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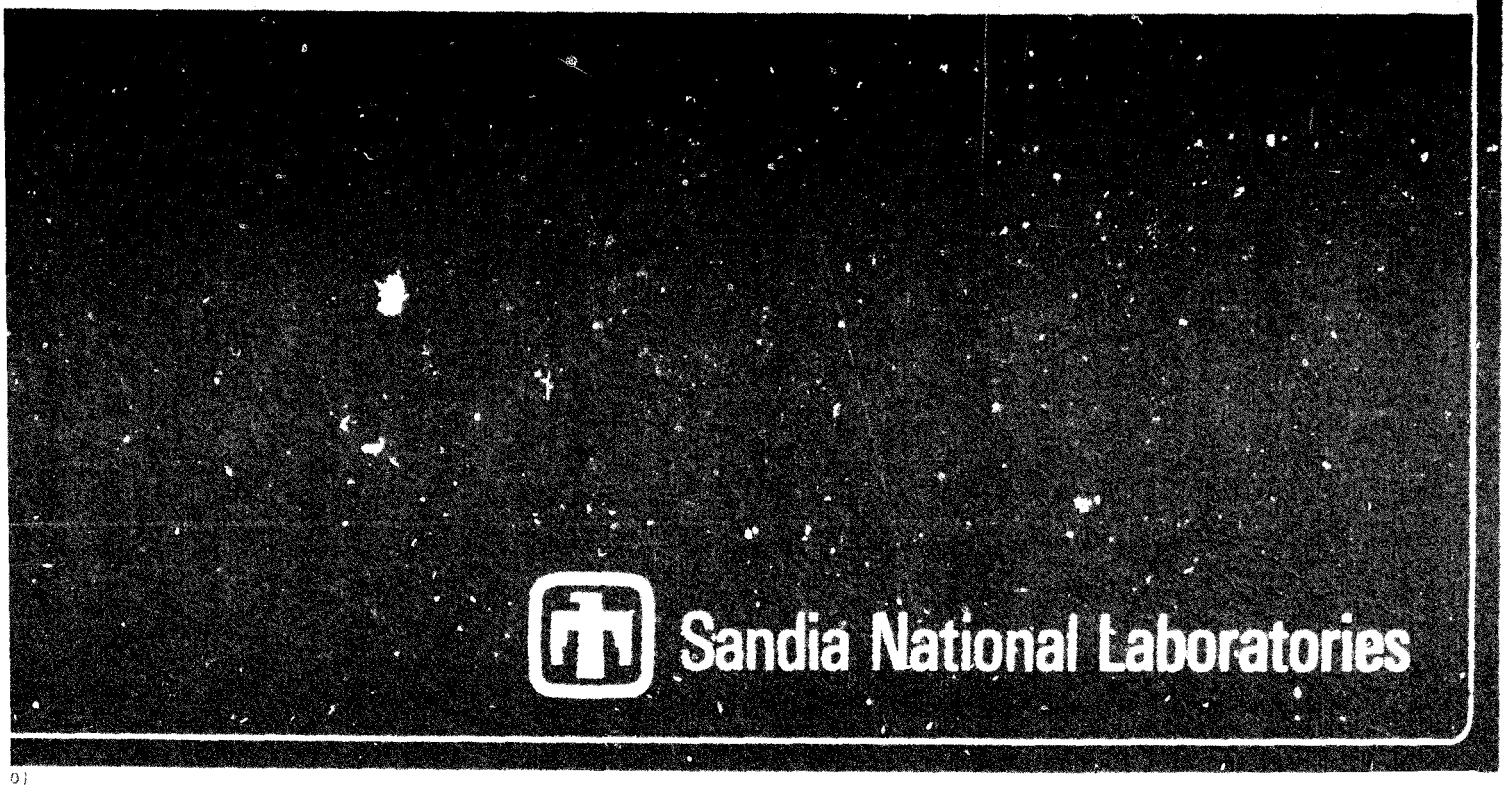
Arthur C. Ratzel, Carl E. Sisson



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ANNULAR SOLAR RECEIVER THERMAL CHARACTERISTICS

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ABSTRACT

This report presents results from thermal studies performed for an annular solar receiver assembly to be used with the Sandia Laboratories 2-m, 90-deg parabolic collector trough. The receiver configuration modeled consists of a 2.54-cm o.d. steel tube with a black-chrome selective surface and an enclosing concentric Pyrex glass envelope. Previous thermal work conducted on the parabolic-cylindrical collector design established the geometry and solar-noon absorbed flux distributions used in the current study. One- and two-dimensional thermal models have now been developed to provide receiver assembly temperatures, heat losses, and working fluid energy extraction data with the Therminol-66 (T-66) bulk temperature maintained at 315°C. Parameters varied in the work include wind velocity, ambient air temperature, annulus gas pressure, and T-66 flow condition (Reynolds number). Heat loss and energy extraction results are tabulated and temperature distributions from two-dimensional thermal modeling are graphically presented in the Appendices.

The thermal studies indicate excessive temperatures (≥340°C) for the receiver tube surfaces when the operating Reynolds number is low (30000). Such temperature levels can result in T-66 and black-chrome degradation. Therefore, it is recommended that the Reynolds number be maintained above 50000. The studies also show the importance of receiver assembly alignment. Misalignments, particularly an upward misalignment, can greatly increase the peak temperature experienced by the T-66 fluid and black-chrome selective coating. Further, since one-dimensional and two-dimensional heat loss and energy extraction results are comparable, one-dimensional thermal modeling is recommended so long as receiver temperature distributions are not needed. Increasing wind velocity and decreasing ambient air temperatures have been found to increase receiver heat loss. These increased losses are minimized if the annular space of the receiver assembly is evacuated.

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Glossary of Abbreviations and Acronyms

CINDA	Chrysler Improved Numerical Differencing Analyzer
DOE	U. S. Department of Energy
MSSTF	Midtemperature Solar Systems Test Facility
Sandia	Sandia Laboratories, Albuquerque, New Mexico
T-66	Therminol 66® heat transfer fluid produced by Monsanto Corporation
TRASYS	Thermal Radiation Analysis System
1-D	One-dimensional
2-D	Two-dimensional

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NOMENCLATURE

a	absorption coefficient
C_p, C_i	specific heat
d	misalignment distance
g	acceleration of gravity
HAIR	convection coefficient from glass to environment
HFLUID	convection coefficient for working fluid
HGAP	convection coefficient for annular space
h_{ij}	convection coefficient for heat transfer from i to j
k, k_i	thermal conductivity
k_{ef}	effective thermal conductivity (Eqs. 10)
L	receiver assembly elemental length
n	glass index of refraction
Nu	Nusselt number
P_{an}	annulus gas pressure
Pr	Prandtl number
QAIR	convective heat loss from glass to environment
Q_{fluid}, QFLUID	energy transferred to the working fluid
Q_{glass}, QGLASS	solar energy absorbed by the glass
Q_{loss}, QLOSS	receiver assembly heat loss
Q_s	direct normal solar-radiation on the trough
QSPACE	radiative heat loss from glass to environment
Q_{tube}, QTUBE	solar energy absorbed by receiver tube
Ra	Rayleigh number
Re	Reynolds number
r_i	radius of surface i
SIGT	total collector error at solar noon
X	glass thickness

T_i	temperature of surface i
T_m	mean temperature
V_i	velocity

Greek

β	coefficient of volumetric thermal expansion or misalignment angle
$\varepsilon_{i_{IR}}$	thermal emissivity of surface i
η	overall collector efficiency
η_{opt}	collector optical efficiency
θ	angular position or incidence angle
$\Delta\theta$	angular increment
κ	glass extinction coefficient
μ, μ_i	dynamic viscosity
ρ, ρ_i	density
σ	Stefan-Boltzmann constant

Subscripts

1	inner surface of receiver tube
2	outer surface of receiver tube
3	inner surface of glass jacket
4	outer surface of glass jacket
a	ambient
f	fluid
IR	infrared (thermal) wavelength band
s	blackbody sky

ANNULAR SOLAR RECEIVER THERMAL CHARACTERISTICS

I. INTRODUCTION

Thermal parametric studies[1] of a second-generation E-W-oriented, 2-m, 90-deg parabolic-cylindrical solar collector, proposed for use at the Sandia/DOE Midtemperature Solar Test Facility (MSSTF), resulted in recommending use of an annular receiver assembly composed of a 2.54-cm receiver tube with a concentric 4.8-cm o.d. glass envelope. An additional set of thermal studies was performed to improve the definition of thermal characteristics of this receiver assembly over a realistic range of system operating conditions. The additional studies are discussed in this report.

The previous heat loss calculations[1] made for the 2.54-cm receiver tube assumed uniform tube wall temperatures in order to simplify the calculations used in the parametric studies. This assumption, however, is not valid for large solar flux variations around the receiver tube; furthermore, it does not allow for estimation of local hot spots on the receiver tube. Although the absorbed solar flux variations may diffuse circumferentially, the possibility of local hot spots is particularly important at high fluid operating temperatures (near 315°C) since the black-chrome selective surface and the Therminol-66 (T-66) working fluid will experience degradation at temperature levels above 340°C.

To improve the definition of receiver assembly thermal characteristics, two thermal models have been developed to study the temperature distributions in the receiver assembly resulting from various circumferential solar flux distributions. A one-dimensional (1-D) thermal model has been developed to calculate the circumferentially averaged heat losses and receiver assembly temperatures. This 1-D model

allows investigation of receiver performance over a significant range of fluid temperature, Reynolds number, receiver annulus air pressure, and variation in ambient conditions such as wind velocity, insolation, and temperature. A two-dimensional (2-D) thermal model was prepared to provide the circumferential temperature variations throughout the receiver assembly under a select subset of operating conditions. The 2-D model also provides estimates of receiver assembly heat losses and energy absorbed by the working fluid. It is shown that 1-D and 2-D models predict the same magnitudes of heat loss and energy absorbed by the fluid.

The analyses reported herein assume that the T-66 bulk fluid temperature is 315^{o}C and use calculated solar-noon (absorbed) flux distributions resulting from (1) vertical misalignment, (2) horizontal misalignment, (3) collector tracking errors, and (4) collector structural (slope) errors. Energy extraction rate (by fluid) and collector heat loss rates are calculated at four (4) Reynolds numbers (10000, 30000, 50000, and 70000) for various ambient conditions and collector operating conditions.

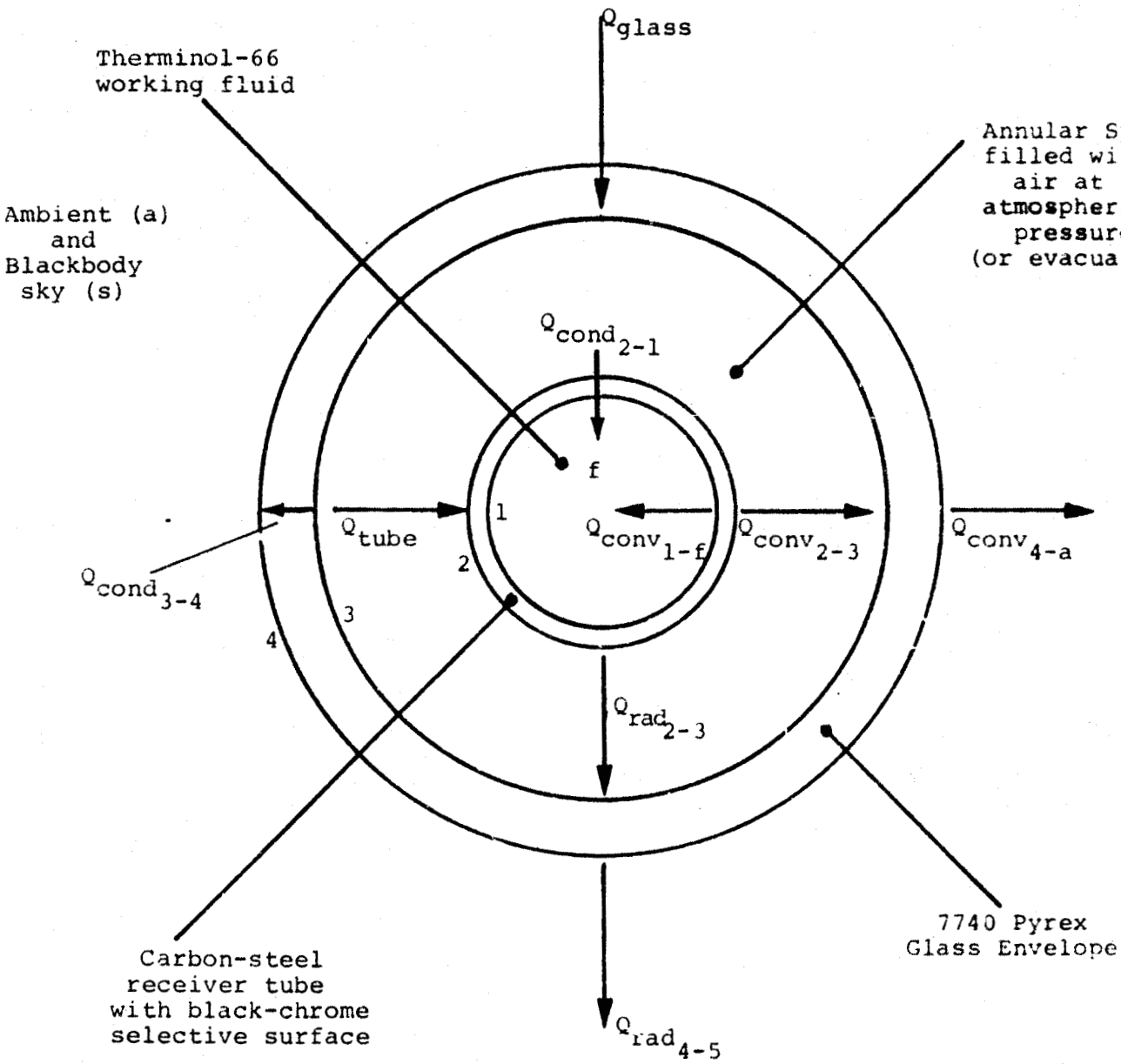
II. DESCRIPTION AND ANALYSIS

The receiver assembly configuration consists of a 2.54-cm o.d. carbon-steel tube with a black-chrome selective surface and an enclosing concentric Pyrex glass envelope. Figure 1 shows a schematic of the energy transfer mechanisms associated with this design. Note that the annular space of the receiver assembly may be either (1) evacuated or (2) filled with air at atmospheric pressure. Choice of the annulus gas pressure condition establishes whether the energy transfer across the space is solely by radiation exchange or whether convection (and conduction) effects are included.

Assumptions used in the thermal modeling are discussed in the following section. In addition, brief presentations of the pertinent convective heat transfer correlations for energy exchanges, (1) to the working fluids, (2) across the annular space, and (3) to the environment are included. Discussion of the 1-D and 2-D thermal models are also presented. These two sections describe the methods for obtaining the steady state thermal solutions and highlight the additional assumptions inherent in each model.

A. Assumptions and Correlations

The different modes of energy exchange for the selected geometry are schematically presented in Fig. 1. The geometry is subdivided circumferentially in the 2-D thermal model to accurately model the absorbed solar energy distributions on the receiver tube and glass. The 1-D model considers only radial energy transfer, using integrated values from the absorbed solar energy data. The same heat transfer correlations (described below) are used in the two analyses in order to provide results which can be directly compared.



Notation

$Q_{cond_{i-j}}$ = Conduction heat transfer from surface i to j

$Q_{conv_{i-j}}$ = Convection heat transfer from surface i to j

$Q_{rad_{i-j}}$ = Radiation heat transfer from surface i to j

Q_{glass} = Solar radiation absorbed by glass

Q_{tube} = Solar radiation absorbed by receiver tube

FIGURE 1. Energy Transfer Schematic for the Annular Receiver Assembly

For radiation energy exchange in the annulus, the analyses assume that the glass and receiver tubes are opaque, diffuse-gray surfaces. The assumption that the glass is opaque for the thermal energy exchange is reasonable for receiver tube temperature < 400°C. The restriction that the surface is radiatively diffuse is essential for obtaining radiation configuration (form) factors for the surface elements to be used in the 2-D thermal model. In addition, it is assumed that the surface thermal emissivities are independent of temperature, with the glass and receiver tube values at 0.92 and 0.25, respectively.[16]

For radiation losses from the glass surface, the sky is treated as a blackbody surface which encloses (view factor = 1.0) the glass outer surface. The effective blackbody sky temperature is obtained from work by Whillier[2] given in Eq. (1)

$$T_s = T_a - 6^{\circ}C \qquad (1)$$

All variables are defined in the report nomenclature.

The transfer of absorbed solar energy from the steel receiver tube to the working fluid (T-66) is by convection. It is assumed that the T-66 bulk fluid temperature and flow rate are known. The convection coefficient is obtained from the fully developed turbulent-flow heat transfer correlation given by Sieder and Tate[3] [Eq. (2)]. The correlation depends on the working fluid Reynolds (Re) and Prandtl (Pr) numbers and a dynamic viscosity ratio. The viscosity dependence models the convection process where differences between the tubewall and bulk fluid temperatures in excess of 6°C are encountered.

$$Nu = 0.027\ (Re)^{0.8}\ (Pr)^{0.33}\ (\mu_f/\mu_l)^{0.14} \qquad (2)$$

with

$$Nu = 2h_{lf}r_l/K_f \tag{3}$$

$$Re = 2\rho_f v_f r_l/\mu_f \tag{4}$$

$$Pr = \mu_f c_f/K_f \tag{5}$$

All properties are evaluated at the bulk fluid temperature except for μ_l, which is evaluated at the average wall temperature.

Convection heat transfer coefficients from the glass to the surroundings are a function of the ambient wind velocity. The receiver assembly is horizontal and the air is assumed to flow over the receiver (not along the tube). Two cases are considered for analysis. The more conservative case models natural convection energy exchange where there is no apparent wind velocity. Equation (6) defines the convection coefficient in terms of the average temperature difference between the glass and surroundings[4]

$$h_{4a} = 3.795\ (T_4 - T_a)^{0.25} \quad (W/m^2 - {}^oK) \tag{6}$$

The convection coefficient is modeled using Eq. (7) for the case where there is forced air flow over the receiver assembly. The diameter used in Re and Nu is the external diameter of the cylinder, and the velocity used in computing the Reynolds number is that of the air stream approaching the cylinder. All fluid properties are based on the mean film temperature ($T_m = [T_4 + T_a]/2$).

$$Nu = C(Re)^m \tag{7}$$

where C and m are given below[5]

Range of Re	C	m
1-4	0.891	0.330
4-40	0.821	0.385
40-4000	0.615	0.466
4000-40,000	0.174	0.618
40,000-250,000	0.0239	0.805

Energy transfer across the annular space by mechanisms other than radiation depends on the annulus gas pressure. For the case where the annular space is evacuated, it is assumed that the annulus gas pressure (P_{an}) $\leq 10^{-3}$ Pa, and thus there is no convective or conductive energy exchange.[6,7] Therefore,

$$h_{23} = 0. \tag{8}$$

When the annular space is maintained at atmospheric pressure, the following correlations are incorporated.

$$h_{23} = K_{ef}/r_2 \ln (r_2/r_1) \tag{9}$$

with

$$K_{ef} = K \quad \text{for } Ra \leq 1000 \tag{10a}$$

$$K_{ef} = 0.1558\ K\ (Ra)^{0.2667} \quad \text{for } Ra > 1000 \tag{10b}$$

The Rayleigh number (Ra) is defined in Eq. (11) below.

$$Ra = C_p \rho^2 g \beta (r_2 - r_3)^3\ (T_2 - T_3)/\mu K \tag{11}$$

All properties are evaluated at the mean air temperature for the annular space except for the coefficient of volumetric thermal expansion (β) which is evaluated at the inside glass surface average temperature (T_3). Note that Eq. (10b) has also been shown to be valid by Hickox and Gartling[8] for asymmetric receiver tube temperature distributions and for eccentric cylinders.

The solar energy distributions absorbed by the receiver and glass tubes have been obtained from a simulation model already described.[1] The energy is assumed to be absorbed by the receiver tube at the tube surface. The solar energy absorbed by the glass, on the other hand is assumed to be uniformly absorbed through the thickness. This simplifies the glass absorption process normally defined by the absorption coefficient (a) which depends on the glass thickness (x), extinction coefficient (κ) and index of refraction (n) and the radiation incidence angle (θ).[9] Equation (12) presents the exponential form of the absorption coefficient.

$$a = e^{-\kappa x'} \tag{12}$$

and

$$x' = x/\sqrt{1 - \sin^2(\theta)/n^2} \tag{13}$$

Additional information on the absorbed solar energy distributions is given in Section III.

All analyses model the steady-state thermal problem for a fixed length of receiver assembly (1 m). Material conductivity properties for the glass and steel tube are assumed constant while the T-66 fluid properties and air properties are allowed to vary with temperature. Information on these data will also be provided in Section III, "Definition of Problem Parameters."

