B-C POSSIBLE PLANT FAILURE
SOL48-B	SEPS0251	BUS A 480V L.C. DISCONNECTOR FAILS TO REMAIN CLOSED	ANNUNCIATED IN CONTROL ROOM	LOSS OF 480V L.C. INCOMING LINE FROM BUS A	CATEGORY C REDUNDANCY PROVIDED BY BUS B INCOMING LINE
SOL48-B	SEPS0261	BUS A 480V L.C. TRANSFORMER FAILS	ANNUNCIATED IN CONTROL ROOM	LOSS OF 480V L.C. INCOMING LINE FROM BUS A	CATEGORY C REDUNDANCY PROVIDED BY BUS B INCOMING LINE
SOL48-B	SEPS0271	BUS A 480V L.C. CIRCUIT BREAKER FAILS OPEN OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF 480V L.C. INCOMING LINE FROM BUS A	CATEGORY C REDUNDANCY PROVIDED BY BUS B INCOMING LINE
SOL48-B	SEPS0291	BUS B 480V L.C. DISCONNECTOR FAILS TO REMAIN CLOSED	ANNUNCIATED IN CONTROL ROOM	LOSS OF 480V L.C. INCOMING LINE FROM BUS B	CATEGORY C REDUNDANCY PROVIDED BY BUS B INCOMING LINE
SOL48-B	SEPS0301	BUS B 480V L.C. TRANSFORMER FAILS	ANNUNCIATED IN CONTROL ROOM	LOSS OF 480V L.C. INCOMING LINE FROM BUS B	CATEGORY C REDUNDANCY PROVIDED BY BUS B INCOMING LINE
SOL48-B	SEPS0311	BUS B 480V L.C. CIRCUIT BREAKER FAILS OPEN OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF 480V L.C. INCOMING LINE FROM BUS B	CATEGORY C REDUNDANCY PROVIDED BY BUS B INCOMING LINE
SOL48-C	SEPS0341	RECIR DR PUMP CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A LOSS OF 480V POWER
SOL48-C	SEPS0351	SOLAR DR PUMP CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A LOSS OF 480V POWER

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS POWER TO SOLAR 480V BUS FMEA-SOL480V SH 1

FTSM	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SOL48-C	SEPS0361	MCC TOWER CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A LOSS OF 480V POWER
SOL48-C	SEPS0371	MCC PUMP HOSE CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A LOSS OF 480V POWER
SOL48-C	SEPS0381	FIRE PUMP CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A LOSS OF 480V POWER
SOL48-A	SEPS21	LOSS OF SOLAR 115-2.4 KV POWER LINE		LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A REVIEW APPROPRIATE FMEA
SOL48-A	SEPS22	LOSS OF SOLAR 2400V BUSES A AND B		LOSS OF SOLAR 480V POWER	***SINGLE FAILURE*** CATEGORY A REVIEW APPROPRIATE FMEA

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*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                              *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: LOSS OF SOLAR 480V POWER
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SEPS0291	1.00000D-05	8.00000D+00
2	SEPS0301	1.00000D-05	6.00000D+01
3	SEPS0311	5.20000D-06	9.00000D+00
4	SEPS0251	1.00000D-05	8.00000D+00
5	SEPS0261	1.00000D-05	6.00000D+01
6	SEPS0271	5.20000D-06	9.00000D+00
7	SEPS0341	2.50000D-06	6.00000D+00
8	SEPS0351	2.50000D-06	6.00000D+00
9	SEPS0361	2.50000D-06	6.00000D+00
10	SEPS0371	2.50000D-06	6.00000D+00
11	SEPS0381	2.50000D-06	6.00000D+00
12	SEPS0011	1.50000D-05	2.00000D+00
13	SEPS0021	8.00000D-06	8.00000D+00
14	SEPS21	1.83000D-05	4.10000D+00
15	SEPS22	2.07000D-05	1.21000D+01

SYSTEM INFORMATION-UPPER BOUNDS

D.7 LOSS OF POWER TO SOLAR 480V BUS

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	7.45000000D-05	7.45000000D-05
7.30000000D+02	4.94867978D-04	7.45288961D-05	7.45657963D-05
1.46000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
2.19000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
2.92000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
3.65000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
4.38000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
5.11000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
5.84000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
6.57000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
7.30000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
8.03000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05
8.76000000D+03	4.94867978D-04	7.45288961D-05	7.45657963D-05

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.30000000D+02	5.43955471D-02	5.29553288D-02
1.46000000D+03	1.08801641D-01	1.03127930D-01
2.19000000D+03	1.63207735D-01	1.50642484D-01
2.92000000D+03	2.17613830D-01	1.95639808D-01
3.65000000D+03	2.72019924D-01	2.38253260D-01
4.38000000D+03	3.26426018D-01	2.78609134D-01
5.11000000D+03	3.80832112D-01	3.16827032D-01
5.84000000D+03	4.35238206D-01	3.53020219D-01
6.57000000D+03	4.89644300D-01	3.87295960D-01
7.30000000D+03	5.44050394D-01	4.19755839D-01
8.03000000D+03	5.98456489D-01	4.50496057D-01
8.76000000D+03	6.52862583D-01	4.79607716D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

D.8 POWER SOLAR 2400V BUSES

FTSH	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SEPS2-B	SEPS0071	BUS A SHORT CIRCUIT	ANNUNCIATED IN CONTROL ROOM	LOSS OF BUS A-HALF FIELD AND AUXILIARIES	CATEGORY B TIE BREAKER OPENS 50% POWER FROM BUS B
SEPS2-B	SEPS0081	BUS A-1500HP LC CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF BUS A-HALF FIELD AND AUXILIARIES	CATEGORY B TIE BREAKER OPENS LOSS OF ONE 1500HP PUMP
SEPS2-A	SEPS0091	BUS B SHORT CIRCUIT	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 2400 V BUSES	***SINGLE FAILURE*** CATEGORY A SOLAR PLANT SHUTDOWN
SEPS2-A	SEPS0101	BUS B 1500HP LC CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 2400 V BUSES	***SINGLE FAILURE*** CATEGORY A SOLAR PLANT SHUTDOWN
SEPS2-B	SEPS0111	BUS TIE BREAKER FAILS TO OPEN ON DEMAND	ANNUNCIATED IN CONTROL ROOM	FAILURE OF BUS TIE	CATEGORY C IF FAULT ON BUS A SOLAR PLANT SHUTDOWN
SEPS2-B	SEPS0121	BUS A-LOOP 1 CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF BUS A-HALF FIELD AND AUXILIARIES	CATEGORY B TIE BREAKER OPENS BUS B SUPPLY TO FIELD
SEPS2-A	SEPS0131	BUS B-LOOP 2 CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 2400 V BUSES	***SINGLE FAILURE*** CATEGORY A SOLAR PLANT SHUTDOWN
SEPS2-B	SEPS0141	BUS A-LOOP 2 CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF BUS A-HALF FIELD AND AUXILIARIES	CATEGORY B TIE BREAKER OPENS BUS B SUPPLY TO FIELD
SEPS2-A	SEPS0151	BUS B-LOOP 1 CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 2400 V BUSES	***SINGLE FAILURE*** CATEGORY A SOLAR PLANT SHUTDOWN
SEPS2-B	SEPS0241	BUS A-480V LC CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF BUS A-HALF FIELD AND AUXILIARIES	CATEGORY B TIE BREAKER OPENS 50% POWER FROM BUS B

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS LOSS OF SOLAR 2400V BUSES FMEA-SEPS22 SH 1

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SEPS2-A	SEPS0281	BUS B-480V LC CB FAILS TO OPEN ON FAULT OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 2400 V BUSES	***SINGLE FAILURE*** CATEGORY A SOLAR PLANT SHUTDOWN
SEPS2-B	SEPS0331	BUS TIE BREAKER RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	FAILURE OF BUS TIE	CATEGORY C IF FAULT ON BUS A SOLAR PLANT SHUTDOWN

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS LOSS OF SOLAR 2400V BUSES FMEA-SEPS22 SH 2

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*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                                              *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: LOSS OF SOLAR 2400V BUSES*
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SEPS0121	2.50000D-06	6.00000D+00
2	SEPS0141	2.60000D-06	6.00000D+00
3	SEPS0131	2.50000D-06	6.00000D+00
4	SEPS0151	2.50000D-06	6.00000D+00
5	SEPS0331	4.20000D-06	4.00000D+00
6	SEPS0111	1.00000D-06	8.00000D+00
7	SEPS0071	1.30000D-05	2.00000D+01
8	SEPS0081	5.20000D-06	9.00000D+00
9	SEPS0241	2.50000D-06	6.00000D+00
10	SEPS0091	8.00000D-06	2.00000D+01
11	SEPS0101	5.20000D-06	9.00000D+00
12	SEPS0281	2.50000D-06	6.00000D+00

*Case A: Loss of solar 480 V bus or 1500 hp motors

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*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                                               *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: LOSS OF SOLAR 2400V BUSES *
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	SEPS0121	5.20000D-06	9.00000D+00
2	SEPS0141	5.20000D-06	9.00000D+00
3	SEPS0131	5.20000D-06	9.00000D+00
4	SEPS0151	5.20000D-06	9.00000D+00
5	SEPS0331	4.20000D-06	4.00000D+00
6	SEPS0111	1.00000D-06	8.00000D+00
7	SEPS0071	1.30000D-05	2.00000D+01
8	SEPS0081	2.50000D-06	6.00000D+00
9	SEPS0241	2.50000D-06	6.00000D+00
10	SEPS0091	8.00000D-06	2.00000D+01
11	SEPS0101	2.50000D-06	6.00000D+00
12	SEPS0281	2.50000D-06	6.00000D+00

* Case B: Loss of power to heliostat field

SYSTEM INFORMATION-UPPER BOUNDS

D.8 LOSS OF SOLAR 2400V BUSES

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	2.07000000D-05	2.07000000D-05
7.30000000D+02	2.51762809D-04	2.07008362D-05	2.07060492D-05
1.46000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
2.19000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
2.92000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
3.65000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
4.38000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
5.11000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
5.84000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
6.57000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
7.30000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
8.03000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05
8.76000000D+03	2.51762809D-04	2.07008362D-05	2.07060492D-05

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.30000000D+02	1.51113052D-02	1.49995766D-02
1.46000000D+03	3.02229156D-02	2.97763081D-02
2.19000000D+03	4.53345260D-02	4.43313628D-02
2.92000000D+03	6.04461364D-02	5.86680661D-02
3.65000000D+03	7.55577469D-02	7.27896938D-02
4.38000000D+03	9.06693573D-02	8.66994723D-02
5.11000000D+03	1.05780968D-01	1.00400580D-01
5.84000000D+03	1.20892578D-01	1.13896147D-01
6.57000000D+03	1.36004189D-01	1.27189256D-01
7.30000000D+03	1.51115799D-01	1.40282946D-01
8.03000000D+03	1.66227409D-01	1.53180208D-01
8.76000000D+03	1.81339020D-01	1.65883988D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

*Case A: Loss of solar 480 V bus or 1500 hp motors

SYSTEM INFORMATION-UPPER BOUNDS

D.8 LOSS OF SOLAR 2400V BUSES (CONT)

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	2.34000000D-05	2.34000000D-05
7.30000000D+02	2.835540880D-04	2.340085700D-05	2.340749430D-05
1.46000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
2.19000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
2.92000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
3.65000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
4.38000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
5.11000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
5.84000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
6.57000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
7.30000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
8.03000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05
8.76000000D+03	2.835540880D-04	2.340085700D-05	2.340749430D-05

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.30000000D+02	1.708231280D-02	1.693961890D-02
1.46000000D+03	3.416493850D-02	3.359493070D-02
2.19000000D+03	5.124756410D-02	4.996806310D-02
2.92000000D+03	6.833018970D-02	6.606379680D-02
3.65000000D+03	8.541281540D-02	8.188683160D-02
4.38000000D+03	1.024954410D-01	9.744178770D-02
5.11000000D+03	1.195780670D-01	1.127332070D-01
5.84000000D+03	1.366606920D-01	1.277655540D-01
6.57000000D+03	1.537433180D-01	1.425432190D-01
7.30000000D+03	1.708259440D-01	1.570705160D-01
8.03000000D+03	1.879085690D-01	1.713516870D-01
8.76000000D+03	2.049911950D-01	1.853909020D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

*Case B: Loss of power to heliostat field

D.9 POWER SOLAR 115-2.4KJ POWER LINE

FTSM	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SEPS2-B	EPS10011	LOSS OF GRID FEED TO MAIN XFMR NO. 1	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C REDUNDANCY PROVIDED BY BACKUP SOURCE 2
SEPS2-C	EPS20011	LOSS OF GRID FEED TO RES. STA. SERV. XFMR	ANNUNCIATED IN CONTROL ROOM	LOSS OF BACKUP POWER SOURCE 2	CATEGORY C BACKUP POWER SUPPLY
SEPS2-A	EPS30011	LOSS OF POWER SUPPLY TO SOLAR PLANT FROM GRID	ANNUNCIATED IN CONTROL ROOM	LOSS OF SOLAR 115-2.4 KV POWER LINE	***SINGLE FAILURE*** CATEGORY A SOLAR PLANT SHUTDOWN
SEPS2-B	EPS10021	115-2.4 KV MAIN XFMR NO. 1 FAILS	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-C	EPS20021	115-2.4 KV RES. STA. SERV. XFMR FAILS	ANNUNCIATED IN CONTROL ROOM	LOSS OF BACKUP POWER SOURCE 2	CATEGORY C BACKUP POWER SUPPLY
SEPS2-D	EPS10031	INCOMING LINE 1 DISCONNECTOR FAILS OPEN	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-C	EPS20031	RES. STA. SERV. XFMR DISCONNECTOR FAILS OPEN	ANNUNCIATED IN CONTROL ROOM	LOSS OF BACKUP POWER SOURCE 2	CATEGORY C BACKUP POWER SUPPLY
SEPS2-D	EPS10041	SOLAR AUX XFMR NO. 1 FAILS	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-C	EPS20041	INCOMING LINE 2 DISCONNECTOR FAILS OPEN	ANNUNCIATED IN CONTROL ROOM	LOSS OF BACKUP POWER SOURCE 2	CATEGORY C BACKUP POWER SUPPLY
SEPS2-D	EPS10051	INCOMING LINE 1 CIRCUIT BREAKER FAILS TO REMAIN CLOSED	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-C	EPS20051	INCOMING LINE 2 CIRCUIT BREAKER FAILS TO CLOSE ON DEMAND	ANNUNCIATED IN CONTROL ROOM	LOSS OF BACKUP POWER SOURCE 2	CATEGORY C REQUIRED IF POWER SOURCE 1 UNAVAILABLE

4	3	2	1	FAILURE MODES AND EFFECTS ANALYSIS SOLAR 115-2.4 KV POWER LINE FMEA-SEPS21 SH 1

FTSK	COMPONENT IDENTIFIER	COMPONENT AND FAILURE MODE	METHOD OF FAILURE DETECTION	EFFECT ON SYSTEM	OTHER REMARKS
SEPS2-B	EPS10061	UNIT 1 GENERATOR FAILS	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-C	EPS20061	INCOMING LINE 2 BREAKER RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF BACKUP POWER SOURCE 2	CATEGORY C REQUIRED IF POWER SOURCE 1 UNAVAILABLE
SEPS2-D	EPS10071	INCOMING LINE 1 BREAKER RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-B	EPS10081	NORM. STA. SERV XFMR DISCONNECTOR FAILS OPEN	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-B	EPS10091	NORM. STA. SERV. XFMR FAILS	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-B	EPS10101	UNIT 1 2400V BUS SHORT CIRCUIT	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2
SEPS2-B	EPS10111	NORM. STA. SERV. XFMR BREAKER OPEN OR RELAYS FAIL	ANNUNCIATED IN CONTROL ROOM	LOSS OF POWER SOURCE 1	CATEGORY C FAST TRANSFER TO POWER SOURCE 2

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********************************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM - TREBIL.V6L1                                           *
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EL PASO SOLAR REPOWERING NEWMAN UNIT 1: LOSS OF SOLAR 115-2.4 KV POWER LINE
* OPERATING MODE
ENDOPM
* RATES

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	EPS20021	1.00000D-05	6.00000D+01
2	EPS20031	1.00000D-05	8.00000D+00
3	EPS20051	1.00000D-06	8.00000D+00
4	EPS20061	4.20000D-06	4.00000D+00
5	EPS10031	1.00000D-05	8.00000D+00
6	EPS10041	1.00000D-05	6.00000D+01
7	EPS10051	1.00000D-06	8.00000D+00
8	EPS10071	4.20000D-06	4.00000D+00
9	EPS10081	1.00000D-05	8.00000D+00
10	EPS10091	1.00000D-05	6.00000D+01
11	EPS10101	1.30000D-05	2.00000D+01
12	EPS10111	5.20000D-06	9.00000D+00
13	EPS20011	3.50000D-05	8.00000D+00
14	EPS20041	1.00000D-05	8.00000D+00
15	EPS10011	3.50000D-05	8.00000D+00
16	EPS10021	1.00000D-05	6.00000D+01
17	EPS10061	2.85000D-05	5.00000D+01
18	EFS30011	1.79000D-05	4.00000D+00

SYSTEM INFORMATION-UPPER BOUNDS

D.9 LOSS OF 115-2.4KJ POWER LINE

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	H	L
0.0	0.0	1.790000000D-05	1.790000000D-05
7.300000000D+02	7.584485850D-05	1.832461150D-05	1.832600140D-05
1.460000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
2.190000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
2.920000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
3.650000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
4.380000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
5.110000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
5.840000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
6.570000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
7.300000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
8.030000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05
8.760000000D+03	7.584485850D-05	1.832461150D-05	1.832600140D-05

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	HSUM	FSUM
7.300000000D+02	1.322198320D-02	1.313545740D-02
1.460000000D+03	2.659894960D-02	2.624979530D-02
2.190000000D+03	3.997591600D-02	3.918985810D-02
2.920000000D+03	5.335288240D-02	5.195796190D-02
3.650000000D+03	6.672984880D-02	6.455639160D-02
4.380000000D+03	8.010681520D-02	7.698740220D-02
5.110000000D+03	9.348378160D-02	8.925321840D-02
5.840000000D+03	1.068607480D-01	1.013560350D-01
6.570000000D+03	1.202377140D-01	1.132980190D-01
7.300000000D+03	1.336146810D-01	1.250813080D-01
8.030000000D+03	1.469916470D-01	1.367080090D-01
8.760000000D+03	1.603686140D-01	1.481802040D-01

*****CONCLUSION OF OUTPUT FROM KITT-1*****

APPENDIX E

APPENDIX E

DETAILS OF FOSSIL AND SOLAR SIMULATION MODELS

E.1 OBJECTIVE

The objectives of this report are to describe the fossil and solar simulation models and to present the detailed results from these simulation models.

E.2 OVERVIEW

This report documents the support information and data for the Solar/Fossil System Transient Analysis described in Section 4.5.2 of the report. A summary of results is presented in Section 4.5.2.3. Section E.3 presents a description of the fossil simulation model and the comparisons of model predictions and test data. Section E.4 presents a description of the solar simulation model and a graphic representation of the predictions.

All of the simulation models were programmed in the ACSL language, a FORTRAN-based simulation language (Reference 1). The programs were run on an IBM 4341 in the interactive mode (VM-CMS operating system). The run times for the models are as follows:

1. Fossil system model, approximately 4 simulated seconds per CPU second.

2. Solar system model approximately 2 simulated seconds per CPU second.

E.3 FOSSIL SYSTEM SIMULATION

E.3.1 Fossil Simulation Model

The fossil system simulation was derived from a previous simulation model of a bark burning boiler system performed by SWEC.

The fossil system simulation includes models of the fossil boiler, feed pump system, and attemporation system. The component models included in the fossil system representation are the following:

- Combustion model
- Superheater
- Radiant evaporator
- Economizer
- Air preheater
- Steam drum
- Downcomer
- Riser

- Feed pump system
- Controls

A block diagram of the fossil boiler air/gas path is presented in Figure E.3-1. The models used in the feedwater system, boiler water/steam path, and reheater are illustrated in block diagram form in Figures E.3-2 through E.3-4. These component models had been fully developed by SWEC for prior simulation activities with exception of the radiant evaporator.

A brief description of each of the component models is presented as follows:

1. Combustion Model - This is an algebraic model utilizing fuel and air inlet flow and temperature to determine the theoretical combustion temperature and oxygen level of the exhaust gas.

2. Superheater - The steam and flue gas temperatures leaving the superheater are evaluated in this model. The rate of change of steam outlet temperature is related to the exhaust gas flow and inlet temperature, steam flow and inlet temperature, overall heat transfer coefficient, and surface area.

3. Radiant Evaporator - This is a one-dimensional nodal model which divides the radiant evaporator length into small sections. The heat transfer to each section is determined sequentially using the gas inlet temperature, section surface area, and radiant heat transfer coefficient. The effect of changing the burner pattern is modeled by changing the length of the radiant evaporator. This length is currently determined by the weighted mean distance from the operating burners to the superheater.

4. Economizer - This model is basically structured in the same manner as the superheater model. The outputs are water and flue gas outlet temperatures.

5. Air Preheater - Outlet air and flue gas temperatures are determined differentially. Heat transfer is governed by air and gas flows raised to the 0.6 power.

6. Steam Drum Model - The steam drum model is the center of the steam/water side representation. This model evaluates the drum pressure and the corresponding saturation properties, drum level, drum water subcooling, primary superheater outlet pressure, and total steam production rate. This model feeds data to the downcomer and riser models to evaluate circulation flow and quality.

In the first sequence of calculations, the heat input to steam generation is evaluated accounting for feedwater and drum subcooling and steam condensation within the drum. Based on the heat input to steam generation and the steam outflow from the boiler, the boiler drum pressure and superheater outlet pressure are evaluated.

The subcooling level (liquid enthalpy) of the steam drum is calculated based on an energy balance of the water within the drum. Flashing of drum water is predicted, if drum pressure falls while the drum water is at saturation. The drum water subcooling is input to the downcomer model to evaluate flashing in the downcomer and the overall natural circulation flow of the drum/downcomer/riser circuit.

Level of water in the steam drum is the final calculation. The level is determined from the mass of water in the drum and the liquid density. A constant is used to represent volume per unit level change, and this is fairly representative over the level control range in the boiler. Drum level swell due to steam flashing within the steam drum is neglected, since its impact is typically very minor.. Flashing and steaming in the risers have the largest impact on drum level swell.

7. Downcomer - The downcomer model was developed to predict the impact on natural and forced circulation of flashing of the downcomer water. Using the DELAY routine (Reference 1, ACSL), the enthalpy of drum water is transported through the downcomer. The pressure is evaluated at the base of the downcomer accounting for elevation head and friction. The steam quality and density of the fluid at the base of the downcomer is then determined from the enthalpy and pressure. The average downcomer density is determined as the average of the inlet and base downcomer densities.

8. Riser - The riser model makes use of the continuity of mass, energy, and momentum equations to determine the inlet and outlet mass flow rates and outlet steam quality. The rate of change of inlet flow is calculated based on the momentum equation, and the outlet flow is determined from the continuity of mass and energy equations.

   One aspect of the riser model is the use of the homogeneous two-phase flow equations for friction calculations. To verify this approach, it was compared with the Martinelli-Nelson correlation. Due to the favorable comparison and the simplicity of the approach, it is used in the riser section.

The model is configured to accept a pump by inputting a pump head flow function. This allows the model to handle both natural and forced circulation and, thereby, makes it more general.

9. Feedpump System - Feedwater flow is determined based on the manufacturer's pump map and the calculated pressure rise across the pump. A deaerator pressure model, pump suction line, pump discharge line, and control valve models are included to determine pressures and flows in the feedwater line. Pressures at the superheat and reheat attemperator feed lines are predicted. The flows through the attemperator lines are evaluated based on the pressure drop across the lines, the line resistances, and valve positions.

10. Controls - There are four control loops represented in the simulation model: the combustion control, feedwater control, superheat temperature control, and reheat temperature control. The combustion control is based on turbine inlet pressure with a feed forward from steam flow and regulates fuel and air flow. Feedwater is regulated by a 3-element control (steam flow, feedwater flow, and drum level). Superheat temperature control has superheat outlet temperature as its primary input with feed forward signals from the superheat attemperator outlet temperature and air flow. Reheat temperature control is based on reheat outlet temperature with a feed forward from steam flow.

The Newman Unit 1 has symmetrical "north/south" primary and secondary superheaters and reheaters. Since the heat flux loadings to the north and south sides appear to be equivalent for symmetric burner patterns, the fossil simulation model represents a single primary superheater, secondary superheater, and reheater representing the total heat transfer area of the north and south sides. It is noteworthy that during transient testing and observed normal operation, EPE operators maintained symmetric burner patterns with the exception of the burner sequence test, where burner patterns were intentionally varied.

E.3.2 Fossil Simulation Comparisons with Test Data

A series of transient tests were conducted on Newman Unit 1 and are described in Section E.5. To test the validity of the fossil simulation model, comparisons were made with a step change test, Test 1B, a step change of 15 percent to half load. Initially the comparisons were not favorable. Upon further investigation the model was found to be deficient in certain areas and the following changes were made:

1. A steam flow feed forward to the combustion control had been retrofitted to the unit and was added to the model.

2. A manual fuel/air ratio bias control was added to the model and calibrated according to the plant circular day chart recordings of oxygen level.

3. The capacitance effect for the large mass of metal associated with the evaporator was included in the model.

4. The plant drum pressure reading which was indicating a very large superheater pressure drop was reduced to more closely reflect expected values.

With these changes the model was again compared to the test data. Steam flow test data was the driving function for the simulation model. The resulting comparisons are highly favorable and are illustrated in Figures E.3–5 through E.3–12.

The first figure (E.3–5) illustrates the driving function (steam flow) and the comparisons between drum level and feedwater flow predictions and data. Since drum level upsets are primarily determined by transient two-phase flow variations in the riser section, this close agreement is a strong verification of the downcomer, riser, and drum circuit models.

Turbine inlet pressure along with fuel and air flow are illustrated in Figure E.3–6. To obtain reasonable agreement with the superheat and reheat temperature data, it was crucial to properly predict the turbine inlet pressure profile. The relatively small variation in turbine inlet pressure for such a large change in steam flow was a key in determining that the drum pressure data was about 50 psi high.

The slow recovery of turbine inlet pressure is an indication of the slow response of the combustion controls. This slow response apparently results in superheater temperature transients presented in Figure E.3-7. At approximately 60 seconds, steam flow is rapidly reduced. However, fuel and air flow decrease at a much slower rate. The short-term effect is to have more energy available to the superheater than the steam flow can remove, resulting in an increase in superheat steam temperature. Then fuel and air flow undershoot the steady state value, causing steam temperatures to drop. On the fuel/air upswing, temperatures rise. This case illustrates the tight coupling between superheat temperatures and the combustion control.

The predictions of superheat temperature and attemperator valve position were initialized according to the average of east and west side conditions and agree very well with the time average data.

Figure E.3–8 presents the comparisons of reheat temperature predictions and data. The reheat attemperator block valves were closed so reheat attemperator temperature reflects cold reheat temperature. Note how this temperature drops. This drop is associated with the throttling action of the governor valves. This temperature profile was input to the fossil simulation model for lack of a turbine stage temperature model.

The air preheater flue and air gas temperature comparisons are illustrated in the next figure (Figure E.3-9). It appears the plant temperature measurement has a much longer time constant than the data.

To make comparisons with the predicted primary superheater outlet temperature, the metal temperature data from the primary to secondary superheater cross-over was used. The variations in temperature are significantly larger than the predictions; however, the attemperator outlet temperatures are very close. It may be possible that the cross-over temperature dropped more due to the reduction in steam to wall heat transfer and high heat losses.

The percentage of oxygen in the flue gas is illustrated in the next figure, E.3-11. The oxygen sensor data acquired during testing was not sufficiently amplified to obtain good resolution. To obtain a comparison, oxygen data was taken form the 24-hour circular day chart. Time resolution was difficult, but the interpreted data is presented. The manual excess air control bias input to the model was based on an average value over the 2-day test period. The difference may be a result of operator adjustments. Such adjustments were often observed during the test period.

The last figure, E.3-12, illustrates pump suction and discharge pressure comparisons. In the fossil simulation model, both pumps are assumed to perform identically. During the test the measured discharge pressure of Pump A was considerably less than B (200 psi). Pump A performance limited testing at full load.

The overall agreement of the model with the test data is very good. However, further comparisons with other tests should be conducted to ensure validity over the entire operating range.

E.4 SOLAR SYSTEM SIMULATION

E.4.1 Solar Simulation Model

The solar system simulation program was developed to stand alone, i.e., without the fossil program. With this approach the programs have been structured for smooth integration when the two models are required for a total solar/fossil plant simulation. Wherever possible, the programs share the same component models.

The solar system simulation model includes models of the solar receiver, attemperation system, bias valve system, external reheater, turbine, piping, and controls. The component models included in the solar system simulation program are briefly described as follows:

1. Solar superheater - A differential model which evaluates outlet steam temperature and average metal surface temperature based on input flux (total flux less reflected). Radiant and convective heat losses are based on the calculated average metal surface temperature.

2. Solar evaporator - An algebraic model determining net heat input by subtracting calculated radiant and convective losses from the input flux.

3. Solar economizer - It is the same as the superheater model evaluating water outlet temperature and average metal surface temperature.

4. Reheater - This model is the same as the air preheater model (fossil system).

5. Steam drum, downcomer, and riser models are the same models used in the fossil system.

6. Biasing valve flow - The biasing valve was modeled as an orifice with linearly variable area. The steam flow was calculated according to the perfect gas relationship for orifice flow. This model effectively represents the dynamic characteristics of biasing valve flow control.

7. Attemperator flow - Since attemperator valve data and solar feedwater hydraulic data were not available, attemperator flow was modeled to linearly vary with control valve position.

8. Turbine - The turbine governor valve was represented by a variable orifice model similar to the biasing valves. Turbine power was determined from inlet steam properties assuming constant efficiency.

9. Feedwater flow - For lack of feedwater system hydraulic data, feedwater flow was assumed to vary linearly with valve position.

10. The controls for the receiver subsystem are described in detail in Section 5.3.

An overview of the solar system simulation is illustrated in block diagram form in Figure E.4-1. The solar simulation model of the receiver represents both east and west sides, which are symmetrical. Each panel type on a given side of the boiler is represented by one component model. The correspondence between component models and number of panels of this type on a given side is as follows:

1. One economizer - two economizer panels

2. One evaporator - seven pairs of evaporator sections (one per superheater panel)

3. One PS1 (primary superheater 1) - two PS1 panels

4. One PS2 - one PS2 panel

5. One PS3 - one PS3 panel

6. One FS1 (final superheater 1) - two FS1 panels

7. One FS2 - one FS2 panel

This lumping was required to maintain a more manageable program. Even with these simplifications, 4 Mbytes of storage were required to compile the solar simulation model.

The lumping of the economizer and evaporator panels appears to provide adequate representation of these sections, based on prior modeling experience. The lumping of the PS1 panels and FS1 panels removes four biasing valves from the representation. However, four biasing valves are left in the model (vs eight in the actual receiver). It is felt that the biasing valve control logic can be adequately tested with the four biasing valves represented. The predominant east/west division is maintained in the model.

The detailed structure of the solar model is illustrated in block diagram form in Figures E.4-2 through E.4-6. These illustrate the economizer and evaporator paths, the primary superheat thermal and hydraulic representations including biasing valves and attemperators, and the final superheat thermal and hydraulic models.

The control logic for the attemperators, drum level, and turbine throttle valve are illustrated in Figures E.4-7 through E.4-9. The biasing valve control logic is presented in Section 5.3.

E.4.2 Solar Simulation Results

The results from three case studies are presented here. Case 1 and 1A represent the response to a fast rectangular cloud (20 m/sec), 4800 meters wide, covering the heliostat field from west to east and uncovering the field 4 minutes later. The primary difference in the cases is the change in biasing valve control. In Case 1 the biasing valves are held closed by the biasing valve temperature control function even after solar flux is reinitiated. This resulted in a rapid rise in superheater outlet panel temperatures and the model terminated (see Figures E.4-10 through E.4-21).

In Case 1A the biasing valve temperature control function was removed by setting the gain to zero. The simulation continued to its normal termination. These results are illustrated in Figures E.4-22 through E.4-33.

The first two graphs (Figures E.4-22 and E.4-23) illustrate primary and final superheater outlet temperature for each stage on the east and west sides. In the initial stages of the transient these temperatures cool at a rate of 0.5° to 1°C/sec (1° to 2°F/sec). At 4 minutes, when the cloud begins to uncover the field, panel outlet steam temperatures rise at a rate of approximately 3°C/sec (5°F/sec) as the cloud clears. Peak temperatures are effectively controlled by the attemperator system and do not exceed setpoints by more than 28°C (50°F). The fast temperature rise may be the limiting aspect of this transient for the superheater panels. (Note that the final superheat panels are designated "SS" as opposed to "FS" in the graphs).

Figure E.4-24 illustrates reheat and main steam temperatures at the turbine. The large thermal capacity of the piping has tempered the drop in steam temperatures at the receiver. Main steam temperature drops about 22°C (40°F) and reheat temperature about 14°C (25°F).

The effect of biasing valve regulation of steam drum pressure is displayed in Figure E.4-25. The turbine is operating in sliding pressure and its inlet pressure drops to about 0.7 kPa (100 psia). Drum pressure rises rapidly approximately 0.06 kPa/sec (8 psi/sec), when the cloud clears, which may exceed manufacturer's recommendations.

Turbine power level and system steam flows are illustrated in Figure E.4-26. Note that turbine power is maintained above 2 MW.

The attemperator flows for the primary and final superheaters are illustrated in Figures E.4-27 and E.4-28. At the beginning of the transient, attemperator flow increases to the east side as available steam flow is dropping and eastern solar flux is still at a maximum. Both first and second-stage attemperation are required to hold steam outlet temperature when the cloud initially clears. These high attemperation rates are required because steam flow has not yet reached its initial value.

Biasing valve action is illustrated in Figure E.4-29. The primary superheater biasing valves close down to regulate steam drum depressurization. The upward valve position spikes are caused by high superheater outlet temperature override logic. Recall the normal temperature control gain was set to zero to allow the biasing valves to reopen when flux was reapplied.

Drum level variations are illustrated in Figure E.4-30. A high drum level condition develops when heat flux is increased rapidly. This is followed by a rapid decrease in level as the steam drum pressurizes.

The evaporator circuit flows and qualities are illustrated in Figure E.4-31. The prediction of flashing at the pump suction for approximately a 60-second duration is also illustrated.

The last two figures, E.4-32 and E.4-33, illustrate the average panel metal temperatures used in the convection and radiation heat loss circulations.

Case 2 represents the predicted response to a round cloud travelling west to east a 6 m/sec. The cloud area is equal to half the area of the collector field and moves tangent to the southern edge of the field.

The predicted parameters are illustrated in Figures E.4-34 through E.4-45. These results illustrate the biasing and attemperator systems adequately control temperature. Some valve cycling is predicted. Drum level control appears adequate as well. Refer to the graphical data for more detail.

E.5 TRANSIENT TEST DATA

Test data was taken during the week of June 13, 1983. The following seven individual plant transient tests were run:

1. A step up in power of greater than 10 percent from 40 MW followed by a step down back to 40 MW
2. A burner sequence test at 40 MW changing the burner pattern at constant load
3. A ramp from 40 MW to 80 MW in 10 minutes
4. A rapid unloading of greater than 10 percent from 80 MW followed by a loading back up to 80 MW
5. A ramp down from 80 MW to 40 MW in 10 minutes
6. A ramp from 25 MW (minimum load) to 65 MW in 20 minutes followed by a ramp down from 65 MW to 25 MW in 20 minutes
7. A step down from 36 MW to 25 MW and back up to 36 MW

A detailed description of test procedures and data analysis has been prepared and issued separately, due to its very detailed nature.

REFERENCE

1. "Advanced Continuous Simulation Language (ACSC)," Mitchell and Gauthier, Assoc, Inc., 1981, Version 7.

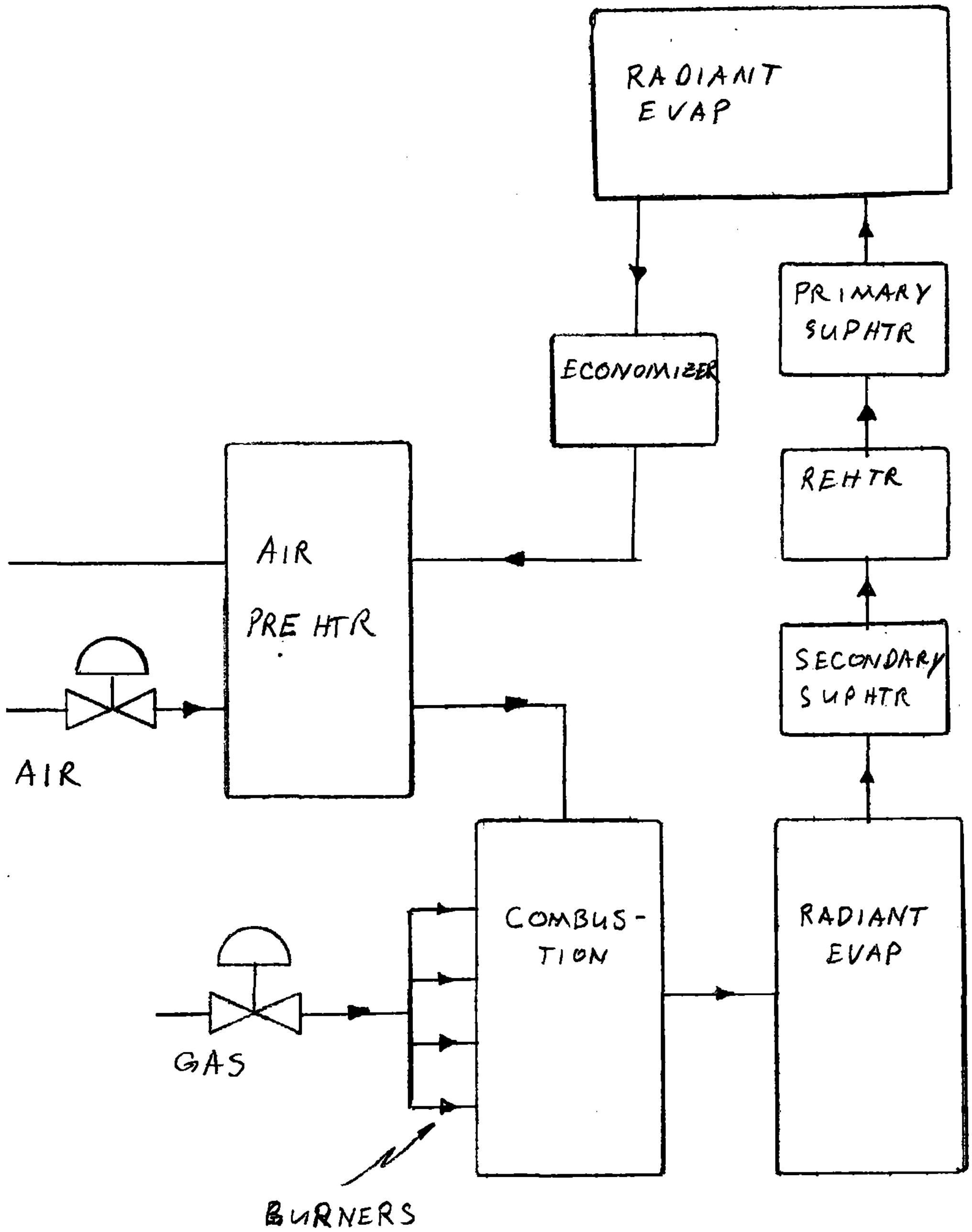


FIGURE E.3-1

NEWMAN 1 FOSSIL BOILER GAS PATH SIMULATION BLOCK DIAGRAM

OEL
1/19/83

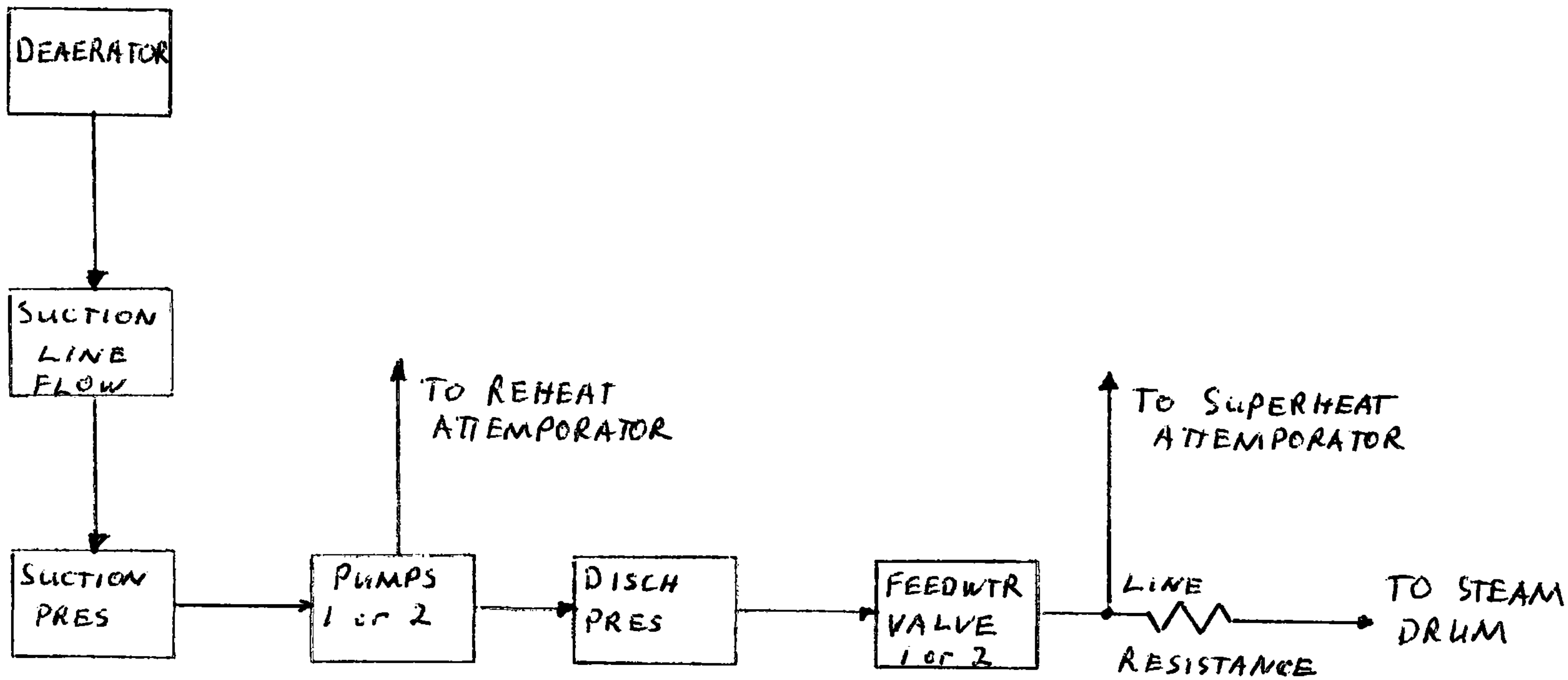


FIGURE E.3-2

NEWMAN 1 FOSSIL FEEDWATER

SIMULATION BLOCK DIAGRAM

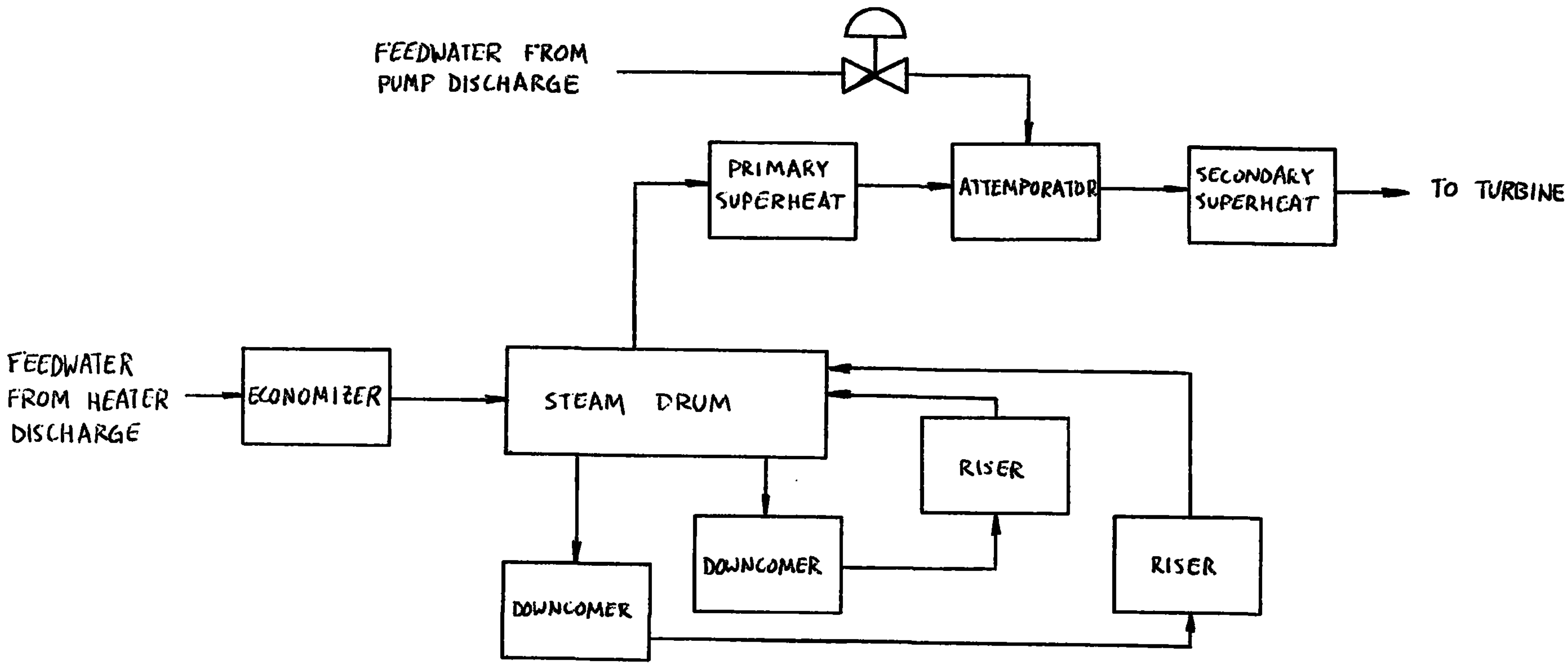


FIGURE E.3-3

NEWMAN I FOSSIL BOILER WATER/STEAM PATH

SIMULATION BLOCK DIAGRAM

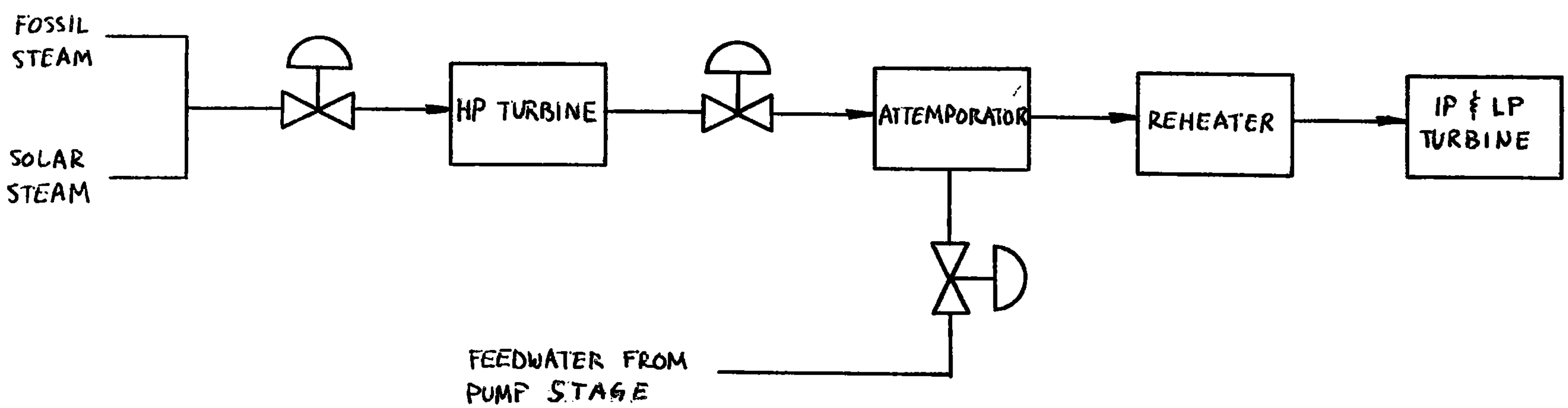
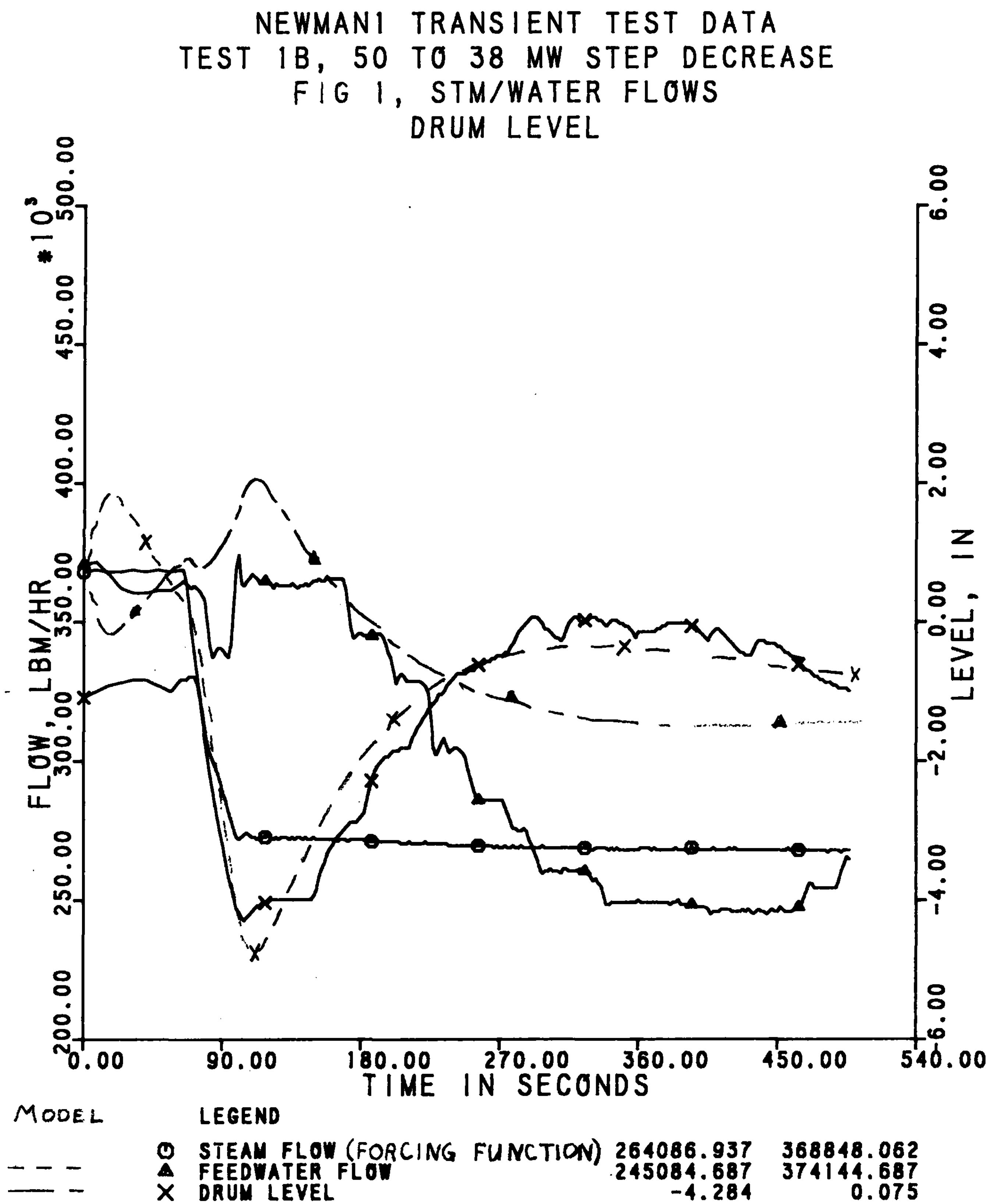


FIGURE E.3-4

NEWMAN I TURBINE/REHEAT PATH

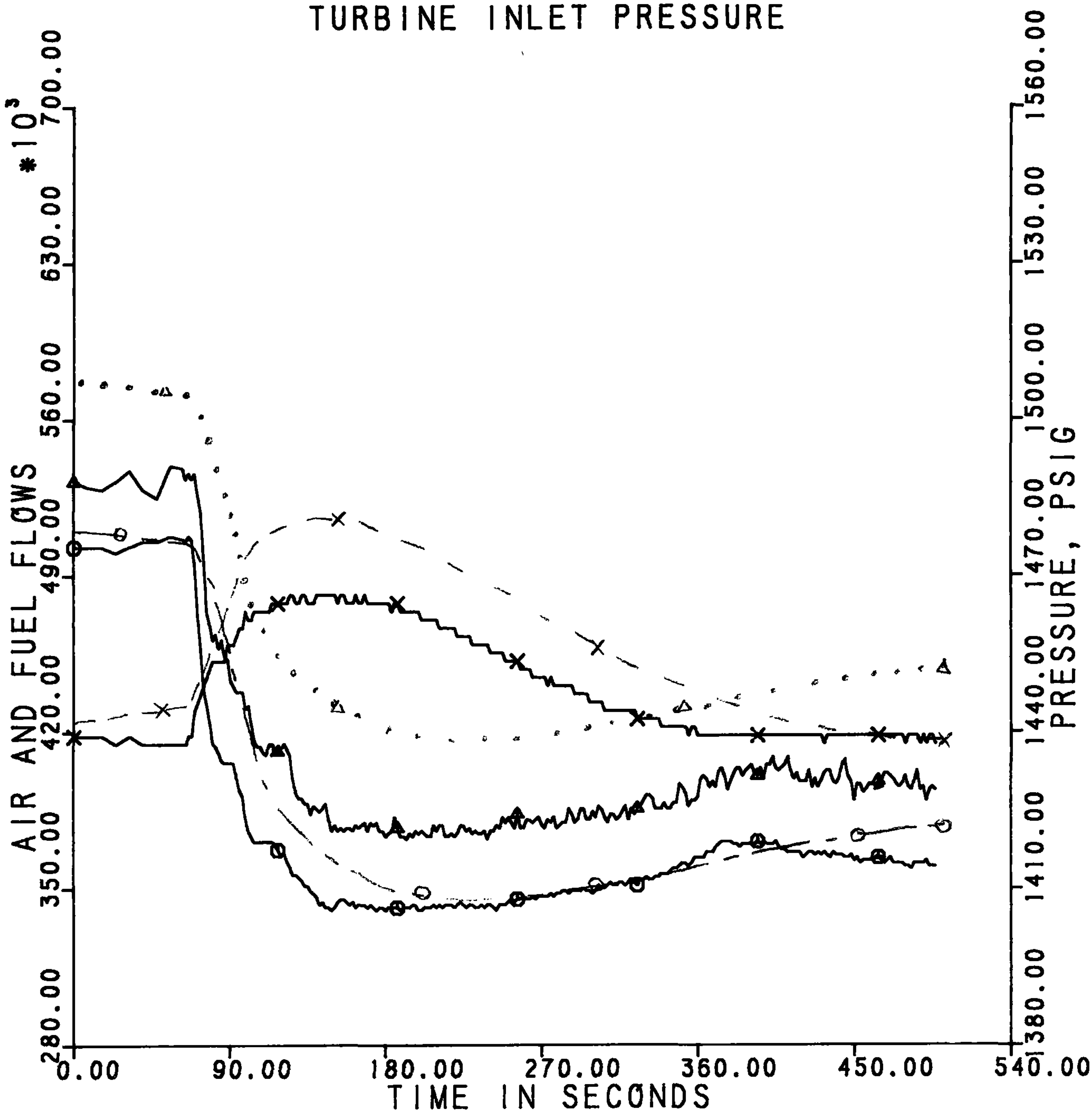
SIMULATION BLOCK DIAGRAM



NEWMAN1 TRANSIENT TEST DATA
TEST 1B, 50 TO 38 MW STEP DECREASE
FIG 1, STM/WATER FLOWS
DRUM LEVEL
FLOW, LBM/HR *10^3
200.00
250.00
300.00
350.00
400.00
450.00
500.00
LEVEL, IN
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
0.00
90.00
180.00
270.00
360.00
450.00
540.00
TIME IN SECONDS
MODEL
LEGEND
STEAM FLOW (FORCING FUNCTION) 264086.937 368848.062
FEEDWATER FLOW 245084.687 374144.687
DRUM LEVEL -4.284 0.075

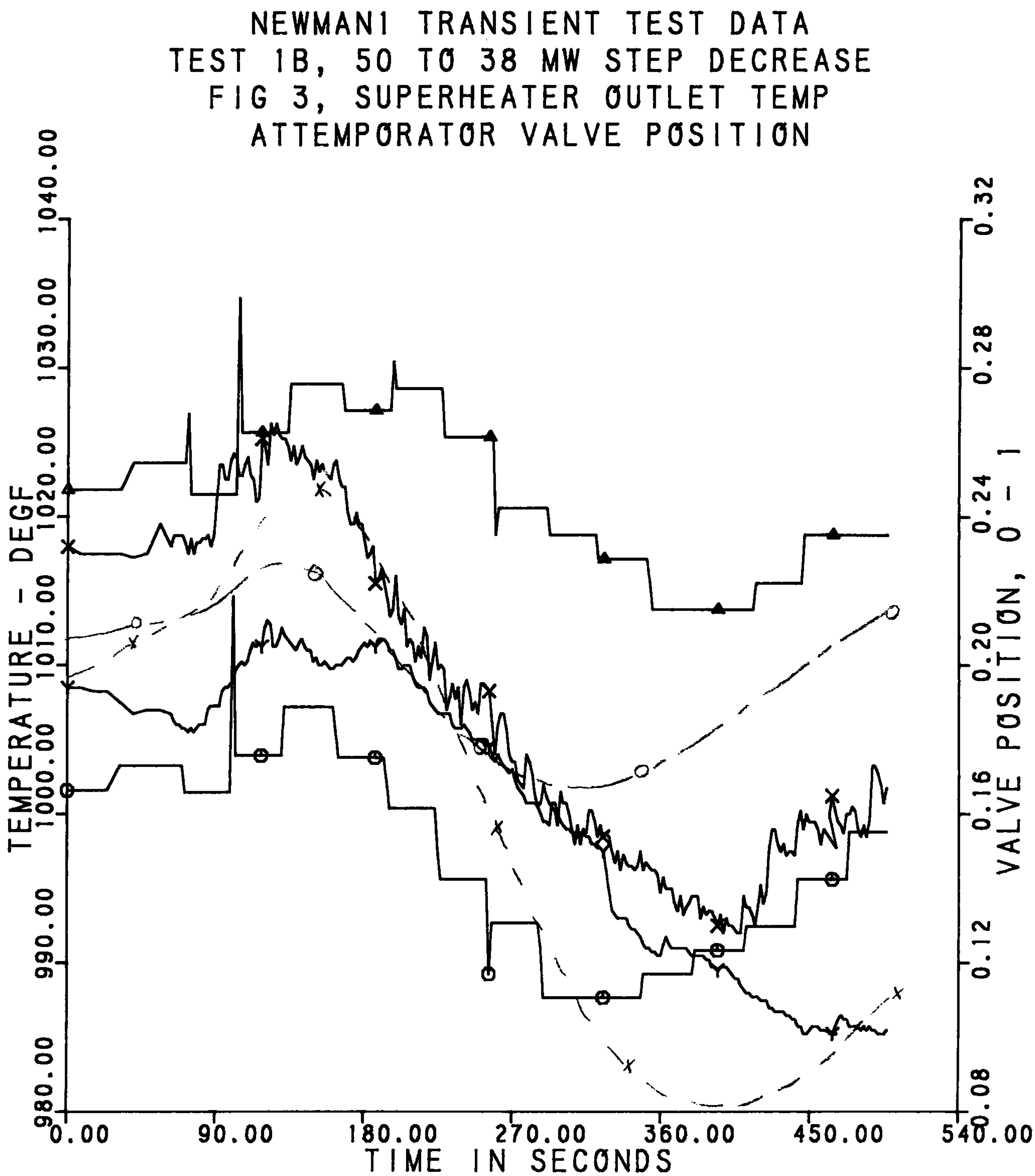
FIGURE E.3-5

NEWMAN1 TRANSIENT TEST DATA
TEST 1B, 50 TO 38 MW STEP DECREASE
FIG 2, FUEL/AIR FLOWS
TURBINE INLET PRESSURE



MODEL		LEGEND		
—— —	⊙	FUEL FLOW, SCFH	340353.000	507629.812
. . . . .	△	AIR FLOW, SCFH	372098.437	539375.250
— — —	X	TURBINE INLET PRESSURE, PSIG	1431.349	1466.267

FIGURE E.3-6



MODEL

LEGEND

MODEL				
— —	O SOUTH SUPERHEATER OUT TEMP		987.656	1014.597
	△ NORTH SUPERHEATER OUT TEMP		1013.709	1034.707
— — —	X SOUTH SUP ATTEMP VALVE POS		0.128	0.265
	Y NORTH SUP ATTEMP VALVE POS		0.101	0.212

FIGURE E.3-7

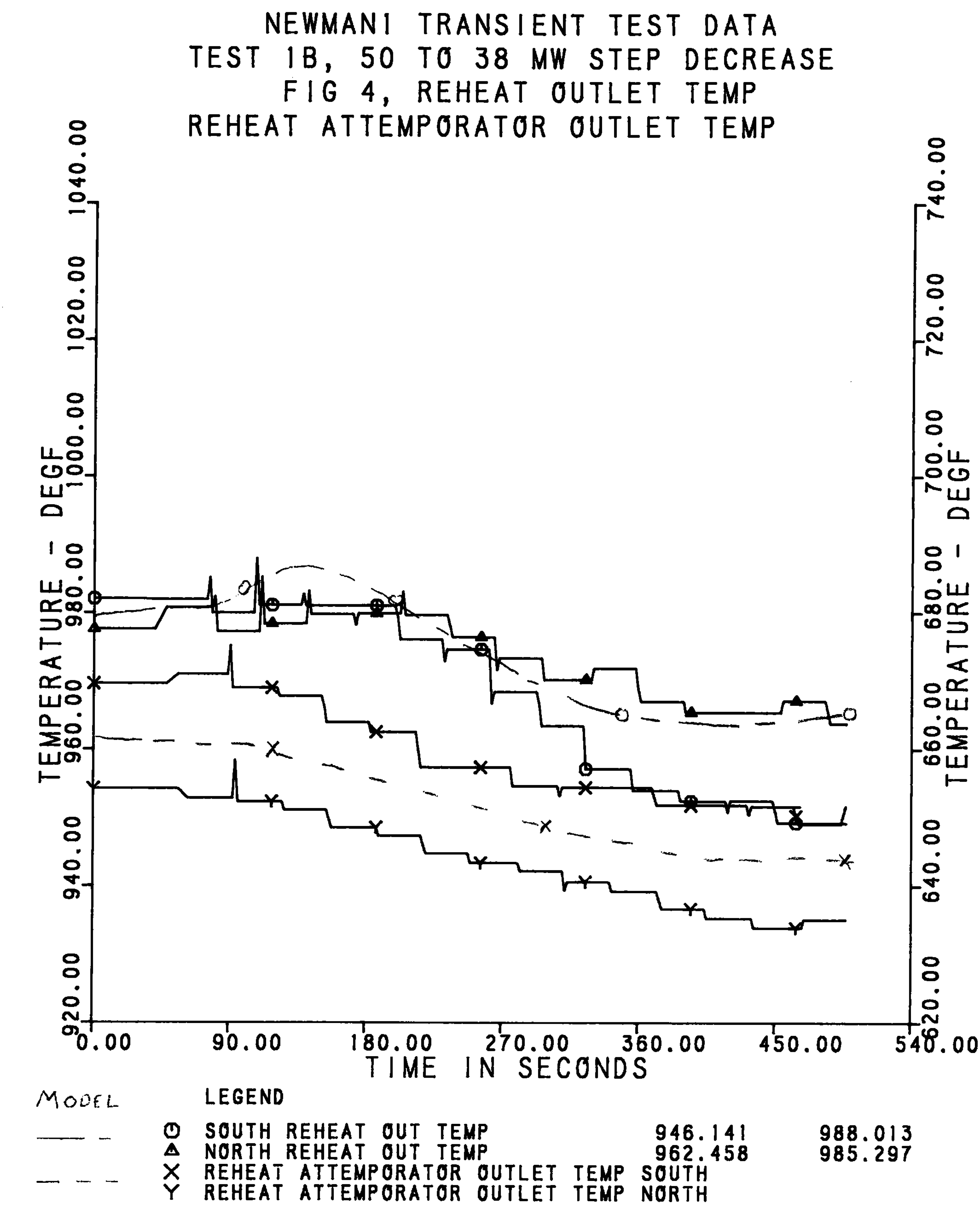
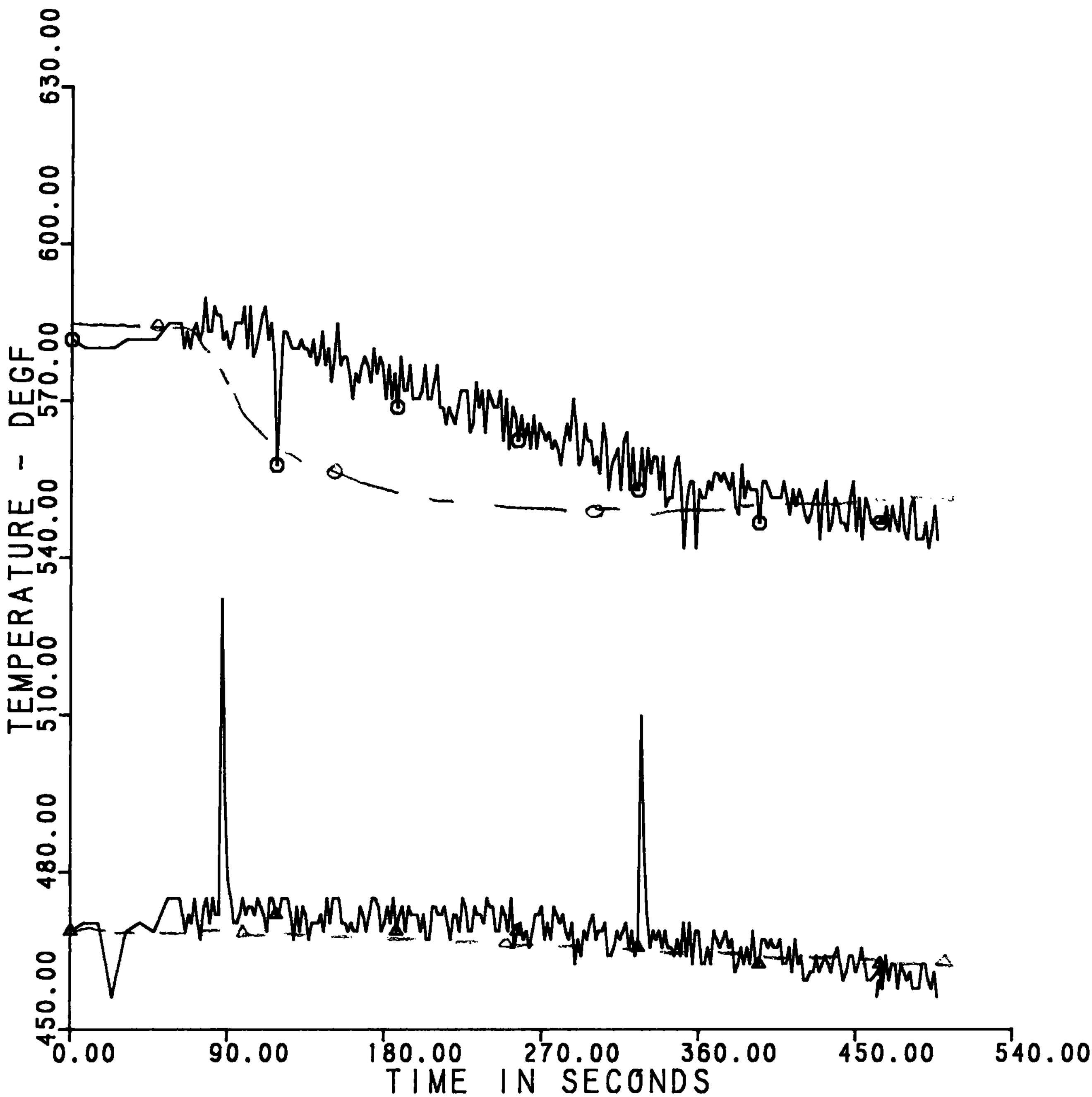

NEWMAN1 TRANSIENT TEST DATA
TEST 1B, 50 TO 38 MW STEP DECREASE
FIG 4, REHEAT OUTLET TEMP
REHEAT ATTEMPORATOR OUTLET TEMP
TEMPERATURE - DEGF
920.00
940.00
960.00
980.00
1000.00
1020.00
1040.00
620.00
640.00
660.00
680.00
700.00
720.00
740.00
0.00
90.00
180.00
270.00
360.00
450.00
540.00
TIME IN SECONDS
MODEL
LEGEND
SOUTH REHEAT OUT TEMP 946.141 988.013
NORTH REHEAT OUT TEMP 962.458 985.297
REHEAT ATTEMPORATOR OUTLET TEMP SOUTH
REHEAT ATTEMPORATOR OUTLET TEMP NORTH

FIGURE E.3-8

NEWMAN1 TRANSIENT TEST DATA
TEST 1B, 50 TO 38 MW STEP DECREASE
FIG 5, AIR PREHEATER TEMPS

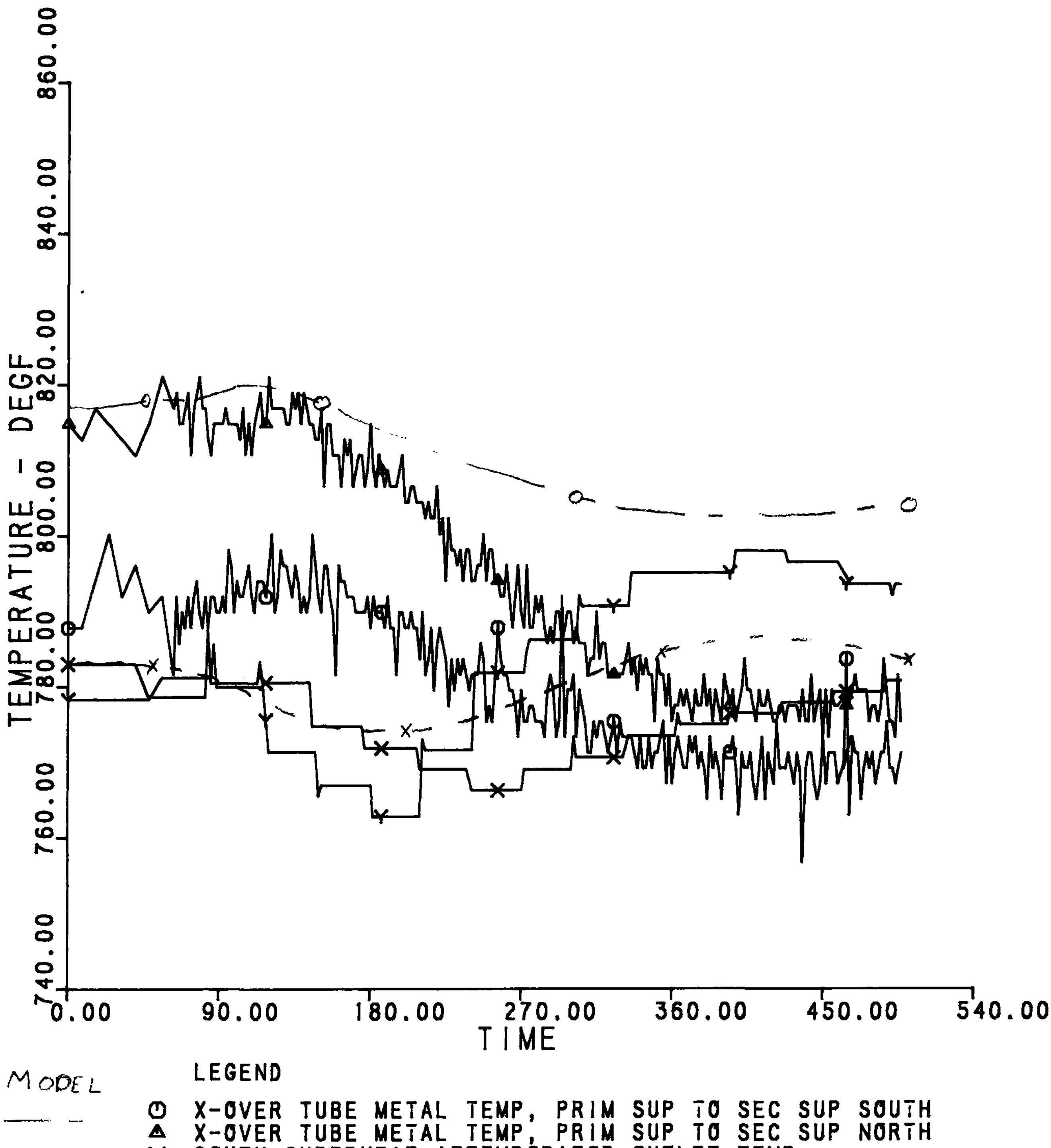


MODEL LEGEND

O AIR PREHEATER FLUE GAS IN TEMP
△ AIR PREHEATER AIR OUT TEMP 440.412 532.268

FIGURE E.3-9

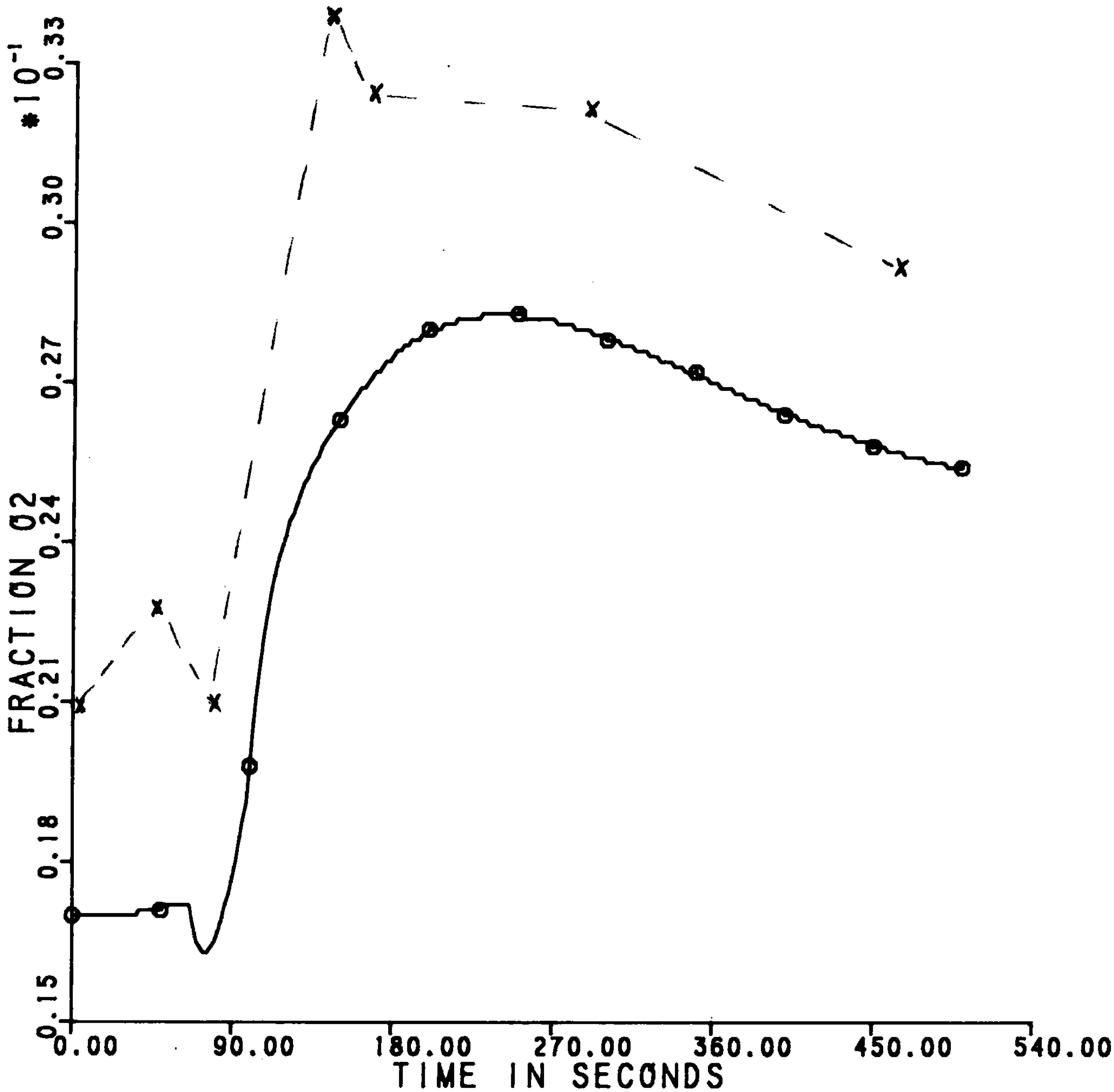
NEWMAN1 TRANSIENT TEST DATA
TEST 1B, 50 TO 38 MW STEP DECREASE
FIG 6, PRI SUP AND ATTEMP OUTLET TEMPS



LEGEND
- O X-OVER TUBE METAL TEMP, PRIM SUP TO SEC SUP SOUTH
- ▲ X-OVER TUBE METAL TEMP, PRIM SUP TO SEC SUP NORTH
- X SOUTH SUPERHEAT ATTEMPORATOR OUTLET TEMP
- Y NORTH SUPERHEAT ATTEMPORATOR OUTLET TEMP

FIGURE E.3-10

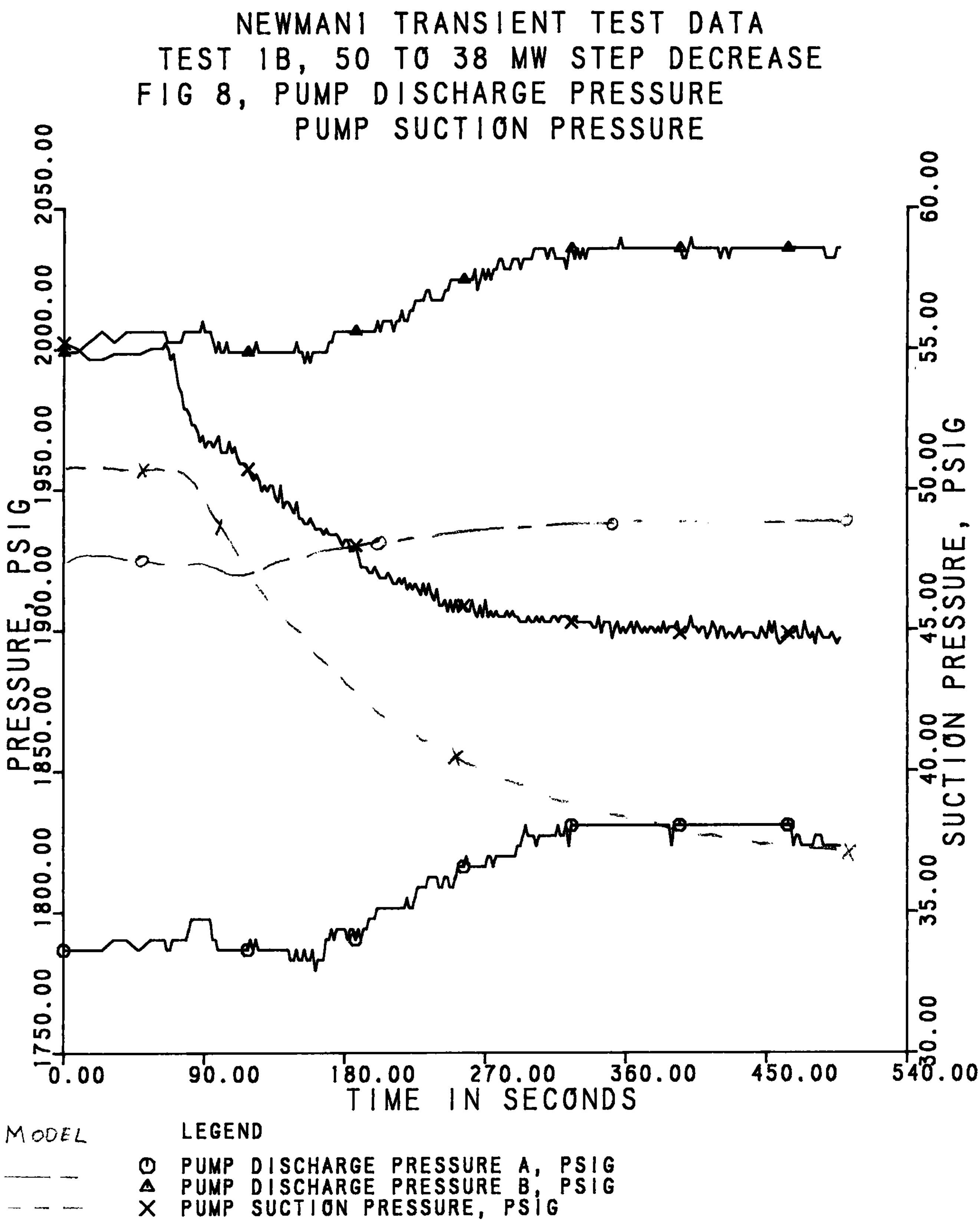
NEWMAN1 TRANSIENT TEST PREDICTIONS
TEST 1B, 50 TO 38 MW STEP DECREASE
FIG 7, O2 FRACTION IN FLUE GAS



LEGEND

O	O2 FRACTION (0 - 1)	0.016	0.028
x	TEST DATA FROM DAY CHART	0.021	0.034

FIGURE E.3-11



NEWMAN1 TRANSIENT TEST DATA
TEST 1B, 50 TO 38 MW STEP DECREASE
FIG 8, PUMP DISCHARGE PRESSURE
PUMP SUCTION PRESSURE
PRESSURE, PSIG
SUCTION PRESSURE, PSIG
2050.00
2000.00
1950.00
1900.00
1850.00
1800.00
1750.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
0.00
90.00
180.00
270.00
360.00
450.00
540.00
TIME IN SECONDS
MODEL
LEGEND
PUMP DISCHARGE PRESSURE A, PSIG
PUMP DISCHARGE PRESSURE B, PSIG
PUMP SUCTION PRESSURE, PSIG

FIGURE E.3-12

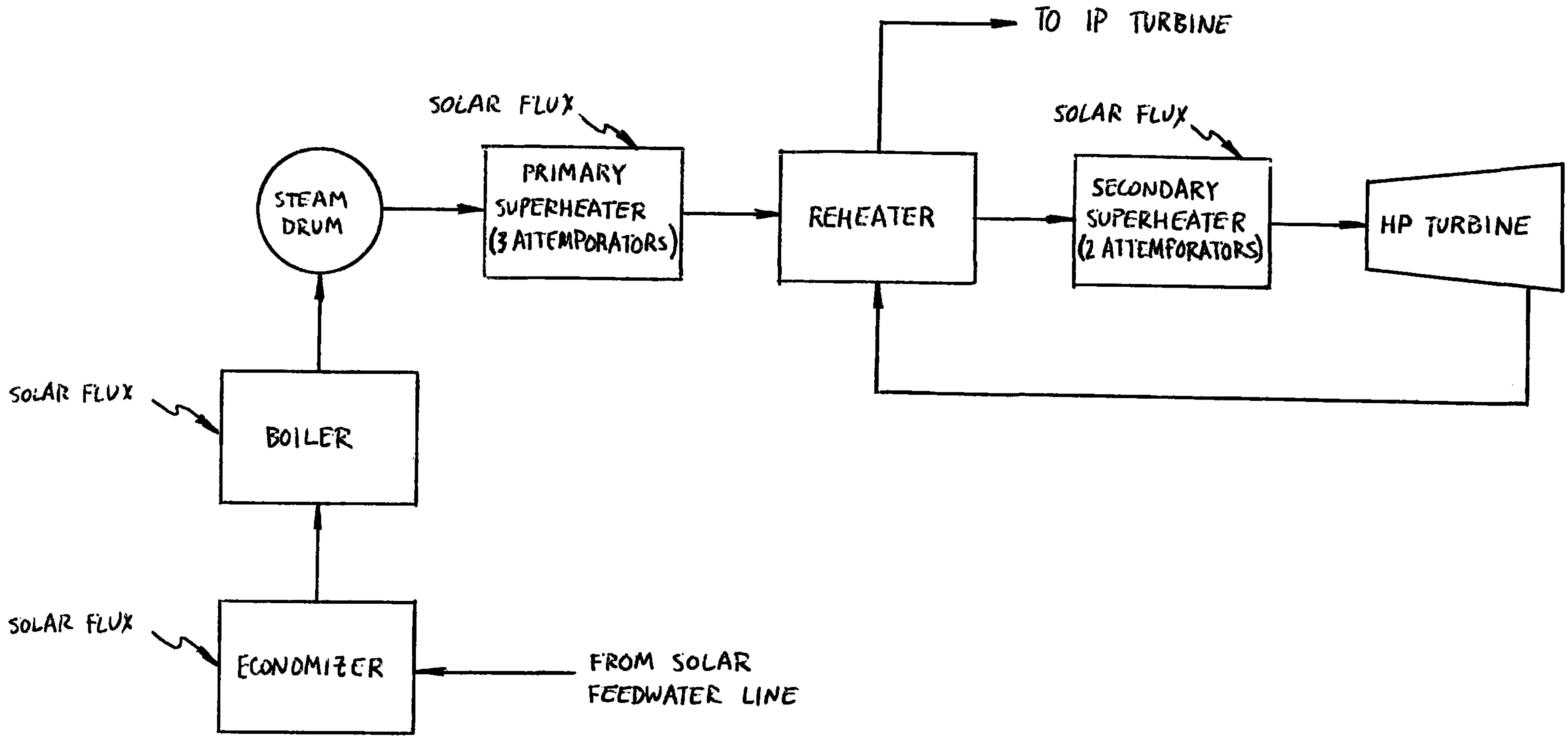


FIGURE E.4-1

SOLAR SIDE STEAM GENERATION

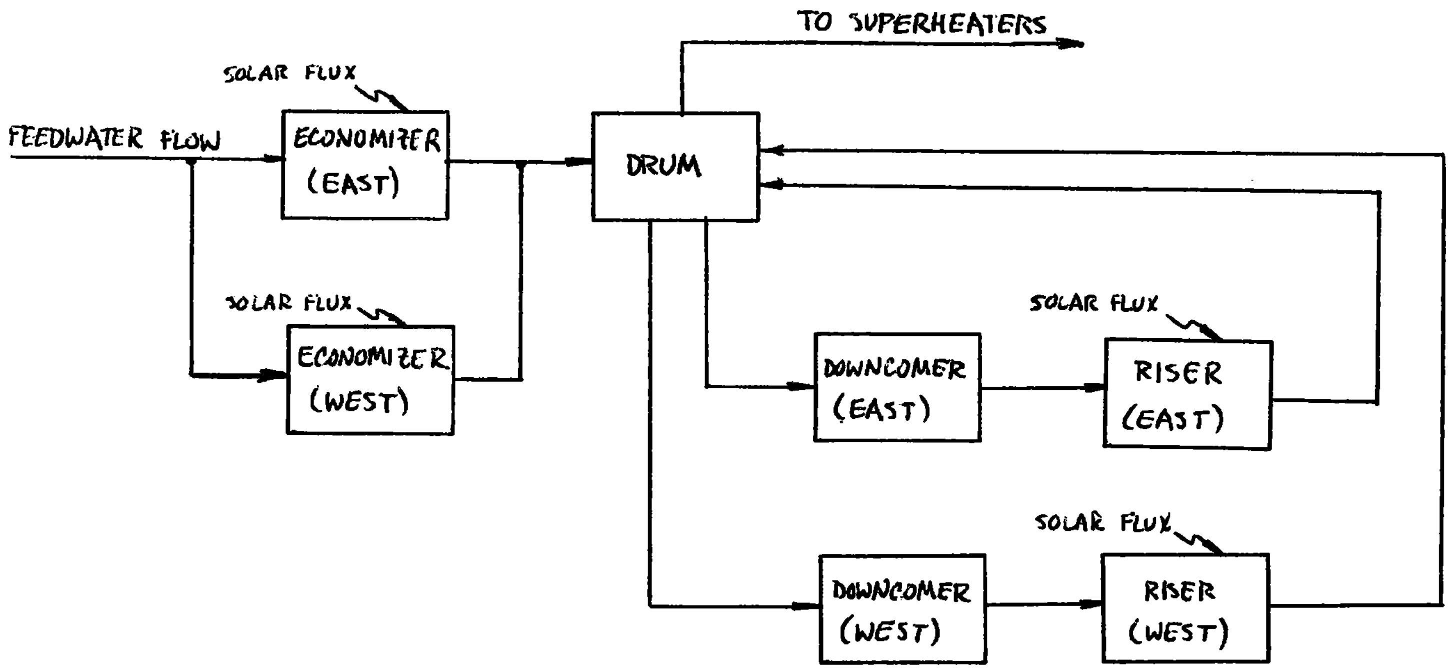


FIGURE E.4-2

NEWMAN I TRANSIENT SIMULATION

SOLAR STEAM GENERATION MODEL

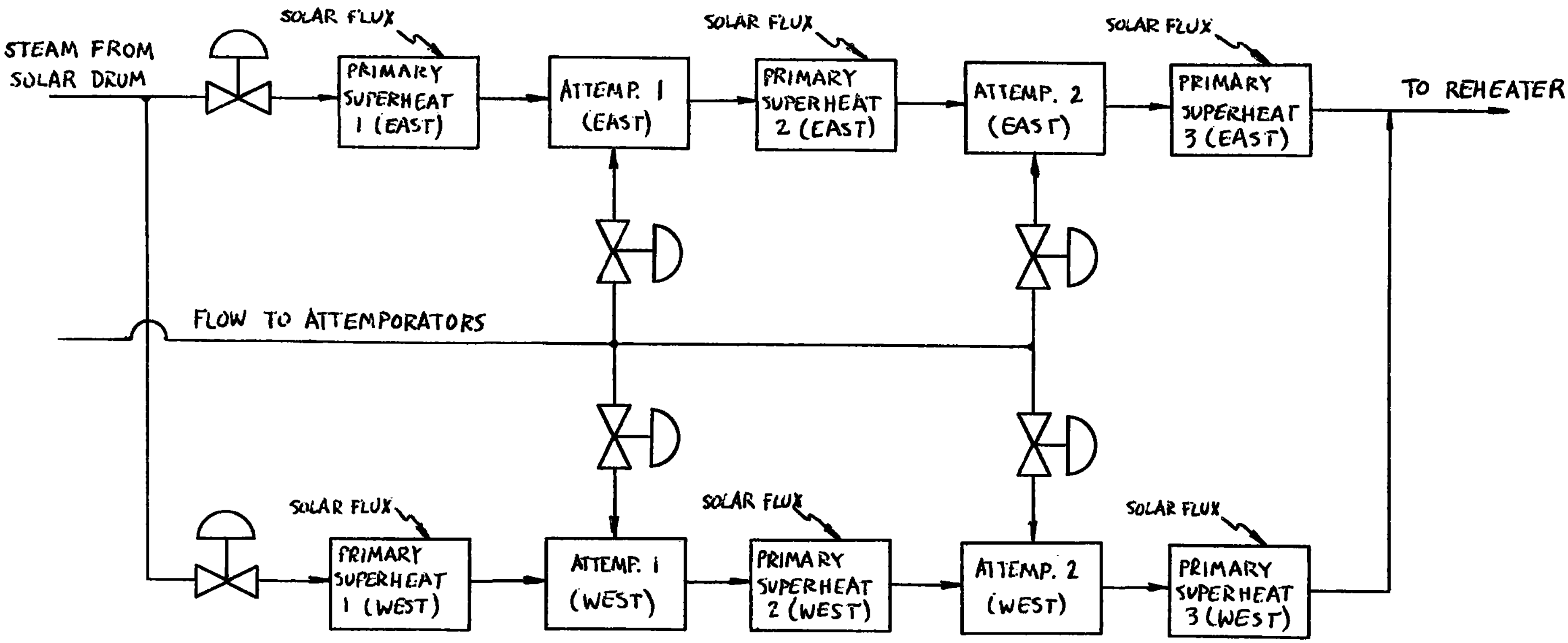


FIGURE E.4-3

NEWMAN I TRANSIENT SIMULATION

SOLAR SUPERHEAT MODEL

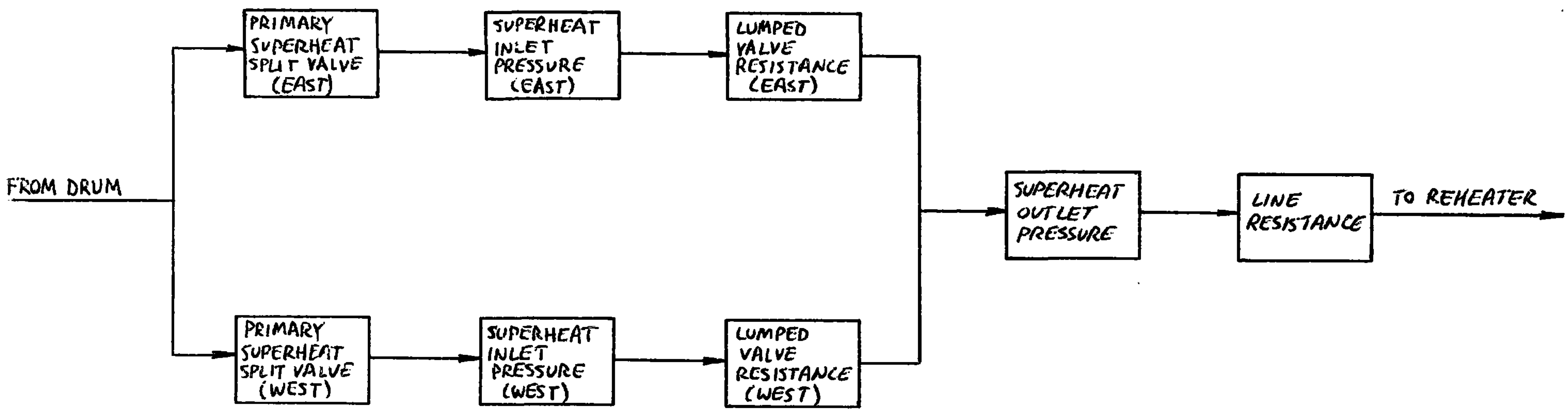


FIGURE E.4-4

PRIMARY SUPERHEATER HYDRAULIC MODEL

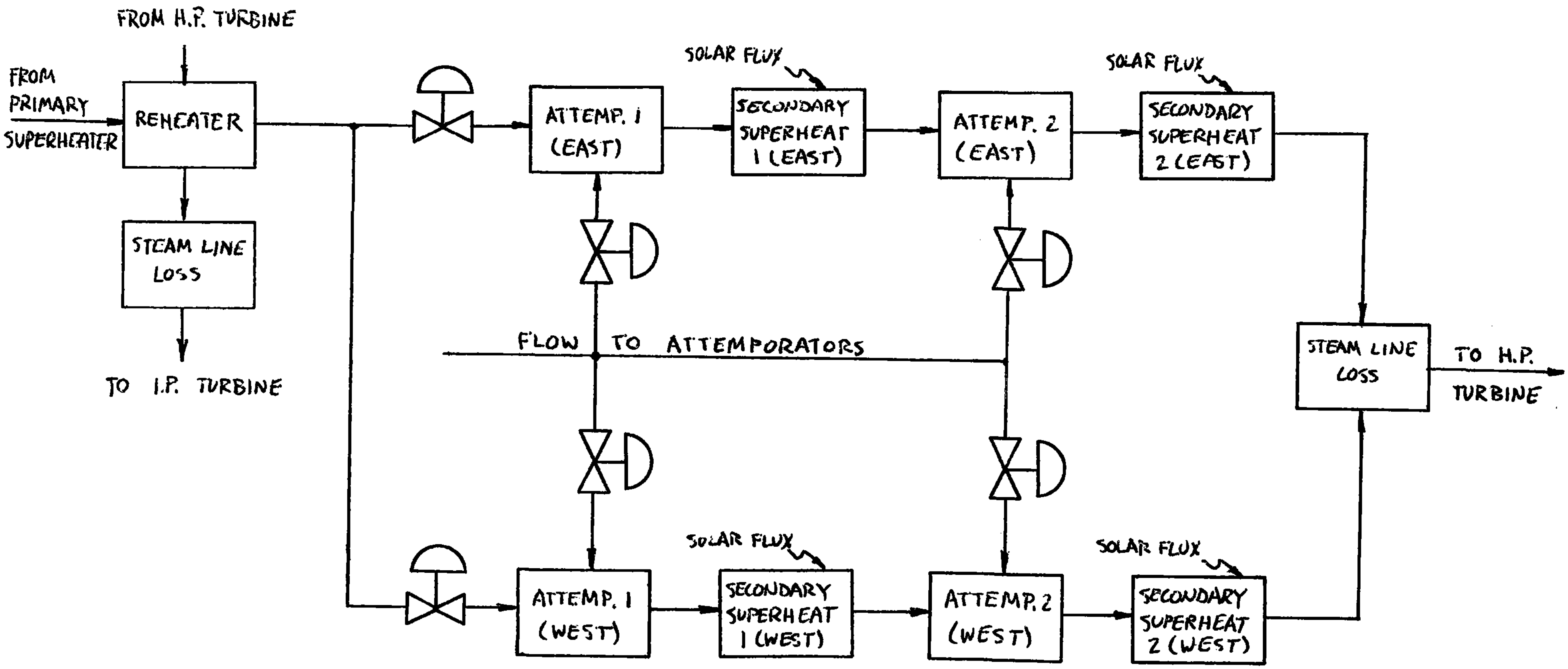


FIGURE E.4-5

NEWMAN I TRANSIENT SIMULATION

SECONDARY SUPERHEAT MODEL

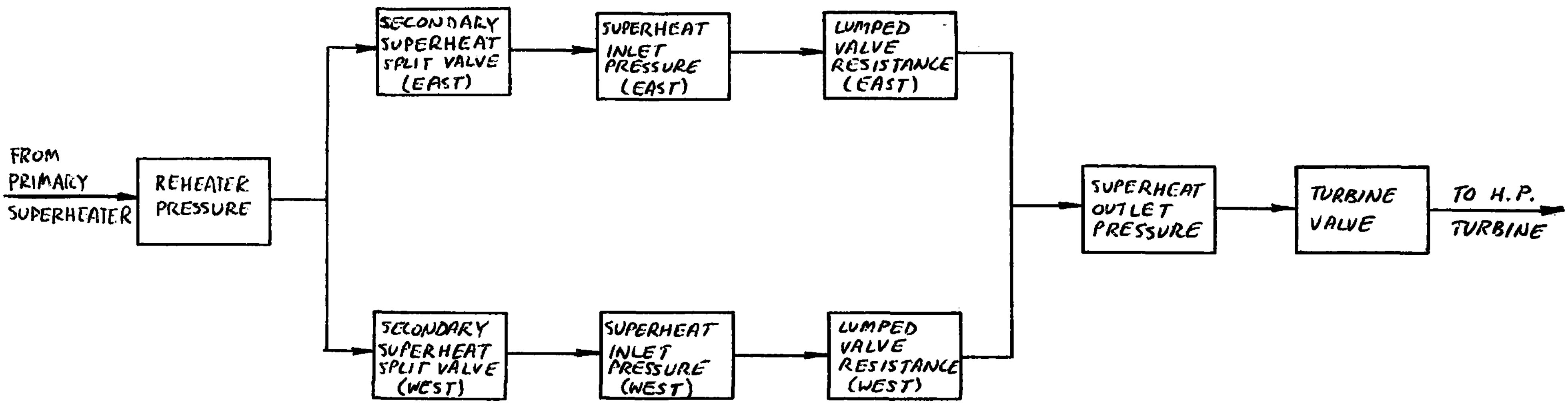


FIGURE E.4-6

SECONDARY SUPERHEATER HYDRAULIC MODEL

ATTEMPORATOR CONTROL

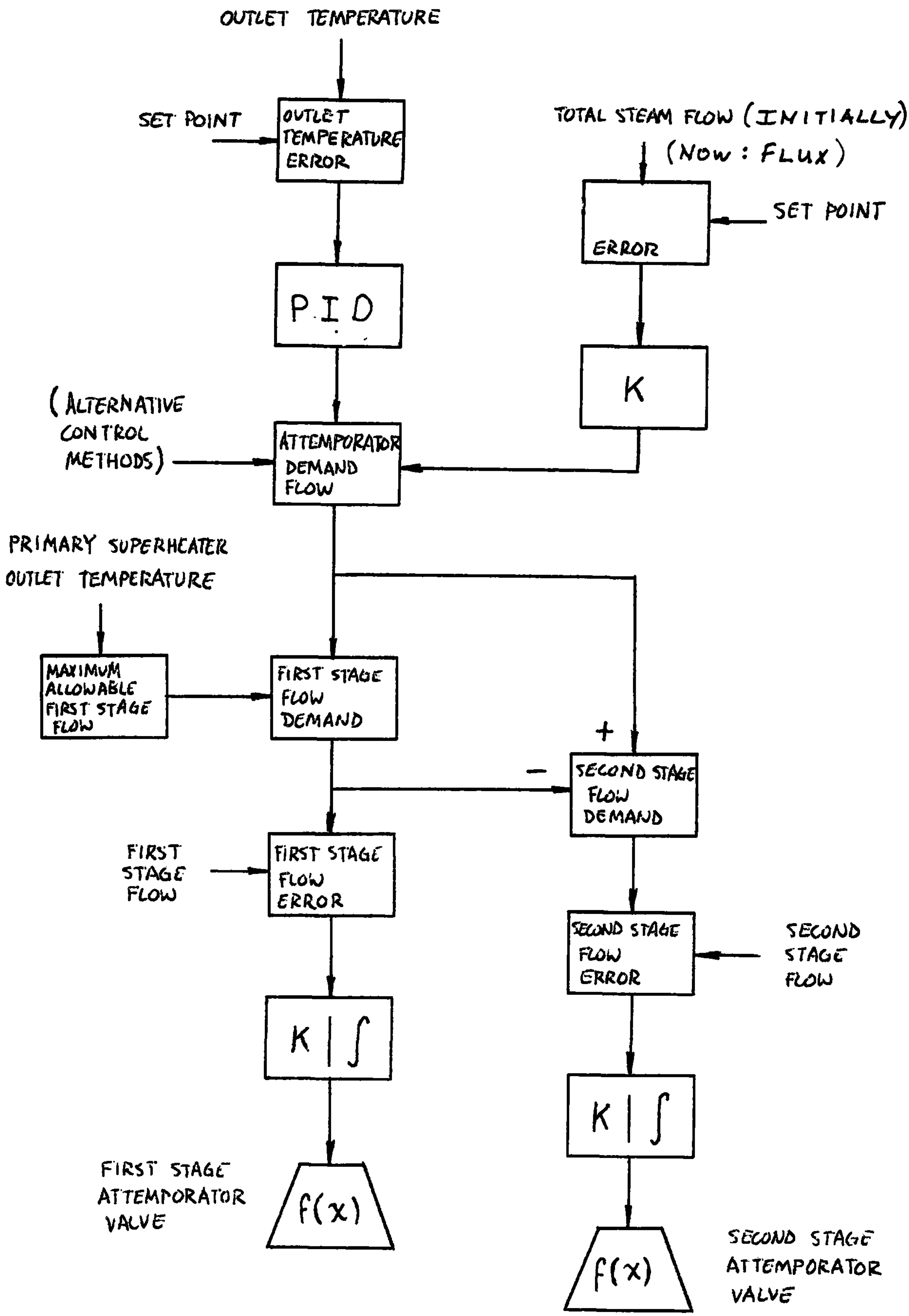


FIGURE E.4-7

DRUM LEVEL CONTROL

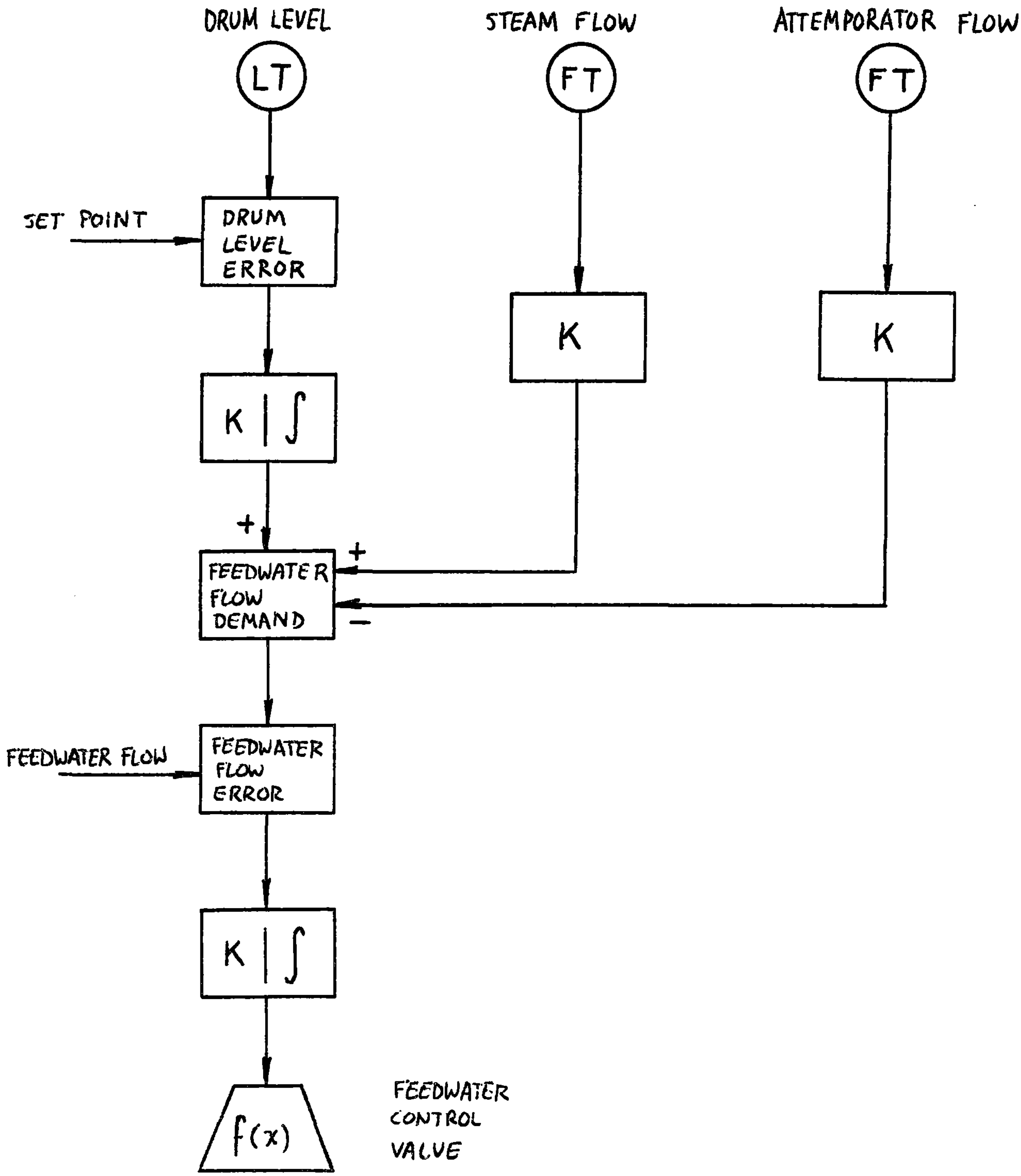


FIGURE E.4-8

THROTTLE VALVE CONTROL

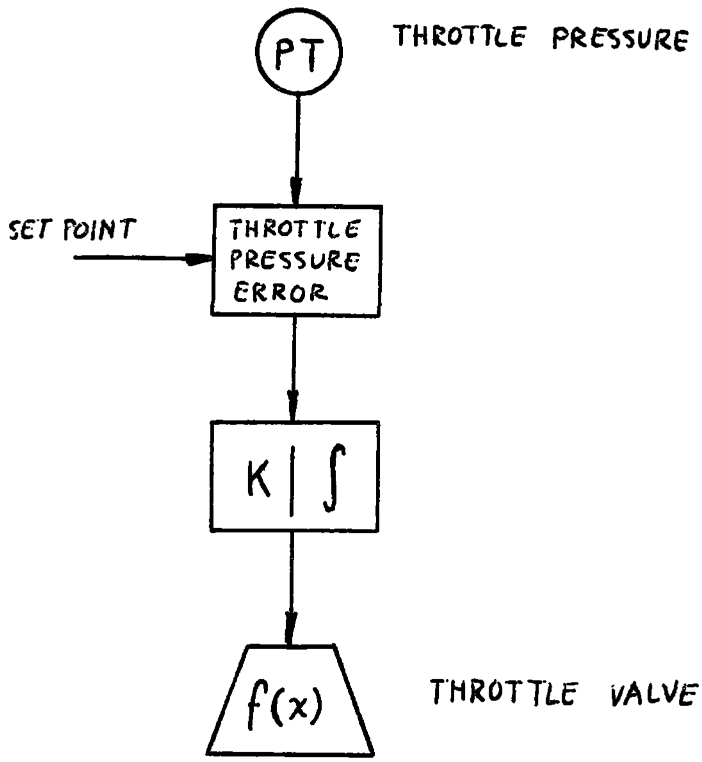


FIGURE E.4-9

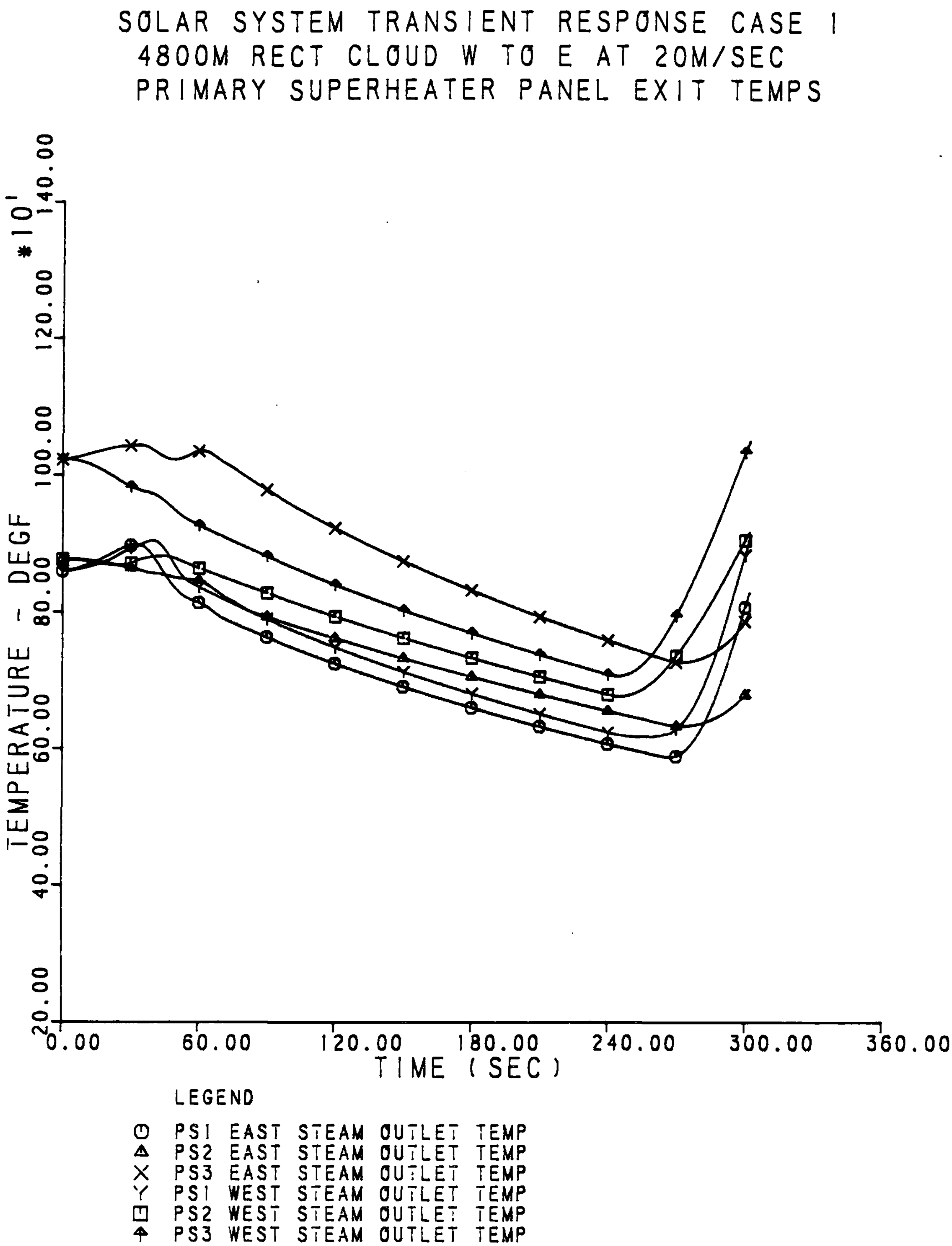

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
PRIMARY SUPERHEATER PANEL EXIT TEMPS
TEMPERATURE - DEGF *10[1]
20.00
40.00
60.00
80.00
100.00
120.00
140.00
0.00
60.00
120.00
180.00
240.00
300.00
360.00
TIME (SEC)
LEGEND
PS1 EAST STEAM OUTLET TEMP
PS2 EAST STEAM OUTLET TEMP
PS3 EAST STEAM OUTLET TEMP
PS1 WEST STEAM OUTLET TEMP
PS2 WEST STEAM OUTLET TEMP
PS3 WEST STEAM OUTLET TEMP

