DOE/SF/10736-1/3

SOLAR INDUSTRIAL RETROFIT SYSTEM, NORTH COLES LEVEE NATURAL GAS PROCESSING PLANT

Appendices

July 1980

Work Performed Under Contract No. AC03-79SF10736

Northrup, Incorporated
Hutchins, Texas

and

ARCO Oil and Gas Company
Bakersfield, California

U.S. Department of Energy

Solar Energy

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NORTH COLES LEVEE NATURAL GAS PROCESSING PLANT

APPENDICIES

July 1980

Prepared for the

U. S. DEPARTMENT OF ENERGY

As part of

Contract No. DE-AC03-79SF10736

by

Northrup, Incorporated

and

ARCO Oil and Gas Co.

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APPENDIX A

SYSTEMS REQUIREMENTS SPECIFICATION

for

North Coles Levee Natural Gas Processing Plant

Solar Retrofit System

NORTHRUP/ARCO OIL & GAS NORTH COLES LEVEE PROJECT SYSTEM REQUIREMENT SPECIFICATION

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B	Roy L. Henry	Program Manager	3/6/80
C	Roy L. Henry	Program Manager	6/16/80

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1. GENERAL

1.1 Scope This specification defines the subsystem characteristics, design requirements, system environmental requirements, plant conceptual design data requirements for a Solar Industrial Retrofit Plant. The plant will provide process heat for operation of ARCO Oil and Gas Company's North Cole's Levee Natural Gas Processing Plant No. 8 located near Bakersfield, California.

1.2 System Description For the purpose of the Industrial Retrofit conceptual design project, a system will consist of the following major elements:

Site
Facilities
Collector System
Receiver System
Specialized Equipment

The plant is a refrigerated absorption oil plant that recovers propane, butane, and gasoline from raw natural gas. The process consists of the raw gas being bubbled through an oil that absorbs hydrocarbons with chains longer than methane. The absorption oil is heated to drive off the absorbed hydrocarbons which are further processed to separate ethane, propane, butane and gasoline. For safety reasons the entire process avoids the use of flame and is powered instead by a "heat medium" oil, operating between 193°C (380°F) and 301°C (575°F) and recirculated to the strippers, deethanizer, depropanizer and debutanizer reboilers (Figure 1). The solar system will heat the heat medium oil and thus directly replace natural gas currently used for heating.

The solar process heat retrofit system consists of 320 heliostats positioned in a radial stagger arrangement within a 120° circular sector located due North of a single cavity receiver 60.95 m (200 ft) above ground level (Figure 2). During periods of sufficient insolation, the heat medium oil will be pumped from the surge tank (37.85 m^3 - 10,000 gal) through the receiver where the temperature of the oil is increased from 215.6°C (420°F) to 293.3°C (560°F) and then returned to the existing system at the inlet to the fired heaters. These heaters complete the required temperature increase to 301°C (575°F). This "topping off" is necessary because the heaters cannot be completely shut down and restarted on an intermittant basis. The heat medium oil will be the hydrotreated light cycle oil that ARCO has used for many years. Proper manifolding and control will permit the utilization of all solar energy produced, while making full use of the heat produced by existing plant equipment that must remain in a state of full or limited operation. The solar energy delivery profile will follow the insolation transients and the fossil fuel heaters will continuously compensate for these variations. There is no high temperature storage tank in the receiver loop.

1.2.1 Site The site is ARCO Oil and Gas Company's North Coles Levee Natural Gas Processing Plant No. 8. ARCO Oil and Gas Company is a subsidiary of the Atlantic Richfield Company. The plant is located 22 miles west of

1.2.1 Continued

Bakersfield, California (Figure 3). This is in the southern portion of the San Joequin Valley. The terrain is flat and relatively level and will require minimum grading during site preparation (details TBD). The collector field is located adjacent to, and north of the central gas processing area. A 4.05×10^5 m^2 (100 acre) tract has been designated for collector field installation. The area contains numerous operating gas wells and service requirements for these wells must be accommodated during the installation and operation of the collector field. The field layout must allow for oil, gas, injection, and water lines and electric power distribution facilities (Figure 2).

1.2.2 Site Facilities The site facilities will consist of a combination operations and maintenance building. The building will house the control and data acquisition equipment, space for data reduction, files, maintenance tools, and materials and spare parts inventory. The building will be supplied with the normal compliment of utilities; electric power, water, gas and wastewater disposal. Other facilities include access roads for heliostat maintenance and mirror cleaning and a security fence.

.2.3 Collector System The collector system is composed of the heliostats, control subsystem and drive power distribution subsystem.

.2.3.1 Heliostats System design is based on the size and performance characteristics of the Northrup II heliostat. The reflective surface of this heliostat is a square array of 12 mirror facets, each of which is itself 1.2 m x 3.65 m (4 ft x 12 ft) producing a total area of 52.6 m^2 (566 ft^2). The heliostat is structurally and operationally designed to meet all requirements of specification A10772.

.2.3.2 Heliostat Tracking and Control Heliostat tracking and control will be provided by a two-level (Heliostat Array Controller and Heliostat Controller) open-loop system.

.2.4 Receiver System The solar energy conversion will be accomplished by a north-facing single-cavity receiver. The receiver will encompass an arc of 2.58 rad (148°) with 7.3 m (24 ft) radius and will be 9.14 m (30 ft) high. The receiver enclosure will provide a 8.23 m x 8.23 m (27 ft x 27 ft) aperture centered on the receiver center of curvature. Except for the target plane open area, the receiver will be completely enclosed and rear wall insulated will be provided to reduce conduction losses. Doors will be provided to reduce receiver heat loss during shut-down periods. Temperature sensors will be placed on the receiver surface to provide a basis for over-temperature control, and performance evaluation.

1.2.4.1 Tower A three legged steel tower will be provided to elevate the receiver aperture horizontal centerline 61 m (200 ft) above ground level. The tower subsystem will also include an elevator, 1.2.4.1 Continued

obstruction lighting, safety stairs, lightning protection, work platforms, and lighting for maintenance personnel.

1.2.4.2 Receiver Fluid The fluid circulating through the receiver will be the same light cycle hydrotreated oil used in the plant heat medium oil system.

1.2.5 Receiver Loop The receiver loop will consist of the riser and downcomer piping between the receiver manifolds and ground level; the piping from the tower to the interface point at the plant site; inlet and outlet system isolation valves; pump(s); and a bypass pipe between the inlet and outlet piping near the plant interface point.

During cold start up the system isolation valves are closed and the receiver fluid is circulated through the bypass until the outlet temperature reaches 215.5°C (420°F) at which time the isolation valves are opened, the bypass valve is closed and the heat medium oil circulates through the solar system until such time as the outlet temperature drops to the level of the inlet and the isolation valves shut in the solar system.

Flow through the system is controlled automatically by air operated TRC valves with provisions for manual override.

1.2.6 Specialized Equipment Specialized equipment requirements fall into two categories; equipment associated with the solar collectors and the data acquisition equipment.

1.2.6.1 Collector Alignment Equipment This equipment will provide for installation and calibration control of heliostat beam pointing and tracking.

1.2.6.2 Collector Washing Equipment Mobile equipment will be provided for efficient periodic cleaning of heliostat mirror surfaces.

1.2.6.3 Data Acquisition Instrumentation The data acquisition instrumentation will include recorders wiring and sensors to provide a data base for evaluating solar system performance. Included will be instrumentation to provide continuous insolation and weather data.

1.3 Definition of Terms

Beam Pointing Error - The angular difference between the aim point and the beam controid of a mirror.

Capacity Factor, Annual - Non-Solar[T] - Annual non-solar MWh divided by the product of 8760h and plant or unit rating* in MW.

1.3 Continued

Capacity Factor, Annual - Overall† - Annual solar MWh plus annual non-solar MWh divided by the product of 8760 hr and plant or unit rating* in MW.

Capacity Factor, Annual - Solar† - Annual Solar MWh divided by the product of 8760h and plant or unit rating* in MW.

Concentration Ratio - The ratio of the received energy on a small area from multiple surfaces with perfect reflectivity to that arriving from the sun often measured in "Suns". Commonly used to refer to the ratio of aperture to receiver areas.

Conversion Efficiency, Gross - Gross output provided by a conversion device divided by total input power at specified conditions.

Conversion Efficiency, Net - Actual net output (after deducting parasitics) provided by a conversion device divided by the required input power at specified conditions.

Demand - The power versus time profile of the energy required to satisfy the energy needs of the final consumer or end use consuming process.

Design Point - The time and day of the year at which the system is sized with reference insolation, wind speed, temperature, humidity, dewpoint and sun angles.

Direct Insolation - Non-scattered solar flux falling on a surface of given orientation (watts/m^2).

Field Receiver Power Ratio - Maximum heliostat field power output divided by maximum receiver power absorption capability.

Fluid, Receiver - The fluid used to cool the solar receiver and distribute the absorbed solar energy to other parts of the system; heat transport fluid of the receiver.

Fluid, Working - The fluid used in the turbine or other prime mover.

Geometric Concentration Ratio - The ratio of the projected area of a reflector system (on a plane normal to the insolation) divided by absorber area.

Hybrid System - A combination of solar and non-solar technology to provide a single plant system that is capable of continuous operation.

Industrial Retrofit Plant - The industrial retrofit plant uses solar energy to partially replace natural gas as an energy source.

Levelized Energy Cost (Category B only) - Annual cost per annual energy delivered over the life of the plant to compensate for fixed and variable costs and interest ($/Million Btu's).

1.3 Continued

Payback Period - A traditional measure of economic viability of investment project. A payback period is defined in several ways - one of which is the number of years required to accumulate fuel savings which exactly equal initial capital cost of system. Payback often does not give an accurate representation of total life-cycle values.

Pointing Error - The difference between the aim point and measured beam centroid for any tracking aim point (on target or at standby) under the specified operating conditions.

Present Value - The present value of capital and operating costs (or annual savings, brought over a given time period such as the life of the plant, is a single value of revenue requirement) or savings at a reference time that account for economical factors such as escalation rates and rate of return on the capital.

Process Heat - Thermal energy which is used in industrial oeprations.

Receiver Efficiency - Ratio of thermal power output from the receiver base to incident solar power upon the receiver.

Repowered/Industrial Retrofit Plant - A repowered/industrial retrofit plant that uses solar energy to partially replace a non-renewable fossil fuels.

Solar Flux - The rate of solar radiation per unit area (watt/m^2).

Solar Fraction - Annual - Ratio of solar energy to the process divided by the total energy consumption, annual average, measured at turbine inlet or process heating end-use device inlet.

Solar Fraction - Design Point - As above, at design point.

Solar Multiple - Defined at the design point as thermal power from receiver(s) after downcomer and piping losses divided by thermal power, prime mover (definition below).

Thermal Power, Fossil Heater Output - Thermal power input to working or transport fluids from the fossil heater after stack losses and misc. losses.

Thermal Power, Receiver Output - Thermal power derived from the receiver, does not include electrical parasitic or downcomer thermal losses.

1.3 Continued

**Note: For utility applications MWh electrical, net, from respective source. For industrial process heat MWh are net, thermal.

*Usually nameplate unless otherwise specified. Additional references: EPRI "Technical Assessment Guide" EPRI PS-1201-SR, Special Report, July, 1979.

2. REFERENCES

The following documents, of the issue in effect on the date of the contract award, form a part of this specification to the extent stated herein.

2.1 Standards and Codes

2.1.1 National

Uniform Building Code - 1976 Edition by International Conference of Building Officials

OSHA Regulations

- OSHA Title 29, Part 1919 - Occupational Safety and Health Standards

ASME Boiler and Pressure Vessel Code

- Section II - Materials Specifications
- Section VIII - Unfired Pressure Vessels

FAA Rules and Regulations Part 17-C
NRC Regulatory Guide 1.60
NRS Regulatory Guide 1.61

Institute of Electrical and Electronic Engineers (IEEE) Codes, as applicable

National Fire Protection Association (NFPA) National Fire Codes - 1975

Human Engineering Design Criteria

- MIL-STD-801C
- MIL-STD-1472

Design, Construction and Fabrication Standards

2.1.1 Continued

- Standards of AISC (American Institute of Steel Construction)
- Standards of ACI (American Concrete Institution)
- Standards of TEMA (Tub. Exchanger Manufacturer's Assn.)
- Standard 650 of API (American Petroleum Institute)
  - Welded Steel Tanks for Oil Storage

2.1.1 Continued

ANSI A 58.1 - 1972 Building Code Requirements for Minimum Design Loads In Buildings and Other Structures

ASCE Paper No. 3269, "Wind Forces on Structures", Transactions, American Society of Civil Engineers, Volume 126, Part II, 1961

Collector Subsystem Requirement Specification A10772, Issue C

2.1.2 California, Kern County and EPA (TBD)

California Building Code
Kern County Environmental Code

2.2 Other Publications and References

National Energy Conservation Policy Act of 1978
Power Plant and Industrial Fuel Use Act of 1978
Public Utilities Regulatory Policy Act
Natural Gas Policy Act of 1978
Energy Tax Act of 1978
Environmental Legislation
- o National Environmental Policy Act (NEPA)

2.3 Permits and Licenses - California, Kern County, ARCO and EPA (TBD)

Kern County Building Inspection Dept - Permit ($6000)
Kern County Planning Dept - Approval ($500)
Federal Aviation Administration - Notice of Proposed Construction.

2.4 Applicable Laws and Ordnances

None

3. REQUIREMENTS

The solar retrofitted plant shall be designed to meet the performance requirements of this section. This specification is applicable as a design requirement only to the new or modified portions of a solar repowered plant.

3.1 Site The solar system site layout is presented in Figure 2. Shown are numerous gas, oil, and injection wells, gas, oil, gas lift, water injection and water pipe lines; and electrical distribution lines. Several of these are located within or pass through the collector field.

3.1 Continued

The following general provisions apply:

a. No heliostat or other above grade structure will be placed with a rectangular area 73.2 m (240 ft) x 30.5 m (100 ft) centered at each well. Rectangular orientation, NE to SW (Figure 2).

b. Access roads comparable to existing roads to each well will be constructed.

c. A 6.1 m (20 ft) easement will be observed along the 76 cm (30 in) water main that runs in a NE by SW direction through the collector field.

d. Heliostat foundations will not be placed with .61 m (2 ft) at ARCO Oil and Gas's oil, gas, lift and injection lines.

.1 Continued

e. Access to the collector field will be controlled.

f. Daily operations must provide for the periodic safe access of inspection and maintenance personnel.

g. Land Requirement is 9.73×10^4 m^2 (24 acres).

Site Preparation Requirements

- Grading - minor filling of low areas (1 week, 1 unit).
- Drilling - None
- Fencing - 1265 m (4150 ft) of 2.44 m (8 ft) chain link fences, 625 m (2050 ft) will be slatted, two vehicle gates, two personnel gates
- Surfacing - Parking area at control building (asphalt) oil well access road (asphalt)
- Ditching - 304.8 m (1000 ft) water and gas, 72.2 m (250 ft) sewer
- Surveying - Fence boundary, tower position, 320 heliostat positions, building foundation, and piping run
- Utility Service - Water, sewer, gas, and telephone between plant and control building
- Electrical Wiring - 11,235 m (36,862 ft) heliostat electrical power, 11,235 m (36,862 ft) heliostat signal cable, 304.8 m (1,000 ft) electrical to control building
- Electrical Power - 115 VAC to control building and tower (50 kW), 115 VAC to heliostat (160 kW), 440 VAC to pump (119 kW)

.2 Site Facilities A building will be constructed near the receiver tower to house the control and data acquisition instrumentation, operator, files and records, and maintenance tools and supplies.

- Size - 6.1 m (20 ft) x 12.2 m (40 ft)
- Insulated and environmentally controlled
- Bathroom facilities
- Utility - water, gas, electrical, and sewer
- Telephone - ARCO system and intercom to plant office
- Furniture and fixtures
- Visitor Parking Area - Paved
- O & M Parking

Data Acquisition Equipment - Seven 24-channel recorders, one flow recorder, one 2-pin recorder, four pressure guages.

Weather Station - Dry and Wet Bulb temperature (existing), pyrheliometer (existing), anemometer.

3.2 Continued

Emergency Power Generator - one 250 kW natural gas powered genrator

3.3 Collector System The Collector System shall reflect solar radiation onto the Receiver Subsystem in a manner which satisfies receiver incident heat flux requirement. In addition, the Collector System shall respond to commands from the Collector Control Subsystem for emergency defocusing of the reflected energy or to protect the heliostat array against environmental extremes. The heliostats shall be properly positioned for repair or maintenance in response to either master control or manual commands. Heliostat design shall provide for stored or safe position for use at night, during periodic maintenance and during adverse weather conditions. The Collector System shall be designed to match the receiver design and provide energy to the receiver working fluid consistent with the end energy requirements of the plant.

3.3 Continued

The collector field will consist of 320 heliostats located on 15 circular arcs in a radial stagger configuration occupying a north circular sector of radius 305.8 m (1000 ft) and 2.09 rad (120°) angle. The field is symmetric about the North - South radius. The field focuses solar energy on a 61 m (200 ft) elevation, North-facing, single-cavity receiver which transfers the energy to the heat medium oil used in the plant process. The system will deliver 11.5 MW_t to the receiver at the noon summer solstice design point.

The field will be operational 365 days per year when sufficient insolation is available.

The field will be brought to focus on the receiver and defocused to emergency defocus and stow positions in such manner and along such path(s) that will prevent harm to persons or damage to structures or equipment.

3.3.1 Heliostats The heliostats will meet or exceed the alignment, structural, operational, and environmental specifications of Collector Subsystem Requirements A10772. The exception is that UBC Zone No. 4 (horizontal minimum acceleration .3g) will be used for the baseline design.

3.3.2 Heliostat Control The heliostat tracking and control accomplished by a 2-level open-loop system. The control system will meet all requirements of SRS No. A10772.

3.4 Receiver System The Receiver System shall provide a means of transferring the incident radiant flux energy from the Collector System into the receiver fluid and transport of the energy charged fluid to the process heat subsystem as determined by solar input and plant energy consumption model.

3.4.1 Structural Design The receiver and tower shall be designed to provide access for maintenance and inspection of tower structure, receiver fluid, instruments and controls, power conversion equipment that may be located on the tower, utilities, 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 the intent of Section VIII Division I of the ASME Unfired Pressure Vessel Code.

The receiver will be a north-facing cavity type having an aperture size of 8.23 x 8.23 m (27 x 27 ft). The receiver absorbing surface will encompass a 148° semi-circular arc with a 7.31 m (24 ft) radius from the aperture center. The absorbing surface will be 9.14 (30 ft) high. The absorber will be fabricated from standard embossed and welded heat transfer panels. A total of 56 panels are required having a total effective absorbing area of 151.2 m^2 (1627 ft^2). A

3.4.1 Continued

black paint will be used to achieve a high absorptivity on the panels. The oil flow rates and flow routing necessary to limit the maximum metal and oil temperature, and to minimize the thermal stresses are shown on Figure 4.

The cavity walls will be fabricated with a main structure, insulation, and a protective outer skin. The structural design will employ 0.305 m (S12 x 31.8) I-beams as the primary structure, and 1.27 mm (.050 inch) thick sheet metal channels as the secondary structure for attaching the insulation and the outer protective skin. A light weight slab insulation of refractory glass and mineral wool fibers will line the inactive walls of the receiver to a thickness of 0.15 m (6 inches). Insulation will be installed using stud welded dagger pins with the insulation impaled on these pins and secured with speed clips. The receiver external skin is a standard 22 gage corrugated steel with a baked-on white finish.

A aperture door will be provided to insulate the aperture during overnight shutdown, to provide environmental protection during adverse weather, and to provide a human safety function for personnel working inside the cavity. In addition to the door, a Nextel 312 ceramic fiber curtain for emergency flux termination will be installed at the aperture. This curtain will be normally stowed in a rolled-up position above the aperture opening, and held in place by solenoid latches. The loss of electrical power; low flow rate, or panel overtemperature would open a relay and deploy the curtain by a gravity drop.

A Halon type of fire extinguishing system will be installed on the receiver in the event of an oil leak and subsequent fire. Temperature sensors located above the receiver panels will trigger the extinguishing system if the air temperature reaches 538 C (1000 F).

An array of temperature sensors will be installed in strategic locations on the panels to sense oil outlet temperature from each panel, between-passage fin temprature, and backside and frontside passage metal temperatures. A total of 140-150 temperatures will be made on the receiver.

Table 1 presents a summary of the physical characteristics of the receiver.

The receiver design criteria is established as follows:

1. Use commercially available standard hardware to the maximum extent possible.

2. Use low cost carbon steel panels, pipe, and fittings. Avoid stainless steel and super alloys.

3. Minimize the use of control valves, pumps, and other "active" components.

4. Design for minimum metal and oil temperatures and minimum receiver pressure loss:

    a. Limit peak oil temperature to 315.6° C (600° F).
    b. Limit peak tube wall temperature to 343.3° C (650° F).
    c. Limit peak non-wetted metal temperature to 357.2° C (675° F).
    d. Limit receiver pressure loss to 413.7 kPa (60 psi).
    e. Limit peak thermal stress to 1.72×10^5 kPa (25,000 psi).

The receiver performance requirements are presented in Table 2.

3.4.1 Continued

Vent and drain valves will be provided to facilitate filling and draining the system.

3.4.2 Tower The tower will provide personnel access to the receiver for periodic maintenance; protect equipment from thermal shock near the receiver; support the riser and downcomer piping and associated expansion loops; and permit thermal expansion of the receiver while providing support and restraint during seismic disturbances.

The tower will be a three-legged steel free standing structure that will support the receiver such that the horizontal centerline of the aperture will be 61 m (200 ft) above ground level.

The tower must support the following weight:

- Receiver = 66,325 kg (146,180 lb),
- Fluid = 4,576 kg (10,836 lb),
- Piping = 3,065 kg (6,759 lb).

The tower will be designed to survive the following conditions:

- Wind - 40.2 m/s (90 mph) at 9.14 m (30 ft) elevation
- Gust Factor - 1.12
- Frequency - .7544 Hz
- Earthquake - UBC Zone 4
  Acceleration - Min. 2.94 Newton/m (.3g)
  Ave. 4.90 Newton/m (.5g)

The tower accessories will include:

- One 408 kg (900 lb) capacity service elevator,
- One 92.9 m^2 (1000 ft^2) receiver service platform,
- Two sets obstruction warning light (red-flashing),
- One emergency step ladder with cage,
- Lightning Protection - 4 air terminals plus ground rod,
- Lighting - each 3.05 m (10 ft) and platform.

3.4.3 Receiver Fluid The receiver fluid will be the Hydrotreated Light Cycle Oil that is used in the plant HMO system.

3.5 Receiver Loop The receiver piping loop interfaces the receiver with the existing heat medium oil system. The system shall transport the receiver fluid (heat medium oil) from the existing plant pump discharge to the tower, up to the receiver (riser), down to ground level (downcomer) and return to the inlet to the fired heaters. The receiver loop will contain a bypass pump and piping to run parallel to the existing heat medium oil system,

3.5 Continued

between the inlet and outlet control valves. The pipes shall be sized for economy of materials and pumping power, and shall be suitably insulated to minimize heat loss, and jacketed for weather protection. The piping system will include the system control valves, bypass valves, bypass piping, bypass pump, pipe supports and hangers, and necessary expansion joints and loops.

In order to meet the system performance and operating requirements, the loop will include the following components.

- 914.4 m (3000 ft) schedule 40 seamless carbon steel pipe with 127 m (5 in) thickness; 315.6° C (600° F) fiberglass insulation (jacketed),
- Two 112 kW (150 hp) centrifugal pumps,
- Two .1 m (4 in) Fisher YS 3-way pneumatic control valves (reverse acting),
- One .15 m (6) Fisher YS 3-way pneumatic control valves (direct acting).

In order to meet the system maintenance and repair requirements the loop will include the following components:

- Two .15 m (6 in) Jamesbury wafer manual bypass valves,
- Eleven (9 plug, 2 gate) isolation valves,
- One .2 m (8 in) Jamesbury wafer downcomer isolation valve,
- Ten ball type drain valves,
- One 37.85 m^3 (10,000 gal) HMO drain tank.

The receiver loop will contain temperature sensors and flow rate instrumentation sufficient to provide the basis for automatic, manual or emergency control of heat medium oil flow through the solar system.

The receiver loop will deliver 9.518 MW_t to the heat medium oil system at noon summer solstice.

3.5 Continued

The constant flow through the system will facilitate the following operational modes:

Energy Supply Modes:	Fossil Fuel Only Solar/Fossil
Solar/Fossil:	Start-up Operating Shut-down Emergency Defocus

3.6 Service Life The system shall be designed for a 30 year service life with no major component replacement required.

3.7 Plant Availability and Reliability The system shall be designed for 98% plant availability, based on documented reliability and maintainability assessment, exclusive of insolation conditions. Consideration shall be given in the design to achieving high reliability by providing design and operating margins and utilizing sound engineering design practices.

3.8 Maintainability The solar repowered plant modifications and new installations shall be designed to be compatible with existing plant maintainability characteristics and practices or improvements. Potential electronic units, motors, drivers, etc., readily replaced. Elements subject to wear and damage, such as supporting wheels, gears, etc., shall be easily serviced or replaced. The plant shall be capable of being serviced with a minimum of specialized equipment or tools.

3.9 Specialized Equipment Unique equipment required to service, maintain, repair, or overhaul any of the functional elements of the specified solar repowered plant. The equipment descriptions shall clearly identify the system functional elements that they are designed to support.

Mirror Wash

- Mobile tank/sprayer
- High pressure spray
- Deionized water
- Remote spray control for one-man operation

Facet Alignment

- Performed in heliostat assembly facility
- One laser per facet (6) overhead mounted
- Overhead reflective gridded target
- Digital readout or laser beam reflected position

3.9 Continued

Beam Point and Tracking

- Reflective target
- TV readout (patterned after Sandia BCS)

4. ENVIRONMENTAL CRITERIA

4.1 Plant Environment The plant environment is obtained from Bakersfield which is 22 miles east. Intervening terrain is relatively flat and clear of any large hills, valleys or mountains and should be representative.

4.1 Continued

a. Temperature Range: -6.7° C (20° F) to 46° C (115° F)
Annual Average: 19.9° C (67.8° F)

b. Rain: Average Annual - .145 m (5.72 in)
Max. 24 hr. - .119 m (4.68 in)

c. Snow: Occasional Accumulation .051 m (2 in)

d. Ice: None

e. Wind: Average Speed - 2.86 m/sec (6.4 mph)
Max. Sustained - 20.56 m/sec (46 mph)
Prevailing Direction - NNW - 340°

f. Hail: 6.4 mm (.25 in)

g. Dust Devils: Wind speed up to: 17 m/sec (35 mph)

h. Earthquake: UBC Zone 4: 2.94 m/s^2 (.3g min) horizontal

4.2 Air Quality Standards Plant pollution emission requirements are:

SO_X	NO_X	Particulates
0.5 ppm/hr	0.25 ppm/hr	100 micrograms/m^3

5. CONCEPTUAL DESIGN DATA

5.1 Plant Characteristics and Performance Data The solar interface with the existing heat medium oil system was selected and the system sized to utilize all solar energy collected while making full use of the heat from existing plant sources that must remain in operation. The design point requires the delivery of 9,518 Kw_t at noon on the summer solstice. The annual average is 2.254 x 10^7 Kw-hr/yr. This results in a solar fraction of 24.4%.

5.1.1 Collector Data

a. Design Characteristics

1. Collector Field
   - No. of heliostats - 320
   - Configuration - North field; Circular sector; 2.09 rad (120°) angle; 305.8 m (1000 ft) radius
   - Heliostat arrangement - Radial stagger
   - Size approximately 1.31 x 10^5 m^2 (32.3 acres)

5.1.1 Continued

2. Heliostat Specifications
   - Reflective area - 52.6 m^2 (566 ft^2)
   - Configuration - Square
   - Number of Panels - 12
   - Reflectivity - .91 (clean)
   - Specification A10772 - Issue C

5.1.1 Continued

b. Operating
- Open loop - 2 level
- Specification A10772 - Issue C

5.1.2 Receiver Data

a. Configuration
- Geometry: Cavity; circular arc segment; 2.58 rad. (148°) 7.3 m (24 ft) radius; arc length (18.9 m (62.0 ft) by 9.1 m (30 ft) height.
- Aperture: 8.23 m x 8.23 m (27 ft x 27 ft)
- Height: 61 m (200 ft) ground to aperture centerline

b. Construction: See Table 1

c. Operating Characteristics: See Table 2
- Pressure: 931 kPa (138 psi) max
- Flow .06 m^3/s (63.750 gal/hr)

d. Thermal: See Table 2

e. Standards and Codes: Section VIII of ASME Unfired Pressure Vessel Code and carry ASME "U" code stamp.

5.1.2.1 Tower

a. Configuration: 3-legged

b. Height: Approximately 57.9 m (190 ft)

5.1.2.2 Receiver Fluid

a.	Fluid:	Hydrotreated Light Cycle Oil
b.	Producer:	ARCO Watson Refinery
c.	Viscosity:	33.9 SUS @ 122° F
d.	Specific Heat:	100° F 0.42 300° F 0.52 600° F 0.67
e.	Specific Gravity:	100° F 0.89 300° F 0.81 600° F 0.65
f.	° API	23.8

5.1.3 Receiver Loop

a. Length: 914.6 m (3000 ft)

b. Temperature:

Inlet: 215° C (420° F)
Outlet: 293.3° C (560° F)

c. Pressure:
Inlet: 862 kPa (125 psig)
Pump discharge: 1.38 x 10^3 kPa (200 psig)
Receiver inlet: 931 kPa (135 psig)
Receiver outlet: 551.7 kPa (80 psig)
Outlet: 793.1 kPa (115 psig)

d. Control: Automatic with manual override

e. Support: Pipe hangers

f. Insulation: .127 (5 in) fiberglass (jacketed)

5.2 Existing Plant Data

5.2.1 Plant Process Characterization Individual Plant Industrial Processes: Table 3 presents data related to plant processes operated by the heat medium oil system. A single transport system supplies all processes. It is not possible at this point to identify fuel usage for each process. The solar system interfaces the heat medium oil transport system at points which will provide most utilization of energy produced.

5.2.2 Heat Medium Oil System

a. Operational:

- System oil capacity: Approximately 75.708 m^3 (20,000 gal)
- Operating Level: Approximately 68.137 m^3 (18,000 gal)
- Total Flow: .092 m^3/sec (1,458 gal/min)
- Flow through fired heaters: .067 m^3/sec (63,750 gal/hr)
- Operating Temperatures: 193° C (380° F) to 301° C (575° F)
- Operating Pressure: 103 kPa (15 psi) to 689 kPa (100 psi)
- Heat Requirement: 9.518 mW_t/hr
- Operating Mode: 24 hrs/day; 365 days/yr

b. Major Equipment

- Fired Heaters: 2 C.F. Braun, each with 2 John Zink CBM 30 Burners
- Heat Recovery Units: 2 Nordberg Waste Heat Recovery Units
- Pumps: 3 - 75 hp G.E. Centrifugal
- Surge Tank: 37.854 m^3 (10,000 gal)

c. Data Requirement

Data measurements will include:

- Heat Medium Oil Flow Rates:
  Flow to Fired Heater No. 2
  Flow to Fired Heater No. 3
- Heat Medium Oil Temperature
  Fired Heater No. 2, outlet
  Fired Heater No. 3, outlet
  Surge Tank
- Natural Gas Fuel Consuption
  Inlet to Fired Heater No. 2
  Inlet to Fired Heater No. 3

d. Previous Years Operating Data:
Fired Heater No. 2 Flow Rate (HMO) - .04 m^3/s (910,000 gal/day)
Fired Heater No. 3 Flow Rate (HMO) - .027 m^3/s (620,000 gal/day)
Fired Heater No. 2 Outlet Temperature - 301.6° C (575° F)
Fired Heater No. 3 Outlet Temperature - 301.6° C (575° F)
Surge Tank Temperature - 193° C (380° C)
Gas to Fired Heater No. 2 - 1.7 m^3 (600 MCF)
Gas to Fired Heater No. 3 - 1.13 m^3 (400 MCF)

5.3 Cost Data The total capital costs of the system have been computed using SRS guidelines. These costs include system costs, owner's and the initial year of O & M costs.

A summary of system capital costs is presented in Table 5. Design phase costs are presented in Table 6. The basis for the owner's costs are presented in Table 7. Construction costs by cost code are presented in Table 8. The cost of equipment items installed with the development module that will be used in the full size field is presented in Table 9. O & M costs are summarized by cost code in Table 10. The cost account sheets for the respective cost codes are presented in Tables 11 through 16. Worksheets for backup of the cost accounts appear immediately following each cost code table. And finally, the work sheets to support the O & M cost codes are presented in Tables 17 through 26.

5.4 Economic Data

5.4.1 Alternate Fuel Cost Assumptions The location of the North Coles Levee plant within the confines of a natural gas producing field and its remote location from other sources of energy precluded serious consideration of fuel costs for other than natural gas sources. The two fuel cost escalation rates used in the economic analysis are presented in Table 4.

5.5 Simualation Model

5.5.1 Insolation Model The insolation model currently used as the basis for the conceptual design contains data developed by Southern California Edison Company at Barstow, California during 1976. Data from Lancaster, California were substituted in cases where Barstow data was not available due to instrumentation malfunction or other causes. The model contains data for a complete year and is presented on a fifteen minute basis.

Barstow is located approximately 125 miles ESE of the North Coles Levee Plant. The data should be representative for this portion of California.

5.5.1 Continued

however, direct insolation measurements are currently being made at the plant site. Analysis of this data and data from Fresno resulted in discounting performance results by an estimated 10%.

5.5.2 Performance Model The performance model used to establish and evaluate the performance of the conceptual design of the solar plant is made up of a system of computer based procedures and techniques. These are utilized in a logical sequence to provide a basis for the evaluation of each step in the system design. A complete exercise of the model includes the following calculations:

Procedure

XY FIELD - Writes file for heliostat x and y coordinates.

TOWSHAD - Develops file of tower shadow.

ATMLOSS - Develops file of atmospheric attenuations.

FLOYD 2 - Develops average cosine as a function of sun azimuth and elevation.

FLOYD 3 - Computes heliostat shadowing and blocking as a function of sun angle.

FLOYD 5 - Uses above to compute Geometric Performance coefficients.

GPEMW - Develops file of Geometric Performance.

AVEBAR 1 - Uses insolation, geometric performance and day to produce total insolation, hours at insolation above 500 w/m^2, average annual field efficiency and file of average hourly collector efficiency.
DISTBAR - Uses AVEBAR 1 file and ATMLOSS to produce performance comparison chart on monthly and annual basis.

COLVEP - Computes energy flux profile incident on the target plane and receiver.

ARCOTHERM - Computes receiver efficiency.

Other algorithms that have not been formalized into computer procedures are used to calculate piping losses.

5.5.3 Economic Model A computer program was developed to generate the economic analyses. The program produces two basic analyses for economic evaluation.

5.3 Continued

The first and most important is year-by-year analysis of cash flow and ultimately the rate of return on the investment. The second is an analysis to compute the unit cost of solar produced energy and a comparison to gas produced energy.

The input parameters for these analyses are:

- Initial System Cost
- Cost of Money Use - Interest Rate
- System Life
- 1st year Operation and Maintenance (O & M)
- O & M Escalation Rate
- Federal Depreciation Period
- Federal Depreciation Formula*
- California Depreciation Period
- California Depreciation Formula*
- Federal Income Tax Rate
- California Income Tax Rate
- Solar Energy into Process
- Burner Efficiency
- Gas Price (at meter) Escalation Schedule
- Federal and California Tax Credits*

(*Semi-built-into program)

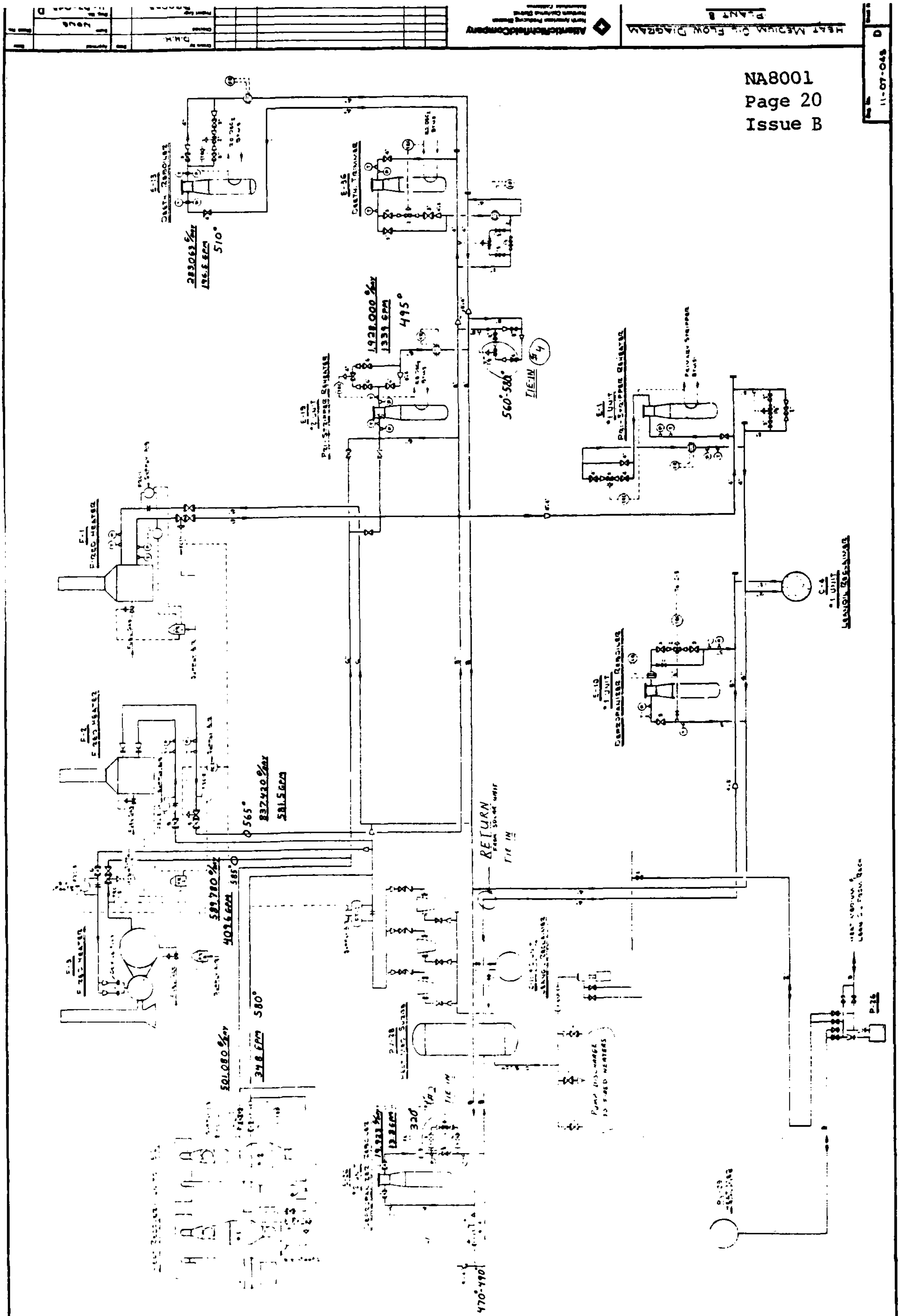
HEAT MEDIUM OIL FLOW DIAGRAM
PLANT 8
AtlanticRichfieldCompany
D.M.M.
11-07-048
D
E-13
Deeth. Reboiler
283063 #/hr
196.6 GPM
510°
E-36
Deeth. Trimmer
E-12
#2 Unit
Pri-Stripper Reboiler
1,928,000 #/hr
1339 GPM
495°
560°-580°
TIE-IN
54
E-1
#1 Unit
Pri-Stripper Reboiler
F-1
Fired Heater
F-2
Fired Heater
565°
837420 #/hr
581.5 GPM
F-3
Fired Heater
588780 #/hr
409.6 GPM
585°
RETURN
FROM SOLAR UNIT
TIE IN
C-6
#1 Unit
Lean Oil Reboiler
E-10
#1 Unit
Depropanizer Reboiler
501080 #/hr
348 GPM
580°
P-28
320°
470°-490°
P-26
PUMP DISCHARGE TO FIRED HEATERS

Figure 1

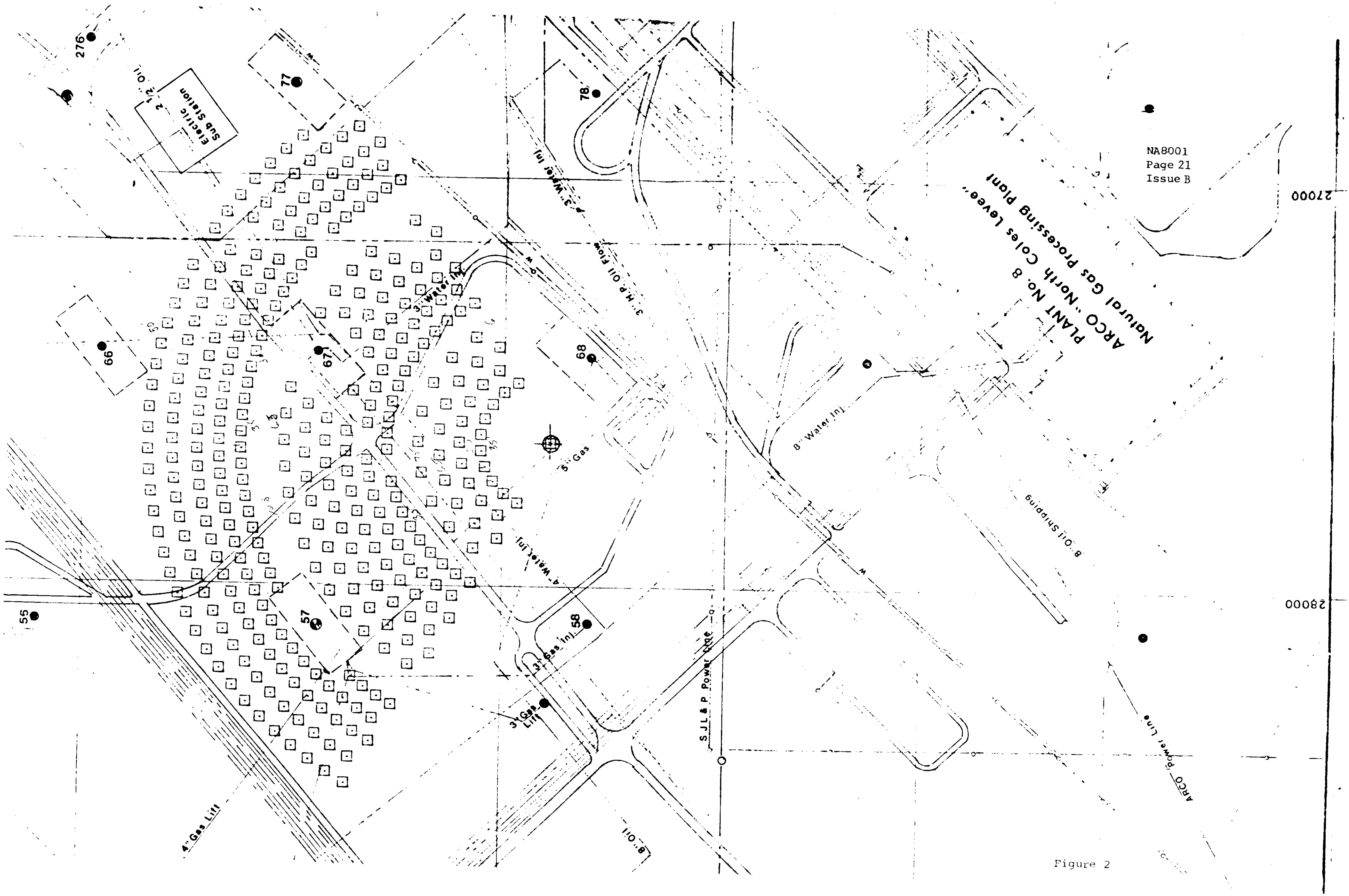
ARCO "North Coles Levee"
PLANT No. 8
Natural Gas Processing plant
27000
28000
276
77
78
Electric Sub Station
2 1/2" Oil
3" Water Inj
3" H.P. Oil Flow
68
66
67
5" Gas
4" Water Inj
58
57
55
3" Gas Inj
3" Gas Lift
S.J.L.& P. Power Line
8" Oil
4" Gas Lift
8" Water Inj
8" Oil Shipping
ARCO Power Line

Figure 2

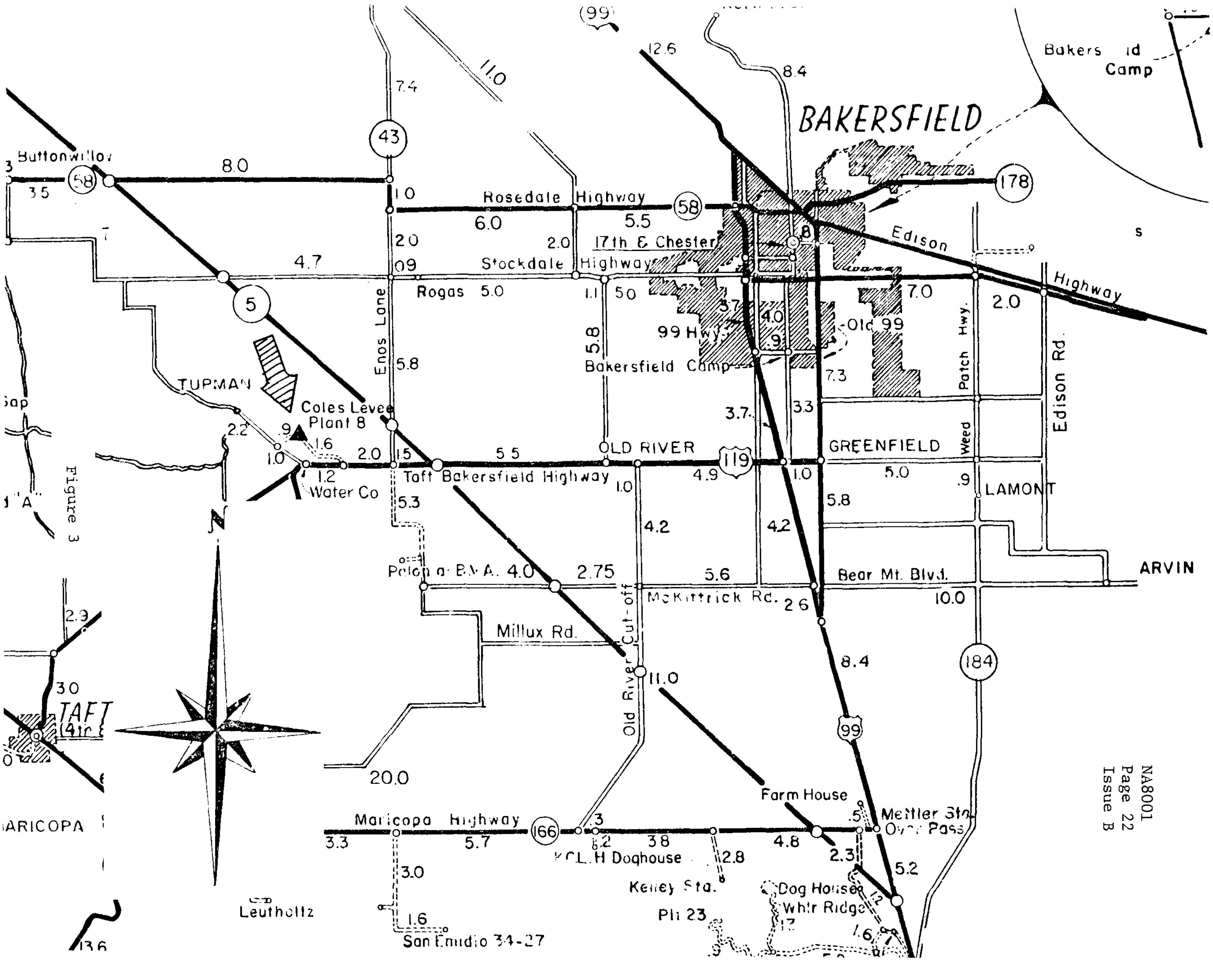
BAKERSFIELD
Bakersfield Camp
Buttonwillow
8.0
3.5
43
7.4
11.0
99
12.6
8.4
58
Rosedale Highway
6.0
5.5
1.0
2.0
17th & Chester
178
Edison
Highway
4.7
09
Stockdale Highway
Rogas
5.0
1.1
5.0
5
3.7
4.0
99 Hwy
.9
Old 99
7.0
2.0
Enos Lane
5.8
Bakersfield Camp
7.3
Patch Hwy.
Edison Rd.
TUPMAN
Coles Levee
Plant 8
2.2
.9
1.6
1.0
1.2
2.0
.15
5.5
OLD RIVER
119
GREENFIELD
Weed
Water Co
Taft Bakersfield Highway
4.9
1.0
5.0
.9
LAMONT
5.3
4.2
4.2
5.8
Paloma B.V.A.
4.0
2.75
5.6
Bear Mt. Blvd.
ARVIN
McKittrick Rd.
2.6
10.0
Millux Rd.
Old River Cut-off
11.0
8.4
184
2.9
3.0
TAFT
99
20.0
Farm House
MARICOPA
Maricopa Highway
166
3.3
5.7
.3
.2
3.8
4.8
.5
Mettler Sta.
Over Pass
K.C.L.H Doghouse
2.8
2.3
3.0
Kelley Sta.
Dog House
5.2
Leutholtz
Pli 23
White Ridge
1.6
San Emidio 34-27
1.6
N

Figure 3

Figure 4

RECEIVER FLOW PATH & FLOW DISTRIBUTION

$m^3/s \times 10^3$ (gpm)

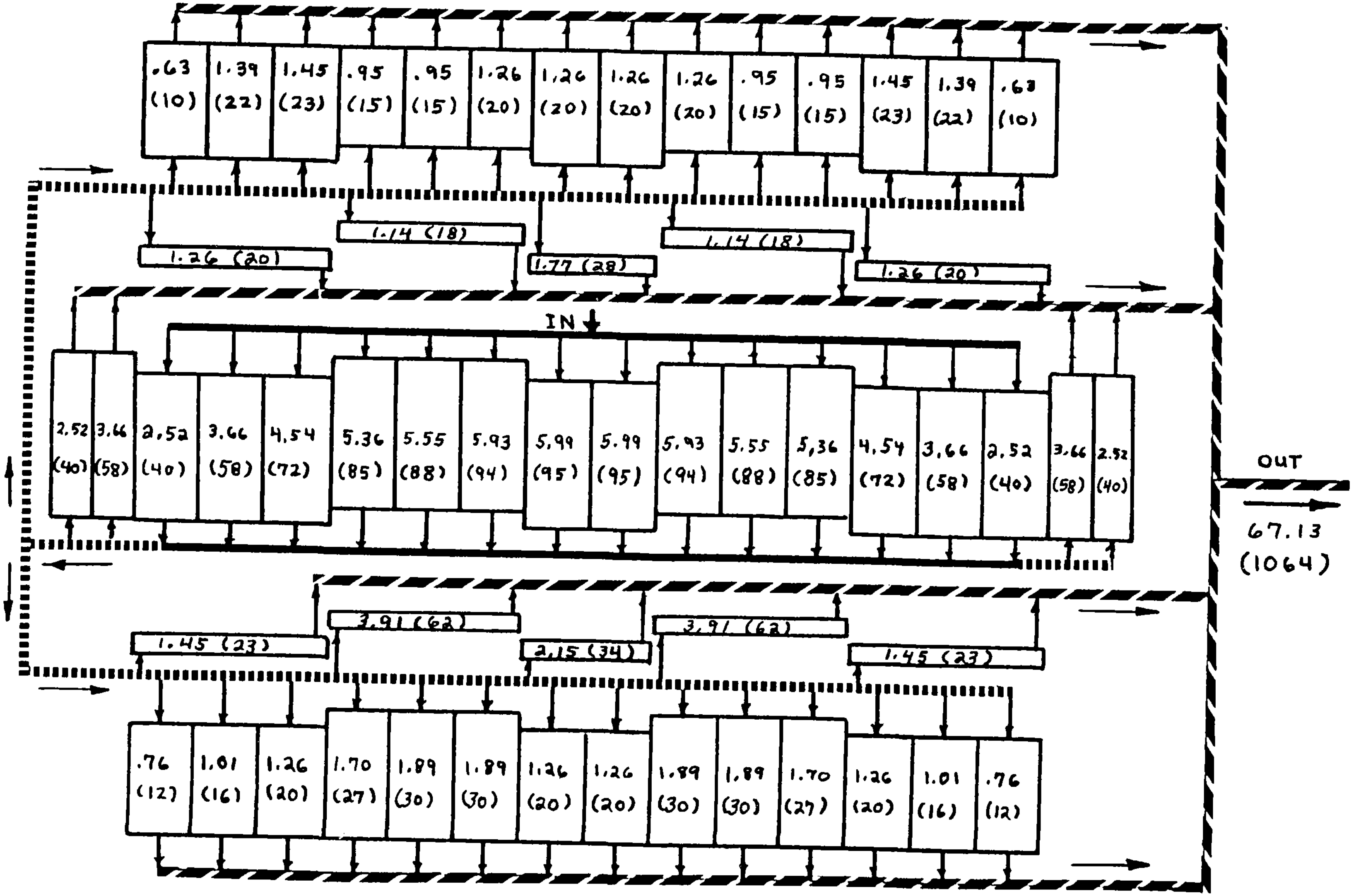

Table 1

Receiver Physical Characteristics

Aperture Size, m (ft)-------8.23 x 8.23 (27 x 27)

Aperture Area, m^2 (ft^2)-----67.73 (729)

Cavity Depth, m (ft)--------7.32 (24)

Absorber Width, m (ft)------18.85 (61.84)

Absorber Height, m (ft)-----9.14 (30.00)

Absorber Area, m^2 (ft^2)-----151.2 (1627.2)

Absorber Type----------------Embossed and Welded Panels

Absorber Material-----------AISI 1008 Carbon Steel

Absorber Sheet Thickness
(each), mm (in)---------3.4 (.1345)

Absorber Weight, kg/m^2
(lb/ft^2)----------------54.94 (11.25)

Insulation Type--------------Semi-rigid; fiberglass, mineral
wool, binder

Insulation Thickness, m (ft)-0.15 (0.50)

Receiver Weight Breakdown:

Absorber Panels, kg (lb)-----9276 (20444)

Insulation, kg (lb)----------10835 (23880)

Piping, kg (lb)---------------8576 (18902)

Hangers and Misc., kg (lb)---3316 (7309)

Structure, kg (lb)-----------23807 (52470)

Aperture Door, kg (lb)-------6806 (15000)

Flooring, kg (lb)------------2348 (5175)

Miscellaneous----------------1361 (3000)

Total Dry Weight, kg (lb)----66,325 (146,180)

Heat Transfer Oil, kg (lb)---4576 (10,086)

Total Wet Weight, kg (lb)----70,901 (156,266)

Table 2

North Coles Levee Receiver Performance

Parameter	Day 355 12:00	Day 355 10:00	Day 355 8:00	Day 80 12:00	Day 80 10:00	Day 80 8:00	Day 173 12:00	Day 173 10:00	Day 173 8:00
1. Energy Available, Kw	13021	12669	10256	12512	12119	10925	11509	11118	9971
2. Aperture Cutoff, Kw	89	118	168	116	142	135	171	195	257
3. Panel Miss, Kw	104	108	80	92	83	72	101	93	18
4. Reflected Loss, Kw	126	123	99	120	117	106	110	106	96
5. Convection Loss, Kw	503	499	473	498	493	480	487	482	470
6. Conduction Loss, Kw	53	52	50	52	52	50	51	51	49
7. Radiation Loss, Kw	329	324	290	322	316	300	307	302	286
8. Energy to Oil, Kw	11817	11444	9096	11312	10917	9782	10282	9890	8796
9. Receiver Efficiency, %	90.76	90.33	88.69	90.41	90.08	89.54	89.34	88.95	88.21
10. Oil Outlet Temp. C (F)	306.4 (583.5)	303.7 (578.7)	286.5 (547.7)	302.7 (576.7)	299.9 (571.8)	291.6 (556.8)	295.2 (563.4)	292.4 (558.3)	284.3 (543.7)

Annual Average Receiver Efficiency = 89.59%

TABLE 3

PLANT INDUSTRIAL PROCESSES

	Process					
a. Name of Process	Primary Stripper	No. 2 Primary Stripper	Deethanizer Trimmer	Deethanizer Reboiler	Depropanizer Reboiler	Debutanizer Reboiler
b. Process Heat Temp. (°F.) Inlet-Outlet	557-453	575-505	562-490	550-485	510-455	453-325
c. Material Temp. (°F.) Inlet-Outlet	385-450	290-370	240-330	240-300	240-250	245-?
d. Flow Rate (lb/hr)	40,150	382,250	94,000	79,175	7,870	34,700
e. Pressure (psi)	75	75	75	75	75	75
f. Heat Medium	HLC* oil	HLC oil	HLC oil	HLC oil	HLC oil	HLC oil
g. Process Medium	Absorb oil	Absorb oil	Absorb oil	Absorb oil	Absorb oil	Absorb oil
h. Period of Oper.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.
i. Sched. Downtime	None	None	None	None	None	None
j. Unsched. Down-time (wks/yr)	.5	.5	.5	.5	.5	.5
k. Fuel Type	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
l. Annual Fuel Usg.	← 333 (3) MMBTU/yr (not allocated between processes) →					
m. Cost ($/MMBTU)	← $2.50 →					
n. Supply Schedule	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.
o. Back-up Fuel	None	None	None	None	None	None

*Hydrotreated Light Cycle Oil

TABLE 4

GAS PRICE ESCALATION TABLES

Year	SNLL SCHEDULE (11%) $/kw-hr	SNLL SCHEDULE (11%) $/10^6 BTU	NORTHRUP SCHEDULE (ARCO Average) $/kw-hr	NORTHRUP SCHEDULE (ARCO Average) $/10^6 BTU
1980	.0085	2.49	.0086	2.52
1981	.0094	2.76	.0098	2.86
1982	.0105	3.07	.0111	3.24
1983	.0116	3.41	.0126	3.69
1984	.0129	3.78	.0141	4.13
1985	.0143	4.20	.0180	5.27
1986	.0159	4.66	.0218	6.39
1987	.0176	5.17	.0256	7.50
1988	.0196	5.74	.0294	8.62
1989	.0217	6.37	.0332	9.73
1990	.0241	7.07	.0370	10.85
1991	.0268	7.85	.0396	11.60
1992	.0297	8.71	.0423	12.40
1993	.0330	9.67	.0452	13.23
1994	.0366	10.73	.0481	14.10
1995	.0407	11.91	.0512	15.00
1996	.0451	13.22	.0546	15.98
1997	.0501	14.68	.0615	18.00
1998	.0556	16.29	.0724	21.20
1999	.0617	18.09	.0830	24.30
2000	.0685	20.08	.0935	27.38
2001	.0761	22.28	.0998	29.24
2002	.0844	24.73	.1066	31.23
2003	.0937	27.46	.1139	33.37
2004	.1041	30.48	.1217	35.65
2005	.1155	33.83	.1301	38.10
2006	.1282	37.55	.1390	40.71
2007	.1423	41.68	.1485	43.51
2008	.1579	46.26	.1588	46.51
2009	.1753	51.35	.1697	49.71
2010	.1946	57.00	.1815	53.15

5.3 COST DATA

The total program costs are presented in Table 5.

Table 5

1.	Design Phase	$1,658,762
2.	Owner's Cost	118,973
3.	Construction Cost	6,558,299
	TOTAL	8,336,034

The Design Phase costs are presented in Table 6.

Table 6

Engineering & Planning		964,924
Task 1 - System Design	518,200	
Task 2 - Site Preparation Plan	71,476	
Task 3 - Procurement Plan	41,694	
Task 4 - Operation and Maintenance	35,738	
Task 5 - Development Module	226,340	
Task 6 - Project Management & Reports	71,476	
Development Module Construction Cost		693,838
Total Design Phase		$1,658,762

The basis for Owner's Costs is presented in Table 7.

Table 7

OWNER'S COSTS (CONSTRUCTION PHASE)

1.	Land Lease		$ 7,500
	Tenneco West, Inc. 1 Year		
2.	Governmental Approval		10,055
	Building Permit	6,000	
	Planning Commission Fee	555	
	Environmental Impact Statement	1,500	
	Legal & Planning	2,000	
3.	Consumable Supplies		7,500
	10,000 gal. Oil @ .50	5,000	
	Misc.	2,500	
4.	Start-up Costs		52,200
	System Calibration	4,800	
	Plant Shutdown (2 days)	40,000	
	System Checkout	2,400	
	Planning & Scheduling	5,000	
5.	Property Taxes and Insurance		0
			77,255
		Overhead 40%	30,902
		G & A 10%	10,816
		TOTAL	$ 118,973

The construction costs are summarized by cost code in Table 8

Table 8

CONSTRUCTION COST SUMMARY

5100	Site Improvements		$ 95,390
5200	Site Facilities		138,605
5300	Collector System		4,840,602
5400	Receiver System		1,176,411
5410	Receiver	$ 612,489	
5420	Tower	563,922	
5900	Receiver Loop System		792,553
	Total Construction Costs		7,043,561
	Reduced by items common to Development Module (Ref. Table 9)		485,262
	Net Construction Phase Cost		$6,558,299

The equipment items which are installed during the Design Phase (Development Module) but which are common to the Construction Phase and are priced in the Construction cost codes are listed in Table 9.

Table 9

EQUIPMENT ITEMS INSTALLED DURING DESIGN PHASE
DEVELOPMENT MODULE (But common to Construction Phase)

Cost Code	Item	Cost
5100	Clearing Storage Yard	$22,822
5200	Fencing	13,000
5300	Heliostats (19)	414,640
5900	3- Way Valves & Plug Valves	19,800
	Control Equipment	15,000
	TOTAL	$485,262

The detail construction cost worksheets supporting the cost code totals are presented in Tables 11 through 16.

The operation and maintenance costs are summarized by cost code in Table 10.

The worksheets to support the operation and maintenance costs by cost code are presented in Tables 17 through 26.

Table 10

OPERATION AND MAINTENANCE

COST SUMMARY

OM100	Operations			$ 154,082
OM110	Operating Personnel		78,375	
OM120	Operating Consumables		45,534	
OM130	Fixed Charges		30,173	
OM200	Maintenance Materials			27,852
OM210	Spare Parts		13,518	
OM212	Collector Equipment	8,854		
OM213	Receiver Equipment	1,597		
OM215	Non-Solar Energy Subsystem Equipment	3,067		
OM220	Materials for Repairs		2,288	
OM230	Other		12,046	
OM300	Maintenance Labor			36,110
OM310	Scheduled Maintenance		13,340	
OM320	Corrective Maintenance		22,770	
	Total Operation and Maintenance Cost			$ 218,044

NA8001
Page 32
Issue B

TABLE 11 PG 1 CONSTRUCTION COST ESTIMATE

CLIENT DOE
DESCRIPTION 5100
SITE IMPROVEMENTS
LOCATION SAN FRAN OPER OFF
PROJECT NORTH COLES LEVEE
CONT. NO.
MADE BY
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil			60,091		60.091
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS					60,091
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS				21%	12,619
	TOTAL FIELD COSTS					72,710
R	Engineering					
	Design & Engineering				5%	3,640
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management				3%	2,180
	TOTAL OFFICE COSTS					5,820
	TOTAL FIELD & OFFICE COSTS					78,530
U	Labor Productivity				3.4%	2,670
V	Contingency				10%	8,120
W	Fee				5.3%	6,070
	TOTAL CONSTRUCTION COST					95,390

DATE
REVISION NO.
REVISION DATE
PAGE NO.

TABLE 11 PG 2

CONSTRUCTION COSTS

5100

SITE IMPROVEMENTS

CLIENT DOE
LOCATION SAN FRANCISCO OPER. OFF.
PROJECT NORTH COLES LEVEE

BY ______ **CHKD.** ______ **APVD.** ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
A	EXCAVATION & CIVIL												60091
A1	CLEARING STORAGE YARD										37700		37700
A2	INSTL. SEWAGE LINE (4")	100	LF					2.58			258		983
	4'Dx8' CATCH BASIN	1	EA								725		
A3	WATER LINE	500	LF					2.52			1260		1260
A4	POWER LINE	900	LF					2.20			1980		1930
A5	PHONE LINE	900	LF					1.00			900		900
A6	GAS LINE	900	LF					2.52			2268		2268
A7	ROAD	2000	LF					7.50			15000		15000

DATE ______ **REVISION NO.** ______ **REVISION DATE** ______ **PAGE NO.** ______ **OF** ______

REVISION NO. ______ **REVISION DATE** ______

TABLE 12 PG 1

CONSTRUCTION COST ESTIMATE

CLIENT DOE
DESCRIPTION 5200
SITE FACILITIES
LOCATION SAN FRAN OPER OFF
CONT. NO.
MADE BY
APPROVED
PROJECT NORTH COLES LEVEE

A/C NO.	ITEM & DESCRIPTION	MANHOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings BLDG & FENCE			120,000		120,000
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS			120,000		120,000
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS			INCLUDED		
	TOTAL FIELD COSTS					120,000
R	Engineering			INCLUDED		
S	Major Equipment Procurement					
T	Construction Management				3%	3,600
	TOTAL FIELD & ENGR. COSTS					123,600
U	Labor Productivity EST. FOR SITE				0%	
V	Contingency				5%	6,180
W	Fee				6.8%	8,825
						# 138,605
	TOTAL CONSTRUCTION COST					

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TABLE 12 PG 2

CONSTRUCTION COSTS

5200 SITE FACILITIES

CLIENT DOE

LOCATION SANFRANCISCO OPER. OFF

PROJECT NORTH COLES LEVEE

BY ______ **CHKD.** ______ **APVD.** ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
D	BUILDINGS												120 000
D1	CONTROL BUILDING	1	EA					80,000			80 000		80 000
	2-STORY, STEEL, INSUL,												
	20'x40' A/C												
D2	FENCE	4200	L.F.					9.52			40 000		40 000
	8' CHAIN LINK 11ga												
	3 STR. B.W.												
	2 VEH. GATES (1 POWERED)												
	HALF SLATTED												

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CONSTRUCTION COST ESTIMATE

CLIENT D.O.E.

LOCATION S.F. Oper. Office

PROJECT

DESCRIPTION
Collector System
(Cost Code 5308)

CONT. NO.

MADE BY JA

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil			58,000		58,000
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment (Non-Field)		579,004	1,706,918	1,533,850	3,819,772
E	Machinery + Equipment (Field Related) *		140,240	80,320	150,000	370,560 *
G	Electrical		54,265		30,935	85,200
H	Instruments		19,500		55,000	74,500
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS – With Heliostats		793,009	1,845,238	1,769,785	4,408,032
	DIRECT FIELD COSTS – Without Heliostats		214,005	138,320	235,935	588,260 *
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					21%
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					123,535
	TOTAL FIELD COSTS – With Heliostats					4,531,567
	TOTAL FIELD COSTS – Without Heliostats					711,795 *
R	Engineering					
	Design & Engineering 13%					92,533
	Home Office Costs					
	R & D					
						23,594
S	Major Equipment Procurement 10%	of material cost				
T	Construction Management 3%					21,354
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS	– With Heliostats				4,669,048
	TOTAL FIELD + OFFICE COSTS	– Without Heliostats				849,276 *
U	Labor Productivity 3.4%					28,875
V	Contingency 10%					84,928
W	Fee 6.8%					57,751
*NOTE: only this amount is burdened with field related O.H., G+A, fee, etc						
	TOTAL CONSTRUCTION COST					4,840,602

(Per Heliostat Avg = $15,126.88)

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TABLE 13 PG 2

CONSTRUCTION COSTS

5300 COLLECTOR SYSTEM

CLIENT D.O.E.
LOCATION S.F. Operations Office
PROJECT North Coles Levee

BY JA CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
A	Excavation & Civil										58 000		58 000
A-1	Trenching For Wiring	20000	ft					.50			10 000		10 000
A-2	Pile Driving	320	ea					150			48 000		48 200
E	Machinery & Equipment									719 244	1787 238	1683 850	4190 332
E-1	Heliostat Reflective Surface	19	ea				774		2204	14 706		41 876	56 582
E-2	Heliostat Pedestal (Pile)	19	ea					1447			27 493		27 493
E-3	Heliostat Drive Unit	19	ea					5922			112 518		112 518
E-4	Heliostat Structure	19	ea					2574			48 906		48 906
E-5	Heliostat Control Electronics	19	ea				994		1865	18 886		35 435	54 321
E-6	Heliostat Reflective Surface	301	ea				480		1619	144 480		487 319	631 799
E-7	Heliostat Pedestal (Pile)	301	ea				164		750	49 364		225 750	275 114
E-8	Heliostat Drive Unit	301	ea					4501			1354 801		1354 801
E-9	Heliostat Structure	301	ea				568		1345	170 968		404 845	575 813
E-10	Heliostat Control Electronics	301	ea				600		1125	180 600		338 625	519 225
E-11	Heliostat Transportation	320	ea					510			163 200		163 200
	NOTE: Items E-1 through E-11 are mfg. costs plus transportation and include factory overhead, G+A, and fee. These are not subject to field overhead and fee rates									579 004	1706 918	1533 850	3819 772
E-12	Heliostat Field Assy Tooling						50000		150000	50 000		150 000	200 000
E-13	Heliostat Assy + Installation	320	ea				282			90 240			90 240
E-14	Heliostat Install. Equip. Rental							80320			80 320		80 320
NOTE	Items E-12 thru E-14 are field related heliostat costs subject to field overhead and fee rates									140 240	80 320	150 000	370 560

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TABLE 13 PG 3

CONSTRUCTION COSTS

Collector System

(5200)

CLIENT D.O.E.

LOCATION S.F. Operations Office

PROJECT North Coles Levee

BY ______ **CHKD.** ______ **APVD.** ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
G	Electrical									54,265		30,935	85,200
G-1	Lightning Wiring	36860	ft				.1975		.21	7,280		7741	15,020
G-2	Power Wiring	36860	ft				.64		.35	23,590		12 901	36,491
G-3	Control Wiring	73720	ft				.1425		.095	10,505		7 003	17,508
G-4	Boxes - NEMA 3R	320	ea				12.85		8.00	4,112		2,560	6,672
G-5	Panel Board -30 circuit	1	ea				570		730	570		730	1,300
G-6	Junction Connections	960	ea				8.55			8,208			8,208
H	Instruments						19,500		55,000	19,500		55,000	74,500
H-1	Heliostat Interface Module	1	ea.				1500		5000	1 500		5 000	6,500
H-2	Computer, HP9825 plus peripherals, installation, and check-out	1	ea.				18000		50000	18 000		50 000	68,000

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TABLE 14 PG 1 CONSTRUCTION COST ESTIMATE

NA8001
Page 39
Issue B

CLIENT DEPT. OF ENERGY

DESCRIPTION 5410

RECEIVER SYSTEM

(RECEIVER)

LOCATION SAN FRANCISCO OPER. OFF.

PROJECT NO. COLES LEVEE

CONT. NO. DE-AC03-79SF10

MADE BY R.T.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel		12,245		35,715	47960
D	Buildings					
E	Machinery & Equipment		8,744	44900	71,430	125,074
F	Piping		27,844		31,172	59,016
G	Electrical					
H	Instruments		15,000		35,564	50,564
J	Painting		3,100		2,320	5,420
K	Insulation		47,670		21,784	69,454
			114,603	44,900	197,985	357,488
	DIRECT FIELD COSTS					
L	Temporary Construction Facilities					21 %
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					
	TOTAL FIELD COSTS					75,072
R	Engineering					
	Design & Engineering				13 %	46,473
	Home Office Costs					
	R & D					
S	Major Equipment Procurement				10% Matl	19,800
T	Construction Management				3 %	10,725
	TOTAL OFFICE COSTS					76,998
	TOTAL FIELD & OFFICE COSTS					509,558
U	Labor Productivity 3.4%					17,325
V	Contingency 10.0%					50,956
W	Fee 6.8%					34,650
	TOTAL CONSTRUCTION COST					612,489

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TABLE 14 PG 2

CONSTRUCTION COSTS

5410 RECEIVER

CLIENT DEPT OF ENERGY
LOCATION S. F. OPER. OFF
PROJECT NO. COLES LEVEE

BY RT CHKD._____ APVD._____

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
	RECEIVER SUBSYSTEM												
C	STRUCTURAL STEEL									12 245		35 715	47 960
C1	FRAMES, COLUMNS, STUDS	22.1	TON				220^{00}		880^{00}	4 860		19 450	24 310
C2	SIDING	8440	S.F.				.77		1.35	6 500		11 400	17 900
C3	FLOOR PLATE	2.6	TON				175^{00}		825^{00}	455		2 145	2 600
C4	FLASHING	450	LB				.95		6.05	430		2 720	3 150
E	MACHINERY & EQUIPMENT									8 744	44 900	71 430	125 074
E1	PLATECOIL PANELS	1650	S.F.				4.36		39.17	7 194		64 630	71 824
E2	FIRE SYSTEM (HALON)	1						21000			21 000		21 000
E3	CAVITY DOOR	1						23900^{00}			23 900		23 900
E4	ACCESS DOORS	3					250^{00}		1100^{00}	750		3 300	4 050
E5	FLUX CURTAIN	1					800		3500^{00}	800		3 500	4 300

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TABLE 14 PG 3

CONSTRUCTION COSTS

5410 RECEIVER

CLIENT DEPT OF ENERGY
LOCATION S.F. OPER. OFF.
PROJECT NO. COLES LEVGE

BY R T **CHKD.** ____ **APVD.** ____

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
F	PIPING									27 844		31 172	59 016
F1	PIPE (HUNG/WELDED)									21 882		9 840	31 722
F2	FITTINGS									2 960		4 890	7 850
F3	FLANGES & ORIFICES - SETS	56					31.60		202^{09}	1 770		11 312	13 082
F4	VALVES									200		1 000	1 200
F5	HANGERS & SUPPORTS									1 032		4 130	5 162
J	PAINTING									3 100		2 320	5 420
J1	REC. & APERS.	2000	S.F.				.45		.55	900		1 100	2 000
J2	EXTER. STL & TRIM	2000	S.F.				1.10		.61	2 200		1 220	3 420
K	INSULATION									47 670		21 784.	69 454
K1	BLOCK INSUL.	8440	S.F.				5.00		2.14.	42 200		18 062	60 262
K2	STUDS	4220	EA				1.00		.60	4 220		2 532	6 752
K3	Kaowool Blanket	500	S.F.				2.50		2.38	1 250		1 190	2 440

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TABLE 14 PG 4

CONSTRUCTION COSTS

5410 Receiver

CLIENT Dept of Energy

LOCATION S.F. Operations Office

PROJECT No. Coler Levee

BY JA **CHKD.** ______ **APVD.** ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
H	INSTRUMENTS									15 000		35 564	50 564
H-1	Thermocouple Wire Cr - Al	50000	ft				.25		.35	12 500		17 500	30 000
H-2	Terminal Blocks + Lugs	400					1.50		1.10	600		440	1 040
H-3	Multipoint Recorders With Control Function	6					150		16824	900		16 824	17 724
H-4	Instrumentation Rack	2					500		400	1 000		800	1 800

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TABLE 15 PG1 CONSTRUCTION COST ESTIMATE

CLIENT DOE
DESCRIPTION 5420
RECEIVER SYSTEM
(TOWER)
LOCATION SAN FRAN OPER.OFF.
PROJECT NORTH COLES LEVEE
CONT. NO.
MADE BY
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete			30,690$^{\underline{00}}$		30,690
C	Structural Steel			181,370$^{\underline{00}}$		181,370
D	Buildings					
E	Machinery & Equipment			89,962 =		89,962
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS					302,022
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS				21%	63,420
	TOTAL FIELD COSTS					365,442
R	Engineering					87,840
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management				3%	10,960
	TOTAL OFFICE COSTS					98,800
	TOTAL FIELD & OFFICE COSTS					464,242
U	Labor Productivity				3.4%	15,780
V	Contingency				10%	49,000
W	Fee				6.8%	35,900
	TOTAL CONSTRUCTION COST					563,922

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TABLE 15 PG 2

CONSTRUCTION COSTS

5420
TOWER

CLIENT DOE
LOCATION SAN FRAN OPER. OFF.
PROJECT NORTH COLES LEVEE

BY ______ **CHKD.** ______ **APVD.** ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
B	CONCRETE												
B1	FOUNDATION IN PLACE	122.8	CY					250^{00}			30 690		30 690
C	STRUCTURAL STEEL												
C1	TOWER DELIVERED	1	EA					181,370			181 370		181 370
E	MACHINERY & EQUIP												89 962
E1	900 LB ELEV. (SEEDE INT)	1	EA					69,562			69 562		69 562
E2	SERVICE PLATFORM	1	EA					10,000			10 000		10 000
E3	OBSTRUCT LIGHTING	1	EA					1,200			1 200		1 200
E4	SAFETY LADDER (CAGE)	1	EA					2,000			2 000		2 000
E5	LIGHTNING PROTECTION	1	EA					5,000			5 000		5 000
E6	LIGHTING	1	EA					1,200			1 200		1 200

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TABLE 16 PG1 CONSTRUCTION COST ESTIMATE

CLIENT DOE

DESCRIPTION 5900
RECEIVER LOOP
SYSTEM

LOCATION SAN FRAN OPER OFC

PROJECT NORTH COLES LEVEE

CONT. NO.

MADE BY

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete			18,000		18,000
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment		2,135		15,950	18,085
F	Piping		72,975		212,700	285,675
G	Electrical					
H	Instruments		4,260		22,222	26,482
J	Painting					
K	Insulation		28,200		75,000	103,200
	DIRECT FIELD COSTS		107,570	18,000	325,872	451,442
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS 21%	OF DF	C			94,800
	TOTAL FIELD COSTS					546,242
R	Engineering 10	% OF	TFC			54,624
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement 10	% OF	MATL			32,597
T	Construction Management 3	% OF	TFC + R + S			19,000
	TOTAL OFFICE COSTS					106,211
	TOTAL FIELD & OFFICE COSTS					652,453
U	Labor Productivity 3.4%					22,190
V	Contingency 10 %					67,460
W	Fee 6.8 %					50,460
	TOTAL CONSTRUCTION COST					792,553

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TABLE 16 PG 2

CONSTRUCTION COSTS

5900

RECEIVER LOOP SYSTEM

CLIENT DOE

LOCATION SAN FRAN OPER OFF

PROJECT NORTH COLES LEVEE

BY ______ **CHKD.** ______ **APVD.** ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
B	CONCRETE												18 000
B1	PIPE SUPPORTS (IN PLC)	60	EA					300			18 000		18 000
E	MACHINERY & EQUIP												18 085
E1	DRAIN & STORAGE TANK	1					2135		15,950	2 135		15 950	18 085
	8'x27' BEL. GR.												
F	PIPING									72 975		212 700	285 675
F1	8" PIPE (FTGS INSTLN., HUNG)	3 000	LF				20.30		15,70	60 900		47 100	108 000
F2	150 HP CENTRIF PUMPS (UNILINE	2					3850		23,000	7 700		46 000	53 700
F3	EXPANSION JOINTS	18										22 000	22 000
F4	FISHER VS 3WAY VALVES 4"	2							4950			9 900	9 900
	6"	1							7040			7 040	7 040
F5	ROCKWELL PLUG VALVES SS TRIM 4"	6							1650			9 900	9 900
	6"	1							8,250			8 250	8 250
	8"	2							18,150			36 300	36 300
F6	FULL OPENING VALVES 8"	2							1980			3 960	3 960
F7	JAMESBURY WAFER VALVES 6"	2							1980			3 960	3 960
	8"	1							1,430			1 430	1 430
F8	TEES, ELLS, FLGS, 6" PIPE, BOLTS, ETC								16,860			16 860	16 860
F9	TIE IN TO PLANT						4,375			4 375			4 375

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TABLE 16 PG 3

CONSTRUCTION COSTS

5900

RECEIVER LOOP SYSTEM

CLIENT DOE

LOCATION SAN FRAN OPER OFF

PROJECT NORTH COLES LEVEE

BY ____ CHKD. ____ APVD. ____

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
H	INSTRUMENTS									4260		22222	26482
H1	CONTROL INSTRU.	4								100		992	1092
H2	RECORDERS 2 PEN TEMP.	1								180		1770	1950
	24 CHAN. MULTI. PT.	1								240		2420	2660
H3	ENUNCIATOR PANELS	2					70		680	140		1360	1500
H4	AUTO CONTROLS (ALARM)	2					165		1650	330		3300	3630
H5	ORIFICE METER 8"	1								550		5500	6050
H6	TEMP GAGES	2					45		440	90		880	970
H7	FLOW GAGE	1								60		550	610
H8	RACKS & MISC HDW	4					80		800	320		3200	3520
H9	SIGNAL WIRING	5000	L.F.				.40		.40	2000		2000	4000
H10	ANEMOMETER	1								250		250	500
K	INSULATION												103200
K1	5" F/G INSUL .016 AL. COVER ON 8" PIPE	3000	L.F.				9.40		$25^{\underline{00}}$	28200		75000	103200

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Table 17

OPERATIONS AND MAINTENANCE WORKSHEET

OM 110 OPERATING PERSONNEL

DESCRIPTION	HRS/YR	UNIT COST	SUBTOTAL	G & A	OVERHEAD	TOTAL
Operating Engineer	1500	$14	21,000	10%	50%	$34,650
Electrical Technician/operator	1500	9	13,500	10%	50%	22,275
Mechanical Technician/operator	1000	9	9,000	10%	50%	14,850
Plant Technicians	400	10	4,00	10%	50%	6,600

						78,375

Table 18

OM 120 OPERATING CONSUMABLES

DESCRIPTION	QTY PER YR.	UNIT COST	SUBTOTAL	G & A	OVERHEAD	TOTAL
HEAT MEDIUM OIL	2400 gal	$.50	$1200	10%	30%	$1716
ELECTRICITY _Heliostat	116,800 KWH	.035	4,088			5846
Pump	408,800 KWH	.035	14,308			20460
Bldg & Misc	24,000 KWH	.035	840			1201
DEIONIZING CHEMICALS	1920 Hel.Washes	.30	576			824
WATER	150,000 gal.	.002	300			429
PHONE	12 mo.	100.00	240			343
GAS	300 MCF	2.50	750			1073
GASOLINE	1200 gal.	1.25	1500			2145
LUBRICATION OIL	50 gal.	.80	40			57
CHART PAPER	600 Rolls	10.00	6000			2860
MISC. SUPPLIES			2000			8580
						45,534

Table 19

OPERATIONS AND MAINTENANCE WORKSHEET

O M 130 FIXED CHARGES

DESCRIPTION	CHG. PER YEAR	G & A	OVERHEAD	TOTAL
LANDLEASE TENNECO WEST, INC.	$7,500	10%	30%	10725
PROPERTY TAXES	0	0	0	0
INSURANCE	13,600	10%	30%	19448
				30173

Table 20

OPERATIONS AND MAINTENANCE WORKSHEET

SM 212 COLLECTOR EQUIPMENT

PART DESCRIPTION	FAILURE RATE PER YEAR	AVG COST PER UNIT	SUBTOTAL	G & A	OVERHEAD	TOTAL
MIRROR MODULES	.2% = 8	$156	$1248	10%	60%	$2196
RACK STRUCTURE	.1% = .6	806	484	10%	60%	851
DRIVE UNITS	.1% - .3	4500	1350	10%	60%	2376
MOTORS	.25% = 1.6	300	480	10%	60%	845
ELECT. COMPON.	.25% = 16	87	1392	10%	60%	2450
WIRING & INSTRUM	.1%	77,400	77	10%	60%	136
						9854

Table 21

OPERATIONS AND MAINTENANCE WORKSHEET

OM 213 RECEIVER EQUIPMENT

PART DESCRIPTION	FAILURE RATE PER YEAR	AVG. COST PER UNIT	SUBTOTAL	G & A	OVERHEAD	TOTAL
PANELS	.25% = .14	$1050	$147	10%	60%	$259
PIPE, FTGS, VALVES	.25%	28,000	70	10%	60%	123
INSULATION & STUDS	.5% = 42 ft^2	2.20	92	10%	60%	162
DOOR & CURTAIN PARTS	.25%	15,000	38	10%	60%	67
FIRE SYSTEM	.1 Refill	3,600	360	10%	60%	634
INSTRUMENTS	.5%	32,000	160	10%	60%	282
TOWER EQUIPMENT	.1%	40,000	40	10%	60%	70
						1597

Table 22

OPERATIONS AND MAINTENANCE WORKSHEET

OM 215 NON SOLAR ENERGY SUBSYSTEM EQUIPMENT

DESCRIPTION	FAILURE RATE PER YEAR	AVG. COST PER UNIT	SUBTOTAL	G&A	OVERHEAD	TOTAL
PROCESS HEAT LOOP						
PIPING,VALVES, FTGS	.25%	$150,000	$375	10%	30%	$536
PUMPS	6% = .06	20,200	1212	10%	30%	1733
INSULATION	.5%	67,500	338	10%	30%	483
INSTRUMENTS	.5%	20,000	100	10%	30%	143
FACILITIES						
BLDG.			60	10%	30%	86
FENCE			60	10%	30%	86
						3067

Table 23

OPERATIONS AND MAINTENANCE WORKSHEET

OM 220 MATERIALS FOR REPAIRS

DESCRIPTION	NEEDS PER YEAR	AVG COST PER UNIT	SUB TOTAL	G & A	OVERHEAD	TOTAL
EXTERIOR PAINT	10 gal	$60	$600	10%	30%	$858
RECEIVER PAINT	4 gal	$100	400	10%	30%	572
MISC. HOW & SUPPLIES			600	10%	30%	858
						2288

Table 24

OPERATIONS AND MAINTENANCE WORKSHEET

OM 230 OTHER

DESCRIPTION	INITIAL COST	ANNUAL COST 11½% 30 yrs	G&E	OVERHEAD	TOTAL
WASHING RIG	$30,000	$3590	10%	50%	$5924
DEIONIZER & STORAGE TANKS	6,000	720	10%	50%	1188
MAINTENANCE VEHICLE	10,000	1200	10%	50%	1980
TOOLS & EQUIPMENT	15,000	1790	10%	50%	2954
					12046

Table 25

OPERATIONS AND MAINTENANCE WORKSHEET

OM 310 SCHEDULED MAINTENANCE

DESCRIPTION	HOURS PER YR.	UNIT COST	SUBTOTAL	G&A	OVERHEAD	TOTAL
MIRROR WASHING	200	$11	$2200	10%	65%	$3872
RECEIVER PAINTING	20	11	220	10%	60%	387
EXTERIOR PAINTING	60	11	660	10%	60%	1162
EQUIPMENT LUBR.	300	11	3300	10%	60%	5808
INSPECT & REPAIR RECEIVER, HELIOSTAT & LOOP SENSING & CONTROL EQUIP	60	12	720	10%	60%	1267
SEWER PUMPING			40	10%	60%	70
MISC.	40	11	440	10%	60%	774
						13340

Table 26

OPERATIONS AND MAINTENANCE WORKSHEET

OM 320 CORRECTIVE MAINTENANCE

DESCRIPTION	HOURS PER YR.	UNIT COST	SUBTOTAL	G&A	OVERHEAD	TOTAL
HELIOSTAT REPAIR	640	$11	$7040	10%	50%	$11,616
RECEIVER REPAIR	200	11	2200	10%	50%	3,630
TOWER REPAIR	20	11	220	10%	50%	363
SOLAR HMO LOOP REPAIR	200	11	2200	10%	50%	3,630
FACILITY REPAIR	60	10	600	10%	50%	990
MAINT. EQUIP REPAIR	80	11	880	10%	50%	1452
MISC.	60	11	660	10%	50%	1089
						22,770

APPENDIX B - ENVIRONMENTAL IMPACT ASSESSMENT

FOREWORD

The goal of the National Energy Program is to develop and introduce the uses of energy supplied by the sun that can be both environmentally and economically acceptable. The solar energy retrofit project will be concerned with the solar thermal conversion approach for commercial application and identification and solution of practical design and operational problems associated with the operation of the equipment involved. The proven feasibility and broad use of solar energy would reduce commercial utility dependency and enhance the conservation of present oil and natural gas reserves.

The objective of this project is to develop a solar energy retrofit system that will be practical and cost effective in producing process heat for a typical industrial, petrochemical complex.

This appendix is an environmental impact assessment concerning the probable impacts of construction, operation, and site restoration of a solar energy retrofit project. The site proposed for this facility is in the North Coles Levee Oil Field, located 35.4 km (22 miles) southwest of Bakersfield, California. In this appendix, the relationship of the project with respect to local environmental regulations and standards is evaluated, and the impact on the surrounding area is examined.

I. DESCRIPTION OF THE PROPOSED PROJECT

Objective

This project provides for the design, construction, and operation of a solar energy retrofit heat generating system (about 9518 kwt or 32.5 million BTU per hour capacity) to augment the heat requirements of ARCO Oil and Gas Company's North Coles Levee Natural Gas Processing Plant No. 8 in Kern County, California. This plant is considered to be an appropriate site for the application of solar process heat because the insolation and climatology are excellent for testing solar energy systems.

Location

The natural gas processing plant is located in the North Coles Levee Oil Field, twenty-two miles southwest of the City of Bakersfield, Kern County, California. The oil field is bordered on the south by Highway 119 and on the west by the Elk Hills. Agricultural lands border it on the north and east. The plant complex is surrounded by oil producing wells and their ancilliary facilities. The solar system is to be installed adjacent to Natural Gas Processing Plant No. 8.

Plant No. 8 is an excellent example of an industral gas processing plant wherein heat requirements are met by a hot oil heating and distribution system. This plant uses a refrigerated absorption oil process that recovers propane, butane, and gasoline from raw natural gas. The process starts with the mixing of raw natural gas with the refrigerated oil to absorb hydrocarbons with molecular chains which are longer than methane. The absorption oil is then heated to selected temperature to release the absorbed hydrocarbons which are processed to separate ethane, propane, butane, and gasoline.

For safety reasons, hot "heat-medium" oil is used instead of fire to heat the vessels where required in this process. The oil temperature ranges between 193°C (380° F) and 301°C (575° F). The retrofitted solar system will be used to add heat to the heat-medium oil and thus replace some of the natural gas currently being used for heating this oil.

Structure of the Solar Process Heat System

A single module field was selected as the design for the North Coles Levee solar process heat system. The collector field consists of 320 heliostats located at ground level. The receiver is a north-facing cavity type mounted on a 61m (200-ft) tower. The receiver geometry will be a circular arc segment, 120° included angle on a 7.3m (24-ft) radius, approximately 9.1 m (30 ft) in height. A building will be located at the base of the receiver tower to house the controls and monitoring devices. Steel pipes and pumps will be used to convey the heat-medium oil between the plant and the receiver. Automatic shutdown devices will be installed to prevent rupture of the piping. The heliostat, tower, and control building areas will be fenced to prevent unauthorized entry.

II. DESCRIPTION OF EXISTING ENVIRONMENT

The North Coles Levee Natural Gas Processing Plant No. 8 is located in Kern County, California, about 161 km (100 miles) north of Los Angeles, about 35.4 km (22 miles) southwest of the City of Bakersfield, and in the southern end of the San Joaquin Valley. The proposed project site is confined to an area adjacent to Plant No. 8.

The southern end of the North Coles Levee Oil Field borders on State Highway 119 between Taft and State Highway 99. State Highway 119 has an interchange with Interstate Highway 5 about3.2 km (2 miles) east of the field boundary. Scheduled airline services are available at Bakersfield. Railheads exist in Taft, Buttonwillow, and Bakersfield.

Historic land uses within the valley have included oil field development, agriculture, and livestock raising. The development of the California Water Project has made available great quantities of new water to the area via the California Aqueduct which has led to a great expansion of cultivation and associated urban land uses.

A. GEOLOGICAL RESOURCES

1. Regional Setting

The North Coles Levee Oil Field is located on the San Joaquin Valley floor about 1.6 Km (1 mile) northeast of the Elk Hills, a foothill spur that extends from the Temblor Range southeastward about a third of the distance across the San Joaquin Valley. The elevation at Plant No 8, is 94.5 m (310 ft) above sea level.

The San Joaquin Valley is the southern half of a large structural depression called the Great or Central Valley of California. The

Central Valley extends for nearly 805 km (500 miles), and separates the Coast Ranges on the west side from the Sierra Nevada Ranges on the east side of the valley. The southern boundary of the Central Valley is the Tehachapi Mountains.