B. One-Dimensional Thermal Model

The 1-D thermal model considers radial energy exchange assuming that the solar radiation absorbed by the glass and receiver tube is uniformly distributed. The model, therefore, cannot provide circumferential temperature distribution data for the receiver assembly. It will, however, estimate receiver assembly heat loss characteristics and energy collection data for the receiver working fluid given ambient conditions and bulk fluid operating constraints.

The 1-D thermal model uses the net radiation method described in Siegel and Howell[10] to define the radiative energy exchange mechanisms. The conduction and convection energy transfer modes are also included to develop a series of energy balance equations for the receiver tube and glass envelope. A Newton-Raphson iteration method[10] is used to solve these coupled nonlinear equations, allowing use of temperature-dependent conduction, convection, and radiation coefficients. Convergence of the surface temperatures to $\pm 0.1^{\circ}C$ is obtainable usually within five iterative calculations. Energy extraction by the fluid (Q_{fluid}) and overall receiver assembly heat loss (Q_{Loss}) data are obtained using the surface temperatures of the inner diameter of the receiver tube and outer diameter of the glass envelope, respectively. Equations 14 and 15 define these values. Note that the heat-transfer correlations (h_{1f} and h_{4a}) have been presented in the previous section.

Energy Extraction

$$Q_{Fluid} = 2\pi r_1 L h_{1f} (T_1 - T_f) \tag{14}$$

Receiver Heat loss

$$Q_{Loss} = 2\pi r_4 L \left[\varepsilon_{4IR} \sigma \, (T_4^4 - T_s^4) + h_{4a} \, (T_4 - T_a) \right] \tag{15}$$

C. Two-Dimensional Thermal Model

A 2-D thermal model was prepared to provide the circumferential temperature variation throughout the receiver assembly. Of particular interest from the 2-D model are the peak temperatures associated with the receiver tube. The black-chrome selective coating on the receiver tube and the T-66 working fluid considered must both be maintained below 340°C to prevent degradation. The 2-D model (discussed below) has been employed for a select subset of parametric variations (Section III) to show the peak temperatures, and to provide heat loss from the glass envelope and energy transferred to the working fluid. These latter results can be compared to the 1-D model results.

The 2-D thermal model is a lumped-mass thermal network prepared for solution by CINDA*. Figure 2 describes the circumferential and radial node structuring (finite-difference discretization) to represent a unit length of the receiver assembly. Physical dimensions, boundary conditions, material properties, and absorbed solar flux distributions are given in Section III. All heat transfer mechanisms (shown by Figure 1) discussed earlier are incorporated in the thermal model.

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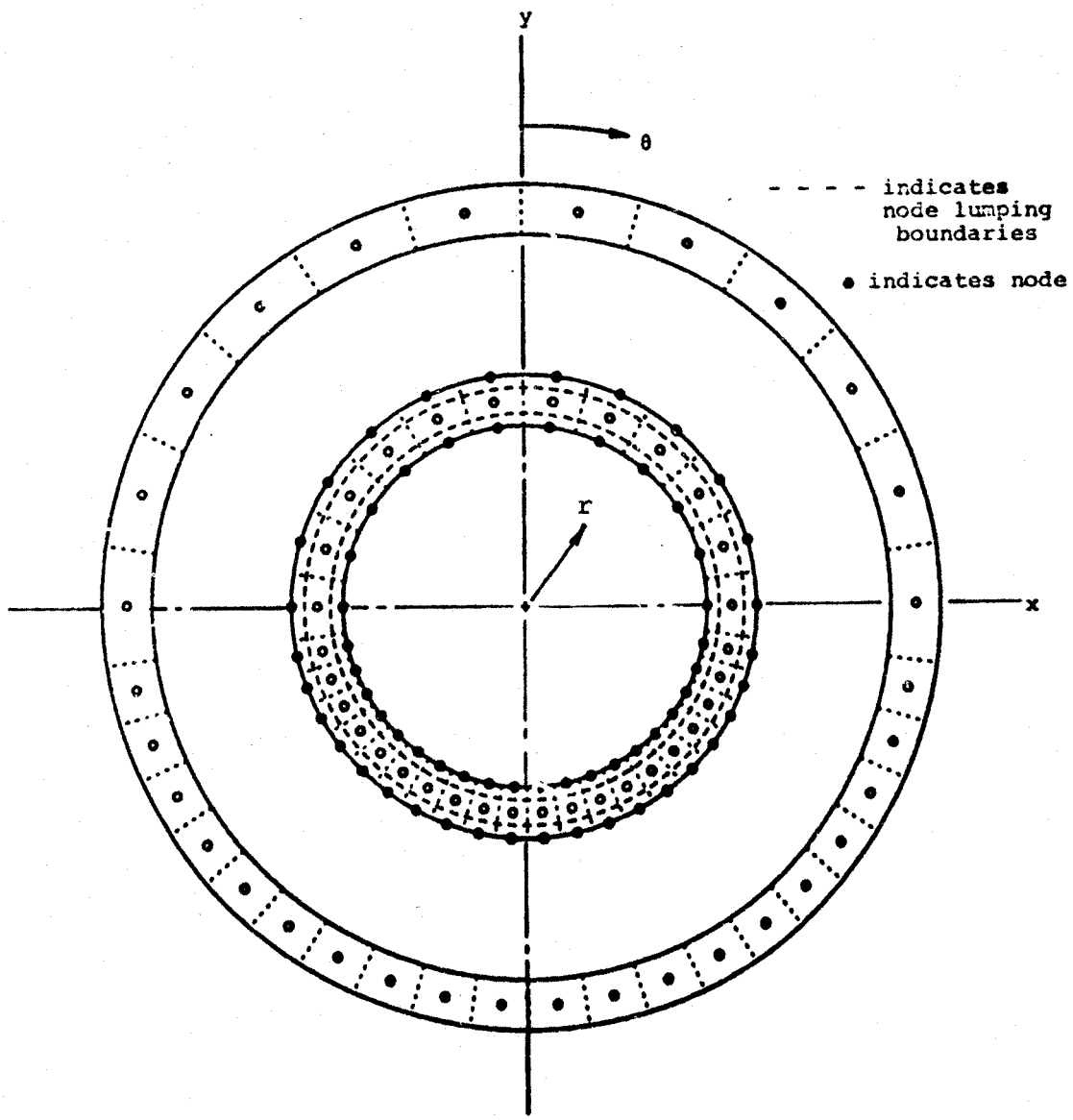
*CINDA[11, 12] is a multi-option finite difference code which analyzes a mathematical model of an arbitrary 1-D, 2-D, or 3-D lumped-parameter representation of a physical system governed by a set of diffusion equations. To use the code, a thermal analog network representing the physical system is constructed. Material properties and boundary conditions can be specified as constants or as functions of one or more independent variables. CINDA allows choice of various steady-state or transient solution methods. Optional capabilities incude the capability to solve a separate radiosity network representing an enclosure (with diffuse surfaces), and the capability to account for material phase change energies. CINDA also allows the user to incorporate needed logic and subroutines necessary for a particular thermal model.



<u>32 Angular Segments</u>: 12 @ $\Delta\theta = \pi/11$ $\left(\frac{-6\pi}{11} \leq \theta \leq \frac{6\pi}{11}\right)$

20 @ $\Delta\theta = \pi/22$ $\left(\frac{6\pi}{11} \leq \theta \leq \frac{16\pi}{11}\right)$

<u>Conductances (G) Values Between Adjoining Nodes</u>:

Circumferential: $G_{cir} = \frac{4K(r_{max} - r_{min})L}{(r_{max} + r_{min})(\Delta\theta_1 + \Delta\theta_2)}$ (r, over range representing node volume)

Radial: $G_{rad} = \frac{k(\Delta\theta)L}{\ln(r_{max}/r_{min})}$ (r, over range between node centers)

FIGURE 2. Network Definition for 2-D Thermal Model

For radiation exchange across the annulus between the receiver tube and glass envelope, the 2-D thermal model employs a radiosity network solution for a multiple diffuse-gray surface enclosure containing a nonabsorbing media. The radiation form factors required for the surface elements were calculated using TRASYS.[13] Surface emissivities were discussed earlier.

The radiative and convective heat losses from the surface of the glass envelope and energy transfer to the working fluid employ parameter definitions as described by Eqs. (1) through (11). Solution of the thermal model (for each selected condition) employed the steady-state solution subroutine CINDSR available in CINDA.[11,12] CINDSR employs a "successive point" iteration technique to solve the set of simultaneous (linear) difference equations representing the network. A linear extrapolation is performed (every third iteration) on the error function plot of each node in an attempt to accelerate convergence. Successive solutions were employed to adequately iterate the dependent variables described by eqs. (1) through (11) as temperatures converged to the desired steady-state solution. An energy balance for each solution indicated convergence to within 0.01 percent.

III. DEFINITION OF PROBLEM PARAMETERS

This section defines and discusses the fixed data and parametric data used in the thermal analysis of the 2.54-cm receiver tube assembly. Design conditions, defined in Table I include (1) receiver geometry, (2) receiver material properties, (3) working fluid properties, and (4) ambient and annulus gas pressure conditions. The current study assumes that the data given in Table I are constant unless indicated otherwise. In addition to Table I, specific descriptions are provided for (1) the absorbed solar flux distributions, (2) the working fluid, and (3) the operating conditions. These descriptions are given in the following three subsections respectively.

A. Solar Flux Distributions

The possible receiver assembly-collector trough inaccuracies considered for analysis are listed below and schematically represented in Figure 3.

- Variation in tracking, slope and receiver errors
- Receiver misalignment below the focal line
- Receiver misalignment above the focal line
- Receiver misalignment to the left of the focal line
- Tracking bias (angular error of tracking)

These different operating scenarios for receiver assembly-collector trough are modeled using EDEP, a solar energy deposition computer program created by F. Biggs.[14] This program was incorporated in the simulation model described in Reference 1. Absorbed solar flux distributions on the receiver tubes are shown in Figures 4 for various magnitudes of inaccuracy. The distributions have been obtained for a solar-noon insolation of 977.2 W/m^2 on the 2-m trough. It is assumed that the trough reflectivity is 0.95. Solar radiative properties for the glass

TABLE I

BASELINE RECEIVER ASSEMBLY DESIGN CONDITIONS

Receiver Assembly Geometry

Receiver Tube od: 2.54 cm
Receiver Tube Surface: Black Chrome
Receiver Tube Wall Thickness: 0.15 cm
Glass Jacket od: 4.80 cm
Glass Thickness: 0.20 cm
Receiver Assembly Length: 1 m

Receiver Assembly Material Properties

Glass Thermal Emissivity: 0.92
Glass Thermal Transmissivity: 0.0
Glass Thermal Conductivity: 1.32 W/m-°C
Receiver Tube Thermal Emissivity: 0.25 (for black chrome)
Receiver Tube Thermal Conductivity: 47.25 W/m-°C

Working Fluid (see discussion)

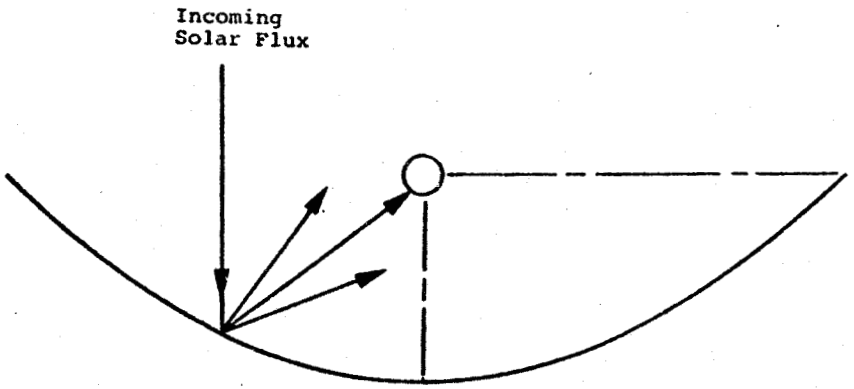
Fluid Type: T-66 (see Reference 15)
Bulk Fluid Temperature: 315°C
Reynolds Number: Variable (10,000, 30,000, 50,000 and 70,000)
Prandtl Number: 10.98
Thermal Conductivity @ 315°C: 0.094 W/m-°C
Dynamic Viscosity: Variable (see Reference 15)

Insolation and Solar Flux Distributions (see discussion)

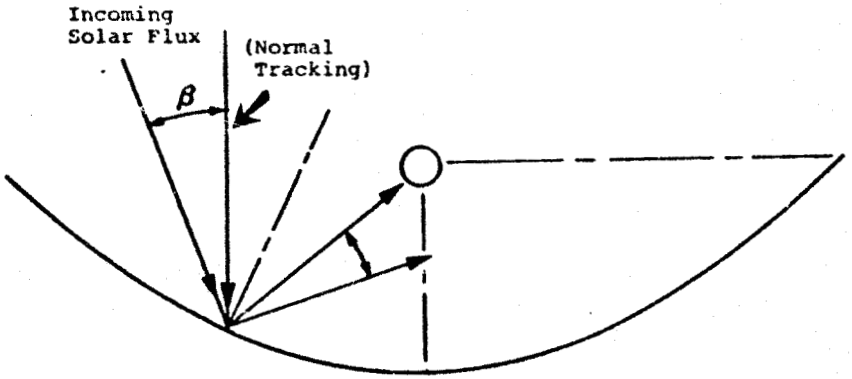
Solar Noon Insolation: 977.2 W/m^2
Absorbed Flux Distributions: Variable (see Figs. 4 and Table 2).

Operating Conditions (see discussion)

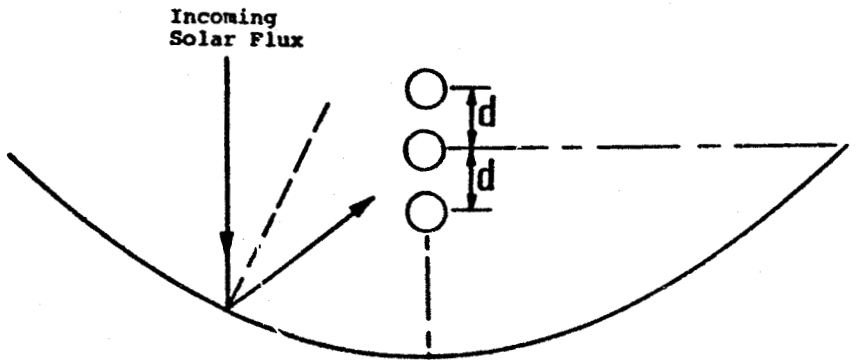
Ambient Temperature: 25°C
Ambient Pressure: 1×10^5 Pa
Ambient Wind Velocity: 0 m/s
Annulus gas: Air
Annulus Pressure: Variable ($<10^{-3}$ Pa or 10^5 Pa)



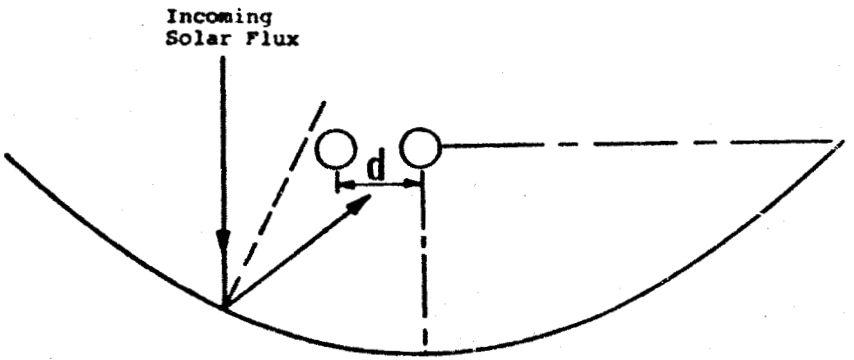
One-Dimens. nal Collector Error
(Associated with Trough Support
Structure, e.g.)



Error Associated with Tracking
Bias



Vertical Misalignment of the
Receiver Assembly



Horizontal Misalignment of the
Receiver Assembly

FIGURE 3. Error Sources Associated with the Parabolic-Cylindrical Solar Collector

Figure Descriptions

A: Variation of Structural (Slope) Error Magnitude

B: Misalignment of Receiver Assembly Below Focal Line

C: Misalignment of Receiver Assembly Above Focal Line

D: Misalignment of Receiver Assembly To Left of Focal Line

E: Collector Tracking Error Variation

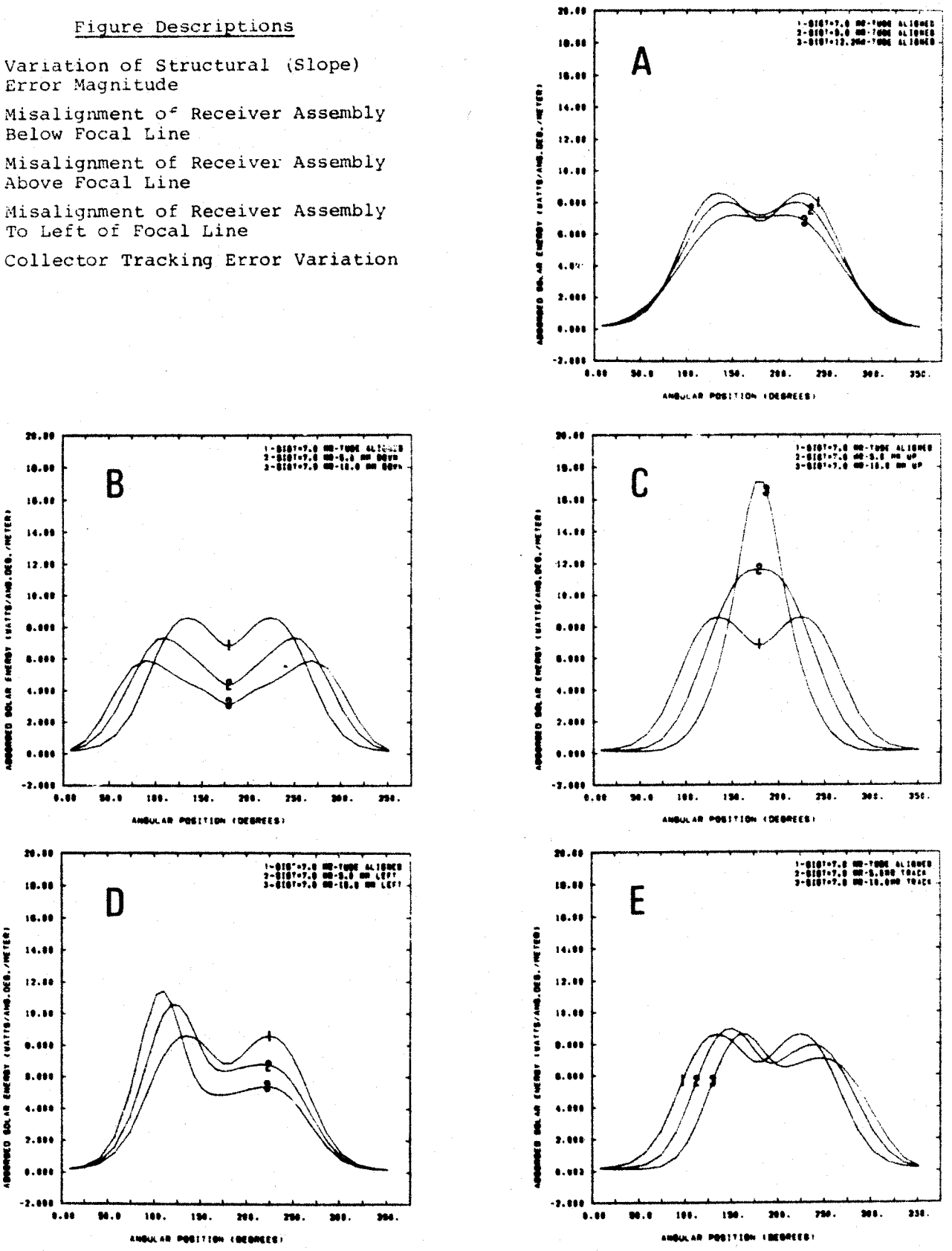


FIGURE 4. Receiver Tube Absorbed Solar Energy Distributions

and receiver tube vary with incidence angle, with the receiver tube normal solar absorptivity and glass normal solar transmissivity fixed at 0.95 and 0.913, respectively. Errors associated with tracking, trough structure, receiver positioning, mirror specularity, and finite sun-shape are treated statistically according to normal error distributions. Reference 1 should be consulted for additional details on the solar energy deposition model used in this work.