FIGURE E.4-10

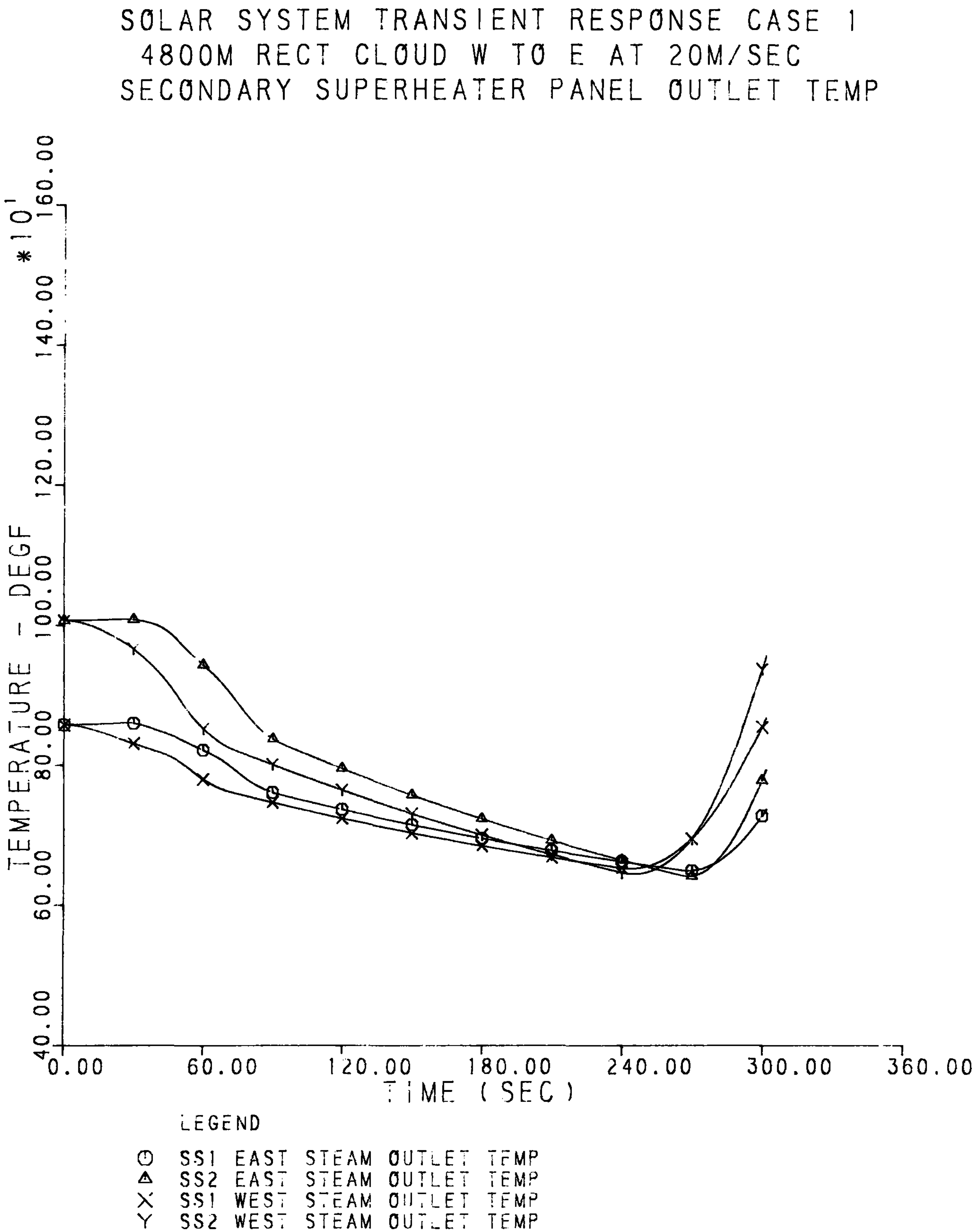


FIGURE E.4-11

JOB CMS 23 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
MAIN AND REHEAT STEAM TEMPS

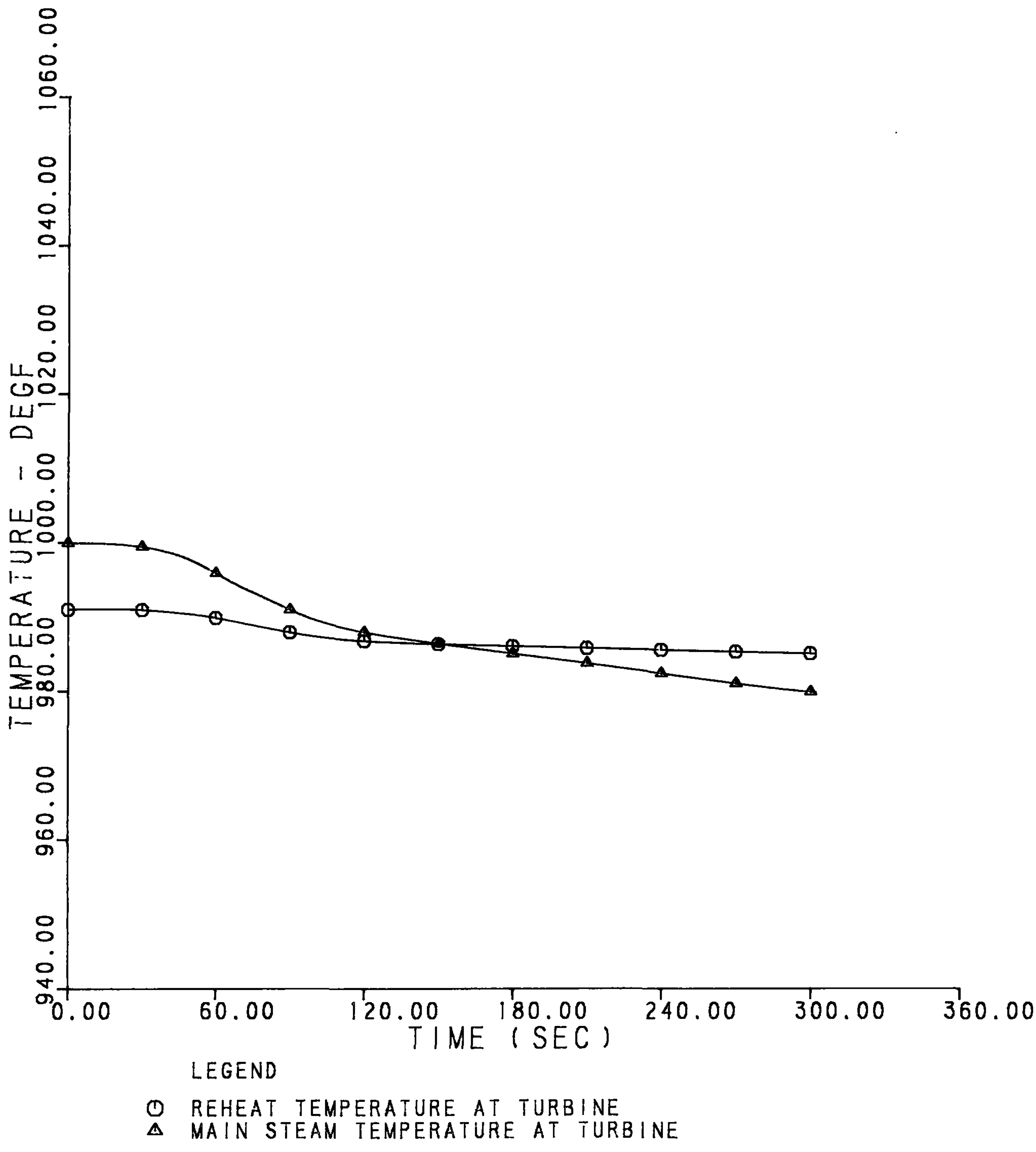


FIGURE E.4-12

JOB CMS 23 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
STEAM PRESSURES

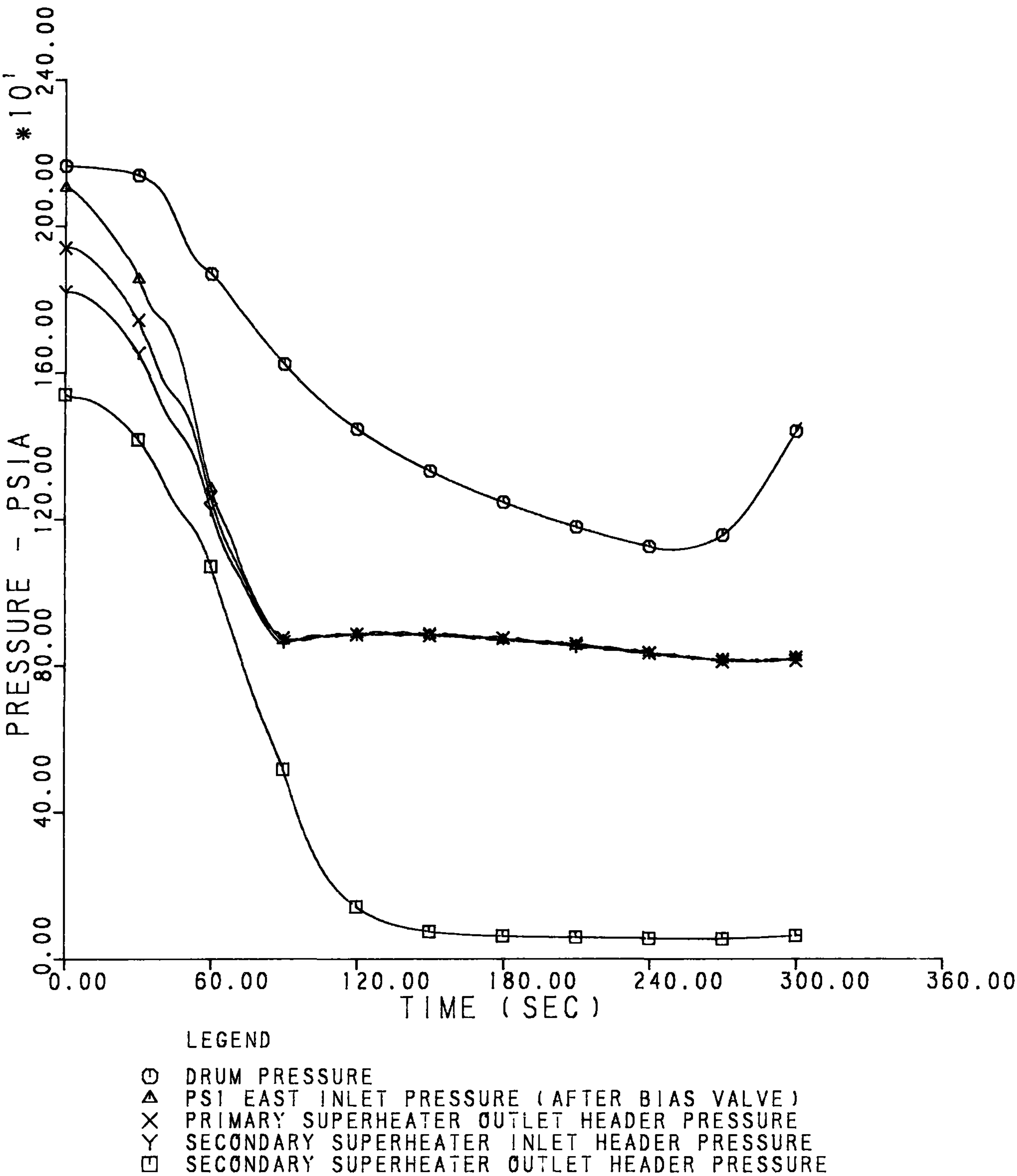


FIGURE E.4-13

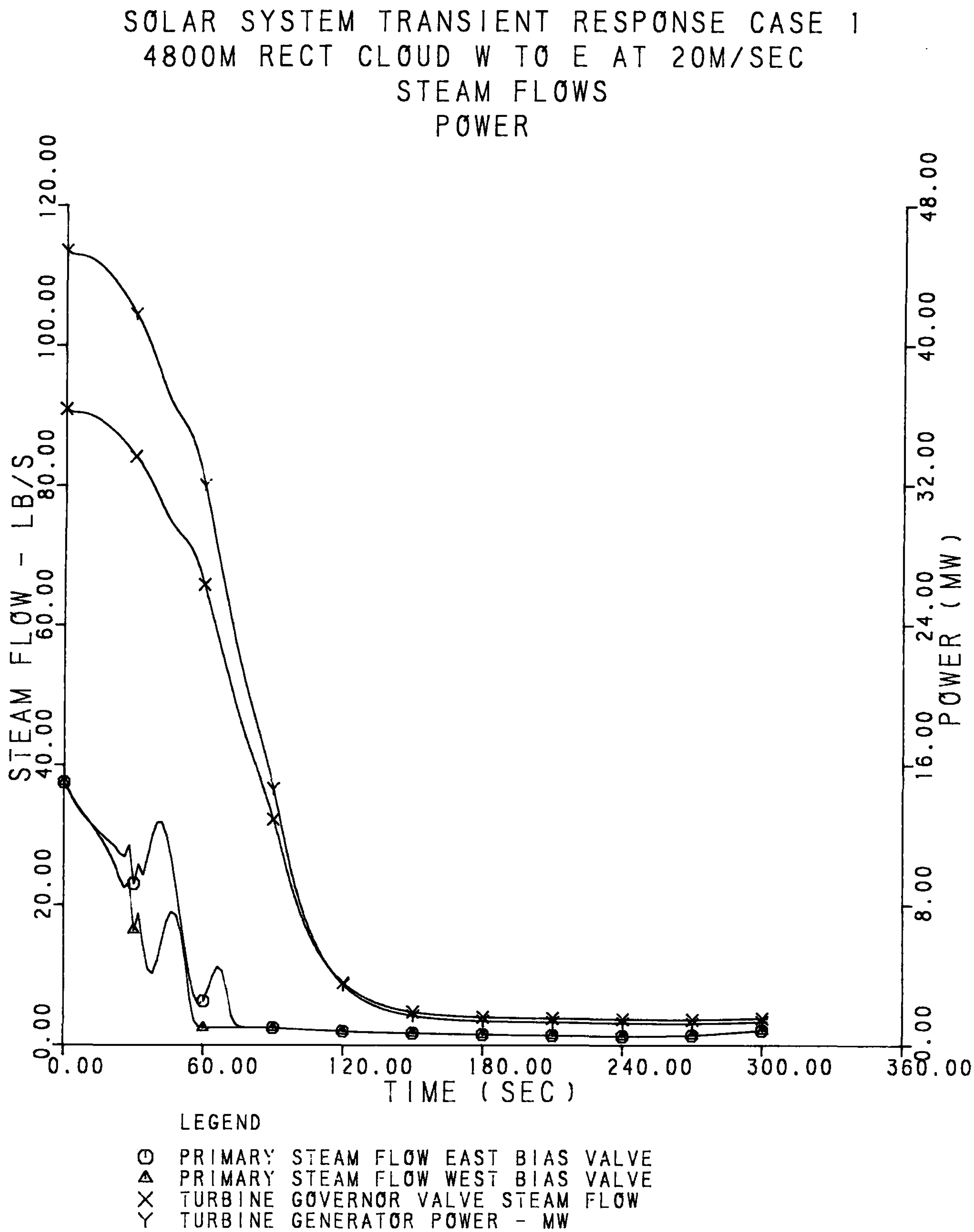

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
STEAM FLOWS
POWER
STEAM FLOW - LB/S
POWER (MW)
TIME (SEC)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
8.00
16.00
24.00
32.00
40.00
48.00
60.00
120.00
180.00
240.00
300.00
360.00
LEGEND
PRIMARY STEAM FLOW EAST BIAS VALVE
PRIMARY STEAM FLOW WEST BIAS VALVE
TURBINE GOVERNOR VALVE STEAM FLOW
TURBINE GENERATOR POWER - MW

FIGURE E.4-14

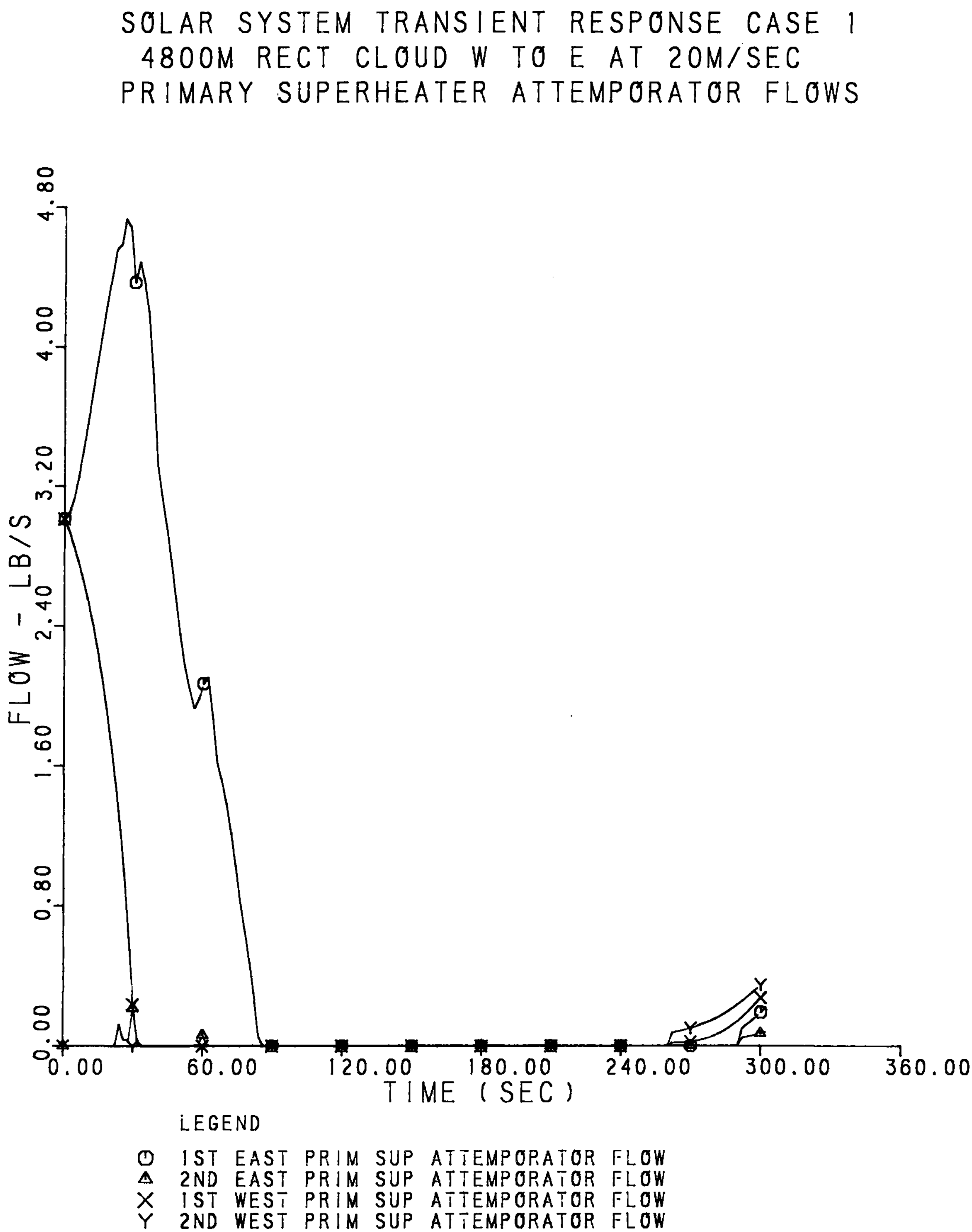


FIGURE E.4-15

JOB CMS 23 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
SECONDARY SUPERHEATER ATTEMPORATOR FLOWS

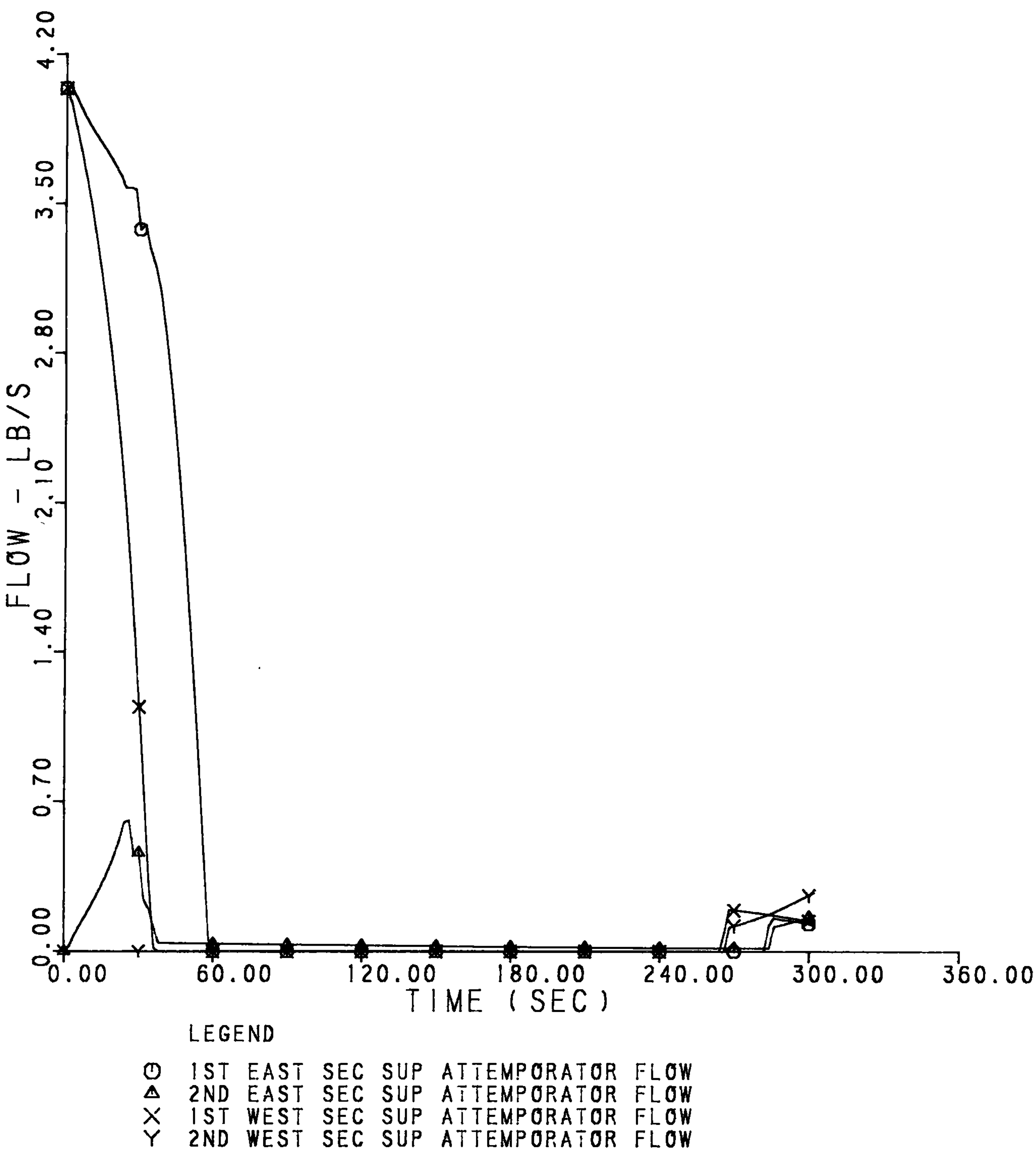


FIGURE E.4-16

JOB CMS 23 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

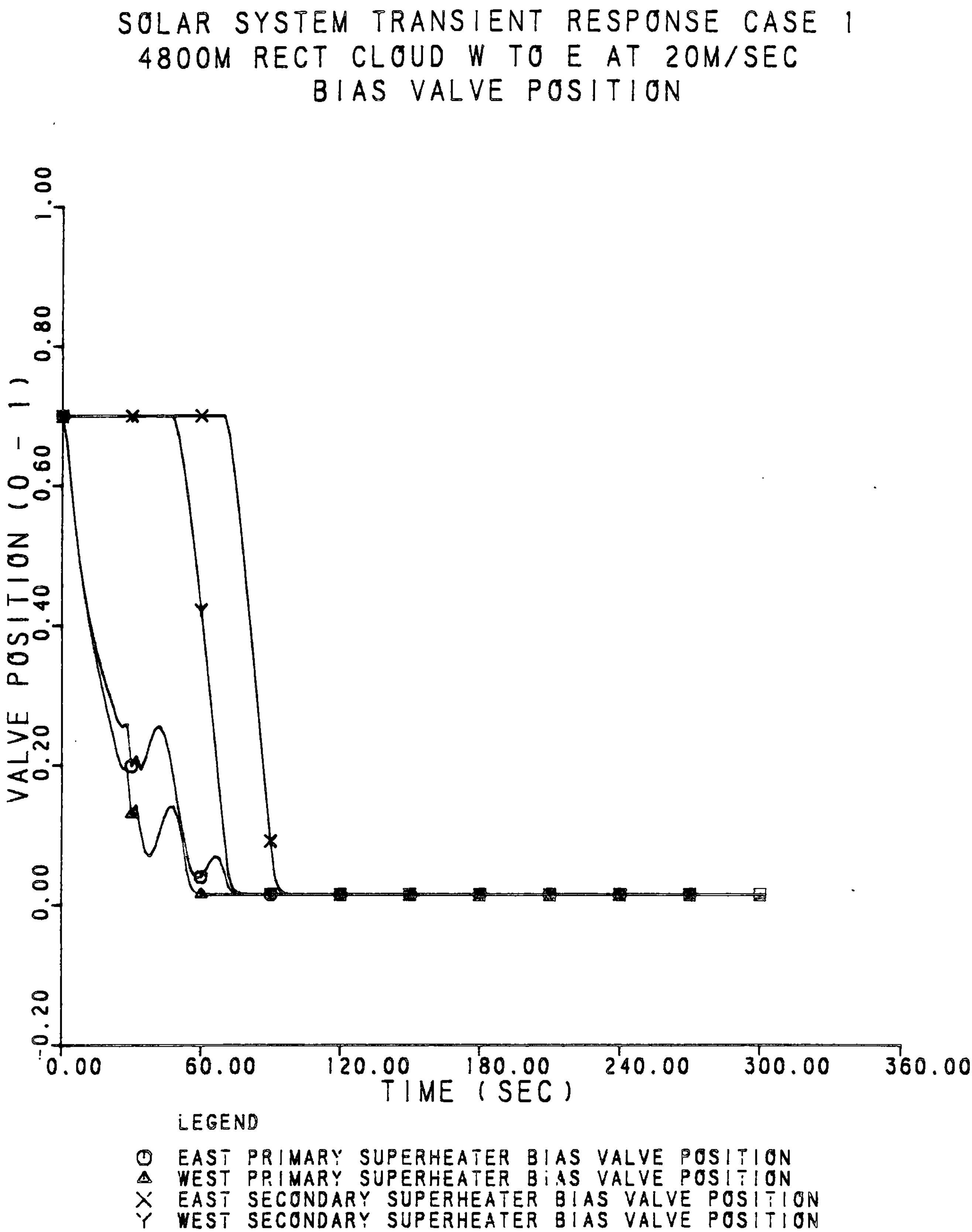

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
BIAS VALVE POSITION
VALVE POSITION (0 - 1)
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
0.00
60.00
120.00
180.00
240.00
300.00
360.00
TIME (SEC)
LEGEND
EAST PRIMARY SUPERHEATER BIAS VALVE POSITION
WEST PRIMARY SUPERHEATER BIAS VALVE POSITION
EAST SECONDARY SUPERHEATER BIAS VALVE POSITION
WEST SECONDARY SUPERHEATER BIAS VALVE POSITION

FIGURE E.4-17

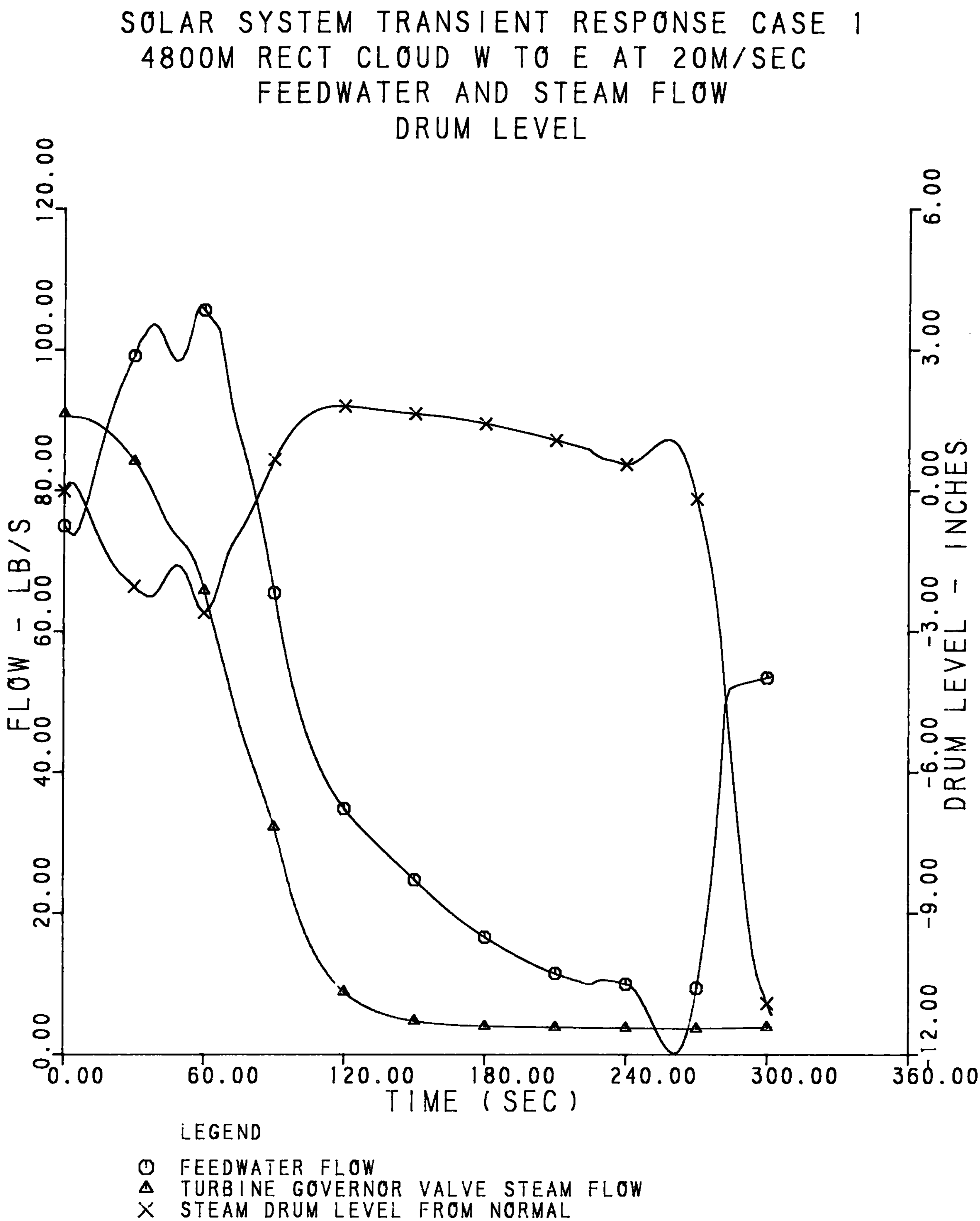

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
FEEDWATER AND STEAM FLOW
DRUM LEVEL
FLOW - LB/S
DRUM LEVEL - INCHES
TIME (SEC)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
-12.00
-9.00
-6.00
-3.00
0.00
3.00
6.00
60.00
120.00
180.00
240.00
300.00
360.00
LEGEND
FEEDWATER FLOW
TURBINE GOVERNOR VALVE STEAM FLOW
STEAM DRUM LEVEL FROM NORMAL

FIGURE E.4-18

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
EVAPORATOR CIRCUIT STEAM QUALITIES
EVAPORATOR CIRCUIT FLOWS

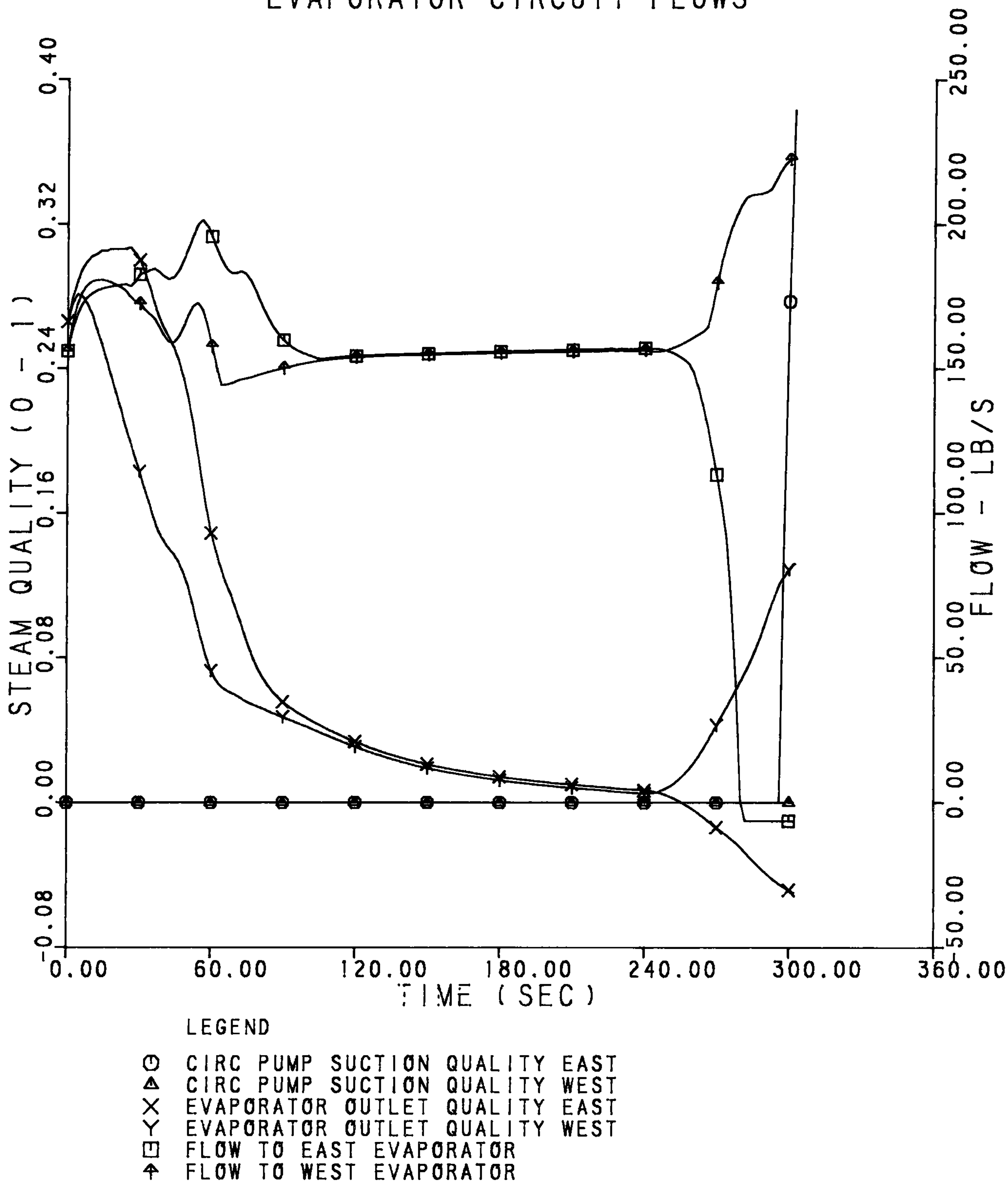


FIGURE E.4-19

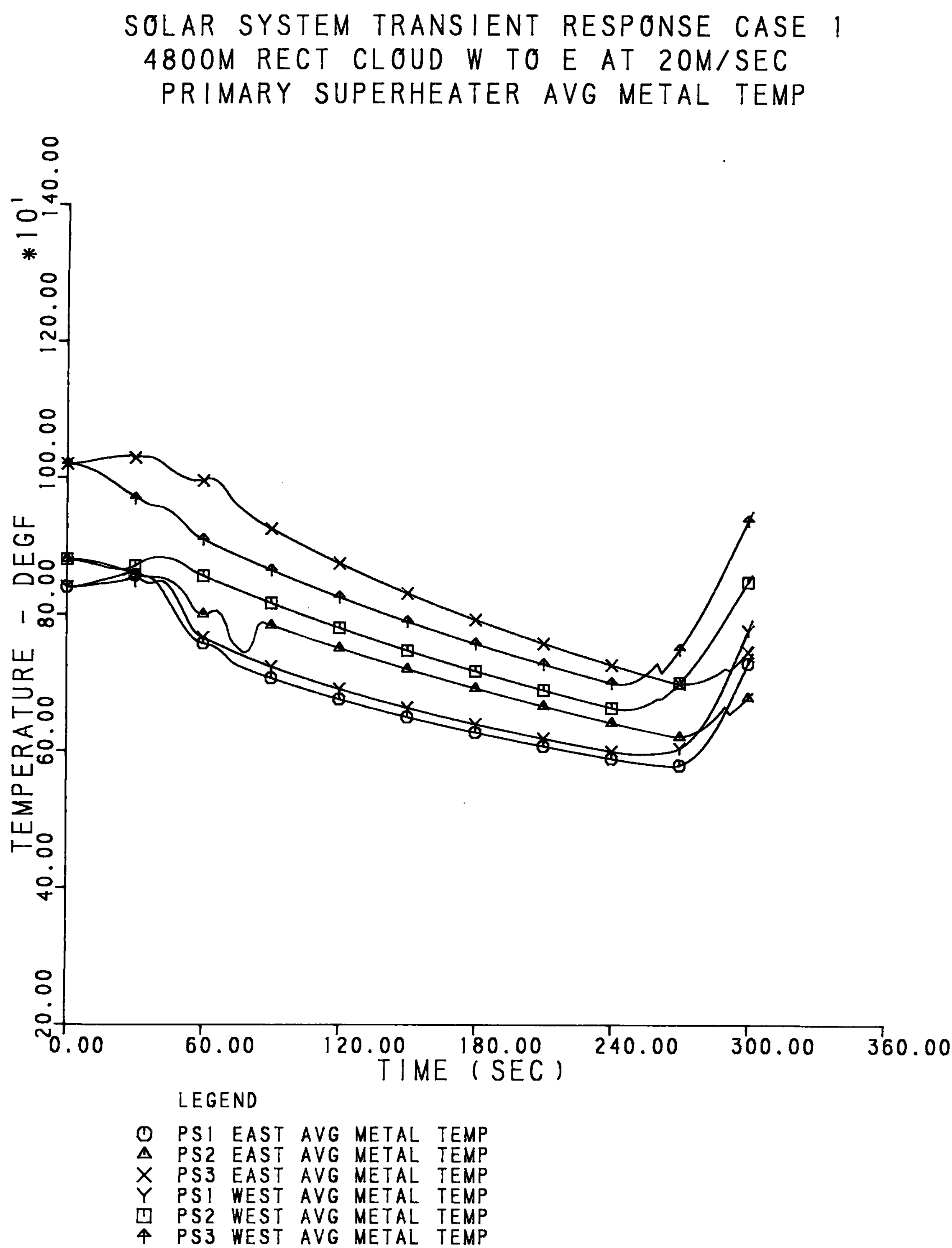
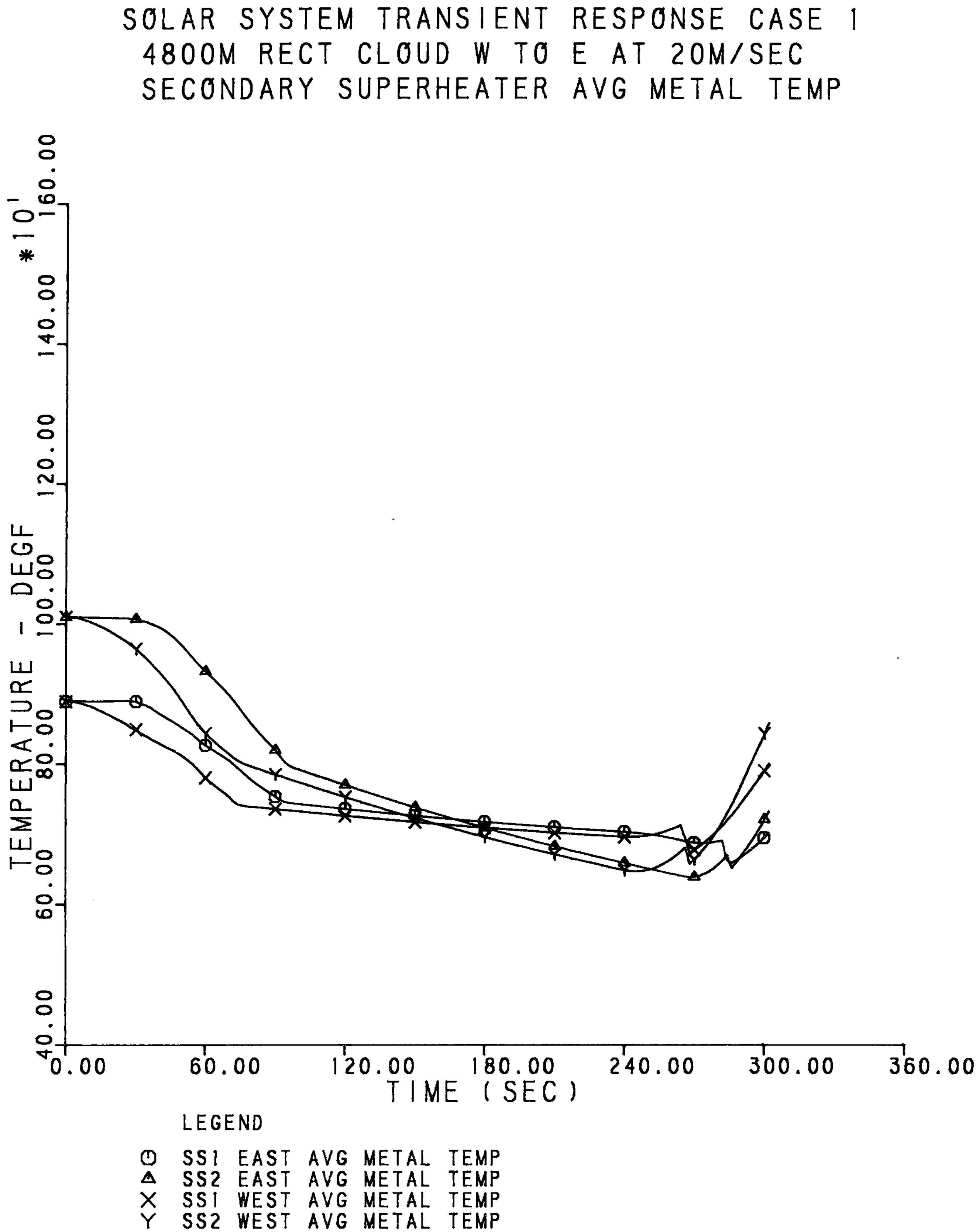

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
PRIMARY SUPERHEATER AVG METAL TEMP
TEMPERATURE - DEGF *10[1]
20.00
40.00
60.00
80.00
100.00
120.00
140.00
0.00
60.00
120.00
180.00
240.00
300.00
360.00
TIME (SEC)
LEGEND
PS1 EAST AVG METAL TEMP
PS2 EAST AVG METAL TEMP
PS3 EAST AVG METAL TEMP
PS1 WEST AVG METAL TEMP
PS2 WEST AVG METAL TEMP
PS3 WEST AVG METAL TEMP

FIGURE E.4-20



SOLAR SYSTEM TRANSIENT RESPONSE CASE 1
4800M RECT CLOUD W TO E AT 20M/SEC
SECONDARY SUPERHEATER AVG METAL TEMP
TEMPERATURE - DEGF *10[1]
40.00
60.00
80.00
100.00
120.00
140.00
160.00
0.00
60.00
120.00
180.00
240.00
300.00
360.00
TIME (SEC)
LEGEND
SS1 EAST AVG METAL TEMP
SS2 EAST AVG METAL TEMP
SS1 WEST AVG METAL TEMP
SS2 WEST AVG METAL TEMP

FIGURE E.4-21

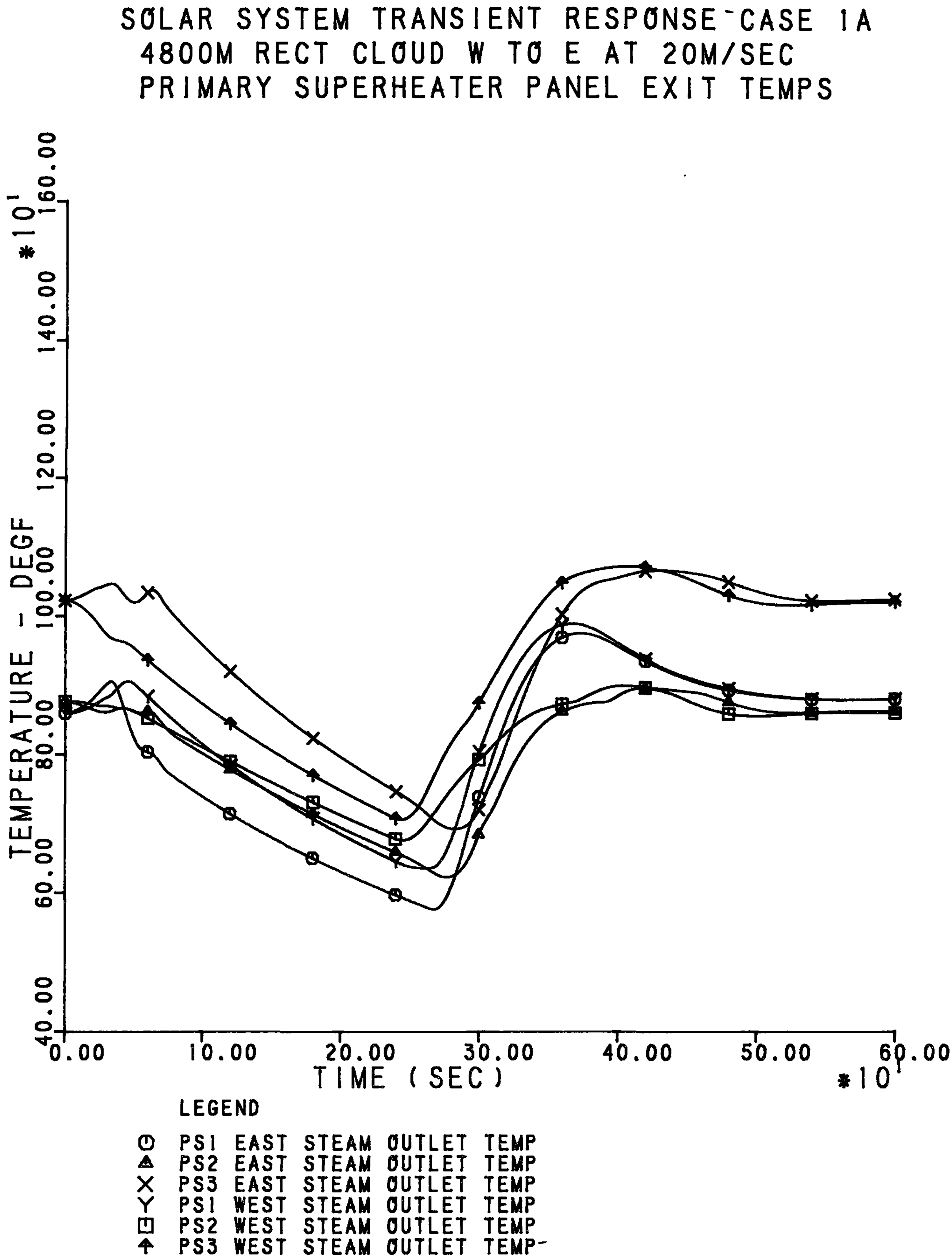

SOLAR SYSTEM TRANSIENT RESPONSE-CASE 1A
4800M RECT CLOUD W TO E AT 20M/SEC
PRIMARY SUPERHEATER PANEL EXIT TEMPS
TEMPERATURE - DEGF *10¹
40.00
60.00
80.00
100.00
120.00
140.00
160.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
TIME (SEC) *10¹
LEGEND
PS1 EAST STEAM OUTLET TEMP
PS2 EAST STEAM OUTLET TEMP
PS3 EAST STEAM OUTLET TEMP
PS1 WEST STEAM OUTLET TEMP
PS2 WEST STEAM OUTLET TEMP
PS3 WEST STEAM OUTLET TEMP

FIGURE E.4-22

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1A
4800M RECT CLOUD W TO E AT 20M/SEC
SECONDARY SUPERHEATER PANEL OUTLET TEMP

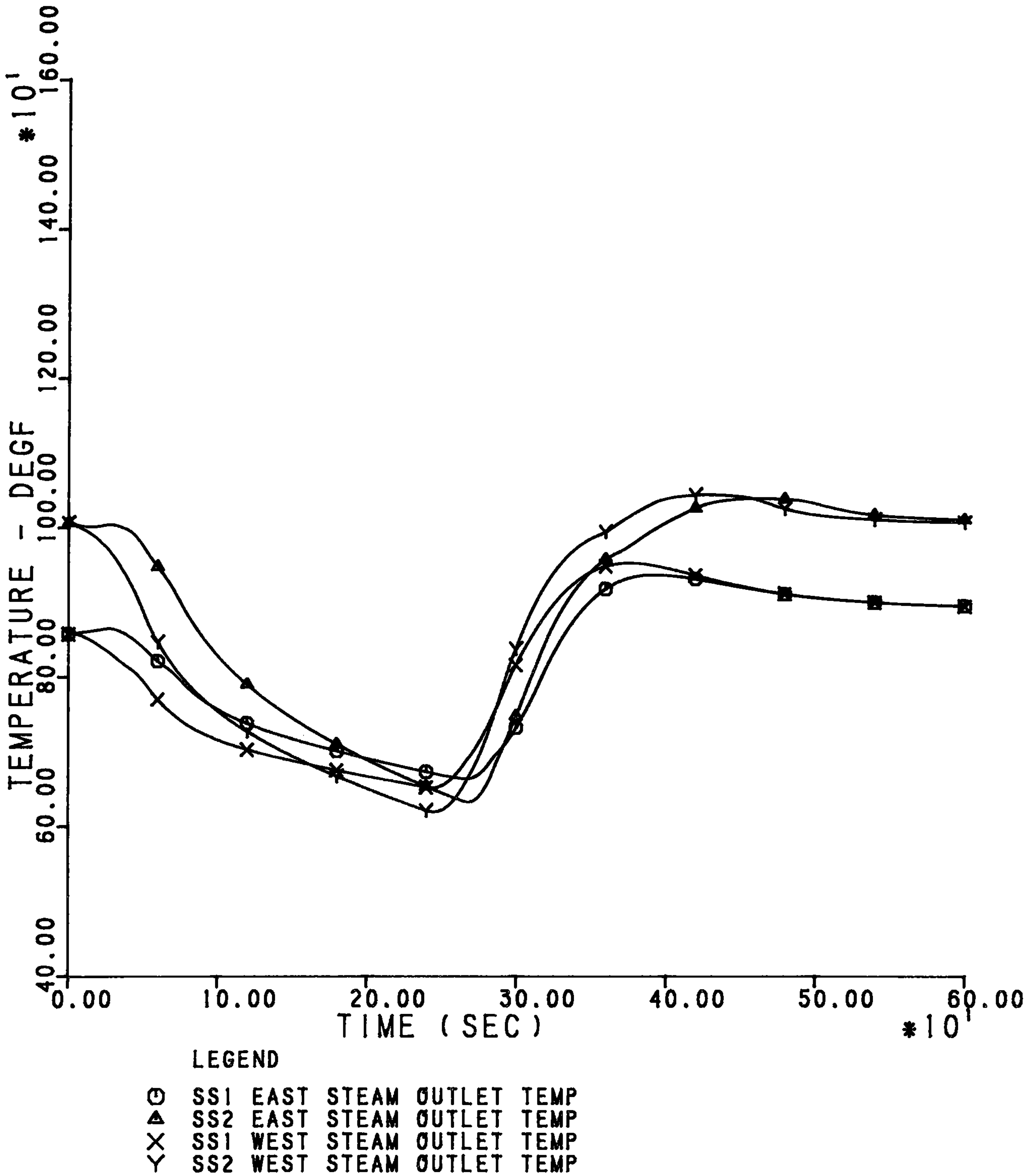


FIGURE E.4-23

JOB CMS 27 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

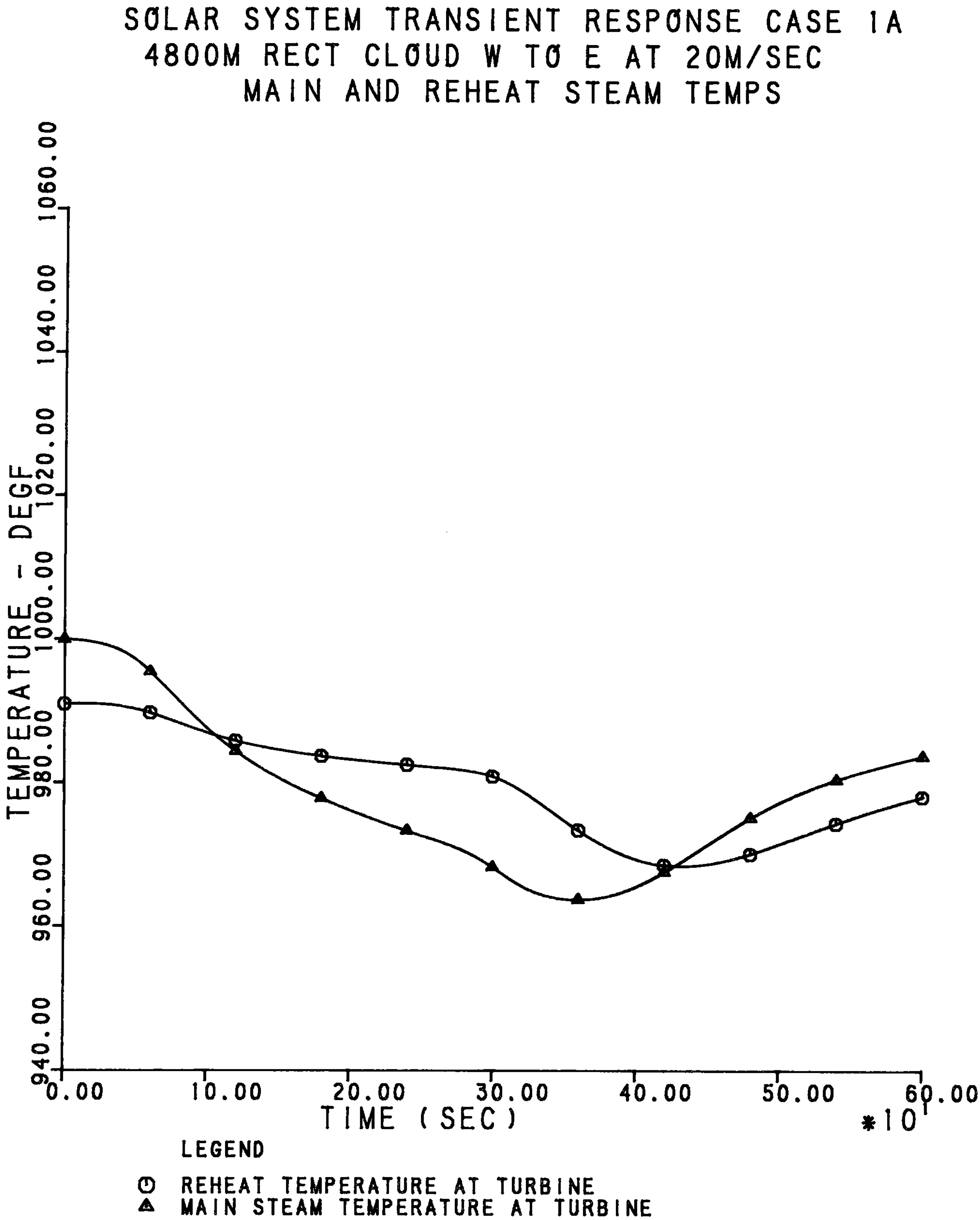
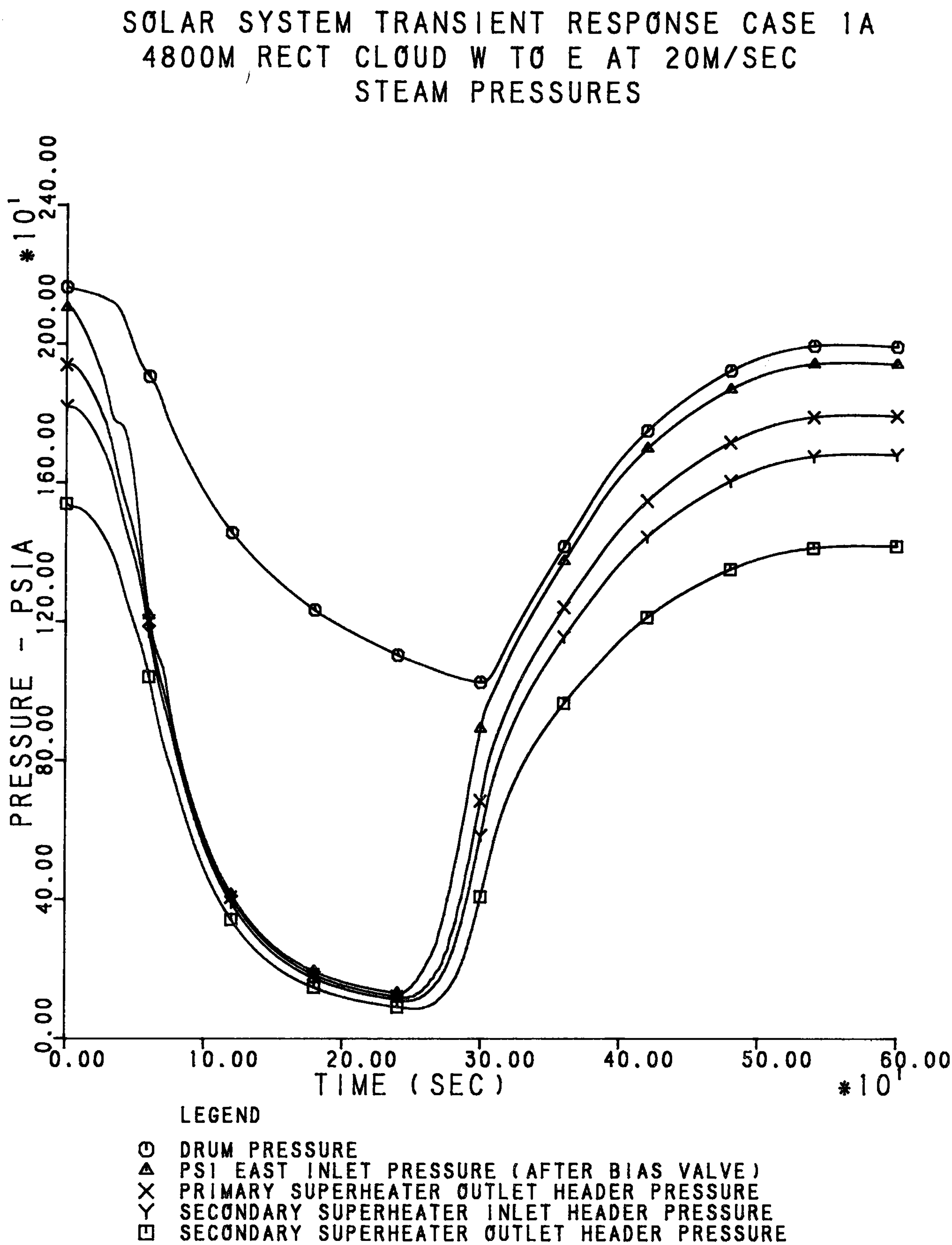


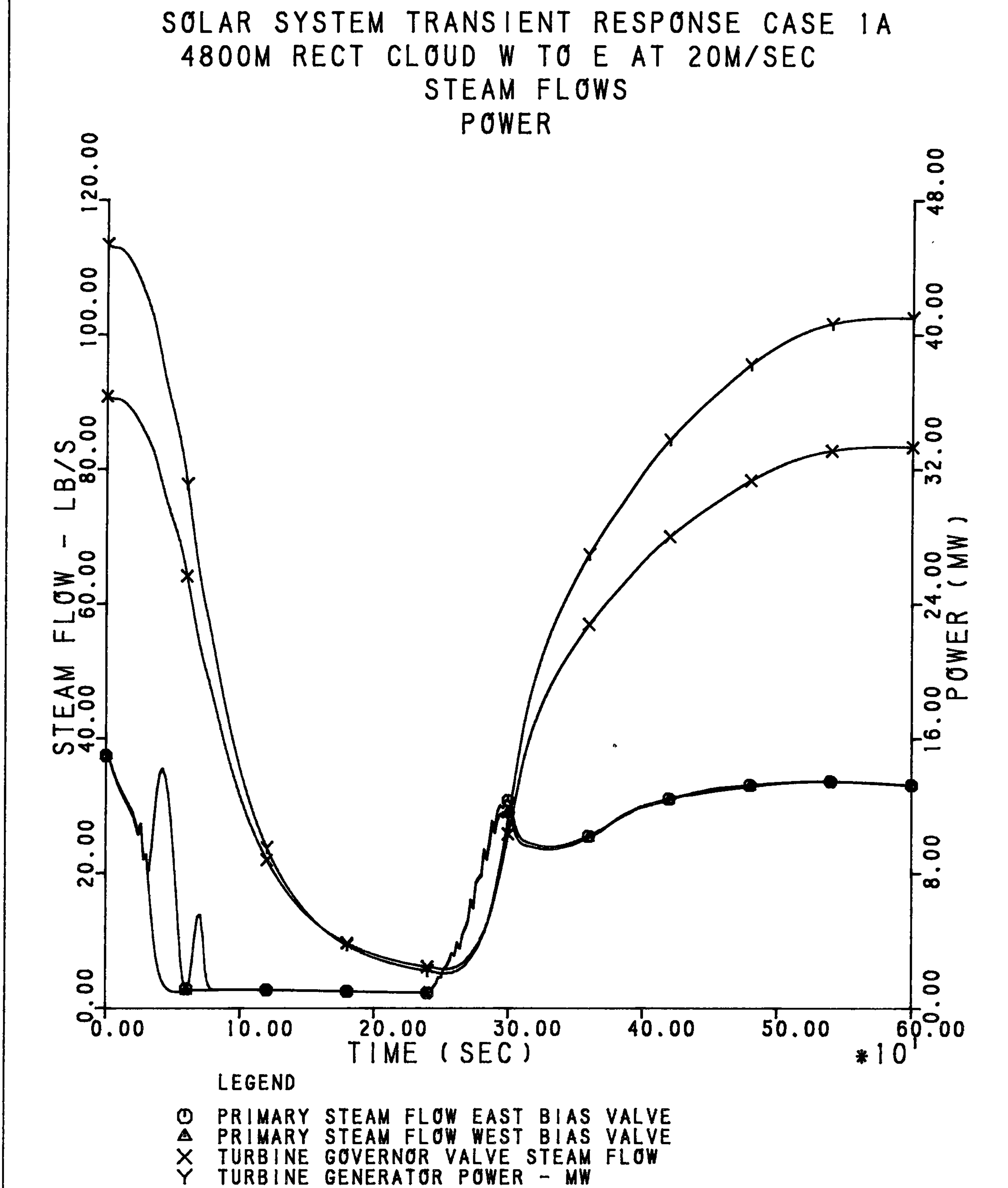
FIGURE E.4-24

JOB CMS 27 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION



SOLAR SYSTEM TRANSIENT RESPONSE CASE 1A
4800M RECT CLOUD W TO E AT 20M/SEC
STEAM PRESSURES
PRESSURE - PSIA *10^1
0.00
40.00
80.00
120.00
160.00
200.00
240.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
TIME (SEC) *10^1
LEGEND
DRUM PRESSURE
PSI EAST INLET PRESSURE (AFTER BIAS VALVE)
PRIMARY SUPERHEATER OUTLET HEADER PRESSURE
SECONDARY SUPERHEATER INLET HEADER PRESSURE
SECONDARY SUPERHEATER OUTLET HEADER PRESSURE

FIGURE E.4-25



SØLAR SYSTEM TRANSIENT RESPØNSE CASE 1A
4800M RECT CLØUD W TØ E AT 20M/SEC
STEAM FLØWS
PØWER
STEAM FLØW - LB/S
POWER (MW)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
8.00
16.00
24.00
32.00
40.00
48.00
10.00
30.00
50.00
60.00
TIME (SEC)
*10[1]
LEGEND
PRIMARY STEAM FLØW EAST BIAS VALVE
PRIMARY STEAM FLØW WEST BIAS VALVE
TURBINE GØVERNØR VALVE STEAM FLØW
TURBINE GENERATØR PØWER - MW

FIGURE E.4-26

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1A
4800M RECT CLOUD W TO E AT 20M/SEC
PRIMARY SUPERHEATER ATTEMPORATOR FLOWS

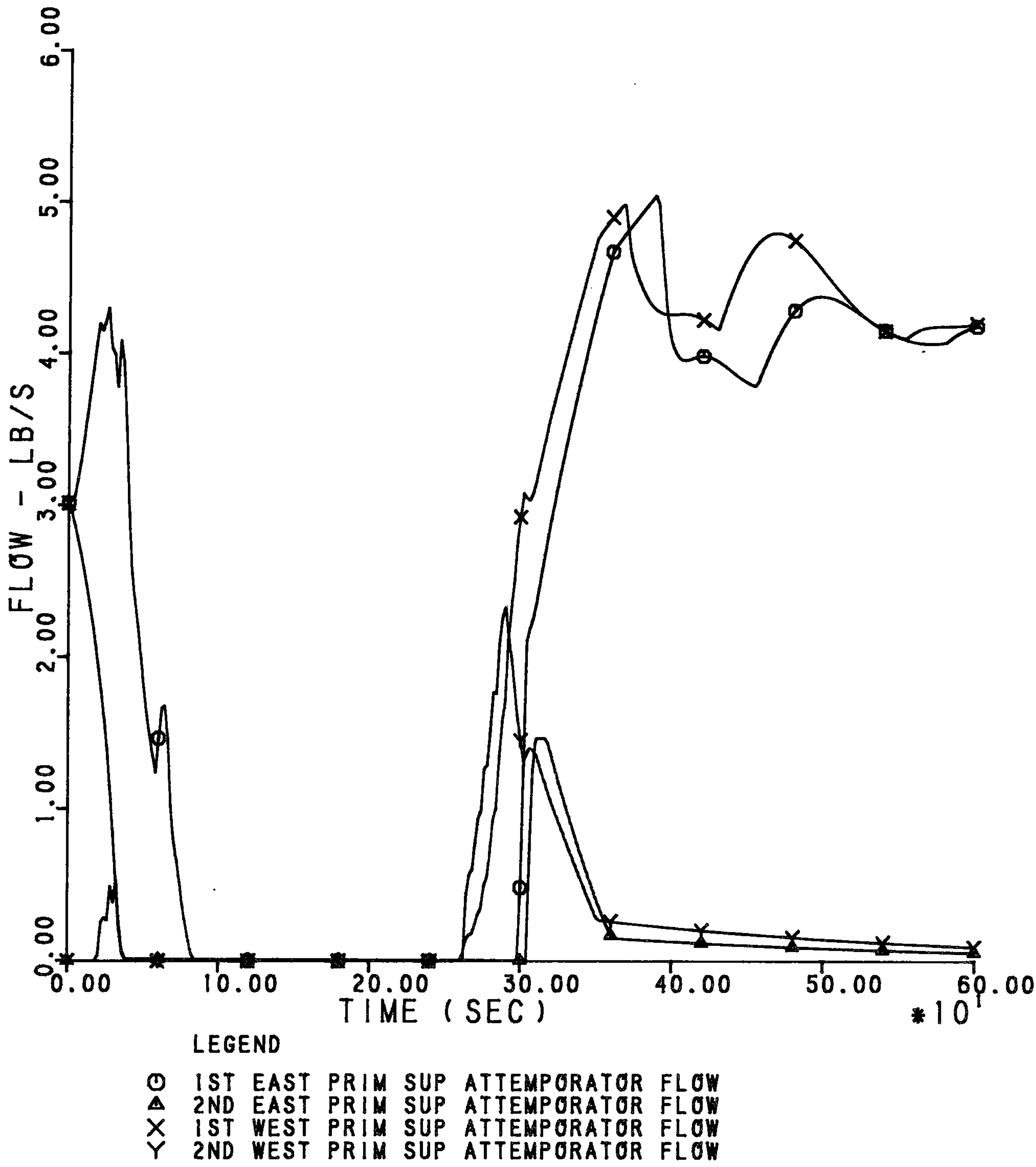


FIGURE E.4-27

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1A
4800M RECT CLOUD W TO E AT 20M/SEC
SECONDARY SUPERHEATER ATTEMPORATOR FLOWS

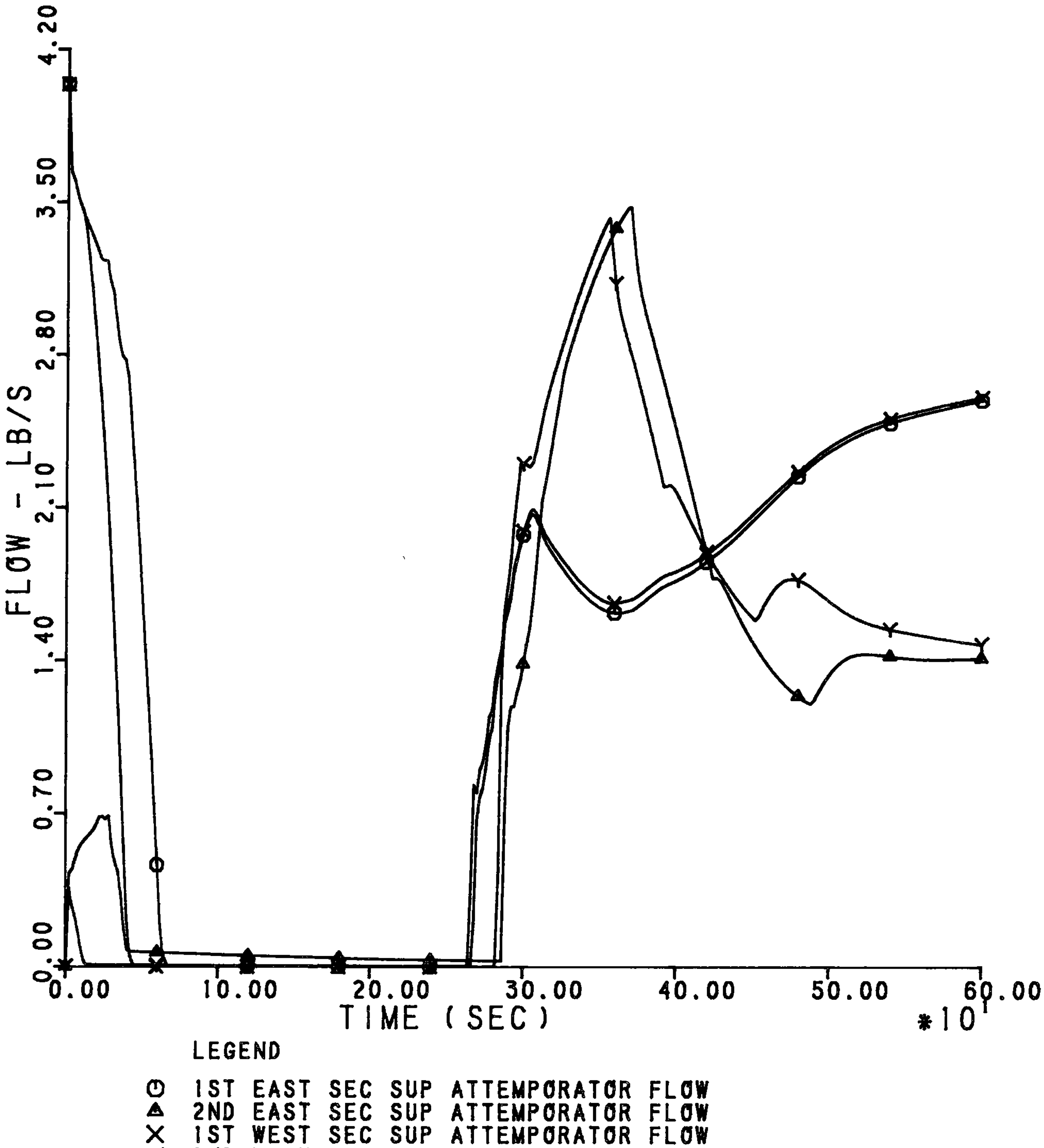


FIGURE E.4-28

JOB CMS 27 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

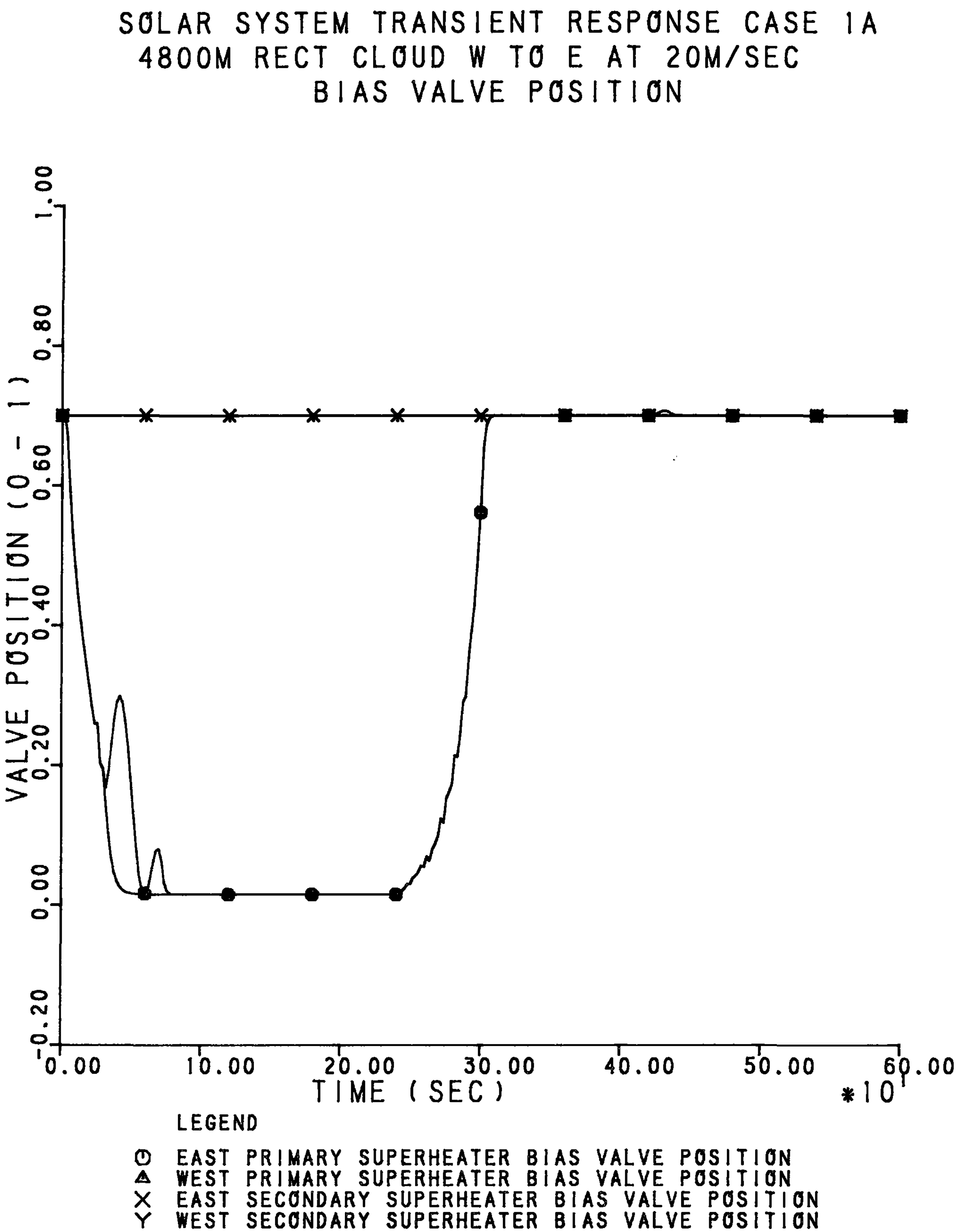
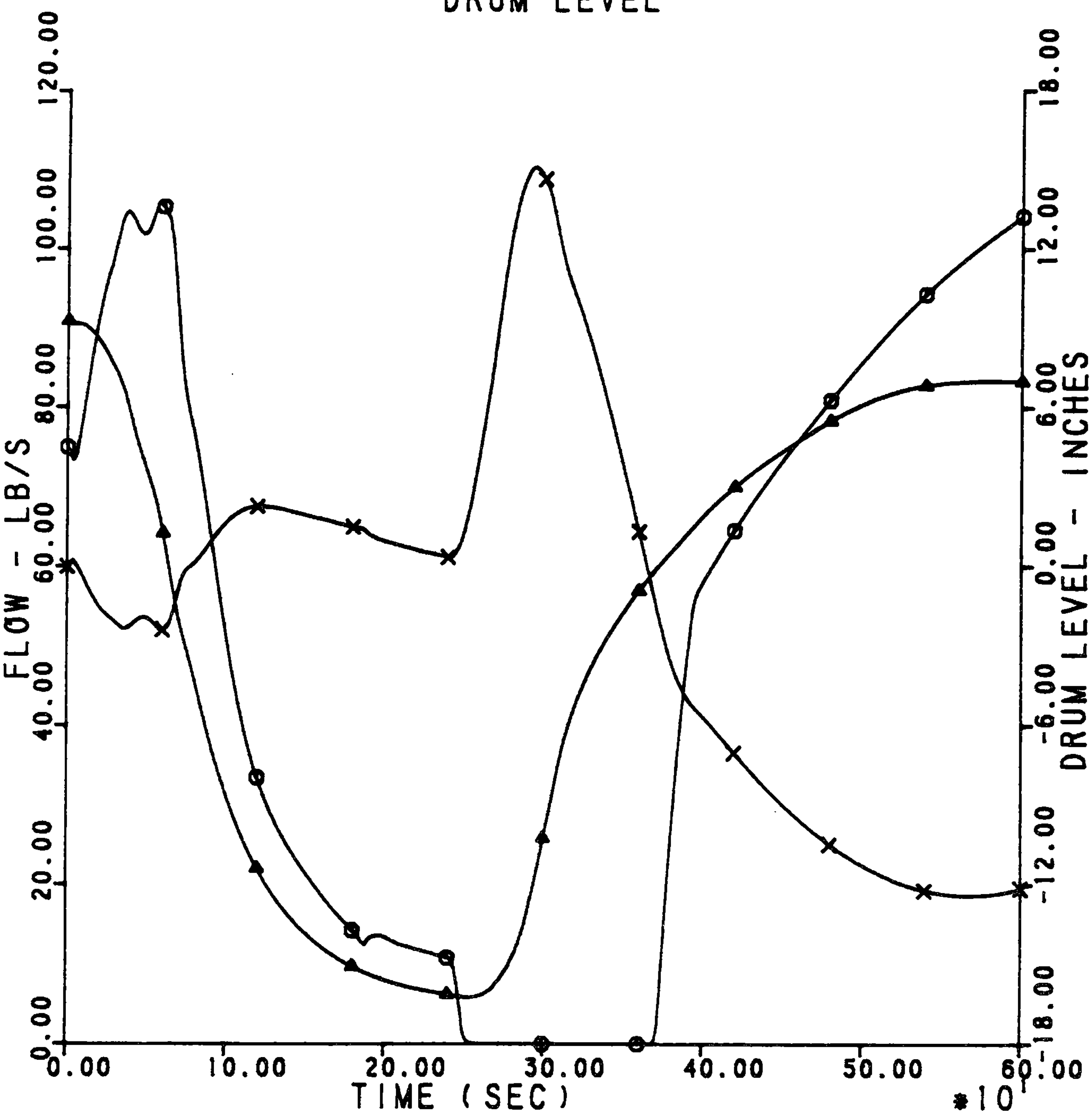


FIGURE E.4-29

JOB CMS 27 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1A
4800M RECT CLOUD W TO E AT 20M/SEC
FEEDWATER AND STEAM FLOW
DRUM LEVEL



LEGEND

- ⊙ FEEDWATER FLOW
- ▲ TURBINE GOVERNOR VALVE STEAM FLOW
- × STEAM DRUM LEVEL FROM NORMAL

FIGURE E.4-30

JOB CMS 27 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

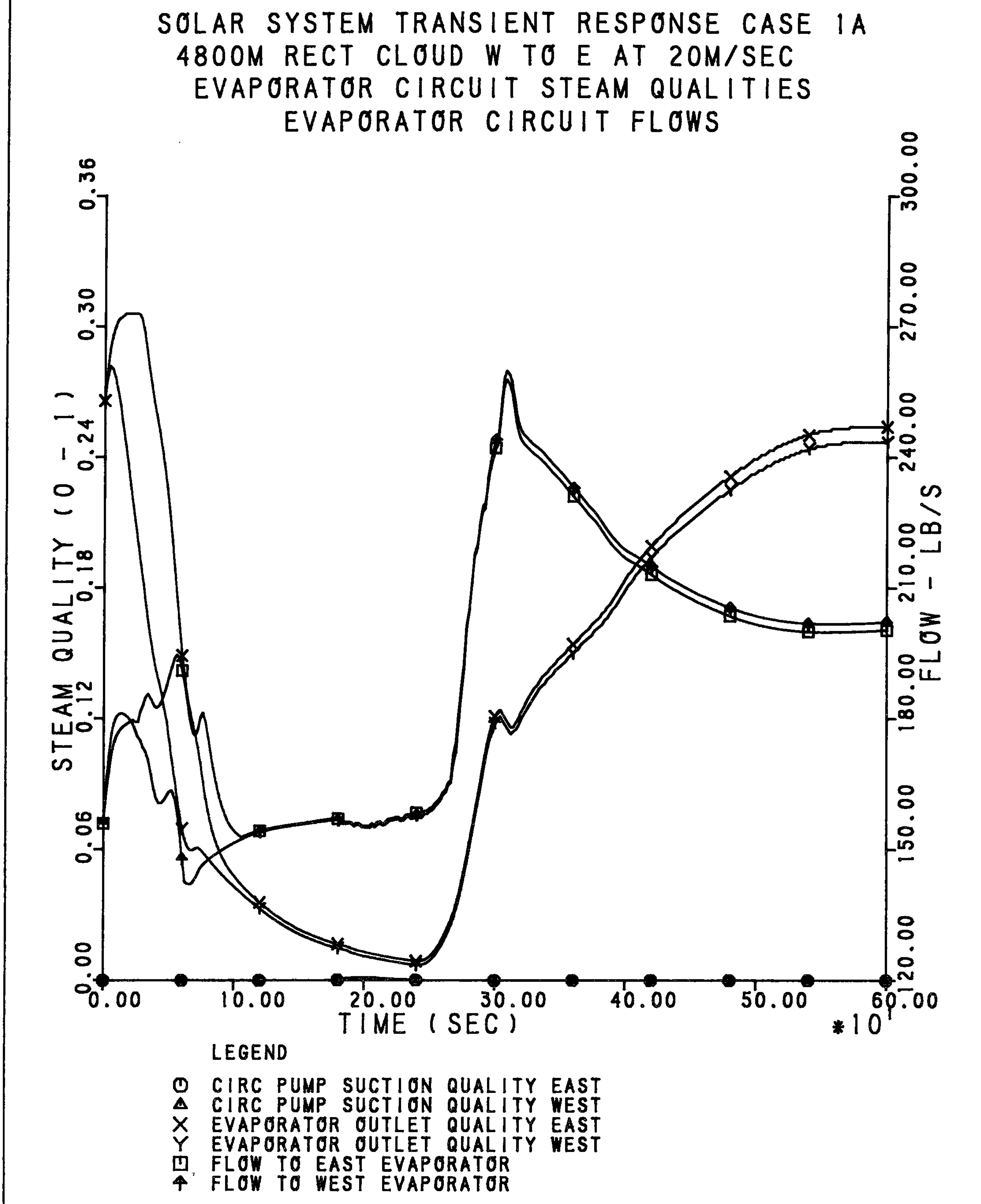

SOLAR SYSTEM TRANSIENT RESPONSE CASE 1A
4800M RECT CLOUD W TO E AT 20M/SEC
EVAPORATOR CIRCUIT STEAM QUALITIES
EVAPORATOR CIRCUIT FLOWS
STEAM QUALITY (0 - 1)
0.00
0.06
0.12
0.18
0.24
0.30
0.36
FLOW - LB/S
120.00
150.00
180.00
210.00
240.00
270.00
300.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
TIME (SEC)
*10[1]
LEGEND
CIRC PUMP SUCTION QUALITY EAST
CIRC PUMP SUCTION QUALITY WEST
EVAPORATOR OUTLET QUALITY EAST
EVAPORATOR OUTLET QUALITY WEST
FLOW TO EAST EVAPORATOR
FLOW TO WEST EVAPORATOR

FIGURE E.4-31

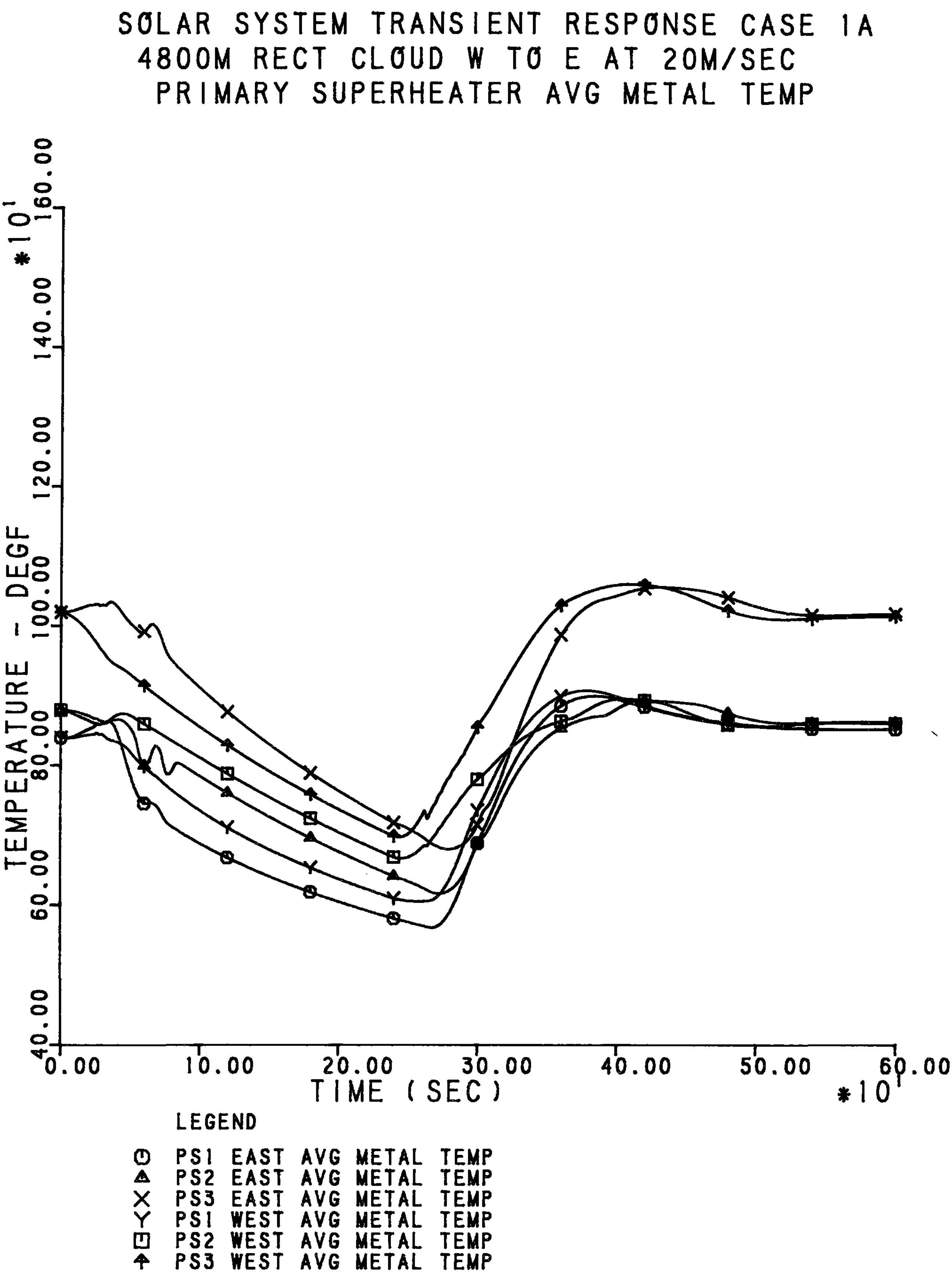
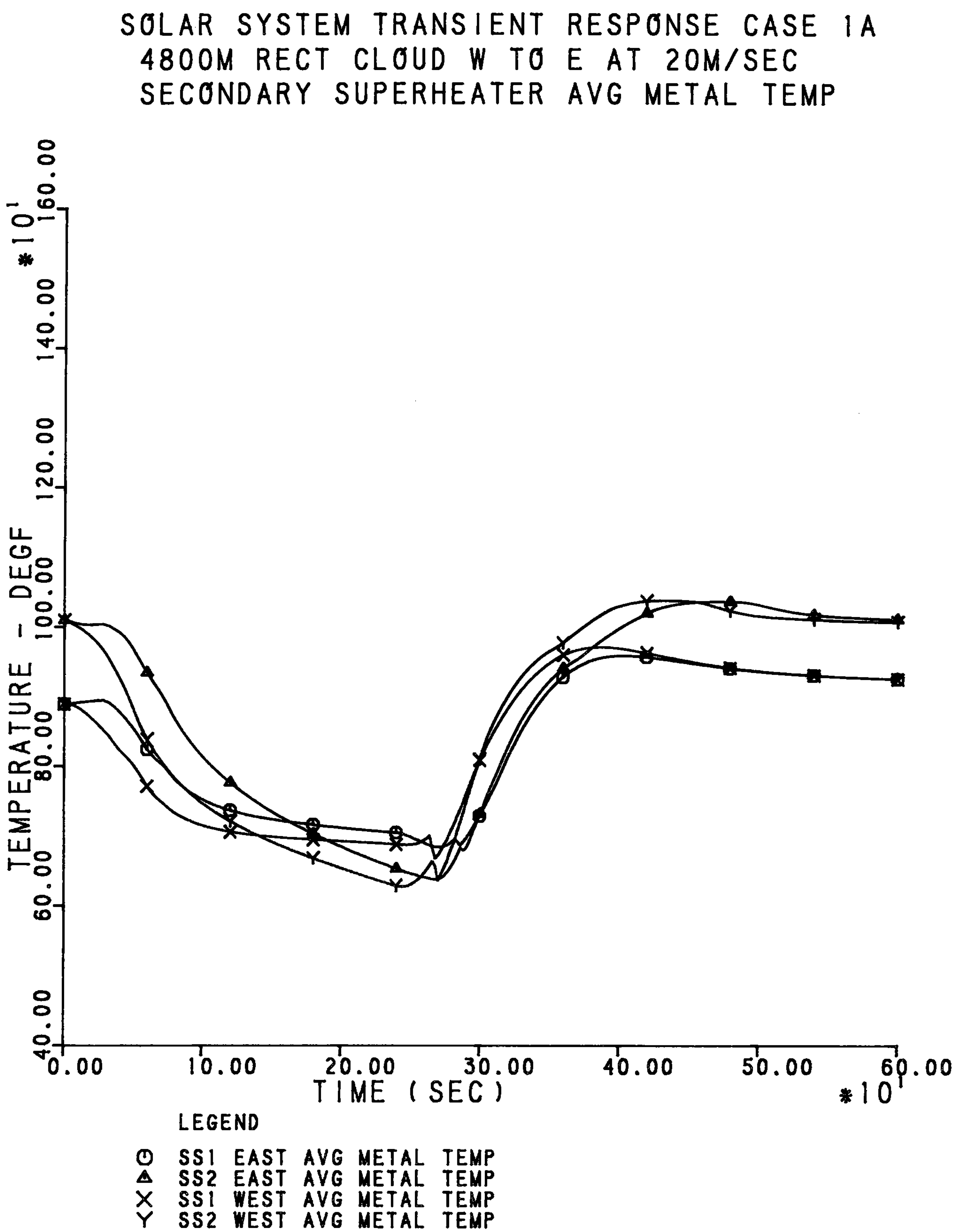


FIGURE E.4-32

JOB CMS 27 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION



SOLAR SYSTEM TRANSIENT RESPONSE CASE 1A
4800M RECT CLOUD W TO E AT 20M/SEC
SECONDARY SUPERHEATER AVG METAL TEMP
TEMPERATURE - DEGF
*10^1
40.00
60.00
80.00
100.00
120.00
140.00
160.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
TIME (SEC)
*10^1
LEGEND
SS1 EAST AVG METAL TEMP
SS2 EAST AVG METAL TEMP
SS1 WEST AVG METAL TEMP
SS2 WEST AVG METAL TEMP

FIGURE E.4-33

SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
PRIMARY SUPERHEATER PANEL EXIT TEMPS

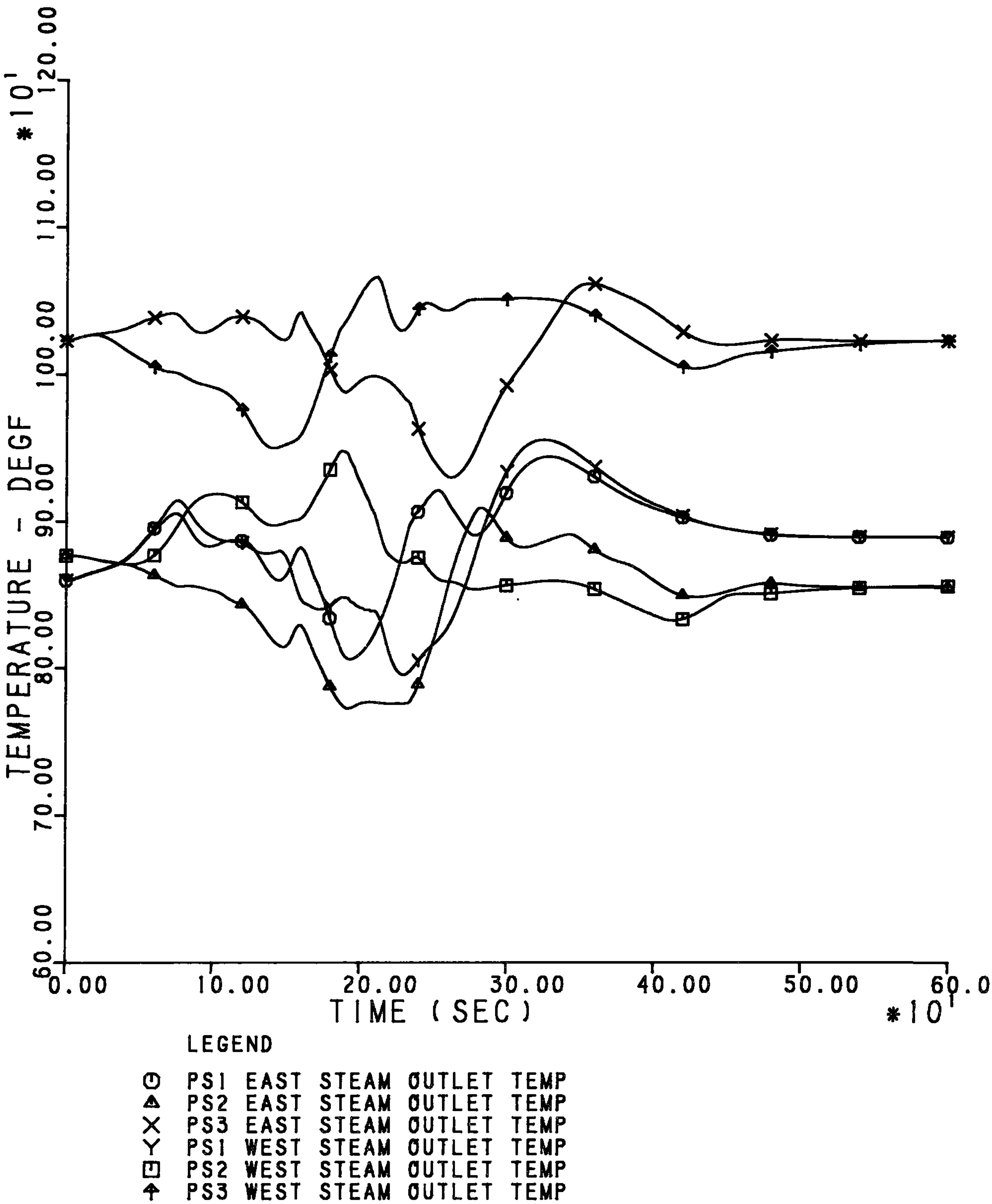
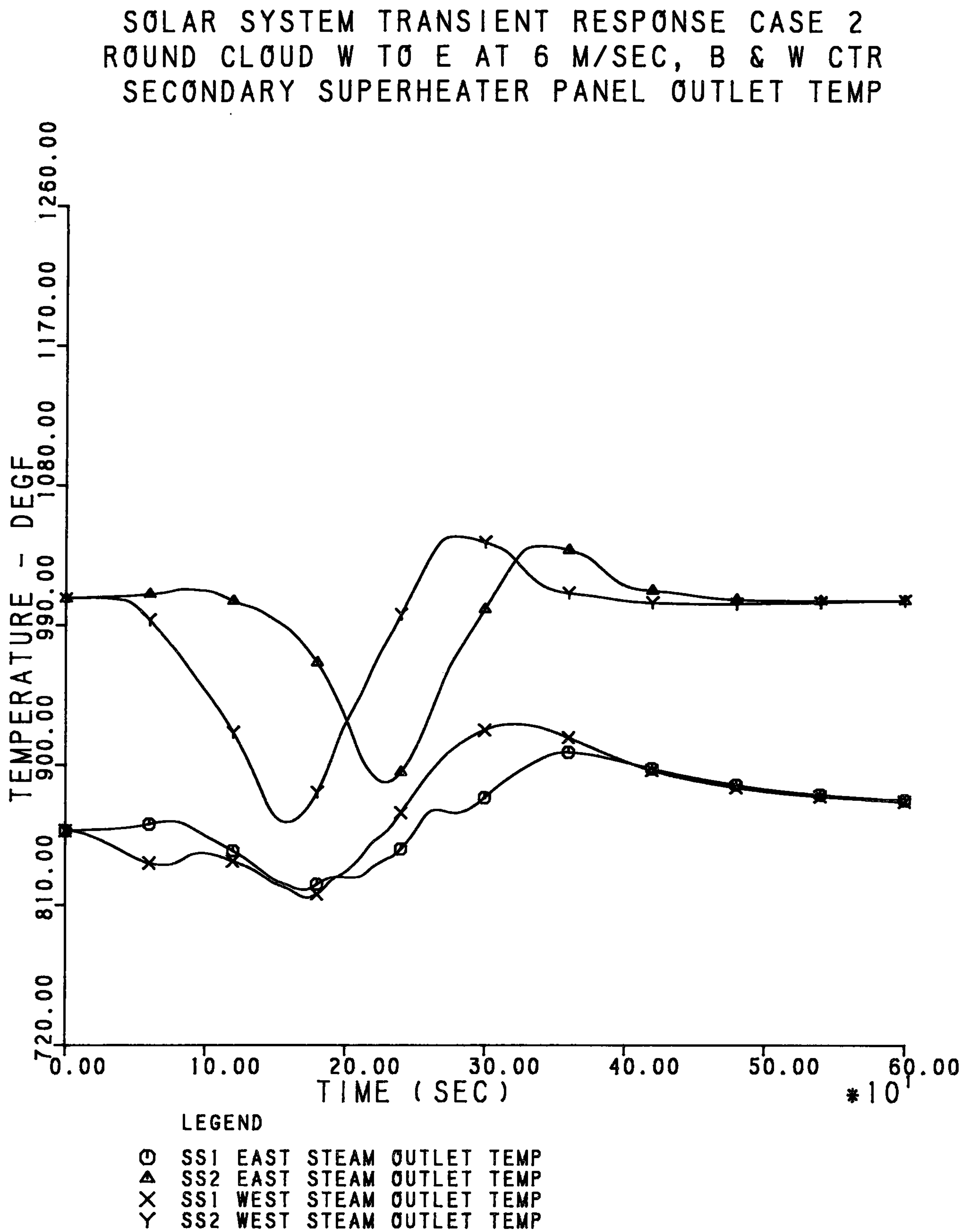