The Central Valley is filled with deep layers of unconsolidated and partially consolidated sediments that have been eroded from the surrounding uplands. The attitude and structure of the strata in the east side of the San Joaquin Valley differ markedly from the strata on the west side. The sedimentary strata in the eastern part of the valley dips gently westward toward the axis of the Central Valley Trough and reflects the subsurface extension of the westward-tilted Sierra Nevada fault blocks. The sedimentary strata beneath the western side of the valley dip steeply eastward and are sharply folded and broken by low-angle faults. The structure of the strata on the west flank of the San Joaquin Valley was formed by the development of the adjacent Temblor Range. This range is composed of a series of tight folds that diverge from the southerly trend of the other ranges within the Coast Ranges and plunge south-eastward into the valley. The Elk Hills represent one of the upfolds associated with the Temblor Range.

2. Local Setting

The North Coles Levee Oil Field is located on the San Joaquin Valley floor at the southern tip of the Elk Hills. It is situated on a portion of an ancient lake bed with an average elevation of 91.4 m (300 ft) above sea level.

Soils

The soils of the North Coles Levee area are characteristic of a semiarid region that has hot, dry summers and mild, somewhat moist winters. The representative soil is a loose, light-colored, well-drained loam containing rock fragments. Like most soils developed in a semiarid region, they contain an abundance of gypsum or alkaline salts.

Mineral Resources

No mineral resources other than oil and gas have been commercially developed within the North Coles Levee Field.

Unique/Unusual Features

The Elk Hills, west of the North Coles Levee Field, are interesting as a geomorphic feature. Their relatively isolated location within the San Joaquin Valley makes them a conspicuous feature on the landscape.

No invertebrate or vertebrate fossils or artifacts of past civilizations have been found in the area covered by the North Coles Levee Field. Some vertebrate fossils, fossil alge (*Chara*) and silicified wood have been found in outcrops in the Elk Hills. The vertebrates include remains of a camel (*procamelus*), a rabbit (*Lepus*), a wood rat (*Neotoma*), a cotton rat (*Sigmodon*), and some horse teeth. These were found in buff mudstone and a sandy limestone (Maher, Carter, and Lantz, 1975 page 76).

Geologic Hazards

Naturally occurring geologic conditions at North Coles Levee Field that could result in hazards include erosion, subsidence, flooding, and corrosive soils.

The loose soils and sediments existing on the surface are easily erodible. Little natural vegetation is present to prevent further erosion during winter rains. These rains could also cause local flooding.

Portions of the southern San Joaquin Valley have experienced subsidence from groundwater withdrawal (deep subsidence), from hydrocompaction (shallow subsidence), and from oil and gas withdrawal.

Hydrocompaction occurs on irrigated lands when alluvial deposits above the water table compact upon application of water. This kind of subsidence is usually irregular, and can cause construction problems for structures. Such problems were experienced at several locations along the west side of the San Joaquin Valley during the construction of the California Aqueduct. The alluvial deposits along the west side of the North Coles Levee Field did not create hydrocompaction problems for the California Aqueduct.

Subsidence related to groundwater withdrawal has occurred and is continuing the alluvial sediments of southern San Joaquin Valley. The potential for subsidence due to excessive withdrawals of groundwater exists in most alluvial areas of the San Joaquin Valley, including the area of the North Coles Levee Field.

Subsidence associated with oil and gas withdrawals centers over and extends beyond the producing areas. As pore pressures in reservoirs are reduced by fluid withdrawal, the overburden load is gradually transferred to reservoir rocks, causing compaction of the poorly consolidated reservoir strata and subsidence at the surface.

To date no subsidence has been observed in the North Coles Levee Field or the Elk Hills Field located 4.8 km (3 miles) to the west.

The soils that occur throughout the area of the North Coles Levee Field have demonstrated corrosion potential for unprotected iron and steel. Present corrosion prevention measures include elevation of pipe above the ground on supports and coating buried pipe with protective materials.

Seismic Setting

No known active fault zones cross the North Coles Levee Field or are near the project site, and no earthquake epicenters of Richter magnitude greater than 4.0 have been recorded as occurring on the North Coles Levee Field.

B. AIR RESOURCES

1. Climate

Summer winds in the San Joaquin Valley are dominated by a light prevailing northwesterly flow caused by the semi-permanent high pressure system and by the flow of marine air from the ocean through the Sacramento-San Joaquin Delta area.

Mixing depth is the depth of the layer of air beneath the inversion level. During the summer, a persistent inversion exists in the San

Joaquin Valley between 1585 m (5,200 ft) and 2012 m (6,600 ft) above sea level. Night and early morning inversion heights are generally lower but usually rise or dissipate with the heat of the sun. Sunlight during the summer months is abundant in the San Joaquin Valley because of the presence of a persistent high-pressure area. Intermittent fog and clouds occur during the winter months. The annual average rainfall is less than .15 m (6 inches).

2. General Climate

The North Coles Levee Field area is situated in the extreme south end of the San Joaquin Valley and is partially surrounded by mountainous terrain on three sides. This field is located on the Valley floor near the base of the Elk Hills. The peaks of the Tehachapi Mountains lie about 48 km (30 miles) to the south and southeast. The relatively flat plains of the southern San Joaquin Valley separate the North Coles Levee area from the peaks of the Greenhorn Mountains which lie due east of the study area. The broad plains of the great Central Valley extend north and northeast of the Field.

The surrounding topography has a significant influence on the general climate. The Sierra Nevada Mountains, located to the northeast, insulate the Central Valley from the cold polar air that moves southward over the continent during the winter. The Tehachapi Mountains, forming the southern boundary, force moist air emanating from the northwest and north to rise, thus promoting heavier precipitation on the windward slopes. This also causes a higher frequency of cloudiness over the foothill areas. The coastal ranges, situated due west of the North Coles Levee area, tend to shield the local region from the true marine environment that dominates some 80 km (50 miles) to 113 km

(70 miles) to the west. Because of the nature of the encompassing terrain, large climatic variations can exist within relatively short distances of the study area.

The general climate of the North Coles Levee study area is warm and semiarid. Nearly 90% of all precipitation (about .15 m (6 inches) annually) falls from October through April. Winters are mild and tend to be fairly humid. As a result, nocturnal fog is frequently experienced during December and January. Occasionally, dense foggy conditions persist during the day as radiational fog (induced by nocturnal cooling) is trapped in the valley regions by large-scale high pressure systems. During the winter season, warm, dry south and southwesterly flow is occasionally observed as drainage winds emanating from Tehachapi Pass move into the Central Valley regions. Summer skies are clear and conditions are usually hot and dry.

Ambient atmospheric pressure is generally highest during the winter months. During the relatively cloudless summer season, thermal convection is promoted at the surface, causing the atmosphere to expand and flow laterally. This action tends to decrease the surface pressures as a "thermal" or heat-induced low pressure system develops over the area. In winter, this effect is generally absent and average surface pressures tend to be higher.

Monthly normal temperatures range from approximately 7°C (45°F) in January to 30°C (85°F) during July. Record temperatures have been observed to exceed 43°C (110°F) during the Summer and drop below 5.6°C (22°F) during the Winter.

Wind speeds between 2.1 m/sec (6.9 ft/sec) and 3.6 m/sec (11.8 ft/sec) are experienced most often at North Coles Levee. Wind speeds in excess of 10.8 m/sec (35.4 ft/sec) are rarely experienced but have been observed to be sustained for as long as 6 consecutive hours.

Air Quality

National ambient air quality standards have been promulgated for the following pollutants: Carbon monoxide, sulfur dioxide, suspended particulates, nitrogen dioxide, non-methane hydrocarbons, and photochemical oxidants. Kern County is a nonattainment area for Ox, CO, SO_2, and TSP.

The solar energy project will not increase emissions of air contaminants in the North Coles Levee Field or Plant No. 8. Based on an annual average operating time of 8 hours per day, this project will supplant $11518m^3$ ($406,724 ft^3$) of fuel gas per day used by Plant No. 8. This will cause a reduction in the annual emission rate of air contaminants from Plant No. 8.

C. NOISE

The noise levels at North Coles Levee Field are typical of a wilderness/rural environment (40 to 45 dBA) except near Plant No. 8, pump stations, well pumps, and well drilling operations. The noise levels near Plant No. 8 and pump stations are similar to those in an industrial area (60 to 80 dBA). Noise levels in these areas are generally constant and occur over a 24-hour period. Noise levels near well pumps are localized noise sources and occur throughout the field.

Well drilling creates noise levels typical of a construction site. These noise levels are temporary, lasting only until a well is drilled. The noise generated by the solar project will be insignificant, being completely masked by the ambient noise level of the area.

D. WATER RESOURCES

The North Coles Levee Field is situated within the boundaries of Basin 5D (Tulare Lake Basin). This basin encompasses the southern half of the San Joaquin Valley and is essentially closed from a hydraulic standpoint. Surface and ground water flows within the basin converge towards the basin's central valley floor. In the past, this convergence resulted in the development of several large lakes (Tulare, Kern, and Buena Vista). The North Coles Levee Field and farms are situated on the dry portion of the Buena Vista Lake bed. Upstream diversions, heavy ground water pumping, and high evaporation rates have helped reduce the aerial extent of Buena Vista Lake and reduce Tulare and Kern to dry lake beds which are now used as farm lands.

While the water resources of the basin are quite large, the project site and adjacent foothills have relatively limited water resources. The ground waters underlying the North Coles Levee Field can be divided into two distinct groups, which are the fresh waters found in the Tulare Formation and the brackish waters of the underlying marine formations. Because of the local geologic structure, the fresh water aquifers located onsite are limited to the first few hundred meters of strata, while the brackish waters of the underlying marine formations extend a few kilometers in depth.

The quality of both these ground waters is poor. The fresh waters are highly mineralized with dissolved solids (TDS) concentrations averaging 5,000 mg/liter. The cause of this degradation is not completely known, but the high TDS levels (3,400 mg/L) associated with local surface streams, which are the primary source of recharge for these aquifers, probably are a major contributing factor (California State Water Resources Control Board, 1975). The water quality of the brackish waters is even poorer, with TDS levels averaging in excess of 27,000 mg/L (ARCO Oil and Gas Company, 1978).

Because of the poor quality of the above waters, the most important water resource within the project site is imported water. The California Aqueduct which passes through the western edge of the North Coles Levee field carries more than 6.17×10^8 m^3 (500,000 acre feet) (annually) of high quality water into the Tulare Lake Basin for agricultural and limited commercial use.

Except for mirror washing, the operation of the proposed project would not increase the current demand for water in the North Coles Levee Field.

E. BIOLOGICAL RESOURCES

1. Vegetation

The vegetation of the North Coles Levee Field consists entirely of the Lower Sonoran grassland described by Twisselman (1967). This vegetation type is characterized by few or no trees, a scattered shrub stratum, and a herbaceous ground cover composed of annual plants. The density of the ground cover depends upon yearly rainfall.

The dominant shrub in the study area is common saltbush (Atriplex Polycarpa). A species of goldenbush (Haplopappus cf. Linearifolius), bladder pod (Isomeris Arborea), white burrobrush (Hymenoclea Salsola), and the Russian thistle (Salsola Kali) are also present.

The dominant herb is red-stemmed filaree (Erodium Cicutarium). The only grass species is the red brome (Bromus Rubens).

Oil production and agricultural development has had considerable impact on the native vegetation in the North Coles Levee Field. The site of the solar project is located on land presently devoted to oil production activities.

2. Wildlife

The most frequently observed mammal in the North Coles Levee Field is the black-tailed hare (Lepus Californicus). Kangaroo rats (Dipodomys spp.) and mice are occasionally seen. San Joaquin antelope ground squirrels (Ammospermophilus Relsoni), Botta pocket gophers (Thomomys Bottae), and California ground squirrels (Otospermophilus Beecheyi) are abundant. Badgers (Taxidea Taxus) and coyotes (Canis Latrons) are seen occasionally at night. The San Joaquin kit fox (Vulpes Macrotis Mutical) has not been observed in the North Coles Levee Field.

Amphibians such as the western toad (Bufo Boreas) and the western spadefoot toad (Scaphiopus Hammondi) are occasionally observed. Reptiles are rarely sighted.

The bird life of this region is not abundant. The thin ground cover provides good hunting for birds of prey like the red-tailed hawk (Buteo Jamaicensis) and the American kestrel (Falco Sparverius). Say's phoebes (Sayornis Saya), loggerhead shrikes (Lanius Ludovicianus) and sparrows are observed. The mourning dove (Zenaidura Macroura), shore birds, and waterfoul occur as migratory transients.

3. Ecological Relationships

The southern end of the San Joaquin Valley in which the North Coles Levee is located is a true desert. Its annual rainfall averages less than .15 m (6 inches). The primary factor that limits and shapes the biotic communities of this region is moisture. The scant rainfall, the winter fogs, and the atmospheric moisture, that results from the area's proximity to the coast, combine to provide sufficient moisture for germination of the seeds of the annual plant species. However, there is not enough moisture to support predominatly perennial vegetation.

Rapidly growing winter annual plants are more successful than perennials, which would require more moisture throughout the year. Those surface areas of the North Coles Levee Field which are farmed must be irrigated.

Oil production development and agricultural activities have affected the wildlife habitat within the North Coles Levee Field. Plowed ground, recontoured areas around well sites, and other earthworks have been colonized by pocket gophers and other burrowing animals because of less compacted soil. This has probably resulted more in a redistribution of the animal population than in an increase in the number of animals present. The limiting resource in this extremely arid region is food, not living space. The reduced ground cover that has resulted from oil production development has reduced the value of the region as wildlife habitat.

F. CULTURAL RESOURCES

The southern San Joaquin Valley was populated by various Yokut tribes for hundreds of years before European contact. Archaeological evidence has been found along the ancient shorelines of what once were Kern Lake, Buena Vista Slough, and Buena Vista Lake. The area of the North Coles Levee Field is located in what was once the Buena Vista Lake bottom. Therefore, this area is of low sensitivity to archaeological resources.

No physical structures or features dating from the 18th or 19th century history of the area are in existance in the North Coles Levee Field. More recent history of the area includes petroleum production and farming.

G. LAND USE

The project site is located in the southwestern portion of Kern County.

1. Regional

The valley floor and Temblor foothills in western Kern County are sites of extensive agricultural and petroleum development. Western Kern County also contains the majority of the County's urban development, located in centers along major transportation routes. The mountainous areas include major U. S. Forest Service holdings. The desert in eastern Kern County is also the site of major federal landholdings.

The San Joaquin Valley's resources were first developed for cattle ranching. Later, the development of ground water resources and the availability of imported water led to the development of cultivated agriculture. Kern County is presently one of the leading agricultural counties in the nation. Approximately 14 x 10^9 m^2 (3,450,000 acres) are devoted to agriculture. The County's major crops include potatoes, alfalfa hay, grapes, and corn.

Bakersfield began as a cattle town. Later, the primary economic activities there shifted to agriculture and oil. With this shift, the western edge of the County experienced urban growth and many small oil "boom towns" appeared. Petroleum production became a major land use in Kern County in the early 1900's.

The primary land uses in the Tehachapi and Sierra Mountains are recreation and cattle grazing.

2. Local

The North Coles Levee Field encompasses 22 x 10^6 m^2 (5,440 acres). It was discovered in November 1938 and has undergone development ever since. At the present time, oil production and support facilities, and agriculture are the only uses of the property. Public access is restricted.

Land use in the immediate vicinity of the solar project site is devoted to oil producing wells and their ancilliary facilities.

H. SOCIOECONOMICS

1. Employment and Trade

The solar project site's regional economic environment comprises the Bakersfield Community and Kern County's Westside including the communities of Taft and Buttonwillow. These communities are strongly resource based. The region draws its economic energy from cultivatable land and petroleum resources.

Agriculture has provided a stable and enduring economic base. Prospects for continued agricultural development are good as additional acreage comes under cultivation, and as more intensive farming techniques are applied to existing cultivated land.

Petroleum production provides a vital source of economic support to the region. The development of viscous heavy crude oil production is reaching maturity in Kern County. Technology to produce oil from the diatomite formations is emerging. This will add even more recoverable reserves of petroleum in Kern County.

Though dominated by the petroleum industry, the local work force is nevertheless a diverse occupational group. About 15 percent of the local labor pool is employed in construction and manufacturing, 20 percent in agriculture, and 55 percent are employed in wholesale and retail trade, finance, insurance, government and other support services. The remaining 10 percent of the local work force is comprised of undefined occupational characteristics.

2. Transportation

Regional transportation needs are served by a large number of Federal, State and County highway systems in Kern County. Interstate 5, located 4.9 km (3 miles) east of the solar project site, is the major north-south traffic route. The transportation needs of the

North Coles Levee Field are served primarily by State Route 119. There is no railroad service to within the field. The closest rail lines are the Sunset Western Railroad which terminates in Taft, and the Southern Pacific line passing through Buttonwillow. The closest air line service is located in Bakersfield.

3. Public Services

Police services in the unincorporated areas of Kern County are provided by the Kern County Sheriff Department. There are three sheriff department offices in the North Coles Levee Field area. Six men are stationed at Wasco, three at Buttonwillow, and five at Taft. There is at least one officer on duty at all times at each location.

Fire protection in Kern County is provided by the Kern County Fire Department, which maintains 46 fire stations. The County Fire Department maintains a foam unit at a county fire station in Bakersfield and Taft. This firefighting equipment is used to control oil fires. There are four Kern County Fire Department stations in the North Coles Levee Field area. These include stations at McKittrick, Fellows, Buttonwillow, and Taft.

Each county station has at least one engine carrying 3.785 m^3 (1000 gallons) of water, and one pickup truck carrying 0.76 m^3 (200 gallons) of water.

The North Coles Levee Field is equipped with water hydrants at oil well, tank, and plant locations. All company vehicles carry fire extinguishers. Plant 8, adjacent to the solar project site, is equipped with large, wheel mounted, fire extinguishers. Brush is cleared from areas adjacent to structures, equipment, and well sites to minimize brush fire hazards.

4. Solid Waste

Solid wastes generated by oil well drilling and production facilities in the North Coles Levee Field are hauled to a county landfill for disposal.

III. POTENTIAL ENVIRONMENTAL IMPACTS

The environmental impacts of the construction phase, operational phase, and site restoration phase of the solar energy retrofit syastem are assessed in this section

A. CONSTRUCTION PHASE

The construction phase would consist of the following:

Site Preparation
Construction of the Tower and Receiver
Construction of the Thermal System
Construction of the Control Building
Construction of the Perimeter Fence
Installation of the Controls and Heliostats
Testing and Calibration of the System

1. Impact on Air Quality

The impact of the construction of the facilities for this solar project on air quality would be similar to any other medium-scale construction activity. Major emission sources would include motor vehicles and construction equipment. Exhaust emissions and fugitive dust, created by moving vehicles and excavation, are the major potential impacts to the local air quality. Some gasses and particulate matter would be emitted while paving in the area of the collector field. Fugitive dust would be controlled by frequent wetting of the work area.

Construction equipment would include graders, bulldozers, backhoes, cranes, pile drivers, and delivery trucks. It is estimated that one truck would be required for each 7.65 m^3 (10 cubic yards) of concrete, or 18,149 kg (20 tons) of material delivered to the construction site.

For the purpose of analysis, it is assumed that materials and equipment would be delivered from Bakersfield, a distance of 35.4 km(22 miles) or a round trip of 70.8 km (44 miles) per delivery. Fuel consumption is estimated to be 0.52 liters per km (0.22 gallons per mile). Emission factors were obtained from the U. S. Environmental Protection Agency's Compilation of Air Pollution Emission Factors, AP 42 Third Edition. Approximately 100 truck loads of material would be delivered to the site. The total operating time for the construction equipment was estimated to be 1088 unit hours. Using these factors, total emissions are estimated to be 82 kg (0.09 tons) of sulfur oxides, 120 kg (1.32 tons) of nitrogen oxides, 100 kg (0.11 tons) of hydrocarbons, and 263 kg (0.29 tons) of carbon monoxide. The Kern County Emmision Inventory for 1976 shows an annual emission rate of 90.9 x 15^6 kg (100,171 tons) of sulfur oxides 70.3 x 10^6 kg (77,471 tons) of nitrogen oxides, 127 x 10^6 kg, (139,948 tons) of hydrocarbons, and 141 x 10^6 kg (155,552 tons) of carbon monoxide. Due to the relatively small amounts of emissions generated by this construction activity, their effects on local air quality are considered to be small and of minor consequence.

2. Impact on Climate

The preparation of the site and construction of the solar energy retrofit project would not alter the climate of the project area or the surrounding territory. No moisture would be added or removed from the atmosphere.

3. Noise Impact

The vehicles and equipment used in the construction of this solar retrofit project will temporarily contribute to the noise profile of the area. The construction area is over 274 m (900 ft) from the natural gas processing plant. The pile driver will be the noisiest type of equipment used. Data derived from the "Report of the Administration of the Environmental Protection Agency to the President and Congress on Noise," February 1972, indicates that the pile driver may emit a sound level of 79-80 dB(A) at 274 m (900 ft) distance. This noise level will not interfere with activities in the surrounding area. The U.S. Environmental Protection Agency considers as normally acceptable a resultant noise level exposure of 80 dB(A) for eight hours.

4. Solid Waste Impact

Solid wastes produced during construction would consist of packing materials, crates, construction rubble, and materials enerated by the construction workers. Based on information contained in Supplement No. 9 for the "Compilation of Air Pollutant Emission Factors," 1979, U. S. Environmental Protection Agency, an average of 2.5 kg (5.5 pounds) of urban rufuse and garbage is collected per capita per day in the United States. Using this factor, it is estimated that up to 2995 kg (3.3 tons) of refuse would be generated by the workers during construction. Local construction workers would be employed; therefore, this would not represent an additional disposal requirement for the county landfill.

5. Impact on Water

Water will be required for dust control, drinking and sanitary requirements, and concrete foundations. Approximately 73 m^3 (95 cubic yards) of concrete will be used for foundations. This will require 5.8 m^3 (15,390 gallons) of water. Dust control may require 477 m^3 (126,000 gallons) for a total of 535 m^3(141,390 gallons) for construction use. Construction personnel would require 2270 m^3 (1.84 acre-feet) of water, based on 20 people working for 60 days using 37.85 m^3 (10,000 gallons) per day. This would not represent an additional water demand since local personnel would be used to construct the facilities. The total requirement of 2805 m^3 (2.274 acre-feet) of water should not have any major impact on the local water supply. Construction activity will have no effect on local water quality. Oil and grease dripping from the construction machinery might be mixed with runoff water from the construction site. Impacts from this source of pollutants should be relatively minor.

6. Biological Impacts

The proposed construction site for this solar retrofit project is located in an area presently devoted to oil production activities. An equipment storage yard and two oil well sites with access roads are present. Construction activities would destroy vegetation over several hundred square meters and would disturb the small mammals which would occasionally visit the construction area. However, due to the present activities in the area, there would be no major impacts to any floral or faunal species.

7. Socio Economic Impact

The total labor force required for construction is estimated to be 20 workers. Local construction workers would be employed. Due to the fact that the workers would be from the local area, no major economic demands, such as additional housing, school construction, police, fire or health services would be required. The capital expenditure for this solar retrofit project is estimated to be $ At this time, the portion that would be spent in the project area for materials is not known. Additional economic impacts could occur in areas in which the retrofit project materials were manufactured and sold.

8. Land Use Impacts

There are two oil well sites and a storage yard presently located on the area to be occupied by the proposed solar retrofit project. The area also contains access roads for these facilities. The storage area will be removed. The two oil well sites with their access roads will remain in place. Approximately 16.2×10^4 m^2 (40 acres) will be fenced in for the project. This is 0.7% of the 22×10^6 m^2 (5,440 acres) encompassed by the North Coles Levee Field. Due to the small area disturbed, the construction of this project should not create any significant impacts on land use.

9. Impacts on Topography and Soils

No significant impacts are anticipated to occur to the existing topography. There will be some grading done on the 16.2 $\times 10^4$ m^2 (40 acre) area of the project; however, impacts would be of minor consequence. Impacts on the soil should also be minor. There would be limited trenching for piping, power supply and control cables. Grading of several hundred square meters for the placement of the equipment and excavation for foundations would be required. This may alter the character of the soils disturbed during construction. However, such an impact would be limited to a 16.2×10^4 m^2 (40 acre) area of the North Coles Levee Field's 22×10^6 m (5,440 acres). Due to the arid climate and the small area disturbed, soil errosion that might occur would be very minor.

10. Impacts on Drainage

Grading, trenching, and excavating operations during construction could potentially affect drainage patterns in the immediate construction area; however, such impacts should be slight considering the small area which will be affected by construction.

11. Impacts on Aesthetics

The aesthetics of the area would be affected to some degree by the construction of this solar retrofit project. The single module solar field and the receiver tower have architectural features which resemble the existing natural gas processing plant and oil well drilling rigs which have been operating in the North Coles Levee Field for many years. Aesthetic impacts caused by constructing this solar retrofit project would be minimal because of the context in which the project's equipment appears. Considering the project would be constructed near an existing natural gas processing plant in an active oil field in a rural area, the aesthetic impacts should be minor. A potential glare problem created by the mirrors may or may not exist. This will be evaluated during the operation of this project.

B. OPERATIONAL PHASE

1. Impact on Air Quality

Operation of the Solar Industrial Retrofit System at North Coles Levee natural gas processing plant would not generate any air pollutant emissions. The operation could result in a minor reduction of air pollutants. The heat generated by this system could replace about 9518 kw_t (32.5 million BTU per hour) capacity that is now supplied by burning natural gas.

2. Impact On Climate

No significant impacts on the climate of the area due to the operation of this system are anticipated.

3. Noise Impact

The operation of the electric motors moving the heliostats would be the only additional source of noise in the area while this project is in operation. The project area is located near the natural gas processing Plant No. 8. The noise levels near this plant are similar to those in an industrial area. The noise generated by this solar project will be insignificant, being completely masked by the ambient noise level of the area.

4. Solid Waste Impact

The operation of this solar energy retrofit project would not produce significant solid wastes. The operational personnel would generate up to one ton of refuse per year. Since local workers would be used, disposal of these wastes would not be an additional requirement on the local area.

5. Impact on Water Quality

Water will be required for washing the mirrors about once a month. Approximately 15.8 m^3 (4200 gallons) of fresh water containing cleaning agents will be used for washing and approximately 15.9 m^3

(4200 gallons) of fresh water will be used for rinsing the mirrors. Cleaning agents which might be added to the water used to wash the mirrors would not alter the quality of local water supplies significantly.

6. Biological Impacts

Operation of this solar energy retrofit project would not result in major impacts to the biological environment due to the industrialized nature of the area. No significant operational effects on the biological environment will be generated. A leak or blowout in the piping carrying the heat medium oil could create a potential hazard until the oil spill was cleaned up. Biodegradable solvents used in the water to clean the mirrors could have minor impacts.

7. Socio Economic Impact

It is expected that two workers would be required to operate and maintain this solar energy retrofit system. These workers would be from the local area; therefore, there would be no effect on the demography or local population. There would be no impact on local services and facilities. The estimated operating cost for this project is $ per year. It is expected that such an expenditure would not have any major economic impact on the area.

8. Land Use Impacts

The operation of this project will not cause any additional change in land use beyond that which was caused by construction of the project.

9. Impacts on Topography and Soils

Normal operation of the solar energy retrofit project would not have any impact on topography or soils. If there should be a leak in the heat medium oil system, there could be some temporary impacts to soil contacted by the spilled oil. Clean up of an oil spill would restore the soil to a condition similar to what it was prior to the spill.

C. SITE RESTORATION PHASE

Upon termination of this project, the heliostats, tower and control building would be removed. The area would be restored to its original use.

1. Impact on Air Quality

The impacts of the removal of the facilities for this solar energy retrofit project on air quality would be similar to the impacts produced during the project's construction. Major emission sources would include motor vehicles and cranes. Exhaust emissions and fugitive dust would be the major impacts to local air quality The number of vehicles used during the removal of the facilities should not be greater than those used during the construction phase. Therefore, the effects of emissions during site restoration on air quality should be small.

2. Impact on Climate

The removal of the solar energy retrofit project's facilities would have no effect on the climate in the project area.

3. Noise Impact

The noise created by trucks and equipment used to dismantle and remove the project's equipment would br at about the level attained during construction. It is estimated that the sound level would be less than 75 dB(A) at 274 m (900 ft) distance. This noise level will not interfere with activities in the surrounding area.

4. Solid Waste Impact

Rubble produced by dismantling the project's equipment would be the primary type of solid waste to be disposed of in a county landfill. Equipment not used for other projects would be sold. It is estimated that about one ton of refuse would be generated by the workers during dismantling.

5. Impact on Water

Water may be required for dust control, drinking, and sanitary requirements. The paved areas would reduce the amount of water needed for dust control. Oil and grease dripping from the equipment might be mixed with runoff water from the site. Impacts from this source of pollutants should be relatively minor.

6. Biological Impacts

The site would be restored to essentially what it was prior to construction. Dismantling activities could disturb birds or mammals which may be in the area. Site restoration would not result in significant alterations to natural habitats.

7. Socio Economic Impact

Local workers would be employed in dismantling the project. Therefore, there would be no additional demands on housing, schools, police, fire, or health services in the area.

Land Use Impacts

The site of the solar energy retrofit project would be returned to its original use after removal of the equipment.

9. Impacts on Topography and Soils

No major impacts are expected to occur to the existing soils or topography during the dismantling of this project.

10. Impacts on Drainage

Some temporary alteration to the drainage patterns on the site could occur while removing equipment. Such impacts should be insignificant.

D. UNAVOIDABLE ENVIRONMENTAL EFFECTS

It is not expected that there would be any permanent environmental impacts resulting from this solar energy retrofit project. There may be some short-term impacts to air quality during construction and dismantling. An increase in noise levels during construction and dismantling is expected. A potential glare problem created by the mirrors may or may not exist. This will be evaluated during the operation of the project.

E. CONDITIONS THAT OFFSET POTENTIAL ADVERSE ENVIRONMENTAL EFFECTS

Methods to utilize the energy supplied by the sun that can be both environmentally and economically acceptable are needed in the national interest. Fossil fuels presently used to supply the nation's energy needs are depletive resources. The use of solar energy to augment the nation's energy supply will conserve fossil fuel. The beneficial effects from this project consist of developing the design and operation techniques of an efficient solar energy retrofit heat generating system, and testing the solar thermal conversion approach for commercial application to a typical industrial, petrochemical complex.

IV. ALTERNATIVES

A. NO ACTION

The "No Action" alternative would delay the goal of the National Energy Program, which is to develop and introduce environmentally and economically acceptable uses of solar energy. Taking no action would avoid the short-term adverse environmental effects of this project, but it would be of minor benefit compared to the gain that the development of solar energy retrofit heat generating systems would bring to the national interest.

B. ALTERNATIVE SITES

The other sites considered for the location of this project were in the vicinity of the North Coles Levee Plant No. 8. The site chosen afforded close proximity to the plant while requiring the least disturbance to the existing environment. The isolation and climatology at this location are excellent for testing solar energy systems.

V. CONCLUSION

This proposed solar energy retrofit project will make an important contribution to the attainment of the National Energy Program's goal of developing and introducing the solar thermal conversion approach for commercial application to produce heat for industrial use. No significant long-term adverse impact on the environment by this project is anticipated.

APPENDIX C

HELIOSTAT PERFORMANCE

Detail heliostat performance data on major specification items, pointing error, beam quality, structural deflection, and operating speeds are included in the first seven tables.

Control characteristic data begins with a map of the analysis heliostat positions in the field on page C-9 and is followed by axis position data against time of day and axis envelop position data showing the azimuth and elevation angles plotted against each other. The "time of day" plots highlight any rapid travel periods and verify that no singularities are present. The "Elevation and Azimuth" plots establish the data needed for limit switch positioning.

TABLE 3-17

REFLECTED BEAM POINTING ERROR SUMMARY

	Uncorrected		Correction	Net Pointing Error	
	AZIM	ELEV		AZIM	ELEV
1. Control Resolution	.22	.22	NONE	.22	.22
2. Analytics					
A. Computation	.44	.18	NONE	.44	.18
B. Sun Location	.14	.14		.14	.14
3. Backlash	.76	0	Software	.22	0
4. Alignment (Initialization)	.22	.22	NONE	.22	.22
5. Gravity Deflection					
A. Rack	0	0.702	Software	0	.1
B. Drive	0	0.6	Software		
6. Foundation Movement	0.9	0.9	Software	0.1	0.1
7. Non Orthogonal Axes	0.6	0.6	Software	0.3	0.3
Sum of Worst	3.28	3.56		1.64	1.26
RSS TOTAL	1.434	1.474		.677	.509

TABLE 3-18

REFLECTED BEAM QUALITY ERROR SUMMARY

	Uncorrected		Correction	Net Beam Quality	
	AZIM	ELEV		AZIM	ELEV
1. Alignment (canting)	.36	.36	None	.36	.36
2. Focusing (out of flat fixture)	.1	.1		.1	.1
3. Thermal Defocusing	.23	0	None	.23	0
4. Gravity Deflections					
A. Beam	0	.250	Canting Offset	.644	.456*
B. Torque tube	1.434	0			
C. Module	0	.311	None	0	.311
5. Mirror Waviness	0	(Long Radius Concave)	None	0	0
6. Mirror Specularity	.2	.2	None	.2	.2
SUM OF WORST	2.094	1.22		1.534	1.427
RSS TOTAL	1.495	.58		.805	.696

* The value is higher than the uncorrected value due to the fringe angle increase caused by the software elimination of the gravity pointing error.

TABLE 3-19

STRUCTURAL DEFLECTION ERRORS
FROM A 12 m/s (27 mph) WIND

	Worst Case Elevation Angle Deflection Error, mrad		RMS Field Average Deflection Error, mrad	
	AZIM	ELEV	AZIM	ELEV
MIRROR MODULE	.023	.302	.020	.231
TRUSS PURLINS	0	.041	0	.020
TORQUE TUBE	.223	.186	.215	.109
DRIVE UNIT	.80	.20	.56	.14
TOTAL	1.046	.729	.795	.500

TABLE 3-15

DRIVE UNIT PERFORMANCE CHARACTERISTICS

MOTOR SPEED STEPS/SEC.	MOTOR SPEED RPM	DRIVE UNIT EFFICIENCY, %	DRIVE OUTPUT TORQUE kg-m, (lb-ft)	OUTPUT POWER kw (hp)	SLEW RATE, DEG/MIN
200	60	20.33	1285 (9274)	.004 (.006)	1.20
400	120	20.38	1455 (10505)	.010 (.013)	2.40
600	180	20.44	1580 (11401)	.016 (.022)	3.60
800	240	20.50	1655 (11944)	.022 (.030)	4.80
1000	300	20.55	1636 (11807)	.028 (.037)	5.99
1200	360	20.61	1540 (11113)	.031 (.042)	7.19
1400	420	20.67	1397 (10089)	.034 (.045)	8.39
1600	480	20.73	1238 (8934)	.034 (.045)	9.59
1800	540	20.78	1083 (7820)	.034 (.045)	10.79
2000	600	20.84	954 (6887)	.033 (.044)	11.99

TABLE 3- 14

DRIVE MOTOR TORQUE AND POWER

MOTOR STEPPING RATE, STEPS/SEC	MOTOR SPEED, RPM	MOTOR TORQUE, kg-cm (oz-in)	MOTOR POWER, kw (hp)
250	75	36.7 (510)	.028 (.038)
500	150	41.4 (575)	.064 (.086)
750	225	44.9 (623)	.104 (.139)
1000	300	44.1 (612)	.136 (.182)
1250	375	40.7 (565)	.157 (.210)
1500	450	35.3 (490)	.163 (.219)
1750	525	29.7 (413)	.160 (.215)
2000	600	25.3 (352)	.156 (.209)

FIGURE 3-16

"NORTHWIN" COMPUTER OUTPUT - DRIVE EVALUATION -
1000 STEPS/SEC

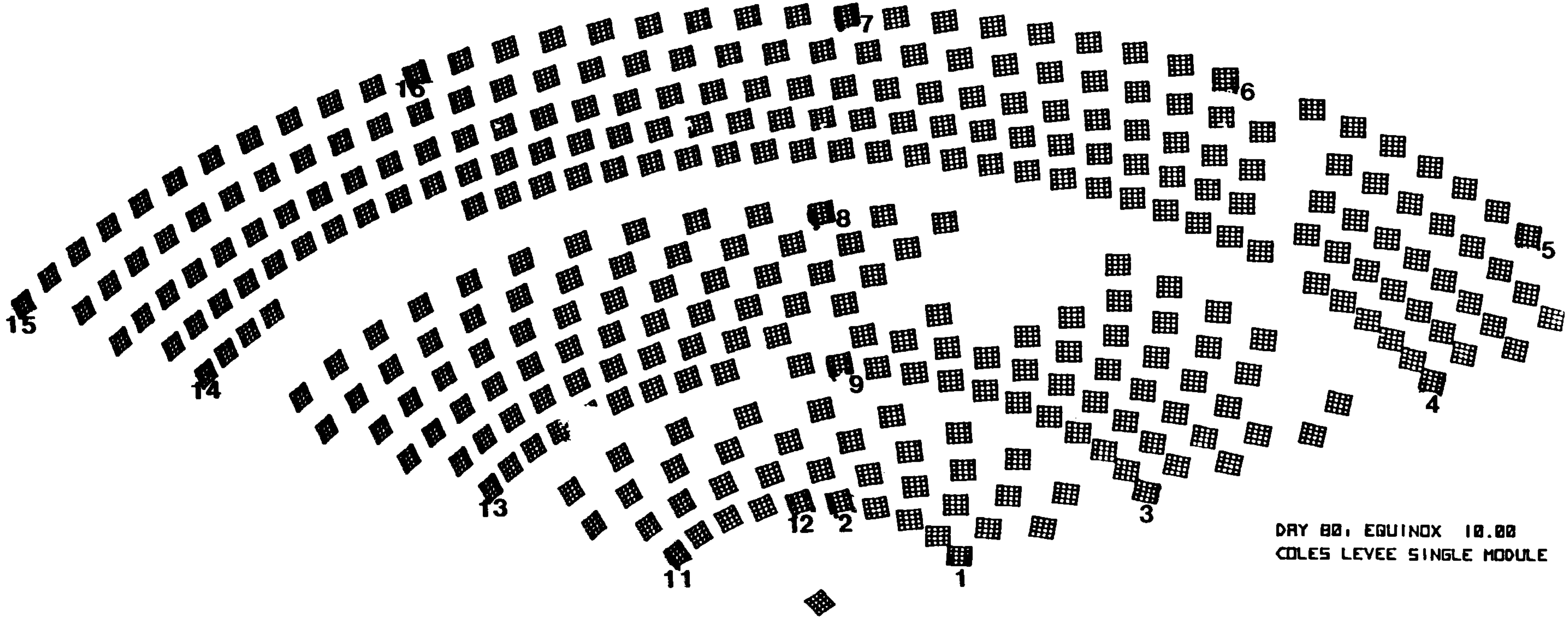
```
        NORTHRUP-WINSMITH PLANETARY-WORM DRIVE UNIT
        -------------------------------------------


  INPUT GEAR BOX RATIO AT MOTOR 450.45

  INPUT GEAR BOX EFFICIENCY,% 54.87

  INPUT STEPPING RATE,STEPS/SEC 1000

  INPUT WORM/GEAR REDUCTION RATIO 40

  INPUT WORM P.D. 3.12099528

  INPUT WORM LEAD ANGLE 7.7


 INPUT STAGE
 -----------
   MOTOR STEP RATE, STEPS/SEC = 1000
   MOTOR RPM = 300
   MOTOR TORQUE,OZ-IN= 612
   MOTOR OUTPUT HP = .18207
   GEAR BOX OUTPUT TORQUE,IN-LB= 9453.9
   GEAR BOX EFFICIENCY,%= 54.87


 OUTPUT STAGE
 ------------
   INPUT TORQUE,FT-LB= 787.82
   EFFICIENCY,%= 37.46
   OUTPUT TORQUE,FT-LB= 11807.49
   WORM RPM= .666


 TOTAL DRIVE UNIT
 ----------------
   INPUT TORQUE,OZ-IN= 612
   EFFICIENCY,%= 20.55
   OUTPUT TORQUE,FT-LB= 11807.49
   DRIVE OUTPUT HP = .037
   COMBINED RATIO= 18018
   SLEW RATE, DEG/MIN = 5.994
```

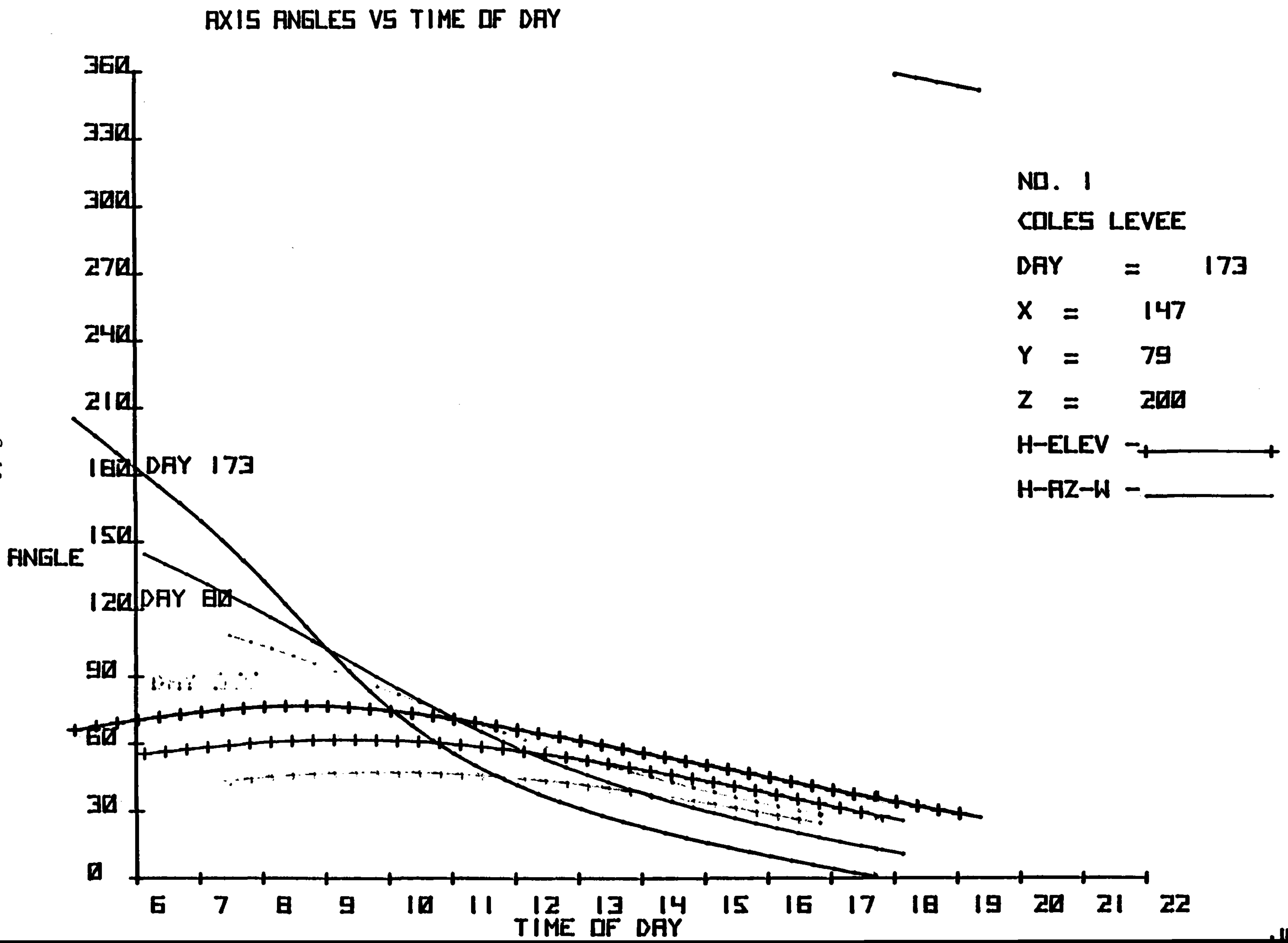
FIGURE 3-17

"NORTHWIN" COMPUTER OUTPUT - DRIVE EVALUATION - 2000 STEPS/SEC

```
NORTHRUP-WINSMITH PLANETARY-WORM DRIVE UNIT
-------------------------------------------


INPUT GEAR BOX RATIO AT MOTOR 450.45

INPUT GEAR BOX EFFICIENCY,% 54.87

INPUT STEPPING RATE,STEPS/SEC 2000

INPUT WORM/GEAR REDUCTION RATIO 40

INPUT WORM P.D. 3.12099528

INPUT WORM LEAD ANGLE 7.7


INPUT STAGE
-----------
  MOTOR STEP RATE, STEPS/SEC = 2000
  MOTOR RPM = 600
  MOTOR TORQUE,OZ-IN= 352
  MOTOR OUTPUT HP = .20944
  GEAR BOX OUTPUT TORQUE,IN-LB= 5437.5
  GEAR BOX EFFICIENCY,%= 54.87


OUTPUT STAGE
------------
  INPUT TORQUE,FT-LB= 453.13
  EFFICIENCY,%= 37.99
  OUTPUT TORQUE,FT-LB= 6886.84
  WORM RPM= 1.332


TOTAL DRIVE UNIT
----------------
  INPUT TORQUE,OZ-IN= 352
  EFFICIENCY,%= 20.84
  OUTPUT TORQUE,FT-LB= 6886.84
  DRIVE OUTPUT HP = .044
  COMBINED RATIO= 18018
  SLEW RATE, DEG/MIN = 11.988
```

Control Analysis Heliostat Positions

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ANGLE
360
330
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240
210
180
150
120
90
60
30
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DAY 173
DAY 80
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8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
TIME OF DAY
NO. 1
COLES LEVEE
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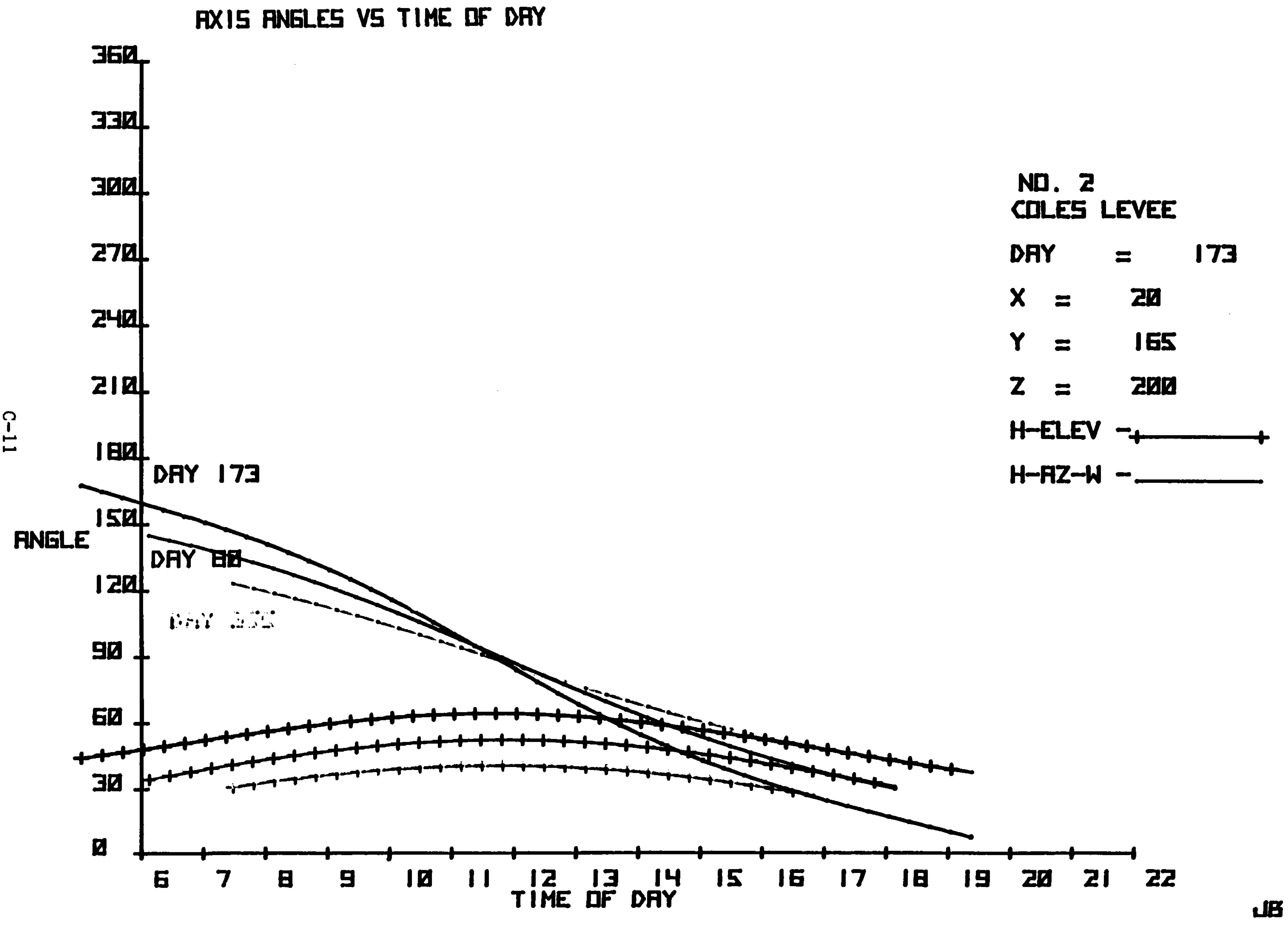
Y = 79
Z = 200
H-ELEV -
H-AZ-W -

AXIS ANGLES VS TIME OF DAY
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90
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ANGLE
DAY 173
DAY 80
DAY 355
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
TIME OF DAY
NO. 2
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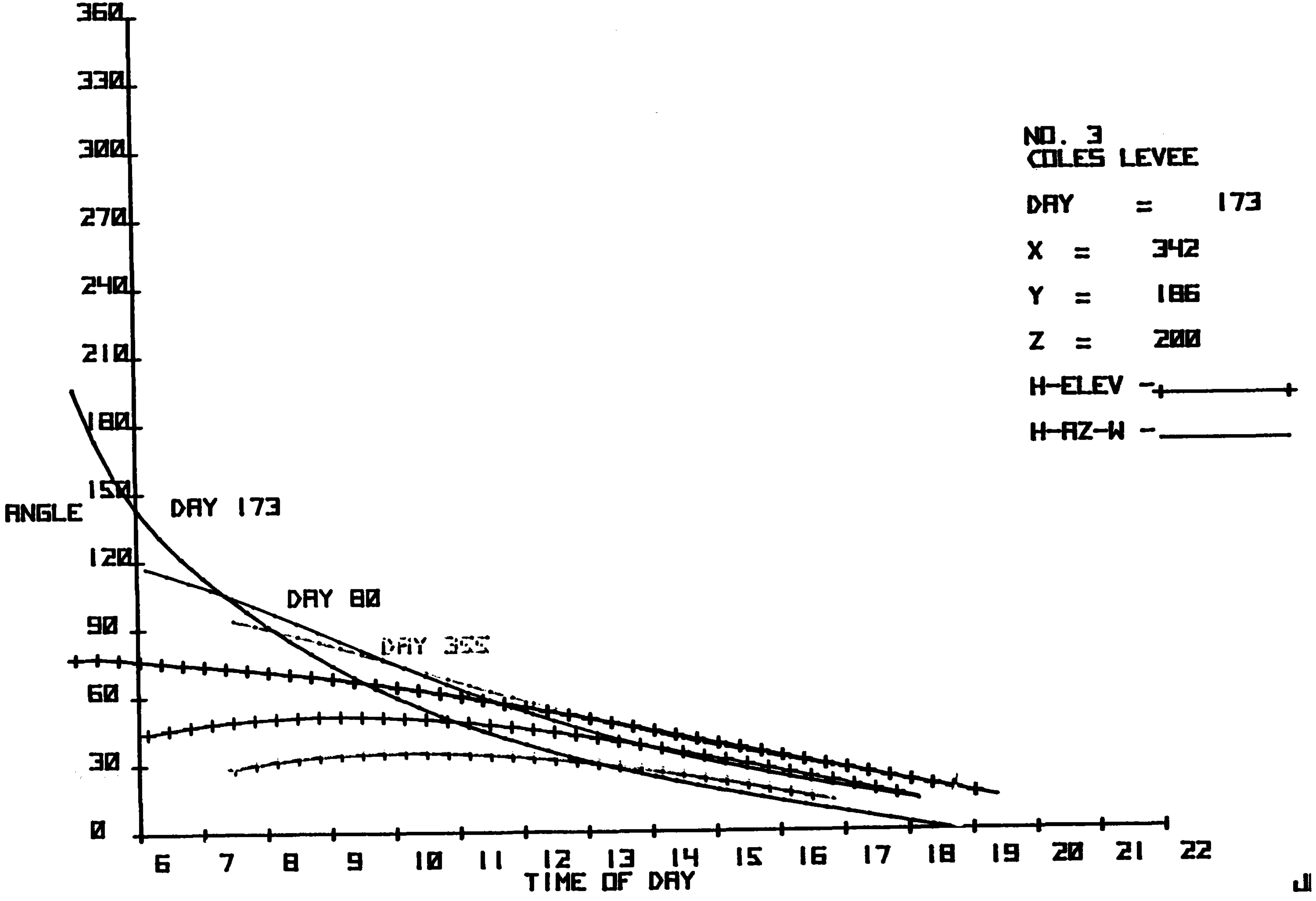
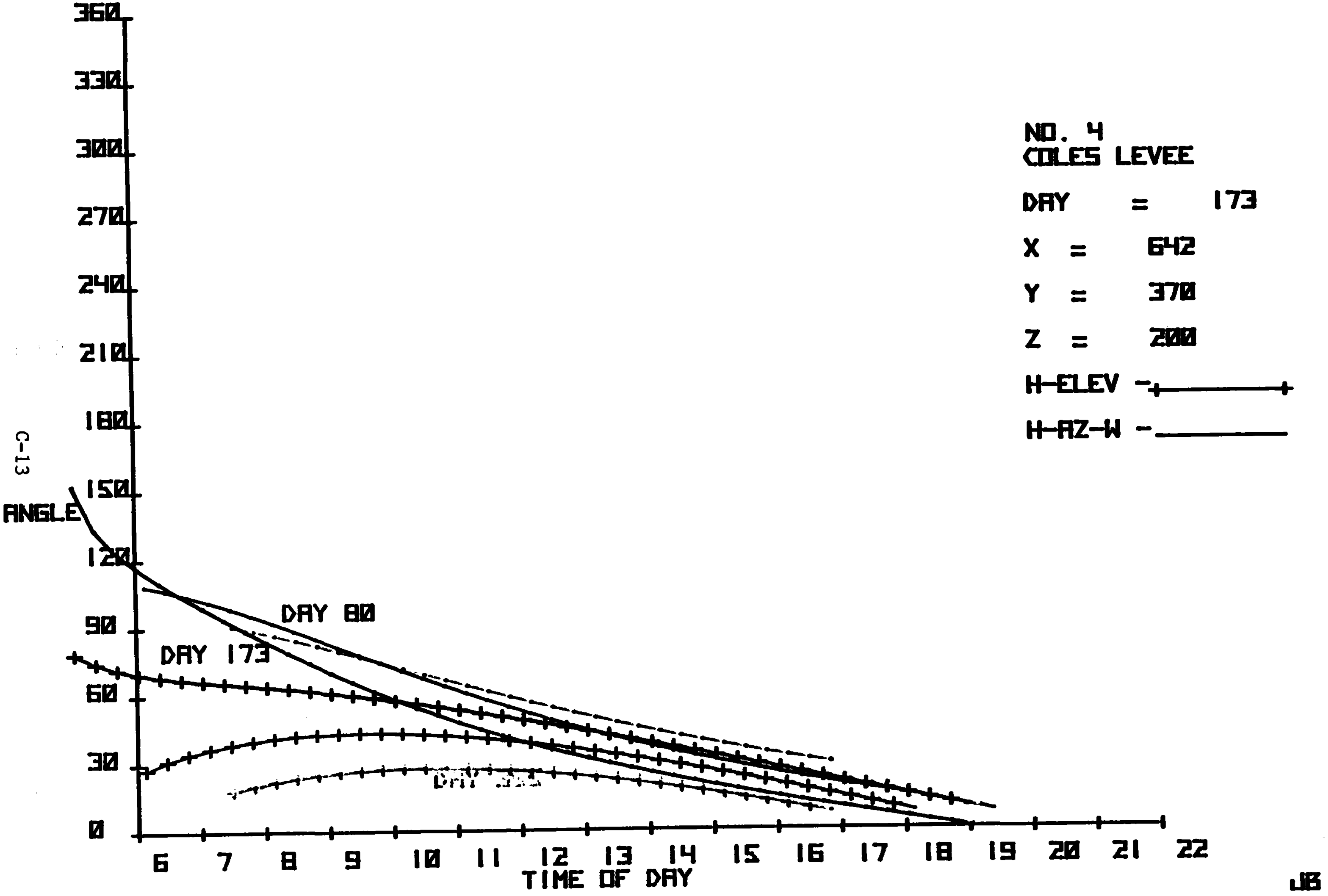
X = 20
Y = 165
Z = 200
H-ELEV -
H-AZ-W -
JB

AXIS ANGLES VS TIME OF DAY



AXIS ANGLES VS TIME OF DAY



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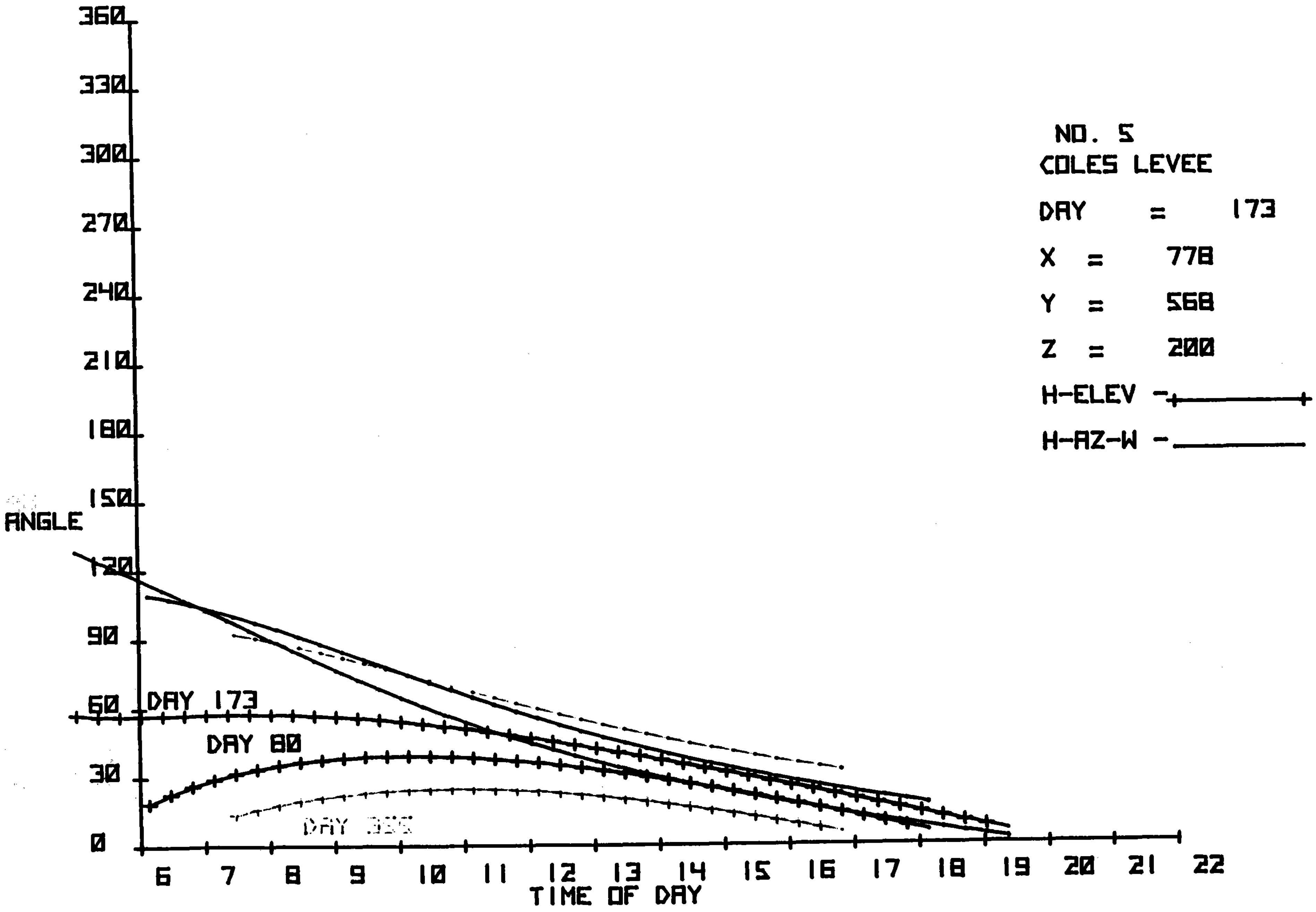

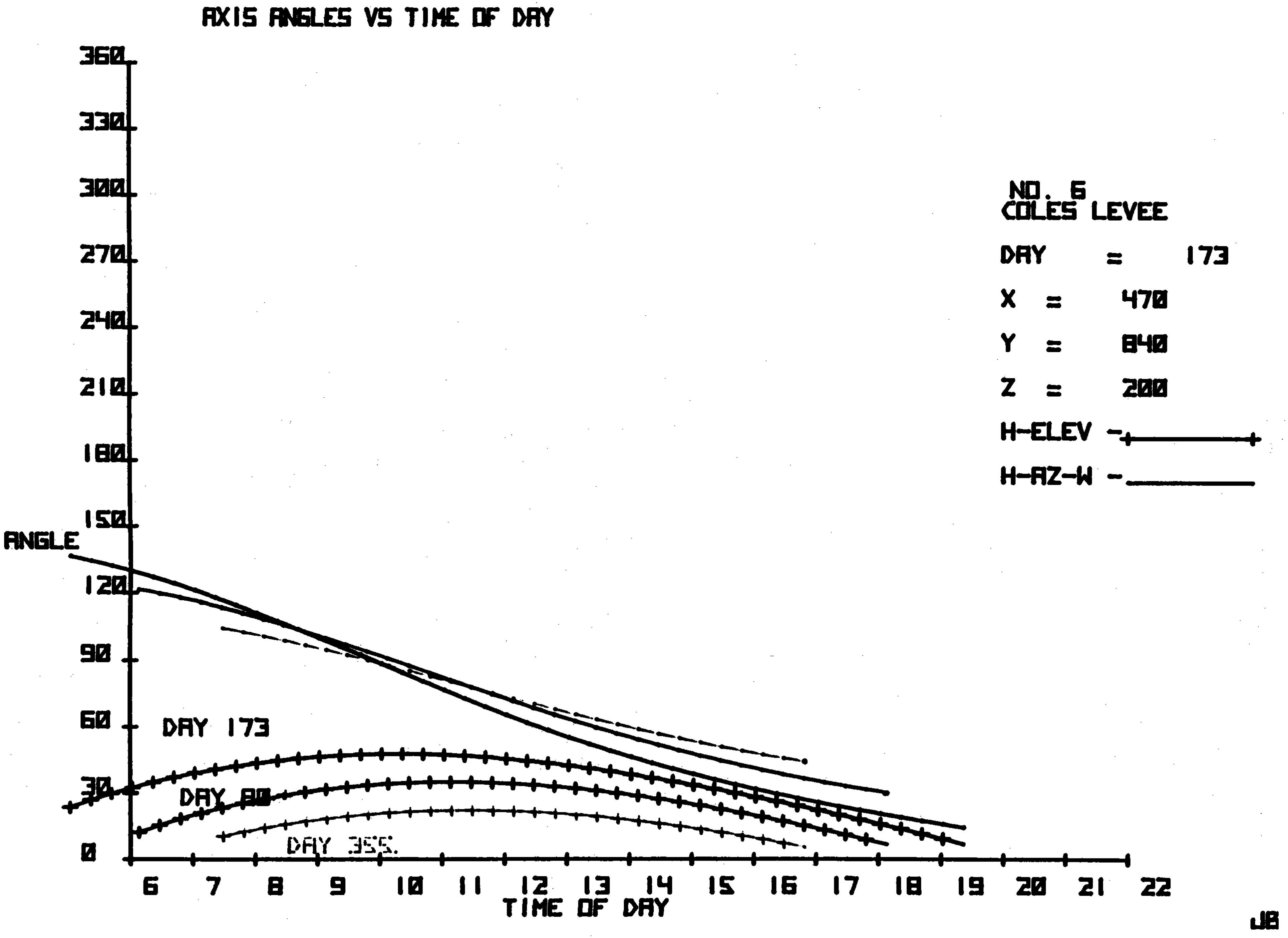
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22
TIME OF DAY
DAY 173
DAY 80
DAY 355.
NO. 6
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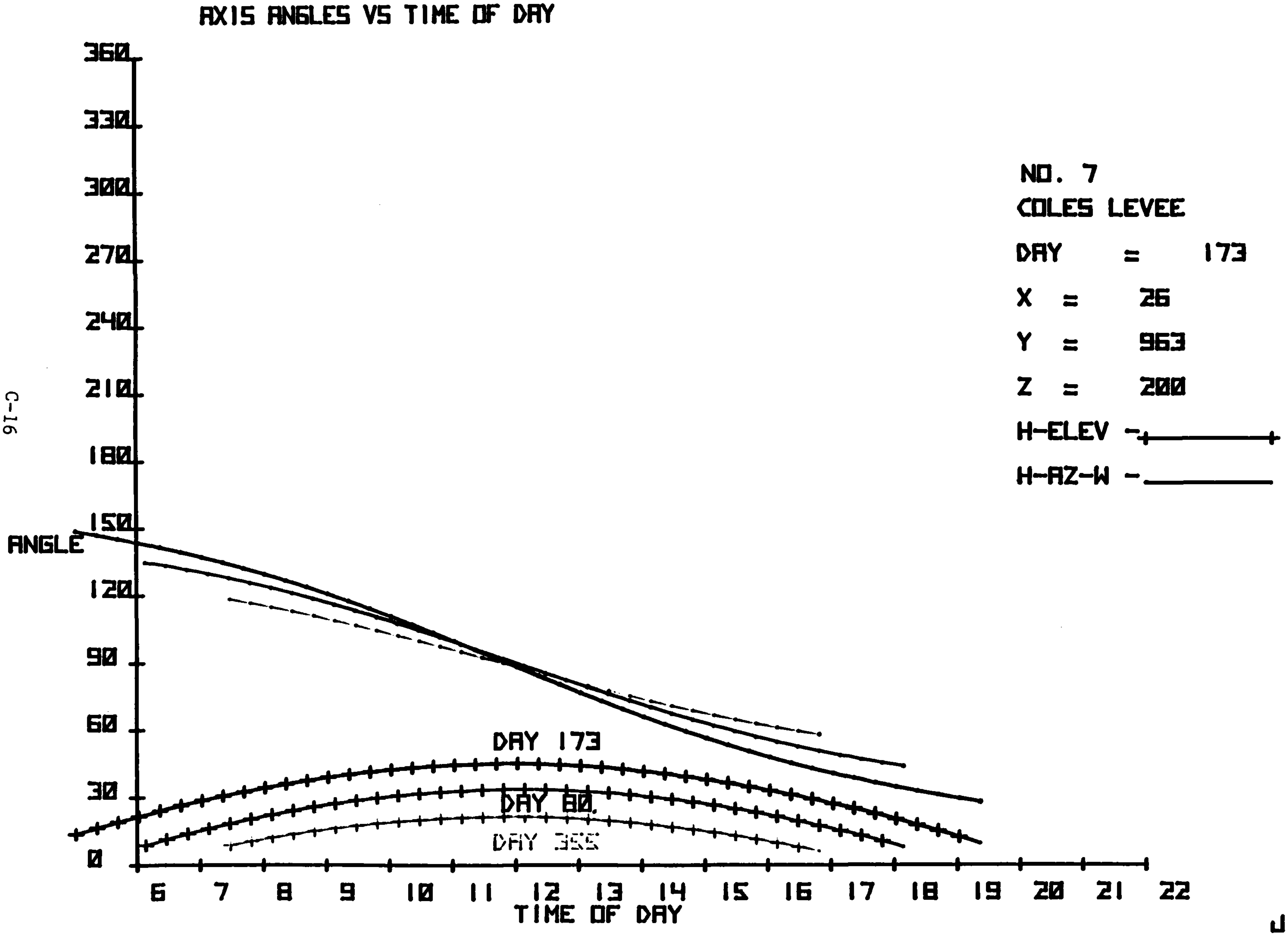
Y = 840
Z = 200
H-ELEV -
H-AZ-W -
JB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NO. 7
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Y = 963
Z = 200
H-ELEV
H-AZ-W
ANGLE
360
330
300
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240
210
180
150
120
90
60
30
0
DAY 173
DAY 80
DAY 355
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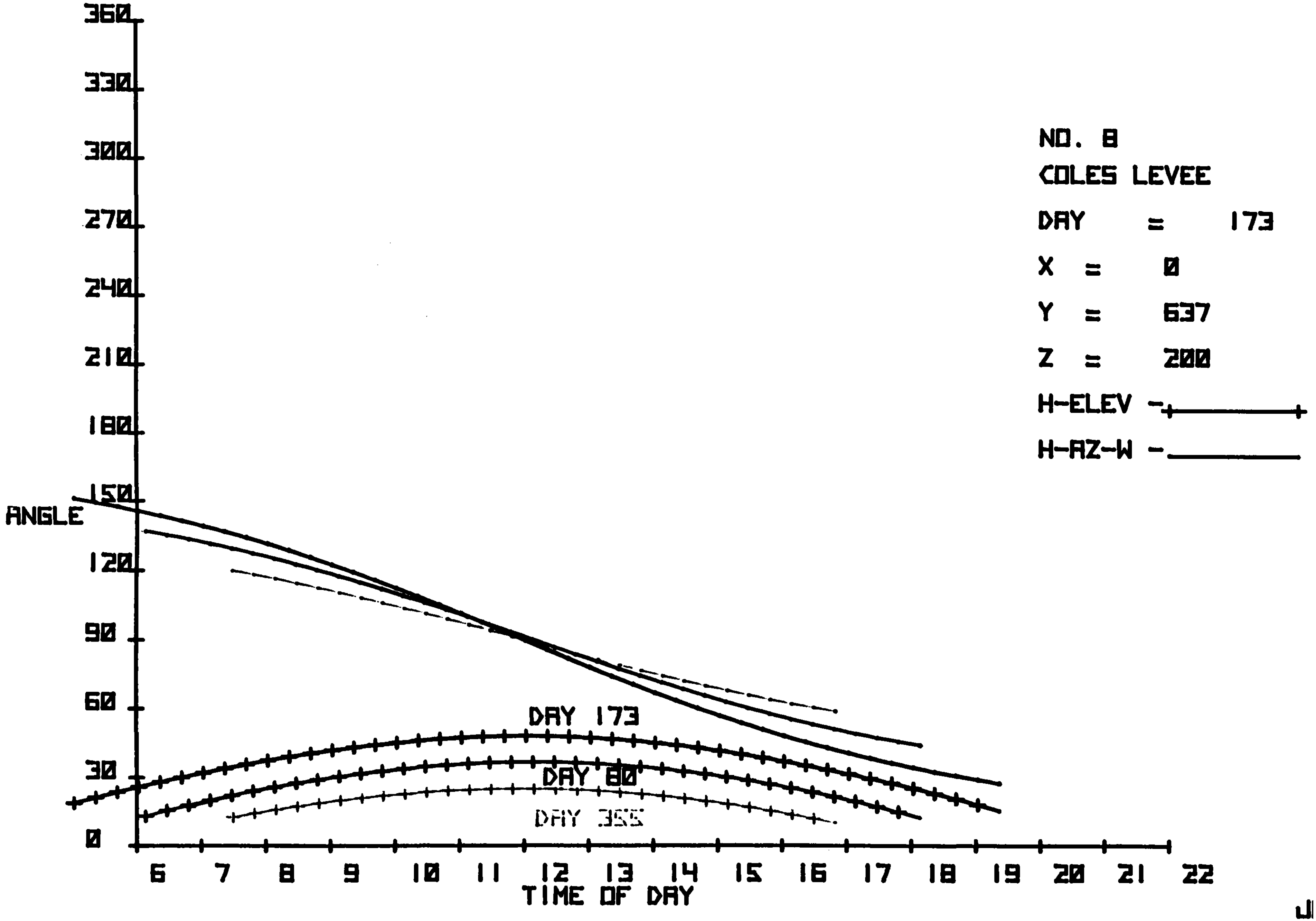
TIME OF DAY

AXIS ANGLES VS TIME OF DAY



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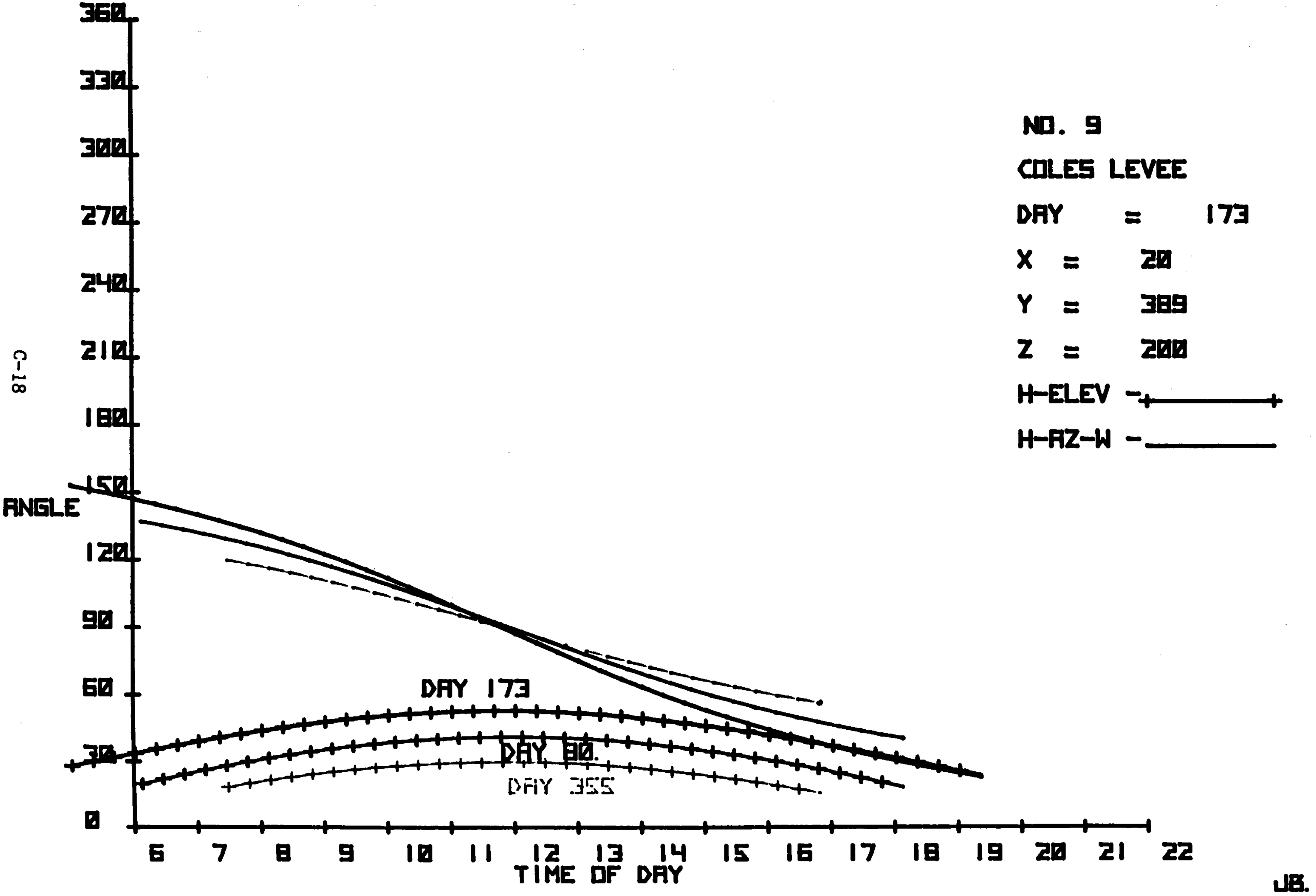

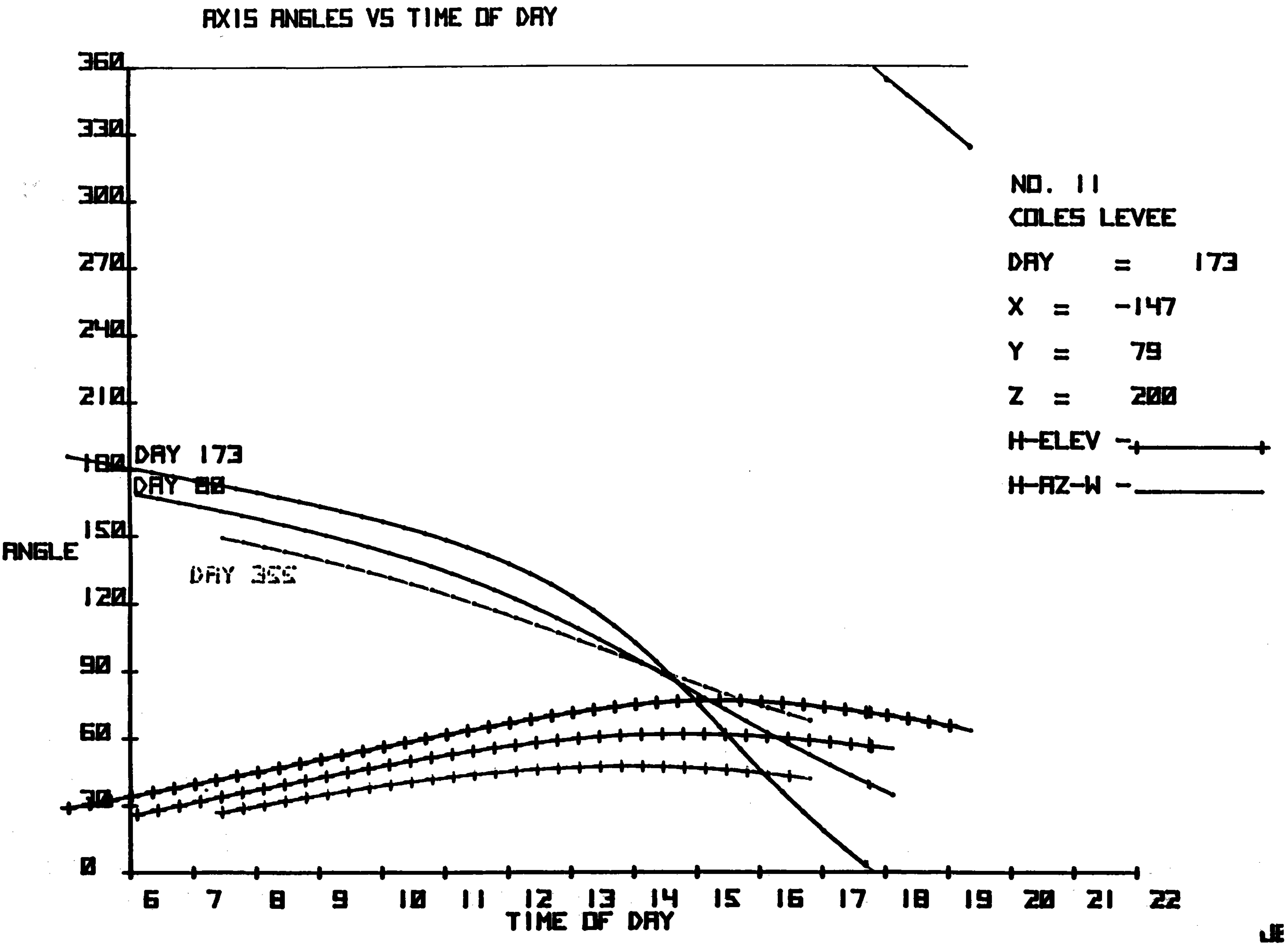
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21
22
TIME OF DAY
DAY 173
DAY 88
DAY 355
NO. 11
COLES LEVEE
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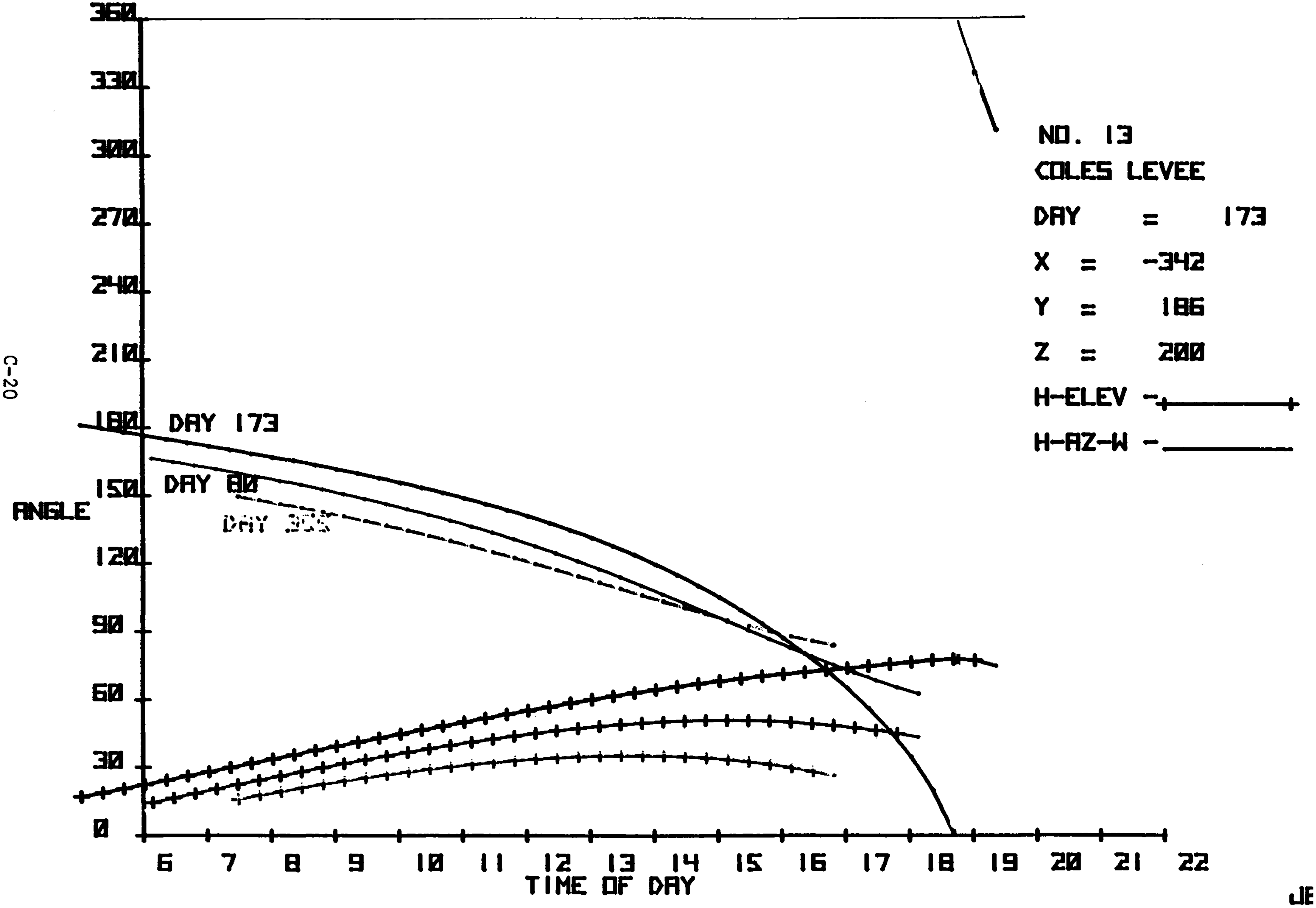
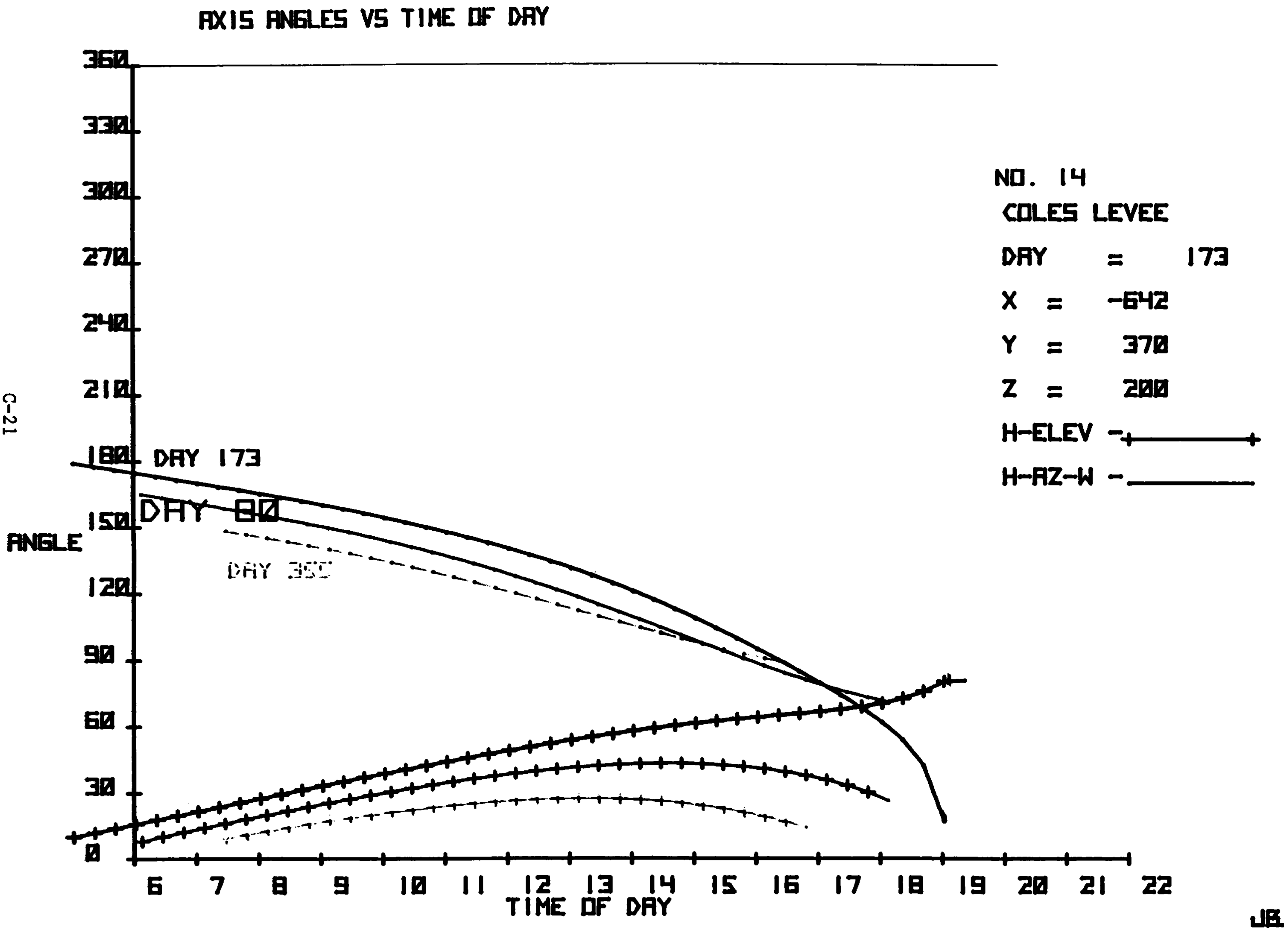
X = -147
Y = 79
Z = 200
H-ELEV -
H-AZ-W -
JE

AXIS ANGLES VS TIME OF DAY




AXIS ANGLES VS TIME OF DAY
ANGLE
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0
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8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
TIME OF DAY
DAY 173
DAY 80
DAY 355
NO. 14
COLES LEVEE
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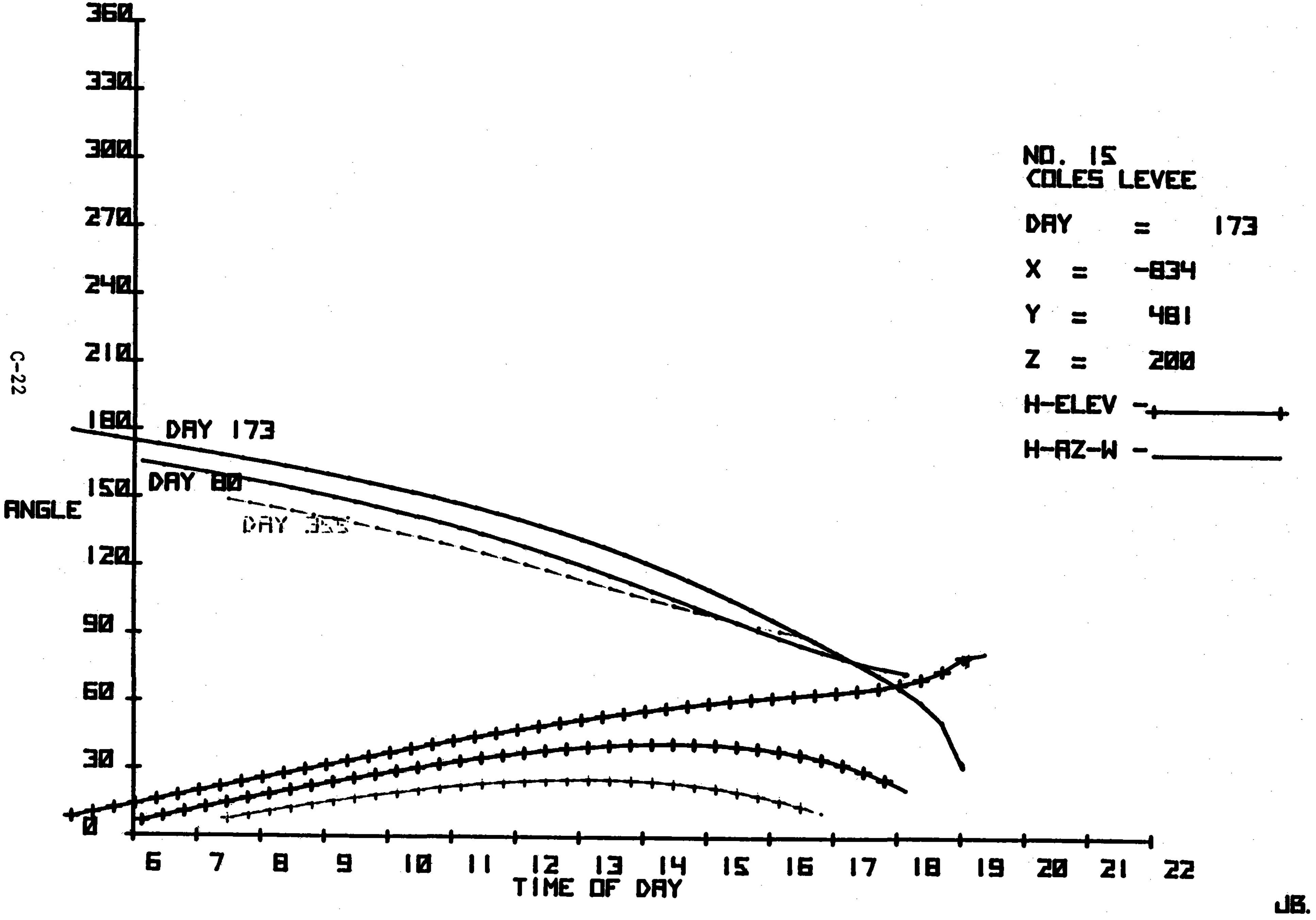
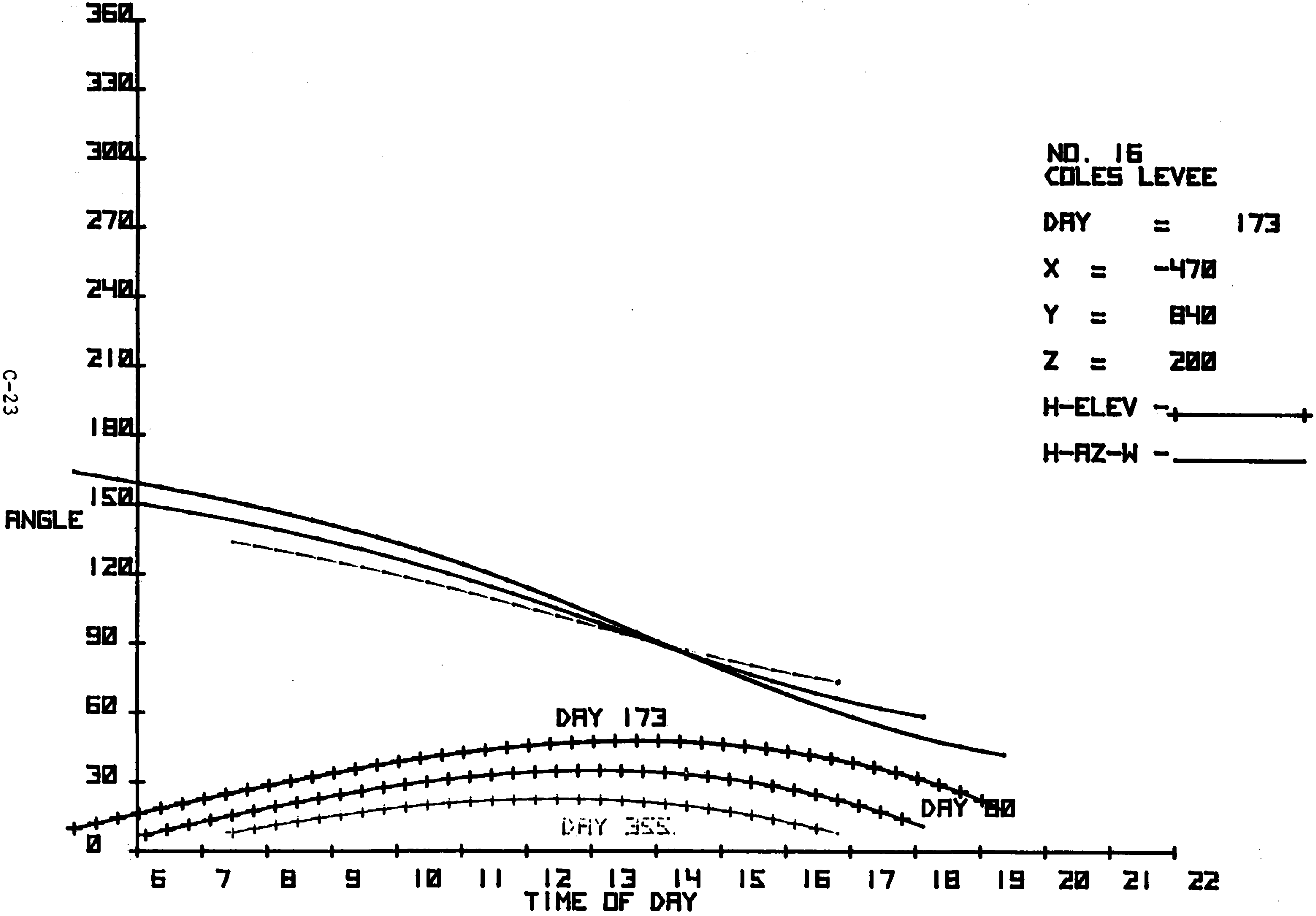
Z = 200
H-ELEV -
H-AZ-W -
JB.