Table II shows cumulative results obtained from the absorbed energy distribution curves. Optical efficiency (η_{opt}) data are also provided to show the effect of misalignment and other inaccuracies in collecting solar radiation. Note that the optical efficiency, defined by Eq. (16), does not include the detrimental heat loss effect. The optical efficiency provides the maximum theoretical efficiency for a collector system prior to selection of operating temperature constraints.

$$\eta_{opt} \equiv \frac{Q_{Tube}}{Q_s} = \frac{\text{Energy absorbed by the Receiver Tube}}{\text{Energy incident on the Trough Aperture}} \qquad (16)$$

The absorbed solar energy distributions for the glass and receiver tubes are used in the 2-D thermal model. Cumulative absorbed energy totals are used in the 1-D thermal study with the energy assumed to be uniformly distributed about the tube circumferences.

Note: The terms 'flux' and 'energy' are used interchangeably throughout the report. The results are presented assuming a 1-m section of receiver assembly. Thus, results given in terms of flux units (W/m) are identical to their counterpart energy units (W). Note also that the calculations are performed at one instant in time-solar noon. Hence, energy is actually expressed as an energy rate (W-hr/hr).

TABLE II

CUMULATIVE SOLAR ENERGY COLLECTION DATA*

Cases Modeled	Solar Flux Absorbed Receiver Tube (Q_{Tube}) (W)	Solar Flux Absorbed by Glass (Q_{Glass}) (W)	Optical Efficiency (η_{opt}) (%)
I. Alignment (1-D)			
6.41mR(7.0mR total)+	1567.4	32.6	80.2
8.55mR (9.0mR total)	1513.1	32.8	77.4
11.88mR (12.2mR total)	1382.3	33.0	70.7
II. Misalignment below the focal line			
2.5mm (7.0mR total)	1555.5	32.7	79.6
5.0mm (7.0mR total)	1516.9	32.8	77.6
10.0mm (7.0mR total)	1324.1	33.4	67.8
III. Misalignment above the focal line			
2.5mm (7.0mR total)	1555.4	32.7	79.6
5.0mm (7.0mR total)	1516.1	32.8	77.6
10.0mm (7.0mR total)	1320.4	33.4	67.7
IV. Misalignment left of the focal line			
2.5mm (7.0mR total)	1564.2	32.7	80.0
5.0mm (7.0mR total)	1550.3	32.8	79.3
10.0mm (7.0mR total)	1420.3	33.2	72.7
V. Tracking bias			
2.5mR (7.0mR total)	1558.5	32.7	79.7
5.0mR (7.0mR total)	1529.9	32.8	78.2
10.0mR (7.0mR total)	1392.6	33.2	71.3

*Direct Normal Solar Radiation on the 2-m Collector aperture is 1954.4 W.

+Numbers in parentheses correspond to the total error associated with tracking, receiver, and slope errors and with sun and mirror errors (SIGT).

Numbers outside the parentheses represent the error magnitudes depicted by Figure 3 (in milli-radians or millimeters).

B. Working Fluid

Therminol-66, produced by Monsanto Corporation, St. Louis, Mo., is the heat-transfer fluid modeled in the study. T-66 is currently used in the parabolic-cylindrical collector field at the MSSTF. It is designed for use in nonpressurized indirect heating systems and is suitable for high-temperature performance to ~ 340°C.

It is assumed in the study that the T-66 bulk fluid temperature is 315°C, corresponding to the maximum outlet fluid temperature allowed at the MSSTF. The Prandtl number and T-66 thermal conductivity, used in Eq. (2) in determining the convection heat transfer coefficient, are evaluated at the bulk temperature and are given in Table I. The dynamic viscosity ratio was obtained from a curve fit of data reported by Monsanto Corporation.[15] Other pertinent properties used in the Prandtl number calculation, and the thermal conductivity of T-66 have also been obtained from this source.

C. Operating Conditions

The operating conditions defined in Table I were chosen to obtain maximum receiver tube and glass temperatures for given Reynolds numbers and annulus gas pressure conditions. With no external wind velocity, the convection energy transfer from the glass to ambient is minimized. Similarly, evacuation of the annulus gas minimizes the energy transfer across the annular space, since the only mode of energy exchange is by radiation. Additional results are also obtained with the annulus gas pressure maintained at 10^5 Pa, which is more typical of current receiver assembly conditions. For this case, the energy exchange mechanisms also include conduction and minimal convection. The annular space has been sized previously to limit natural convection effects so that the resulting heat loss is minimized and the receiver temperatures are maximized.

The ambient temperature selected for baseline studies is 25°C. This represents a typical late spring-early fall solar-roon ambient temperature. Results are also provided for different ambient temperatures (-25°, 0°, 25°, and 50°C) and different wind velocities (0.0, 2.5, 5.0, and 10.0 m/s) to show the effects of these changes on collector performance.

IV. DISCUSSION OF THERMAL MODEL RESULTS

Complete details of the parametric solutions from the 1-D and 2-D thermal models are presented in Appendices A, B, and C. Appendix A contains tabulated and plotted results from the 2-D thermal model for the baseline conditions shown in Table I. These conditions (25°C ambient air, no wind) result in the highest receiver tube temperatures. Appendices B and C contain tabulated results from solution of the 1-D thermal model for various ambient temperatures (-25, 0, 25, and 50°C) and various wind velocities (0.0, 2.5, 5.0, and 10.0 m/s). Note that all solutions are for the assumed bulk fluid temperature of 315°C corresponding to the maximum exit temperature condition specified at the MSSTF. Some of the more interesting results from the thermal model solutions will be discussed below.

A sample of detailed 2-D model results is given in Figures 5 through 7 for nominal (aligned) and extreme (10 mm misalignment up) receiver conditions. The operating Reynolds number is 30,000, the annular space is evacuated, and there is no wind velocity for the results presented. Figure 5 shows the solar flux absorbed by the receiver tube (see Section III for discussion), plus the reduced flux* after subtracting the energy radiated from the receiver tube outer surface to the glass envelope. Figure 6 shows the circumferential temperature distributions in the glass and at the outside surface of

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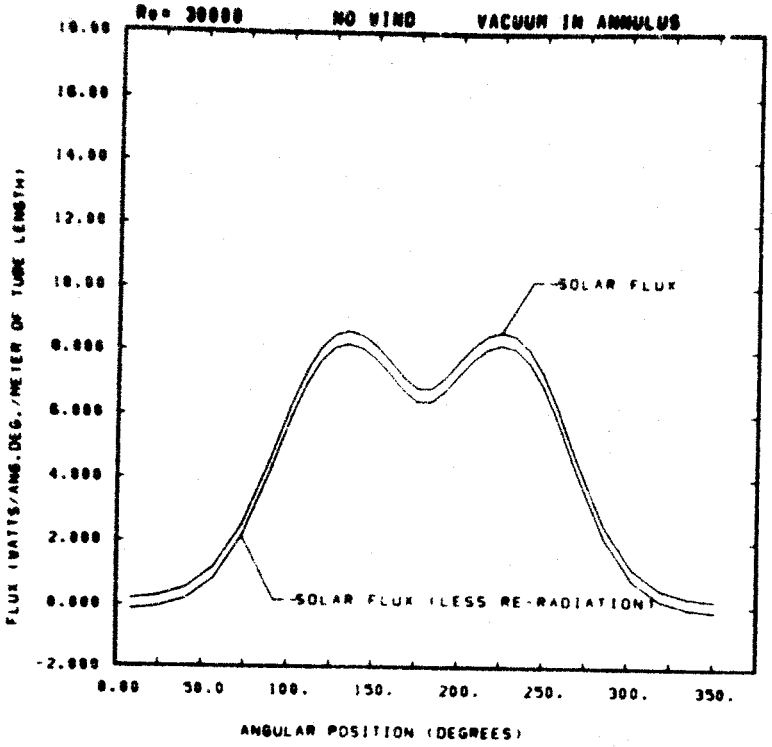
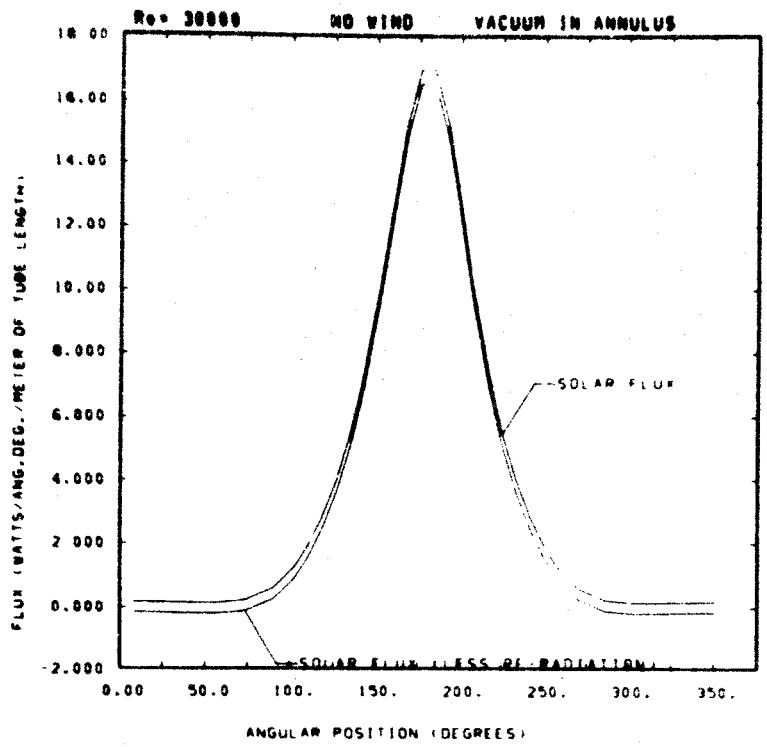
*The reduced flux (absorbed solar flux, less re-radiation) shown by Figure 5, is actually the distribution of solar energy which is transferred to the working fluid. However, the circumferential variation is not considered when calculating the convective heat transfer from the receiver tube to the working fluid (see Eqs. 2 through 5). The average temperature at the inner surface of the receiver tube, together with bulk fluid parameters, was used to determine an average convective coefficient.

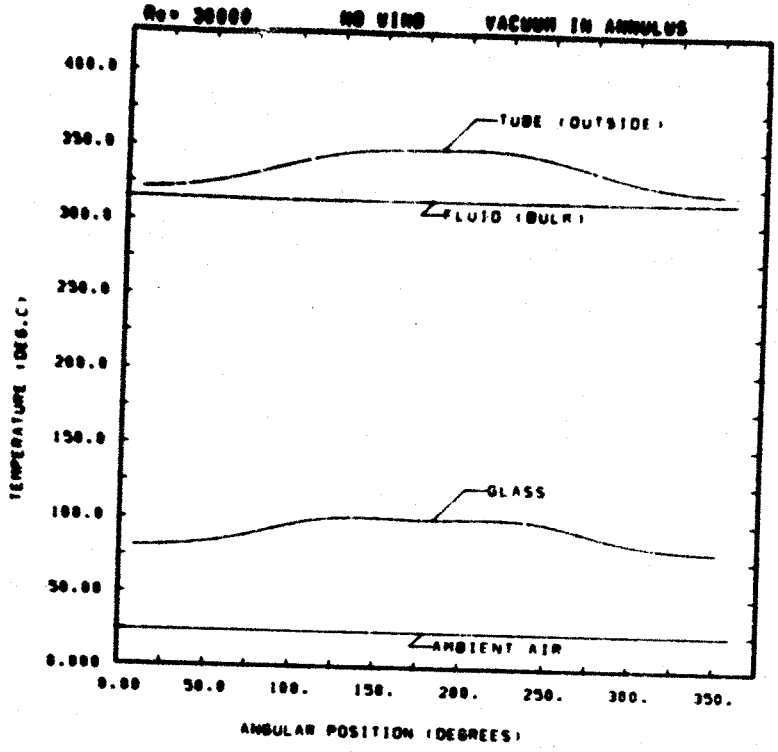


SIGT = 7.0 mR - Tube Aligned

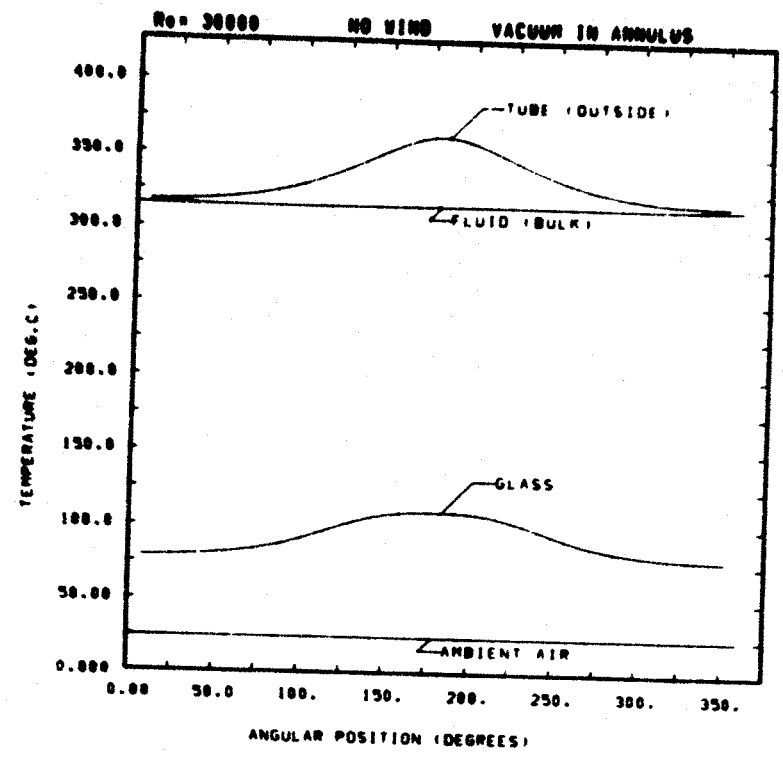


SIGT = 7.0 mR - Tube Misaligned
10.0 mm Up

FIGURE 5. Flux into Surface of Steel Receiver Tube



SIGT = 7.0 mR - Tube Aligned



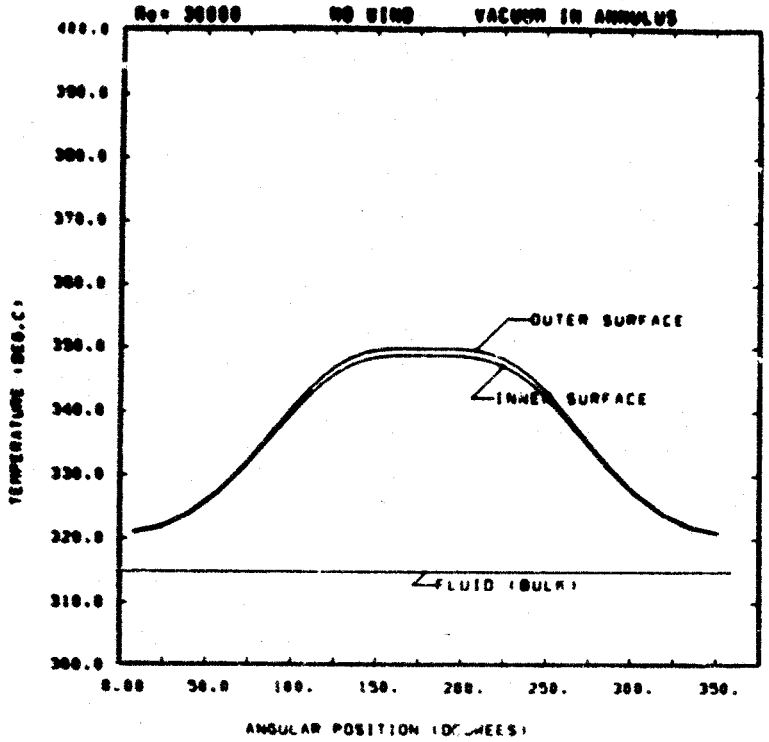
SIGT = 7.0 mR - Tube Misaligned
10.0 mm Up

FIGURE 6. Receiver Assembly Temperature Distributions for Absorbed Flux Distributions of Figure 5

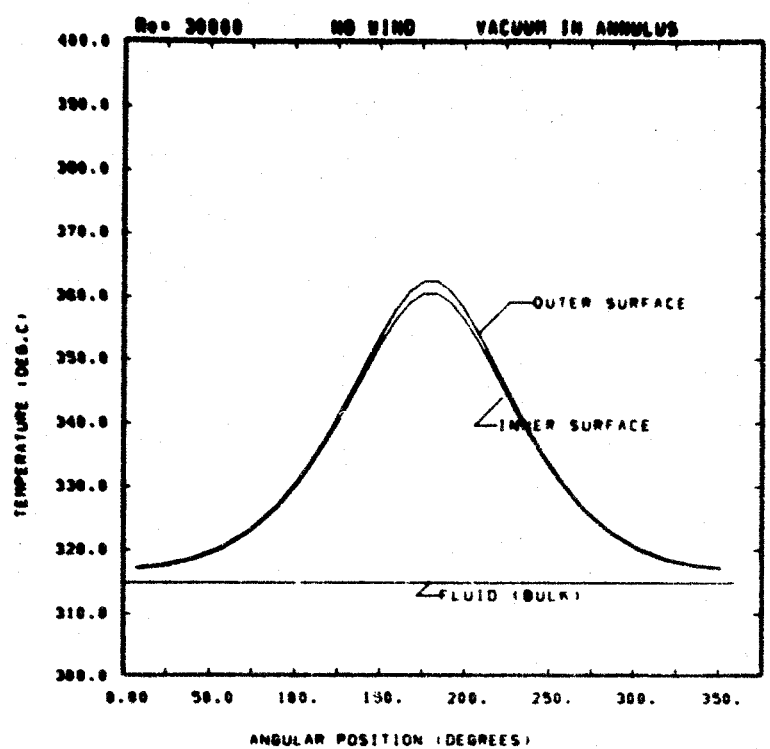
the receiver tube, as compared to the definition of bulk fluid and ambient air temperatures. Figure 7 provides a close look at the receiver tube temperatures by expanding the temperature scale. The complete set of plots for each condition considered (i.e., like Figures 5-7) are not presented. However, except for circumferential temperature distributions in the glass (Figure 6) and the re-radiation increment (Figure 5), all results are available in the appendices.

A major concern in this study has been to show the circumferential variation of receiver tube surface temperature. Figure 8 shows such receiver tube surface temperature distributions (resulting from the solar energy distributions shown by Figure 4) for various error/misalignment conditions, 25°C ambient air, no wind, and annulus evacuated. Figure 9 shows the circumferential average and peak receiver tube temperatures plotted versus Reynolds number for nominal (aligned) and extreme (misaligned 10 mm up) conditions. Additional plots, showing the circumferential variation of receiver tube surface temperature for the different receiver error/misalignment conditions, are given by Appendix A. A summary of the peak temperatures are tabulated in Tables A-I and A-II for the two annulus gas pressure conditions. A quick perusal of these peak temperatures will point out that nearly all tube alignment and fluid Reynolds number conditions result in peak temperatures near or above 340°C (the desired maximum). Recognizing that this report deals with peak solar insolation and worst case thermal conditions, proper alignment and high Reynolds numbers seem necessary if the black-chrome selective coating is to be restrained to the 340°C limit.