FIGURE E.4-34

JOB CMS 23 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION



SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
SECONDARY SUPERHEATER PANEL OUTLET TEMP
TEMPERATURE - DEGF
1260.00
1170.00
1080.00
990.00
900.00
810.00
720.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
TIME (SEC)
*10[1]
LEGEND
SS1 EAST STEAM OUTLET TEMP
SS2 EAST STEAM OUTLET TEMP
SS1 WEST STEAM OUTLET TEMP
SS2 WEST STEAM OUTLET TEMP

FIGURE E.4-35

SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
MAIN AND REHEAT STEAM TEMPS

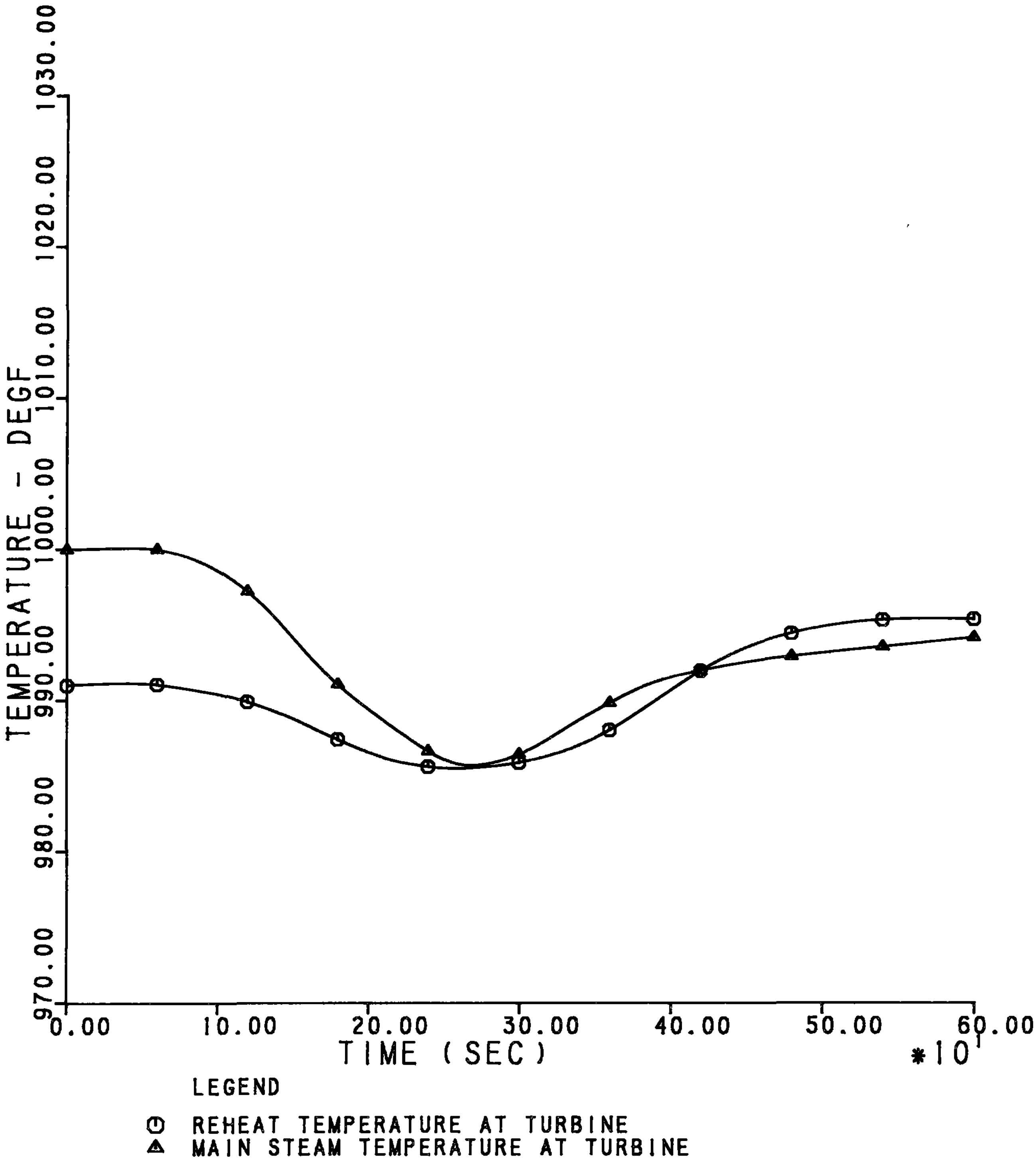
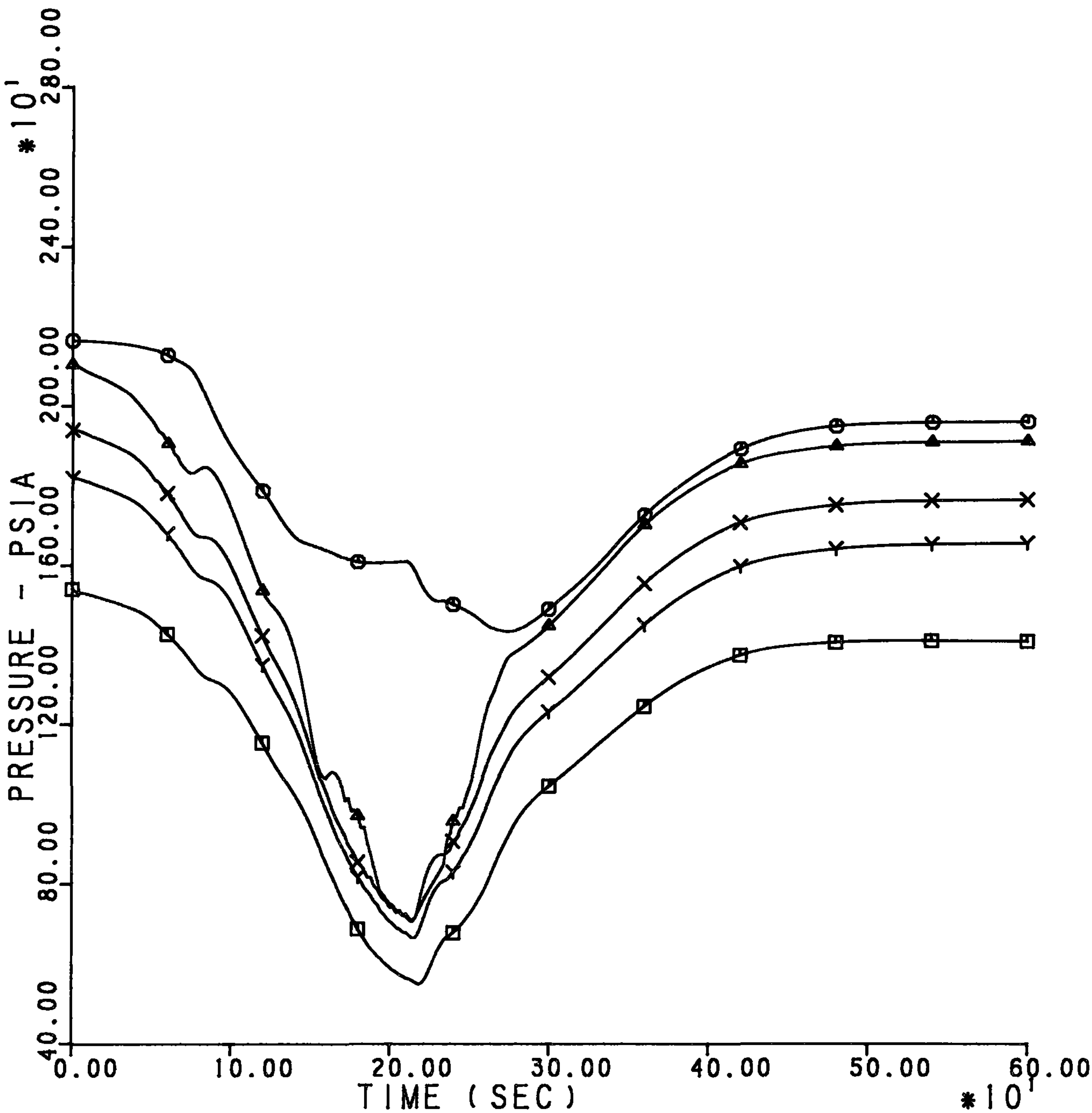


FIGURE E.4-36

JOB CMS 23 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

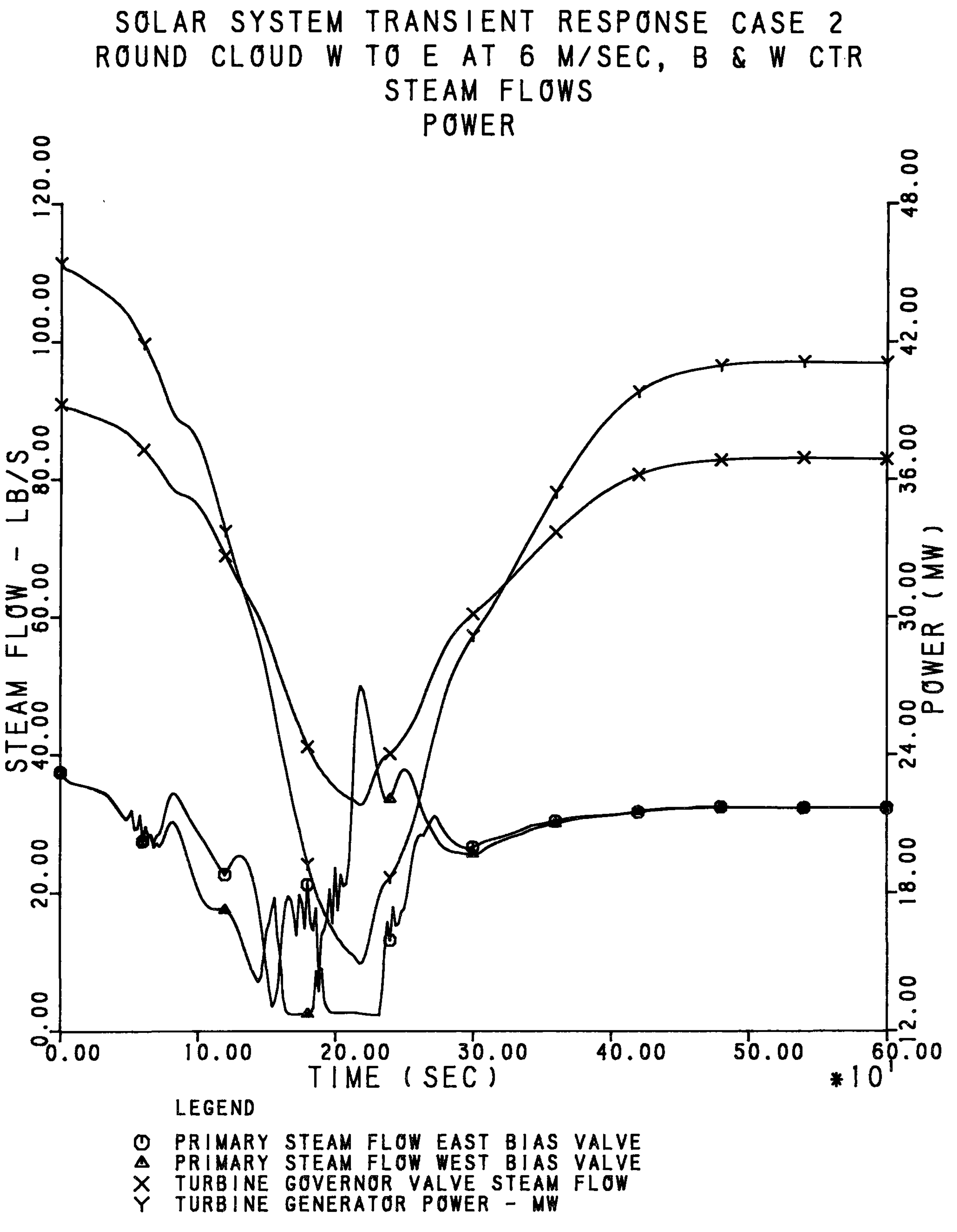
SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
STEAM PRESSURES



LEGEND

- ⊙ DRUM PRESSURE
- △ PSI EAST INLET PRESSURE (AFTER BIAS VALVE)
- X PRIMARY SUPERHEATER OUTLET HEADER PRESSURE
- Y SECONDARY SUPERHEATER INLET HEADER PRESSURE
- ⊡ SECONDARY SUPERHEATER OUTLET HEADER PRESSURE

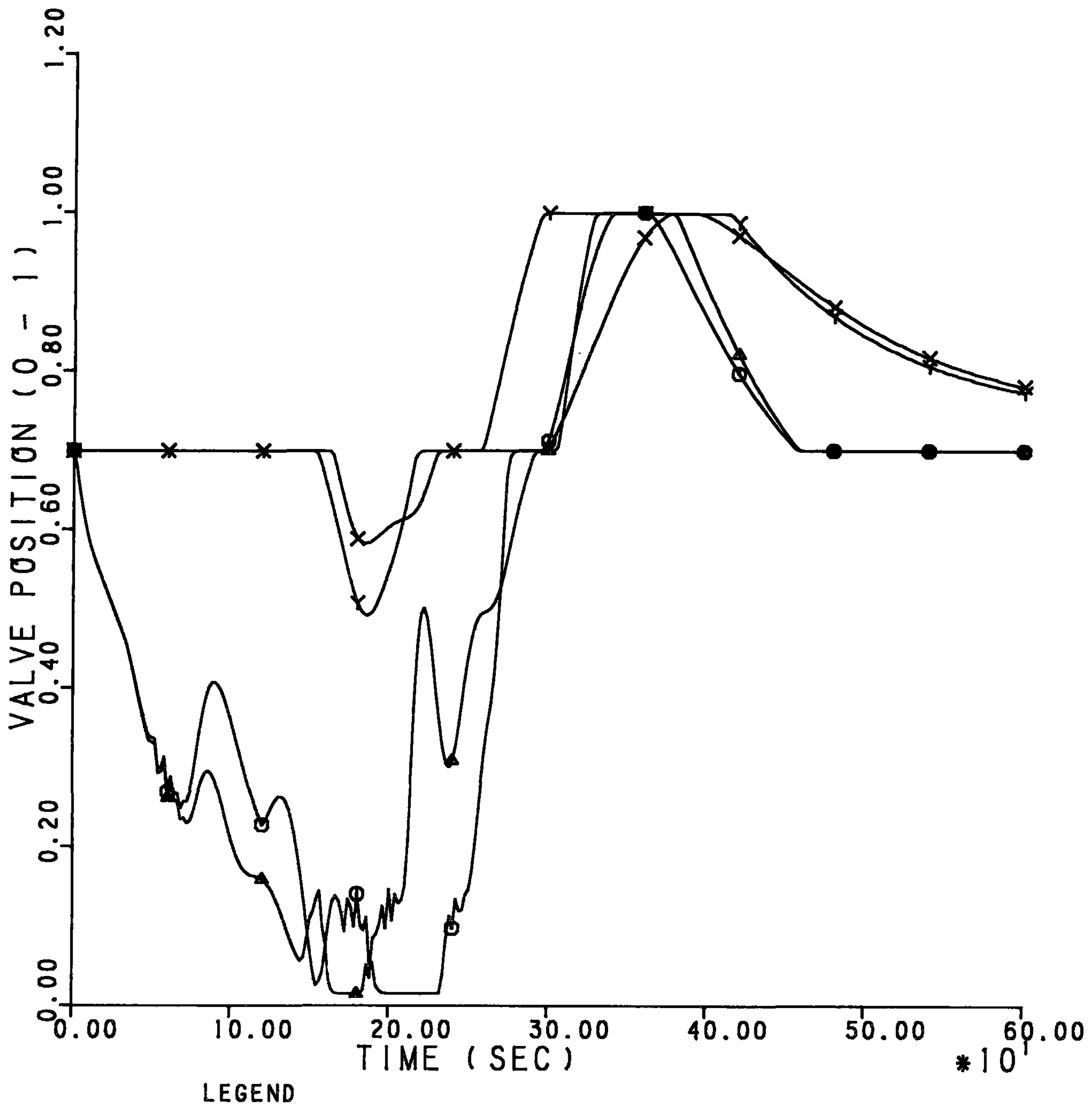
FIGURE E.4-37



SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
STEAM FLOWS
POWER
STEAM FLOW - LB/S
POWER (MW)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
12.00
18.00
24.00
30.00
36.00
42.00
48.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
TIME (SEC)
*10[1]
LEGEND
PRIMARY STEAM FLOW EAST BIAS VALVE
PRIMARY STEAM FLOW WEST BIAS VALVE
TURBINE GOVERNOR VALVE STEAM FLOW
TURBINE GENERATOR POWER - MW

FIGURE E.4-38

SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
BIAS VALVE POSITION



LEGEND
- O EAST PRIMARY SUPERHEATER BIAS VALVE POSITION
- △ WEST PRIMARY SUPERHEATER BIAS VALVE POSITION
- X EAST SECONDARY SUPERHEATER BIAS VALVE POSITION
- Y WEST SECONDARY SUPERHEATER BIAS VALVE POSITION

FIGURE E.4-39

SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
PRIMARY SUPERHEATER ATTEMPORATOR FLOWS

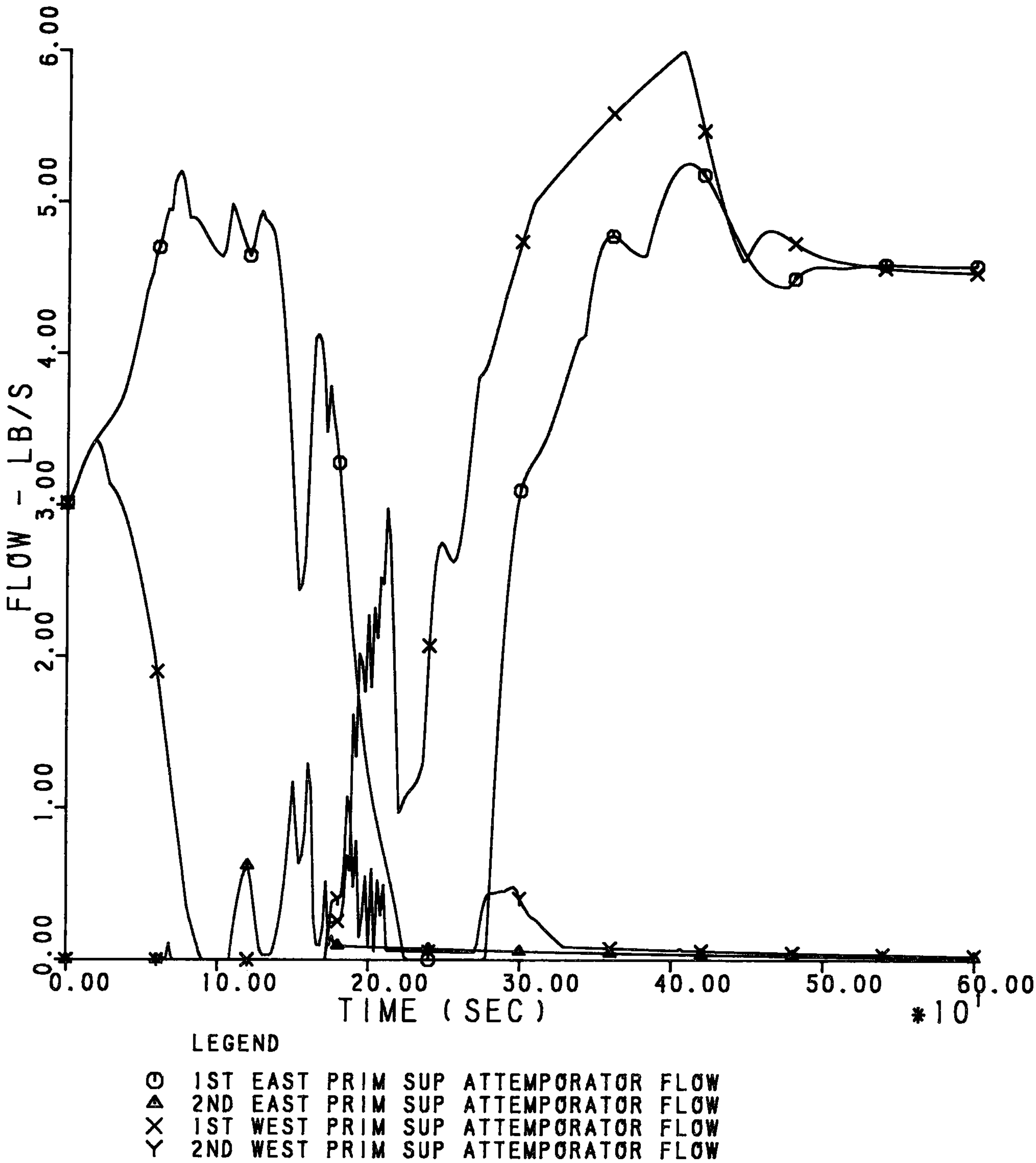


FIGURE E.4-40

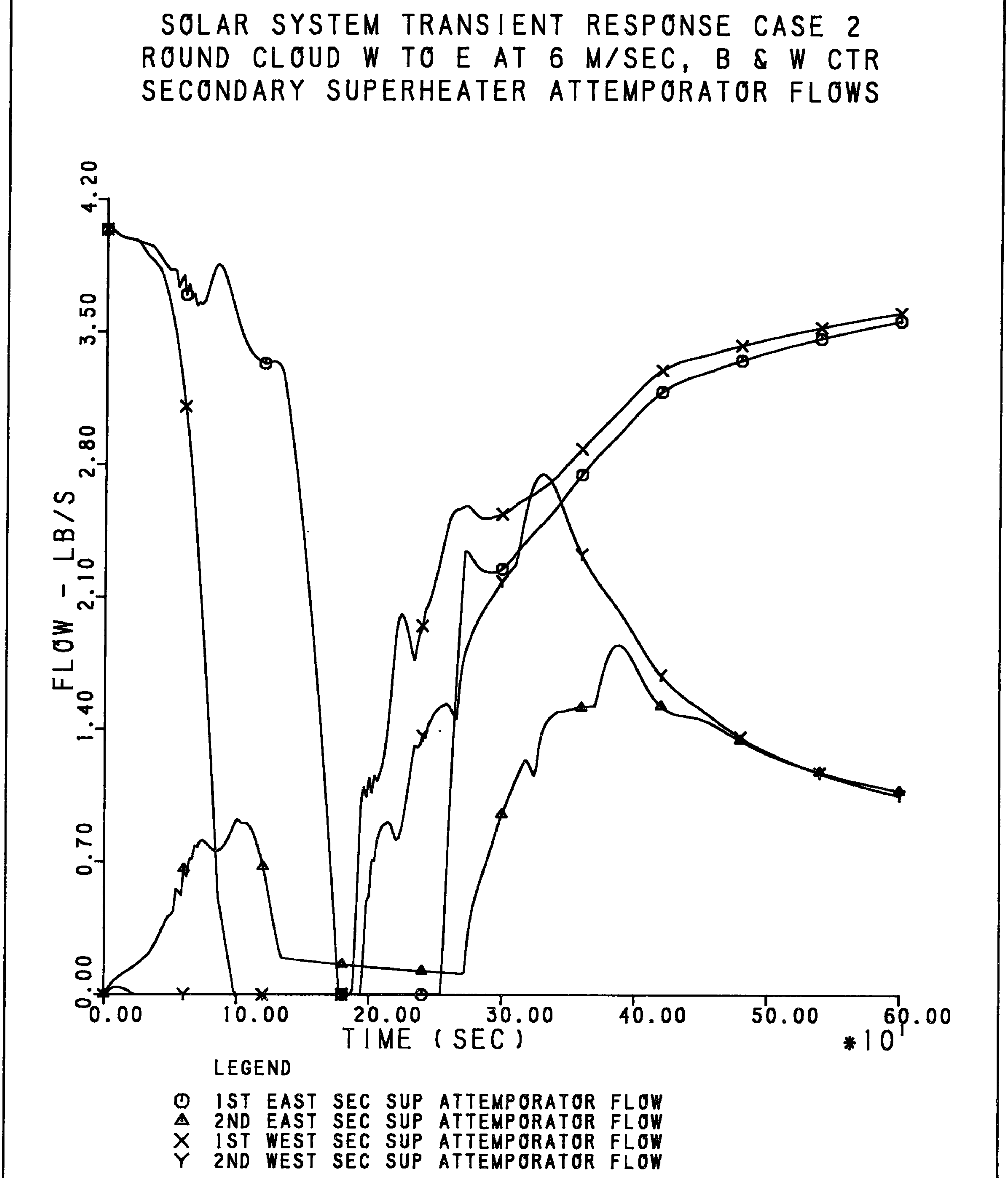

SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
SECONDARY SUPERHEATER ATTEMPORATOR FLOWS
FLOW - LB/S
4.20
3.50
2.80
2.10
1.40
0.70
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
TIME (SEC)
*10[1]
LEGEND
1ST EAST SEC SUP ATTEMPORATOR FLOW
2ND EAST SEC SUP ATTEMPORATOR FLOW
1ST WEST SEC SUP ATTEMPORATOR FLOW
2ND WEST SEC SUP ATTEMPORATOR FLOW

FIGURE E.4-41

SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
FEEDWATER AND STEAM FLOW
DRUM LEVEL

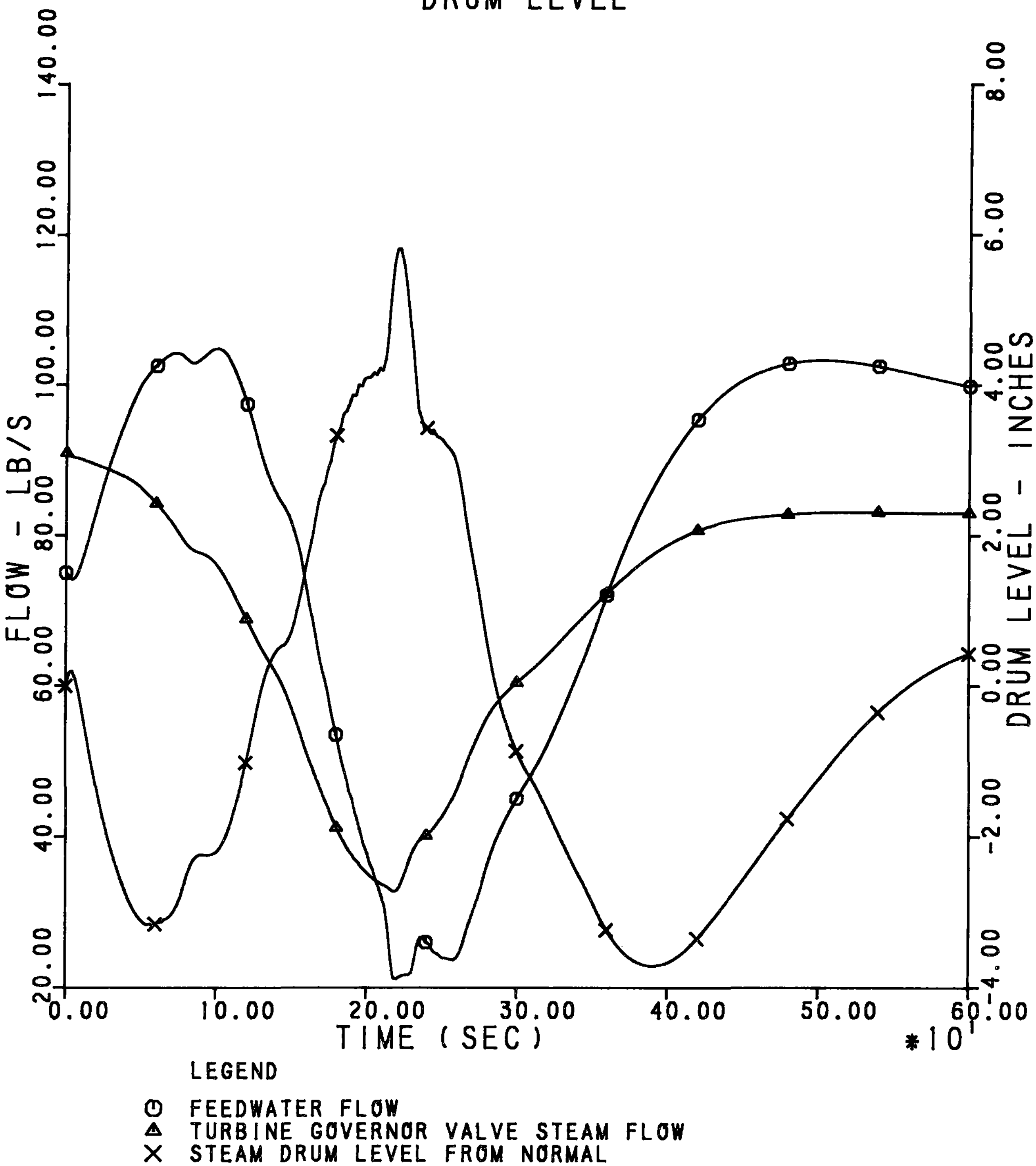


FIGURE E.4-42

SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
SECONDARY SUPERHEATER AVG METAL TEMP

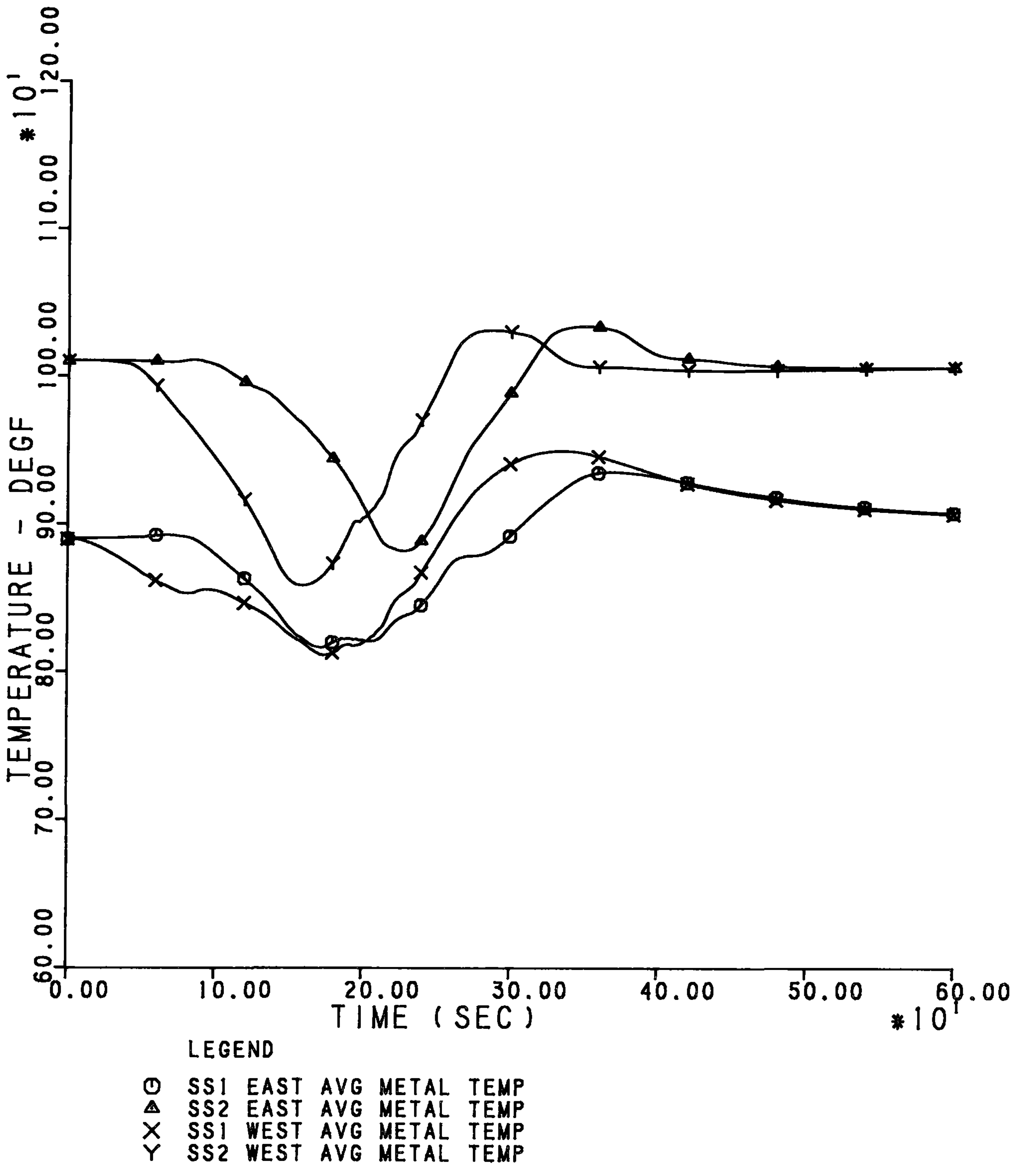


FIGURE E.4-43

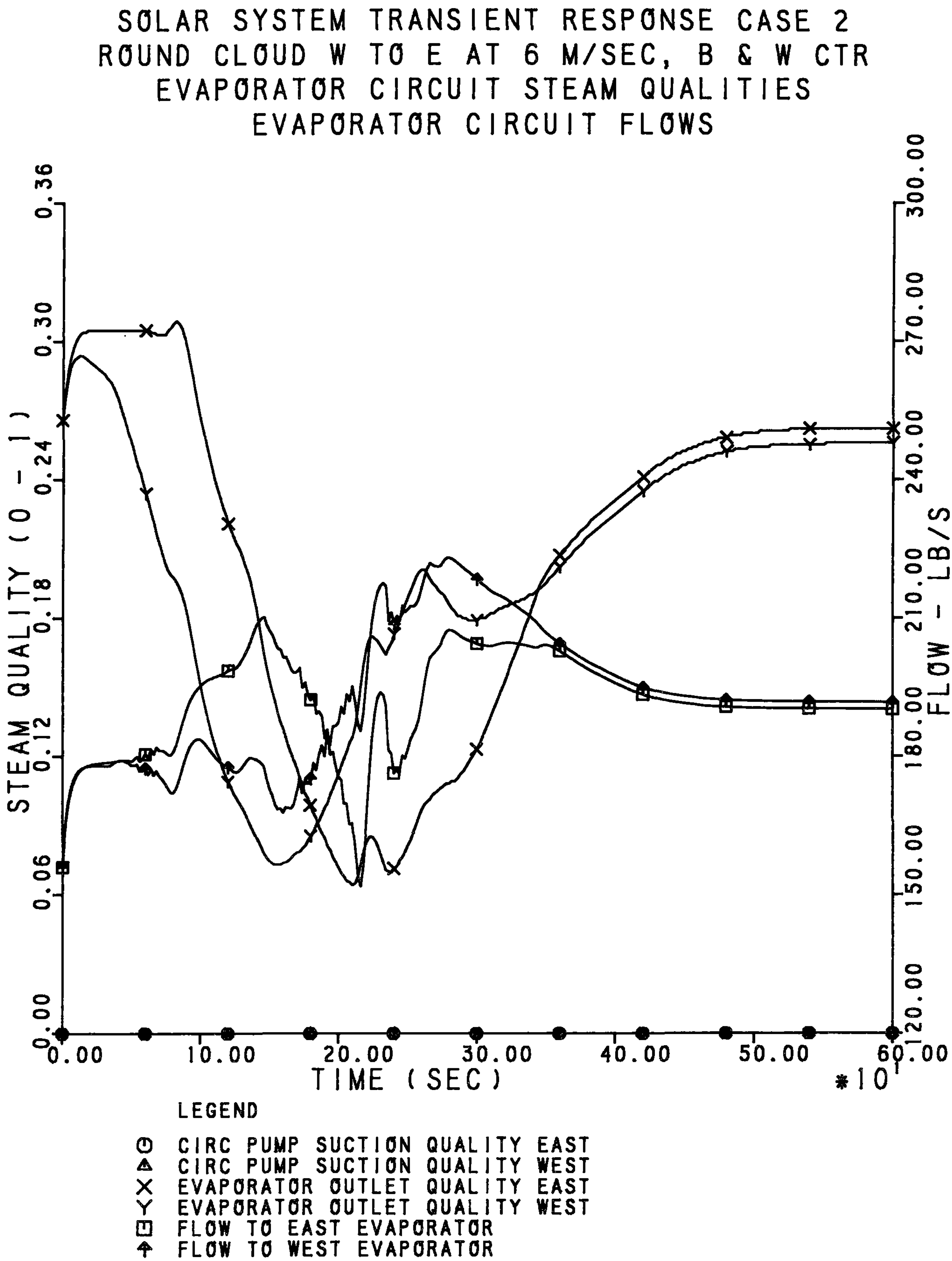
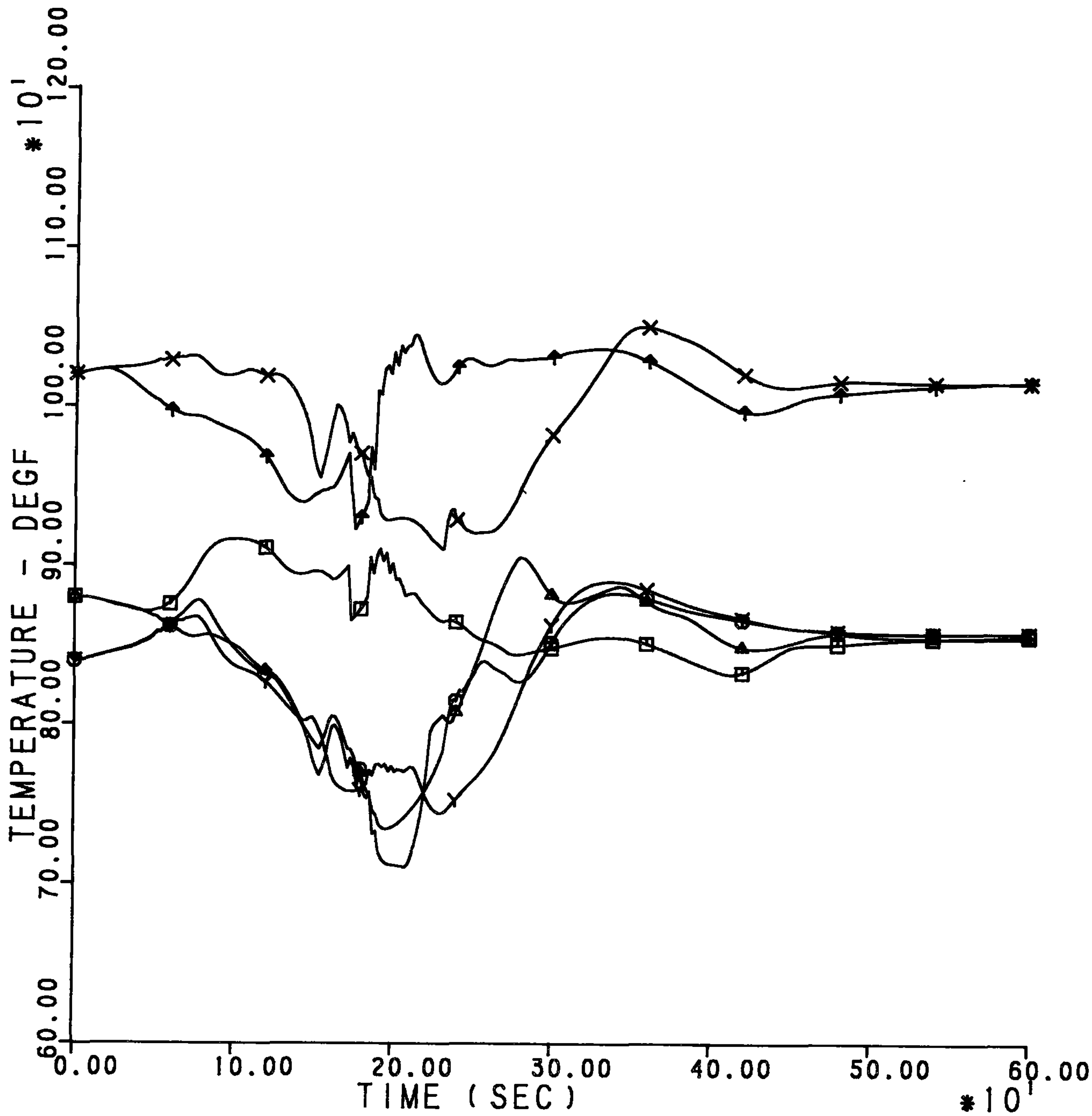


FIGURE E.4-44

JOB CMS 23 SEP 1983 STONE AND WEBSTER ENGINEERING CORPORATION

SOLAR SYSTEM TRANSIENT RESPONSE CASE 2
ROUND CLOUD W TO E AT 6 M/SEC, B & W CTR
PRIMARY SUPERHEATER AVG METAL TEMP



LEGEND

- O PS1 EAST AVG METAL TEMP
- △ PS2 EAST AVG METAL TEMP
- X PS3 EAST AVG METAL TEMP
- Y PS1 WEST AVG METAL TEMP
- □ PS2 WEST AVG METAL TEMP
- ↑ PS3 WEST AVG METAL TEMP

FIGURE E.4-45

APPENDIX F

APPENDIX F

RECEIVER SUPERHEATER HOT TUBE ANALYSIS REPORT

IIE/10/14/1761/13/P
OCTOBER 1983

INSTITUTO DE
INVESTIGACIONES
ELECTRICAS
DIVISION FUENTES DE ENERGIA
DEPARTAMENTO DE FUENTES
NO CONVENCIONALES

TRANSIENT ANALYSIS OF A SOLAR RECEIVER SUPERHEATER TUBE.

REPORT IIE/10/14/1761/I3/P
OCTOBER 1983

INSTITUTO DE INVESTIGACIONES ELECTRICAS
DIVISION FUENTES DE ENERGIA
DEPTO. FUENTES NO CONVENCIONALES DE ENERGIA

TRANSIENT ANALYSIS OF A SOLAR RECEIVER SUPERHEATER TUBE

DR. EDUARDO GLEASON GARCIA
ING. CARLOS RAMOS BERUMEN

APARTADO POSTAL 475
CUERNAVACA, ESTADO DE MORELOS
MEXICO 62000.

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INSTITUTO DE INVESTIGACIONES ELÉCTRICAS

ABSTRACT

This report presents the work performed by the Instituto de Investigaciones Eléctricas (México), and it represents the contribution to NEWMAN UNIT 1 SOLAR REPOWERING, EL PASO ELECTRIC COMPANY PRELIMINARY DESIGN, in collaboration with Stone & Webster Eng. Corp., responsible of architect/engineer services. El Paso Electric Co. is the prime contractor to the Departament of Energy of the United States of America.

A dynamic mathematical model is developed to analyse time-space performance of superheater panels or tubes of a water/steam external solar receiver.

Model implementation in a digital computer is described and simulation results are presented for typical transient situations. Model output is compared, under steady and transient states, in cases where data are available from other participants (Stone & Webster ,Babcock & Wilcox). Results obtained provide detailed information of time-space characteristics performance that complements input-output dynamic data of Stone & Webster. As a consequence of this results control aspects and control strategies are suggested for future developments.

I. INTRODUCTION

In a central receiver solar thermal power plant, the receiver component can be considered as the boiler of a conventional fossil plant from the point of view of conversion from primary energy to thermal energy. However, the analysis of heat transfer in a solar receiver requires more detailed methods and mathematical models to predict the performances than in a conventional boiler (1).

Under normal operating conditions only in short periods of time the receiver will be in a steady state, most of the time it will be in a transient state. Three kinds of transient conditions may be identified, first, is the one corresponding to intrinsic evolution of solar radiation, second, is the random cloud passages affecting incident solar power and third, the daily startup and shutdown of operation.

Mathematical modeling of these transient states is very usefull for the preliminary and detailed engineering design of solar receivers. Design requirements of reliability and longevity and operating conditions make the receiver one of the most critical components of solar power plants (2). Industry standards must be complemented by analytical tools to investigate potential operational and control problems (1,3).

The objective of this study is to develop a mathematical model of a superheater panel or tube of a water/steam external solar receiver, such that time-space performance may be evaluated.

Chapter II contains a description of the problem, a discussion of modeling and the set of equations obtained. Computer implementation of this model is presented in chapter III and also the results obtained by digital simulation for specific transient state situations.

II. MATHEMATICAL MODELING OF A SUPERHEATER TUBE.

II.1. PROBLEM DESCRIPTION.

The external water/steam solar receiver is integrated by 18 panels arranged in a partial arc facing North. There are 4 economizer panels and 14 interlaced boiler/superheater panels and they are simetrically located around receiver periphery. There are three primary superheater passes and two high pressure final superheater passes.

Any transient i.e. in solar flux density, in steam mass flow rate etc, leads to different time-space characteristics of absorbing panels. The evaluation of this change must be accomplished at least for the hottest panels of the receiver and for our case this corresponds to the superheater sections.

Mathematical modeling and simulation of these phenomena may prevent catastrophic situations and may be used to design more performant control strategies.

II.2. MODELING REQUIREMENTS.

The mathematical model will be used to predict time-space characteristics of a superheater tube or a panel, digital computer simulations will be accomplished.

The thermophysical properties of the superheater tube or panel are given as input data (diameters, length, metal density, thermal conductivity, etc.).

Simulation conditions must be specified i.e. time history at the inlet (pressure, temperature, steam flow rate, etc.), and the time-space distribution of incident solar heat flux at tube or panel surface.

The model must be able to analyse any transient condition at one or more of the inputs. Only open-loop responses are considered, no extra control actions are included.

II.3.MODELING APPROACH.

Given that the purpose of the model is not to describe microscopic details ocurring at the superheater, but more to evaluate the overall performance of this component i.e. to detect by simulation catastrophic situations or to redesign the controllers of temperature, some assumptions can be made. Fluid flow and heat transfer phenomena are, in their most general form, governed by a system of time-space partial differential equations (4). In general it is a formidable task and, may be impossible, to find a closed solution for this system. Still numerical solutions for time varying three dimensional case involve computer time and cost that would be prohibitive. In general the two principal methodologies of analysis i.e. distributed and lumped parameters models (3) with different degrees of complexity are the most commonly used.

In lumped parameters models, the system to analyse is divided in a finite number of sections, the number of which depending on the required accuracy. The space dependency is represented by this sections, and therefore the model is simplified to a set of ordinary non linear differential equations with time as independet variable and with the order defined by the number of sections.

Distributed parameters models involve the solution of time-space partial differential equations using well-known approaches over the space dependency i.e. finite difference methods (5), time integration is accomplished after this.

Given that the model will be built to predict the performance of a single superheater tube, some simplifications are possible getting still a good accuracy. Tube dimensions range: external diameter of 1.125 inch, wall thickness in the order of 0.237 inch, gives the possibility of considering the radial and circumferential temperatures effects in a single average temperature. In other words for a specific section of the tube it can be assumed that the differences between temperatures along the radial and circumferential directions are not considerable.

It has been shown that the hypothese of considering the performance of a single tube as representative of the whole panel, depends on the uniformity of the lateral heat flux distribution (6). In our case this is not a restriction if it is possible to specify the solar flux distribution corresponding to each tube to be analysed.

Most of published dynamic models for fossil boilers or solar receivers only consider one dimensional case with time as independent variable. Heat transfer studies made for Barstow's solar one receiver component utilize a model with the following principal characteristics: Lumped parameter approach, a tube as representative of the performance of the whole panel, three sections of analysis (subcooled, saturated an superheated sections), one point at each section reflecting the average performance (1,6,7).

A sodium cooled receiver for Almeria pilot plant, has also been analysed with time-axial distribution of temperatures along the sodium pipes, seemingly using a distributed parameter methodology. Heat transfer between nodes due to radiation, convection, conduction and mass flow has been evaluated with a computer program which solves the heat conduction equation for steady state and transient conditions (8).

For the French solar thermal pilot power plant the simulation studies for the receiver were made with a lumped parameter methodology, the receiver is divided in zones . Modeling includes calculation of metal mean temperature and molten salt temperature at the output of each zone and also a more accurate evaluation of the performance at two points, the more exposed and the hottest, output at this points are: external and internal metal temperatures, and molten salt temperature (9).

There are many dynamic analysis reported for conventional boiler systems, we have mentionned only those concerning solar receivers. From the above discussions we may conclude the following.

- A dynamic model for the one dimensional case (axial distribution), furnishes desired information about the performance of the superheater tube.

- For this case a lumped parameter approach gives more versatility. If only the output of the superheater tube or panel is of interest this can be easily implemented and this is not possible to do with the distributed parameter methodology.

- A detailed axial distribution dynamic evaluation of properties along the tube can also be done (that is our objetive). The same level of accuracy than distributed parameters approach can be obtained by varying the number of sections to analyse.

II.4.MODEL DESCRIPTION.

Development of the model is based on the following considerations:

- The superheater(SH) tube is divided in N volumes (Figure 1), along the axis there is an incident solar flux density profile, its distribution is time dependent.

- Tubes are jointed by a web to form a panel, incident power along the tube is obtained from solar power density multiplied by the projected area of the tube plus the exposed area of the web. In this way conduction heat transfer between the tube and web will be approximated. No conduction model of this components will be included.

II.4.1.MODEL EQUATIONS.

II.4.1.1.HYPOTHESES.

In addition to a lumped parameter methodology the following assumptions are made: (1,10,11,12).

- Fluid properties at any given cross section are uniform.

- Axial and lateral conduction along the tube is not considered.

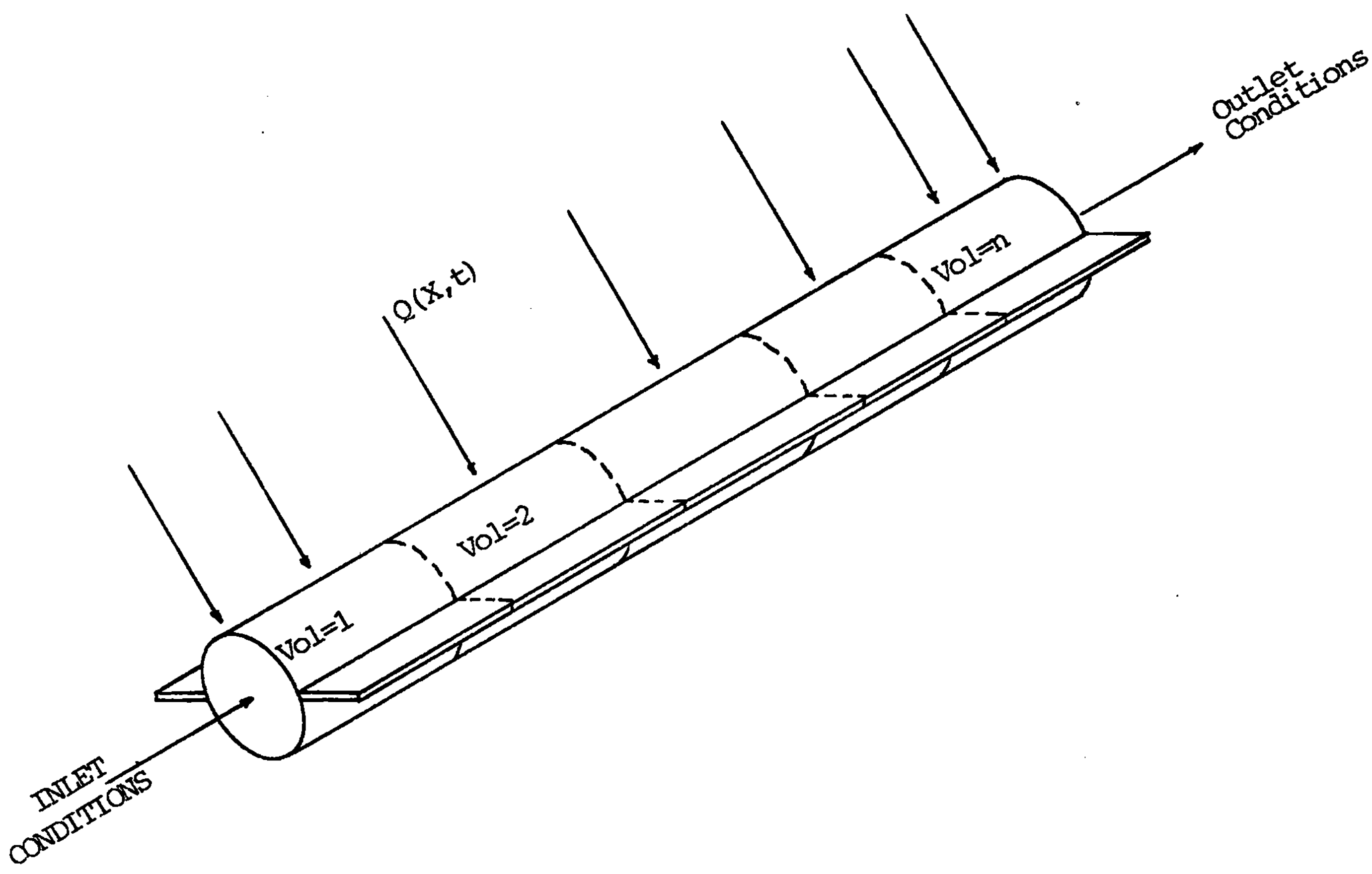

Fig. 1 Schematic representation of the superheater tube.

- Uniform metal properties (thermal conductivity, density, etc.).

- Thermodynamic equations and simplified steam table properties fits will be used to obtain the thermodynamic properties required.

- Radiative interchange between adjacent tubes is not included.

- Lag time associated to mass transport is negligible compared to state variables time constant.

- Internal energy is approximated by the enthalpy, the contribution of the term pressure multiplied by specific volume is neglected. In this way, energy equation complexity is reduced without significative loss of accuracy.

- Pressure drop includes only friction and gravity losses, momentum losses are neglected.

II.4.1.2.CONTINUITY EQUATION.

Mass conservation principle gives:

[RATE OF CHANGE OF STORED MASS] = [RATE OF MASS INFLUX] - [RATE OF MASS EFFLUX]

For a fluid flow through a lumped component, the equation is reduced to the form:

$$V d\rho a/dt = Wi - Wo \quad (1)$$

Where:

V = Fluid volume

Wi = Inlet mass flow

Wo = Outlet mass flow

ρa = Average density

II.4.1.3.ENERGY CONSERVATION EQUATION.

[RATE OF CHANGE OF STORED ENERGY] = [RATE OF ENERGY INFLUX]
- [RATE OF ENERGY EFFLUX]
+ [RATE OF HEAT INPUT]
- [RATE OF WORK OUPUT]

For a lumped component:

$$V\, d(\rho a h a)/dt = Wihi - Woho + Q - W \quad (2)$$

Where:

hi = Inlet enthalpy

ho = Outlet enthalpy

ha = Average enthalpy

Q = Heat input

W = Work done, zero in our case

II.4.1.4.DYNAMIC EQUATION FOR METAL ENERGY STORAGE

[RATE OF CHANGE OF STORED ENERGY] = [RATE OF ENERGY INPUT] - [RATE OF ENERGY OUTPUT]

$$V_m C_{pm} \rho_m \, dT_{ma}/dt = Q_i - Q_o \qquad (3)$$

Where:

V_m = Metal volume

C_{pm} = Metal specific heat

ρ_m = Metal density

T_{ma} = Metal average temperature

Q_i = Heat rate absorbed by the metal

Q_o = Convective heat transfer rate to cooling fluid

II.4.1.5.MOMENTUM EQUATION.

Momentum conservation is expressed in terms of the following relationship:

[RATE OF CHANGE OF STORED MOMENTUM]= [RATE OF MOMENTUM INFLUX]

- [RATE OF MOMENTUM EFFLUX]

+ [NET FORCE APPLIED]

For a fluid flow, neglecting inertia terms, we have:

$$P_i - P_o = K_F W^2 / \rho a + L \rho a g \quad (4a)$$

$$K_F = f \quad r_i L / 2 g_o A_i \quad (4b)$$

Where:

P_i = Inlet pressure

P_o = Outlet pressure

r_i = Internal radius

A_i = Internal area

g_o = 32.16 lbm/lbf ft/sec

f = Friction factor

W = Mass flow rate

L = Tube length

g = Acceleration due to gravity

Friction factor is obtained from geometry, material properties and manufacturers data (15); for fully turbulent flow the following simplified relation may be used:

$$f = 0.00140 + 0.125/Re$$

Where:

Re=Reynolds Number

II.4.1.6.MODEL SIMPLIFICATION.

Certain authors have proposed simplifications to the above equations. Masses of metal and fluid may be lumped in an equivalent efective mass, in this way Eq (3) can be avoided, instead an algebraic relation for an equivalent metal steam temperature may be used (11). In our case we will not do this assumption, because accuracy requirements over metal temperature profile along the tube.

Assuming steam flow is incompressible inside the superheater tube, inlet and outlet mass flow rate will have the same value (1), then differential equation (1) is eliminated, and the density along the tube will be equal to its inlet value (inlet conditions are time varying). Our early simulations have shown the validity of this assumption and it is included in the final version of our model. Some numerical integration problems may araise due to very fast transient responses of enthalpy, this is a characteristic of stiff type differential equation systems, reference (1) proposes to eliminate the derivative term of equation (2) obtaining an algebraic solution for internal energy, in this way a closed form solution for fluid temperature may be obtained. We have avoided this simplifications by using a numerical integration routine specially conceived for solving stiff differential systems of equations.

In short, the only significant simplification to the model will be elimination of differential equation (1), the consequences will be discussed latter.

II.4.1.7.HEAT TRANSFER MECHANISMES.

Heat transfer at the metal surface involves the evaluation of the following phenomena, Figure (2).

A fraction of receiver incident solar radiation comming from heliostat field is reflected by the absorbing surfaces, reflectivity of metal takes account of this loss:

$$Qref = \beta \; Qinc \qquad (6)$$

where:

Qref = Reflected power

β = Reflectivity

Qinc = Incident power

Reflectivity is considered a constant.

Radiative losses at the receiver are modeled considering Steffan-Boltzmann law:

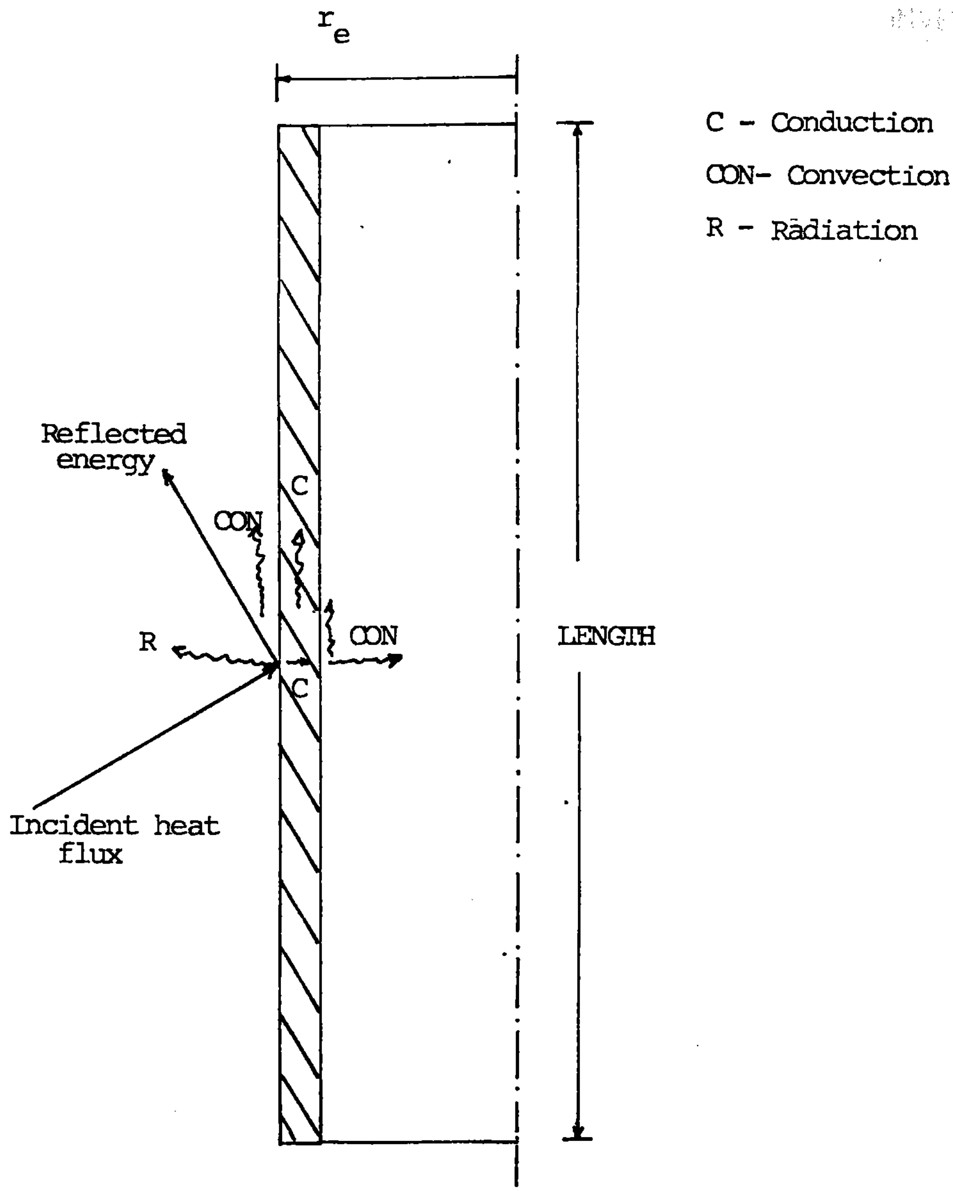

Fig.2.- Heat transfer mechanismes at the metal surface.

$$Qr = \tau \varepsilon Ar (Tma^4 - To^4) \quad (7)$$

where:

Qr = Radiative heat loss

τ = Steffan-Botzmann constant

ε = Metal emissivity

Ar = Radiation area

Tma = Absolute average metal temperature

To = Absolute air temperature

Convective heat losses are obtained from (13):

$$Qc = Achc (Tma - To) \quad (8)$$

where:

Qc = Convective heat losses

Ac = Convective area

hc = Convective heat transfer coefficient

Tma = Average metal temperature

To = Air temperature.

Conduction heat losses are neglected (6). From equations (6), (7), (8), metal heat absorption is:

$$Qm = Qinc - Qref - Qr - Qc \qquad (9)$$

Heat transfer from external tube surface to fluid is due to radial conduction through tube wall and forced convection from inner tube surface to fluid:

$$Qf = Hmf\ (Tma - Tfa) \qquad (10)$$

where:

Qf = Heat transfer rate to fluid

Tfa = Average fluid temperature

Hmf = Overall heat transfer coefficient

Evaluation of Hmf is made with metal resistance and inside convective film heat transfer coefficient:

$$1/Hmf = [1/AiHi] + [\ln(ro/ri)/2\pi Lkm] \qquad (11)$$

where:

Ai = Inner heat transfer area

Hi = Inside film convection coefficient

ro = External radius

ri = Internal radius

L = Tube length

Km = Thermal conductivity of metal

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Inside film convection coefficient is determined by using Dittus and Boelter correlation (14):

$$Nu = 0.023\ Re^{0.8} Pr^{0.4} \quad (12)$$

$$Re = Di\ W/\mu \quad (13)$$

$$Pr = Cp\ \mu/k \quad (14)$$

$$Hi = Nu\ k/Di \quad (15)$$

Where:

Nu = Nusselt Number

Re = Reynolds number

Pr = Prandtl number

Di = Internal diameter

W = Mass flow rate

μ = Fluid viscosity

Cp = Fluid specific heat

k = Fluid thermal conductivity

II.4.1.8.STEAM PROPERTIES RELATIONS.

With the aid of model equations, pressure and enthalpy of superheater steam are defined. Other thermodynamic properties as temperature, density, thermal conductivity, etc. are evaluated by functional relationships involving these two independent intensive properties. Use of steam tables is not adequate to dynamic computer simulations.

Steam temperature relation was obtained by non linear least squares minimisation of the following expression (16).

$$T = C1 + C2P + C3h + C4Ph \qquad (16)$$

Range of validity is:

$T \in [740, 1090]$

$P \in [360, 2100]$

$h \in [1274.6, 1572.2]$

where:

h = Steam enthalpy (Btu/lbm)

P = Steam pressure (psia)

T = Steam temperature (F)

C1 = -2046.96

C2 = 0.422947

C3 = 1.990311

C4 = -0.000274

With this relation the residual standard deviation has a value of 4.6 deg. F, i.e. values of temperature are predicted with a high accuracy.

Thermal conductivity and viscosity are calculated with relations given by reference (12), pages 144-146.

Prandtl number was calculated by means of a similar expression to that employed to predict temperature:

$$Pr=0.457505+0.000467T+0.001286P-0.00001PT \quad (17)$$

Finally given that tube inlet properties are time varying, with pressure and temperature other properties needed by the model are obtained (enthalpy, density, etc), with a general formulation in a very accurate way for any thermodynamic state. Formulation is from (12) and was implemented in a digital program(19).

III.COMPUTER SIMULATION.

III.1.STEADY STATE SPECIFICATION.

Steady state performance for nominal conditions has been supplied by Babcock & Wilcox (B & W), designer of the solar receiver under analysis (17). Available are two computer printouts, one for nominal operating conditions and the other for upset and unbalanced conditions. On this latter case nominal incident heat flux on each zone is enhanced by a given factor, also mass flow rate is diminished i.e. this corresponds to a critical case.

III.1.1.NOMINAL CONDITIONS.

B & W divides tube or panel in twelve zones along the heigth, the lower and upper zones are almost half the lenght of the other zones. For each zone fluid outlet conditions and tube metal average temperature are specified for the nominal operating point. Following is a list of principal simulation conditions (Table I).

Table I

-Site specification:
Location: El Paso Texas, Newman Unit 1, El Paso Electric Co.
Time: 12 Noon, winter solstice
Wind velocity: 18.04 (ft/s)
Air temperature:(57 F)

-Superheater panel specifications:
Material: Incoloy 800H
Number of tubes: 26 or 29
Exposed heigth: 85 ft
Tube internal diameter: 0.888 inch.
Tube external diameter: 1.125 inch.
Web width: 0.273 inch.
Web thickness: 0.187 inch.
Metal specific heat: 0.11 Btu/lbm F
Metal density: 353.33 lbm/cu ft
Metal thermal conductivity: 0.00333 Btu/s ft F
Emissivity of tube: 0.9
Reflectivity: 0.05

-Fluid inlet conditions:
Five sets depending on type of superheater to be analysed, i.e., primary superheater 3 (PSH3);
Number of tubes: 29
Pressure: 1969.53 psia
Enthalpy: 1391.36 Btu/lbm
Temperature: 873.06 F
Mass flow rate: 136429.1 lb/h

-Solar flux density profile:
Five profiles depending on location of superheater, i.e.
For PSH3, see Fig.(3)

FIGURE 3
SOLAR FLUX DENSITY
NORTH AND HOTTEST PANELS

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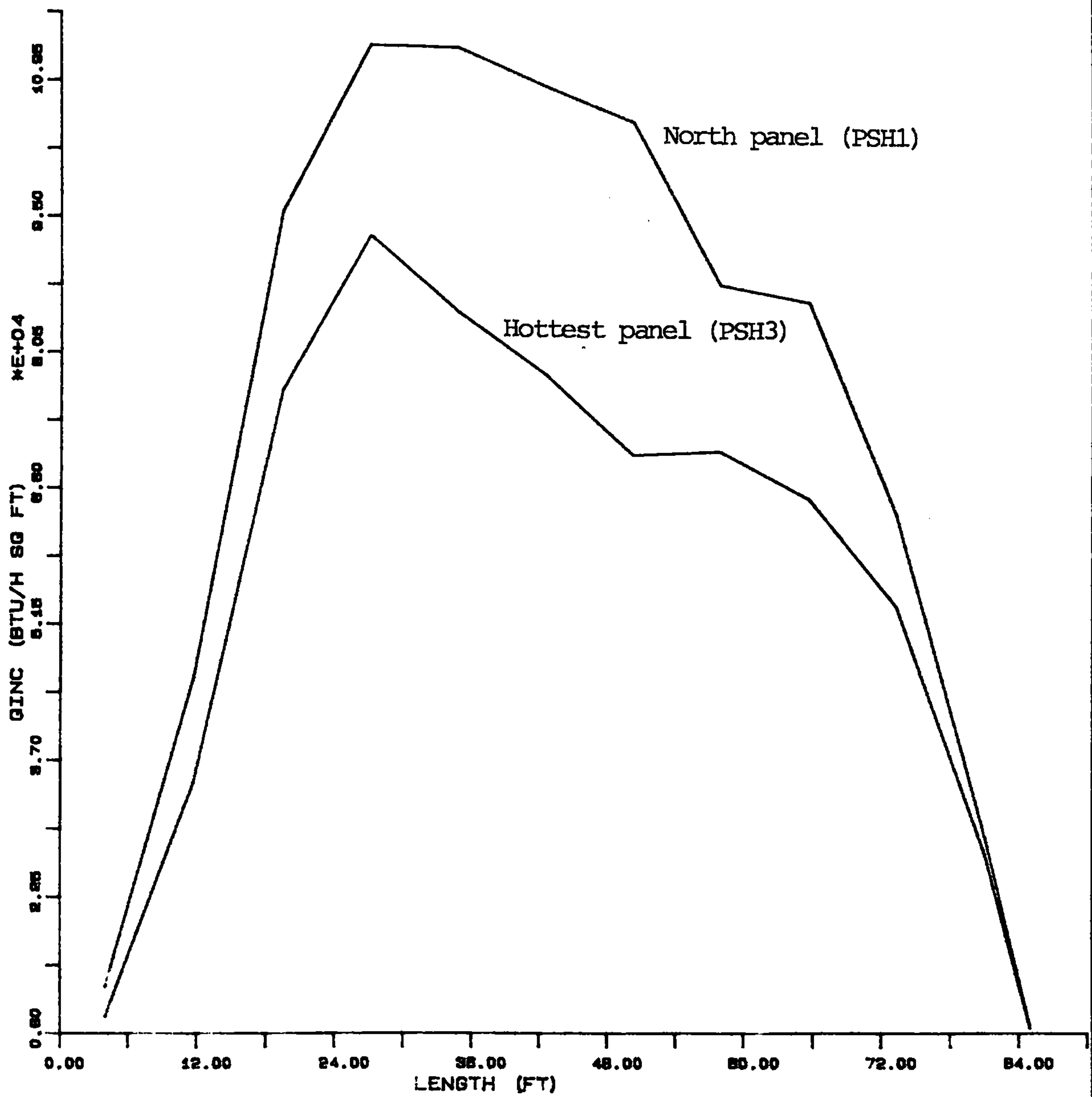

III.2.STEADY STATE PERFORMANCE.

Babcock & Wilcox had sent us printouts for nominal conditions only, for the purpose of dynamic simulation the need of several steady states is evident. Because this, we had developed and implemented a steady state model from dynamic equations.

A short description of the algorithm follows:

- From equation (3) equal zero, heat absorbed by the metal and fluid are the same, and using the expressions (9), (10), it is obtained a quartic polynome in metal temperature.

- From pressure drop, equation (4), and given that average density equals inlet value, the pressure at the outlet of each volume is evaluated.

- System solution is obtained by iteration, first, average temperature is approximated to its inlet value, then solution of quartic equation gives the average metal temperature, with this value, heat losses are evaluated, eqs (6,7,8), and so heat transfer to metal, eq.(9). After this, outlet enthalpy is obtained from equation (2) and with outlet pressure, temperature is determined. This fluid average temperature is substituted in quartic equation and process is repeated until the new value of temperature compared to the old one, is less than or equal to a fixed value (10^{-7}).

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Babcock & Wilcox suggested the analysis of superheated tube under worst case operating conditions, i.e. the hottest panel of the receiver under upset and unbalanced conditions. This corresponds to the outlet panel of the primary superheater (PSH3) and it is located 45 to 56.25 degrees from north.

Simulation conditions are those of table I except for the mass flow rate and solar flux density, the first is multiplied by 0.943 and for each tube:

$$W = 4436.2979 \text{ lbm/hr}$$

For solar flux, table II shows: the nominal values given by B & W, the flux multiplier for each zone and the values we have obtained from the nominal for our own zone division.

Steady state performance is given by Table III a and b.

Table II

B & W			IIE	
X(ft)	Q(Btu/h sq.ft)	FQ	X(ft)	Q.FQ
4.00	9829.32	1.251	7.08	20000.00
16.70	34561.16	1.250	14.17	61250.00
19.40	76415.06	1.218	21.25	97000.00
27.10	92902.94	1.206	28.33	108500.00
34.80	84659.00	1.195	35.42	100750.00
42.50	78000.37	1.182	42.50	92000.00
50.20	69439.37	1.212	49.58	85500.00
57.90	69756.50	1.171	56.67	81250.00
65.60	64683.28	1.151	63.75	76000.00
73.30	53268.61	1.181	70.83	65000.00
81.00	26951.36	1.141	77.92	44250.00
85.00	8561.02	1.211	85.00	15500.00

Table III.a.

B & W Steady State Performance.

X	P	T	h	Tm	Usm*
(ft)	(psia)	(F)	(Btu/lbm)	(F)	(Btu/h sq.ft F)
4.00	1965.4	873.20	1396.70	877.50	1067.01
11.70	1960.4	882.00	1398.00	926.80	1003.90
19.40	1955.1	904.70	1413.70	1015.10	995.79
27.10	1949.7	933.20	1432.90	1068.50	985.78
34.80	1944.1	959.20	1450.00	1080.10	978.20
42.50	1938.4	983.00	1465.40	1091.90	973.45
50.20	1932.5	1004.50	1479.20	1102.00	970.59
57.90	1926.5	1025.60	1492.50	1119.90	968.97
65.60	1920.4	1044.60	1504.50	1129.40	968.24
73.30	1914.20	1060.20	1514.20	1128.90	968.09
81.00	1908.00	1066.00	1517.90	1092.60	968.03
85.00	1900.80	1065.50	1517.80	1063.90	967.64

*Apparently Usm represents an overall steam-metal transfer coefficient.

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Table III.b.*

IIE Steady State Performance.

X (ft)	P (psia)	T (F)	h (Btu/lbm)	Tm (f)	Hi** (Btu/h sq.ft F)
7.08	1964.31	878.21	1392.82	893.41	1115.63
14.17	1959.10	891.06	1401.54	967.63	1110.35
21.25	1953.88	912.98	1416.23	1042.53	1101.99
28.33	1948.67	937.71	1432.74	1083.99	1092.89
35.42	1943.45	960.31	1447.82	1094.53	1084.66
42.50	1938.23	980.55	1461.32	1101.15	1077.28
49.58	1933.02	999.00	1473.63	1109.34	1070.52
56.67	1927.80	1016.26	1485.16	1119.70	1064.15
63.75	1922.59	1032.07	1495.67	1127.09	1058.25
70.83	1917.37	1044.97	1504.28	1122.88	1053.39
77.92	1912.15	1052.50	1509.36	1098.52	1050.55
85.00	1906.94	1052.63	1509.59	1054.68	1050.51

*Friction factor may be calculated by program, however, this results correspond to a fixed value of 4.3×10^{-3}, obtained from B & W data pressures. Fluid density has a fixed value of 2.87 lbm/cu ft.

**Represents inside film convection coefficient.

As can be seen a close agreement between steady states is obtained.

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III.3.TRANSIENT ANALYSIS.

III.3.1.ALGORITHM DESCRIPTION.

Model equations given in chapter II were implemented in a Fortran computer code. Fig.(4), shows a flow diagram.

III.3.2.TRANSIENT RESPONSE TO A STEP IN MASS FLOW RATE.

Two cases are analysed, for upset and unbalanced steady state conditions (III.2), nominal mass flow rate ($\dot{W}$) has been varied +50%, -50%.

Simulation conditions were:

- Fixed inlet conditions except $\dot{W}$

  T = 873.06 F

  P = 1969.53 psia

  h = 1391.08 Btu/lbm

  ρ = 2.87 lbm/cu ft

- Steady state

  As given by tables II and III.b.

- Transient

  From:

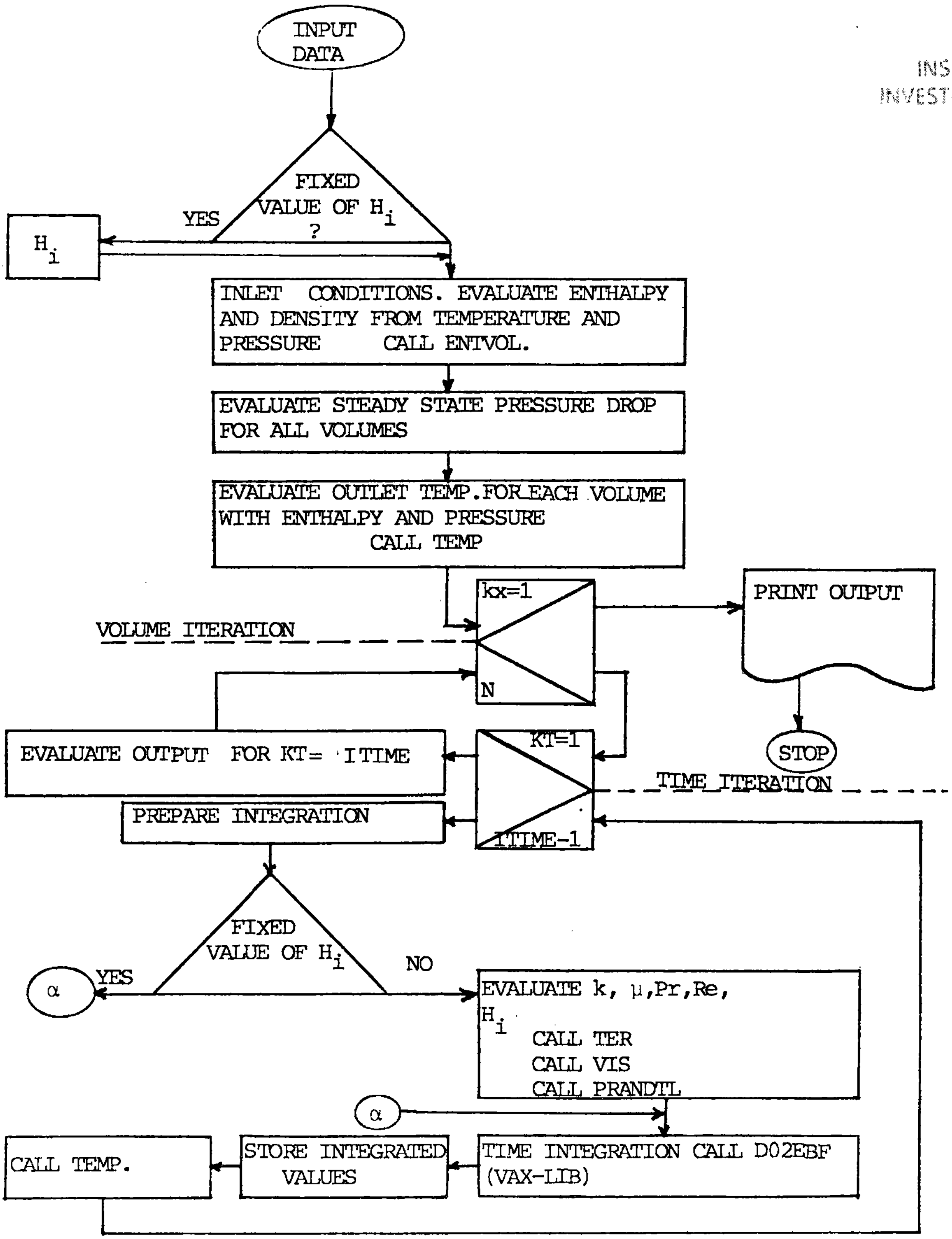

FIG. 4 TRANSIENT SIMULATION FLOW DIAGRAM

0-50 sec, steady state is maintained

50-300 sec, step in W is introduced (+50% or -50%).

300-550 sec, return to nominal value of W

Time step integration fixed by library subroutine

Program evaluates pressure, temperature, enthalpy, inside film convection coefficient, Reynolds number, metal temperature, heat transfered to metal and fluid, radiation and convection losses. Figs.(5,6,7,8), show time evolution of T,P,h,Tm, for selected instants of time. Time history for tube outlet characteristics are shown in Figs.(9 through 16).

Axial characteristics shown correspond to steady states attained when forcing function W is up or down from nominal value. A non-linear performance is evident for the same absolute variation of W. Metal temperature profiles (Fig.8), show a maximum around 60 ft. heigth and the axial evolution tends to follow that of solar heat flux. This result shows the need of evaluation of axial metal temperature distribution for design purposes, tube or panel mean temperature would not reflect realistic thermal stresses, variations from this value are 25%, Also it is important to define the heigth where the maximum occurs for a given solar flux profile.

Figures (9 through 12) correspond to a negative step in W and return to nominal value and figures (13 through 16) to a positive step and return to nominal value. It is observed the different settling times for the same variable, this

FIGURE 5
TEMPERATURE PROFILE ALONG TUBE AXIS
+50%, −50% STEP IN W

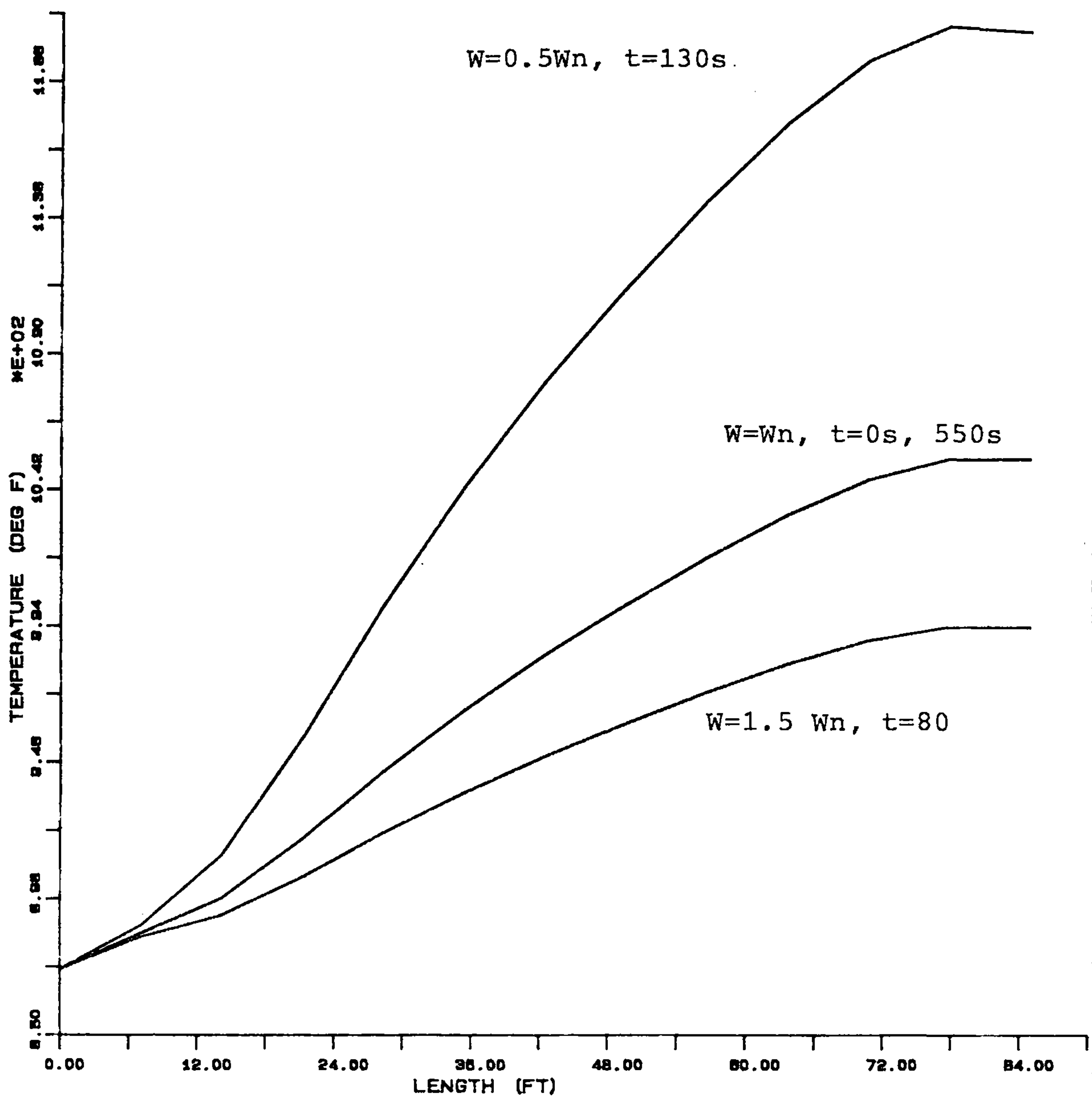

FIGURE 6
PRESSURE PROFILE ALONG TUBE AXIS
+50%, -50% STEP IN W

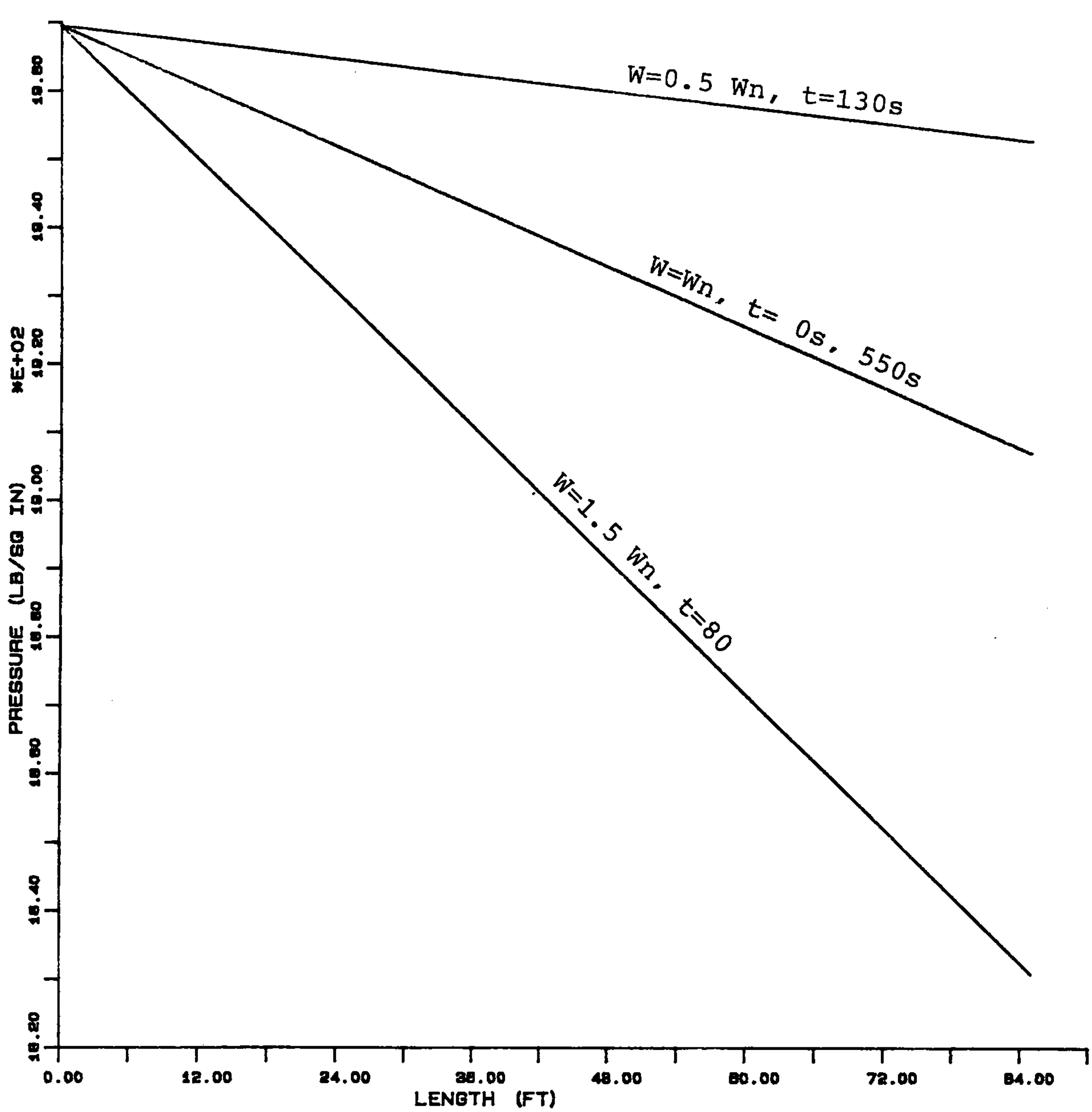

FIGURE 7
ENTHALPY PROFILE ALONG TUBE AXIS
+50%, −50% STEP IN W

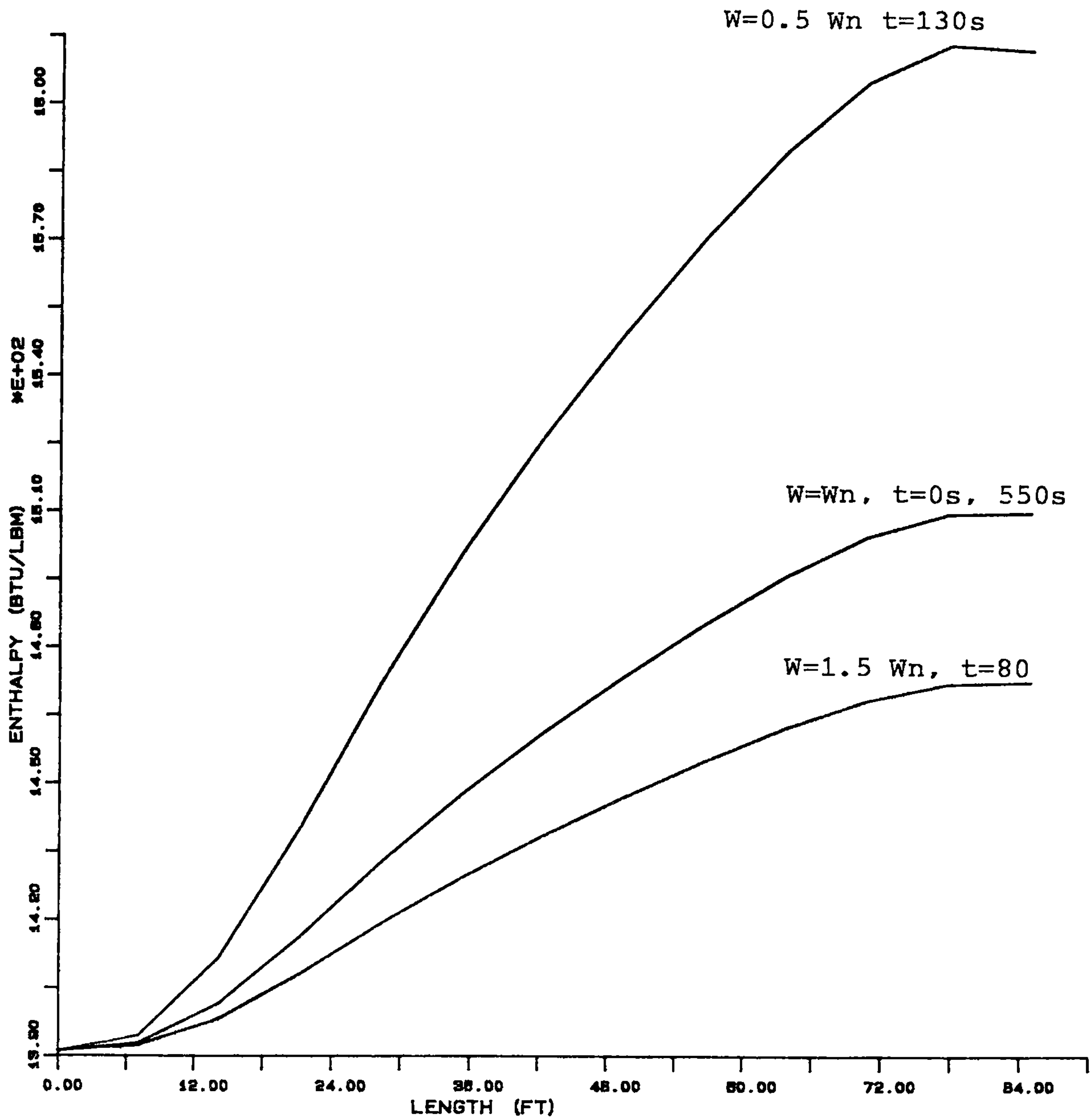

FIGURE 8
METAL TEMPERATURE PROFILE
ALONG TUBE AXIS
+50%, −50% STEP IN W

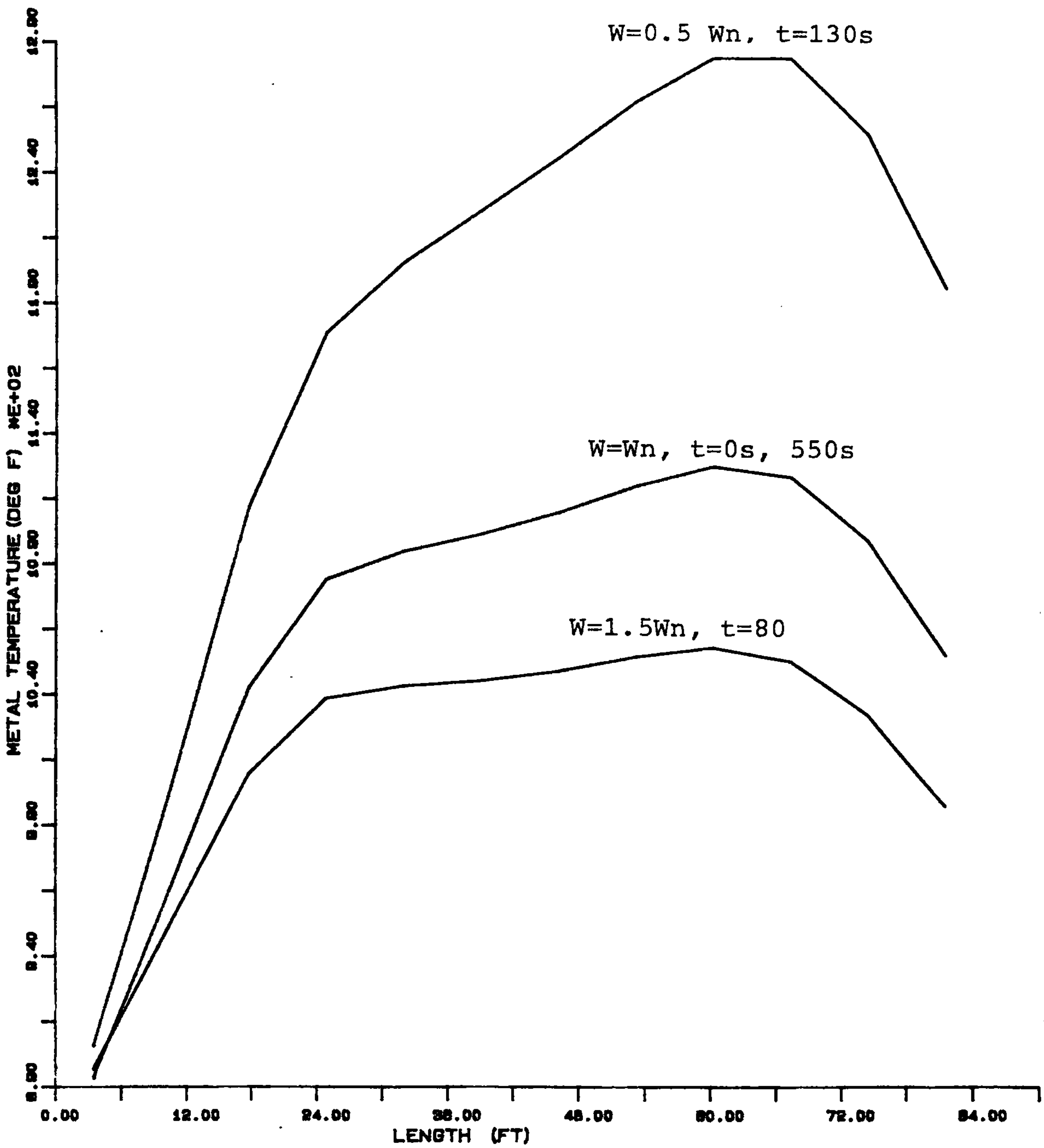

FIGURE 9
TEMPERATURE TRANSIENT RESPONSE
STEPS IN W

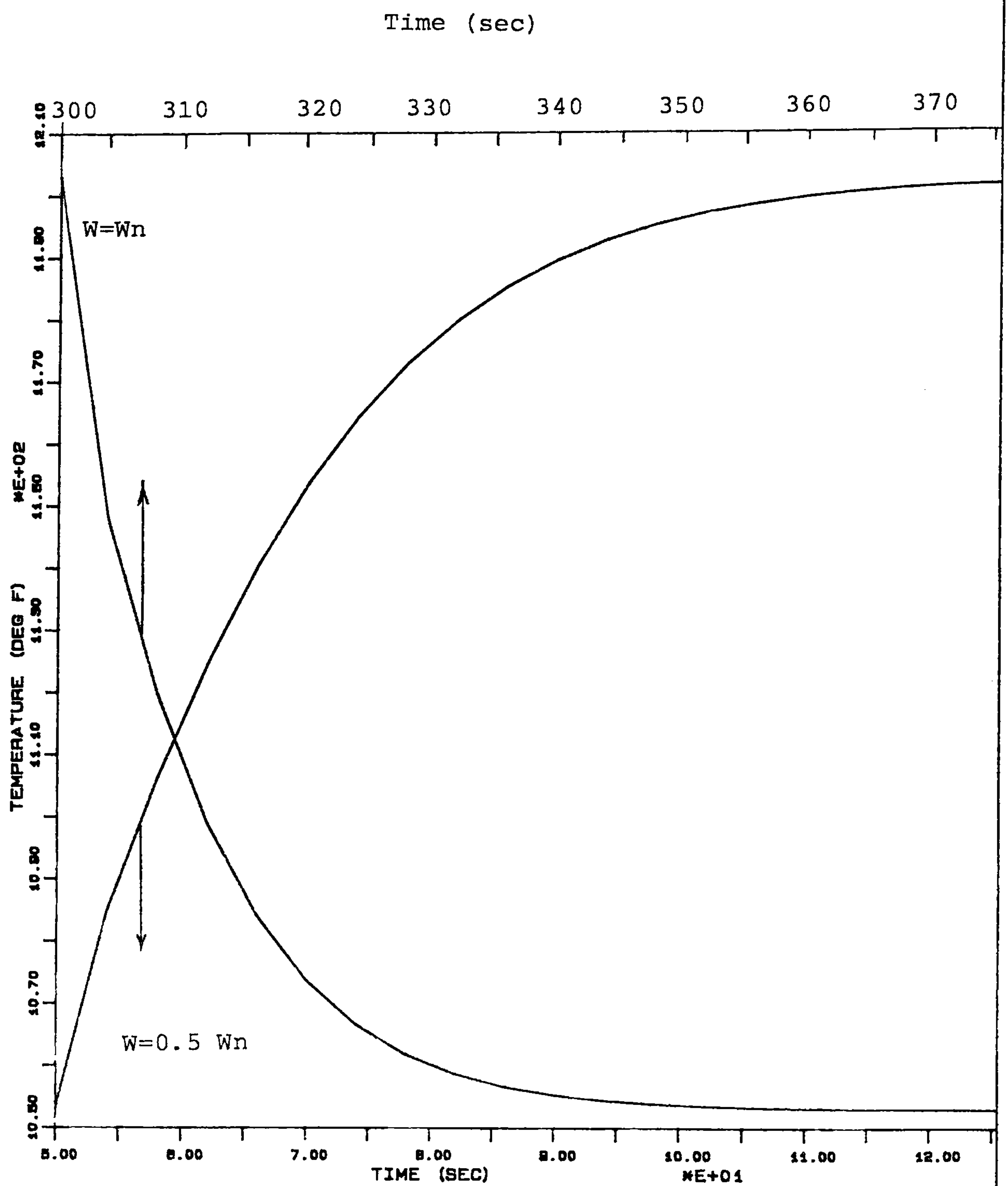

FIGURE 10
PRESSURE TRANSIENT RESPONSE
STEPS IN W

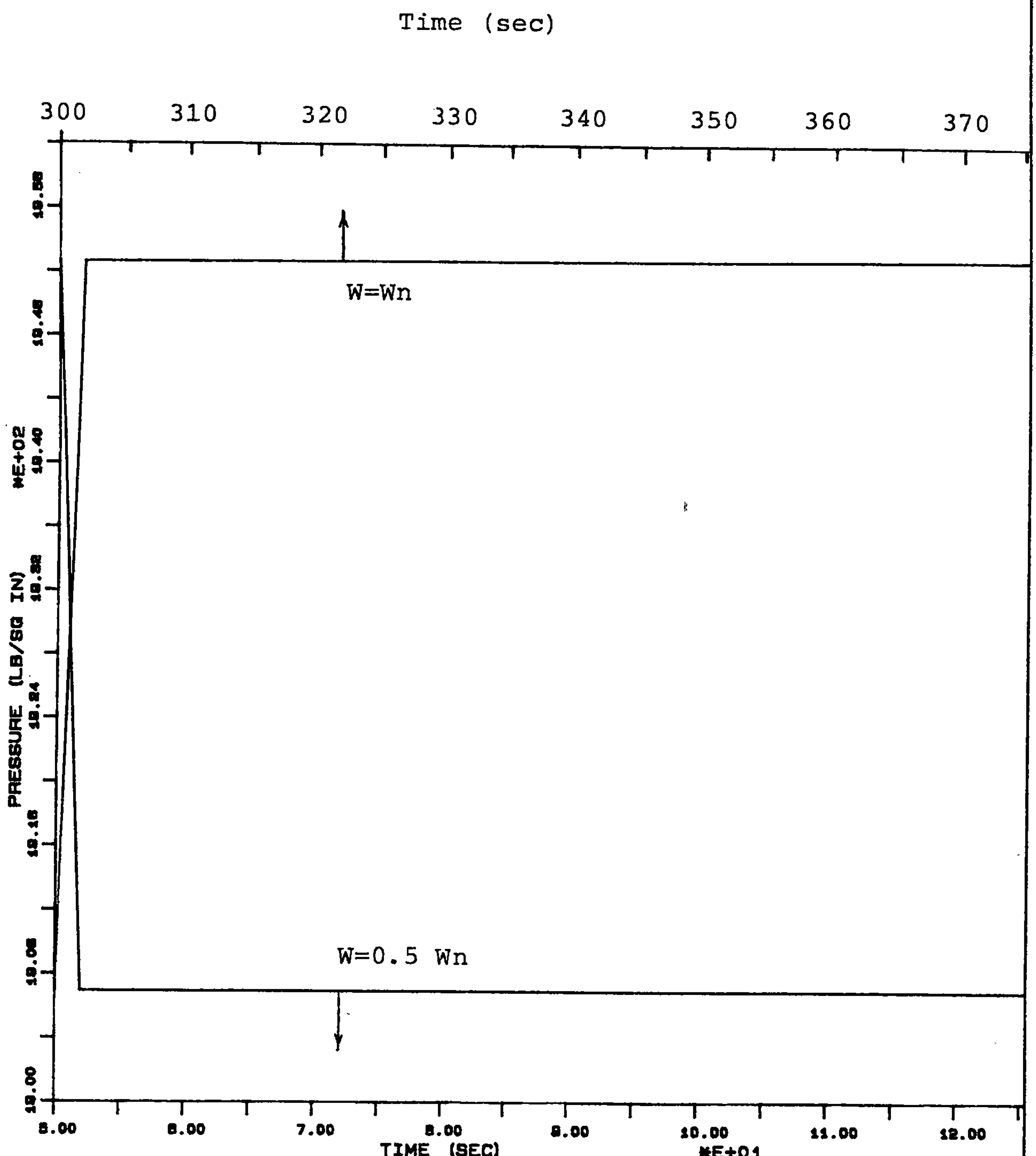

FIGURE 11
ENTHALPY TRANSIENT RESPONSE
STEPS IN W

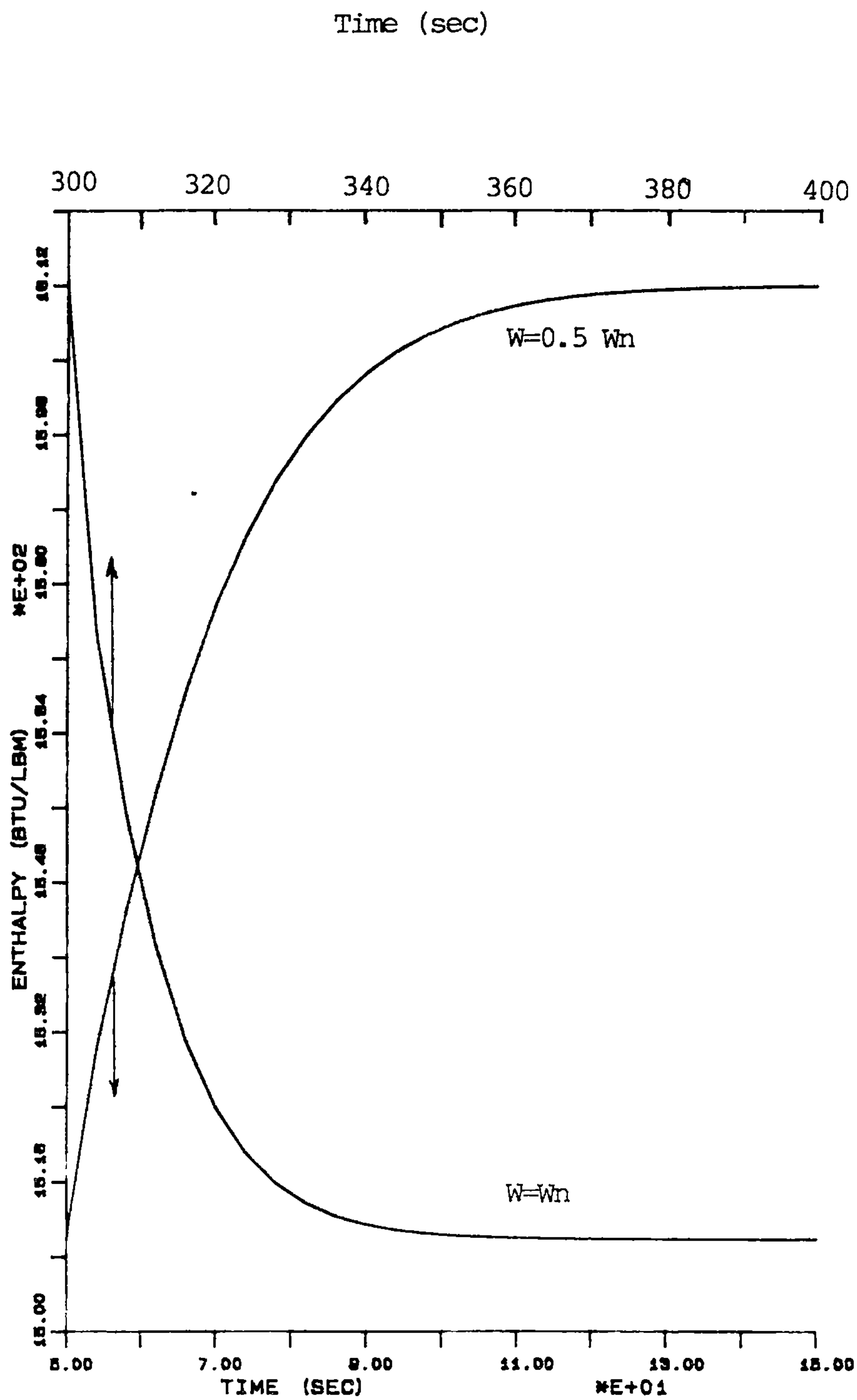

FIGURE 12
METAL TEMPERATURE TRANSIENT RESPONSE
STEPS IN W

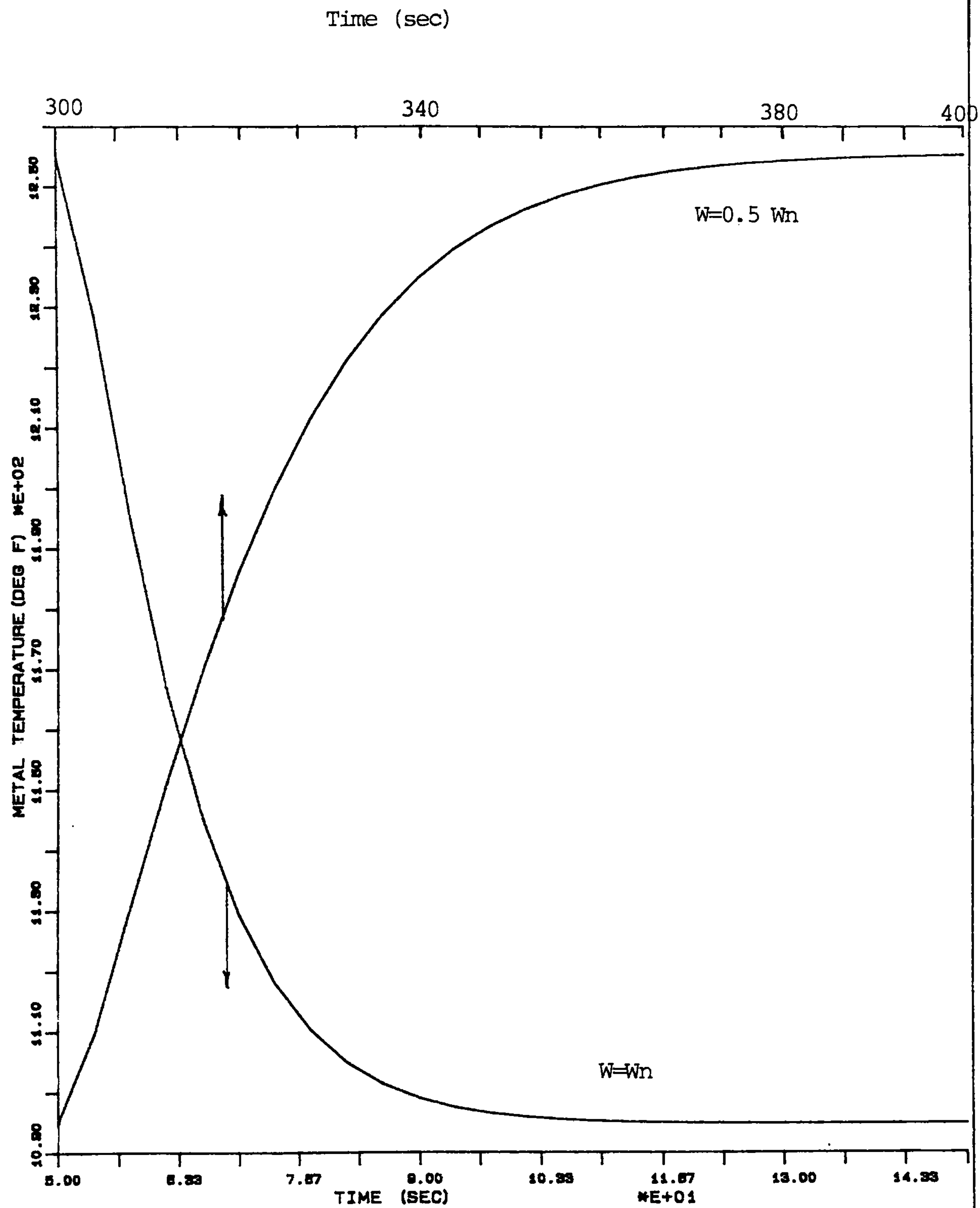

FIGURE 13
TEMPERATURE TRANSIENT RESPONSE
STEPS IN W

Time (sec)