AXIS ANGLES VS TIME OF DAY

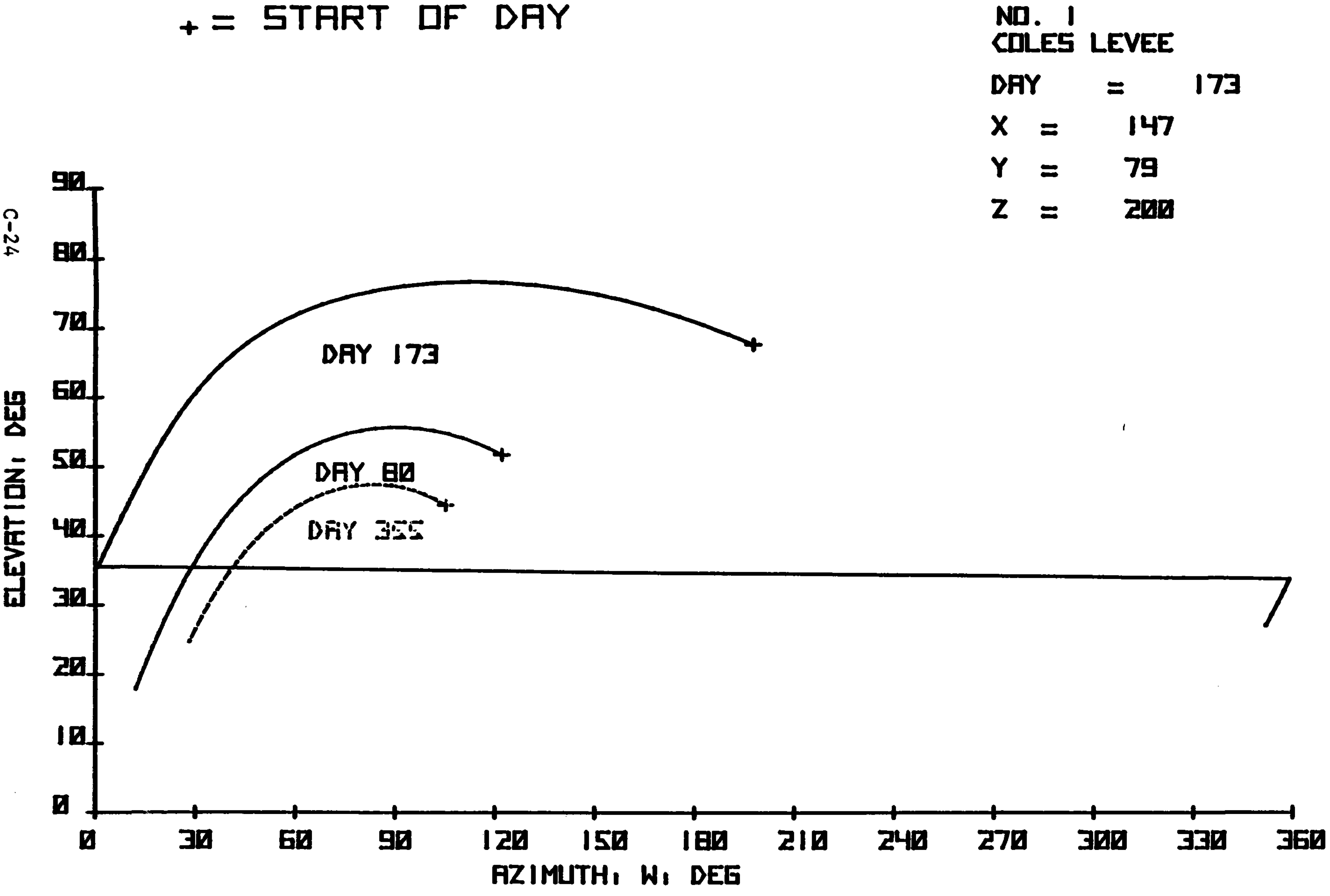


AXIS ANGLES VS TIME OF DAY



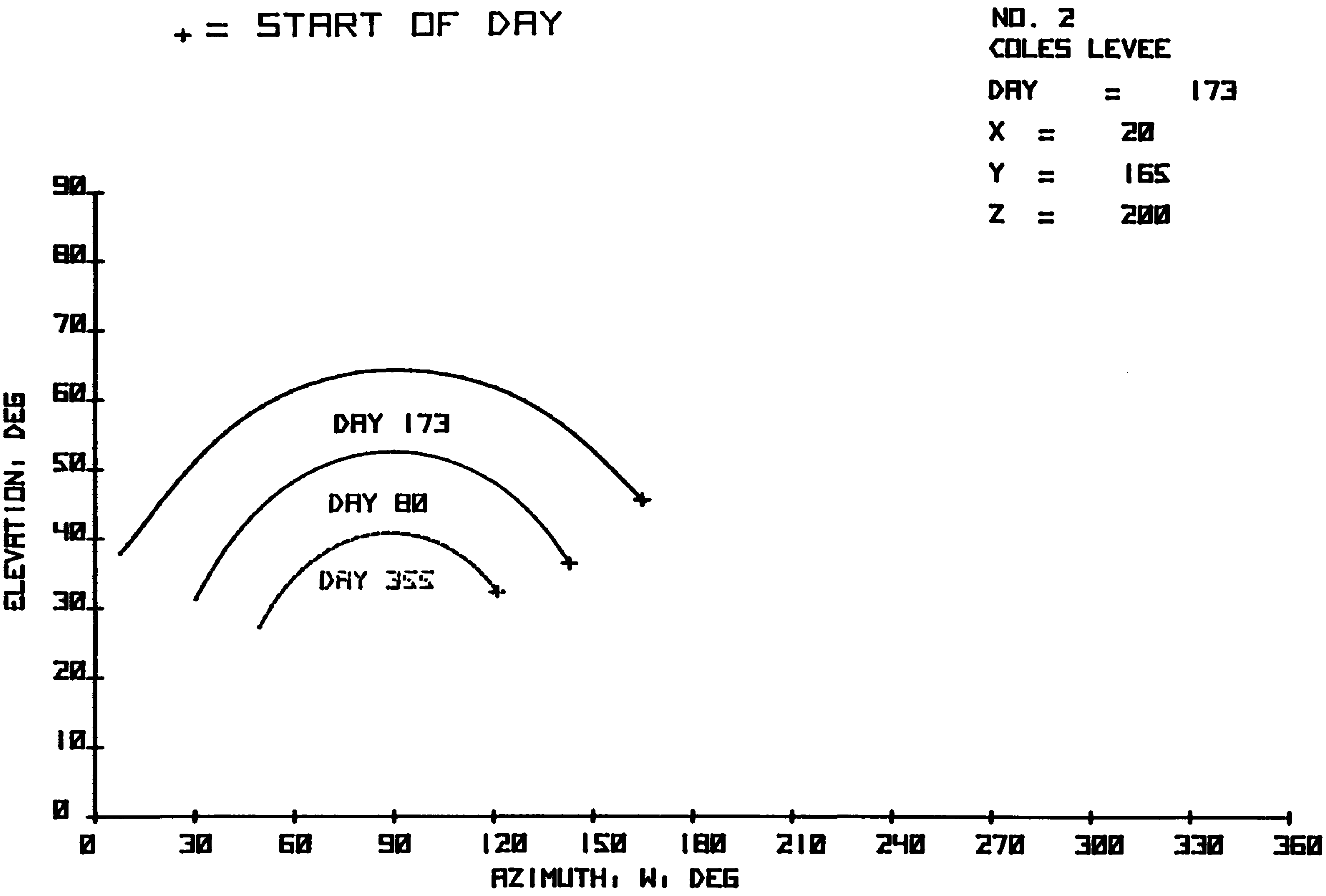
ELEVATION VS AZIMUTH ANGLE

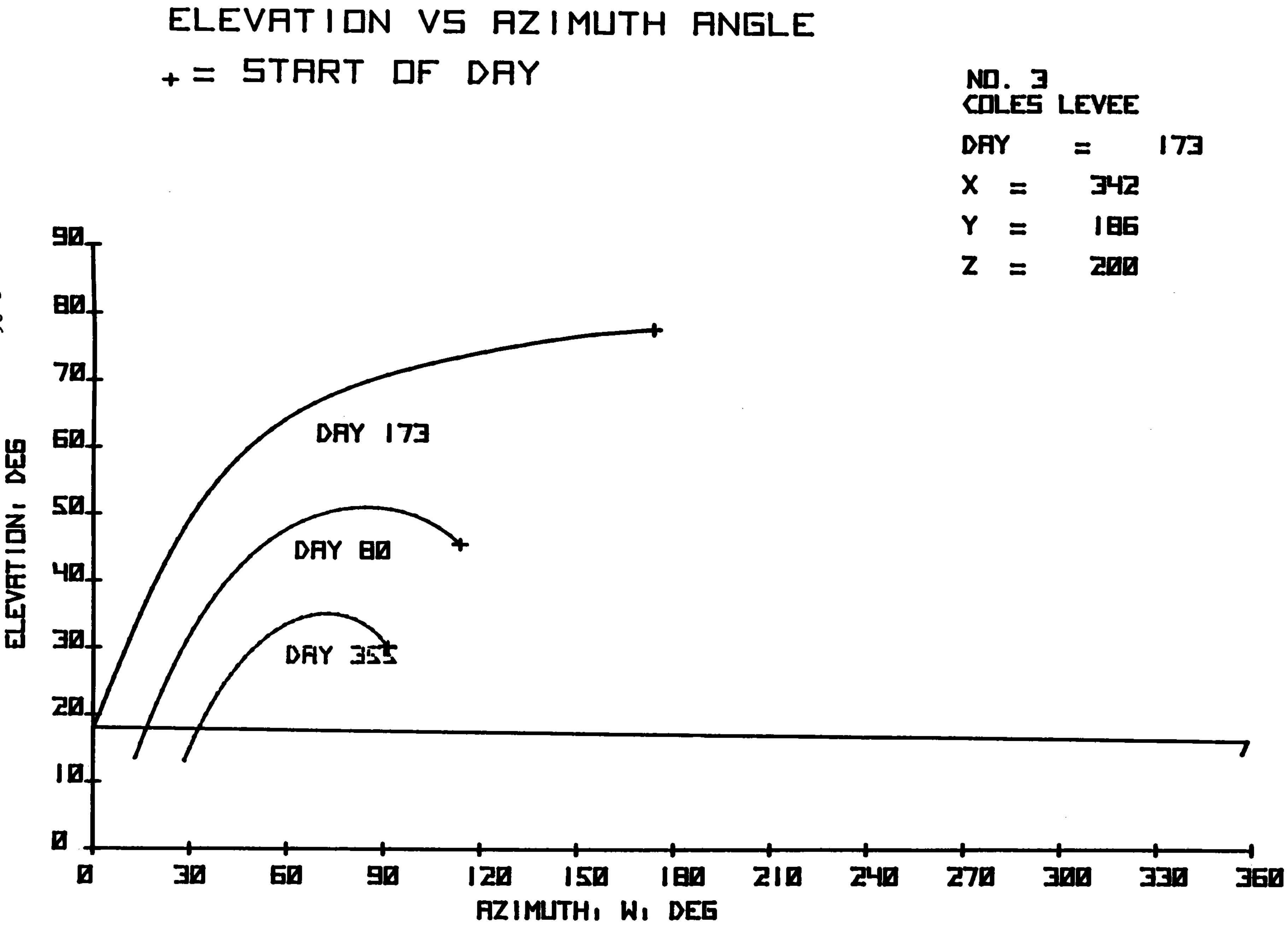
+ = START OF DAY



ELEVATION VS AZIMUTH ANGLE

+ = START OF DAY




ELEVATION VS AZIMUTH ANGLE
+ = START OF DAY
NO. 3
COLES LEVEE
DAY = 173
X = 342
Y = 186
Z = 200
DAY 173
DAY 80
DAY 355
ELEVATION, DEG
0
10
20
30
40
50
60
70
80
90
AZIMUTH, W, DEG
0
30
60
90
120
150
180
210
240
270
300
330
360

ELEVATION VS AZIMUTH ANGLE

+ = START OF DAY

NO. 4

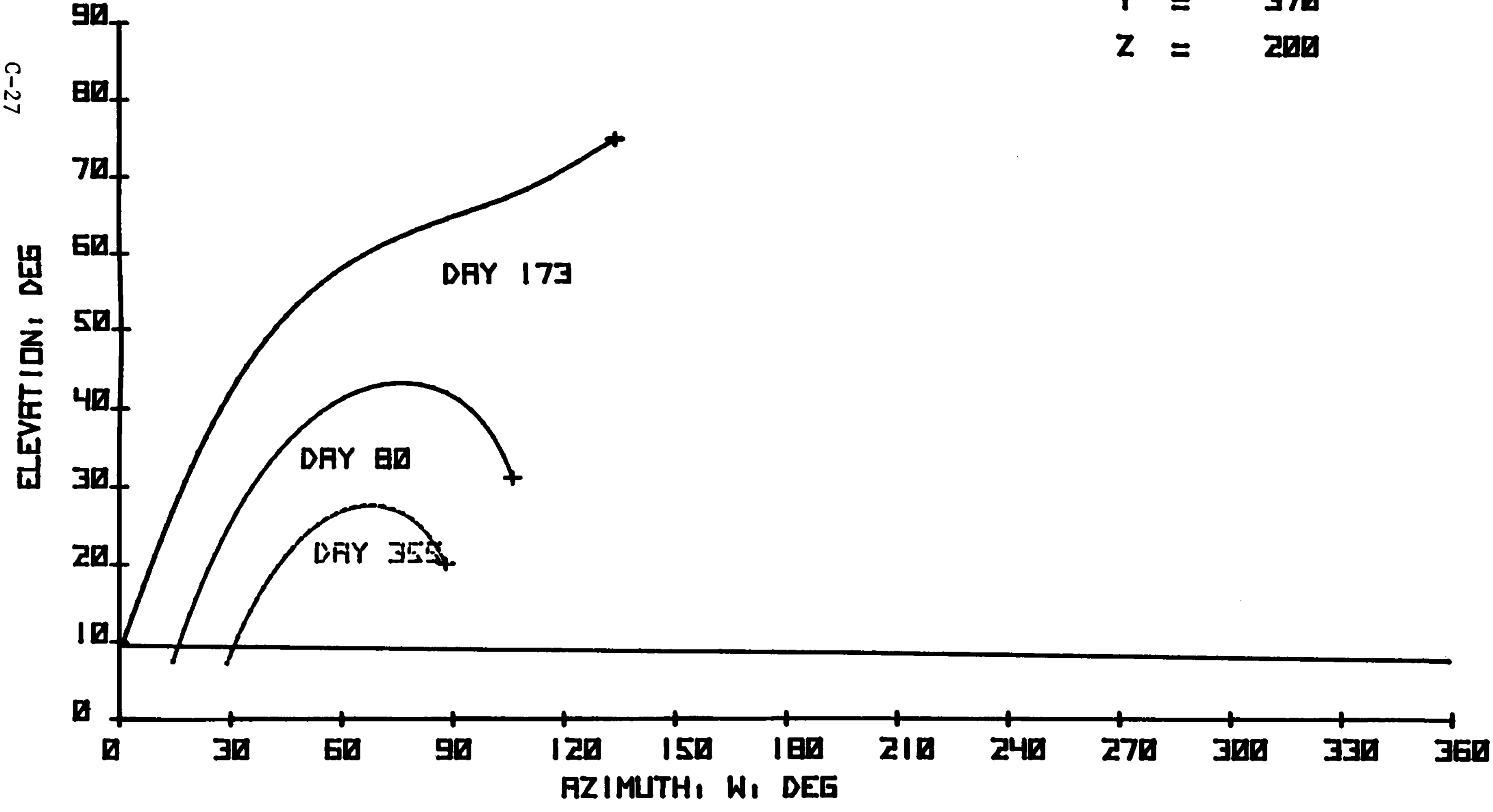
COLES LEVEE

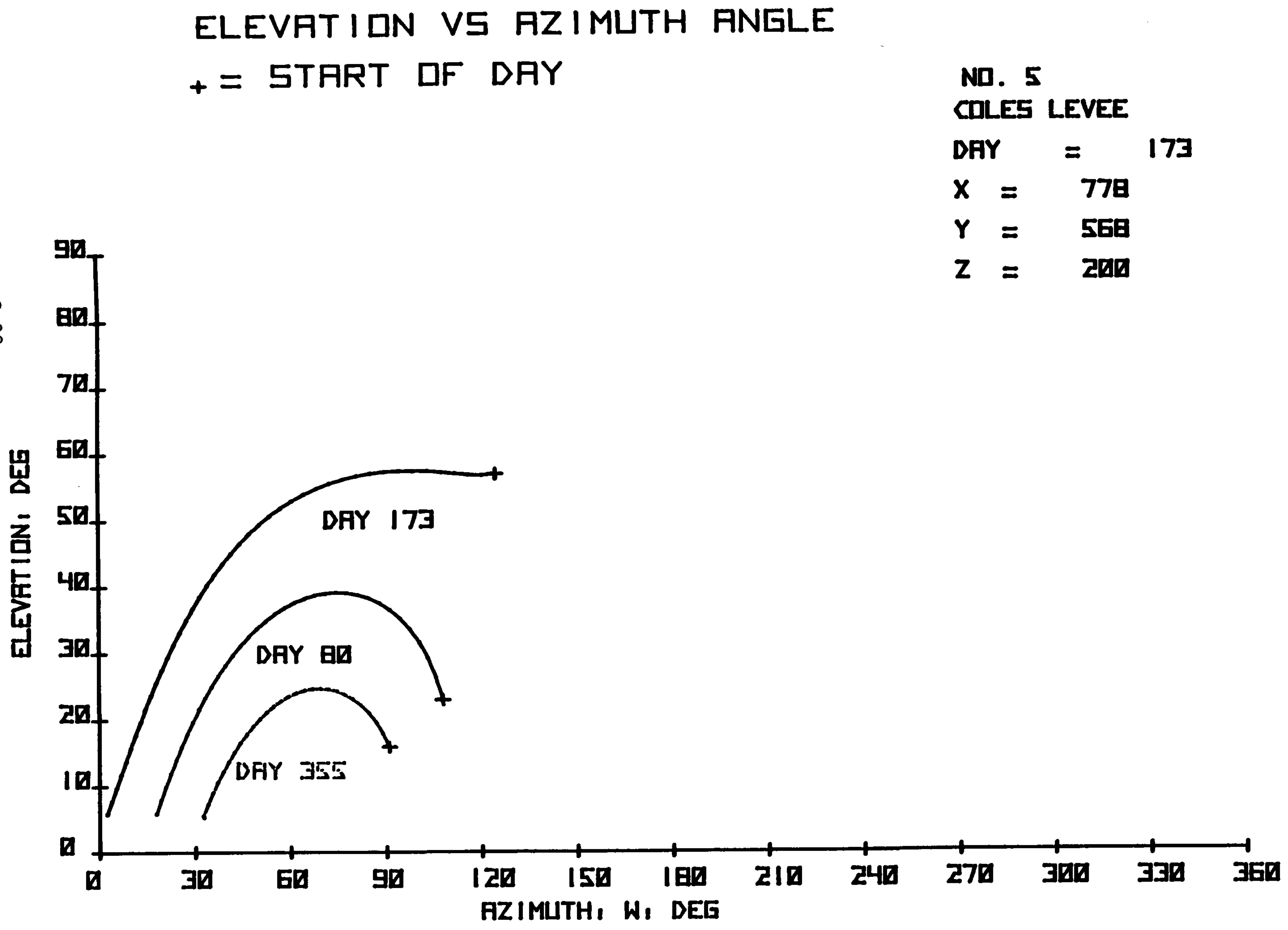
DAY = 173

X = 642

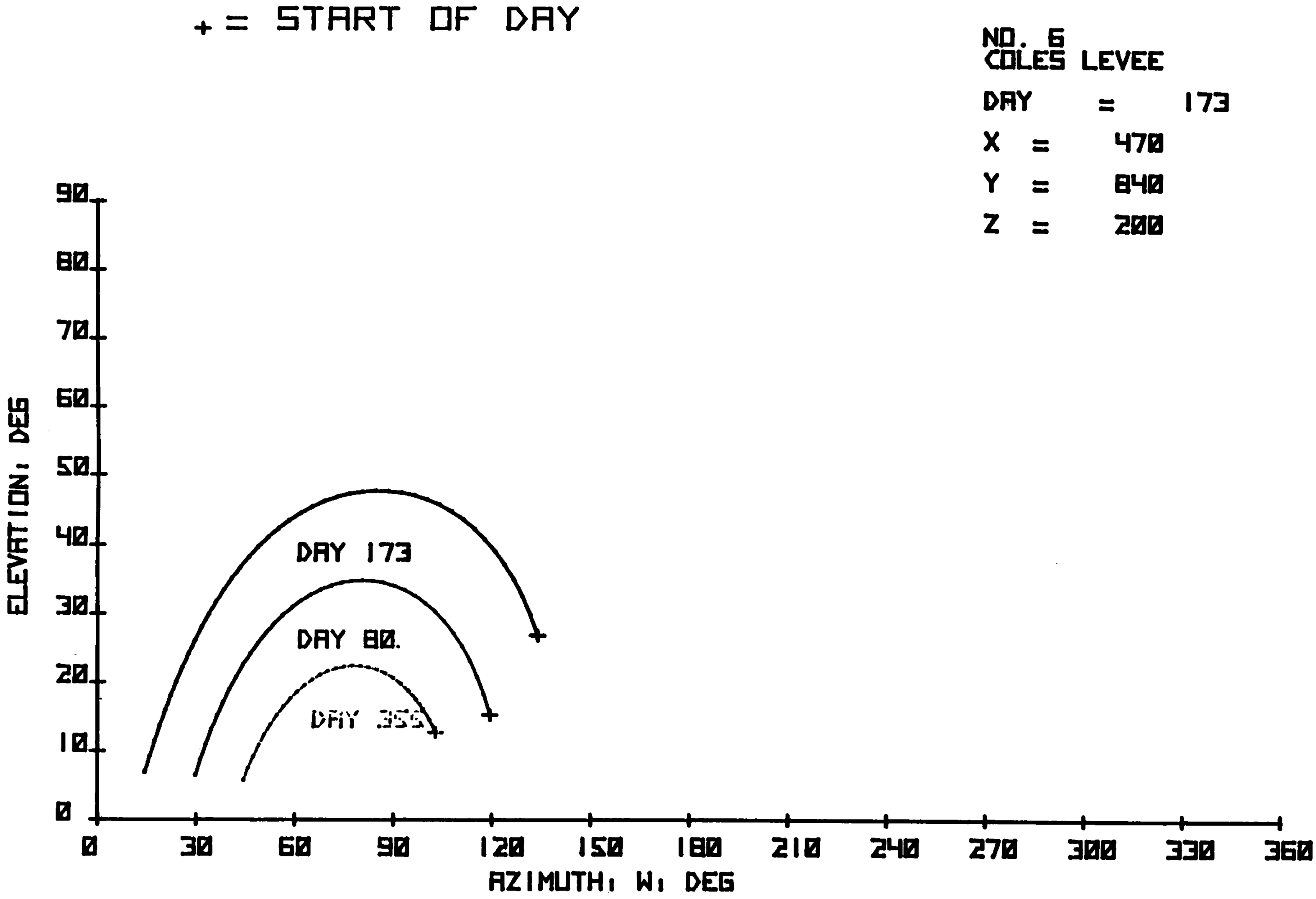
Y = 370

Z = 200




ELEVATION VS AZIMUTH ANGLE
+ = START OF DAY
NO. 5
COLES LEVEE
DAY = 173
X = 778
Y = 568
Z = 200
DAY 173
DAY 80
DAY 355
ELEVATION, DEG
0
10
20
30
40
50
60
70
80
90
AZIMUTH, W, DEG
0
30
60
90
120
150
180
210
240
270
300
330
360

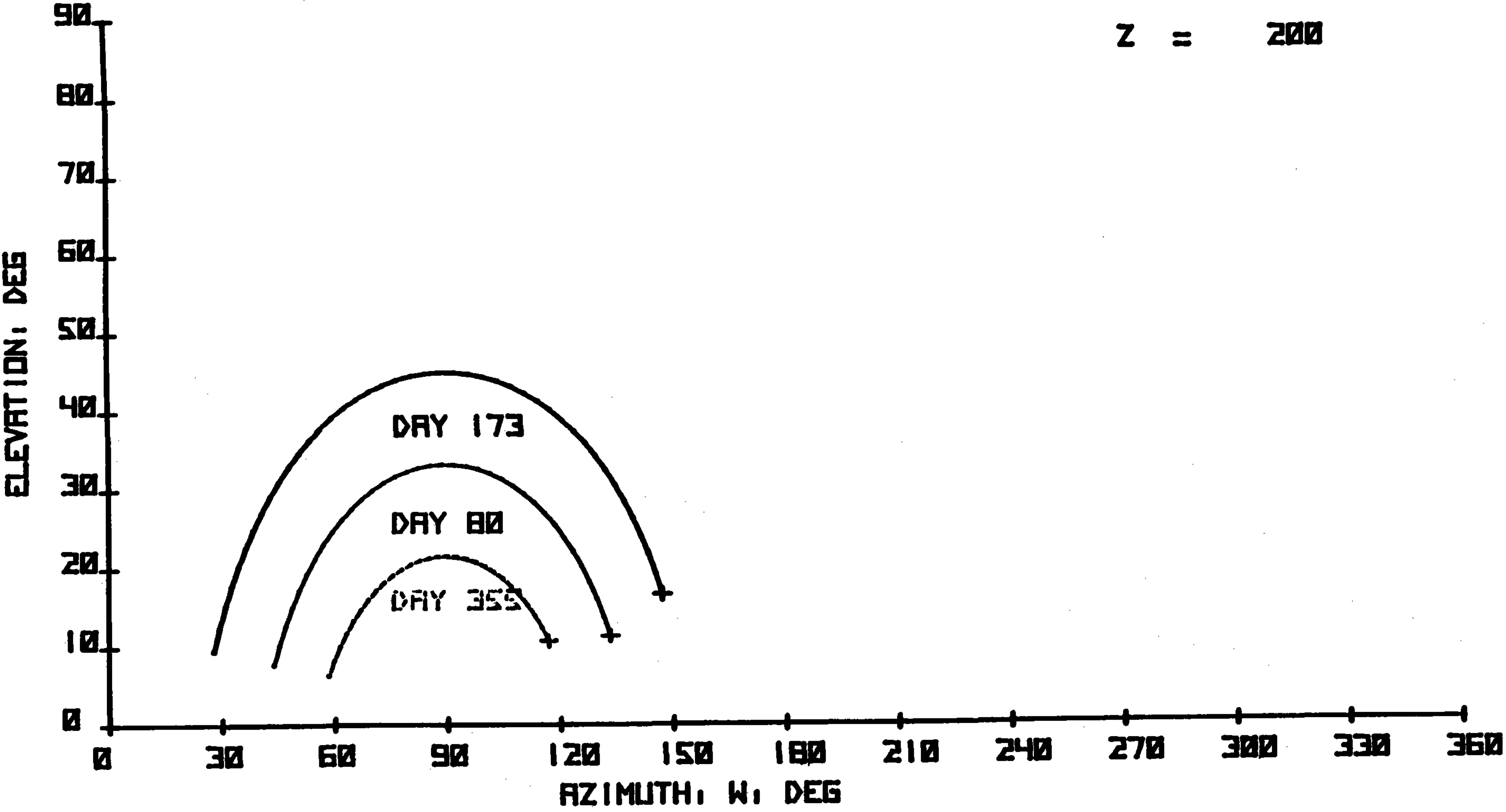
ELEVATION VS AZIMUTH ANGLE



ELEVATION VS AZIMUTH ANGLE

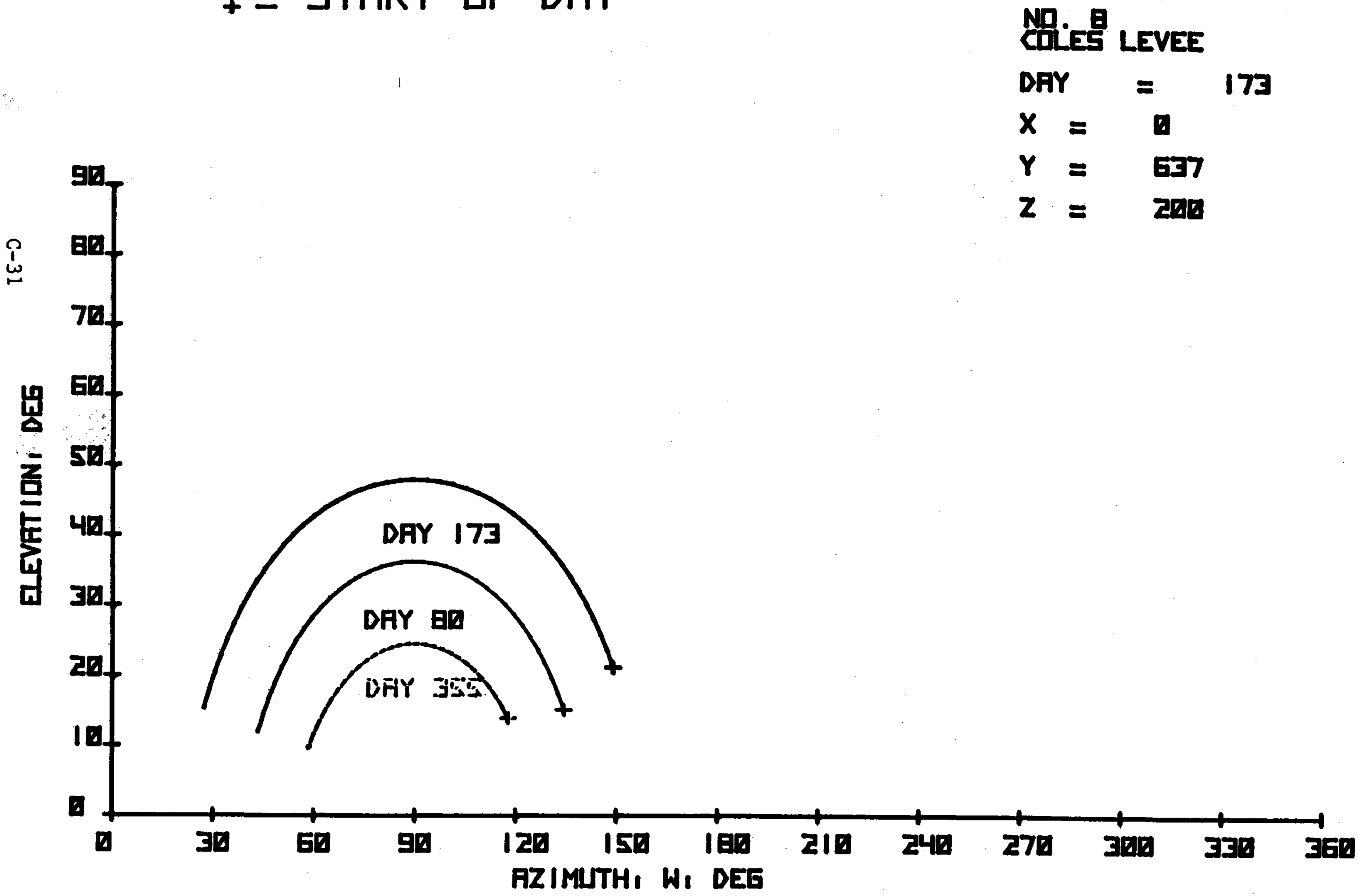
+ = START OF DAY

NO. 7
COLES LEVEE
DAY = 173
X = 26
Y = 963
Z = 200



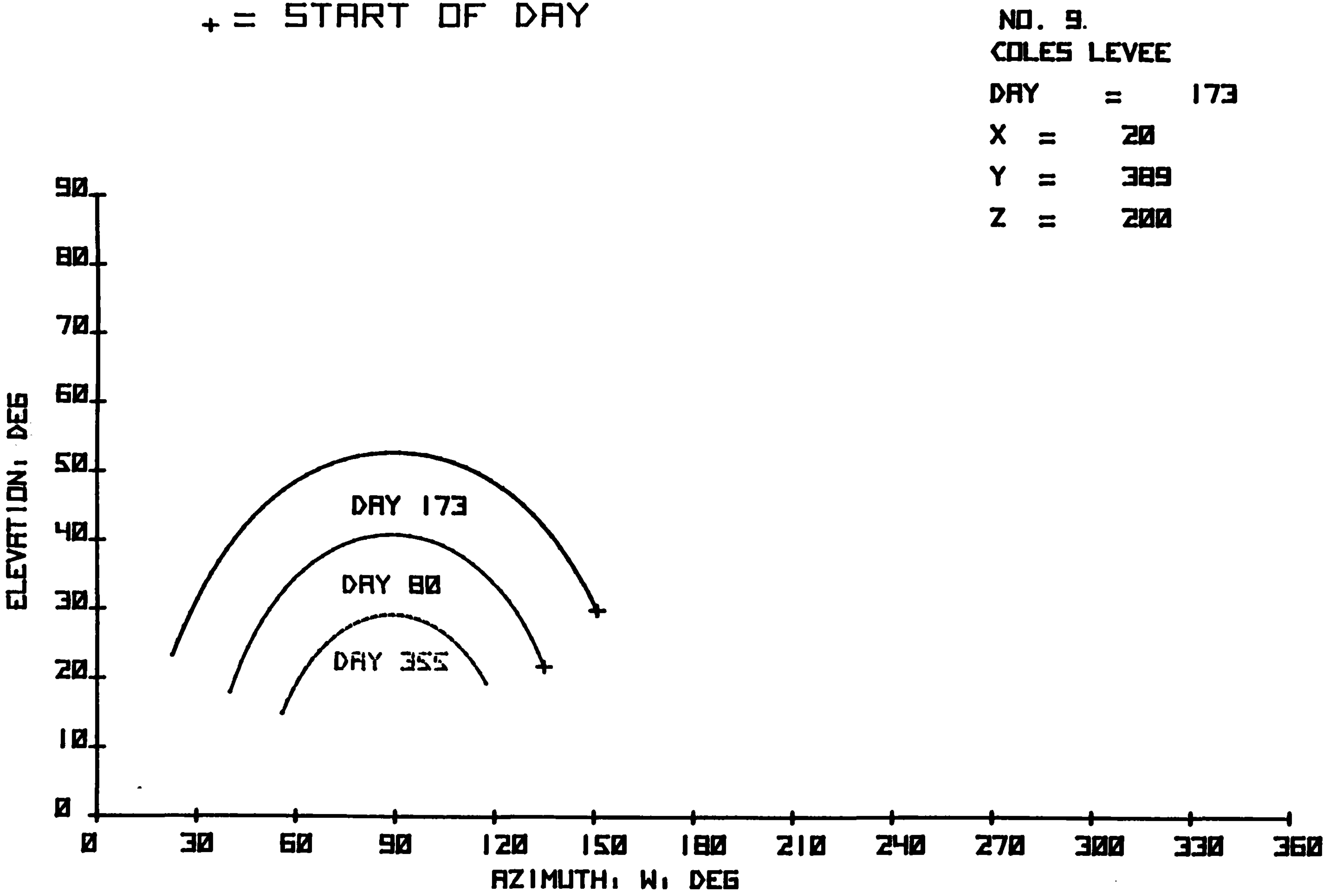
ELEVATION VS AZIMUTH ANGLE

+ = START OF DAY

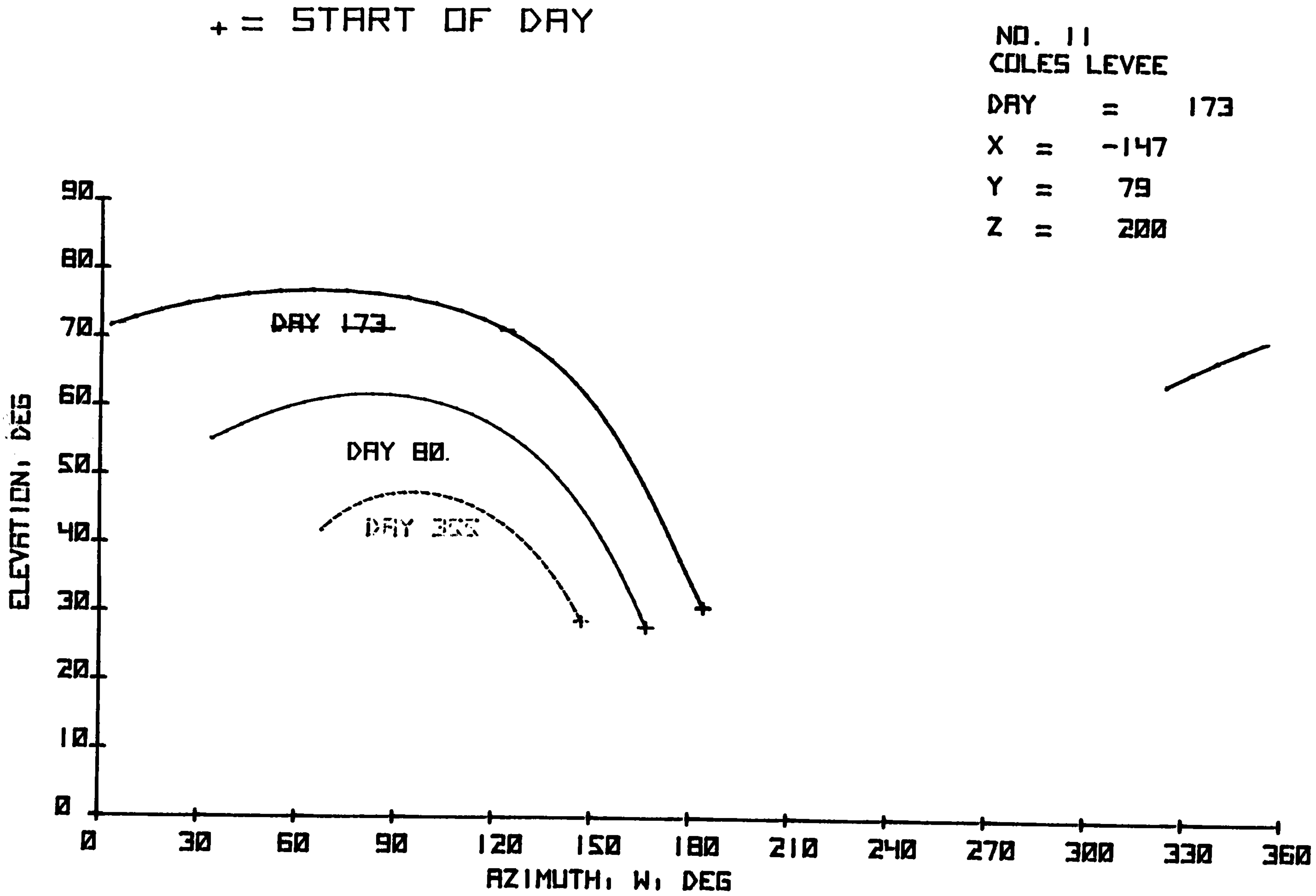


ELEVATION VS AZIMUTH ANGLE

+ = START OF DAY

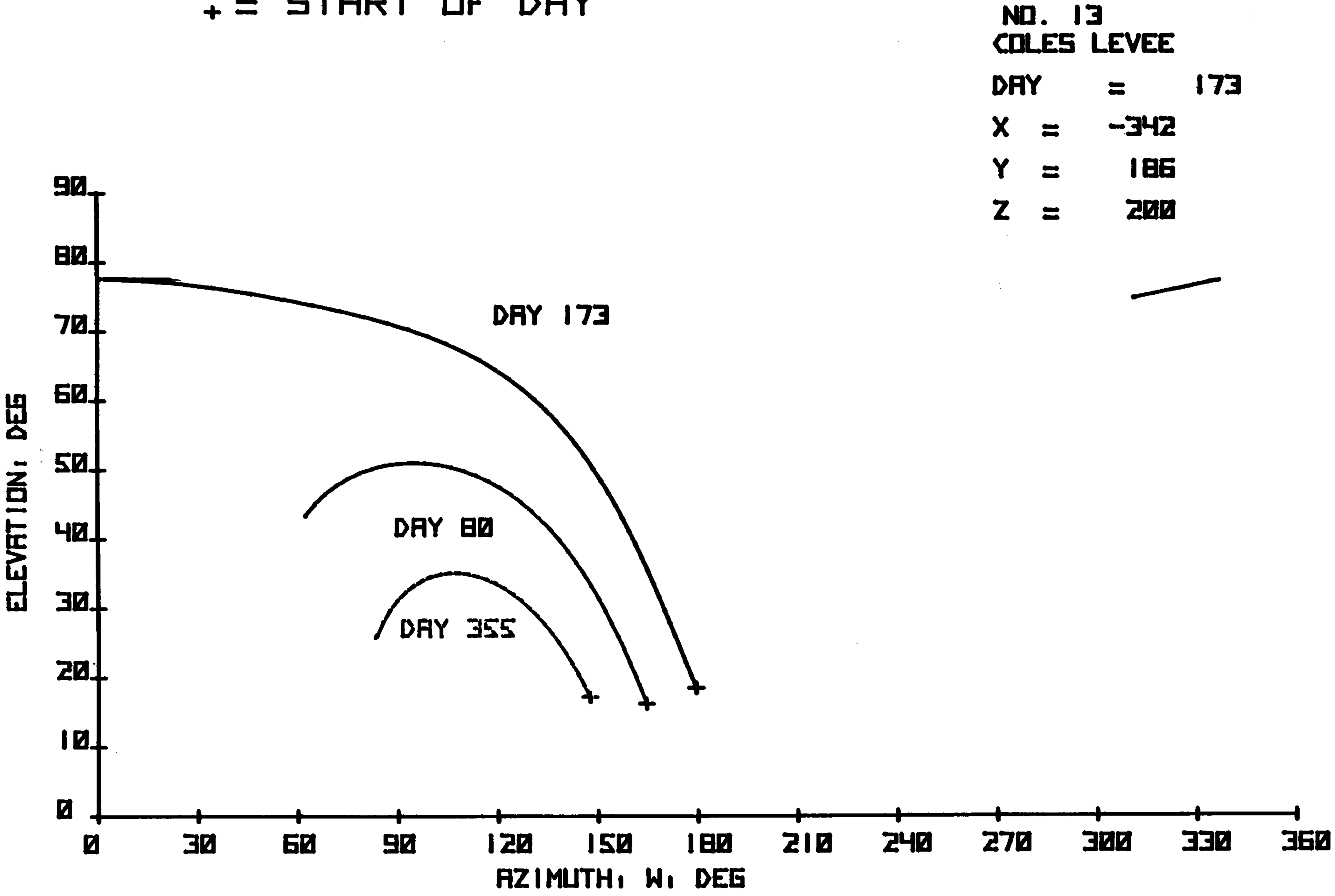


ELEVATION VS AZIMUTH ANGLE



ELEVATION VS AZIMUTH ANGLE

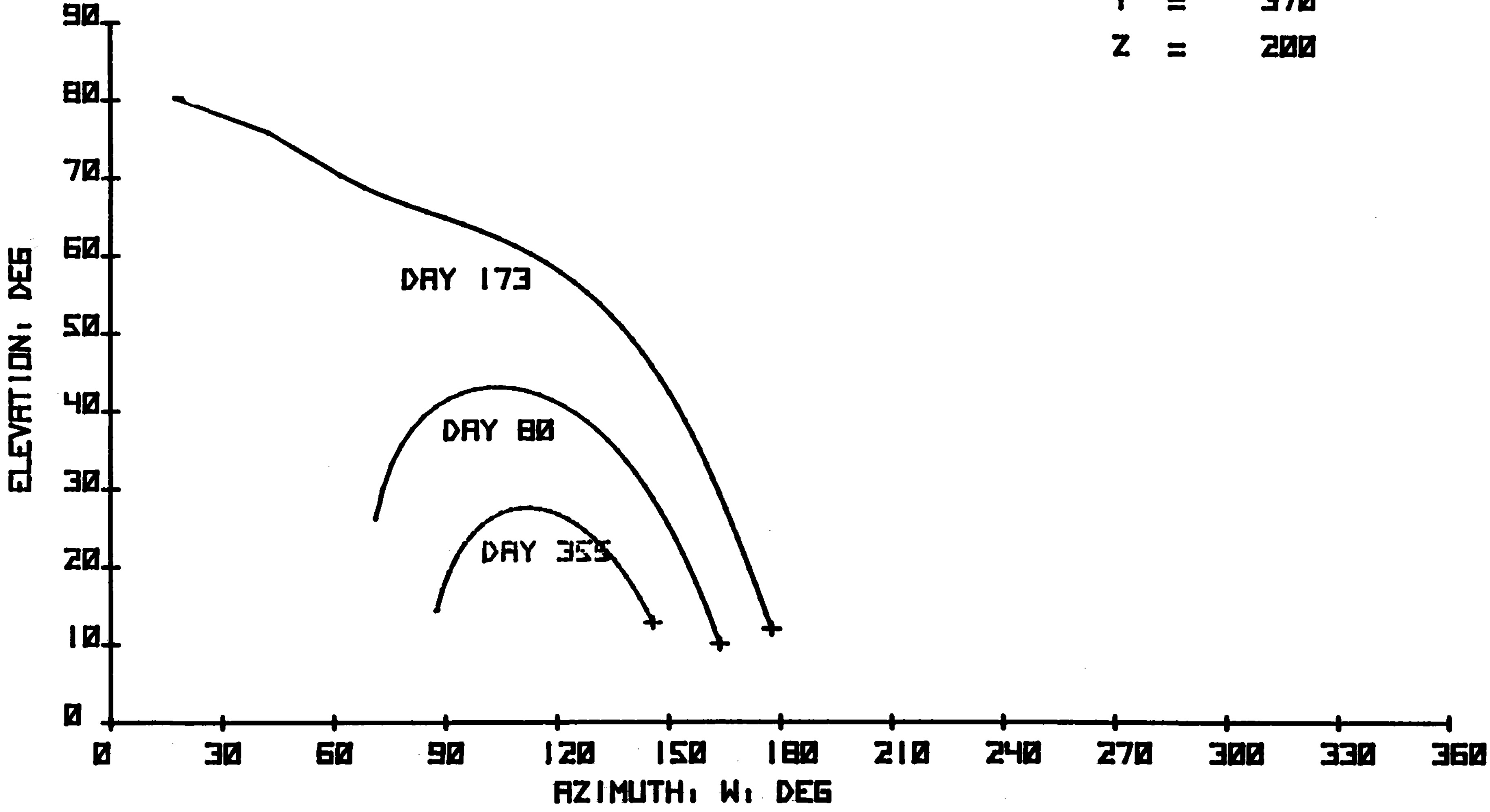
+ = START OF DAY



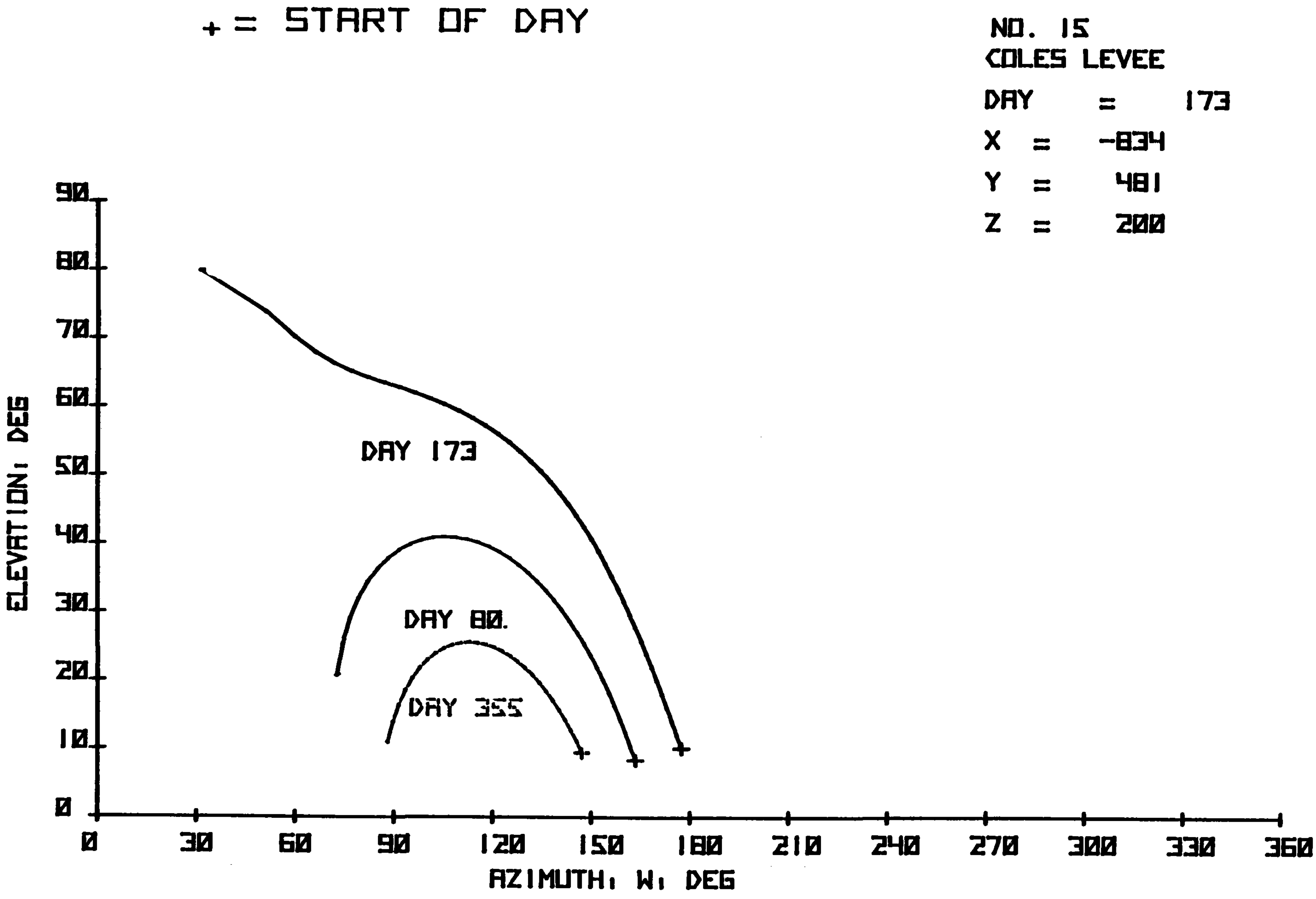
ELEVATION VS AZIMUTH ANGLE

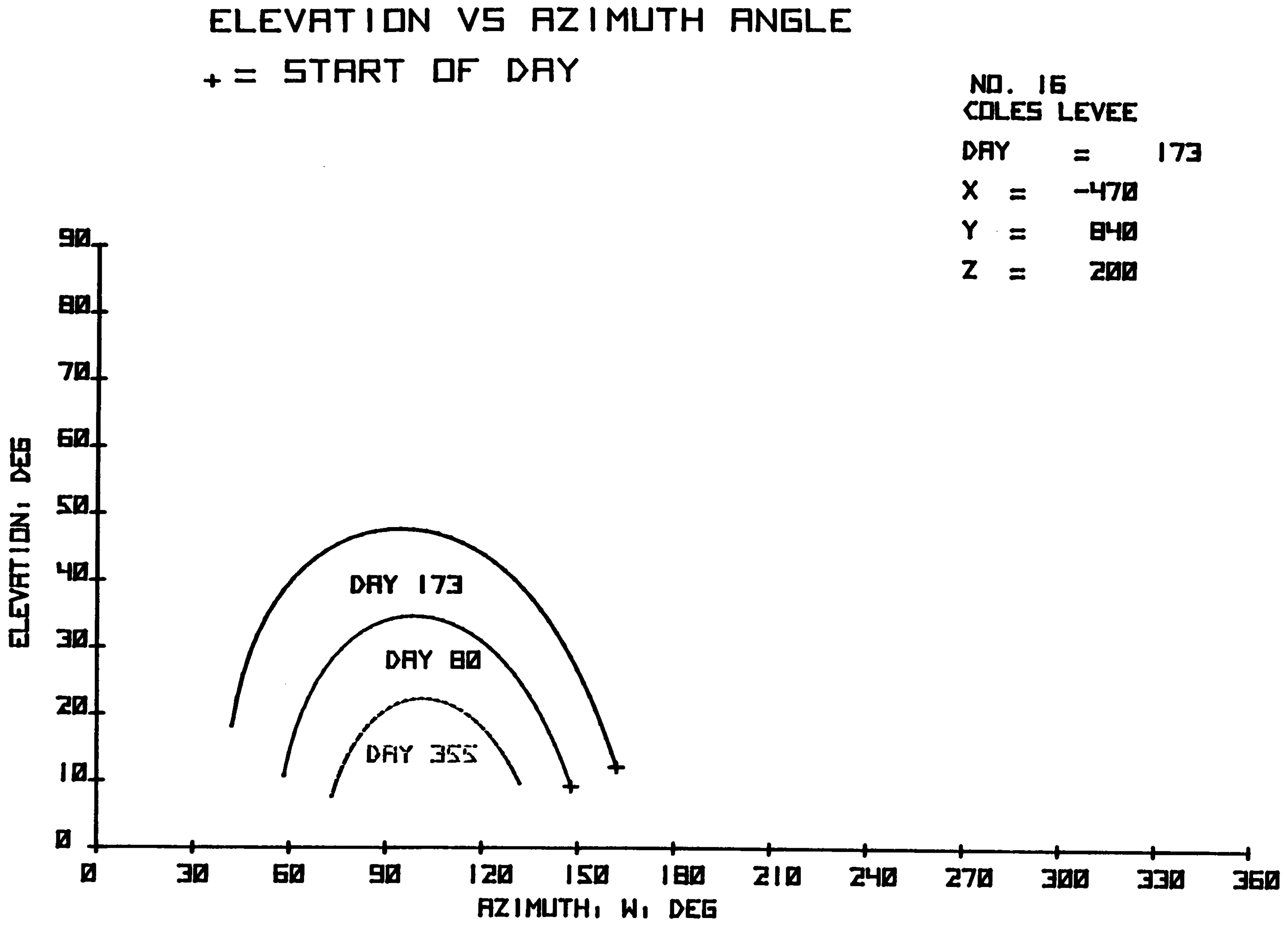
+ = START OF DAY

NO. 14
COLES LEVEE
DAY = 173
X = -642
Y = 370
Z = 200



ELEVATION VS AZIMUTH ANGLE





ELEVATION VS AZIMUTH ANGLE

+= START OF DAY

Appendix D

Solar Flux Maps

The numeric solar flux grids generated for the conceptual design collector of 320 heliostats and 7.3 M(24 ft) radius receiver together with the graphic plots of the flux patterns form Appendix D.

Focal plane flux grids and patterns are included on pages D-2 to D-19. Receiver panel flux grids and patterns are included on pages D-20 to D-37. Data shown are for winter solstice (Day 355), equinox (Day 80) and summer solstice (Day 173).

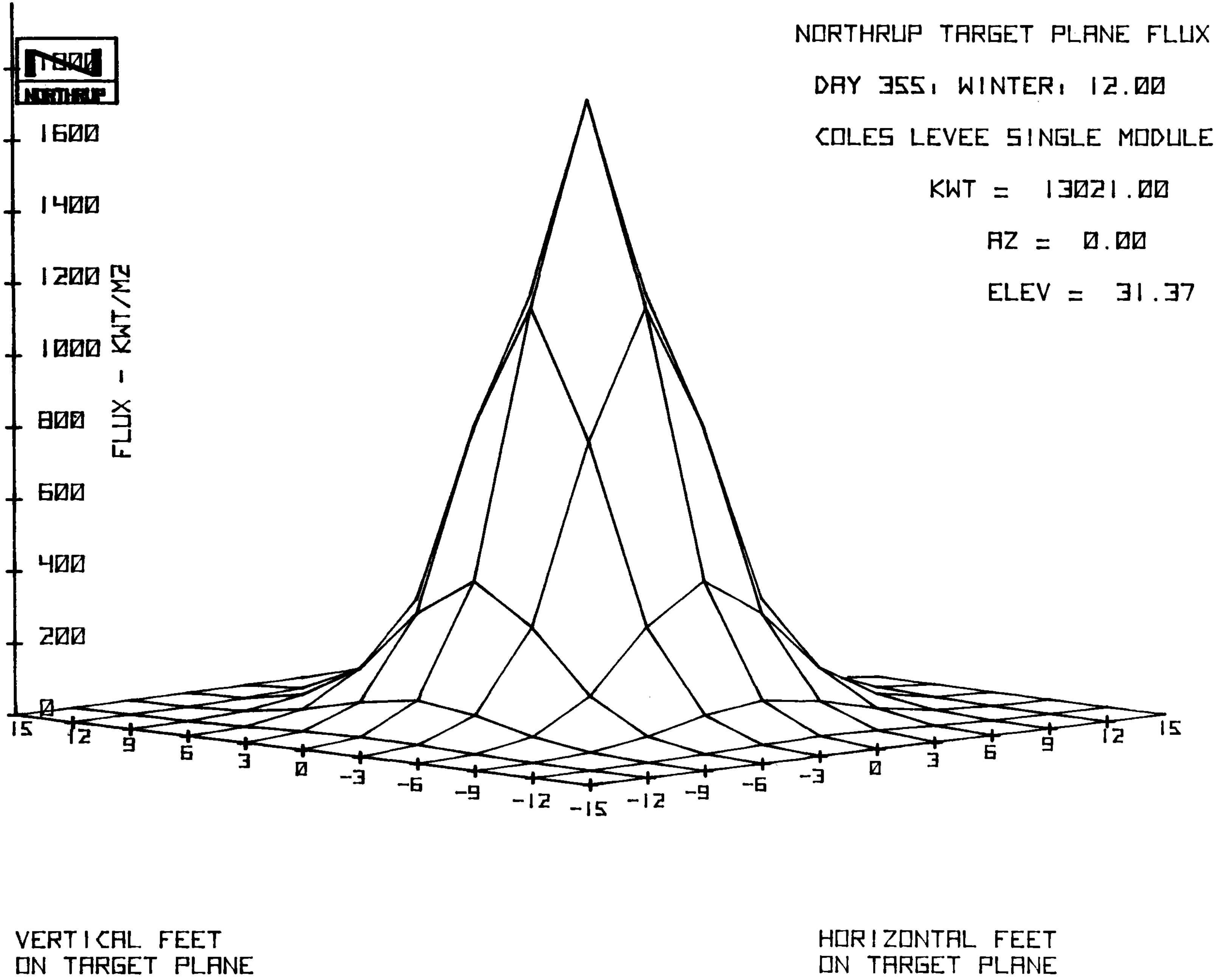
FILE NO. = 40 FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. = 355
TIME = 12
HR ANGLE = 0
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG

Vertical Dimension - ft

15	0	0	0	1	2	2	2	1	0	0	0
12	0	0	2	7	13	17	13	7	2	0	0
9	0	2	10	34	74	96	74	34	10	2	0
6	1	7	34	126	299	407	299	126	34	7	1
3	2	13	74	299	794	1147	794	299	74	13	2
0	2	17	97	407	1147	1707	1147	407	97	17	2
-3	2	13	74	299	795	1148	795	299	74	13	2
-6	1	7	35	127	299	408	299	127	35	7	1
-9	0	2	10	35	74	97	74	35	10	2	0
-12	0	0	2	7	13	17	13	7	2	0	0
-15	0	0	0	1	2	2	2	1	0	0	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

Horizontal Dimension - ft

Focal Grid Energy = 13021


NORTHRUP TARGET PLANE FLUX
DAY 355, WINTER, 12.00
COLES LEVEE SINGLE MODULE
KWT = 13021.00
AZ = 0.00
ELEV = 31.37
1800
NORTHRUP
1600
1400
1200
1000
800
600
400
200
0
FLUX - KWT/M2
15
12
9
6
3
0
-3
-6
-9
-12
-15
-12
-9
-6
-3
0
3
6
9
12
15
VERTICAL FEET
ON TARGET PLANE
HORIZONTAL FEET
ON TARGET PLANE

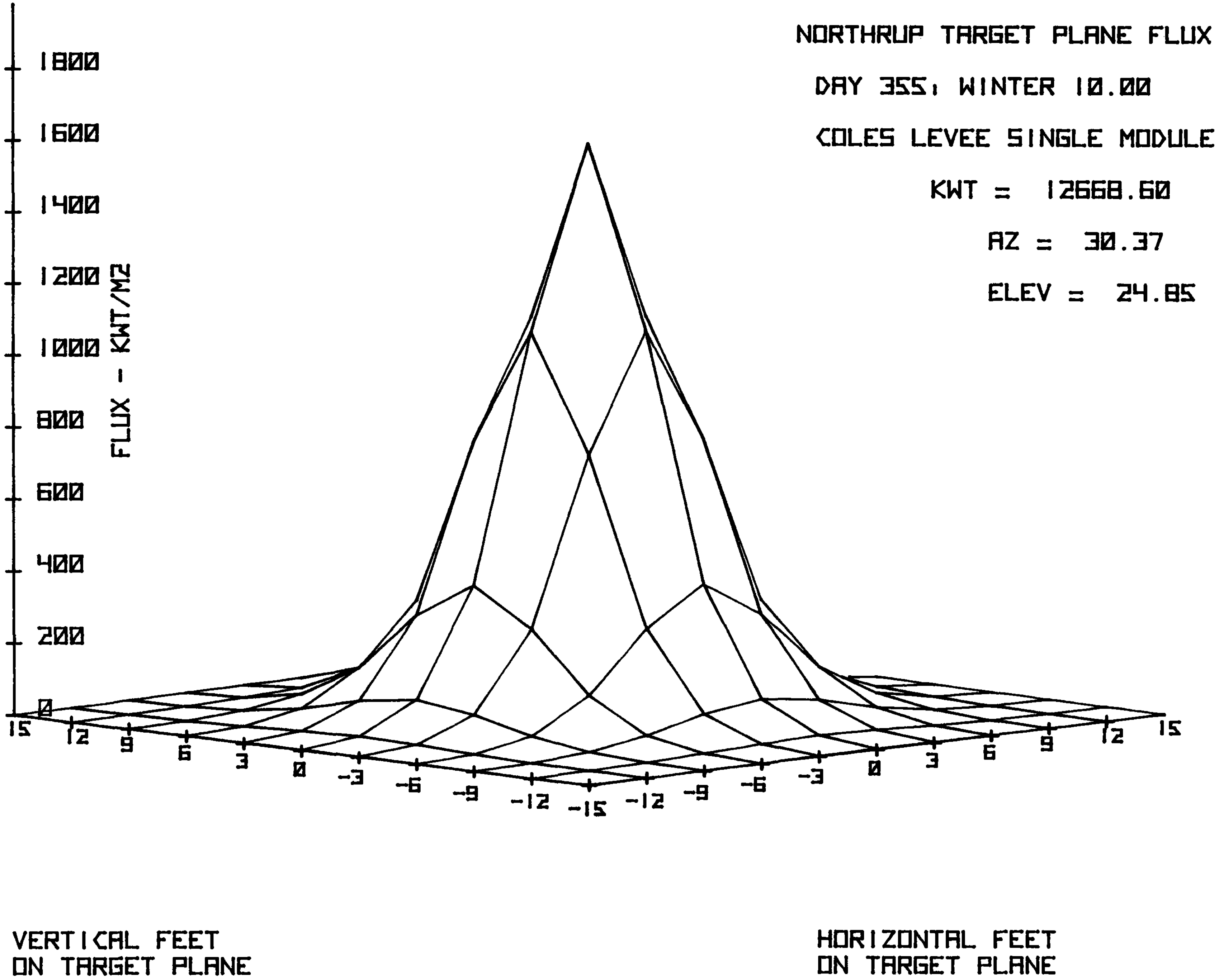
FILE NO. = 42 FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. = 355
TIME = 10
HR ANGLE = -30
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG

Horizontal Dimension - ft

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	1	3	3	3	1	1	0	0
12	0	1	3	8	16	19	16	8	3	1	0
9	1	3	13	38	78	100	78	38	13	3	1
6	1	8	38	129	295	398	296	130	38	8	1
3	3	15	78	295	758	1083	760	296	78	16	3
0	3	19	100	397	1081	1587	1084	399	100	19	3
-3	3	16	78	295	758	1082	760	296	78	16	3
-6	1	8	38	129	295	398	296	130	38	8	1
-9	1	3	13	38	78	100	78	38	13	3	1
-12	0	1	3	8	16	19	16	8	3	1	0
-15	0	0	1	1	3	3	3	1	1	0	0

Horizontal Dimension - ft

Focal Grid Energy = 12668.6


NORTHRUP TARGET PLANE FLUX
DAY 355, WINTER 10.00
COLES LEVEE SINGLE MODULE
KWT = 12668.60
AZ = 30.37
ELEV = 24.85
FLUX - KWT/M2
1800
1600
1400
1200
1000
800
600
400
200
0
15
12
9
6
3
0
-3
-6
-9
-12
-15
-12
-9
-6
-3
0
3
6
9
12
15
VERTICAL FEET
ON TARGET PLANE
HORIZONTAL FEET
ON TARGET PLANE

EJB/JB

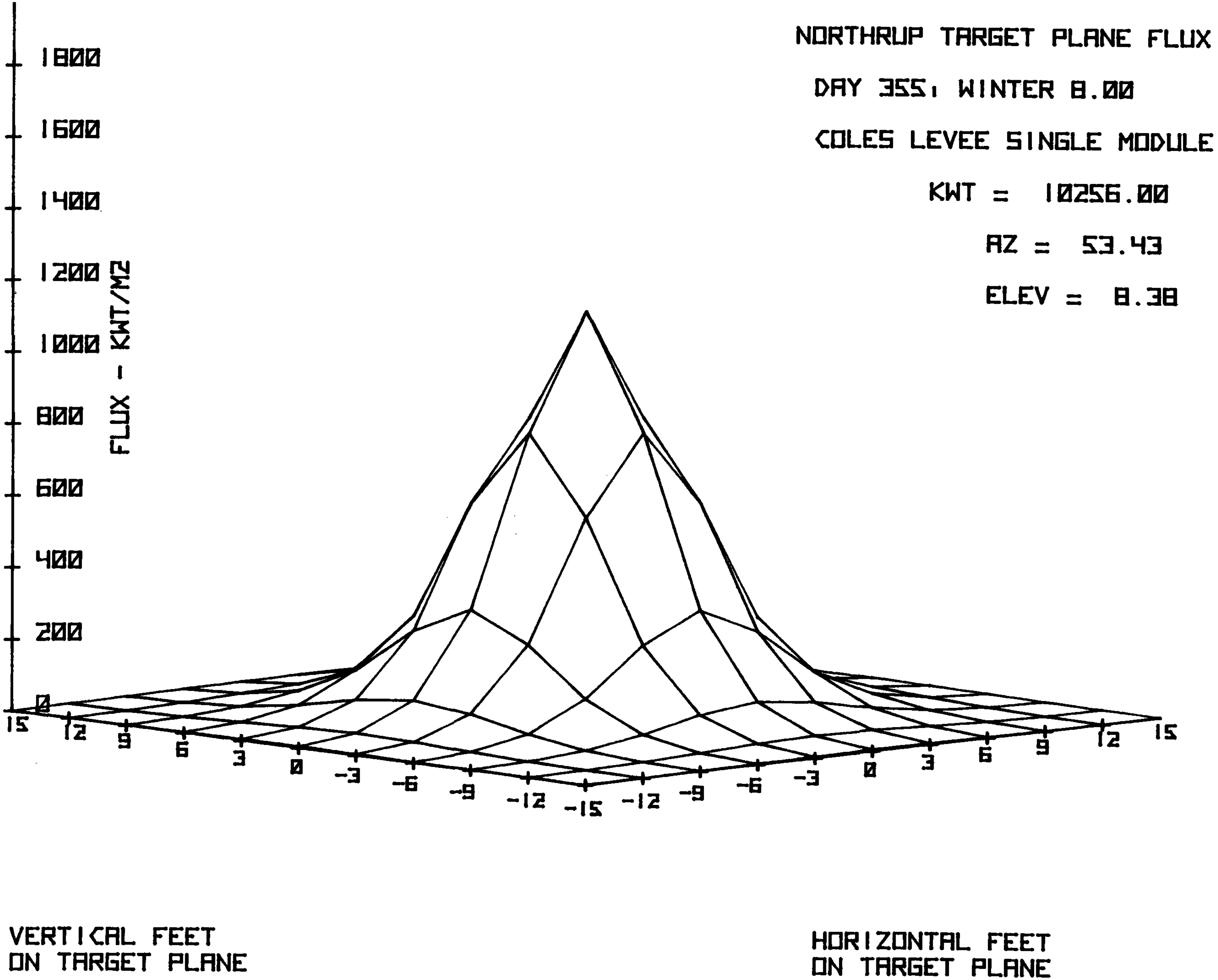
```
FILE NO. = 44     FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. = 355
TIME = 8
HR ANGLE = -60
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG
```

Vertical Dimension - ft

15	0	1	1	3	4	5	4	3	1	1	0
12	1	2	5	11	19	23	19	11	5	2	1
9	1	5	16	40	75	94	76	40	16	5	1
6	3	11	40	118	249	327	250	119	41	11	3
3	4	19	75	249	583	800	585	251	76	19	4
0	5	22	94	326	798	1116	801	328	95	23	5
-3	4	19	75	249	582	799	585	251	76	19	4
-6	3	11	40	118	249	327	250	119	41	11	3
-9	1	5	16	40	75	94	76	40	16	5	1
-12	1	2	5	11	19	23	19	11	5	2	1
-15	0	1	1	3	4	5	4	3	1	1	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

Horizontal Dimension - ft

Focal Grid Energy = 10262.1



NORTHRUP TARGET PLANE FLUX

DAY 355, WINTER 8.00

COLES LEVEE SINGLE MODULE

KWT = 10256.00

AZ = 53.43

ELEV = 8.38

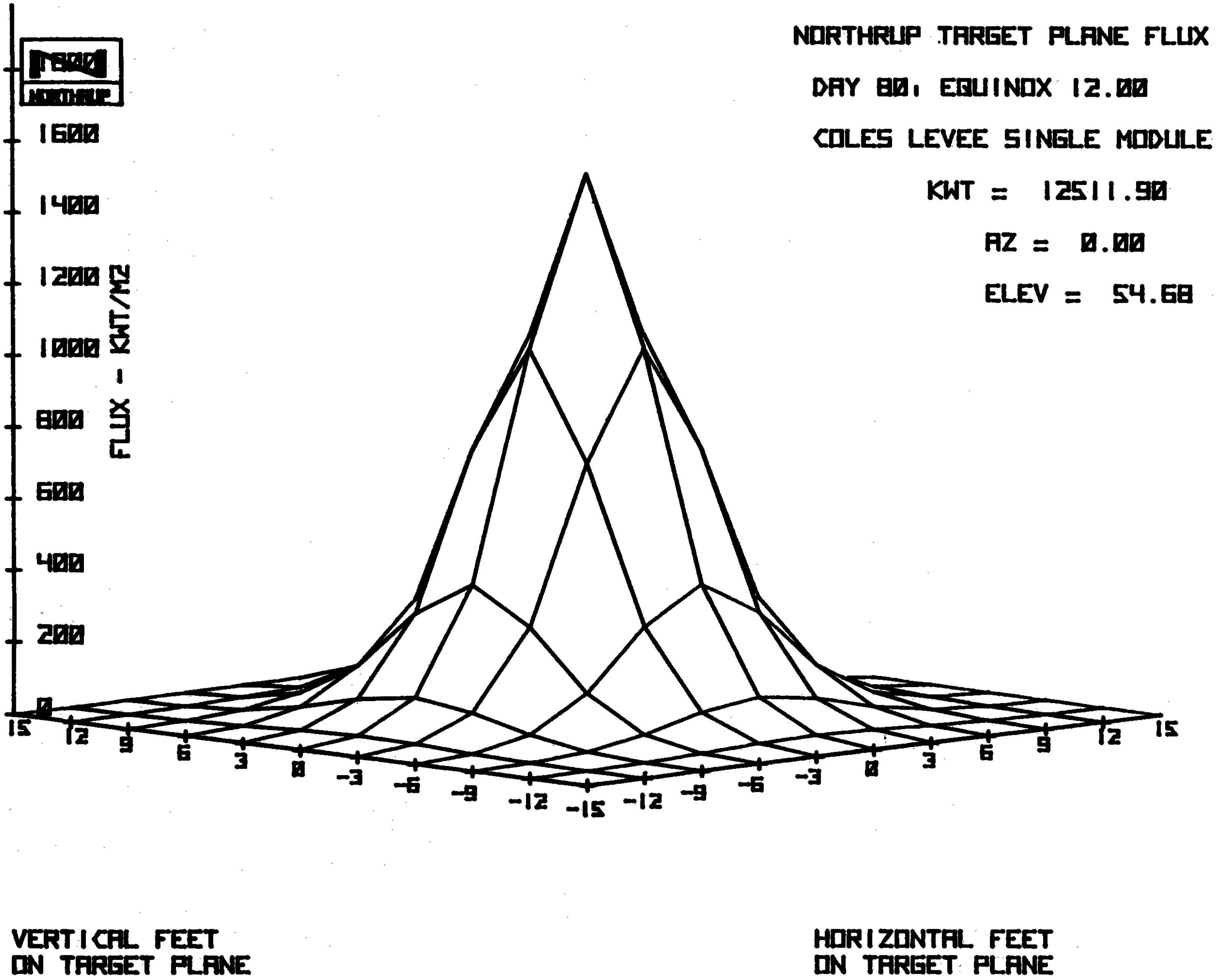
EJB/1

```
 0
FILE NO. =   28    FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. =   8080
TIME =   12
HR ANGLE =  0
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG
```

Vertical Dimension - ft	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	1	3	3	3	1	1	0	0
12	0	1	3	9	17	21	17	9	3	1	0
9	1	3	14	41	83	106	83	41	14	3	1
6	1	9	41	136	298	396	298	136	41	9	1
3	3	17	83	299	734	1033	734	299	83	17	3
0	3	21	106	397	1035	1505	1035	397	106	21	3
-3	3	17	83	300	737	1038	737	300	83	17	3
-6	1	9	41	136	300	399	300	136	41	9	1
-9	1	3	14	41	84	107	84	41	14	3	1
12	0	1	3	9	17	21	17	9	3	1	0
15	0	0	1	1	3	3	3	1	1	0	0

Horizontal Dimension - ft

Focal Grid Energy = 12511


NORTHRUP TARGET PLANE FLUX
DAY 80, EQUINOX 12.00
COLES LEVEE SINGLE MODULE
KWT = 12511.90
AZ = 0.00
ELEV = 54.68
1800
NORTHRUP
1600
1400
1200
1000
800
600
400
200
0
FLUX - KWT/M2
15
12
9
6
3
0
-3
-6
-9
-12
-15
-12
-9
-6
-3
0
3
6
9
12
15
VERTICAL FEET
ON TARGET PLANE
HORIZONTAL FEET
ON TARGET PLANE

EJB/JB
2-4

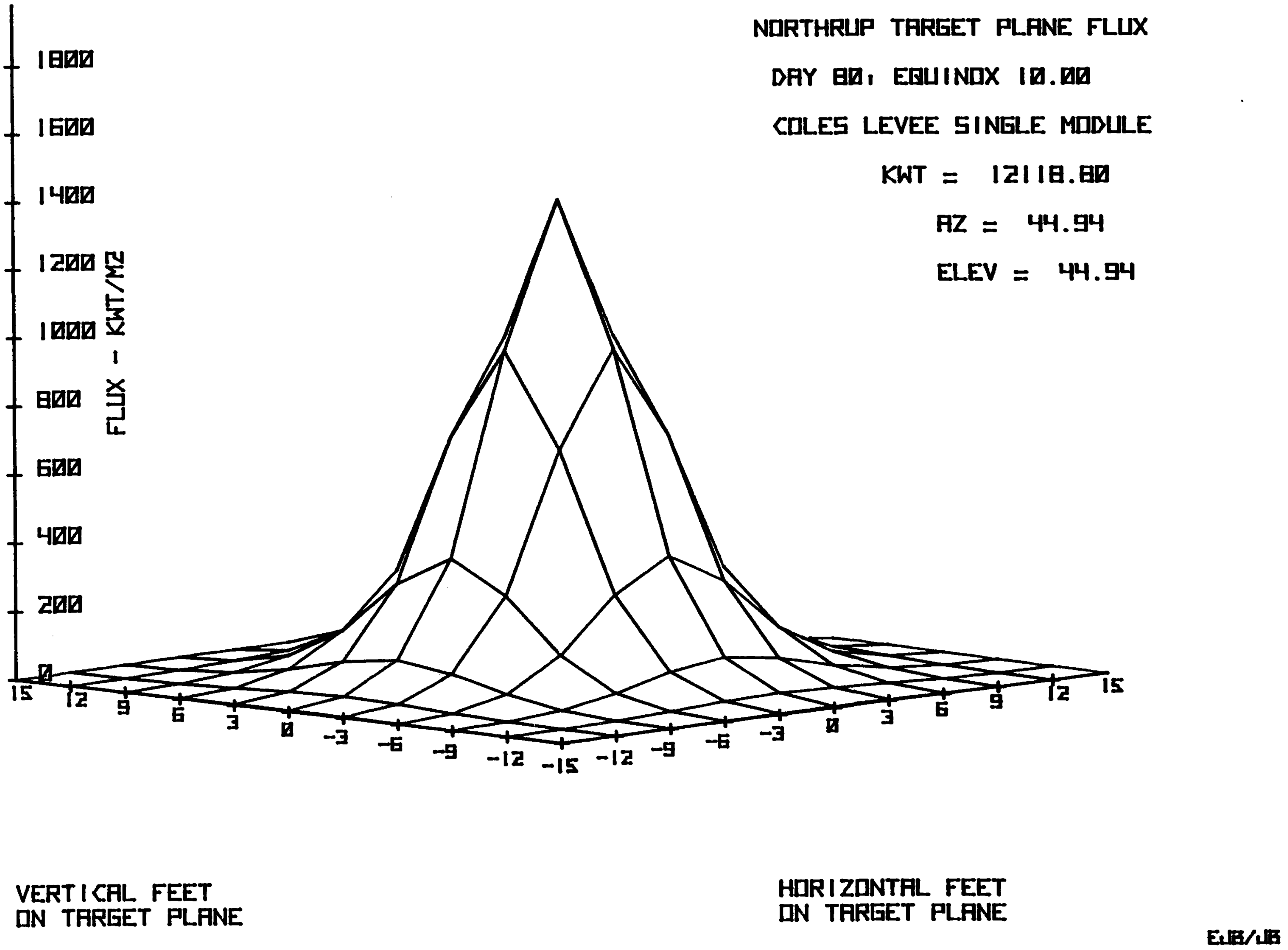
```
0:SINGLE2FILE NO. =   30      FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. =   80
TIME =   10
HR ANGLE = -30
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG
```

Vertical Dimension - ft

15	0	0	1	2	4	4	4	2	1	0	0
12	0	1	4	11	20	24	20	11	4	1	0
9	1	4	16	44	86	108	86	45	16	4	1
6	2	11	44	137	291	383	292	137	45	11	2
3	4	20	86	291	695	969	697	293	86	20	4
0	4	24	108	383	970	1394	972	385	109	24	4
-3	4	20	86	292	698	973	699	293	86	20	4
-6	2	11	45	137	293	385	293	138	45	11	2
-9	1	4	16	45	86	109	86	45	16	4	1
-12	0	1	4	11	20	24	20	11	4	1	0
-15	0	0	1	2	4	4	4	2	1	0	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

Horizontal Dimension - ft

Focal Grid Energy = 12195


NORTHRUP TARGET PLANE FLUX
DAY 80, EQUINOX 10.00
COLES LEVEE SINGLE MODULE
KWT = 12118.80
AZ = 44.94
ELEV = 44.94
FLUX - KWT/M2
1800
1600
1400
1200
1000
800
600
400
200
0
15
12
9
6
3
0
-3
-6
-9
-12
-15
-12
-9
-6
-3
0
3
6
9
12
15
VERTICAL FEET
ON TARGET PLANE
HORIZONTAL FEET
ON TARGET PLANE
EJB/JB

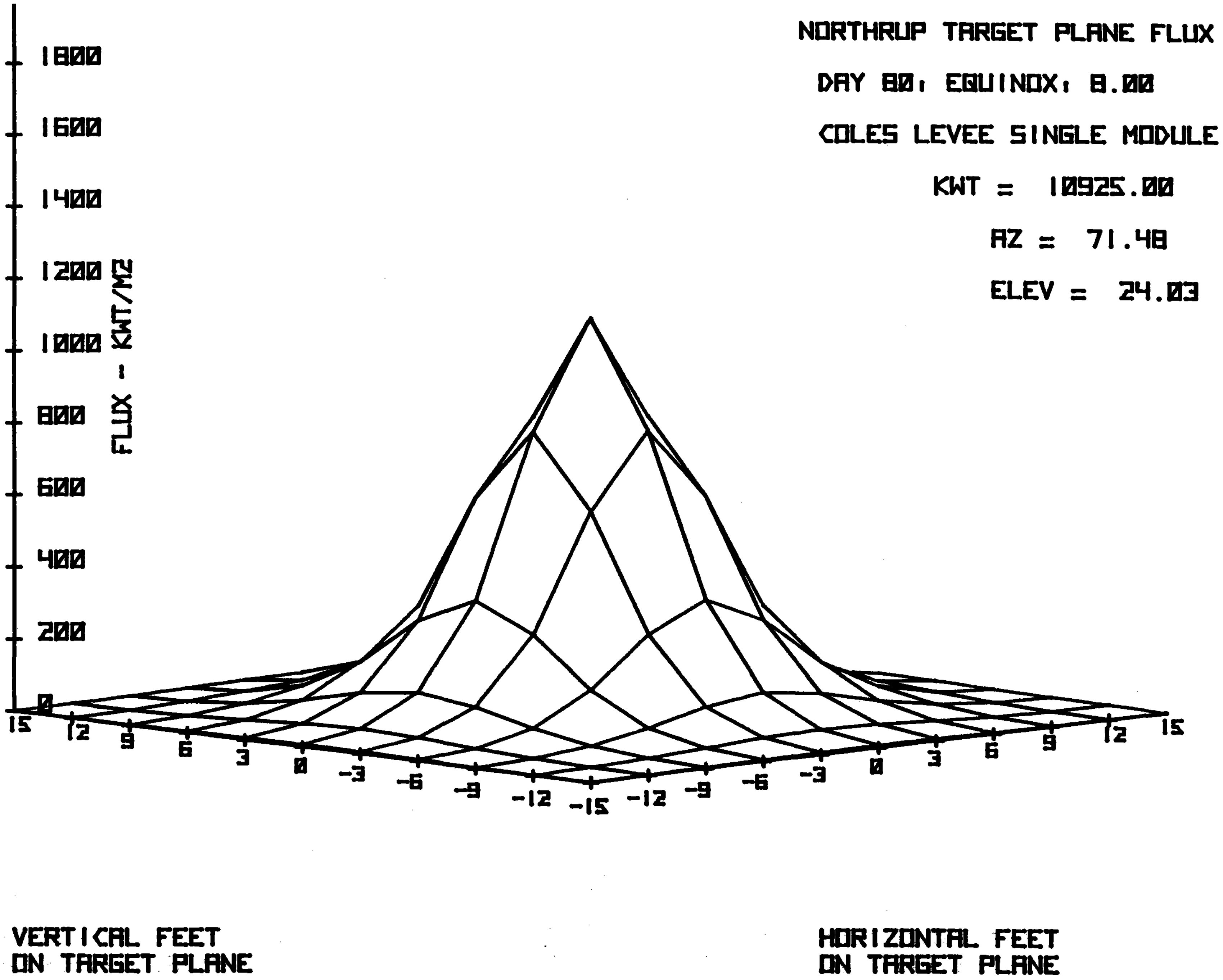
FILE NO. = 32 FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. = 80
TIME = 8
HR ANGLE = -60
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG

Vertical Dimension - ft

15	0	1	2	4	7	7	7	4	2	1	0
12	1	3	7	16	25	30	25	16	8	3	1
9	2	7	21	51	90	111	91	51	22	8	2
6	4	16	51	136	270	346	271	137	51	16	4
3	6	25	90	269	591	794	593	271	91	26	7
0	7	30	110	345	793	1089	797	348	112	30	8
-3	6	25	90	270	592	796	594	272	91	26	7
-6	4	16	51	137	271	347	272	138	51	16	4
-9	2	7	21	51	91	111	91	51	22	8	2
-12	1	3	7	16	25	30	25	16	8	3	1
-15	0	1	2	4	7	8	7	4	2	1	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

Horizontal Dimension - ft

Focal Grid Energy = 11014



NORTHRUP TARGET PLANE FLUX

DAY 80, EQUINOX, 8.00

COLES LEVEE SINGLE MODULE

KWT = 10925.00

AZ = 71.48

ELEV = 24.03

EJB/JB

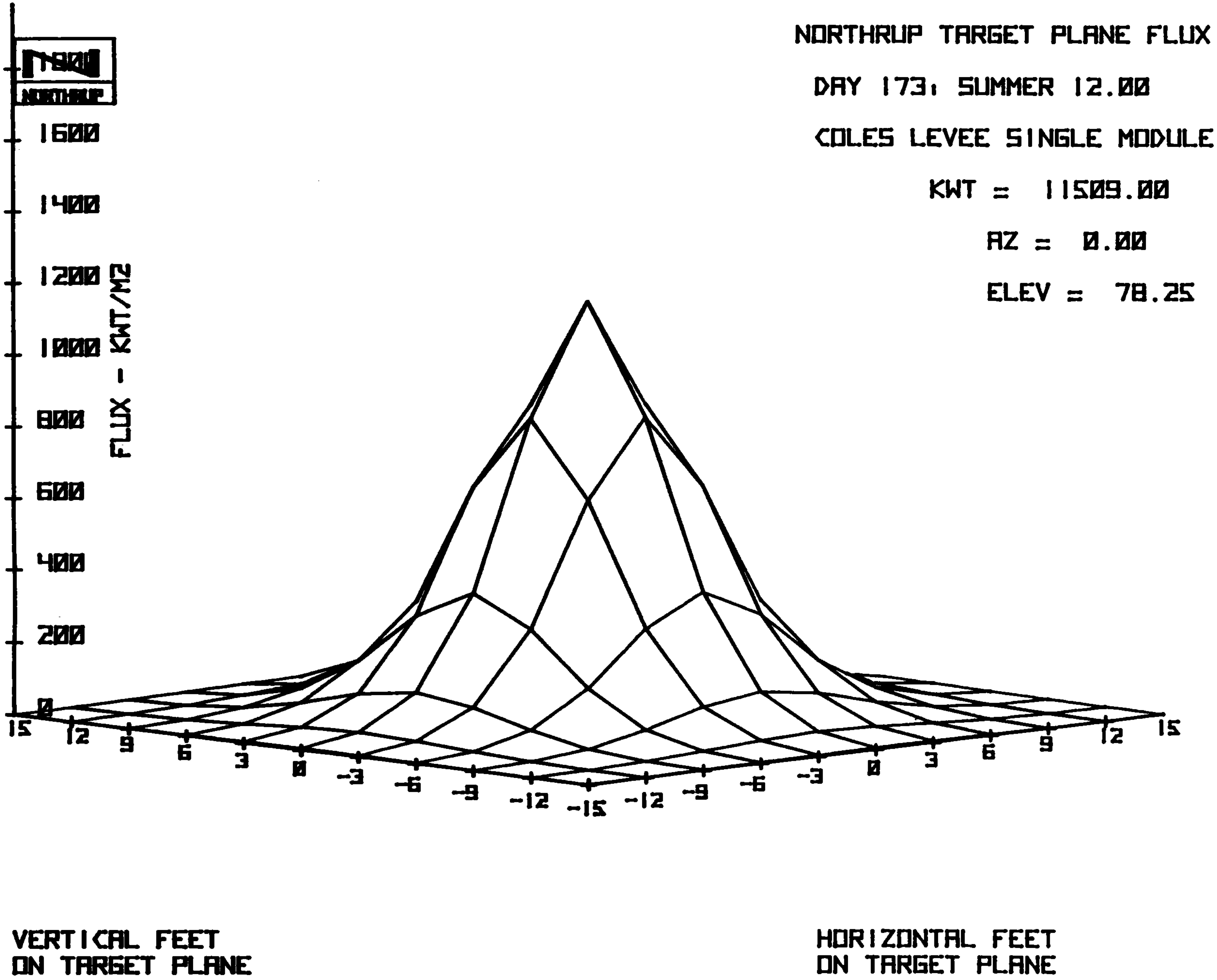
ILE NO. = 34 FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. = 173
TIME = 12
HR ANGLE = 0
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG

Vertical Dimension - ft

15	0	0	1	3	5	6	5	3	1	0	0
12	0	2	6	14	24	29	24	14	6	2	0
9	1	6	20	53	96	119	96	53	20	6	1
6	3	14	53	148	291	371	291	148	53	14	3
3	5	24	97	291	627	836	627	291	97	24	5
0	6	30	120	372	839	1145	839	372	120	30	6
-3	5	24	97	293	631	841	631	293	97	24	5
-6	3	14	53	149	293	374	293	149	53	14	3
-9	1	6	20	53	97	120	97	53	20	6	1
-12	0	2	6	14	25	30	25	14	6	2	0
-15	0	0	1	3	5	6	5	3	1	0	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

Horizontal Dimension - ft

Focal Grid Energy = 11509


NORTHRUP TARGET PLANE FLUX
DAY 173, SUMMER 12.00
COLES LEVEE SINGLE MODULE
KWT = 11509.00
AZ = 0.00
ELEV = 78.25
1800
NORTHRUP
1600
1400
1200
1000
800
600
400
200
0
FLUX - KWT/M2
15
12
9
6
3
0
-3
-6
-9
-12
-15
-12
-9
-6
-3
0
3
6
9
12
15
VERTICAL FEET
ON TARGET PLANE
HORIZONTAL FEET
ON TARGET PLANE