Another concern is that the inner surface temperatures of the receiver tube not cause degradation of the T-66 working fluid. The 2-D thermal model results indicate a small thermal gradient through the receiver tube thickness (see Figure 7 and Appendix A). Average temperatures of the inner surface of the receiver tube, tabulated in



SIGT = 7.0 mR - Tube Aligned



SIGT = 7.0 mR - Tube Misaligned
10.0 mm Up

FIGURE 7. Receiver Tube Surface Temperature Distributions for Absorbed Flux Distributions of Figure 5

Figure Description

A. Variation of structural (slope) error magnitude

B. Misalignment of receiver assembly below focal line

C. Misalignment of receiver assembly above focal line

D. Misalignment of receiver assembly to left of focal line

E. Collector tracking error variation

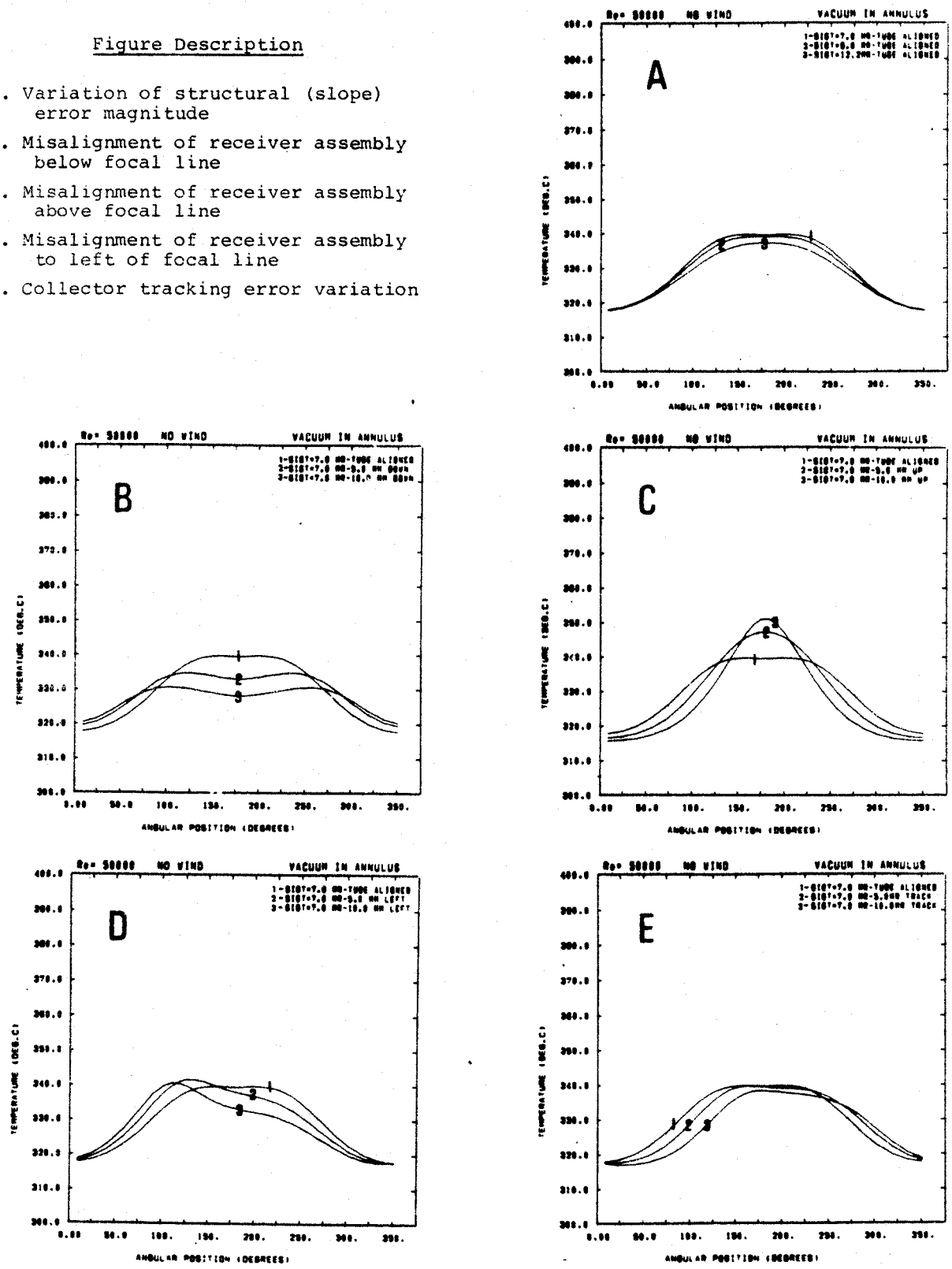


FIGURE 8. Circumferential Temperature Distributions at the Receiver Tube Surface - Re = 50,000, Annular Space Evacuated and No Wind Velocity

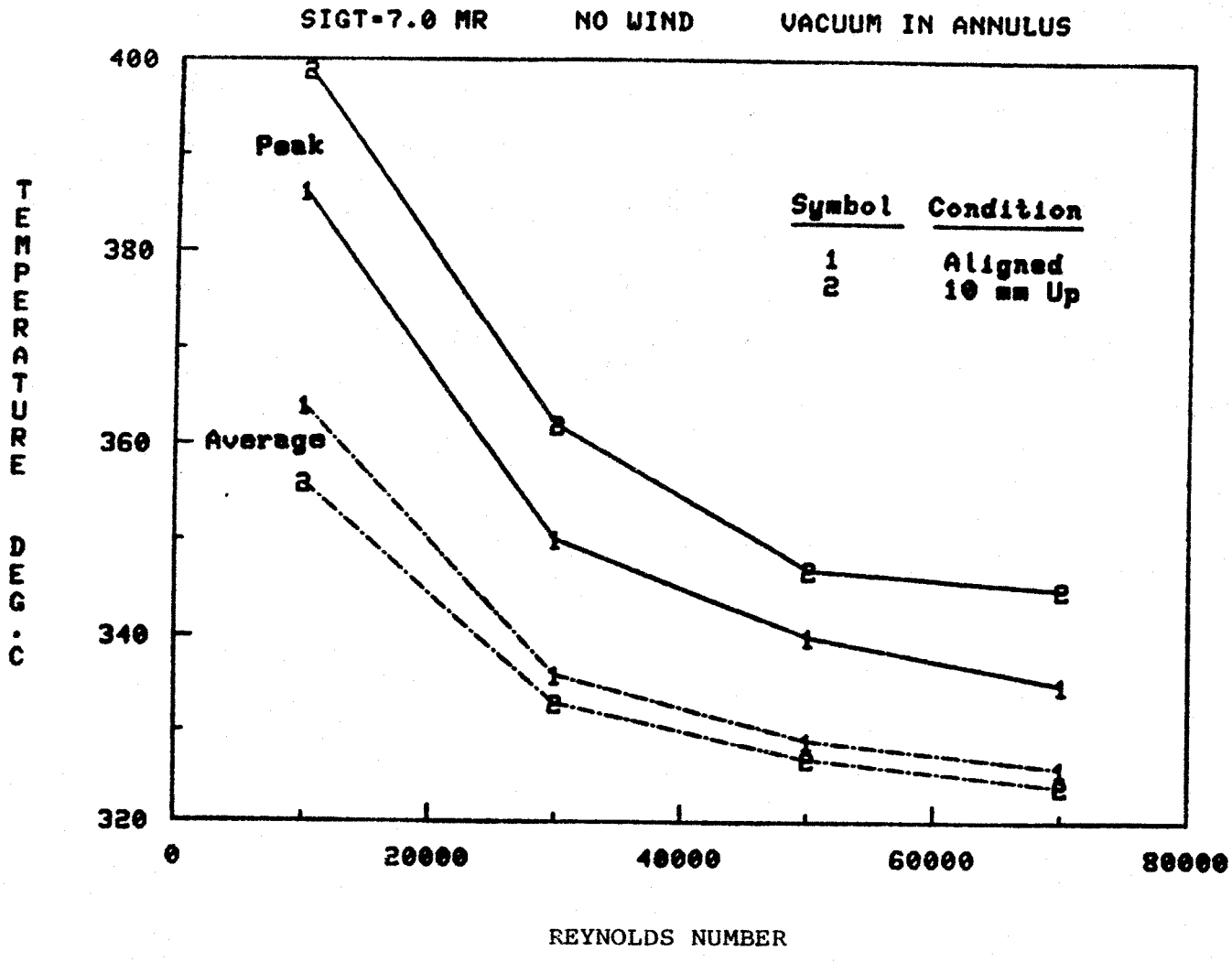


FIGURE 9. Circumferential Average and Peak Receiver Tube Temperatures for Nominal and Extreme Alignment Conditions

Appendix A along with the average temperature of the outer surface of the tube, indicate negligible differences between inner and outer surface temperatures. Thus, as shown by Figure 9, it appears possible to exceed 340°C in the working fluid boundary layer. In order to prevent degradation of either the working fluid or black chrome, it is necessary to maintain the exit Reynolds number > 50,000. Note that the results shown by Figure 9 (and Table I) indicate a slow decrease in peak temperature as Reynolds number is increased above 50,000. Thus, if the peak operating conditions and potential collector misalignments approach those considered by this study, it may be necessary to operate at an exit bulk fluid temperature less than the 315°C used in this study. A possible alternative, if mass flow rate is too high at Re > 50,000, would be to use turbulence generators (i.e., spirally grooved tubes or inserted twisted tapes).

The 1-D thermal model was used to study the baseline performance conditions for the receiver assembly under varied absorbed solar flux conditions. Results for the same operating conditions as defined by Table I, are summarized in Tables B-V and B-VI of Appendix B both for the annular space evacuated and maintained at atmospheric pressure, respectively. Although the 1-D thermal model cannot be used to predict receiver tube local hot spots, the predicted receiver heat loss and fluid energy extraction compares very favorably with the 2-D results. Table III presents comparative 1-D and 2-D thermal model results for some of the extreme receiver misalignment conditions. Note the close agreement in the 1-D and 2-D average receiver tube temperatures as well as in the heat loss and energy extraction results.

The fact that the 1-D thermal model results compare so closely with the more detailed 2-D results is particularly noteworthy, since the 1-D analysis is easier to use and computationally less expensive. Additional results for varied ambient temperature and wind velocity conditions are provided in Appendices B and C, respectively.

TABLE III

COMPARATIVE RESULTS OF 1-D AND 2-D THERMAL MODELING

Case Modeled	Reynolds Number (N_{R_e})	Receiver Tube OD Temperatures				Receiver Heat Loss		Energy Absorbed by Fluid	
		1-D Temperature (°C)	2-D Temperatures						
			Maximum (°C)	Minimum (°C)	Average (°C)	1-D (W)	2-D (W)	1-D (W)	2-D (W)
	10000	364	386	340	363	195	195	1405	1405
Sigt = 7.0mR	30000	336	350	321	336	167	167	1433	1434
Tube aligned	50000	329	340	318	330	160	160	1440	1440
	70000	326	335	317	326	157	157	1443	1444
	10000	358	378	338	358	189	188	1227	1227
Sigt = 12.2mR	30000	333	346	321	334	165	164	1251	1252
Tube aligned	50000	327	337	318	328	159	159	1256	1257
	70000	324	333	317	325	157	156	1259	1260
	10000	358	380	336	358	189	189	1237	1238
Sigt = 7.0mR	30000	333	347	320	334	165	165	1261	1261
10.0mR tracking	50000	327	338	317	328	159	159	1267	1268
bias	70000	324	334	316	325	157	156	1269	1270
	10000	356	362	344	356	187	187	1171	1172
Sigt = 7.0mR	30000	332	337	324	333	164	164	1193	1195
10.0mm Misalign-	50000	327	331	320	327	159	158	1199	1200
ment down	70000	324	328	319	324	156	156	1201	1202
	10000	356	399	330	356	187	188	1167	1167
Sigt = 7.0mR	30000	332	362	317	333	164	164	1190	1190
10.0mm Misalign-	50000	327	351	351	327	159	159	1195	1196
ment up	70000	324	345	315	324	156	156	1197	1198
	10000	359	382	338	359	190	190	1264	1264
Sigt = 7.0mR	30000	334	350	321	334	165	165	1288	1288
10.0mm Misalign-	50000	328	341	318	328	160	159	1294	1295
ment left	70000	325	336	317	325	157	157	1297	1298

*Baseline conditions of Table I used with the annular space evacuated.

Evacuated and nonevacuated annular space conditions are considered in these appendices to provide minimum and maximum heat loss predictions. Previous work[7] can be consulted for a description of alternate annulus gas options for reducing the heat loss.

Figure 10 presents representative heat loss and fluid energy extraction results for varied ambient temperatures. The results are obtained for four Reynolds numbers and two annulus gas pressure conditions. The absorbed solar flux data used in this analysis correspond to the integrated values for the receiver assembly aligned at the focal line and with the solar-noon total collector error (SIGT) = 7.0 mR, as presented in Table II. As can be seen from Figures 10-A and 10-C, the receiver assembly heat loss decreases with increasing ambient temperature. This occurs because the glass temperature-ambient temperature difference decreases. High glass temperatures are maintained by the fixed bulk fluid T-66 temperature of 315°C, while the ambient temperature fluctuates. Note conversely that the energy extraction increases with increasing temperature (Figures 10-B and 10-D). The sum of the heat loss and energy extraction is equal to the energy absorbed by the tube and glass, as would be expected to maintain conservation of energy. Additional results for the other misalignment conditions are tabulated in Appendix B.

Variation of wind velocity on the receiver assembly thermal characteristics is provided in Figure 11. Results are again presented for the aligned receiver assembly with SIGT = 7.0 mR. Increasing the wind velocity is shown to increase the receiver assembly heat loss for both the evacuated and nonevacuated annular space conditions. The detrimental effects of increasing wind, however, are much more significant when the annular space is maintained at atmospheric pressure (Figures 11-B and 11-D). Appendix C provides additional wind velocity effects in tabulated form for the different receiver assembly operating conditions. Note that for both Figures 10 and 11, the

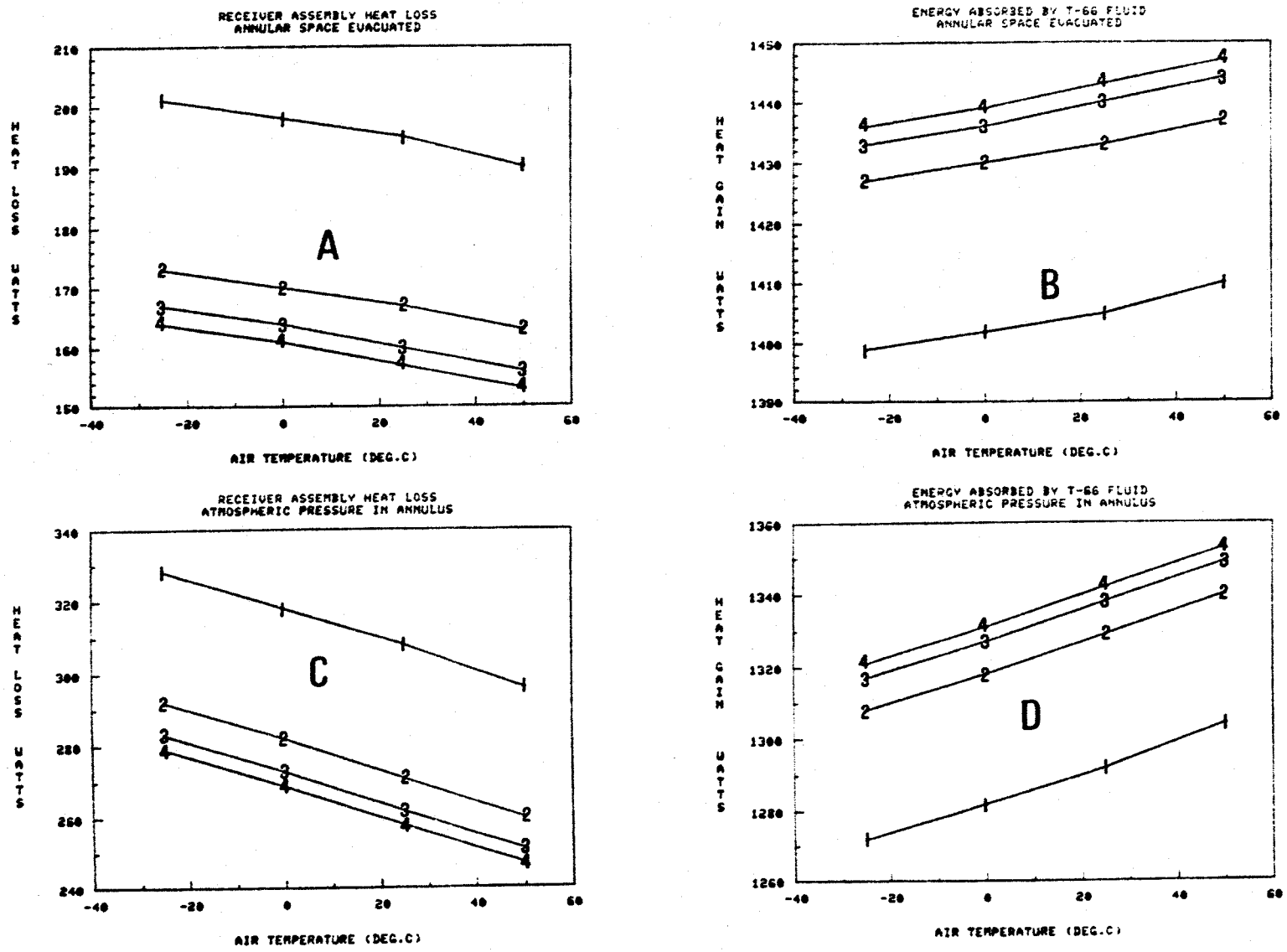


FIGURE 10. 1-D Heat Loss and Energy Extraction Results for Varied Ambient Temperature Conditions (1:Re = 10000, 2:Re = 30000, 3:Re = 50000, and 4:Re = 70000 with SIGT = 7.0 mR and the Receiver Aligned)

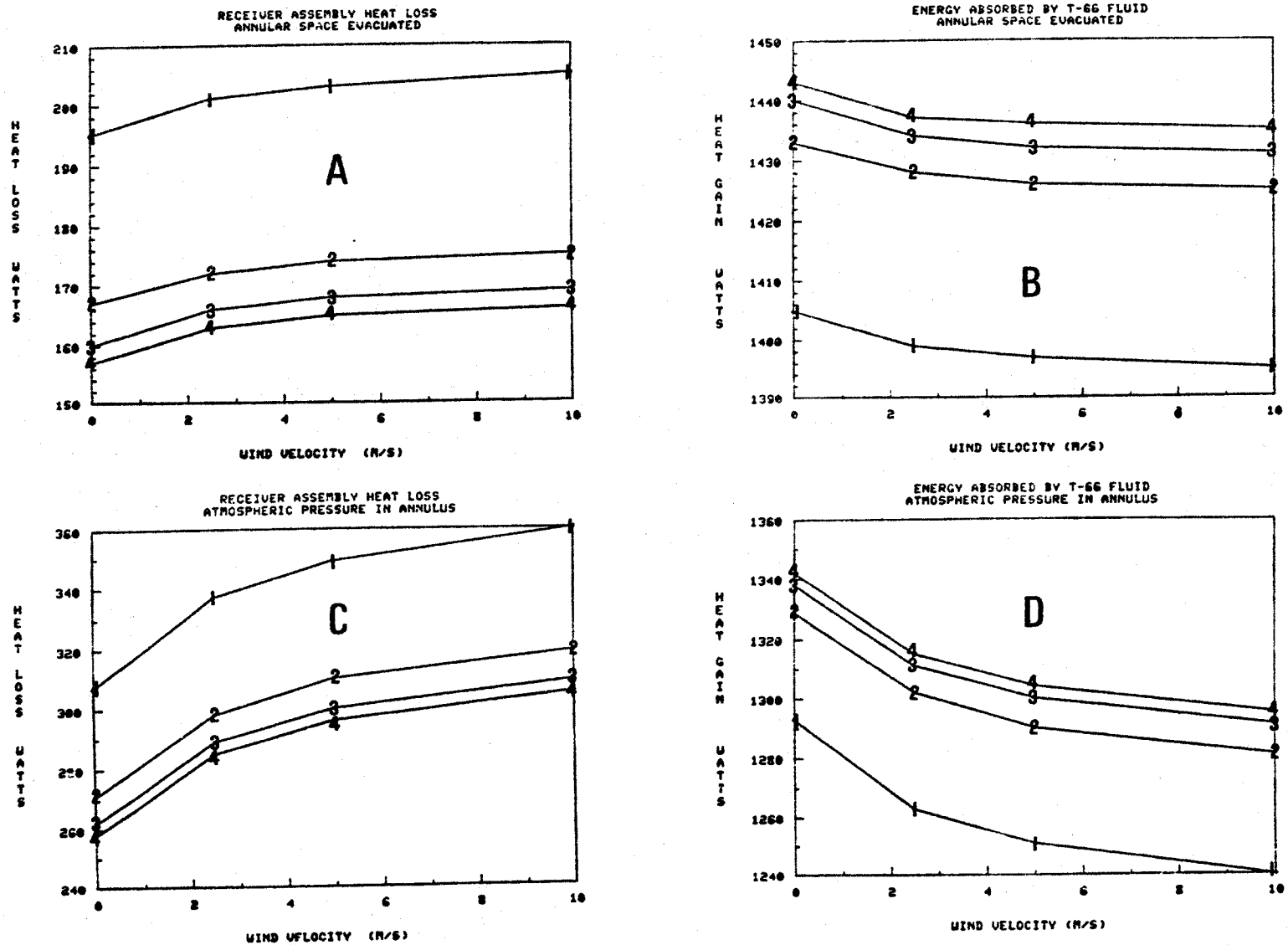


FIGURE 11. 1-D Heat Loss and Energy Extraction Results for Varied Wind Velocity Conditions (1:Re = 10000, 2:Re = 30000, 3:Re = 50000, and 4:Re = 70000 with SIGT = 7.0 mR and the Receiver Aligned)

baseline conditions defined by Table I were used unless indicated otherwise.

The results presented in the appendices and described in this section have demonstrated that the working fluid Reynolds number is critical in maximizing energy extraction and minimizing receiver assembly local hot-spot problems. The work reported from both the 1-D and 2-D analyses indicates that Reynolds numbers in excess of 50,000 are necessary. Parasitic power (e.g., pumping power) requirements to obtain such high Reynolds numbers have not been considered in this analysis. Hence, tradeoffs between Reynolds numbers of 50,000 and 70,000 for maximizing receiver collection of energy are not provided in this work.