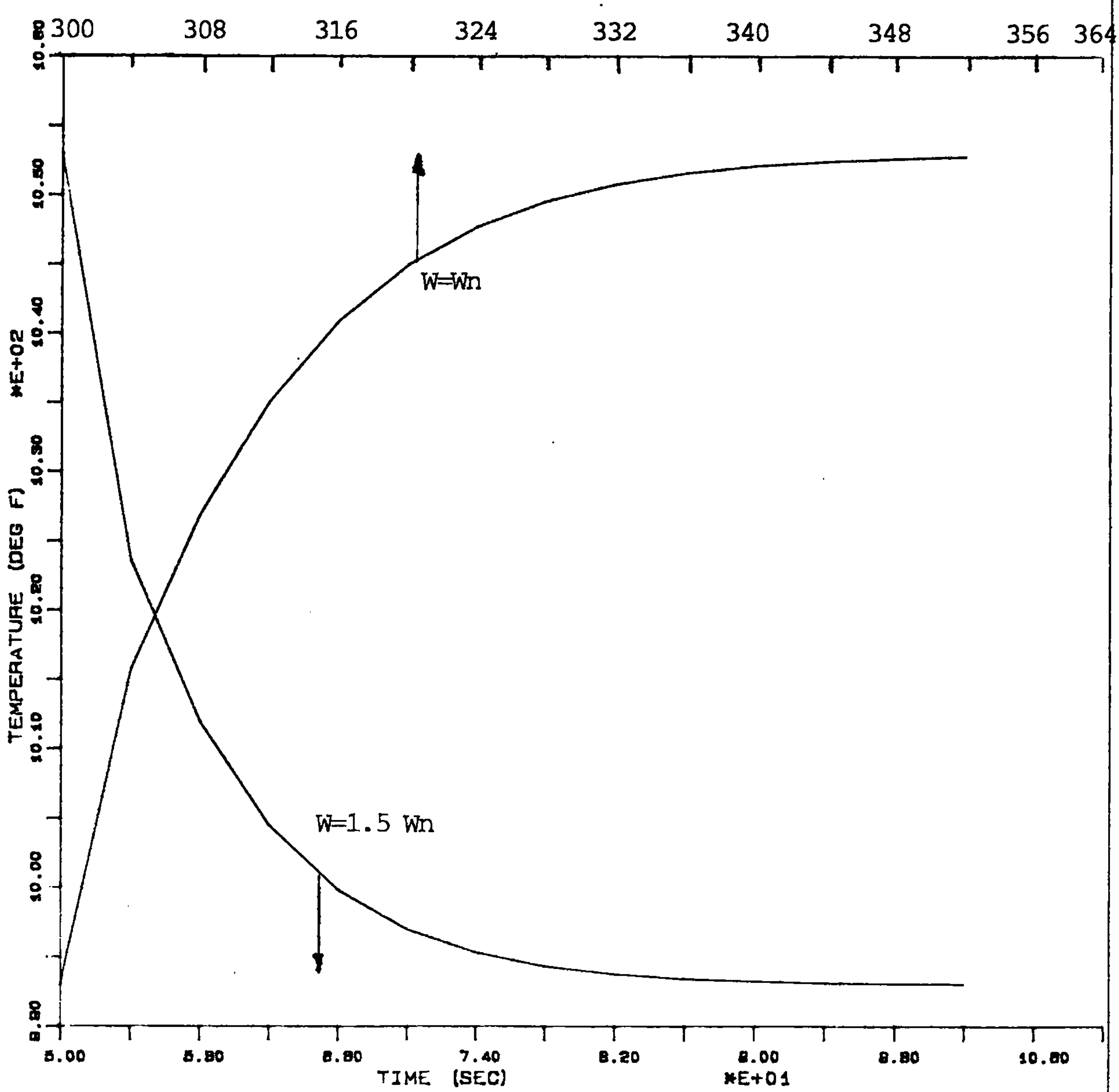

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FIGURE 14
PRESSURE TRANSIENT RESPONSE
STEPS IN W

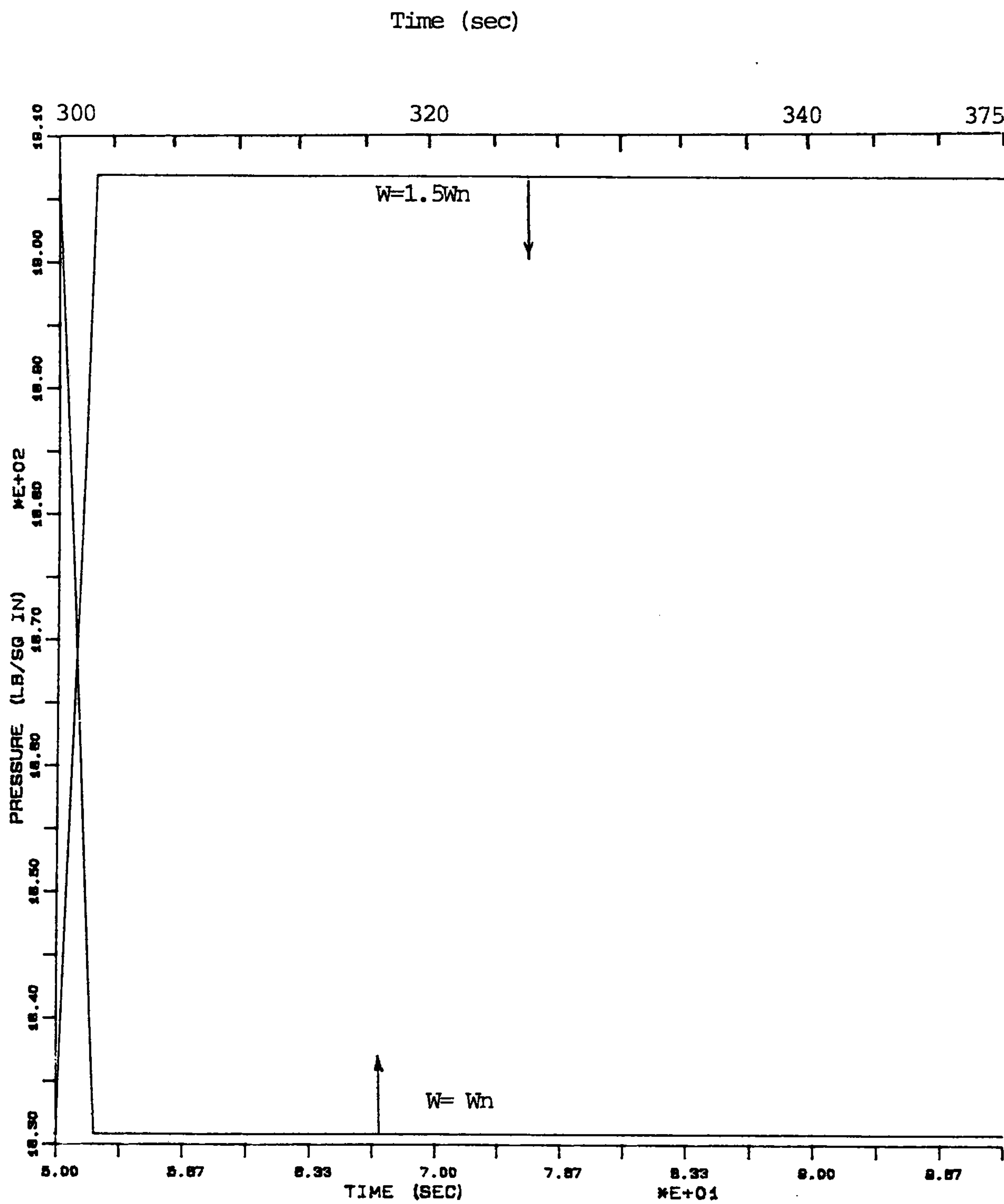


FIGURE 15
ENTHALPY TRANSIENT RESPONSE
STEPS IN W

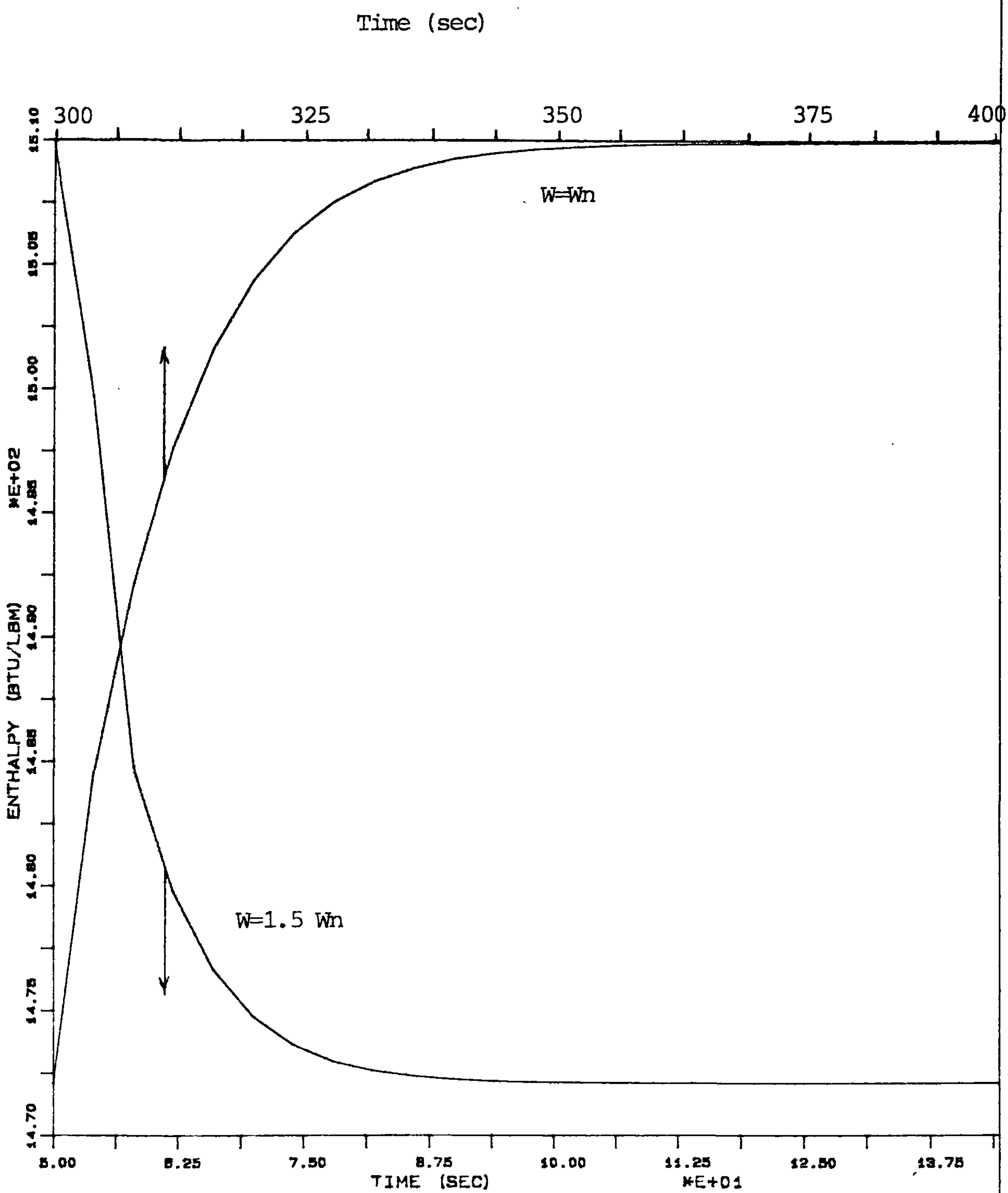
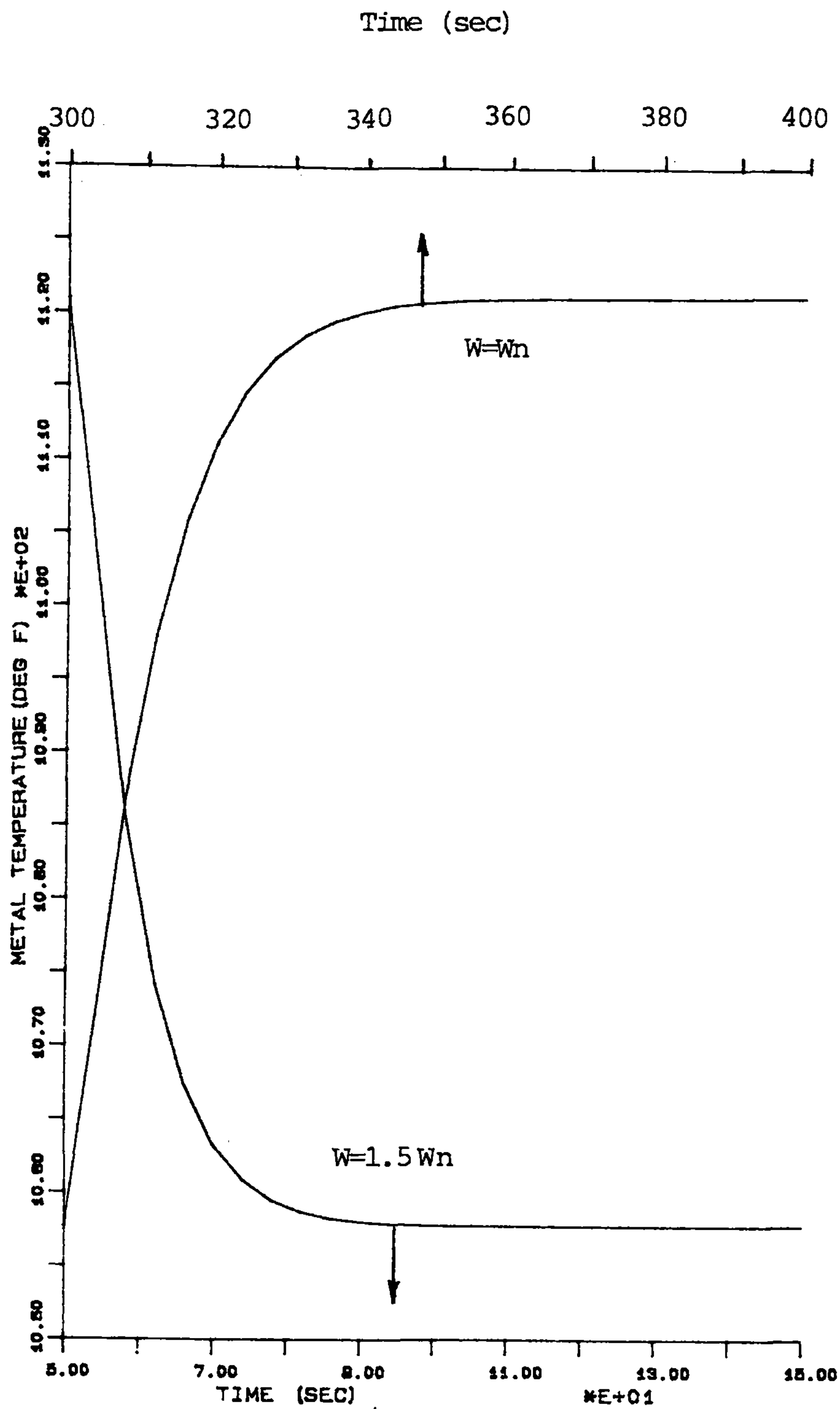


FIGURE 16
METAL TEMP. TRANSIENT RESPONSE
STEPS IN W



non-linearity must be taken in account when designing linear controllers. Pressure response is directly proportional to mass flow rate dynamics, and in our case is a stepwise, due to modeling assumptions. Enthalpy transient responses are faster than fluid and metal temperature. In all cases characteristics shown are outlet conditions except Figs.(12,16) showing maximum metal temperature transient responses at a tube heigth of 60 ft.

III.3.3. TRANSIENT RESPONSE TO A STEP IN SOLAR HEAT FLUX.

Solar flux (Q) has been set to a fixed value along the tube axis. A steady state was obtained and starting from this conditions a transient analysis was made for step variations of solar flux around the nominal value. All other inlet characteristics were maintained to their steady state value.

- Inlet conditions were:

  T = 873.06 F

  P = 1969.53 psia

  h = 1391.08 Btu/lbm

  ρ = 2.87 lbm/cu ft

- Transient

  From: 0 - 50 sec. Q = Qn = 48020.69 Btu/h

  50 - 300 sec. Q = Qn + 50%,-50%

  300 - 550 sec. Q = Qn

Figures (17-19), show tube axis profiles for T,h,Tm. Pressure profile is not shown, it remains the same for any Q. Non - linearities are less intensive than those associated to W changes.

Time history for tube outlet characteristics are shown in figures (20-22) and (23-25), the first group correspond to a positive step in Q and then return to nominal value and the second to a negative step.

Settling times for this cases are near to 100 sec., with this information and given that settling times for mass flow rate as varying input (III.3.2) are similar to this value it follows that two control strategies may be of interest, first a proportional control involving a relation betwenen Q and W and second the same but using a feedforward control scheme.

III.3.4.TRANSIENT RESPONSE TO A CLOUD PASSAGE.

Stone & Webster sent us a computer printout (18) corresponding to a simulation of superheaters performance when a cloud from west to east travels over heliostat field. These data contain time history of inlet and outlet characteristics of all superheater panels. Our simulation will complement this information by means of evaluation of time-space evolution, under this conditions, of metal temperature and thermodynamical properties.

We will present results corresponding to the hottest

FIGURE 17
TEMP. PROFILE ALONG TUBE AXIS
+50%, -50% STEP IN SOLAR HEAT FLUX

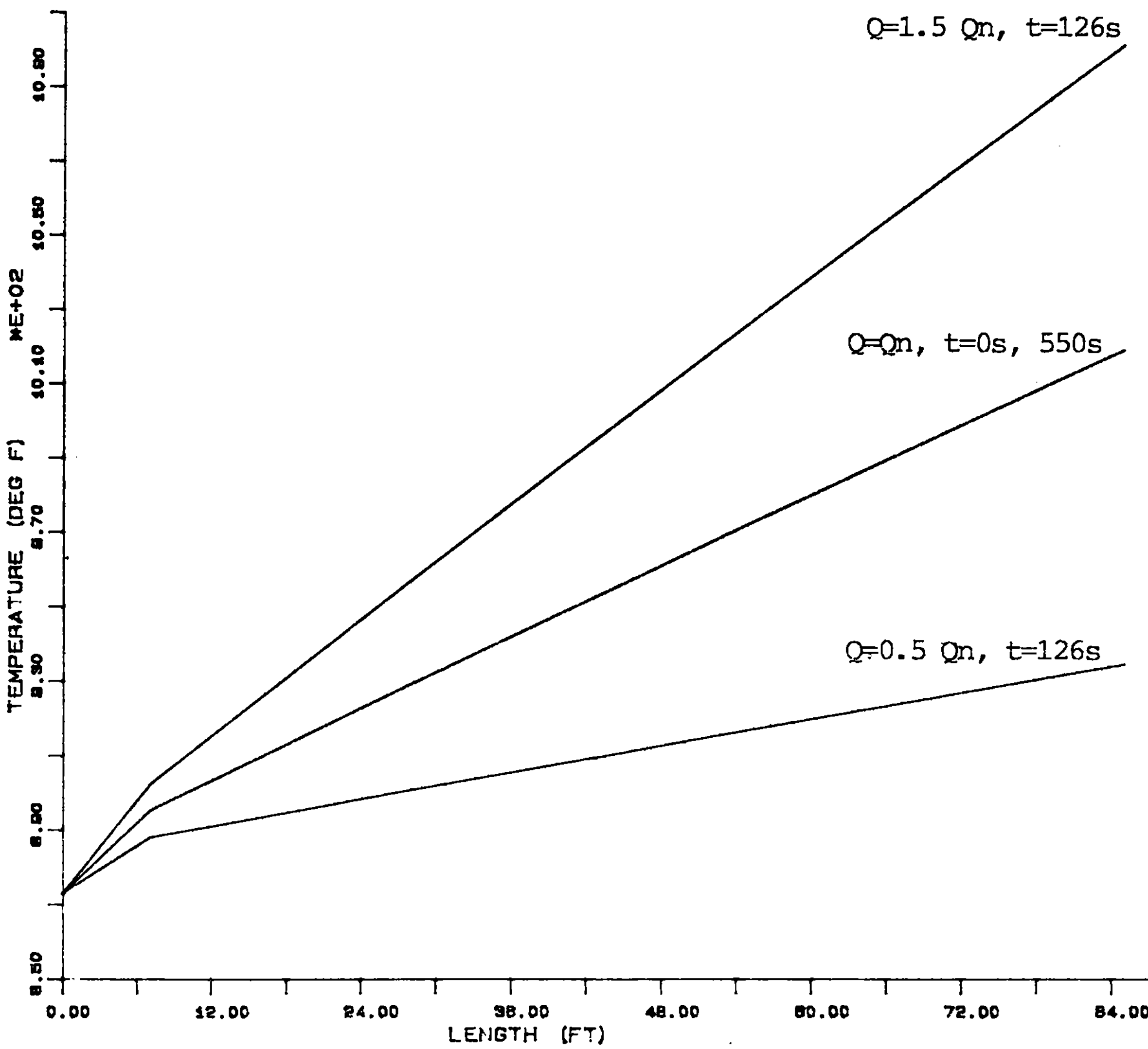


FIGURE 18
ENTHALPY PROFILE ALONG TUBE AXIS
+50%, −50% STEP IN SOLAR HEAT FLUX

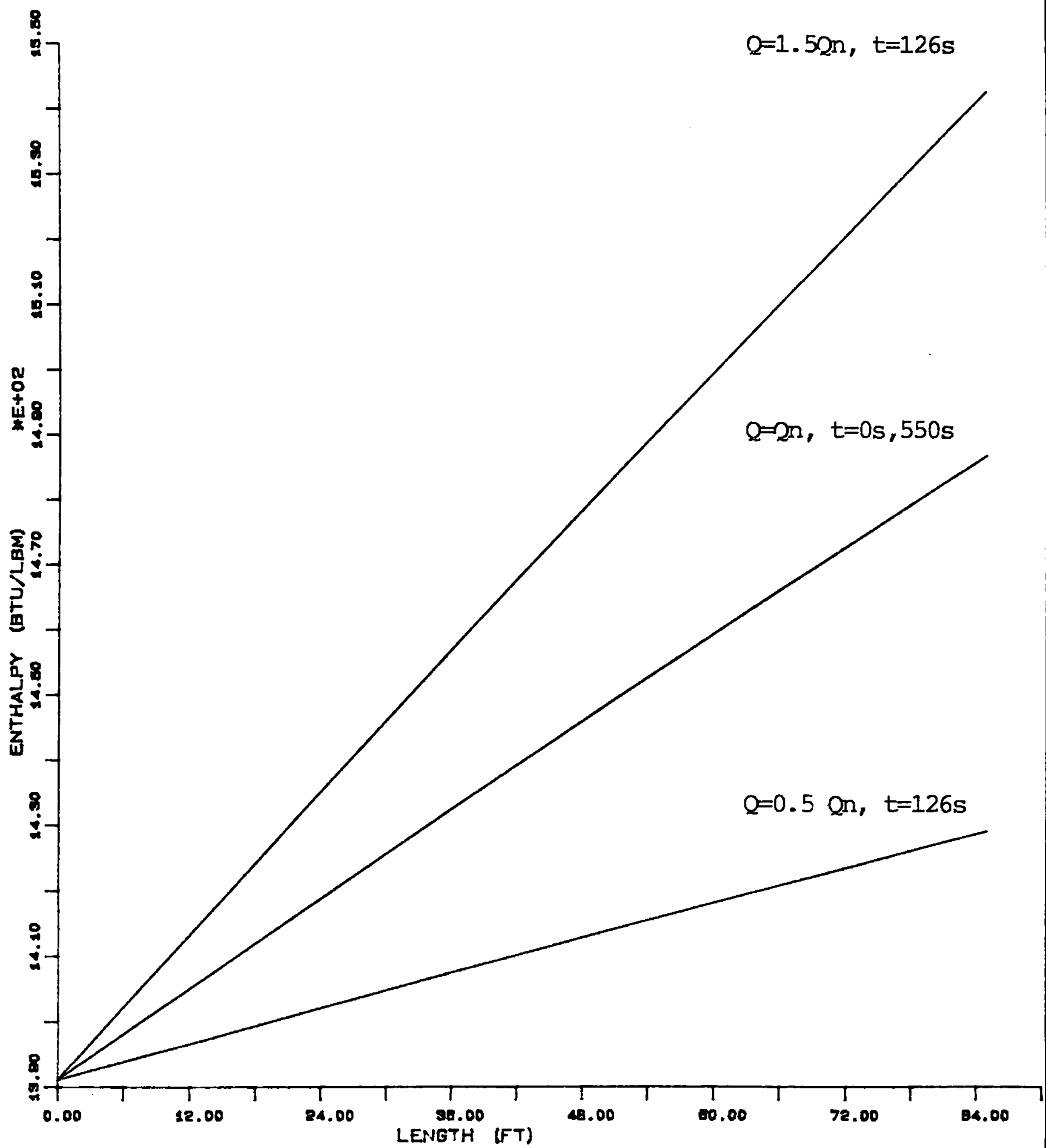


FIGURE 19
METAL TEMPERATURE PROFILE
+50%, -50% STEP IN SOLAR HEAT FLUX

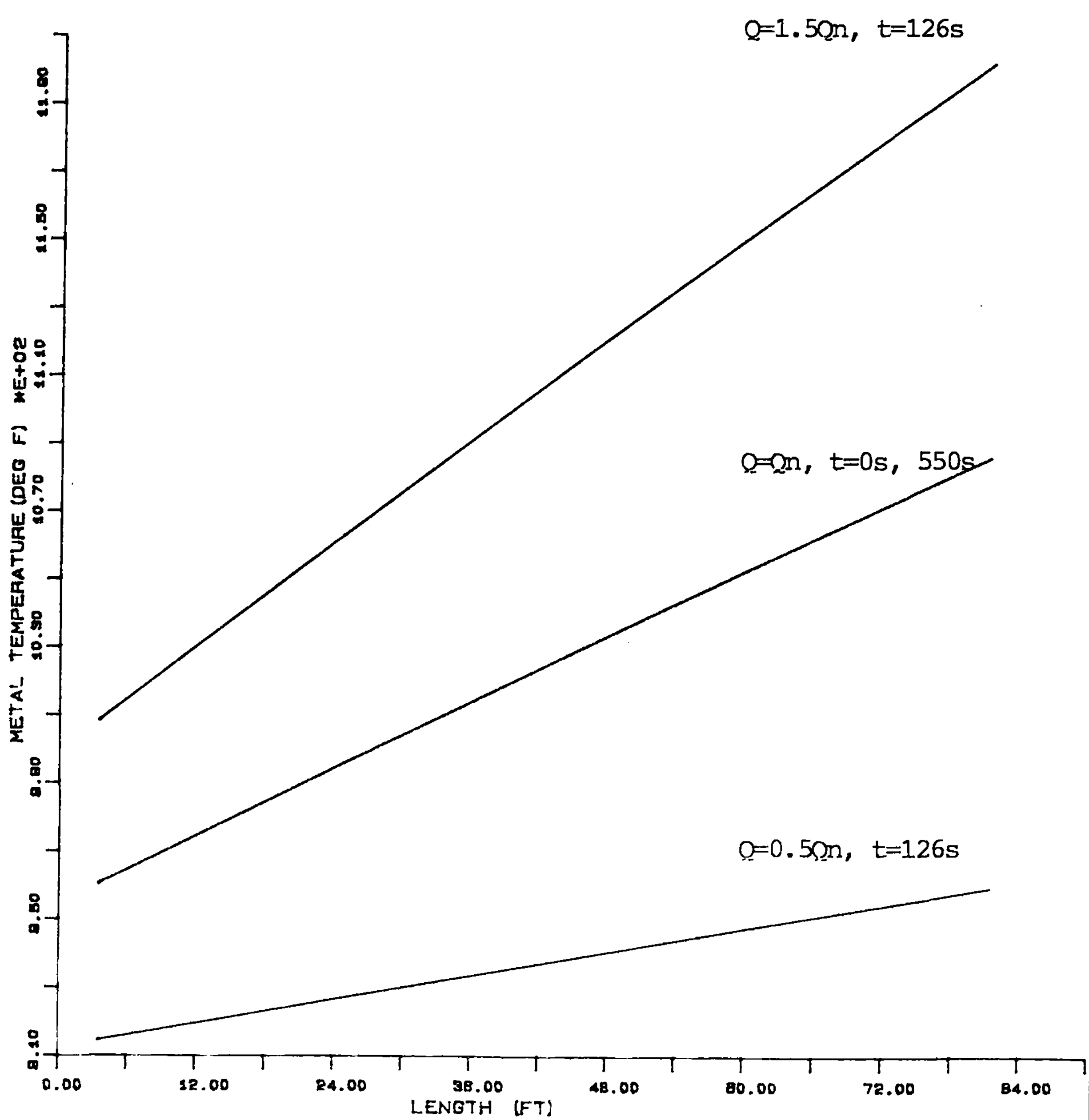


FIGURE 20
TEMPERATURE TRANSIENT RESPONSE
STEPS IN SOLAR HEAT FLUX

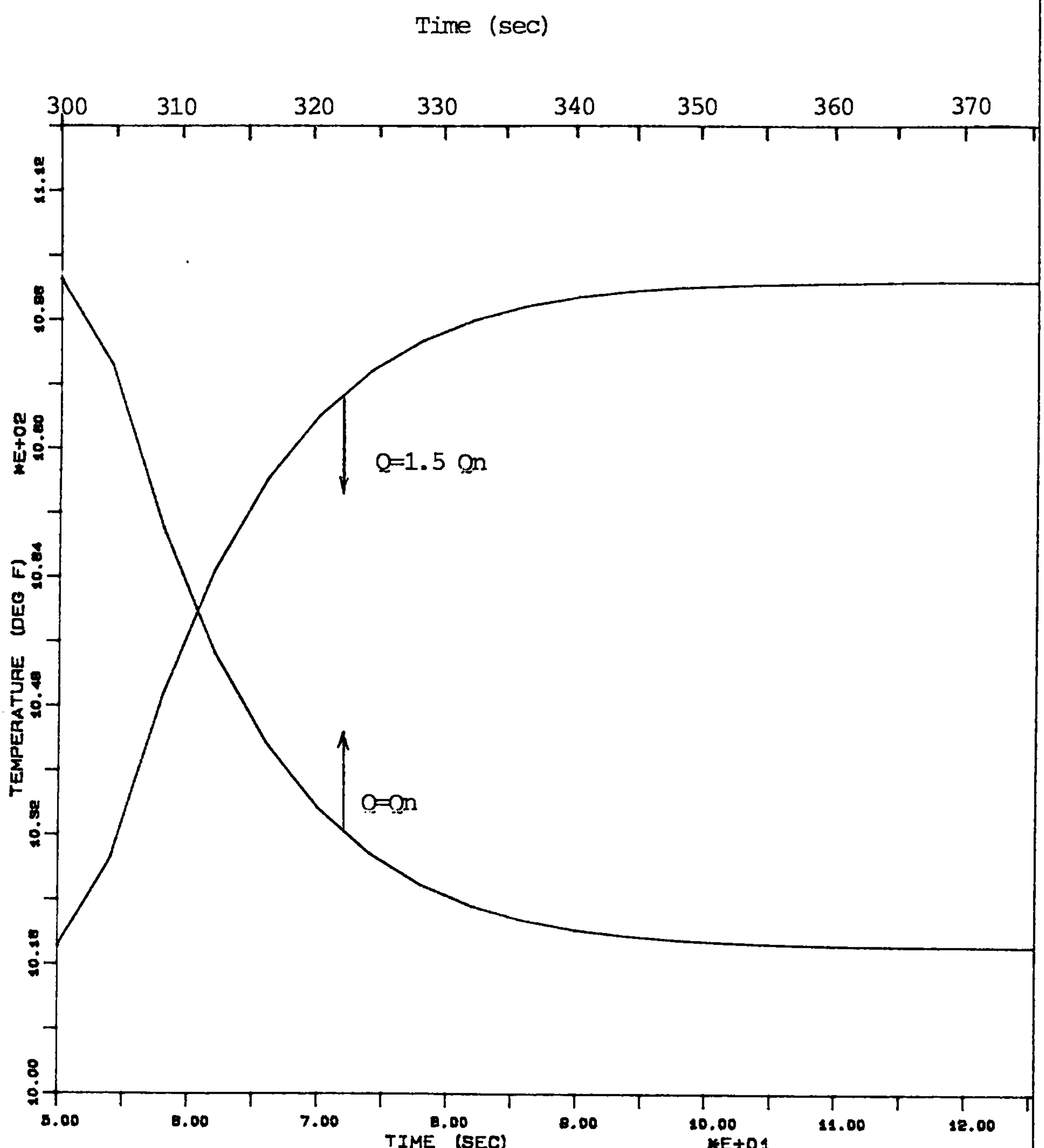


FIGURE 21
ENTHALPY TRANSIENT RESPONSE
STEPS IN SOLAR HEAT FLUX

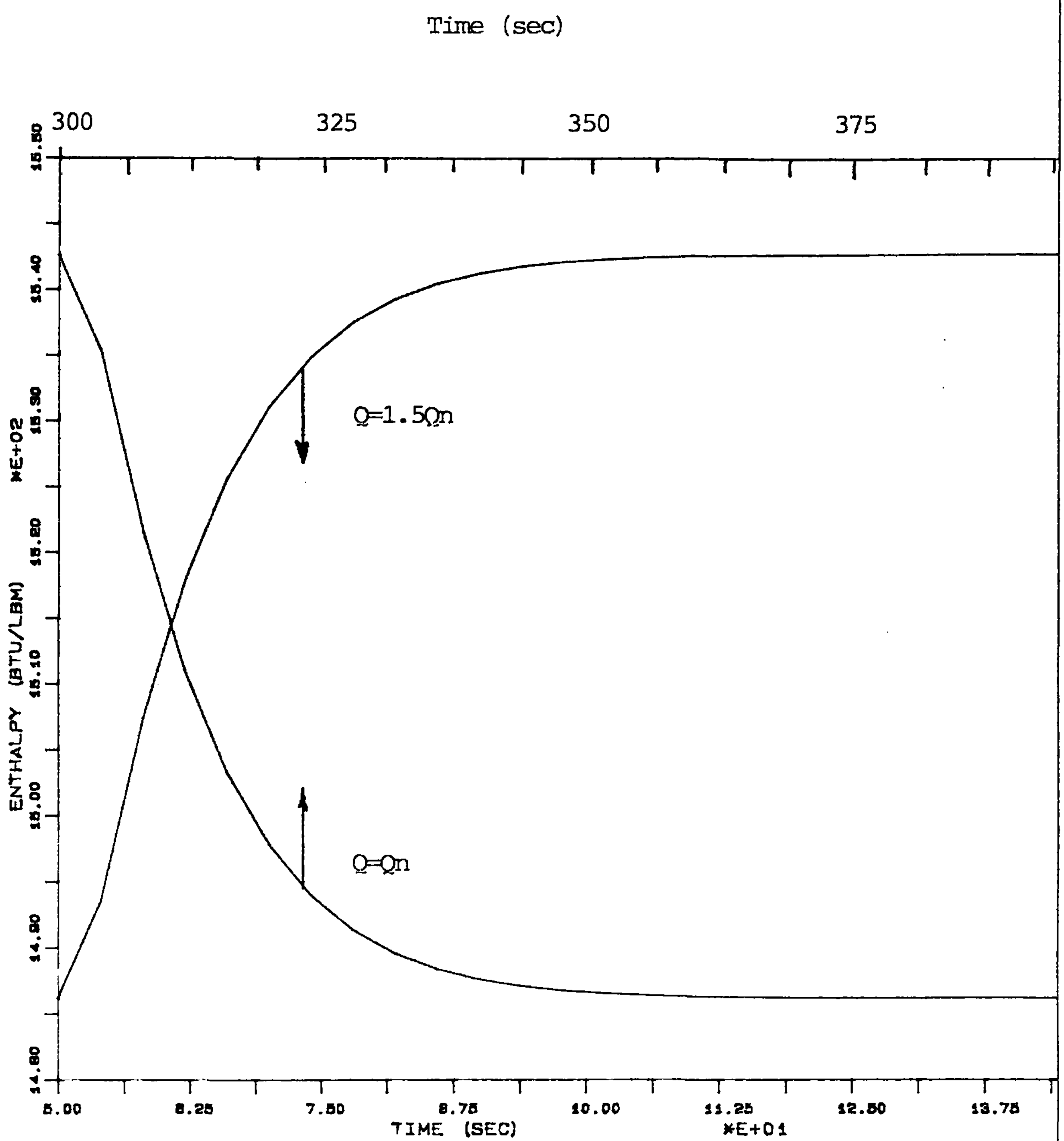


FIGURE 22
METAL TEMP. TRANSIENT RESPONSE
STEPS IN SOLAR HEAT FLUX

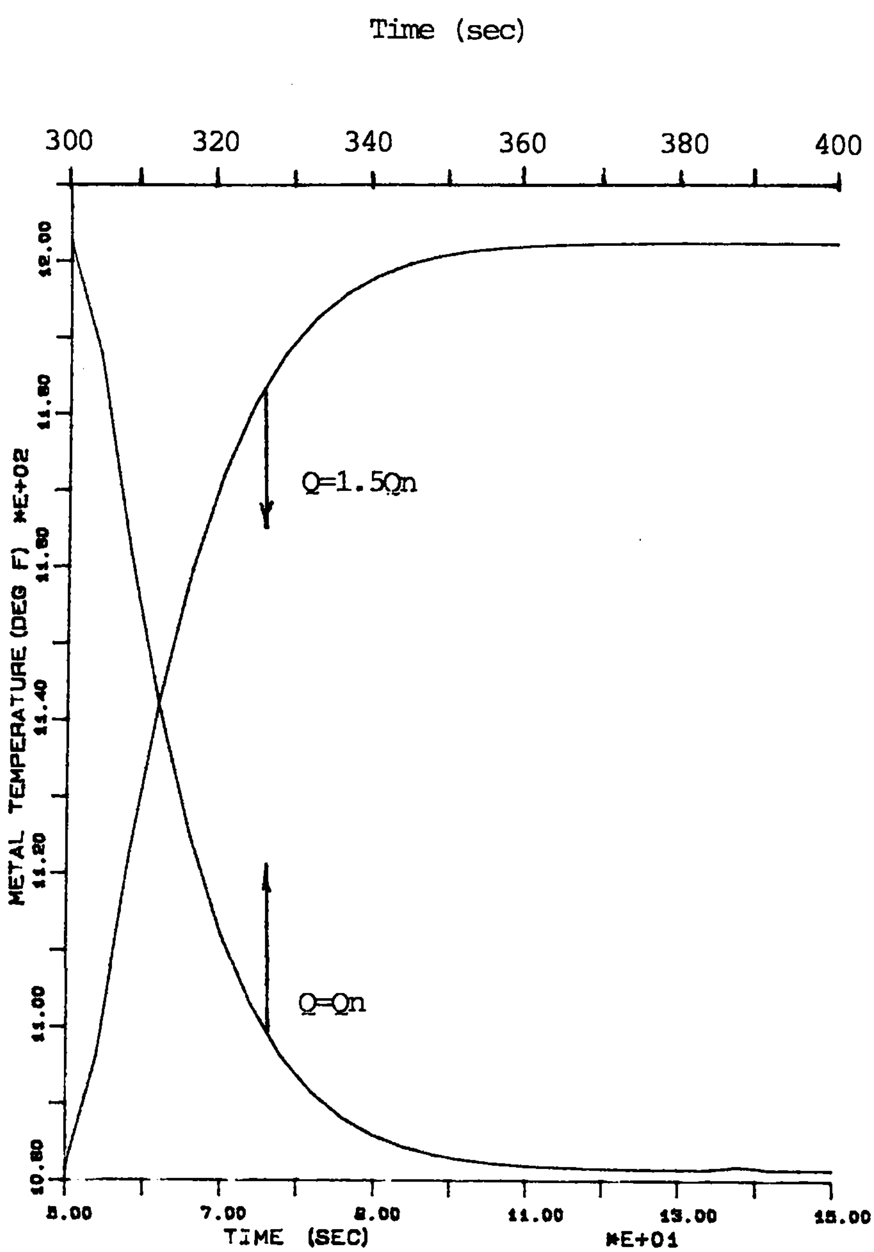


FIGURE 23
TEMPERATURE TRANSIENT RESPONSE
STEPS IN SOLAR HEAT FLUX

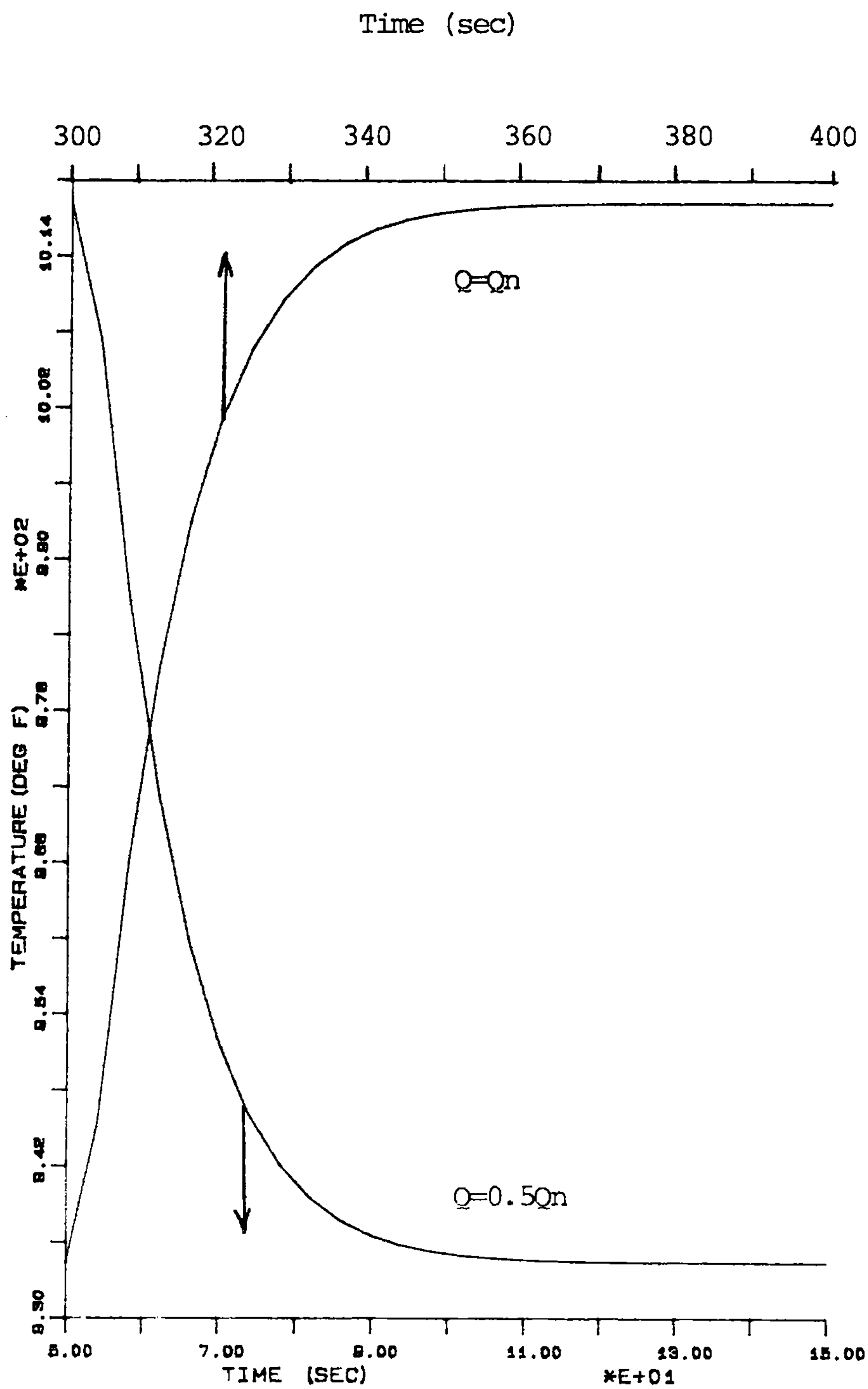


FIGURE 24
ENTHALPY TRANSIENT RESPONSE
STEPS IN SOLAR HEAT FLUX

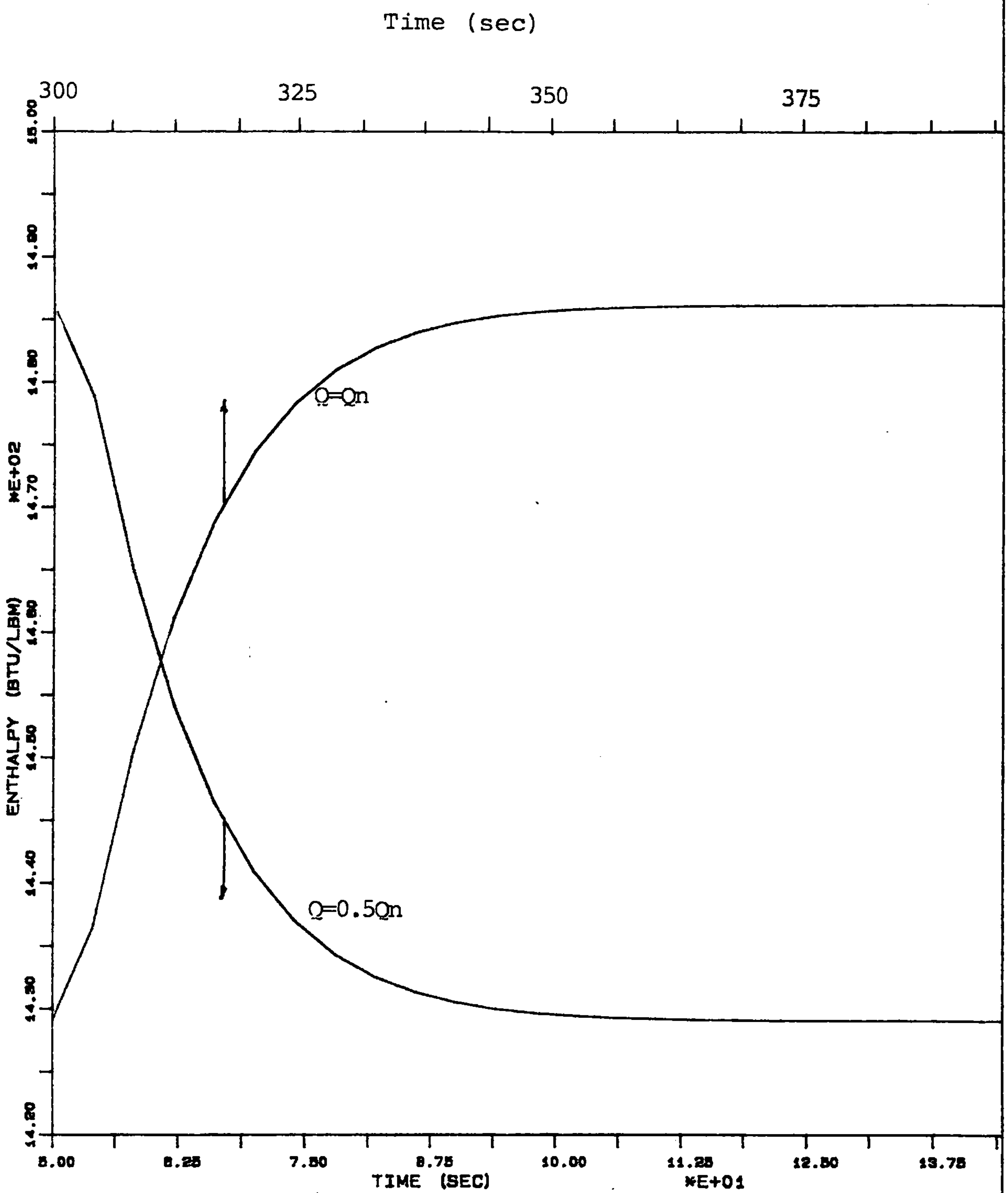
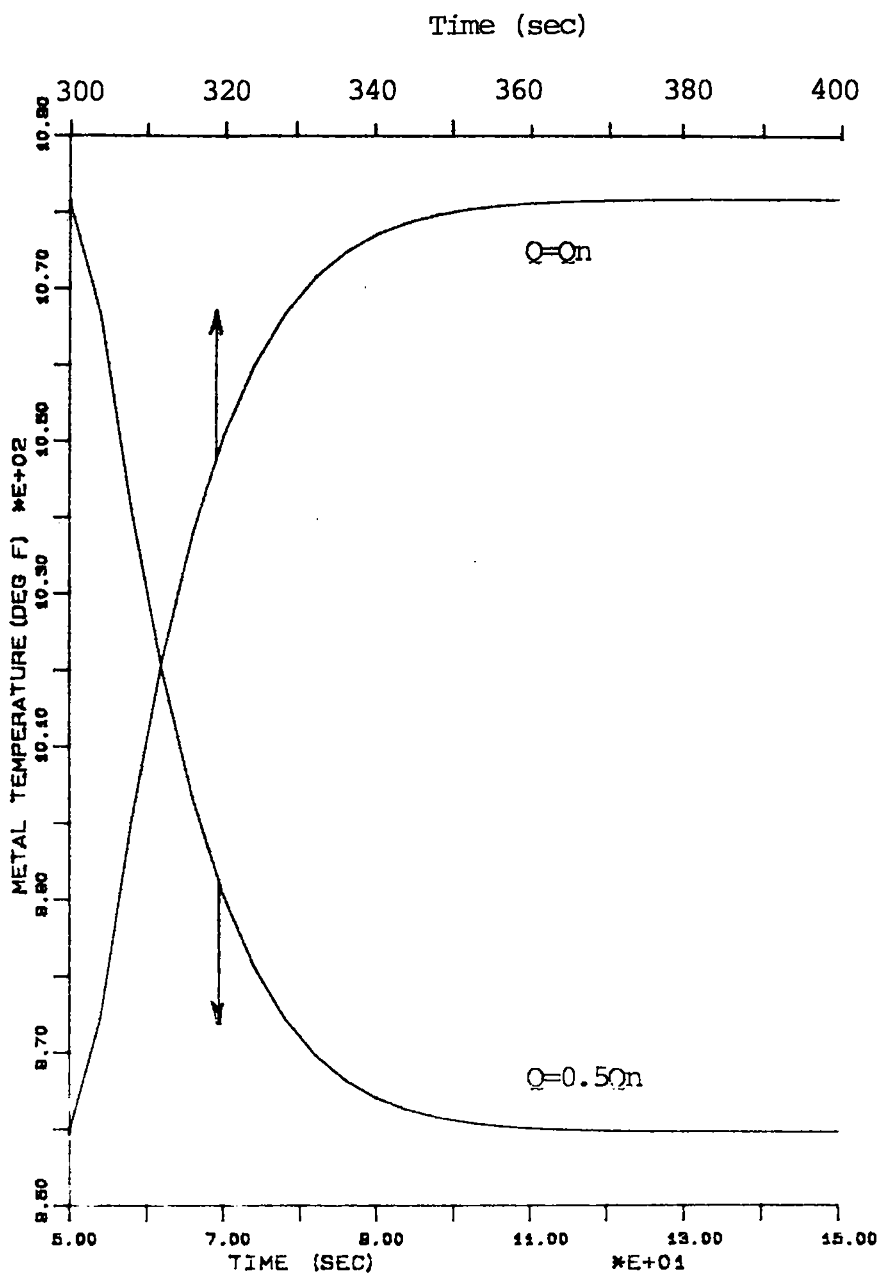


FIGURE 25
METAL TEMP. TRANSIENT RESPONSE
STEPS IN SOLAR HEAT FLUX



superheater panel as suggested by Babcock & Wilcox (17), see (III.1.1).

Simulation conditions were:

- Cloud;

  Infinitely long

  wide: 4800m

  speed: 20 m/s

  direction: West to East

- Steady state inlet conditions;

  P = 2028.9 psia

  T = 877.07 F

  h = 1391.18 Btu/lbm

  ρ = 2.96 lbm/cu.ft

  Qn = 160.09 Btu/s/tube

  W = 5029.32 lbm/h/tube

- Transient conditions from Stone & Webster

  Time varying inputs

  Transient solar heat flux as given in fig.(33)

Steady state profiles were obtained for this specific conditions. Friction factor was obtained from pressure drop data sent by Stone & Webster, this drop is several times less than that specified in table III. This difference is a consequence of program run time optimization for Stone & Webster simulation (18).

Figures (26 through 29) show P,h,T,Tm profiles for selected instants of time. It can be observed that the initial and final steady states are not the same, this is due to different inlet conditions for both cases.

Time varying inlet characteristics are shown in fig.(30-32) and transient solar heat flux in figure (33).

We have maintained the steady state conditions for 50 sec., as can be seen in figs. (30-33). It is shown a closed agreement between steady state outlet characteristics at time 0 sec. (Data from Stone & Webster) and the values obtained from our model for time greather than cero until 50 sec. (Figs.34-37).

The inlet characteristics are controlled variables, control action W can be considered as preliminary i.e. if outlet steam temperature is diminishing in time there is not reason to increase W under this conditions, this can be observed in figures (30,36).

Inlet and outlet pressure evolutions are very similar, Figs.(32-34), sensitivity of outlet pressure to variations of control action W is very low, this is due to the friction factor used.

Average metal temperature is shown for a tube height of 81.46 ft. figure (37), for this special case of a constant value profile of solar flux, the maximum metal temperature coincides at this tube location. It has been shown that for a more

FIGURE 26
PRESSURE PROFILE ALONG TUBE AXIS
CLOUD FROM WEST TO EAST

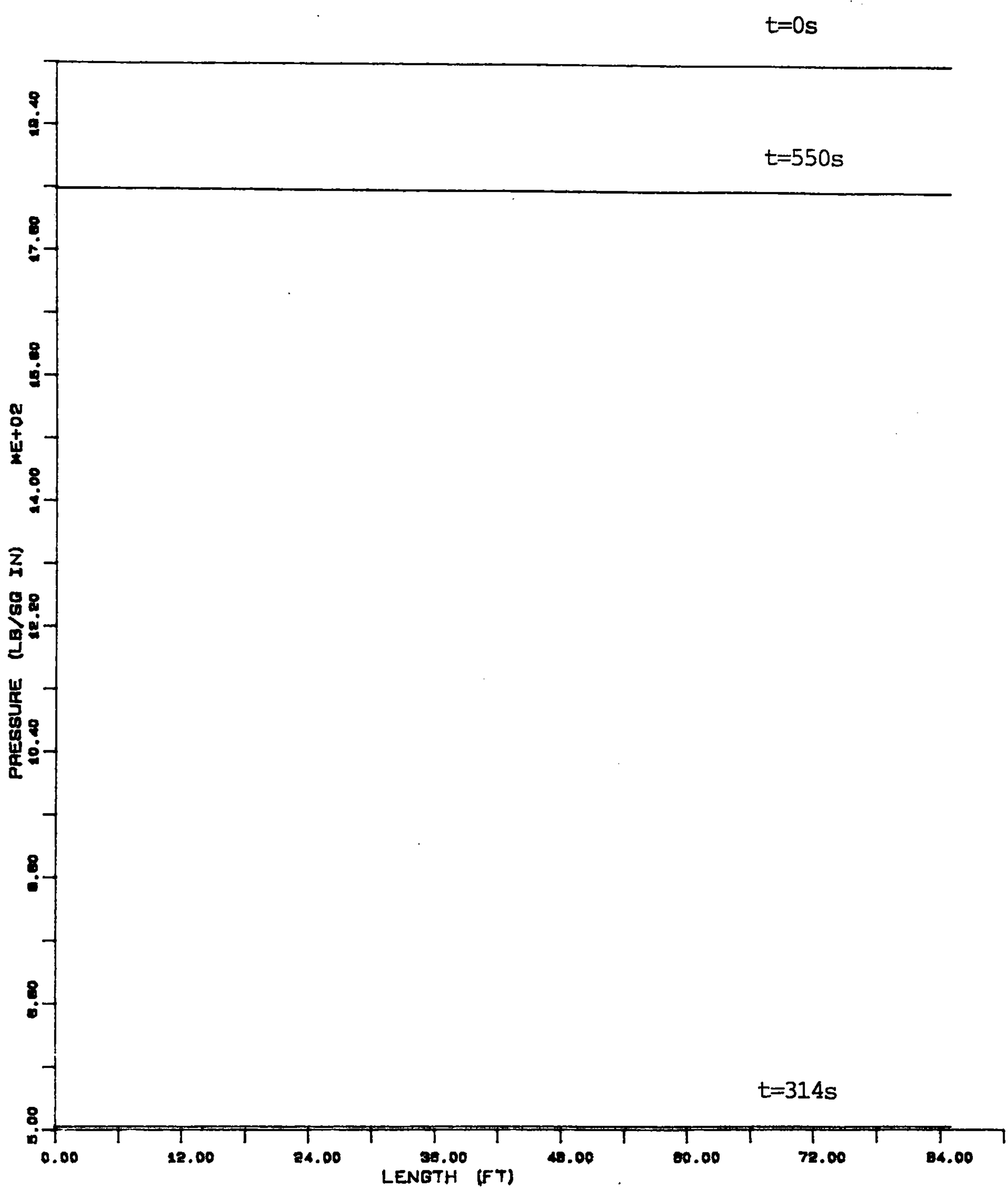


FIGURE 27
ENTHALPY PROFILE ALONG TUBE AXIS
CLOUD FROM WEST TO EAST

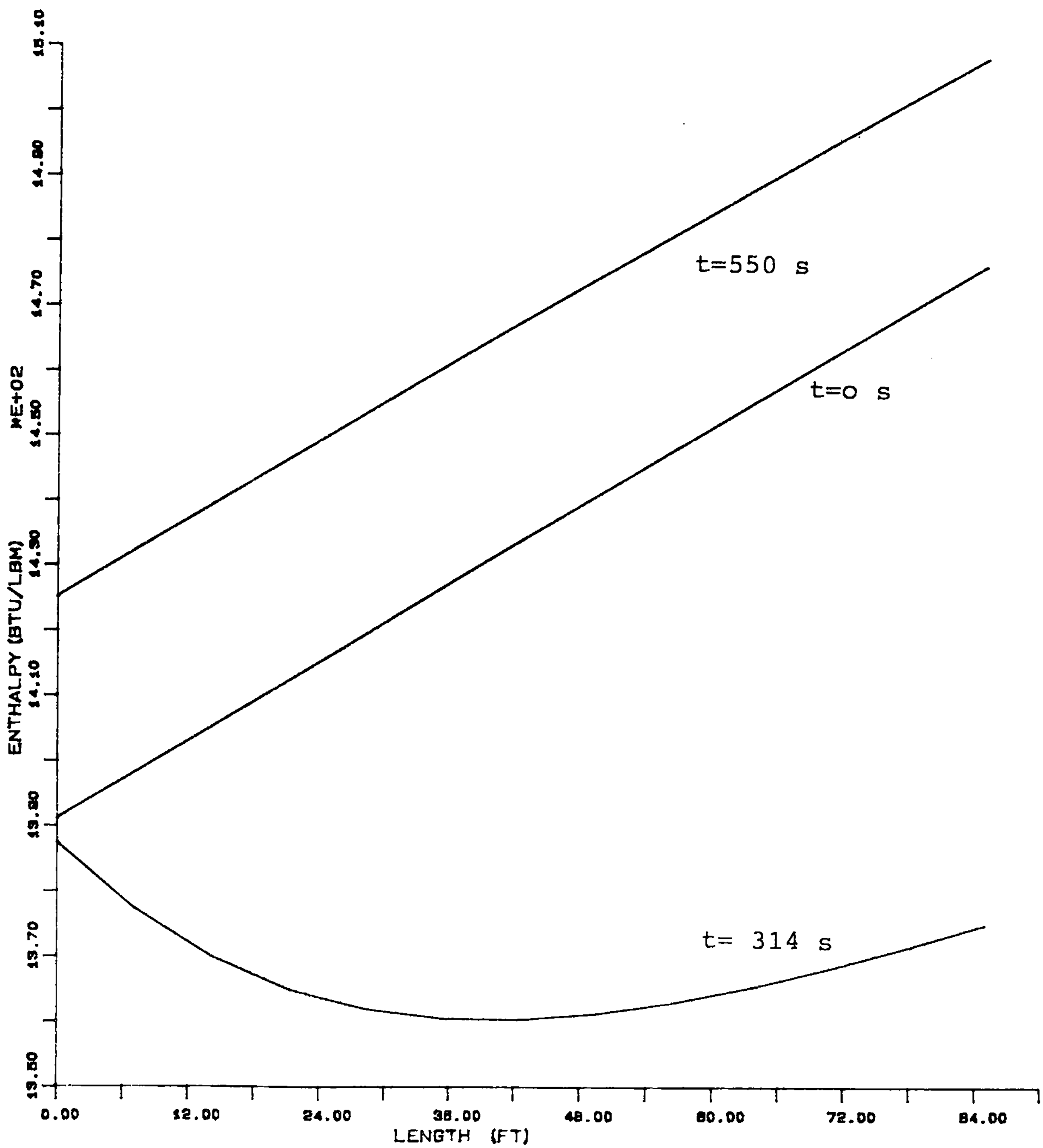
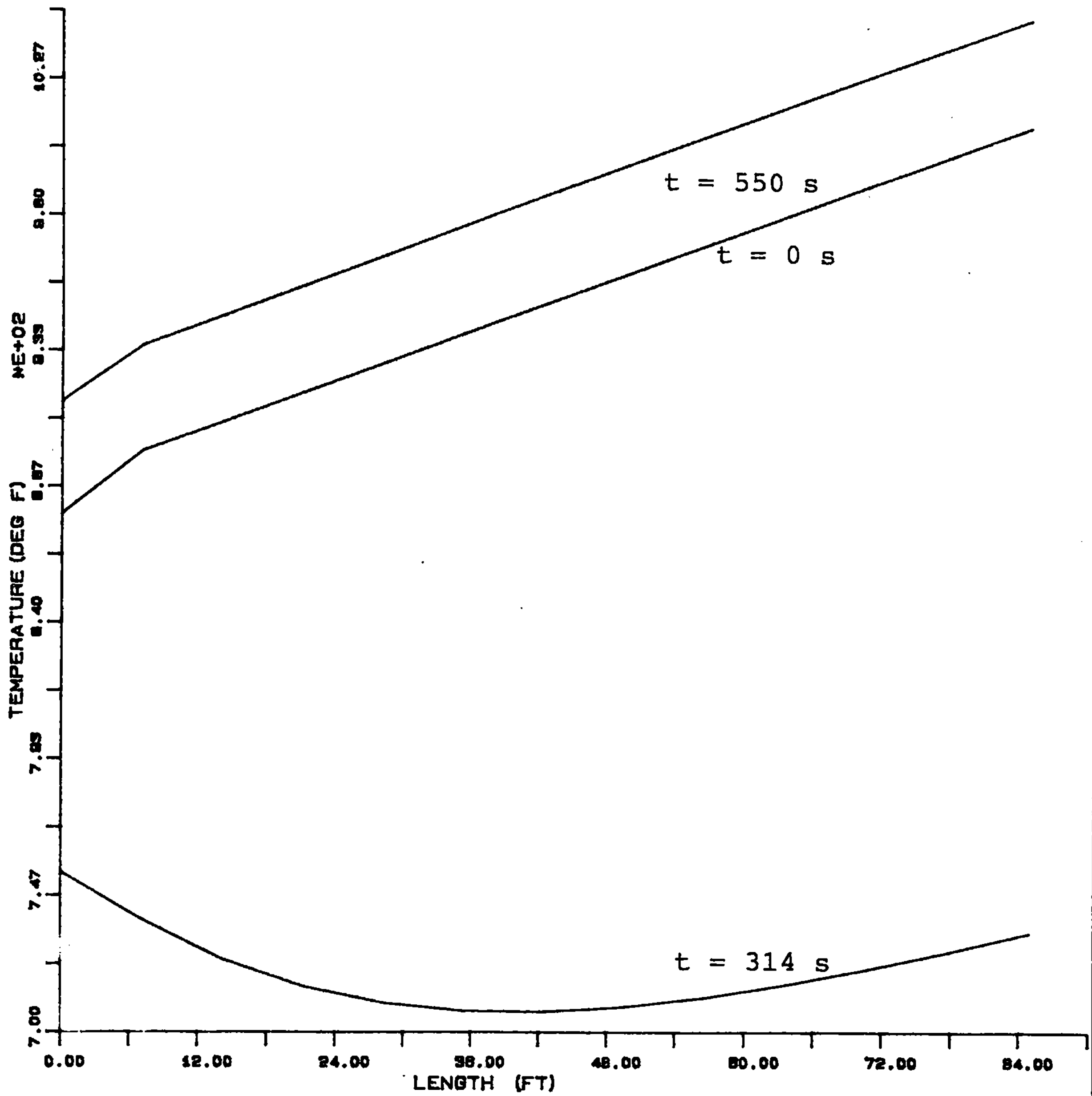


FIGURE 28
TEMPERATURE PROFILE
CLOUD FROM WEST TO EAST



INSTITUTO DE INVESTIGACIONES ELECTRICAS

FIGURE 29
METAL TEMPERATURE PROFILE
CLOUD FROM WEST TO EAST

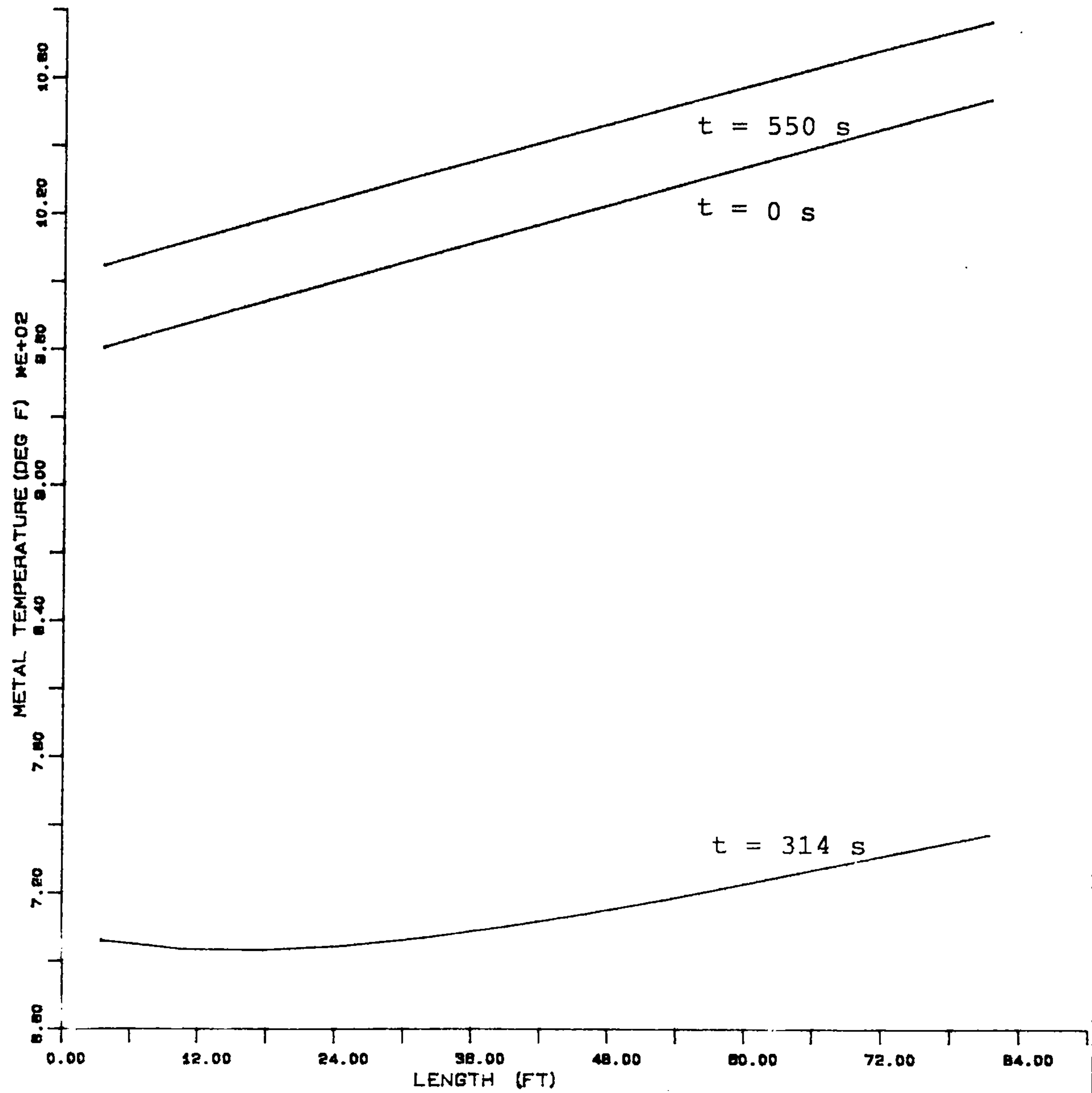


FIGURE 30
INLET MASS FLOW RATE
CLOUD FROM WEST TO EAST

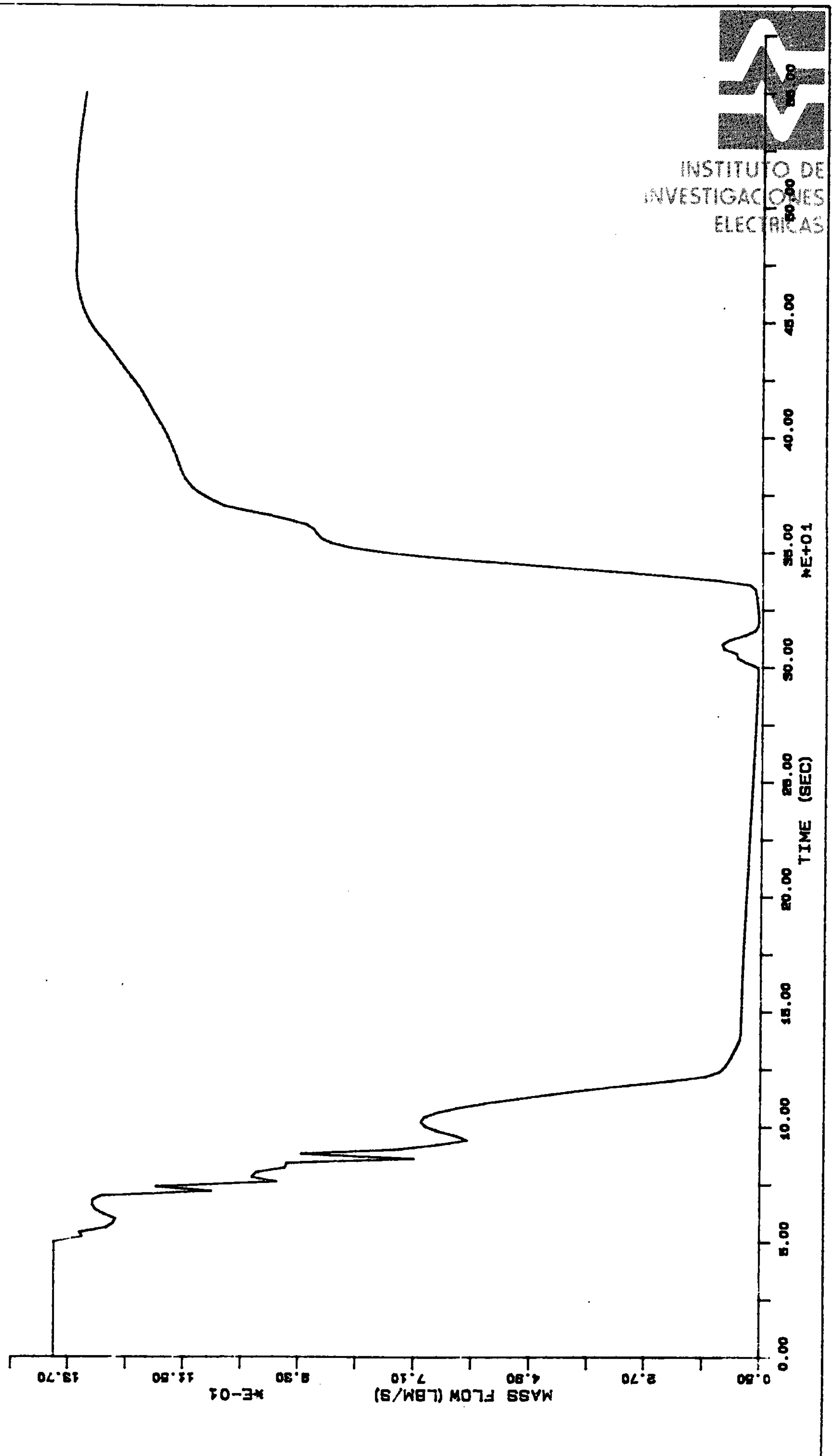


FIGURE 31
INLET TEMPERATURE
CLOUD FROM WEST TO EAST

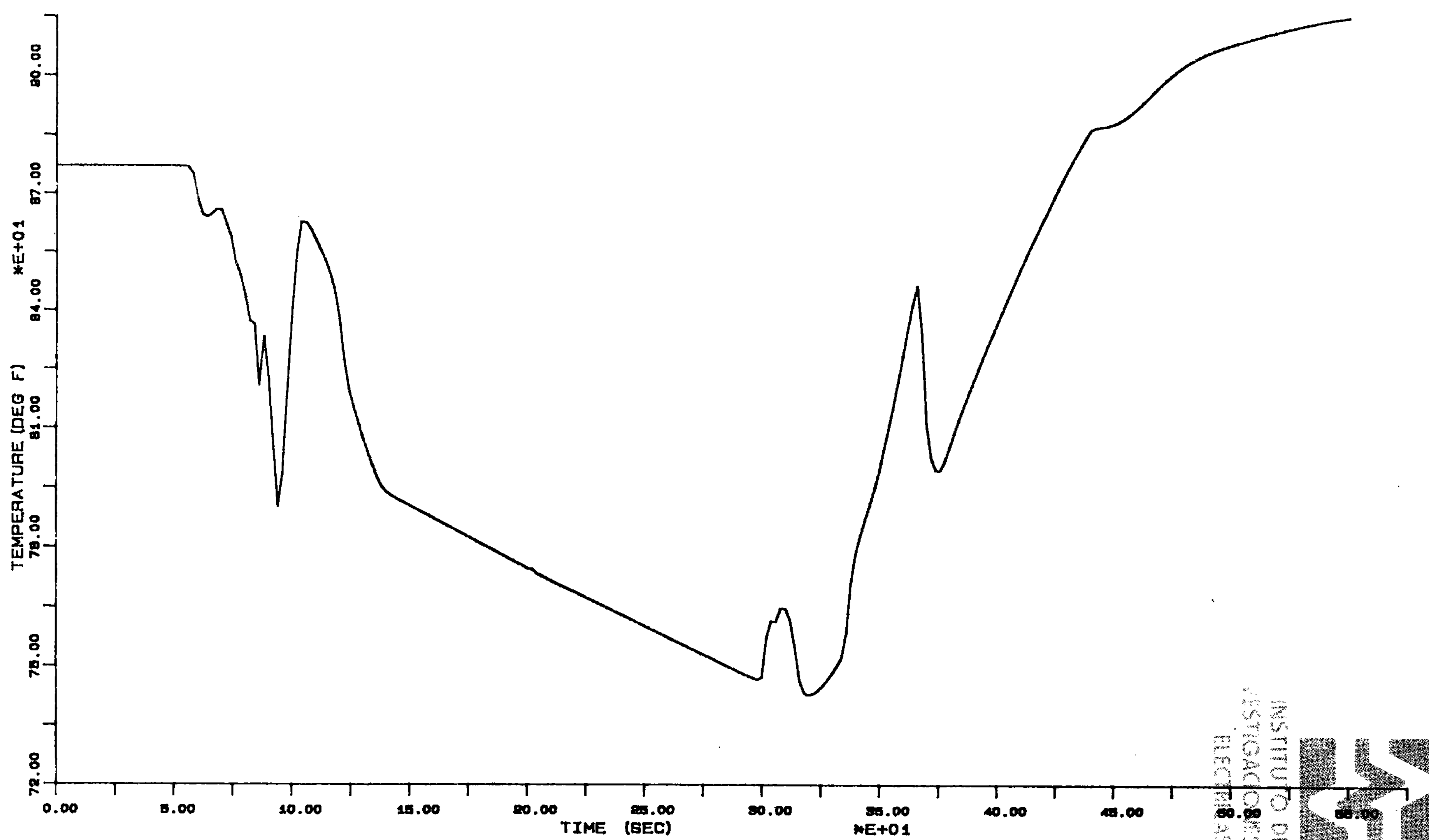


FIGURE 32
INLET PRESSURE
CLOUD FROM WEST TO EAST

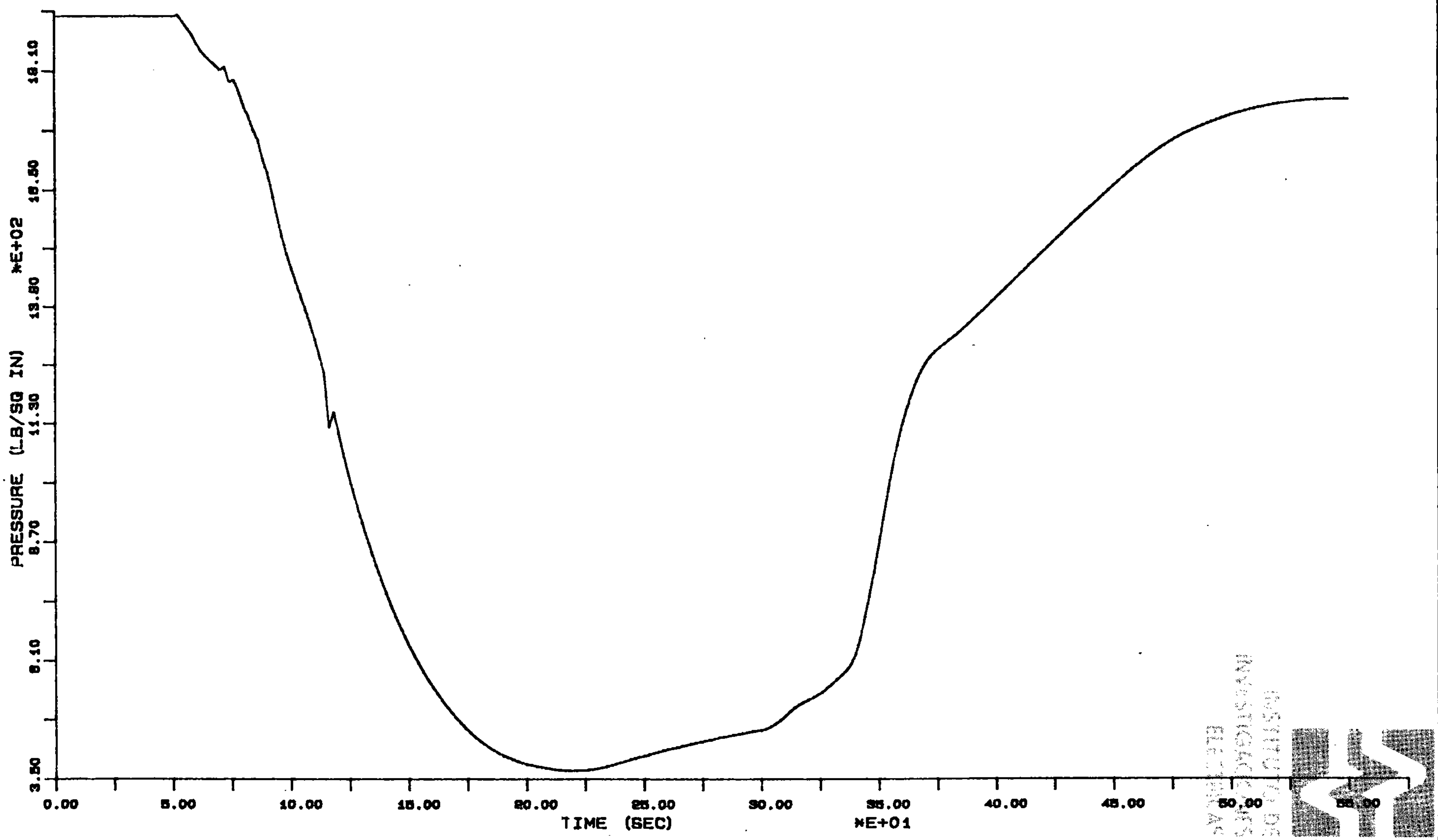


FIGURE 33
SOLAR HEAT FLUX PROFILE
CLOUD FROM WEST TO EAST

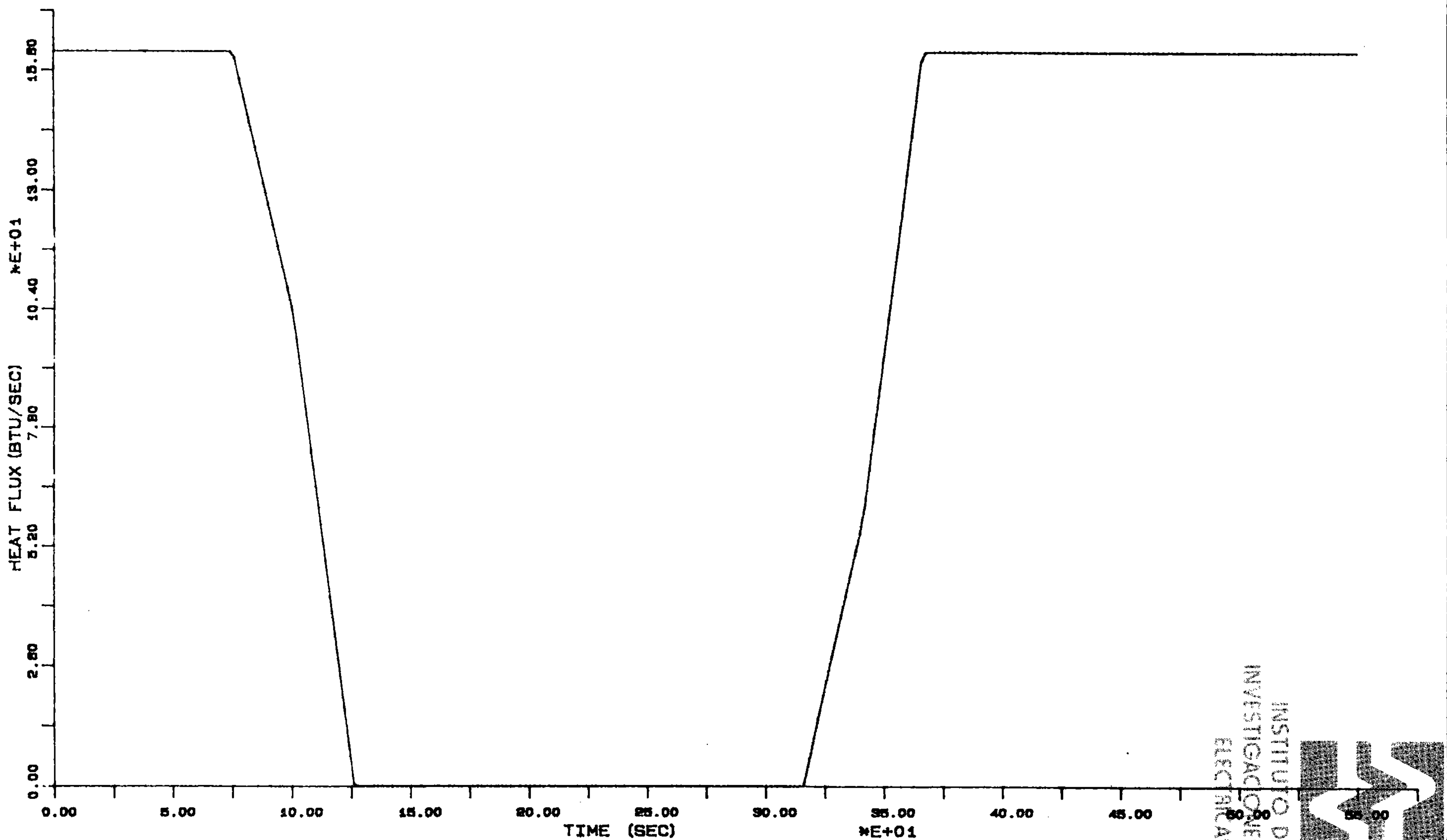


FIGURE 34
OUTLET PRESSURE
CLOUD FROM WEST TO EAST

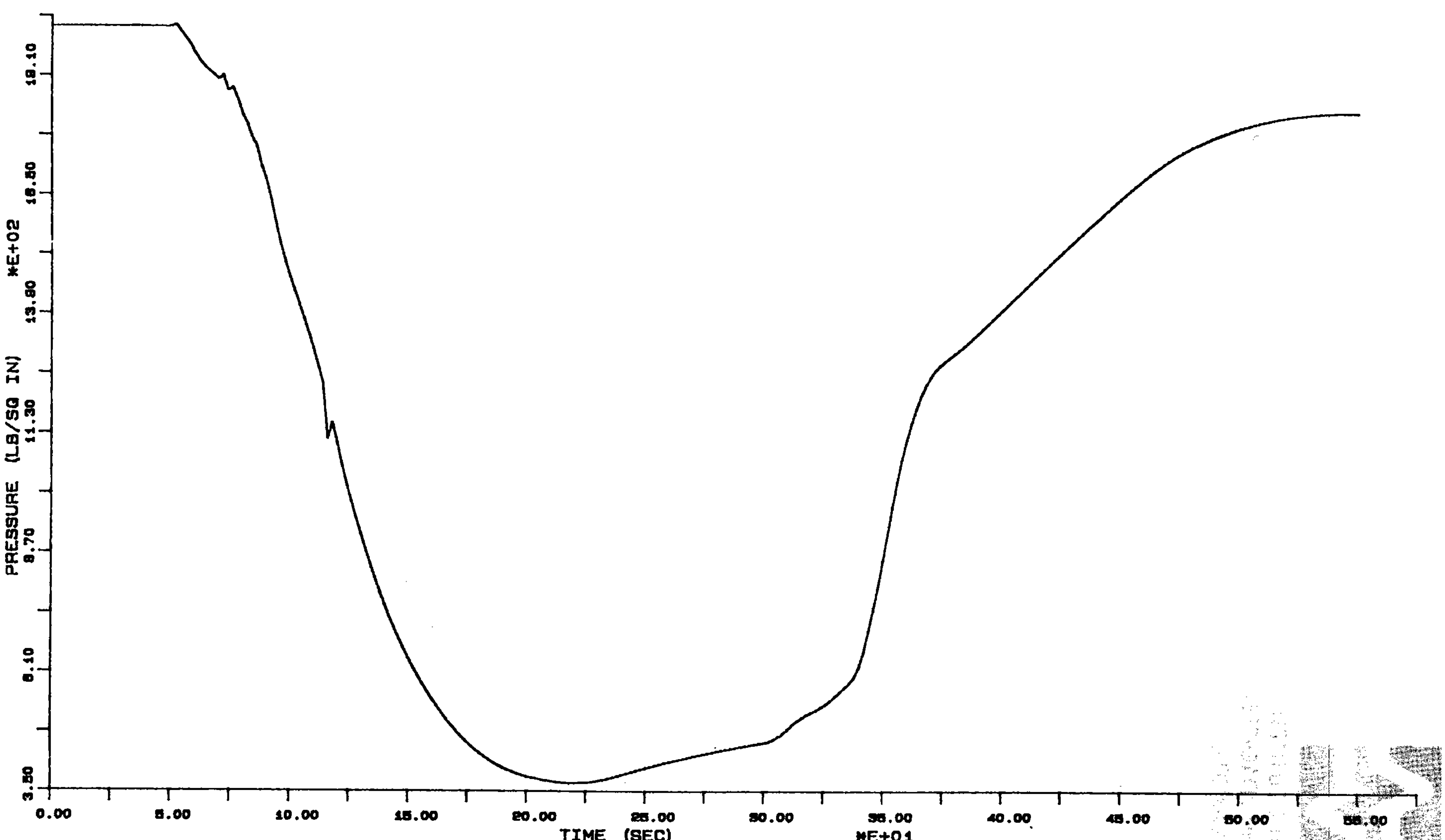


FIGURE 35
OUTLET ENTHALPY
CLOUD FROM WEST TO EAST

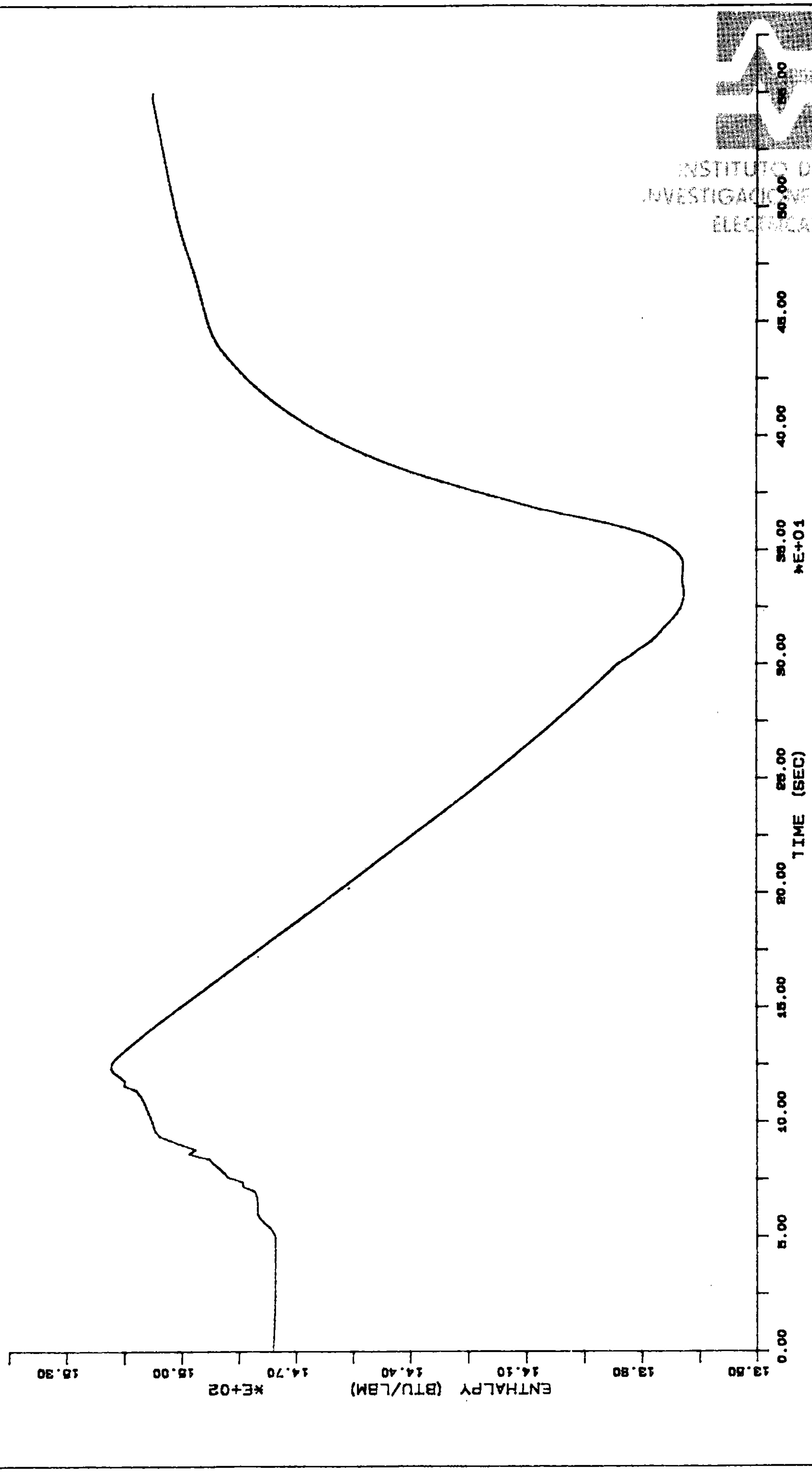


FIGURE 36
OUTLET TEMPERATURE
CLOUD FROM WEST T.O EAST

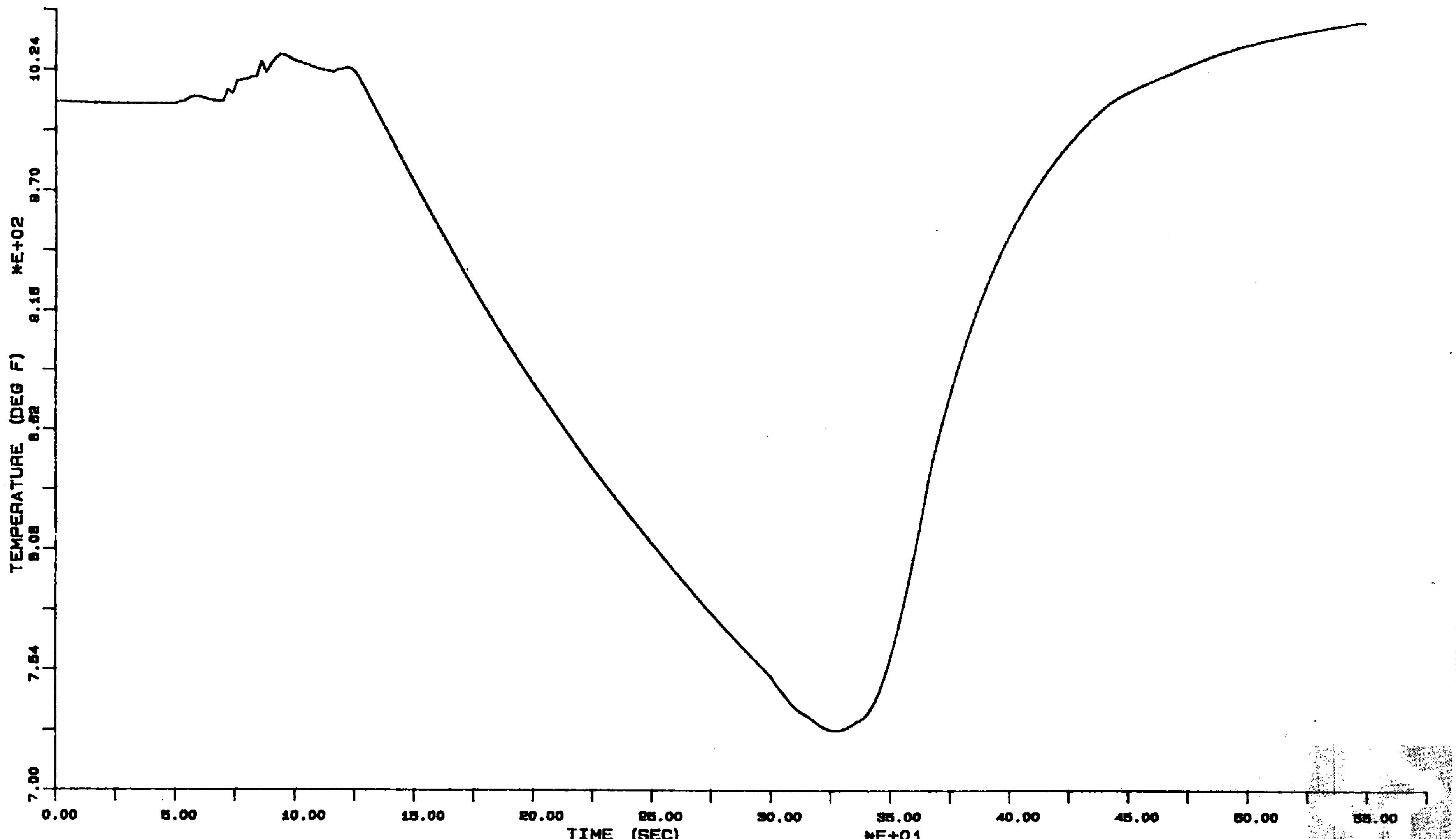
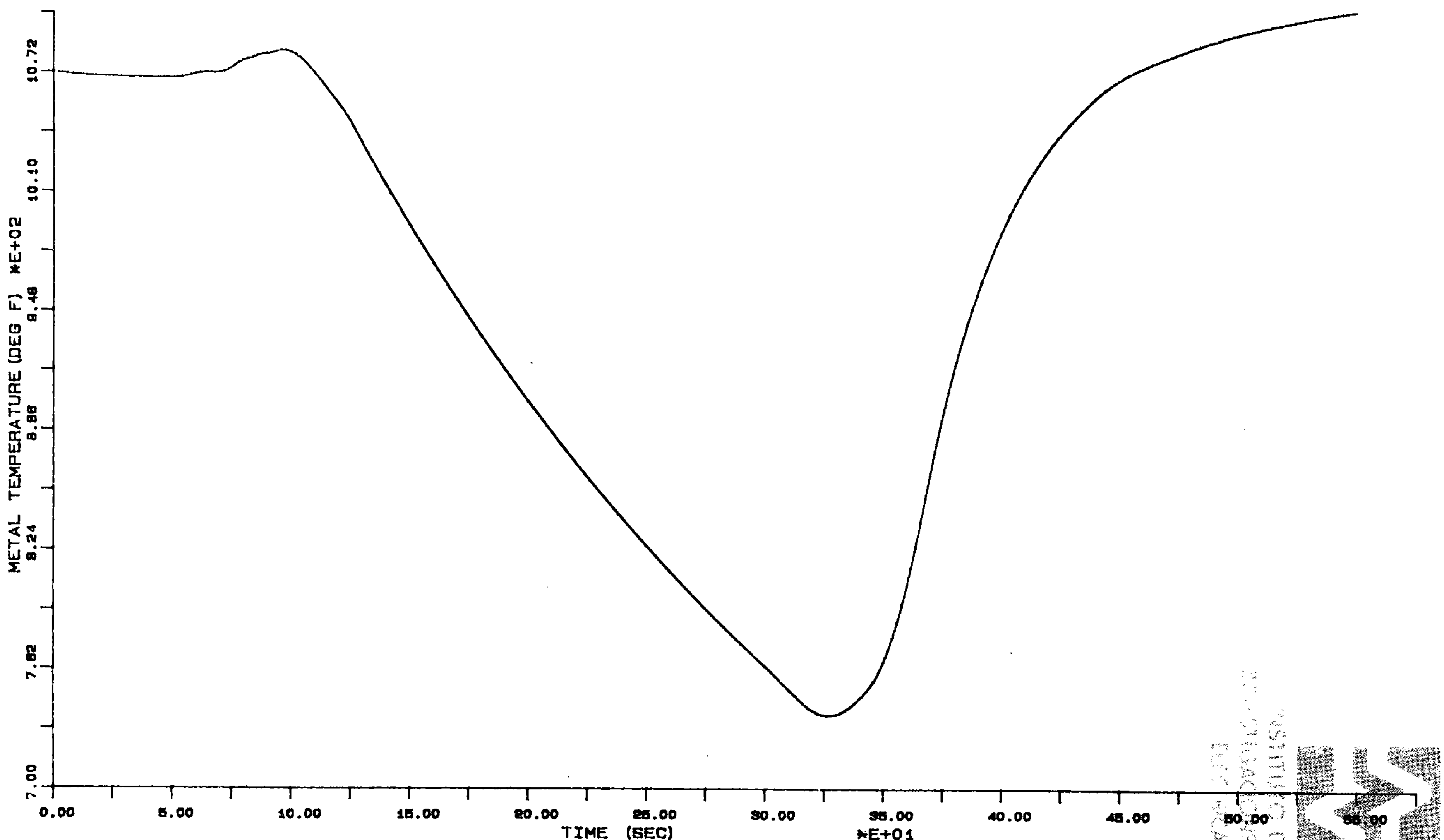


FIGURE 37
OUTLET METAL TEMPERATURE
CLOUD FROM WEST TO EAST



realistic solar flux profile this maximum occurs in a lower heigth (III.3.2). Given that the control action is conceived to regulate superheater steam outlet temperature and also as we have shown that for a more realistic solar flux profile (III.3.2), this temperature is maximum at the outlet and metal temperature maximum value is not located at this position, there is a risk of up setting metal maximum design temperature. This possibility is observed in fig.(37) for a time around 100 sec.