EJB/JB
2-4A3

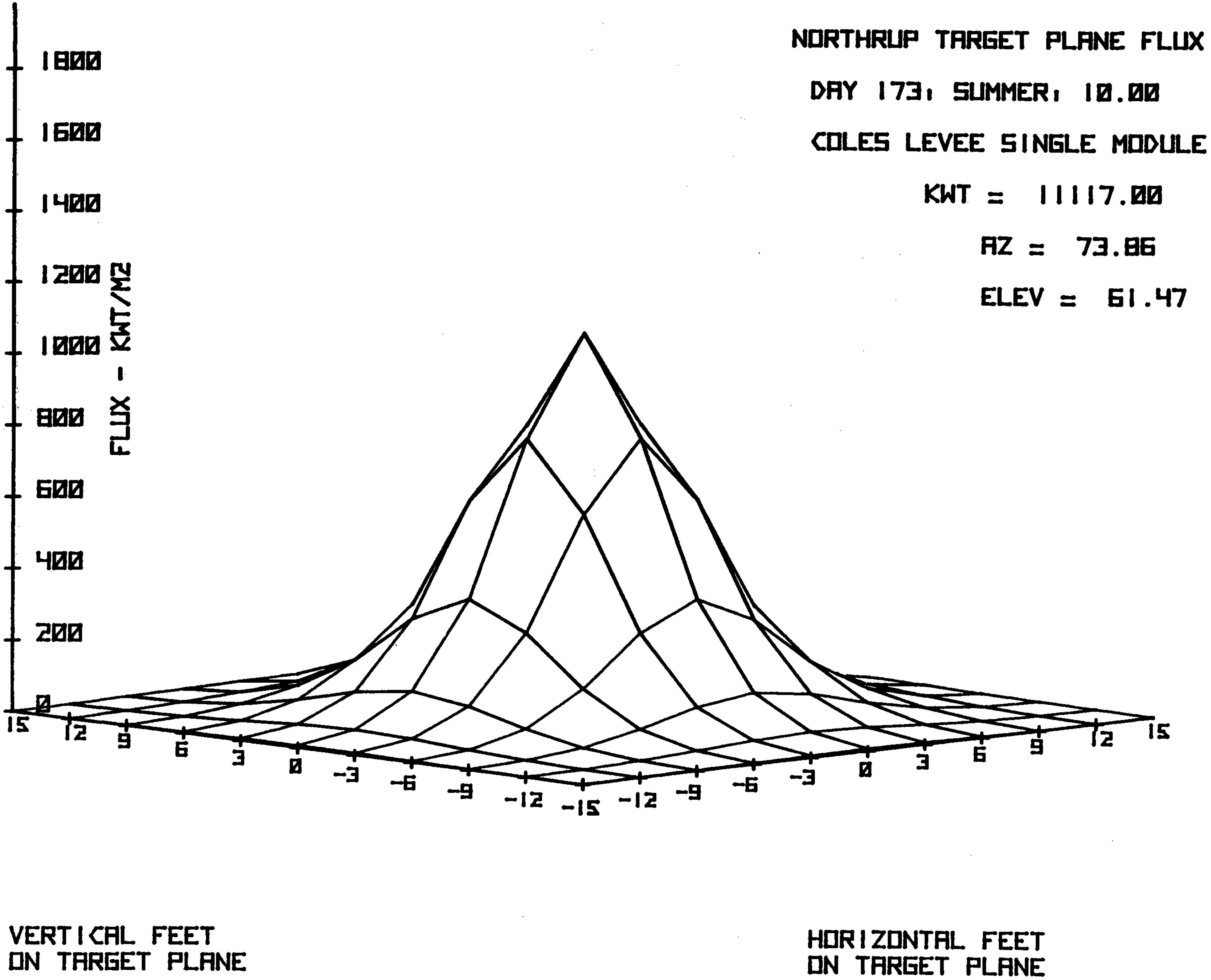
ILE NO. = 36 FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. = 173
TIME = 10
HR ANGLE = -30
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG

Vertical Dimension - ft

15	0	1	2	4	6	7	6	4	2	1	0
12	1	2	7	16	26	32	26	16	7	2	1
9	2	7	22	55	97	119	97	55	22	7	2
6	4	16	55	146	281	356	282	146	55	16	4
3	6	26	97	281	592	783	593	282	98	27	6
0	7	32	119	357	784	1061	786	358	120	32	7
-3	6	27	98	282	595	787	596	283	98	27	6
-6	4	16	55	147	283	359	284	147	55	16	4
-9	2	7	22	55	98	120	98	55	22	7	2
-12	1	2	7	16	27	32	27	16	7	2	1
-15	0	1	2	4	6	7	6	4	2	1	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

Horizontal Dimension - ft

Focal Grid Energy = 11117



NORTHRUP TARGET PLANE FLUX

DAY 173, SUMMER, 10.00

COLES LEVEE SINGLE MODULE

KWT = 11117.00

AZ = 73.86

ELEV = 61.47

EJB/JB

FILE NO. = 38 FOCAL PLANE
COLES LEVEE SINGLE TOWER
DAY NO. = 173
TIME = 8
HR ANGLE = -60
LONGITUDE = 119.35 DEG. LATITUDE = 35.192 DEG

Vertical Dimension -ft

15	1	2	3	6	9	10	9	6	3	2	1
12	2	4	10	20	31	36	31	20	10	4	2
9	3	10	26	58	97	116	97	58	27	10	3
6	6	20	58	140	254	315	254	140	58	20	6
3	9	31	97	254	498	640	500	255	97	31	9
0	10	36	116	315	640	836	643	317	117	36	10
-3	9	31	97	254	500	643	502	256	98	31	9
-6	6	20	58	140	255	317	256	141	58	20	6
-9	3	10	27	58	97	117	98	58	27	10	3
-12	2	4	10	20	31	36	31	20	10	4	2
-15	1	2	3	6	9	10	9	6	3	2	1
	-15	-12	-9	-6	-3	0	3	6	9	12	15

Horizontal Dimension - ft

Focal Grid Energy = 9971.5

NORTHRUP TARGET PLANE FLUX

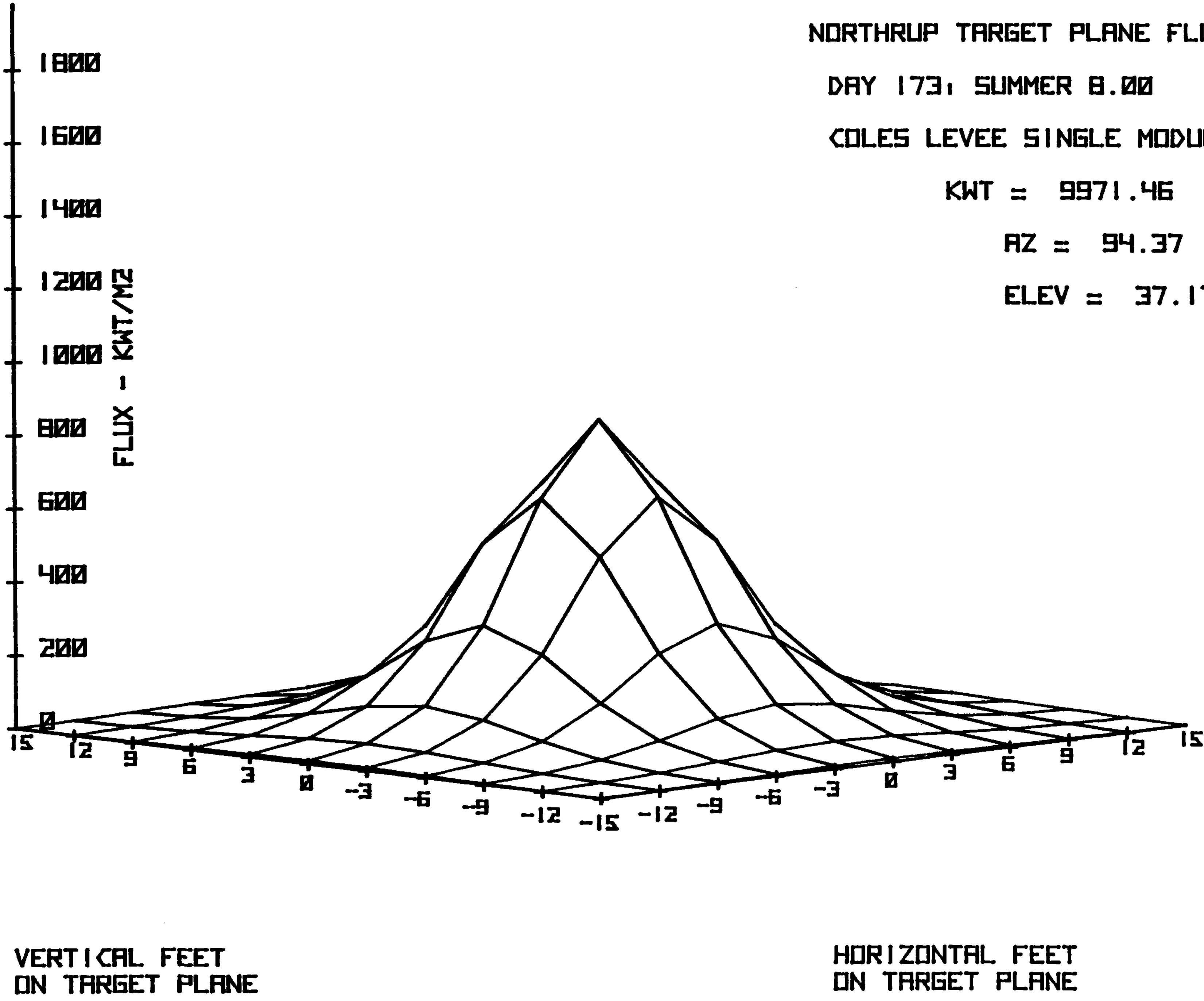
DAY 173; SUMMER 8.00

COLES LEVEE SINGLE MODULE

KWT = 9971.46

AZ = 94.37

ELEV = 37.17



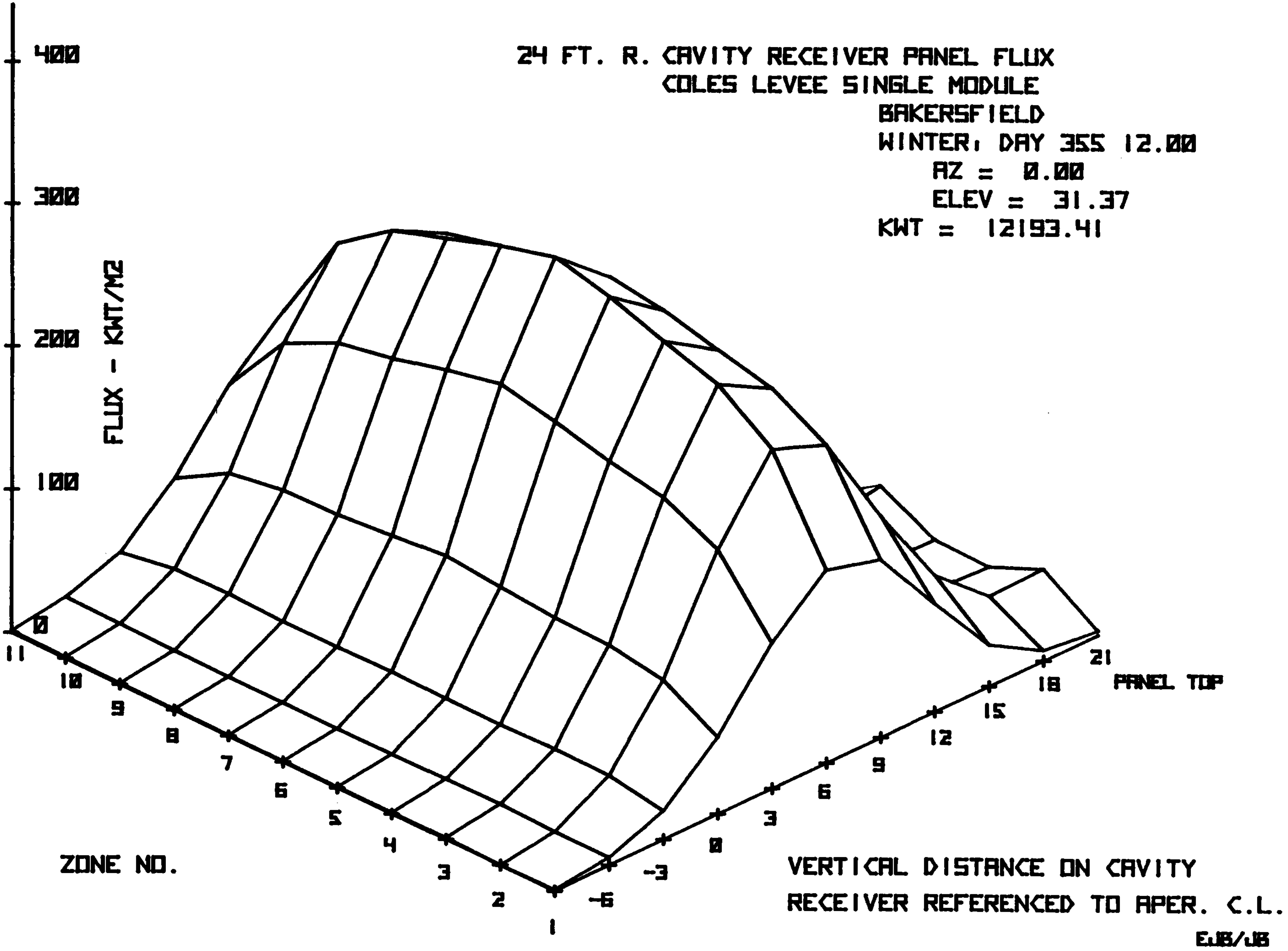
EJB/JB

```
FILE NO. =  41    CAVITY FLUX
COLES LEVEE SINGLE TOWER
DAY NO. =  355
TIME =  12
HR ANGLE =  0
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG
```

21	3	28	11	12	32	3	32	12	11	28	3
18	7	27	14	13	25	6	25	13	14	27	7
15	29	59	45	44	60	34	60	44	45	59	29
12	75	119	120	121	130	122	130	121	120	119	75
9	124	186	207	216	225	231	225	216	207	186	124
6	135	201	228	240	253	263	253	240	228	201	135
3	101	148	167	174	184	192	184	174	167	148	101
0	54	75	82	83	86	90	86	83	82	75	54
-3	20	27	27	26	26	27	26	26	27	27	20
-6	5	7	6	6	5	6	5	6	6	7	5
-9	1	1	1	1	1	1	1	1	1	1	1
	1	2	3	4	5	6	7	8	9	10	11

Panel No.

Direct Energy on Panels = 12193


24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
WINTER, DAY 355 12.00
AZ = 0.00
ELEV = 31.37
KWT = 12193.41
FLUX - KWT/M2
400
300
200
100
0
ZONE NO.
11
10
9
8
7
6
5
4
3
2
1
-6
-3
0
3
6
9
12
15
18
21
PANEL TOP
VERTICAL DISTANCE ON CAVITY
RECEIVER REFERENCED TO APER. C.L.
EJB/JB

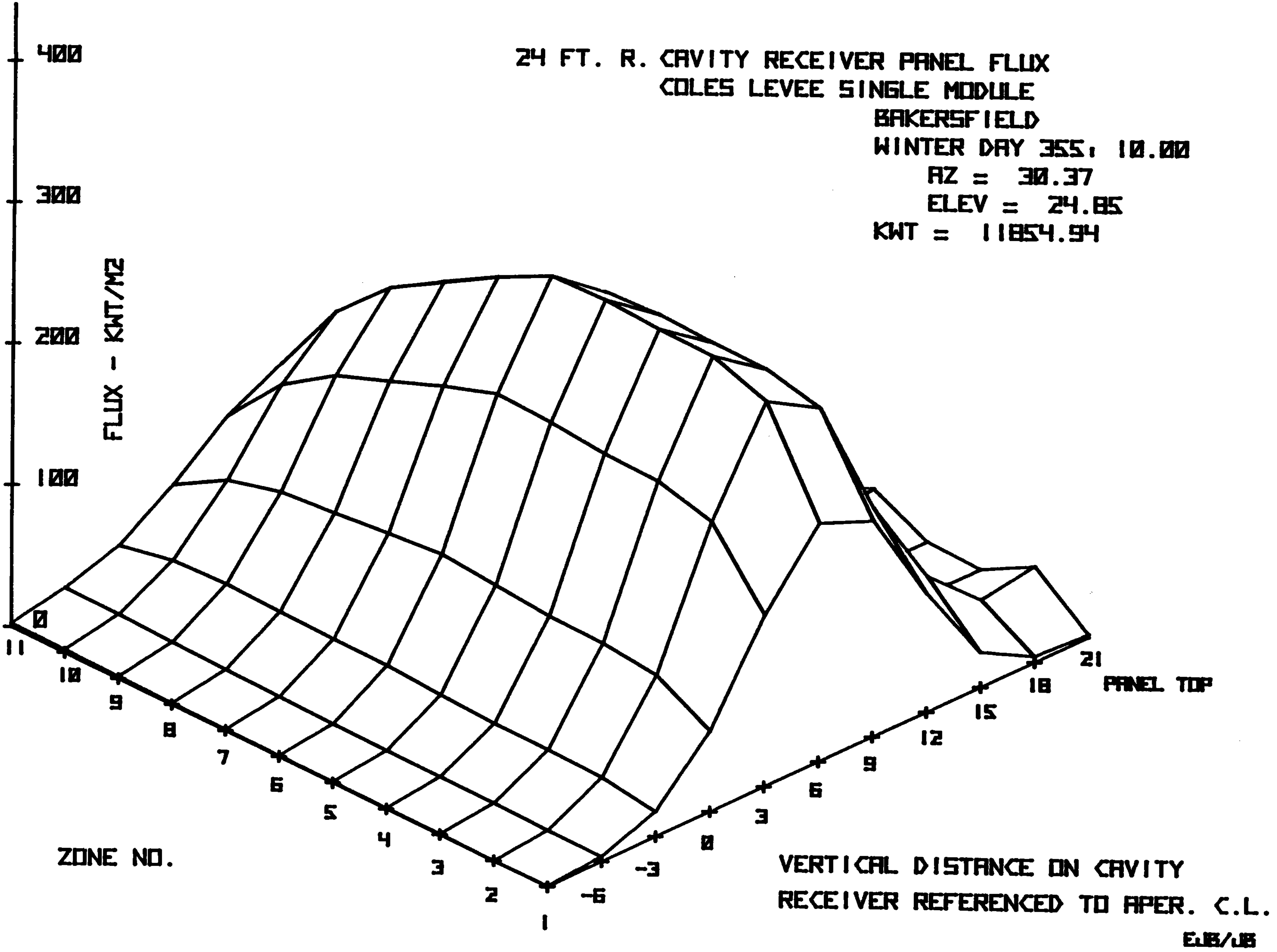
2-4G6

FILE NO. = 43 CAVITY FLUX
COLES LEVEE SINGLE TOWER
DAY NO. = 355
TIME = 10
HR ANGLE = -30
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG

21	2	32	11	12	31	4	26	14	12	21	6
18	4	26	11	12	25	8	26	18	19	28	13
15	24	60	41	42	60	37	58	50	50	55	32
12	83	125	121	121	129	121	127	118	112	101	63
9	152	213	222	222	224	221	209	192	174	144	91
	168	235	249	249	251	250	231	209	187	152	97
3	121	168	178	179	183	185	172	157	143	118	78
0	57	78	82	83	86	90	86	82	78	68	47
-3	17	23	24	25	26	29	29	30	31	30	22
-6	4	5	5	5	5	6	7	8	9	10	8
-9	1	1	1	1	1	1	1	2	2	3	2
	1	2	3	4	5	6	7	8	9	10	11

Panel No.

Direct Energy on Panels = 11854.9

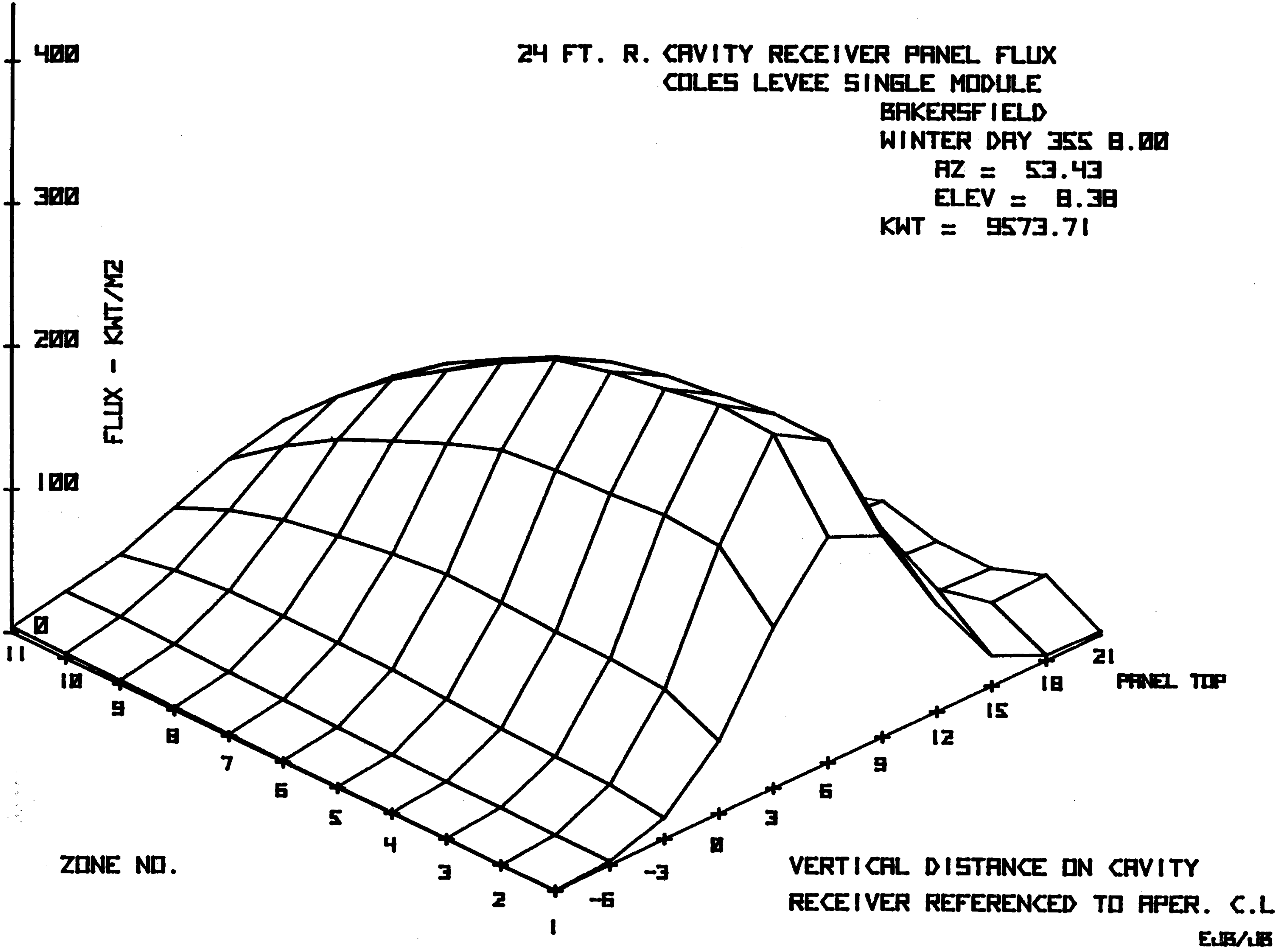

24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
WINTER DAY 355, 10.00
AZ = 30.37
ELEV = 24.85
KWT = 11854.94
FLUX - KWT/M2
400
300
200
100
0
11
10
9
8
7
6
5
4
3
2
1
ZONE NO.
-6
-3
0
3
6
9
12
15
18
21
PANEL TOP
VERTICAL DISTANCE ON CAVITY
RECEIVER REFERENCED TO APER. C.L.
EJB/JB

```
LE NO. = 45    CAVITY FLUX
LES LEVEE SINGLE TOWER
Y NO. = 355
ME = 8
NGLE = -60
ITUDE = 119.35 DEG, LATITUDE = 35.192 DEG
```

21	2	23	10	11	21	6	17	13	11	13	7
18	4	22	12	13	23	12	23	21	20	22	14
15	21	49	37	39	51	39	50	48	44	41	26
12	74	109	104	104	109	102	102	93	82	67	42
9	140	188	189	184	180	171	156	137	116	89	55
6	157	211	213	206	200	191	171	147	123	93	58
3	112	151	154	151	149	145	132	116	99	76	49
0	51	69	72	73	75	77	73	67	61	49	33
-3	15	20	22	23	26	28	29	30	29	26	18
-6	3	4	4	5	6	7	9	10	11	11	8
-9	0	1	1	1	1	1	2	3	3	4	3
	1	2	3	4	5	6	7	8	9	10	11

Panel No.

Direct Energy on Panels = 9573.7

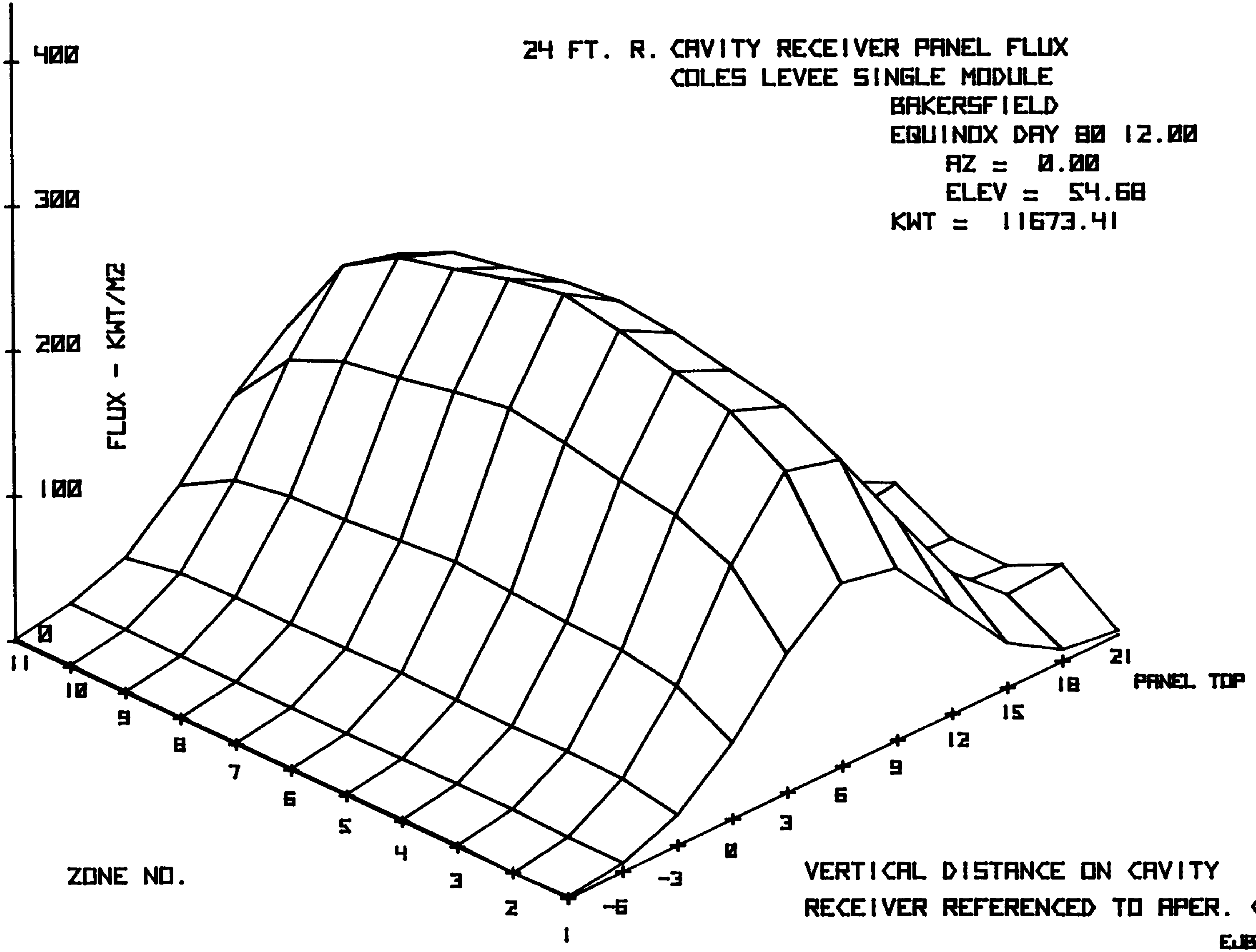

24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
WINTER DAY 355 8.00
AZ = 53.43
ELEV = 8.38
KWT = 9573.71
FLUX - KWT/M2
400
300
200
100
0
ZONE NO.
11
10
9
8
7
6
5
4
3
2
1
-6
-3
0
3
6
9
12
15
18
21
PANEL TOP
VERTICAL DISTANCE ON CAVITY
RECEIVER REFERENCED TO APER. C.L
EJB/JB

```
0:SINGLE1FILE NO. = 29    CAVITY FLUX
COLES LEVEE SINGLE TOWER
DAY NO. = 80
TIME = 12
HR ANGLE = 0
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG
```

21	3	30	12	13	32	3	32	13	12	30	3
18	8	28	15	14	26	8	26	14	15	28	8
15	30	61	48	48	62	39	62	48	48	61	30
12	75	117	119	120	129	120	129	120	119	117	75
9	118	175	194	201	209	213	209	201	194	175	118
6	126	185	209	218	229	236	229	218	209	185	126
3	96	139	155	161	169	176	169	161	155	139	96
0	53	74	81	82	85	88	85	82	81	74	53
-3	21	28	29	29	29	30	29	29	29	28	21
-6	6	8	8	7	7	7	7	7	8	8	6
-9	1	2	1	1	1	1	1	1	1	2	1
	1	2	3	4	5	6	7	8	9	10	11

Panel No.

Direct Energy on Panels = 11673



24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
EQUINOX DAY 80 12.00
AZ = 0.00
ELEV = 54.68
KWT = 11673.41

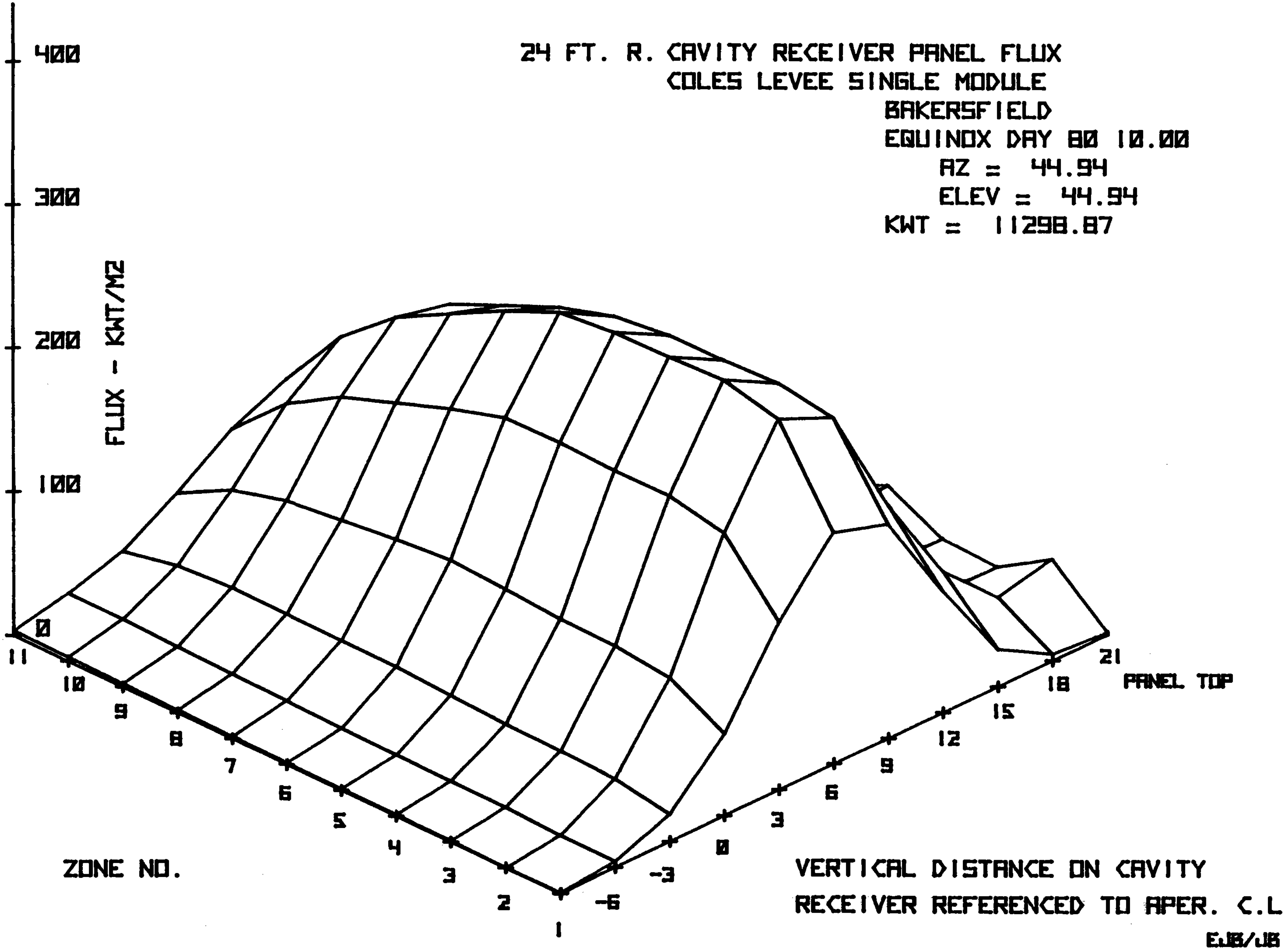
EJB/JB
2-4G4

```
0:SINGLE2FILE NO. =   31     CAVITY FLUX
COLES LEVEE SINGLE TOWER
DAY NO. =   80
TIME =   10
HR ANGLE = -30
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG
```

21	2	34	11	12	31	5	26	14	13	22	7
18	5	26	12	14	26	10	27	20	21	29	14
15	26	62	44	45	62	42	60	53	52	55	32
12	84	125	120	121	128	119	123	114	107	95	60
9	148	204	210	208	207	202	191	174	157	130	83
6	160	221	230	228	227	223	206	186	166	135	88
3	116	160	168	167	169	168	157	143	129	107	71
0	57	77	82	82	85	88	84	79	75	64	44
-3	19	25	27	27	29	32	32	32	33	30	22
-6	4	6	6	6	7	8	9	10	11	11	9
-9	1	1	1	1	1	2	2	2	3	3	3
	1	2	3	4	5	6	7	8	9	10	11

Panel No.

Direct Energy on Panels = 11298.9



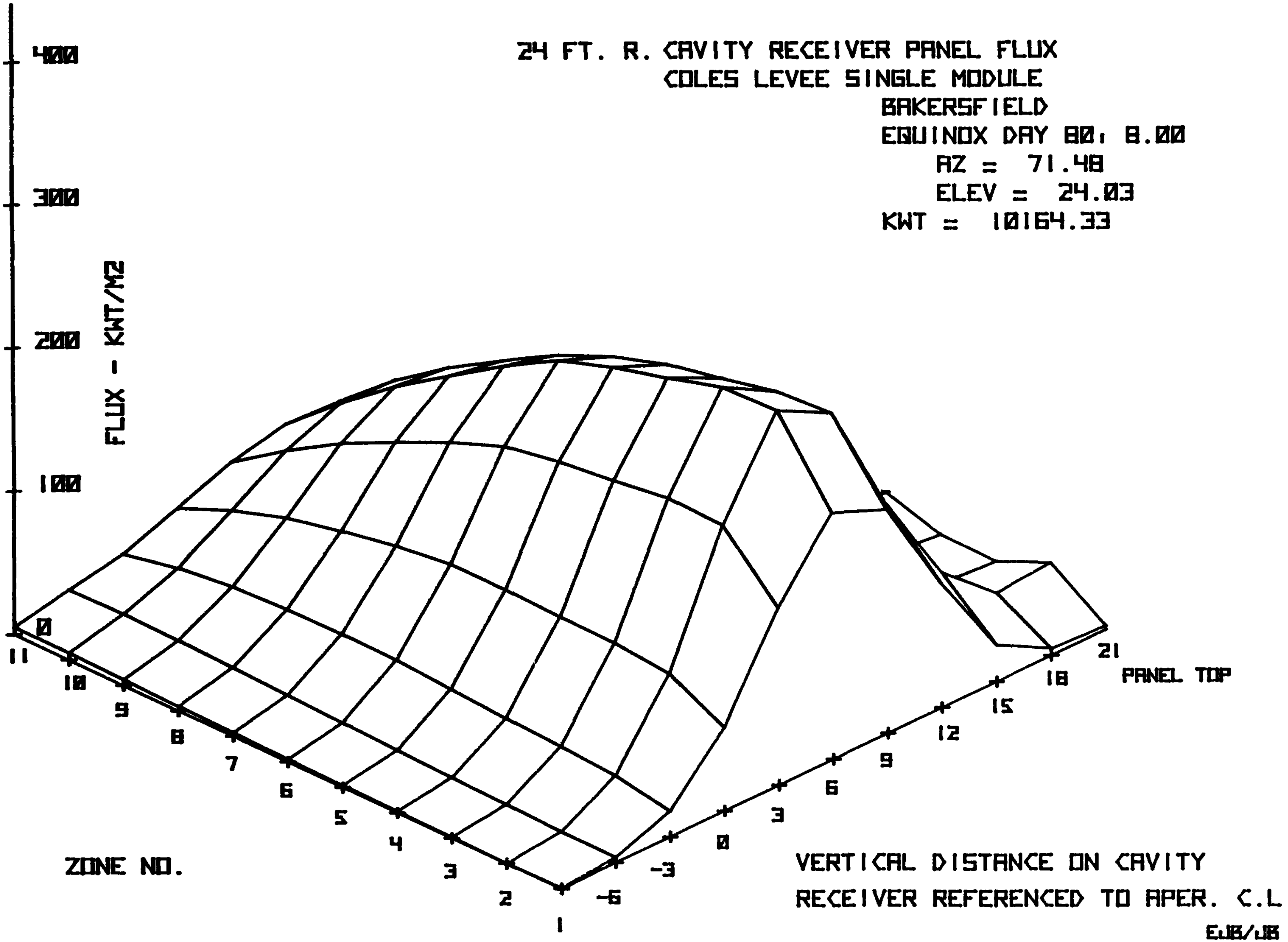
24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
EQUINOX DAY 80 10.00
AZ = 44.94
ELEV = 44.94
KWT = 11298.87

```
0:SINGLE2FILE NO. =  33    CAVITY FLUX
COLES LEVEE SINGLE TOWER
DAY NO. =  80
TIME =  8
HR ANGLE = -60
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG
```

21	2	28	12	12	24	8	19	16	13	16	9
18	5	26	14	17	27	17	28	26	25	26	16
15	25	58	46	47	59	49	57	54	49	44	28
12	86	124	118	117	120	110	108	97	83	67	42
9	156	205	202	193	185	173	156	135	112	85	54
6	171	225	223	212	201	188	167	142	117	88	56
3	123	163	164	158	154	147	132	114	96	73	47
0	58	78	81	81	83	83	78	71	62	49	33
-3	18	25	27	29	32	34	35	34	32	28	20
-6	4	5	6	7	9	11	12	13	14	13	10
-9	1	1	1	1	2	3	3	4	5	5	4
	1	2	3	4	5	6	7	8	9	10	11

Panel No.

Direct Energy on Panels = 10164



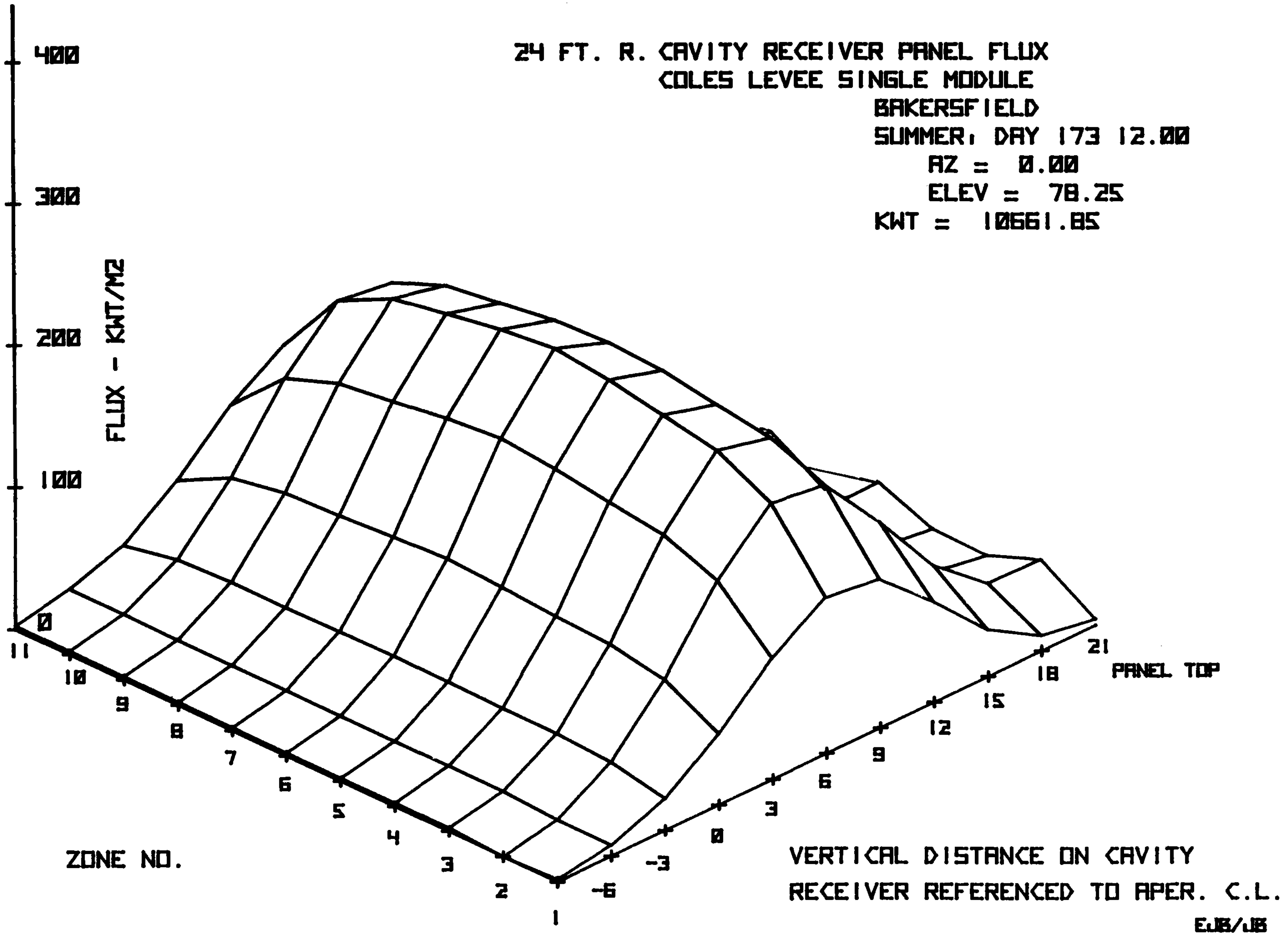
24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
EQUINOX DAY 80: 8.00
AZ = 71.48
ELEV = 24.03
KWT = 10164.33

FILE NO. = 35 CAVITY FLUX
COLES LEVEE SINGLE TOWER
DAY NO. = 173
TIME = 12
HR ANGLE = 0
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG

21	4	28	13	14	29	6	29	14	13	28	4
18	11	29	19	19	28	13	28	19	19	29	11
15	33	60	52	53	62	47	62	53	52	60	33
12	71	109	112	114	121	114	121	114	112	109	71
9	104	152	168	173	179	181	179	173	168	152	104
6	109	158	177	184	191	195	191	184	177	158	109
3	85	121	136	141	146	150	146	141	136	121	85
0	50	70	77	79	82	84	82	79	77	70	50
-3	22	30	32	32	33	34	33	32	32	30	22
-6	8	10	10	10	10	10	10	10	10	10	8
-9	2	2	2	2	2	2	2	2	2	2	2
	1	2	3	4	5	6	7	8	9	10	11

Panel No.

Direct Energy on Panels = 10661.8



24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
SUMMER; DAY 173 12.00
AZ = 0.00
ELEV = 78.25
KWT = 10661.85

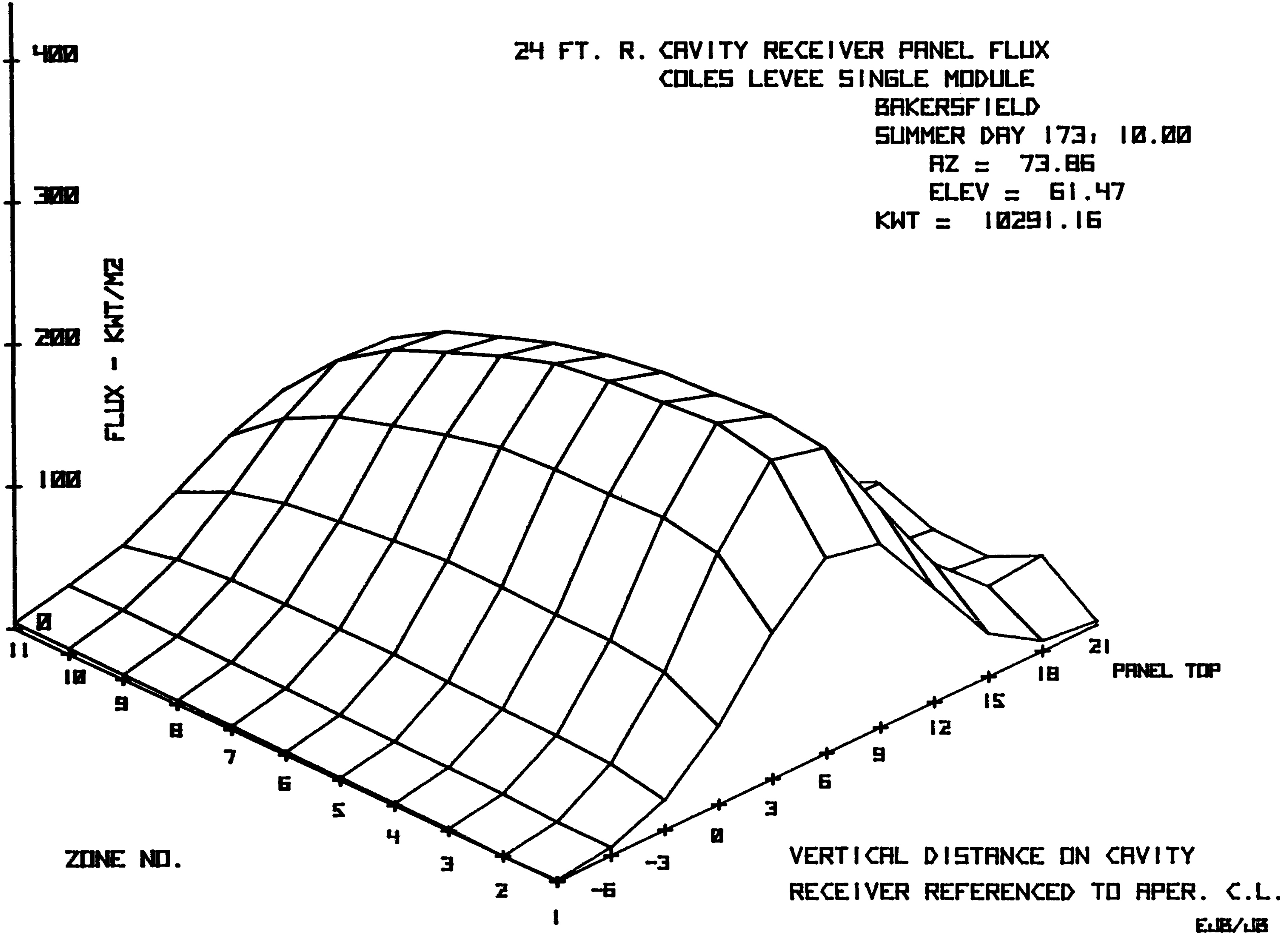
2-4G5

FILE NO. = 37 CAVITY FLUX
COLES LEVEE SINGLE TOWER
DAY NO. = 173
TIME = 10
HR ANGLE = -30
LONGITUDE = 119.35 DEG. LATITUDE = 35.192 DEG

21	3	31	12	13	28	7	24	15	14	21	8
18	7	28	17	18	28	15	29	24	24	30	15
15	30	62	50	51	62	49	60	55	53	53	32
12	80	119	116	115	120	111	113	105	98	87	56
9	129	178	183	180	178	172	162	149	135	113	74
6	137	188	196	193	190	184	172	156	140	115	77
3	103	141	148	146	146	143	134	123	112	93	63
0	55	75	79	80	81	82	79	74	69	59	41
-3	21	29	31	31	33	35	35	34	34	30	22
-6	6	8	9	9	10	11	12	12	13	12	9
-9	1	2	2	2	2	3	3	3	4	4	3
	1	2	3	4	5	6	7	8	9	10	11

Panel No.

Direct Energy on Panels = 10290.9



24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
SUMMER DAY 173, 10.00
AZ = 73.86
ELEV = 61.47
KWT = 10291.16

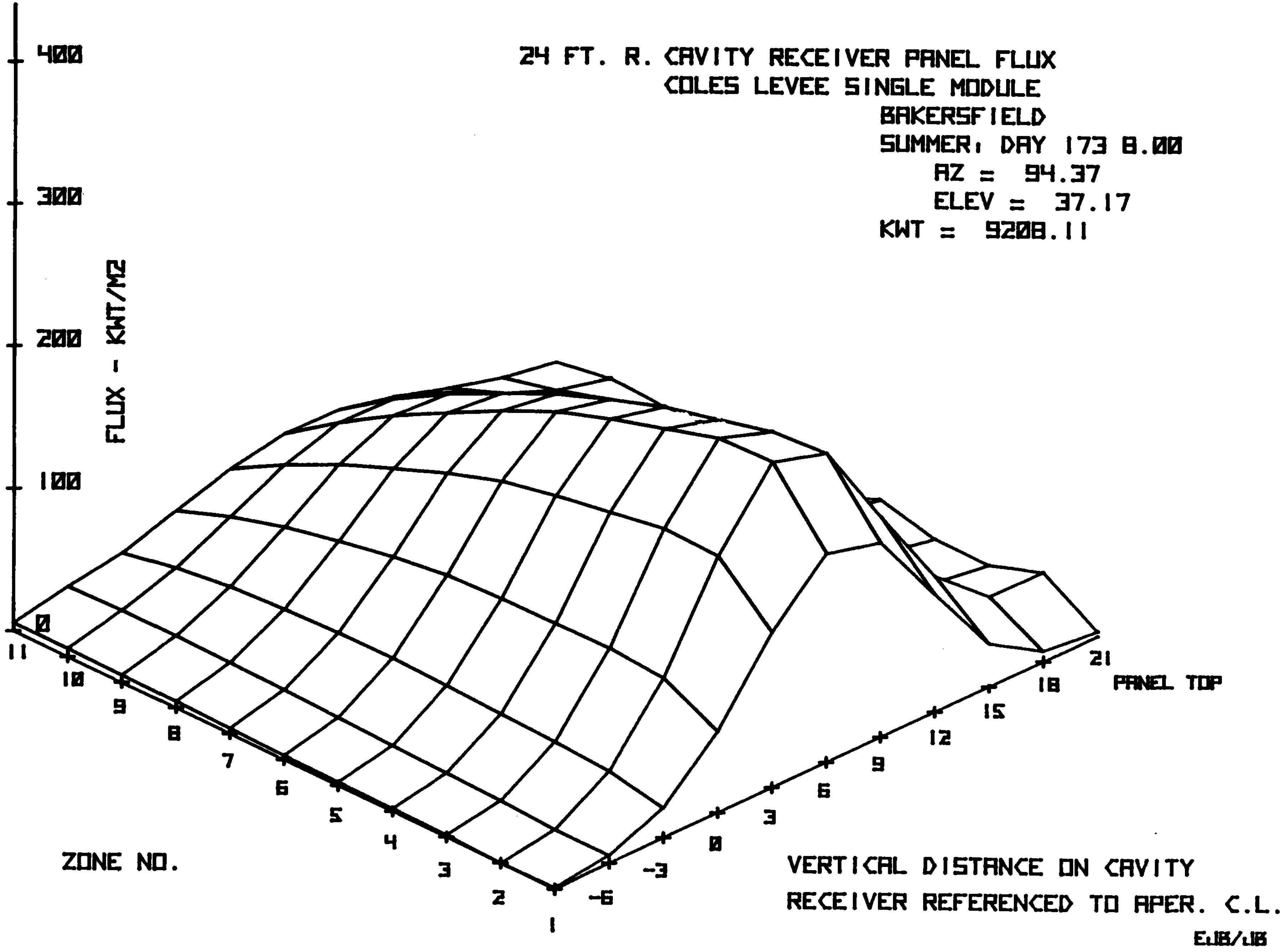
FILE NO. = 39 CAVITY FLUX
COLES LEVEE SINGLE TOWER
DAY NO. = 173
TIME = 8
HR ANGLE = -60
LONGITUDE = 119.35 DEG, LATITUDE = 35.192 DEG

	1	2	3	4	5	6	7	8	9	10	11
21	3	26	13	13	22	10	19	17	15	16	9
18	7	27	19	20	29	21	29	28	26	26	16
15	30	59	51	51	59	51	56	53	47	41	27
12	82	119	114	110	110	101	96	86	74	60	39
9	136	180	177	167	158	145	131	113	95	73	47
6	146	192	190	179	168	155	137	117	97	74	49
3	109	144	145	138	132	124	111	96	81	63	42
0	57	76	79	78	78	76	70	63	55	44	30
-3	21	29	31	33	34	36	35	34	31	26	19
-6	5	8	9	10	12	13	14	15	15	13	10
-9	1	2	2	2	3	4	5	5	6	6	4

Panel No.

Direct Energy on Panels = 9208.0

on panels = ,72727x 12661.
= 9203.



24 FT. R. CAVITY RECEIVER PANEL FLUX
COLES LEVEE SINGLE MODULE
BAKERSFIELD
SUMMER: DAY 173 8.00
AZ = 94.37
ELEV = 37.17
KWT = 9208.11

Appendix E

Receiver Thermal Performance Maps

North Coles Levee Project

Northrup/Atlantic Richfield, Inc.

Appendix E

In this Appendix, the thermal results for the 9 day and time cases are presented. The winter solstice (day 355), vernal and/or autumnal equinox (day 80), and summer solstice (day 173) were analyzed for solar times of 8:00 am, 10:00 am, and 12:00 noon.

The organization of this appendix is to first present a run summary for each of the 9 cases in which the receiver energy balance, average maximum temperatures, maximum thermal stress, and average transport properties are presented (Figures E-1 through E-9).

Following the run summaries are a dimensional node map (Figure E-10), and sets of thermal maps organized by thermal parameter (i.e. 9 cases showing incident power, 9 cases showing conduction losses, etc). The following parameters are presented:

Incident Power, kw	Pages	E-11 through E-19
Conductive Losses, kw		E-20 through E-28
Convective Losses, kw		E-29 through E-37
Radiative Losses, kw		E-38 through E-46
Reflective Losses, kw		E-47 through E-55
Net Power into Oil, kw		E-56 through E-64
Maximum Passage Frontside Temperature		E-65 through E-73
Maximum Fin Temperature		E-74 through E-82
Oil Outlet Temperature, Each Panel		E-83 through E-91
Maximum Thermal Stress		E-92 through E-100

Figure E-1

```
          RUN SUMMARY,DAY 355  TIME=12:00 NOON
         --------------------------------------


APERTURE PLANE ENERGY, KW= 13021
ENERGY ON RECEIVER, KW= 12828.477
ENERGY APERTURE CUT-OFF, KW= 88.5428012
ENERGY MISSING PANELS, KW= 103.98
ABSORPTIVITY LOSS, KW= 125.972
CONVECTION LOSS, KW= 503.275
CONDUCTION LOSS, KW= 52.603
RADIATION LOSS, KW= 329.262
ENERGY TO FLUID, KW= 11817.371

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 90.76

MAX OIL TEMPERATURE, DEG-F= 594.1
MAX FIN TEMPERATURE, DEG-F= 669.5
MAX FRONT TEMPERATURE, DEG-F= 632.2
MAX BACK TEMPERATURE, DEG-F= 593.8

MAXIMUM THERMAL STRESS, PSI= 22001

AVERAGE TUBE SURFACE TEMP = 576
AVERAGE FIN SURFACE TEMP = 606
AVERAGE SURFACE TEMP (CONVECTION) = 580
AVERAGE SURFACE TEMP (RADIATION) = 582
AVERAGE CAVITY WALL TEMP = 543

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 537.1
PASS #2 OUTLET TEMP = 583.5
FLUID AVERAGE TEMP = 501.8

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .621
AVERAGE VISCOSITY, LB/FT-HR = .557
AVERAGE DENSITY, LB/CU-FT = 43.83
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .06843

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Figure E-2

```
 RUN SUMMARY,DAY 355  TIME=10:00 NOON
---------------------------------------


APERTURE PLANE ENERGY, KW= 12669
ENERGY ON RECEIVER, KW= 12442.853
ENERGY APERTURE CUT-OFF, KW= 117.821703
ENERGY MISSING PANELS, KW= 108.325
ABSORPTIVITY LOSS, KW= 122.545
CONVECTION LOSS, KW= 499.393
CONDUCTION LOSS, KW= 52.217
RADIATION LOSS, KW= 324.248
ENERGY TO FLUID, KW= 11444.449

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 90.33

MAX OIL TEMPERATURE, DEG-F= 591.4
MAX FIN TEMPERATURE, DEG-F= 679.9
MAX FRONT TEMPERATURE, DEG-F= 635
MAX BACK TEMPERATURE, DEG-F= 591.1

MAXIMUM THERMAL STRESS, PSI= 21703

AVERAGE TUBE SURFACE TEMP = 572
AVERAGE FIN SURFACE TEMP = 600
AVERAGE SURFACE TEMP (CONVECTION) = 575
AVERAGE SURFACE TEMP (RADIATION) = 578
AVERAGE CAVITY WALL TEMP = 539

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 533.3
PASS #2 OUTLET TEMP = 578.7
FLUID AVERAGE TEMP = 499.3

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .62
AVERAGE VISCOSITY, LB/FT-HR = .563
AVERAGE DENSITY, LB/CU-FT = 43.91
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .0685


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```

Figure E-3

```
             RUN SUMMARY,DAY 355  TIME=8:00 A.M.
            ------------------------------------------


APERTURE PLANE ENERGY, KW= 10256
ENERGY ON RECEIVER, KW= 10007.516
ENERGY APERTURE CUT-OFF, KW= 168.198401
ENERGY MISSING PANELS, KW= 80.286
ABSORPTIVITY LOSS, KW= 99.275
CONVECTION LOSS, KW= 472.732
CONDUCTION LOSS, KW= 49.543
RADIATION LOSS, KW= 289.627
ENERGY TO FLUID, KW= 9096.341

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 88.69

MAX OIL TEMPERATURE, DEG-F= 569.1
MAX FIN TEMPERATURE, DEG-F= 657.6
MAX FRONT TEMPERATURE, DEG-F= 606.9
MAX BACK TEMPERATURE, DEG-F= 563.7

MAXIMUM THERMAL STRESS, PSI= 19202

AVERAGE TUBE SURFACE TEMP = 543
AVERAGE FIN SURFACE TEMP = 565
AVERAGE SURFACE TEMP (CONVECTION) = 545
AVERAGE SURFACE TEMP (RADIATION) = 547
AVERAGE CAVITY WALL TEMP = 516

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 510.2
PASS #2 OUTLET TEMP = 547.7
FLUID AVERAGE TEMP = 483.9

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .612
AVERAGE VISCOSITY, LB/FT-HR = .598
AVERAGE DENSITY, LB/CU-FT = 44.43
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .0689

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```

Figure E-4

```
        RUN SUMMARY,DAY 80  TIME=12:00 NOON
      ---------------------------------------


APERTURE PLANE ENERGY, KW= 12512
ENERGY ON RECEIVER, KW= 12295.381
ENERGY APERTURE CUT-OFF, KW= 116.361603
ENERGY MISSING PANELS, KW= 100.258
ABSORPTIVITY LOSS, KW= 120.438
CONVECTION LOSS, KW= 497.684
CONDUCTION LOSS, KW= 52.045
RADIATION LOSS, KW= 321.603
ENERGY TO FLUID, KW= 11303.617

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 90.34

MAX OIL TEMPERATURE, DEG-F= 588.4
MAX FIN TEMPERATURE, DEG-F= 655.4
MAX FRONT TEMPERATURE, DEG-F= 628
MAX BACK TEMPERATURE, DEG-F= 588

MAXIMUM THERMAL STRESS, PSI= 20131

AVERAGE TUBE SURFACE TEMP = 570
AVERAGE FIN SURFACE TEMP = 598
AVERAGE SURFACE TEMP (CONVECTION) = 573
AVERAGE SURFACE TEMP (RADIATION) = 575
AVERAGE CAVITY WALL TEMP = 538

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 530.1
PASS #2 OUTLET TEMP = 576.8
FLUID AVERAGE TEMP = 498.4

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .619
AVERAGE VISCOSITY, LB/FT-HR = .565
AVERAGE DENSITY, LB/CU-FT = 43.94
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .06852