V. CONCLUSIONS

The results presented in Appendices A through C are difficult to summarize, since so many different solar-noon absorbed flux conditions and working fluid Reynolds numbers have been considered. None the less, since the purpose of this work has been to thermally characterize a 2.54-cm receiver tube assembly under the conditions in Table I, the following summary conclusions are presented:

1. To obtain exiting bulk-fluid temperatures near 315°C without degrading the black-chrome receiver surface or the T-66 working fluid, it is essential that high Reynolds number flow be maintained. Reynolds numbers $\leq$ 30,000 will yield local hot spots in the receiver assemblies in excess of 340°C for all receiver alignment conditions considered.
2. Receiver assembly alignment has a significant effect on peak temperatures of the receiver tube. Of the variations considered, the upward misalignment condition caused the greatest concentration of solar flux and the highest receiver tube temperatures.
3. One- and two-dimensional thermal models of the receiver assembly predict nearly identical receiver heat loss and working fluid energy extraction results. The 1-D model is easier and more economical to use. However, it cannot predict receiver assembly temperature extremes.
4. Increasing ambient temperature and decreasing wind velocity improves the collection of solar energy by reducing the receiver assembly heat loss.
5. Evacuating the annulus gas from the receiver assembly minimizes the heat losses resulting from wind velocity and ambient air temperature variation. However, evacuation of

the annulus gas maximizes the temperatures of the receiver tube.

Of the summary conclusions presented, the comments on maintaining high Reynolds number are particularly noteworthy. High Reynolds number flows not only avoid possible overheating of T-66 and black chrome but will also improve the collector performance. The choice of Reynolds number to optimize performance is not offered since the parasitic energy requirements of pumping the working fluid have not been included in this analysis. None-the-less, exit fluid Reynolds numbers > 50,000 are imperative if degradation actually occurs at 340°C. Otherwise, lower exit fluid bulk temperatures could be selected to insure safe operation of the collector system.

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APPENDIX A

TWO-DIMENSIONAL THERMAL MODEL RESULTS

The 2-D thermal model, as discussed earlier, was solved for the baseline conditions of Table I (25°C ambient air, no wind) as follows:

Annulus Condition	Reynolds Number
Vacuum in Annulus	10000, 30000, 50000, 70000
Annulus Gas at 100 KPa	10000, 30000, 50000

The calculated results are provided in two forms:

(1) The maximum, minimum, and average receiver tube temperatures, and heat loss results have been tabulated in Tables A-I and A-II.

(2) Circumferential variations (covering various Reynolds numbers) are plotted as follows:

Misalignment Condition	Figure Number	
	Annulus Evacuated	Ambient Air in Annulus
Aligned	A-1	A-2
Track	A-3	A-4
Left	A-5	A-6
Up	A-7	A-8
Down	A-9	A-10

Table A-I. Tabulation of 2-D Thermal Model Results- Baseline Conditions - Vacuum in Annulus

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES (C)				GLASS TEMPERATURES (C)			CONVECTIVE COEFFICIENTS (W/M**2-K)			ABSORBED SOLAR FLUX (W)		HEAT GAIN BY FLUID (W)	HEAT LOSSES (W) FROM RECEIVER		
		OUTSIDE			INSIDE												
	(---)	MAX	MIN	AVG	AVG	MAX	MIN	AVG	HAIR	HGAP	HFLUID	QTUBE	QGLASS	QFLUID	QAIR	QSPACE	QLOSS
SIGT=7.0 MR-TUBE ALIGNED	10000.	386.	340.	364.	363.	112.	88.	102.	8.34	0.00	412.7	1567.4	32.6	1405.1	96.3	98.4	194.7
SIGT=9.0 MR-TUBE ALIGNED	10000.	384.	340.	362.	362.	112.	88.	101.	8.33	0.00	412.1	1515.1	32.8	1353.6	95.5	97.5	193.0
SIGT=12.2MR-TUBE ALIGNED	10000.	374.	334.	358.	357.	110.	87.	100.	8.29	0.00	410.8	1382.3	32.9	1226.5	93.3	95.1	188.4
SIGT=7.0 MR-2.5MR TRACK	10000.	386.	340.	364.	363.	112.	88.	101.	8.34	0.00	412.6	1568.5	32.7	1397.4	96.2	98.3	194.5
SIGT=7.0 MR-5.0MR TRACK	10000.	383.	339.	363.	362.	112.	88.	101.	8.33	0.00	412.3	1529.9	32.8	1369.3	95.8	97.8	193.6
SIGT=7.0 MR-10.0MR TRACK	10000.	380.	336.	358.	356.	111.	87.	100.	8.30	0.00	411.0	1392.6	33.2	1237.8	93.6	95.6	189.2
SIGT=7.0 MR-2.5 MM DOWN	10000.	385.	340.	364.	363.	110.	89.	101.	8.34	0.00	412.6	1565.8	32.7	1395.4	96.1	98.1	194.2
SIGT=7.0 MR-5.0 MM DOWN	10000.	383.	342.	364.	362.	108.	90.	101.	8.33	0.00	412.2	1516.9	32.8	1357.3	95.5	97.3	192.8
SIGT=7.0 MR-10.0 MM DOWN	10000.	382.	344.	362.	362.	104.	91.	99.	8.28	0.00	410.4	1324.1	33.4	1172.1	92.5	94.0	186.5
SIGT=7.0 MR-2.5 MM UP	10000.	382.	337.	364.	363.	115.	87.	101.	8.34	0.00	412.6	1555.4	32.7	1394.1	96.2	98.5	194.7
SIGT=7.0 MR-5.0 MM UP	10000.	378.	335.	362.	362.	117.	86.	101.	8.33	0.00	412.1	1516.1	32.8	1356.0	95.6	98.0	193.7
SIGT=7.0 MR-10.0 MM UP	10000.	399.	330.	356.	355.	120.	84.	99.	8.28	0.00	410.3	1320.4	33.4	1167.1	92.5	95.0	187.5
SIGT=7.0 MR-2.5 MM LEFT	10000.	386.	340.	364.	363.	113.	88.	102.	8.34	0.00	412.7	1564.2	32.7	1402.6	96.3	98.4	194.7
SIGT=7.0 MR-5.0 MM LEFT	10000.	387.	340.	364.	363.	114.	88.	101.	8.34	0.00	412.5	1550.3	32.8	1388.8	96.1	98.2	194.3
SIGT=7.0 MR-10.0 MM LEFT	10000.	382.	338.	359.	359.	114.	88.	100.	8.30	0.00	411.2	1420.3	33.2	1263.9	94.2	96.0	190.0
SIGT=7.0 MR-TUBE ALIGNED	30000.	350.	321.	336.	336.	102.	81.	93.	8.09	0.00	977.7	1547.4	32.6	1434.0	82.5	84.0	166.5
SIGT=9.0 MR-TUBE ALIGNED	30000.	349.	321.	336.	335.	102.	81.	92.	8.08	0.00	977.3	1513.1	32.8	1381.5	82.2	83.7	166.0
SIGT=12.2MR-TUBE ALIGNED	30000.	346.	321.	334.	333.	101.	81.	92.	8.07	0.00	976.3	1392.3	32.9	1251.8	81.4	82.8	164.2
SIGT=7.0 MR-2.5MR TRACK	30000.	350.	321.	336.	336.	102.	81.	93.	8.09	0.00	977.6	1559.5	32.7	1425.9	82.5	84.0	166.5
SIGT=7.0 MR-5.0MR TRACK	30000.	349.	321.	336.	335.	102.	81.	93.	8.09	0.00	977.4	1529.9	32.8	1398.4	82.3	83.8	166.2
SIGT=7.0 MR-10.0MR TRACK	30000.	347.	320.	334.	333.	102.	81.	92.	8.07	0.00	976.4	1392.6	33.2	1261.3	81.6	83.1	164.7
SIGT=7.0 MR-2.5 MM DOWN	30000.	346.	322.	336.	336.	100.	82.	93.	8.09	0.00	977.6	1555.8	32.7	1422.5	82.5	83.9	166.4
SIGT=7.0 MR-5.0 MM DOWN	30000.	343.	324.	336.	335.	99.	83.	92.	8.09	0.00	977.3	1516.9	32.8	1384.0	82.3	83.6	165.9
SIGT=7.0 MR-10.0 MM DOWN	30000.	337.	324.	333.	332.	96.	84.	92.	8.06	0.00	975.9	1324.1	33.4	1194.6	81.2	82.4	163.7
SIGT=7.0 MR-2.5 MM UP	30000.	356.	320.	336.	336.	104.	81.	93.	8.09	0.00	977.6	1555.4	32.7	1419.7	82.4	84.0	166.5
SIGT=7.0 MR-5.0 MM UP	30000.	354.	319.	336.	335.	105.	80.	92.	8.08	0.00	977.3	1516.1	32.8	1383.6	82.3	84.0	166.2
SIGT=7.0 MR-10.0 MM UP	30000.	362.	317.	333.	332.	110.	79.	92.	8.06	0.00	975.9	1320.4	33.4	1190.1	81.1	83.0	164.1
SIGT=7.0 MR-2.5 MM LEFT	30000.	351.	321.	336.	336.	103.	81.	93.	8.09	0.00	977.7	1564.2	32.7	1431.1	82.5	84.0	166.5
SIGT=7.0 MR-5.0 MM LEFT	30000.	352.	321.	336.	336.	104.	81.	93.	8.09	0.00	977.5	1550.3	32.8	1416.4	82.5	84.0	166.4
SIGT=7.0 MR-10.0 MM LEFT	30000.	350.	321.	334.	334.	105.	81.	92.	8.07	0.00	976.6	1420.3	33.2	1287.6	81.8	83.2	165.0
SIGT=7.0 MR-TUBE ALIGNED	50000.	343.	318.	330.	329.	99.	80.	91.	8.03	0.00	1465.9	1567.4	32.6	1440.3	79.3	80.7	160.0
SIGT=9.0 MR-TUBE ALIGNED	50000.	339.	318.	329.	329.	99.	80.	90.	8.02	0.00	1465.5	1513.1	32.8	1388.7	79.2	80.6	159.7
SIGT=12.2MR-TUBE ALIGNED	50000.	337.	318.	328.	327.	99.	80.	90.	8.01	0.00	1464.5	1382.3	32.9	1257.2	78.6	80.0	158.6
SIGT=7.0 MR-2.5MR TRACK	50000.	340.	318.	330.	329.	99.	80.	91.	8.03	0.00	1465.8	1559.5	32.7	1431.7	79.3	80.7	160.0
SIGT=7.0 MR-5.0MR TRACK	50000.	340.	318.	329.	329.	100.	80.	90.	8.02	0.00	1465.6	1529.9	32.8	1403.2	79.2	80.6	159.9
SIGT=7.0 MR-10.0MR TRACK	50000.	338.	317.	328.	327.	100.	80.	90.	8.02	0.00	1464.9	1392.6	33.2	1267.5	78.8	80.2	159.0
SIGT=7.0 MR-2.5 MM DOWN	50000.	337.	319.	329.	329.	99.	81.	91.	8.03	0.00	1465.8	1555.8	32.7	1429.0	79.3	80.7	160.0
SIGT=7.0 MR-5.0 MM DOWN	50000.	336.	319.	329.	329.	99.	81.	90.	8.02	0.00	1465.5	1516.9	32.8	1390.7	79.2	80.5	159.7
SIGT=7.0 MR-10.0 MM DOWN	50000.	334.	320.	327.	327.	99.	82.	90.	8.01	0.00	1464.0	1324.1	33.4	1199.5	78.4	79.8	158.4
SIGT=7.0 MR-2.5 MM UP	50000.	344.	317.	329.	329.	101.	79.	91.	8.02	0.00	1465.8	1555.4	32.7	1428.8	79.3	80.8	160.0
SIGT=7.0 MR-5.0 MM UP	50000.	342.	316.	329.	329.	103.	79.	90.	8.02	0.00	1465.5	1516.1	32.8	1390.5	79.1	80.6	159.9
SIGT=7.0 MR-10.0 MM UP	50000.	341.	316.	327.	327.	107.	78.	90.	8.01	0.00	1464.0	1320.4	33.4	1196.8	78.4	79.2	158.6
SIGT=7.0 MR-2.5 MM LEFT	50000.	341.	314.	330.	329.	100.	80.	91.	8.03	0.00	1465.9	1564.2	32.7	1436.4	79.3	80.7	160.0
SIGT=7.0 MR-5.0 MM LEFT	50000.	342.	318.	329.	329.	101.	80.	91.	8.03	0.00	1465.2	1550.3	32.8	1424.0	79.3	80.7	160.0
SIGT=7.0 MR-10.0 MM LEFT	50000.	341.	314.	328.	328.	102.	80.	90.	8.02	0.00	1464.8	1420.3	33.2	1294.7	78.7	80.5	159.2
SIGT=7.0 MR-TUBE ALIGNED	70000.	333.	317.	326.	326.	98.	79.	90.	8.00	0.00	1915.2	1567.4	32.6	1443.5	77.8	79.2	157.1
SIGT=9.0 MR-TUBE ALIGNED	70000.	334.	317.	326.	325.	98.	80.	89.	7.99	0.00	1914.8	1513.1	32.8	1389.3	77.7	79.1	156.8
SIGT=12.2MR-TUBE ALIGNED	70000.	333.	317.	325.	324.	97.	80.	89.	7.99	0.00	1913.7	1382.3	32.9	1259.8	77.3	78.7	156.0
SIGT=7.0 MR-2.5MR TRACK	70000.	335.	316.	326.	326.	98.	79.	90.	8.00	0.00	1915.1	1559.5	32.7	1434.2	77.8	79.2	157.0
SIGT=7.0 MR-5.0MR TRACK	70000.	335.	316.	326.	325.	98.	79.	90.	7.99	0.00	1914.9	1529.9	32.8	1406.4	77.8	79.2	156.9
SIGT=7.0 MR-10.0MR TRACK	70000.	334.	316.	325.	324.	99.	79.	89.	7.99	0.00	1913.8	1392.6	33.2	1270.0	77.5	78.9	156.4
SIGT=7.0 MR-2.5 MM DOWN	70000.	333.	317.	326.	326.	97.	80.	90.	8.00	0.00	1915.1	1555.8	32.7	1432.1	77.8	79.2	157.0
SIGT=7.0 MR-5.0 MM DOWN	70000.	331.	318.	326.	325.	96.	81.	90.	7.99	0.00	1914.8	1516.9	32.8	1393.4	77.8	79.1	156.9
SIGT=7.0 MR-10.0 MM DOWN	70000.	329.	319.	324.	324.	94.	82.	89.	7.99	0.00	1913.3	1324.1	33.4	1202.1	77.4	78.6	156.0
SIGT=7.0 MR-2.5 MM UP	70000.	334.	316.	326.	326.	99.	79.	90.	7.99	0.00	1915.1	1555.4	32.7	1431.7	77.8	79.3	157.1
SIGT=7.0 MR-5.0 MM UP	70000.	341.	316.	326.	325.	101.	79.	89.	7.99	0.00	1914.8	1516.1	32.8	1392.6	77.7	79.2	157.0
SIGT=7.0 MR-10.0 MM UP	70000.	349.	315.	324.	324.	105.	78.	89.	7.98	0.00	1913.2	1320.4	33.4	1198.2	77.2	78.9	156.1
SIGT=7.0 MR-2.5 MM LEFT	70000.	336.	317.	326.	326.	99.	79.	90.	8.00	0.00	1915.2	1564.2	32.7	1440.5	77.8	79.2	157.1
SIGT=7.0 MR-5.0 MM LEFT	70000.	337.	317.	326.	326.	100.	79.	90.	8.00	0.00	1915.1	1550.3	32.8	1426.7	77.8	79.2	157.1
SIGT=7.0 MR-10.0 MM LEFT	70000.	336.	317.	325.	325.	101.	79.	89.	7.99	0.00	1914.1	1420.3	33.2	1297.6	77.6	79.0	156.6

Table A-II. Tabulation of 2-D Thermal Model Results- Baseline Conditions - Annulus Gas at 100 KPa