With the purpose of comparing the outlet characteristics evaluated by our model and those furnished by Stone & Webster, fig.(38), shows time evolution of outlet steam temperatures. It is observed a difference around 1% for the first and last 150 sec. and a maximum difference of 19% in 325 sec. i.e. when solar heat flux starts to increase ,fig(33). We believe that this difference is acceptable for preliminary results and comparisons, it can be explained because significant differences between the values of tube inside heat transfer coeffiecient. Stone & Webster used a fixed value for their simulation (18) and in our case this coefficient is evaluated at each time for the given set of thermodynamic properties, i.e. for:

t = 50 sec.	Hi = 1190
t = 326 sec.	Hi = 64
t = 550 sec.	Hi = 1110

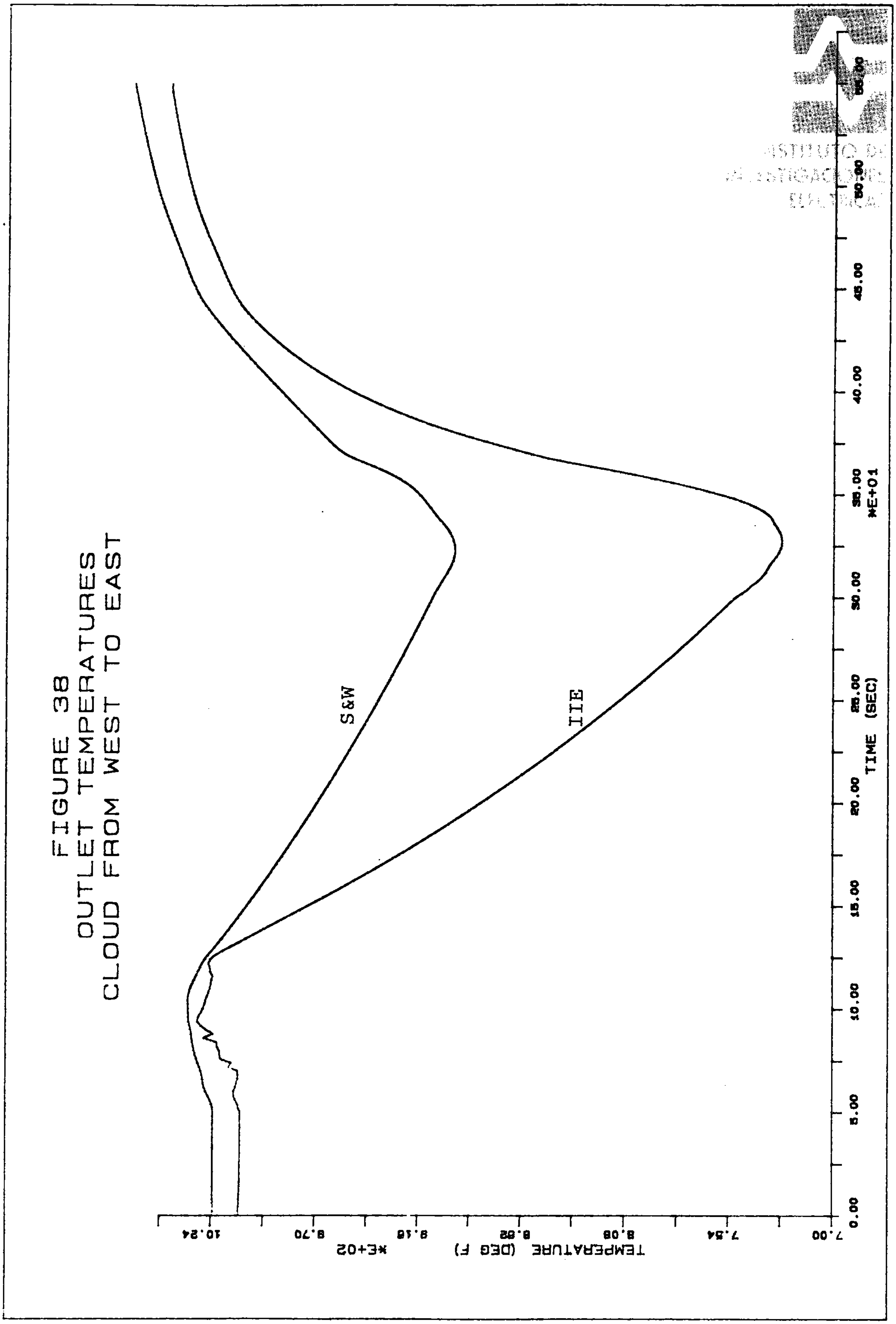


FIGURE 38
OUTLET TEMPERATURES
CLOUD FROM WEST TO EAST
S&W
IIE
TEMPERATURE (DEG F) *E+02
7.00
7.54
8.08
8.62
9.16
9.70
10.24
TIME (SEC) *E+01
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00

IV. CONCLUSIONS.

Time space modeling of a superheater tube or panel has been performed by means of a lumped parameter approach, the model has been implemented in a digital computer.

We have obtained a close agreement for steady state conditions between our model output and that specified by Babcock & Wilcox and Stone & Webster. For dynamic conditions the performance predicted by our model has been also compared to that furnished by Stone & Webster, the preliminary results obtained show differences in the range of 1% to 19% in steam temperature predictions, seemingly due to values of inside heat transfer coefficients.

The link between our dynamic superheater model and that of Stone & Webster has been established. With the inputs specified by Stone & Webster we can furnish more detailed information of phenomena ocurring along the superheater panels or tubes. We have shown the possibility of using this information to synthesize improved control actions with the purpose of governing and protecting the superheater in a better way.

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Division Fuentes de Energía, Depto. Geotermia.
Instituto de Investigaciones Eléctricas

APPENDIX G

APPENDIX G
RECEIVER DESIGN AND PERFORMANCE DETAILS

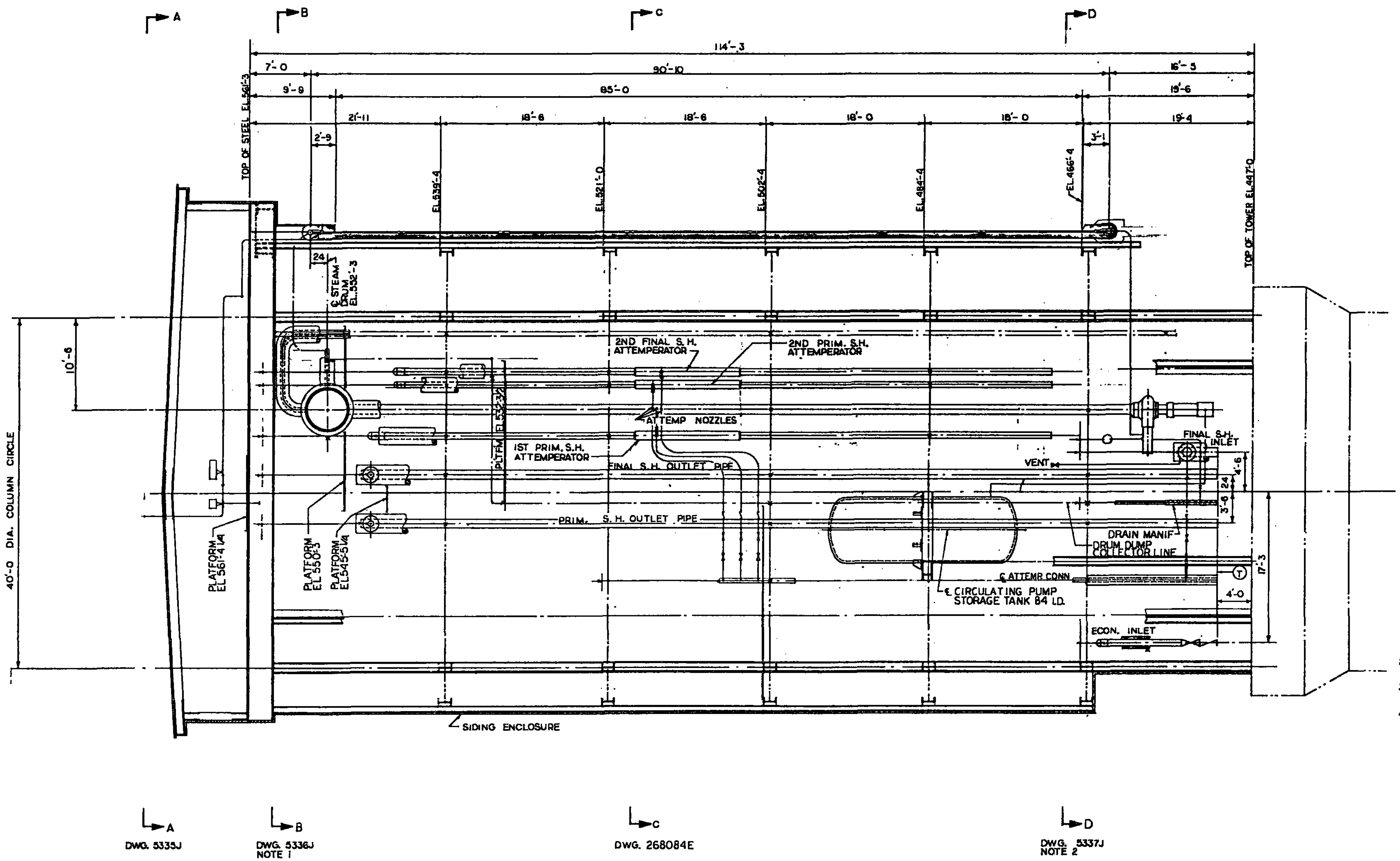
G.1 Summary

Appendix G includes the following sections:

APPENDIX G.2

LIST OF DRAWINGS

LIST OF DRAWINGS



NOTES:

1. FOR LAYOUT RISER TUBES REFER TO SECTION B-B DWG. 5336J.
2. FOR LAYOUT SUPPLY TUBES REFER TO SECTION D-D DWG. 5337J.
3. THE SYMBOL (T) DENOTES A TERMINAL WHERE THE B & W CO. WORK STOPS.
4. THE SYMBOL × DENOTES A LATERAL TIE.

The Babcock & Wilcox Company
Power Generation Group

891-1104-45

ARRGT. SOLAR RECEIVER
SECTIONAL SIDE VIEW

Scale ¼-12"

5334J 0

5334J

(A) PRIMARY SH 1, 26 TUBE PANEL
** 2-3 1/2 OD × .320 THK, CR 1 1/4 CONNS
EVAP × 2-4 OD × .260 THK SA 210C CONNS

(B) FINAL SH 1, 26 TUBE PANEL
** 2-4 OD × .480 THK CR 2 1/4 CONNS
EVAP × 2-4 OD × .260 THK SA 210C CONNS

(C) PRIMARY SH 1, 26 TUBE PANEL
** 2-3 1/2 OD × .320 THK, CR 1 1/4 CONNS
EVAP × 2-4 OD × .260 THK SA 210C CONNS

(D) FINAL SH 2, 29 TUBE PANEL
** 4-3 1/2 OD × .320 THK SB 407-800 CONNS
EVAP × 2-4 OD × .260 THK SA 210C CONNS

(E) PRIMARY SH 3, 29 TUBE PANEL
** 4-3 1/2 OD × .320 THK SB 407-800 CONNS
EVAP × 1-4 OD × .260 THK SA 210C CONN
& 1-4 OD CONN CAPPED

(F) PRIMARY SH 2, 29 TUBE PANEL
** 4-4 OD × .480 THK CR 2 1/4 CONNS
EVAP × 1-4 OD × .260 THK SA 210C CONN
& 1-4 OD CONN CAPPED

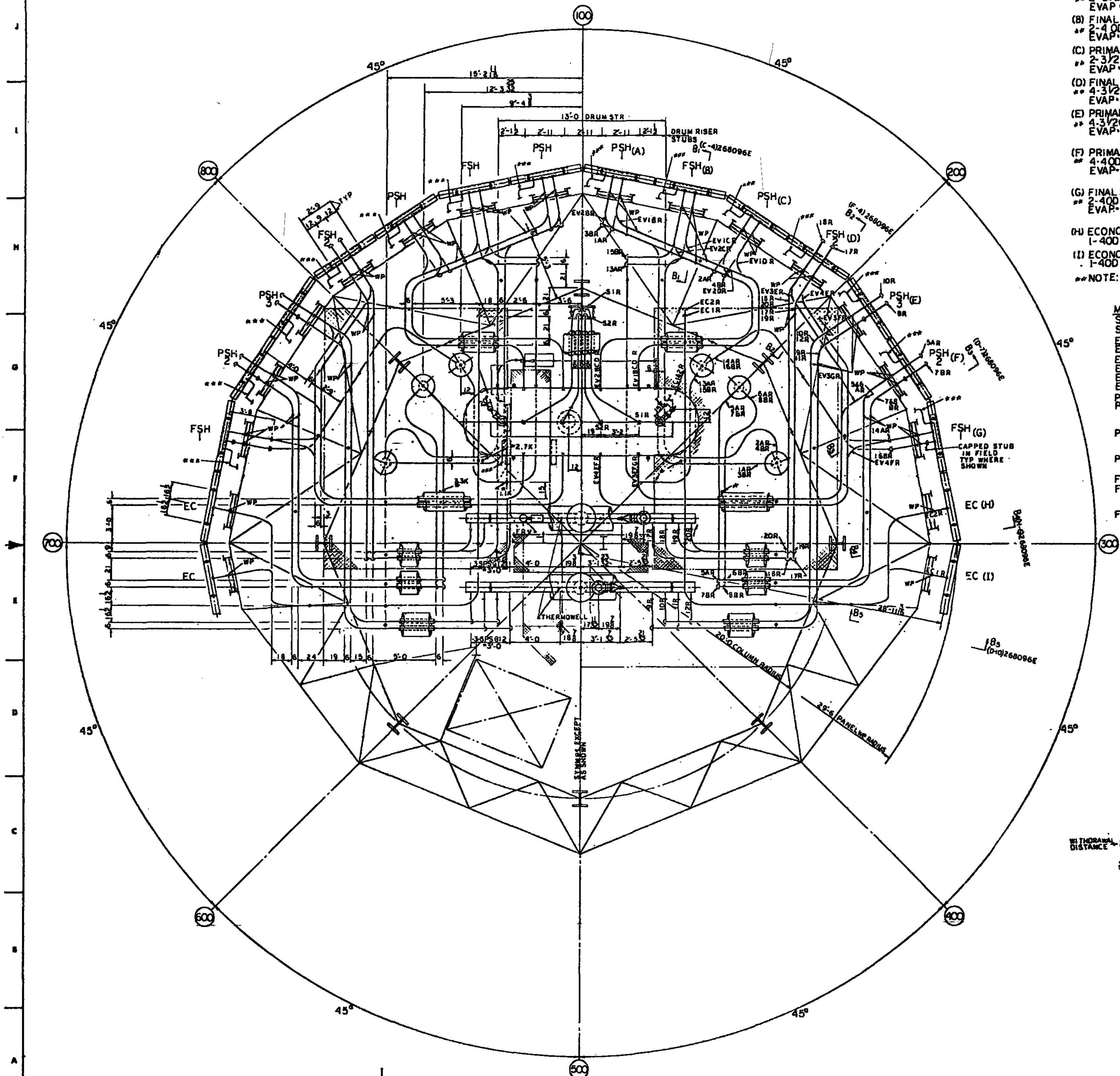
(G) FINAL SH 1, 26 TUBE PANEL
** 2-4 OD × .480 THK CR 2 1/4 CONNS
EVAP × 1-4 OD × .260 THK SA 210C CONN
& 1-4 OD CONN CAPPED

(H) ECONOMIZER TUBE PANEL
1-4 OD × .270 THK SA 210C CONN

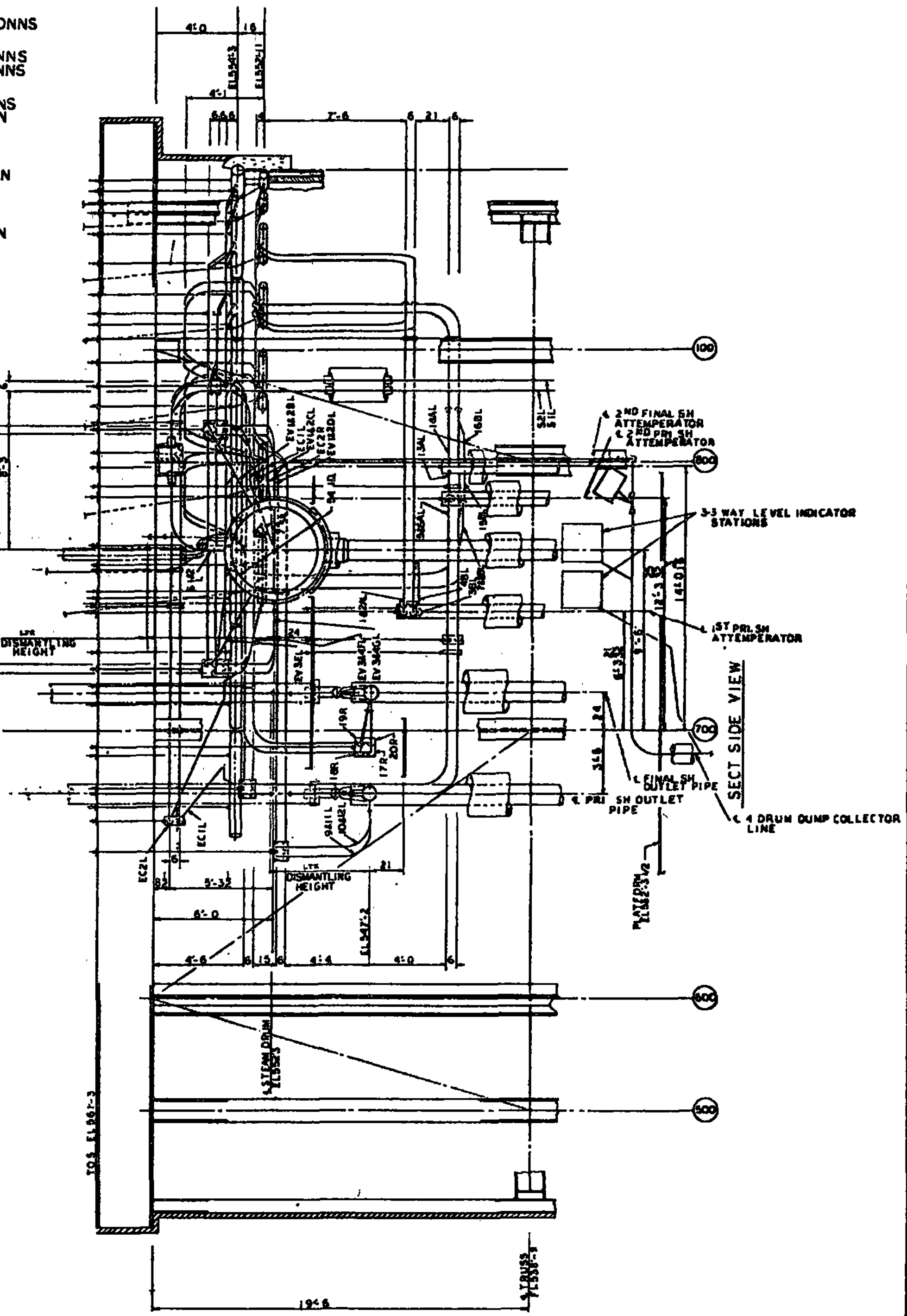
(I) ECONOMIZER TUBE PANEL
1-4 OD × .270 THK SA 210C CONN

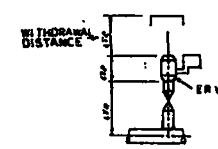
** NOTE: ALL PSH & FSH HDR NOZ. ARE 3 3/4 OD

MARK NOS
SAT CONNS 5 OD × .300 THK SA 210C
S-1&2 R/L
ECONOMIZER
EC-1&2 R/L
EVAP PANEL
EV-1&2, BC&D R/L
EV-3&4, EF R/L
EV-3G R/L
PRIMARY SH
PSH-1 1&2, A R/L
3&4, B R/L
PSH-2 5&6, A R/L
7&8, B R/L
PSH-3 9, 10, 11 & 12 R/L
FINAL SH
FSH-1 13, 14, A R/L
15, 16, B R/L
FSH-2 17, 18, 19 & 20 R/L
BEND RADII
3 1/2 OD = 14
4 OD = 16
5 OD = 20



SECTION B-B
(C-10) DWG 5334J





SECT. L-L
(E-10)

FOR LAYOUT RISER TUBES SECTIONS B_1-B_1, B_2-B_2, B_3-B_3, B_4-B_4 & B_5-B_5 SEE DWG 268096E

FOR ROD LOADS NOT SHOWN SEE PLAN SECTION A-A DWG 268084E

FOR ARRGT SOLAR RECEIVER SECTIONAL SIDE VIEW SEE DWG 5334J

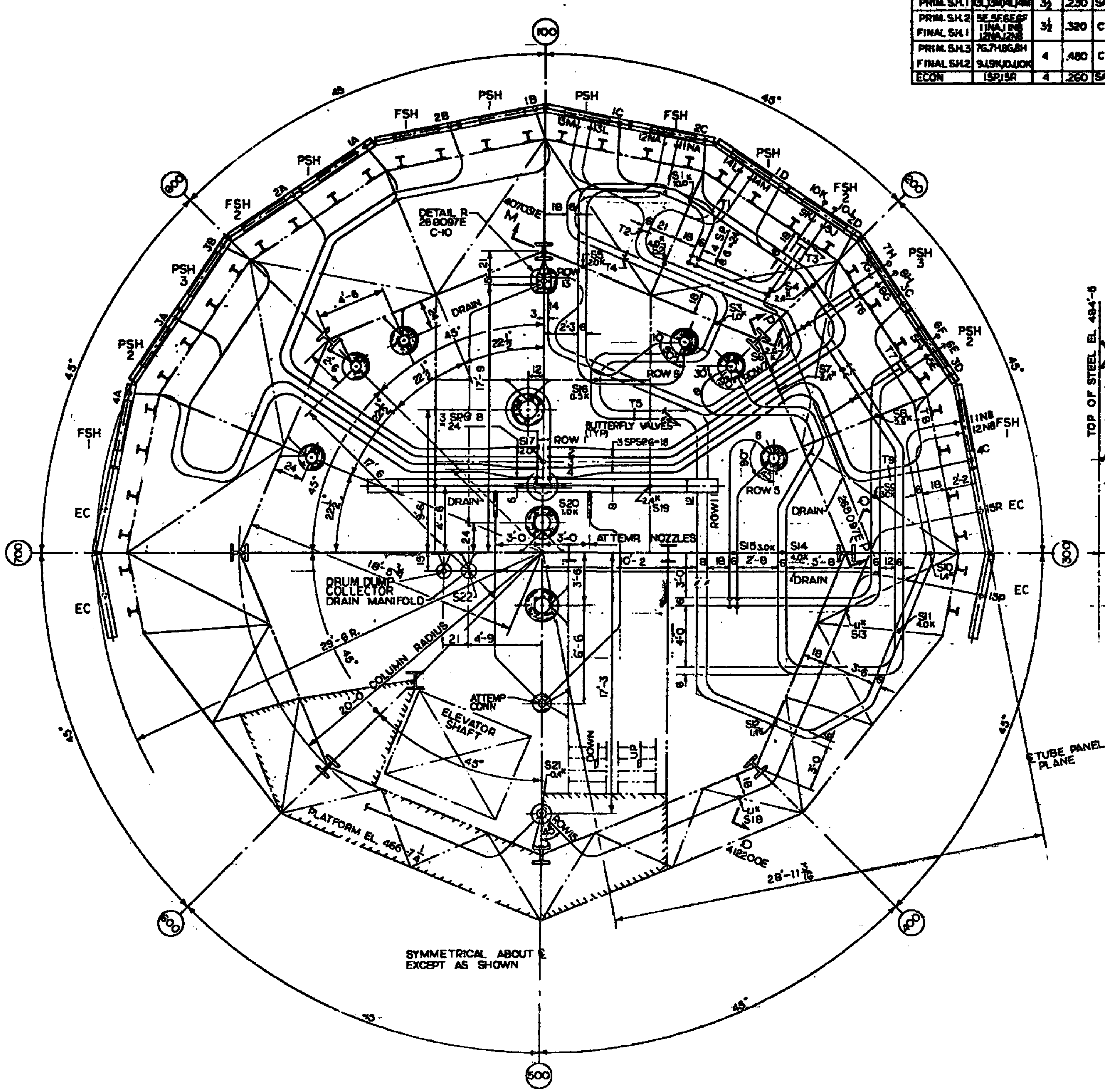
* SUPPORTED FROM DRUM PLATFORM STEEL. ALL OTHERS SUPPORTED FROM TOP STEEL

*** FOR ROUTING OF VENTS ABOVE TOP STEEL SEE L/O VALVE STATION DWG 412201E

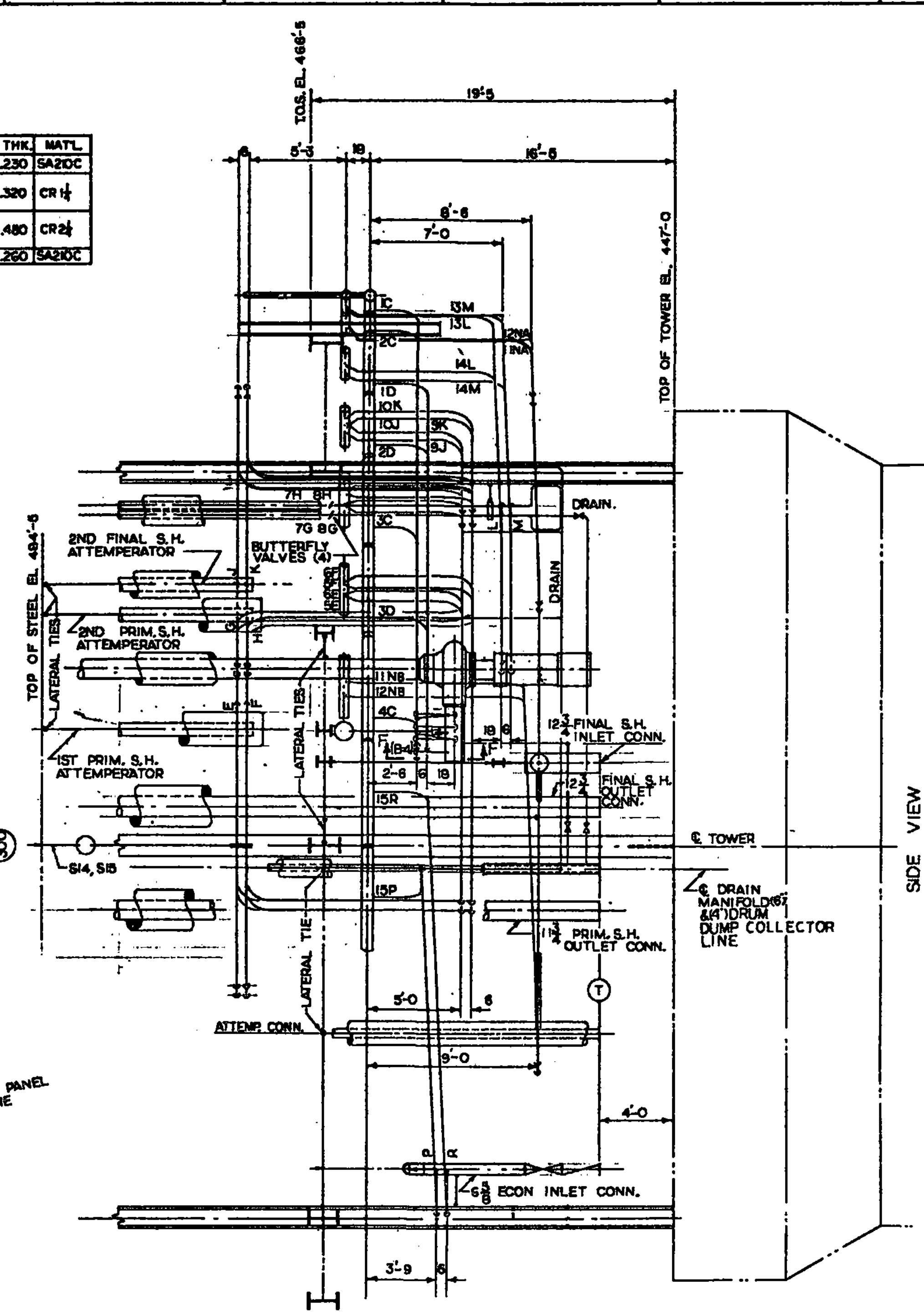
DRN	J L MULLINAX
The Babcock & Wilcox Company Power Generation Group	
L/O RISER TUBES SOLAR RECEIVER SECT SIDE VIEW & PLAN SECT. B-B	
891-1104-45	
SCALE 3/8 = 12	5336 J REV 0

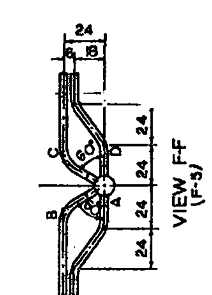
5336J

CIRCUIT	MARK №	O.D.	THK.	MAT'L.
PRIM. S.H. 1	13L,13M,14L,14M	3½	.230	SA210C
PRIM. S.H. 2 / FINAL S.H. 1	5E,5F,6E,6F 11NA,11NB 12NA,12NB	3½	.320	CR 1¼
PRIM. S.H. 3 / FINAL S.H. 2	7G,7H,8G,8H 9J,9K,10J,10K	4	.480	CR 2¼
ECON	15P,15R	4	.260	SA210C



PLAN SECTION D-D





VIEW F-F (F-5)

NOTES:
1. FOR MAIN ARRGT. REFER TO DWG. 5334J SECTIONAL SIDE VIEW.
2. THE SYMBOL (T) DENOTES A TERMINAL WHERE THE B&W CO. WORK STOPS.
3. ALL SUPPORTS ARE CONSTANT SPRING HANGERS EXCEPT S19 THRU S21 WHICH ARE SOLID SUPPORTS.

5337J

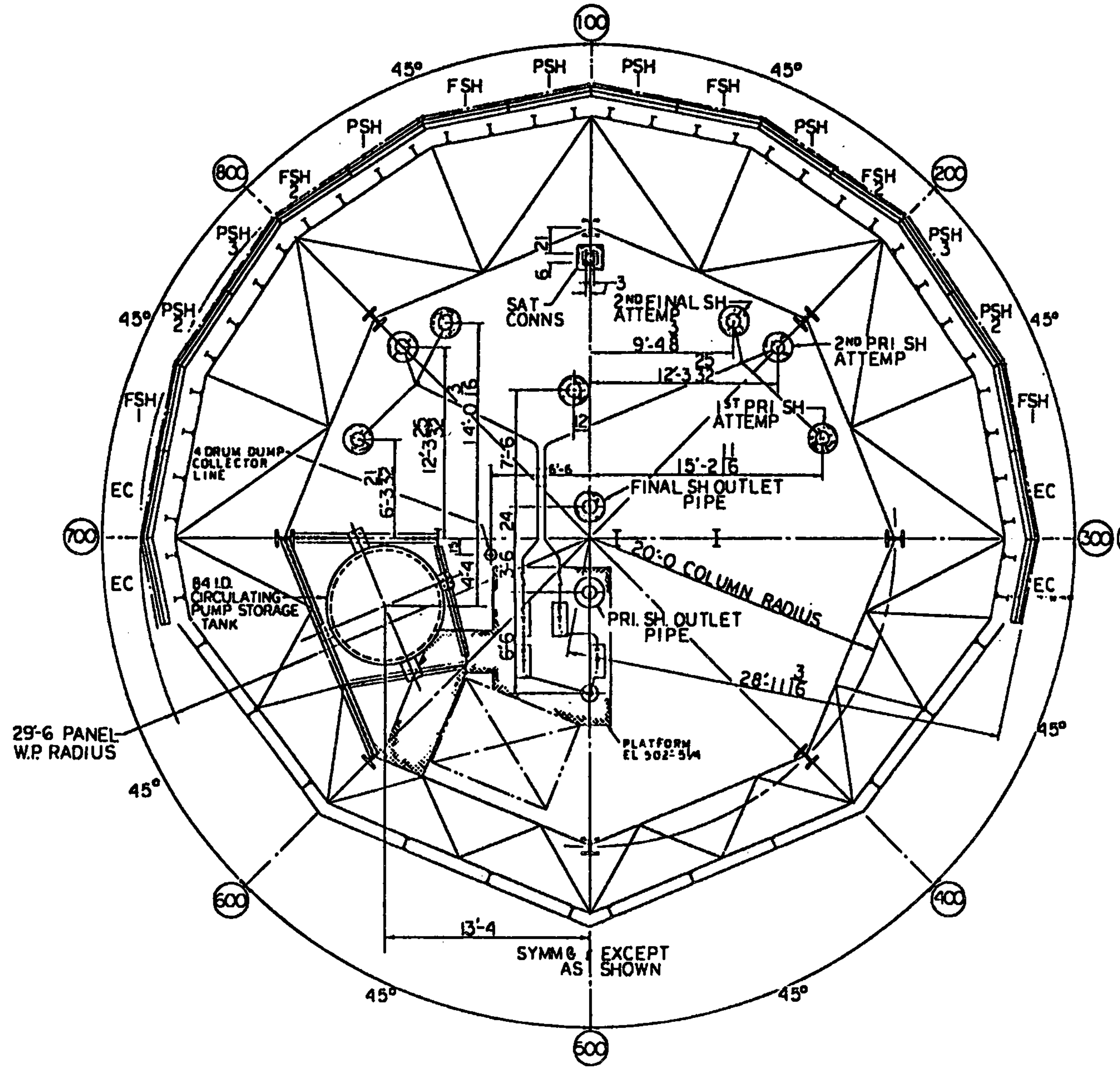
The Babcock & Wilcox Company
Power Generation Group

DR. KIDALOSKI
PASSED P. Mas
APP'D L.G. Cas

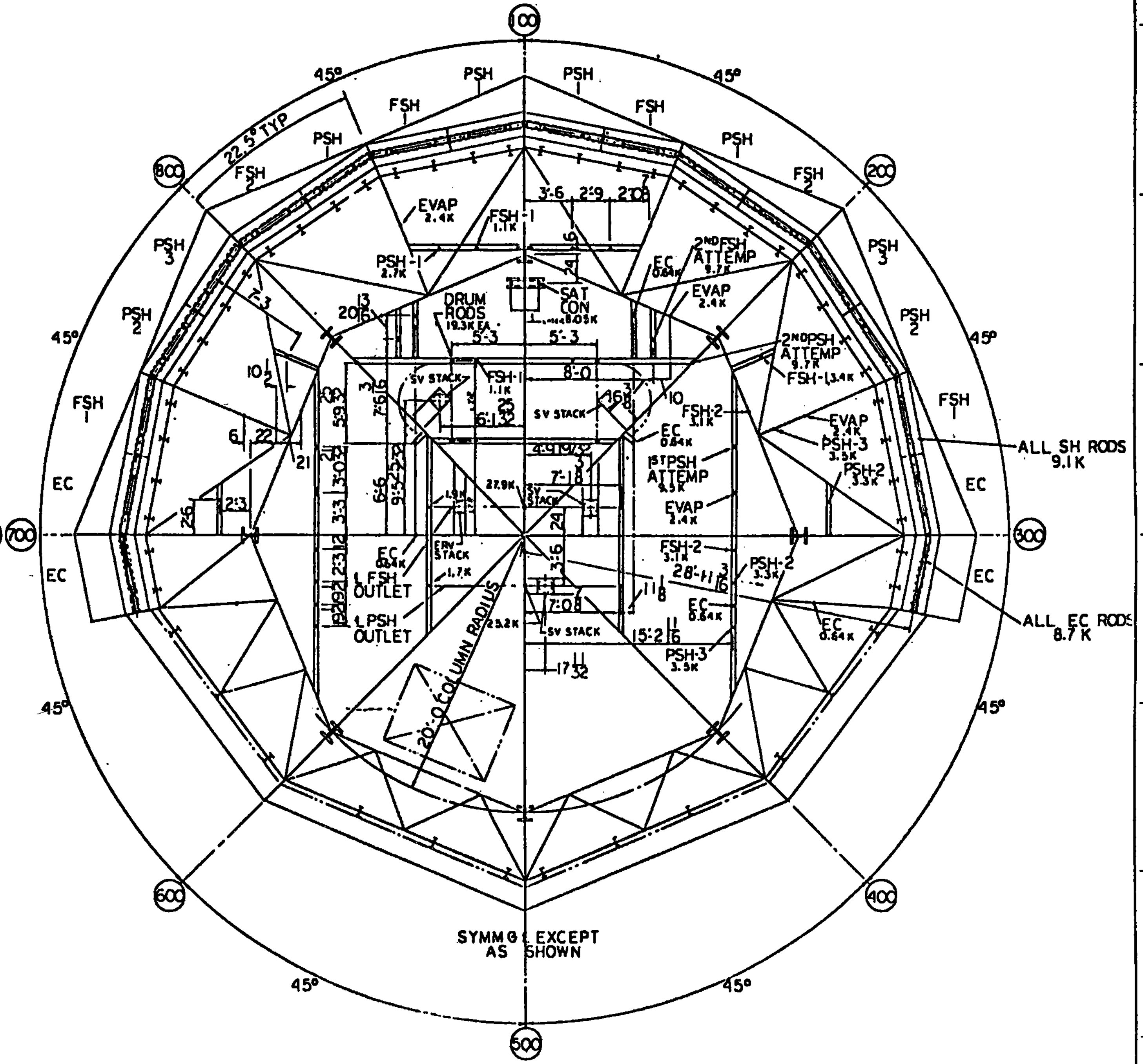
891-1104-45

LAYOUT SUPPLY TUBES
SOLAR RECEIVER
PLAN SECTION D-D

SCALE 3/8 = 12
DWG. NO. 5337J REV. 0



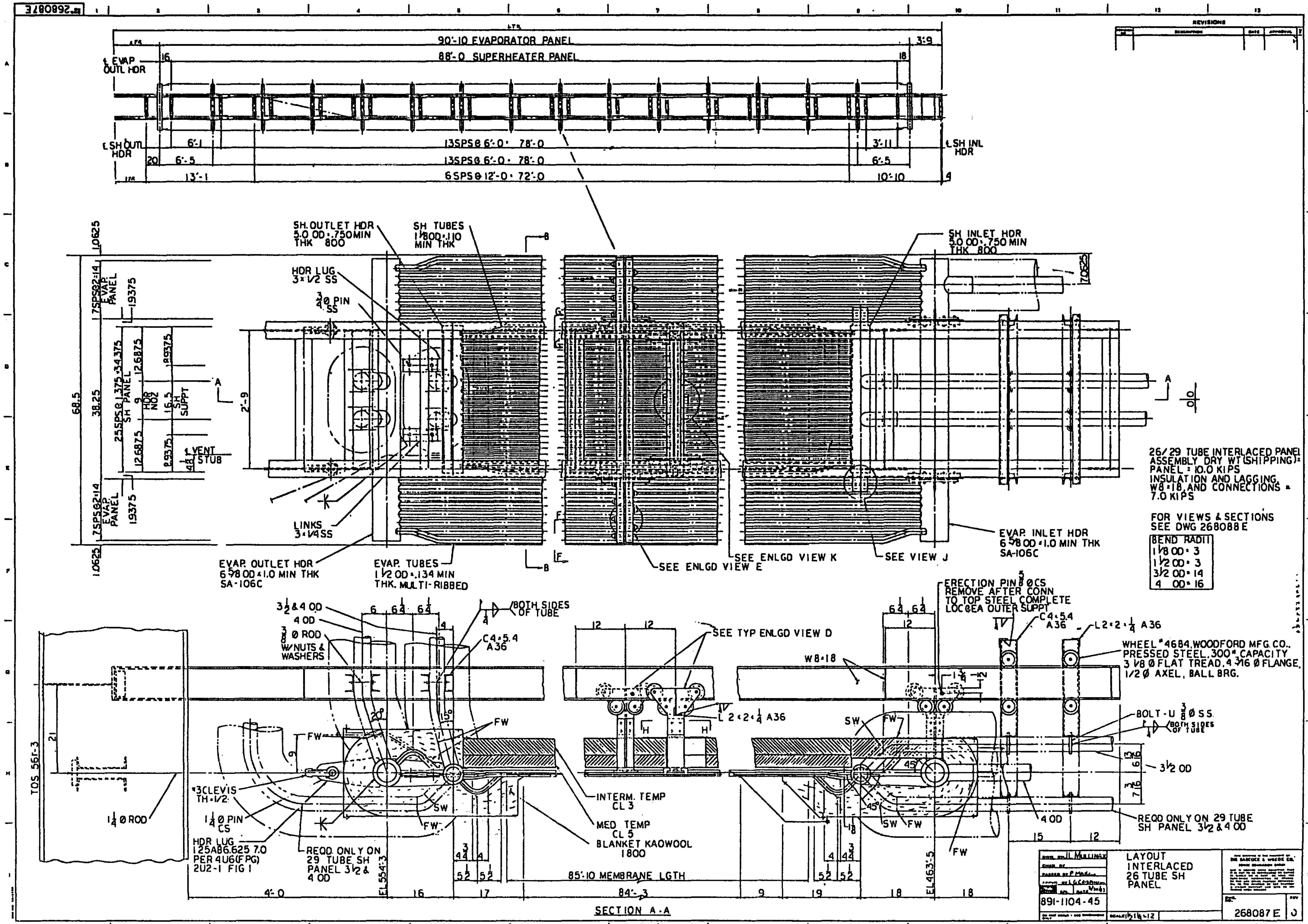
PLAN SECTION C-C
(C-6) DWG 5334J



PLAN SECTION A-A
(C-11) DWG 5334J

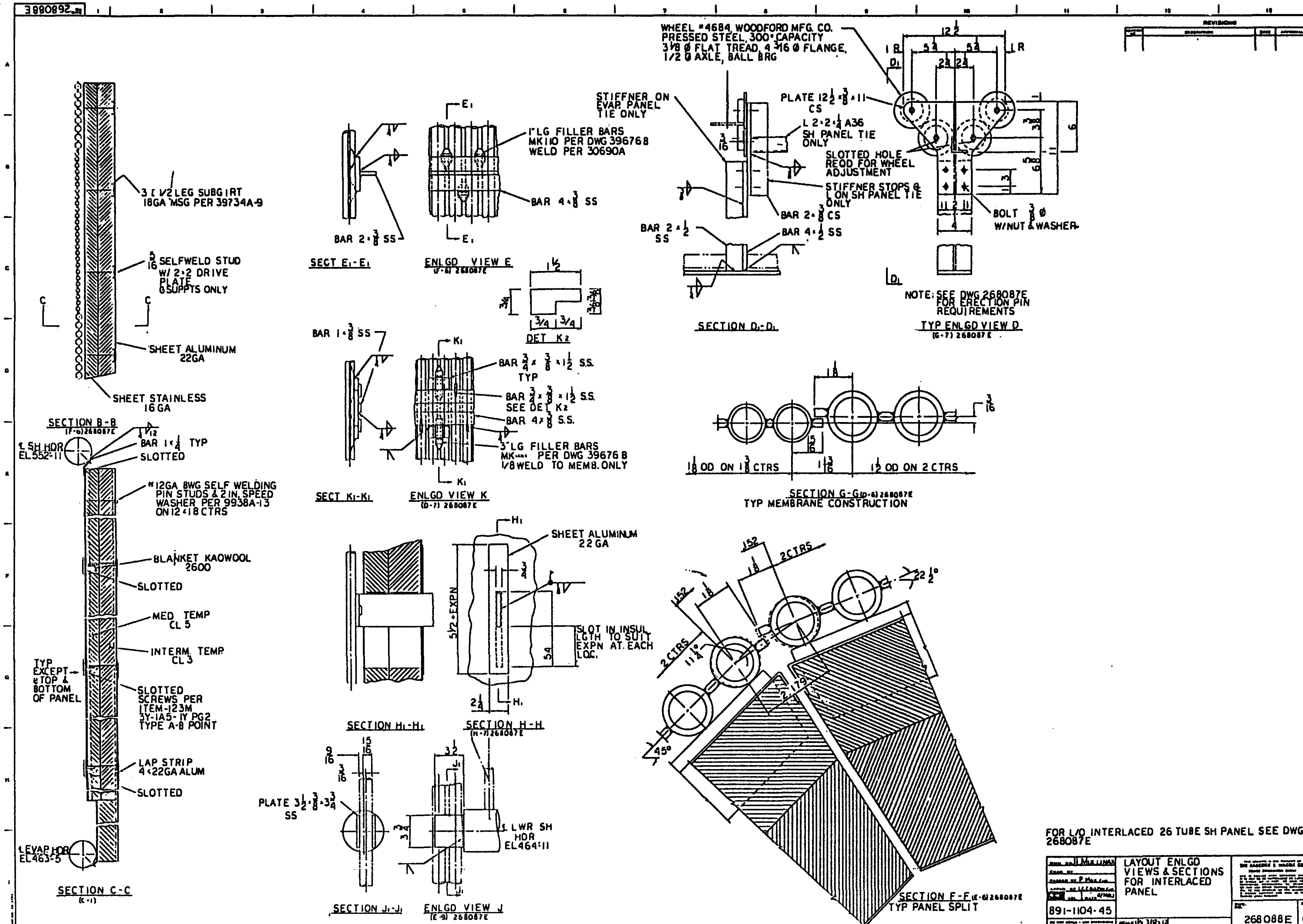
FOR ARRGT SOLAR RECEIVER SECTIONAL SIDE VIEW SEE DWG 5334J
FOR L/O RISER TUBES SEE DWG 5336J

DRN. BY J.L. Mullinax CHKD. BY PASSED BY P Max APPVD. BY DATE 891-1104-45	ARRGT SOLAR RECEIVER PLAN SECTIONS A-A & C-C SCALE 1/4 = 12	THE BABCOCK & WILCOX CO. DWG. NO. 268084E REV 0

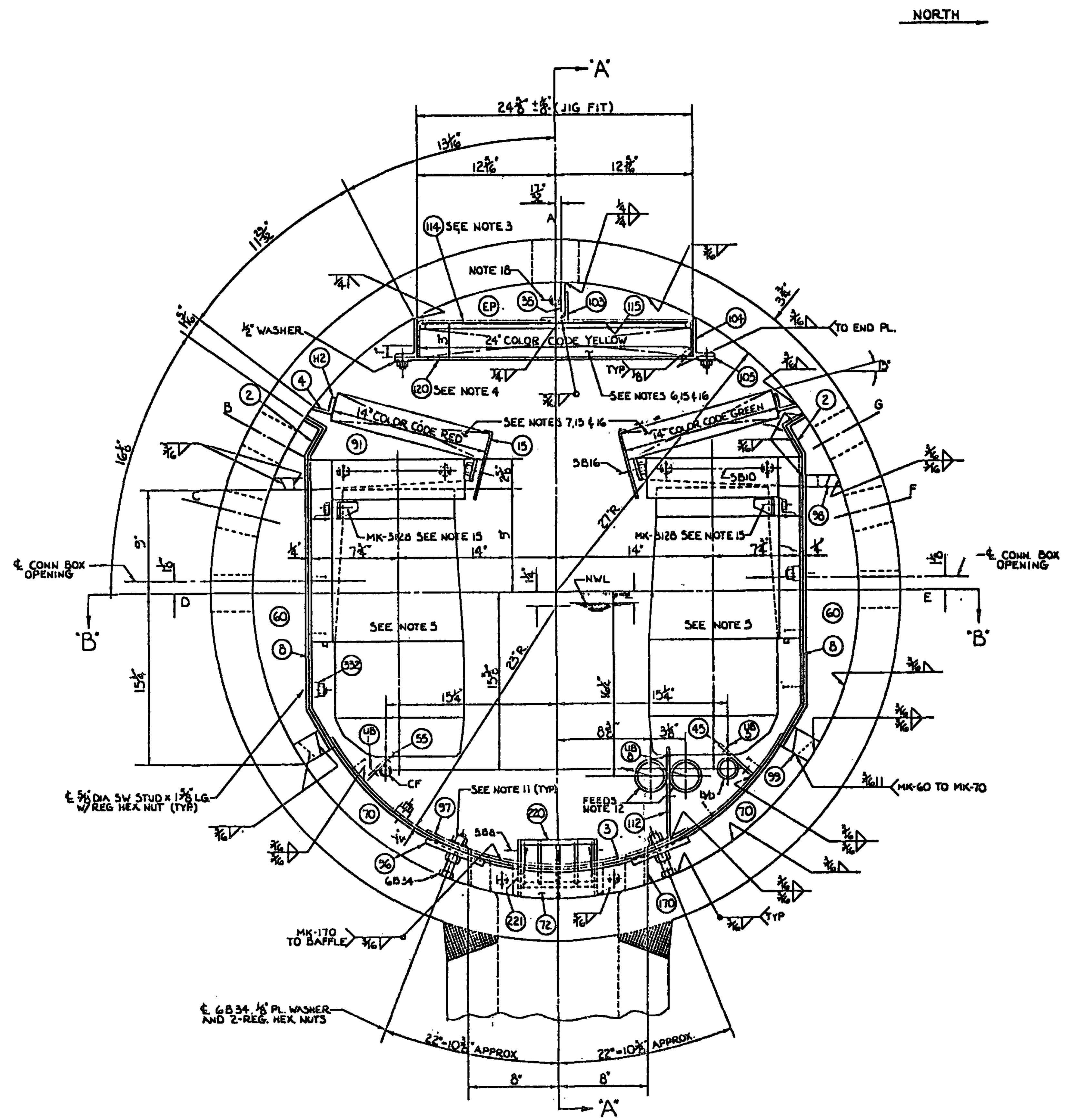


90'-10 EVAPORATOR PANEL
88'-0 SUPERHEATER PANEL
℄ EVAP OUTL HDR
℄ SH OUTL HDR
℄ SH INL HDR
13SPS@6'-0 = 78'-0
6SPS@12'-0 = 72'-0
SH. OUTLET HDR 5.0 OD × .750 MIN THK 800
SH TUBES 1 1/8 OD × .110 MIN THK
SH INLET HDR 5.0 OD × .750 MIN THK 800
HDR LUG 3 × 1/2 SS
3/4 Ø PIN SS
LINKS 3 × 1/4 SS
EVAP. OUTLET HDR 6 5/8 OD × 1.0 MIN THK SA-106C
EVAP. TUBES 1 1/2 OD × .134 MIN THK. MULTI-RIBBED
SEE ENLGD VIEW E
SEE ENLGD VIEW K
SEE VIEW J
EVAP. INLET HDR 6 5/8 OD × 1.0 MIN THK SA-106C
26/29 TUBE INTERLACED PANEL ASSEMBLY DRY WT (SHIPPING): PANEL = 10.0 KIPS INSULATION AND LAGGING, W8×18, AND CONNECTIONS = 7.0 KIPS
FOR VIEWS & SECTIONS SEE DWG 268088E
BEND RADII
1 1/8 OD = 3
1 1/2 OD = 3
3 1/2 OD = 14
4 OD = 16
ERECTION PIN 5/8 Ø CS REMOVE AFTER CONN TO TOP STEEL COMPLETE LOC@EA OUTER SUPPT
C4×5.4 A36
L2×2×1/4 A36
WHEEL #4684, WOODFORD MFG. CO., PRESSED STEEL, 300# CAPACITY 3 1/8 Ø FLAT TREAD, 4 3/16 Ø FLANGE, 1/2 Ø AXEL, BALL BRG.
SEE TYP ENLGD VIEW D
W8×18
BOLT-U 3/8 Ø SS.
BOTH SIDES OF TUBE
3 1/2 & 4 OD
4 OD
3/4 Ø ROD W/NUTS & WASHERS
#3 CLEVIS TH = 1/2
1 1/4 Ø PIN CS
HDR LUG 1.25 A86.625 7.0 PER 4U6 (FPG) 2U2-1 FIG 1
REQD ONLY ON 29 TUBE SH PANEL 3 1/2 & 4 OD
1 1/4 Ø ROD
TOS 561'-3
INTERM. TEMP CL 3
MED TEMP CL 5 BLANKET KAOWOOL 1800
REQD ONLY ON 29 TUBE SH PANEL 3 1/2 & 4 OD
85'-10 MEMBRANE LGTH
84'-3
EL 554'-3
EL 463'-5
SECTION A-A
LAYOUT INTERLACED 26 TUBE SH PANEL
891-1104-45
268087E

G.2-7


268088E
3 [1/2 LEG SUBGIRT 18GA MSG PER 39734A-9
5/16 SELFWELD STUD W/ 2×2 DRIVE PLATE @SUPPTS ONLY
SHEET ALUMINUM 22GA
SHEET STAINLESS 16 GA
SECTION B-B (F-6) 268087E
℄ SH HDR EL552'-11
BAR 1×1/4 TYP
SLOTTED
#12GA BWG SELF WELDING PIN STUDS & 2 IN. SPEED WASHER PER 9938A-13 ON 12×18 CTRS
BLANKET KAOWOOL 2600
SLOTTED
MED TEMP CL 5
INTERM TEMP CL 3
TYP EXCEPT ℄ TOP & BOTTOM OF PANEL
SLOTTED SCREWS PER ITEM-123M 3Y-1A5-1Y PG2 TYPE A-B POINT
LAP STRIP 4×22GA ALUM
SLOTTED
℄ EVAP HDR EL463'-5
SECTION C-C (C-1)
BAR 2×3/8 SS
SECT E1-E1
1" LG FILLER BARS MK110 PER DWG 396768 WELD PER 30690A
BAR 4×3/8 SS
ENLGD VIEW E (F-6) 268087E
DET K2
BAR 1×3/8 SS
BAR 3/4×3/8×1 1/2 S.S. TYP
BAR 3/4×3/8×1 1/2 S.S. SEE DET K2
BAR 4×3/8 S.S.
3" LG FILLER BARS MK PER DWG 396768 1/8 WELD TO MEMB. ONLY
SECT K1-K1
ENLGD VIEW K (D-7) 268087E
SHEET ALUMINUM 22 GA
5 1/2 + EXPN
SLOT IN INSUL LGTH TO SUIT EXPN AT EACH LOC.
SECTION H1-H1
SECTION H-H (H-7) 268087E
PLATE 3 1/2×3/8×3 3/4 SS
LWR SH HDR EL464'-11
SECTION J1-J1
ENLGD VIEW J (E-9) 268087E
WHEEL #4684 WOODFORD MFG. CO. PRESSED STEEL, 300# CAPACITY 3 1/8 Ø FLAT TREAD, 4 3/16 Ø FLANGE, 1/2 Ø AXLE, BALL BRG
STIFFNER ON EVAP PANEL TIE ONLY
PLATE 12 1/2×3/8×11 CS
L 2×2×1/4 A36 SH PANEL TIE ONLY
SLOTTED HOLE REQD FOR WHEEL ADJUSTMENT
STIFFNER STOPS & L ON SH PANEL TIE ONLY
BAR 2×3/8 CS
BAR 2×1/2 SS
BAR 4×1/2 SS
BOLT 3/8 Ø W/NUT & WASHER
SECTION D1-D1
NOTE: SEE DWG 268087E FOR ERECTION PIN REQUIREMENTS
TYP ENLGD VIEW D (G-7) 268087E
1 3/8 OD ON 1 3/4 CTRS
1 1/2 OD ON 2 CTRS
SECTION G-G (D-6) 268087E TYP MEMBRANE CONSTRUCTION
2 CTRS
SECTION F-F (E-6) 268087E TYP PANEL SPLIT
FOR L/O INTERLACED 26 TUBE SH PANEL SEE DWG 268087E
LAYOUT ENLGD VIEWS & SECTIONS FOR INTERLACED PANEL
891-1104-45
268088E
0

3060992

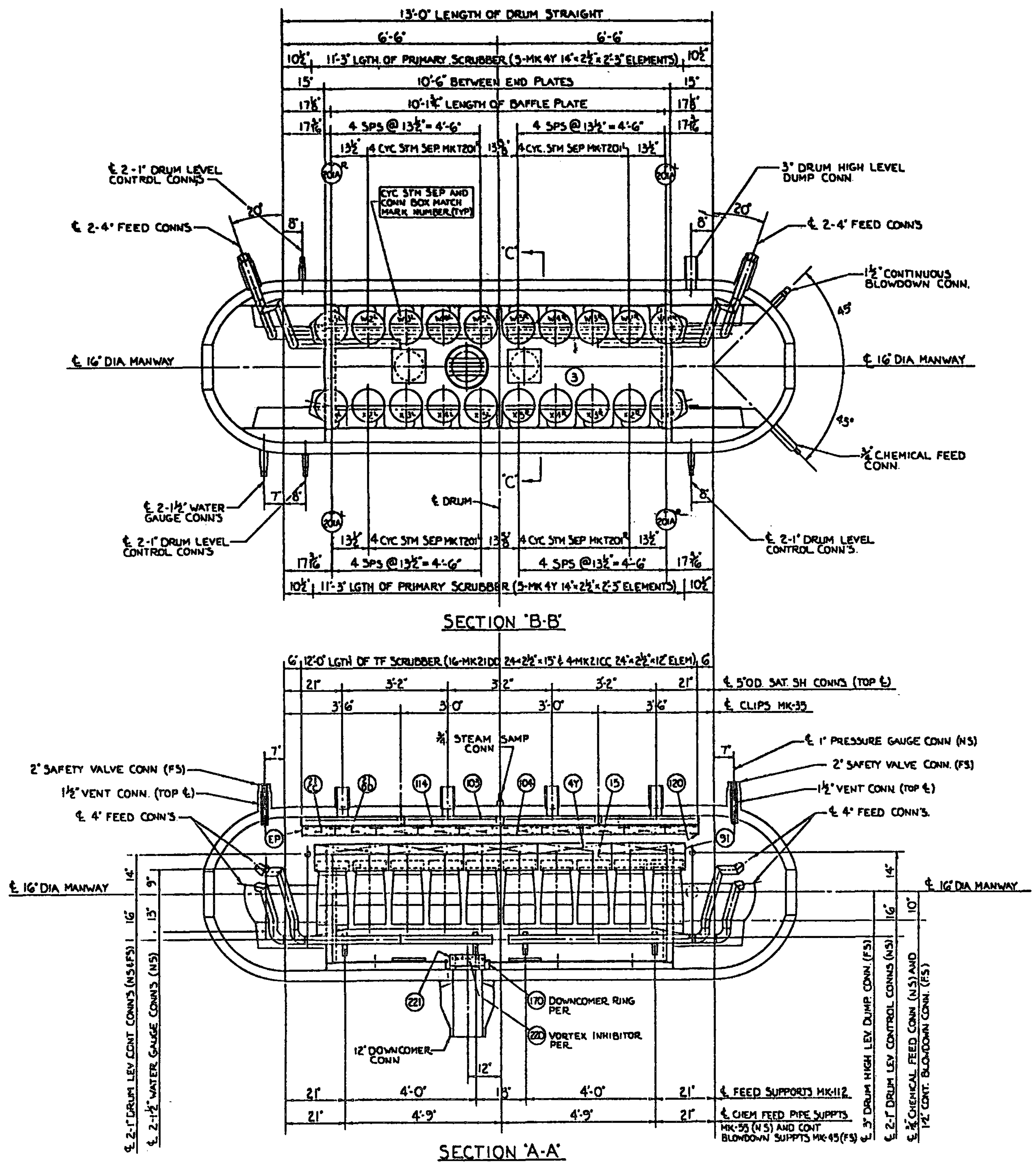


SECTION 'C-C'

NOTES-

1. FOR SECTIONS A-A & B-B SEE. DWG. 268091E.
2. FOR S/O PAGES 20 THRU *later*
3. TF DRY PAN PERFORATED WITH *later* - 1/4" DIA HOLES TOTAL 1/8" SEAL WELD TO END PLATES.
4. SEAL BAR 1/2" x 1/4" x 24 3/8" WELD TO END PLATES AFTER ELEMENTS ARE TIGHT IN PLACE.
5. 11 1/2" I.D. CYCLONE SEPARATOR WITH PERFORATED CONE SEE 109301C FOR ASSEMBLY. SEE SECT. B-B FOR MK NOS.
6. TF SCRUBBER ELEMENTS PER 125451D 24" x 2 1/2"
7. PRIMARY SCRUBBER ELEMENTS PER 79365D 14" x 2 1/2"
8. FOR TF SCRUBBER ASSY. SEE *later*
9. FOR MODULAR BAFFLE PLATE ASSY. SEE *later*
10. FOR SCRUBBER SHELF ASSY. SEE *later*
11. 1/8" x 1/8" SPOT WELD NUT TO BOLT AFTER FINAL FIT-UP
12. FOR FEED ASSY SEE *later*
13. FOR CONT. BLOWDOWN ASSY. SEE *later*
14. FOR CHEMICAL FEED ASSY SEE *later*
15. COLOR CODE TF AND PRIMARY SCRUBBER ELEMENTS AS INDICATED AFTER ELEMENTS ARE LAID OUT TO SUIT SCRUBBER LENGTH.
16. DRUM TO BE STRESS RELIEVED BEFORE TF AND PRIMARY SCRUBBER ELEMENTS ARE INSTALLED.
17. USE MK-3128 WITH 1/2" EXTERNAL TOOTH LOCK WASHER FOR EACH CYCLONE. MK-3128 IS A 1/2" DIA x 2" BOLT HEX. WITH SPECIAL FULL DOG POINT PER 154856A.
18. 3/4" STEAM SAMPLER WITH 1-1/8" DIA HOLE (ON BOTTOM ℄) UNDER S.H CONN'S. SEE DWG. *later* FOR ASSY. & DETAIL.

DRN. BY R. McENTEE	ARRGT. OF MODULAR INTERNALS 54" I.D. DRUM	268090E
891-1104-45		REV. 0



NOTES:-

1. FOR SECTION 'C-C' SEE DWG 268050E.
2. FOR S/O SEE PAGES 20 THRU *later*
3. MATCH MARK CYCLONE STEAM SEPARATORS AND CONN. BOXES AS INDICATED
4. FOR ASSEMBLY AND FITTING OF TF SCRUBBER SEE DWG *later*
5. FOR ASSEMBLY AND FITTING OF MODULAR BAFFLE PLATES SEE DWG *later*
6. 4-2½" FEED PIPES WITH 18-⅜" DIA HOLES EACH PIPE. FOR ASSEMBLY SEE DWG. *later* WELD SUPPORTS MK-112 AS INDICATED TO BAFFLE PLATE
7. 1½" CONT. BLOWDOWN PIPE WITH 16-¼" DIA HOLES ON TOP ℄ AND 1-¼" DIA HOLE ON BOTTOM ℄ SEE DWG *later* WELD SUPPORTS MK-45 AS INDICATED TO BAFFLE PLATE.
8. ¾" CHEMICAL FEED PIPE WITH 4-⅛" DIA HOLES ON TOP ℄ AND 1-⅛" DIA HOLE ON BOTTOM ℄ SEE DWG *later* WELD SUPPORTS MK-55 AS INDICATED TO BAFFLE PLATE
9. INTERNALS TO BE INSTALLED AND SHIPPED COMPLETE IN DRUM
10. ESTIMATED WEIGHT OF DRUM (DRY) = 48,000 #
(FULL OF WATER) = 63,850 #
(NORMAL WATER LEVEL) = 55,540 #

REVISIONS

DWN. BY R. MENTCE

CHKD. BY

PASSED BY

891-1104-45

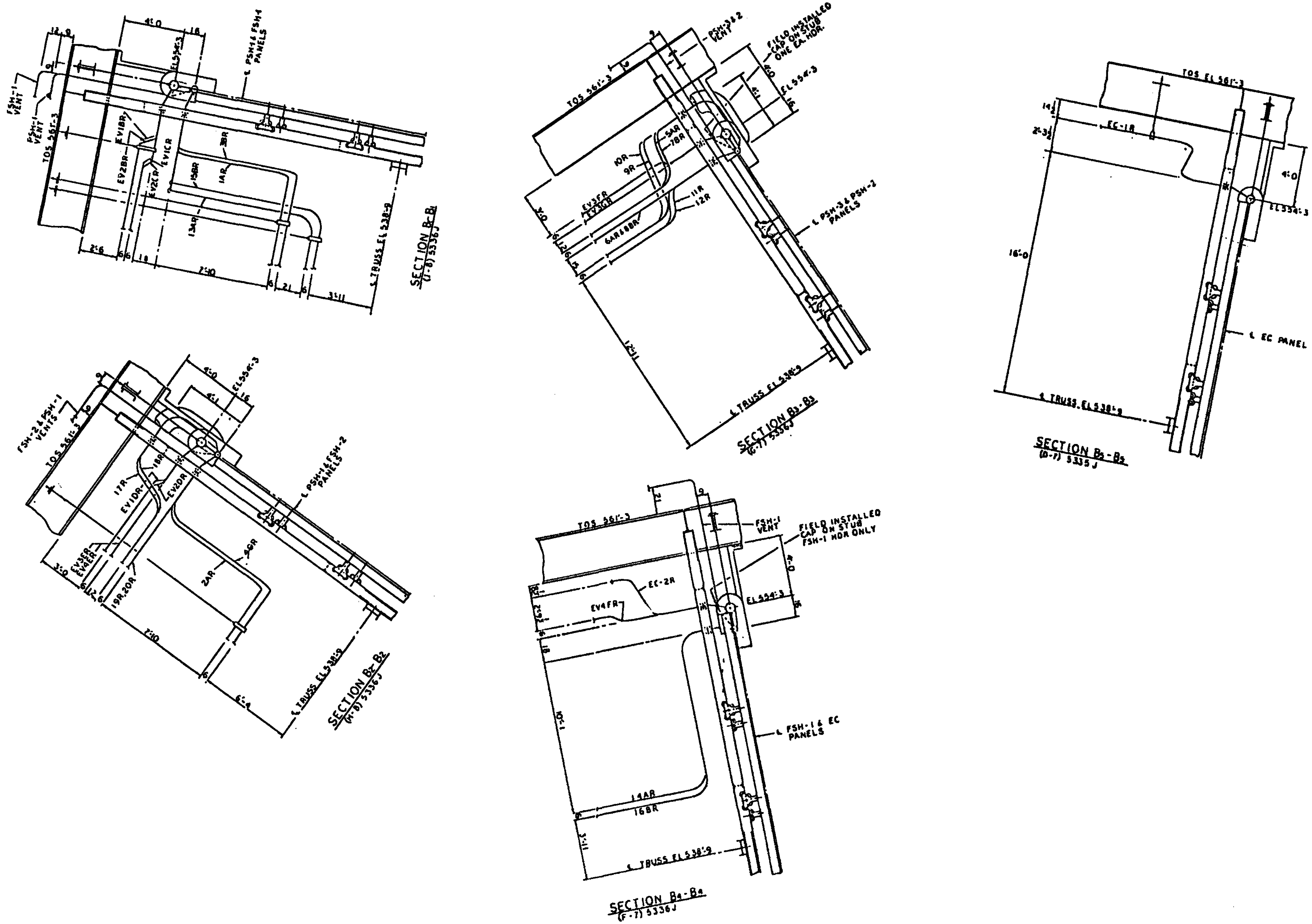
ARRGT. OF MODULAR INTERNALS 54" I.D. DRUM

THE BABCOCK & WILCOX CO.

DWG. NO. 268091E

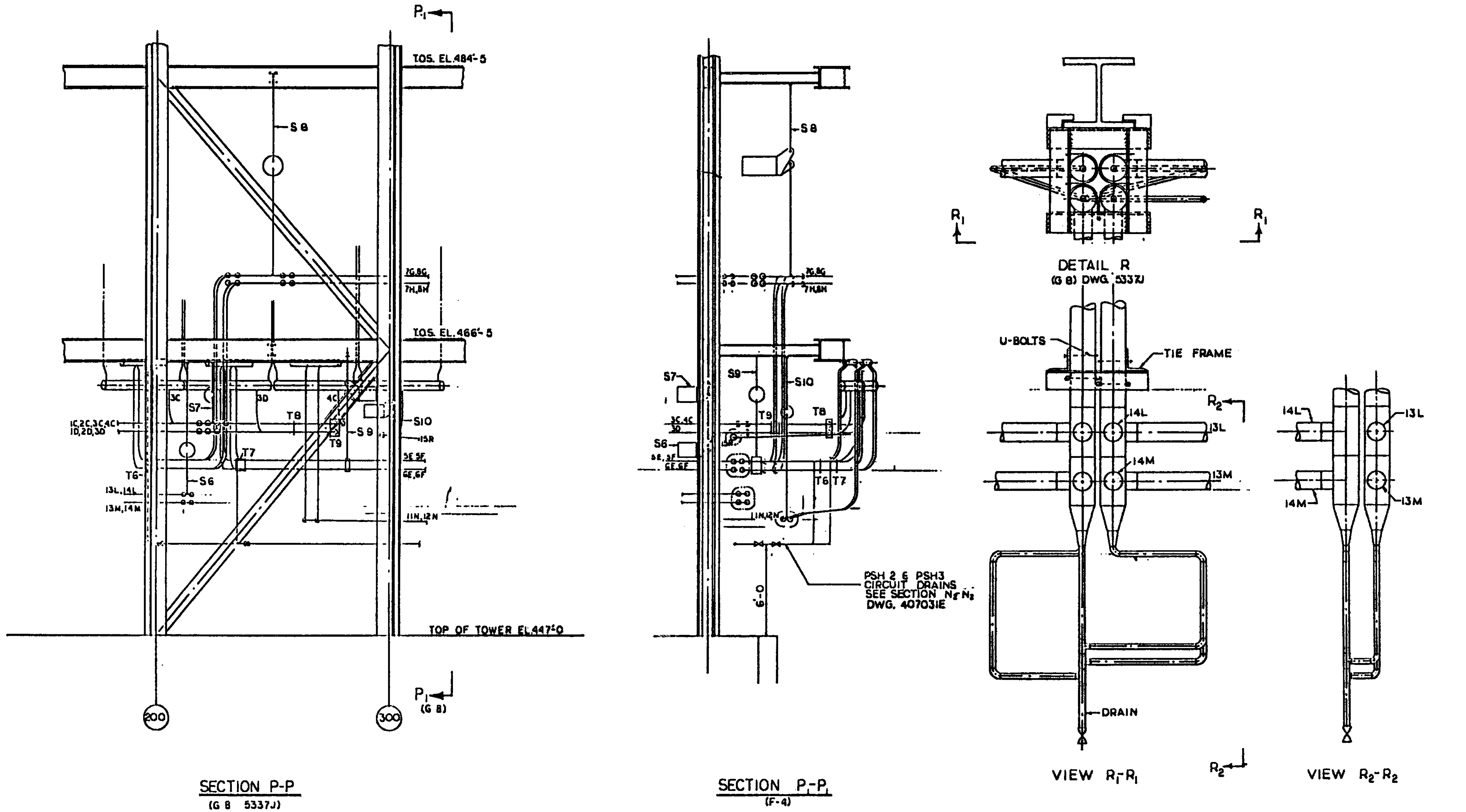
REV 0

3960892



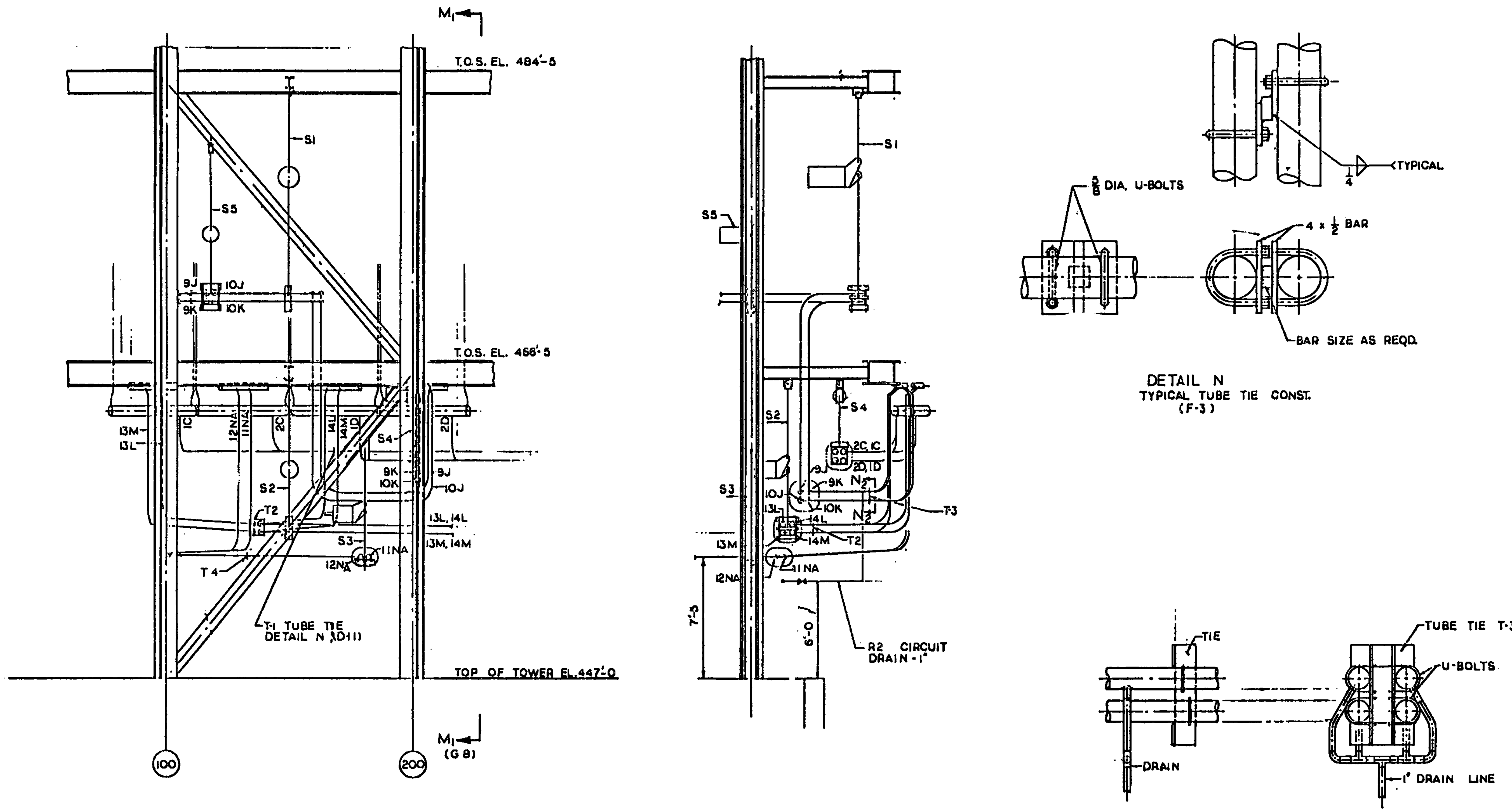
FOR L/O RISER TUBES SEE DWG 5336J

DWN. BY	J L MULLINAX
Title	L/O RISER TUBES SOLAR RECEIVER SECTIONS B1, B2, B3, B4 & B5
	891-1104-45
SCALE	1/2" = 1'-0"
DWG. NO.	268096E
REV	0



1. FOR MAIN ARRG'T. SUPPLY TUBES SEE DWG. 5337J.
2. FOR SECTIONAL SIDE VIEW SEE DWG. 5334J.
3. ALL SUPPORTS INDICATED (S6 THRU S10) ARE CONSTANT SPRING HANGERS.

DWN. BY KIDALOSKI	ARRG'T. SOLAR RECEIVER SECTIONS & VIEWS
891-1104-45	SCALE 1/2"=1'-0"
DWG. NO. 268097E	REV 0



SECTION M-M
(G-10 5337J)

SECTION M_1-M_1
(F 4)

DETAIL N
TYPICAL TUBE TIE CONST.
(F-3)

SECTION N_2-N_2
(E 8)

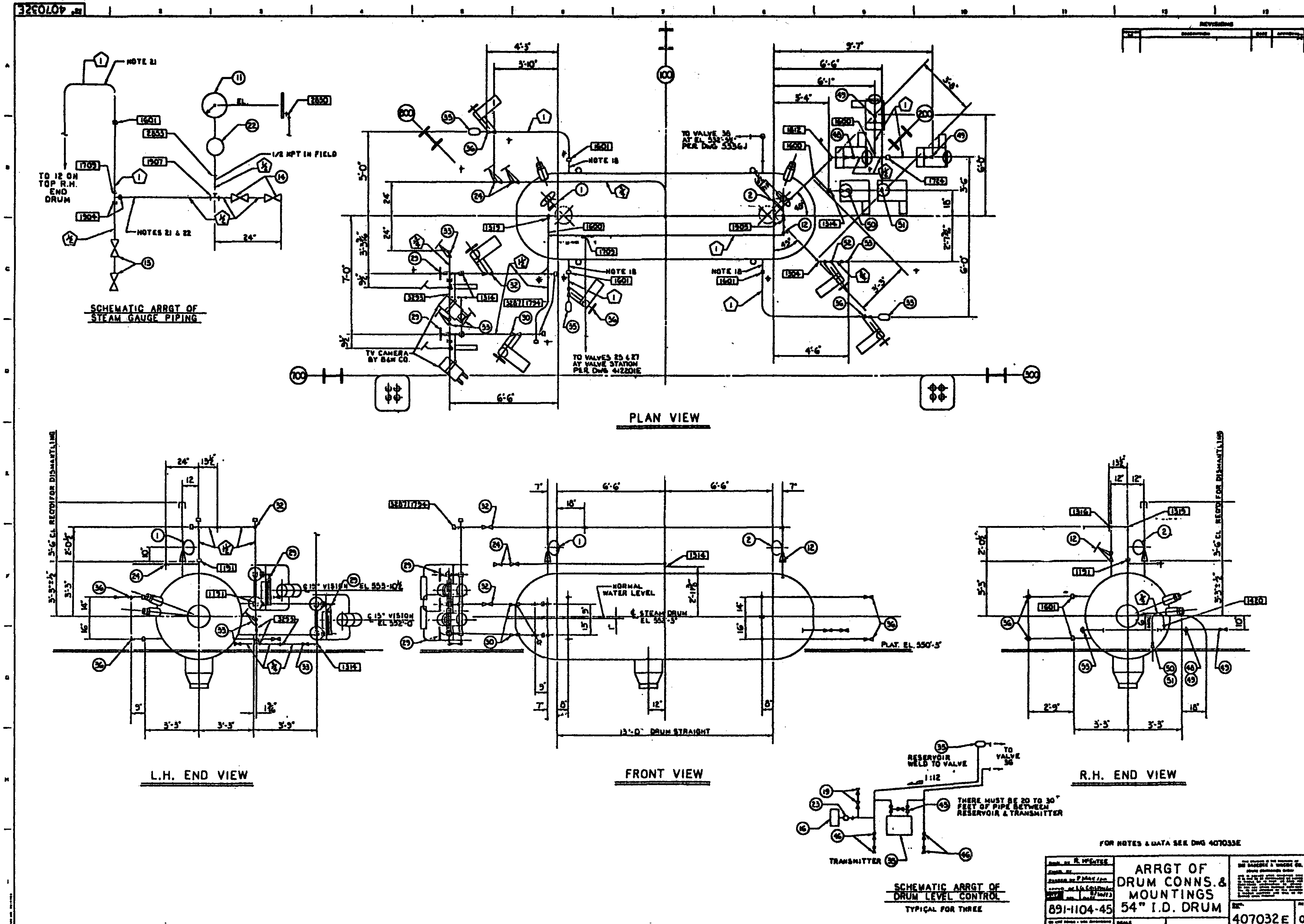
NOTES:

1. FOR MAIN ARRGT. SUPPLY TUBES SEE DWG. 5337J.
2. FOR SECTIONAL SIDE VIEW SEE DWG. 5334J.
3. ALL SUPPORTS INDICATED (S1 THRU S5) ARE CONSTANT SPRING HANGERS.

ARRGT SOLAR RECEIVER SECTIONS & VIEWS

891-1104-45

407031E 0



SCHEMATIC ARRGT OF STEAM GAUGE PIPING
TO 12 ON TOP R.H. END DRUM
NOTES 21 & 22
1/2 NPT IN FIELD
PLAN VIEW
TV CAMERA BY B&W CO.
TO VALVES 25 & 27 AT VALVE STATION PER DWG 412201E
TO VALVE 36 AT EL 558'-5½" PER DWG 5336J
L.H. END VIEW
FRONT VIEW
R.H. END VIEW
NORMAL WATER LEVEL
℄ STEAM DRUM EL 552'-3"
PLAT. EL. 550'-5"
13'-0" DRUM STRAIGHT
3'-6" CL. REQ'D FOR DISMANTLING
SCHEMATIC ARRGT OF DRUM LEVEL CONTROL
TYPICAL FOR THREE
RESERVOIR WELD TO VALVE
TO VALVE 36
THERE MUST BE 20 TO 30 FEET OF PIPE BETWEEN RESERVOIR & TRANSMITTER
TRANSMITTER
FOR NOTES & DATA SEE DWG 407033E
ARRGT OF DRUM CONNS. & MOUNTINGS 54" I.D. DRUM
891-1104-45
407032E
0

G.2-14

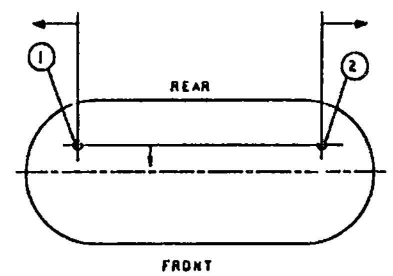
VALVE & MOUNTING INFORMATION

ITEM	DESCRIPTION	SUPPLY B&W	SUPPLY OTHER	QTY/ BLR	SIZE	MAKE	TYPE	MARK NO.	CUST. NO.	REMARKS
1	SAFETY VALVE	X		1	2"	DRESSER	1729WB	BW-SV-01		SET PRESS. PSI
2	" "	X		1	2"	DRESSER	1729WB	BW-SV-02		SET PRESS. PSI
3										
4										
5										
6										
7										
8										
9										
10										
11	STEAM GAUGE	X		1	12"	ASHCROFT	1010D			RANGE 0-5000 PSI
12	STM GAUGE S.O. VLV.	X		1	1"	ROCKWELL	36124	BW-P-05		W/LOCK-OPEN
13										
14	STM GAUGE TEST VLV.	X		2	1/2"	ROCKWELL	36124	BW-P-37		
15	STM GAUGE DRAIN VLV.	X		2	1/2"	ROCKWELL	36124	BW-D-110		2ND VLV AT OPER FLOOR SEE NOTE 10.
16	PRESS. TRANS.		X	3						
17										
18										
19	PRESS. TRANS. TEST VLV.	X		6	1"	ROCKWELL	36124	BW-P-40		
20										
21										
22	SYPHON	X		1	1/2"	ASHCROFT	1098CD			W/ ITEM 11
23	SYPHON		X	3	1/2"	"	"			W/ ITEM 16
24	STM SAMPLING VLV.	X		2	3/4"	ROCKWELL	36124	BW-S-06		
25	VENT VLV.	X		2	1"	ROCKWELL	36124	BW-V-09		MOTORIZED OPERATOR
26										
27	NITROGEN VLV.	X		1	1"	ROCKWELL	36124	BW-N-01		MOTORIZED OPERATOR
28										
29	WATER GAUGE	X		2	15"	DIAMOND	DP3000			W/ TV VIEWING EQUIPT
30	WATER GAUGE (NORM) VLV.	X		2	1 1/2"	ROCKWELL	3624	BW-L-01		MOTORIZED OPERATOR
31										
32	WATER GAUGE (HIGH) VLV.	X		2	1 1/2"	ROCKWELL	3624	BW-L-17		MOTORIZED OPERATOR
33	WATER GAUGE DRAIN VLV.	X		5	3/4"	ROCKWELL	36124	BW-D-112		
34										
35	DRUM LEVEL CONTROL		X	3		BAILEY				
36	DRUM LEVEL CONTROL VLV.	X		6	1"	ROCKWELL	3624	BW-L-09		MOTORIZED OPERATOR
37										
38	DRUM DUMP VLV.	X		2	3"					MOTORIZED OPERATOR
39										
40										
41										
42										
43										
44										
45	TRANSMITTER INSTRU. VLV.		X	3	1/2"			BW-L-05		3-VALVE MANIFOLDS W/ ITEM 35
46	TRANSMITTER DRAIN VLV.		X	12	1/2"			BW-D-115		
47										
48	CONT. BLOWDOWN VLV.	X		1	1 1/2"	ROCKWELL	36124	BW-M-04		MOTORIZED OPERATOR
49	CONT. BLOWDOWN S.O. VLV.	X		2	1"	ROCKWELL	36124	BW-M-05		" "
50	WATER SAMPLING VLV.	X		1	3/4"	ROCKWELL	36124	BW-S-04		" "
51	WATER SAMPLING VLV.	X		1	3/4"	ROCKWELL	36124	BW-S-05		" "
52	CHEMICAL FEED VLV.	X		1	3/4"	ROCKWELL	36124	BW-M-01		" "
53	CHEMICAL FEED VLV. S.O.	X		1	3/4"	ROCKWELL	36124	BW-M-02		

PIPE FITTINGS

MK NO	QTY/ BLR	DESCRIPTION
1191	3	CPLG S/W 1 1/2 6000# SA105
1304	1	ELB S/W 45D 3/4 6000# SA105
1316	1	ELB S/W 90D 1 IN. 6000# SA105
1420	1	INSR S/W 1 IN. X 3/4 6000# SA105
1600	3	TEE S/W 1 1/2 X 1 1/2 X 1 6000# SA105
1601	4	CPLG S/W 1 IN. 6000# SA105
1709	2	TEE S/W 1 IN. 6000# SA105
1794	7	CAP S/W 1 1/2 6000# SA105
1812	1	ELB S/W 45D 1 1/2 6000# SA105
1905	1	INSR S/W 1 1/2 X 1 IN. 6000# SA105
1904	2	INSR S/W 1 IN. X 1/2 6000# SA105
2850	1	ELB SCRD 90D 1/2 6000# SA105
2853	1	UNION SCRD 1/2 6000# SA105
3287	4	CROSS S/W 1 1/2 6000# SA105
3293	3	TEE S/W 3/4 6000# SA105
1314	6	ELB S/W 90D 3/4 6000# SA105
1319	2	ELB S/W 90D 1 1/2 6000# SA105
1724	1	CPLG S/W 1 1/2 X 1 IN. 6000# SA105
1907	1	TEE S/W 1/2 6000# SA105

REVISIONS



PLAN VIEW

SAFETY VALVE MOTIONS

SUPPORT INFORMATION (SEE NOTE 20)

MK NO	LOAD TO STL	ARRGT DWG	SPRT STL ELEV	ROD MK NO	REMARKS
S1					
S2					
S3					
S4					
S5					
S6					
S7					
S8					
S9					

24. WATER GAUGE CHAINS TO BE OPERATED FROM PLATFORM EL.
23.
22. ERECTOR TO PROVIDE FOR EXPANSIONS IN INSTRUMENT LINES.
21. INSTRUMENT LINES CANNOT BE IN DRAIN CHASES.
20. SUPPORT MAT'L VENDOR: GRINNELL CATALOG NO: PH 81
19. FOR FIELD MAT'L SEE S/O
18. NO OTHER CONN. MAY BE TEED INTO THIS LINE.
17. ✦ SUPPORT MOUNTING TO LIMIT LOAD ON THESE CONNS. TO 300# AT THIS POINT.
16. INDICATES DIRECTION OF SLOPE.
15. SAFETY VALVE ALIGNMENT TO BE WITHIN ONE DEGREE OF VERTICAL.
14. ALL VALVES TO BE INSTALLED TO CLOSE AGAINST DRUM PRESSURE.
13. INSULATE INSTRUMENT PIPING:
    WATER GAGE PER 133861A.
    LEVELTRANSMITTER PER 133858A
12. PRESSURE PART FIELD WELD SCHEDULE PER DWG.
11. RING WELD PER 60205C:
    SAFETY VALVES D:2 250 RING MK W1
10. FOR ARRGT:
    DRAINS SEE DWG.
9. ALL WELDS TO BE SOCKET WELDED PER DWG. 44443A EXCEPT AS SHOWN.
8. ALL BENDS TO HAVE MIN. RADIUS OF 5 TIMES DIA.
7. ALL PIPING TO BE SCH. 160, MAT'L SA106B. UNLESS NOTED.
6. ALL VALVES LOCATED IN HORIZ. PIPE RUNS ARE TO BE INSTALLED WITH STEMS IN HORIZ. PLANE.
5. ▭ INDICATES B&W MARK NO.
4. ⬠ INDICATES PIPE SIZE
3. ○ INDICATES ITEM NO.
2. Ⓣ INDICATES B&W TERMINAL.
1. (TA) INDICATES TERMINATION OF MAT'L PROVIDED WITH THIS ARRANGEMENT. FOR CONTINUATION SEE NOTE 10

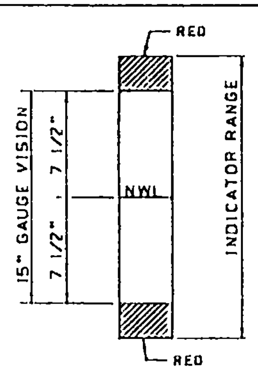


FIG. A

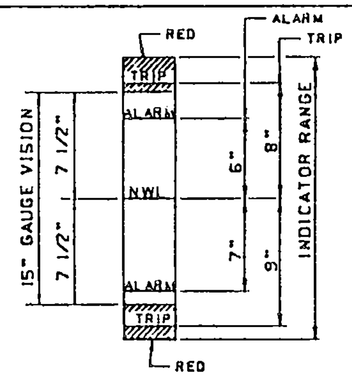
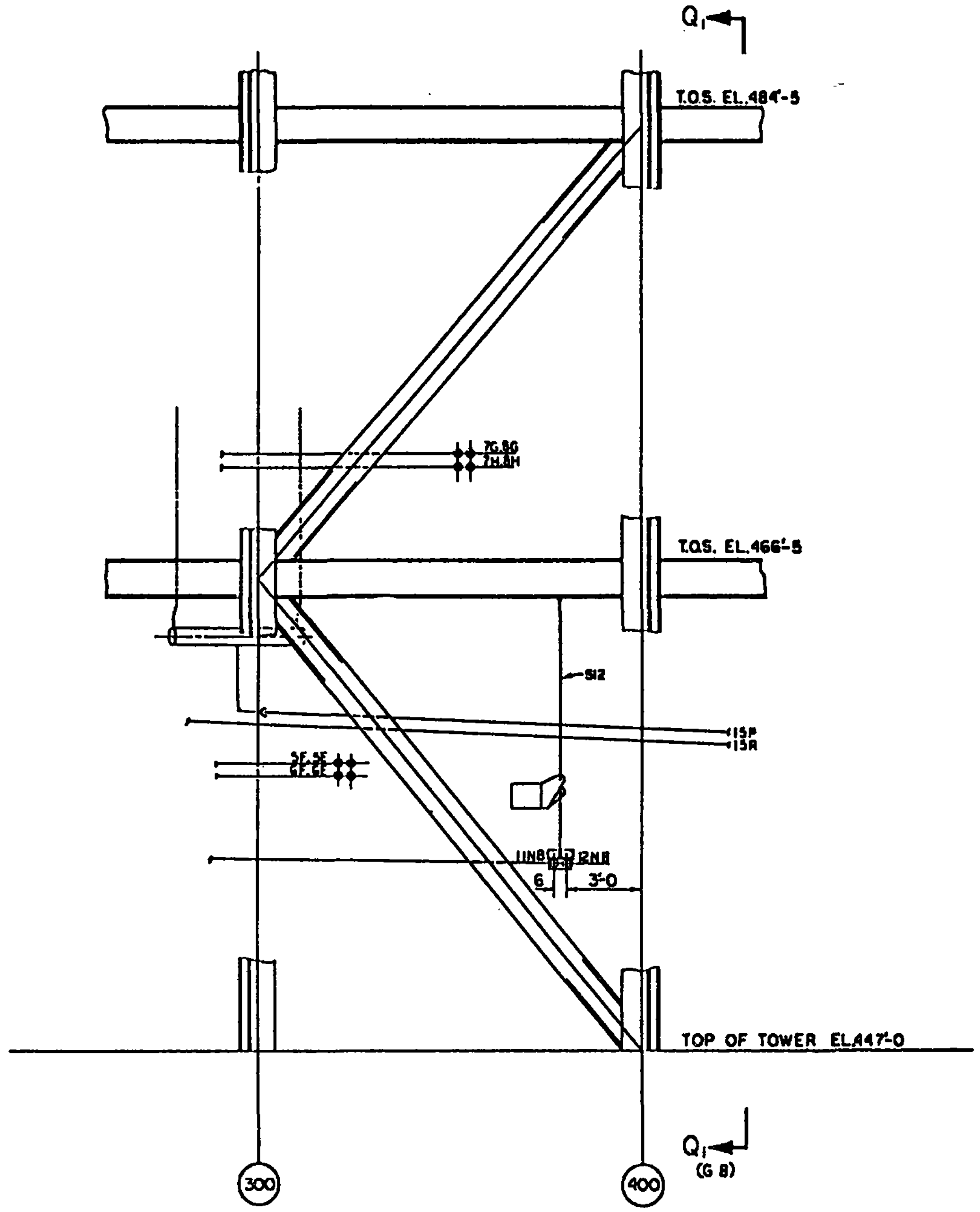


FIG. B

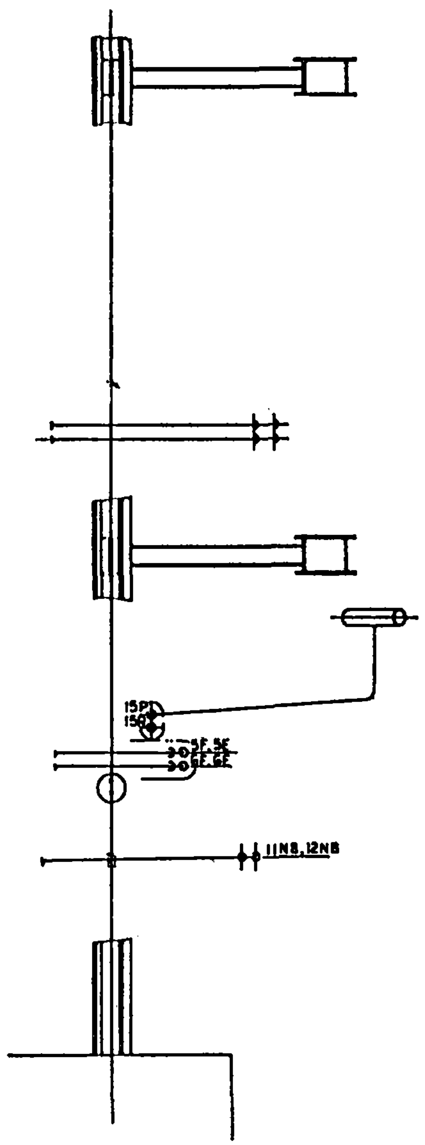
INDICATION NOTES:

1. THE ASME SECTION I CODE PG 60 1.1 REQUIRES THAT THE LOWEST PERMISSIBLE WATER LEVEL BE MARKED WHEN REMOTE LEVEL INDICATORS ARE PROVIDED TO REPLACE WATER GAUGES FOR BOILER OPERATION.
2. THE BABCOCK AND WILCOX COMPANY HAS SET ALARM AND TRIP POINTS FOR BOTH HIGH AND LOW LEVELS FOR SAFE BOILER OPERATION.
3. WHEN THE INDICATOR IS USED FOR INFORMATION AND AS A CHECK OF THE OPERATING INSTRUMENTS, THE INDICATOR DIAL IS TO BE MARKED PER FIGURE A.
   A. THE LETTERS NWL (NORMAL WATER LEVEL) ARE TO BE MARKED ON THE DIAL WITH A LINE TO INDICATE THIS LEVEL.
   B. THE DIAL IS TO BE PAINTED RED BEYOND THE WATER GAUGE VISION.
4. WHEN THE INDICATOR IS USED FOR BOILER OPERATION INCLUDING THE ALARMS AND TRIPS, THE INDICATOR DIAL IS TO BE MARKED PER FIGURE B.
   A. THE WORDS ALARM, TRIP, AND NWL ARE TO BE MARKED ON THE INDICATOR DIAL TO INDICATE THESE LEVELS.
   B. THE DIAL IS TO BE PAINTED RED BEYOND THE WATER GAUGE VISION.
5. THESE DIAL MARKINGS ARE IN ADDITION TO THE STANDARD LINES ON THE DIAL.