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```

Figure E-5

```
RUN SUMMARY,DAY 80  TIME=10:00 A.M.
------------------------------------


APERTURE PLANE ENERGY, KW= 12119
ENERGY ON RECEIVER, KW= 11894.504
ENERGY APERTURE CUT-OFF, KW= 141.792302
ENERGY MISSING PANELS, KW= 82.704
ABSORPTIVITY LOSS, KW= 116.76
CONVECTION LOSS, KW= 493.414
CONDUCTION LOSS, KW= 51.619
RADIATION LOSS, KW= 316.114
ENERGY TO FLUID, KW= 10916.596

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 90.08

MAX OIL TEMPERATURE, DEG-F= 587
MAX FIN TEMPERATURE, DEG-F= 670.5
MAX FRONT TEMPERATURE, DEG-F= 627.6
MAX BACK TEMPERATURE, DEG-F= 586.3

MAXIMUM THERMAL STRESS, PSI= 20557

AVERAGE TUBE SURFACE TEMP = 565
AVERAGE FIN SURFACE TEMP = 592
AVERAGE SURFACE TEMP (CONVECTION) = 569
AVERAGE SURFACE TEMP (RADIATION) = 571
AVERAGE CAVITY WALL TEMP = 534

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 526
PASS #2 OUTLET TEMP = 571.8
FLUID AVERAGE TEMP = 495.9

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .618
AVERAGE VISCOSITY, LB/FT-HR = .57
AVERAGE DENSITY, LB/CU-FT = 44.02
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .06859

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Figure E-6

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RUN SUMMARY,DAY 80  TIME=8:00 A.M.
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APERTURE PLANE ENERGY, KW= 10925
ENERGY ON RECEIVER, KW= 10717.716
ENERGY APERTURE CUT-OFF, KW= 135.470001
ENERGY MISSING PANELS, KW= 71.814
ABSORPTIVITY LOSS, KW= 105.653
CONVECTION LOSS, KW= 480.447
CONDUCTION LOSS, KW= 50.31
RADIATION LOSS, KW= 299.536
ENERGY TO FLUID, KW= 9781.775

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 89.54

MAX OIL TEMPERATURE, DEG-F= 585.7
MAX FIN TEMPERATURE, DEG-F= 679.9
MAX FRONT TEMPERATURE, DEG-F= 626.7
MAX BACK TEMPERATURE, DEG-F= 576.2

MAXIMUM THERMAL STRESS, PSI= 20645

AVERAGE TUBE SURFACE TEMP = 551
AVERAGE FIN SURFACE TEMP = 575
AVERAGE SURFACE TEMP (CONVECTION) = 554
AVERAGE SURFACE TEMP (RADIATION) = 557
AVERAGE CAVITY WALL TEMP = 522

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 514
PASS #2 OUTLET TEMP = 556.8
FLUID AVERAGE TEMP = 488.4

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .614
AVERAGE VISCOSITY, LB/FT-HR = .588
AVERAGE DENSITY, LB/CU-FT = 44.27
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .06878

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Figure E-7

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RUN SUMMARY,DAY 173  TIME=12:00 NOON
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APERTURE PLANE ENERGY, KW= 11509
ENERGY ON RECEIVER, KW= 11236.338
ENERGY APERTURE CUT-OFF, KW= 171.484101
ENERGY MISSING PANELS, KW= 101.178
ABSORPTIVITY LOSS, KW= 110.102
CONVECTION LOSS, KW= 486.525
CONDUCTION LOSS, KW= 50.937
RADIATION LOSS, KW= 306.938
ENERGY TO FLUID, KW= 10281.832

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 89.34

MAX OIL TEMPERATURE, DEG-F= 580
MAX FIN TEMPERATURE, DEG-F= 634.6
MAX FRONT TEMPERATURE, DEG-F= 618.5
MAX BACK TEMPERATURE, DEG-F= 579

MAXIMUM THERMAL STRESS, PSI= 17125

AVERAGE TUBE SURFACE TEMP = 557
AVERAGE FIN SURFACE TEMP = 582
AVERAGE SURFACE TEMP (CONVECTION) = 561
AVERAGE SURFACE TEMP (RADIATION) = 563
AVERAGE CAVITY WALL TEMP = 528

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 517.5
PASS #2 OUTLET TEMP = 563.4
FLUID AVERAGE TEMP = 491.7

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .616
AVERAGE VISCOSITY, LB/FT-HR = .58
AVERAGE DENSITY, LB/CU-FT = 44.16
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .0687
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Figure E-8

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         RUN SUMMARY,DAY 173  TIME=10:00 A.M.
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APERTURE PLANE ENERGY, KW= 11118
ENERGY ON RECEIVER, KW= 10830.293
ENERGY APERTURE CUT-OFF, KW= 194.565001
ENERGY MISSING PANELS, KW= 93.142
ABSORPTIVITY LOSS, KW= 106.428
CONVECTION LOSS, KW= 482.192
CONDUCTION LOSS, KW= 50.505
RADIATION LOSS, KW= 301.527
ENERGY TO FLUID, KW= 9889.641

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 88.95

MAX OIL TEMPERATURE, DEG-F= 577.7
MAX FIN TEMPERATURE, DEG-F= 644
MAX FRONT TEMPERATURE, DEG-F= 615.4
MAX BACK TEMPERATURE, DEG-F= 576.2

MAXIMUM THERMAL STRESS, PSI= 17956

AVERAGE TUBE SURFACE TEMP = 553
AVERAGE FIN SURFACE TEMP = 577
AVERAGE SURFACE TEMP (CONVECTION) = 556
AVERAGE SURFACE TEMP (RADIATION) = 558
AVERAGE CAVITY WALL TEMP = 524

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 513.7
PASS #2 OUTLET TEMP = 558.3
FLUID AVERAGE TEMP = 489.1

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .615
AVERAGE VISCOSITY, LB/FT-HR = .586
AVERAGE DENSITY, LB/CU-FT = 44.25
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .06876

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Figure E-9

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            RUN SUMMARY,DAY 173  TIME=8:00 A.M.
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APERTURE PLANE ENERGY, KW= 9971
ENERGY ON RECEIVER, KW= 9695.801
ENERGY APERTURE CUT-OFF, KW= 257.251797
ENERGY MISSING PANELS, KW= 17.948
ABSORPTIVITY LOSS, KW= 95.624
CONVECTION LOSS, KW= 469.531
CONDUCTION LOSS, KW= 49.222
RADIATION LOSS, KW= 285.731
ENERGY TO FLUID, KW= 8795.696

RECEIVER SURFACE AREA = 1627.17
VIEW FACTOR TO APERTURE = .165
RECEIVER EFFICIENCY, %= 88.21

MAX OIL TEMPERATURE, DEG-F= 569.9
MAX FIN TEMPERATURE, DEG-F= 653.4
MAX FRONT TEMPERATURE, DEG-F= 605.2
MAX BACK TEMPERATURE, DEG-F= 567

MAXIMUM THERMAL STRESS, PSI= 18120

AVERAGE TUBE SURFACE TEMP = 539
AVERAGE FIN SURFACE TEMP = 560
AVERAGE SURFACE TEMP (CONVECTION) = 542
AVERAGE SURFACE TEMP (RADIATION) = 544
AVERAGE CAVITY WALL TEMP = 513

FLUID INLET TEMP = 420
PASS #1 OUTLET TEMP = 502.5
PASS #2 OUTLET TEMP = 543.7
FLUID AVERAGE TEMP = 481.8

TOTAL PANEL SET FLOW RATE, GPM = 1064

AVERAGE SPECIFIC HEAT, BTU/LB-DEG-F = .611
AVERAGE VISCOSITY, LB/FT-HR = .603
AVERAGE DENSITY, LB/CU-FT = 44.49
AVERAGE CONDUCTIVITY, BTU/FT-HR-DEG-F = .06895


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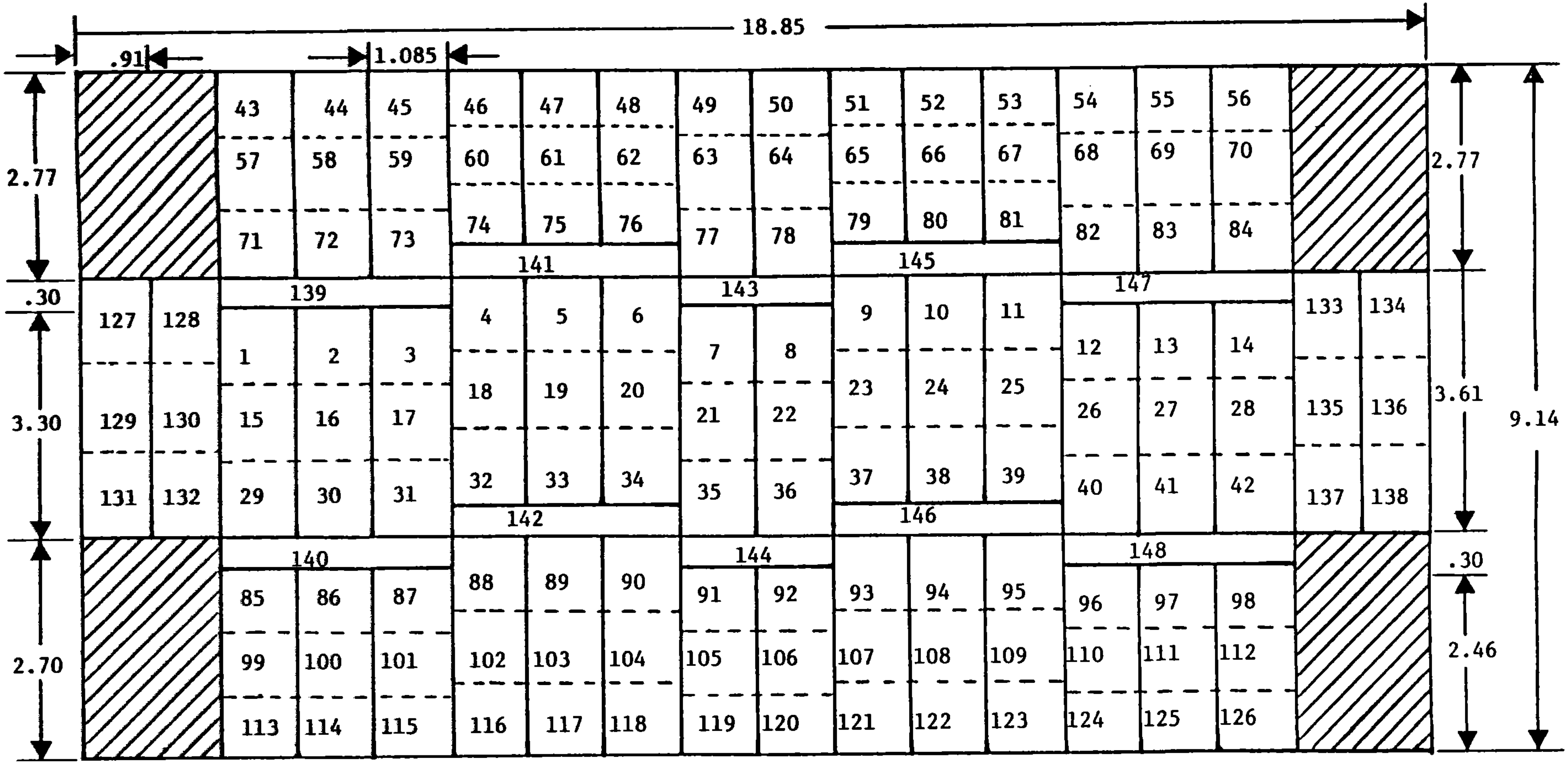
Figure E-10

THERMAL NETWORK NODE BREAKDOWN



Note: Dimensions shown are in meters. Multiply by 3.2808 to obtain feet.

Figure E-11
Incident Power, kw
Day 355 Time 12:00

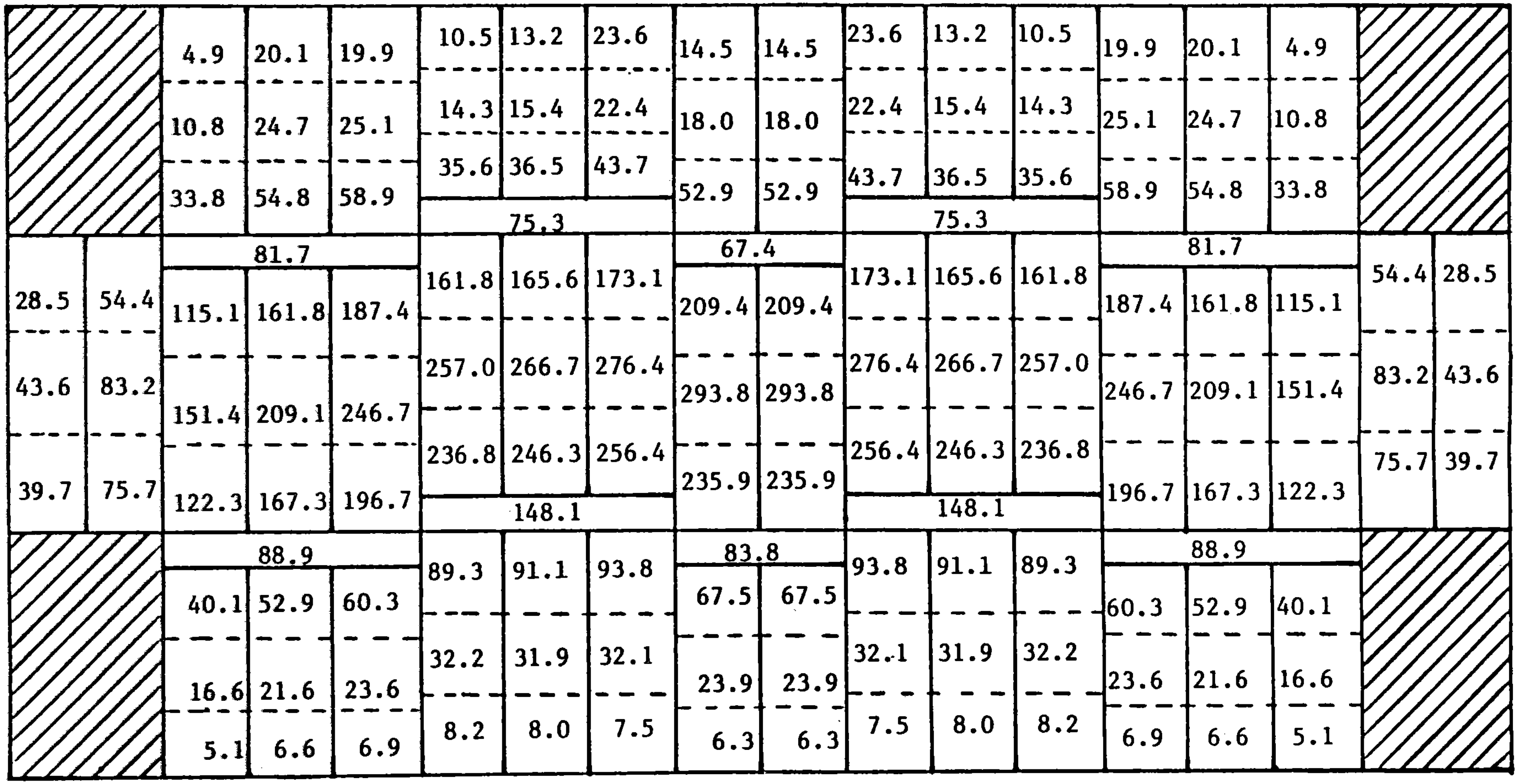
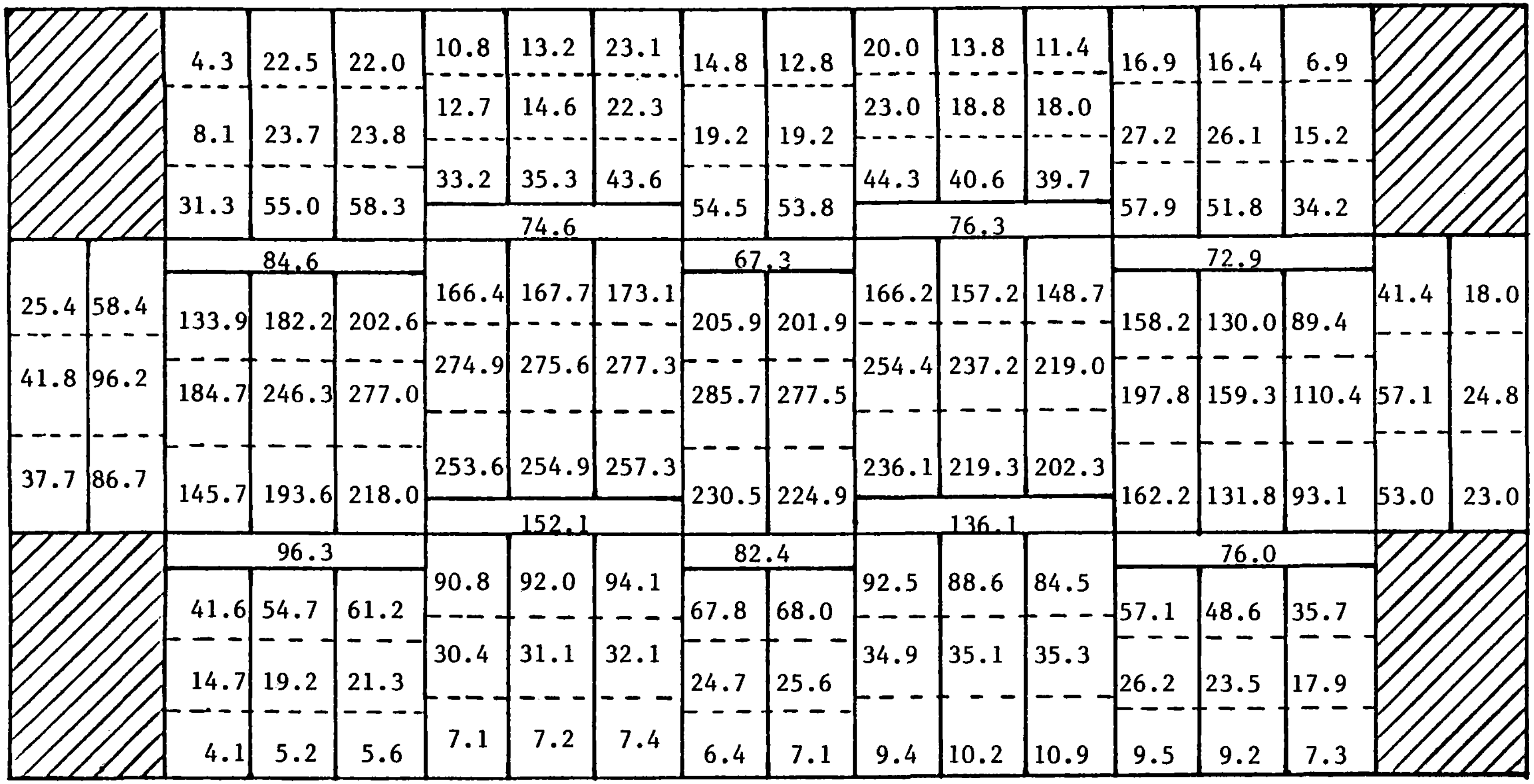


Figure E-12
Incident Power, kw
Day 355 Time 10:00



		4.3	22.5	22.0	10.8	13.2	23.1	14.8	12.8	20.0	13.8	11.4	16.9	16.4	6.9		
		8.1	23.7	23.8	12.7	14.6	22.3	19.2	19.2	23.0	18.8	18.0	27.2	26.1	15.2		
		31.3	55.0	58.3	33.2	35.3	43.6	54.5	53.8	44.3	40.6	39.7	57.9	51.8	34.2		
		84.6			74.6			67.3		76.3			72.9				
25.4	58.4	133.9	182.2	202.6	166.4	167.7	173.1	205.9	201.9	166.2	157.2	148.7	158.2	130.0	89.4	41.4	18.0
41.8	96.2	184.7	246.3	277.0	274.9	275.6	277.3	285.7	277.5	254.4	237.2	219.0	197.8	159.3	110.4	57.1	24.8
37.7	86.7	145.7	193.6	218.0	253.6	254.9	257.3	230.5	224.9	236.1	219.3	202.3	162.2	131.8	93.1	53.0	23.0
		96.3			152.1			82.4		136.1			76.0				
		41.6	54.7	61.2	90.8	92.0	94.1	67.8	68.0	92.5	88.6	84.5	57.1	48.6	35.7		
		14.7	19.2	21.3	30.4	31.1	32.1	24.7	25.6	34.9	35.1	35.3	26.2	23.5	17.9		
		4.1	5.2	5.6	7.1	7.2	7.4	6.4	7.1	9.4	10.2	10.9	9.5	9.2	7.3		

Figure E-13
Incident Power, kw
Day 355 Time 8:00

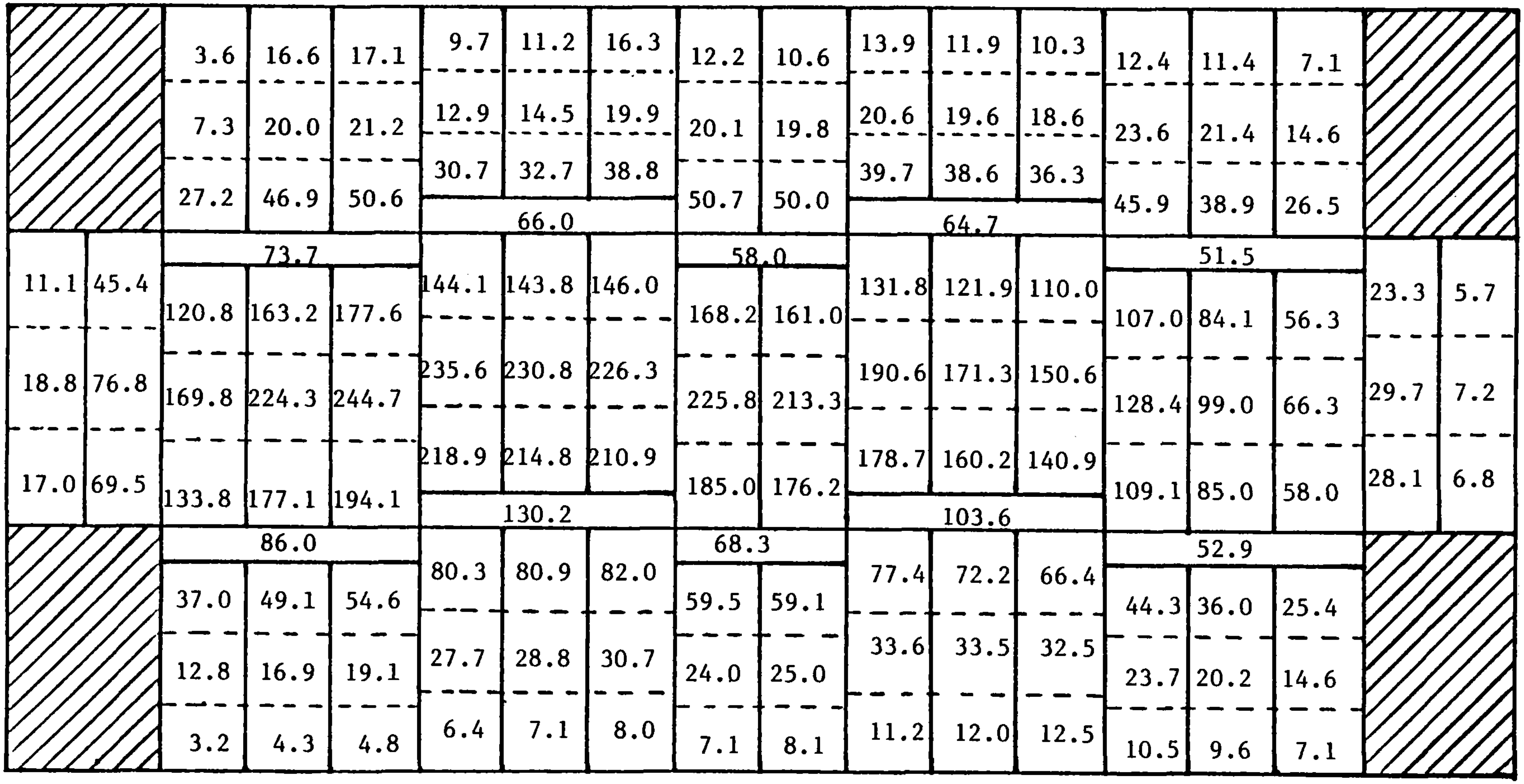


Figure E-14
Incident Power, kw
Day 80 Time 12:00

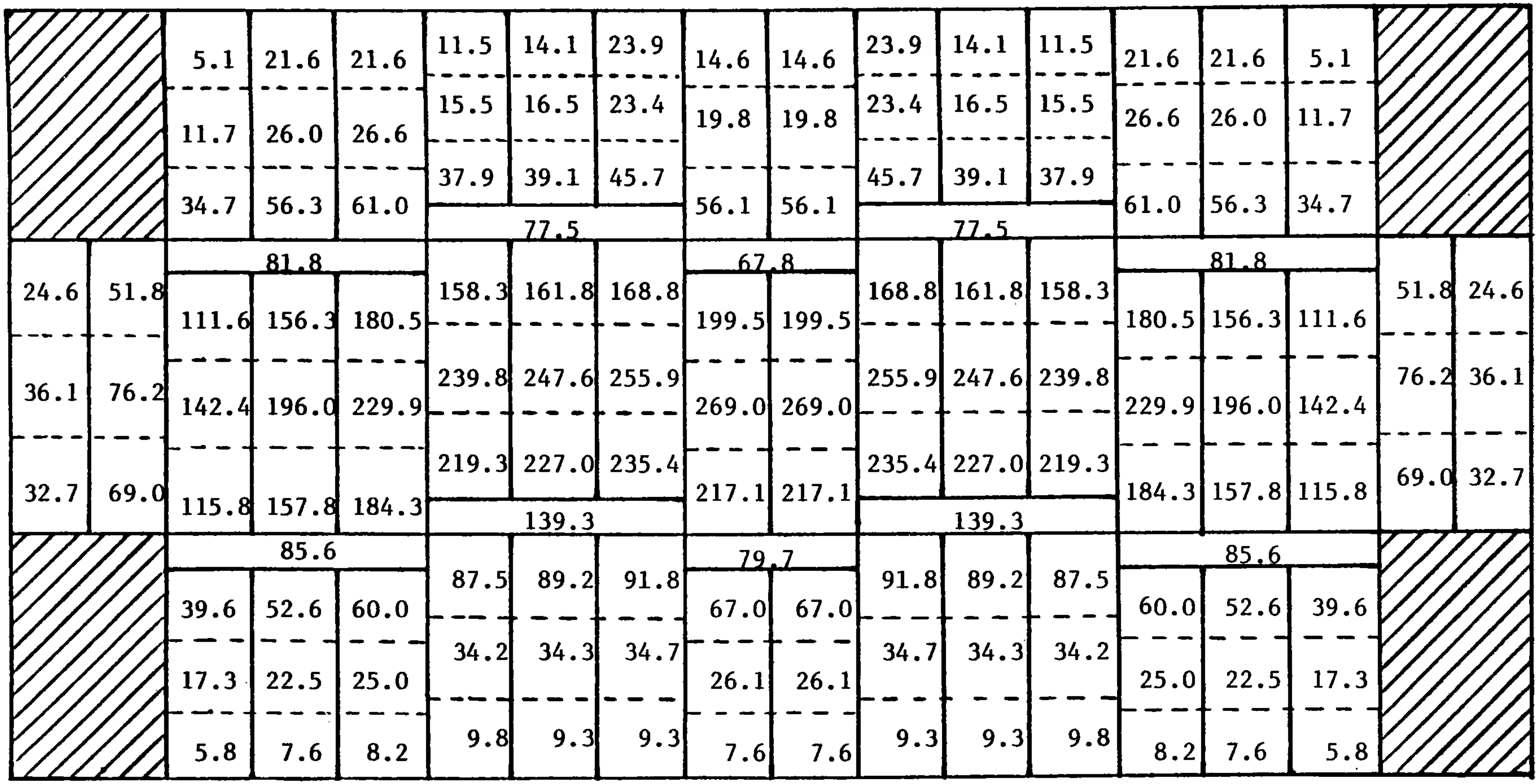


Figure E-15
Incident Power, kw
Day 80 Time 10:00

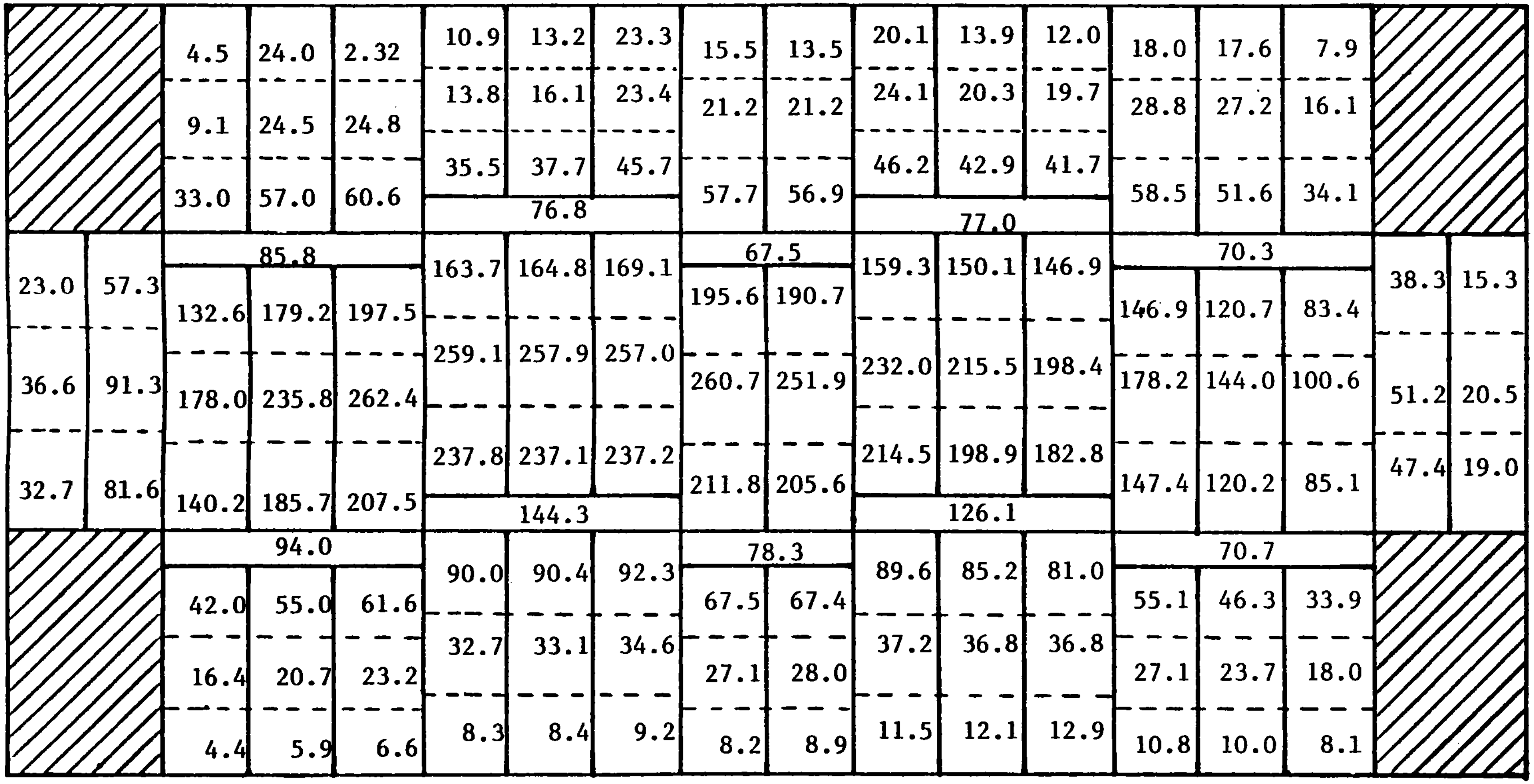


Figure E-16
Incident Power, kw
Day 80 Time 8:00

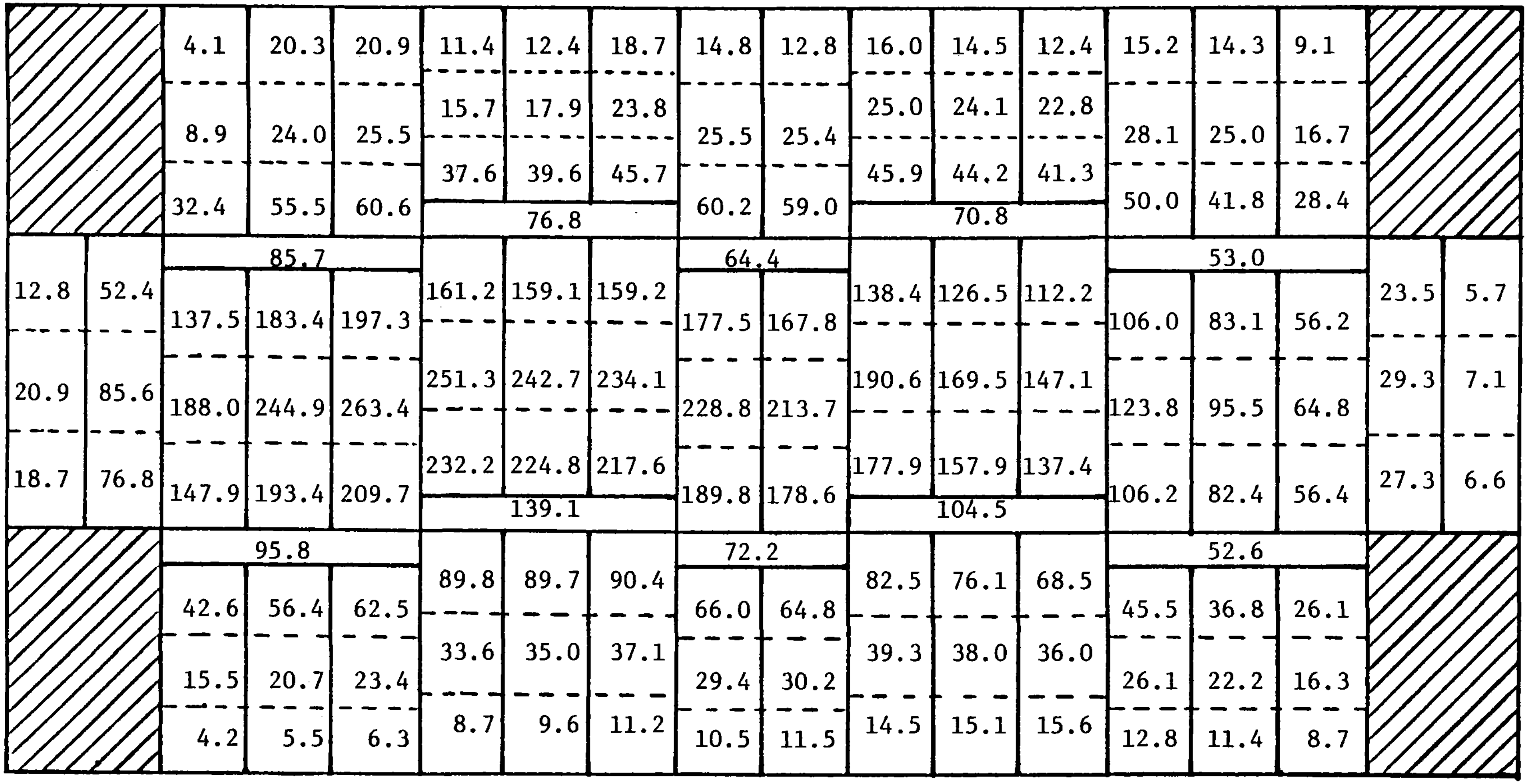


Figure E-17
Incident Power, kw
Day 173 Time 12:00

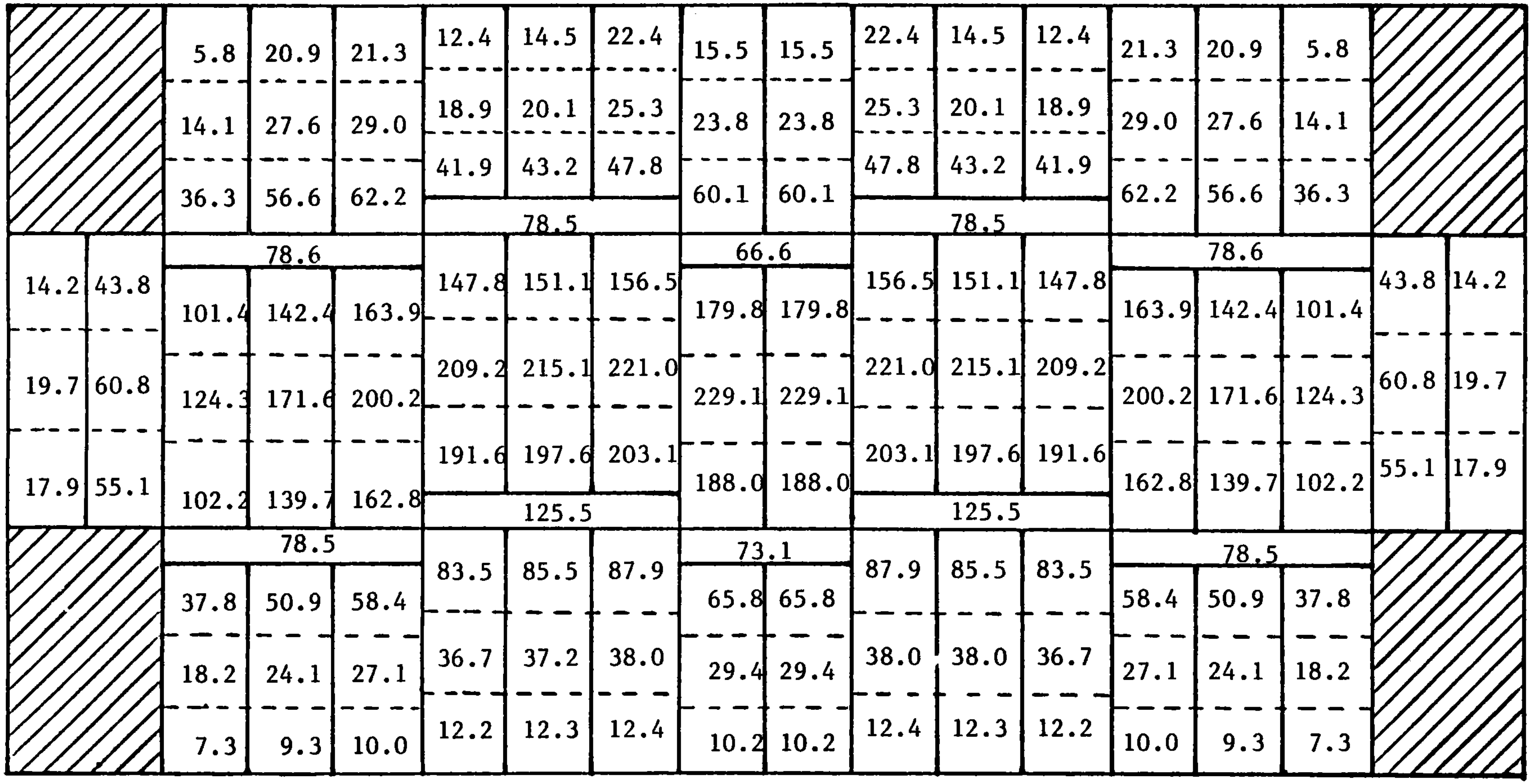


Figure E-18
Incident Power, kw
Day 173 Time 10:00

▨	▨	5.2	22.7	22.5	11.7	13.6	21.7	15.8	14.2	19.2	14.5	13.0	18.3	17.5	8.7	▨	▨
▨	▨	11.1	26.5	28.2	17.6	19.2	25.2	25.1	25.1	26.0	23.2	22.4	30.7	28.2	16.9	▨	▨
▨	▨	35.2	58.3	63.5	40.6	42.2	47.8	61.2	60.2	47.7	45.1	43.5	57.9	50.4	33.4	▨	▨
		83.9			78.6			65.4		75.7			65.9				
10.7	46.3	119.5	164.3	181.5	154.9	154.5	157.0	176.0	170.5	145.4	137.5	129.3	132.2	109.5	75.6	30.9	7.1
15.9	69.2	153.5	206.2	229.2	227.3	225.0	222.8	222.4	214.2	199.3	186.1	172.0	154.6	126.3	88.3	39.6	9.1
14.3	62.1	123.4	165.3	184.5	208.5	206.8	205.1	183.2	177.3	184.0	171.4	158.4	129.4	106.3	75.2	36.5	8.4
		87.2			130.2			71.0		111.8			64.0				
▨	▨	40.9	54.7	61.3	86.7	87.3	88.0	65.2	64.8	84.1	79.8	75.3	52.1	43.8	31.7	▨	▨
▨	▨	17.5	23.5	26.5	36.3	36.7	38.0	30.0	30.6	39.5	38.5	37.8	27.7	23.9	17.8	▨	▨
▨	▨	5.8	7.8	8.9	11.4	11.6	12.3	10.9	11.5	14.3	14.4	14.9	12.2	10.7	8.1	▨	▨

Figure E-19
Incident Power, kw
Day 173 Time 8:00

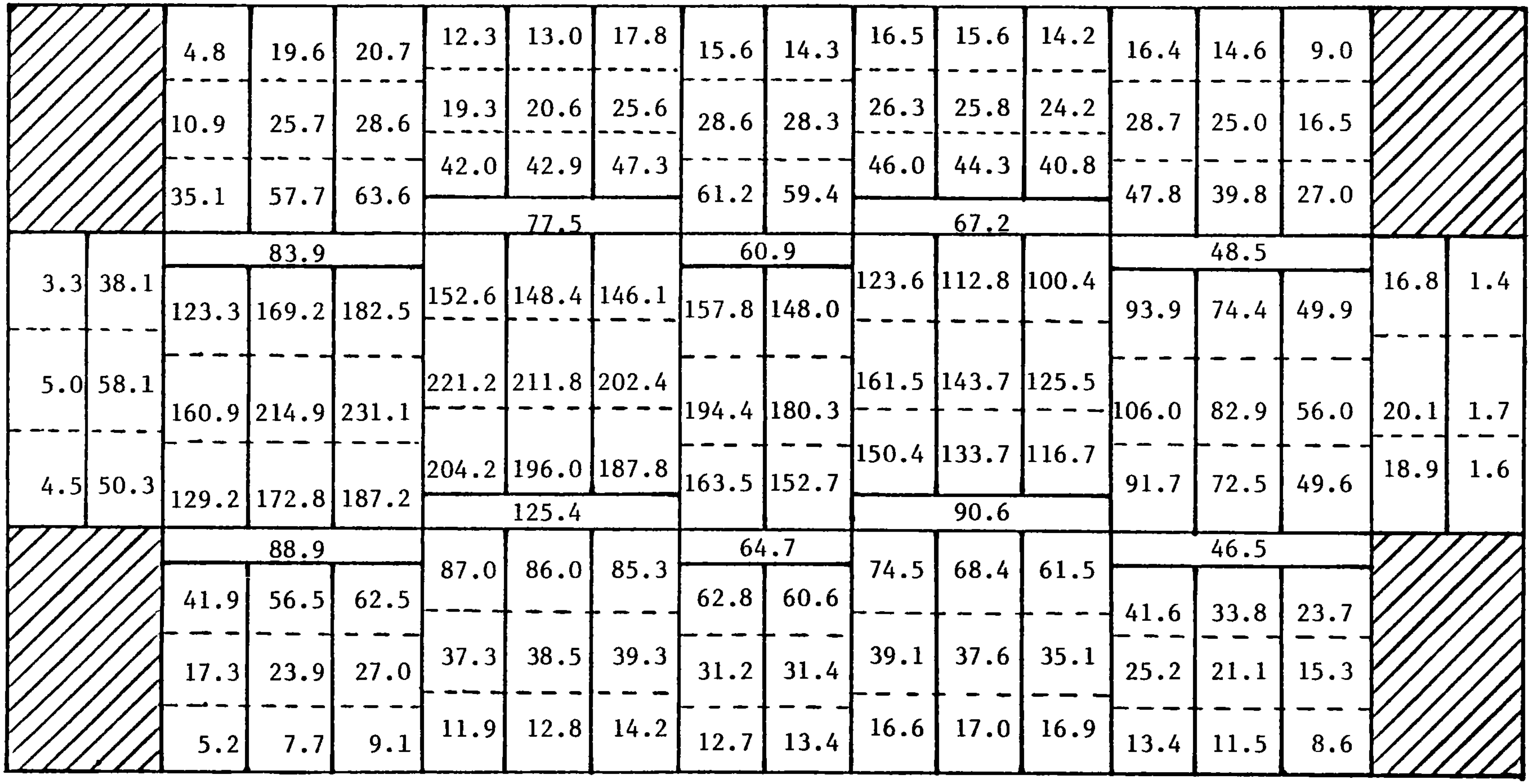
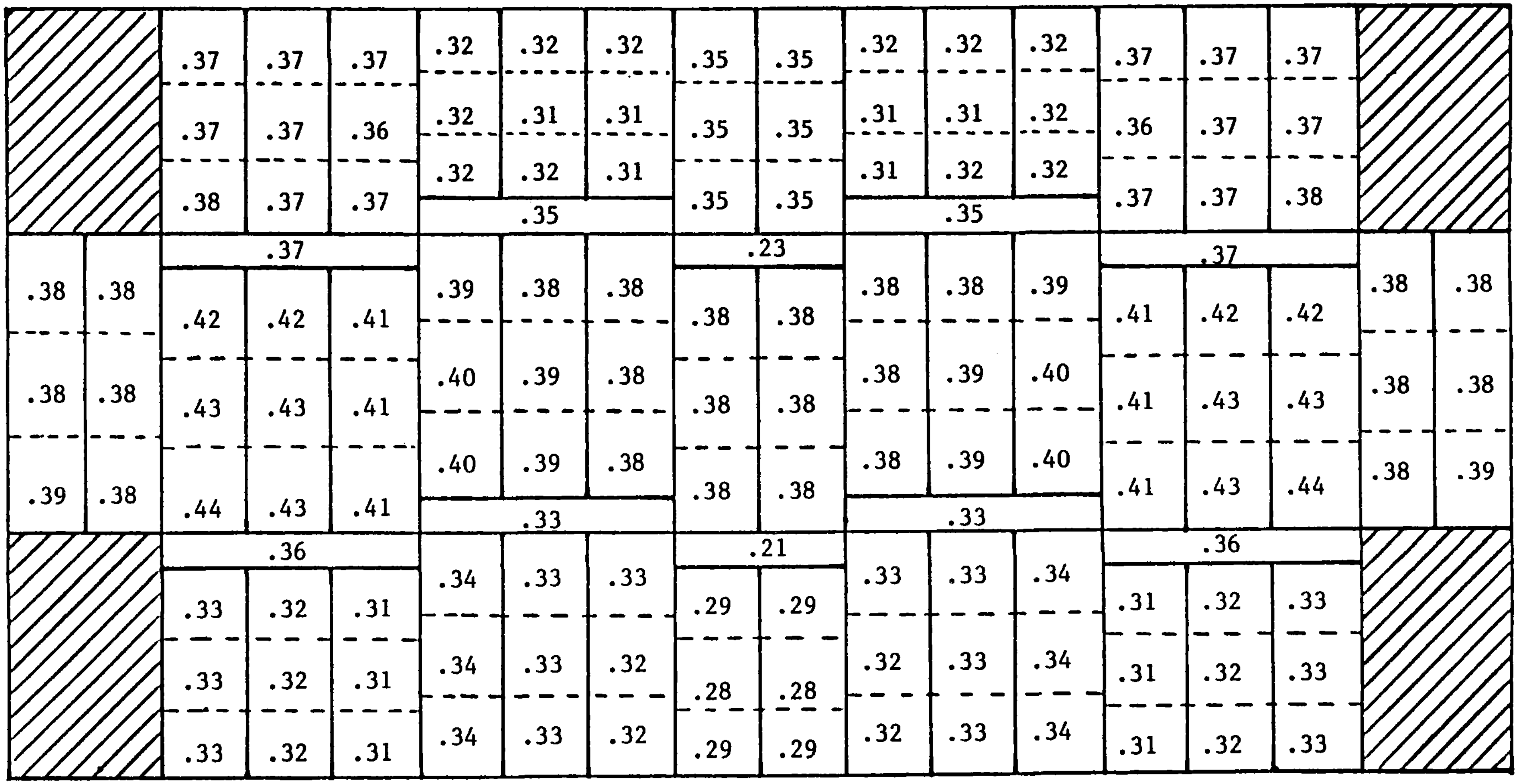


Figure E-20
Conduction Loss, kw
Day 355 Time 12:00



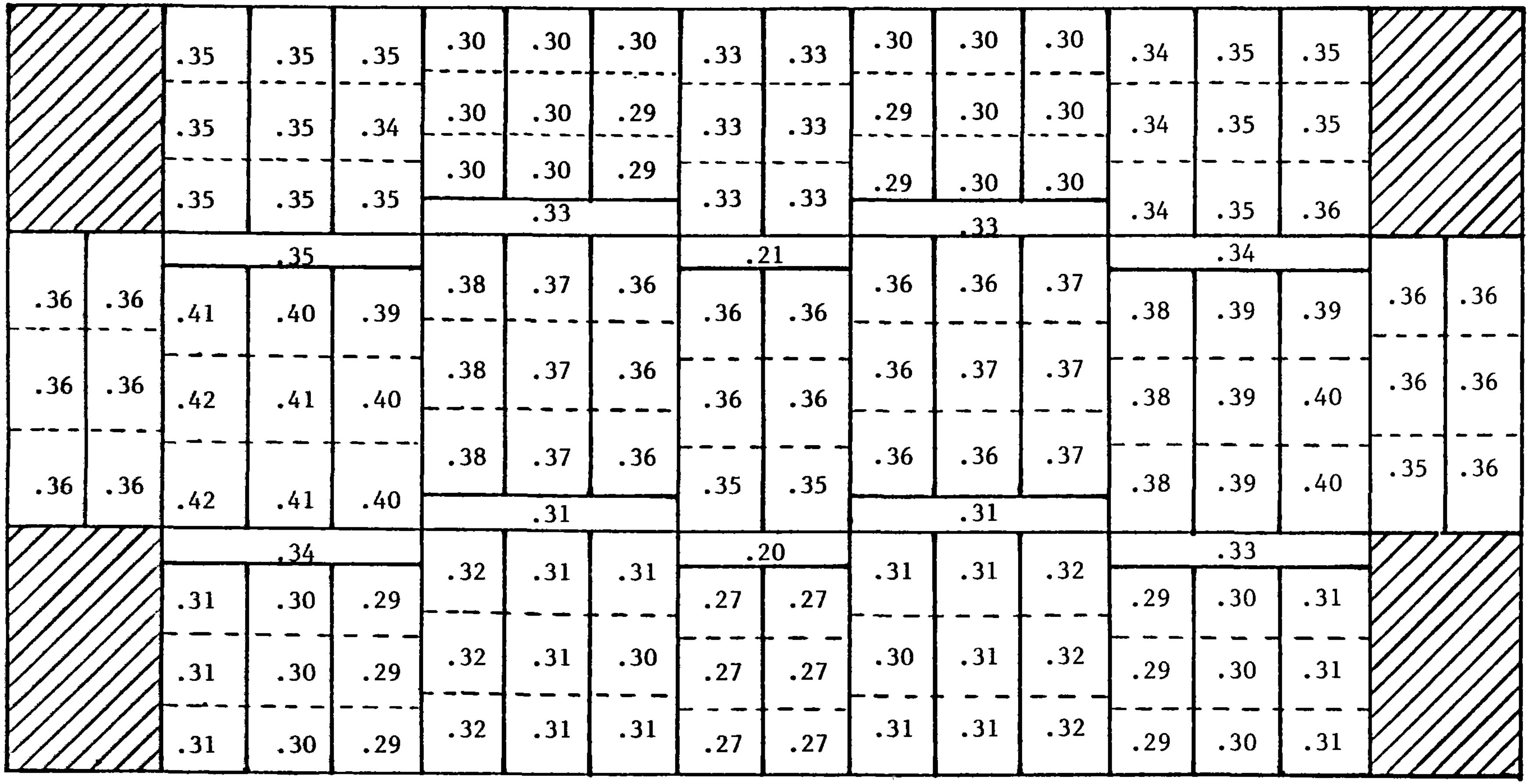
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-21
Conduction Loss, kw
Day 355 Time 10:00

▨	▨	.37	.37	.36	.32	.32	.31	.35	.35	.31	.32	.32	.36	.37	.37	▨	▨
▨	▨	.37	.37	.36	.31	.31	.31	.34	.34	.31	.31	.32	.36	.37	.37	▨	▨
▨	▨	.37	.37	.36	.32	.31	.31	.34	.34	.31	.31	.32	.36	.37	.38	▨	▨
▨	▨				.35					.35						▨	▨
		.37						.22					.37				
.38	.38	.42	.42	.41	.39	.38	.38	.37	.37	.38	.38	.39	.40	.41	.42	.38	.38
.38	.38	.44	.43	.42	.40	.39	.38	.38	.38	.38	.39	.39	.41	.42	.42	.38	.38
.38	.38	.44	.43	.42	.40	.39	.38	.37	.37	.38	.39	.39	.41	.42	.43	.38	.38
					.33					.33							
▨	▨	.36						.21					.36			▨	▨
▨	▨	.33	.32	.31	.34	.33	.32	.28	.28	.32	.33	.34	.31	.32	.32	▨	▨
▨	▨	.32	.32	.31	.34	.33	.32	.28	.28	.32	.33	.34	.31	.32	.32	▨	▨
▨	▨	.32	.32	.31	.34	.33	.32	.28	.28	.32	.33	.34	.31	.32	.32	▨	▨

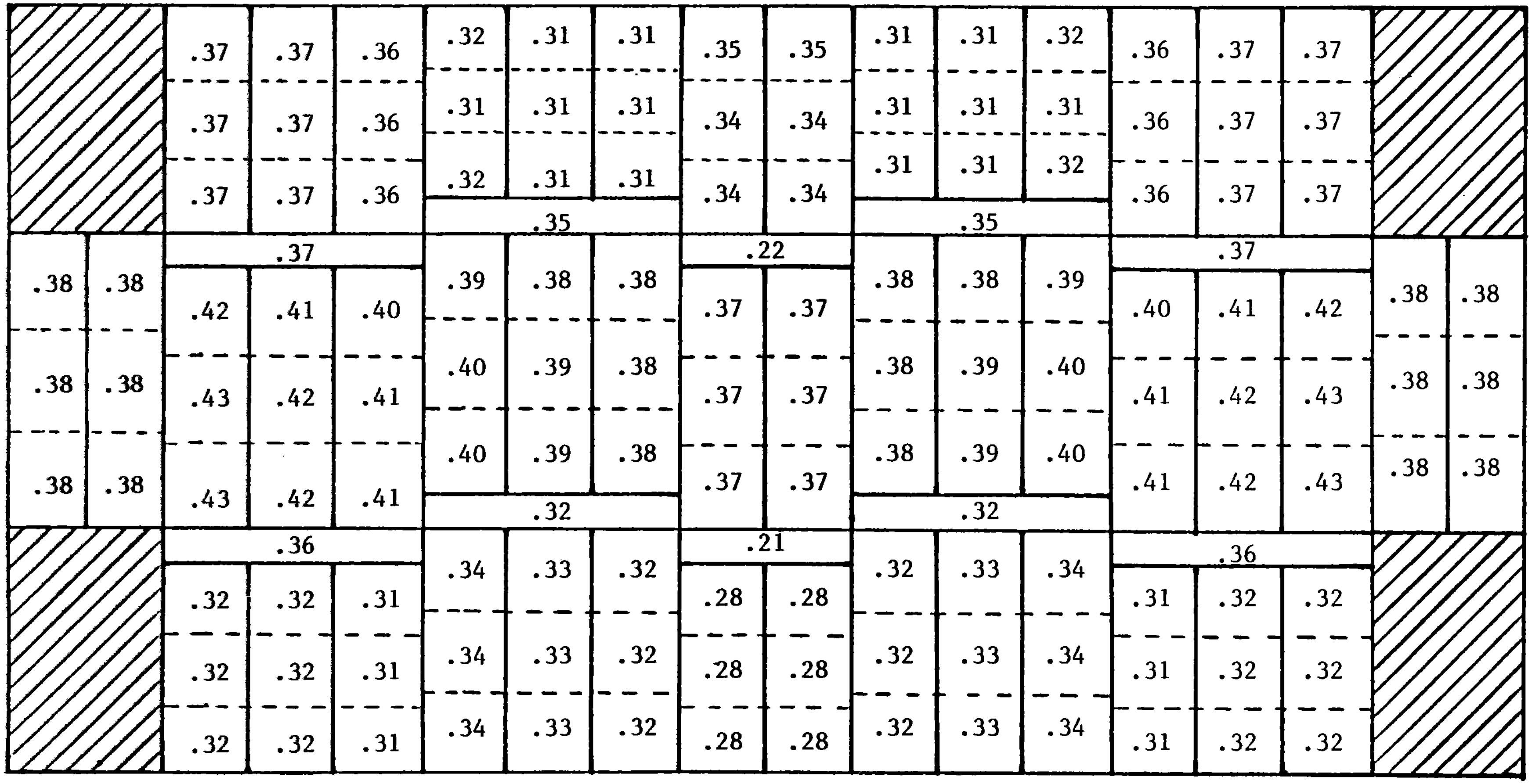
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-22
Conduction Loss, kw
Day 355 Time 8:00



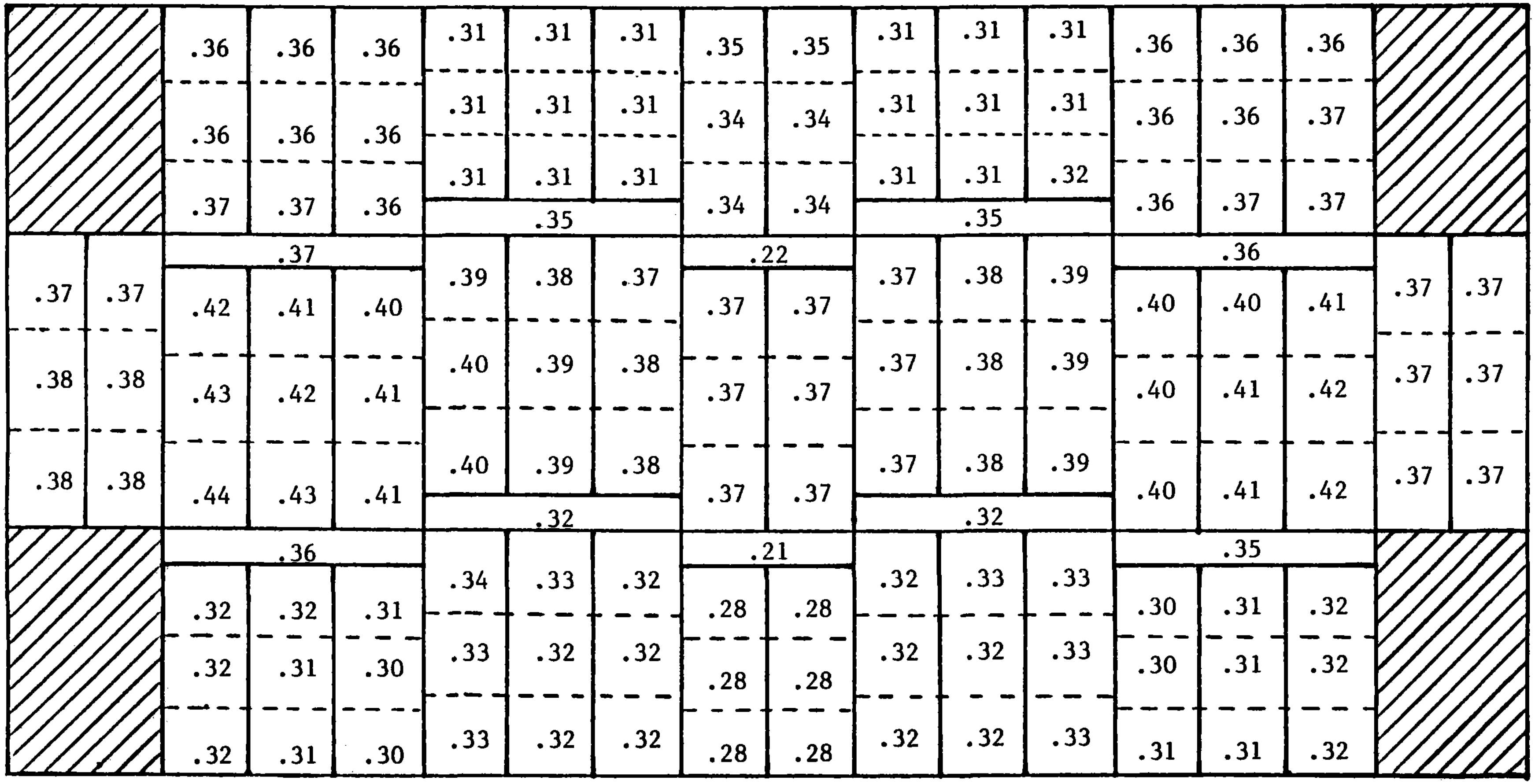
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-23
Conduction Loss, kw
Day 80 Time 12:00



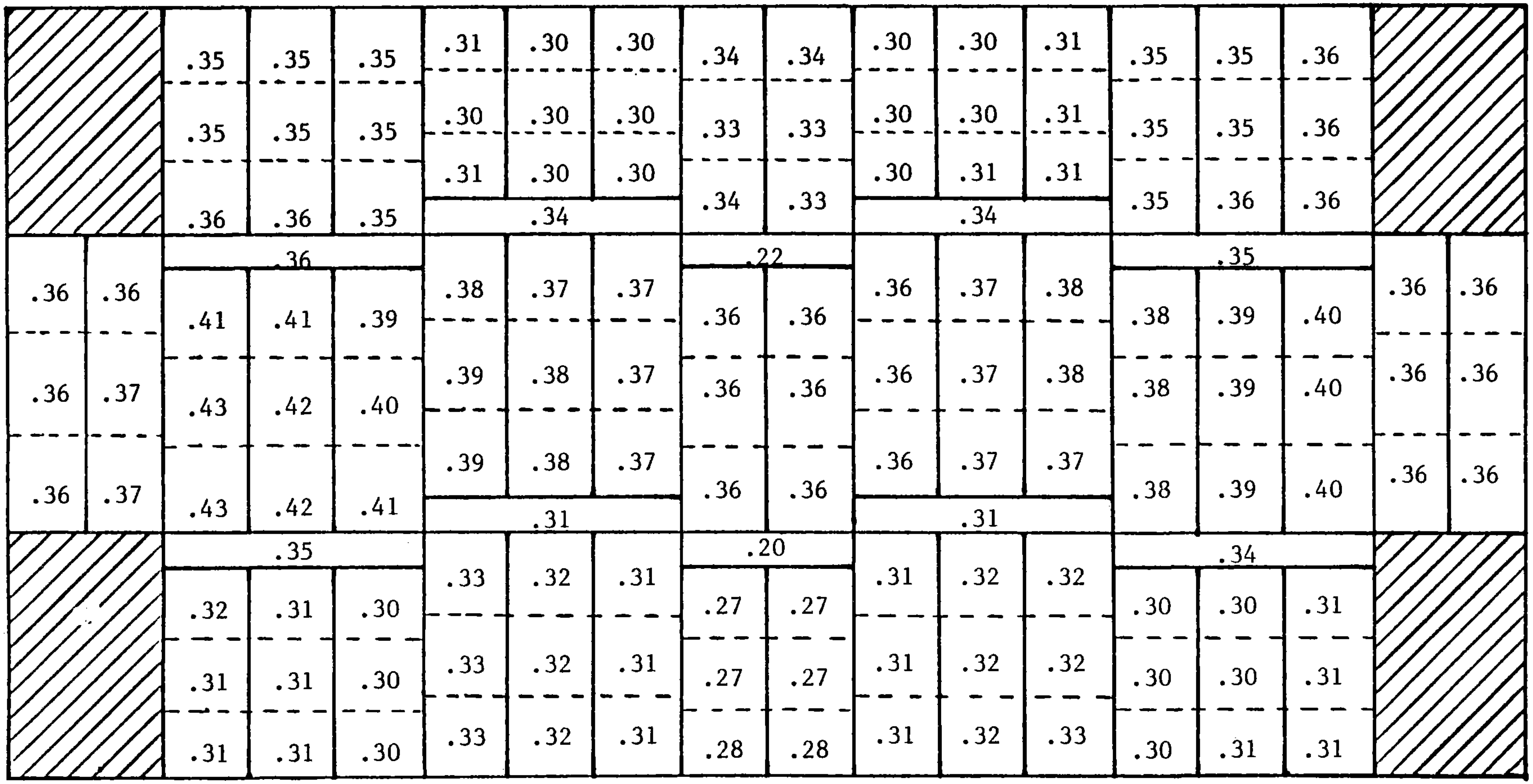
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-24
Conduction Loss, kw
Day 80 Time 10:00



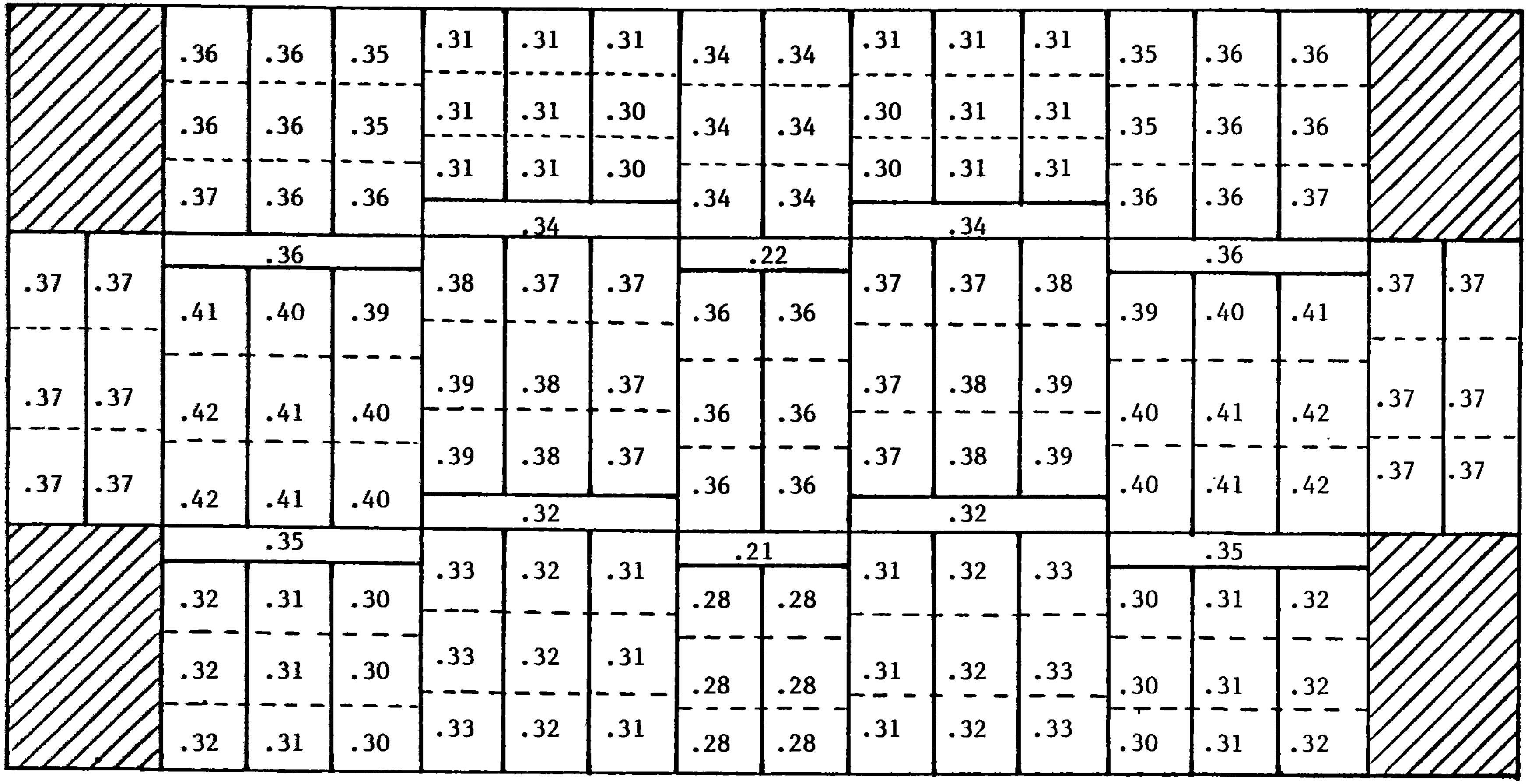
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-25
Conduction Loss, kw
Day 80 Time 8:00



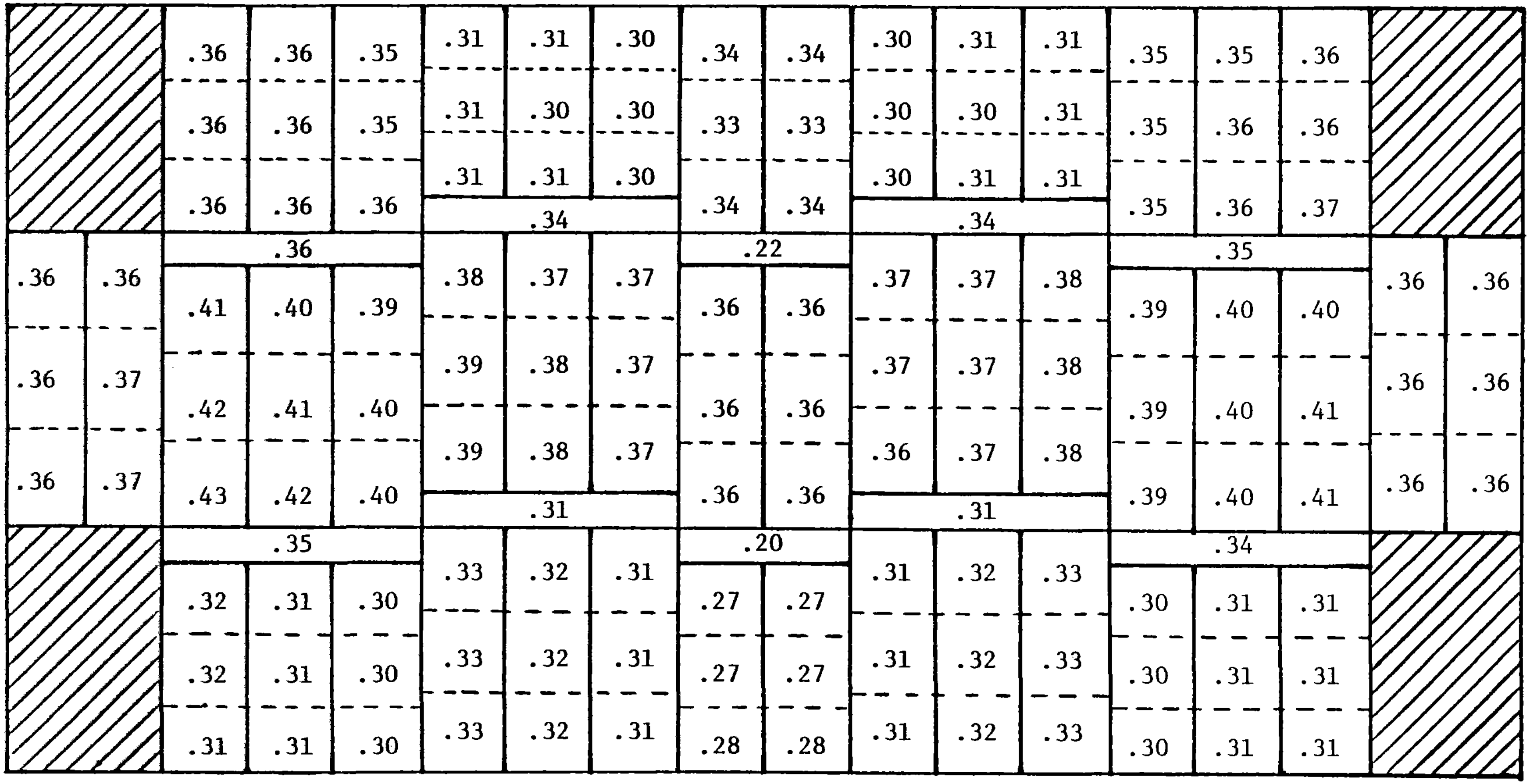
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-26
Conduction Loss, kw
Day 173 Time 12:00



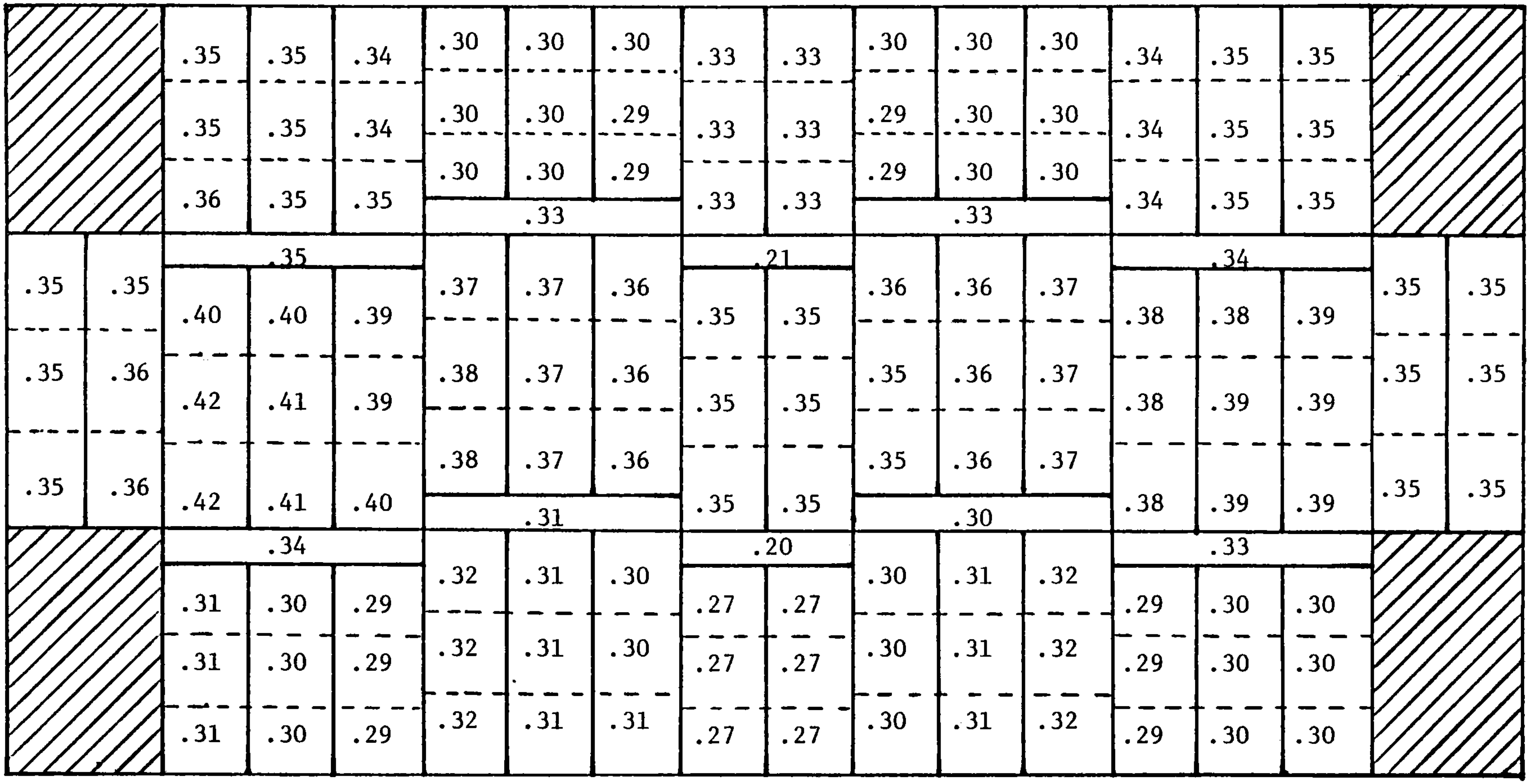
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-27
Conduction Loss, kw
Day 173 Time 10:00



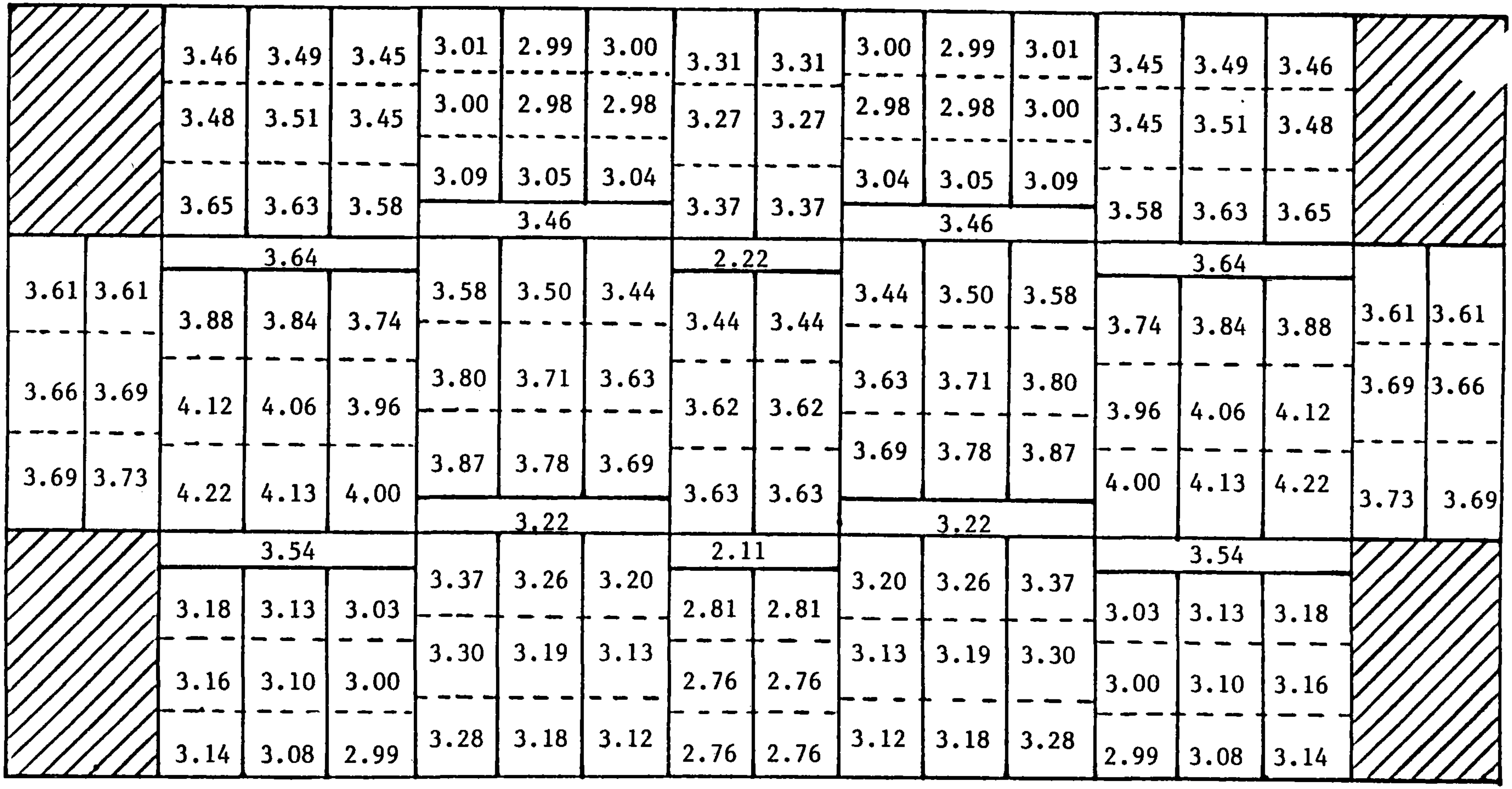
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-28
Conduction Loss, kw
Day 173 Time 8:00



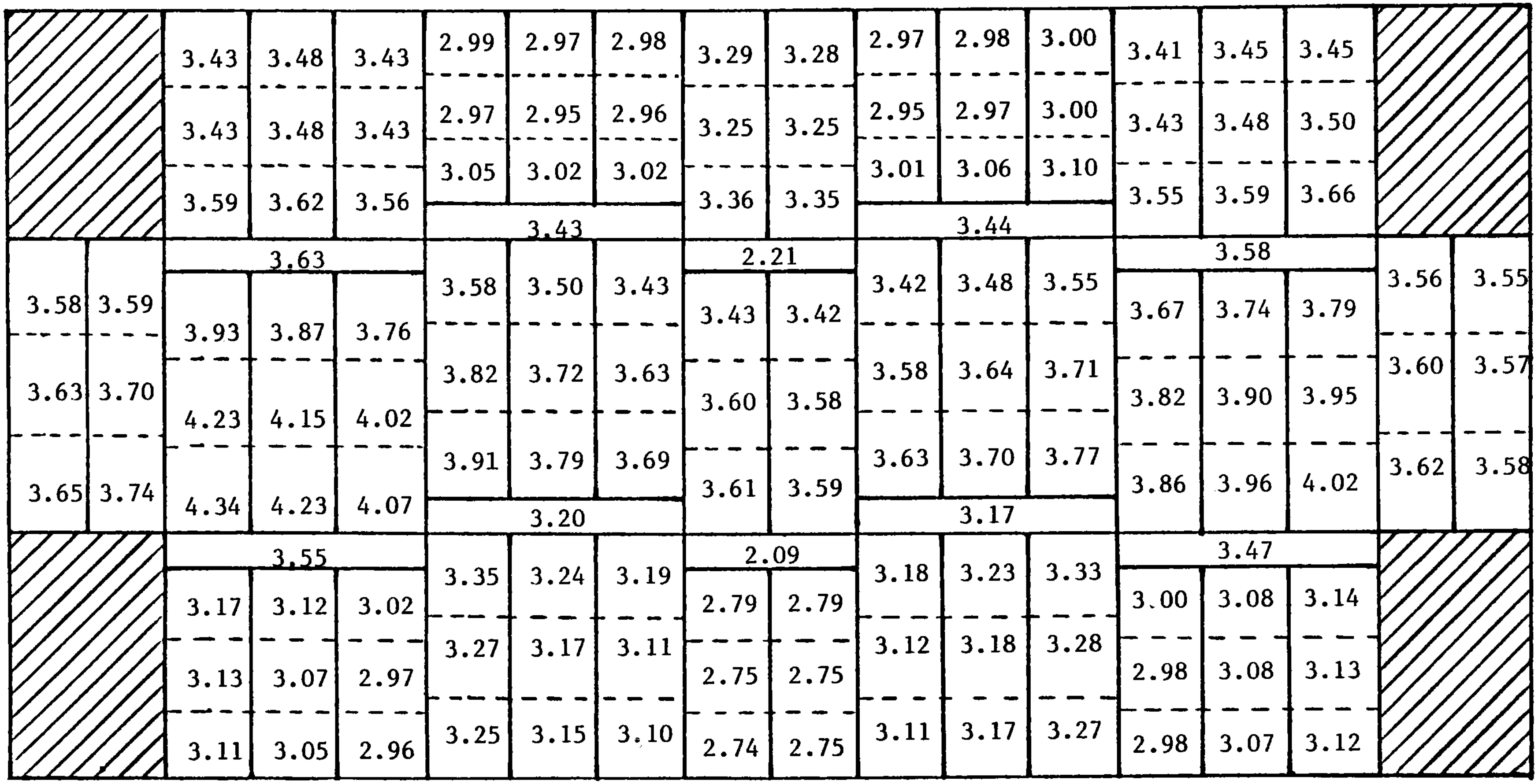
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-29
Convective Loss, kw
Day 355 Time 12:00



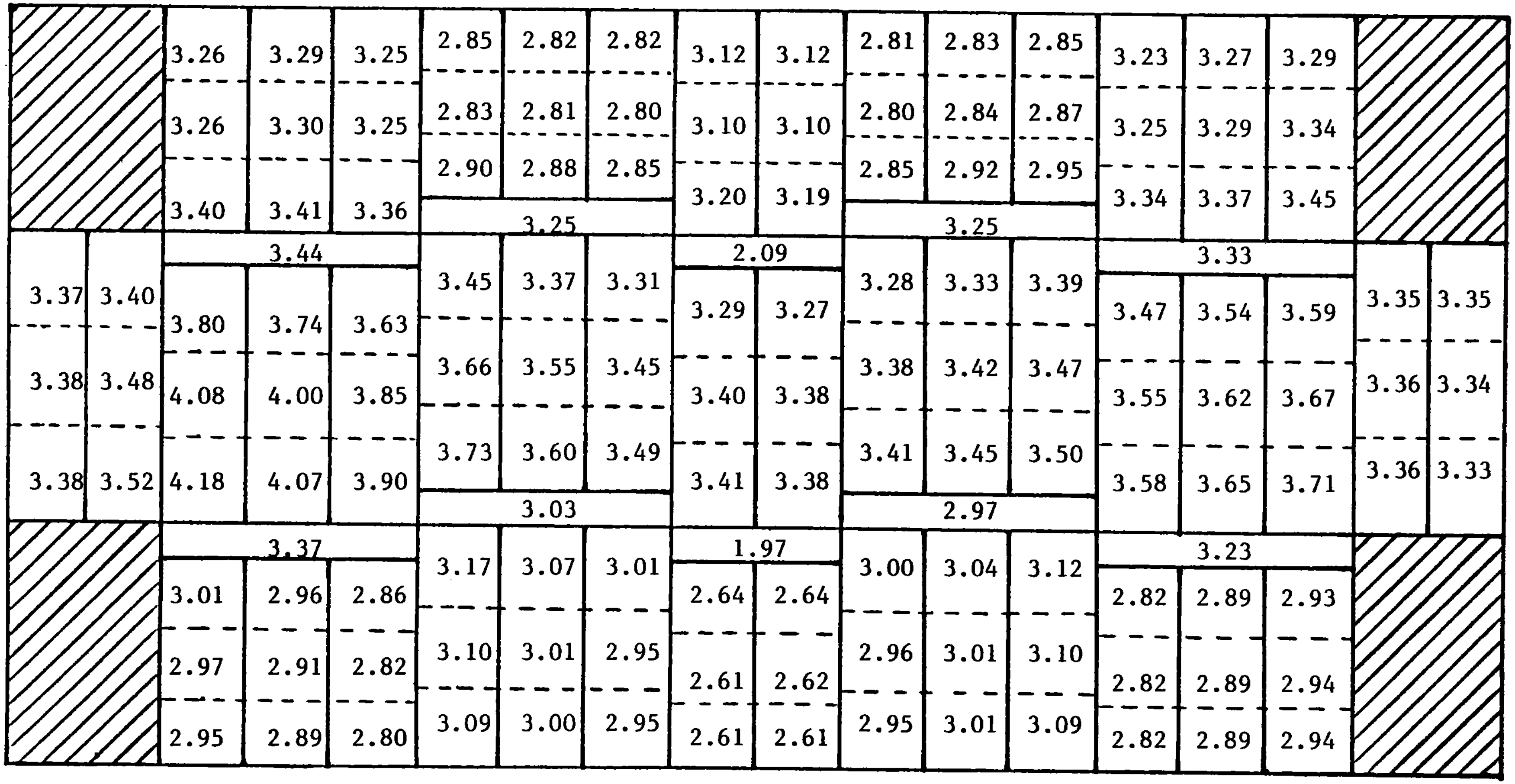
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-30
Convective Loss, kw
Day 355 Time 10:00



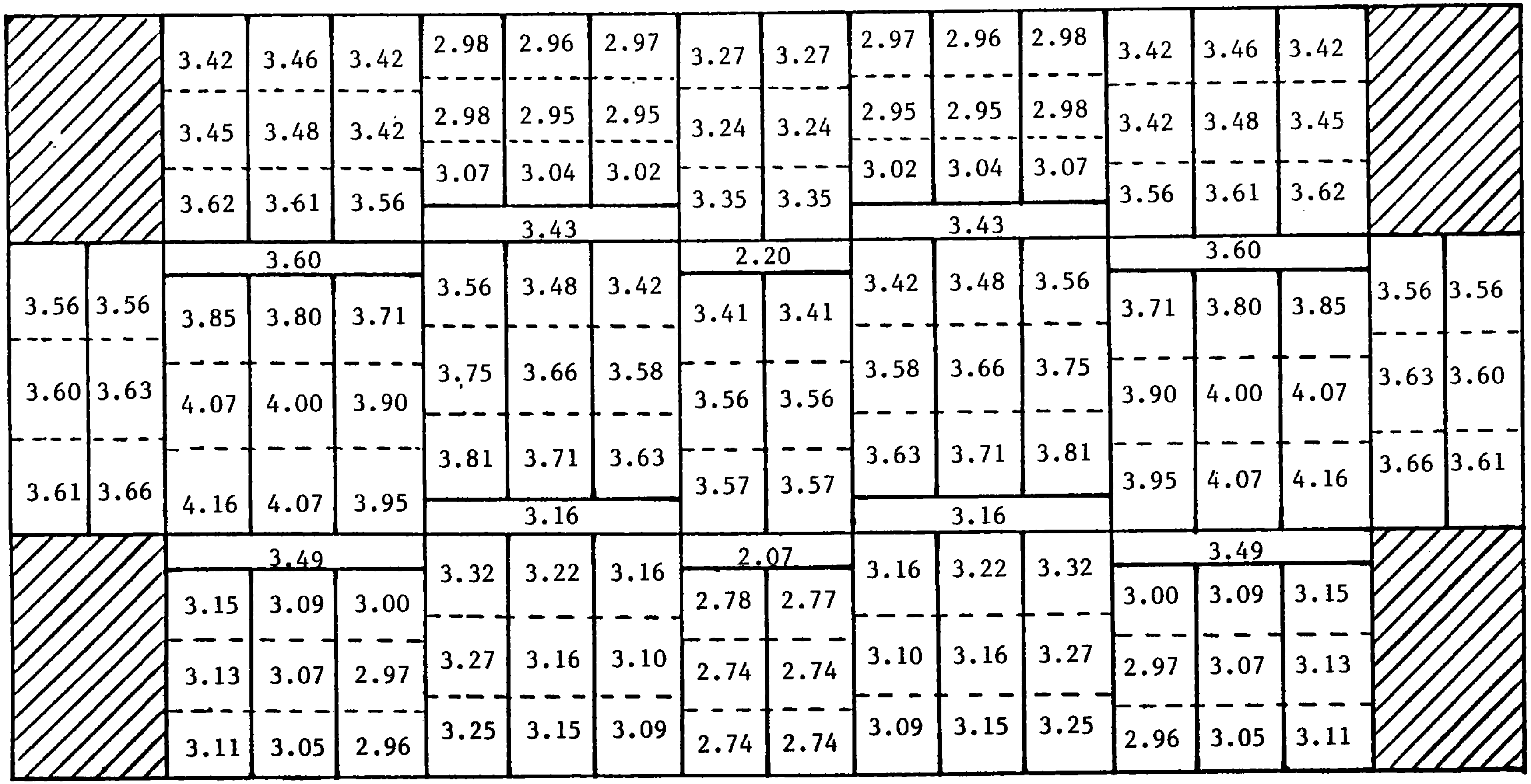
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-31
Convective Loss, kw
Day 355 Time 8:00



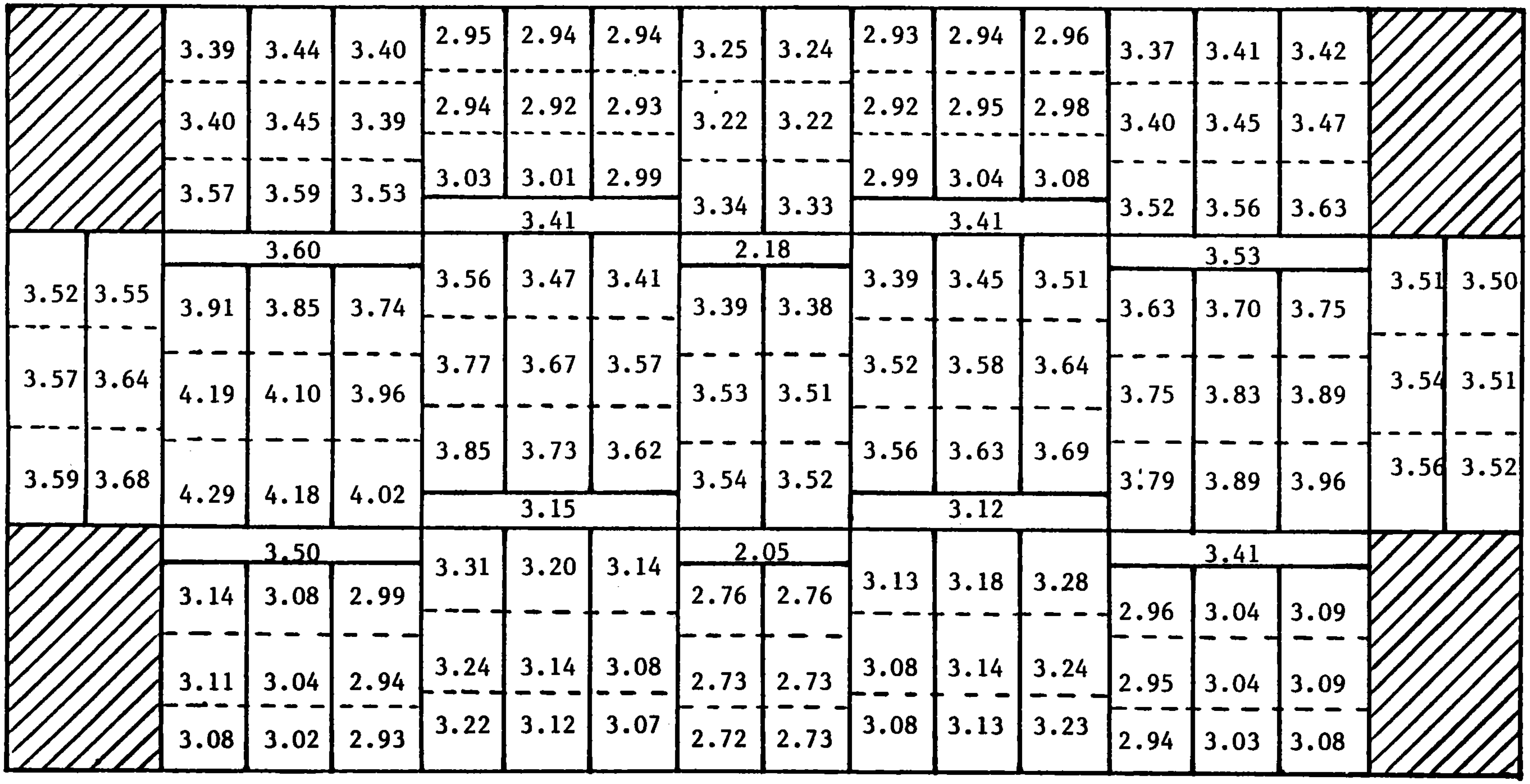
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-32
Convective Loss, kw
Day 80 Time 12:00



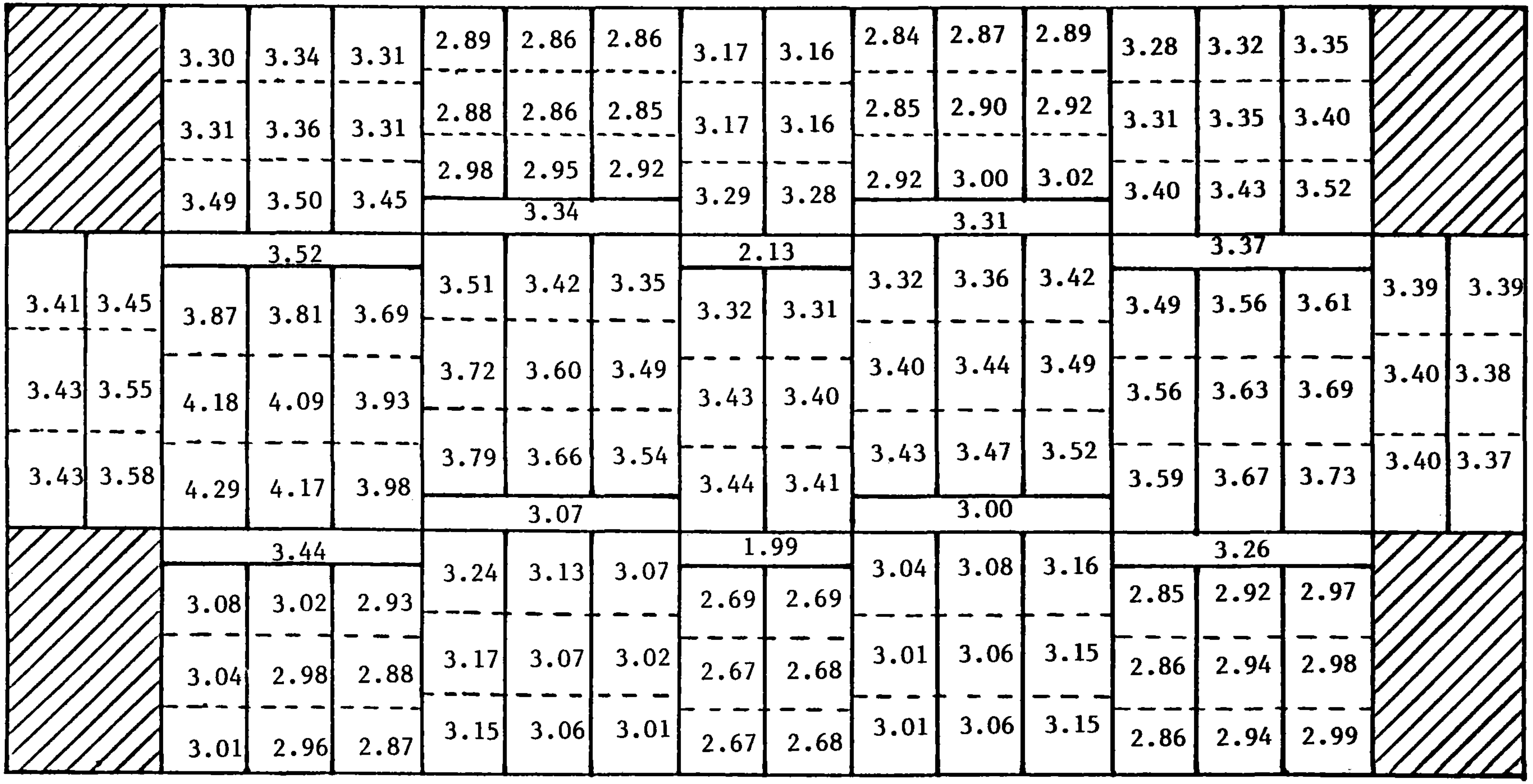
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-33
Convective Loss, kw
Day 80 Time 10:00



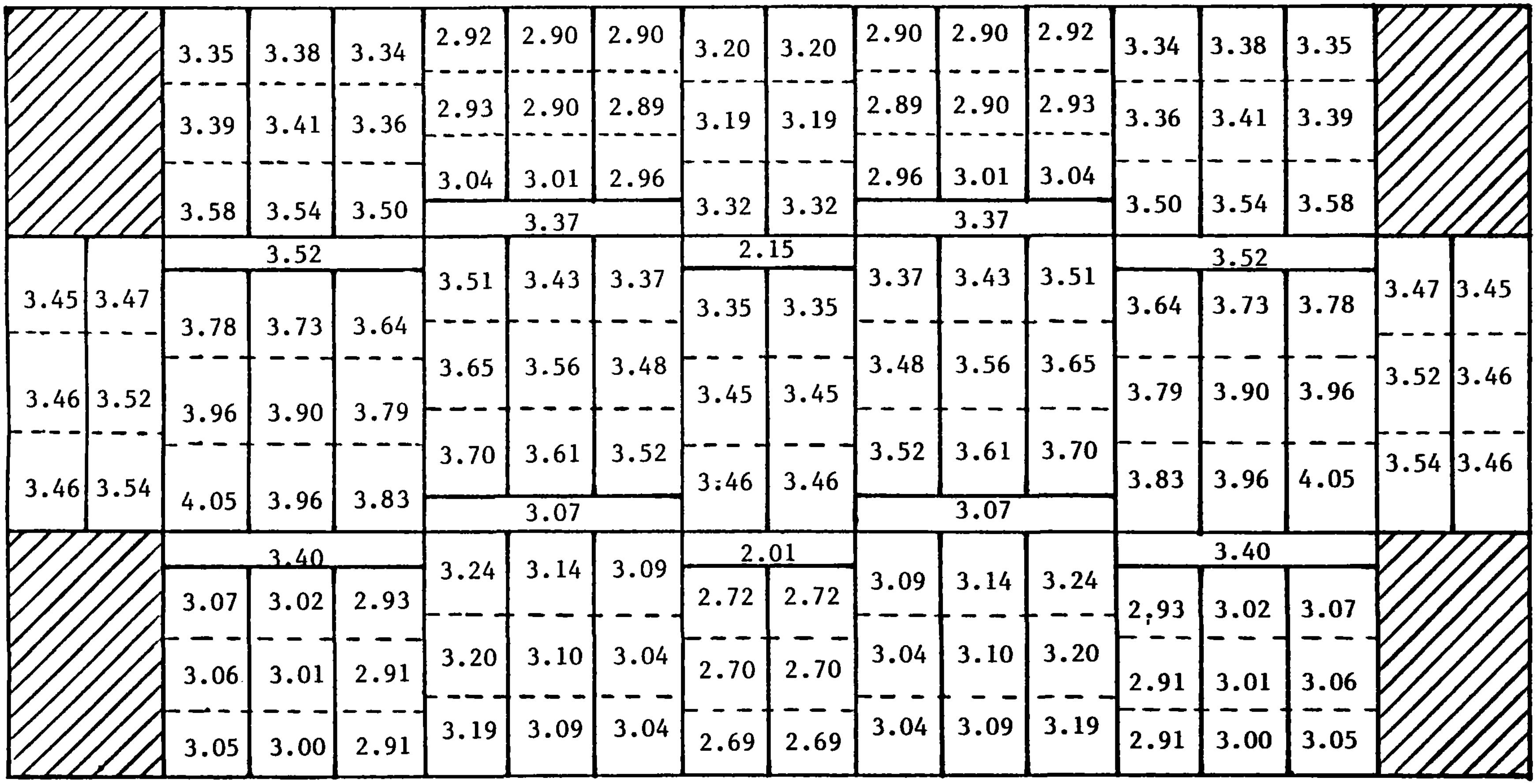
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-34
Convective Loss, kw
Day 80 Time 8:00



*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-35
Convective Loss, kw
Day 173 Time 12:00



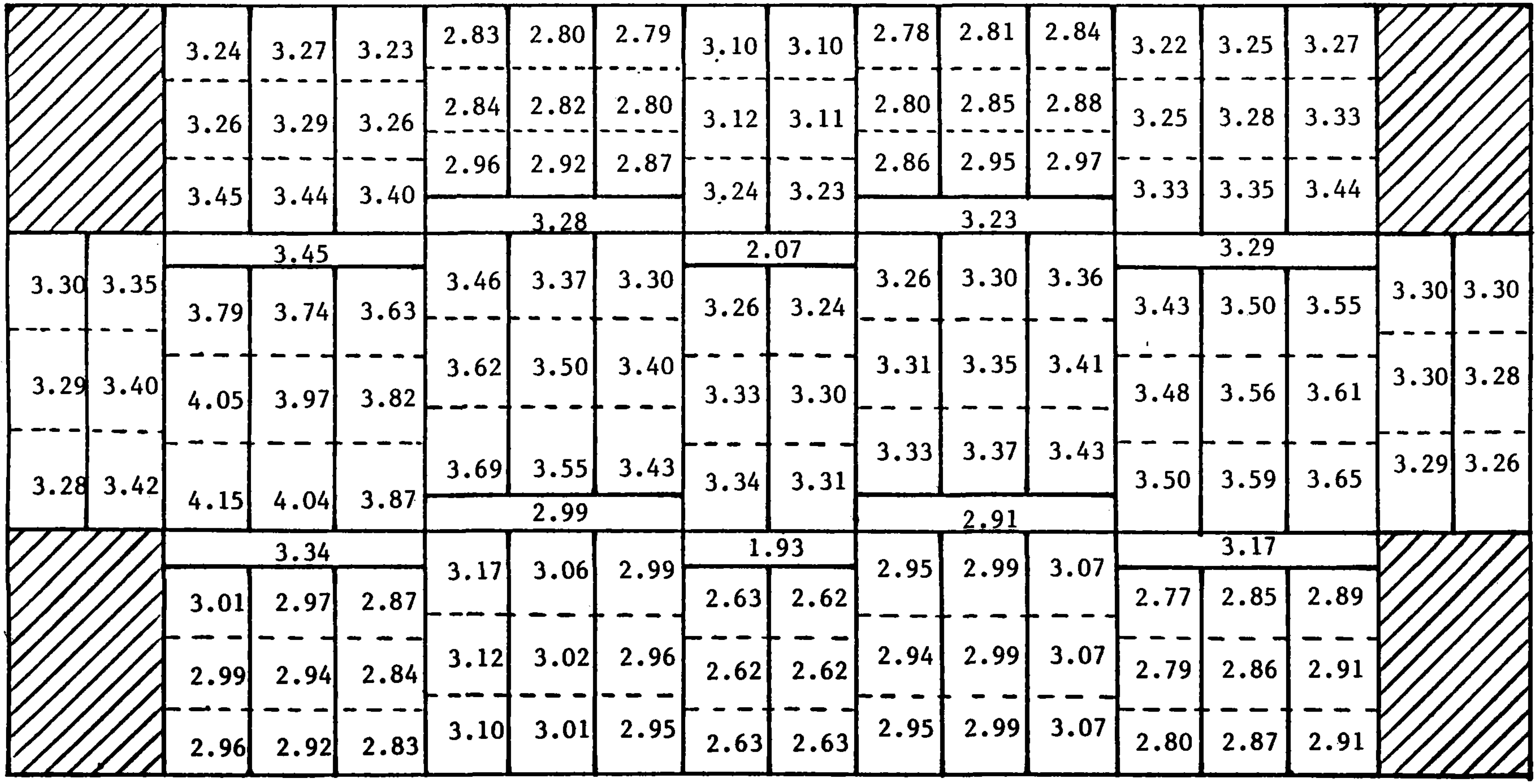
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-36
Convective Loss, kw
Day 173 Time 10:00

▨	▨	3.32	3.36	3.32	2.89	2.87	2.87	3.18	3.17	2.86	2.88	2.90	3.30	3.34	3.35	▨	▨
▨	▨	3.34	3.38	3.33	2.90	2.88	2.87	3.17	3.17	2.87	2.90	2.93	3.33	3.38	3.40	▨	▨
▨	▨	3.53	3.52	3.48	3.01	2.98	2.94	3.30	3.29	2.94	3.00	3.04	3.45	3.48	3.56	▨	▨
▨	▨				3.35					3.34						▨	▨
		3.52						2.13					3.44				
3.41	3.45	3.83	3.77	3.67	3.51	3.42	3.36	3.33	3.32	3.33	3.39	3.46	3.56	3.64	3.68	3.41	3.40
3.42	3.51	4.06	3.99	3.85	3.68	3.57	3.48	3.43	3.41	3.43	3.49	3.55	3.66	3.74	3.80	3.43	3.39
3.41	3.53	4.16	4.06	3.90	3.74	3.62	3.51	3.43	3.41	3.46	3.52	3.59	3.69	3.79	3.86	3.44	3.38
					3.06					3.02							
▨	▨	3.41						1.99					3.31			▨	▨
▨	▨	3.07	3.02	2.92	3.23	3.13	3.07	2.69	2.69	3.05	3.10	3.19	2.88	2.96	3.01	▨	▨
▨	▨	3.05	2.99	2.90	3.18	3.08	3.02	2.68	2.68	3.02	3.07	3.17	2.88	2.97	3.02	▨	▨
▨	▨	3.03	2.98	2.89	3.17	3.07	3.01	2.68	2.68	3.02	3.07	3.16	2.88	2.96	3.01	▨	▨

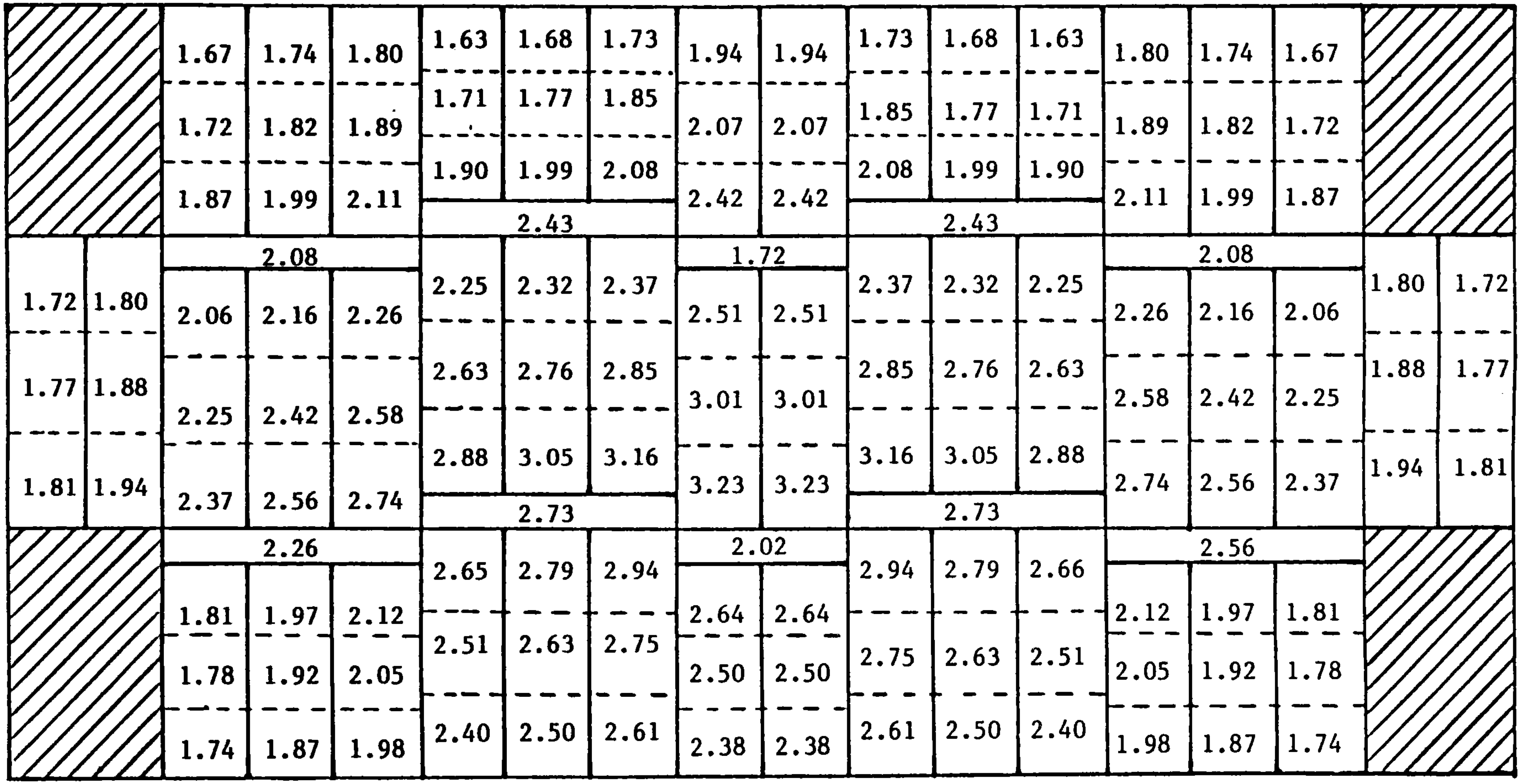
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-37
Convective Loss, kw
Day 173   Time 8:00



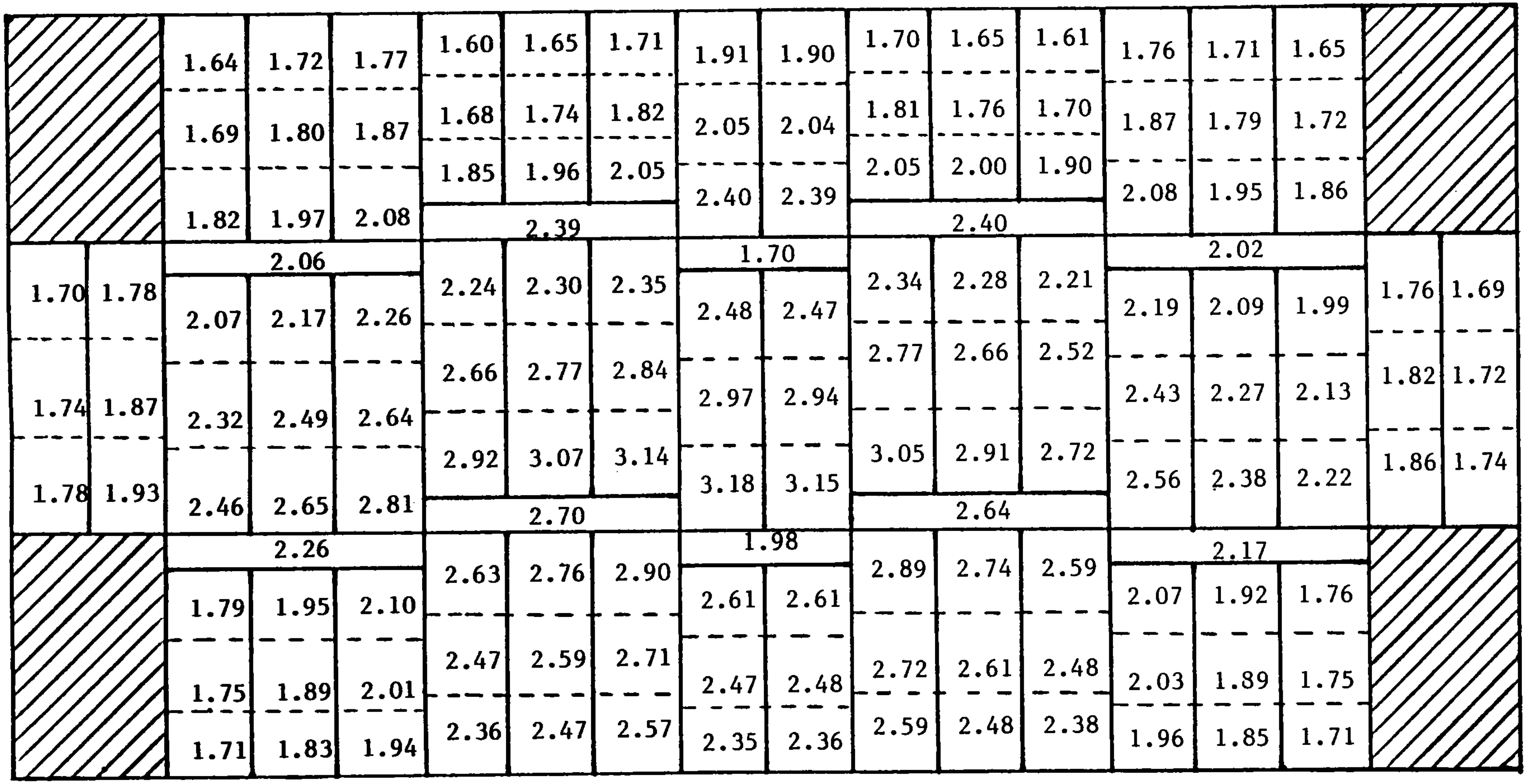
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-38
Radiation Loss, kw
Day 355 Time 12:00



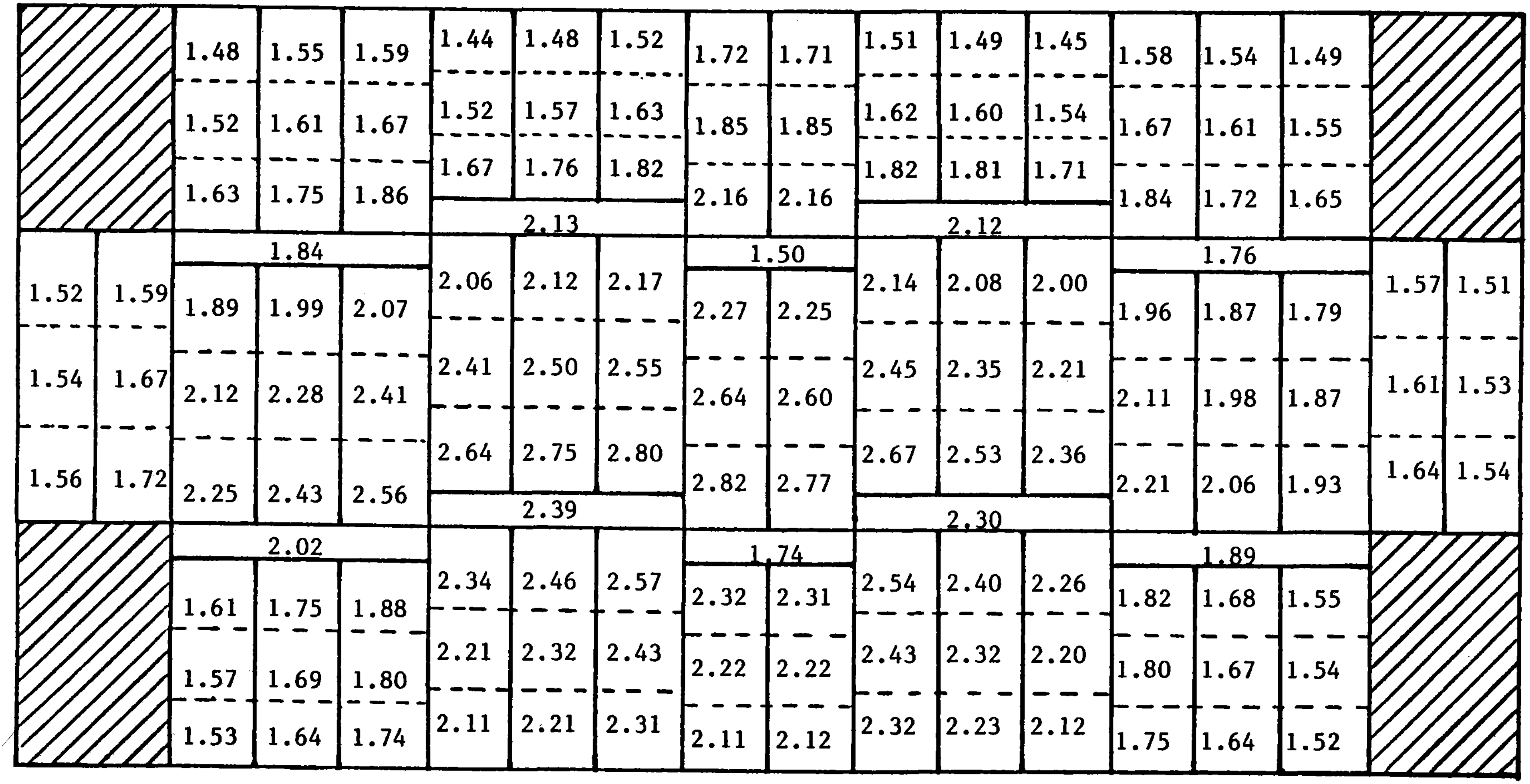
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-39
Radiation Loss, kw
Day 355 Time 10:00



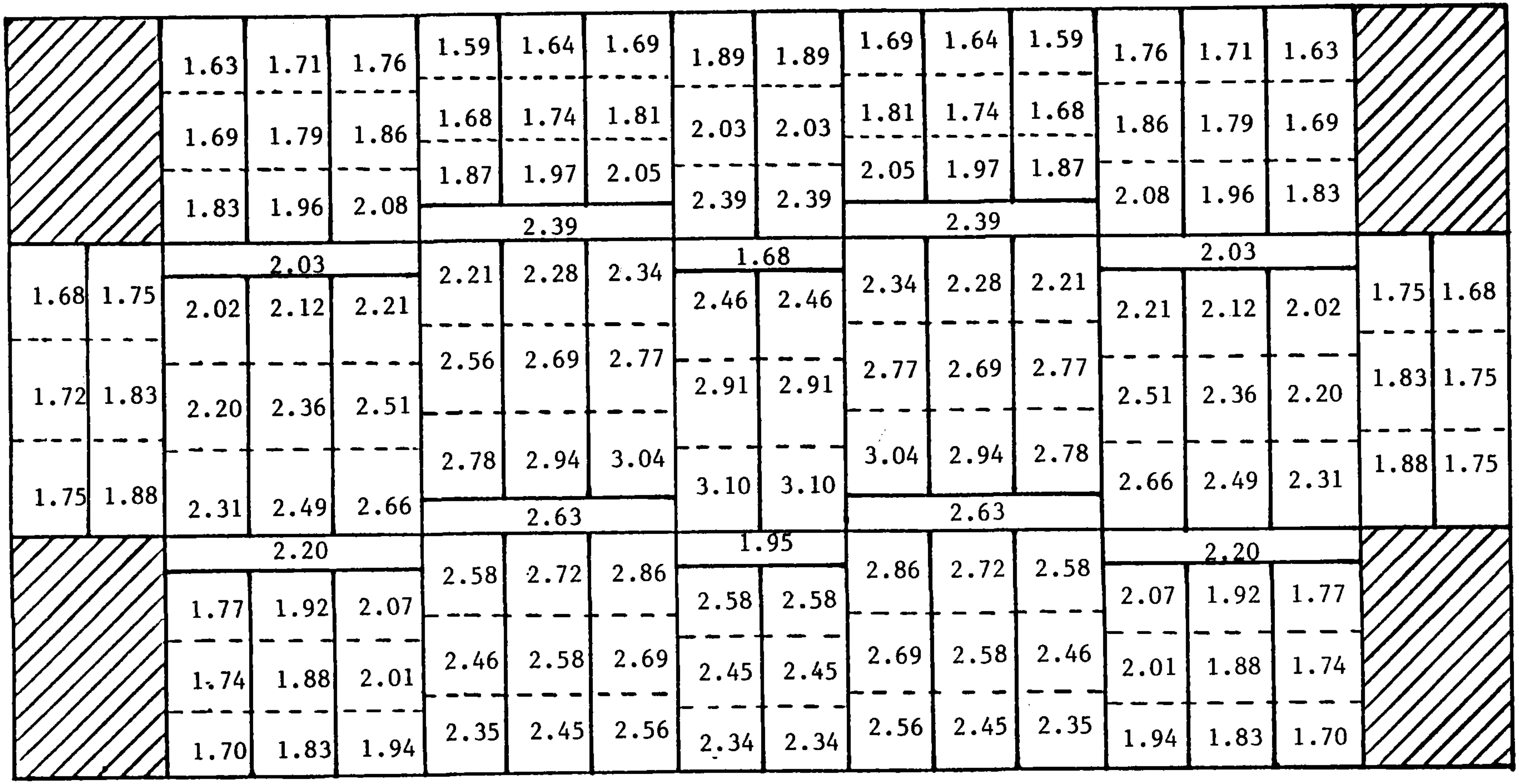
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-40