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES (C) OUTSIDE			INSIDE	GLASS TEMPERATURES (C)			CONVECTIVE COEFFICIENTS (W/M**2-K)			ABSORBED SOLAR FLUX (W)		HEAT GAIN BY FLUID (W)	HEAT LOSSES (W) FROM RECEIVER		
	(---)	MAX	MIN	AVG	AVG	MAX	MIN	AVG	HAIR	HGAP	HFLUID	QTUBE	QGLASS	QFLUID	QAIR	QSPACE	QLOSS
SIGT=7.0 MR-TUBE ALIGNED	10000.	342.	336.	340.	340.	144.	121.	134.	9.10	6.94	411.5	1567.4	32.6	1293.4	149.0	158.6	307.5
SIGT=9.0 MR-TUBE ALIGNED	10000.	340.	336.	339.	338.	143.	121.	133.	9.09	6.94	411.0	1513.1	32.8	1241.5	147.9	157.2	305.2
SIGT=12.2MR-TUBE ALIGNED	10000.	339.	334.	336.	336.	141.	120.	131.	9.06	6.94	409.9	1382.3	32.9	1116.4	145.4	154.8	299.3
SIGT=7.0 MR-2.5MR TRACK	10000.	342.	336.	340.	339.	144.	121.	133.	9.10	6.94	411.4	1559.5	32.7	1284.6	148.8	158.3	307.1
SIGT=7.0 MR-5.0MR TRACK	10000.	341.	335.	339.	339.	143.	121.	133.	9.10	6.94	411.1	1529.9	32.8	1257.3	148.3	157.7	306.0
SIGT=7.0 MR-10.0MR TRACK	10000.	340.	332.	336.	336.	142.	120.	132.	9.06	6.94	410.0	1372.6	33.0	1126.2	145.7	154.5	300.1
SIGT=7.0 MR-2.5 MM DOWN	10000.	341.	335.	339.	339.	141.	122.	133.	9.10	6.94	411.4	1555.8	32.7	1282.2	148.7	158.1	306.8
SIGT=7.0 MR-5.0 MM DOWN	10000.	340.	334.	337.	338.	139.	123.	133.	9.09	6.94	411.0	1516.9	32.8	1245.3	148.0	157.0	305.0
SIGT=7.0 MR-10.0 MM DOWN	10000.	338.	330.	332.	332.	136.	123.	131.	9.05	6.94	409.4	1324.1	33.4	1061.2	144.3	152.4	296.7
SIGT=7.0 MR-2.5 MM UP	10000.	344.	338.	340.	339.	146.	120.	133.	9.10	6.94	411.4	1555.4	32.7	1281.4	148.8	158.5	307.3
SIGT=7.0 MR-5.0 MM UP	10000.	343.	337.	339.	338.	144.	119.	133.	9.09	6.94	411.0	1515.1	32.8	1243.6	148.1	157.8	305.9
SIGT=7.0 MR-10.0 MM UP	10000.	341.	326.	332.	332.	140.	117.	131.	9.05	6.94	409.4	1320.4	33.4	1056.5	144.3	153.4	297.7
SIGT=7.0 MR-2.5 MM LEFT	10000.	343.	336.	340.	340.	144.	121.	133.	9.10	6.94	411.5	1564.2	32.7	1290.1	148.9	158.5	307.4
SIGT=7.0 MR-5.0 MM LEFT	10000.	342.	336.	340.	339.	143.	121.	133.	9.10	6.94	411.3	1538.3	32.8	1265.3	148.7	158.2	306.8
SIGT=7.0 MR-10.0 MM LEFT	10000.	339.	335.	338.	338.	140.	120.	132.	9.07	6.94	410.2	1420.3	33.2	1152.8	146.2	155.1	301.3
SIGT=7.0 MR-TUBE ALIGNED	30000.	340.	328.	335.	334.	132.	114.	124.	8.89	6.74	976.9	1567.4	32.6	1329.7	132.4	138.4	270.9
SIGT=7.0 MR-TUBE ALIGNED	30000.	338.	328.	334.	334.	132.	114.	124.	8.89	6.74	976.5	1513.1	32.8	1276.6	132.1	138.0	270.0
SIGT=12.2MR-TUBE ALIGNED	30000.	338.	327.	332.	332.	131.	114.	123.	8.87	6.74	975.6	1382.3	32.9	1148.1	131.0	136.7	267.7
SIGT=7.0 MR-2.5MR TRACK	30000.	344.	334.	336.	334.	132.	114.	124.	8.89	6.74	976.9	1558.5	32.7	1321.1	132.4	138.4	270.8
SIGT=7.0 MR-5.0MR TRACK	30000.	344.	333.	336.	334.	132.	114.	124.	8.89	6.74	976.6	1529.9	32.8	1293.0	132.2	138.1	270.3
SIGT=7.0 MR-10.0MR TRACK	30000.	343.	331.	332.	332.	132.	113.	123.	8.88	6.74	975.7	1392.6	33.2	1158.2	131.2	136.9	268.1
SIGT=7.0 MR-2.5 MM DOWN	30000.	344.	333.	335.	334.	131.	114.	124.	8.89	6.74	976.8	1555.8	32.7	1318.4	132.4	138.3	270.6
SIGT=7.0 MR-5.0 MM DOWN	30000.	343.	332.	334.	334.	129.	115.	124.	8.89	6.74	976.6	1516.9	32.8	1281.4	132.1	137.9	270.0
SIGT=7.0 MR-10.0 MM DOWN	30000.	341.	328.	331.	331.	127.	116.	123.	8.87	6.74	975.2	1324.1	33.4	1091.3	130.7	136.1	266.8
SIGT=7.0 MR-2.5 MM UP	30000.	345.	336.	338.	336.	134.	113.	124.	8.89	6.74	976.8	1555.4	32.7	1317.9	132.4	138.4	270.4
SIGT=7.0 MR-5.0 MM UP	30000.	344.	337.	338.	336.	136.	112.	124.	8.89	6.74	976.5	1515.1	32.8	1279.2	132.1	138.2	270.3
SIGT=7.0 MR-10.0 MM UP	30000.	341.	326.	331.	331.	137.	111.	123.	8.87	6.74	975.1	1320.4	33.4	1047.0	130.6	136.6	267.2
SIGT=7.0 MR-2.5 MM LEFT	30000.	343.	335.	338.	336.	133.	114.	124.	8.89	6.74	976.9	1564.2	32.7	1326.6	132.4	138.4	270.9
SIGT=7.0 MR-5.0 MM LEFT	30000.	343.	334.	337.	336.	134.	114.	124.	8.89	6.74	976.8	1538.3	32.8	1301.3	132.3	138.3	270.7
SIGT=7.0 MR-10.0 MM LEFT	30000.	340.	331.	333.	333.	134.	114.	123.	8.88	6.74	975.9	1420.3	33.2	1185.4	131.4	137.2	268.6
SIGT=7.0 MR-TUBE ALIGNED	50000.	339.	327.	329.	328.	123.	112.	121.	8.84	6.69	1465.1	1567.4	32.6	1338.4	108.5	135.7	262.2
SIGT=7.0 MR-TUBE ALIGNED	50000.	338.	327.	328.	327.	123.	112.	121.	8.84	6.69	1464.7	1513.1	32.8	1284.8	108.2	135.4	261.7
SIGT=12.2MR-TUBE ALIGNED	50000.	338.	327.	327.	326.	122.	112.	121.	8.83	6.69	1463.7	1382.3	32.9	1159.8	107.5	132.6	260.1
SIGT=7.0 MR-2.5MR TRACK	50000.	339.	327.	328.	328.	123.	112.	121.	8.84	6.69	1465.0	1558.5	32.7	1327.6	108.4	133.7	262.1
SIGT=7.0 MR-5.0MR TRACK	50000.	339.	327.	328.	328.	123.	112.	121.	8.84	6.69	1464.8	1529.9	32.8	1301.4	108.3	133.5	261.8
SIGT=7.0 MR-10.0MR TRACK	50000.	337.	326.	327.	327.	123.	112.	121.	8.83	6.69	1463.7	1392.6	33.2	1185.8	107.7	132....	260.5
SIGT=7.0 MR-2.5 MM DOWN	50000.	339.	328.	329.	328.	122.	113.	121.	8.84	6.69	1465.0	1555.8	32.7	1327.0	108.4	133.6	262.0
SIGT=7.0 MR-5.0 MM DOWN	50000.	338.	328.	329.	328.	121.	113.	121.	8.84	6.69	1464.7	1516.9	32.8	1288.7	108.3	133.4	261.6
SIGT=7.0 MR-10.0 MM DOWN	50000.	336.	325.	326.	326.	120.	114.	121.	8.82	6.69	1463.2	1324.1	33.4	1098.3	107.4	132.3	259.7
SIGT=7.0 MR-2.5 MM UP	50000.	342.	331.	328.	328.	130.	112.	121.	8.84	6.69	1465.0	1555.4	32.7	1326.6	108.4	133.7	262.1
SIGT=7.0 MR-5.0 MM UP	50000.	340.	329.	328.	328.	132.	111.	121.	8.83	6.69	1464.7	1516.1	32.8	1287.7	108....	133.6	261.8
SIGT=7.0 MR-10.0 MM UP	50000.	338.	325.	326.	326.	134.	111.	121.	8.82	6.69	1463.2	1320.4	33.4	1094.3	107.3	132.3	259.4
SIGT=7.0 MR-2.5 MM LEFT	50000.	343.	332.	329.	328.	130.	112.	121.	8.84	6.69	1465.1	1564.2	32.7	1335.5	108.5	133.7	262.2
SIGT=7.0 MR-5.0 MM LEFT	50000.	341.	331.	329.	328.	131.	112.	121.	8.84	6.69	1465.0	1538.3	32.8	1311.6	108.4	133.7	262.1
SIGT=7.0 MR-10.0 MM LEFT	50000.	340.	329.	327.	327.	132.	112.	121.	8.83	6.69	1464.0	1420.3	33.2	1193.2	107.8	133.0	260.8

Figure Description *

A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000
E: Receiver Surface Temperature for Re=70000

*Note 1-Sigt= 7.0mR-Tube Aligned
2-Sigt= 9.0mR-Tube Aligned
3-Sigt=12.2mR-Tube Aligned

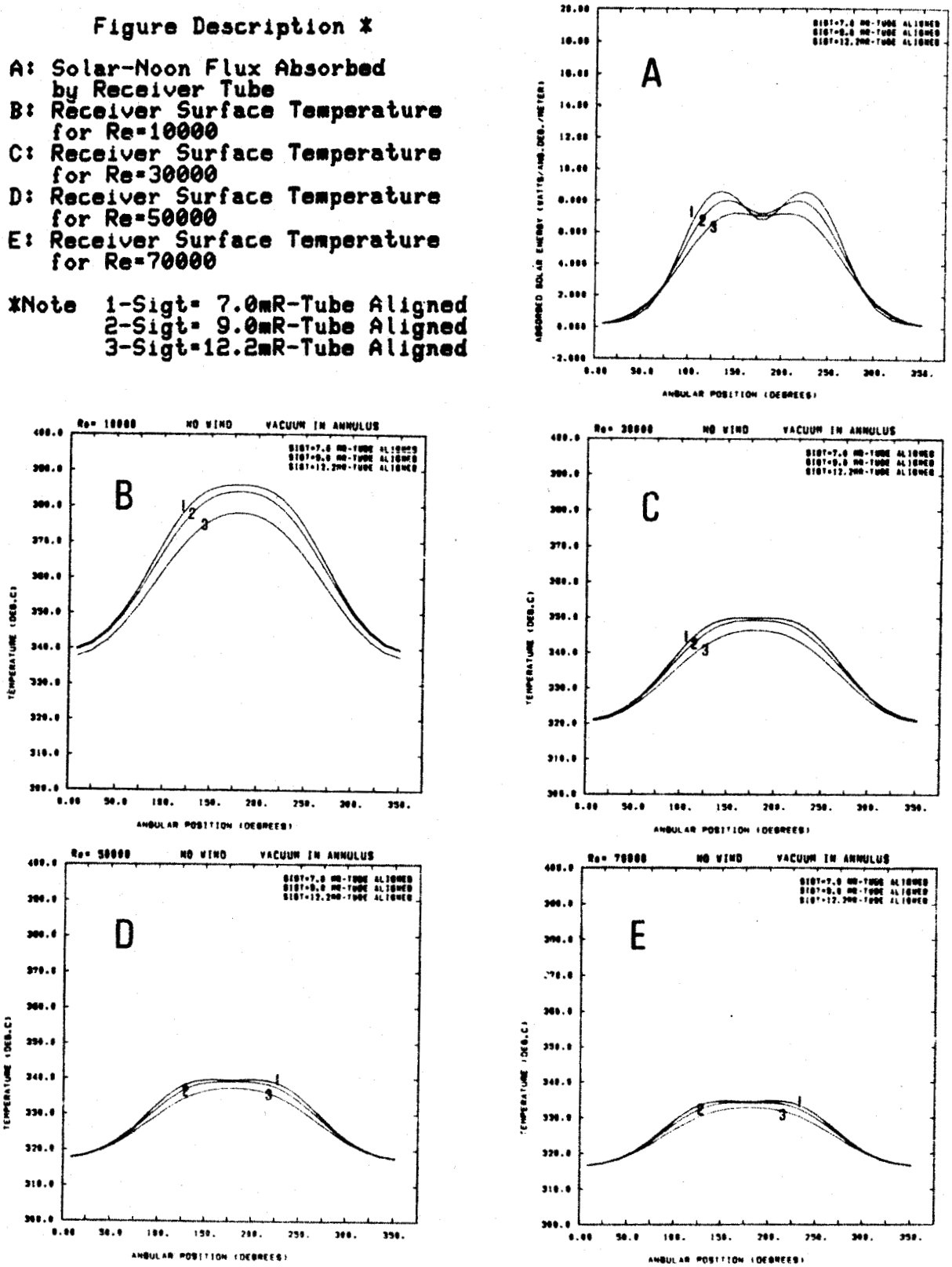
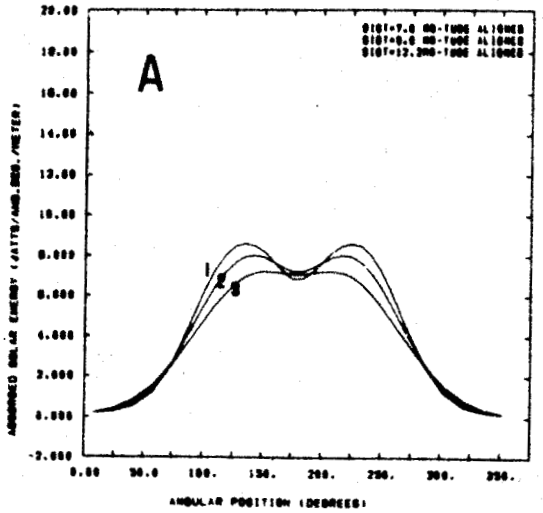


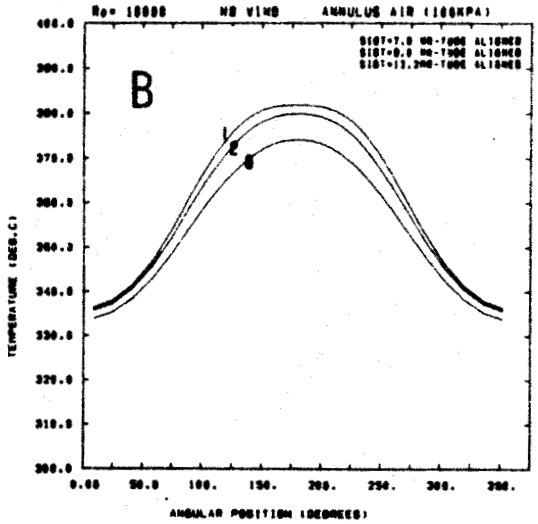
Figure A-1. Circumferential Distributions with Annular Space Evacuated-Trough Structural Error Varied - Receiver Assembly Aligned

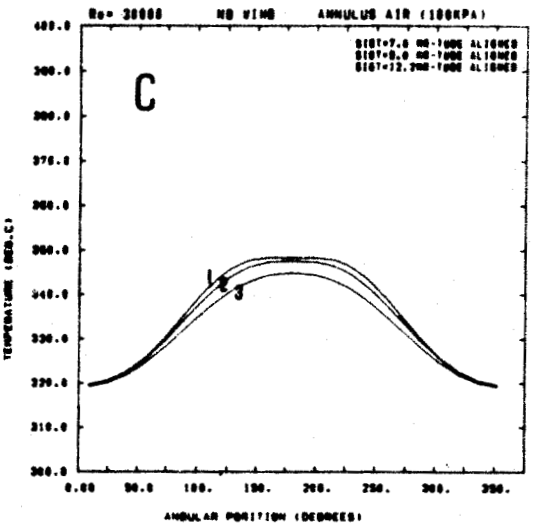
Figure Description *

A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000

*Note 1-Sigt= 7.0mR-Tube Aligned
2-Sigt= 9.0mR-Tube Aligned
3-Sigt=12.2mR-Tube Aligned







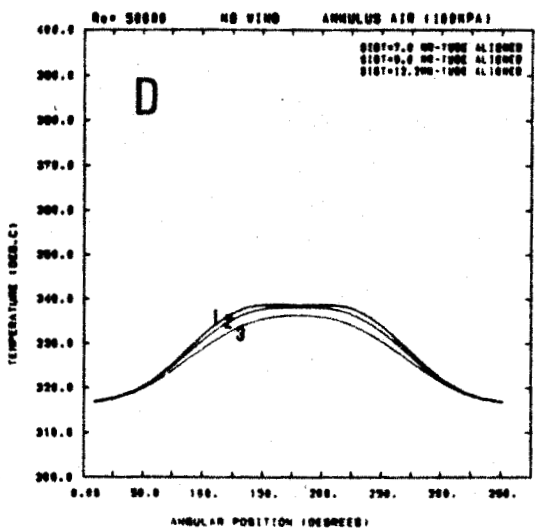
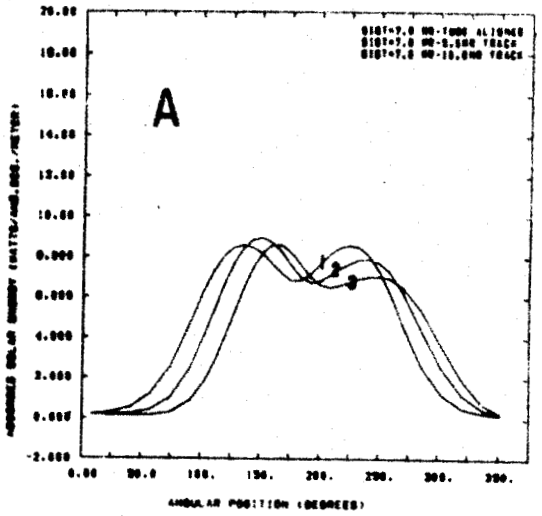


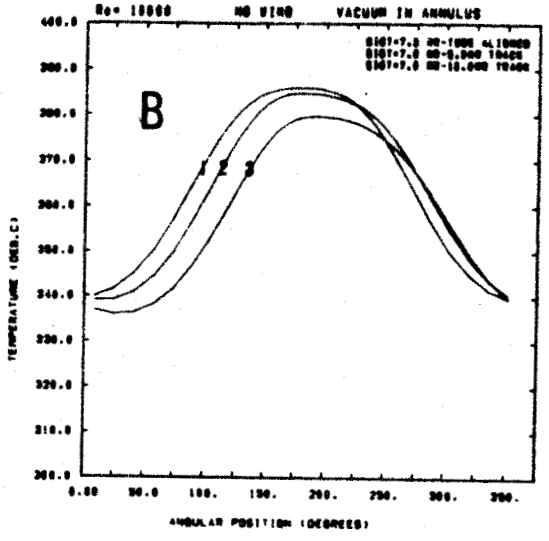
Figure A-2. Circumferential Distributions with Annulus Gas at 100 KPa- Trough Structural Error Varied - Receiver Assembly Aligned

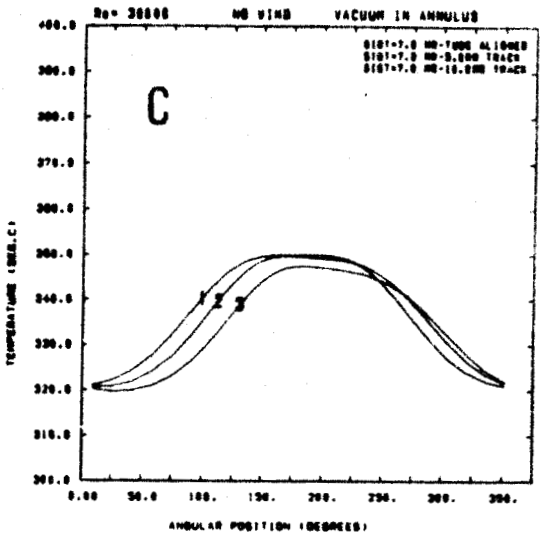
Figure Description *

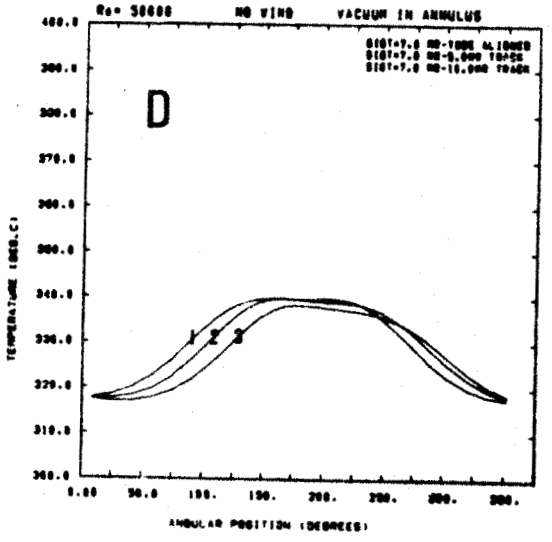
A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000
E: Receiver Surface Temperature for Re=70000

*Note 1-Tube Aligned
2-Tube 5 mR Track
3-Tube 10 mR Track









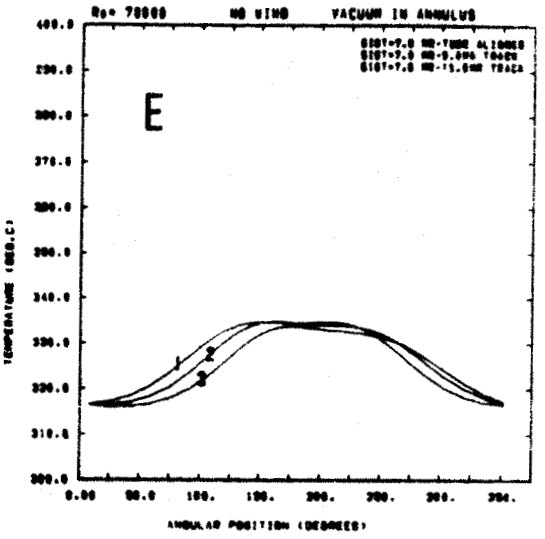
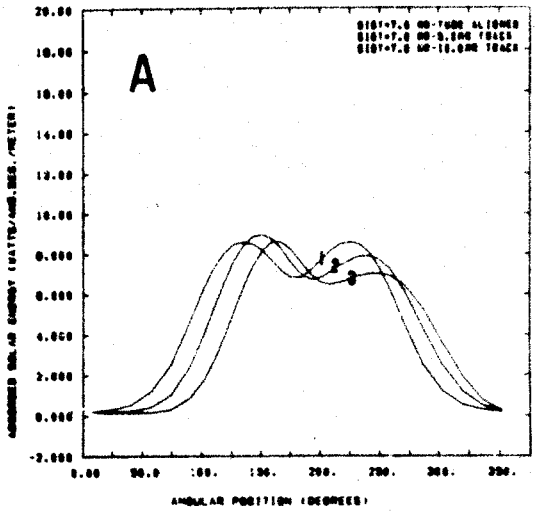


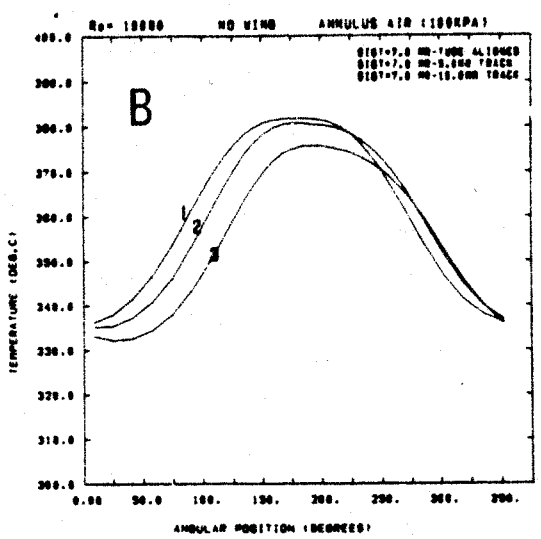
Figure A-3. Circumferential Distributions with Annular Space Evacuated-Trough Tracking Error Varied