DWN. BY R. McENTEE CHKD BY PASSED BY P. MAK /JM APPVD BY LG C.../JM DATE 5/31/83 891-1104-45	DATA AND NOTES FOR ARRGT. OF DRUM CONNS. & MOUNTINGS DWG. 407032E SCALE NONE	THE BABCOCK & WILCOX CO DWG. NO. 407033E	REV 0



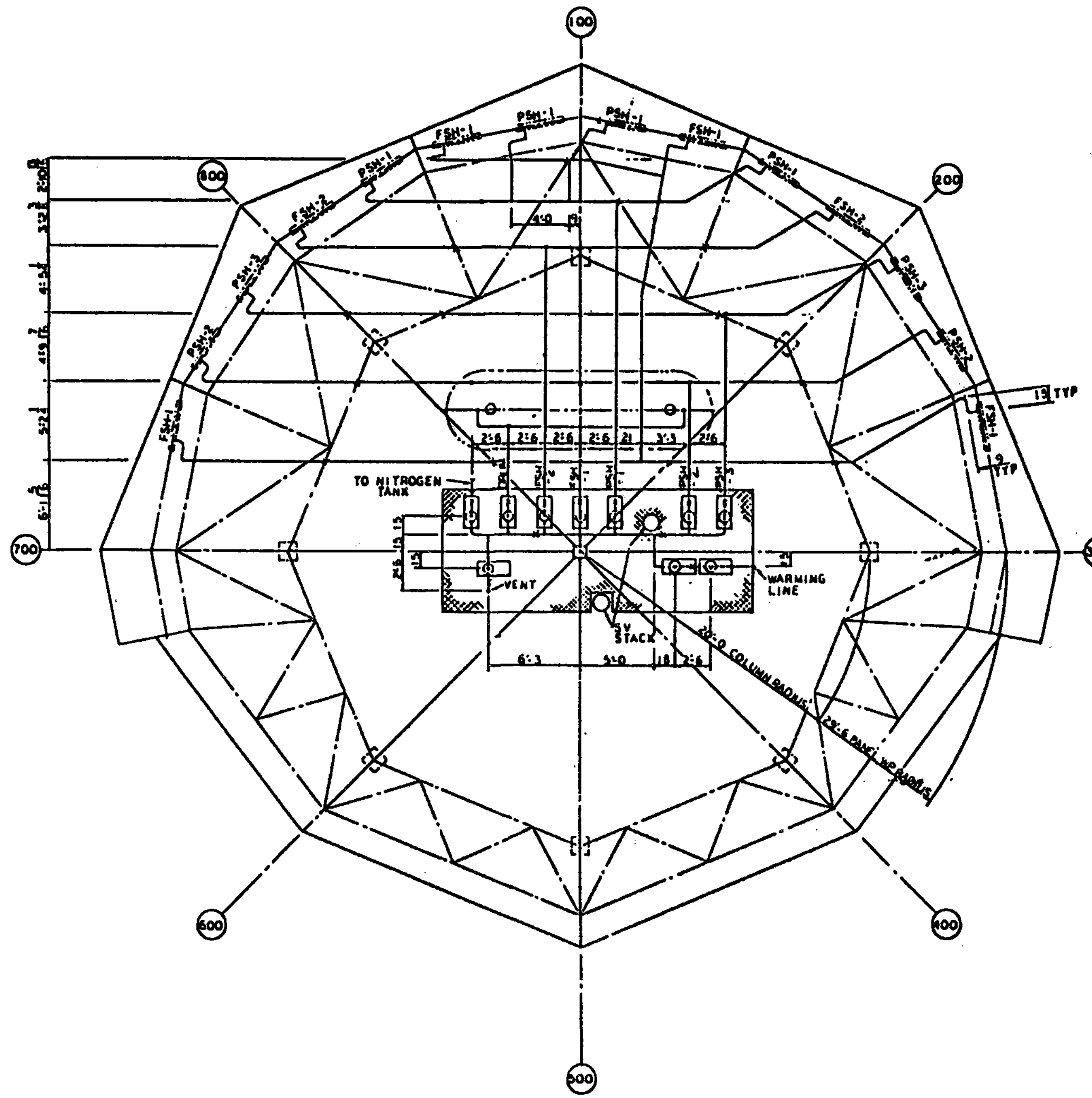
SECTION Q-Q
(G-10 5337J)

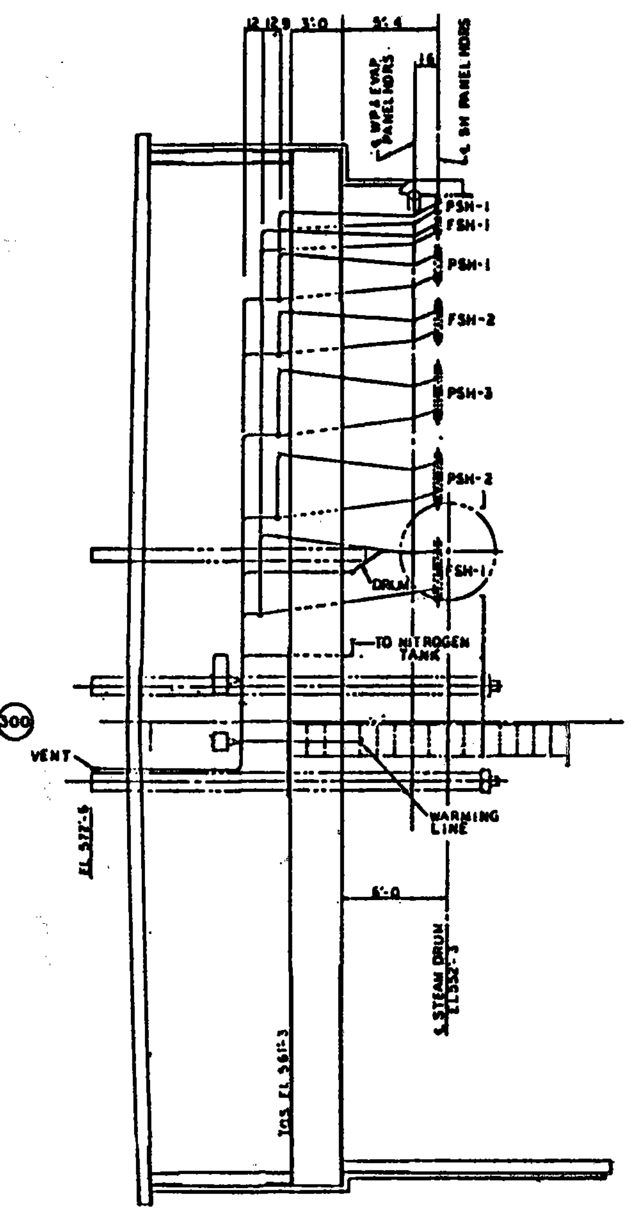


SECTION Q_1-Q_1
G-4

1. FOR MAIN ARRGT. SUPPLY TUBES SEE DWG. 5337J.
2. FOR SECTIONAL SIDE VIEW SEE DWG. 5334J.

DWN. BY WANE GOSS	ARRGT. SOLAR RECEIVER SECTIONS & VIEWS
CHKD. BY KIDALOSKI	
PASSED BY P. MAK	
APPVD. BY L.E. CAIRNS	
891-1104-45	DWG. NO. 412200E REV. 0
	SCALE 3/8 = 12



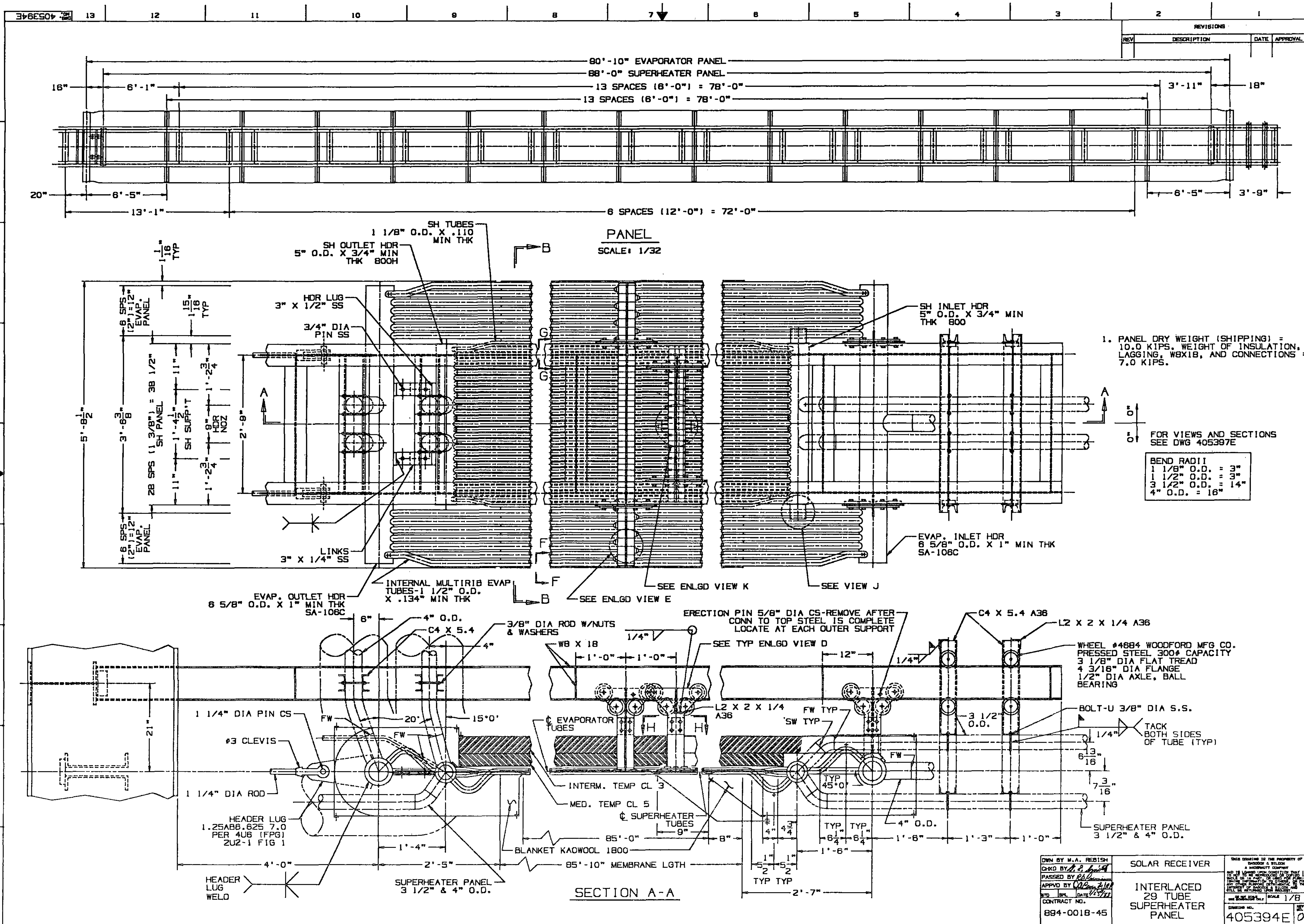


FOR L/O RISER TUBES SEE 5336J
INDICATES HANGER SUPPORT
INDICATES BOTTOM SUPPORT

L/O VALVE STATION
ABOVE TOP STEEL

SCALE 1/4 = 1'

412201 E | 0



1. PANEL DRY WEIGHT (SHIPPING) = 10.0 KIPS. WEIGHT OF INSULATION, LAGGING, W8X18, AND CONNECTIONS = 7.0 KIPS.

FOR VIEWS AND SECTIONS SEE DWG 405397E

BEND RADII	
1 1/8" O.D.	= 3"
1 1/2" O.D.	= 3"
3 1/2" O.D.	= 14"
4" O.D.	= 16"

DWN BY M.A. REBISH
CONTRACT NO. 894-0018-45

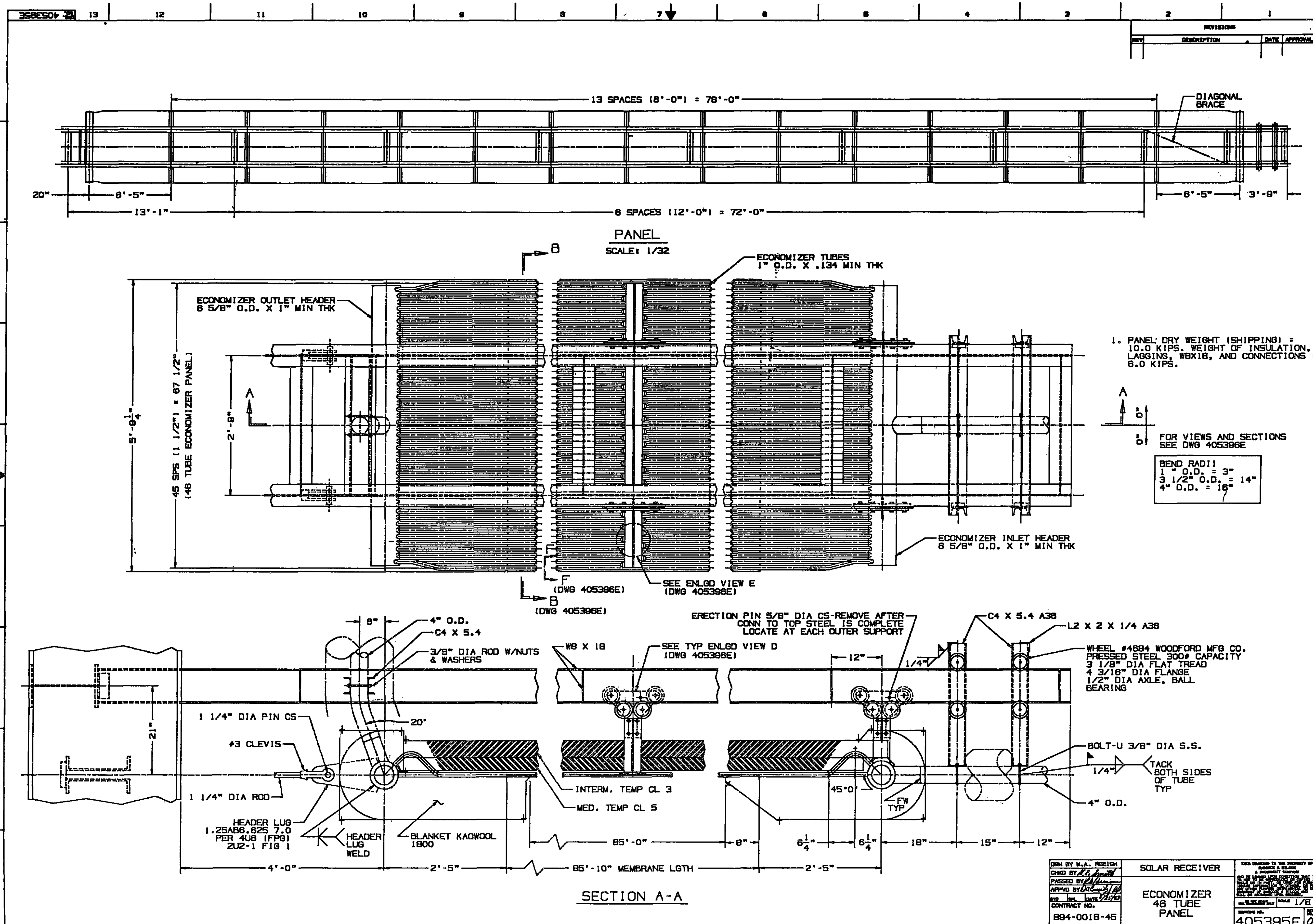
SOLAR RECEIVER

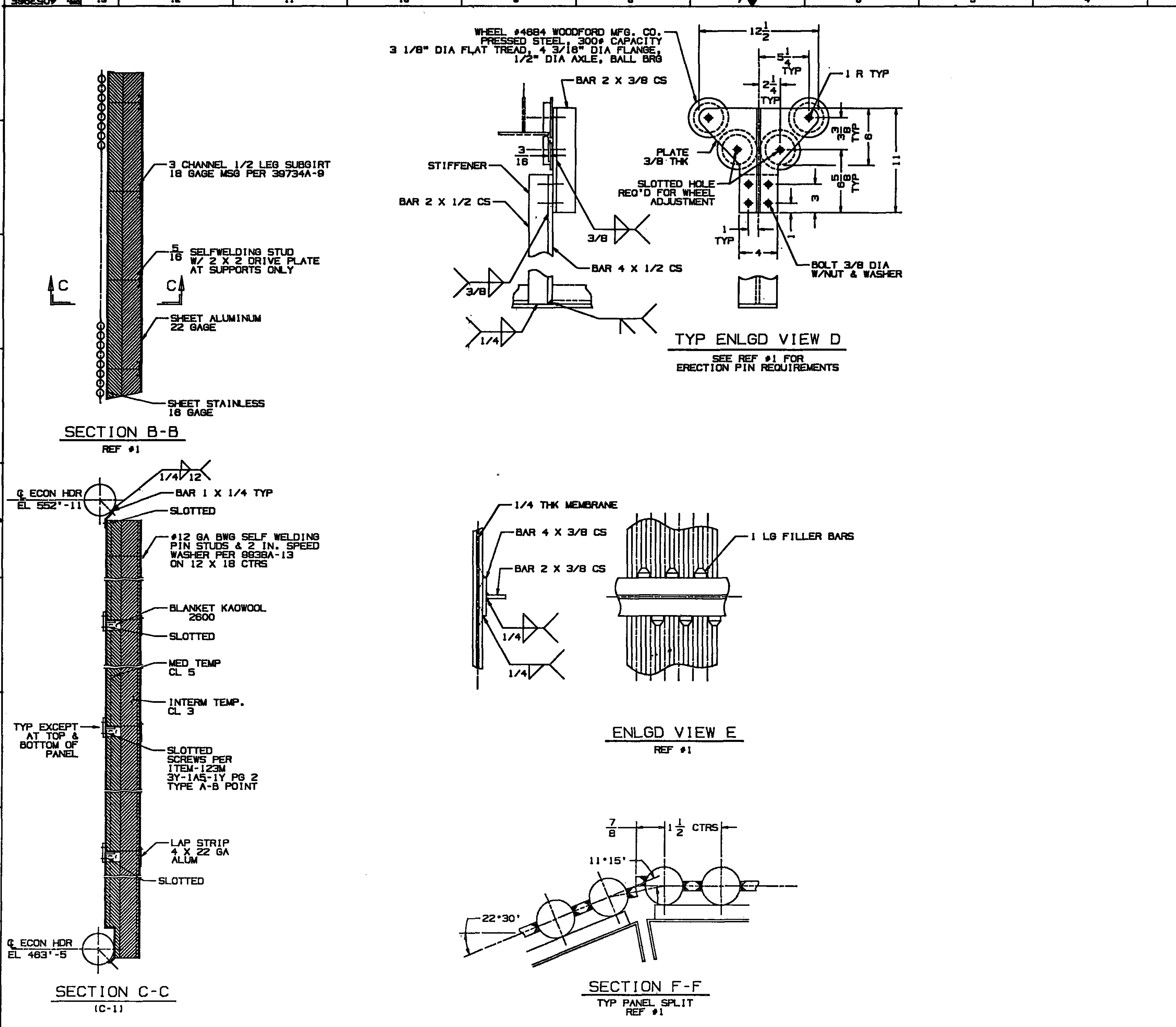
INTERLACED 29 TUBE SUPERHEATER PANEL

SCALE 1/8

405394E 0

G.2-18


REVISIONS
REV DESCRIPTION DATE APPROVAL
13 SPACES (6'-0") = 78'-0"
DIAGONAL BRACE
20"
6'-5"
13'-1"
6 SPACES (12'-0") = 72'-0"
6'-5"
3'-9"
PANEL
SCALE: 1/32
ECONOMIZER TUBES 1" O.D. X .134 MIN THK
ECONOMIZER OUTLET HEADER 6 5/8" O.D. X 1" MIN THK
1. PANEL DRY WEIGHT (SHIPPING) = 10.0 KIPS. WEIGHT OF INSULATION, LAGGING, W8X18, AND CONNECTIONS = 6.0 KIPS.
5'-9 1/4"
45 SPS (1 1/2") = 67 1/2" (46 TUBE ECONOMIZER PANEL)
2'-9"
FOR VIEWS AND SECTIONS SEE DWG 405396E
BEND RADII
1" O.D. = 3"
3 1/2" O.D. = 14"
4" O.D. = 16"
ECONOMIZER INLET HEADER 6 5/8" O.D. X 1" MIN THK
F (DWG 405396E)
SEE ENLGD VIEW E (DWG 405396E)
B (DWG 405396E)
6"
4" O.D.
C4 X 5.4
3/8" DIA ROD W/NUTS & WASHERS
W8 X 18
SEE TYP ENLGD VIEW D (DWG 405396E)
ERECTION PIN 5/8" DIA CS-REMOVE AFTER CONN TO TOP STEEL IS COMPLETE LOCATE AT EACH OUTER SUPPORT
C4 X 5.4 A36
L2 X 2 X 1/4 A36
WHEEL #4684 WOODFORD MFG CO. PRESSED STEEL 300# CAPACITY 3 1/8" DIA FLAT TREAD 4 3/16" DIA FLANGE 1/2" DIA AXLE, BALL BEARING
12"
1/4"
21"
1 1/4" DIA PIN CS
20°
#3 CLEVIS
1 1/4" DIA ROD
INTERM. TEMP CL 3
MED. TEMP CL 5
45°0'
FW TYP
BOLT-U 3/8" DIA S.S.
TACK BOTH SIDES OF TUBE TYP
4" O.D.
HEADER LUG 1.25A86.625 7.0 PER 4U8 (FPG) 2U2-1 FIG 1
HEADER LUG WELD
BLANKET KAOWOOL 1800
85'-0"
8"
6 1/4"
6 1/4"
18"
15"
12"
4'-0"
2'-5"
85'-10" MEMBRANE LGTH
2'-5"
SECTION A-A
DRN BY M.A. REBISH
CHKD BY
PASSED BY
APPVD BY
CONTRACT NO. 894-0018-45
SOLAR RECEIVER
ECONOMIZER 46 TUBE PANEL
SCALE 1/8
405395E 0



NO.	TITLE	DWG. NO.
1	ECONOMIZER 46 TUBE PANEL	405395E

REFERENCES

DWN BY RA WILSON
CONTRACT NO. 894-0018-45

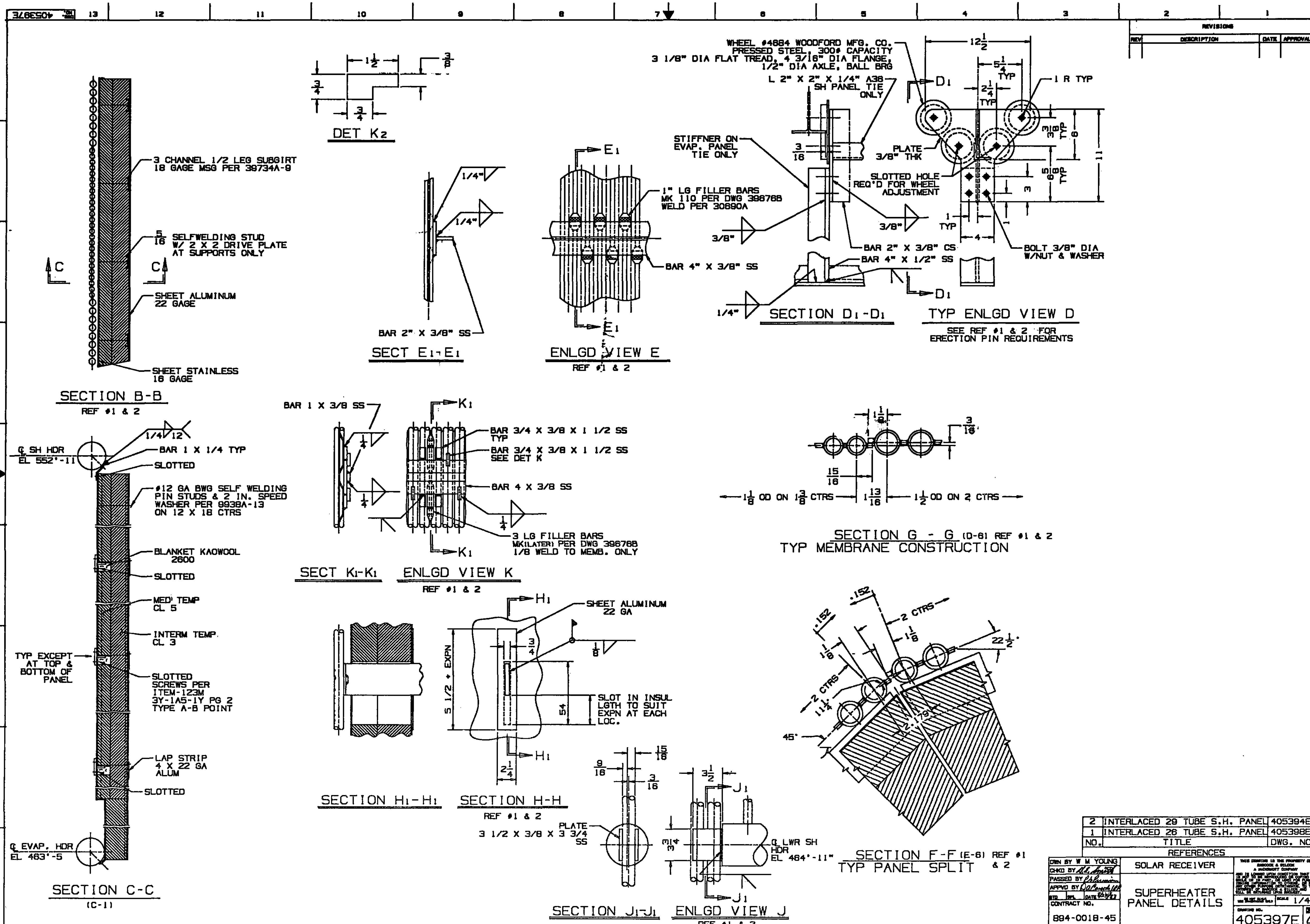
SOLAR RECEIVER

ECONOMIZER PANEL DETAILS

SCALE 1/4

405396E 0

G.2-20



NO.	TITLE	DWG. NO.
2	INTERLACED 29 TUBE S.H. PANEL	405394E
1	INTERLACED 26 TUBE S.H. PANEL	405398E

REFERENCES

DRN BY W M YOUNG

CONTRACT NO. 894-0018-45

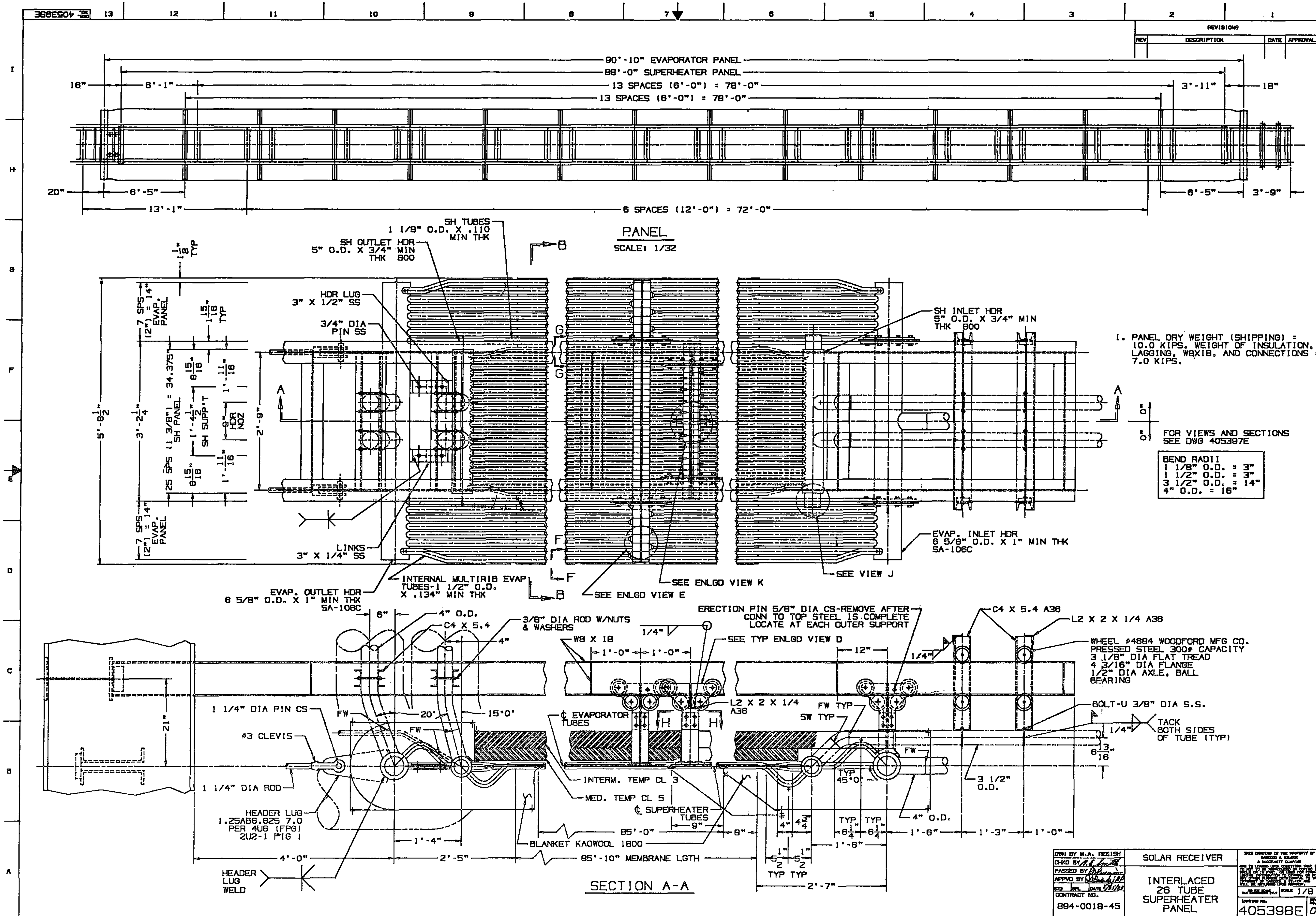
SOLAR RECEIVER

SUPERHEATER PANEL DETAILS

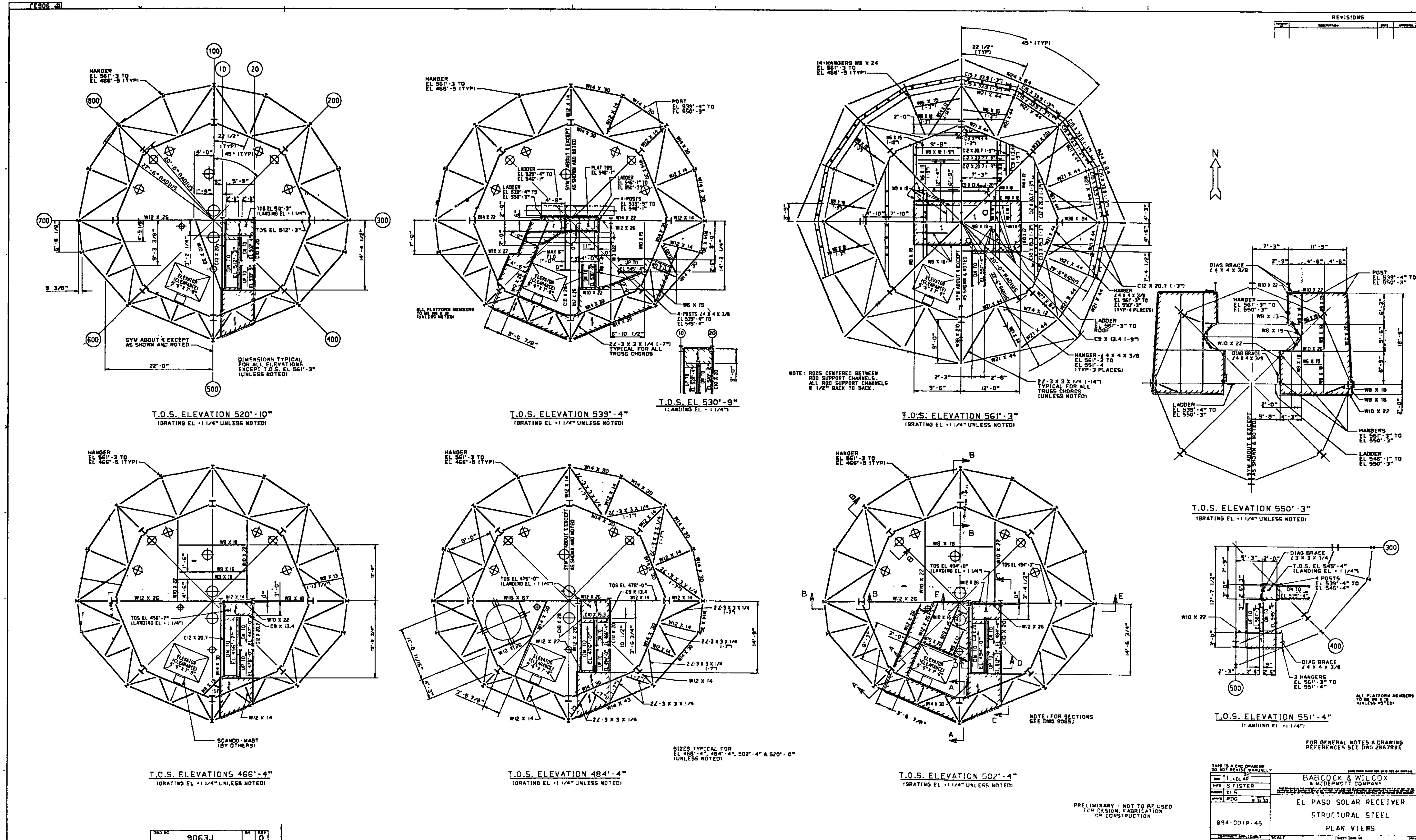
SCALE 1/4

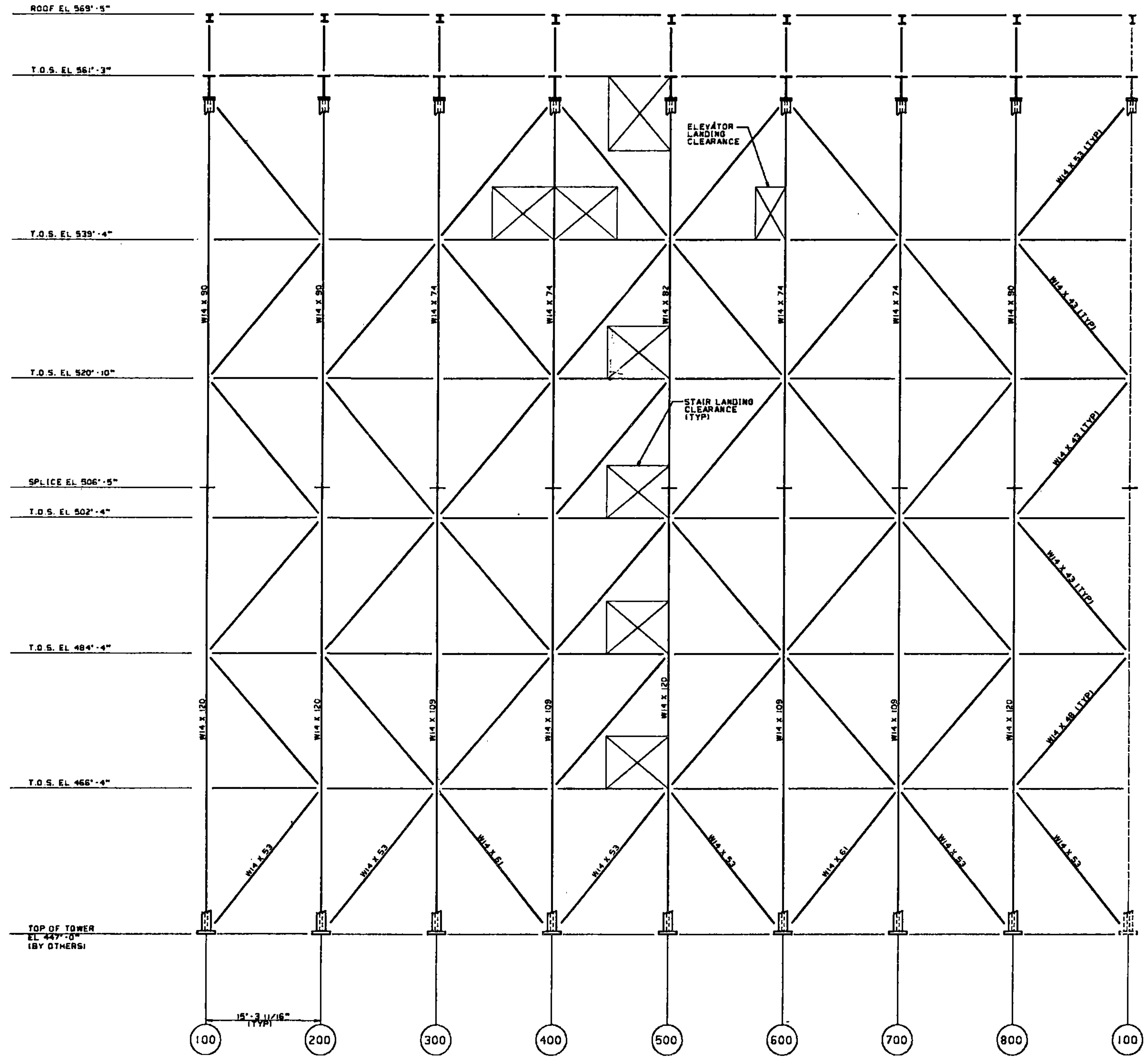
DRAWING NO. 405397E

REV 0



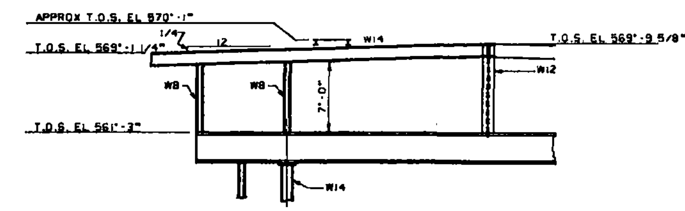
DWN BY M.A. REBISH	SOLAR RECEIVER
CONTRACT NO. 894-0018-45	INTERLACED 26 TUBE SUPERHEATER PANEL
SCALE 1/8	405398E REV 0


T.O.S. ELEVATION 520'-10"
(GRATING EL +1 1/4" UNLESS NOTED)
T.O.S. ELEVATION 539'-4"
(GRATING EL +1 1/4" UNLESS NOTED)
T.O.S. EL 530'-9"
(LANDING EL + 1 1/4")
T.O.S. ELEVATION 561'-3"
(GRATING EL +1 1/4" UNLESS NOTED)
T.O.S. ELEVATION 550'-3"
(GRATING EL +1 1/4" UNLESS NOTED)
T.O.S. ELEVATIONS 466'-4"
(GRATING EL +1 1/4" UNLESS NOTED)
T.O.S. ELEVATION 484'-4"
(GRATING EL +1 1/4" UNLESS NOTED)
T.O.S. ELEVATION 502'-4"
(GRATING EL +1 1/4" UNLESS NOTED)
T.O.S. ELEVATION 551'-4"
DIMENSIONS TYPICAL FOR ALL ELEVATIONS EXCEPT T.O.S. EL 561'-3" (UNLESS NOTED)
SYM ABOUT ℄ EXCEPT AS SHOWN AND NOTED
NOTE: RODS CENTERED BETWEEN ROD SUPPORT CHANNELS. ALL ROD SUPPORT CHANNELS 8 1/2" BACK TO BACK.
SIZES TYPICAL FOR EL 466'-4", 484'-4", 502'-4" & 520'-10" (UNLESS NOTED)
NOTE: FOR SECTIONS SEE DWG 9065J
PRELIMINARY - NOT TO BE USED FOR DESIGN, FABRICATION OR CONSTRUCTION
FOR GENERAL NOTES & DRAWING REFERENCES SEE DWG 286788E
REVISIONS
BABCOCK & WILCOX
A McDERMOTT COMPANY
EL PASO SOLAR RECEIVER
STRUCTURAL STEEL
PLAN VIEWS
894-0018-45
9063J
0

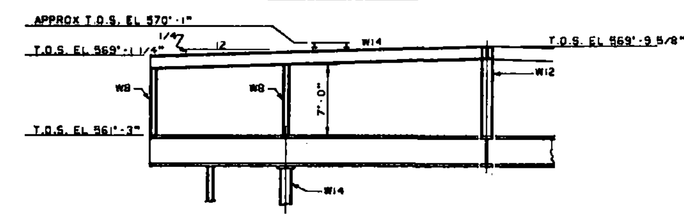


PROJECTED ELEVATIONAL VIEW

(LOOKING OUT FROM CENTER OF TOWER)

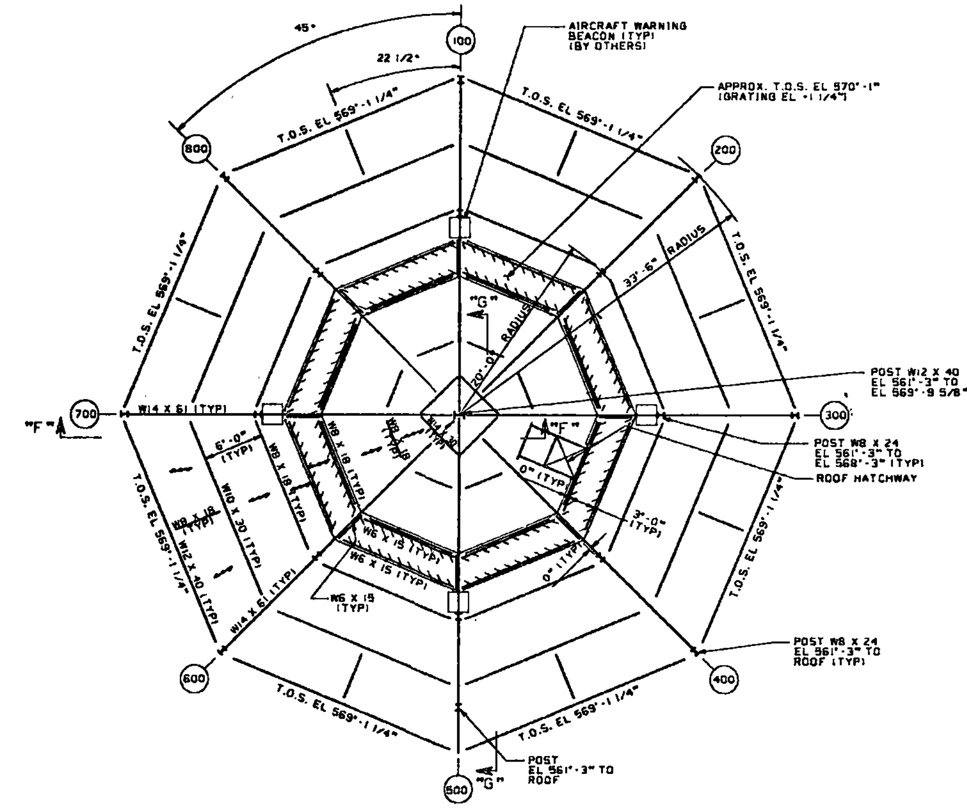


SECTION "G-G"



SECTION "F-F"

N



ROOF STEEL

SLOPED T.O.S. EL. 569'-9 5/8" TO 569'-1 1/4"

FOR GENERAL NOTES & DRAWING REFERENCES SEE DWG 286788E

PRELIMINARY - NOT TO BE USED FOR DESIGN, FABRICATION OR CONSTRUCTION

THIS IS A CAD DRAWING DO NOT REVISE MANUALLY

DR	T.J. FRANK
CHK'D	W. FISTER
894-0018-45	

BABCOCK & WILCOX
A McDERMOTT COMPANY

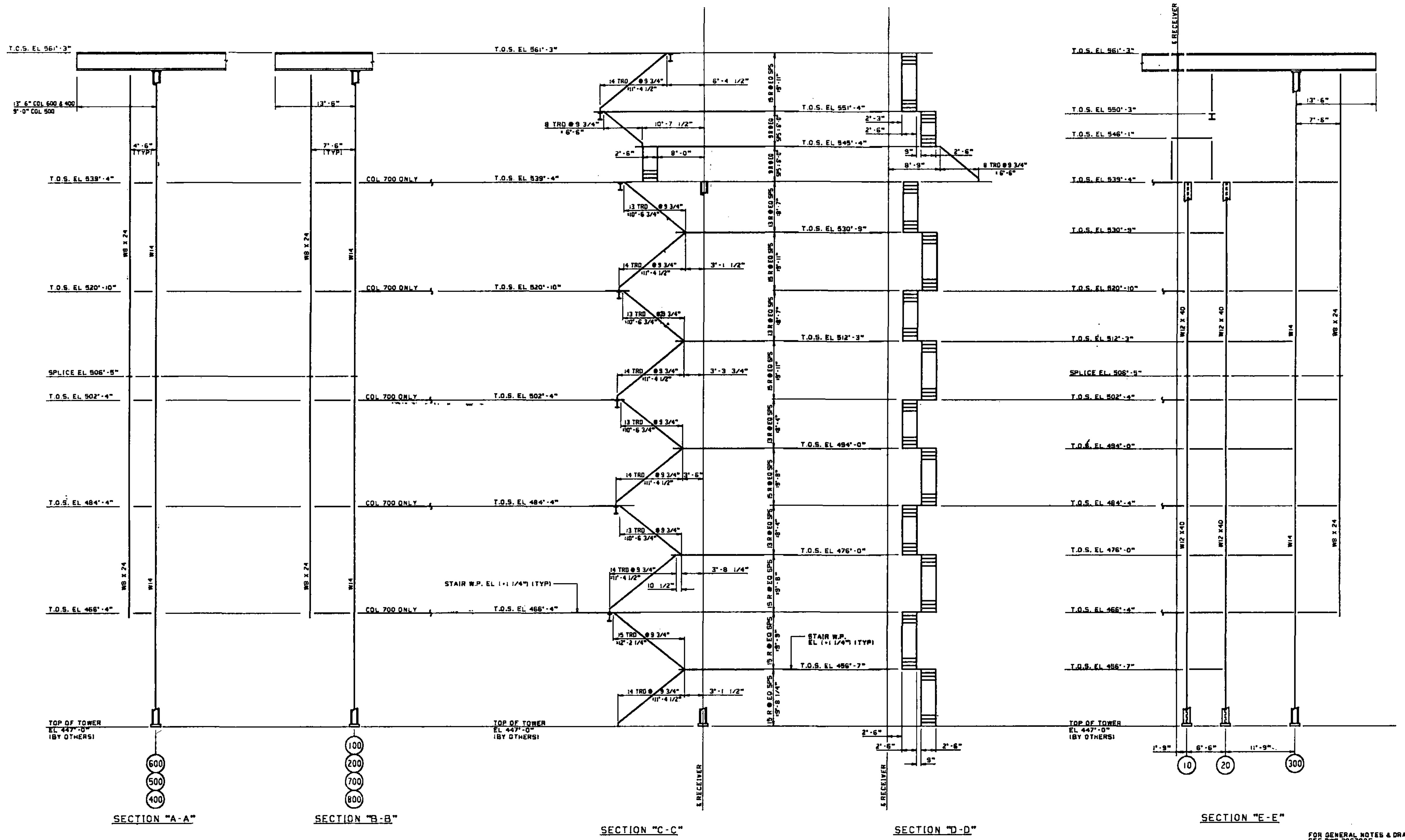
EL PASO SOLAR RECEIVER
STRUCTURAL STEEL
PROJ. ELEV. VIEW & ROOF STEEL

SCALE 3/16"=1'-0"

DWG NO 9064J REV 0

DWG NO 9064J SH REV 0

REVISIONS



FOR GENERAL NOTES & DRAWING REFERENCES SEE DWG 286788E

NOTE: SECTIONS CUT FROM DWG 9063J

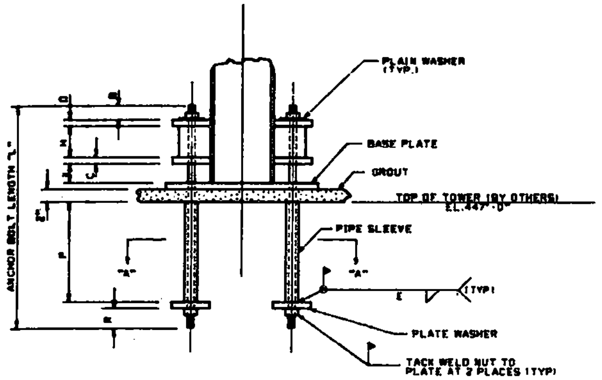
PRELIMINARY - NOT TO BE USED FOR DESIGN, FABRICATION OR CONSTRUCTION

BABCOCK & WILCOX
A MCDERMOTT COMPANY

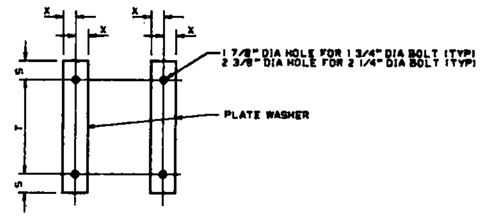
EL PASO SOLAR RECEIVER
STRUCTURAL STEEL
SECTIONAL VIEWS

894-0018-45

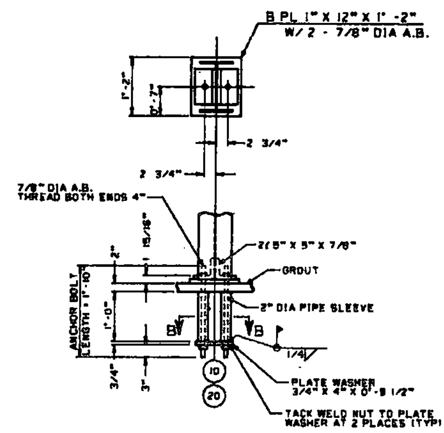
9065J 0



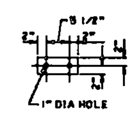
ASSEMBLY FOR 1 3/4" DIA & 2 1/4" DIA ANCHOR BOLTS



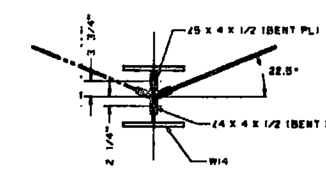
SECTION "A-A"

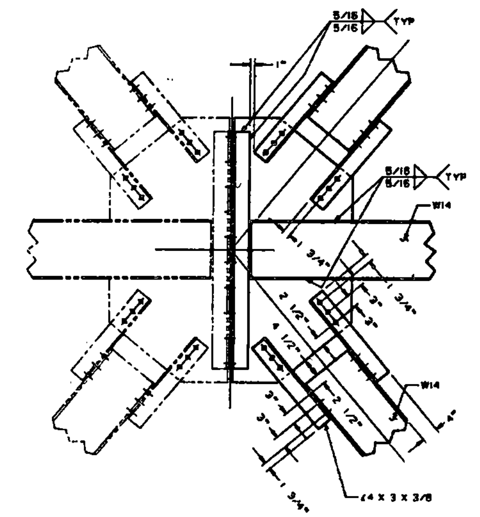


ASSEMBLY FOR 7/8" DIA ANCHOR BOLTS

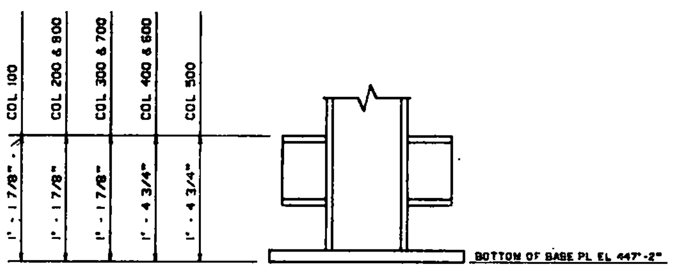


SECTION "B-B"

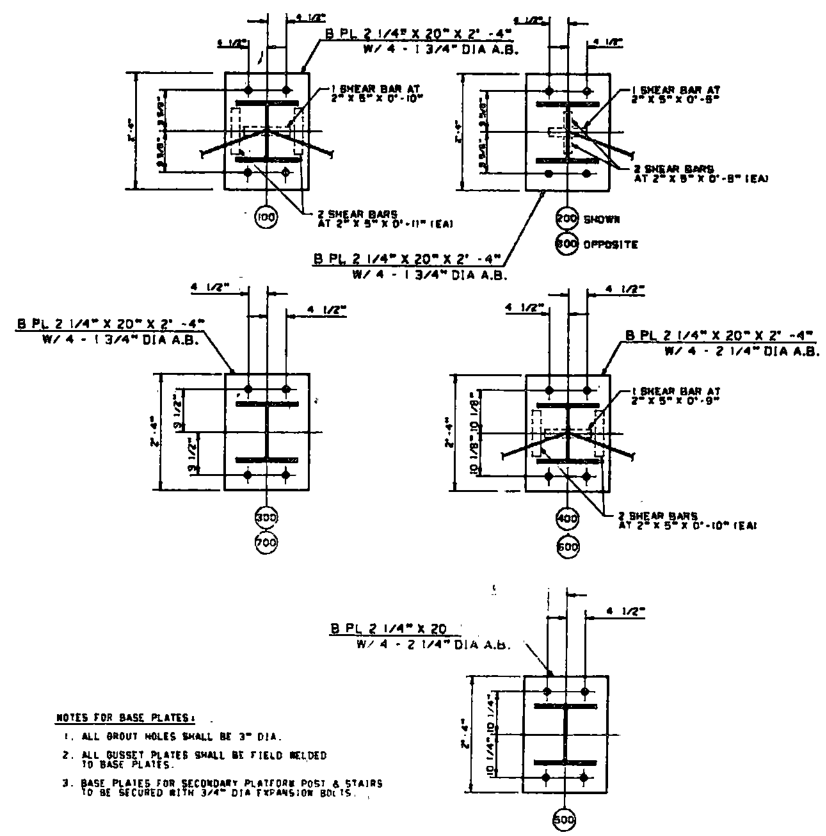


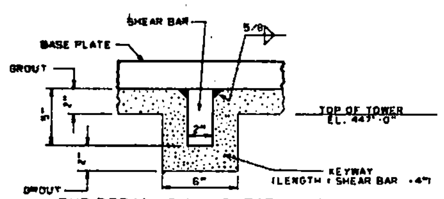


ANCHOR BOLT ASSEMBLIES																
BOLT DIA	THREAD BOTH ENDS	D	H	C	K	P	B	PLATE WASHER THK.	S	T	X	PLATE WASHER DIM.	SIZE SCH. 40 PIPE SA-53A	WELD SIZE E	R	ANCHOR BOLT LENGTH "L"
1 3/4"	6"	1 1/2"	8"	7/8"	1 1/4"	1'-3"	4 1/8"	1"	3 1/2"	9"	3 1/2"	1" X 7" X 1'-4"	3 1/2"	1/4"	4"	3'-4"
2 1/4"	6"	2"	10"	1"	1 1/2"	1'-9"	4 3/4"	1 1/2"	4"	9"	4"	1 1/2" X 8" X 1'-5"	3 1/2"	1/4"	4"	4'-2"



BASE CONNECTION HEIGHT





TYP DETAIL @ ALL SHEAR BARS

NOTES FOR BASE PLATES:

1. ALL GROUT HOLES SHALL BE 3" DIA.
2. ALL GUSSET PLATES SHALL BE FIELD WELDED TO BASE PLATES.
3. BASE PLATES FOR SECONDARY PLATFORM POST & STAIRS TO BE SECURED WITH 3/4" DIA EXPANSION BOLTS.

FOR GENERAL NOTES & DRAWING REFERENCES SEE DWG 286788E

PRELIMINARY - NOT TO BE USED FOR DESIGN, FABRICATION OR CONSTRUCTION

THIS IS A CAD DRAWING DO NOT REVISE MANUALLY

E. J. ROBSON
N. BAKI

BABCOCK & WILCOX
A McDERMOTT COMPANY

894-0018-45

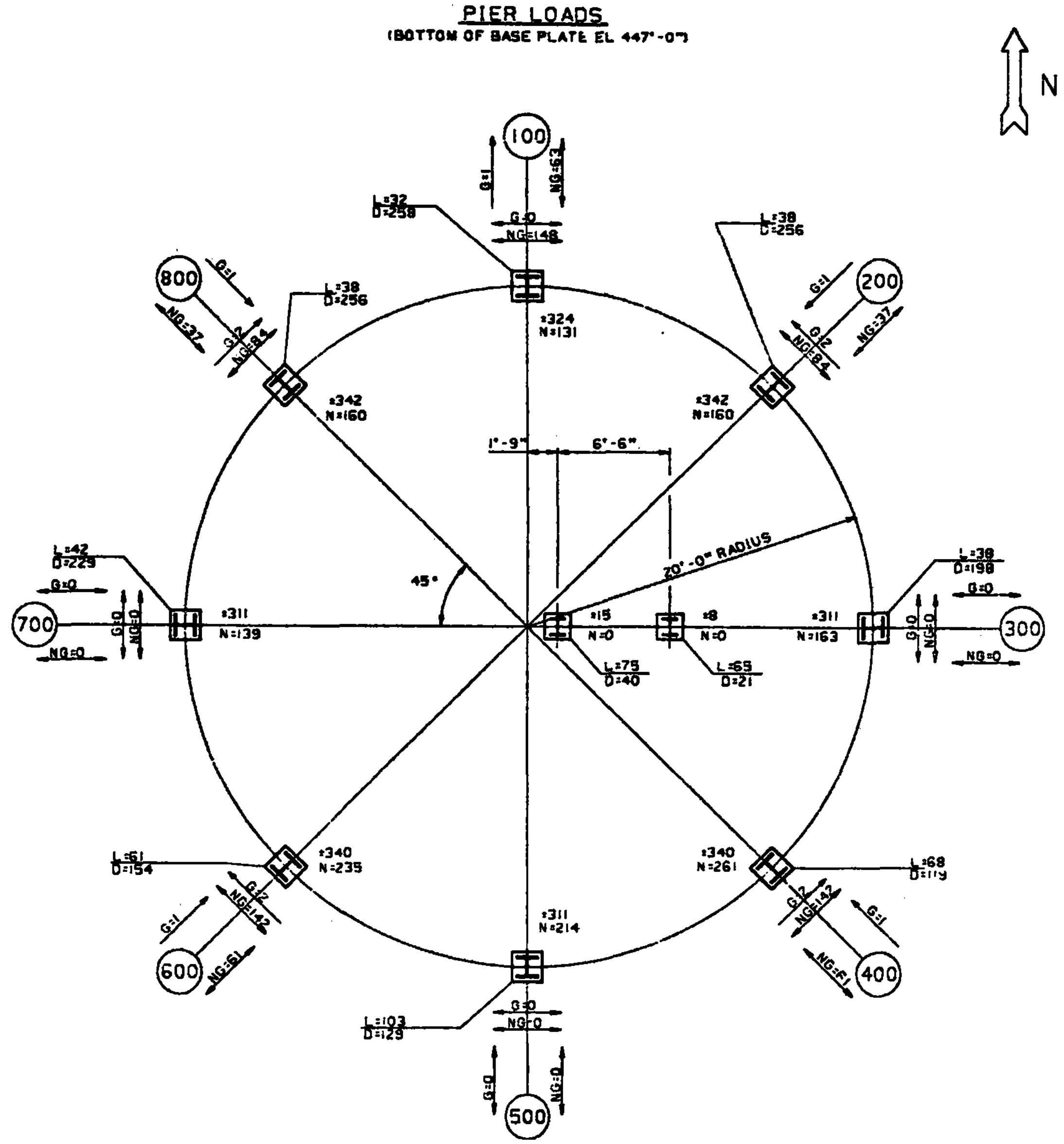
EL PASO SOLAR RECEIVER
STRUCTURAL STEEL
DETAILS & BASE PLATES

SCALE NONE

DWG NO. 3073J REV 0

DWG NO. 3073J 0

PIER LOADS
(BOTTOM OF BASE PLATE EL 447'-0")



PIER LOAD NOTES

1. GRAVITY LOADS
   L - LIVE LOADS
   D - DEAD LOADS
2. OVERTURNING
   ± WIND OR EQ. LOADS
3. N = NET UPLIFT
   N = (±LOAD) - (DEAD X 0.75)
4. SHEAR LOADS
   G - GRAVITY LOAD SHEAR
   NG - WIND OR EQ. LOAD SHEAR

DRAWING REFERENCE

286788E EL PASO SOLAR RECEIVER - GEN. NOTES, PIER LOADS & DWG REF.
9083J EL PASO SOLAR RECEIVER - PLAN VIEWS
9084J EL PASO SOLAR RECEIVER - PROJECTED ELEVATION VIEW & ROOF STEEL
9085J EL PASO SOLAR RECEIVER - SECTIONAL VIEWS
9073J EL PASO SOLAR RECEIVER - DETAILS & BASE PLATES

GENERAL NOTES

1. MATERIAL

THE FOLLOWING STEEL TO CONFORM TO ASTM MATERIAL SPECIFICATION:
A-36 FOR ALL ROLLED SHAPES, GIRDERS, COLUMN BASE PLATES, COVER PLATES, SHEAR BARS AND STIFFENER PLATES UNLESS NOTED.
A-36 FOR ANCHOR BOLTS (NOT BY B&W).
A-325 OR A-490 FOR CONNECTION BOLTS UNLESS NOTED.
A-501 SCHED. 40 PIPE FOR HANDRAIL, SCHED. 80 PIPE FOR HR. POSTS.
A-36 FOR LADDER STRINGERS.
A-569 FOR 10 & 16 GA. FILL PLATE.
A-283D FOR 3/16 INCH THRU 3/8 INCH THICK FILL PLATE.
A-36 FOR KICKPLATE, LADDER RUNGS AND SAFETY CAGES.
A-283D FOR ALL SUPPORT ROD BEARING PLATES.

2. CODES

STRUCTURAL STEEL SHALL COMPLY WITH THE FOLLOWING AISC (EIGHTH EDITION) SPECIFICATIONS AND CODES:
AISC SPECIFICATION FOR THE DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL FOR BUILDINGS.
AISC CODE OF STANDARD PRACTICE.
SPECIFICATION FOR STRUCTURAL JOINTS USING ASTM A-325 OR A-490 BOLTS.

WIND AND EARTHQUAKE CRITERIA SHALL BE AS FOLLOWS PER UNIFORM BUILDING CODE (UBC) AND/OR AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) OR OTHERS AS APPLICABLE:

UBC	ANSI	
	73 M.P.H.	100 YEARS RECURRENCE
	EQ. ZONE I	

MEMBER DESIGN LOADS INCREASED BY 25%: ■ YES □ NO

ALLOWABLE STRESS RATIOS:	GRAVITY LOADS (GL)	GL + NON-GL
MEMBERS	1.00	.33
CONNECTIONS	1.00	.33

3. CONNECTIONS

SHOP CONNECTIONS TO BE WELDED.

ALL WELDS TO BE E70XX ELECTRODES.

ALL FIELD CONNECTIONS SHALL BE MADE WITH 7/8" MINIMUM DIAMETER BEARING TYPE BOLTS, WITH THREADS INCLUDED IN SHEAR PLANES.

WHERE NO END REACTIONS ARE SHOWN, FOR HORIZONTAL BEAMS, THE END CONNECTIONS SHOULD BE DESIGNED & DETAILED USING MINIMUM REQUIREMENTS PER AISC CODE.

(N) DENOTES NUMBERED ROW CONNECTION PER AISC FRAMED BEAM CONNECTION REQUIRED FOR LATERAL BRACING WHERE N EQUALS NUMBER OF ROWS.

UNLESS OTHERWISE NOTED, FORCES AT CONNECTIONS ARE DESIGNATED AS FOLLOWS:

"H"- MAX. AXIAL FORCE (KIPS) THROUGH A CONNECTION DUE TO WIND, EARTHQUAKE OR STABILIZATION LOADS. CONNECTIONS WITH "H" FORCE ARE TO BE DESIGNED FOR BOTH AXIAL TENSION AND COMPRESSION.

"V"- MAX. VERTICAL SHEAR FORCE (KIPS) ON A CONNECTION DUE TO DEAD AND LIVE LOAD.

"V_H"- MAX. HORIZONTAL SHEAR FORCE (KIPS) ON A CONNECTION DUE TO WIND, EARTHQUAKE, OR STABILIZATION LOADS.

"M"- MAX. MOMENT (INCH-KIPS) ON A CONNECTION.

"M_T"- MAX. TORSIONAL MOMENT (INCH-KIPS) ON A CONNECTION. ARE TO BE DESIGNED FOR BOTH AXIAL TENSION AND COMPRESSION.

ALL ATTACHMENTS TO STRUCTURAL STEEL MEMBERS SHALL BE CHECKED LOCALLY FOR STRENGTH AND STABILITY AND STIFFENER PLATES ADDED WHERE NECESSARY BY DETAILERS.

CONNECTIONS FOR POSTS AND HANGERS SHALL BE DESIGNED FOR NOT LESS THAN 10 KIPS AND HAVE NO LESS THAN TWO BOLTS. AXIAL LOADS OF 10 KIPS OR MORE ARE DESIGNATED ON DRAWING AS "P=".

ALL DIAGONALS WITH NO LOAD SHOWN SHALL HAVE MINIMUM END CONNECTION OF TWO BOLTS OR EQUIVALENT WELD.

4. FORCES AND LOADS

FOR ALL DIAGONAL MEMBERS ON THE COLUMN ROWS: "+" FORCE INDICATES MEMBER IS IN TENSION. "-" FORCE INDICATES MEMBER IS IN COMPRESSION. "±" FORCE INDICATES MEMBER CAN BE IN TENSION OR COMPRESSION WITH THE UPPER SIGN REFLECTING EXTERNAL APPLIED FORCES FROM ONE DIRECTION AND THE LOWER SIGN THE OPPOSITE DIRECTION.

LOADS SHOWN ON HORIZONTAL OR VERTICAL DIAGONALS ARE COMPONENTS AND NOT AXIAL FORCES, WITH THE GRAVITY LOAD IDENTIFIED AND THE NON-GRAVITY LOADS NOT IDENTIFIED.

ALL LOADS SHOWN ARE IN KIPS.

5. GRATING, FLOOR PLATE AND HANDRAIL

GRATING FOR PLATFORMS AND WALKWAYS SHALL BE OF RECTANGULAR WELDED STEEL, NON-REVERSIBLE TYPE WITH 1 1/4" x 3/16" THICK BEARING BARS SPACED ON 1 3/16" CENTERS AND WITH CROSS BARS SPACING OF 4" CENTER TO CENTER. ABRASIVE NOSING SHALL BE PROVIDED AT THE HEAD OF ALL STAIRS AND ON STAIR TREADS.

GRATING AND STAIR TREADS TO BE: ■ GALVANIZED □ PAINTED

HANDRAIL TO BE 1 1/4" NOMINAL DIAMETER
HANDRAIL TO BE: □ GALVANIZED ■ PAINTED
KICKPLATE TO BE: □ GALVANIZED ■ PAINTED

6. GENERAL

ALL WIDE FLANGE DIAGONAL BRACING TO HAVE WEBS VERTICAL UNLESS OTHERWISE NOTED.

ALL COLUMN ENDS AT BASE PLATES AND SPLICES TO BE MILLED OR SAWED FOR BEARING.

ALL KNEE AND TENSION BRACES TO BE 45° UNLESS NOTED.

ALL CHANNEL PAIRS TO BE 8 1/2" BACK TO BACK UNLESS NOTED.

ALL BEAMS AND CHANNELS USED IN PAIRS SHALL HAVE DIAPHRAGMS AT INTERVALS NOT TO EXCEED 5'-0".

ALL LADDERS TO HAVE A SAFETY CHAIN UNLESS OTHERWISE NOTED.

(-D) INDICATES DISTANCE (D IN INCHES) FROM ELEVATION INDICATED ON PLAN VIEWS TO TOP FLANGE OF BEAMS OR CENTERLINE OF GUSSETS FOR ANGLES.

ALL DOUBLE ANGLE DIAGONAL BRACING TO HAVE LONG LEGS 3/8" MINIMUM BACK TO BACK AND BE SYMMETRICAL ABOUT CENTERLINE OF GUSSET PLATES UNLESS NOTED.

LLBBTD- INDICATES LONG LEGS 0" BACK TO BACK TOES DOWN.

ATD- INDICATES SINGLE ANGLE TOE DOWN.

ALL STAIR STRINGERS C8 X 13.4 UNLESS NOTED.

7. LEGEND

B&W STEEL
STEEL BY OTHERS
GRATING
HANDRAIL
DIRECTION OF GRATING SPAN
DIRECTION OF ROOF SPAN

8. ABBREVIATION

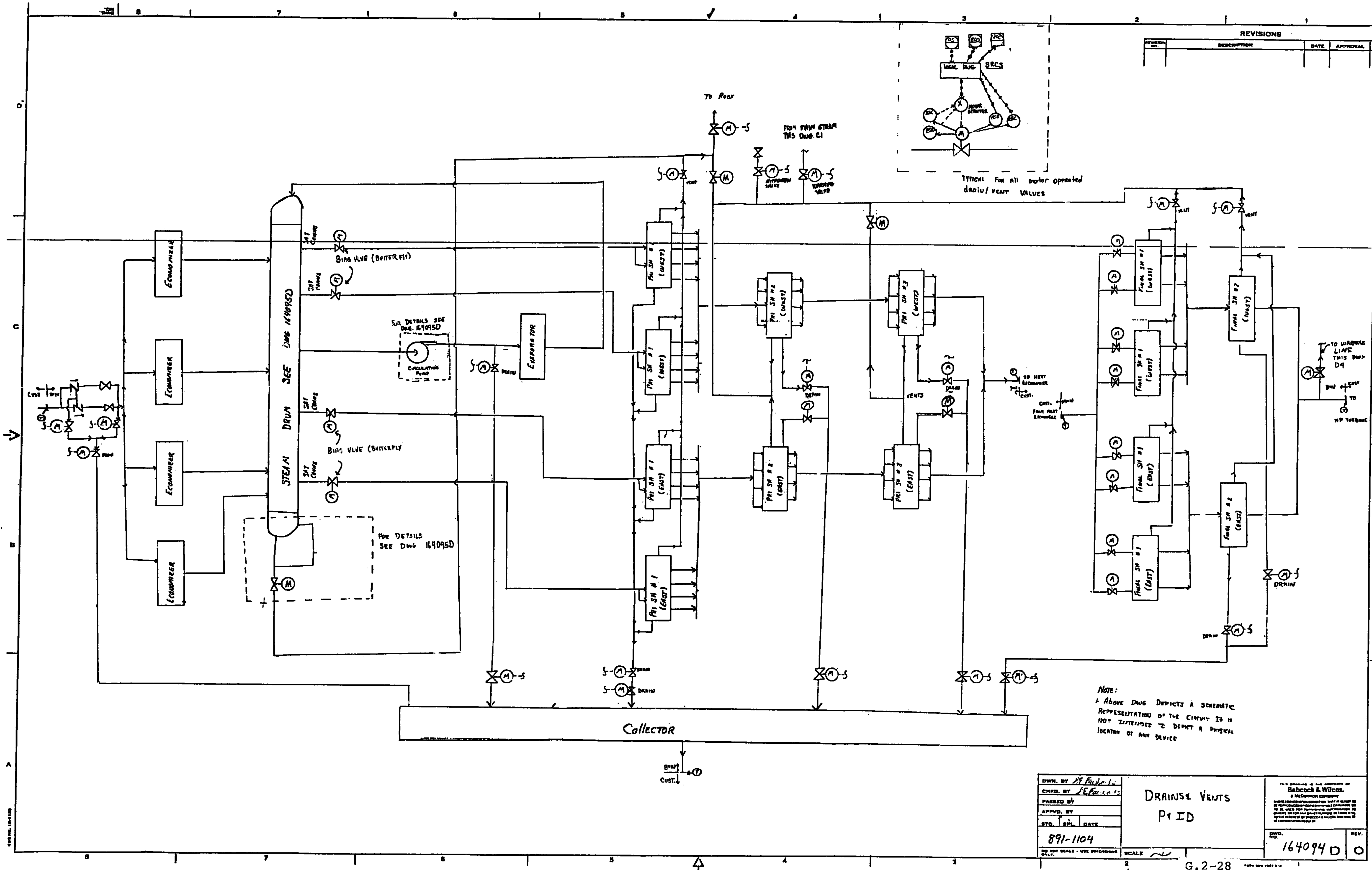
F&A - FORE & AFT	TL - TRANSIENT LOAD
S TO S - SIDE TO SIDE	EQ - EARTHQUAKE LOAD
PR - PRESSURE LOAD	WL - WIND LOAD
FR - FRICTION LOAD	DL - DEAD LOAD

REVISIONS

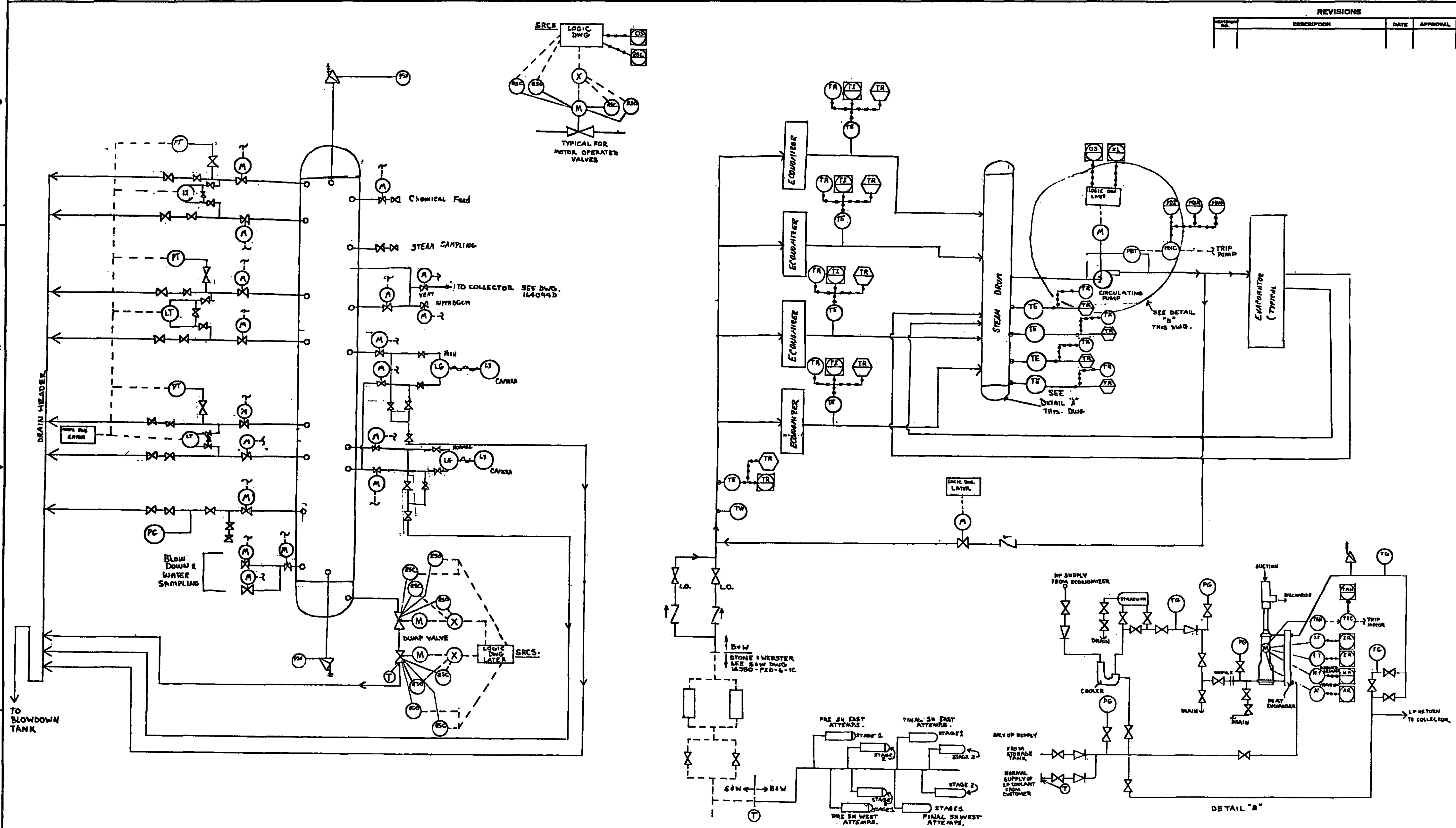
PRELIMINARY - NOT TO BE USED FOR DESIGN, CONSTRUCTION OR FABRICATION

THIS IS A CAD DRAWING
DO NOT REVISE MANUALLY

DWN. BY T. KOLAR	EL PASO SOLAR RECEIVER
CHKD BY S. FISTER	STRUCTURAL STEEL GENERAL
PASSED BY	NOTES, PIER LOADS & DWG REF
APP'D BY	BABCOCK & WILCOX
DATE 8-31-83	
894-0018-45	286788E 0
SCALE NONE	


REVISIONS
DESCRIPTION
DATE
APPROVAL
TO ROOF
FROM MAIN STEAM
THIS DWG. C1
TYPICAL FOR ALL motor operated
drain/vent VALUES
SRCS
ECONOMIZER
STEAM DRUM SEE DWG 164095D
BIAS VLVE (BUTTERFLY)
SEE DETAILS SEE DWG. 164095D
CIRCULATING PUMP
EVAPORATOR
FOR DETAILS
SEE DWG 164095D
PRI SH #1 (WEST)
PRI SH #1 (EAST)
PRI SH #2 (WEST)
PRI SH #2 (EAST)
PRI SH #3 (WEST)
PRI SH #3 (EAST)
FINAL SH #1 (WEST)
FINAL SH #1 (EAST)
FINAL SH #2 (WEST)
FINAL SH #2 (EAST)
VENTS
DRAIN
VENT
TO HEAT EXCHANGER
FROM HEAT EXCHANGER
TO WARMUP LINE THIS DWG. D9
TO HP TURBINE
Collector
CUST.
NOTE:
1. Above DWG Depicts a schematic representation of the circuit. It is not intended to depict a physical location of any device
DRAINS & VENTS
P & ID
891-1104
Babcock & Wilcox
164094 D
0

G.2-28



NOTES:

1. Above Dwg depicts a schematic representation of the circuit. It is not intended to depict a physical location of any device.

DWN. BY	JSF
CHKD. BY	JSF
PASSED BY	PDT
APPVD. BY	
STD. / DATE	6/21/83
	291-1104
DO NOT SCALE - USE DIMENSIONS ONLY	SCALE NONE

WATER/DRUM

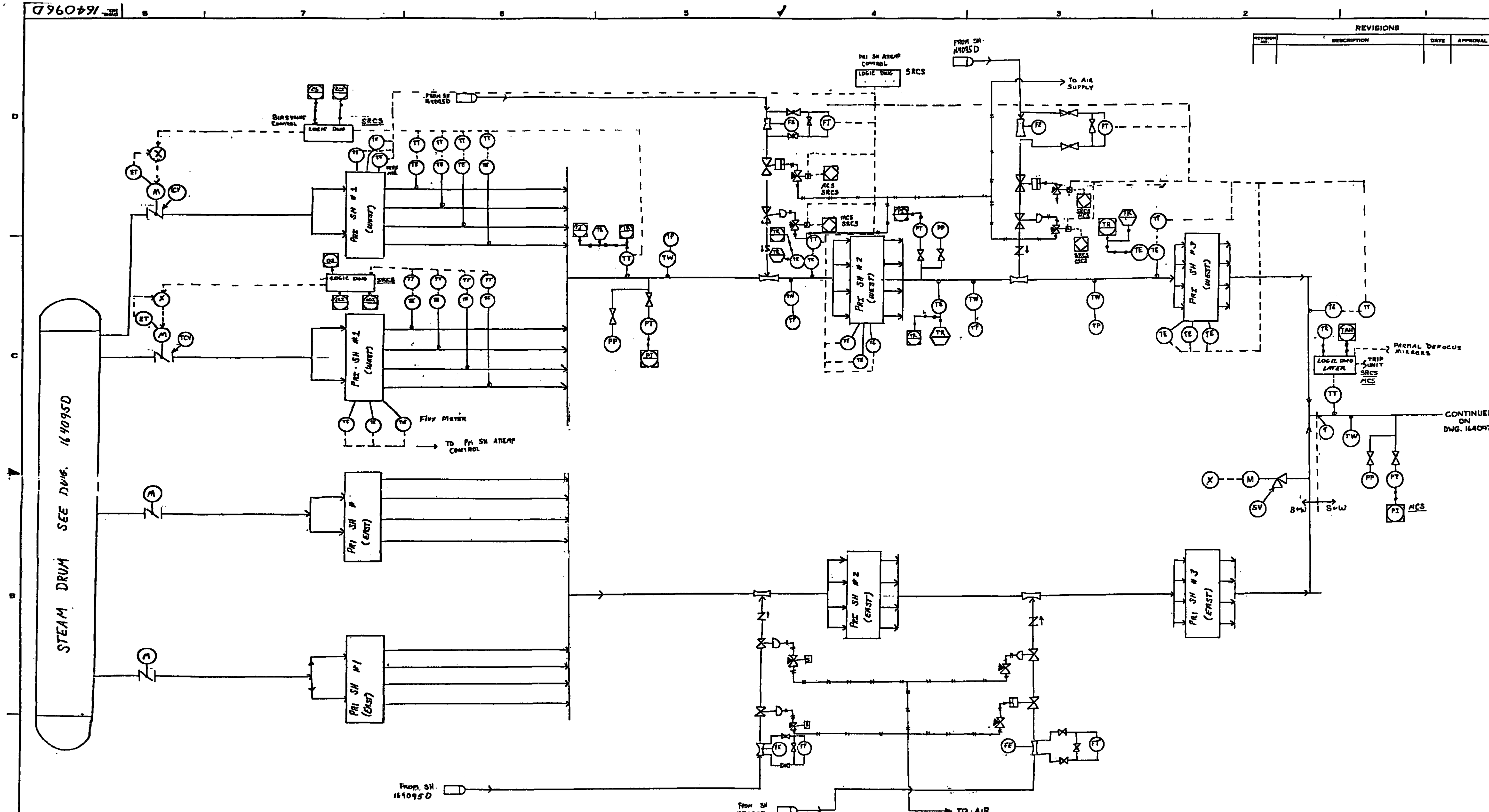
P & ID

Babcock & Wilcox

a McDermott company

DWG. NO. 164095 D

REV. 0



NOTES:

1. ABOVE DWG DEPICTS A SCHEMATIC REPRESENTATION OF THE CIRCUIT. IT IS NOT INTENDED TO DEPICT A PHYSICAL LOCATION OF ANY DEVICE.
2. INSTRUMENTATION SHOWN FOR WEST SIDE ONLY. DUPLICATE FOR EAST SIDE.
3. FOR DRAINS & VENTS SEE DWG. 164094D.

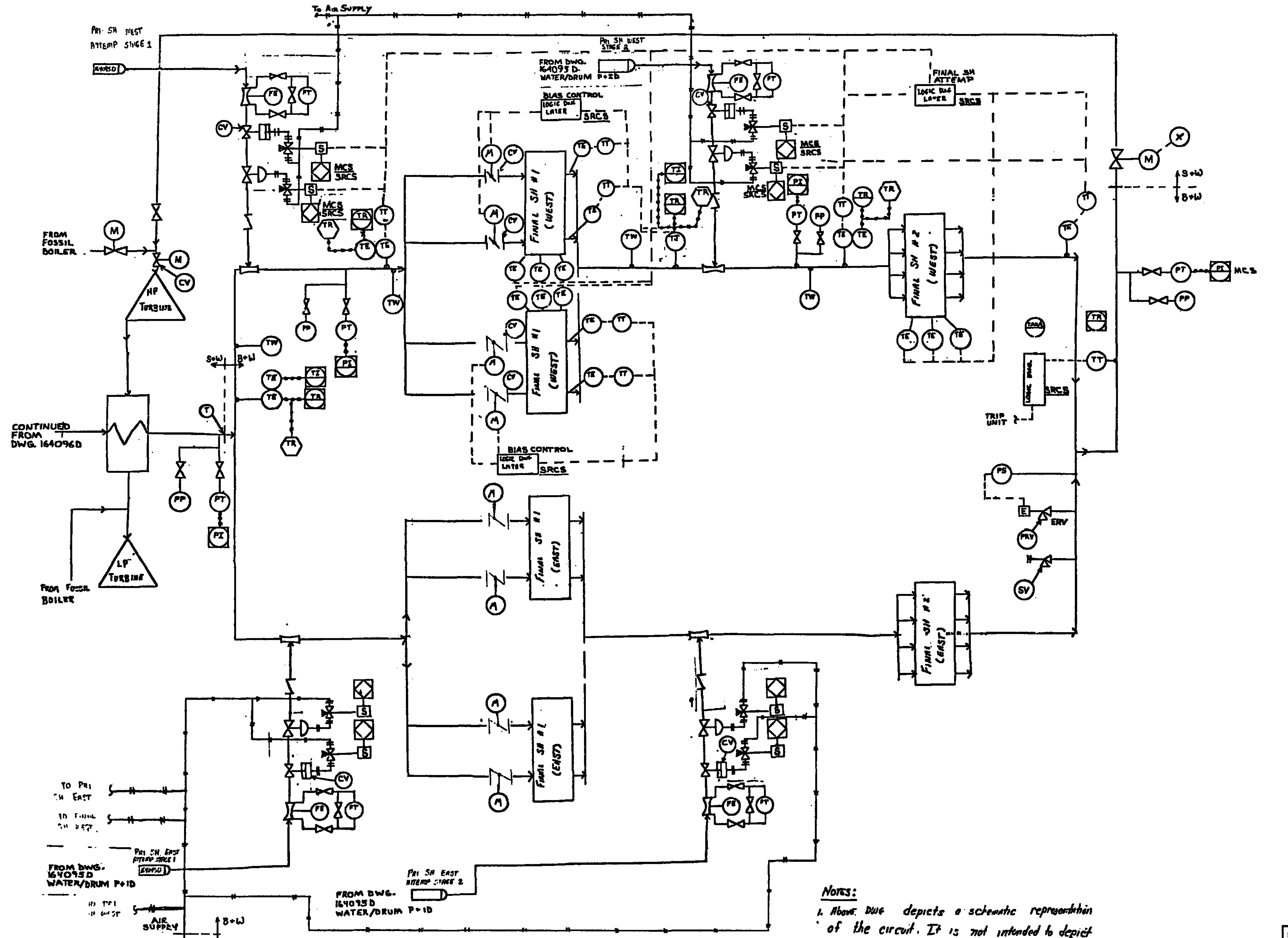
DWN. BY S. EDDY
CHKD. BY D.E. Fairbanks
891-1104

STEAM
P & ID
SH. 1

Babcock & Wilcox

DWG. NO. 164096 D REV. 0

G.2-30



Notes:

1. Above Dwg depicts a schematic representation of the circuit. It is not intended to depict a physical location of any device.
2. Instrumentation shown for West side only. Duplicate for East side
3. For Drains & Vents see Dwg. 164094D.

DWN. BY	S. EDDY
CHKD. BY	J. E. Fairbanks
PASSED BY	R D Rawlings
APPVD. BY	J C Wang
DATE	9/23/83
	891-1104

STEAM P & ID SH. 2

Babcock & Wilcox
a McDermott company

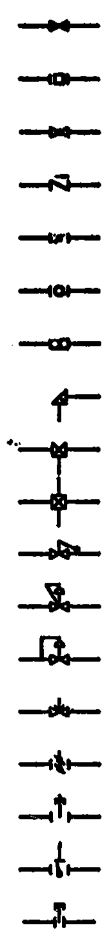
DWG. NO. 164097 D REV. 0

SCALE —

G.2-31

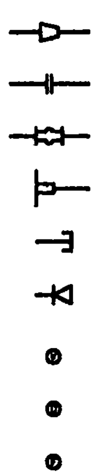
3001082

VALVES



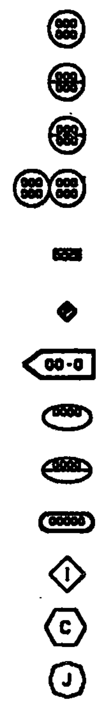
- GATE VALVE
- PLUG VALVE
- GLOBE VALVE
- CHECK VALVE (ARROW INDICATES DIRECTION OF FLOW THROUGH VALVE)
- BUTTERFLY VALVE
- BALL VALVE
- UNCLASSIFIED VALVE
- ANGLE VALVE
- THREE-WAY VALVE
- FOUR-WAY VALVE
- FLOAT VALVE
- PRESSURE REDUCING VALVE SELF CONTAINED
- PRESSURE REDUCING VALVE W/EXTERNAL PIPE TAPS
- NEEDLE VALVE
- LOUVER DAMPER
- GUILLOTINE DAMPER
- TWO-WAY CHECK DAMPER
- SLIDE GATE

JOINTS & FITTINGS



- REDUCER
- FLANGED JOINT
- EXPANSION JOINT
- HOSE CONNECTION
- CAPPED CONNECTION
- PLUG
- VENT
- DRAIN
- FLUSH CONNECTION

INSTRUMENT SYMBOLS



- LOCALLY MOUNTED
- MOUNTED ON BOARD
- MOUNTED BEHIND BOARD OR IN SYSTEM CABINET
- COMBINATION INSTRUMENT OR DEVICE W/2 FUNCTIONS (ADDITIONAL BALLOON MAY BE ADDED AS REQUIRED)
- CHEMICAL SEAL OR GAGE PROTECTOR
- PURGE OR FLUSHING DEVICE
- LINE MATCH SYMBOL
- VALVE TAG NUMBER
- DAMPER TAG NUMBER
- CONNECTION IDENTIFICATION NUMBER
- INTERLOCK OR UNSPECIFIED LOGIC
- COMPUTER CONNECTION, NOT ACCESSIBLE TO OPERATOR.
- JUNCTION BOX CONNECTION

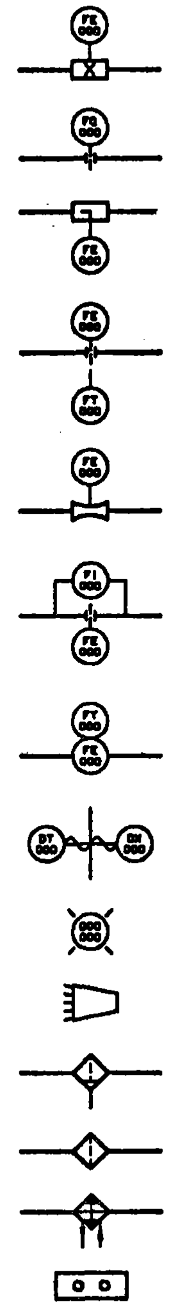
ABBREVIATIONS

- AS - AIR SUPPLY
- M - MOTOR
- PW - PROCESS WATER
- SS - STEAM SUPPLY
- WS - WASTE SLURRY
- GS - GLAND SEAL WATER SUPPLY
- HV - HAND OPERATED VALVE
- AV - AUTO OPERATED VALVE
- MW - MAKE UP WATER
- CW - COOLING WATER

ACTUATORS

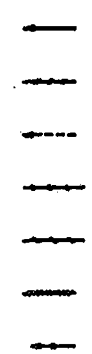
- DIAPHRAGM, SPRING OPPOSED
- MOTOR, ELECTRIC
- SINGLE-ACTING CYLINDER
- DOUBLE-ACTING CYLINDER
- CYLINDER, PNEUMATIC OR HYDRAULIC
- CYLINDER W/POSITIONER
- DIAPHRAGM W/POSITIONER
- HAND ACTUATOR
- SOLENOID - SO - ENERGIZED OPEN - SC - ENERGIZED CLOSED
- SPRING OR WEIGHT-LOADED

MISCELLANEOUS SYMBOLS



- FLOW CONTROL (FC) OR ROTOMETER TYPE FLOW INDICATOR (FI)
- FIXED RESTRICTION ORIFICE
- PITOT TUBE
- ORIFICE PLATE W/FLG OR CORNER TAPS
- VENTURI OR FLOW NOZZLE
- ORIFICE PLATE W/PIPE TAPS
- MAGNETIC FLOW ELEMENT
- NUCLEAR DENSITY METER
- PILOT LIGHT
- ALARM HORN OR LIGHT
- FILTER-SEPARATION
- FILTER
- COOLER
- CRUSHER

LINE LEGEND



- PROCESS LINE
- PNEUMATIC SIGNAL
- ELECTRIC SIGNAL
- HYDRAULIC SIGNAL
- ELECTROMAGNETIC OR SONIC SIGNAL (WITHOUT WIRING OR TUBING)
- FLEXIBLE HOSE
- CAPILLARY TUBING

DISTRIBUTED CONTROL SYSTEM

- DISTRIBUTED CONTROL NORMALLY ACCESSIBLE TO OPERATOR. ACCESS LIMITED TO COMMUNICATION LINK.
- DISTRIBUTED CONTROL, NOT NORMALLY ACCESSIBLE TO OPERATOR. MAY BE ON COMMUNICATION LINK.
- COMPUTER COMPONENT, NORMALLY ACCESSIBLE TO OPERATOR.
- DISTRIBUTED CONTROL INTERCONNECTING LOGIC CONTROLLER WITH BINARY OR SEQUENTIAL LOGIC FUNCTION. NOT NORMALLY ACCESSIBLE TO OPERATOR.
- DISTRIBUTED CONTROL INTERCONNECTING LOGIC CONTROLLER WITH BINARY OR SEQUENTIAL LOGIC FUNCTION. NORMALLY ACCESSIBLE TO OPERATOR.

NOTES :

DISTRIBUTED CONTROL SYSTEM -

THAT CLASS OF INSTRUMENTATION (INPUT / OUTPUT DEVICES, CONTROL DEVICES AND OPERATOR INTERFACE DEVISES) WHICH IN ADDITION TO EXECUTING THE STATED CONTROL FUNCTIONS ALSO PERMITS TRANSMISSION OF CONTROL, MEASUREMENT, AND OPERATING INFORMATION TO AND FROM A SINGLE OR A PLURALITY OF USER SPECIFIABLE LOCATIONS, CONNECTED BY A COMMUNICATION LINK.

ACCESSIBLE.-

A SYSTEM FEATURE THAT IS VIEWABLE BY AND INTERACTIVE WITH THE OPERATOR, AND ALLOWS THE OPERATOR TO PERFORM USER PERMISSIBLE CONTROL ACTIONS E.G. SET POINT CHANGES, AUTO-MANUAL TRANSFERS, OR ON-OFF ACTIONS.

COMMUNICATION LINK -

COMPUTER CONTROL IS A DEVICE IN WHICH CONTROL AND/OR DISPLAY ACTIONS ARE GENERATED FOR USE BY OTHER SYSTEM DEVICES. WHEN USED WITH OTHER CONTROL DEVICES ON THE COMMUNICATION LINK THE COMPUTER NORMALLY PERFORMS OR FUNCTIONS IN A HIERARCHICAL RELATIONSHIP TO THE OTHER CONTROL DEVICES.

INSTRUMENT SYMBOL IDENTIFICATION LEGEND

	FIRST LETTER		SUCCEEDING LETTERS		
	MEASURED VARIABLE	MODIFIER	READOUT OR PASSIVE	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS	ALARM	ALARM	ALARM	ALARM
B	BURNER				
C	COUNTER-COND	CONTROLLER	CONTROLLER	CONTROLLER	CLOSED/STOPPED
D	DRIVE	DIFFERENTIAL			DEVICE
E	VOLTAGE	ELECTRIC.			ELEMENT
F	FLOW	FLOW	FLOW		
G	GAUGE				GAUGE
H	HAND	HYDRAULIC			HIGH
I	AMPERES	INDICATOR			INDICATOR
J	POWER				
K	TIME				CONTROL STATION
L	LEVEL	LEVEL	LIGHT		LOW
M	MOISTURE				METER
N	NUCLEAR				
O	OPERATIONAL				OPEN/RUNNING
P	PRESSURE	PRESSURE	TEST POINT		
Q	SPECIAL				INTEGRATE
R	RELIEF	RECORDER	RECORDER	RECORDER	RECORDER
S	SPEED	SWITCH	SWITCH		SWITCH
T	TEMPERATURE	TEMPERATURE	TEMPERATURE		TRANSMITTER
U					AUTO
V	VISCOSITY-VIB	VALVE	VALVE	VALVE	VALVE
W	WEIGHT				WELL
X	MOTOR STARTER				
Y	TENSION				COMPUTER
Z	POSITION				SIGNAL

REVISIONS

NO.	DESCRIPTION	DATE	APPROVAL	
1	REV'D INTERLOCK SYMBOL DESCRIPTION. LJO	[illegible]	LDR II	
2	REV'D INSTR. SYMBOL LEGEND TO AGREE WITH ISA. LJO	[illegible]	LDR II	
3	ADDED CW TO ABBREVIATIONS & CRUSHER TO MISC SYMBOLS. REV'D 1ST COL "A", 2ND COL "P" ON SYMBOL LEGEND. LJO	[illegible]	[illegible]	
4	ADDED DISTRIBUTED CONTROL SYSTEM SYMBOLS & NOTES. MOVED INST. SYMBOLS - VENT, DRAIN & FLUSH CONNECTION TO JOINTS & FITTINGS. REV'D COMPUTER CONNECTION IN INST. SYMBOLS. SME	[illegible]	LDR II	
5	REV'D DISTRIBUTED CONTROL SYSTEM NOTES. SME	[illegible]	[illegible]	

THIS IS A CAD DRAWING DO NOT REVISE MANUALLY

DWN. BY	L.J. OWENS
CHKD. BY	L.D. RAWLINGS II
PASSED BY	L.D. RAWLINGS II
APPD. BY	J.C. WAUNG
DATE	10/1/82

STANDARD

PROCESS AND INSTRUMENTATION DIAGRAM SYMBOLS

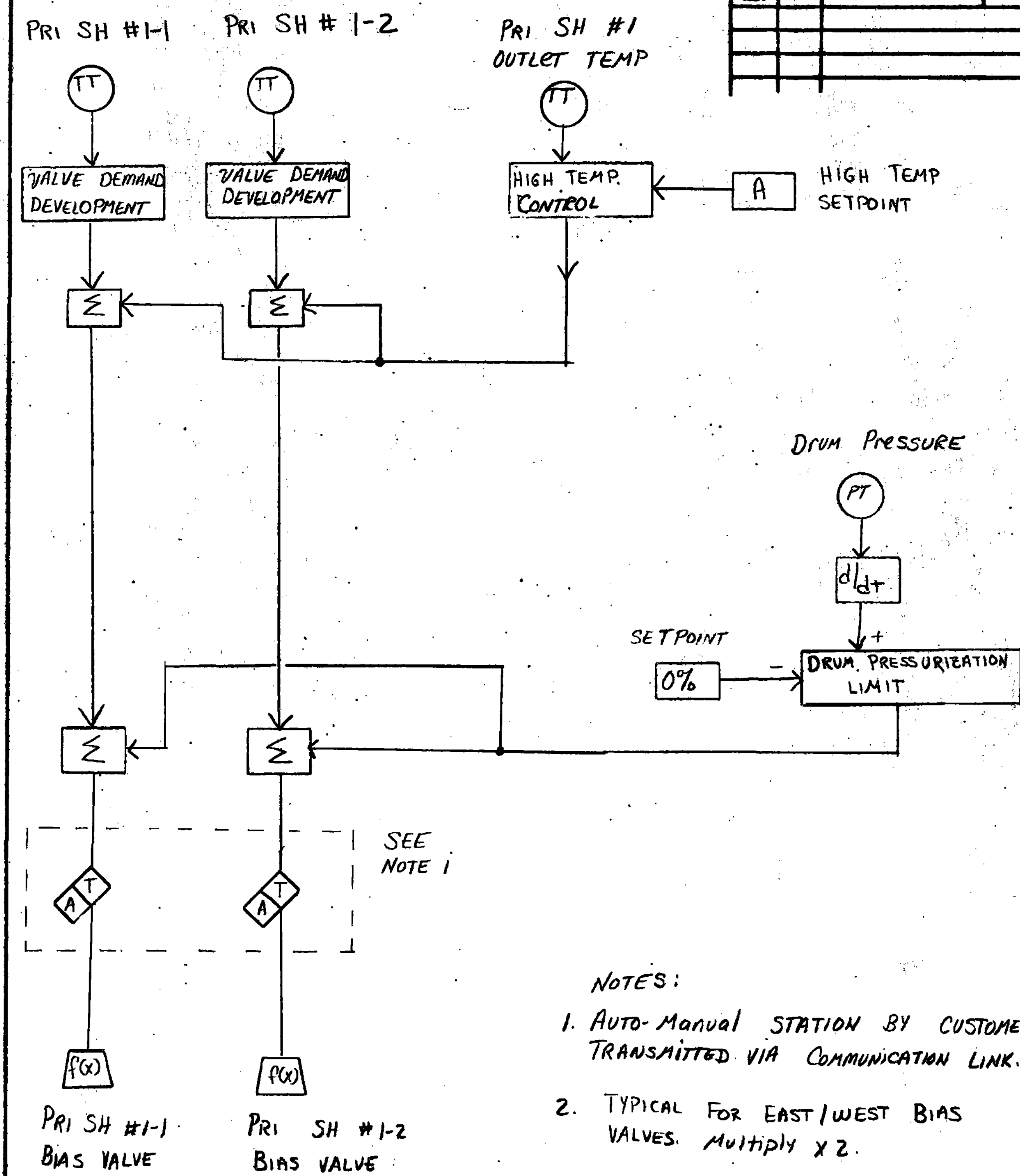
BABCOCK & WILCOX

SCALE NONE

280100E REV. 5

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

REVISIONS			MICRO-FILM
REGN NO.	DATE	DESCRIPTION	CHKG.



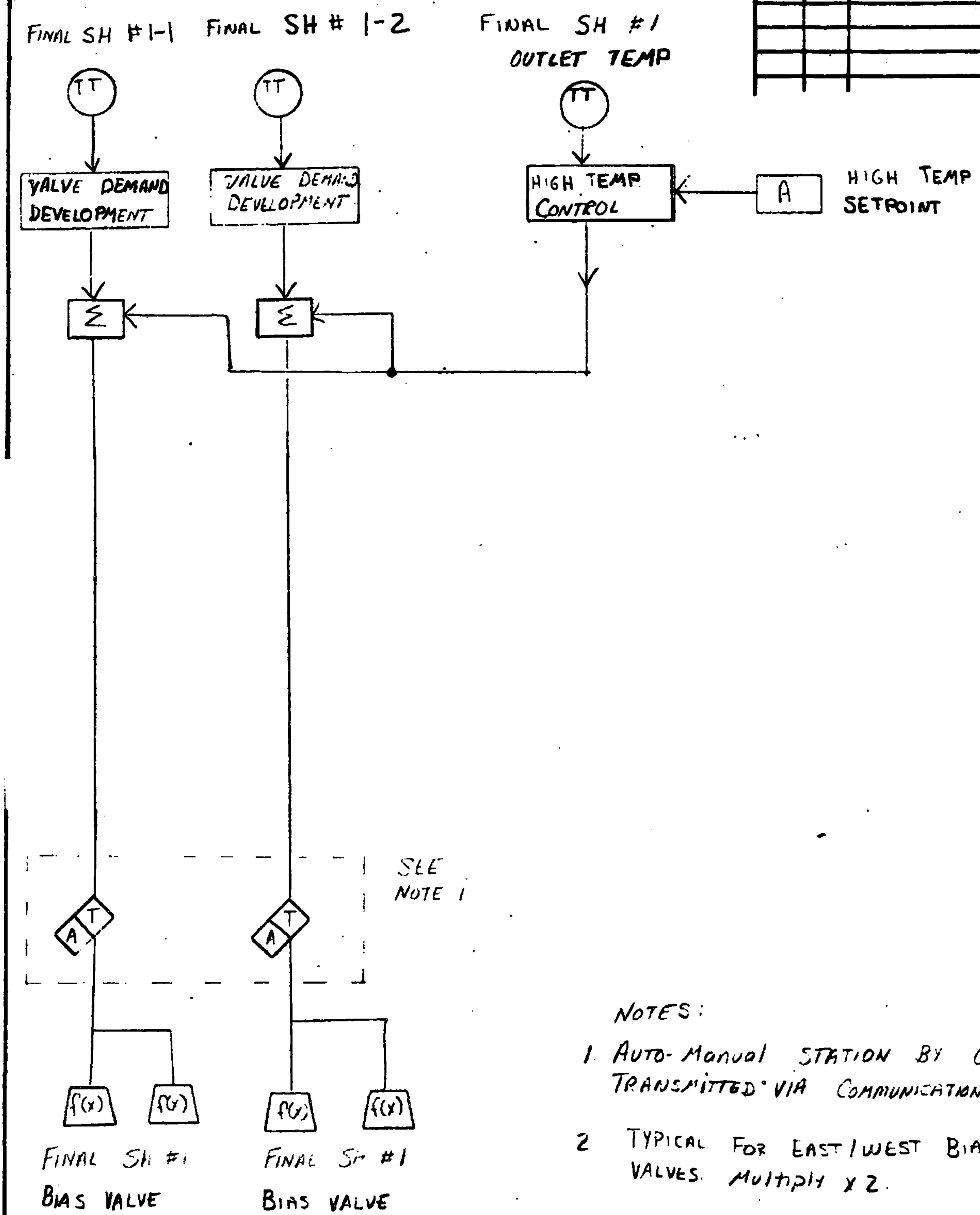
NOTES:

1. AUTO-MANUAL STATION BY CUSTOMER. TRANSMITTED VIA COMMUNICATION LINK.
2. TYPICAL FOR EAST/WEST BIAS VALVES. MULTIPLY X 2.

DWN. BY SEF	CHK'D SEF	PRI SH BIAS VALVE CONTROL FLOW DIAGRAM	SCALE — DATE 9/22/83
PASSED BY	APP'D		DRWG. NO. 891-1104-7 A-0

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

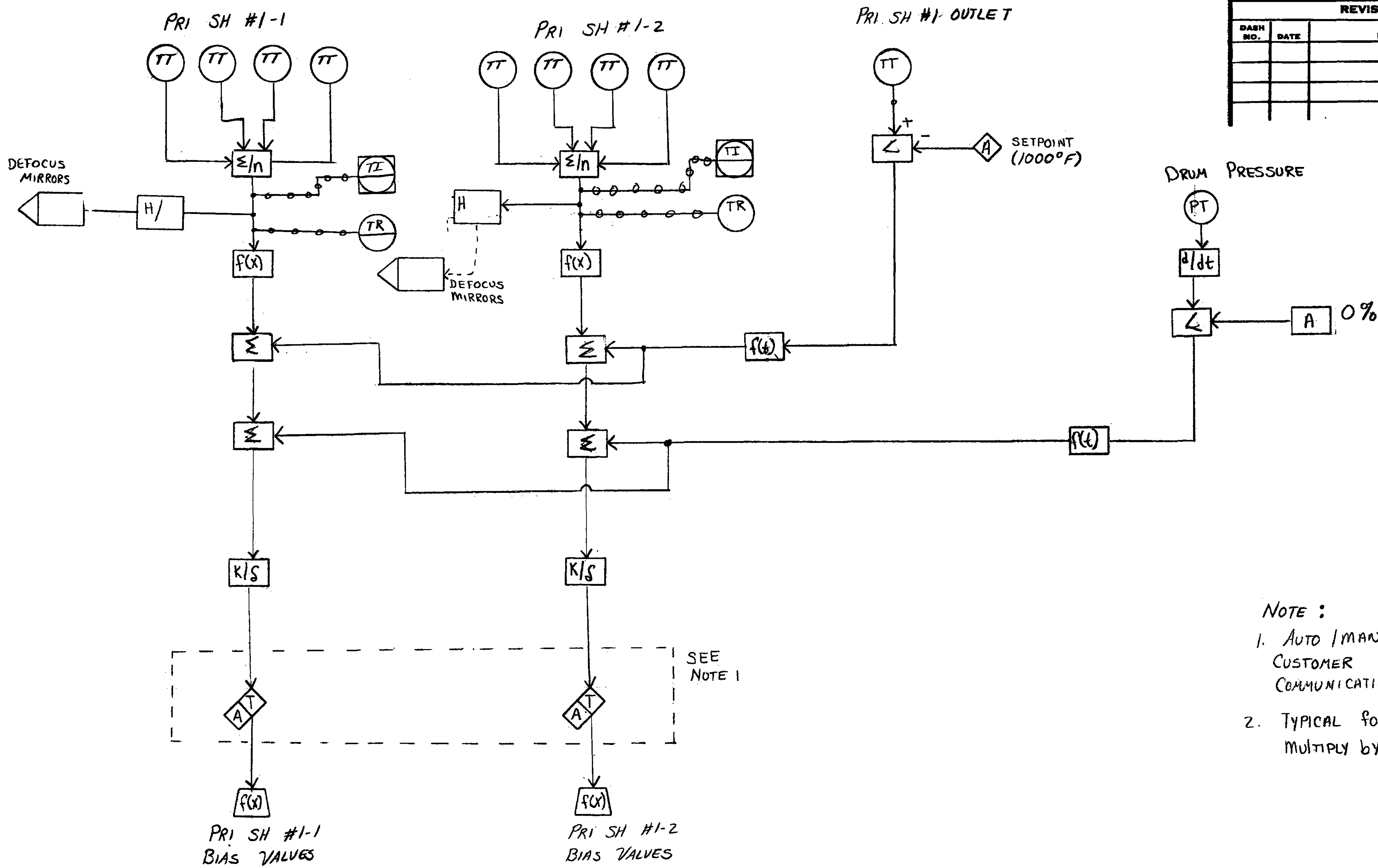
REVISIONS				MICRO-FILM
DASH NO.	DATE	DESCRIPTION	ORIG.	



NOTES:

1. AUTO-MANUAL STATION BY CUSTOMER. TRANSMITTED VIA COMMUNICATION LINK.
2. TYPICAL FOR EAST/WEST BIAS VALVES. Multiply x 2.

DWN. BY SEF	CHK'D SEF	FINAL SH BIAS VALVE CONTROL FLOW DIAGRAM	SCALE —	DATE 9/22/83
PASSED BY	APP'D		DRWG. NO. 891-1104-8	A-0



NOTE :

1. AUTO /MANUAL STATION BY CUSTOMER TRANSMITTED VIA COMMUNICATION BUS.
2. TYPICAL FOR EAST & WEST SIDE MULTIPLY BY 2.

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

REVISIONS			MICROFILM
DASH NO.	DATE	DESCRIPTION	ORIGINAL

DWN. BY SEF | CHK'D
DATE 8/22/83 | APP'D

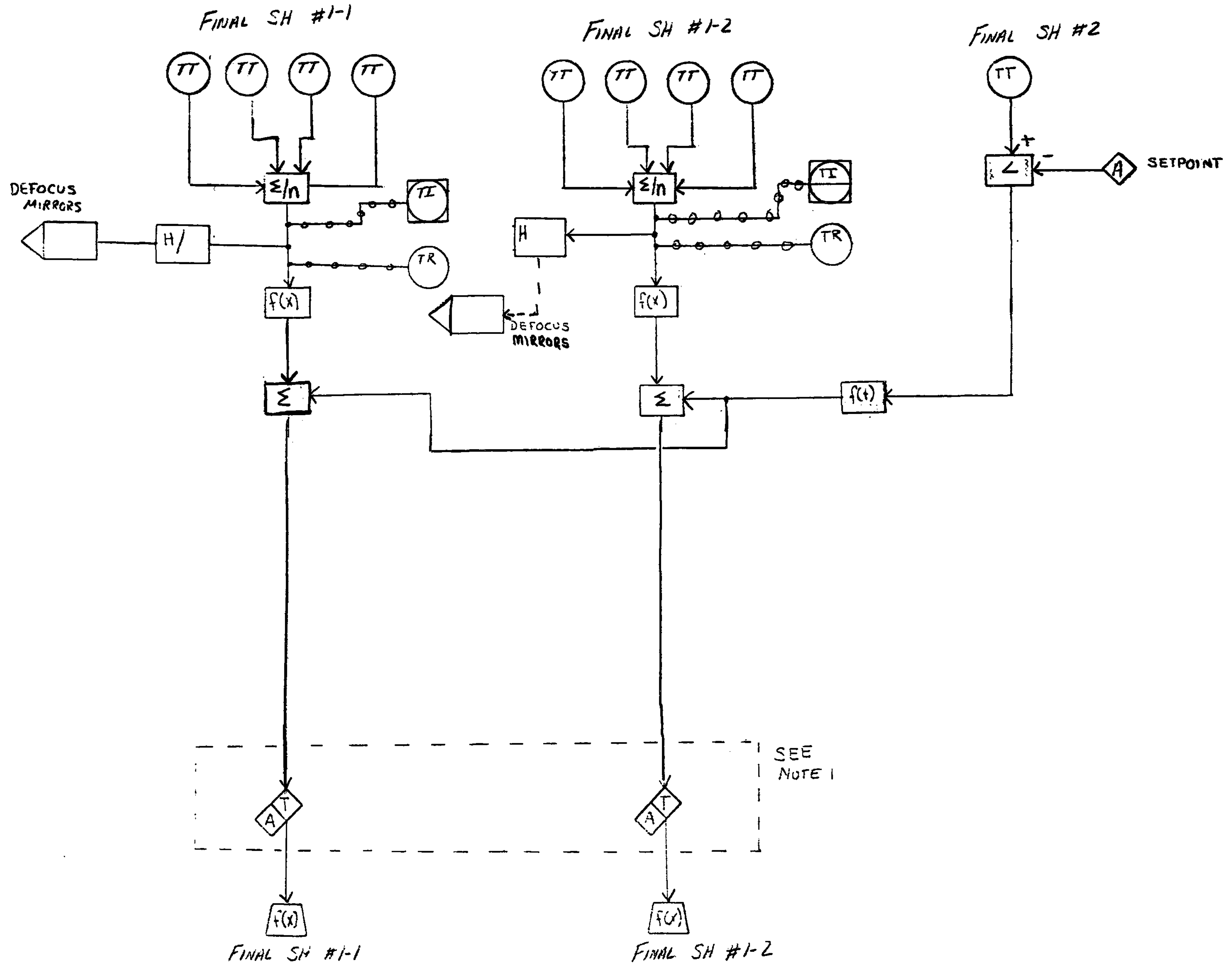
PRI SH BIAS VALVE CONTROL
ANALOG LOGIC DIAGRAM

SCALE | INCHES = 1 FOOT

891-1104-5 B-0

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

REVISIONS			MICROFILM
DASH NO.	DATE	DESCRIPTION	ORIGINAL



NOTE :

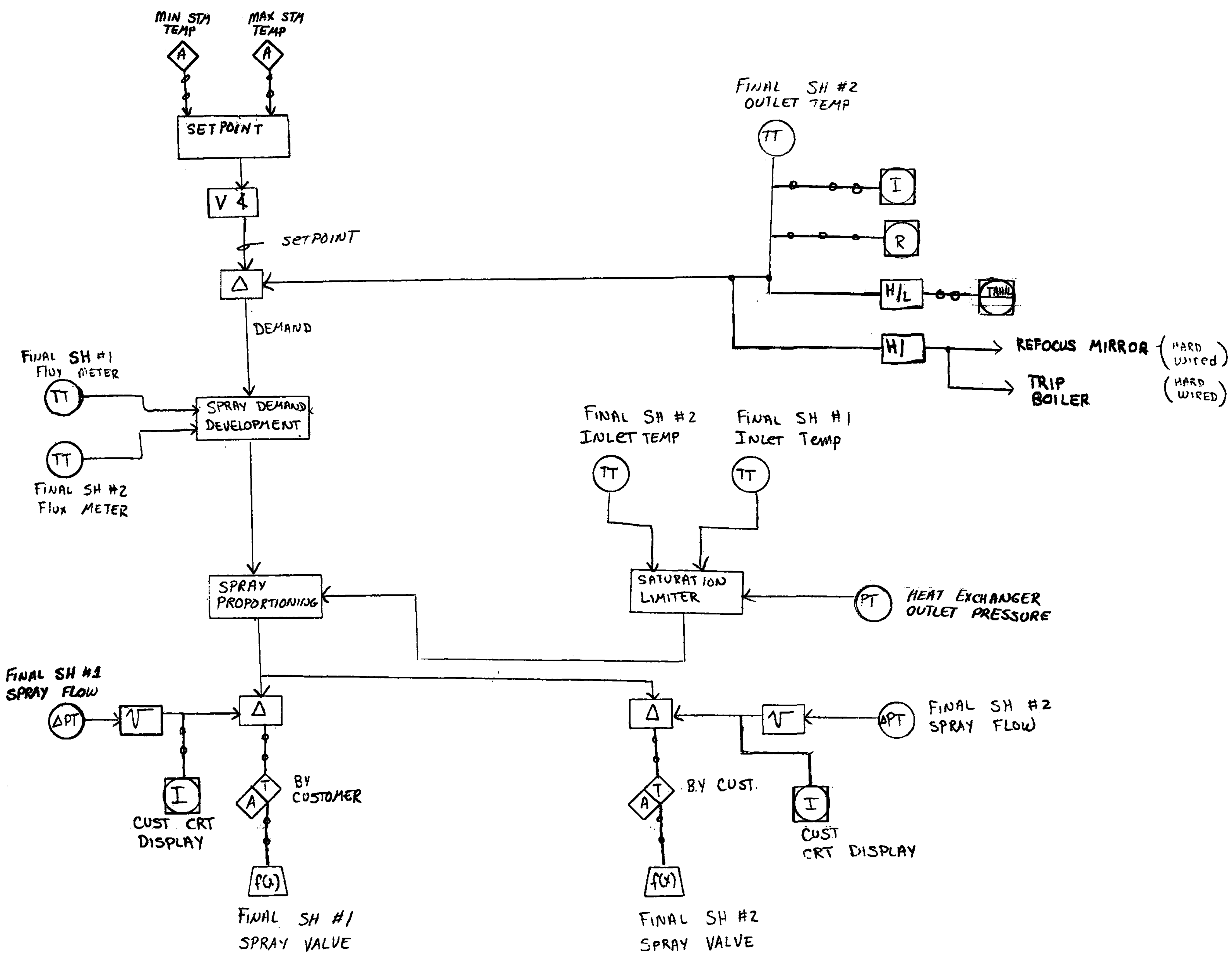
1. AUTO / MANUAL STATION BY CUSTOMER TRANSMITTED VIA COMMUNICATION BUS.
2. TYPICAL FOR EAST & WEST SIDE MULTIPLY BY 2.