Radiation Loss, kw
Day 355 Time 8:00



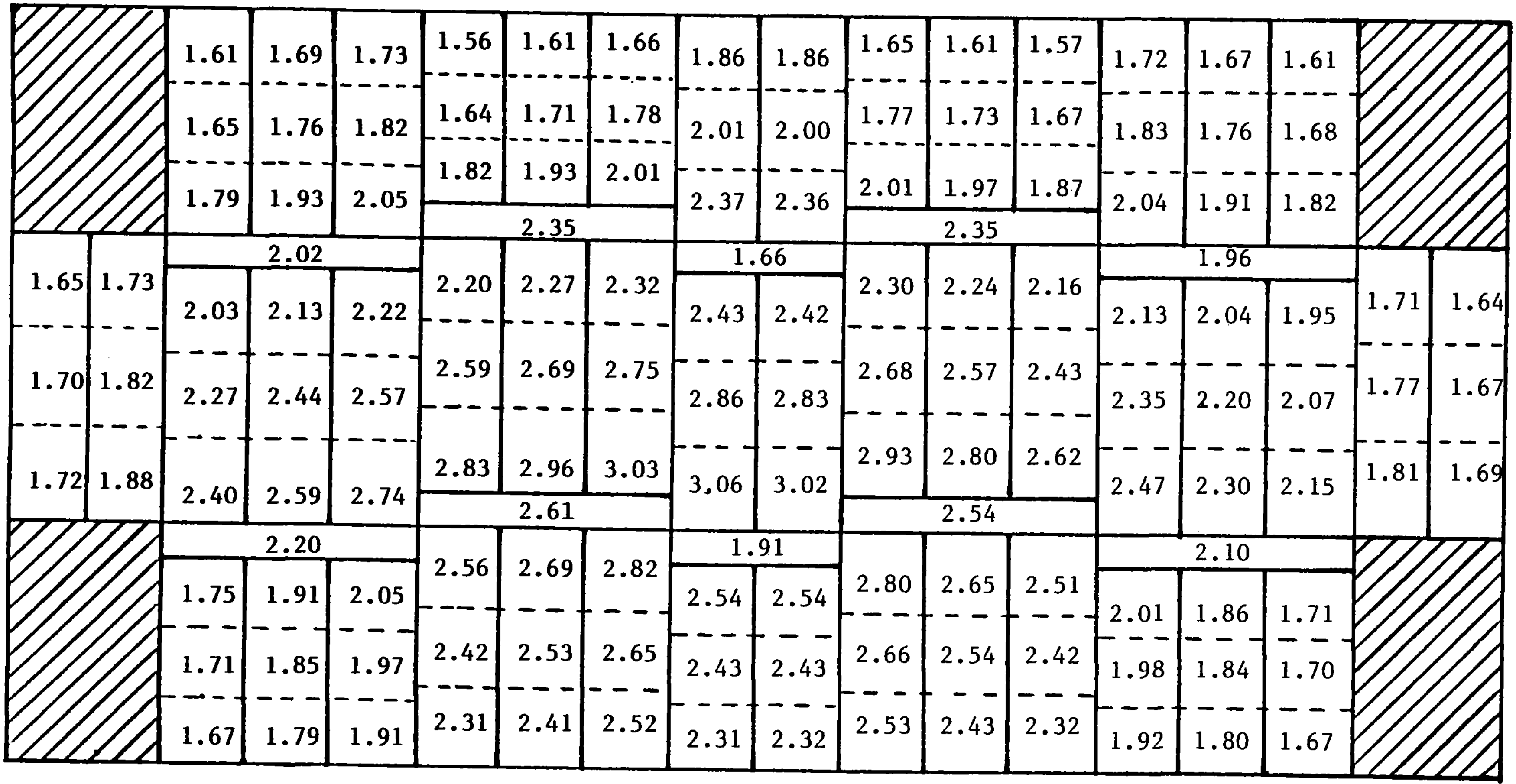
*Node losses shown include an allocated portion of the inacitve cavity wall loss

Figure E-41
Radiation Loss, kw
Day 80 Time 12:00



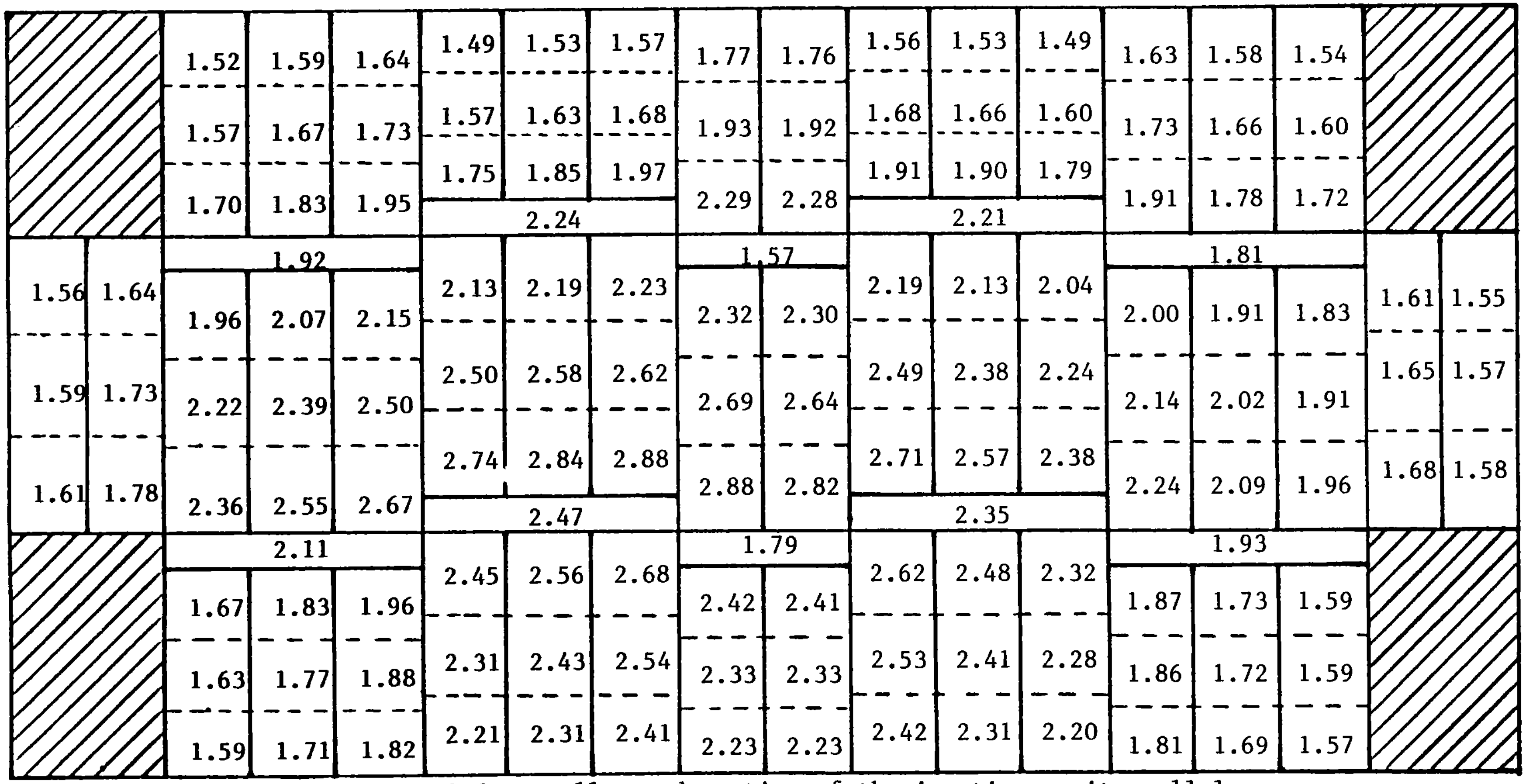
*Node losses shown indicate an allocated portion of the inacitve cavity wall loss

Figure E-42
Radiation Loss, kw
Day 80 Time 10:00



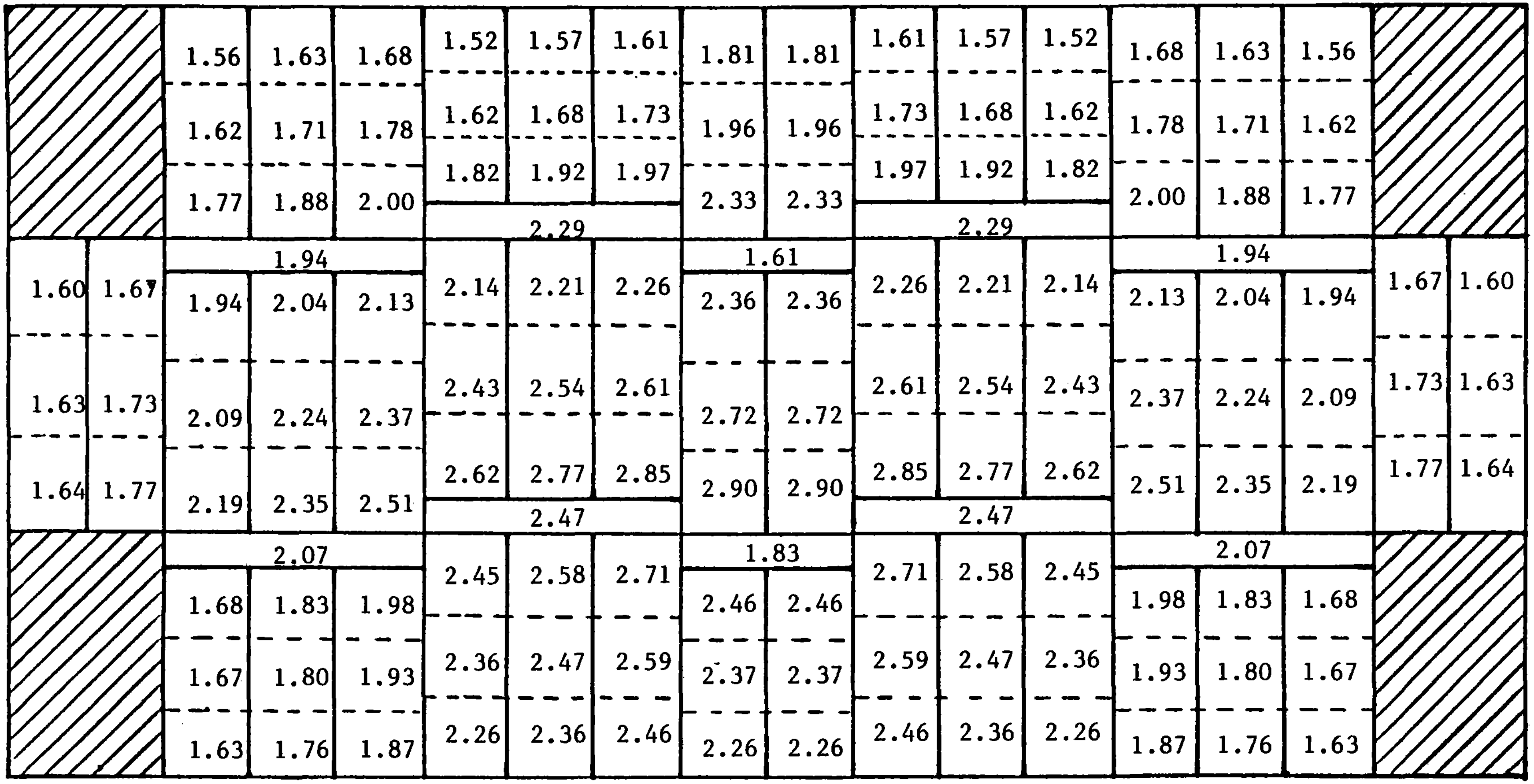
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-43
Radiation Loss, kw
Day 80 Time 8:00



*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-44
Radiation Loss, kw
Day 173 Time 12:00



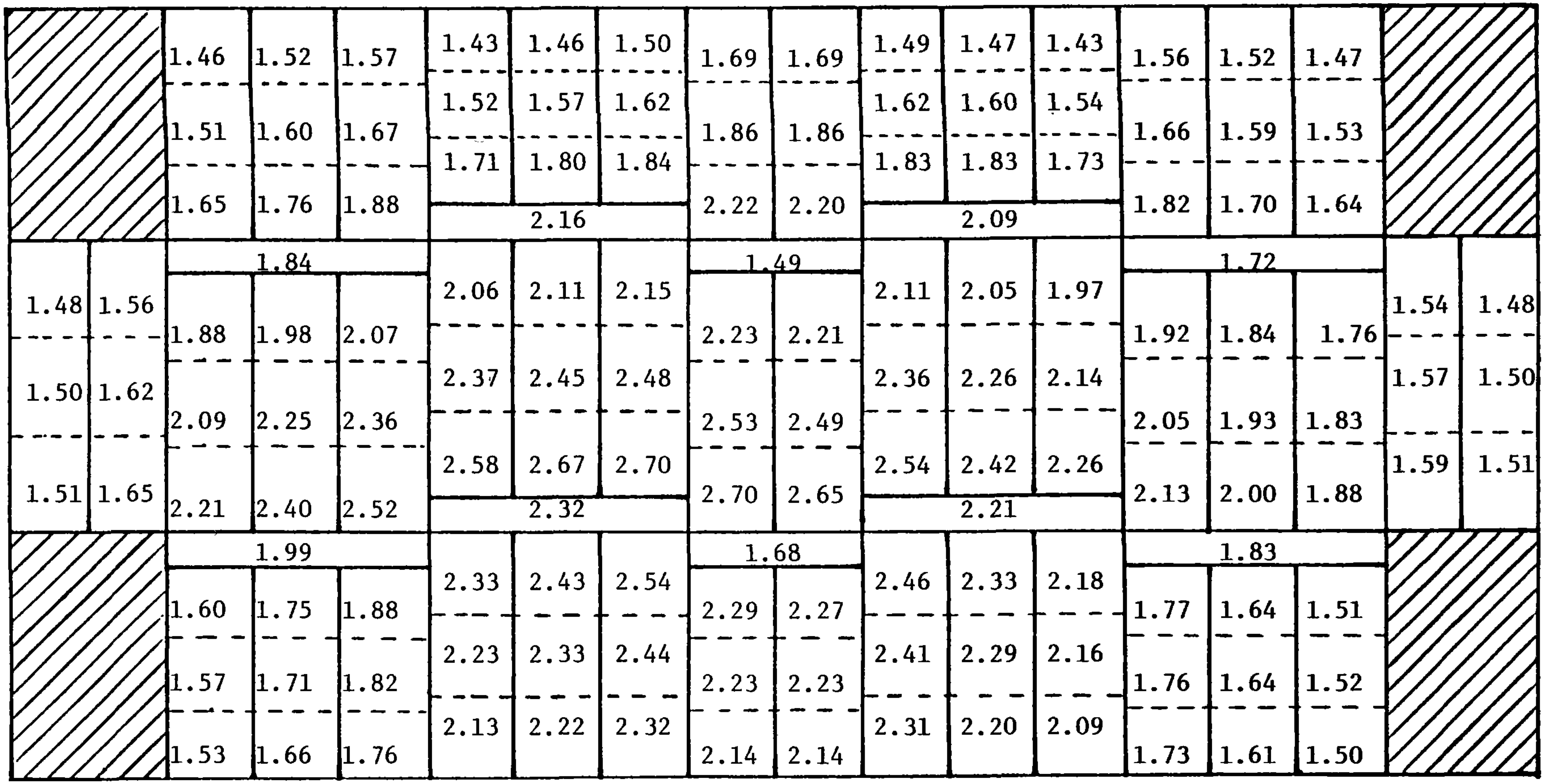
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-45
Radiation Loss, kw
Day 173 Time 10:00

		1.54	1.61	1.66	1.50	1.54	1.59	1.78	1.78	1.58	1.54	1.50	1.65	1.60	1.55		
		1.59	1.68	1.75	1.58	1.65	1.70	1.94	1.93	1.70	1.66	1.61	1.75	1.68	1.61		
		1.73	1.86	1.98	1.78	1.88	1.94	2.31	2.30	1.93	1.91	1.81	1.95	1.83	1.75		
		1.93			2.26			1.58		2.24			1.86				
1.57	1.65	1.94	2.05	2.13	2.13	2.19	2.24	2.33	2.32	2.21	2.16	2.08	2.05	1.96	1.87	1.63	1.56
1.59	1.71	2.14	2.30	2.43	2.45	2.55	2.60	2.68	2.66	2.53	2.44	2.31	2.23	2.10	1.98	1.68	1.58
1.61	1.76	2.26	2.44	2.58	2.66	2.78	2.84	2.86	2.83	2.75	2.64	2.48	2.34	2.19	2.05	1.71	1.60
		2.08			2.45			1.79		2.39			1.98				
		1.67	1.83	1.96	2.43	2.55	2.67	2.42	2.41	2.64	2.51	2.37	1.91	1.77	1.63		
		1.64	1.78	1.90	2.33	2.44	2.55	2.34	2.34	2.55	2.43	2.31	1.89	1.76	1.62		
		1.61	1.73	1.84	2.23	2.32	2.42	2.23	2.24	2.43	2.32	2.22	1.84	1.72	1.59		

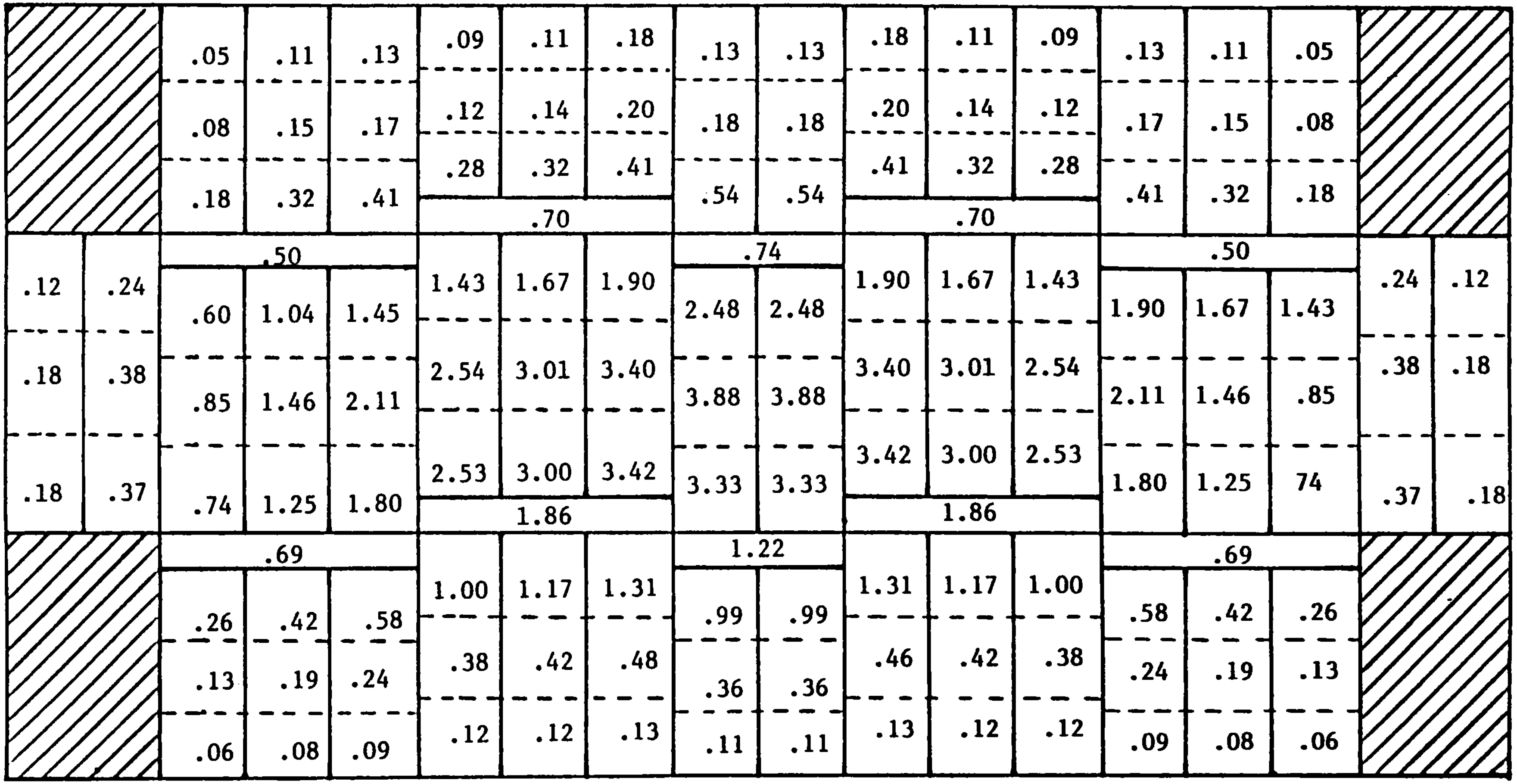
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-46
Radiation Loss, kw
Day 173 Time 8:00



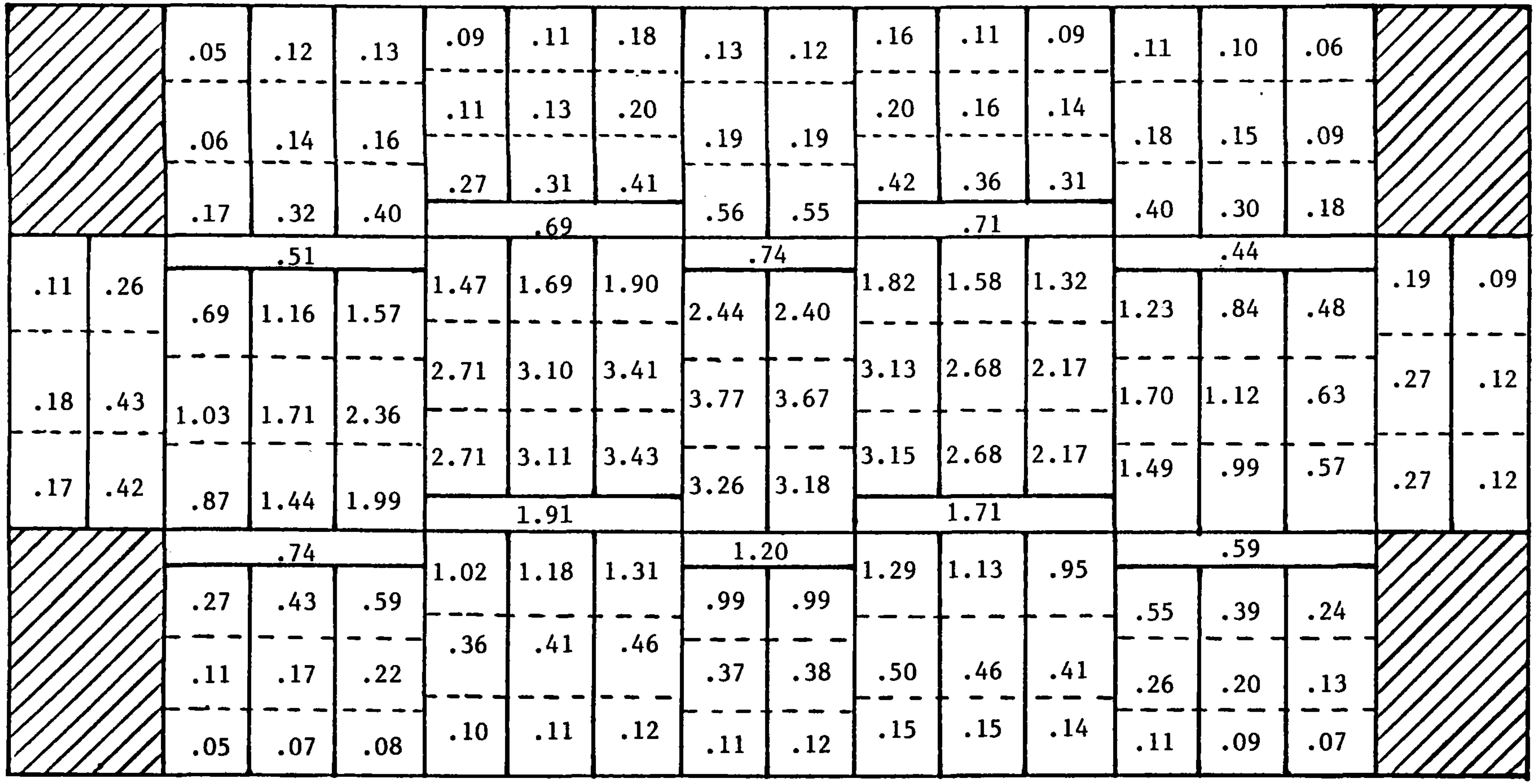
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-47
Reflective Loss, kw
Day 355 Time 12:00



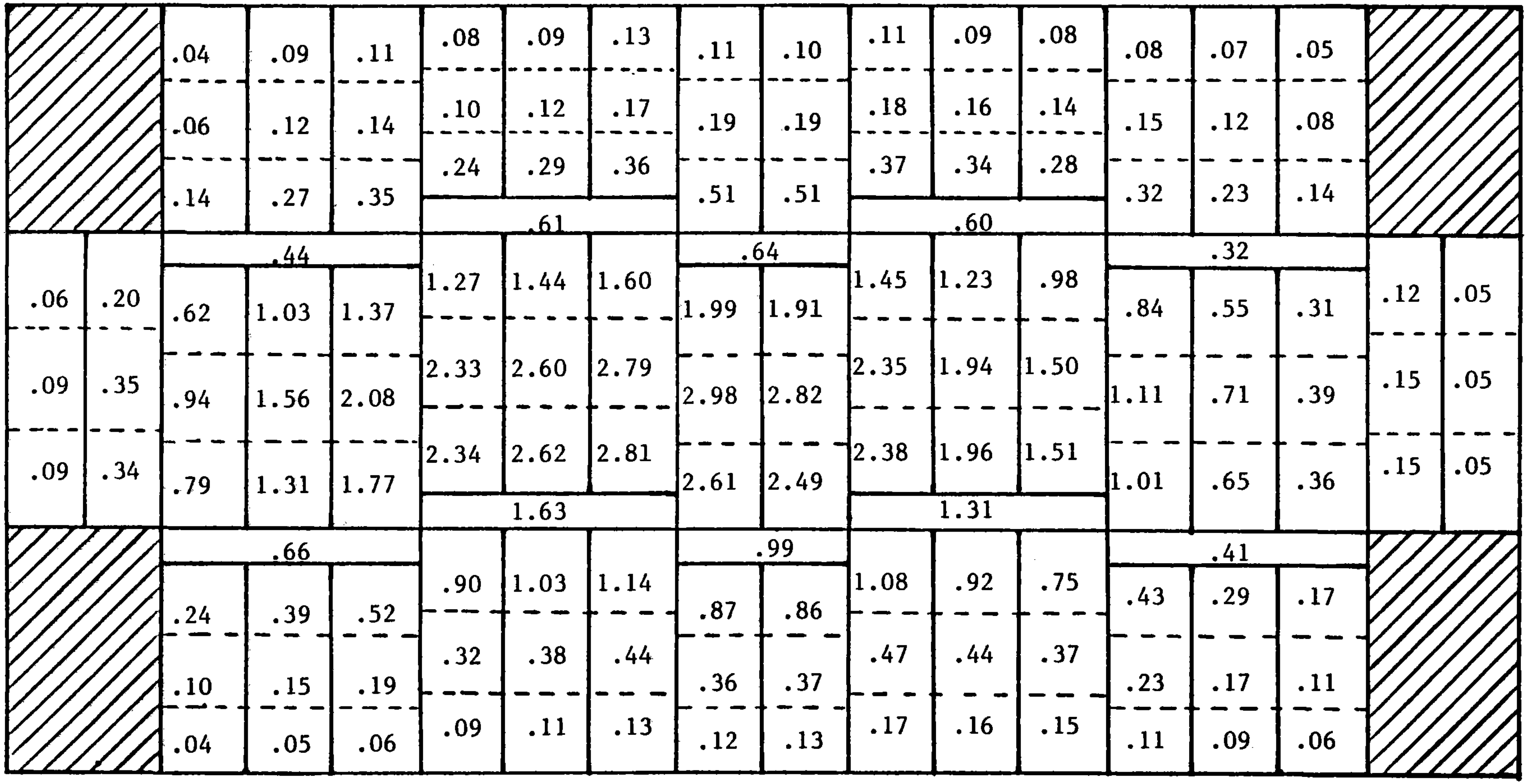
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-48
Reflective Loss, kw
Day 355 Time 10:00



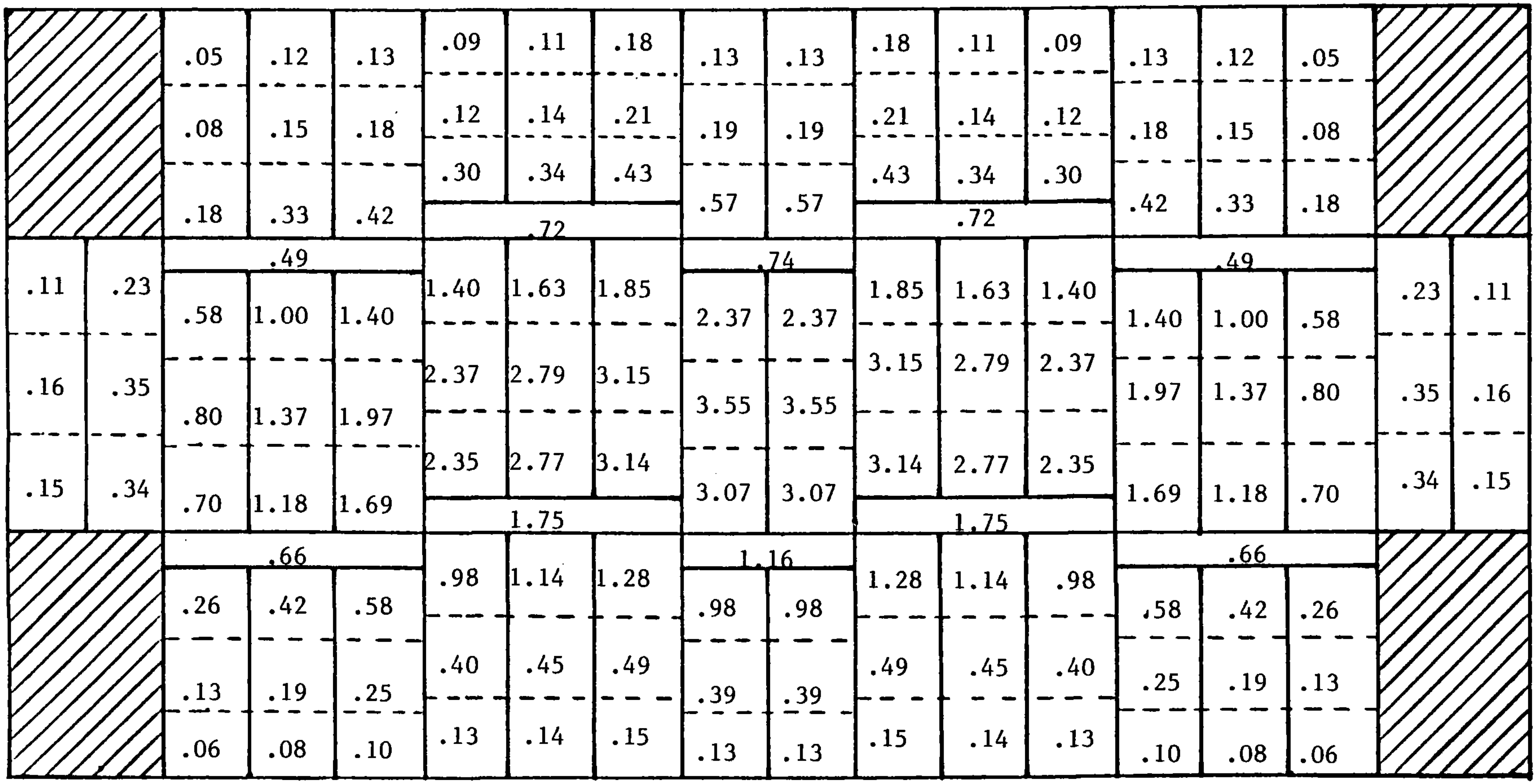
*Node losses shown include an allocated portion of the inacitve cavity wall loss

Figure E-49
Reflective Loss, kw
Day 355 Time 8:00



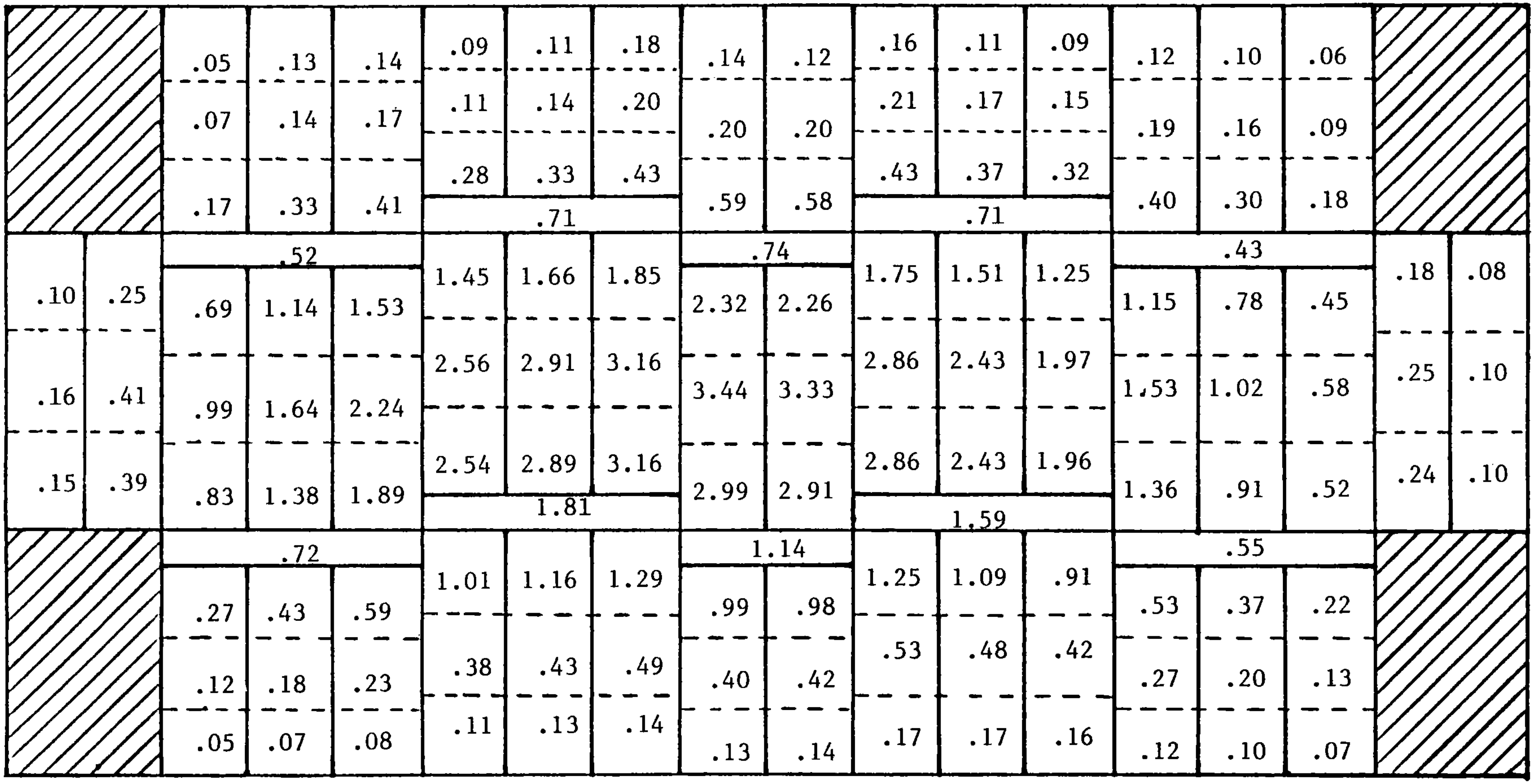
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-50
Reflective Loss, kw
Day 80 Time 12:00



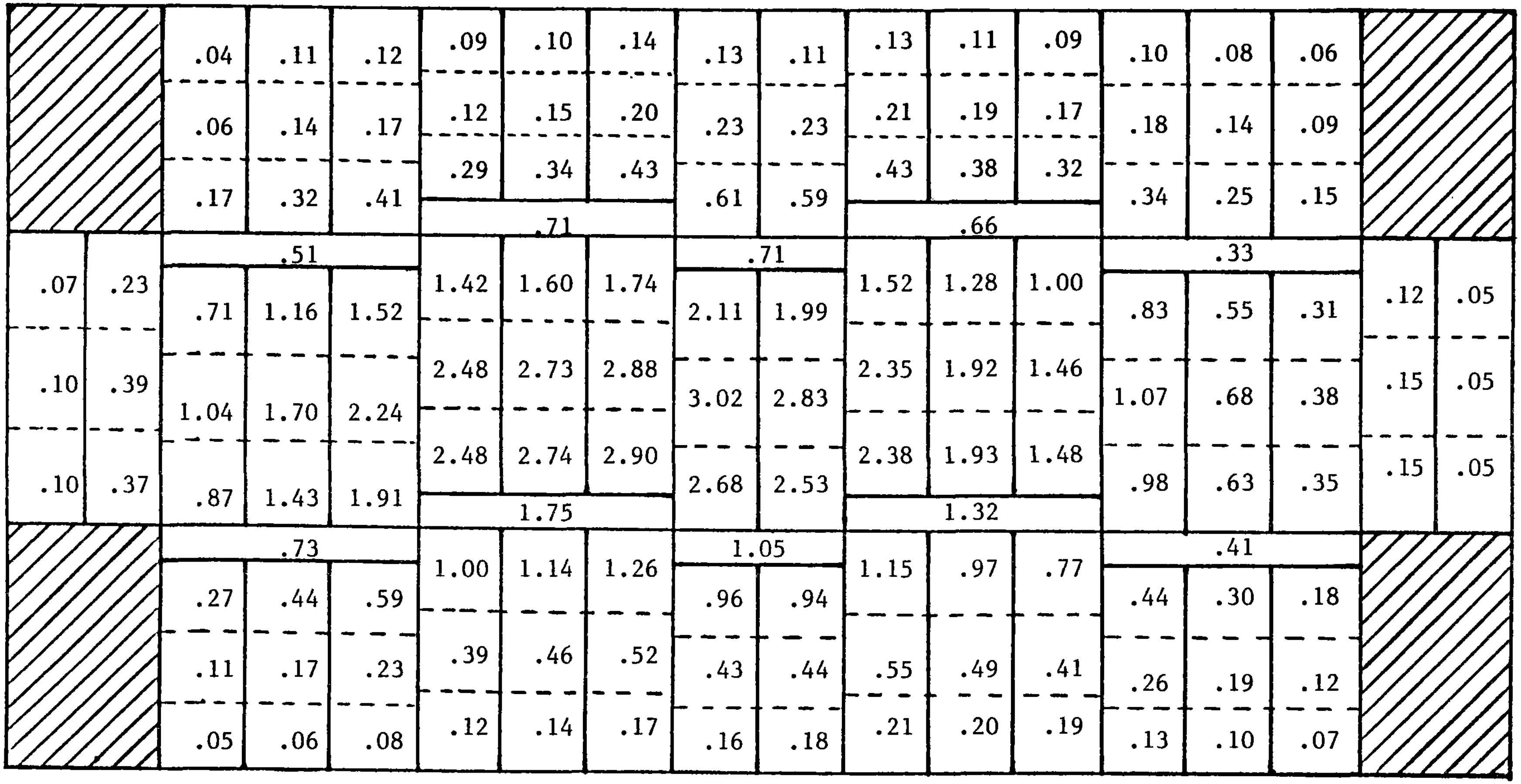
* Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-51
Reflective Loss, kw
Day 80 Time 10:00



*Node losses shown include an allocated portion of the inactive cavity wall

Figure E-52
Reflective Loss, kw
Day 80 Time 8:00



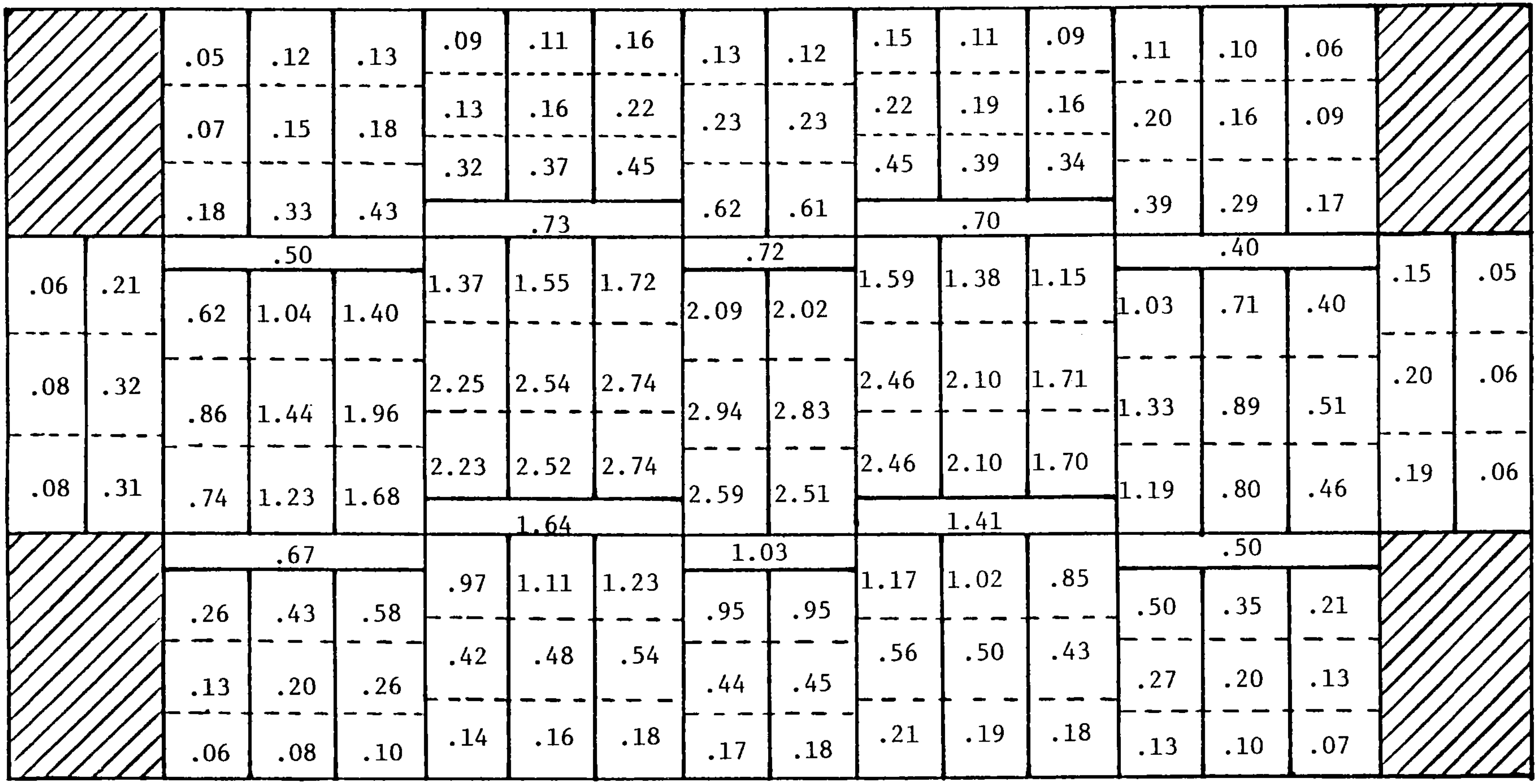
*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-53
Reflective Loss, kw
Day 173 Time 12:00

▨		.05	.11	.13	.09	.11	.17	.13	.13	.17	.11	.09	.13	.11	.05	▨	
		.08	.16	.19	.14	.17	.22	.22	.22	.22	.17	.14	.19	.16	.08		
		.18	.32	.42	.32	.38	.45	.61	.61	.45	.38	.32	.42	.32	.18		
		.47			.73			.73		.73			.47				
.08	.20	.53	.91	1.27	1.31	1.52	1.71	2.13	2.13	1.71	1.52	1.31	1.27	.91	.53	.20	.08
.10	.28	.70	1.20	1.71	2.07	2.43	2.72	3.03	3.03	2.72	2.43	2.07	1.71	1.20	.70	.28	.10
.10	.28	.62	1.05	1.49	2.05	2.41	2.71	2.66	2.66	2.71	2.41	2.05	1.49	1.05	.62	.28	.10
▨		.61			1.58			1.06		1.58			.61			▨	
		.25	.40	.56	.94	1.09	1.22	.96	.96	1.22	1.09	.94	.56	.40	.25		
		.13	.20	.27	.42	.48	.54	.43	.43	.54	.48	.42	.27	.20	.13		
		.07	.09	.11	.15	.17	.18	.16	.16	.18	.17	.15	.11	.09	.07		

*Node losses shown include an allocated portion of the inactive cavity wall loss

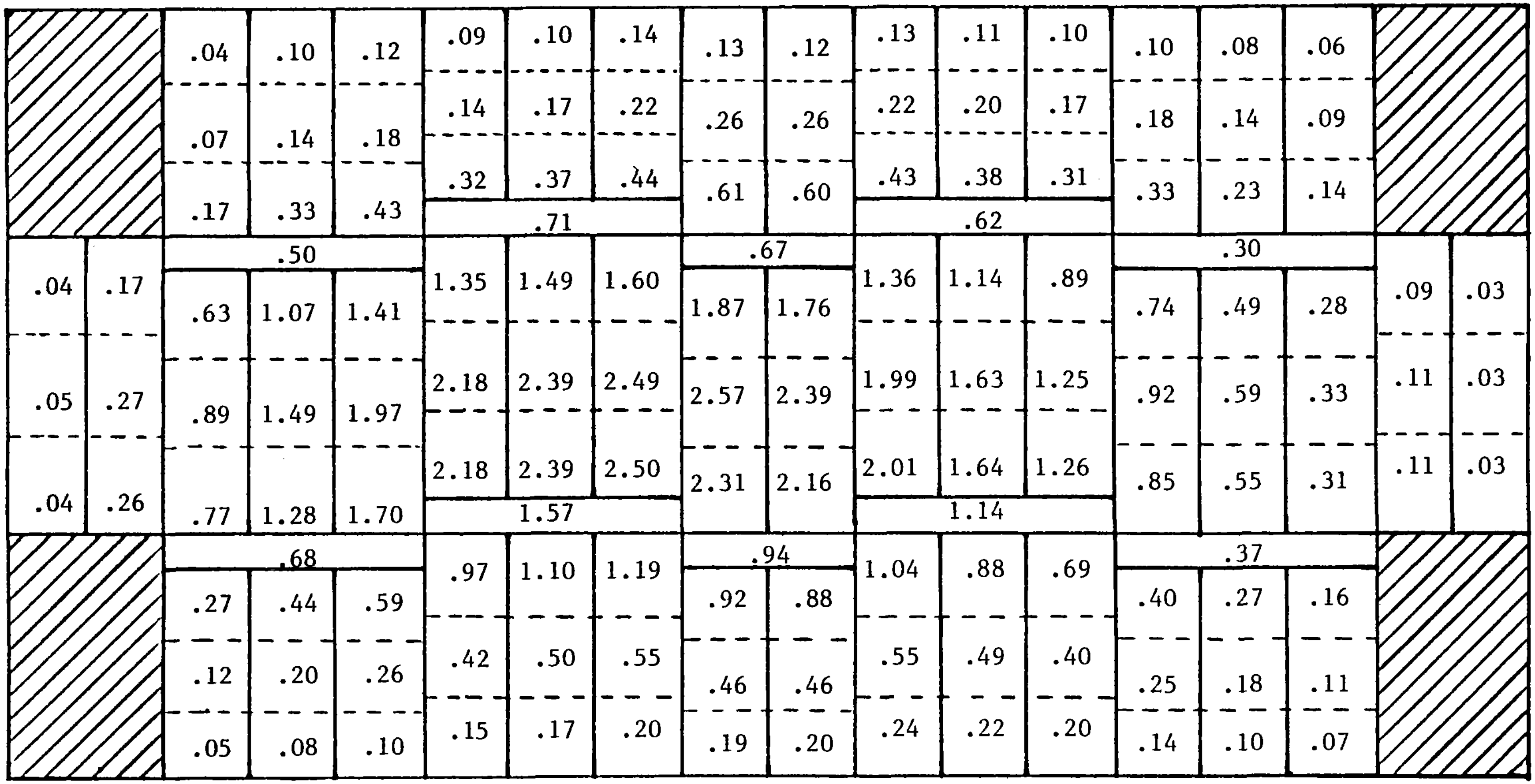
Figure E-54
Reflective Loss, kw
Day 173 Time 10:00



		.05	.12	.13	.09	.11	.16	.13	.12	.15	.11	.09	.11	.10	.06		
		.07	.15	.18	.13	.16	.22	.23	.23	.22	.19	.16	.20	.16	.09		
		.18	.33	.43	.32	.37	.45	.62	.61	.45	.39	.34	.39	.29	.17		
		.50			.73			.72		.70			.40				
.06	.21	.62	1.04	1.40	1.37	1.55	1.72	2.09	2.02	1.59	1.38	1.15	1.03	.71	.40	.15	.05
.08	.32	.86	1.44	1.96	2.25	2.54	2.74	2.94	2.83	2.46	2.10	1.71	1.33	.89	.51	.20	.06
.08	.31	.74	1.23	1.68	2.23	2.52	2.74	2.59	2.51	2.46	2.10	1.70	1.19	.80	.46	.19	.06
		.67			1.64			1.03		1.41			.50				
		.26	.43	.58	.97	1.11	1.23	.95	.95	1.17	1.02	.85	.50	.35	.21		
		.13	.20	.26	.42	.48	.54	.44	.45	.56	.50	.43	.27	.20	.13		
		.06	.08	.10	.14	.16	.18	.17	.18	.21	.19	.18	.13	.10	.07		

*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-55
Reflective Loss, kw
Day 173 Time 8:00



*Node losses shown include an allocated portion of the inactive cavity wall loss

Figure E-56
Net Power Into Oil, kw
Day 355 Time 12:00

		-.6	14.4	14.2	5.5	8.1	18.4	8.8	8.8	18.4	8.1	5.5	14.2	14.4	-.6		
		5.2	18.8	19.3	9.2	10.2	17.1	12.1	12.1	17.1	10.2	9.2	19.3	18.8	5.2		
		27.7	48.4	52.5	30.0	30.8	37.8	46.2	46.2	37.8	30.8	30.0	52.5	48.4	27.7		
					68.4					68.4							
		75.1						62.5					75.1				
22.7	48.4	108.1	154.4	179.5	154.1	157.8	165.0	200.6	200.6	165.0	157.8	154.1	179.5	154.4	108.1	48.4	22.7
37.6	76.9	143.7	200.8	237.6	247.6	256.9	266.1	282.9	282.9	266.1	256.9	247.6	237.6	200.8	143.7	76.9	37.6
33.6	69.2	114.5	158.9	187.8	227.1	236.0	245.8	225.3	225.3	245.8	236.0	227.1	187.8	158.9	114.5	69.2	33.6
					140.0					140.0							
		82.0						78.2					82.0				
		34.5	47.1	54.3	81.9	83.5	86.0	60.7	60.7	86.0	83.5	81.9	54.3	47.1	34.5		
		11.2	16.0	18.0	25.7	25.3	25.5	18.0	18.0	25.5	25.3	25.7	18.0	16.0	11.2		
		-.1	1.3	1.6	2.0	1.8	1.3	.8	.8	1.3	1.8	2.0	1.6	1.3	-.1		

Figure E-57
Net Power Into Oil, kw
Day 355 Time 10:00

		-1.1	16.8	16.3	5.8	8.1	17.9	9.1	7.2	14.9	8.8	6.4	11.2	10.8	1.4		
		2.6	17.9	18.0	7.6	9.5	17.0	13.4	13.4	17.7	13.6	12.9	21.3	20.3	9.5		
		25.3	48.7	51.9	27.7	29.7	37.8	47.8	47.2	38.5	34.8	34.1	51.5	45.5	28.2		
		78.1			67.7			62.4		69.4			66.4				
19.6	52.4	126.8	174.6	194.6	158.7	159.8	165.1	197.1	193.2	158.3	149.4	141.2	150.7	123.0	82.8	35.5	12.3
35.9	89.8	176.7	237.6	267.6	265.3	265.7	267.1	275.0	266.9	244.5	227.8	210.2	189.5	151.5	103.2	51.1	19.0
31.7	80.3	137.6	184.9	208.8	243.6	244.5	246.7	220.1	214.6	225.9	209.7	193.3	153.9	124.1	85.9	46.9	17.2
		89.4			143.9			76.9		128.2			69.4				
		36.0	48.9	55.2	83.5	84.5	86.4	61.2	61.3	84.8	81.1	77.3	51.1	42.9	30.2		
		9.4	13.7	15.8	24.0	24.7	25.5	18.9	19.7	28.2	28.5	28.7	20.6	18.0	12.6		
		-1.0	-.0	0.3	1.0	1.1	1.3	0.9	1.6	3.3	4.1	4.8	4.2	3.9	2.0		

Figure E-58
Net Power Into Oil, kw
Day 355 Time 8:00

		-1.4	11.3	11.8	5.0	6.5	11.6	6.9	5.4	9.2	7.2	5.6	7.2	6.2	1.9		
		2.1	14.6	15.8	8.1	9.7	15.0	14.6	14.4	15.7	14.7	13.7	18.1	16.0	9.2		
		21.7	41.1	44.7	25.6	27.5	33.4	44.5	43.9	34.4	33.2	31.1	40.1	33.2	20.9		
		67.7			59.6			53.6		58.4			45.7				
5.8	39.9	114.0	156.0	170.2	136.9	136.5	138.5	160.3	153.2	124.6	114.9	103.2	100.3	77.7	50.2	17.9	0.4
13.4	70.9	162.3	216.1	236.0	226.8	221.8	217.2	216.4	204.1	182.1	163.2	143.0	121.3	92.3	60.0	24.3	2.0
11.6	63.6	126.2	168.9	185.5	209.8	205.4	201.4	175.8	167.3	169.9	151.9	133.2	102.0	78.3	51.6	22.6	1.5
		79.6			122.8			63.4		96.7			47.0				
		31.9	43.8	49.1	73.6	74.0	75.0	53.4	53.0	70.5	65.5	60.0	38.9	30.8	20.5		
		7.9	11.9	14.0	21.8	22.8	24.6	18.6	19.5	27.4	27.4	26.5	18.5	15.2	9.7		
		-1.5	-0.5	-0.0	.8	1.5	2.3	2.0	3.0	5.4	6.3	6.8	5.6	4.6	2.3		

Figure E-59
Net Power Into Oil, kw
Day 80 Time 12:00

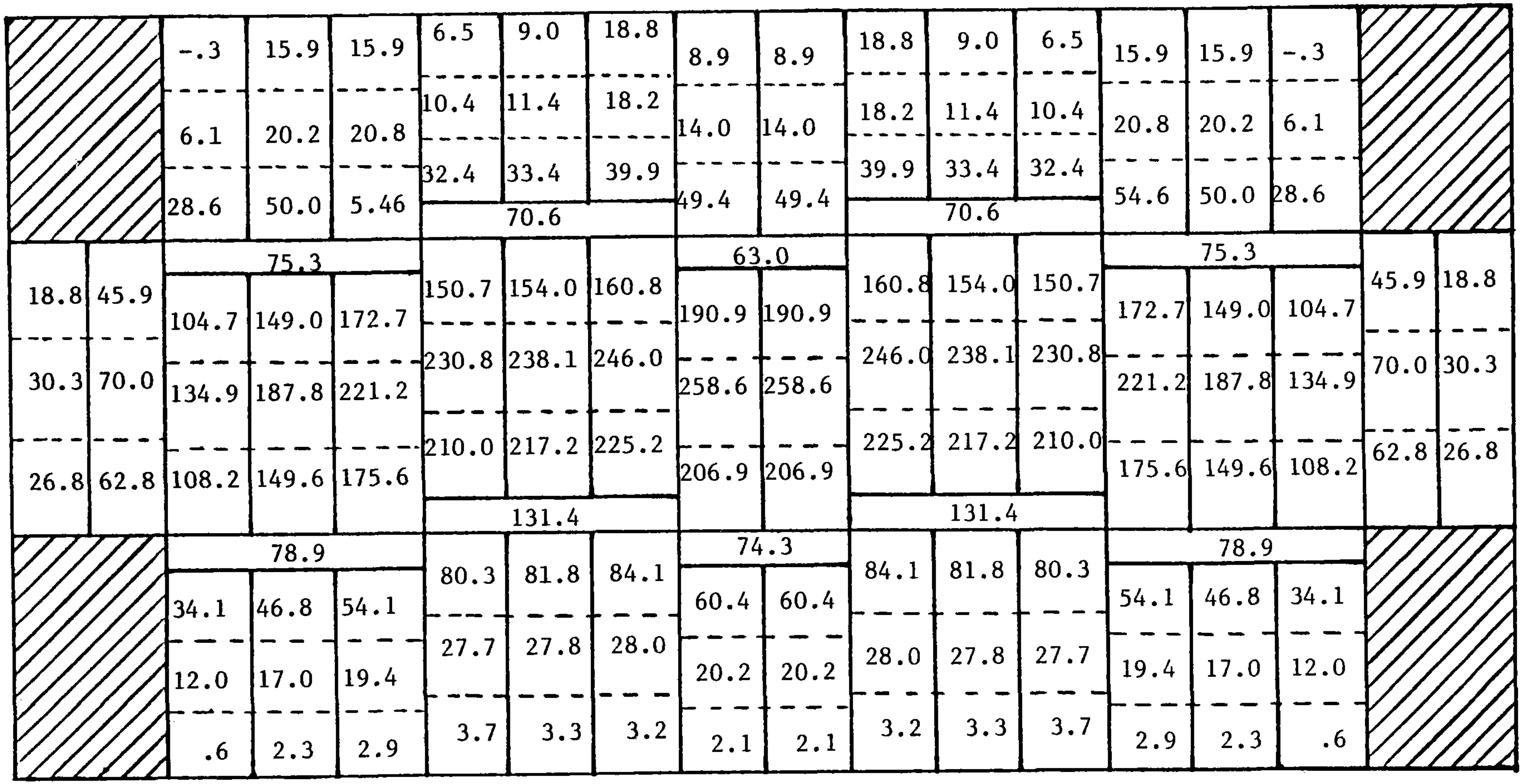


Figure E-60
Net Power Into Oil, kw
Day 80 Time 10:00

▨	▨	-0.8	18.4	17.6	5.9	8.2	18.2	9.9	8.0	15.1	9.0	7.1	12.5	12.0	2.4	▨	▨
▨	▨	3.6	18.8	19.1	8.8	11.0	18.2	15.5	15.4	18.9	15.1	14.6	23.0	21.5	10.5	▨	▨
▨	▨	27.1	50.8	54.3	30.1	32.1	39.9	51.1	50.3	40.5	37.2	36.1	52.2	45.4	28.1	▨	▨
			79.3			70.0		62.7			70.2			64.0			
17.3	51.4	125.6	171.7	189.6	156.1	157.0	161.1	187.1	182.3	151.5	142.5	133.9	139.6	113.8	76.8	32.5	9.7
30.8	85.0	170.1	227.2	253.2	249.8	248.2	247.1	250.5	241.8	222.6	206.5	189.9	170.2	136.6	93.6	45.3	14.9
26.9	75.2	132.2	177.1	198.5	228.2	227.1	227.1	201.8	195.8	204.7	189.6	174.1	139.4	112.7	78.1	41.4	13.3
			87.3			136.4		73.0			118.5			64.3			
▨	▨	36.5	49.2	55.7	82.8	83.1	84.8	60.9	60.8	82.1	78.0	74.0	49.3	40.8	28.5	▨	▨
▨	▨	10.7	15.3	17.8	26.4	26.7	28.0	21.3	22.2	30.6	30.3	30.4	21.6	18.3	12.7	▨	▨
▨	▨	-0.7	0.7	1.4	2.3	2.4	3.1	2.8	3.4	5.4	6.1	6.8	5.5	4.8	2.9	▨	▨

Figure E-61
Net Power Into Oil, kw
Day 80 Time 8:00

		-1.1	14.9	15.5	6.6	7.6	13.9	9.4	7.4	11.1	9.7	7.6	9.8	9.0	3.8		
		3.6	18.5	19.9	10.8	13.0	18.8	19.8	19.7	20.0	19.0	17.8	22.6	19.4	11.3		
		26.7	49.5	54.4	32.3	34.1	40.1	53.7	52.5	40.4	38.6	35.9	44.0	36.0	22.7		
		79.4			70.2			59.8		64.3			47.2				
7.4	46.7	130.5	175.9	189.6	153.8	151.6	151.5	169.4	159.9	131.0	119.4	105.4	99.3	76.7	50.1	18.0	.4
15.4	79.6	180.1	236.3	254.3	242.2	233.4	224.8	219.3	204.5	182.0	161.4	139.5	116.6	88.8	58.4	23.7	1.8
13.3	70.7	139.9	184.9	200.7	222.8	215.2	207.9	180.4	169.5	169.1	149.6	129.6	99.0	75.7	49.9	21.7	1.3
		89.1			131.4			67.2		97.5			46.6				
		37.2	50.8	56.7	82.8	82.5	83.1	59.6	58.4	75.4	69.2	61.9	40.1	31.6	21.0		
		10.4	15.5	18.1	27.4	28.8	30.7	23.7	24.5	32.9	31.7	29.8	20.8	17.0	11.3		
		-.6	.5	1.3	2.9	3.8	5.3	5.2	6.1	8.6	9.2	9.7	7.7	6.3	3.8		

Figure E-62
Net Power Into Oil, kw
Day 173 Time 12:00

		0.5	15.4	15.8	7.5	9.6	17.4	10.0	10.0	17.4	9.6	7.5	15.8	15.4	0.5		
		8.7	22.0	23.3	13.9	15.0	20.2	18.1	18.1	20.2	15.0	13.9	23.3	22.0	8.7		
		30.4	50.5	56.0	36.4	37.6	42.1	53.5	53.5	42.1	37.6	36.4	56.0	50.5	30.4		
		72.3			71.8			61.9		71.8			72.3				
8.7	38.1	94.7	135.3	156.5	140.4	143.6	148.8	171.6	171.6	148.8	143.6	140.4	156.5	135.3	94.7	38.1	8.7
14.2	54.9	117.1	163.9	191.9	200.7	206.2	211.8	219.5	219.5	211.8	206.2	200.7	191.9	163.9	117.1	54.9	14.2
12.3	49.1	94.9	131.9	154.6	182.8	188.4	193.7	178.6	178.6	193.7	188.4	182.8	154.6	131.9	94.9	49.1	12.3
		72.1			118.0			68.0		118.0			72.1				
		32.5	45.3	52.6	76.5	78.4	80.5	59.4	59.4	80.5	78.4	76.5	52.6	45.3	32.5		
		13.0	18.8	21.7	30.4	30.8	31.5	23.7	23.7	31.5	30.8	30.4	21.7	18.8	13.0		
		2.2	4.1	4.8	6.3	6.3	6.4	4.9	4.9	6.4	6.3	6.3	4.8	4.1	2.2		

Figure E-63
Net Power Into Oil, kw
Day 173 Time 10:00

		-.0	17.2	17.1	6.9	8.8	16.8	10.4	8.8	14.3	9.7	8.2	12.9	12.1	3.4		
		5.7	20.9	22.5	12.7	14.2	20.1	19.4	19.4	20.9	18.1	17.4	25.0	22.6	11.4		
		29.4	52.3	57.2	35.2	36.6	42.1	54.6	53.7	42.1	39.5	38.0	51.8	44.5	27.6		
		77.6			72.0			60.8		69.1			59.9				
5.2	40.7	112.7	157.0	173.9	147.5	147.0	149.3	167.9	162.5	137.9	130.2	122.3	125.2	102.8	69.2	25.3	1.7
10.5	63.3	146.0	198.0	220.6	218.6	216.0	213.6	213.0	205.0	190.5	177.7	164.0	147.0	119.2	81.6	34.0	3.7
8.8	56.2	115.8	157.2	175.9	199.5	197.5	195.7	174.0	168.1	175.0	162.8	150.2	121.8	99.1	68.4	30.8	3.0
		80.7			122.7			66.0		104.7			57.8				
		35.6	49.1	55.5	79.7	80.2	80.7	58.9	58.4	76.9	72.9	68.6	46.5	38.4	26.6		
		12.3	18.2	21.1	30.1	30.4	31.6	24.3	24.9	33.1	32.2	31.5	22.4	18.7	12.7		
		.8	2.7	3.8	5.5	5.7	6.4	5.5	6.2	8.4	8.5	9.0	7.0	5.7	3.1		

Figure E-64
Net Power Into Oil, kw
Day 173 Time 8:00

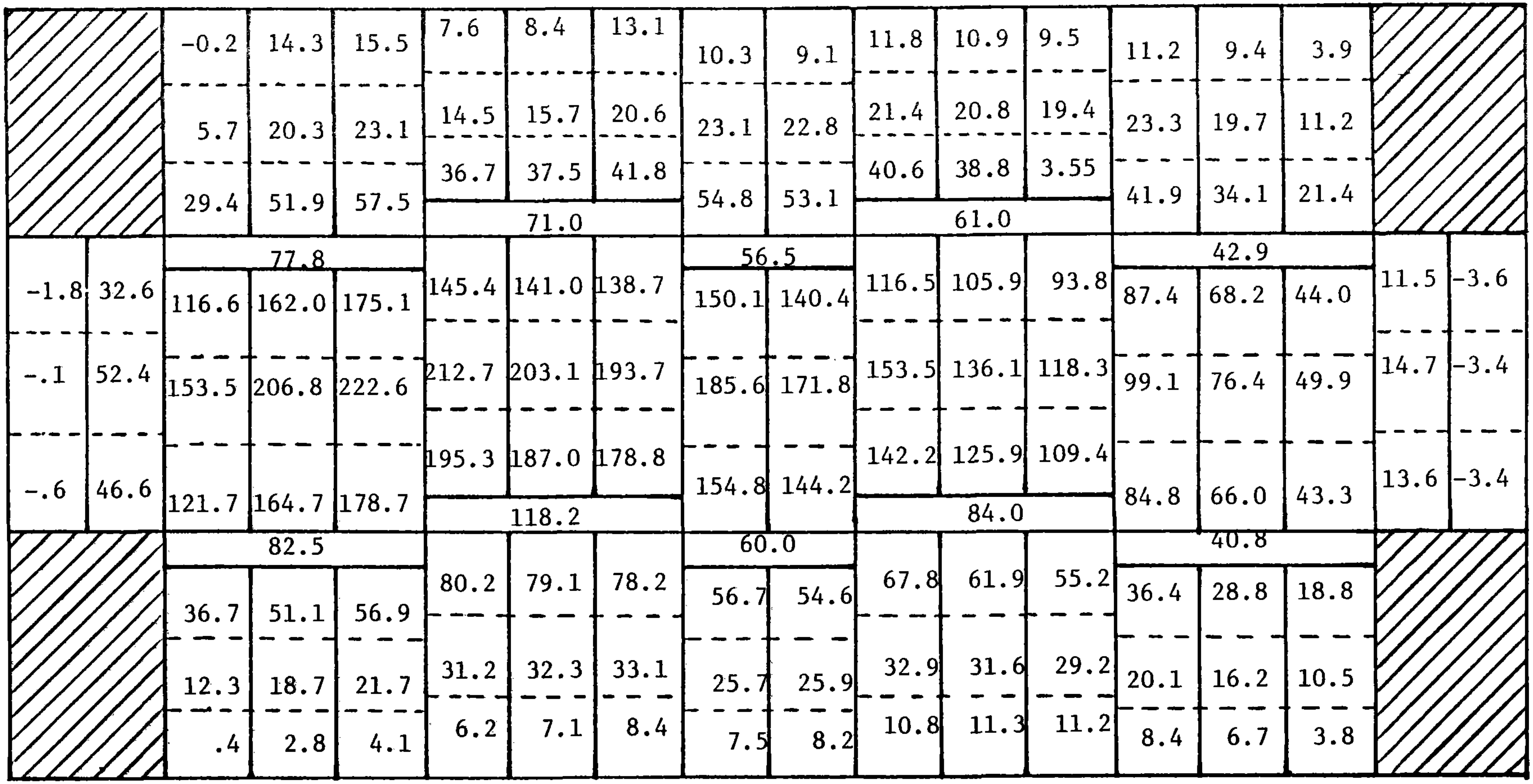
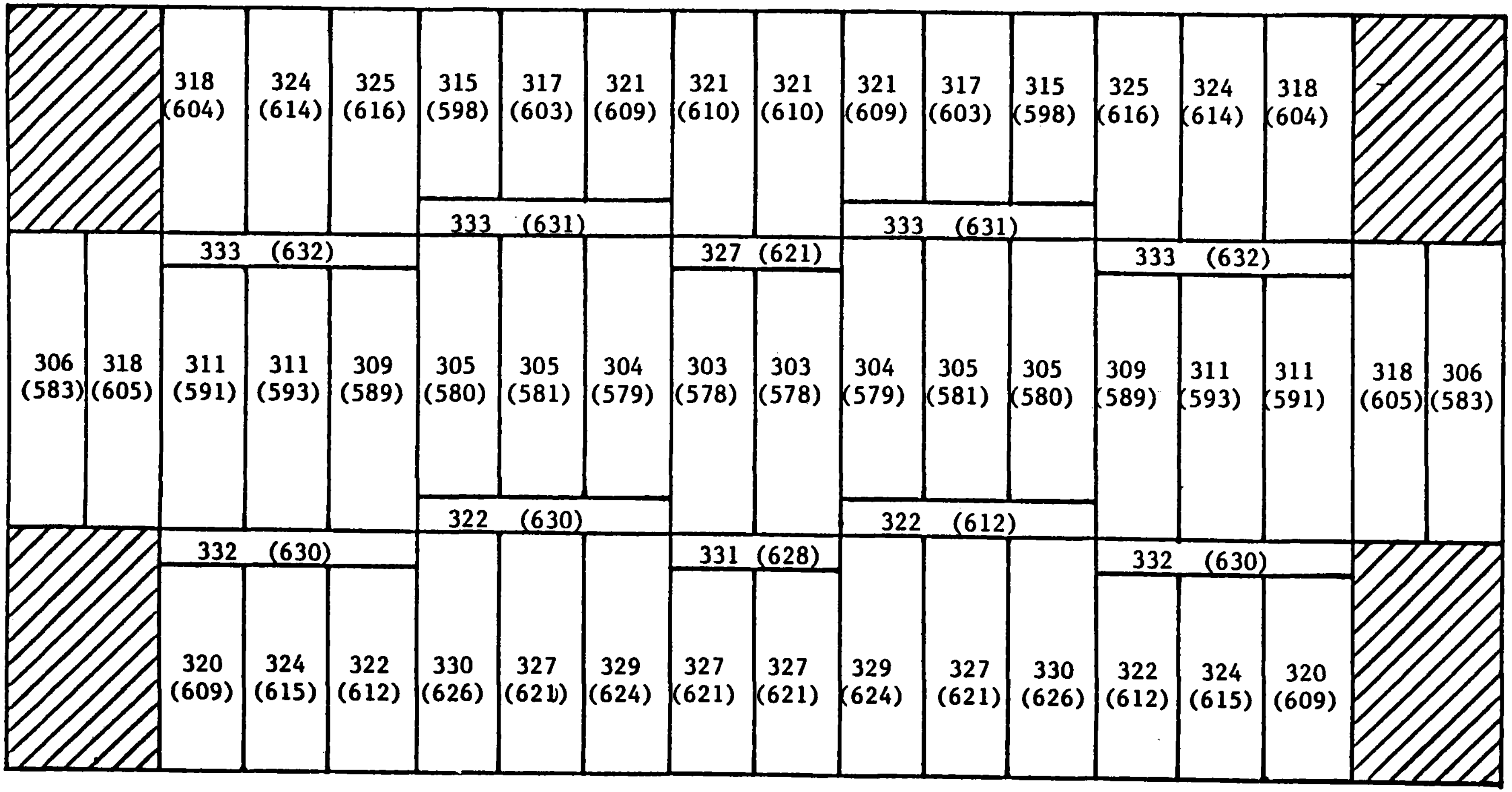


FIGURE E-65

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 355 TIME 12:00

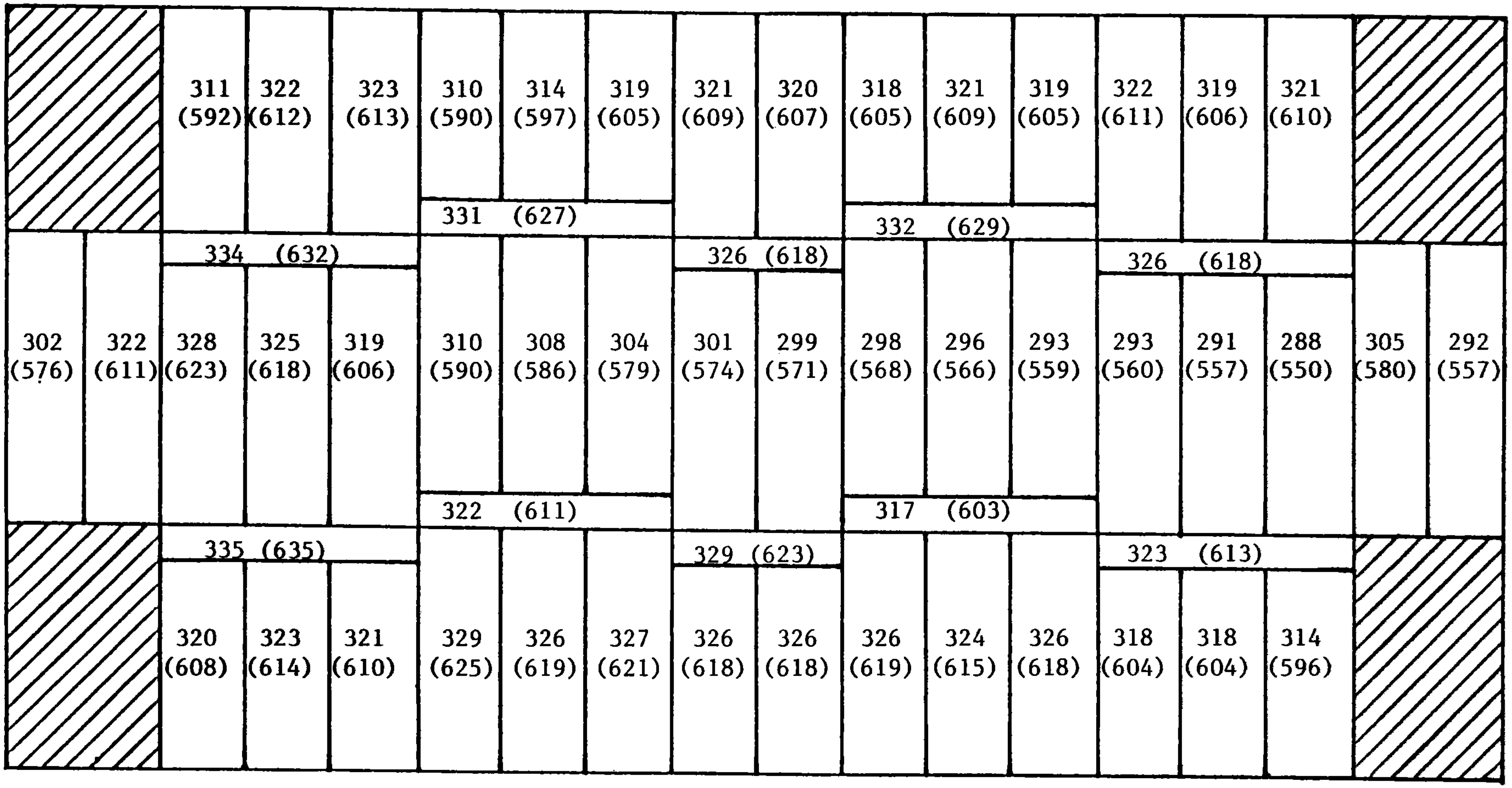


Note: The design goal was to limit the maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 333 C (632° F).

FIGURE E-66

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 355 TIME 10:00

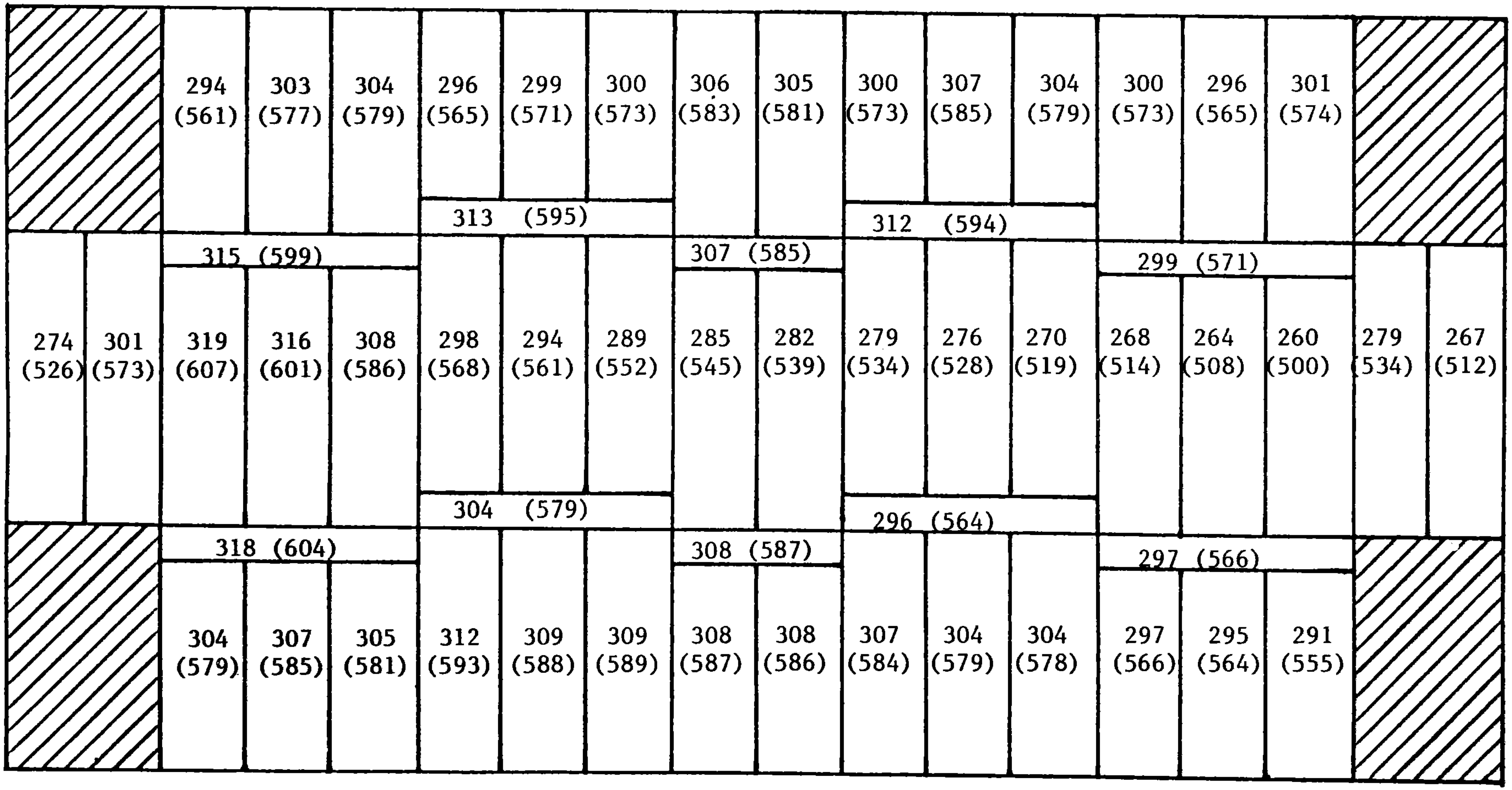


Note: The design goal was to limit the maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 335 C (635° F).

FIGURE E-67

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 355 TIME 8:00

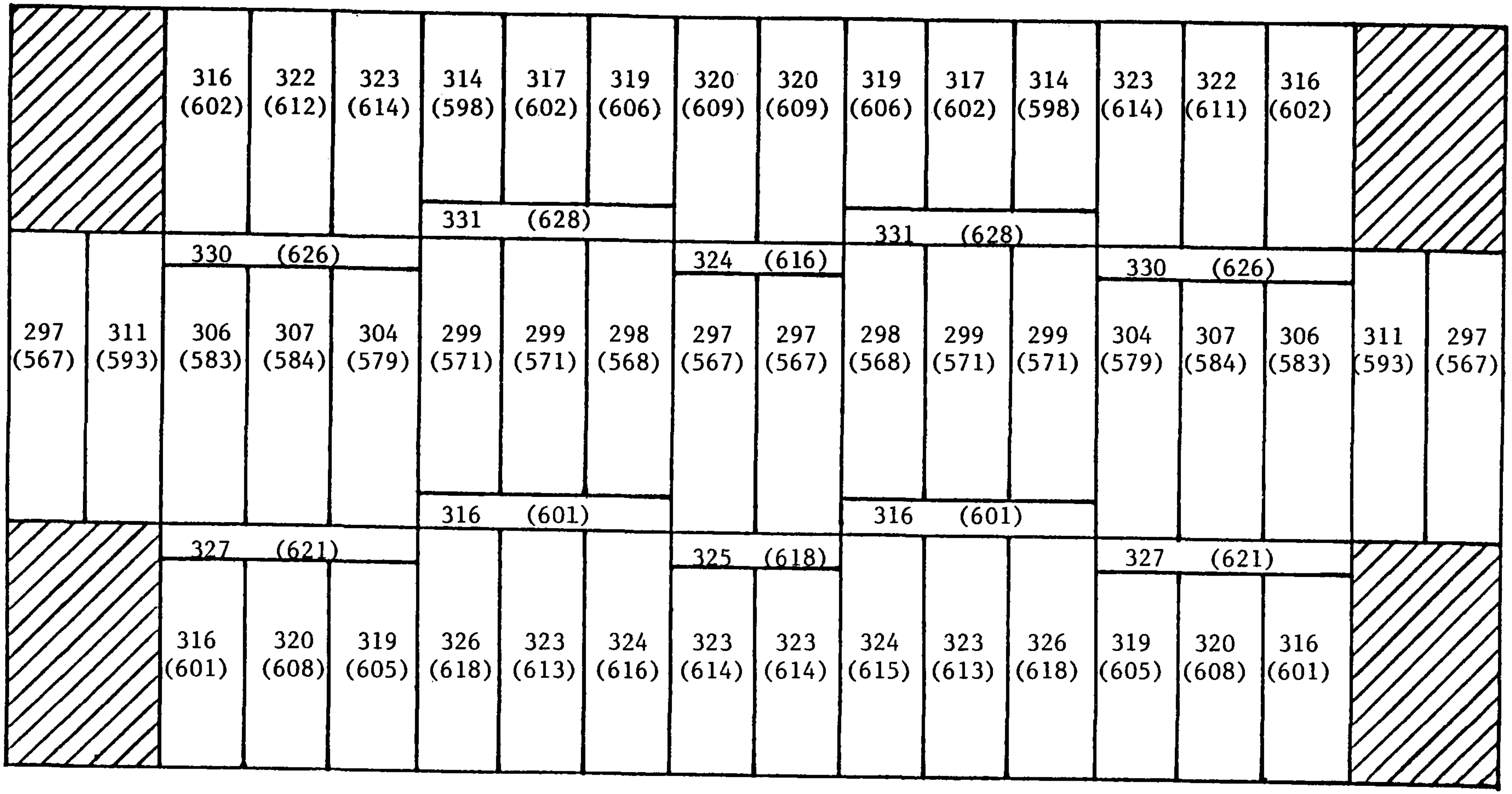


Note: The design goal was to limit the maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 319 C (607° F).

FIGURE E-68

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 80 TIME 12:00



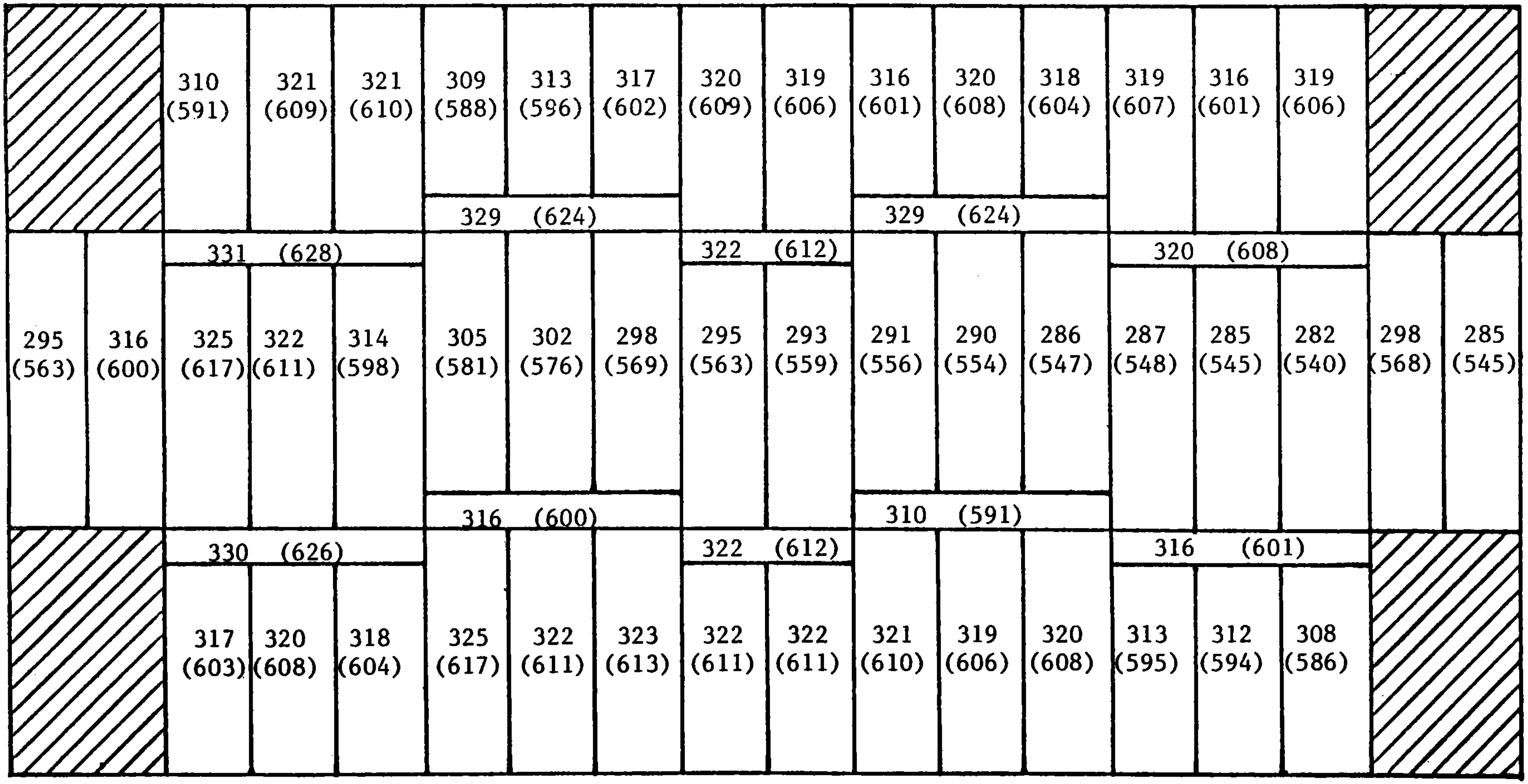
		316 (602)	322 (612)	323 (614)	314 (598)	317 (602)	319 (606)	320 (609)	320 (609)	319 (606)	317 (602)	314 (598)	323 (614)	322 (611)	316 (602)		
		330 (626)			331 (628)			324 (616)		331 (628)			330 (626)				
297 (567)	311 (593)	306 (583)	307 (584)	304 (579)	299 (571)	299 (571)	298 (568)	297 (567)	297 (567)	298 (568)	299 (571)	299 (571)	304 (579)	307 (584)	306 (583)	311 (593)	297 (567)
		327 (621)			316 (601)			325 (618)		316 (601)			327 (621)				
		316 (601)	320 (608)	319 (605)	326 (618)	323 (613)	324 (616)	323 (614)	323 (614)	324 (615)	323 (613)	326 (618)	319 (605)	320 (608)	316 (601)		

Note: The design goal was to limit the maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 331 C (628° F).

FIGURE E-69

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 80 TIME 10:00

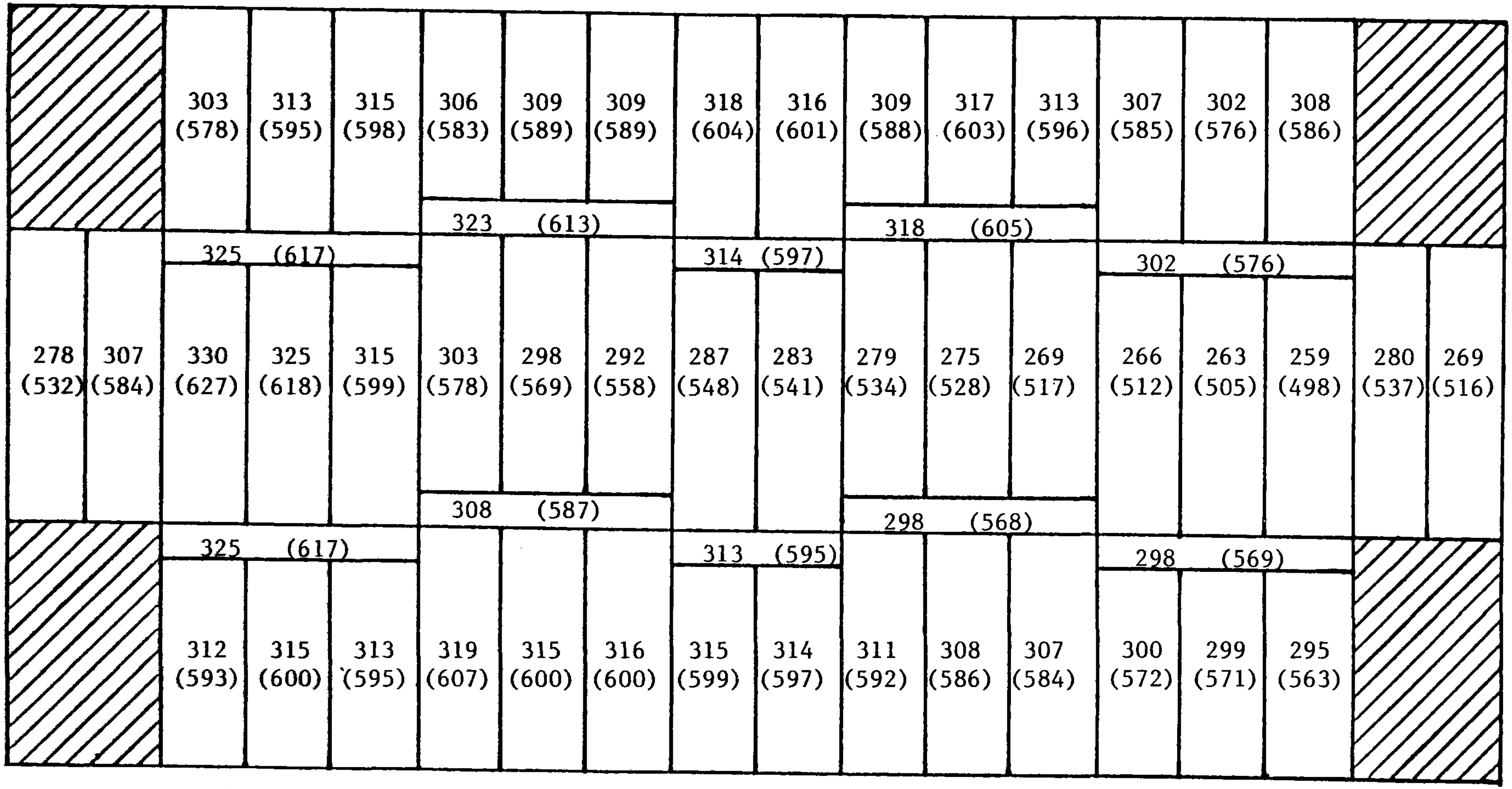


Note: The design goal was to limit maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 331 C (628° F).

FIGURE E-70

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 80 TIME 8:00

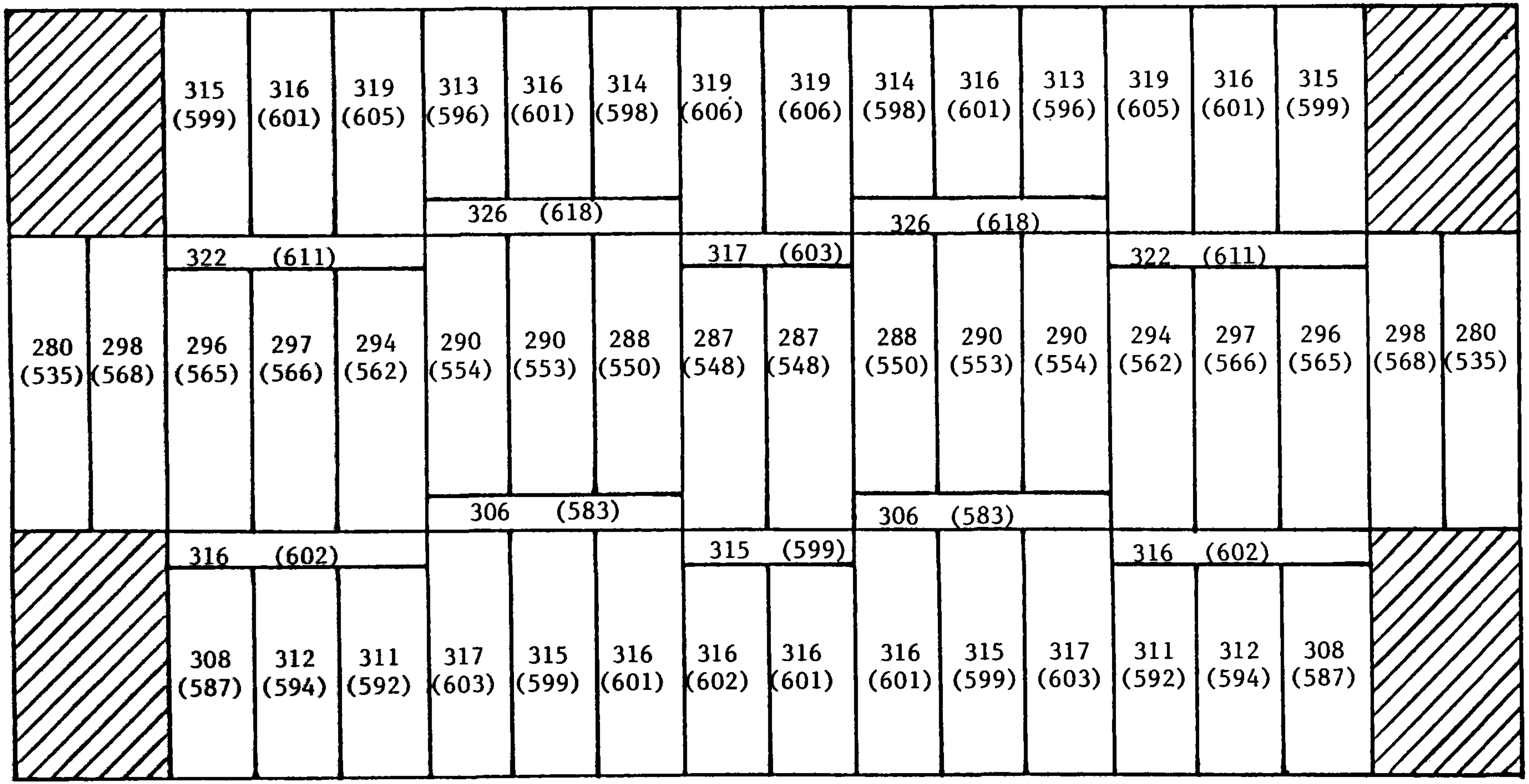


Note: The design goal was to limit the maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 330 C (627° F).

FIGURE E-71

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 173 TIME 12:00

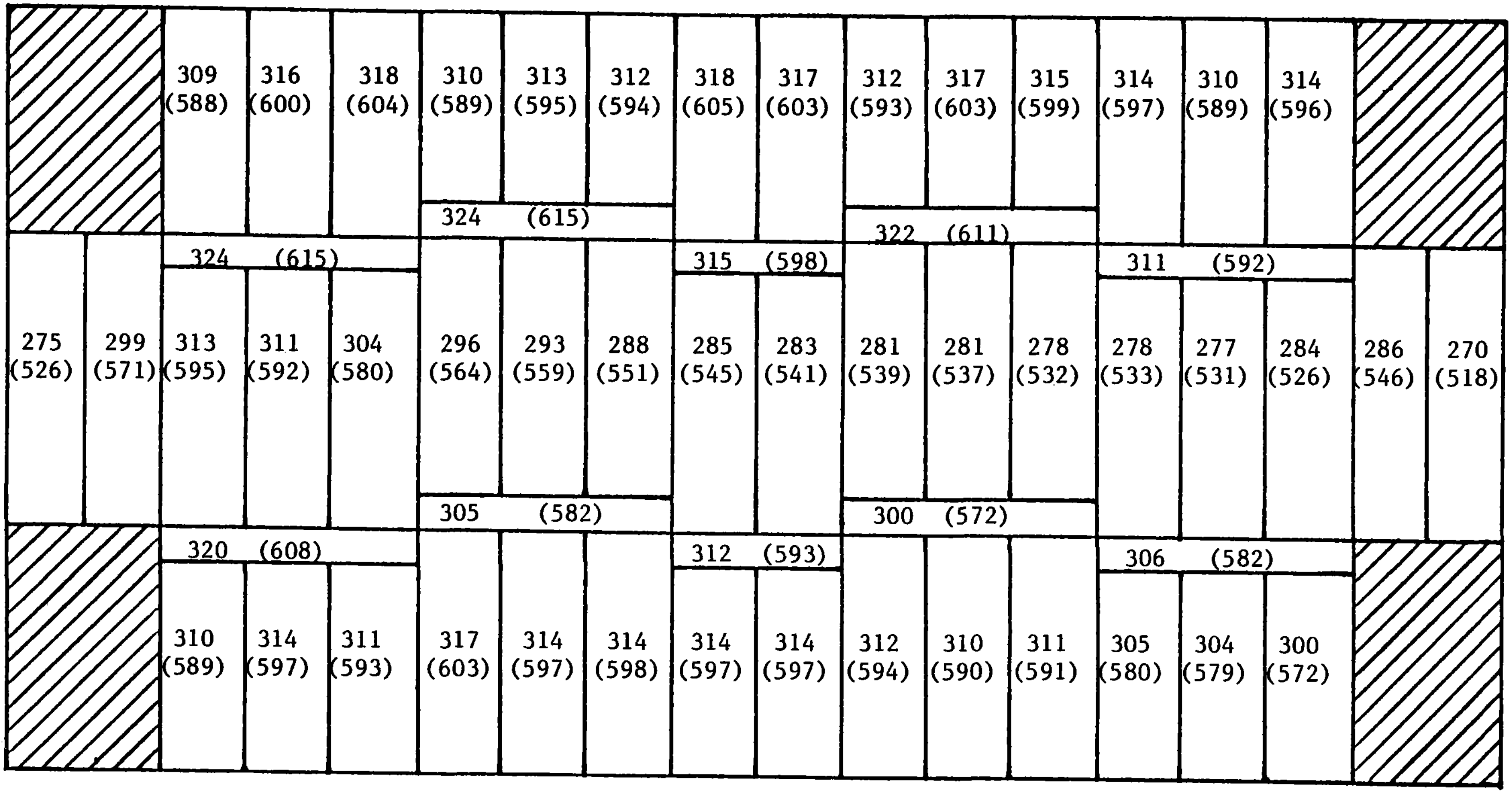


Note: The design goal was to limit the maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 326 C (618° F).

FIGURE E-72

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 173 TIME 10:00