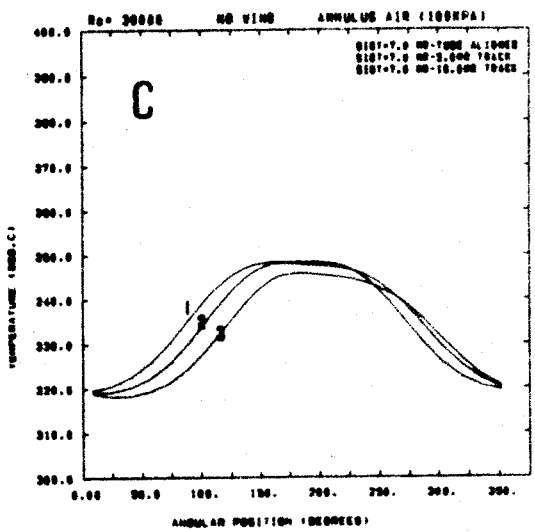
Figure Description *

A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000

*Note 1-Tube Aligned
2-Tube 5 mR Track
3-Tube 10 mR Track







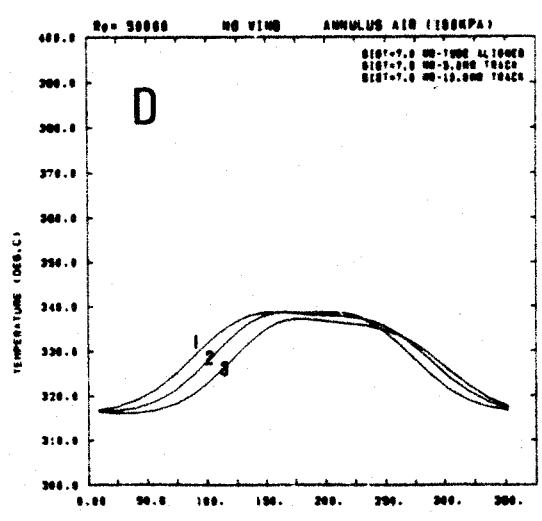
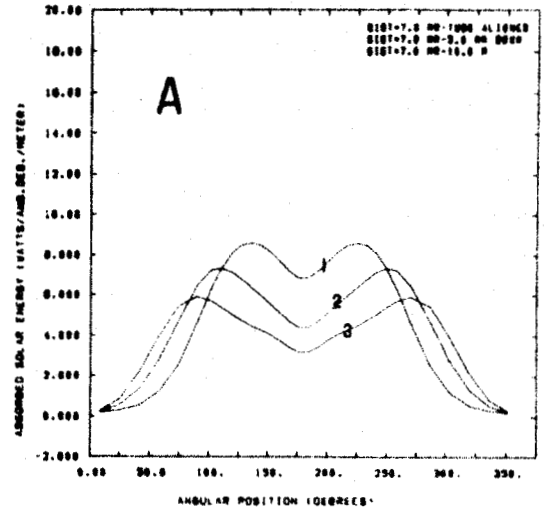


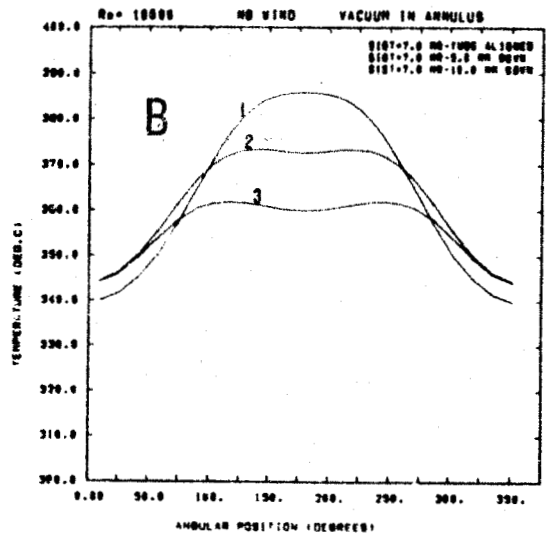
Figure A-4. Circumferential Distributions with Annulus Gas at 100 KPa-Trough Tracking Error Varied

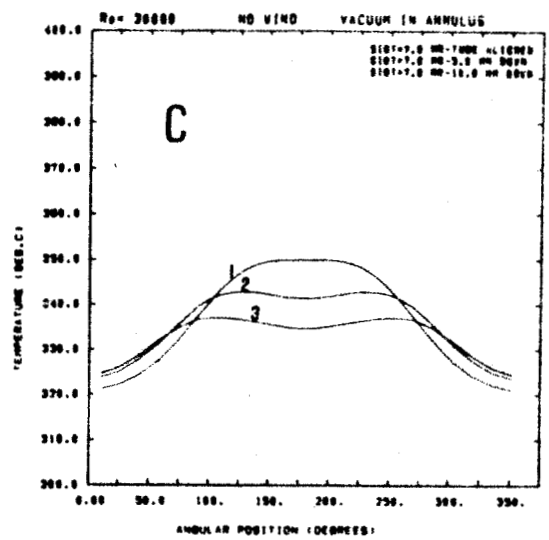
Figure Description *

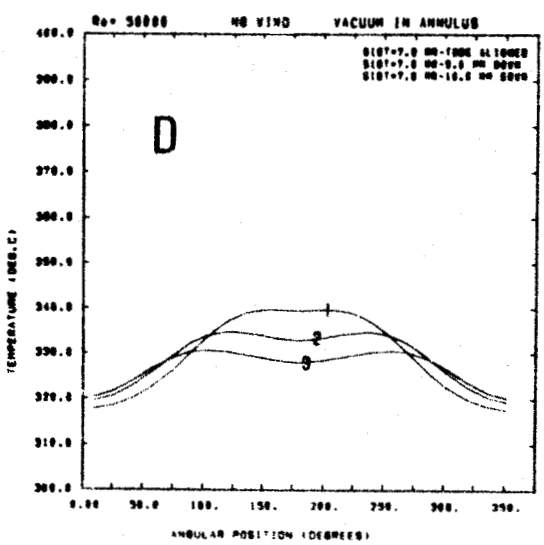
A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000
E: Receiver Surface Temperature for Re=70000

*Note 1-Tube Aligned
2-Tube 5 mm Down
3-Tube 10 mm Down









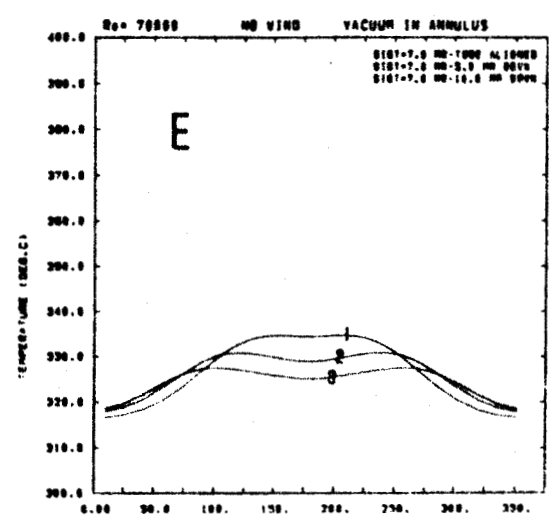
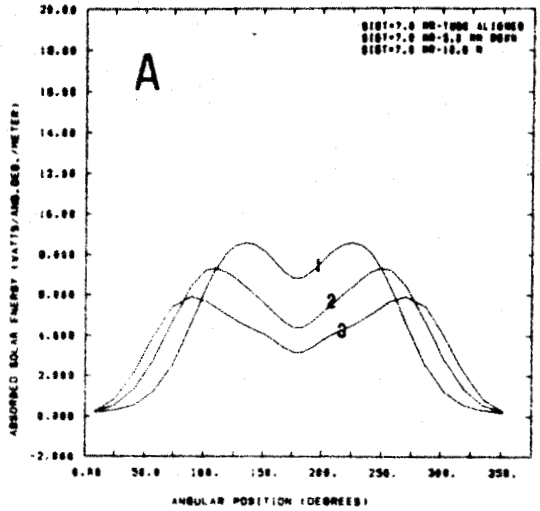


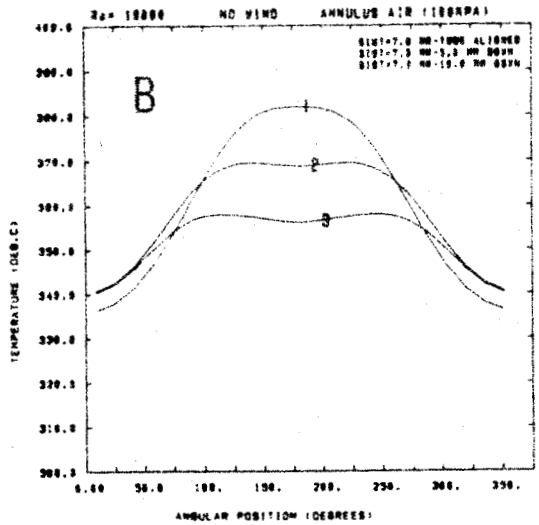
Figure A-5. Circumferential Distributions with Annular Space Evacuated-Receiver Assembly Misaligned Down

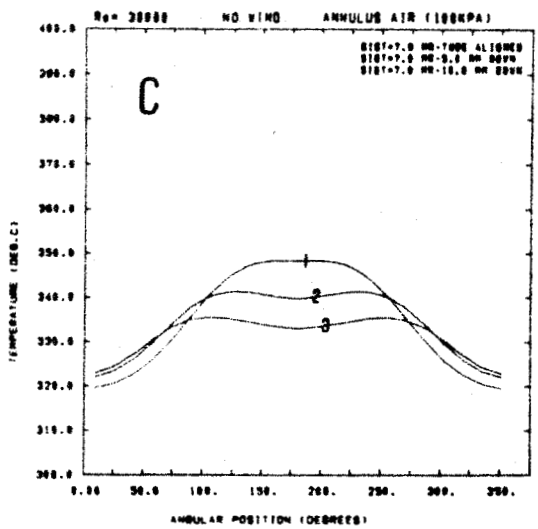
Figure Description *

A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000

*Note 1-Tube Aligned
2-Tube 5 mm Down
3-Tube 10 mm Down







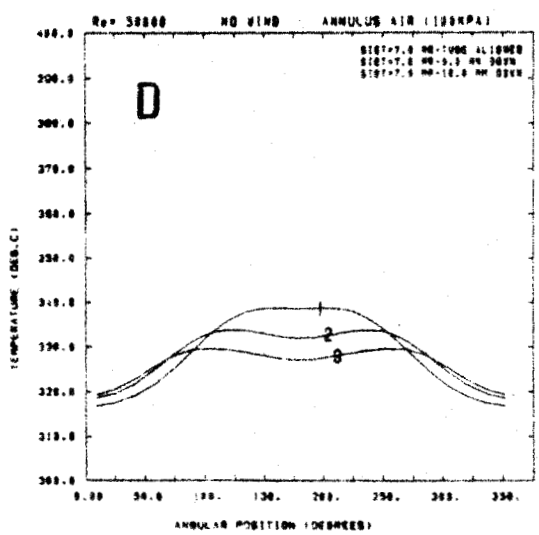
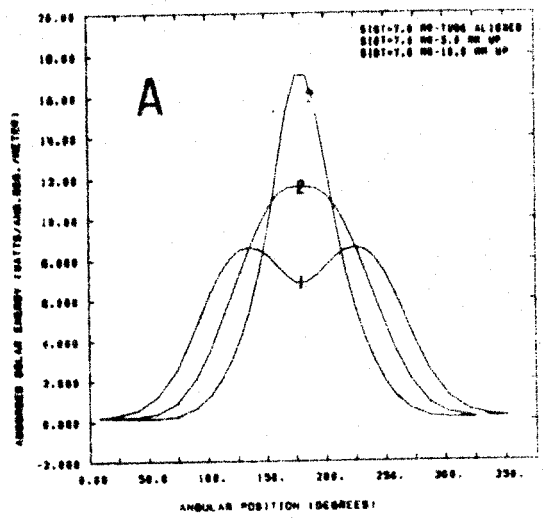


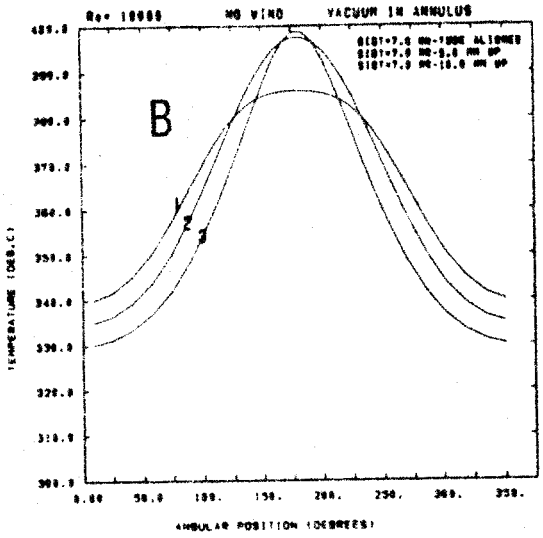
Figure A-6. Circumferential Distributions with Annulus Gas at 100 KPa-Receiver Assembly Misaligned Down

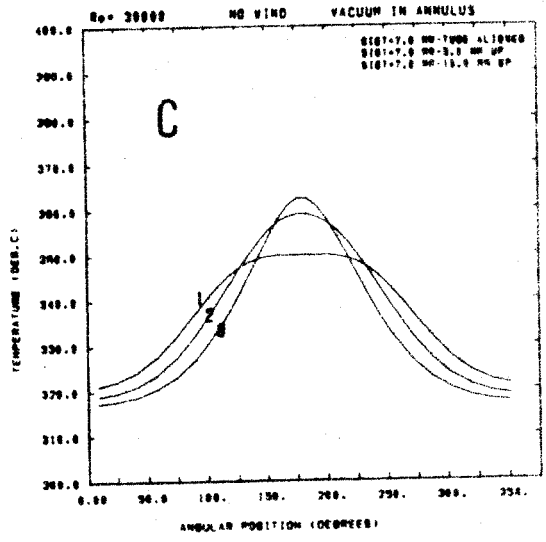
Figure Description *

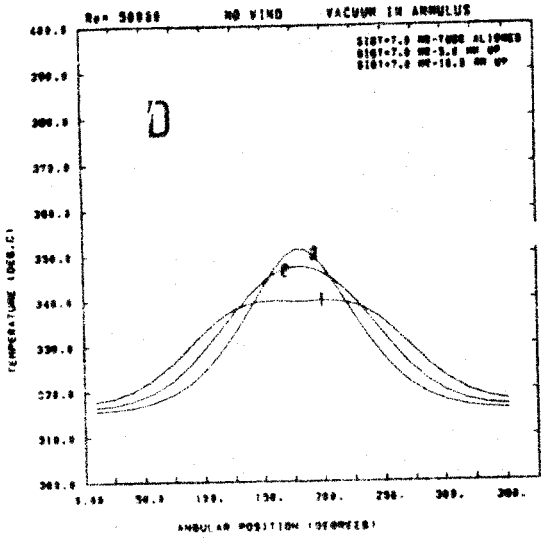
A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000
E: Receiver Surface Temperature for Re=70000

*Note 1-Tube Aligned
2-Tube 5 mm Up
3-Tube 10 mm Up









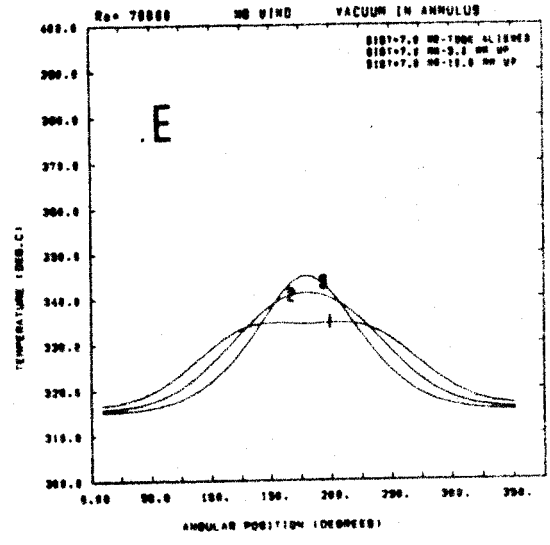
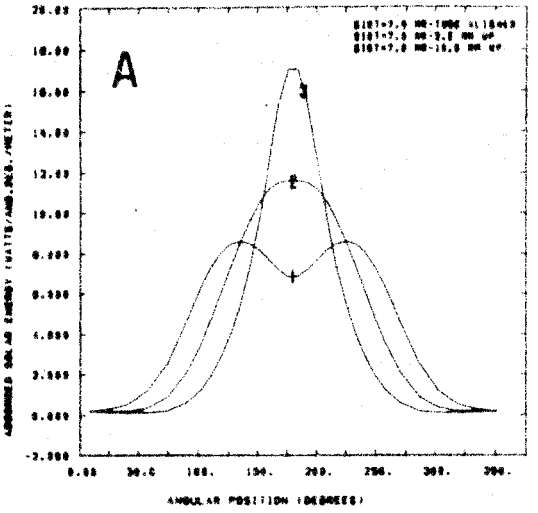


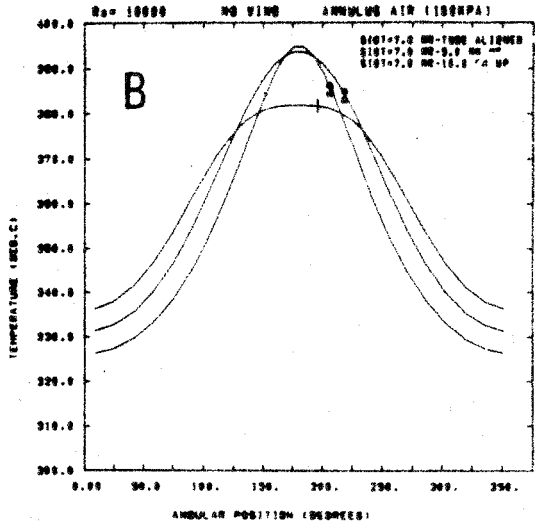
Figure A-7. Circumferential Distributions with Annular Space Evacuated-Receiver Assembly Misaligned Up

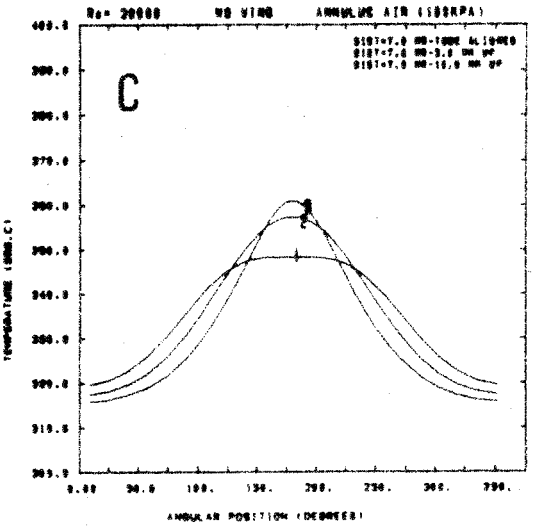
Figure Description *

A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000

*Note 1-Tube Aligned
2-Tube 5 mm Up
3-Tube 10 mm Up







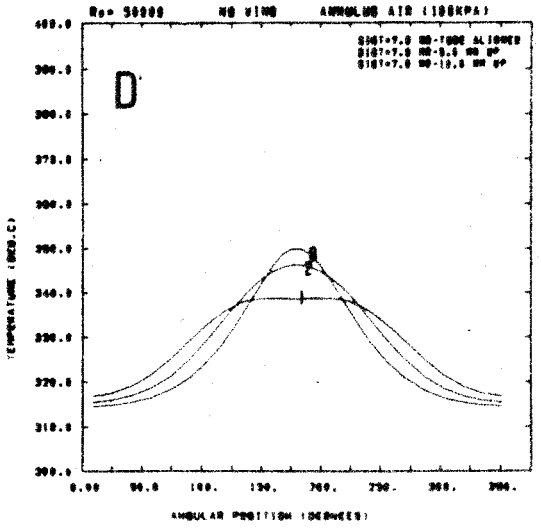
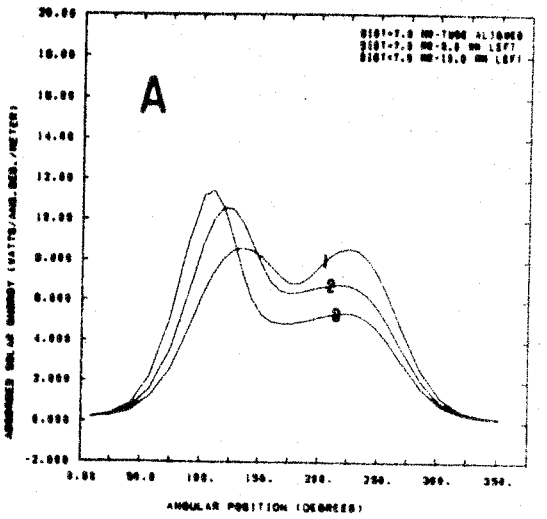