DWN. BY JEF	CHK'D	FINAL SH BIAS VALVE CONTROL	SCALE	INCHES = 1 FOOT
DATE 8/22/83	APP'D	ANALOG LOGIC DIAGRAM	89-1104-6	B-0

THE BABCOCK & WILCOX COMPANY

POWER GENERATION GROUP

REVISIONS			MICROFILM	
DASH NO.	DATE	DESCRIPTION	ORIGINAL	



K&E NO. 19-1283

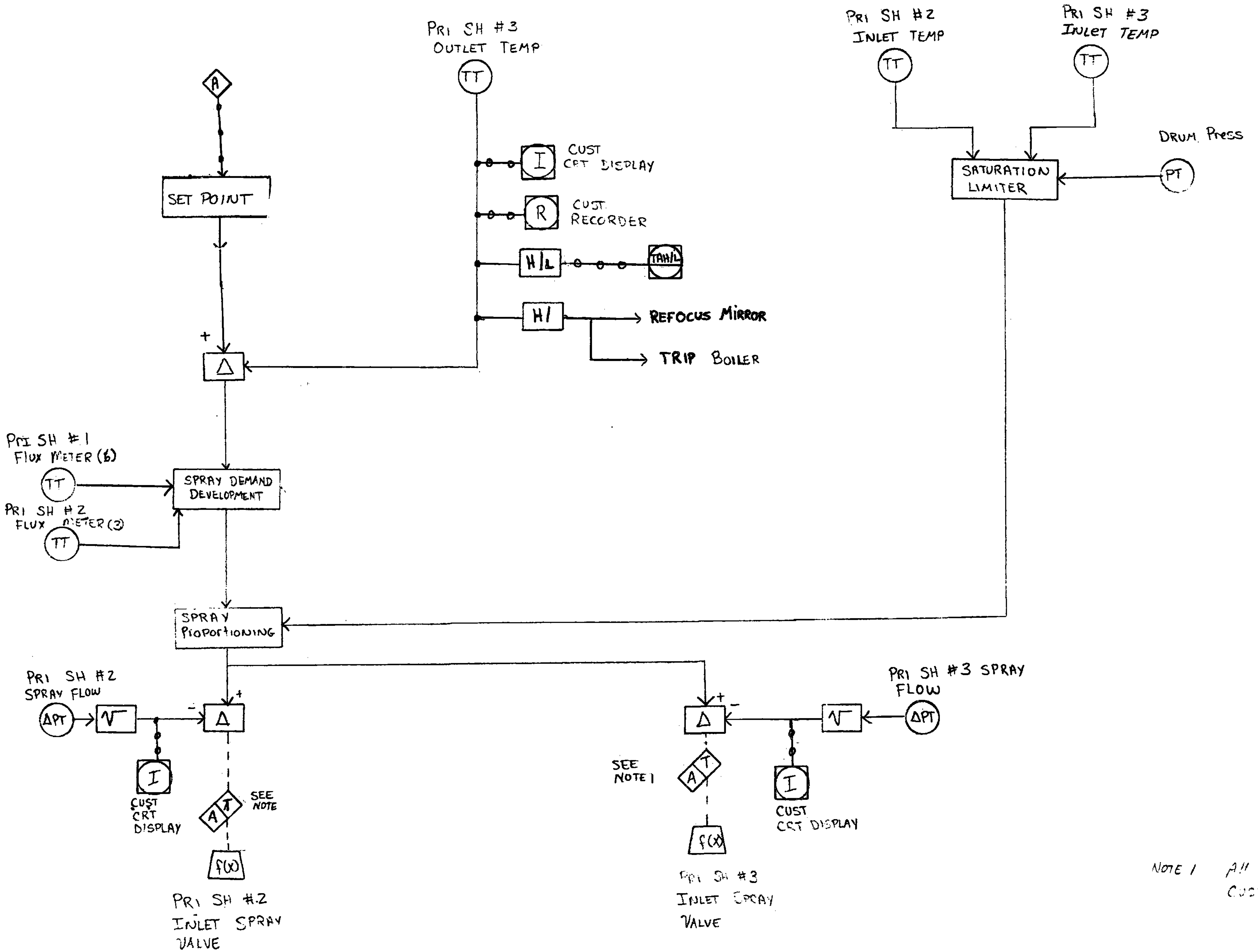
DWN. BY	JEF	CHK'D		FINAL SH SPRAY ATTEMP CONTROL FLOW DIAGRAM	SCALE	INCHES = 1 FOOT
DATE	8/27/83	APP'D			891-1104-4	B-0

FORM BDM 1067 8-4

THE BABCOCK & WILCOX COMPANY

POWER GENERATION GROUP

REVISIONS			MICROFILM	
DASH NO.	DATE	DESCRIPTION	ORIGINAL	



Note 1 All operator's stations by CUSTOMER

DWN. BY SEF	CHK'D	PRI SH SPRAY ATTEMP. CONTROL FLOW DIAGRAM	SCALE	INCHES = 1 FOOT
DATE 8/22/83	APP'D		891-1104-3	B-0

K&E NO. 19-1283

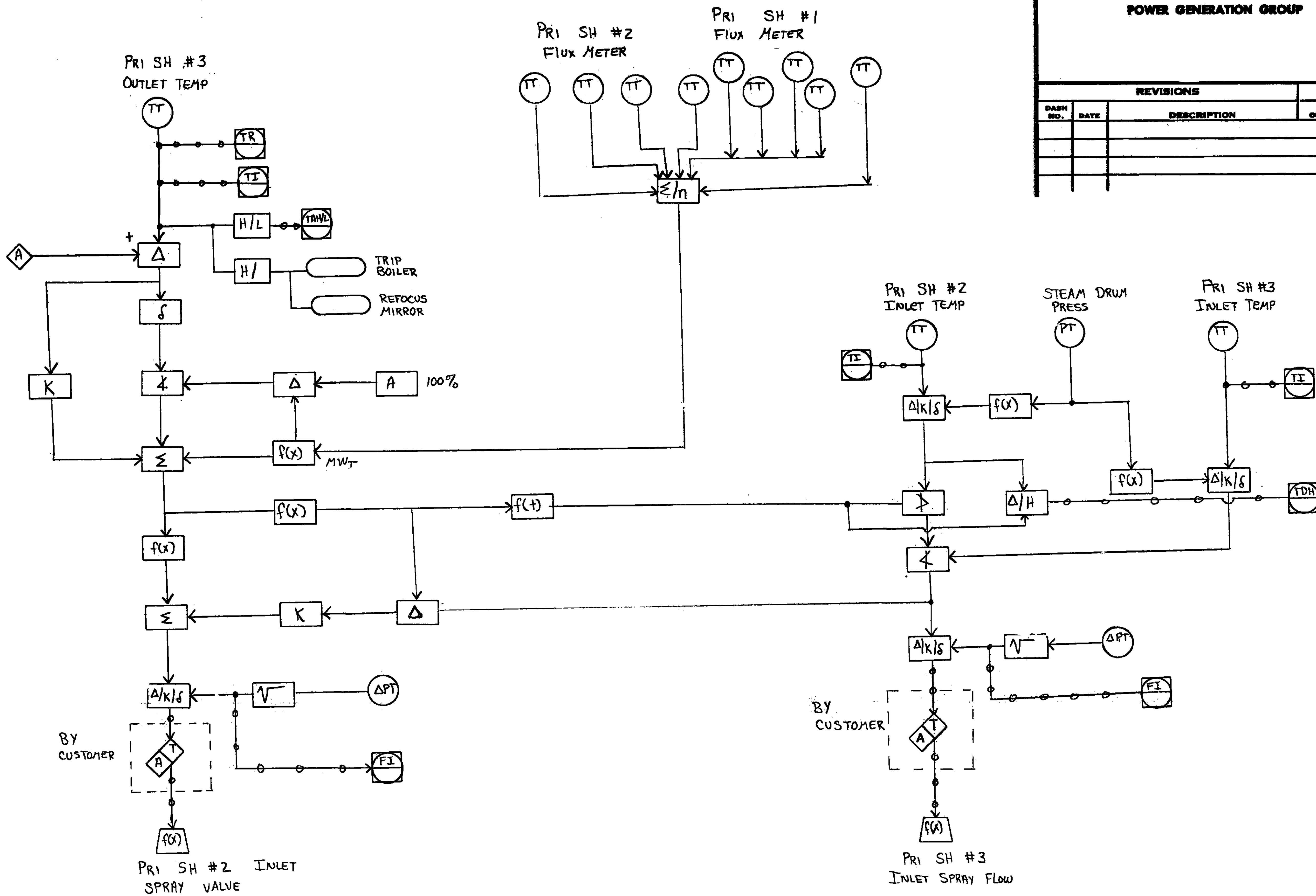
G.2-38

FORM BDM 1087 B-4

THE BABCOCK & WILCOX COMPANY

POWER GENERATION GROUP

REVISIONS			MICROFILM
DASH NO.	DATE	DESCRIPTION	ORIGINAL



DWN. BY SEF	CHK'D
DATE 8/22/83	APP'D

PRI SH CONTROL ANALOG LOGIC DIAGRAM

SCALE INCHES = 1 FOOT

891-1104-1 B-0

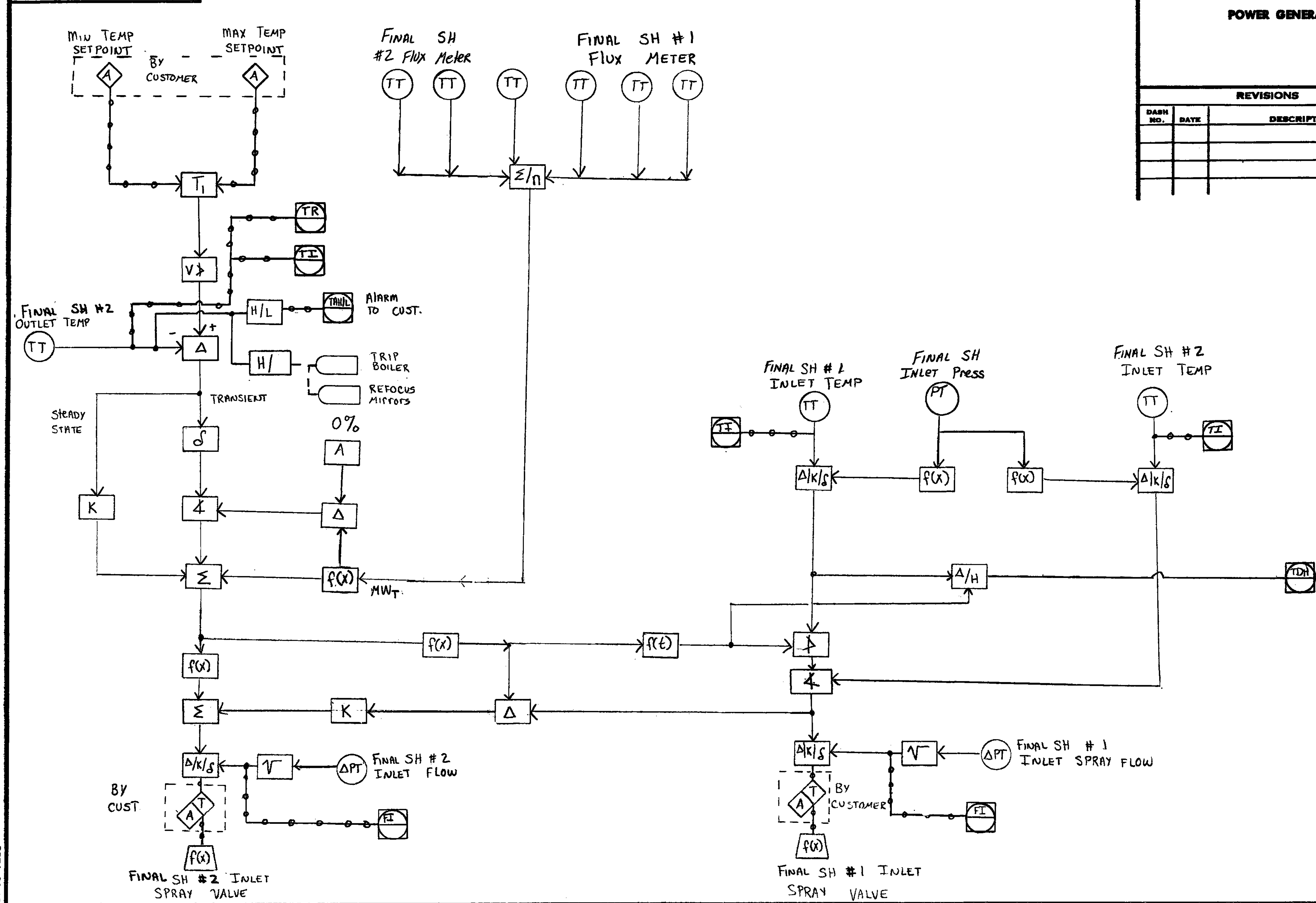
G.2-39

FORM RDM 1087 B-4

K&E NO. 19-1283

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

REVISIONS			MICROFILM
DASH NO.	DATE	DESCRIPTION	ORIGINAL



DWN. BY SEF | CHK'D
DATE 8/22/83 | APP'D

FINAL SH CONTROL ANALOG LOGIC DIAGRAM

SCALE | INCHES = 1 FOOT

891-1104-2 B-0

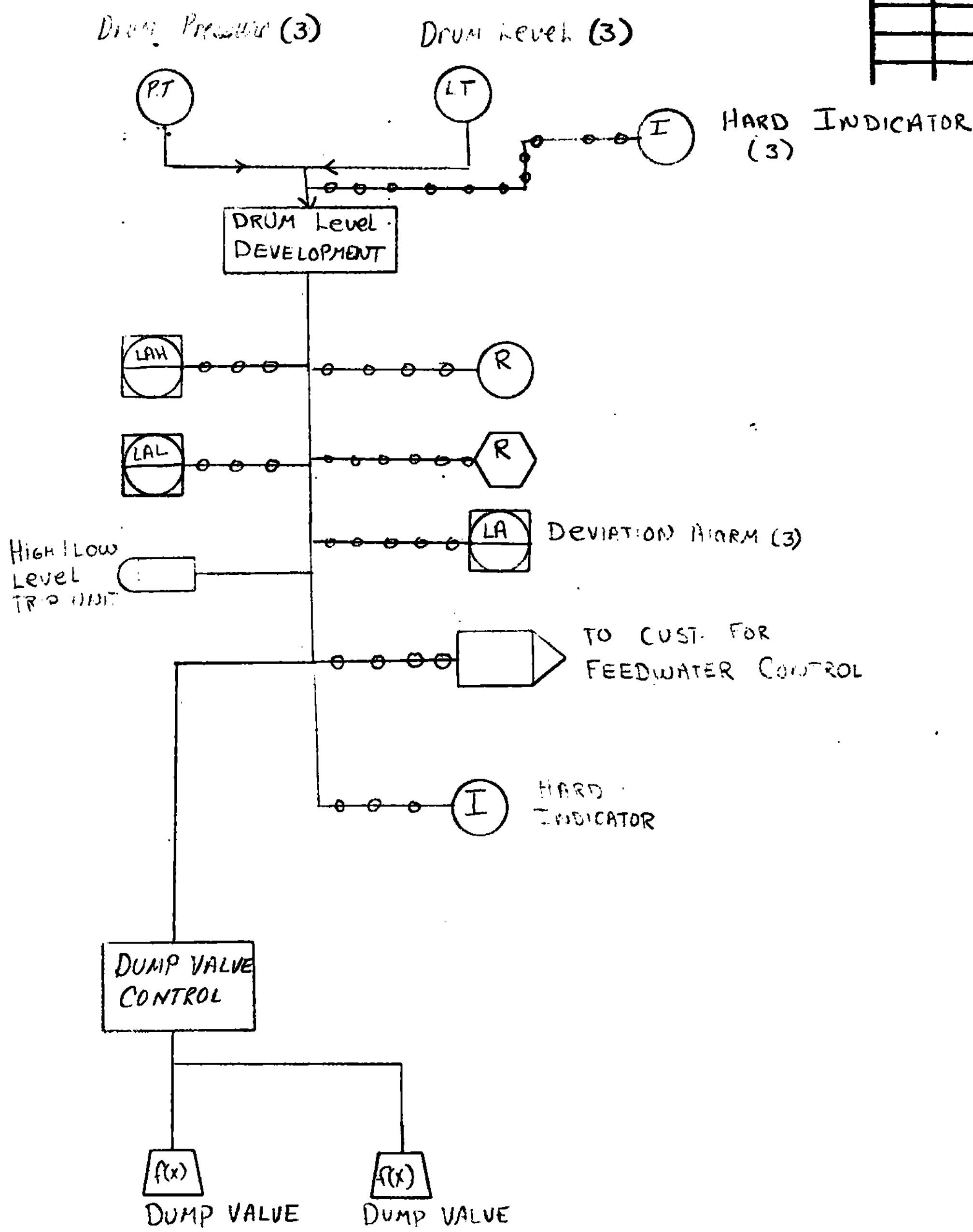
K&E NO. 10-1253

FORM RDM 1067 B-4

THE BABCOCK & WILCOX COMPANY

POWER GENERATION GROUP

REVISIONS			MICRO-FILM
DASH NO.	DATE	DESCRIPTION	ORIG.

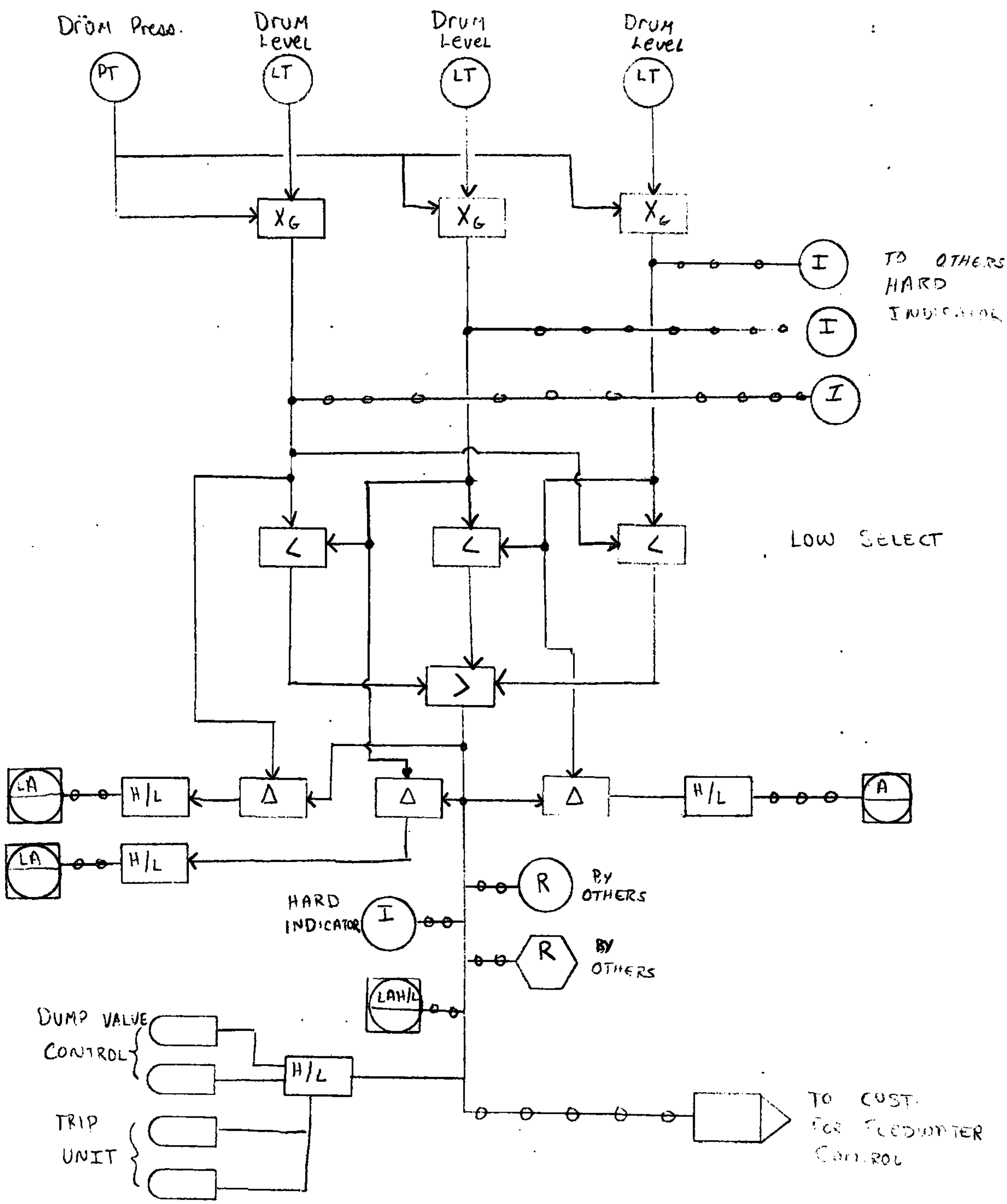


DWN. BY JEF	CHK'D	DRUM LEVEL CONTROL FLOW DIAGRAM	SCALE -N-	DATE 8/22/83
PASSED BY	APP'D		DRWG. NO. 891-1104-10	A-0

FORM BDM 1007 A-4

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

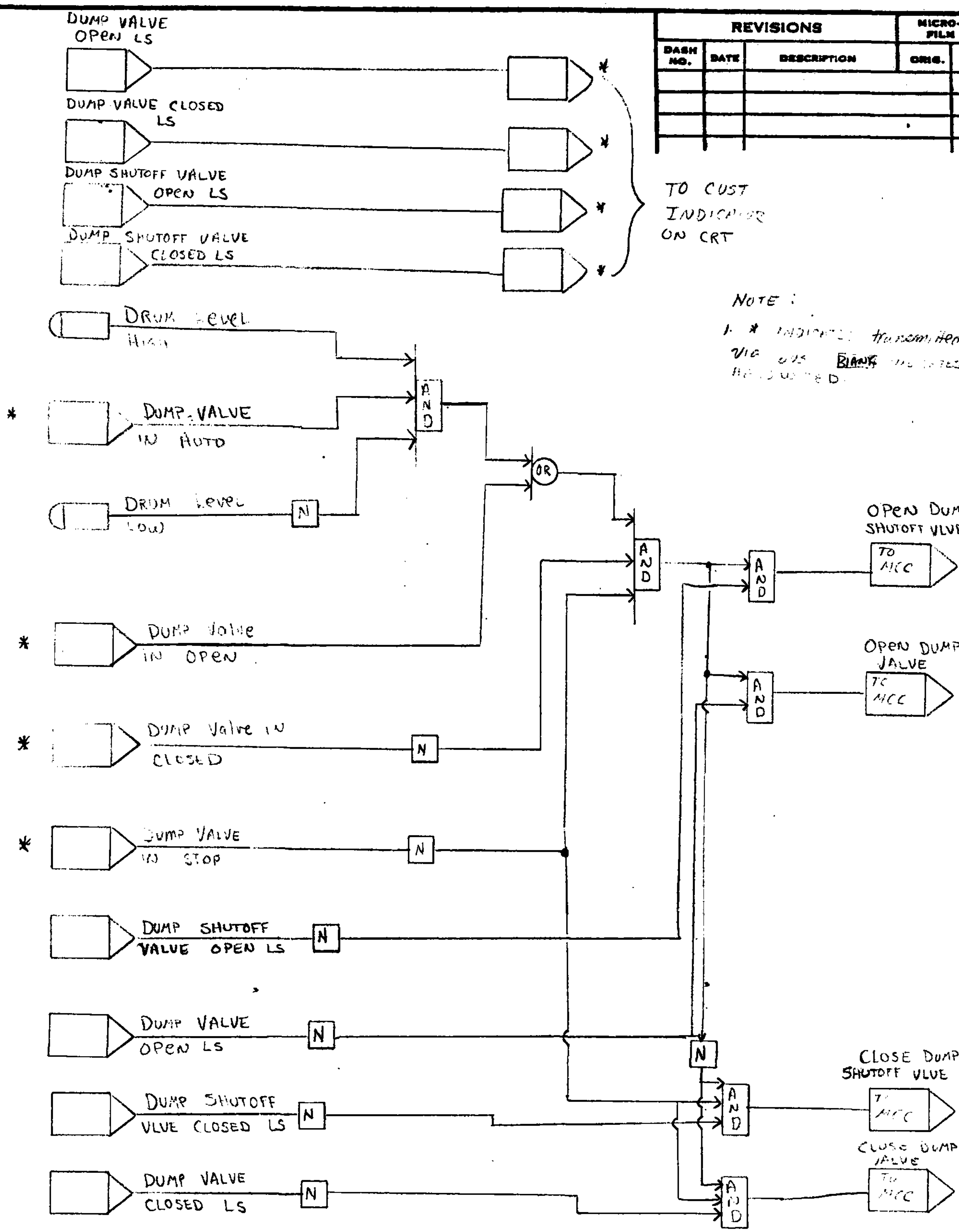
REVISIONS			MICRO-FILM	
DASH NO.	DATE	DESCRIPTION	ORIG.	



DWN. BY SEF	CHK'D	Drum Level Analog Logic Diagram	SCALE N	DATE 8/22/83
PASSED BY	APP'D		DRWG. NO. 891-1104-11	A-0

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

REVISIONS				MICRO-FILM
DASH NO.	DATE	DESCRIPTION	ORIG.	



DWN. BY	CHK'D		SCALE	DATE
DWN. BY *SEF*	CHK'D	DUMP VALVE CONTROL	SCALE	DATE
PASSED BY	APP'D		DRWG. NO. *891-1104-12*	A-0

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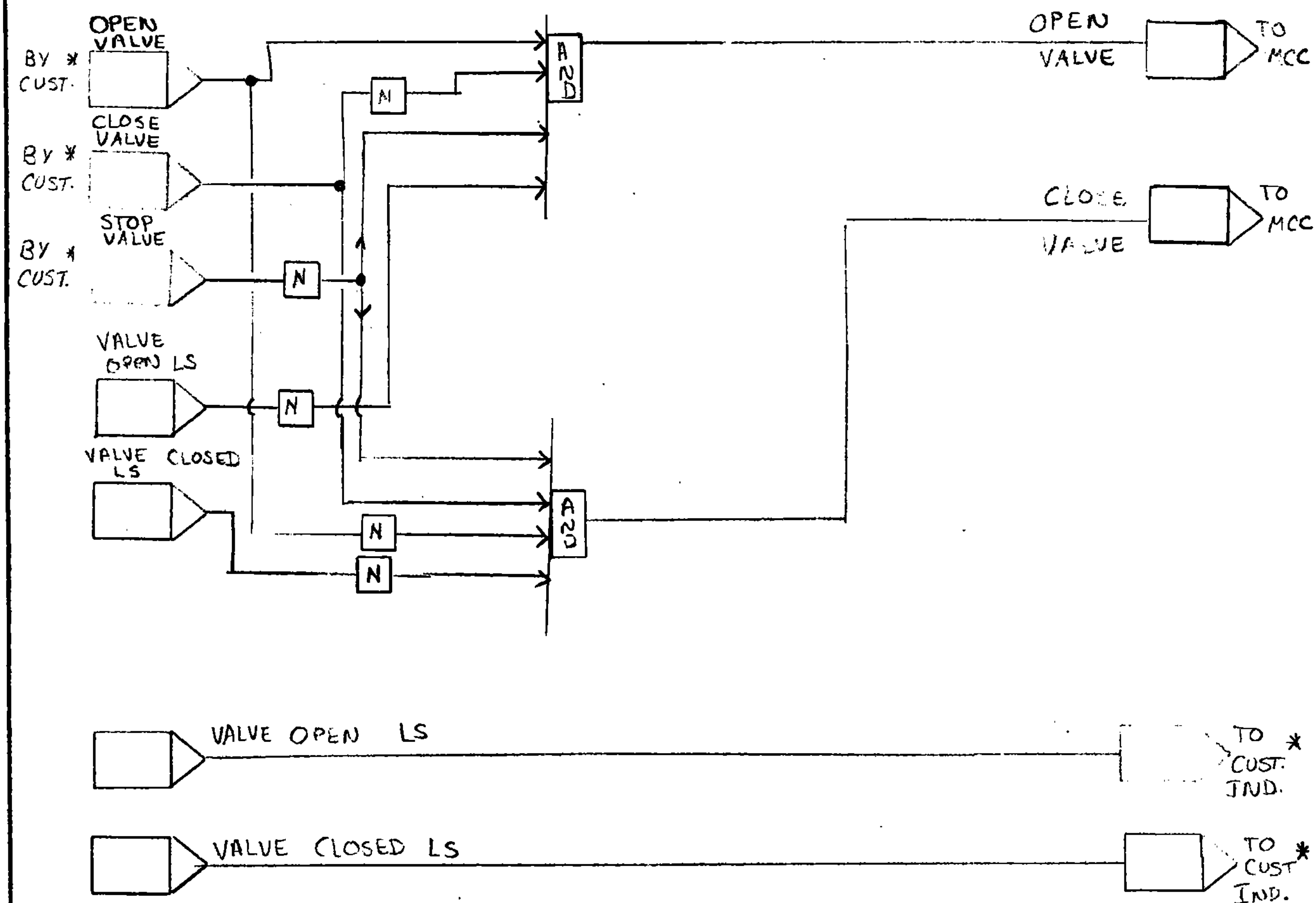
POWER GENERATION GROUP

REVISIONS			MICRO-FILM
DASH NO.	DATE	DESCRIPTION	ORIG.



TYPICAL FOR MOTOR OPERATED MANUAL OPEN/CLOSE VALVE

NOTE:

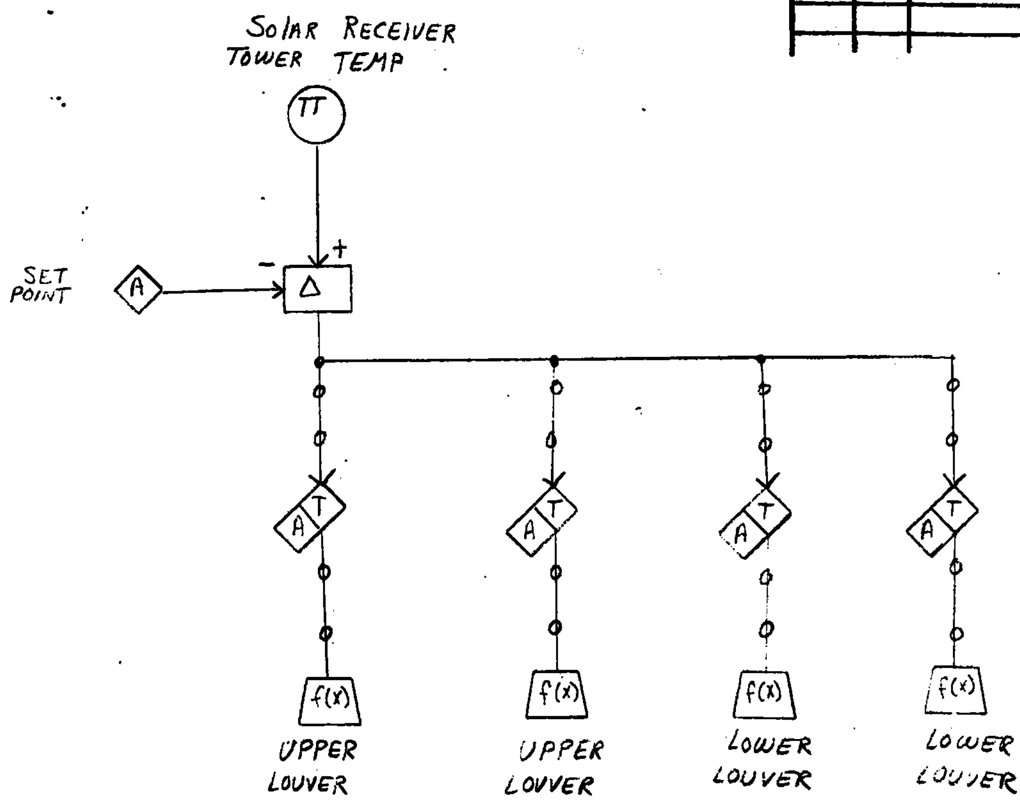
1. * INDICATES COMMUNICATION VIA BUS
   No * INDICATES HARD WIRED

2. Multiply 49 times

DWN. BY SEF	CHK'D	MOTOR OPERATED OPEN/CLOSE VALVE CONTROL TYPICAL	SCALE [illegible]	DATE 8/22/83
PASSED BY	APP'D		DRWG. NO. 891-1104-9	A-0

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

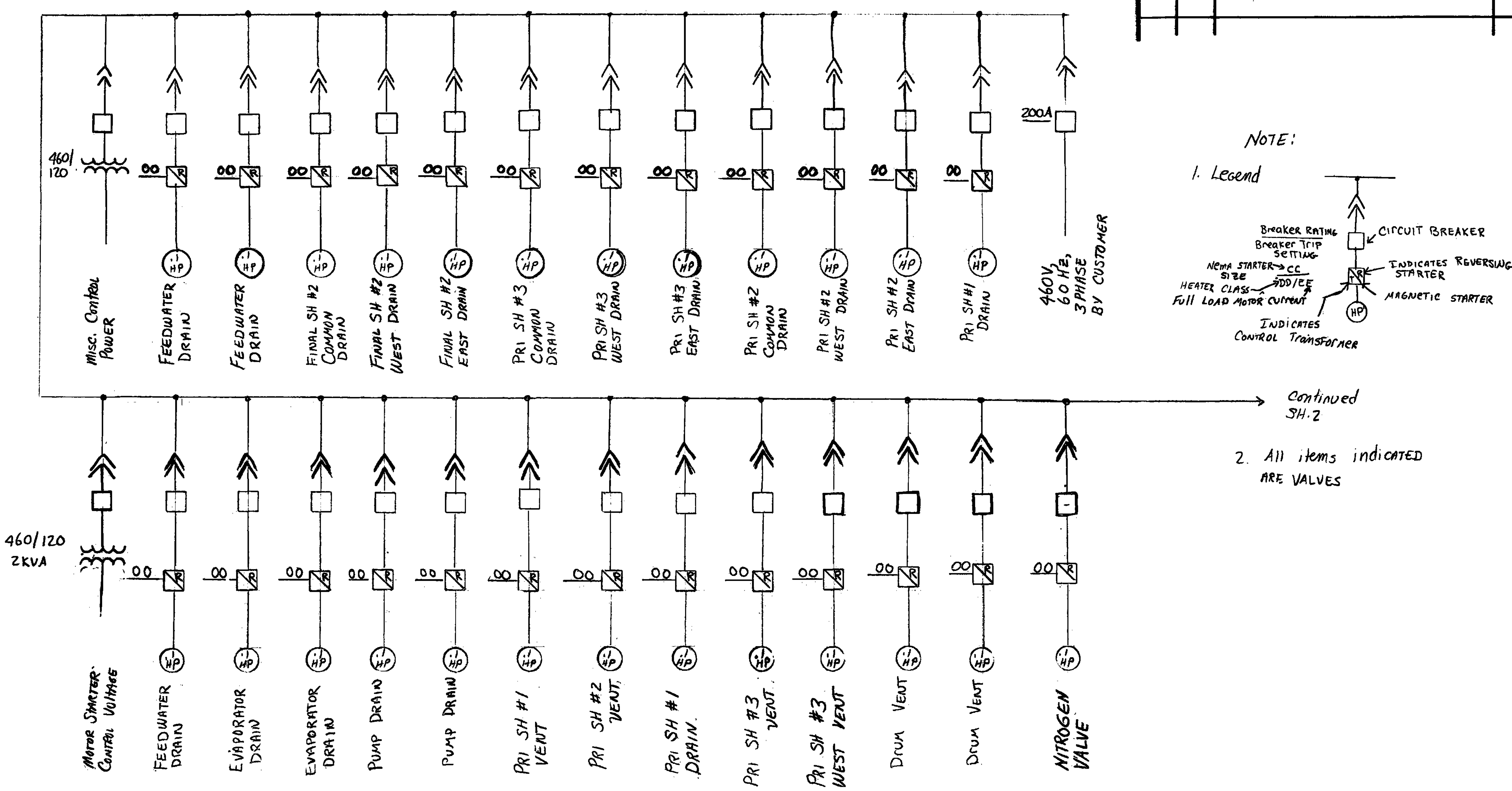
REVISIONS			MICRO-FILM
DASH NO.	DATE	DESCRIPTION	ORIG.



DWN. BY SEF	CHK'D	VENTILATION CONTROL	SCALE [illegible]	DATE [illegible]
PASSED BY	APP'D		DRWG. NO. 891-1104-13	A-0

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

REVISIONS			MICROFILM
DASH NO.	DATE	DESCRIPTION	ORIGINAL



DWN. BY SEF	CHK'D SEF	ONE LINE DIAGRAM 480V SH-1	SCALE INCHES = 1 FOOT
DATE 7/25/83	APP'D		188886 B-0

K&E NO. 19-1253

G.2-46

FORM BDM 1087 B-4

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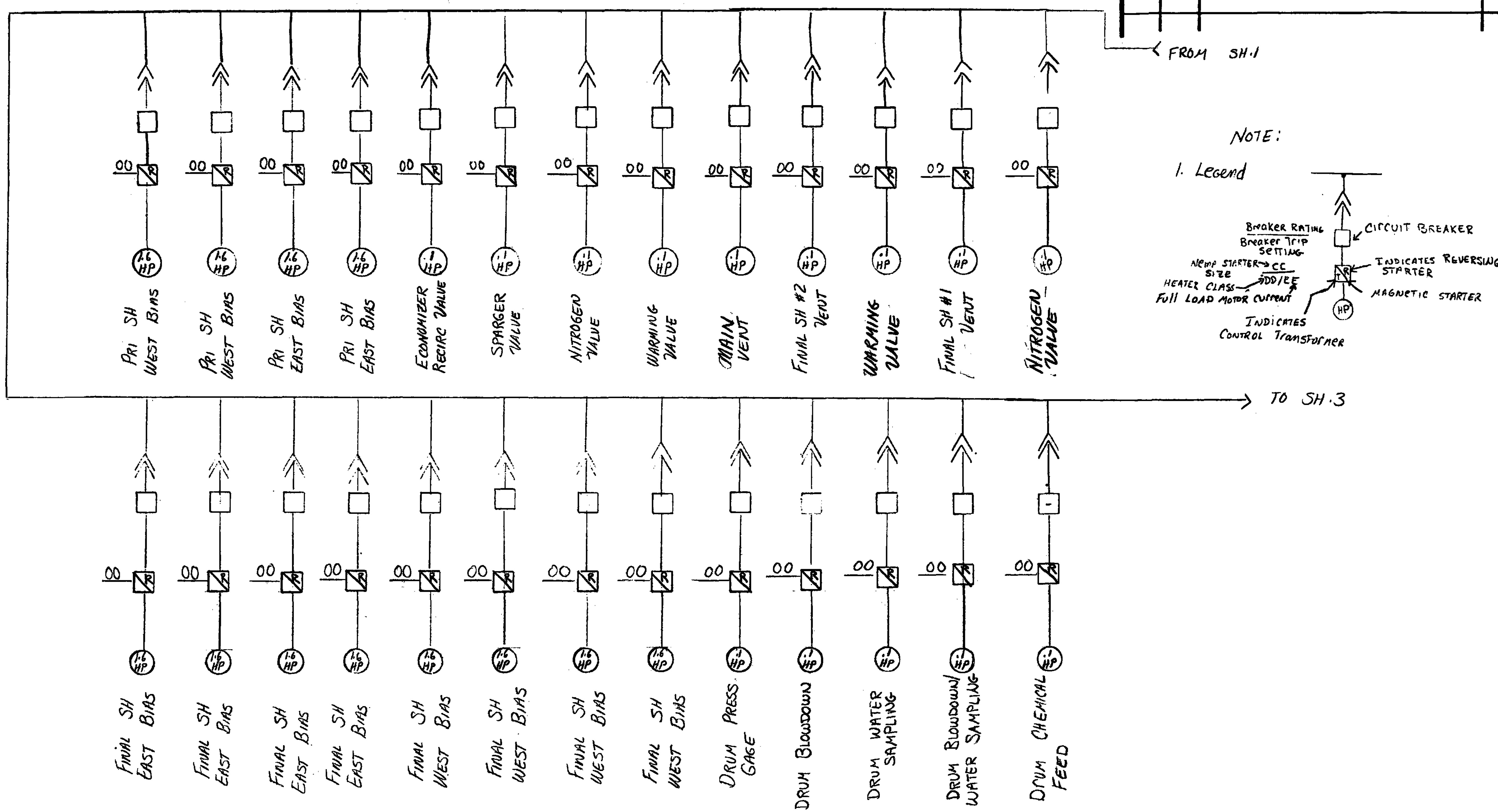
POWER GENERATION GROUP

REVISIONS			MICROFILM
DASH NO.	DATE	DESCRIPTION	ORIGINAL



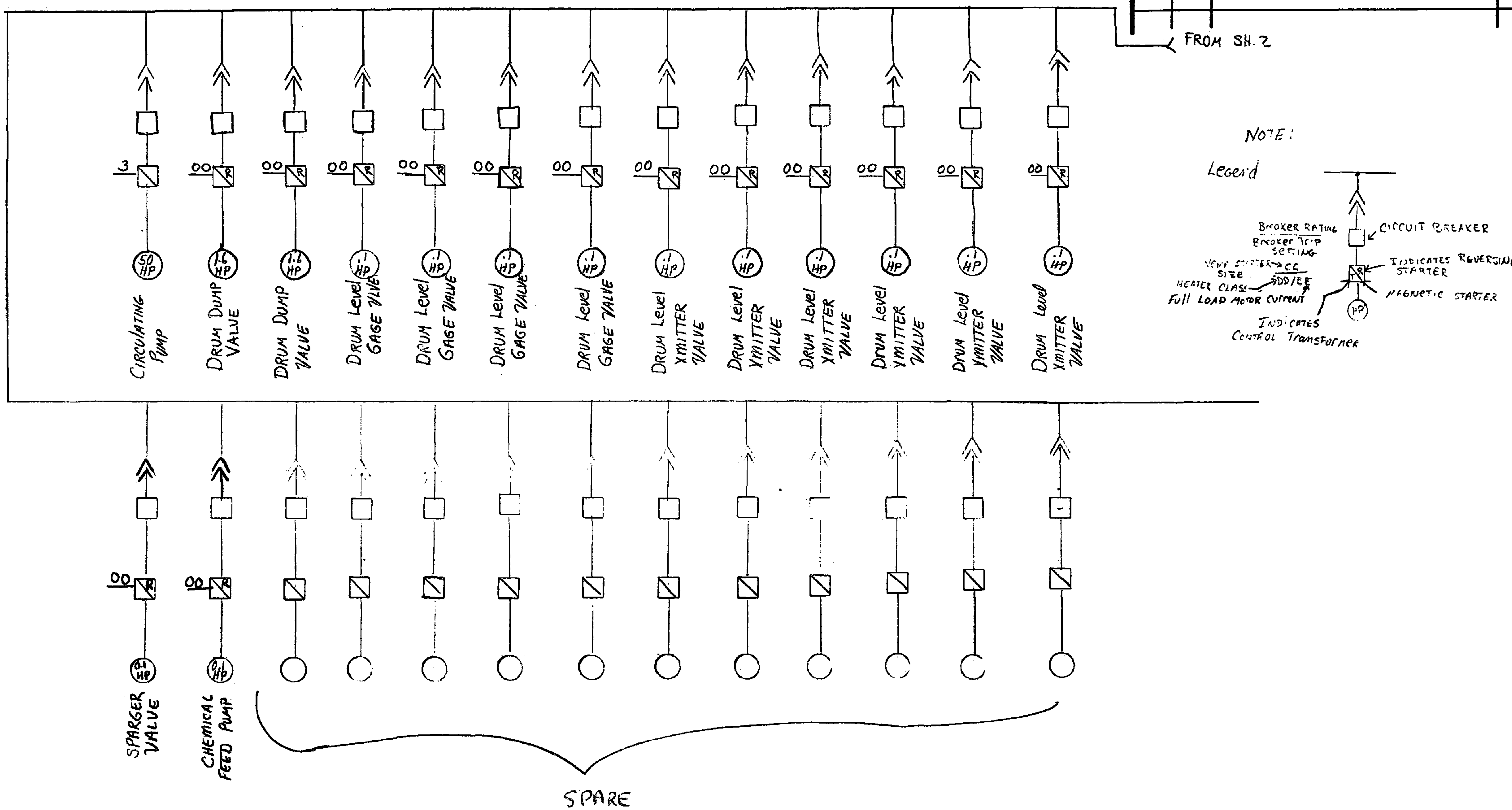
DWN. BY SEF	CHK'D SEF	ONE LINE DIAGRAM 480V SH.2	SCALE INCHES = 1 FOOT
DATE 7/25/83	APP'D		188887 B-0

G.2-47

K&E NO. 19-1253
FORM BDH 1067 B-4

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

REVISIONS			MICROFILM
DASH NO.	DATE	DESCRIPTION	ORIGINAL



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DWN. BY SEF	CHK'D SEF	ONE LINE DIAGRAM 480V SH. 3	SCALE	INCHES = 1 FOOT
DATE 7/25/83	APP'D		188888	B-0

K&E NO. 19-1283

G.2-48

FORM BDM 1097 B-4

APPENDIX G.3

G.3 RECEIVER THERMOHYDRAULIC PERFORMANCE

This section provides detailed computer printouts of the thermohydraulic performance analysis summarized in Section 5.3.3. Figure G.3-1 through G.3-5 present performance parameters for the receiver panels. For each panel, these printouts give information on heat absorption, efficiency flow rates, mass velocity, pressure drop, steam conditions, maximum tube OD temperature and the minimum safety margin at normal operating conditions and also at upset, unbalanced conditions. The superheater first pass flow control valves are assumed to be biased to keep the first pass outlet temperature the same in each panel. The safety margin is defined as the ratio of the maximum allowable heat flux to the actual expected heat flux. The "upset and unbalanced condition" in the computer printout refers to the highest possible steam temperature and highest metal temperatures of the most exposed "hot" tube in the panel, caused by extreme flow unbalance or heat upsets due to a combination of the following reasons:

- Tube manufacturing tolerances
- Header maldistribution
- Flux gradient on panel
- Heat flux peaks resulting from heliostat misalignment
- Insolation peaks on very clear days

The total flux upset factor (Fq) varies in both vertical and horizontal directions along the receiver. However, the flow unbalance factor (Fu) only changes from panel to panel and remains constant along the tube. It is estimated that the maximum heat flux upset factor including the gradiant is about 1.5 (+50 percent); the minimum flow unbalanced factor is about 0.83 (+17 percent) at the design point.

PANEL	9		10		7		12		4		15		5		14		8		11		3		16	
TYPE	BLR-	SH 1	BLR-	SH 1	BLR-	SH 1	BLR-	SH 1	BLR-	SH 2	BLR-	SH 2	BLR-	SH 3	BLR-	SH 3	BLR-	BLR	BLR-	BLR	BLR-	BLR	BLR-	BLR
OD	1.50	1.13	1.50	1.13	1.50	1.13	1.50	1.13	1.50	1.13	1.50	1.13	1.50	1.13	1.50	1.13	0.0	1.50	0.0	1.50	0.0	1.50	0.0	1.50
SPACE	2.03	1.40	2.03	1.40	2.03	1.40	2.03	1.40	2.03	1.40	2.03	1.40	2.03	1.40	2.03	1.40	0.0	2.03	0.0	2.03	0.0	2.03	0.0	2.03
NO. OF TUBES	16	26	16	26	16	26	16	26	14	29	14	29	14	29	14	29	0	16	0	16	0	16	0	16

PANEL ABSORPTION (MEMBRANE) (BTU/HR)												
	17065360.	16873712.	16161678.	15336605.	18505516.	13731912.	13712416.	14693460.	15836511.	15055388.	5072305.	8739228.
PANEL ABSORPTION (SCREEN) (BTU/HR)												
	15271896.	15100386.	14463172.	13724888.	7431432.	9640316.	9626627.	10315362.	0.	0.	0.	0.
PANEL PRESS DROP (PSI)												
	16.60	16.28	15.20	14.00	44.30	73.04	67.31	77.24	0.0	0.0	0.0	0.0
PANEL FLOW RATES (LBM/HR)												
	62495.2	61793.2	59185.8	56164.3	115632.9	150000.1	128229.7	137403.2	69886.9	69886.9	69886.9	69886.9
PANEL MASS VELOCITY (LBM/HR/SQ.FT)												
	558882.7	552604.8	529286.6	502266.4	927108.1	1202653.0	1028104.8	1101655.0	551537.3	551537.3	551537.3	551537.3
PANEL OUTLET CONDITIONS												
P (PSIA)	2037.03	2037.34	2038.42	2039.62	1982.78	1954.04	1871.75	1861.81	2055.54	2055.54	2055.54	2055.54
H(BTU/LB)	1407.49	1407.49	1407.50	1407.50	1385.57	1385.56	1492.62	1492.63	847.33	836.14	693.27	745.76
T (F)	900.59	900.61	900.71	900.77	865.69	863.78	1023.10	1022.61	639.70	639.70	639.70	639.70
MIN. SAFTY MARGIN												
MS =	1.15	1.17	1.21	1.17	1.85	1.52	1.36	1.20	0.0	0.0	0.0	0.0

FIGURE G.3-1
PERFORMANCE SUMMARY
COMPUTER PRINTOUT

PANEL	9	10	7	12	4	15	5	14	8	11	3	16
TYPE	BLR- SH 1	BLR- SH 1	BLR- SH 1	BLR- SH 1	BLR- SH 2	BLR- SH 2	BLR- SH 3	BLR- SH 3	BLR- BLR	BLR- BLR	BLR- BLR	BLR- BLR
---MAX. MEMBRANE OD TEMP. (F)---												
TOD =	1035.13	1025.92	1014.72	1006.41	928.64	942.96	1104.30	1096.60	731.57	723.56	668.07	708.96
UPSET AND UNBALANCED CONDITIONS -												
--- PANEL OUTLET CONDITIONS ---												
P (PSIA)	2037.24	2037.49	2030.51	2039.84	1908.88	1958.42	1877.16	1866.46	0.0	0.0	0.0	0.0
H(BTU/LB)	1444.09	1441.85	1452.06	1452.63	1423.11	1405.87	1521.04	1513.16	0.0	0.0	0.0	0.0
T (F)	955.28	951.07	967.60	968.55	920.72	893.33	1069.71	1056.31	0.0	0.0	0.0	0.0
--- MIN. SAFTY MARGIN ---												
FQ =	1.083	1.089	1.161	1.099	1.249	1.184	1.206	1.151	0.0	0.0	0.0	0.0
FU =	0.969	0.973	0.969	0.963	0.902	0.955	0.943	0.958	0.0	0.0	0.0	0.0
MS =	1.00	1.04	1.02	1.04	1.42	1.26	1.10	1.02	0.0	0.0	0.0	0.0
---MAX. MEMBRANE OD TEMP. (F)---												
FQ =	1.083	1.113	1.098	1.159	1.305	1.135	1.151	1.168	0.0	0.0	0.0	0.0
FU =	0.969	0.973	0.969	0.963	0.902	0.955	0.943	0.958	0.0	0.0	0.0	0.0
TOD =	1100.82	1090.19	1093.44	1091.95	1003.89	980.02	1163.31	1141.33	0.0	0.0	0.0	0.0

FIGURE G.3-2
PERFORMANCE SUMMARY
COMPUTER PRINTOUT

PANEL	6	13	2	17	1	18	8	11	3	16	6	13
TYPE	BLR- BLR	BLR- BLR	BLR- ECON	BLR- ECON	BLR- ECON	BLR- ECON	BLR- RH 1	BLR- RH 1	BLR- RH 1	BLR- RH 1	BLR- RH 2	BLR- RH 2
OD	0.0 1.50	0.0 1.30	0.0 1.00	0.0 1.00	0.0 1.00	0.0 1.00	0.0 1.13	0.0 1.13	0.0 1.13	0.0 1.13	0.0 1.13	0.0 1.13
SPACE	0.0 2.03	0.0 2.03	0.0 1.50	0.0 1.50	0.0 1.50	0.0 1.50	0.0 1.40	0.0 1.40	0.0 1.40	0.0 1.40	0.0 1.40	0.0 1.40
NO. OF TUBES	0 14	0 14	0 46	0 46	0 46	0 46	0 26	0 26	0 26	0 26	0 29	0 29
PANEL ABSORPTION (MEMBRANE) (BTU/HR)	12282170.	11999572.	4299210.	9756119.	571870.	2710966.	16054720.	16042740.	5375903.	9241552.	15870190.	15459777.
PANEL ABSORPTION (SCREEN) (BTU/HR)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PANEL PRESS DROP (PSI)	0.0	0.0	32.26	31.02	33.03	32.60	34.27	33.01	17.13	10.49	100.93	96.03
PANEL FLOW RATES (LBM/HR)	61151.0	61151.0	59909.6	59909.6	59909.6	59909.6	82781.9	82781.9	61106.7	61106.7	146038.2	142312.9
PANEL MASS VELOCITY (LBM/HR/SQ.FT)	551537.3	551537.3	480433.9	480433.9	480433.9	480433.9	740302.1	740302.1	547180.4	547180.4	1170888.0	1141019.0
PANEL OUTLET CONDITIONS												
P (PSIA)	2055.54	2053.54	2055.50	2056.75	2054.74	2055.16	1670.73	1671.19	1687.07	1686.51	1571.41	1576.31
H(BTU/LB)	821.56	816.95	446.04	537.96	384.57	420.32	1423.76	1413.94	1307.98	1371.22	1492.35	1492.32
T (F)	639.70	639.70	464.10	542.49	406.97	440.17	902.17	887.00	741.01	824.59	1007.49	1007.69
MIN. SAFTY MARGIN												
MS =	0.0	0.0	0.0	0.0	0.0	0.0	1.14	1.17	3.30	1.03	1.10	1.13

FIGURE G.3-3
PERFORMANCE SUMMARY
COMPUTER PRINTOUT

PANEL	5	13	2	17	1	18	8	11	3	16	6	13
TYPE	BLR- BLR	BLR- BLR	BLR- ECON	BLR- ECON	BLR- ECON	BLR- ECON	BLR- RH 1	BLR- RH 1	BLR- RH 1	BLR- RH 1	BLR- RH 2	BLR- RH 2

--MAX. MEMBRANE OD TEMP. (F) --

TOD =	721.59	713.87	473.88	564.29	411.30	448.76	1024.18	997.47	706.05	896.99	1092.38	1091.75

UPSET AND UNBALANCED CONDITIONS -

-- PANEL OUTLET CONDITIONS --

P (PSIA)	0.0	0.0	0.0	0.0	0.0	0.0	1671.36	1672.06	1691.44	1687.97	1576.51	1580.31
H(BTU/LB)	0.0	0.0	0.0	0.0	0.0	0.0	1452.36	1443.64	1379.15	1434.51	1512.51	1510.15
T (F)	0.0	0.0	0.0	0.0	0.0	0.0	947.49	933.58	836.37	920.06	1041.46	1037.69

-- MIN. SAFTY MARGIN --

FQ =	0.0	0.0	0.0	0.0	0.0	0.0	1.089	1.089	1.567	1.289	1.112	1.111
FU =	0.0	0.0	0.0	0.0	0.0	0.0	0.969	0.968	0.838	0.914	0.963	0.969
MS =	0.0	0.0	0.0	0.0	0.0	0.0	1.03	1.05	1.94	1.29	1.05	1.00

--MAX. MEMBRANE OD TEMP. (F) --

FQ =	0.0	0.0	0.0	0.0	0.0	0.0	1.089	1.123	1.533	1.259	1.147	1.130
FU =	0.0	0.0	0.0	0.0	0.0	0.0	0.969	0.968	0.830	0.914	0.963	0.969
TOD =	0.0	0.0	0.0	0.0	0.0	0.0	1076.47	1057.30	903.44	1012.97	1139.47	1128.85

HEAT ABSORBED BY COMPONENTS -

```
QECON  =  17338128.0 BTU/HR
QBLR   = 164558144.  BTU/HR
QSH 1  =  65437072.0 BTU/HR
QSH 2  =  24317360.0 BTU/HR
QSH 3  =  28405824.0 BTU/HR
QRH 1  =  47514720.0 BTU/HR
QRH 2  =  31329904.0 BTU/HR
```

FIGURE G.3-4
PERFORMANCE SUMMARY
COMPUTER PRINTOUT

DRUM PRESSURE = 2055.54 PSIA
FEEDWATER PRESSURE = 2087.76 PSIA

EXIT CONDITIONS (TO TURBINE) -

FROM SUPERHEATER			FROM REHEATER		
PRESSURE	=	1825.49 PSIA	PRESSURE	=	1553.66 PSIA
TEMPERATURE	=	1020.79 F	TEMPERATURE	=	1006.55 F
ENTHALPY	=	1492.63 BTU/LBM	ENTHALPY	=	1492.33 BTU/LBM
STEAM FLOW	=	265633.06 LBM/HR	STEAM FLOW	=	288351.31 LBM/HR

HEAT TOTALS -

		SH-BLR-ECON	REHEATER	SUM TOTAL
TOTAL INCIDENT	=	105.108 MW	28.297 MW	133.405 MW
TOTAL LOSSES -				
RADIATION	=	6.219 MW	2.231 MW	8.450 MW
CONVECTION	=	5.185 MW	1.406 MW	6.591 MW
CONDUCTION	=	0.526 MW	0.141 MW	0.667 MW
REFLECTION	=	5.255 MW	1.415 MW	6.670 MW
TOTAL ABSORPTION	=	87.924 MW	23.103 MW	111.027 MW

THERMAL EFFICIENCY OF SH-BLR-ECON PANELS = 83.651 %

THERMAL EFFICIENCY OF REHEATER PANELS = 81.647 %

OVERALL THERMAL EFFICIENCY OF RECEIVER = 83.226 %

FIGURE G.3-5
PERFORMANCE SUMMARY
COMPUTER PRINTOUT

G.4 RECEIVER MECHANICAL DESIGN

This section provides a detailed description of receiver panel assembly, including panel assembly, buckstay spacing, vortex shedding, insulation, and material selection.

G.4.1 Panel Assembly

The receiver panels incorporate a membrane wall construction. This type of panel construction is widely used in the power industry having several distinct advantages for solar application - structural integrity, increased absorption area, and light- and water-tightness.

The panel design differs for each receiver section. The evaporator portion of the receiver uses a 38.1-mm OD X 3.40-mm (1.5-in. OD X 0.134-in.) tube with a 12.7-mm (0.5 in.) web that is fabricated using standard B&W shop methods and equipment. The economizer panel, 25.4-mm OD X 3.40-mm (1.0-in. OD X 0.134-in.) tube and 12.7-mm (0.5-in.) web (width), is also shop fabricated according to B&W methods. The superheat panels use 28.6-mm OD X 3.0-mm (1 1/8-in. OD X 0.110-in.) tubes and 6.35-mm (0.25-in.) web, constructed of Incoloy 800H material and require a somewhat modified method of fabrication. Conventional membrane wall construction uses a larger bar to form the web which separates the water tubes. Weldment of the bar to the tube wall becomes increasingly difficult for smaller web sizes because of twisting and distortion that occurs. For the smaller web size of the superheat panel, a rod is used in place of the bar. Fillet welds are applied on both sides at the corners to achieve the desired geometry. These superheat panels will be shop fabricated using existing equipment. Approximately 17 months will be required for this fabrication since the process is much slower than for the normal panel geometries.

Three types of panel assemblies are used in this design - an economizer and a 26 or 29 superheat tube interlaced panel. Details of the geometry and material are given in Table G.4-1. The panel assembly is shop fabricated to minimize field work and includes a lateral restraint system and attached headers. The panels are shipped to the site, three panels per rail carrier, where they are completed. Ground work includes installation of insulation, casing, connections and vertical members. An erection rig orients the panel to a vertical position at which time the panel assembly is hoisted external to the tower to the receiver level. The panel assembly facilitates the erection process by reducing the amount of work performed in the field.

Each panel is supported from a cantilevered top support steel arrangement which is similar to the method employed by conventional fossil boiler designs. Downward thermal growth is permitted via roller connections that guide each panel independently in the vertical position. The receiver panels are laterally restrained to remove wind and seismic loads, limit vibration, and maintain the vertical plane of the receiver, thereby offering a light-tight and weatherproof design. The interlaced panel design combines the evaporator and superheat panel into a single assembly. The superheat panel is "sandwiched" between two evaporator panels on either side in the panel assembly. The evaporator discharge headers (at the top of the panel) extend across the full panel assembly width and support the entire weight of the panel assembly. Two support rods transfer this vertical load to top steel. The interlaced superheat panel is supported from the evaporator header by lug connections and links that allow for differential growth of the headers. Operating at higher temperatures, the superheat panel is permitted to thermally grow independently from the surrounding evaporator panel. Gaps are provided between the superheat panel and evaporator panels and between panel assemblies that allow for horizontal thermal growth. A stainless steel horizontal tee section or buckstay is attached to the superheat panel and transfers lateral loads to a vertical buckstay that is bolted to the main support structure. The weight of the vertical buckstays is then supported from the main steel structure at the trussed elevations.

The evaporator panels located on either side of the superheat panel are supported from a carbon steel horizontal tee section or buckstay and guided by the same vertical buckstays independent of the superheat panel. This scheme is shown in the sketch of Figure G.4-1. The centerline of each panel assembly is a line of zero thermal growth. This limits the maximum panel movement that occurs. In cold position, a clearance that allows for thermal expansion is provided between the roller flange and the vertical buckstay. In the hot position, the flanges of the roller assemblies make contact with the vertical buckstay maintaining vertical alignment of the superheat panel. This alignment is necessary to eliminate the potential for sliding surfaces between the panels which can lead to excessive wear patterns. Since all of the evaporator panels operate at approximately the same temperatures, the differential downward growth is negligible, and therefore some contact between adjacent panel assemblies is permissible.

The roller assembly consists of four flat tread trolley wheels bolted to a stem that is rigidly attached to the horizontal panel buckstay (Figure G.4-1). The use of four wheels permits the vertical growth of the panels and prevents rotation of the support, which significantly reduces lateral displacement due to thermal bowing. Limiting panel deflection is an important design consideration to reduce the possibility of gap formations between panel sections and to prevent contact of overlapping panels. The tapered flanges of the trolley wheels serve to guide the individual panel sections vertically without any possibility for hangup or binding against the vertical buckstay. A lateral support system using linkage was investigated that posed numerous design problems associated with wearing surfaces. A system of roller supports was selected as an alternative which lessened the complexity involved, eliminated the design uncertainties, and proved to be comparable in cost without sacrificing structural integrity.

The centerline of the superheat panel is maintained by a bumper tie located on the top and bottom of each horizontal buckstay. This tie, which also removes lateral load occurring in the plane of a receiver panel, consists of a square lug and filler bar welded to the panel and is guided vertically by small bars welded to the buckstay. Lateral restraint normal to the panel is accomplished using stainless steel tube clips welded to the backside of the panel and allows for lateral thermal growth by sliding on the buckstay. Lateral movement is limited to the thermal growth of half of the width of a superheat panel for which the possibility for binding or excessive wear is non-existent.

The evaporator panel operates at lower temperatures; therefore the use of tube clips here is not necessary. The panel is welded directly to the bottom of the buckstay. Vertical alignment of the evaporator panel section is also maintained by flanged roller assemblies mounted to the horizontal buckstay and roll along the flanges of the vertical buckstays.

The use of filler bars and tube clips to anchor the panels to the buckstays is not new and is justified by their use in the fossil power industry. Experience indicates that the tube clip is the best method for tieing back membrane walls. Concentrated stresses that develop in the tube wall at the attachment have been determined to be insignificant. This is reasonable since temperatures are much lower on the tube backside and thermal gradients are small.

Return lines are anchored to the vertical buckstays near the top of the panel assembly using bolted clamp connections which totally constrain these pipe ends. The supply lines are also anchored to the vertical buckstays but utilize roller supports to permit downward growth. The roller supports are designed to provide constraint for the remaining five degrees of freedom. Some vertical piping deadweight is absorbed by the panel assembly, but the amount is negligible.

G.4.2 Buckstay Spacing

The panel design is established on the basis of internal pressure, deadweight, frequency of vibration, wind, seismic, thermal loads, and geometric requirements. The lateral restraint spacing has been set at 1.83 m (6 ft) to satisfy stress and deflection requirements. This spacing assures straightness of the superheat portion of the panel during maximum thermal loading. To verify the selected spacing, the membrane panels are assumed to act as beams having fixed end supports (the lateral restraints do not permit rotation).

The controlling load is wind and the resulting moment is therefore:

$$M_x = \frac{w\ell^2}{12}$$

$$= 150 \text{ cm-kg } (130 \text{ in.-lb})$$

and the corresponding longitudinal stress is:

$$S = \frac{M_x}{S_x}$$

$$= 108 \text{ kg/cm}^2 \ (1530 \text{ psi})$$

Where: M_x = bending moment
S^x = bending stress
w = unit lateral load = 5.36 kg/m (0.300 lb/in.)
ℓ = span length = 183 cm (72 in.)
S_x = section modulus = 1.40 cm^3 (0.085 $in.^3$)

Due to the presence of insulation and to prevent cracking of paint on the absorption surface, maximum lateral deflection is limited to:

$$\text{Max.} = \frac{\ell}{360}$$

$$= 0.51 \text{ cm } (0.20 \text{ in.})$$

$$\text{actual} = \frac{w\ell^4}{384\ EI}$$

$$= 0.051 \text{ cm } (0.020 \text{ in.})$$

Where: ℓ = span length = 183 cm (72 in.)
E = modulus of elasticity = 160 X 10^4 kg/cm^2 (22.7 X 10^6 psi)
I = moment of inertia of 1 tube = 2.08 cm^4 (0.050 $in.^4$)

and $0.051 < 0.51$ cm.

Therefore deflection limit is satisfied.

The membrane panels are designed to exceed a natural frequency of vibration of 5 hertz to prevent development of resonance. For fully restrained ends, and neglecting the beneficial effects of tension (deadweight), the natural frequency for a 1.83 m (6 ft) span of the superheat panel is:

$$f = \frac{[(2i + \ell)\ \pi/2]^2}{2\pi\ell^2} = \frac{EI}{m}^{0.5}$$

Where: i = 1 for first mode shape
l = span length
E = modulus of elasticity
I = moment of inertia
m = mass = weight per unit length divided by gravitational acceleration

The panel frequency was determined to be 35 hertz, which is acceptable.

Deflection due to thermal bowing is insignificant and does not control the lateral restraint spacing. For a 1.83m(6 ft) span, the applied heat flux can be considered constant at any point along the span and the resultant fixed-end moment is defined by:

$$M = \frac{\alpha\ \Delta T\ EI}{d}$$

Where, α = Coefficient of thermal expansion
ΔT = through-wall temperature differential (for a linear gradient)
E = modulus of elasticity
I = moment of inertia
d = depth of wall

and deflection is zero for this condition. The above equation shows the thermal moment is not a function of span length but is linearly proportional to T/d. The resulting longitudinal stress is accounted for in the elastic thermal tube analysis by assuming a generalized plane strain condition.

The joint between the superheater and evaporator panels represents an important design consideration for buckstay spacing requirements. In hot position, the membrane extension of the evaporator panel overlaps the membrane edge of the superheater panel to prevent shinethrough. Although lateral displacements caused by elastic thermal stresses are negligible, inelastic action may present some bowing or "warpage" of the superheater panel. To minimize the possibility for contact between the different panels, supports are designed to prevent panel rotation and buckstay spacing is limited to a 1.83 m (6 ft-0) spacing, which provides a sufficient margin above the mechanical design requirements of the panel. Necessary adjustments are possible during shop assembly to ensure design clearance between the individual panels is maintained. Upon final assembly of one shipping unit, the superheater panel is "locked" into place between the evaporator panel sections, and the complete assembly may be shipped without any concern for readjustments. The use of the web extension of the evaporator panel is common in the boiler industry and has proven successful; therefore, its use is justifiable and any thermal stress analysis deemed unnecessary.

G.4.3 Vortex Shedding

The phenomenon of vortex shedding was investigated to ensure resonance would not occur for this receiver design. In vortex shedding, naturally occurring turbulences are shed alternately from the sides of the receiver/tower structure. If the frequency of vortex shedding (induced by a steady wind) occurs at one of the harmonic frequencies of the structure, then transverse oscillations will develop. The frequency at which vortices are shed is given by the following equation for tublar structure:

$$f = 0.20\ V/D\ (1 - 20/N_R)$$

Where, V = wind velocity
D = structure diameter
N_R = Reynold's number

Because of the large diameter of the receiver structure, the Reynold's number is very large and the equation can be simplified:

$$f = 0.20\ V/D$$

which offers a good approximation. Maximum wind velocity at the receiver level is determined by increasing ground wind velocity exponentially according to the following equation:

$$V_Z = V_O\ (Z/V_O)^{1/7}$$
$$= 70\ \text{mph}\ ((650\ \text{ft/sec})/70\ \text{mph})^{1/7}$$
$$= 96\ \text{mph}\ (43\ \text{m/s})$$

Where, Z = height
V = basic ground wind speed

and

$$f = 0.20 \times \frac{43\ \text{m/s}}{18.3\ \text{m}} = 0.47\ \text{hz}$$

To check the resistance of the receiver/tower structure to wind induced vibration, the following criteria have been proposed. (Eduardo P. Zorrilla, "Predicting Aerodynamic Behavior of Stacks," The Oil and Gas Journal, November 1, 1971.)

$$\frac{W}{LD_R^2} = 25$$

$$= \frac{30 \times 10^6}{650 \ (40)^2}$$

$$= 29 > 25$$

Where: W = weight of structure, lb
L = height of structure, ft
D_R= average diameter, ft

The receiver/tower structure is therefore adequately designed to resist wind-induced vibration. Drag and lift forces were calculated for the receiver and do not exceed the component forces of design wind pressure.

G.4.4 Insulation

The panel assembly also includes 7.6 cm (3 in.) of medium temperature block insulation (CL 5), 10.2 cm (4 in.) of intermediate temperature block insulation (CL 3), stainless steel and aluminum. The insulation consists of 61 cm x 91 cm (2 ft x 3 ft) squares sandwiched between a stainless steel casing and aluminum-ribbed lagging and are held in place by pin studs which connect the casing to the lagging. The insulation is assembled on the ground prior to the panel being lifted in place on the tower. The 16-gage stainless steel casing separates the insulation from the panel tubes and is supported by the evaporator bottom horizontal buckstays. This casing serves three functions: permits differential thermal expansion between the evaporator and superheat panels, protects the insulation against the environment, and provides an effective method of supporting the insulation. All insulation and lagging are supported from the evaporator buckstays. Pin studs welded to these buckstays support subgirts attached to the aluminum lagging. Expansion joints allow for differential thermal expansion that exists between the various components of the panel assembly. Expansion slots of variable sizes are provided at each point where the superheat panel supports penetrate the insulation and lagging. Maximum expansion of the superheat panels is approximately 230 mm (9 in.). Insulation is also installed on the superheat panel support, behind the panel insulation sandwich, to cover the slots.

Blanket insulation (Kaowool 2600) surrounds the headers at either end of the panel and is held in place by stainless steel casing. The exposed casing above and below the heated surface is painted with a highly reflective white pyrolitic paint. The header insulation, casing and shroud are installed in place to effectively weatherproof the design.

G.4.5 Materials

The receiver components are designed for the mechanical loads given in Section 5.3.4 and loads defined by the thermal hydraulic analysis. These loads include thermal upset conditions, design pressures and temperatures. Incoloys and stainless steels are used for the pressure boundary part that see high operating temperatures. Carbon steels commonly used in the boiler industry are used for lower temperature applications. The allowable stress properties shown in Figure G.4-2 describe the strengths of various materials used. In addition to the strength requirement of materials, other considerations for material selection include material availability, fabricability, maintainability and cost. To summarize the material selection for tubes, headers, and piping, the following materials apply in general up to the given temperatures:

Material	Limit
SA-210C	To 510°C (950°F)
SA-213-T11 (Cr-1-1/4)	566°C (1050°F)
SA-213-T22 (Cr-2-1/4)	607°C (1125°F)
SA-407 (Alloy 800 and 800H)	816°C (1500°F)

The material breakdowns for all receiver components are given in Tables G.4-1 and G.4-2.

G.4.6 Sizing and Geometry

The pressure boundary parts are sized in accordance with the ASME Codes as applicable. Tube and header sizes were established in the thermal hydraulic analysis as given in Table G.4-1. Sizing is based on pressure, elastic thermal stresses and corrosion allowance. Tube thickness is determined by the following equation of ASME Section I "Power Boilers":

$$t_{req'd} = \frac{PD}{25+P} + 0.005D$$

$$= 2.62 \text{ mm } (0.103 \text{ in.})$$

$$t_{actual} = 2.79 \text{ mm } (0.110 \text{ in.})$$

Where, P = design pressure 162 kg/cm² (2300 psi)
D = tube outside diameter, 2.86 cm (1.125 in.)
S = allowable stress = 858 kg/cm^2 (12,200 psi) for Incoloy 800H @ 610°C (1130°F)

Tube-to-header junctions use the typical socket weld shown in Figure G.4-3. The panel tube attachments to the header are non-radial entry connections which reduce axial tube bending stress concentrations due to deadweight. The larger diameter inlet and outlet tube lines require radial entry connections to the headers. Offset tube entries are required at the header ends. Flat end closures are used for all headers. Header design is based on internal design pressure and considers thermal transients events such as upset condition and cloud transient.

G.4.7 Piping

Piping components include return lines, downcomers, saturation connections, attemperator piping, vent and drain piping. All piping is designed, fabricated, and constructed to ANSI B31.1 rules (Power Piping Code). Pipe routings are determined from flexibility analyses and geometric requirements to facilitate the use of piping bundles. Material savings involving insulation, lagging and supports are realized when piping of the same temperature is bundled together instead of insulating individually. All piping, attemperator lines and collectors are adequately sloped for drainage. Solid rod hangers support the return lines and downcomers transferring deadweight to top support steel. Supply lines are supported from el 142 m (466 ft, 4 in.) using constant load spring hangers to permit thermal growth of the receiver panels and downcomers and miminize load transferal to fixed portions of the piping. The term "downcomers" figuratively describes all vertical piping such as the feedwater line. Intermediate steel elevations are provided to laterally support the downcomers. The lower elevation of piping represents one of the most difficult areas to design. The flexibility analysis of the superheat supply lines accounts for a 25.4-cm (10-in.) vertical movement between anchor points (panel and downcomer) that can occur during startup when the dry superheat panel is heated and the downcomer is cold. To arrive at an acceptable piping layout, many arrangements have been proposed and investigated involving numerous flexibility analyses. These analyses consider the combined conditions of pipe expansion and differential movement between anchor points. Due to the various pipe sizes and materials, each piping layout becomes unique. Positioning all of the necessary expansion loops is a difficult task given the highly restrictive receiver geometry. Piping sizes and materials are given in Table G.4-3.

G.4.8 Steam Drum

The steam drum configuration conforms to steam drum standards used for industrial and utility fossil type boilers. The pressure boundary complies with the requirements of the ASME Section I, Rules of Construction for Power Boilers. The internals design and arrangement have been proven to be very efficient for the intended purpose, namely to supply dry steam to the superheater. The structural adequacy under cyclic loads has been found to be acceptable in "peaking" type operation where daily shutdown is required. The significant concern of the steam drum is the ability to handle the large through-thickness thermal gradient that occurs in the shell wall during rapid startup and during severe cloud transients.

This problem is minimized by using an oversized steam drum, increasing the water inventory, and by careful control of the unit during startup and cloud transients. Materials and sizes are given in Table G.4-2.

G.4.9 Codes

The receiver design is consistent with the following Codes:

- ASME Section I "Power Boilers"
- ANSI/ASME B31.1 "Power Piping Code
- Uniform Building Code (UBC), 1979 edition
- American Institute of Steel Construction (AISC), 8th edition (1980)
- American Welding Society Specifications
- Miscellaneous:

  - OSHA
  - Local Codes
  - Utility Co. Specs
  - NEMA
  - ANSI A-58.1
B-16.5
  - ASME Section VIII Div. I
  - ASME Section III Div. I, CCN-47

In addition to the above Codes, the B&W Fossil Boiler Standards were used extensively for design, sizing, analysis, drawing preparations, and manufacturing purposes.

TABLE G.4-1

RECEIVER TUBES AND HEADERS

Tubes

	Tube Size	Web Size	Material	Tubes/Panel
Econ	1.0" OD x 0.134	1/2" x 3/16"	210 Al	46
Evap	1.5" OD x 0.134	1/2" x 3/16"	210 Al	14/16
PS1	1-1/8" OD x 0.110	1/4" x 3/16"	I800H	26
PS2	1-1/8" OD x 0.110	1/4" x 3/16"	I800H	29
PS3	1-1/8" OD x 0.110	1/4" x 3/16"	I800H	29
FS1	1-1/8" OD x 0.110	1/4" x 3/16"	I800H	26
FS2	1-1/8" OD x 0.110	1/4" x 3/16"	I800H	29

Headers

	OD x Thk	Material	Design Pressure
Econ	6-5/8" OD x 1"	SA-106C	2400 psi
Evap	6-5/8" OD x 1"	SA-106C	2320 psi
PS1	5" OD x 0.75"	I800	2300 psi
PS2	5" OD x 0.75"	I800	2300 psi
PS3	5" OD x 0.75"	I800	2300 psi
FS1	5" OD x 0.75"	I800	2300 psi
FS2	5" OD x 0.75"	I800	2300 psi

TABLE G.4-2

PRESSURE BOUNDARY MATERIALS AND SIZES

Return Lines	#	OD	THK	Material
	PS-1	8 - 3.5	x 0.320	CR 2-1/4
	PS-2	8 - 4.0	x 0.480	CR 2-1/4
	PS-3	8 - 8.5	x 0.320	I-800
	FS-1	8 - 4.0	x 0.480	CR 2-1/4
	FS-2	8 - 3.5	x 0.320	I-800
	Econ	4 - 4.0	x 0.260	210 C
	Evap	22 4.0	x 0.260	210-C
Supplies				
	PS-1	8 - 3.5	x 0.230	210-C
	PS-2	8 - 3.5	x 0.320	CR 2-1/4
	PS-3	8 - 4.0	x 0.480	CR 2-1/4
	FS-1	8 - 3.5	x 0.320	CR 2-1/4
	FS-2	8 - 4.0	x 0.480	CR 2-1/4
	Econ	4 - 4.0	x 0.260	210 C
	Evap	14 4.0	x 0.260	210-C
Downcomers				
	(1A)2	- 8-5/8	x 0.75	CR 1-1/4
	Drum	- 12-3/4	x 1.00	SA-106C
	(2)2	- 8-5/8	x 0.875	CR 2-1/4
	(3)2	- 8-5/8	x 0.875	CR 2-1/4
Steam Drum				
	61-1/2"	3-3/4"		SA302B
	(Hemispherical Heads 3-1/2" Thk)			
Saturation Connections				
	5" OD	0.3"		210 C

TABLE G.4-3

SUMMARY OF RESULTS

	Reference Study	El Paso Loc. 1	El Paso Loc. 2	El Paso Loc. 3
Tube Size (OD x thickness)	38.1 mm x 1.65 mm (1.5" x 0.65")		28.6 mm x 2.79 mm (1 1/8" x 0.110")	
Material*	Alloy 800	Alloy 800H	Alloy 800H	Alloy 800H
Maximum Metal Temperature (OD crown)	633°C (1,172°F)	622°C (1,152°F)	628°C (1,163°F)	642°C (1,187°F)
Max. Load & Disposal Controlled Stress Intensity (Elastic) kg/cm² (psi)	-2,390 (-34,000)	-2,390 (-34,000)	-1,968 (-28,000)	-1,195 (-17,000)
Operating Cyles	60,000	60,000	60,000	60,000
Operating Time (hrs)	100,000	100,000	100,000	100,000
Initial Strain (%)	0.142	0.142	0.142	0.142
Final Strain Range (%)	0.131	0.131	0.108	0.066
Creep Damage (T/T_D)	0.6	0.27	0.41	0.57
Fatigue Damage (n/N_D)	0.6	0.60	0.08	0.06

* The reference study uses the material properties of Incoloy 800H.

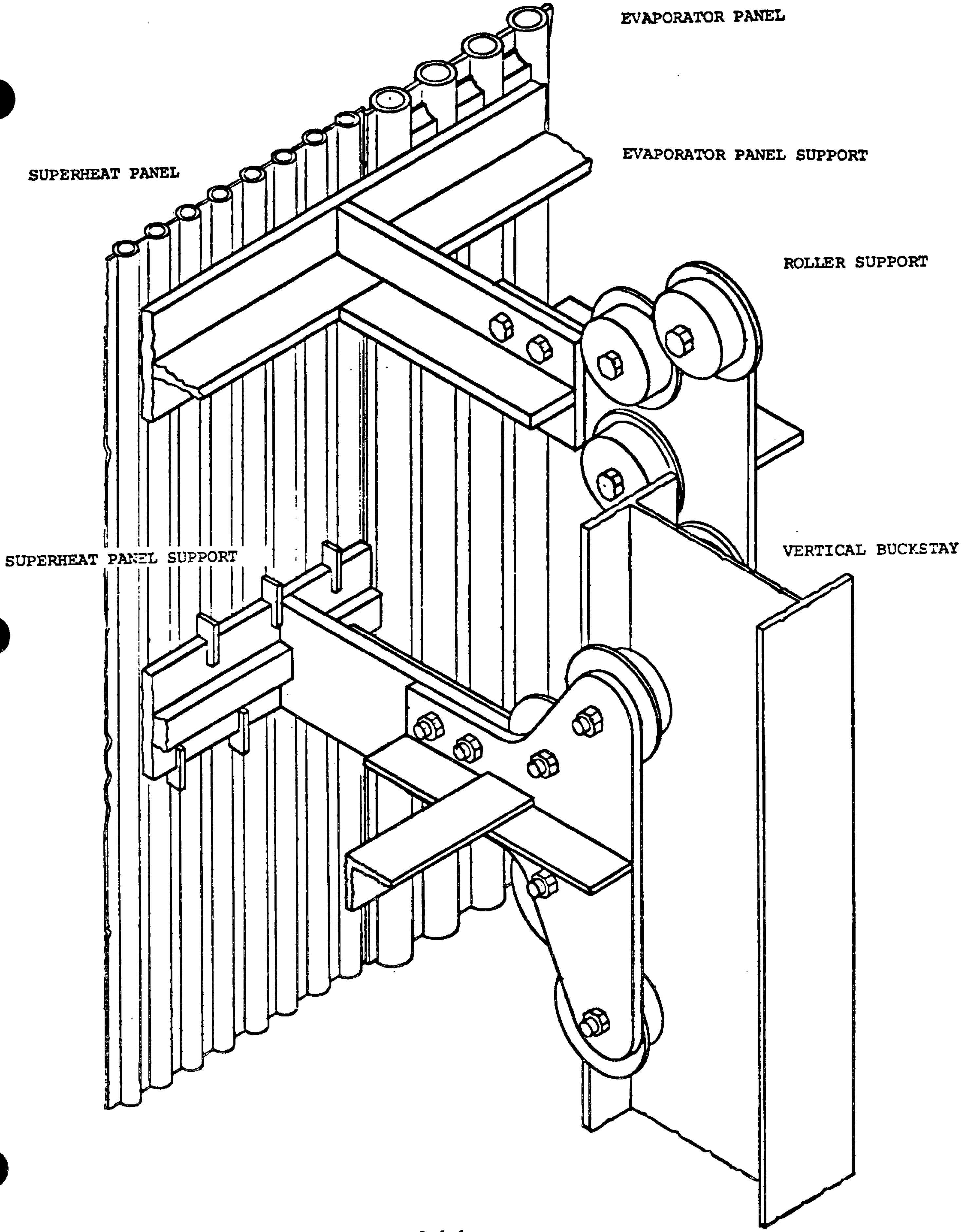


FIGURE G.4-1 - Panel Support Scheme

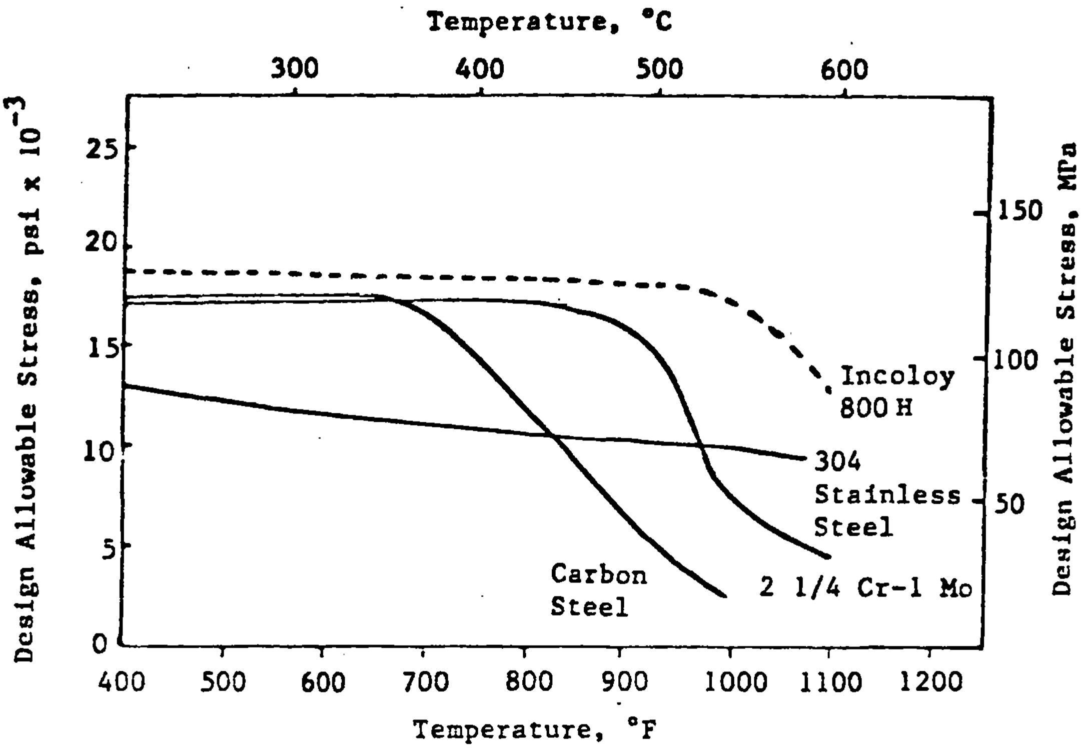


FIGURE G.4-2 Design Allowable Stress Versus Temperature

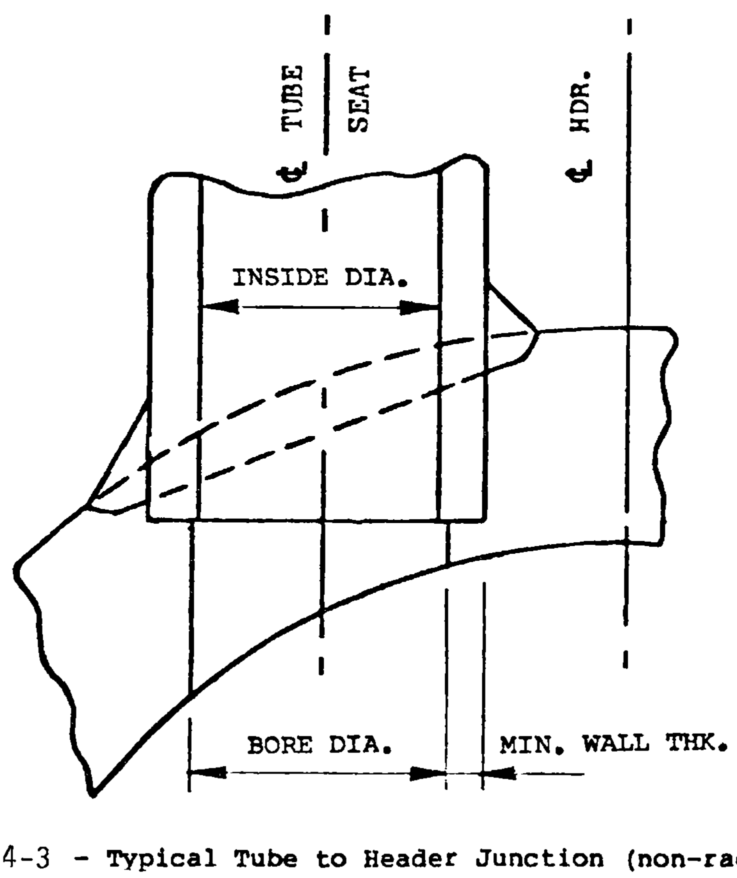


FIGURE G.4-3 - Typical Tube to Header Junction (non-radial entry)

G.5 CREEP-FATIGUE AND STARTUP STRESS ANALYSIS OF THE TUBE PANEL

This section describes the tube panel creep-fatigue analysis, startup stress analysis, and resulting materials selection.

G.5.1 Creep-Fatigue Analysis

A creep-fatigue analysis of the superheat (Incoloy 800H) panels has been performed to verify a superheat tube will not fail in fatigue, or result in excessive distortion, or rupture as the result of creep. Analysis of an evaporator tube is not needed because the boiler portion of the receiver operates at lower temperatures. The evaporator tube is sized in the thermo-hydraulic design (Section 5.3.2). Two methods are employed to evaluate the membrane wall superheat tube - a simplified elastic technique proposed by the B&W internal report, "Supplemental Elevated Temperature Rules For ASME Section VIII - Division I," and an inelastic analysis that conforms to the requirements of Code Case N-47. The inelastic results were derived using data from the creep-fatigue evaluation presented in Section G.6-G.7.

Three locations representing the worse-case conditions were evaluated. Figure G.5-1 depicts these locations in relation to the allowable absorbed heat flux map. Location 1 is subjected to the highest heat flux level and lowest fluid temperature. Location 2 experiences a combination of high heat flux and metal temperature. Location 3, which is in a region of high fluid temperature, exhibits the highest metal temperature. All three locations see the same number of thermal cycles.

Location 1 is, therefore, most susceptible to fatigue damage, with Location 3 being most susceptible to creep damage. Location 2 represents a combination of the fatigue damage and creep damage.

The maximum loading condition for each of the locations in given in Table G.5-1. Deadweight, wind, and seismic stresses are small in comparison to the pressure and thermal stresses and are excluded from the analysis. The thermal stresses listed in Table G.5-1 are compressive and occur at the tube crown. These stresses were obtained using the B&W membrane wall program and include a 10 percent increase to account for cloud transients during maximum operating conditions. The 10 percent increase is an approximation of the transient and would be refined in a subsequent design stage. The B&W membrane wall program is a finite difference program, used extensively in the design of conventional fossil boiler walls. Given a specific tube-wall configuration, a thermal load, and film coefficient, the program calculates thermal gradients and elastic thermal stresses. The program conservatively assumes a general plane strain condition in the calculation of stresses.

The thermal loading is approximated by a cosine distribution across the tube surface with maximum heating assumed at the tube crown and face of the web (Figure G.5-2). The assumed thermal load is based on direct incident heating. The skewed heating is negligible for this receiver design and, therefore, was not considered in the analysis (see Section 5.3.3).

The temperature profile for Location 1 at maximum operating condition is shown in Figure G.5-3. The temperatures listed are metal temperatures minus fluid temperature. The maximum delta-T is 107°C (224°F) at the tube crown. During a cloud transient, metal temperatures are assumed to increase by 10 percent, resulting in the following maximum temperature at the crown:

$$T_{cl} = 1.10\ (T_{oper} = T_f) + T_f$$

$$T_{cl} = 1.10\ (610-486) + 486 = 622°C\ (1152°F)$$

Where, T_{cl} = tube crown temperature for a cloud transient
T_{oper} = steady-state tube crown temperature during maximum operation conditions
T_f = fluid temperature at maximum operating conditions

The temperature contours show two types of thermal gradients to be present - a nearly linear through-wall gradient and a circumferential gradient. These produce a combination of through-wall and circumferential gradient at points away from the tube apex (Figure G.5-4). The longitudinal (axial) stress that develops as a result of these gradients is the most significant of the component stresses. The effective stress is slightly larger than the longitudinal stress. It is also maximum at the tube crown and is compressive in nature (Figure G.5-5).

The approach to be used in performing an inelastic analysis which conforms to the rules of Code Case N-47 follows:

1. Define the load histogram.

2. Determine maximum metal temperatures and elastic stresses.

3. Obtain the results of a previous inelastic analysis which has an identical load histogram and nearly identical temperature and stresses.

4. Adjust the inelastic strains using a ratio of elastic stresses (except for initial strain which is not elastic) and account for different maximum metal temperatures when entering the stress-to-rupture and cycles-to-failure curves in accordance to N-47.

5. Calculate creep-fatigue damage.

An inelastic analysis was performed on a 38.1-mm OD x 1.65-mm (1.5-in. OD x 0.065-in.) tube which is summarized in Table G.5-2. Details of this analysis are given in Section G.6. The results were applied to the three locations investigated for the El Paso study. The comparison of Location 1 to a reference tube describes the close similarity of the load conditions (Table G.5-2). By adjusting the results to account for different stress and metal temperature, each location was evaluated.

The load histogram used for the inelastic analysis is shown in Figure G.5-5. A total of seven load steps was analyzed with different hold times to fully assess the creep damage. A simplified inelastic evaluation, using the ANSYS Computer Program, was performed where a pure strain-controlled condition is assumed neglecting the beneficial effect of strain redistribution in the tube. The model consisted of a single cube element which is reasonable to use since the major stress is longitudinal. For this type of analysis, a difference of tube sizes does not impact the solution, and the results of the APS study are satisfactory for this case.

The total number of operating cycles used in the inelastic analysis is 60,000, which includes 50,000 cycles of cloud transient and 10,000 cycles of startup/shutdown. The total operating time used is 100,000 hours, which is representative of a 3-year operating plant lifetime.

The elastic rules of Code Case N-47 are followed for determining the elastic strain ranges. The program CREEPF is used for this purpose. The fatigue damage is based on two partial strain ranges. The maximum value occurs initially and consists of elastic and plastic strains. This strain is E = 0.142 percent. Following elastic shakedown (approximately 4 cycles), the strain range becomes elastic, and a ratio of the stresses is then used to determine the strain ranges for each of the three locations.

For creep damage calculation, the hold time stresses of the reference analysis are conservatively used for Locations 1 and 2 but were reduced for Location 3. This reduction of hold time stress is based on the relaxation curve that corresponds to the higher temperature and lower stress for Location 3. The results of the inelastic analysis (Table G.5-2) contain an overall conservatism since the maximum metal temperature and stress include a 10 percent increase to account for the severe conditions of a cloud transient. The results of the inelastic analysis are given in Table G.5-2 and also in Figure G.5-5.

An elastic analysis was also performed. The analysis considers 50,000 cycles of operation, and the load histogram is shown in Figure G.5-6. This histogram also considers a 10 percent increase of temperature and stress for cloud transient. The total operating time used is 100,000 hours. The results are shown in Figure G.5-7.

The difference between load histograms reflects the difference between an elastic and inelastic analysis. Events 2 and 3 of the elastic load histogram (Figure G.5-6) are included to improve the accuracy of the creep damage calculation. For the fatigue damage calculation, Events 1 through 4 represent one load cycle, which is the same used for the inelastic load histogram (Figure G.5-5).

To satisfy the limits of Code Case N-47, the total creep fatigue damage must be less than or equal to 1.0:

$$\sum (T/T_d) + \sum (n/N_d) \leq 1.0$$

Comparing the results of each method of analysis (inelastic and elastic), a high degree of similarity is noted, with the inelastic results satisfying the limits and the elastic results exceeding the limits. This comparison illustrates that a high degree of conservatism exists in the elastic approach.

G.5.2 Startup Stress Analysis

During startup and prior to the time when operating temperatures are reached, heat flux is applied to the entire receiver surface at a time when the superheat panels will be dry. The level of heat flux that a dry panel receives is governed by the maximum metal temperature and thermal stress limits of the tube. A two-dimensional finite element analysis has been performed to verify that the startup operating mode did not impair structural adequacy. The finite element grid is shown in Figure G.5-8.

The heating distribution applied to the thermal model is identical to that assumed for normal operating conditions (See Section G.2). A film coefficient, defining convection and radiation losses, is applied to the exposed surface of the panel with the inside and backside surfaces insulated. To reduce the effects of thermal shock, the level of heat flux is applied gradually until a constant level of 20,000 Btu/hr-ft^2 is reached after 15 minutes (Figure G.5-9). This heat flux is used to conservatively account for any peaks that exist in the startup process. The results of the thermal analysis are shown in Figures G.5-9 and 5.3-10. Figure G.5-10 shows the change of metal temperature during heatup for a point at the tube crown and a point opposite the crown on the rear of the panel. The maximum metal temperature occurs approximately at 30 minutes and does not exceed 538°C (1,000°F). The temperature of the panel back lags the panel front by a temperature difference, as is seen by the plot in Figure 5.3-11.

A maximum delta-T of 46.7 °C (116°F) occurs at approximately 9 minutes. The delta-T then decreases to -1 °C (30°F) at about 30 minutes where steady state conditions prevail. The front-to-back thermal gradient can be assumed to be linear, and maximum stress is calculated by the following:

$$\sigma_c = \frac{E \alpha \Delta T}{2(1-\nu)}$$

$$= \frac{(23.6 \times 10^6)(9.4 \times 10^{-4})(116)}{2(1 - 0.37)}$$

$$= 20{,}400 \text{ psi } (1434 \text{ kg/cm}^2)$$

Where, σ_c = maximum longitudinal compressive stress
E^c = modules of elasticity, psi
α = coefficient of thermal expansion, micro in./in. - °F
ΔT = front-to-back delta-T, °F
ν = Poisson's ratio

Since the resulting temperature and stress do not exceed the assumed conditions of the creep-fatigue analysis, then the loading scheme proposed by Figure G.5-9 is acceptable. The maximum allowable metal temperature has been set at 650°C (1,200°F) to prevent excessive creep damage; therefore, the heat flux limits of the startup condition can be further improved (see Figure G.5-10).

G.5.3 Material Selection

Incoloy 800H was selected over Incoloy 800, for the high temperature superheat panels, because of its excellent mechanical properties and higher allowable stresses that exist above 602°C (1,115°F). The new alloy, Modified 9Cr-1Mo, was considered as a substitute for 800H because of its low cost and comparable properties to many stainless steels. Also referred to as Croloy 9V, the alloy is characterized by a higher strength than other carbon steels and a high fatigue life, creep properties similar to TP304 stainless steel, excellent fabricability and weldability, and minimal stress corrosion in boiler application. Because of its lower coefficient of thermal expansion, post-weld heat treatment is required at a minimum temperature of 732°C (1,350°F).

For high temperature application, Croloy 9V does not exhibit the desirable creep properties that 800H offers. At 996°C (1050°F), the stress allowables drop off readily; whereas, for 800H, the allowables remain significantly higher. In conclusion, Incoloy 800H appears to be the preferred material where creep concerns are significant.