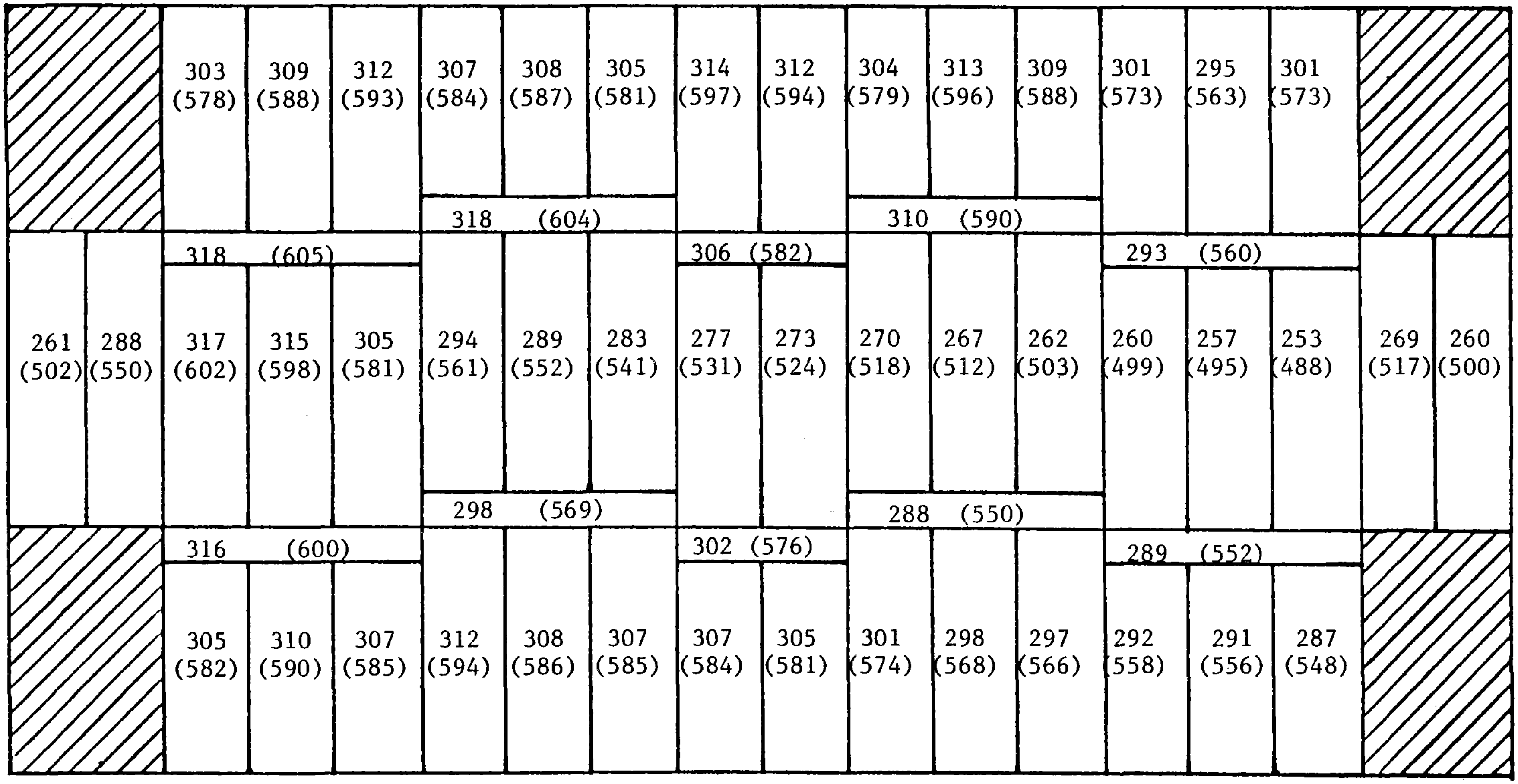


Note: The design goal was to limit the maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 324 C (615° F).

FIGURE E-73

MAXIMUM FLOW PASSAGE FRONT SIDE TEMPERATURE, C (°F)

DAY 173 TIME 8:00

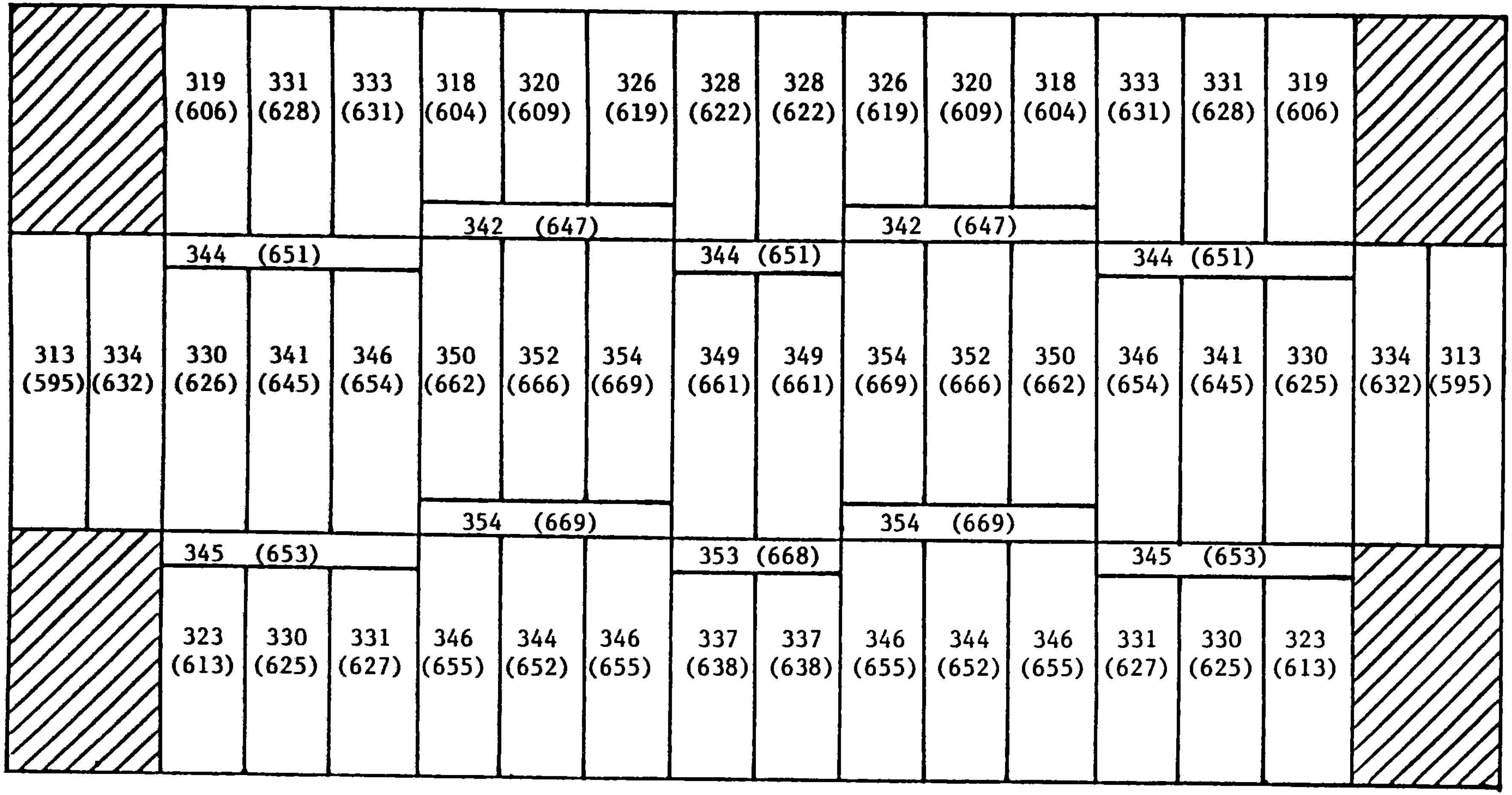


Note: The design goal was to limit the maximum passage front side temperature to 343 C (650° F). The actual maximum for this day and time is 318 C (605° F).

FIGURE E-74

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 355 TIME 12:00

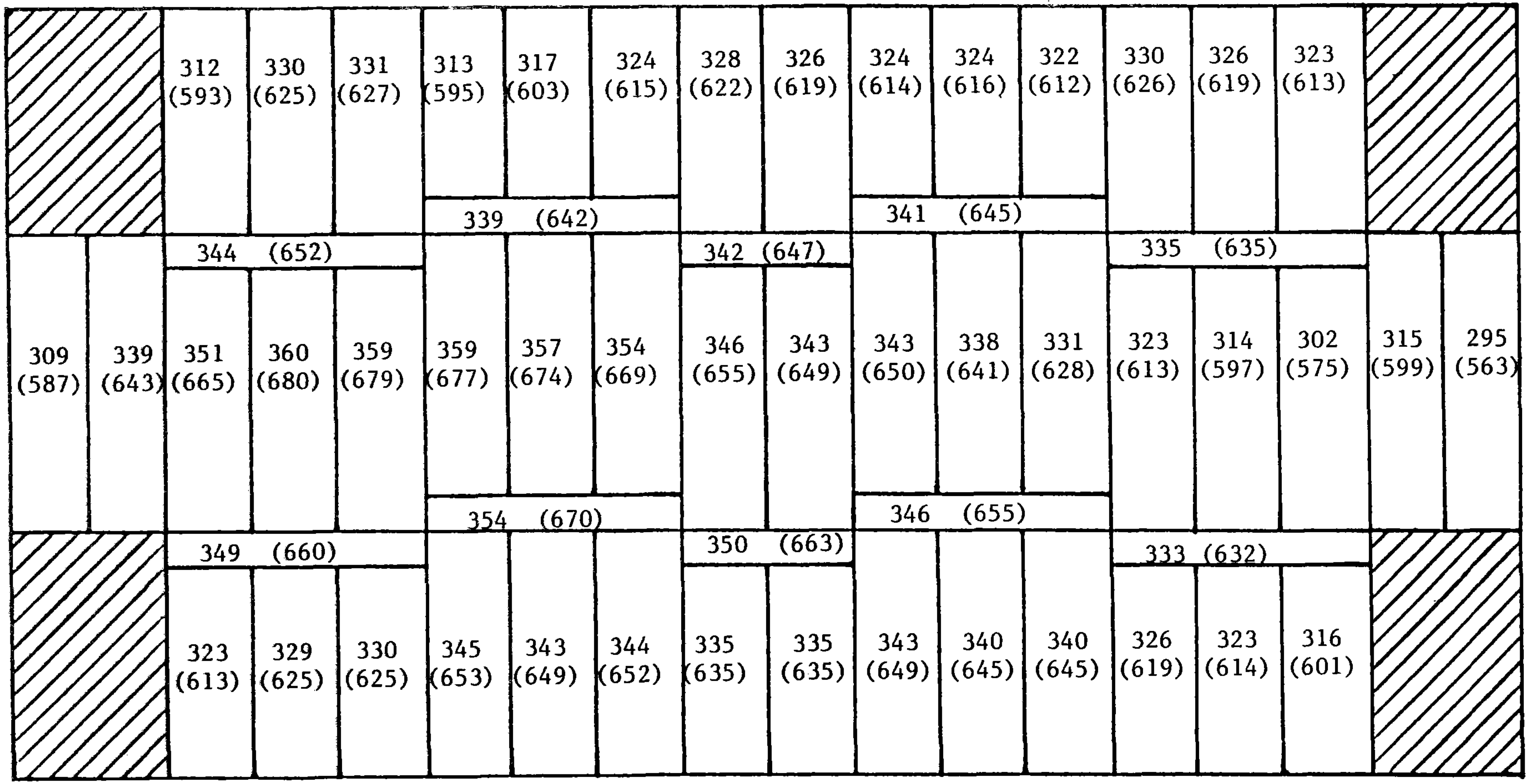


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 354 C (669° F).

FIGURE E-75

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 355 TIME 10:00

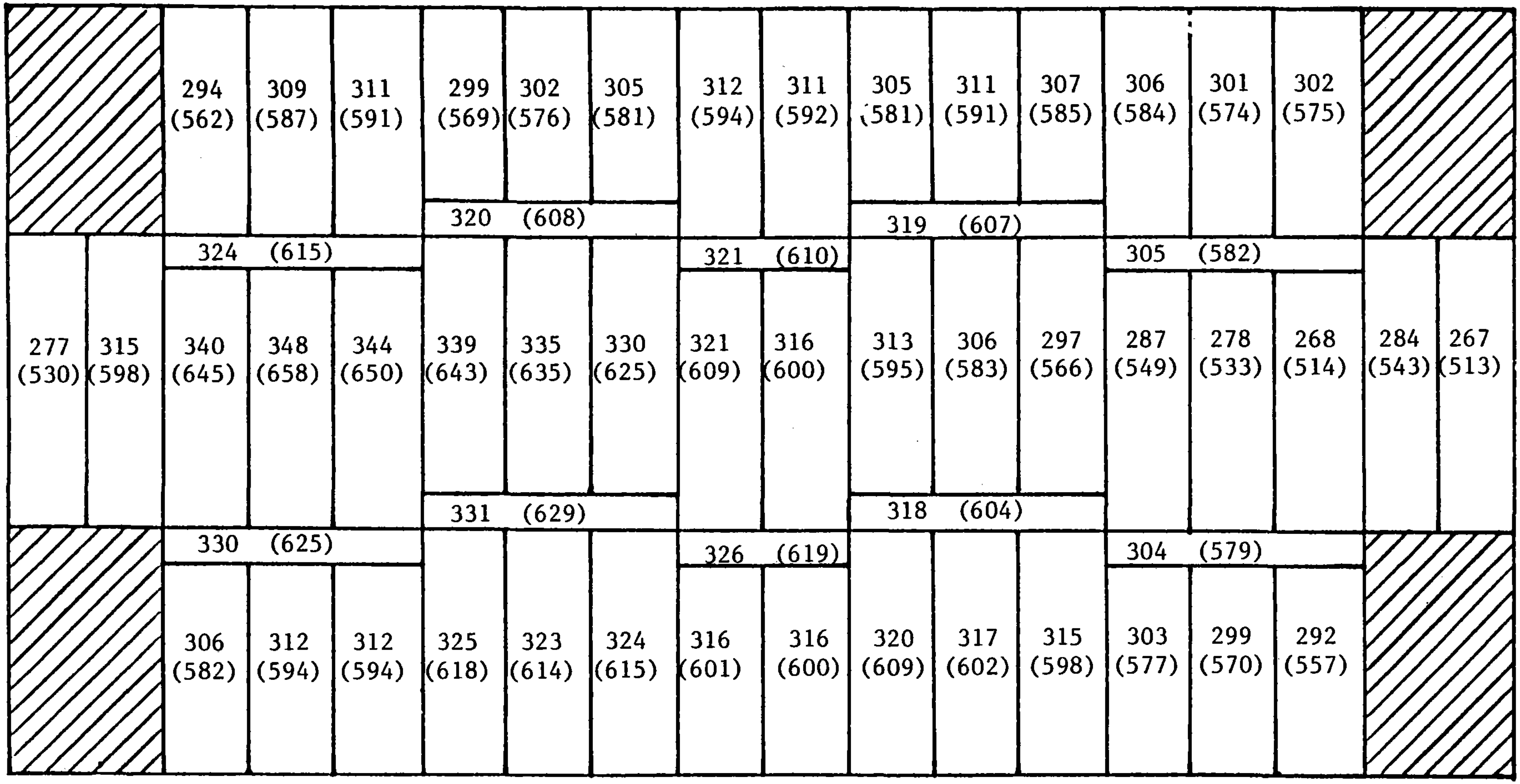


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 360 C (680° F).

FIGURE E-76

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 355 TIME 8:00

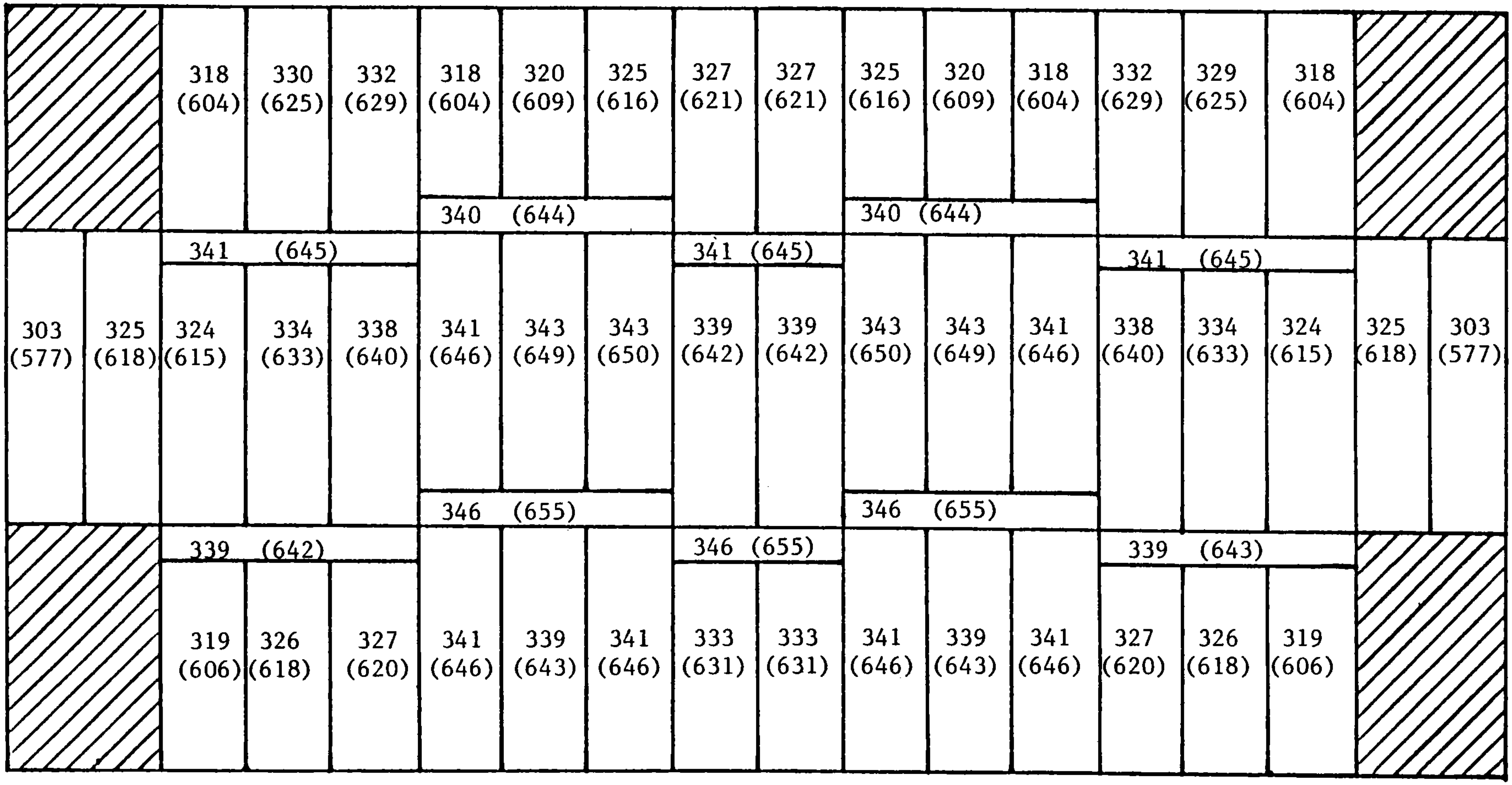


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 348 C (658° F).

FIGURE E-77

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 80 TIME 12:00

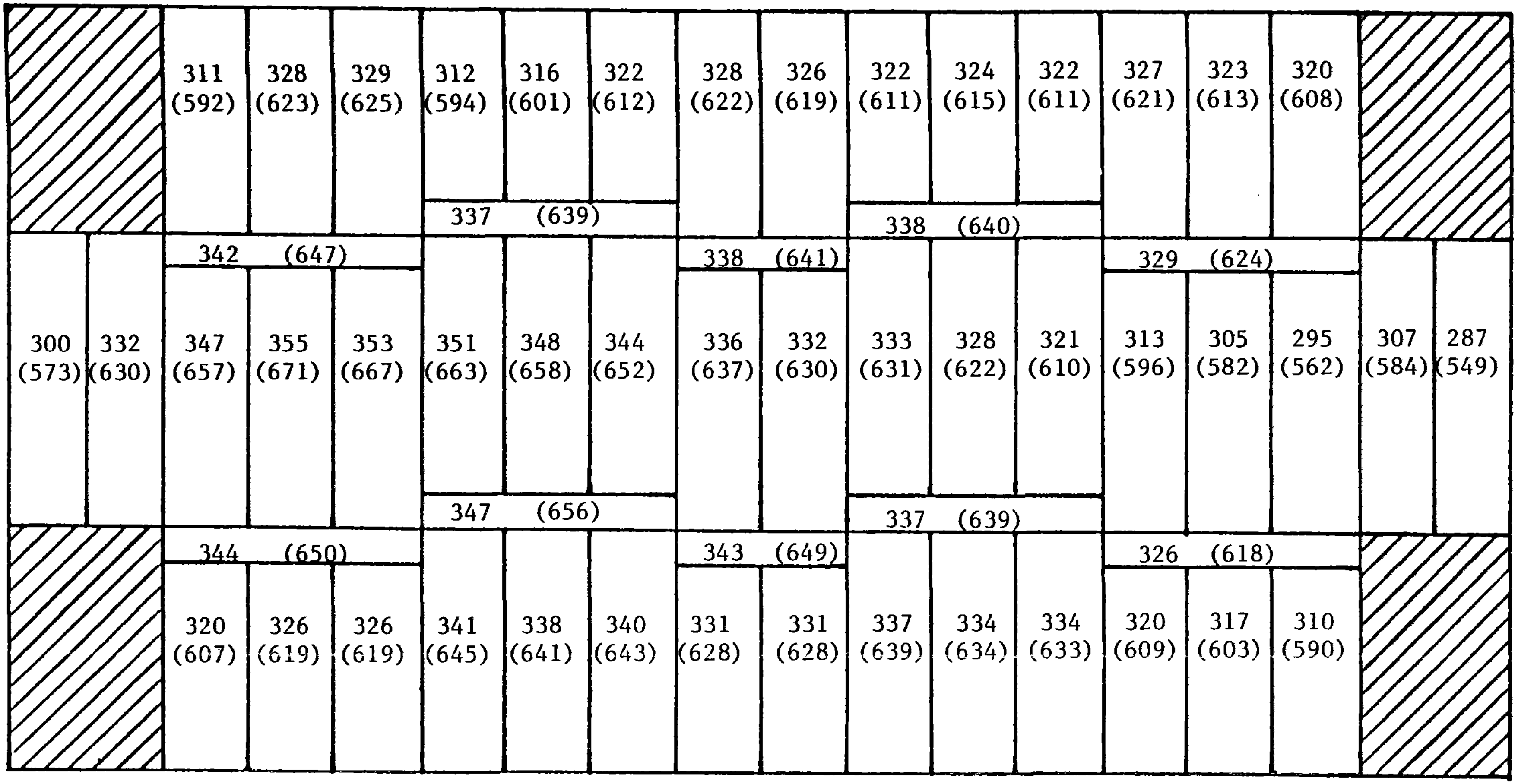


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 346 C (655° F).

FIGURE E-78

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 80 TIME 10:00

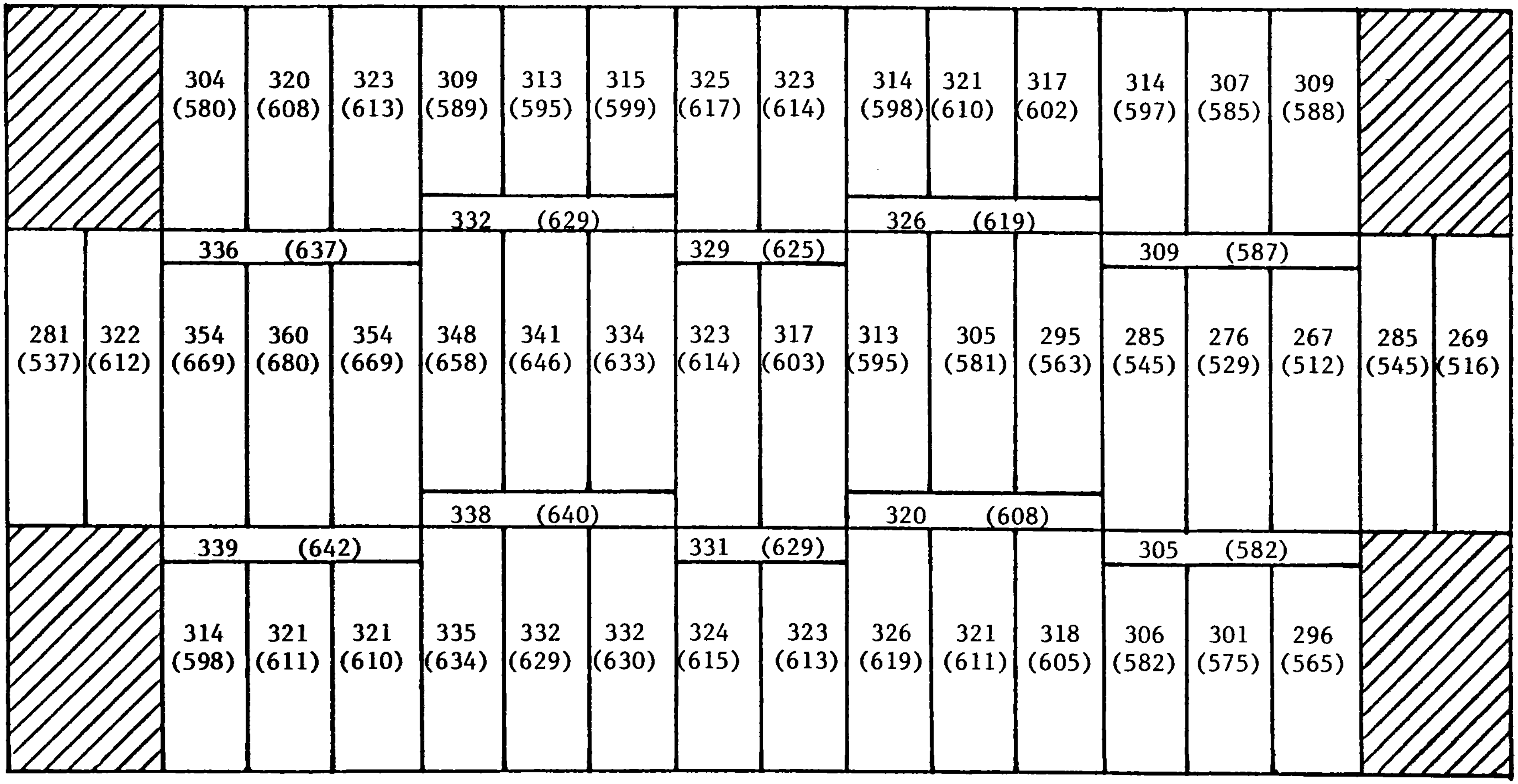


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 355 C (671° F).

FIGURE E-79

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 80 TIME 8:00

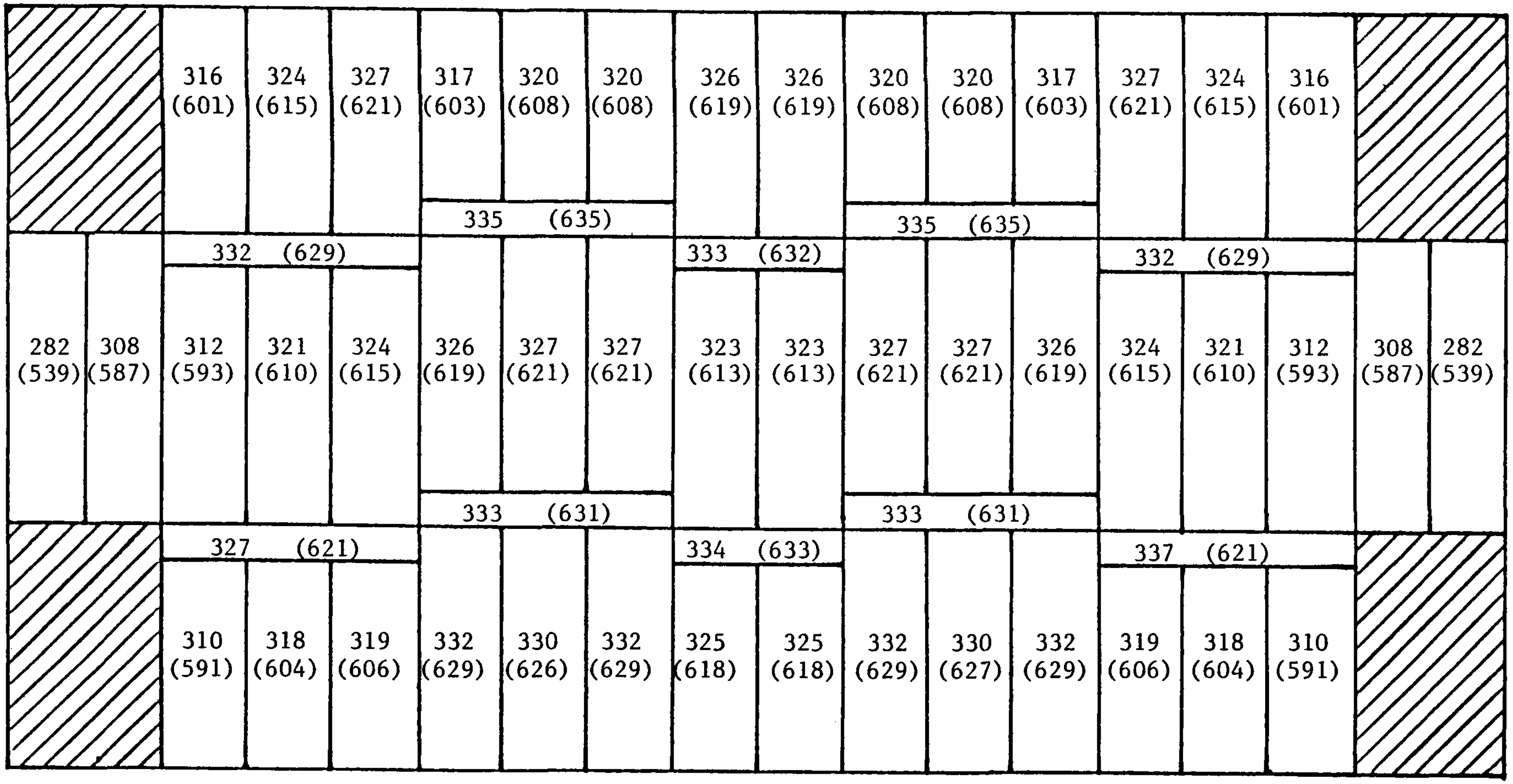


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 360 C (680° F)

FIGURE E-80

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 173 TIME 12:00

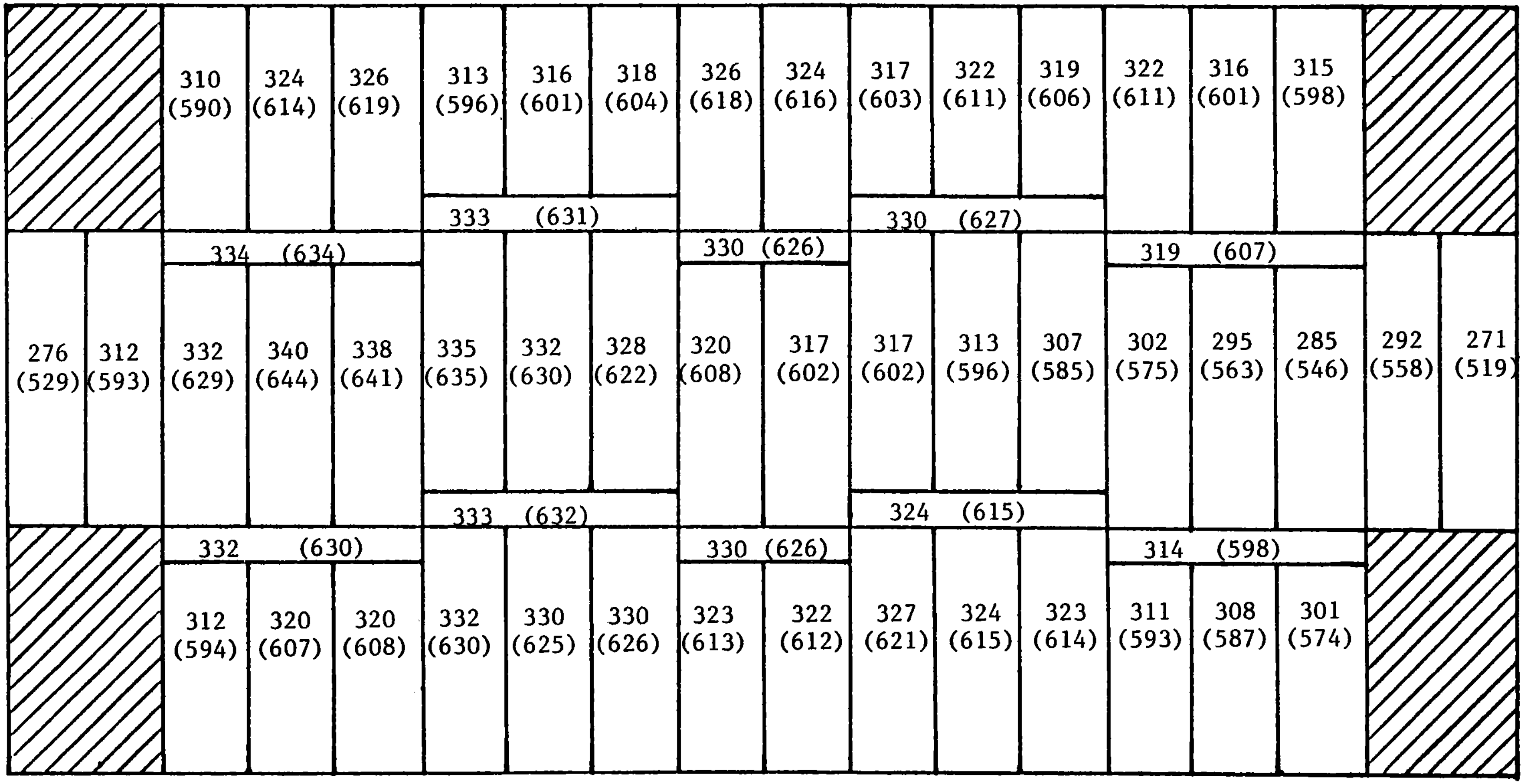


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 335 C (635° F).

FIGURE E-81

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 173 TIME 10:00

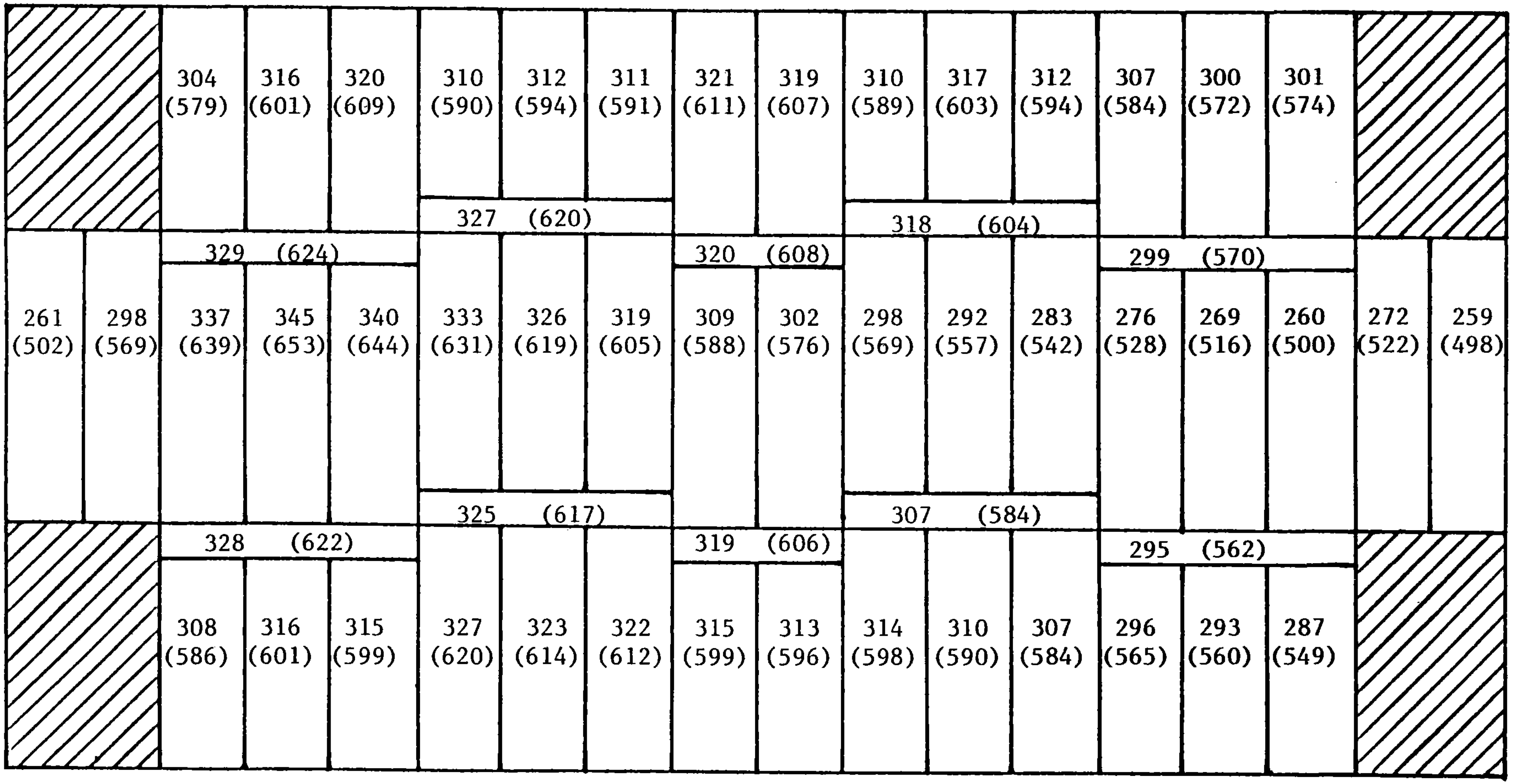


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 340 C (644° F).

FIGURE E-82

MAXIMUM BETWEEN-PASSAGE (FIN) TEMPERATURE, C (°F)

DAY 173 TIME 8:00

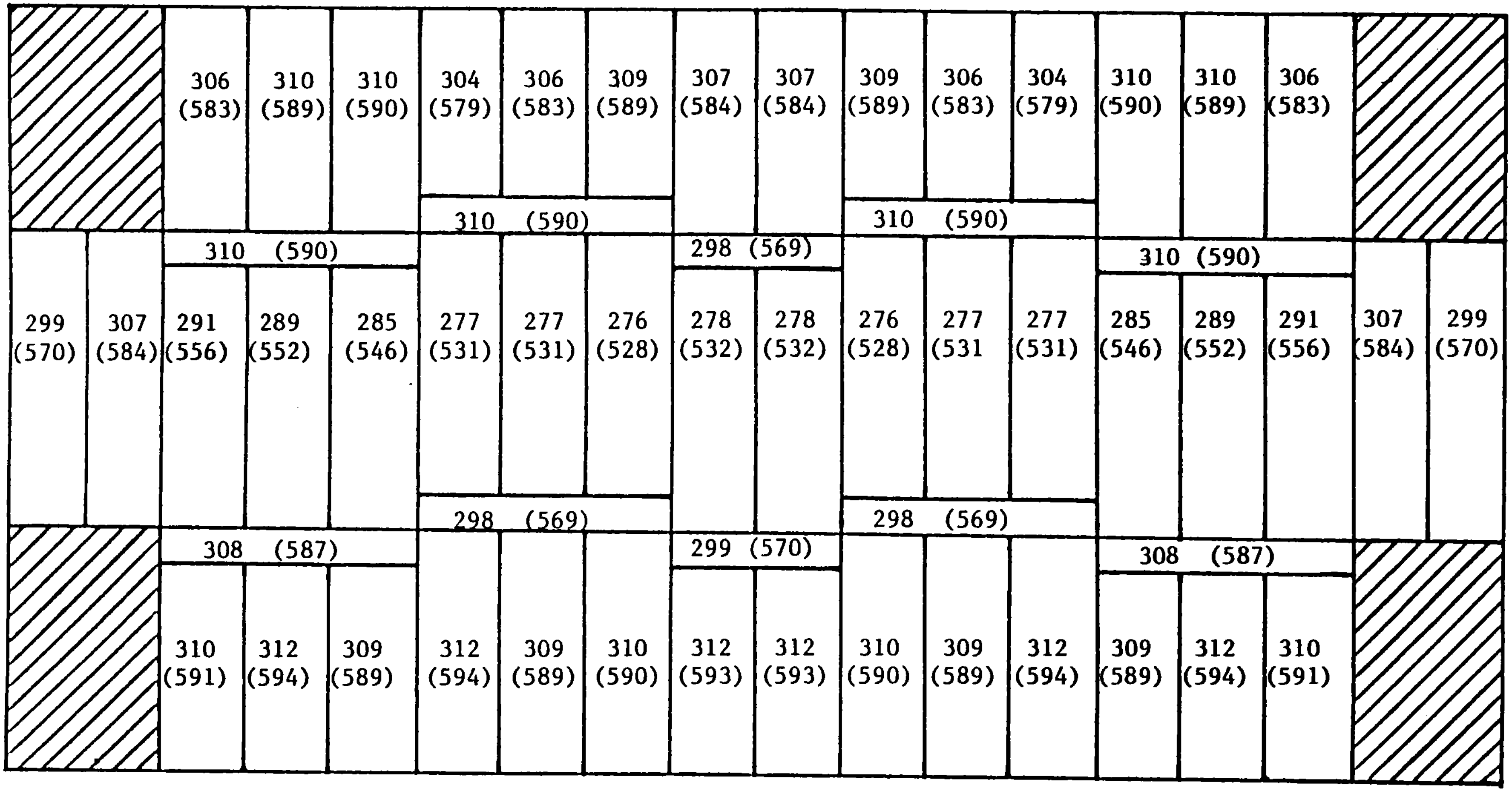


Note: The design goal was to limit the maximum between-passage (fin) temperature to 357 C (675° F). The actual maximum for this day and time is 345 C (653° F).

FIGURE E-83

OIL OUTLET TEMPERATURE, C (°F)

DAY 355 TIME 12:00

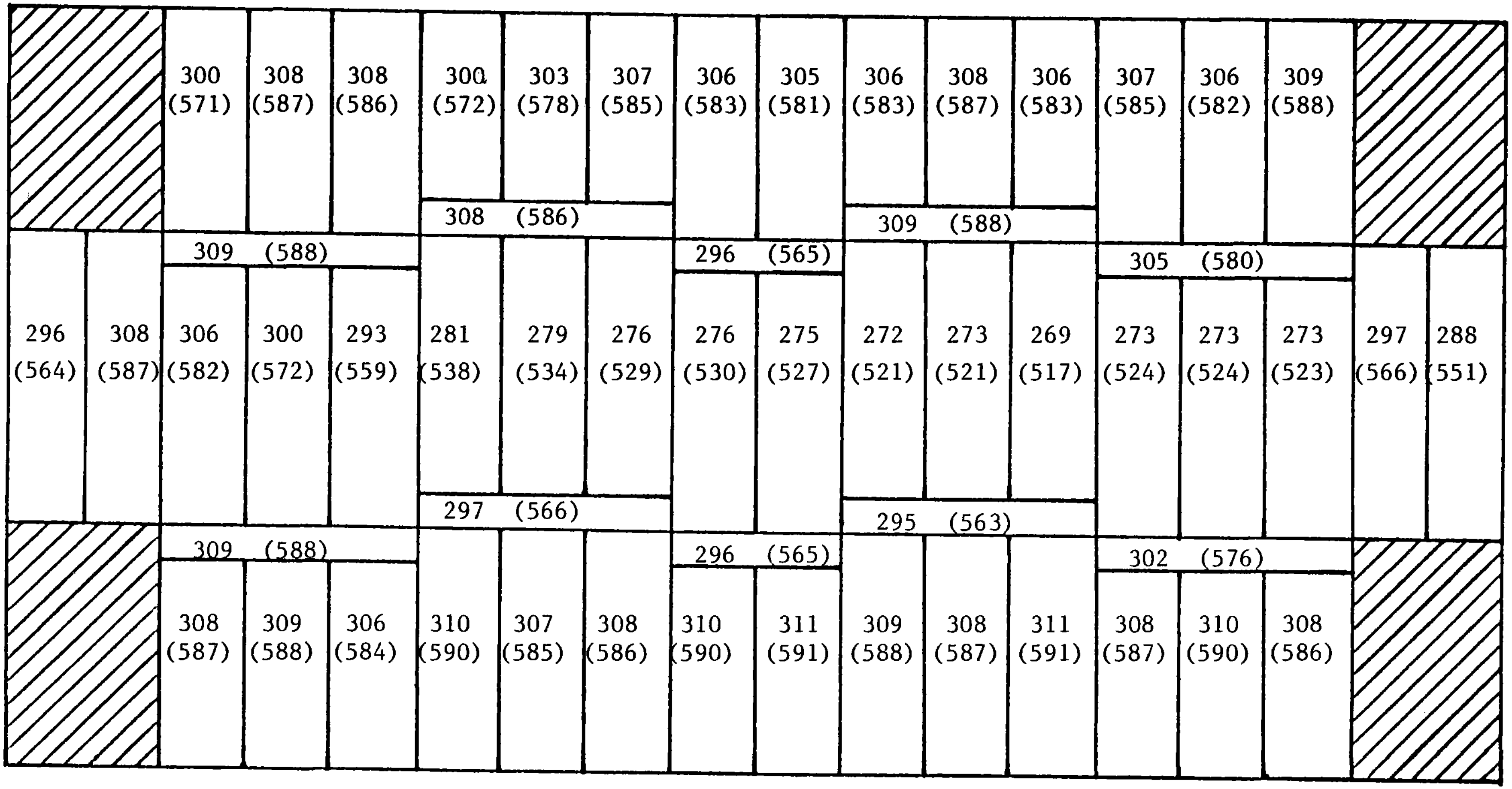


Note: The design goal was to limit the maximum oil outlet temperature to 316 C (600° F).
The actual maximum for this day and time is 312 C (594° F).

FIGURE E-84

OIL OUTLET TEMPERATURE, C (^{O}F)

DAY 355 TIME 10:00

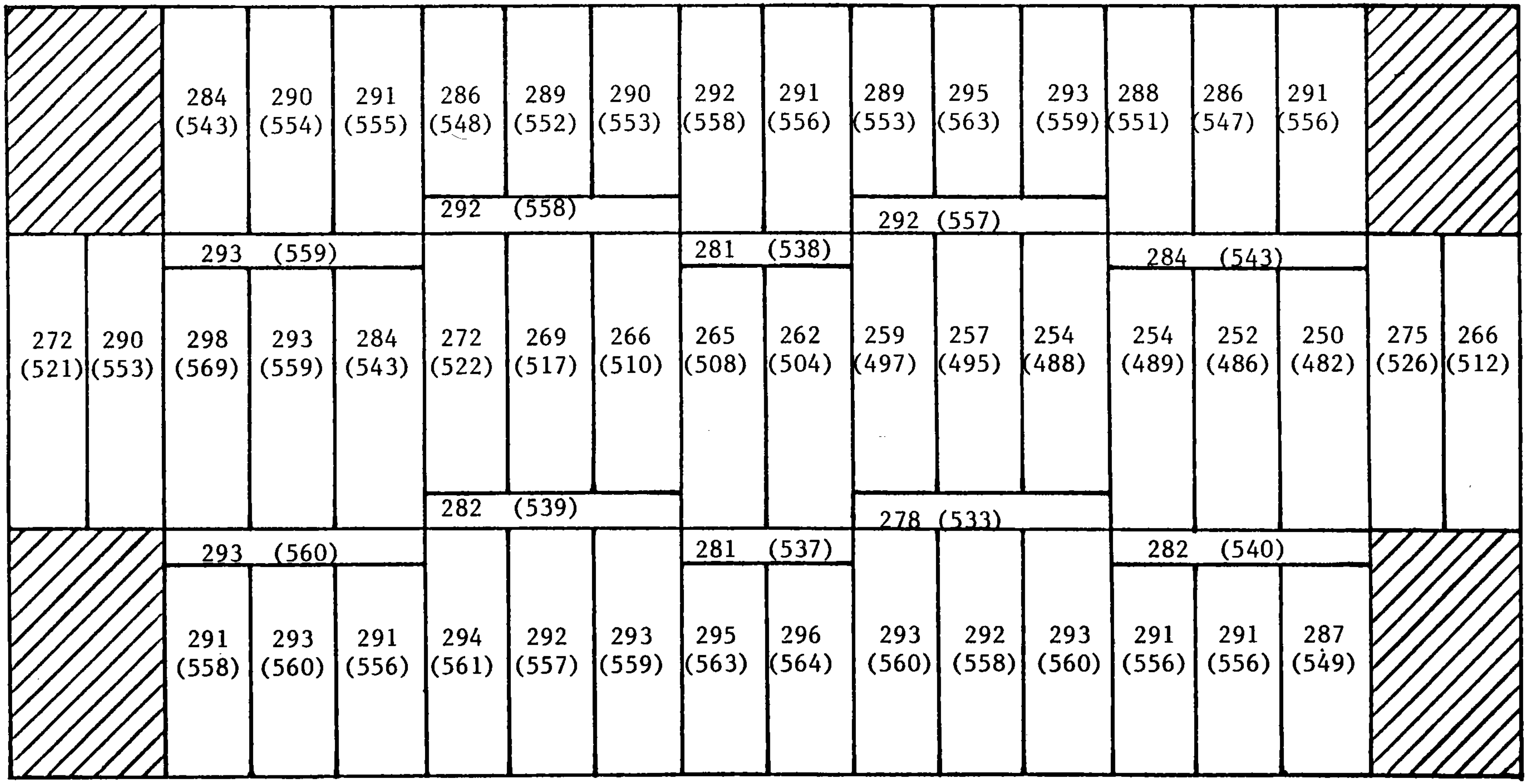


Note: The design goal was to limit the maximum oil outlet temperature to 316 C (600° F).
The actual maximum for this day and time is 311 C (591° F).

FIGURE E-85

OIL OUTLET TEMPERATURE, C (°F)

DAY 355 TIME 8:00

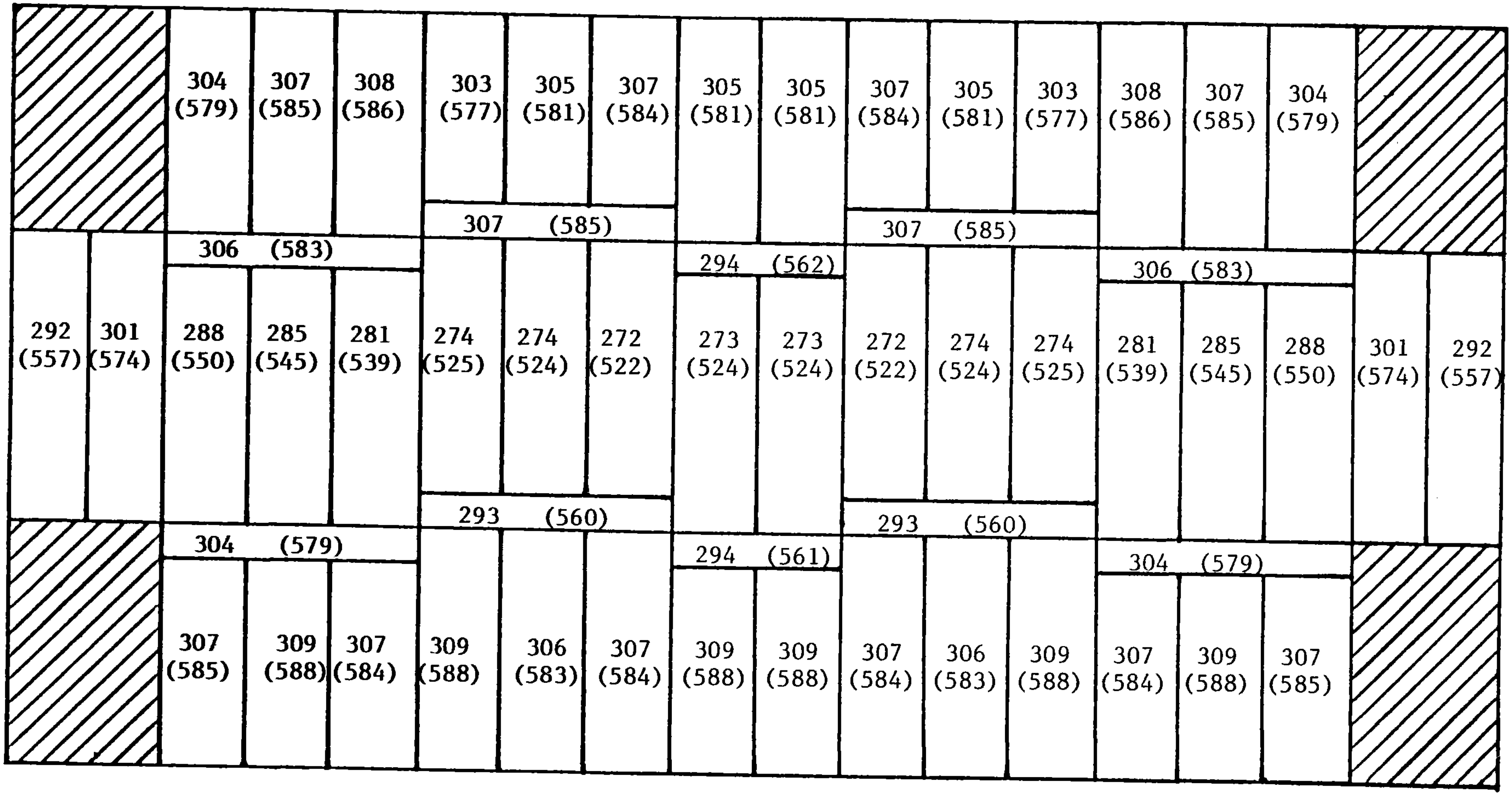


Note: The design goal was to limit the maximum oil outlet temperature to 316 C (600° F).
The actual maximum for this day and time is 298 C (569° F).

FIGURE E-86

OIL OUTLET TEMPERATURE, C (°F)

DAY 80 TIME 12:00

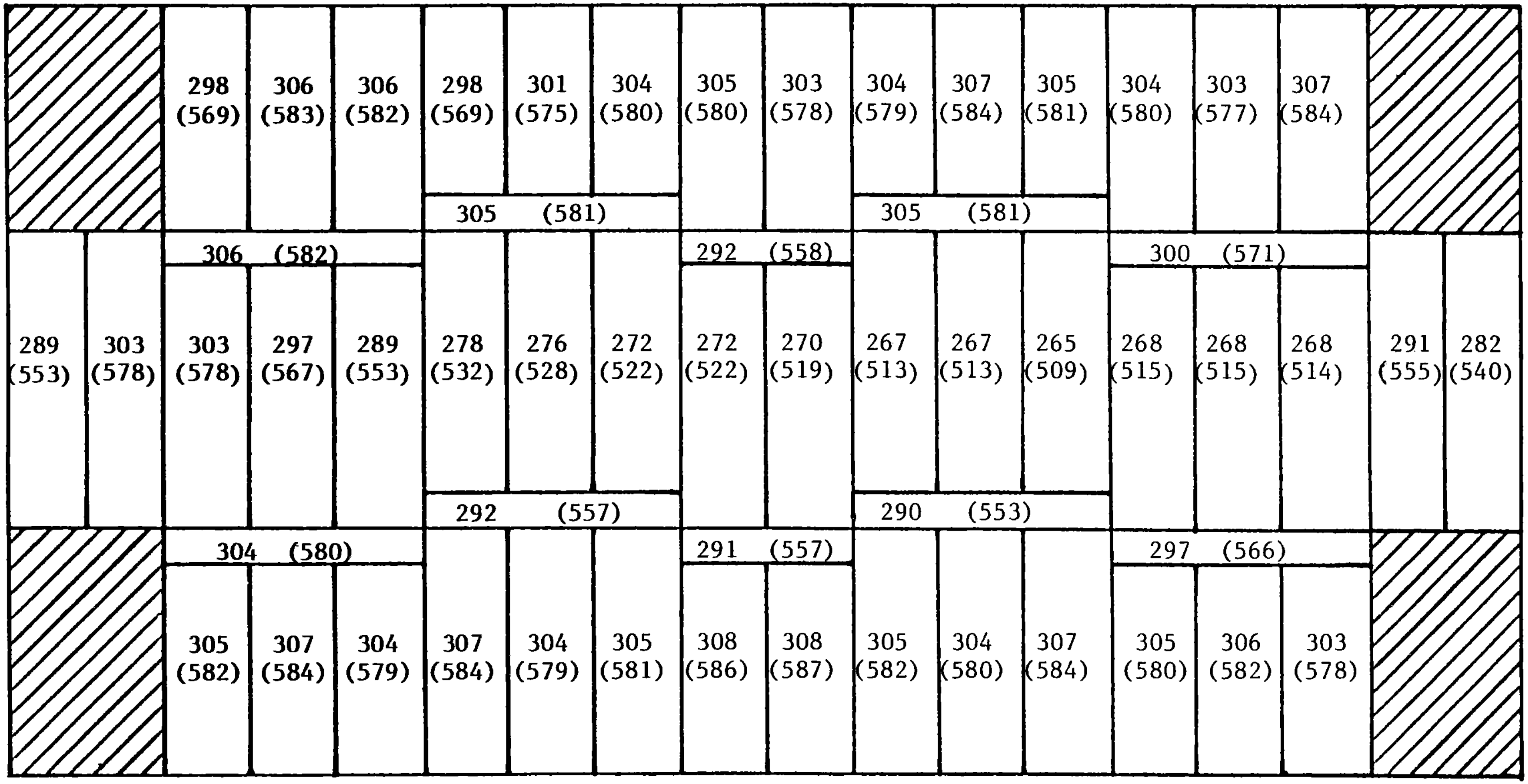


Note: The design goal was limit the maximum oil outlet temperature to 316 C (600° F). The actual maximum for this day and time is 309 C (588° F).

FIGURE E-87

OIL OUTLET TEMPERATURE, C (°F)

DAY 80 TIME 10:00

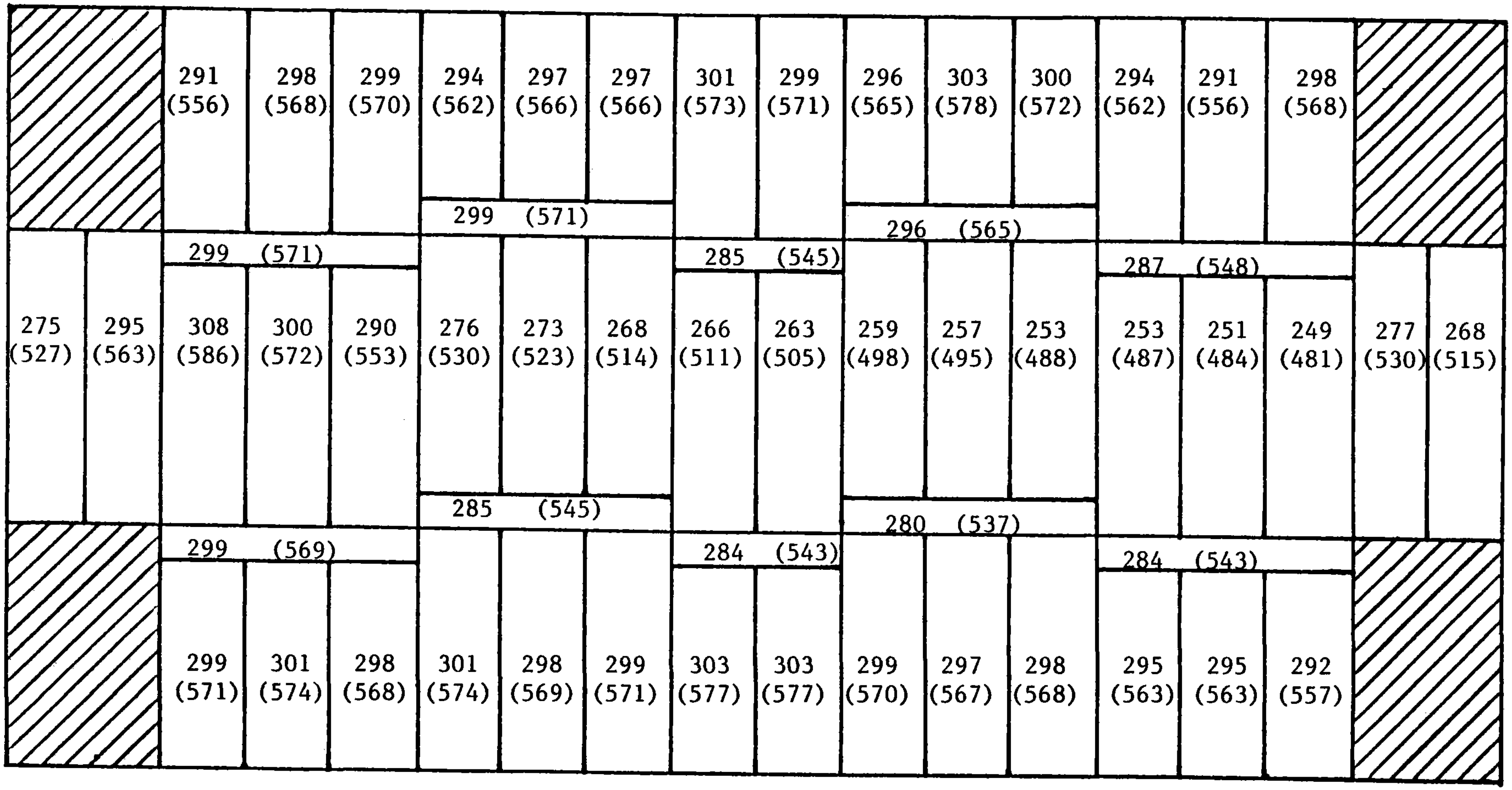


Note: The design goal was to limit the maximum oil outlet temperature to 316 C (600° F). The actual maximum for this day and time is 308 C (587° F).

FIGURE E-88

OIL OUTLET TEMPERATURE, C (°F)

DAY 80 TIME 8:00

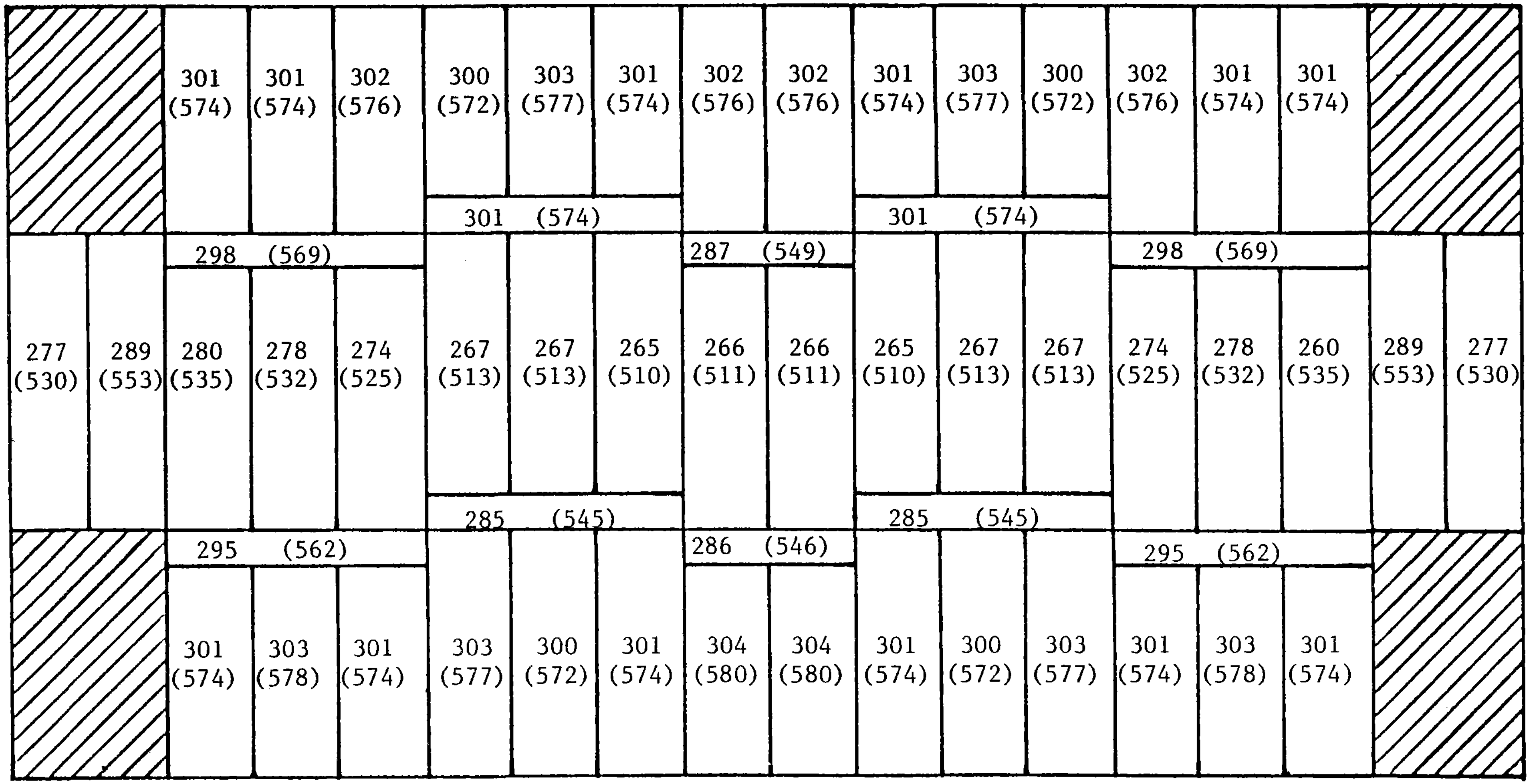


Note: The design goal was to limit the maximum oil outlet temperature to 316 C (600° F). The actual maximum for this day and time is 308 C (586° F).

FIGURE E-89

OIL OUTLET TEMPERATURE, C (^{o}F)

DAY 173 TIME 12:00

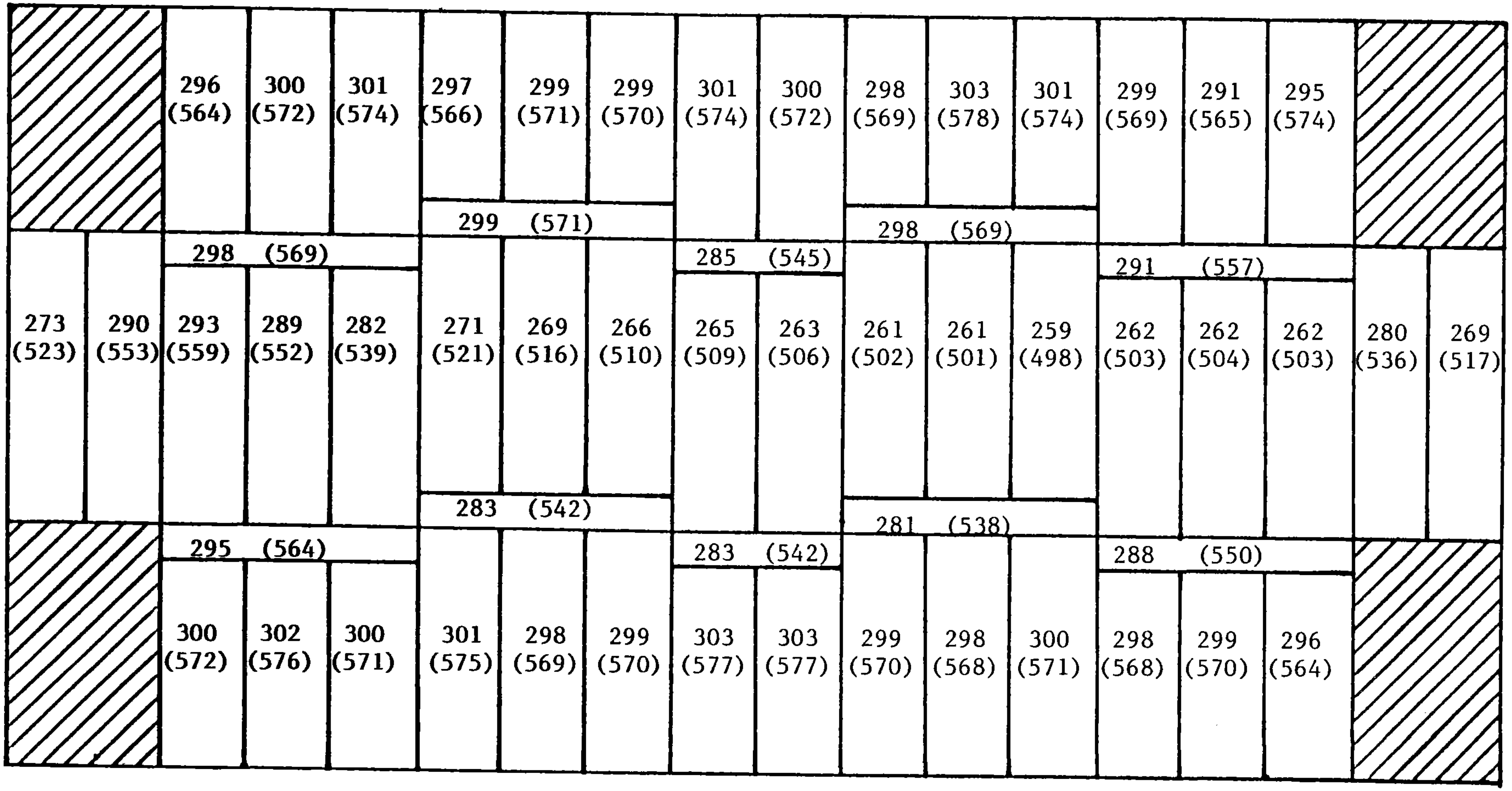


Note: The design goal was to limit the maximum oil outlet temperature to 316 C (600° F).
The actual maximum for this day and time is 304 C (580° F).

FIGURE E-90

OIL OUTLET TEMPERATURE, C (^{o}F)

DAY 173 TIME 10:00

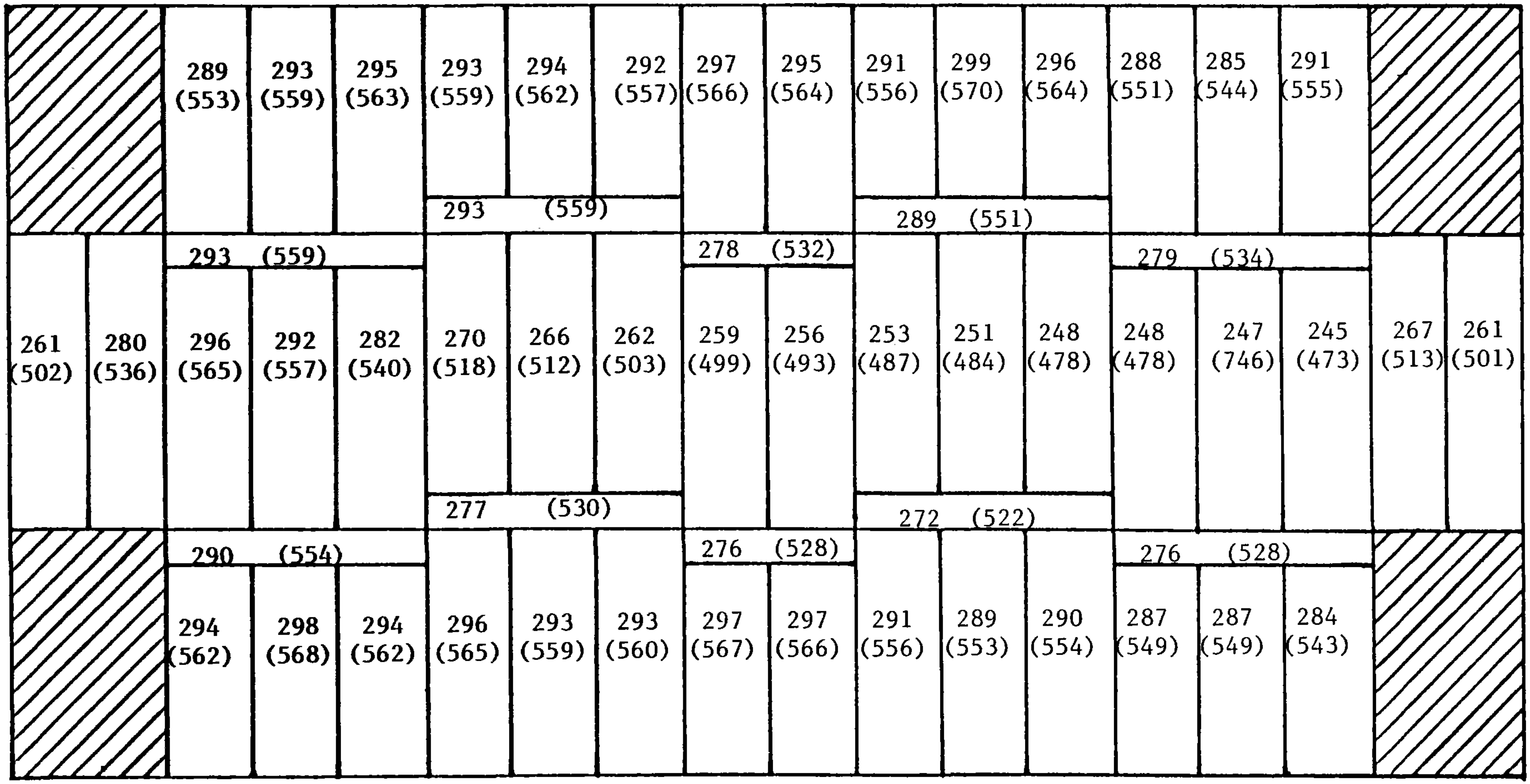


Note: The design goal was to limit the maximum oil outlet temperature to 316 C (600° F). The actual maximum for this day and time is 303 C (578° F).

FIGURE E-91

OIL OUTLET TEMPERATURE, C (°F)

DAY 173 TIME 8:00

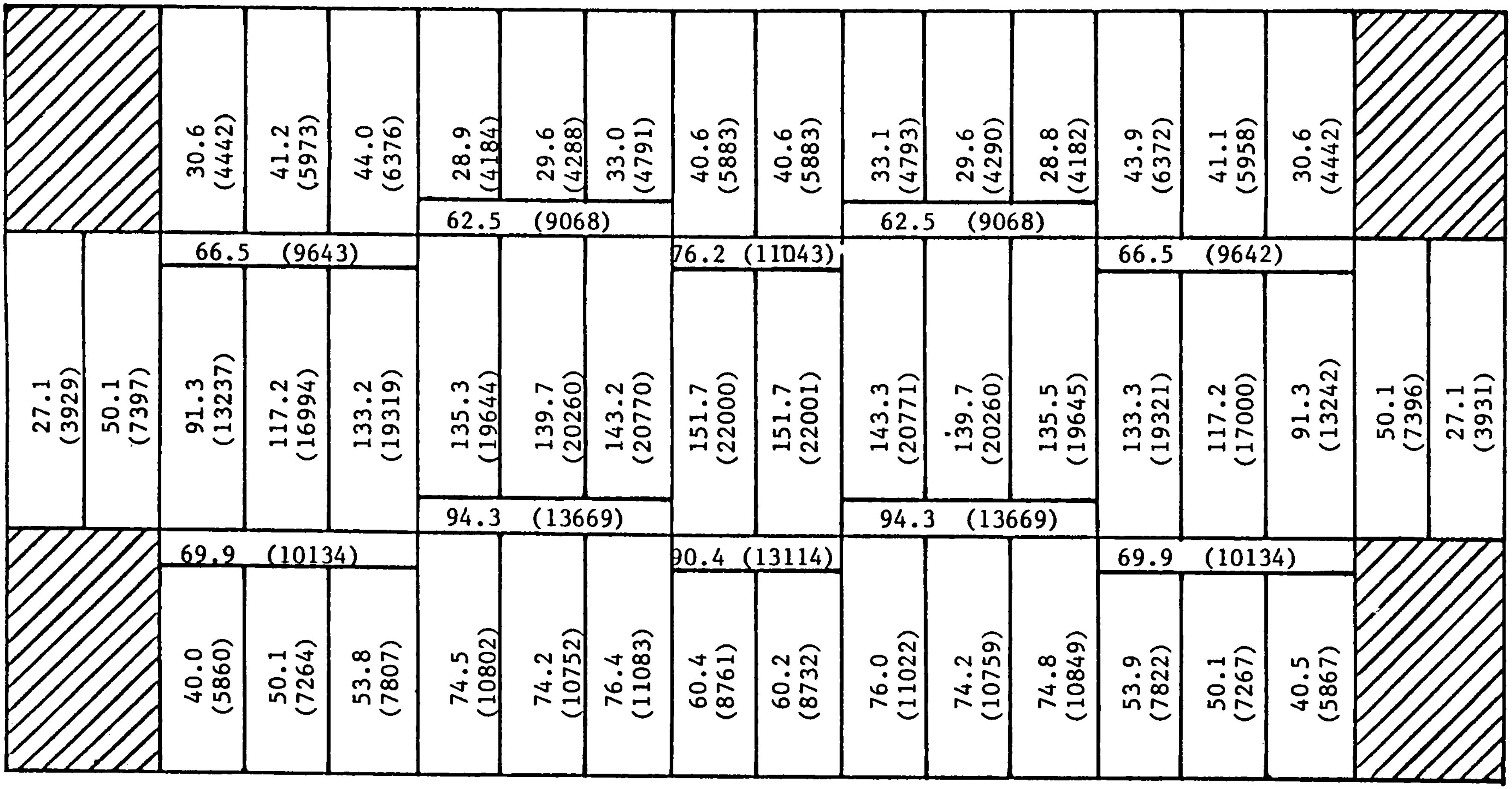


Note: The design goal was to limit the maximum oil outlet temperature to 316 C (600° F). The actual maximum for this day and time is 299 C (570° F).

FIGURE E-92

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

DAY 355 TIME 12:00

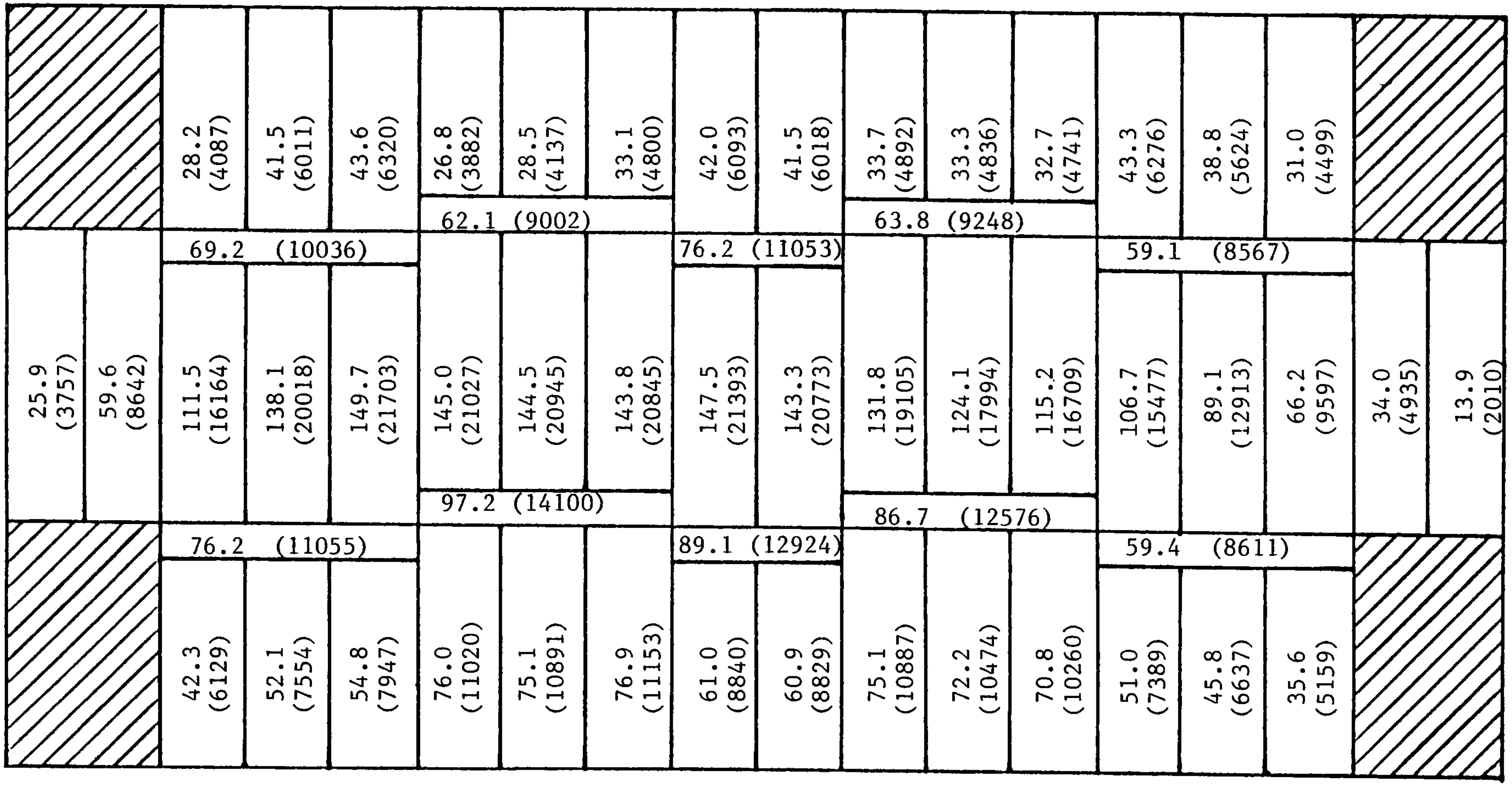


Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 151.7 x 10^6 Pa (22,001 psi).

FIGURE E-93

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

DAY 355 TIME 10:00

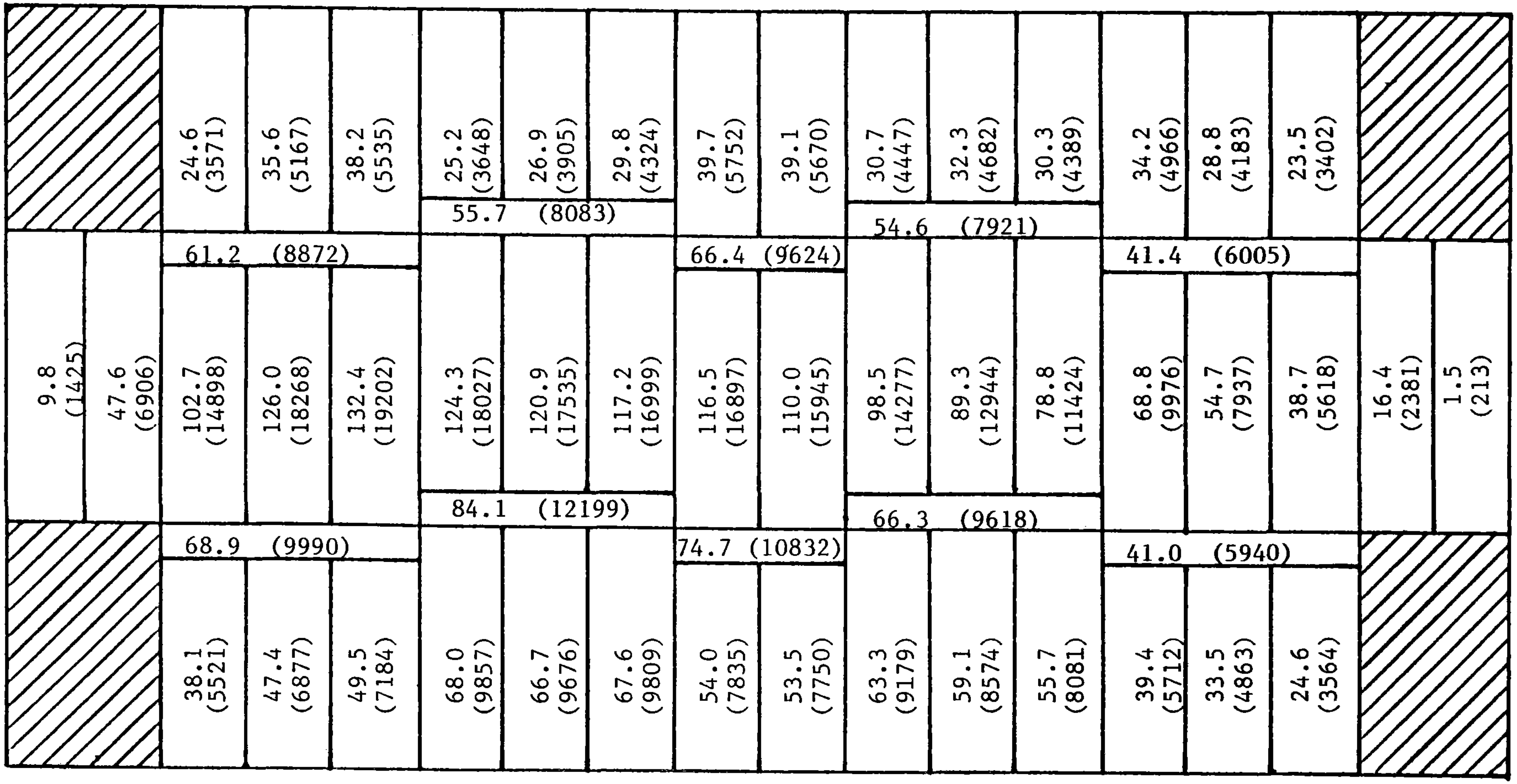


Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 149.7 x 10^6 Pa (21,703 psi).

FIGURE E-94

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

DAY 355 TIME 8:00

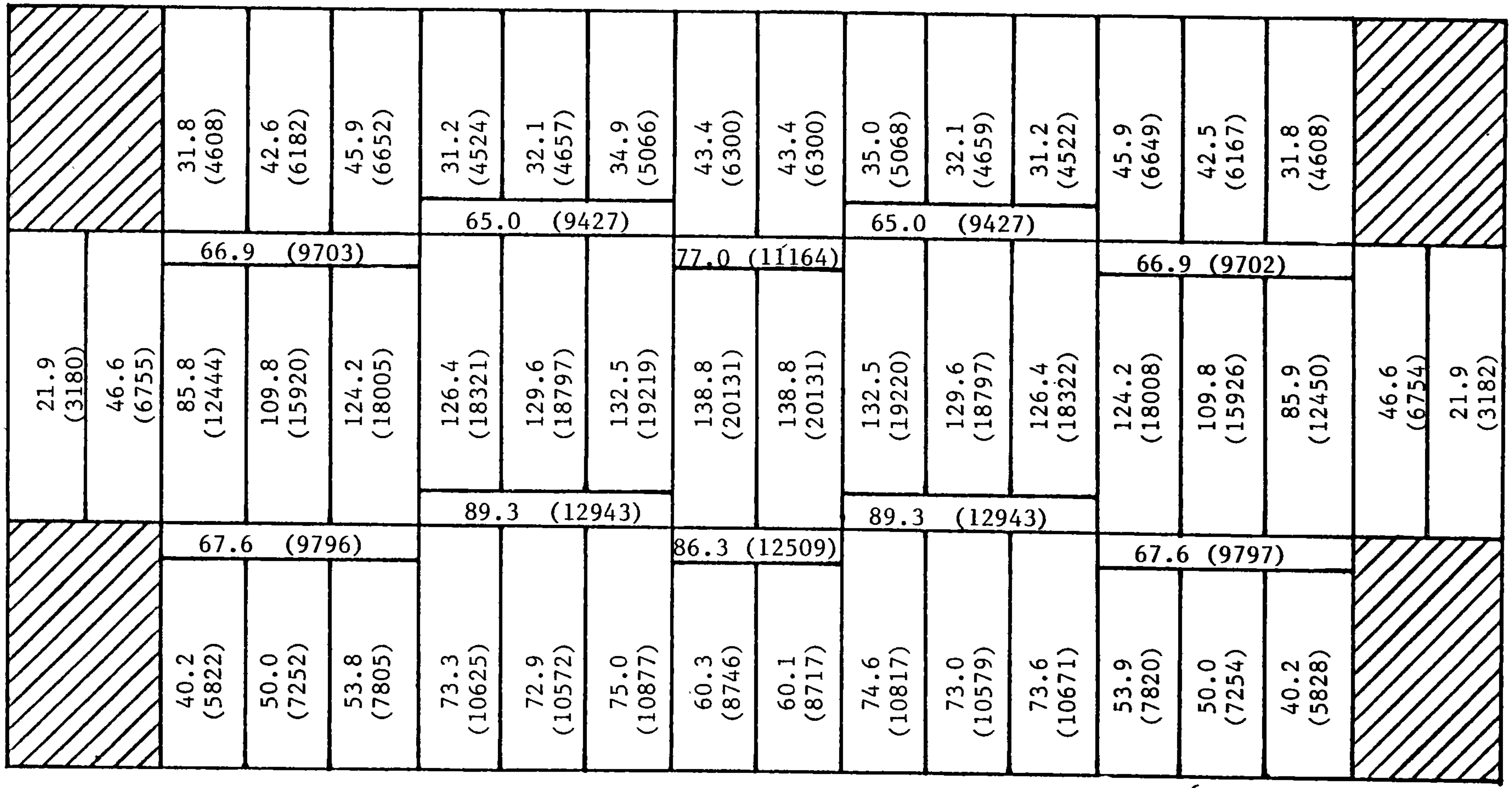


Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 132.4 x 10^6 Pa (19,202 psi).

FIGURE E-95

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

DAY 80 TIME 12:00

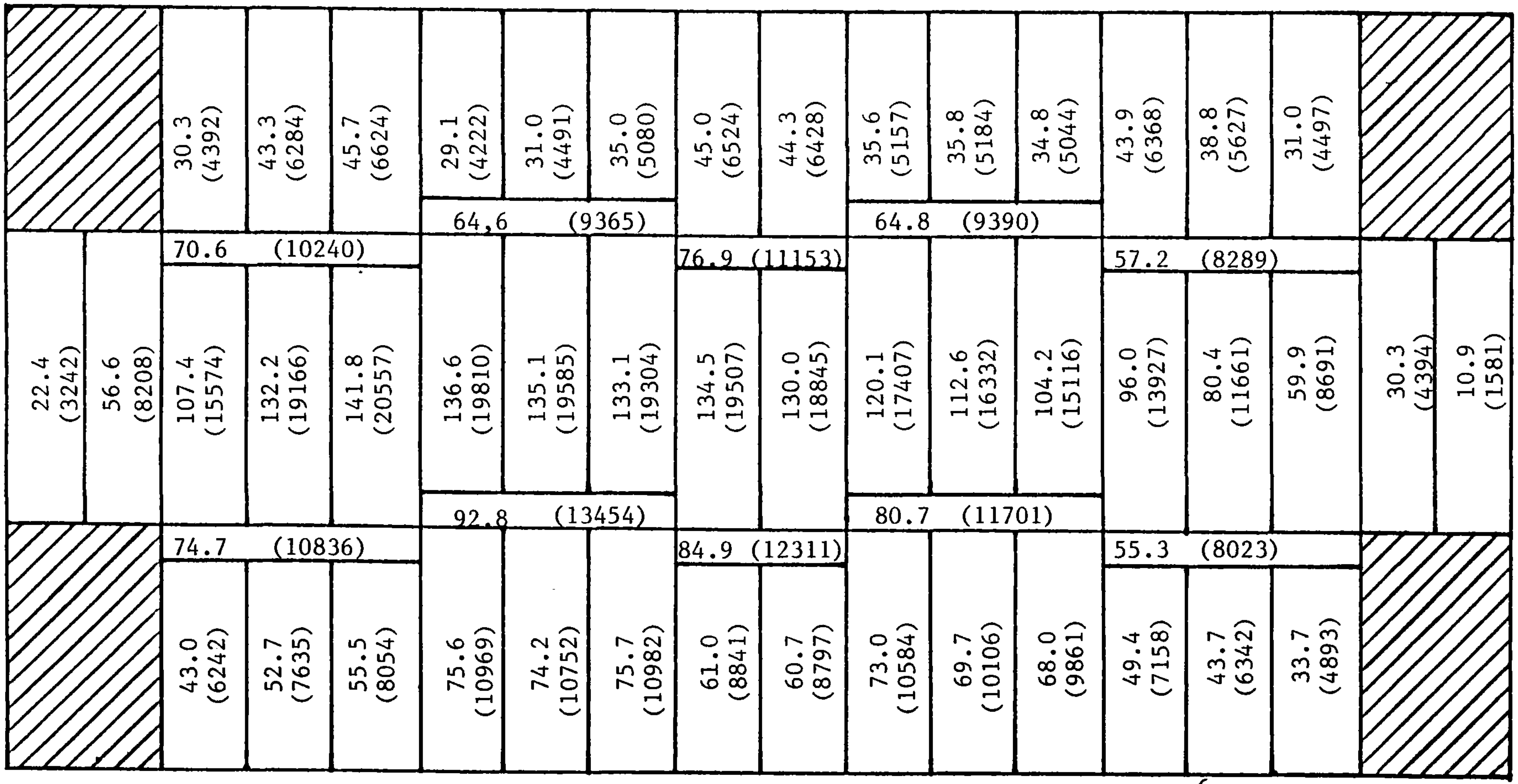


Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 138.8 x 10^6 Pa (20,131 psi).

FIGURE E-96

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

DAY 80 TIME 10:00

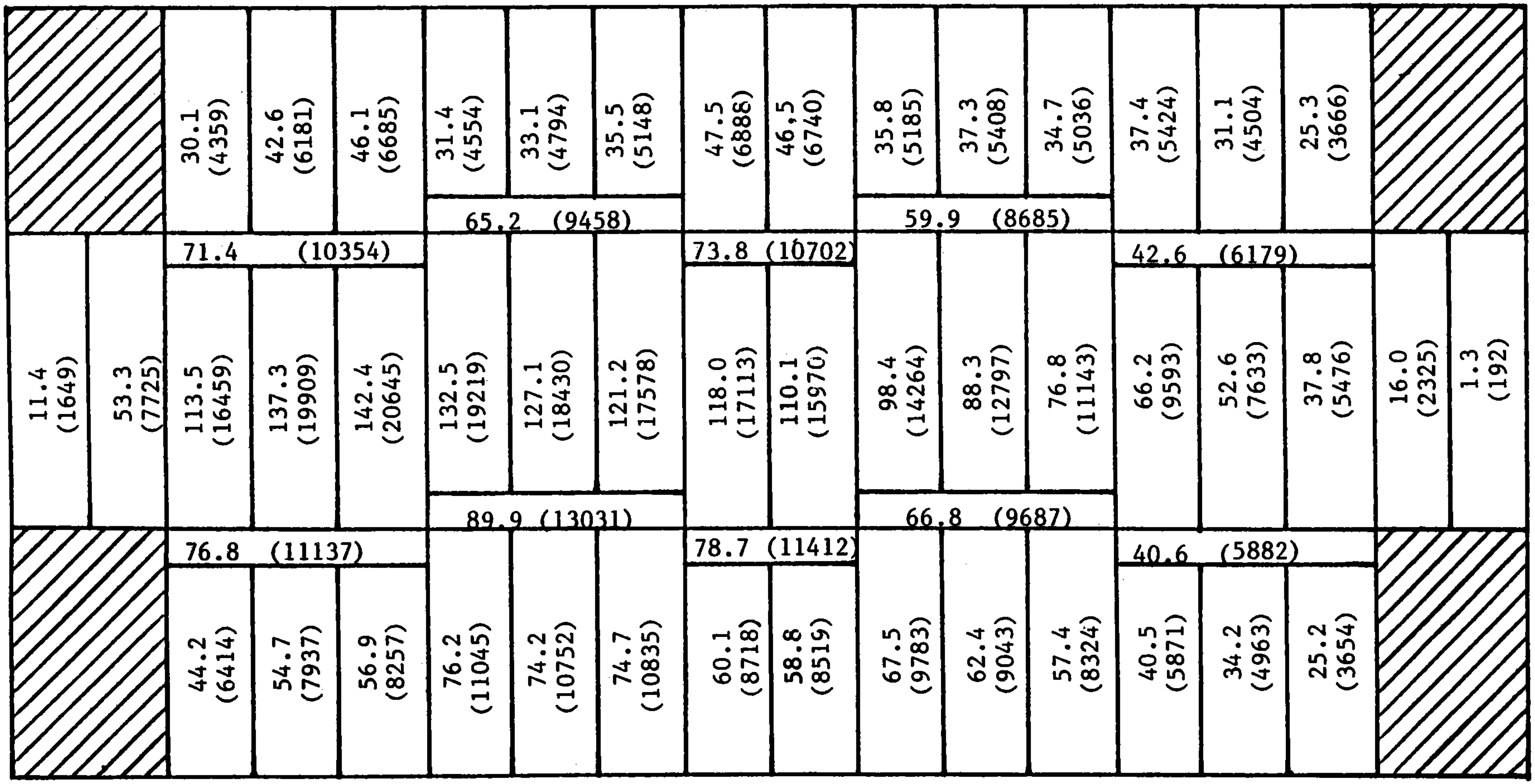


Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 141.8 x 10^6 Pa (20,557 psi).

FIGURE E-97

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

DAY 80 TIME 8:00

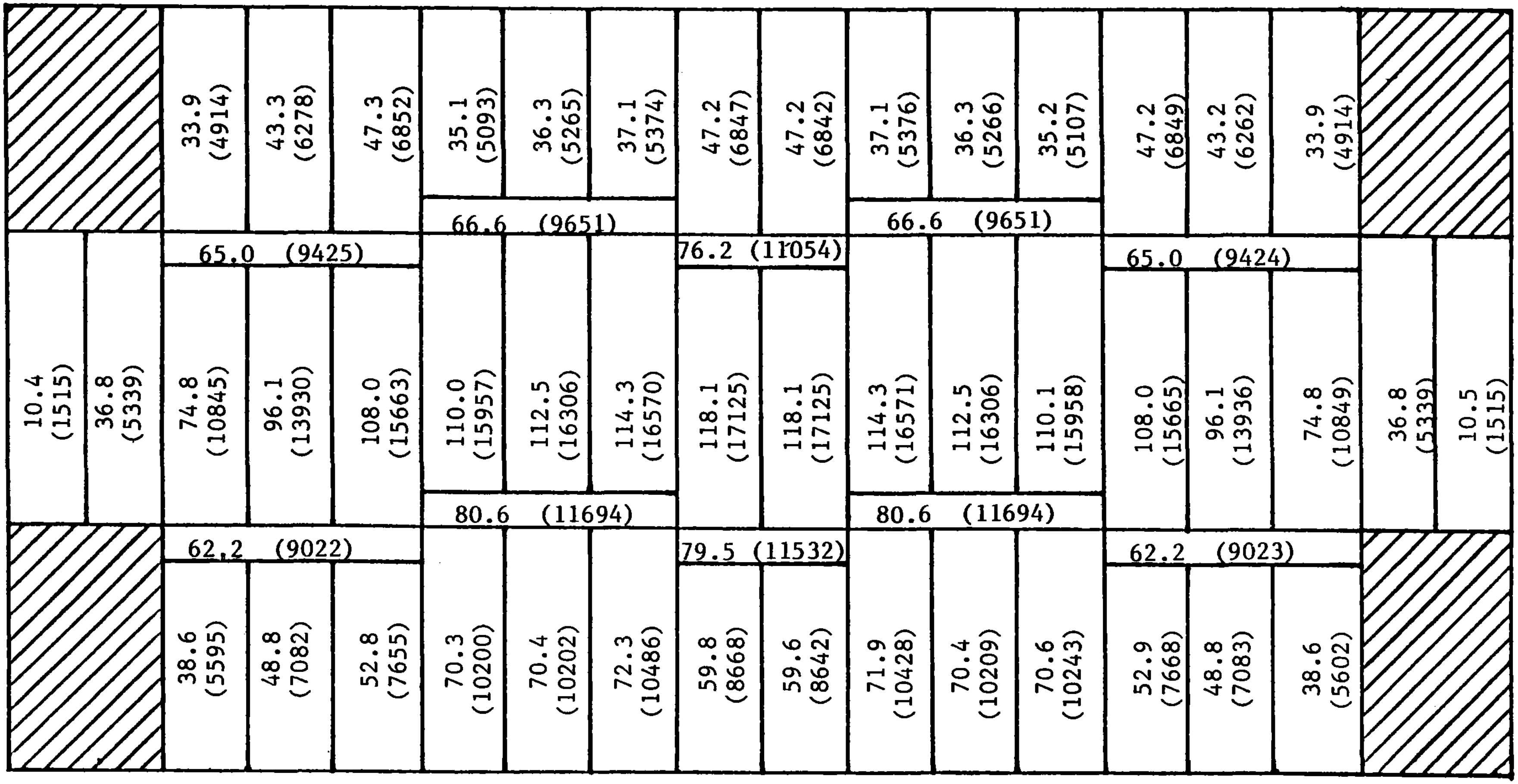


Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 142.4 x 10^6 Pa (20,645 psi).

FIGURE E-98

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

DAY 173 TIME 12:00



Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 118.1 x 10^6 Pa (17.125 psi).

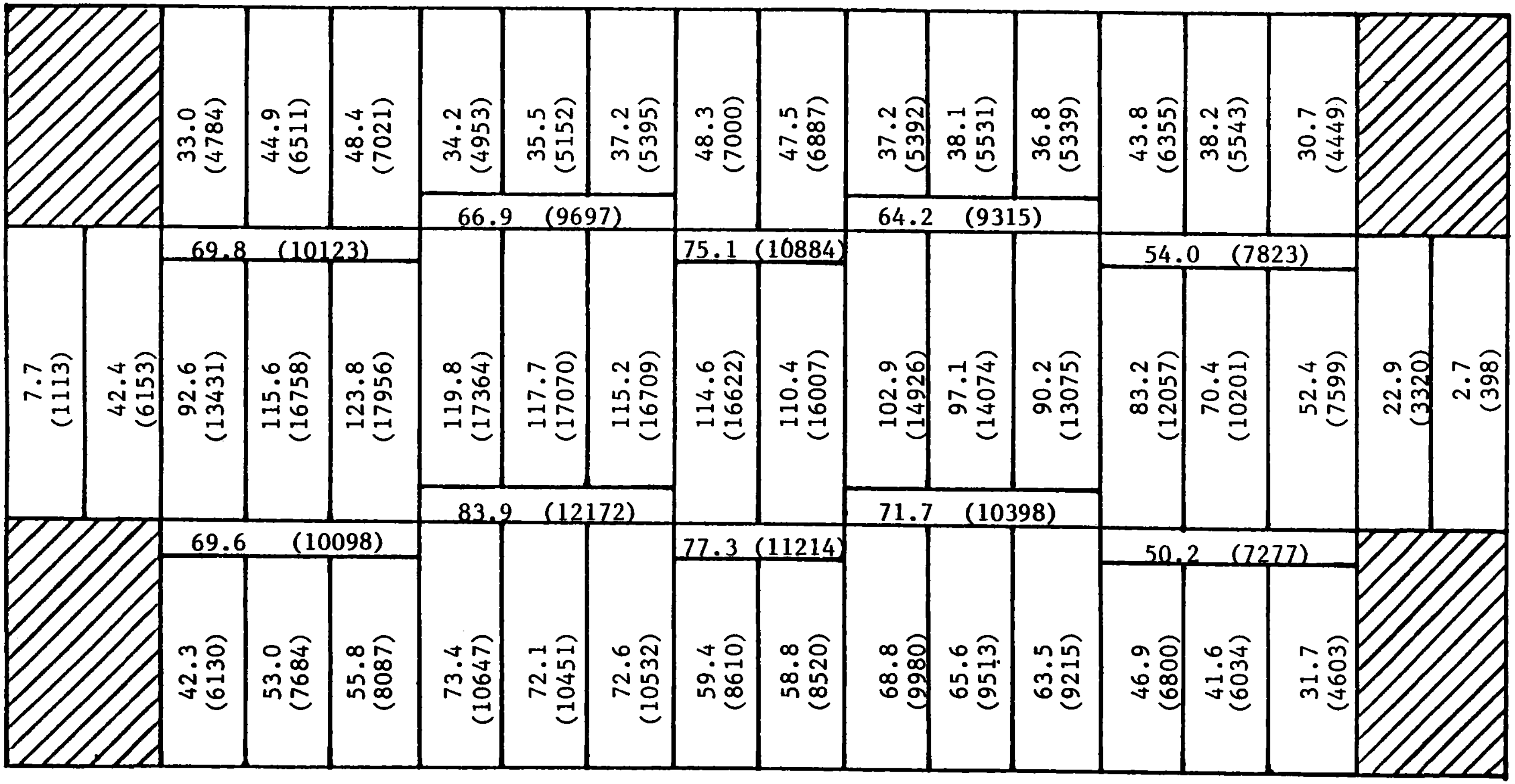


FIGURE E-99

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

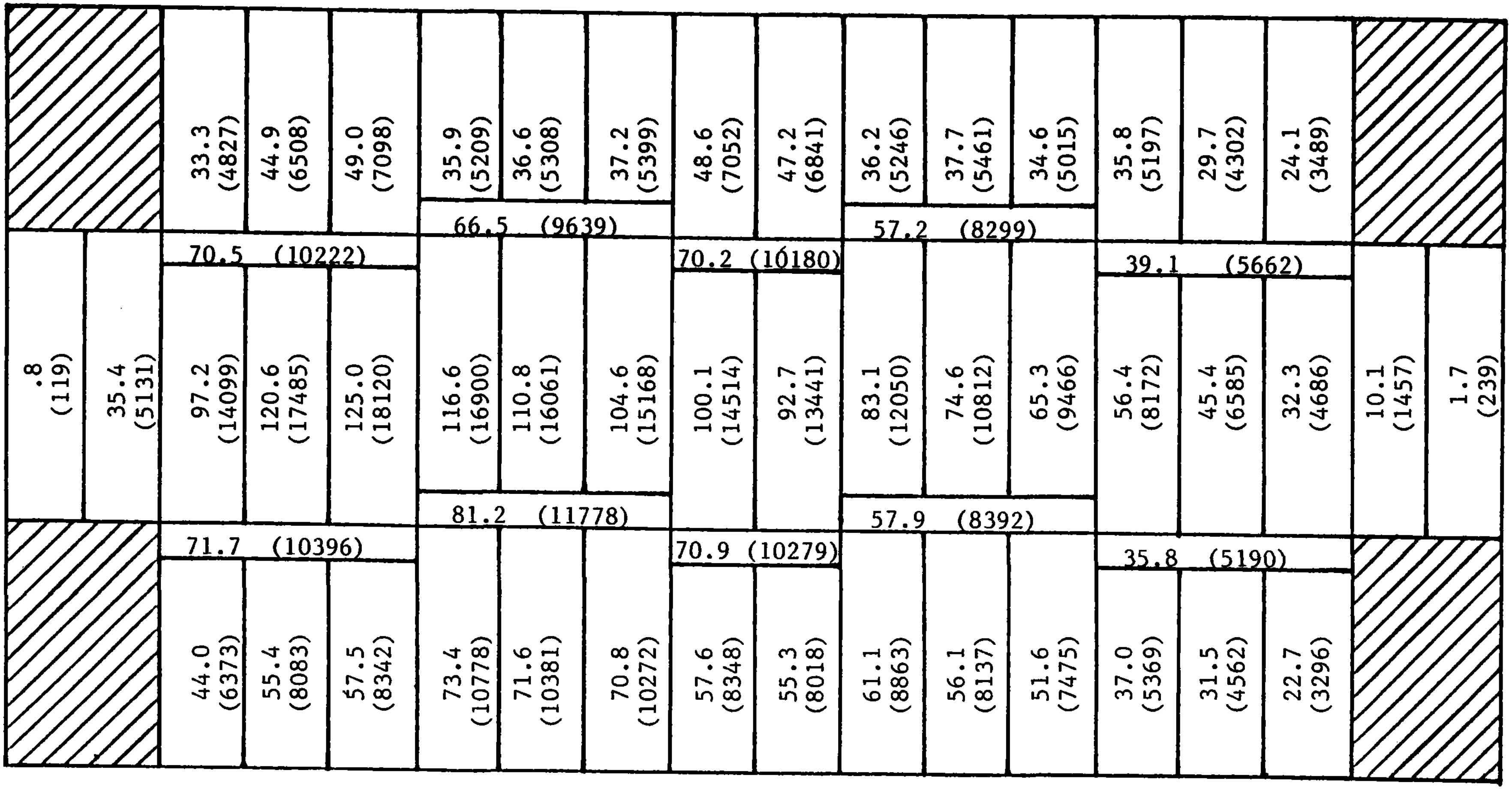
DAY 173 TIME 10:00

Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 123.8 x 10^6 Pa (17,956 psi).

FIGURE E-100

MAXIMUM THERMAL STRESS, PASCALS X 10^{-6} (psi)

DAY 173 TIME 8:00



Note: The design goal was to limit the maximum thermal stress to 172.4 x 10^6 Pa (25,000 psi). The actual maximum for this date and time is 125.0 x 10^6 Pa (18,120 psi).

Appendix F

SELECTIVE SURFACE FINISH

VS

BLACK PAINT TRADE-OFF STUDY

BY

A. J. ANDERSON

CONTRACT NO. DE-AC03-79SF10736

TASK 2.2

NORTHRUP, INCORPORATED

302 NICHOLS DRIVE

HUTCHINS, TEXAS 75141

SELECTIVE SURFACE VS BLACK PAINT TRADEOFF STUDY

The question of using a selective surface vs black paint on the North Coles Levee solar receiver(s) is one which cannot be answered by a simple trade-off study. The problem is really one of availability; if a selective surface finish is available which can withstand the thermal environment it would undoubtedly be used. Fortunately, rapid progress is being made in the development of selective surfaces with good-to-excellent optical properties and thermal stability at the temperature levels applicable for the North Coles Levee receiver (400-700°F). It appears very likely that a selective surface finish will be available. The benefit of a selective surface vs a non-selective, black painted surface is an improvement of about 5 points in receiver efficiency. This corresponds to an energy gain of approximately 7.3 billion BTU's per year having a value of $24,000 at today's natural gas price.

Using the baseline, 23-receiver module concept and the noon, winter solstice flux levels on the 11 x 11 ft exposed receiver, the resulting heat loss contributions and receiver efficiencies were determined as a function of the surface optical properties. The results are presented in Table 1 for both 0 wind velocity and for the site-average wind velocity of 8.3 mph.

The Table 1 results show that caution must be exercised in the decision to use a selective surface. If a black paint having an $\alpha_s = 0.95$ and $\varepsilon = 0.95$ is compared to a selective surface having an $\alpha_s = 0.90$ and $\varepsilon = 0.24$, very little improvement in efficiency results. The reason is that the gain resulting from the lower radiation loss is almost negated by the lower absorptivity. On the other hand, a selective surface having an $\alpha_s = 0.95$ and $\varepsilon = 0.30$ results in a 5 point efficiency improvement.

Since it appears likely that a good selective surface will be available, the thermal analyses during the course of the study will include the selective

TABLE 1
HEAT LOSSES & RECEIVER EFFICIENCY
NORTH COLES LEVEE
NOON, DEC 21 FLUX CONDITIONS

SOLAR ABSORPTIVITY α_s		IR EMISSIVITY ε	WIND SPEED, mph	INCIDENT ENERGY Kw	REFLECTED LOSS, Kw	RADIATION LOSS, Kw	CONVECTIVE LOSS, Kw	RECEIVER EFFICIENCY, %
0.95	(1)	0.95	0	711.66	35.58	56.52	17.45	84.61%
0.95		0.95	8.3	711.66	35.58	55.87	39.20	81.64
0.90	(2)	0.24	0	711.66	71.17	14.34	17.47	85.53
0.90		0.24	8.3	711.66	71.17	14.18	39.26	82.49
0.95	(3)	0.30	0	711.66	35.58	18.22	17.61	89.97
0.95		0.30	8.3	711.66	35.58	18.02	39.58	86.91
0.95	(4)	0.10	0	711.66	35.58	6.11	17.66	91.66
0.95		0.10	8.3	711.66	35.58	6.04	39.68	88.58

(1) Properties achievable with black paint.
(2) Properties probably achievable with oxidized 321 stainless steel.
(3) Properties probably achievable with black chrome (trivalent C_r controlled).
(4) Properties possible in future, ultimate (no such candidate at present).

option as well as the black paint option. It should also be noted that if a selective surface were actually used on an experiment and subsequent degradation did result, it would be a relatively simple and inexpensive modification to revert to black paint. This fall-back position is particularly attractive in light of some current industry efforts to develop a semi-selective black paint for high temperature use.

A literature survey was performed to determine the status of selective surface development in the temperature range applicable to the North Coles Levee. Conversations were also held with Helen Thobhani and Roland Pitts at SERI, Bernie Seraphin at the University of Arizona, Dr. Kidambi Raghunathan of Berry Solar Products, and Dr. Harry Tabor, Consultant to Miromit Ashkelon Metal Works of Israel.

Perhaps the most encouraging results to date are those reported by R. Pettit and R. R. Sowell, ref. (1), (2), and (3). During testing of solar collectors at the Sandia Mid-Temperature Solar System Test Facility, a thermal degradation of the Harshaw Chemical Chromonyx (electroplated black chrome) coating occurred. This degradation resulted in an 8% reduction in solar absorptance after operation at 310°C (590°F). Subsequent analysis and experimentation led to the discovery that a reduction in the amount of trivalent chromium (C_r^{+++}) in the plating bath results in vastly improved thermal stability. With a concentration of 8 g/l and plating time of 5 minutes, samples were obtained which exhibit the following α_s and ε characteristics:

TEST TIME	TEST TEMPERATURE	α_s	ε
As Plated	350°C (662°F)	0.97	0.40
40 hrs	"	0.97	0.32
157	"	0.97	0.32
752	"	0.98	0.31
1849	"	0.98	0.31
As Plated	400°C (752°F)	0.97	0.40
40 hrs	"	0.97	0.29
157	"	0.97	0.29
755	"	0.96	0.27
1595	"	0.95	0.24

Interestingly, these results show that a higher-than-normal initial emittance occurs with this bath formulation, but the value improves with time and temperature. Most importantly, the results show an excellent improvement in the absorptance thermal stability, particularly at the 662°F test condition. Most regions of the proposed North Coles Levee receiver would operate below 660°F, and the anticipated peak temperature would be less than 700°F.

Sharma and Hutchins, ref (4), describe another candidate of interest. By simply heating austenitic stainless steel, AISI 321 to 843°K (1057°F) for 10-20 minutes in air, a highly selective surface results having a solar absorptivity of 0.92± 0.02, and an emissivity of 0.22± 0.02. Although no thermal stability test results were presented, the surface should be very durable and stable. The undesireable characteristics of this candidate are a somewhat low absorptivity, and a higher receiver cost due to the use of stainless steel.

References (5), (6), and (7) describe a technique involving the chemical vapor deposition of a molybdenum thin film followed by annealing and then overcoating with an anti-reflective layer. The process is still in the development stage. Currently, absorptances of 0.82 and emittance values of 0.08 are being achieved. Satisfactory operation to 700°C (1292°F) is anticipated.

Reference (8) presents a somewhat different "recipe" for a selective black-chrome coating on a copper substrate. Absorptivity values of 0.87 were measured, which although somewhat low, were accompanied by emissivity values of 0.08. The coatings were verified to be thermally stable at 300°C (562°F), and are believed to be stable at even higher temperatures.

Reference (9) is primarily a theoretical work which explains the selective process. The class of solar blacks such as gold black and carbon black are generally stable only below 300°C (562°F). Reference (10) reports the results of research performed by Engelhard Minerals & Chemicals Corp. Surfaces examined included "Doped" gold, palladium cobaltate, ruthenium plumbate, and films containing silver, copper oxide, and ruthenium oxide. This work was aimed at the 500°C (932°F) operating range. Although some degradation was noted after 700 hours of testing, it was interesting to note that material combinations are available which are performing well at temperatures over 900°F with absorptivities near 0.90 and emissivity values of 0.10 or less.

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1. "Optical Properties of Electroplated Black Chrome", R. R. Sowell and D. M. Mattox, Plating and Surface Finishing, Vol. 65, P. 50-52, Jan 78.

2. "The Influence of Bath Composition on Thermal Stability of Electroplated Black Chrome Solar Coating", R. R. Sowell and R. B. Pettit, Plating and Surface Finishing, Vol. 65, p. 42-43, Oct 78.

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4. "Fabrication of Spectrally Selective Surfaces by Termal Treatment of Austenitic Stainless Steel, AISI 321", V. C. Sharma and M. G. Hutchins, Solar Energy, Vol. 23, p. 89-90, 1979.

5. "CVD Molybdenum Thin Films in Photothermal Solar Converters", G. E. Carver, Solar Energy Materials, Vol. 1, no. 5 or 6 (pre-print), 1979.

6. "CVD Molybdenum Film of High Infrared Reflectance", G. E. Carver and B. O. Seraphin, Proceedings, Second Annual Conference on Absorber Surfaces for Solar Receivers, SERI/TP-49-182, Jan 79.

7. "Amorphous Silicone Absorbers for Photothermal Solar Energy Conversion", D. C. Booth and B. O. Seraphin, SERI/TP-49-182, Jan 79.

8. "A New Chrome Black Selective Absorbing Surface", P. M. Driver, R. W. Jones, C. L. Riddleford, and R. J. Simpson, Solar Energy, Vol. 19, p. 301-306, 1977.

9. "The Dependence of Optical Properties on the Structural Composition of Solar Absorbers: Gold Black", P. O'Neill, A. Ignatier, and C. Doland, Solar Energy, Vol. 21, p. 465-468, 1978.

10. "Improved Solar Absorber Coatings", R. P. St. Amand, J. C. Williams, and R. J. Farrauto, SERI/TP-49-182, Jan 1979.

APPENDIX G

COLLECTOR TRADE DATA

The collector performance data generated in the two subsystem level trade off analyses, the straight row vs. radial stagger layout configurations of the towerless module and the module size parametric study from a single full rating collector module to double and quadruple modules is included.

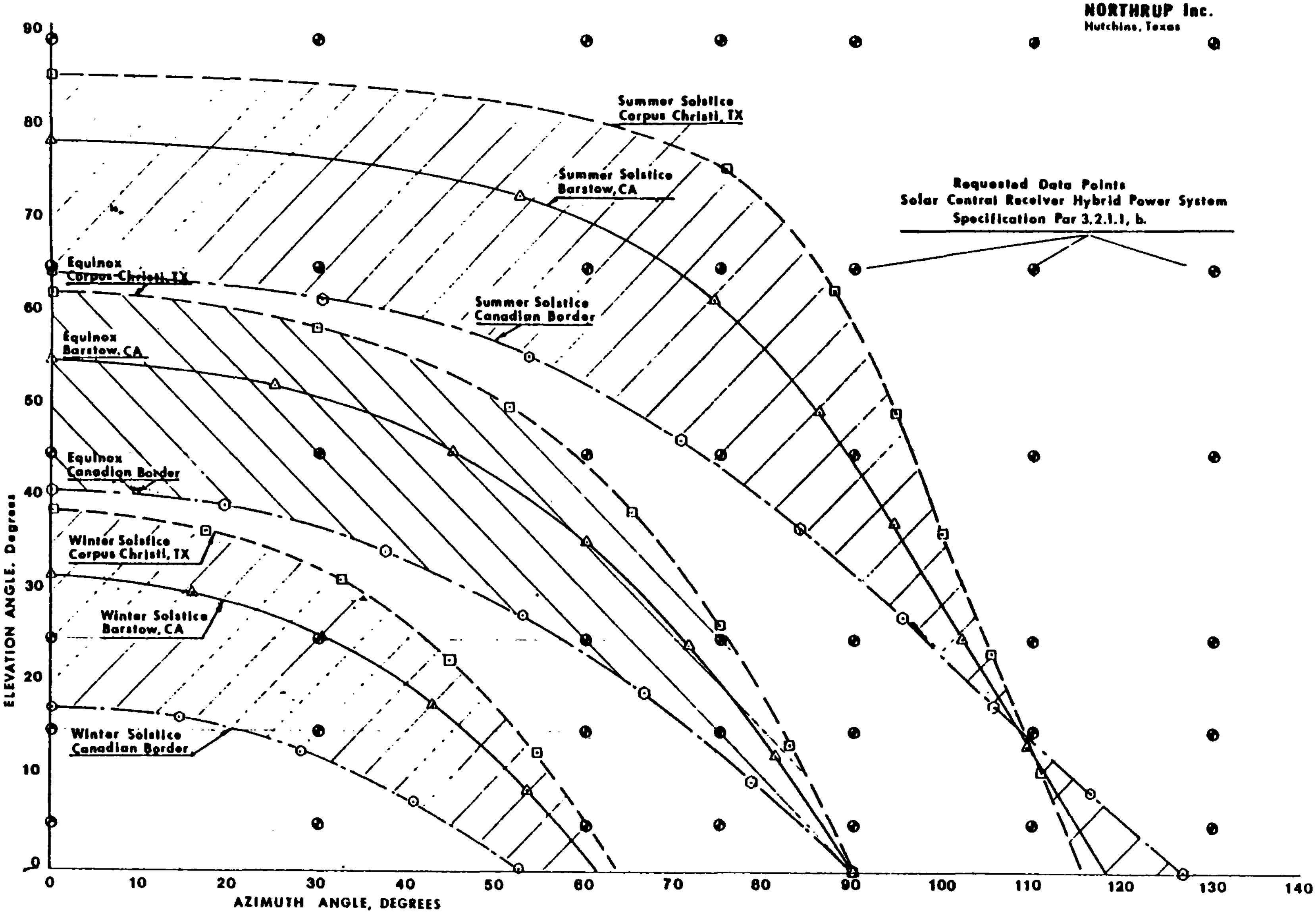


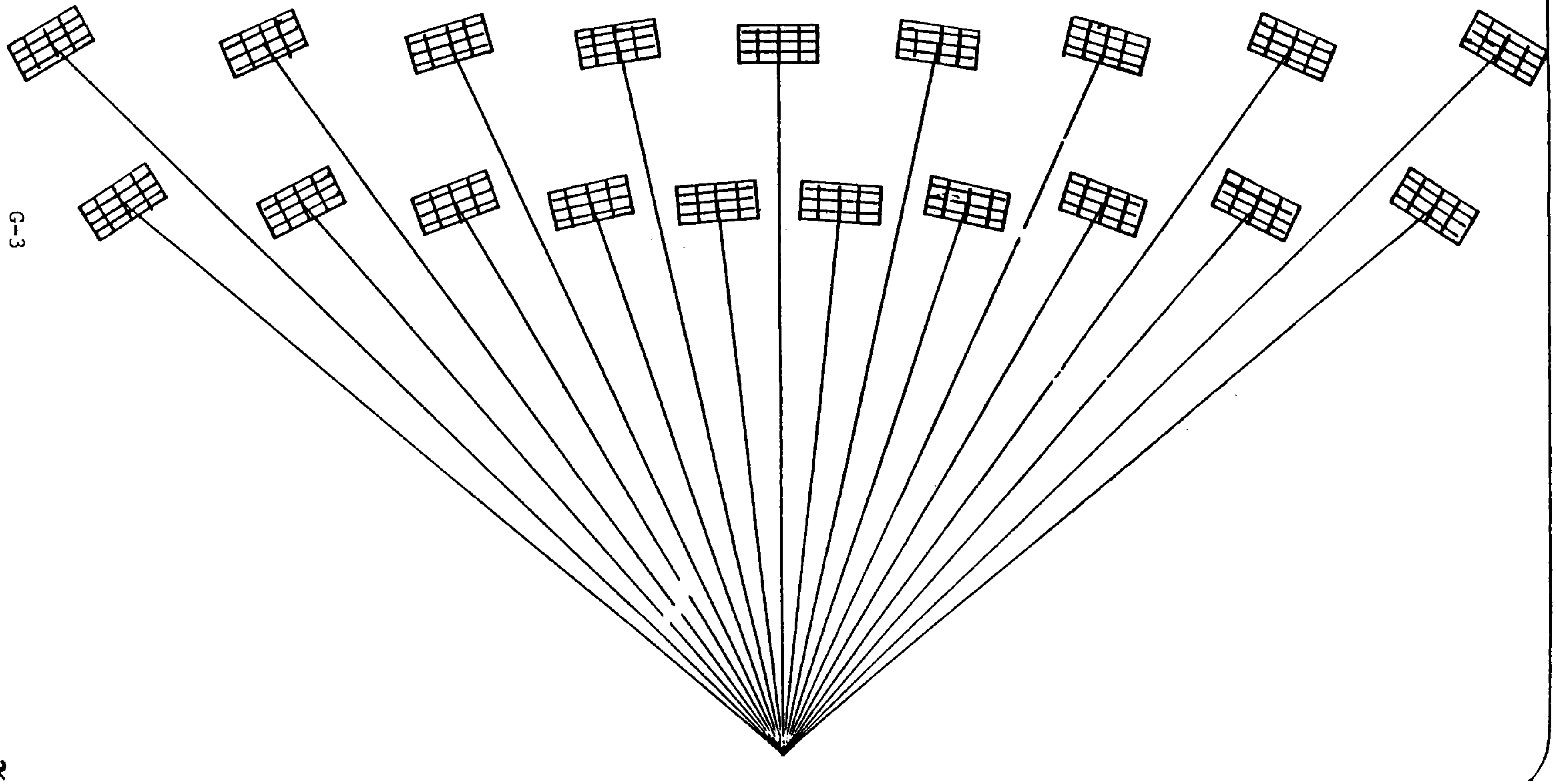
Fig. N100-1. Natural Solar Angle Envelope; Barstow, CA(latitude =34.889°), U.S.-Canada Border (latitude=49.00°), So. U.S. (Corpus Christi, TX, latitude= 27.75°)

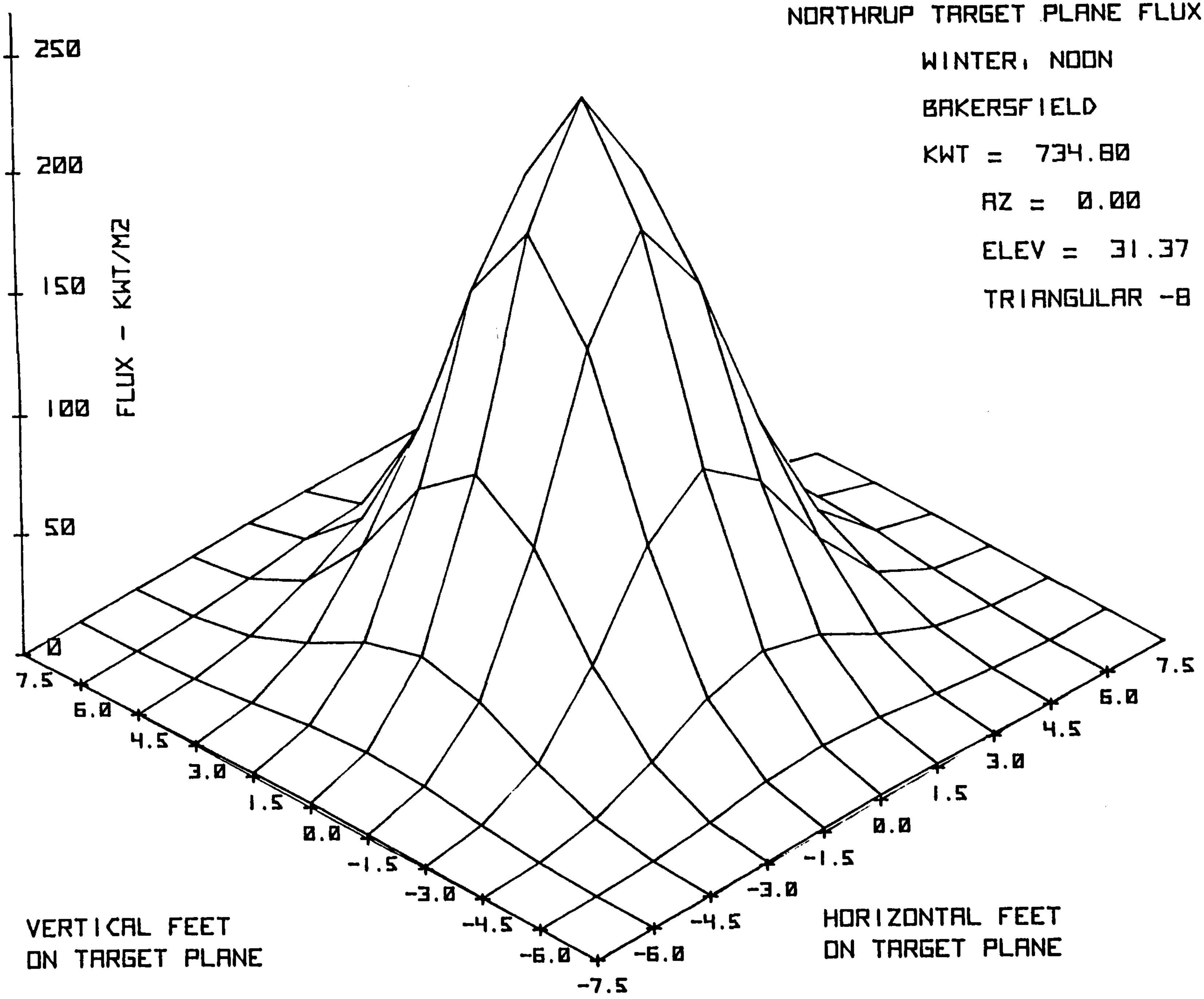
J.A. Blake
10/9/78

TRIANGULAR FLAT FIELD LAYOUT

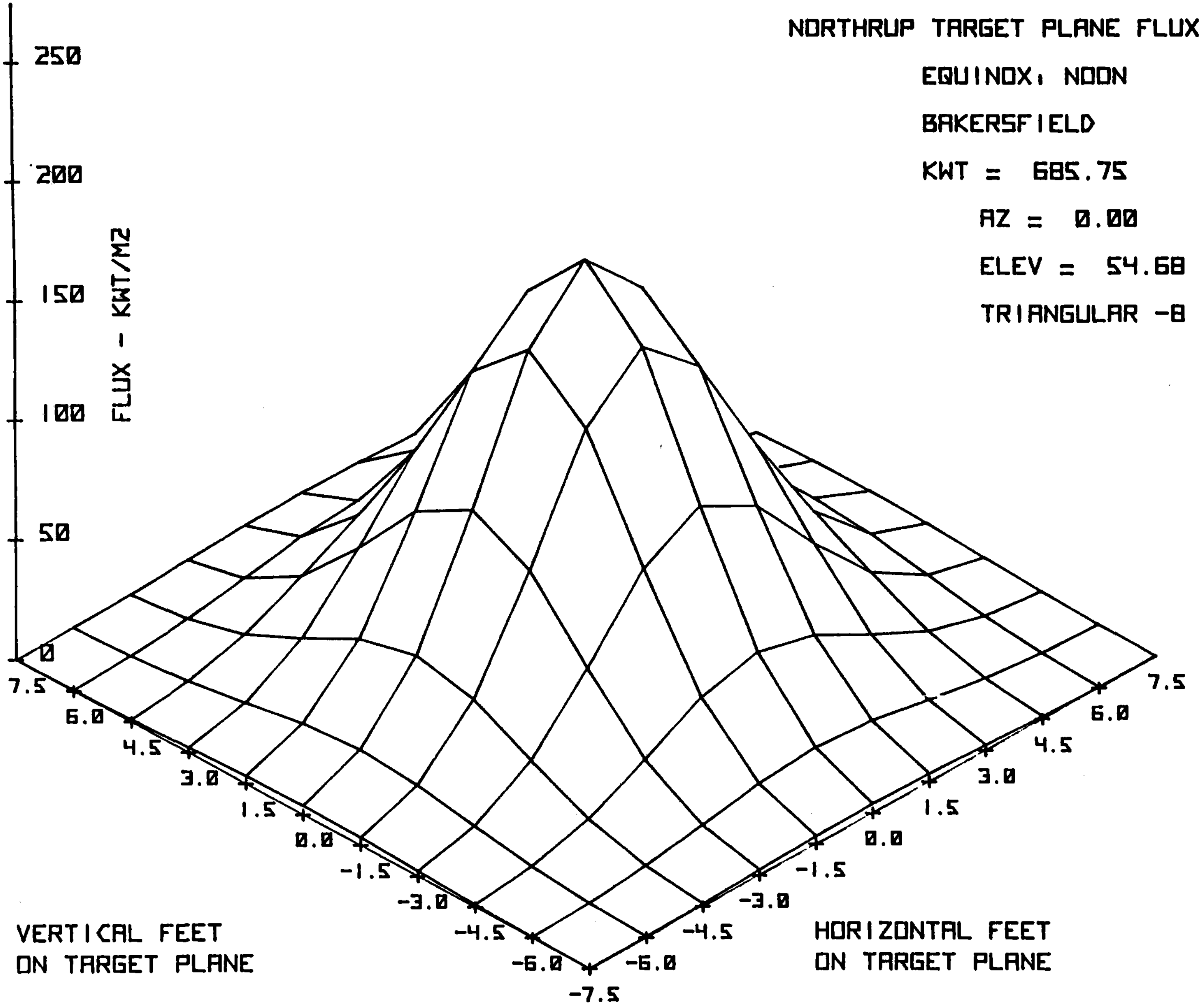
224.8 FT OUTER ROW, 175.3 FT INNER ROW

LAYOUT NO. 8 FOR 19 - 53.51 M² HELIOSTATS





NORTHRUP TARGET PLANE FLUX
WINTER, NOON
BAKERSFIELD
KWT = 734.80
AZ = 0.00
ELEV = 31.37
TRIANGULAR -8



NORTHRUP TARGET PLANE FLUX

EQUINOX, NOON

BAKERSFIELD

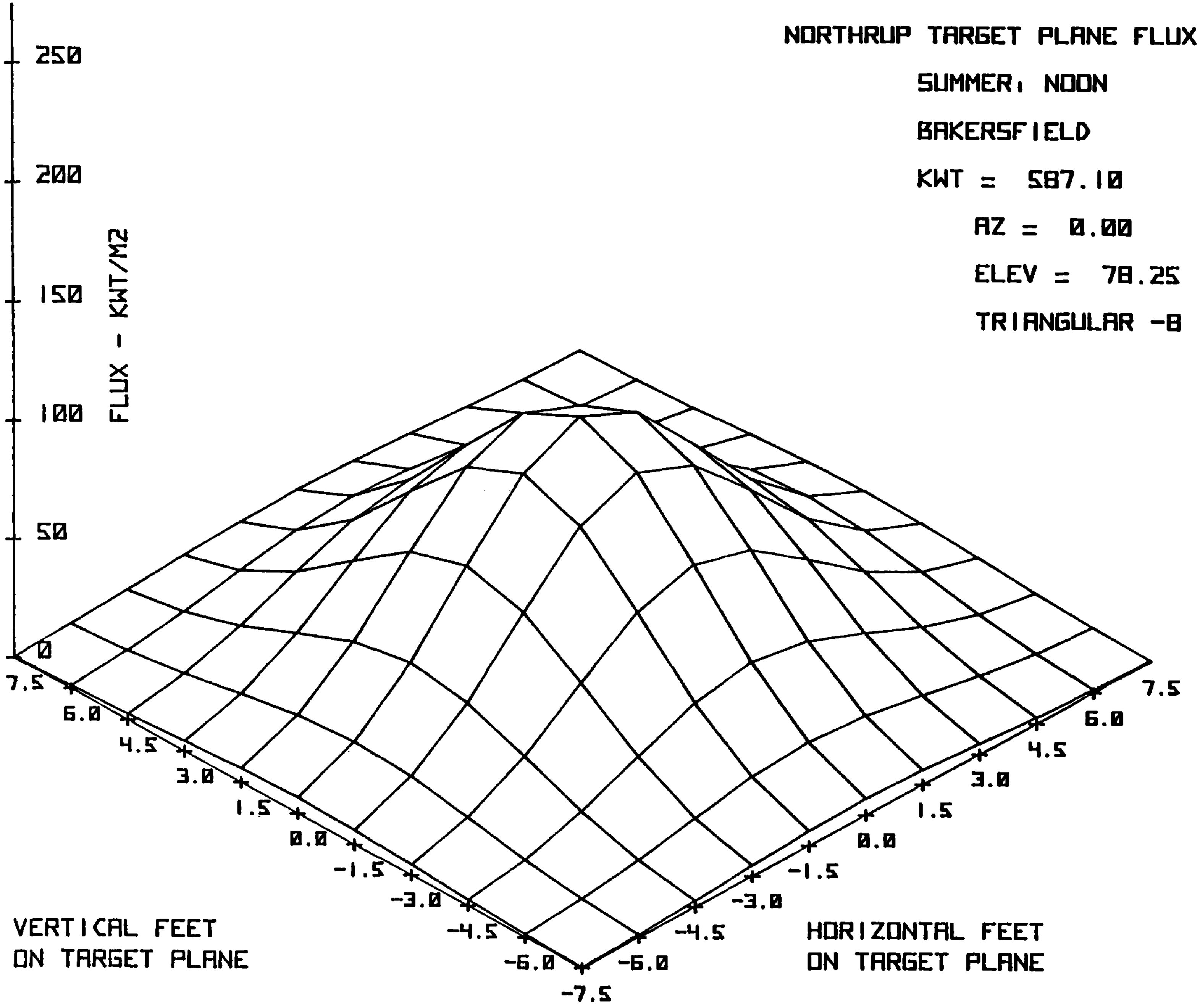
KWT = 685.75

AZ = 0.00

ELEV = 54.68

TRIANGULAR -8

JB


NORTHRUP TARGET PLANE FLUX
SUMMER, NOON
BAKERSFIELD
KWT = 587.10
AZ = 0.00
ELEV = 78.25
TRIANGULAR -8
FLUX - KWT/M2
250
200
150
100
50
0
7.5
6.0
4.5
3.0
1.5
0.0
-1.5
-3.0
-4.5
-6.0
-7.5
-6.0
-4.5
-3.0
-1.5
0.0
1.5
3.0
4.5
6.0
7.5
VERTICAL FEET
ON TARGET PLANE
HORIZONTAL FEET
ON TARGET PLANE

GEOMETRIC PERFORMANCE EFFICIENCY
TRIANGULAR LAYOUT, 224.8,175.3 FT ROWS

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	0.6961	0.6956	0.6947	0.6942	0.6935	0.6927
65	0.8124	0.8008	0.7655	0.7388	0.7075	0.6623
45	0.8869	0.8668	0.8011	0.7548	0.7032	0.6278
25	0.9084	0.8958	0.8166	0.7259	0.6383	0.5811
15	0.8380	0.8364	0.8071	0.6663	0.4535	0.5495
5	0.7628	0.7582	0.7035	0.5912	0.0729	0.5376

AVE. ANNUAL EFF. = 0.7672 ENERGY = 3.4679×10^7 KWT-HRS

COSINE PERFORMANCE EFFICIENCY
TRIANGULAR LAYOUT, 224.8/175.3 FT ROWS

SOLAR ELEVATION, DEGREES	AZIMUTH ANGLE, DEGREES					
	0	30	60	75	90	110
89.5	0.7248	0.7243	0.7234	0.7229	0.7222	0.7213
65	0.8357	0.8205	0.7779	0.7489	0.7168	0.6728
45	0.9024	0.8784	0.8091	0.7607	0.7059	0.6278
25	0.9446	0.9147	0.8275	0.7650	0.6924	0.5849
15	0.9560	0.9245	0.8317	0.7649	0.6860	0.5670
5	0.9608	0.9279	0.8324	0.7632	0.6813	0.5544

NORTHRUP

SHADOWING PERFORMANCE EFFICIENCY
TRIANGULAR LAYOUT, 224.8/175.3 FT ROWS

SOLAR ELEVATION, DEGREES	AZIMUTH ANGLE, DEGREES					
	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	0.9991	0.9996	1.0000
25	0.9699	0.9909	0.9956	0.9539	0.9235	0.9936
15	0.8821	0.9149	0.9788	0.8755	0.6621	0.9692
5	0.7975	0.8259	0.8524	0.7785	0.1072	0.9698

BLOCKING PERFORMANCE EFFICIENCY
TRIANGULAR LAYOUT, 224.8/175.3 FT ROWS

AZIMUTH ANGLE, DEGREES

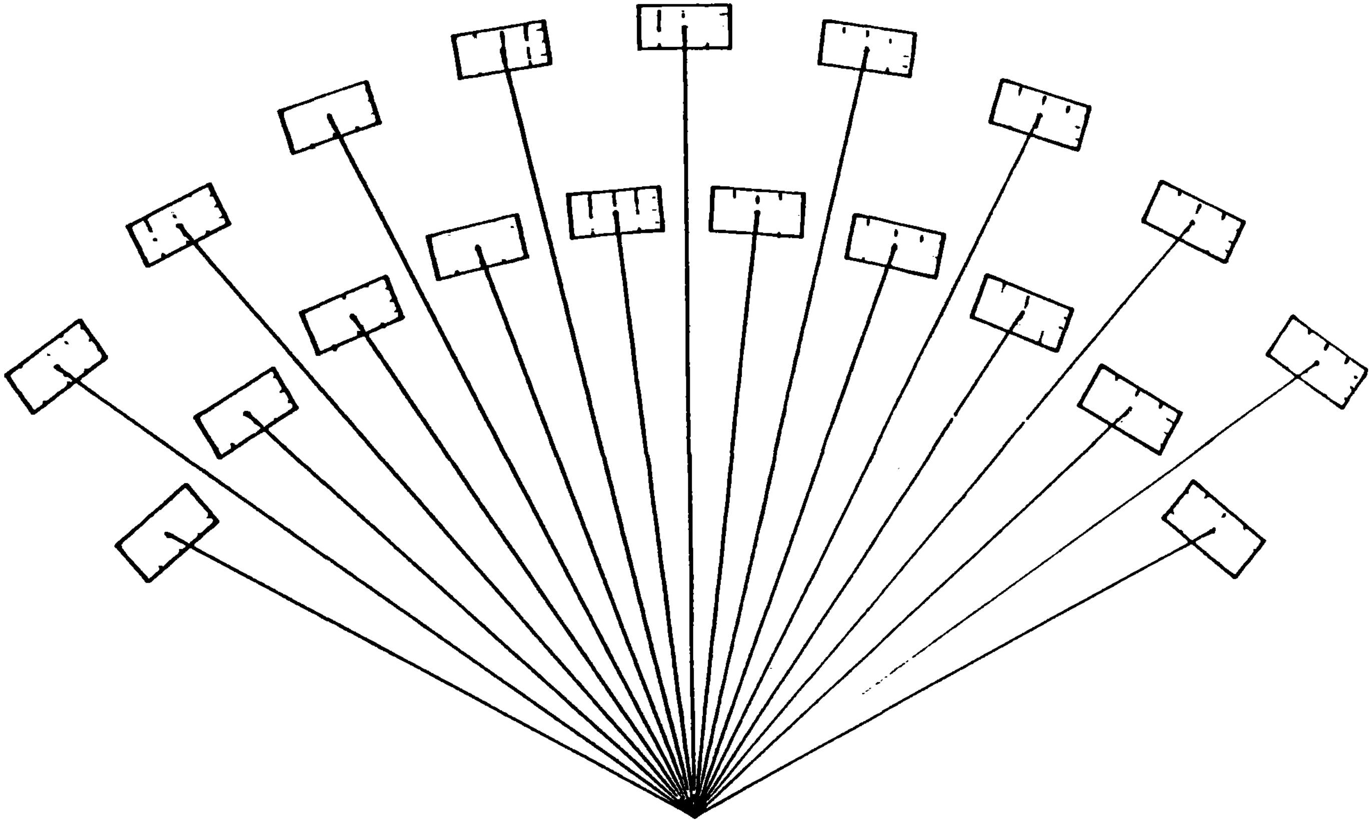
SOLAR ELEVATION, DEGREES

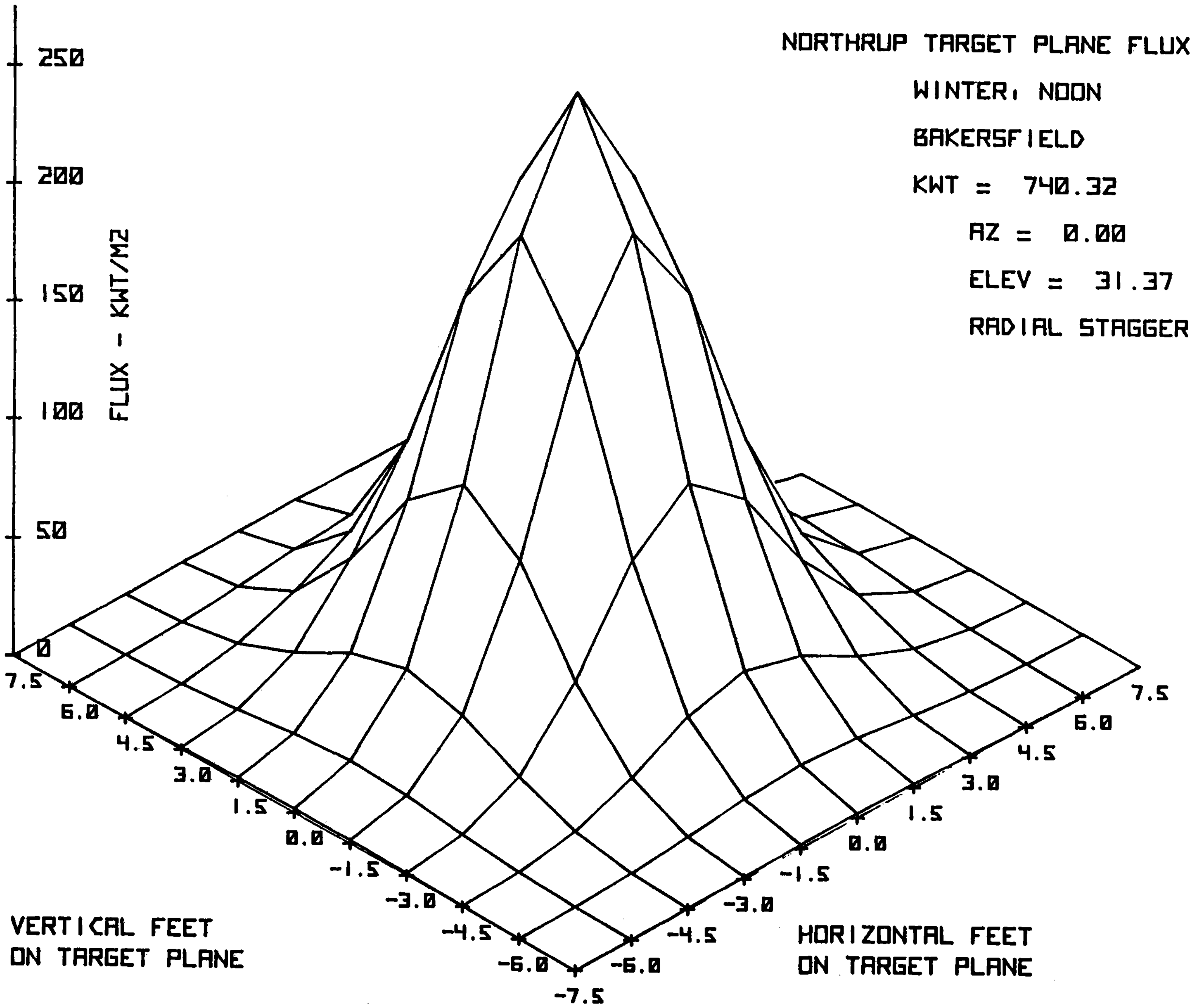
	0	30	60	75	90	110
89.5	0.9604	0.9604	0.9604	0.9604	0.9603	0.9603
65	0.9721	0.9760	0.9841	0.9865	0.9870	0.9844
45	0.9829	0.9868	0.9901	0.9931	0.9966	1.0000
25	0.9915	0.9884	0.9911	0.9948	0.9982	1.0000
15	0.9937	0.9889	0.9914	0.9950	0.9984	1.0000
5	0.9956	0.9893	0.9916	0.9951	0.9985	1.0000

RADIAL STAGGER FLAT FIELD LAYOUT

216 FT OUTER. ROW, 166.5 FT INNER ROW

RADIAL LAYOUT NO. 3 FOR 19 - 53.51 M^2 HELIOSTATS





NORTHRUP TARGET PLANE FLUX

WINTER, NOON

BAKERSFIELD

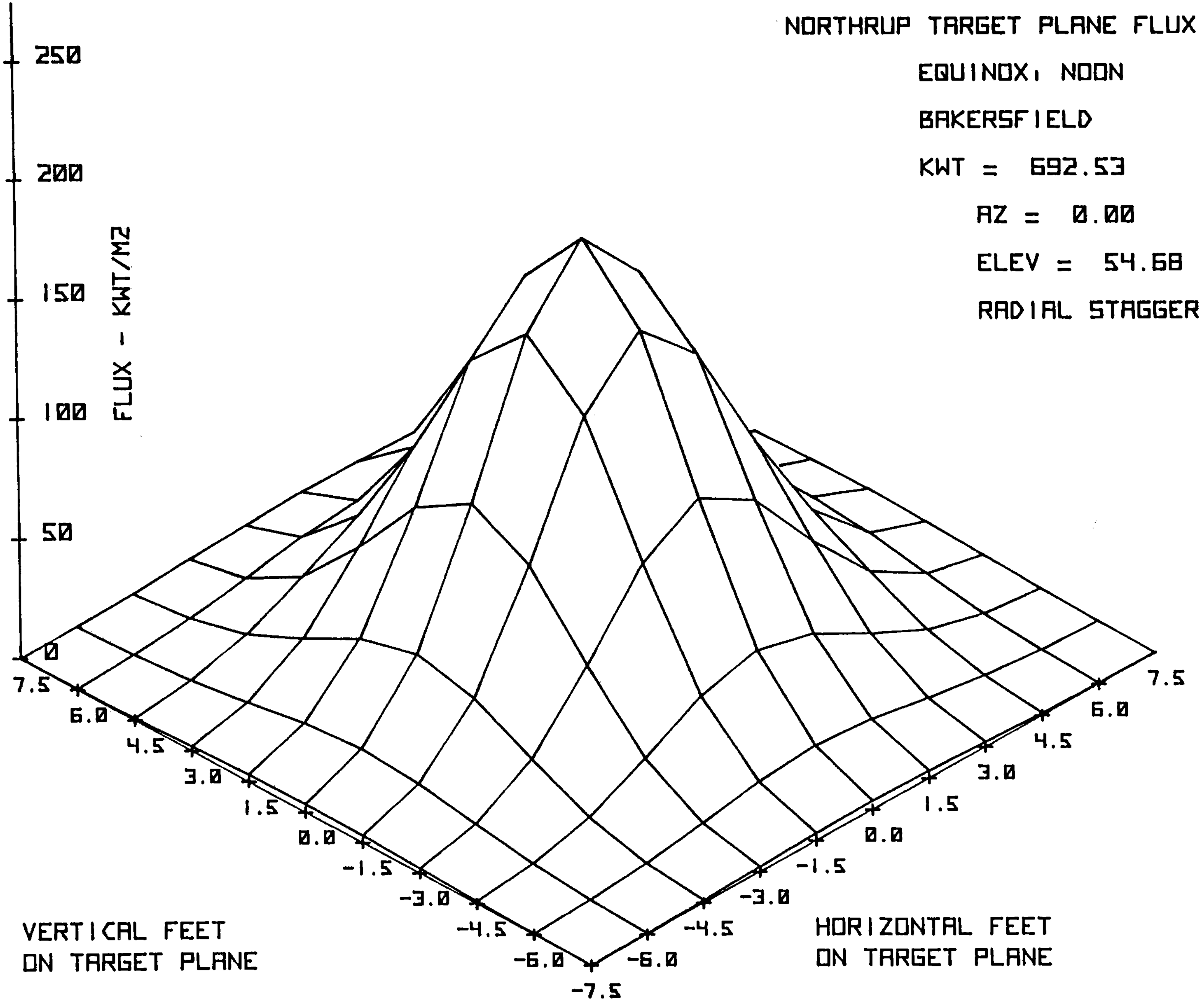
KWT = 740.32

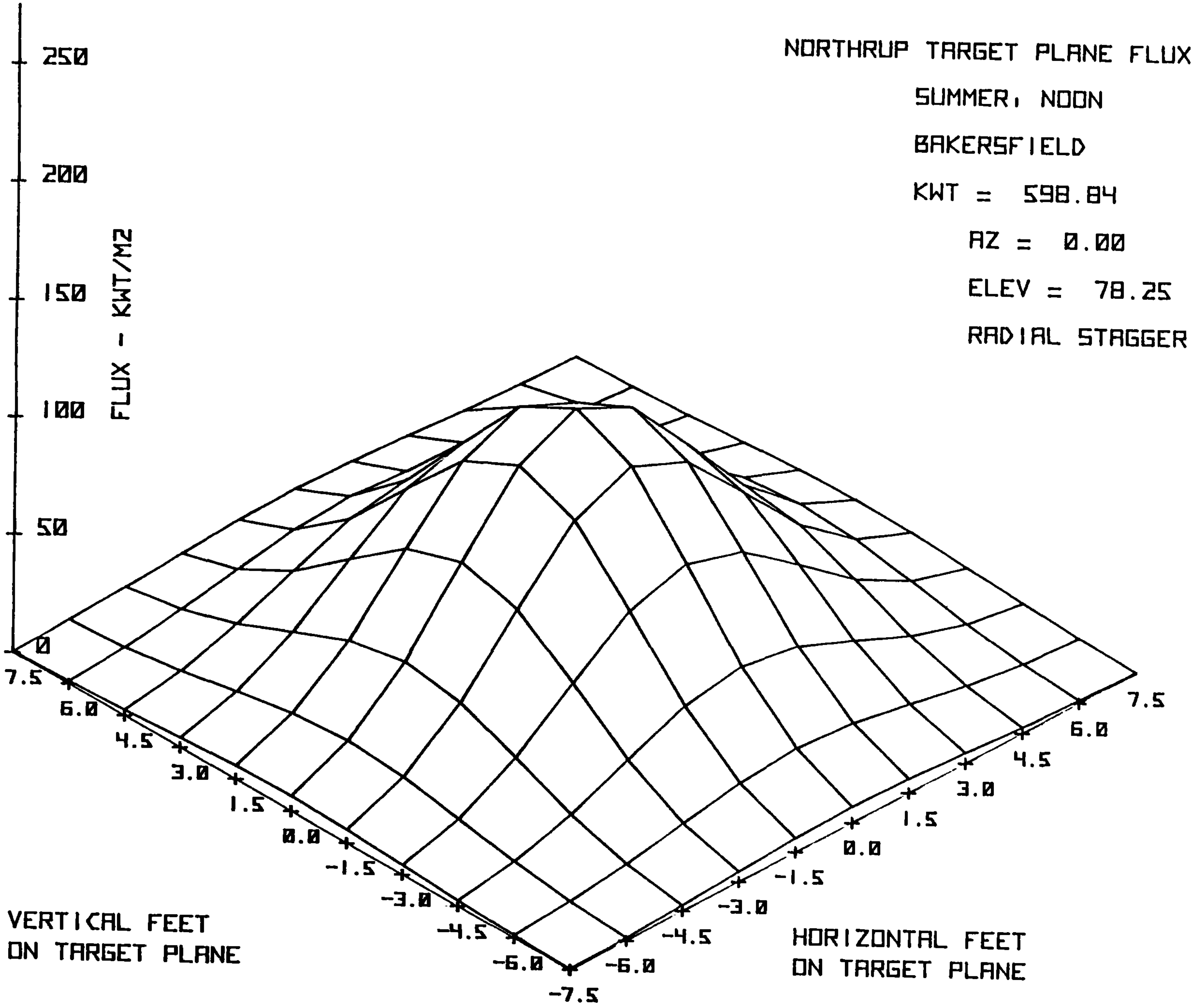
AZ = 0.00

ELEV = 31.37

RADIAL STAGGER

J


NORTHRUP TARGET PLANE FLUX
EQUINOX, NOON
BAKERSFIELD
KWT = 692.53
AZ = 0.00
ELEV = 54.68
RADIAL STAGGER
FLUX - KWT/M2
250
200
150
100
50
0
7.5
6.0
4.5
3.0
1.5
0.0
-1.5
-3.0
-4.5
-6.0
-7.5
-6.0
-4.5
-3.0
-1.5
0.0
1.5
3.0
4.5
6.0
7.5
VERTICAL FEET
ON TARGET PLANE
HORIZONTAL FEET
ON TARGET PLANE


NORTHRUP TARGET PLANE FLUX
SUMMER, NOON
BAKERSFIELD
KWT = 598.84
AZ = 0.00
ELEV = 78.25
RADIAL STAGGER
FLUX - KWT/M2
250
200
150
100
50
0
7.5
6.0
4.5
3.0
1.5
0.0
-1.5
-3.0
-4.5
-6.0
-7.5
VERTICAL FEET
ON TARGET PLANE
-6.0
-4.5
-3.0
-1.5
0.0
1.5
3.0
4.5
6.0
7.5
HORIZONTAL FEET
ON TARGET PLANE

JE

GEOMETRIC PERFORMANCE EFFICIENCY
RADIAL LAYOUT, 216/166.5 FT ROWS

SOLAR ELEVATION, DEGREES	AZIMUTH ANGLE, DEGREES					
	0	30	60	75	90	110
89.5	0.7104	0.7100	0.7091	0.7086	0.7080	0.7070
65	0.8281	0.8137	0.7748	0.7486	0.7182	0.6742
45	0.8934	0.8697	0.8030	0.7569	0.7048	0.6301
25	0.9239	0.8759	0.7864	0.7297	0.6636	0.5641
15	0.8517	0.7927	0.7037	0.6553	0.6025	0.5067
5	0.7384	0.6469	0.5597	0.5126	0.5014	0.4177

AVE. ANNUAL EFF. = 0.7639 ENERGY = 3.4570×10^{7} KWT-HRS

COSINE PERFORMANCE EFFICIENCY
RADIAL LAYOUT, 216/166.5 FT ROWS

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	0.7281	0.7277	0.7269	0.7264	0.7258	0.7249
65	0.8319	0.8174	0.7767	0.7493	0.7190	0.6779
45	0.8941	0.8709	0.8038	0.7574	0.7053	0.6323
25	0.9331	0.9037	0.8185	0.7577	0.6876	0.5860
15	0.9433	0.9123	0.8212	0.7558	0.6790	0.5650
5	0.9472	0.9149	0.8208	0.7528	0.6723	0.5487

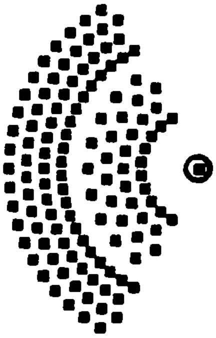
NORTHRUP

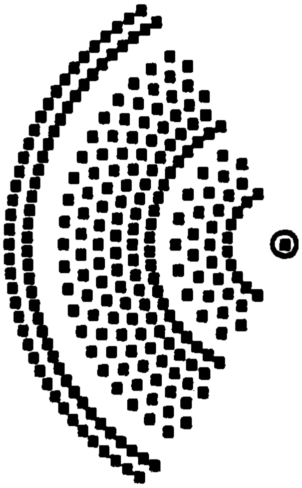
SHADOWING PERFORMANCE EFFICIENCY
RADIAL LAYOUT, 216/166.5 FT ROWS

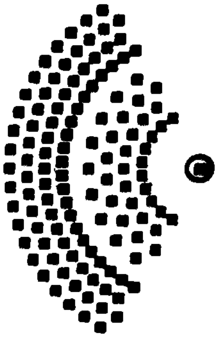
	AZIMUTH ANGLE, DEGREES					
SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	0.9995	0.9994	0.9993	0.9993	0.9995
25	0.9902	0.9692	0.9608	0.9631	0.9651	0.9625
15	0.9029	0.8689	0.8569	0.8670	0.8873	0.8969
5	0.7796	0.7071	0.6819	0.6809	0.7458	0.7612

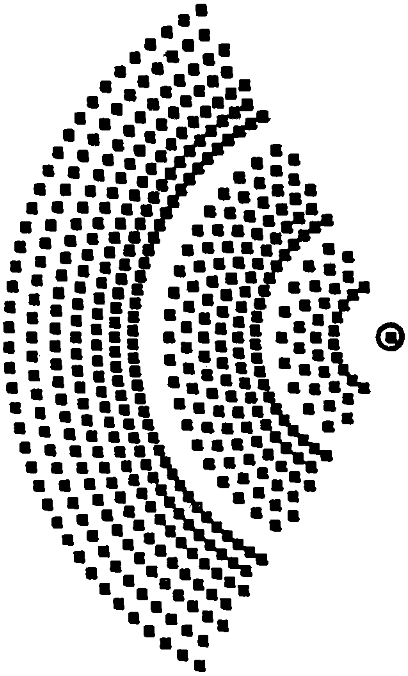
BLOCKING PERFORMANCE EFFICIENCY
RADIAL LAYOUT, 216/166.5 FT ROWS

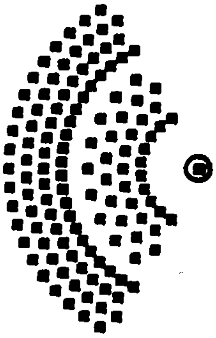
SOLAR ELEVATION, DEGREES	AZIMUTH ANGLE, DEGREES					
	0	30	60	75	90	110
89.5	0.9757	0.9756	0.9756	0.9755	0.9754	0.9754
65	0.9955	0.9955	0.9976	0.9990	0.9989	0.9946
45	0.9992	0.9992	0.9995	1.0000	1.0000	0.9970
25	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

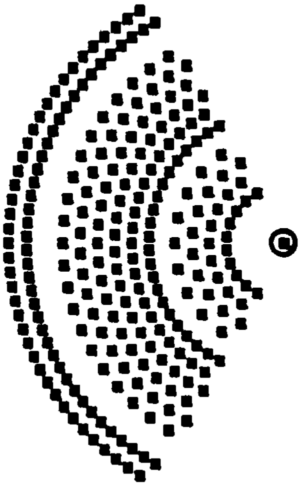


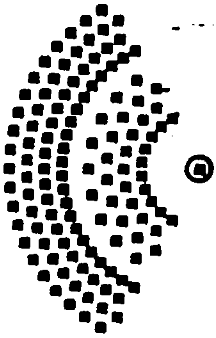




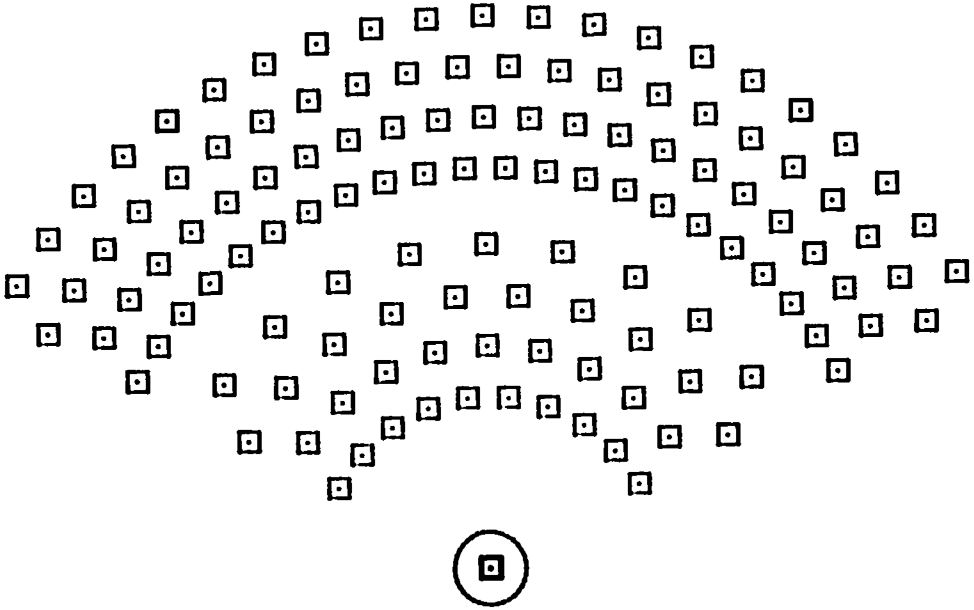








QUAD MODULE LAYOUT



GEOMETRIC PERFORMANCE EFFICIENCY
COLES LEVEE QUAD MOD:41M [135FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	0.8152	0.8148	0.8141	0.8136	0.8131	0.8123
65	0.9020	0.8890	0.8526	0.8281	0.8011	0.7645
45	0.9455	0.9244	0.8636	0.8219	0.7754	0.7104
25	0.9454	0.9187	0.8560	0.0006	0.7376	0.6468
15	0.8695	0.8572	0.8037	0.7480	0.6879	0.5973
5	0.7299	0.7315	0.6798	0.6417	0.6177	0.5019

AVE. ANNUAL EFF. = 0.8331   ENERGY = 4.2701 X10^7 KWT-HRS

[496 HELIOSTATS]

COSINE PERFORMANCE EFFICIENCY
COLES LEVEE QUAD MOD, 41M [135FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES

	0	30	60	75	90	110
89.5	0.8152	0.8148	0.8141	0.8136	0.8131	0.8123
65	0.9020	0.8890	0.8526	0.8281	0.8011	0.7645
45	0.9455	0.9244	0.8636	0.8219	0.7754	0.7104
25	0.9627	0.9354	0.8567	0.8013	0.7379	0.6474
15	0.9611	0.9320	0.8469	0.7862	0.7161	0.6140
5	0.9528	0.9222	0.8327	0.7685	0.6935	0.5815

SHADOWING PERFORMANCE EFFICIENCY
COLES LEVEE QUAD MOD,41M [135FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
25	0.9821	0.9821	0.9991	0.9991	0.9997	0.9991
15	0.9047	0.9196	0.9490	0.9514	0.9607	0.9727
5	0.7761	0.7934	0.8164	0.8351	0.8907	0.8631

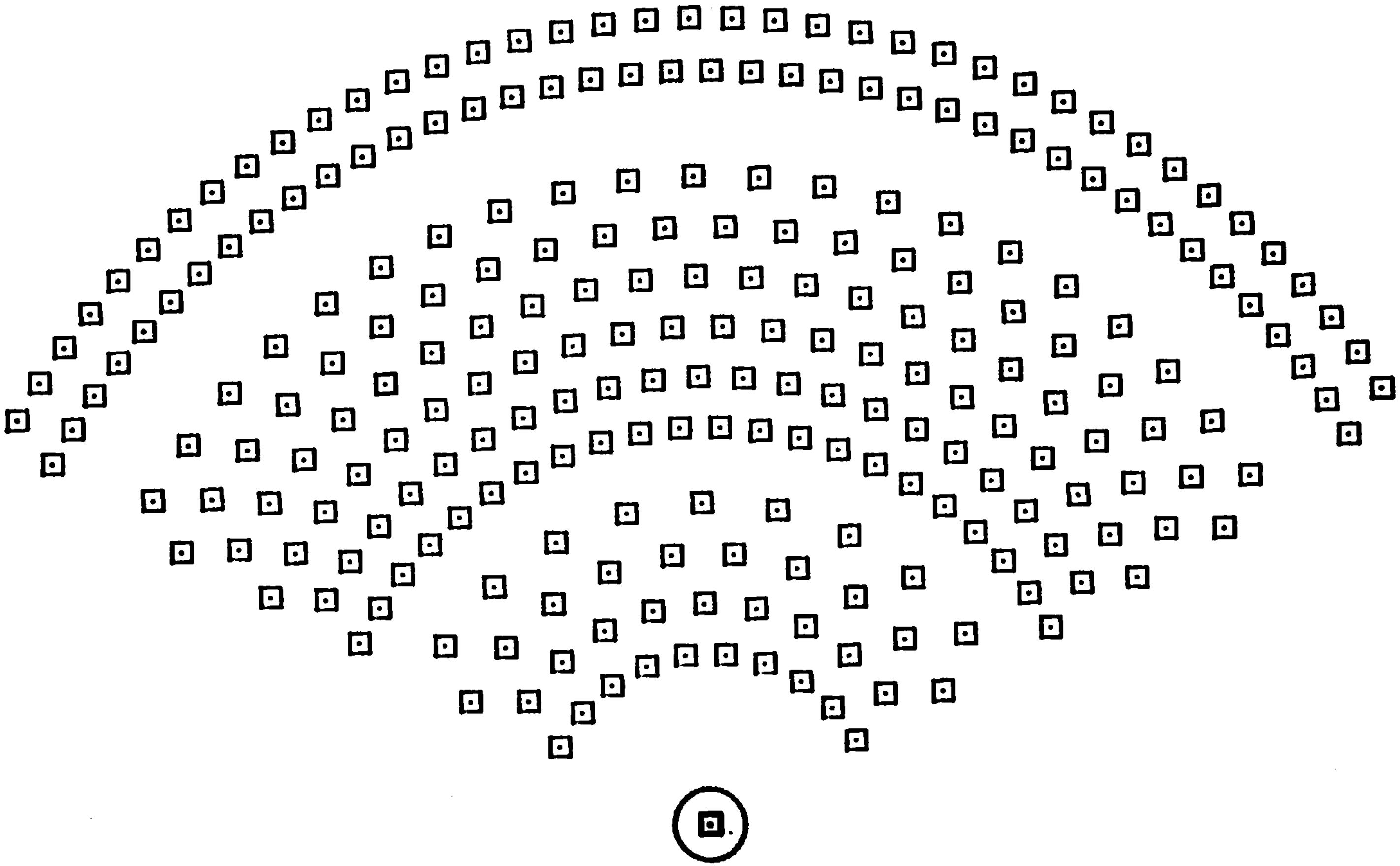
TOWER SHADOW PERFORMANCE EFFICIENCY
COLES LEVEE QUAD MOD,41M [135FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES

	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
25	0.9821	0.9821	1.0000	1.0000	1.0000	1.0000
15	0.9508	0.9196	1.0000	1.0000	1.0000	1.0000
5	0.9472	0.9472	1.0000	1.0000	1.0000	1.0000

DOUBLE MODULE LAYOUT



GEOMETRIC PERFORMANCE EFFICIENCY
COLES LEVEE DOUBLE MOD, 53M [174FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES

	0	30	60	75	90	110
89.5	0.8120	0.8116	0.8109	0.8104	0.8099	0.8092
65	0.8991	0.8861	0.8496	0.8251	0.7981	0.7615
45	0.9426	0.9215	0.8611	0.8194	0.7727	0.7077
25	0.9482	0.9208	0.8531	0.7978	0.7346	0.6442
15	0.8904	0.8690	0.8015	0.7452	0.6871	0.5931
5	0.7467	0.7384	0.6815	0.6494	0.6211	0.5034

ANNUAL AVERAGE EFF = .83144

ANNUAL ENERGY =
3.7544×10^7 KWT-HRS
437 HELIOSTATS

COSINE PERFORMANCE EFFICIENCY
COLES LEVEE DOUBLE MOD, 53M [174FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	0.8120	0.8116	0.8109	0.8104	0.8099	0.8092
65	0.8991	0.8861	0.8496	0.8251	0.7981	0.7615
45	0.9431	0.9219	0.8611	0.8194	0.7727	0.7077
25	0.9608	0.9336	0.8549	0.7994	0.7360	0.6454
15	0.9596	0.9305	0.8454	0.7847	0.7146	0.6125
5	0.9517	0.9293	0.8316	0.7675	0.6925	0.5805

SHADOWING PERFORMANCE EFFICIENCY
COLES LEVEE DOUBLE MOD, 53M [174FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES

	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
25	1.0000	0.9994	0.9980	0.9981	0.9982	0.9981
15	0.9573	0.9634	0.9481	0.9496	0.9616	0.9684
5	0.8171	0.8275	0.8195	0.8461	0.8968	0.8672

BLOCKING PERFORMANCE EFFICIENCY
COLES LEVEE DOUBLE MOD,53M [174FT] TWR

AZIMUTH ANGLE, DEGREES

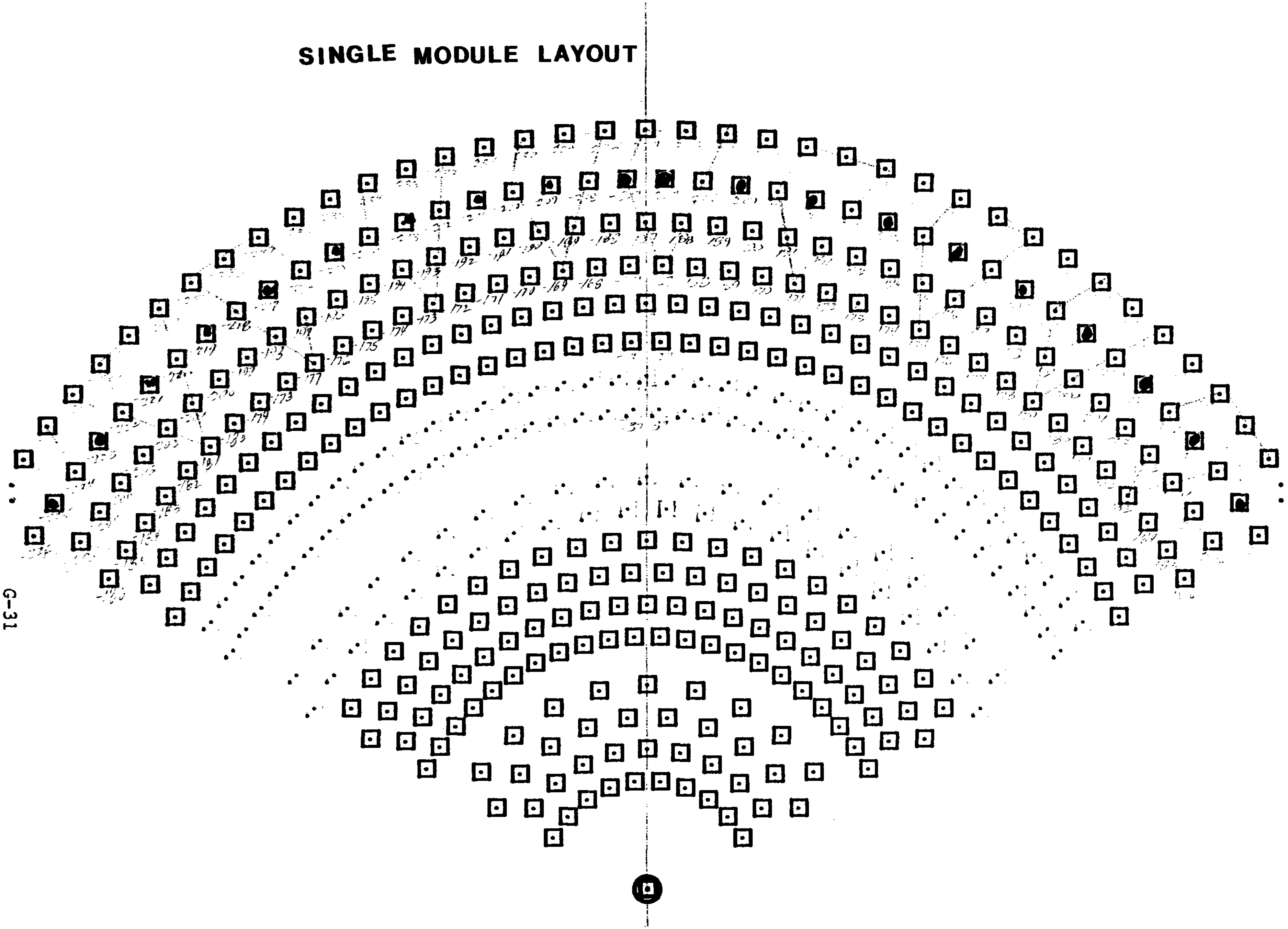
SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

TOWER SHADOW PERFORMANCE EFFICIENCY
COLES LEVEE DOUBLE MOD, 53M [174FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	0.9995	0.9995	1.0000	1.0000	1.0000	1.0000
25	0.9869	0.9869	1.0000	1.0000	1.0000	1.0000
15	0.9693	0.9694	1.0000	1.0000	1.0000	1.0000
5	0.9602	0.9602	1.0000	1.0000	1.0000	1.0000

SINGLE MODULE LAYOUT



GEOMETRIC PERFORMANCE EFFICIENCY
COLES LEVEE SINGLE MOD, 61M [200FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	0.8005	0.8001	0.7993	0.7988	0.7983	0.7975
65	0.8904	0.8770	0.8399	0.8148	0.7872	0.7498
45	0.9363	0.9147	0.8537	0.8111	0.7635	0.6970
25	0.9510	0.9231	0.8494	0.7932	0.7286	0.6363
15	0.9194	0.8904	0.8082	0.7493	0.6848	0.5877
5	0.7704	0.7383	0.6934	0.6545	0.6187	0.5085

ANNUAL EFF. = 0.8298 ENERGY = 3.7420×10^{7} KWT-HRS

[437 HELIOSTATS]

COSINE PERFORMANCE EFFICIENCY
COLES LEVEE SINGLE MOD:61M [200FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	0.8005	0.8001	0.7993	0.7983	0.7983	0.7975
65	0.8904	0.8770	0.8399	0.8148	0.7872	0.7496
45	0.9372	0.9156	0.8537	0.8111	0.7635	0.6970
25	0.9581	0.9304	0.8505	0.7941	0.7295	0.6370
15	0.9586	0.9291	0.8428	0.7812	0.7098	0.6057
5	0.9524	0.9213	0.8310	0.7660	0.6899	0.5758

SHADOWING PERFORMANCE EFFICIENCY
COLES LEVEE SINGLE MOD, 61M [200FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
25	1.0000	0.9995	0.9988	0.9989	0.9988	0.9989
15	0.9751	0.9743	0.9589	0.9592	0.9648	0.9703
5	0.8326	0.8249	0.8345	0.8545	0.8968	0.8832

BLOCKING PERFORMANCE EFFICIENCY
COLES LEVEE SINGLE MOD, 61M [200FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

TOWER SHADOW PERFORMANCE EFFICIENCY
(COLES LEVEE SINGLE MOD, 61M [200FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	0.9991	0.9991	1.0000	1.0000	1.0000	1.0000
25	0.9926	0.9926	1.0000	1.0000	1.0000	1.0000
15	0.9836	0.9836	1.0000	1.0000	1.0000	1.0000
5	0.9715	0.9715	1.0000	1.0000	1.0000	1.0000

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