Table G.5-1 - Tube Stresses

Location	1	2	3
Panel	13	13	5
Distance from bottom of panel, ft	8.2 (27)	21.1 (42)	28.1 (66)
Dead weight	14.1 (200)	21.1 (300)	28.1 (400)
Pressure (tangential)	436 (6200)	436 (6200)	520 (7400)
(longitudinal)	176 (2500)	176 (2500)	176 (2900)
Governing wind or seismic (longitudinal)	±52.7 (±750)	±52.7 (±750)	±52.7 (±750)
Max. thermal (longitudinal)	-2390 (-34000)	-1968 (-28000)	-1195 (-17000)

Stress in units of kgf/cm^2 (psi)

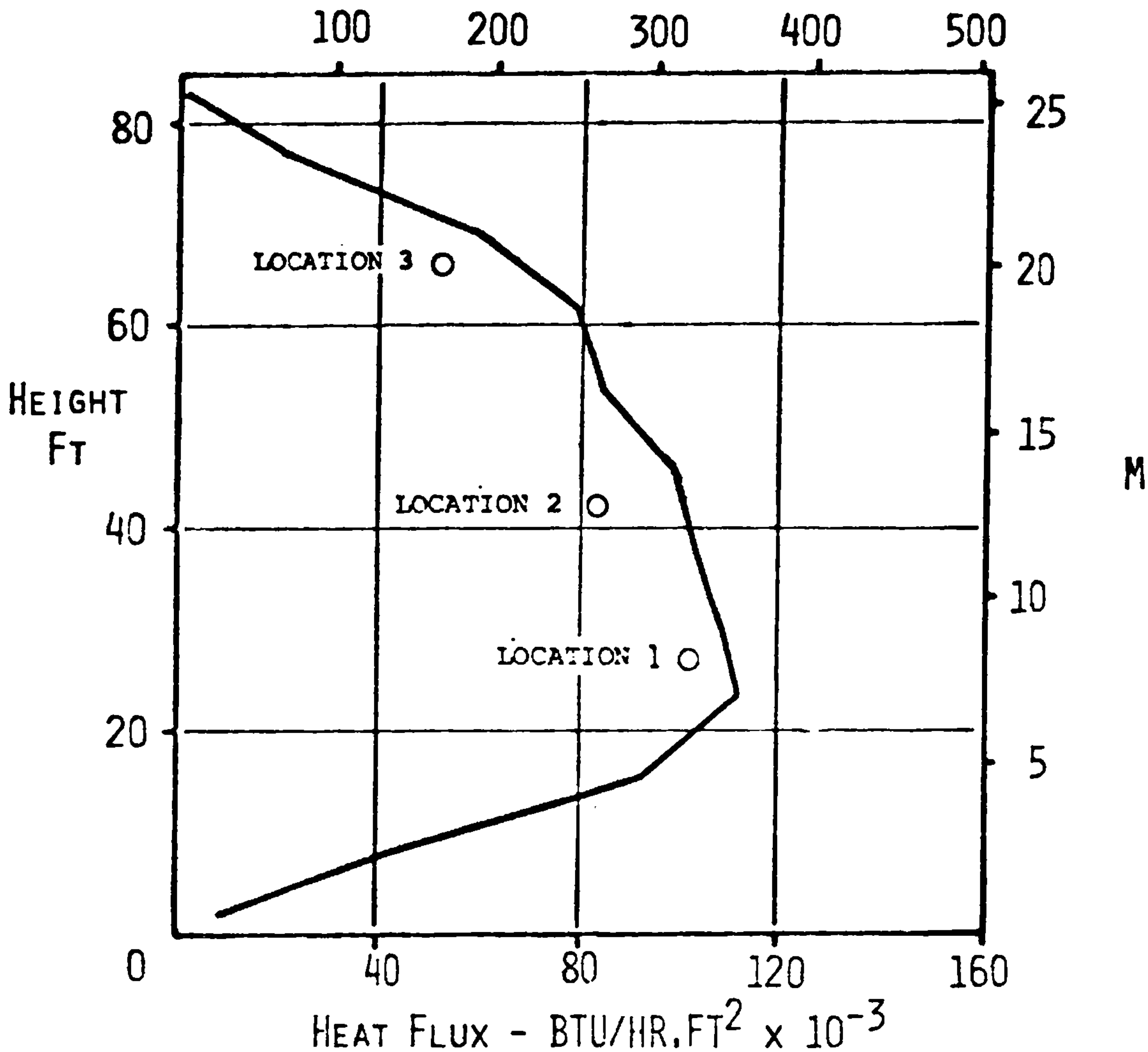


FIGURE G.5-1 - **Actual and Allowable Heat Flux Curves (typical)**

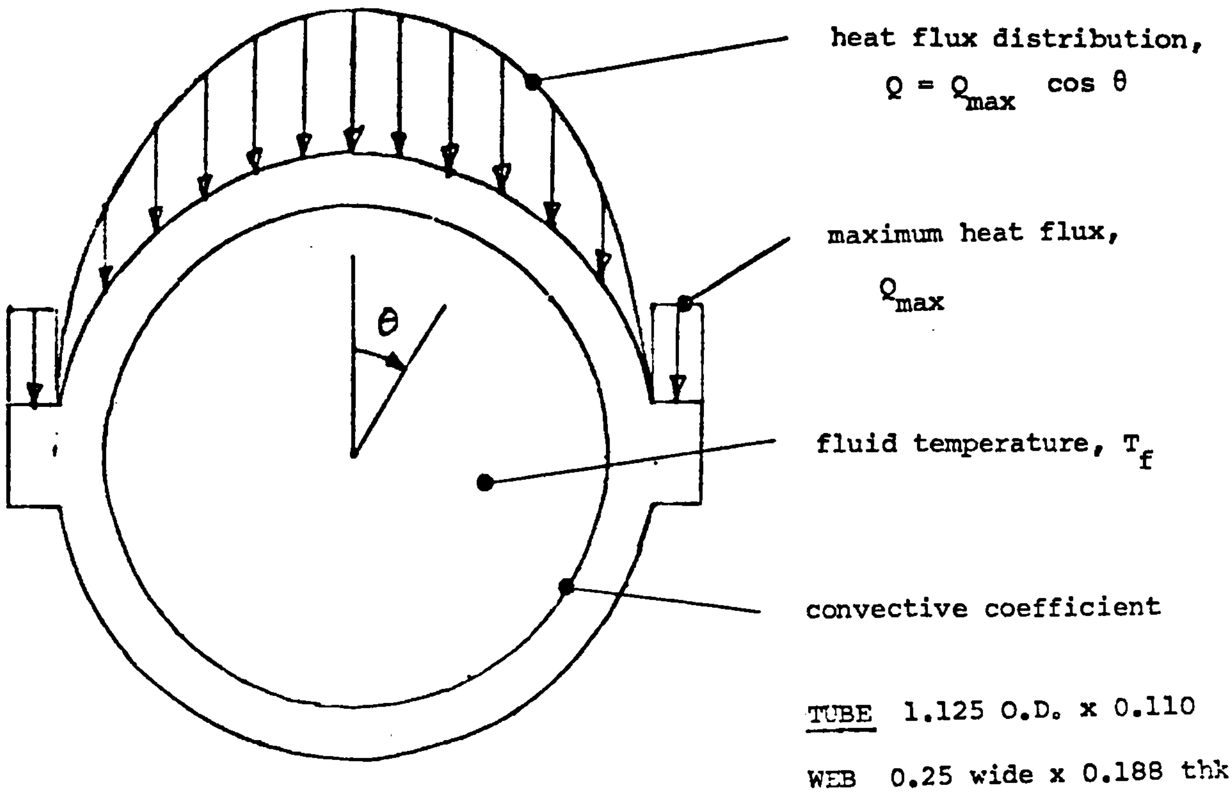


FIGURE G.5-2 - Thermal Load

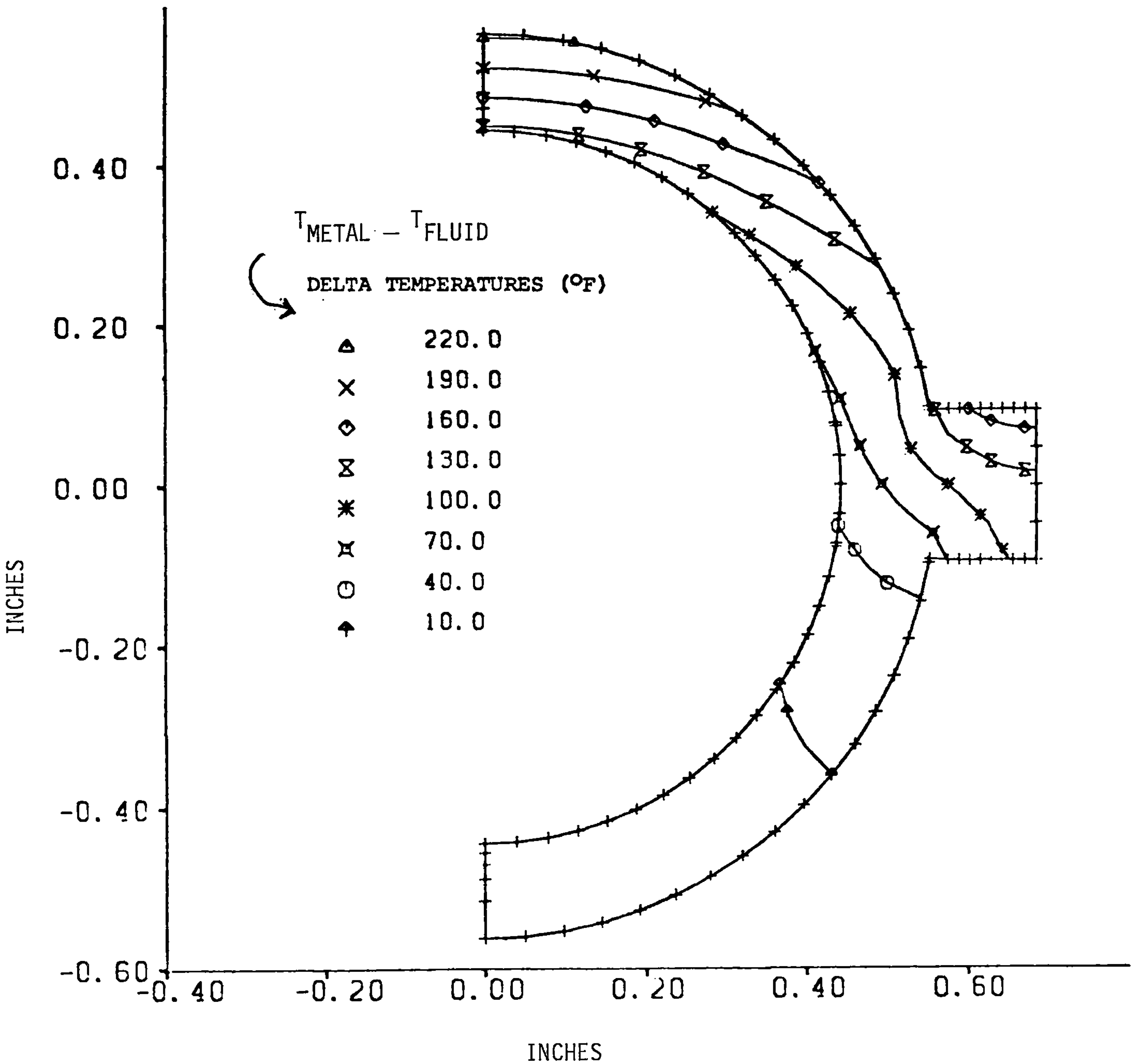


FIGURE G.5-3 - Temperature Contours (Location 1)

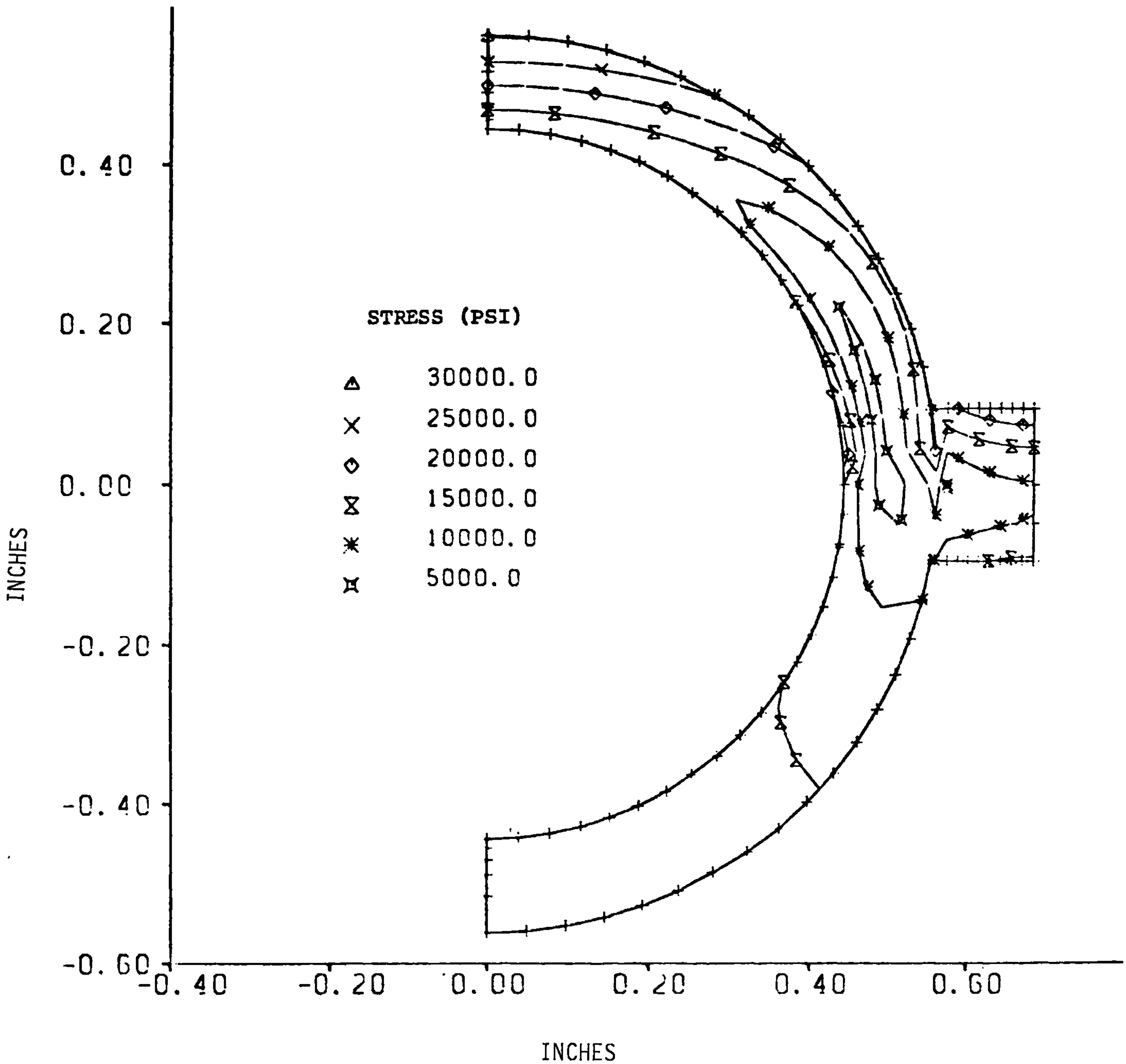


FIGURE G.5-4 - Effective Stress Contours (Location 1)

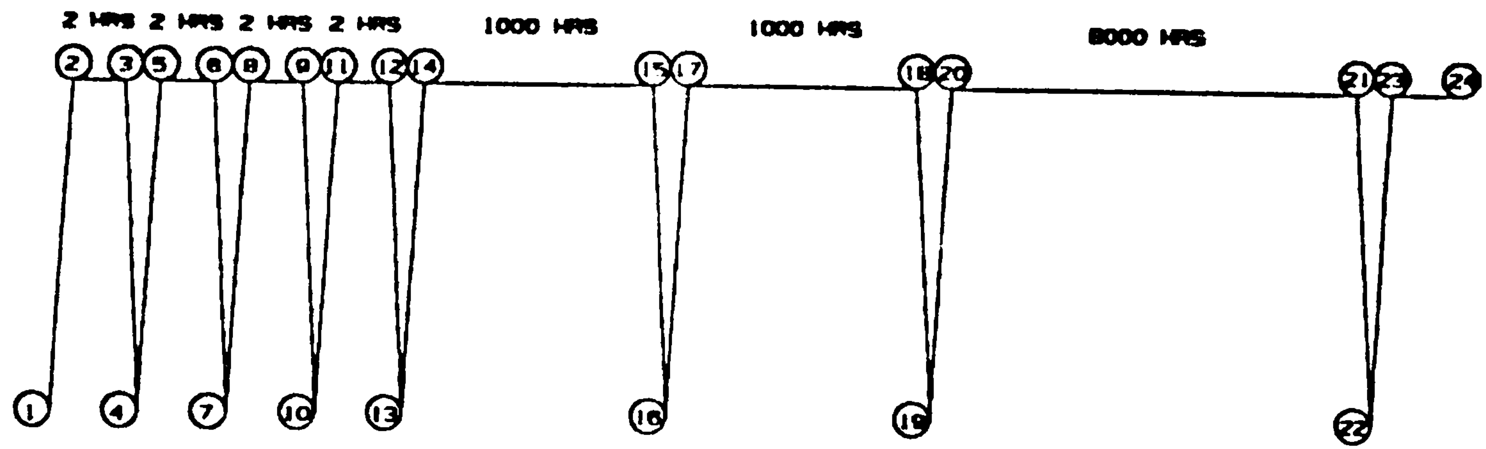


FIGURE G.5-5 - LOAD HISTOGRAM FOR INELASTIC ANALYSIS

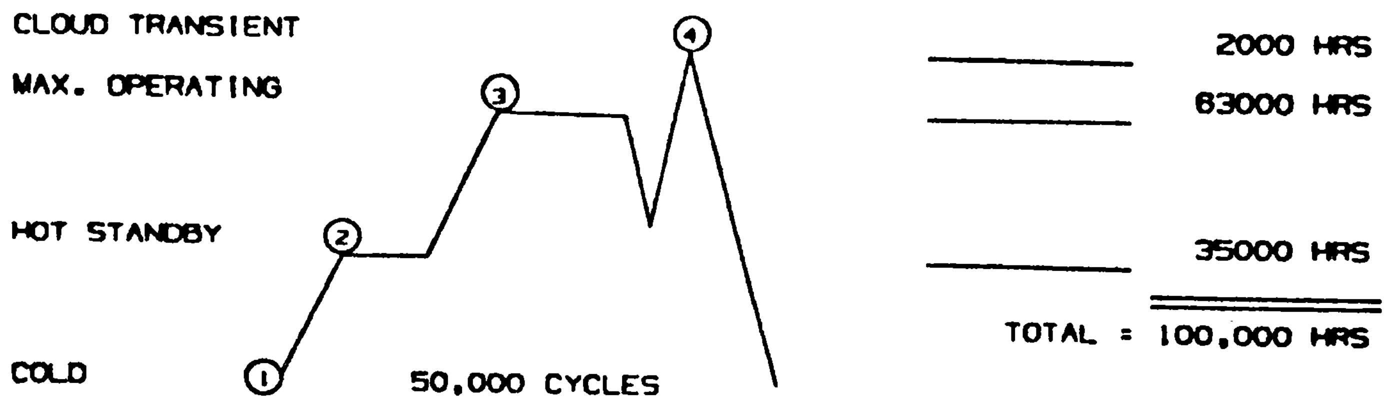


FIGURE G.5-6 - LOAD HISTOGRAM FOR SIMPLIFIED ELASTIC METHOD

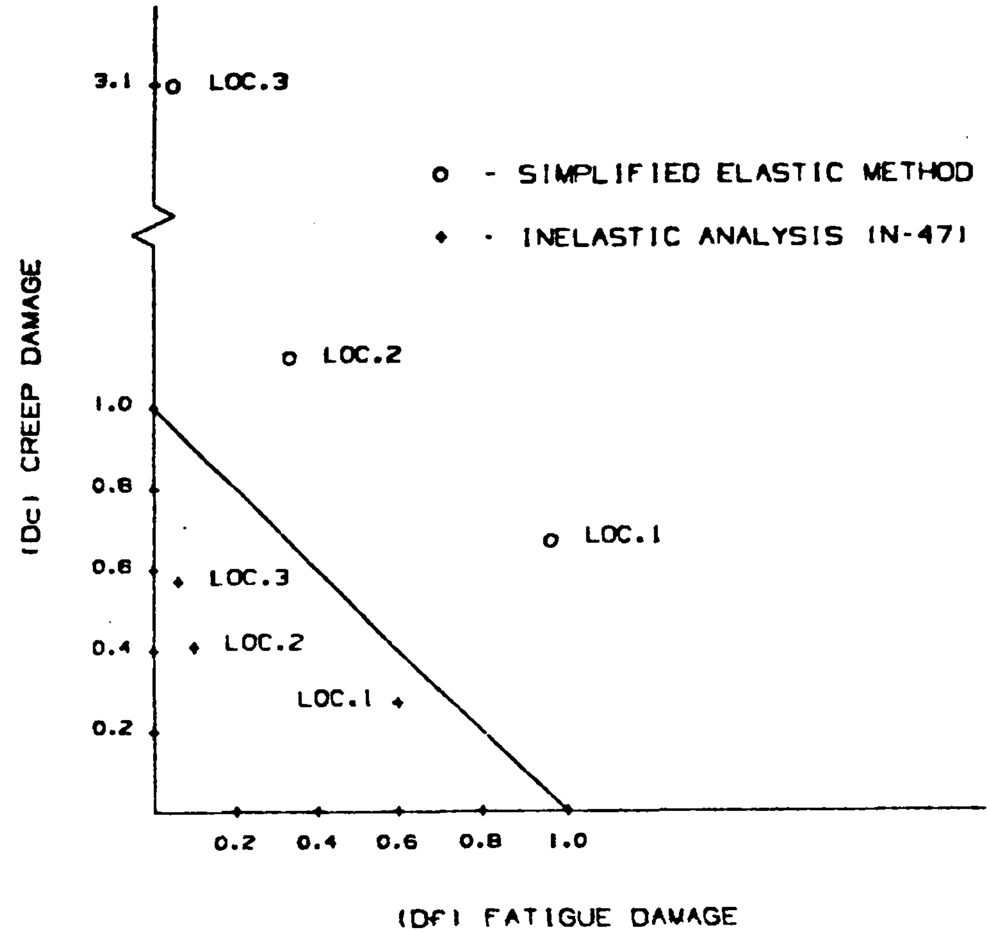


FIGURE G.5-7 - Combined Creep-Fatigue Damage

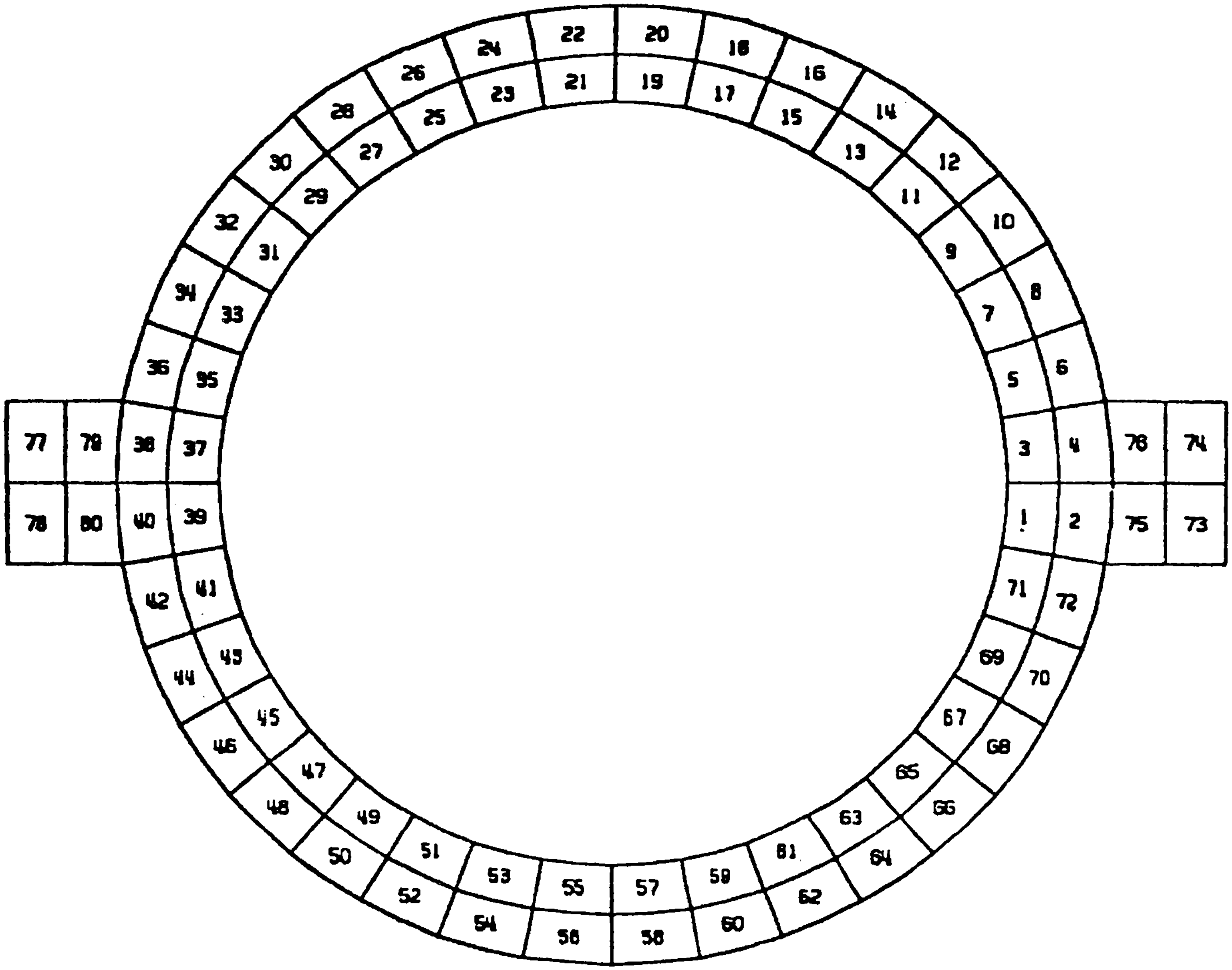


FIGURE G.5-8 - Finite Element Grid

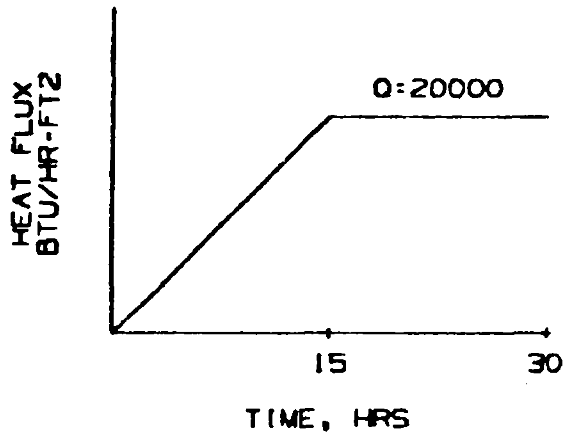


FIGURE G.5-9 - Thermal Loading for Dry Tube Startup

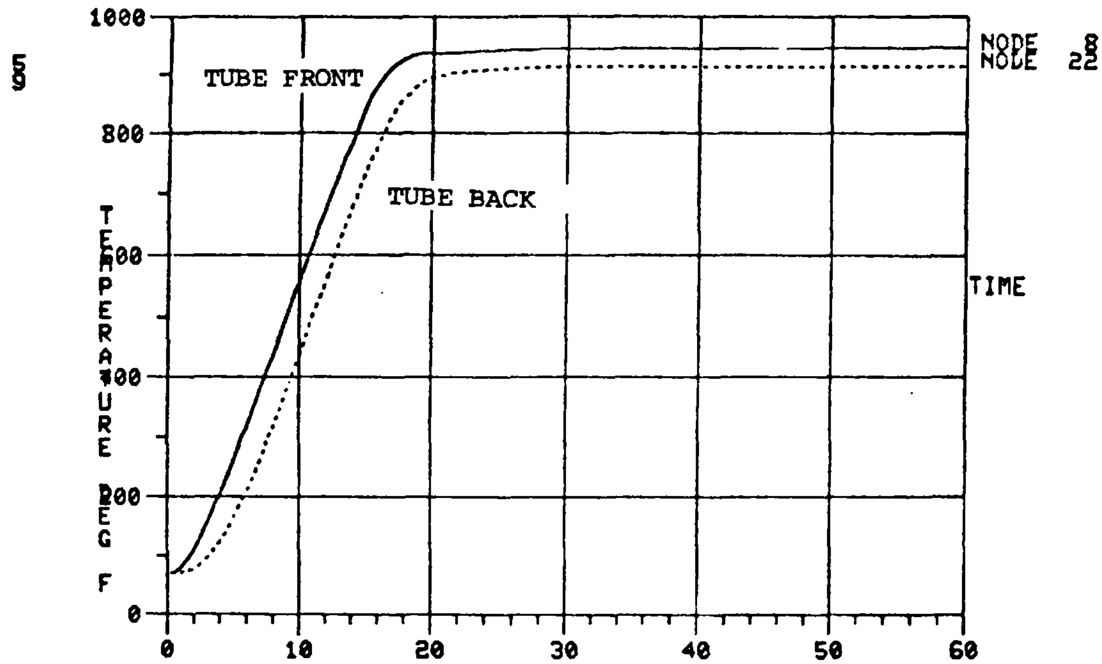


FIGURE G.5-10 - Tube Front and Back Temperatures Versus Time

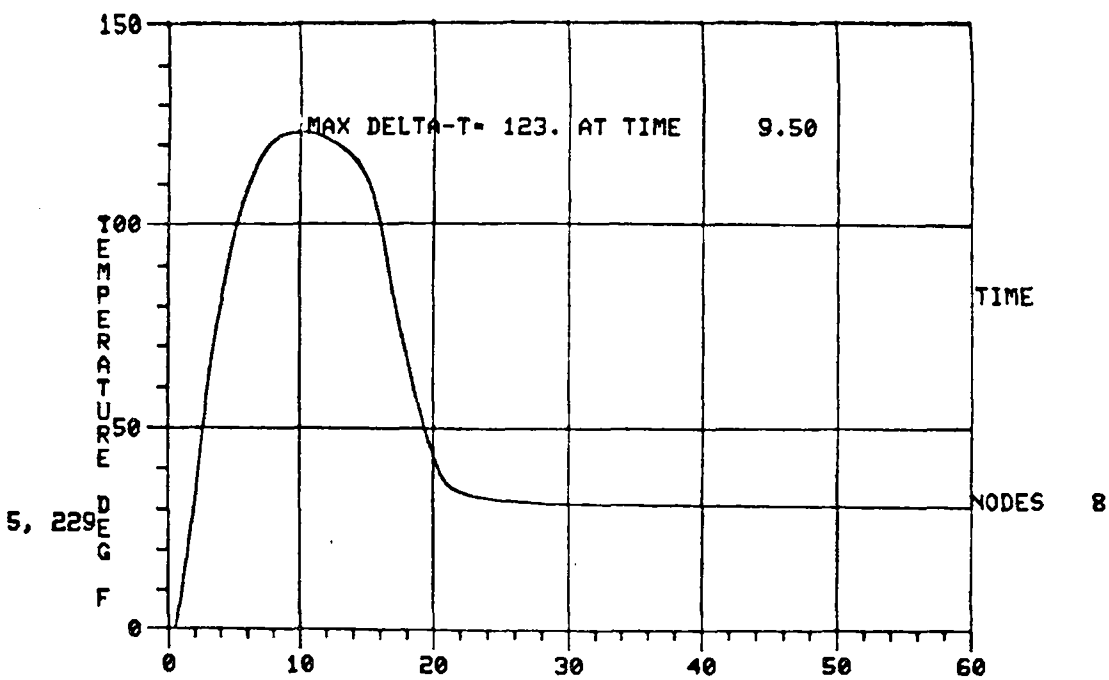


FIGURE G.5-11 - Front-To-Back Delta-Temperature Versus Time

Appendix G.6

Creep - Fatigue Analysis of Tube

Panel (Reference Analysis)

This appendix includes that portion of the report titled "Preliminary Design of a Solar Central Receiver for a Site Specific Repowering Application (Saguaro Power Plant)" Volume II dated September 1983 which was used to evaluate the creep-fatigue damage factors in the receiver tube analysis for this contract. Note that references made to other report sections do not apply to other volumes of this report or other sections of this Appendix.

G.6 Creep-Fatigue Analysis of Tube Panel - In the following absorber tube creep-fatigure analysis, a simplified inelastic analysis was performed using the ANSYS computer program and B&W finite element computer programs. This evaluation used the actual heat flux as the initial input based on the allowable flux envelope as shown in Figure G.6-1. In other words, this detailed analysis solves for the stresses and strains based on the input flux level. In the initial analysis

allowable flux limits were established by
essentially working the problem backwards. For the initial analysis method it was observed that the calculated stress range was greater than the allowable range, but only by 10%, and therefore, it was assumed that the limits on elastic action can be accepted as the limit for elastically calculated effective stresses. The purpose of the inelastic analysis was to determine if this assumption could be validated and to determine if shakedown to elastic action does occur. The slight differences in the results between the two methods is not considered significant. The variations can be attributed to the differences in the programs and also the higher initial strain for the inelastic analysis from which the relaxation is considered. Furthermore, there are some differences in the actual subdivision or integration of the creep relaxation. The creep damage summation for the inelastic analysis was not subdivided in the same manner as was used for the first approach. It is slightly more conservative.

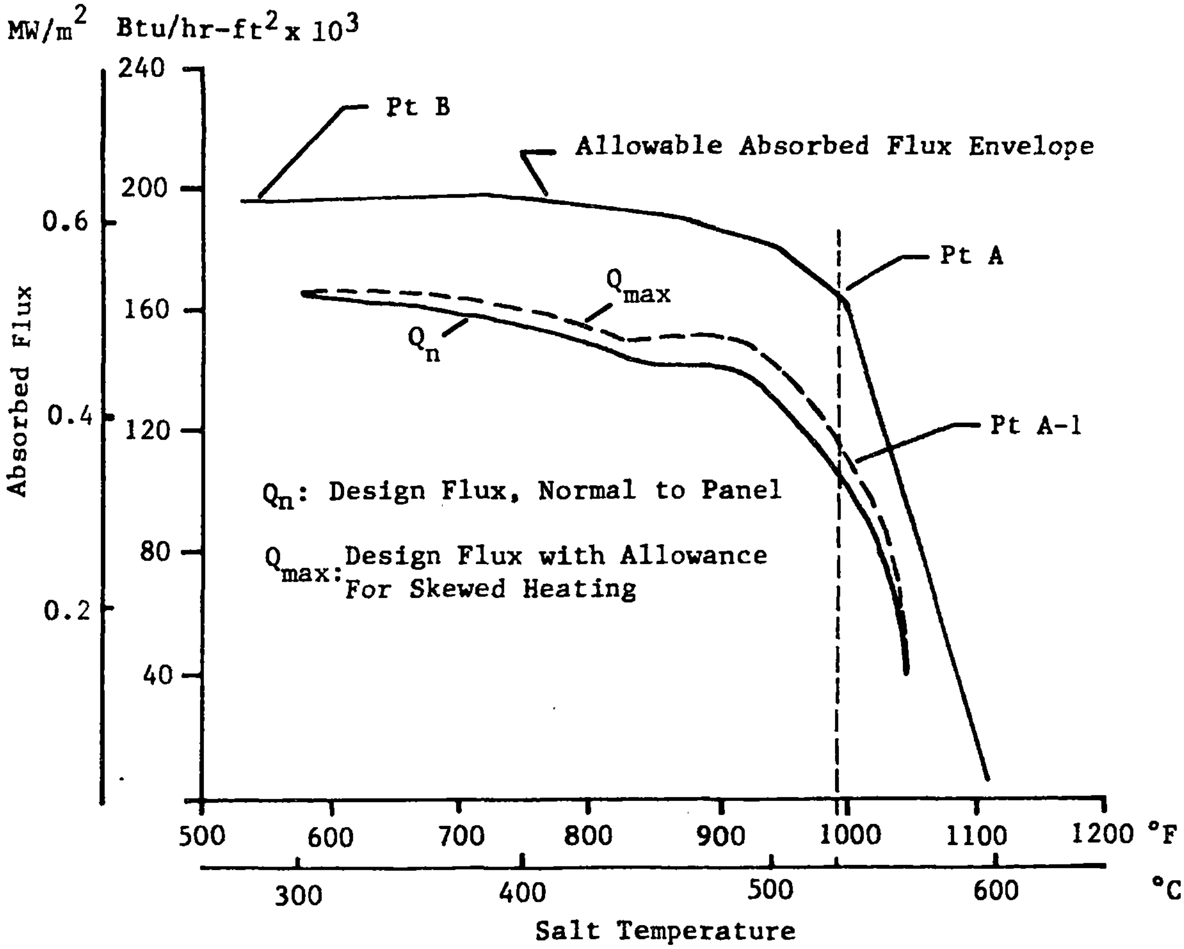


Figure G.6-1 *Creep-Fatigue Analysis Point Locations*

Table G.6-1 *Skewed Heating Effects*

Panel	Tube	C	ϕ_o	Q_{max}
8	First	0.1286	7.33	1.009
10	First	0.1798	10.193	1.016
10	Last	0.1400	13.495	1.029
11	First	0.1480	8.419	1.011

$$\frac{Q}{Q_N} = \cos(\phi_o) + C \sin(\phi_o)$$

Level = 6 m (20 ft) above centerline

The points identified in the creep-fatigue damage envelope all exist at the tube crown region as the strain ranges for these locations are much greater than at the tube weld-clip region where a stress concentration factor for 4.0 is used.

The following results reveal the strain ranges for these locations.

Location	Max Strain Range %	Max Temperature °C	(°F)
Pt A (Pass #10)	0.142	633	(1172)
Pt. A-1 (Pass #10)	0.098	602	(1115)
Pt. B (Pass #1)	0.175	443	(830)
Pass #10 - Weld-Clip Area	0.037	527	(980)
Pass #1 - Weld-Clip Area	0.032	277	(530)

The data for point A were obtained from a simplified inelastic analysis on ANSYS. All other strain calculations were based on the elastic stress rules of Code Case N-47 using B&W Computer Program CREEPF and increased by a factor of 5%. The value of 5% is the difference between the inelastic results from ANSYS and the results calculated in Program CREEPF (Fig. G.6-3).

Thermal Analysis - The finite element thermal analysis was performed using the thermal grid model as illustrated in Figure G.6-4 . The geometry modeled is a planar view where the tube dimensions are 38 x 1.65 mm (1.5 OD x 0.065 in.). The input data consists of heat fluxes on the tube, salt temperature, and heat transfer coefficients. The distribution of the flux is input as a cosine function as shown in Figure G.6-5 . The receiver tube thermal isotherms are presented in Figures G.6-6 and G.6-7 .

Stress Analysis - Finite element elastic stresses were computed first for the thermal load cases, i.e., Pass 1 low temperature with high front-to-back delta-T's and also for Pass 10 where the front-to-back delta-T is smaller but is at maximum temperature conditions at the crown region. The finite element mesh is an 8-node plane strain model as illustrated in Figure G.6-8 .

The main point is that both methods show a reasonable comparison and the conclusion reached is that the design flux envelope as established is acceptable. The creep fatigue analysis results for the worst case tube panel locations are shown in Figures G.6-1 and -2. Three data points are shown in the creep-fatigue damage diagram, with points "A" and "A-1" having the same creep damage. The difference in fatigue damage is a result of the different flux levels used in the thermal analysis.

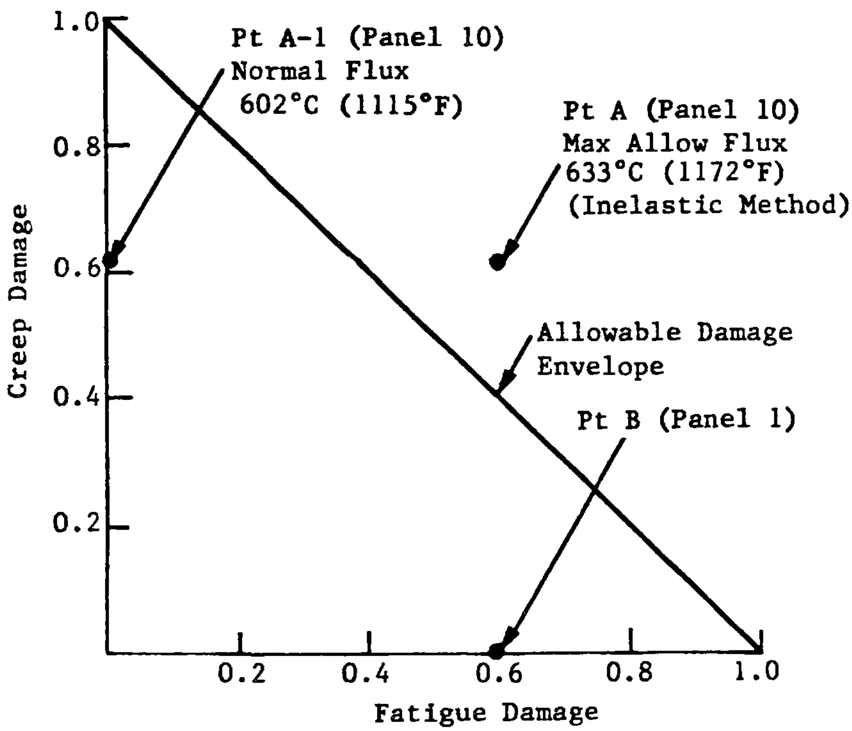


Figure G.6-2 *Creep-Fatigue Damage Envelope*

Point "A" is an overall enveloping worst case situation that falls somewhat outside the allowable damage envelope. The results here were obtained by an inelastic analysis performed on the ANSYS computer program using a simplified single tube element.
The flux level corresponding to point "A" of Figure G.6-1 is shown as point "A" in Figure G.6-2. Point A is for the estimated worst condition with the salt temperature at 577°C (980°F).

The results for Point "A-1" are due to the normal expected flux levels and are approximately 30% lower than at Point A. The method of calculating the strain ranges only includes elastic stress finite element solutions. For Point "A-1", the creep damage is also assumed to be the same as that for Point "A", which is a conservative prediction. Even with this consideration there is ample margin for skewed heating effects which are only 3% more severe than the normal heating fluxes (see Table G.6-1).

The results at Point "B" are acceptable. This point represents the lower temperature extreme for the largest hot-to-cold delta-T condition, which occurs in Pass 1.

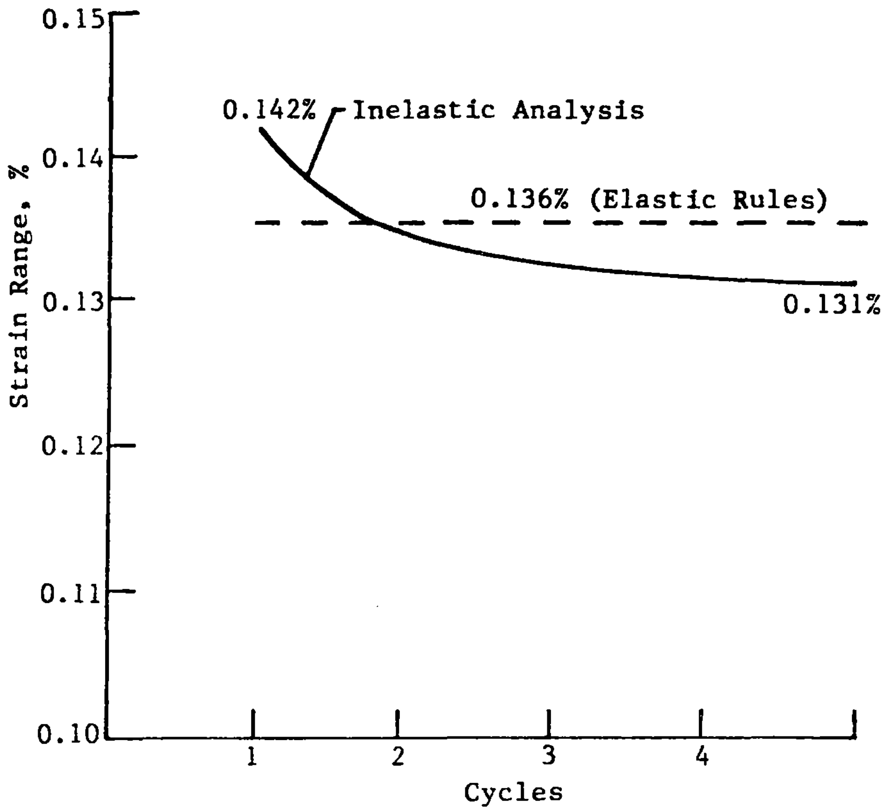


Figure G.6-3
Comparison of Inelastic and Elastic Strain Ranges for Point A

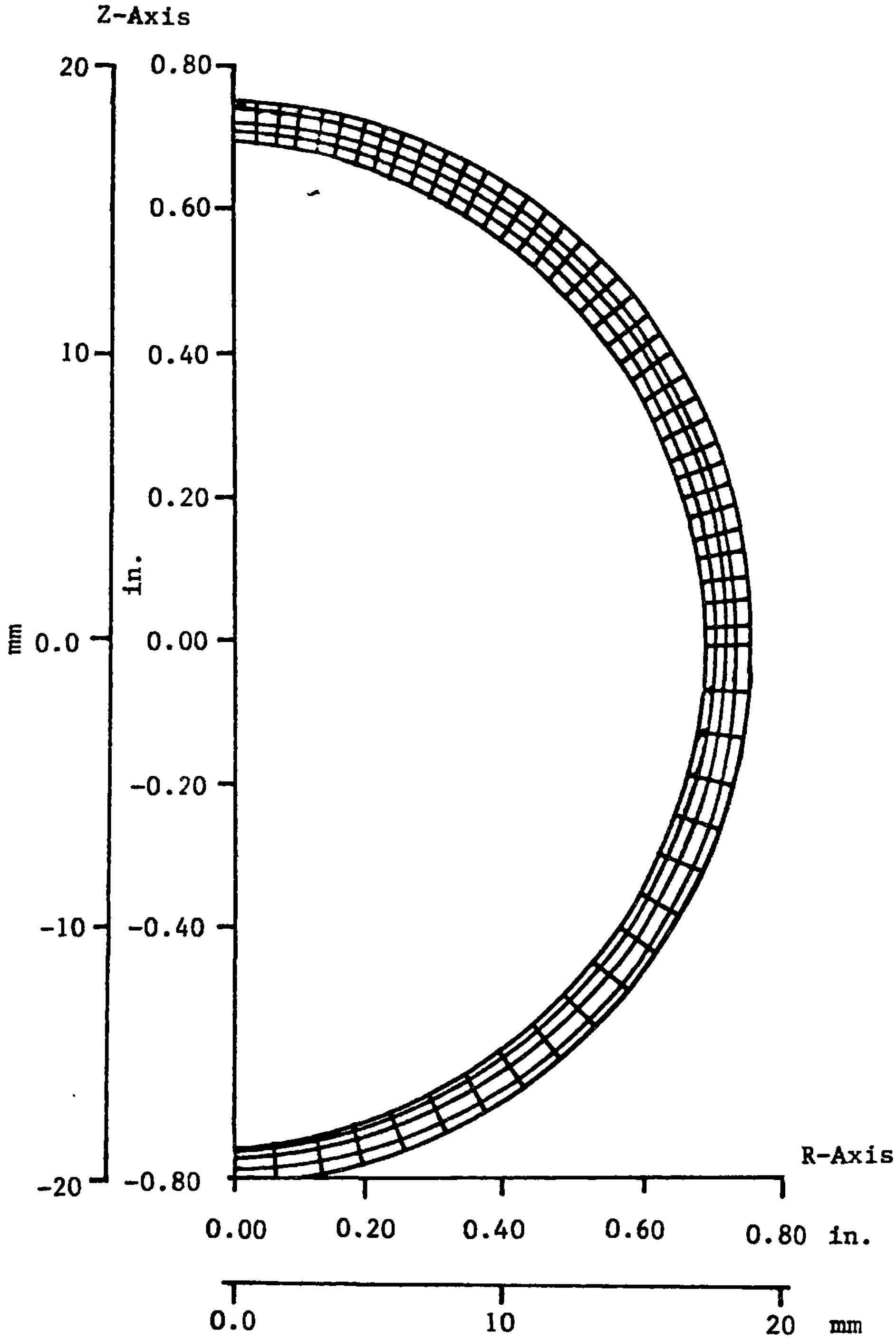


Figure G.6-4 *Receiver Tube Finite Element Thermal Model Grid*

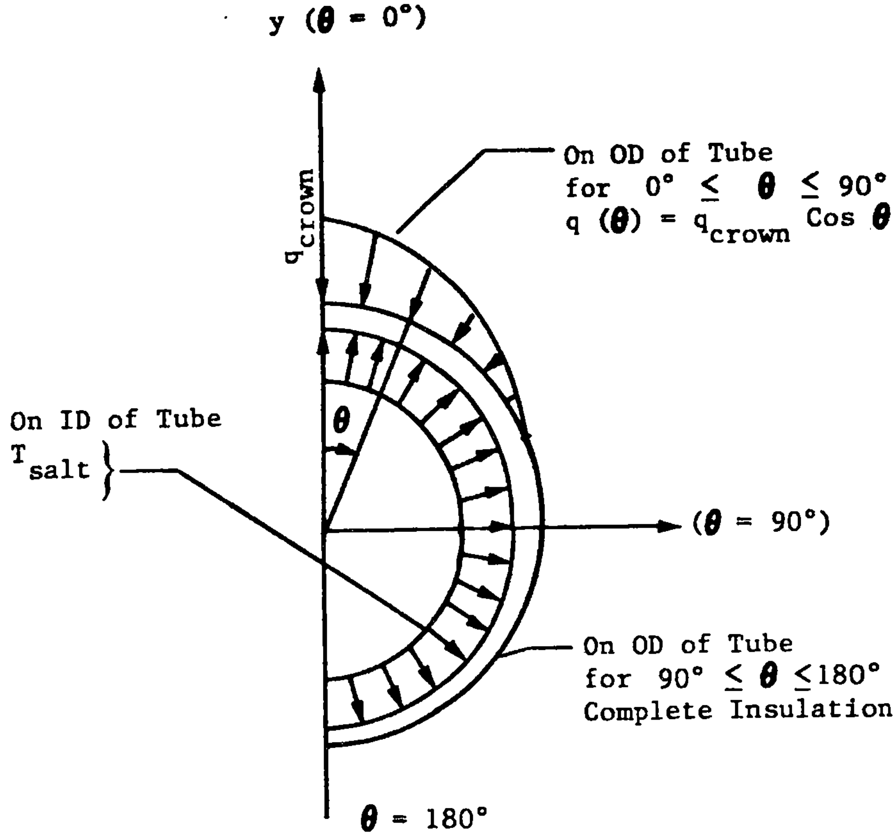


Figure G.6-5 *Thermal Boundary Heat Input*

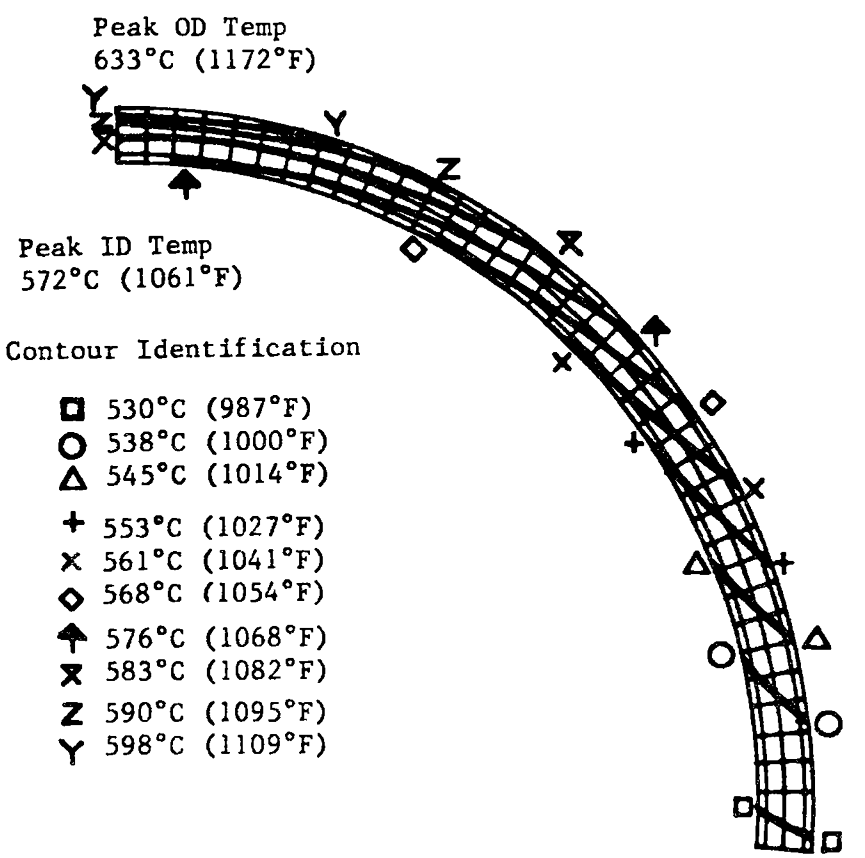


Figure G.6-6 *Tube Temperature Contour Map*

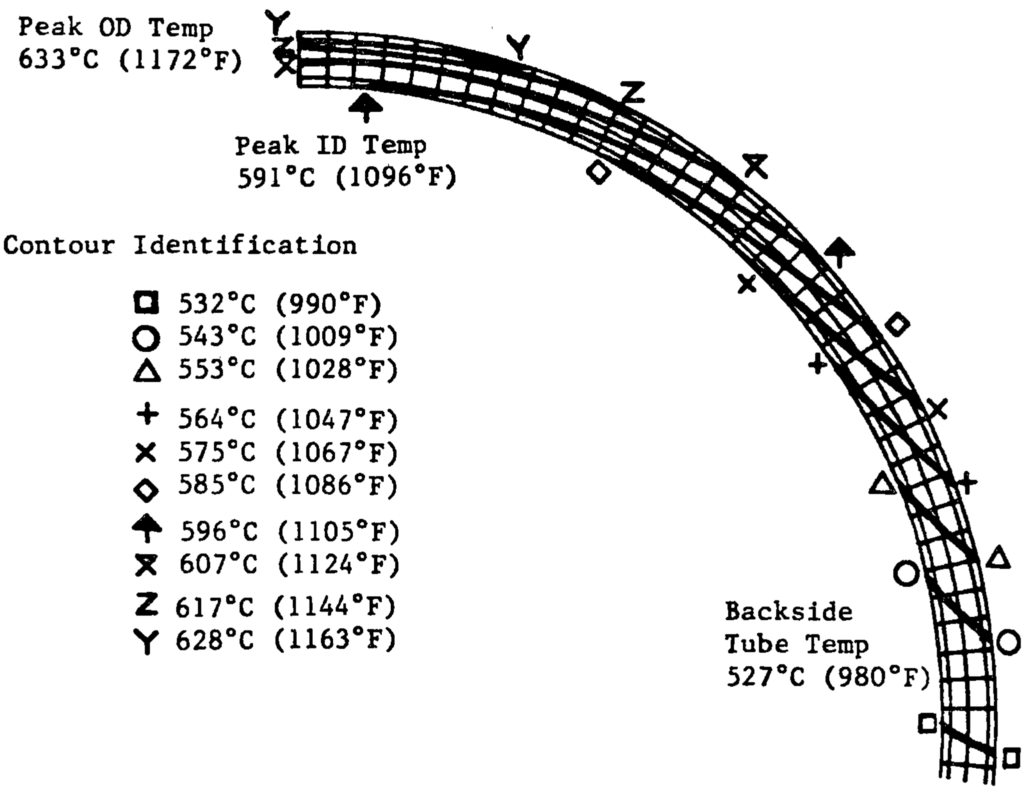


Figure G.6-7 *Tube Temperature Contour Map for Panel 10*

The elastic rules of Code Case N-47 are followed for determining the elastic strain ranges. This is performed through utilization of computer program CREEPF. For the tube and clip weld region, the hoop stresses are concentrated with a stress concentration factor of 4.0.

The stress analysis of point "A" showed the tube crown compressive stresses to be approximately -234.4 MPa (-34,000 psi) while for Point A-1 they are reduced to -165.4 MPa (-24,000 psi). For normal operating conditions (design point), the -165.4 MPa (-24,000 psi) stress level represents the most realistic condition for the tube at the crown region. However, in an attempt to analyze the most conservative situation for parametric evaluations, the stress level of -234.4MPa (-34,000 psi) at a maximum temperature level of 633°C (1172°F) is considered for a simplified inelastic evaluation on the ANSYS computer program. In this evaluation a pure strain-controlled condition is assumed neglecting the beneficial effect of strain redistribution in the tube. The model is simply a single element (i.e., STIF 42 out of ANSYS) which is a 1 in. - 2-D isoparametric solid. A total of seven load cycles are analyzed as depicted in Figure G.6-9. The loading condition consists of displacements applied to the structure such that the calculated elastic stress of -234.4MPa (-34,000 psi) is applied in the load steps shown. Upon unloading, the structure returns to the overnight hot standby conditions. After the fourth load cycle, different hold times are imposed with each being progressively longer to better understand the predicted behavior for the creep damage. The analysis considers the virgin yield stress throughout the loading. The material properties assumed are those for Incoloy 800H. The tube is constructed of Incoloy 800 and the substitution of Incoloy 800H properties from Code Case N-47 is justifiable based on current literature, which indicates similarities in the mechanical properties.

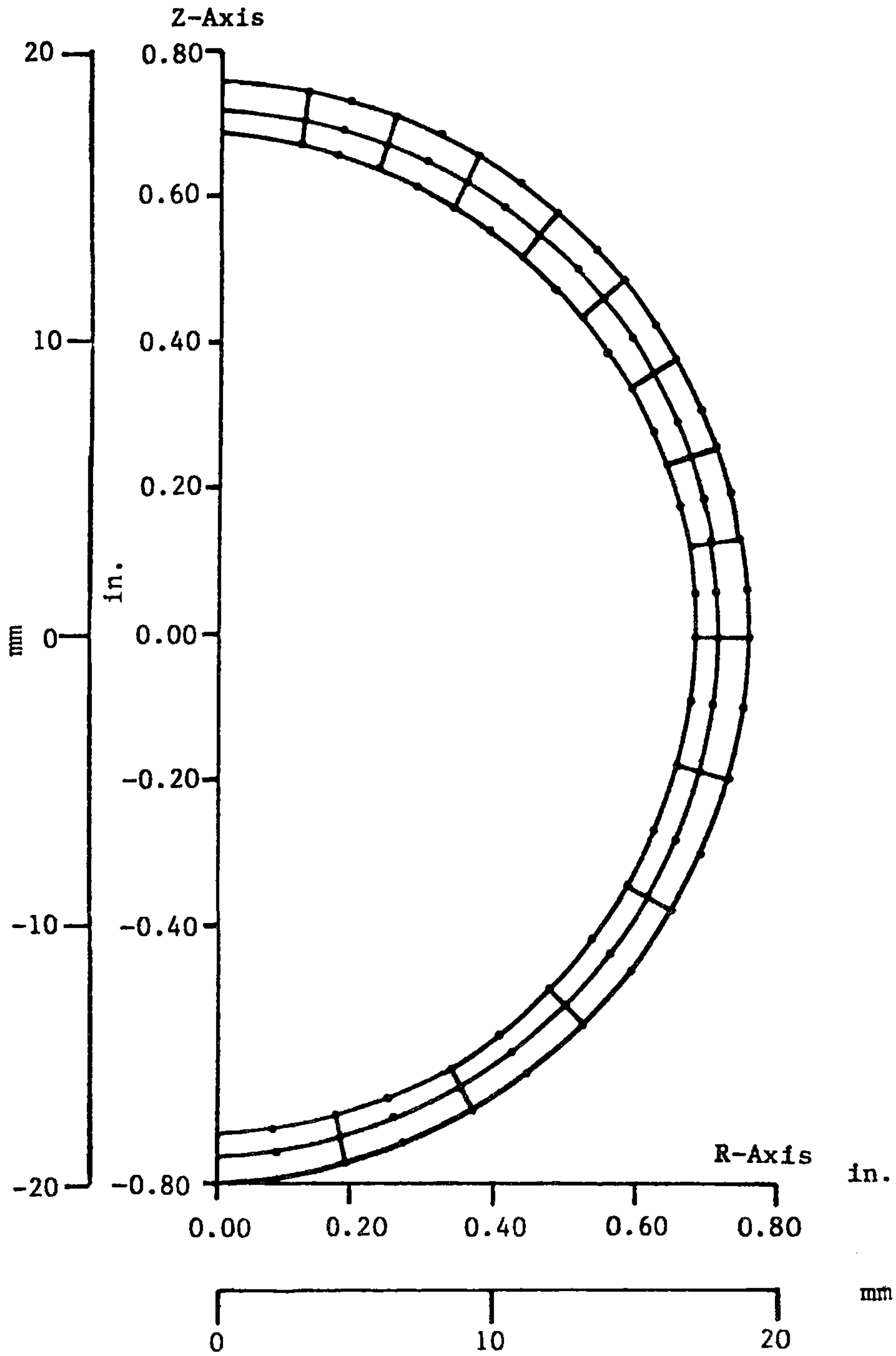
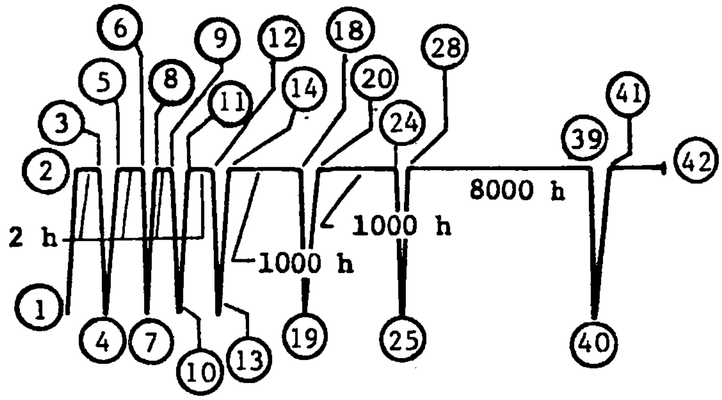


Figure G.6-8 *Receiver Tube Finite Element Stress Model Grid*



○ - Load Change Point

Figure G.6-9 Load Histogram for Inelastic Analysis

The results of the analysis are depicted in Figures G.6-10 **through** G.6-12 **and Table** G.6-2.

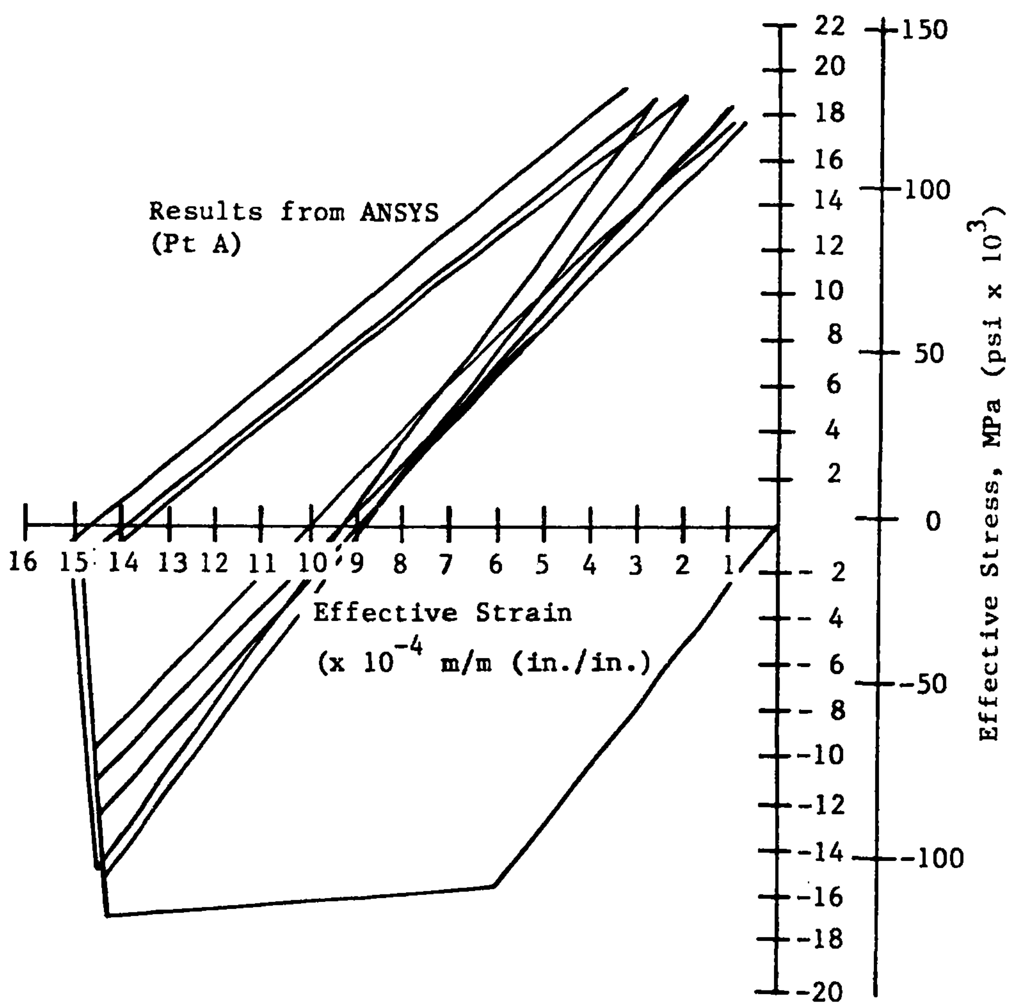


Figure G.6-10
Effective Stress vs Strain Hysteresis Loop Panel 10 (Inelastic)

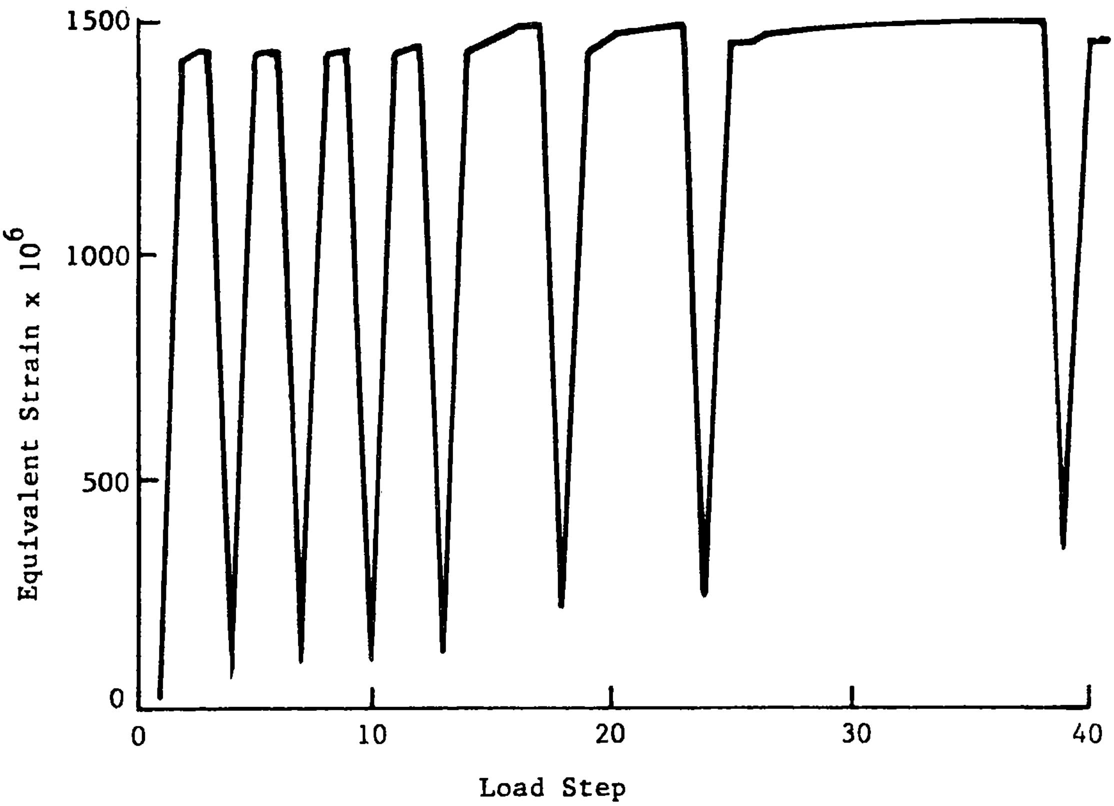


Figure G.6-11 *Inelastic Results for Receiver Tube Equivalent Strain*

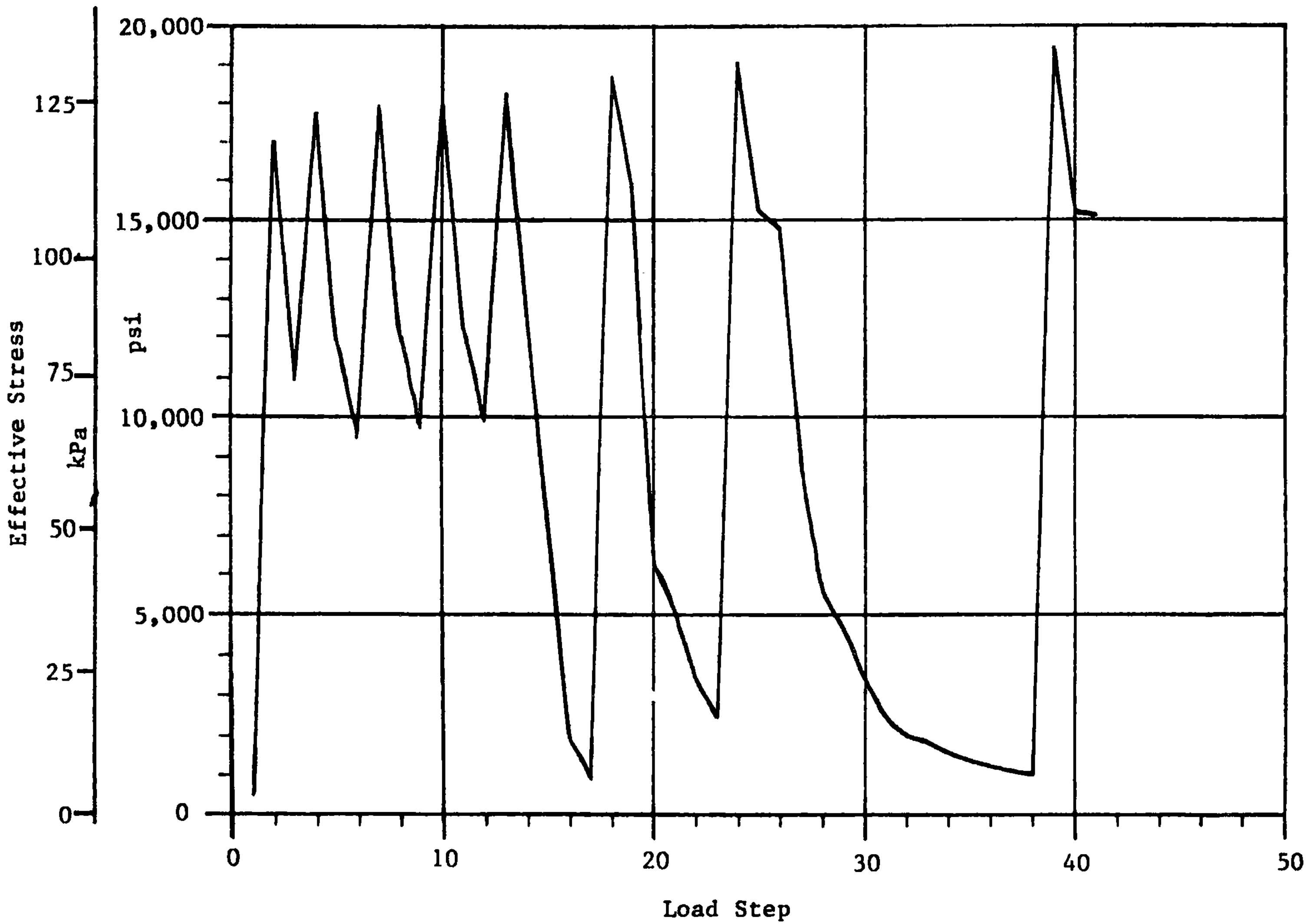


Figure G.6-12 *Inelastic Results for Receiver Tube Effective Stresses*

Table G.6-2 Inelastic Results for Receiver Tube

(A) METRIC UNITS

Input Values and Calculated Equivalent Strain									
Load Step	Strain						Equiv Strain	Stress, psi	
	R	Z	T	RZ	ZT	TP		Eff	Eff/0.9
1.	21.	1.	- 12.	0.	0.	0.	13.	3.806	4.228
2.	-610.	1480.	- 669.	0.	0.	0.	1413.	117.104	130.116
3.	-635.	1480.	- 711.	0.	0.	0.	1436.	75.727	84.142
4.	- 48.	1.	- 136.	0.	0.	0.	80.	120.083	135.648
5.	-613.	1480.	- 723.	0.	0.	0.	1433.	82.016	91.129
6.	-622.	1481.	- 741.	0.	0.	0.	98.	66.192	73.547
7.	- 28.	1.	- 158.	0.	0.	0.	1433.	122.896	136.552
8.	-591.	1480.	- 741.	0.	0.	0.	1433.	84.546	93.941
9.	.602.	1479.	- 760.	0.	0.	0.	116.	66.813	74.236
10.	- 10.	0.	- 179.	0.	0.	0.	1435.	124.482	138.314
11.	-572.	1480.	- 761.	0.	0.	0.	1445.	84.264	93.626
12.	-581.	1481.	- 779.	0.	0.	0.	130.	67.923	74.470
13.	- 9.	1.	- 199.	0.	0.	0.	1436.	125.586	139.540
14.	-552,	1480.	- 778.	0.	0.	0.	1458.	86.525	96.139
15.	-572.	1480.	- 821.	0.	0.	0.	1480.	47.631	52.923
16.	-576.	1480.	- 874.	0.	0.	0.	1487.	13.328	14.808
17.	-564.	1479.	- 900.	0.	0.	0.	210.	6.047	6.719
18.	76.	1.	- 270.	0.	0.	0.	1432.	128.599	142.887
19.	-469.	1479.	- 824.	0.	0.	0.	1470.	108.624	120.693
20.	-504.	1480.	- 895.	0.	0.	0.	1470.	43.311	48.234
21.	-507.	1479.	- 906.	0.	0.	0.	1475.	35.096	38.995
22.	-508.	1480.	- 922.	0.	0.	0.	1483.	24.057	26.730
23	-507.	1480.	- 935.	0.	0.	0.	1488.	16.913	18.793
24.	121.	0.	- 320.	0.	0.	0.	263.	131.184	145.760
25.	-423.	1480.	- 876.	0.	0.	0.	1444.	105.018	116.686
26.	-425.	1480.	- 879,	0.	0.	0.	1445.	102.170	113.522
27.	-448.	1480.	- 922.	0.	0.	0.	1469.	61.076	67.862
28.	-458.	1480.	- 950.	0.	0.	0.	1483.	38.543	42.826
29.	-459.	1480.	- 959.	0.	0.	0.	1488.	31.841	35.379
30.	-460.	1480.	- 972.	0.	0.	0.	1494.	23.533	26.147
31.	-459.	1480.	- 983.	0.	0.	0.	1498.	17.258	19.176
32.	-458.	1480.	- 991.	0.	0.	0.	1502.	13.673	15.192
33.	-457.	1480.	- 993.	0.	0.	0.	1502.	12.487	26.147
34.	-455.	1481.	- 999.	0.	0.	0.	1505.	10.742	11.936
35.	-453.	1480.	-1003.	0.	0.	0.	1506.	9.460	10.511
36.	-451.	1480.	-1006.	0.	0.	0.	1507.	8.446	9.385
37.	-449.	1481.	-1009.	0.	0.	0.	1508.	7.605	8.450
38.	-448.	1480.	-1011.	0.	0.	0.	1508.	7.226	8.029
39.	186.	1.	- 389.	0.	0.	0.	339.	134.004	148.894
40.	-358.	1481.	- 941.	0.	0.	0.	1460.	105.204	116.893
41.	-358.	1481.	- 941.	0.	0.	0.	1460.	104.452	116.058

Table G.6-2 Inelastic Results for Receiver Tube

(B) **ENGLISH UNITS**

Input Values and Calculated Equivalent Strain									
Load Step	Strain						Equiv Strain	Stress, MPa	
	R	Z	T	RZ	ZT	TP		Eff	Eff/0.9
1.	21.	1.	- 12.	0.	0.	0.	19.	552.	613.
2.	-610.	1480.	- 669.	0.	0.	0.	1413.	16894.	18871.
3.	-635.	1480.	- 711.	0.	0.	0.	1436.	10983.	12203.
4.	- 48.	1.	- 136.	0.	0.	0.	80.	17706.	19673.
5.	-613.	1480.	- 723.	0.	0.	0.	1433.	11895.	13217.
6.	-622.	1481.	- 741.	0.	0.	0.	1443.	9600.	10667.
7.	- 28.	1.	- 158.	0.	0.	0.	98.	17884.	19271.
8.	-591.	1480.	- 741.	0.	0.	0.	1433.	12262.	13624.
9.	-602.	1479.	- 760.	0.	0.	0.	1443.	9600.	10767.
10.	- 10.	0.	- 179.	0.	0.	0.	116.	18054.	20060.
11.	-572.	1480.	- 761.	0.	0.	0.	1425.	12221.	13579.
12.	-581.	1481.	- 779.	0.	0.	0.	1445.	9891.	10946.
13.	- 9.	1.	- 199.	0.	0.	0.	130.	18214.	20238.
14.	-552.	1480.	- 778.	0.	0.	0.	1436.	12549.	13943.
15.	-572.	1480.	- 821.	0.	0.	0.	1458.	6908.	7676.
16.	-576.	1480.	- 874.	0.	0.	0.	1480.	1933.	2148.
17.	-564.	1479.	- 900.	0.	0.	0.	1487.	877.	974.
18.	76.	1.	- 270.	0.	0.	0.	210.	18651.	20723.
19.	-469.	1479.	- 824.	0.	0.	0.	1432.	15754.	17504.
20.	-504.	1480.	- 895.	0.	0.	0.	1470.	6296.	6996.
21.	-507.	1479.	- 906.	0.	0.	0.	1475.	5090.	5656.
22.	-508.	1480.	- 922.	0.	0.	0.	1488.	3489.	3877.
23.	-507.	1480.	- 935.	0.	0.	0.	1488.	2453.	2726.
24.	121.	0.	- 320.	0.	0.	0.	263.	19026.	21140.
25.	-423.	1480.	- 876.	0.	0.	0.	1444.	15231.	16923.
26.	-425.	1480.	- 879	0.	0.	0.	1445.	14818.	16464.
27.	-448.	1480.	- 922.	0.	0.	0.	1469.	8858.	9842.
28.	-458.	1480.	- 950.	0.	0.	0.	1483.	5590.	6211.
29.	-459.	1480.	- 959.	0.	0.	0.	1488.	4618.	5131.
30.	-460.	1480.	- 972.	0.	0.	0.	1494.	3413.	3792.
31.	-459.	1480.	- 983.	0.	0.	0.	1498.	2503.	2781.
32.	-458	1480.	- 991.	0.	0.	0.	1502.	1983.	2203.
33.	-457	1480.	- 993.	0.	0.	0.	1502.	1811.	2012.
34.	-455.	1481.	- 999.	0.	0.	0.	1505.	1558.	1731.
35.	-453.	1480.	-1003.	0.	0.	0.	1506.	1372.	1524.
36.	-451.	1480.	-1006.	0.	0.	0.	1507.	1225.	1361.
37.	-449.	1481.	-1009.	0.	0.	0.	1508.	1103.	1226.
38.	-448.	1480.	-1011.	0.	0.	0.	1508.	1048.	1164.
39.	186.	1.	- 389.	0.	0.	0.	339.	19435.	21594.
40.	-358.	1481.	- 941.	0.	0.	0.	1460.	15258.	16953.
41.	-358.	1481.	- 941.	0.	0.	0.	1460.	15149.	16832.

The fatigue damage is calculated based on two partitioned strain ranges. The maximum strain range occurs during the first loading cycle and is shown in Figure G.6-10. The maximum value is 0.142%. The strain range decreases in the subsequent cycles and based on this information it is reasonable to use this maximum value for the first four loading cycles. For the remaining cycles, a strain range value of 0.131% is used (Fig. G.6-3).

The fatigue damage is calculated by entering the continuous cycling curves from Code Case N-47, Figure G.6-13, at the maximum temperature of 633°C (1172°F). The fatigue damage is as follows:

ε_1 = 0.142%
n = 4 cycles
N_d = 50,000 cycles

$$D_{f1} = \frac{4}{5,000} = 0.0$$

For the remaining cycles (approximately 60,000) the strain range is 0.131%.

n = 60,000 cycles
N_d = 100,000 cycles

$$D_{f2} = \frac{60,000}{100,000} = 0.6$$

The total fatigue damage is therefore:

$D_f = 0.0 + 0.6 = 0.6$

Creep Damage - The creep damage is predicted by use of the stress-to-rupture curves from code Case N-47 for Incoloy 800H (Figure G.6-14) and the calculated inelastic effective stresses determined by the ANSYS program. The total operating time is for 100,000 hours of life. The inelastic solution reveals a significant relaxation in stress for long periods of hold time.

For the first hold time segment of eight hours, a hold stress of 117.2 MPa (17,000 psi) is assumed based on the calculated stress value of 117.1 MPa (16,984 psi). No relaxation is considered here, but the benefit is taken into account by subdividing the time remaining into eight segments and evaluating the stress at each.

A plot of the effective stresses is presented in Figure G.6-12 for the complete histogram and the relaxation of the stress for the hold times is illustrated in Figure G.6-15.

Based on these results, Table G.6-3 gives the accumulated creep damage.

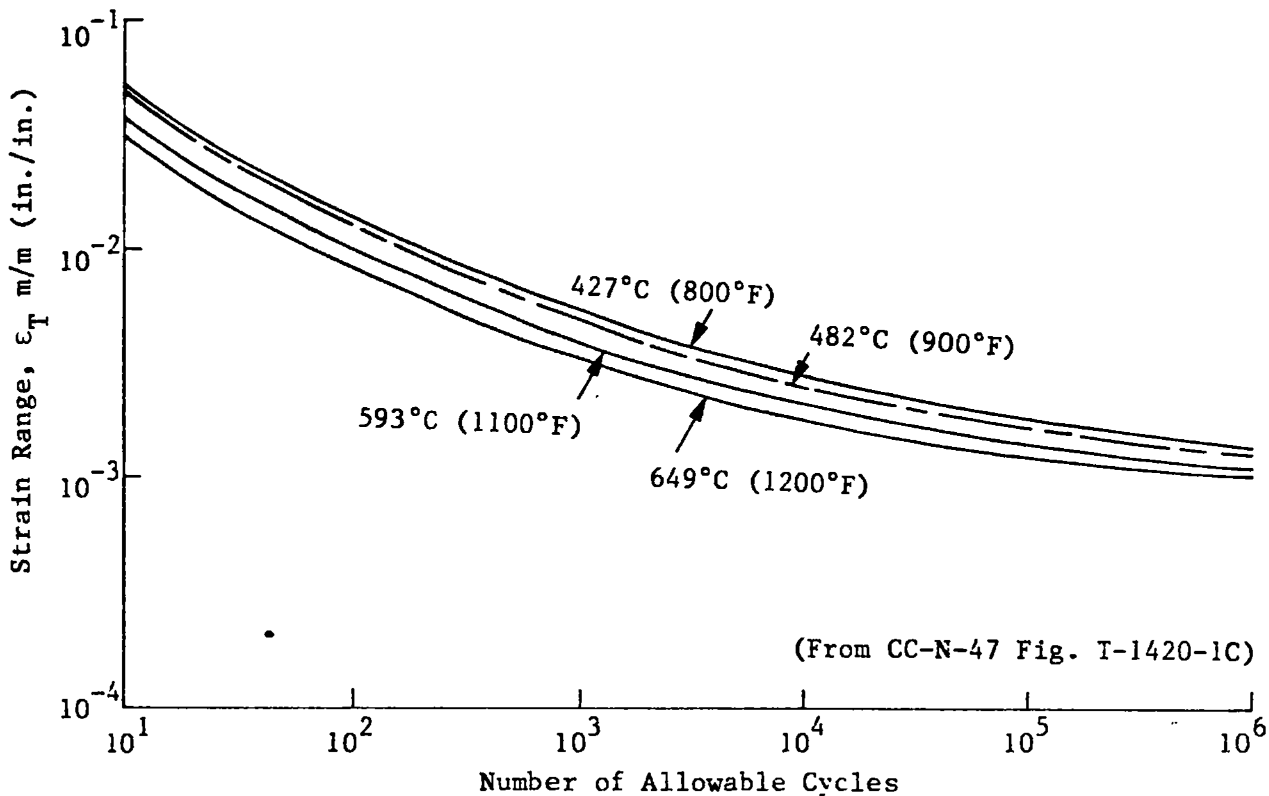


Figure G.6-13 *Design Fatigue Curve (Continuous Cycling to* 10^6 *Cycles)*

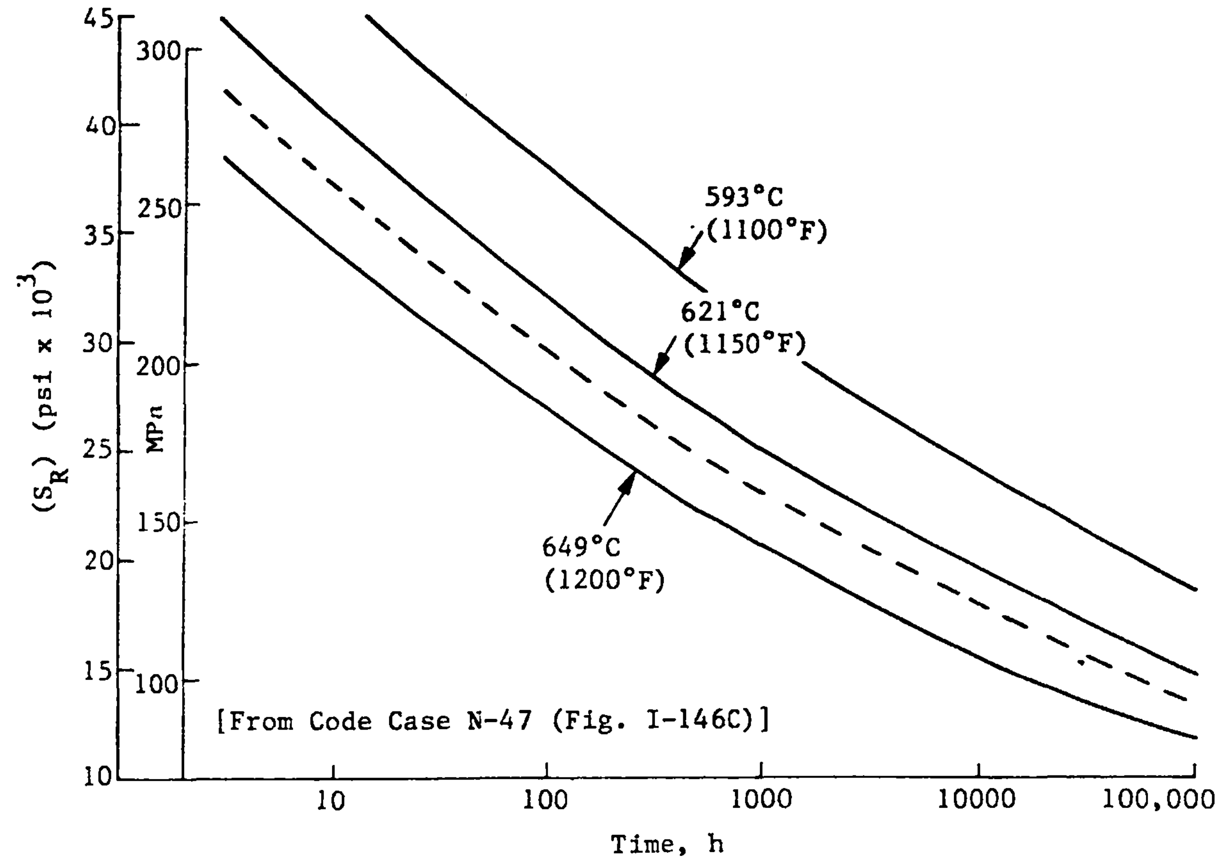


Figure G.6-14 Stress-to-Rupture Curves for Alloy 800H

Table G.6-3 Receiver Tube Creep Damage Results

Hold Time Stress, MPa	Hold Time Stress, (psi)	Hold Time Stress / 0.9, MPa	Hold Time Stress / 0.9, (psi)	Operating Time, t_i hr	Allowable Time,* T_d hr	Creep Damage, $\frac{t_i}{T_d}$
117	17,000	130	18,900	6	5,000	0.0
86	12,500	96	13,900	10,000 †	70,000	0.143
81	11,700	90	13,000	10,000 †	100,000	0.100
76	11,000	84	12,200	10,000 †	100,000	0.05
71	10,300	79	11,400	10,000 †	$>3 \times 10^5$	0.0
86	12,500	96	13,900	15,000 ¶	70,000	0.214
78	11,300	87	12,600	15,000 ¶	140,000	0.107
70	10,200	78	11,300	15,000 ¶	$>3 \times 10^5$	0.0
63	9,200	70	10,200	15,000 ¶	$>3 \times 10^5$	0.0
					Total	0.614

*See Figure G.6-13 (Replotted from (N-47)

†Based on 40,000 hr at 2-hr Cycles (Cloud Transients)

¶Based on 60,000 hr at 8-hr Operating Cycles

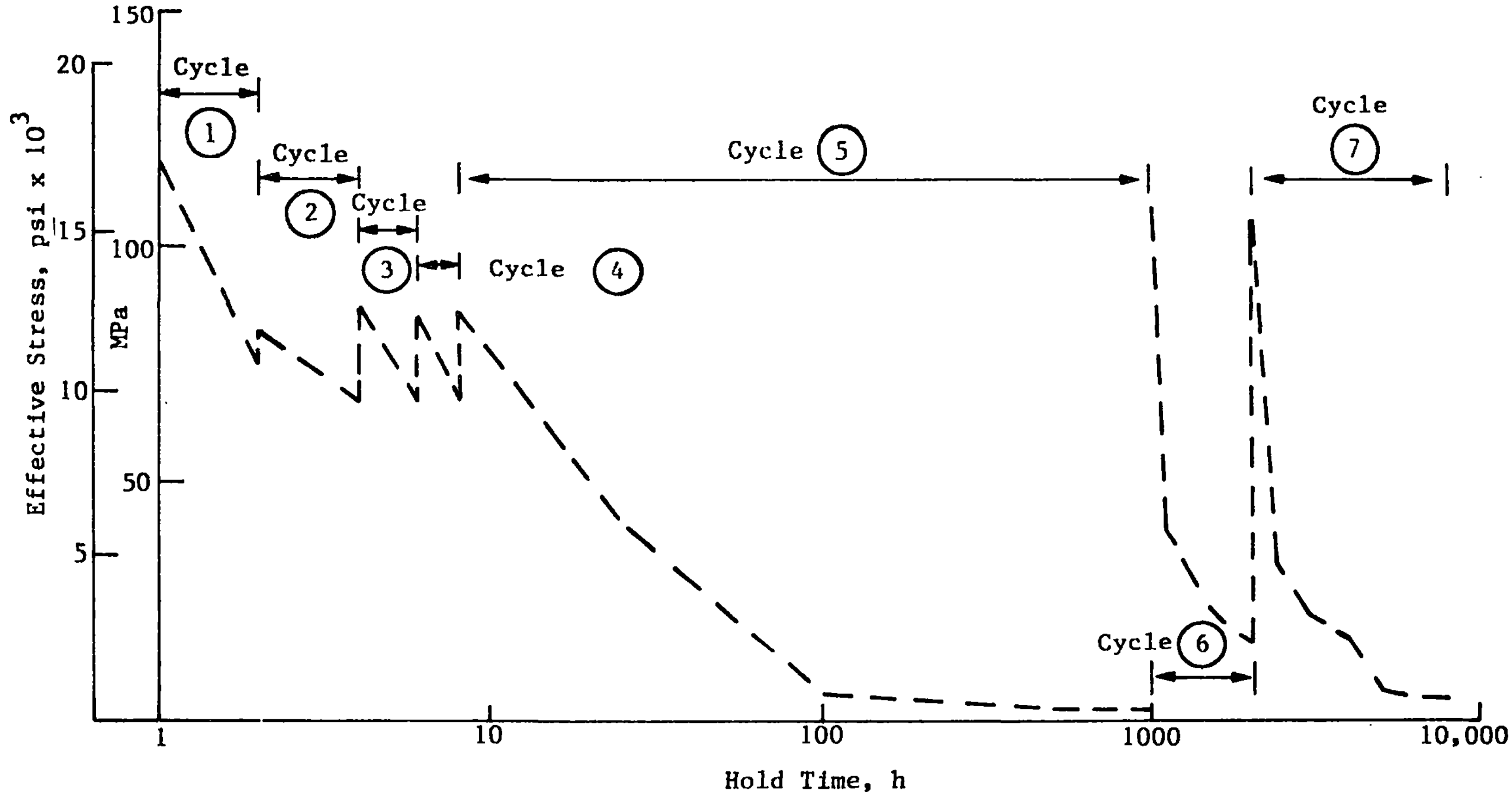


Figure G.6-15 *Plot of Effective Stresses for Hold Times Analyzed on ANSYS*

G.7 Startup Stress Analysis

This section describes various receiver startup (warmup) cases in detail.

Figures G.7-1 through G.7-3 illustrate time profiles of the receiver parameters for this startup with the receiver and piping cold.

Figure G.7-4 shows the following time profiles:

- Average allowable heat flux to the receiver during the startup
- Pressure rise during the startup
- Rate of steam flow leaving the steam drum
- Rate of steam flow through the turbine by-pass valve

After 0.4 hours, steam starts to flow from the drum. Even though the superheater panels are experiencing solar input, heat absorption by the long piping runs results in a delay of 0.6 hours before a steam and water mixture reaches the by-pass valve.

Figure G.7-2 shows the time profiles of:

- Temperature rise rate experienced by average superheater panel prior to the attainment of steam flow.
- Temperature profiles of the fluid leaving economizer and evaporator panels.
- Profile of the quality of steam at turbine by-pass valve.

The average dry superheater panel reaches a temperature of about 404°C (760°F). 404°(760°F) is the equilibrium temperature for an uncooled panel tube subjected to 23.6 kw/m² (7,500 Btu/hr-ft²) heat flux. It has been assumed in this analysis that peak flux on the receiver will be about 2.5 times average flux. Thus, peak flux would be 59.1 km/m² (18,750 Btu/hr-ft²), for which equilibrium temperature is about 650°C (1,200°F), and this temperature level is assumed to be the peak temperature on receiver.) Economizer discharge (once boiling starts) remains in the two-phase region throughout the period of pressure rise, then becomes subcooled as steam flow takes a rapid increase. Initial superheat is attained at the turbine by-pass valve at about 1.9 hours, and the temperature required for steam admission to the hot turbine is attained in about 2.4 hours.

Figure G.7-3 shows steam temperature profiles achieved at the exits of each of the five successive superheater panels and at the turbine by-pass valve. The magnitude of the heat sink capacity of the piping runs can be judged by the long delay in achieving superheat at the turbine throttle. The plot of the steam temperature leaving panel PS3 indicates that some attemperation flow may be required (although a study with actual flux maps would be required to substantiate this).

Solar Startup With Piping Hot

Figures G.7-5 through G.7-6 illustrate similar time profiles of the receiver parameters for startup with the piping hot from the previous day's operation. The plots graphically show the startup time reduction possible when the steam piping does not have to be heated. The thermal capacity of main steam piping heats the initial steam flow to 427°C (800°F) at the turbine by-pass valve. Figure G.7-6 shows that, for the average flux used in this analysis, steam temperature at the turbine throttle started to drop once desired pressure was attained. An increase in flux during the last 0.3 hours could be expected to restore the 427°C (800°F) steam temperature. The figure also indicates that starting the turbine at a lower throttle pressure could be considered to increase the power generation capabilities.

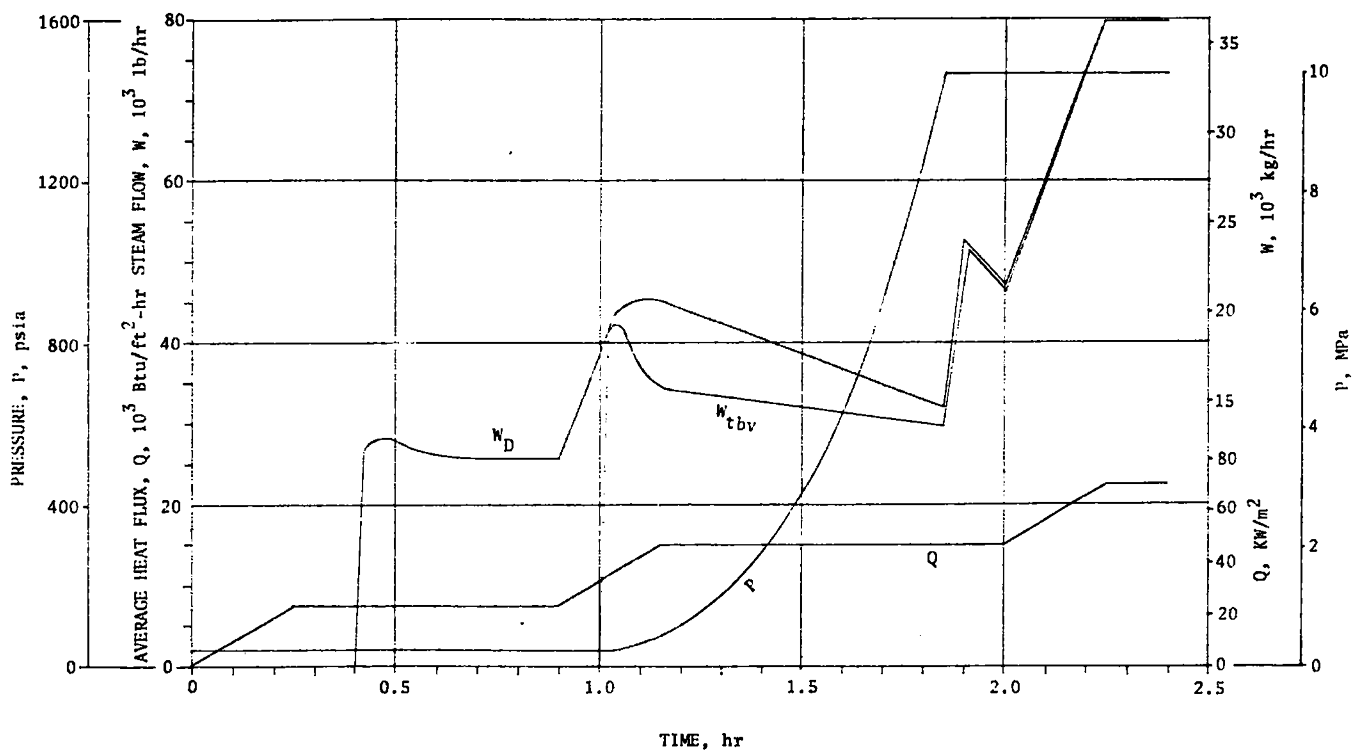


FIGURE G.7-1

SOLAR WARMUP - RECEIVER & PIPES COLD

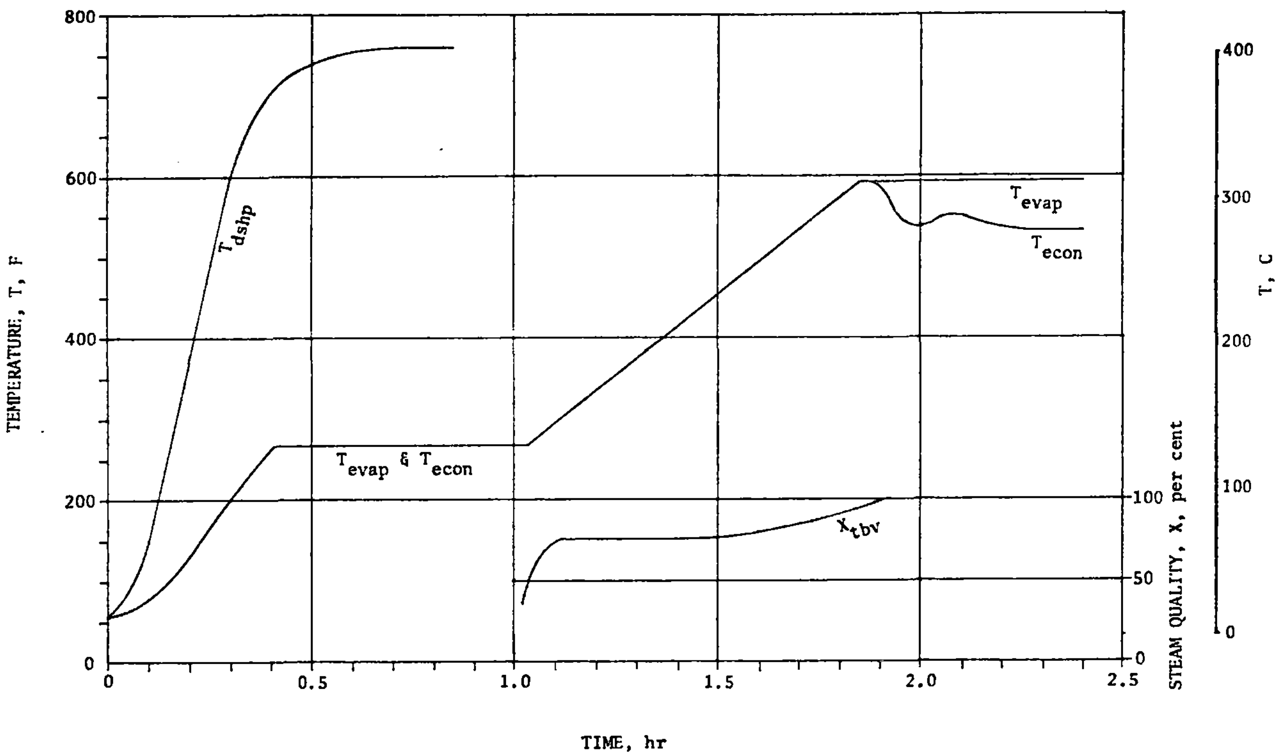


FIGURE G.7-2

SOLAR WARMUP - RECEIVER & PIPES COLD

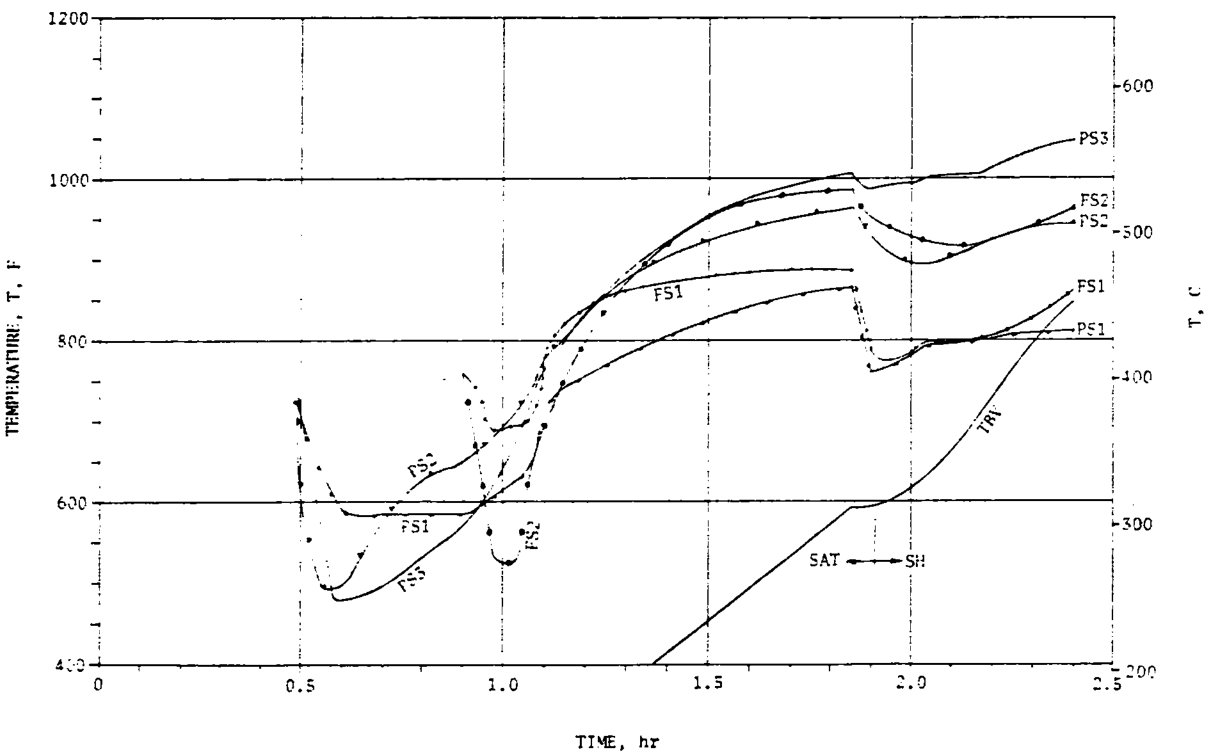


FIGURE G.7-3

SOLAR WARMUP - RECEIVER & PIPES COLD

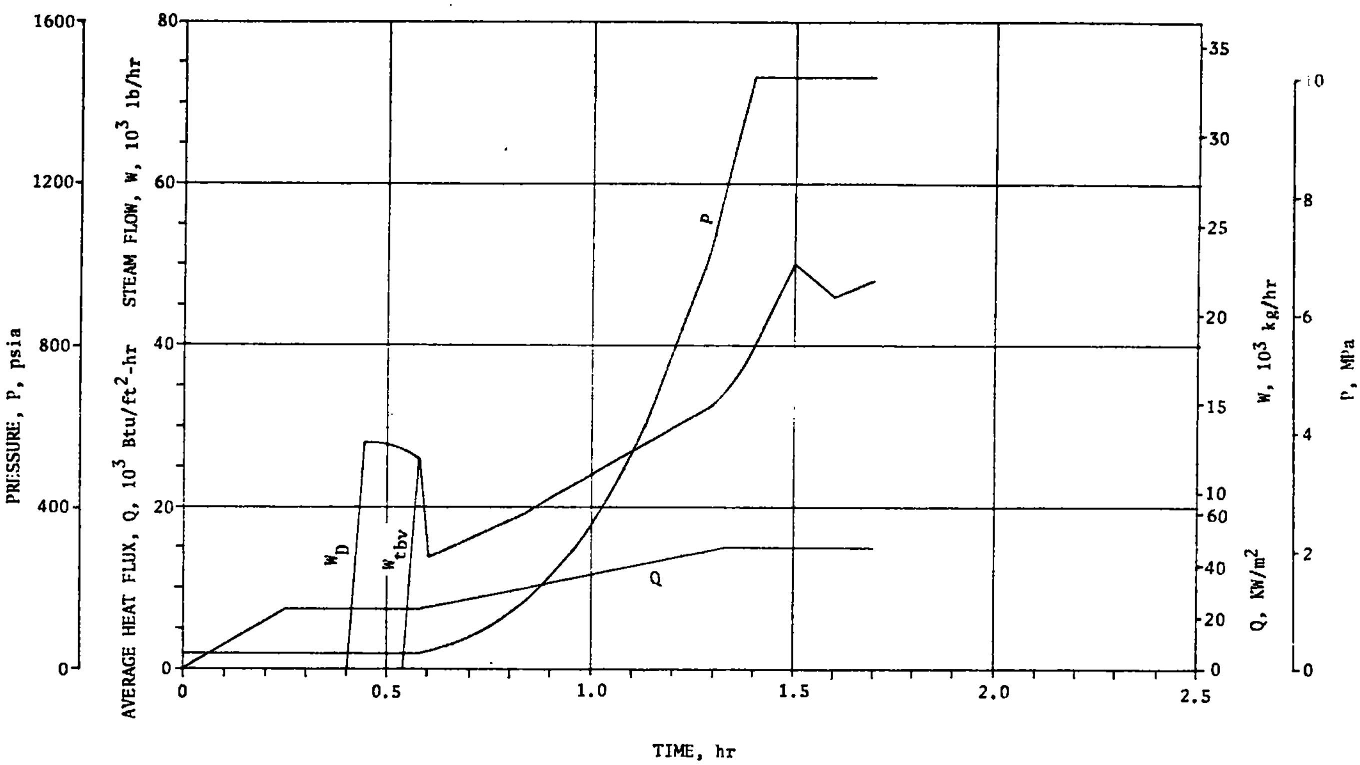


FIGURE G.7-4

SOLAR WARMUP - RECEIVER COLD & PIPES HOT

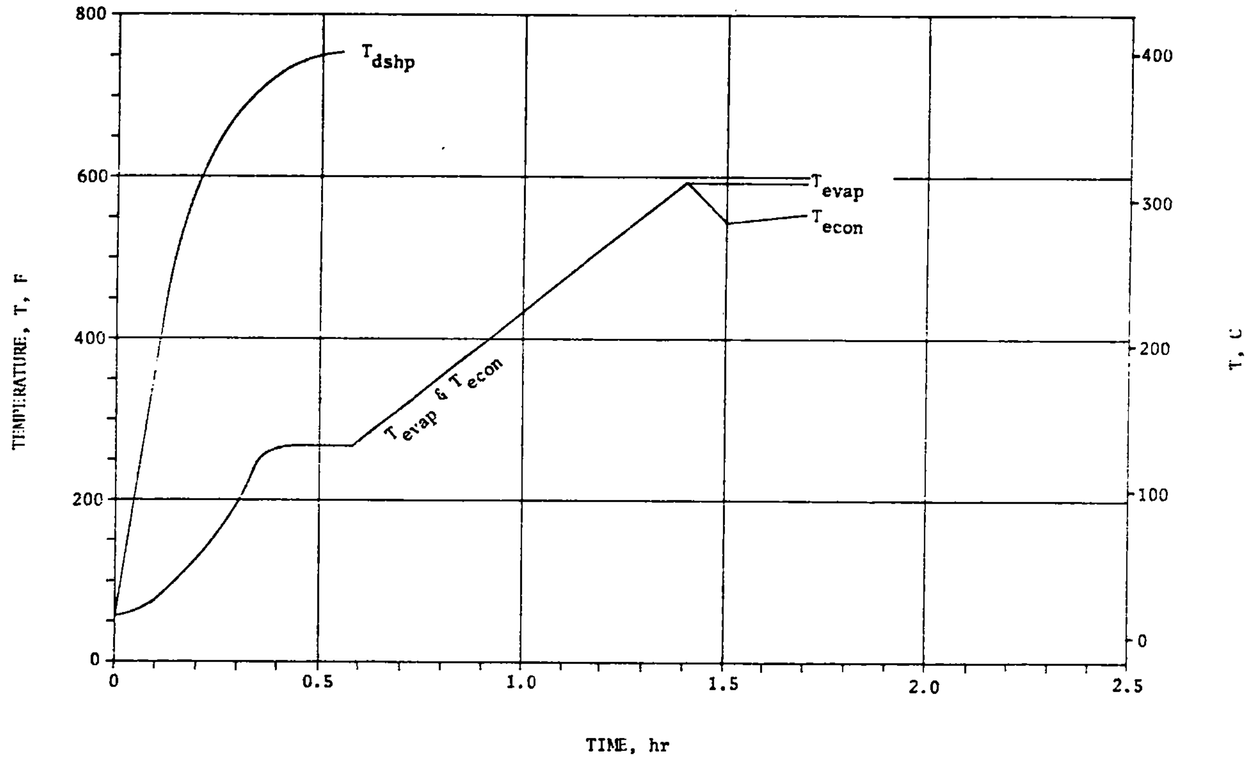


FIGURE G.7-5

SOLAR WARMUP - RECEIVER COLD & PIPES HOT

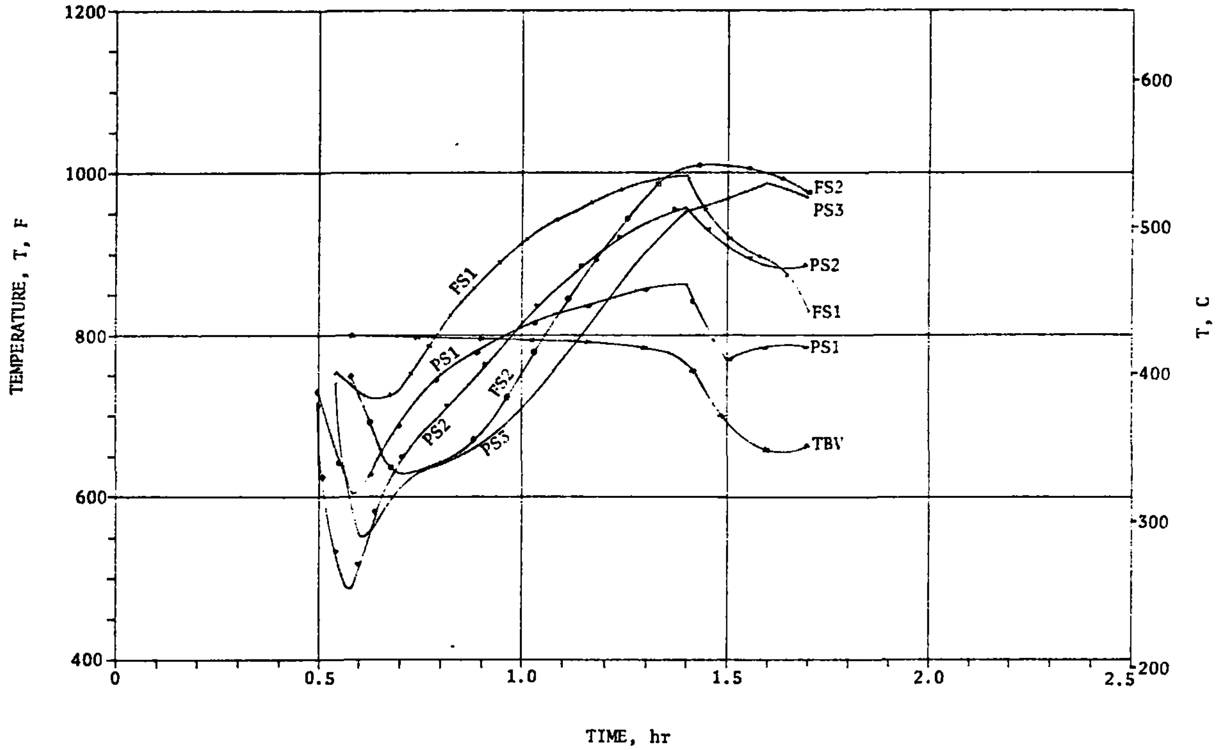


FIGURE G.7-6

SOLAR WARMUP - RECEIVER COLD & PIPES HOT