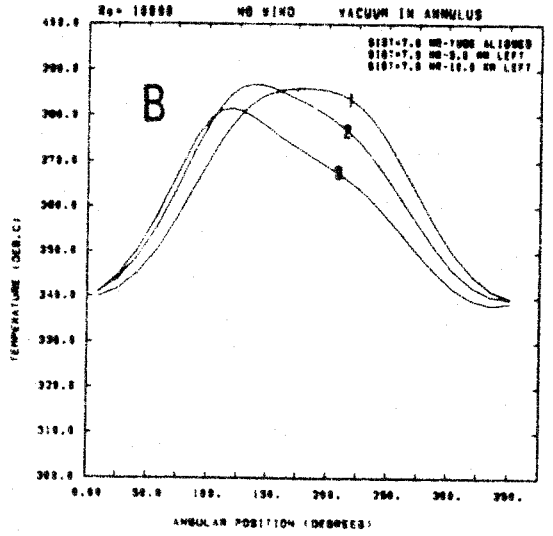
Figure A-8. Circumferential Distributions with Annulus Gas at 100 KPa-Receiver Assembly Misaligned Up

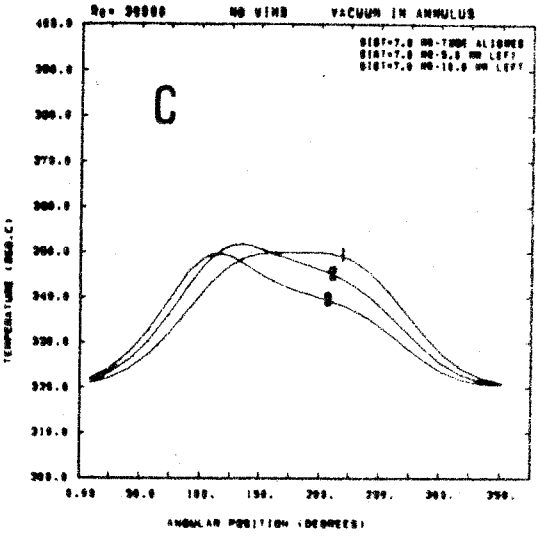
Figure Description *

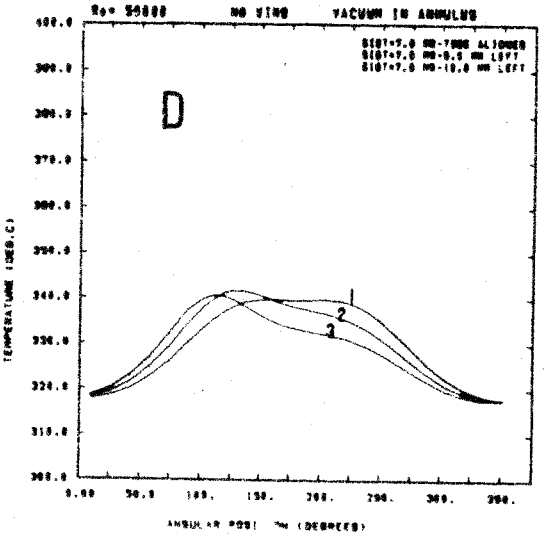
A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000
E: Receiver Surface Temperature for Re=70000

*Note 1-Tube Aligned
2-Tube 5 mm Left
3-Tube 10 mm Left









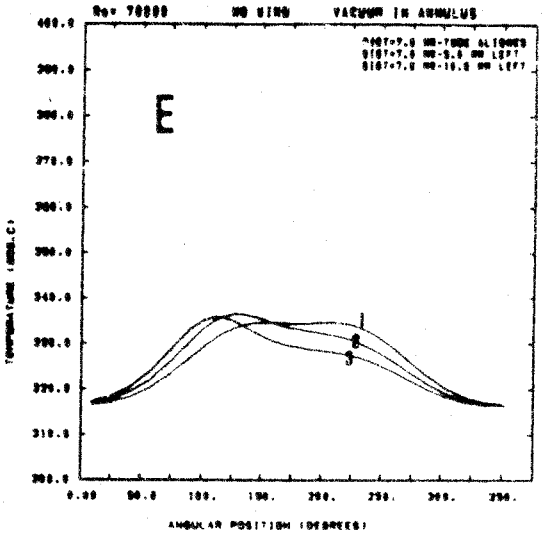
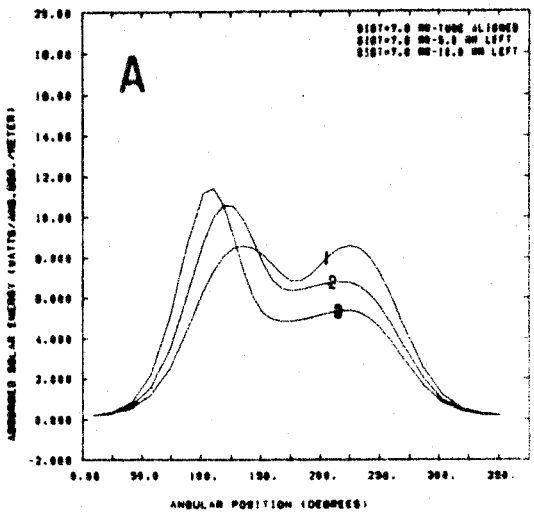


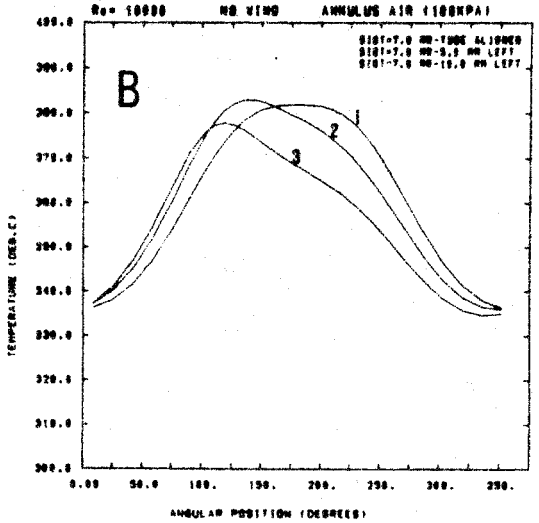
Figure A-9. Circumferential Distributions with Annular Space Evacuated-Receiver Assembly Misaligned Left

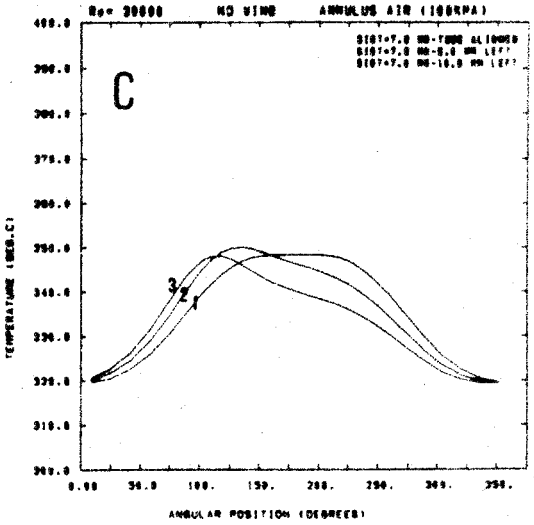
Figure Description *

A: Solar-Noon Flux Absorbed by Receiver Tube
B: Receiver Surface Temperature for Re=10000
C: Receiver Surface Temperature for Re=30000
D: Receiver Surface Temperature for Re=50000

*Note 1-Tube Aligned
2-Tube 5 mm Left
3-Tube 10 mm Left







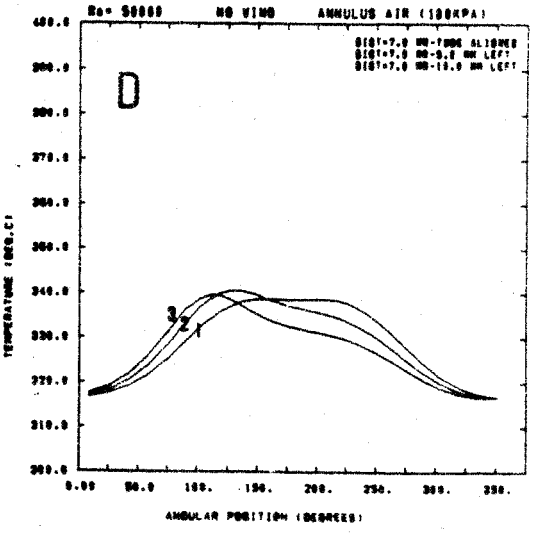


Figure A-10. Circumferential Distributions with Annulus Gas at 100 KPa-Receiver Assembly Misaligned Left

APPENDIX B

ONE-DIMENSIONAL THERMAL MODEL RESULTS FOR VARIED AMBIENT TEMPERATURE CONDITIONS

One-Dimensional thermal modeling results are presented in tabulated form for four ambient temperature (-25, 0, 25, and 50°C) and two annulus gas pressure conditions (10^5 Pa and 10^{-3} Pa). All other conditions modeled in this work are fixed by Table I. A summary of the tabulated results is given below.

Ambient Temperature	Table Presenting Results	
(°C)	Evacuated (10^{-3} Pa)	Atmospheric Pressure (10^5 Pa)
-25	B-I	B-II
0	B-III	B-IV
25	B-V	B-VI
50	B-VII	B-VIII

Table B-I. 1-D Thermal Model Results - Annular Space Evacuated and Ambient Temperature of -25 C

CASE DESIGNATION	REYNOLDS NUMBER (---)	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	363.9	363.3	67.7	8.7	.00	412.5	1567.4	32.6	201.3	1398.7
SIGT=9.00 MR-TUBE ALIGNED	10000.	362.1	361.5	67.1	8.7	.00	412.0	1513.1	32.8	199.6	1346.3
SIGT=12.2 MR-TUBE ALIGNED	10000.	357.8	357.3	65.6	8.7	.00	410.7	1392.3	33.0	195.2	1220.1
SIGT=7.00 MR-2.5 MR TRACK	10000.	363.6	363.0	67.6	8.7	.00	412.4	1558.5	32.7	201.1	1391.1
SIGT=7.00 MR-5.0 MR TRACK	10000.	362.6	362.1	67.3	8.7	.00	412.1	1529.9	32.8	200.2	1362.5
SIGT=7.00 MR-10. MR TRACK	10000.	358.2	357.6	65.8	8.7	.00	410.8	1392.6	33.2	195.7	1230.1
SIGT=7.00 MR-2.5 MM DOWN	10000.	363.5	362.9	67.6	8.7	.00	412.4	1555.8	32.7	201.0	1387.5
SIGT=7.00 MR-5.0 MM DOWN	10000.	362.2	361.6	67.2	8.7	.00	412.0	1516.9	32.8	199.7	1350.0
SIGT=7.00 MR-10. MM DOWN	10000.	355.9	355.4	65.0	8.7	.00	410.2	1324.1	33.4	193.5	1163.9
SIGT=7.00 MR-2.5 MM UP	10000.	363.5	362.9	67.6	8.7	.00	412.4	1555.4	32.7	201.0	1387.1
SIGT=7.00 MR-5.0 MM UP	10000.	362.2	361.6	67.2	8.7	.00	412.0	1516.1	32.8	199.7	1349.2
SIGT=7.00 MR-10. MM UP	10000.	355.8	355.3	65.0	8.7	.00	410.2	1320.4	33.4	193.4	1160.4
SIGT=7.00 MR-2.5 MM LEFT	10000.	363.8	363.2	67.7	8.7	.00	412.5	1564.2	32.7	201.3	1395.6
SIGT=7.00 MR-5.0 MM LEFT	10000.	363.3	362.7	67.6	8.7	.00	412.4	1550.3	32.8	200.9	1382.2
SIGT=7.00 MR-10. MM LEFT	10000.	359.1	358.5	66.1	8.7	.00	411.1	1420.3	33.2	196.7	1256.8
SIGT=7.00 MR-TUBE ALIGNED	30000.	336.4	335.8	57.8	8.5	.00	977.5	1567.4	32.6	173.3	1426.7
SIGT=9.00 MR-TUBE ALIGNED	30000.	335.6	335.0	57.6	8.5	.00	977.1	1513.1	32.8	172.7	1373.2
SIGT=12.2 MR-TUBE ALIGNED	30000.	333.7	333.1	57.0	8.5	.00	976.1	1392.3	33.0	171.1	1244.2
SIGT=7.00 MR-2.5 MR TRACK	30000.	336.3	335.7	57.7	8.5	.00	977.4	1558.5	32.7	173.2	1417.9
SIGT=7.00 MR-5.0 MR TRACK	30000.	335.8	335.2	57.6	8.5	.00	977.2	1529.9	32.8	172.9	1389.8
SIGT=7.00 MR-10. MR TRACK	30000.	333.8	333.3	57.1	8.5	.00	976.2	1392.6	33.2	171.4	1254.4
SIGT=7.00 MR-2.5 MM DOWN	30000.	336.2	335.6	57.7	8.5	.00	977.4	1555.8	32.7	173.2	1415.3
SIGT=7.00 MR-5.0 MM DOWN	30000.	335.7	335.1	57.6	8.5	.00	977.1	1516.9	32.8	172.8	1376.9
SIGT=7.00 MR-10. MM DOWN	30000.	332.8	332.3	56.8	8.5	.00	975.7	1324.1	33.4	170.7	1186.8
SIGT=7.00 MR-2.5 MM UP	30000.	336.2	335.6	57.7	8.5	.00	977.4	1555.4	32.7	173.2	1414.9
SIGT=7.00 MR-5.0 MM UP	30000.	335.6	335.0	57.6	8.5	.00	977.1	1516.1	32.8	172.7	1376.1
SIGT=7.00 MR-10. MM UP	30000.	332.8	332.3	56.8	8.5	.00	975.7	1320.4	33.4	170.6	1183.2
SIGT=7.00 MR-2.5 MM LEFT	30000.	336.3	335.7	57.8	8.5	.00	977.4	1564.2	32.7	173.3	1423.6
SIGT=7.00 MR-5.0 MM LEFT	30000.	336.1	335.5	57.7	8.5	.00	977.3	1550.3	32.8	173.2	1409.9
SIGT=7.00 MR-10. MM LEFT	30000.	334.2	333.7	57.2	8.5	.00	976.4	1420.3	33.2	171.8	1281.7
SIGT=7.00 MR-TUBE ALIGNED	50000.	329.5	328.9	55.4	8.4	.00	1465.6	1567.4	32.6	166.8	1433.2
SIGT=9.00 MR-TUBE ALIGNED	50000.	329.0	328.4	55.3	8.4	.00	1465.2	1513.1	32.8	166.5	1379.4
SIGT=12.2 MR-TUBE ALIGNED	50000.	327.7	327.2	54.9	8.4	.00	1464.2	1382.3	33.0	165.5	1249.8
SIGT=7.00 MR-2.5 MR TRACK	50000.	329.4	328.8	55.4	8.4	.00	1465.5	1558.5	32.7	166.8	1424.3
SIGT=7.00 MR-5.0 MR TRACK	50000.	329.2	328.6	55.3	8.4	.00	1465.3	1529.9	32.8	166.7	1396.0
SIGT=7.00 MR-10. MR TRACK	50000.	327.8	327.2	55.0	8.4	.00	1464.2	1392.6	33.2	165.8	1260.0
SIGT=7.00 MR-2.5 MM DOWN	50000.	329.4	328.8	55.4	8.4	.00	1465.5	1555.8	32.7	166.8	1421.7
SIGT=7.00 MR-5.0 MM DOWN	50000.	329.0	328.4	55.3	8.4	.00	1465.2	1516.9	32.8	166.6	1383.1
SIGT=7.00 MR-10. MM DOWN	50000.	327.1	326.6	54.9	8.4	.00	1463.7	1324.1	33.4	165.4	1192.1
SIGT=7.00 MR-2.5 MM UP	50000.	329.4	328.8	55.4	8.4	.00	1465.5	1555.4	32.7	166.8	1421.3
SIGT=7.00 MR-5.0 MM UP	50000.	329.0	328.4	55.3	8.4	.00	1465.2	1516.1	32.8	166.6	1382.3
SIGT=7.00 MR-10. MM UP	50000.	327.1	326.6	54.8	8.4	.00	1463.7	1320.4	33.4	165.3	1188.5
SIGT=7.00 MR-2.5 MM LEFT	50000.	329.5	328.9	55.4	8.4	.00	1465.6	1564.2	32.7	166.9	1430.8
SIGT=7.00 MR-5.0 MM LEFT	50000.	329.4	328.8	55.4	8.4	.00	1465.5	1550.3	32.8	166.9	1416.2
SIGT=7.00 MR-10. MM LEFT	50000.	328.1	327.5	55.1	8.4	.00	1464.5	1420.3	33.2	166.1	1287.4
SIGT=7.00 MR-TUBE ALIGNED	70000.	326.3	325.7	54.3	8.4	.00	1914.8	1567.4	32.6	163.9	1436.1
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.9	325.3	54.2	8.4	.00	1914.4	1513.1	32.8	163.7	1382.2
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.9	324.3	54.0	8.4	.00	1913.4	1382.3	33.0	162.9	1252.4
SIGT=7.00 MR-2.5 MR TRACK	70000.	326.2	325.6	54.3	8.4	.00	1914.8	1558.5	32.7	163.9	1427.3
SIGT=7.00 MR-5.0 MR TRACK	70000.	326.0	325.4	54.3	8.4	.00	1914.5	1529.9	32.8	163.8	1398.9
SIGT=7.00 MR-10. MR TRACK	70000.	324.9	324.4	54.0	8.4	.00	1913.4	1392.6	33.2	163.2	1262.6
SIGT=7.00 MR-2.5 MM DOWN	70000.	326.2	325.6	54.3	8.4	.00	1914.7	1555.8	32.7	163.9	1424.6
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.9	325.3	54.2	8.4	.00	1914.4	1516.9	32.8	163.7	1386.0
SIGT=7.00 MR-10. MM DOWN	70000.	324.4	323.9	53.9	8.4	.00	1912.9	1324.1	33.4	162.9	1194.6
SIGT=7.00 MR-2.5 MM UP	70000.	326.2	325.6	54.3	8.4	.00	1914.7	1555.4	32.7	163.9	1424.2
SIGT=7.00 MR-5.0 MM UP	70000.	325.9	325.3	54.2	8.4	.00	1914.4	1516.1	32.8	163.7	1385.2
SIGT=7.00 MR-10. MM UP	70000.	324.4	323.9	53.9	8.4	.00	1912.9	1320.4	33.4	162.9	1190.9
SIGT=7.00 MR-2.5 MM LEFT	70000.	326.3	325.7	54.3	8.4	.00	1914.8	1564.2	32.7	163.9	1433.0
SIGT=7.00 MR-5.0 MM LEFT	70000.	326.2	325.6	54.3	8.4	.00	1914.7	1550.3	32.8	163.9	1419.2
SIGT=7.00 MR-10. MM LEFT	70000.	325.2	324.6	54.1	8.4	.00	1913.7	1420.3	33.2	163.4	1290.1

Table B-II. 1-D Thermal Model Results - Annular Space Maintained at Atmospheric Pressure and Ambient Temperature of -25 C

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES		GLASS TEMP.	CONVECTION COEFFICIENTS			ABSORBED SOLAR ENERGY		RECEIVER HEAT LOSS	ENERGY ABSORBED BY FLUID
		I.D.	O.D.		HAIR	HGAP	HFLUID	QTUBE	QGLASS		
	(---)	(C)	(C)	(C)	(UNITS OF W/M**2-K)			(W)	(W)	(W)	(W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	359.6	359.0	107.5	9.5	6.96	411.2	1567.4	32.6	328.1	1271.9
SIGT=9.00 MR-TUBE ALIGNED	10000.	357.8	357.3	106.6	9.5	6.94	410.7	1513.1	32.8	325.6	1220.2
SIGT=12.2 MR-TUBE ALIGNED	10000.	353.6	353.1	104.8	9.5	6.91	409.6	1382.3	33.0	319.5	1098.8
SIGT=7.00 MR-2.5 MR TRACK	10000.	359.3	358.7	107.2	9.6	6.95	411.1	1558.5	32.7	327.8	1243.4
SIGT=7.00 MR-5.0 MR TRACK	10000.	358.4	357.8	106.8	9.6	6.95	410.9	1529.9	32.8	326.5	1236.2
SIGT=7.00 MR-10. MR TRACK	10000.	353.9	353.4	105.0	9.5	6.91	409.7	1392.6	33.2	320.1	1105.7
SIGT=7.00 MR-2.5 MM DOWN	10000.	359.2	358.7	107.1	9.6	6.95	411.1	1555.8	32.7	327.6	1260.8
SIGT=7.00 MR-5.0 MM DOWN	10000.	357.9	357.4	106.6	9.5	6.94	410.8	1516.9	32.8	325.8	1223.9
SIGT=7.00 MR-10. MM DOWN	10000.	351.6	351.2	104.1	9.5	6.89	409.2	1324.1	33.4	317.0	1040.5
SIGT=7.00 MR-2.5 MM UP	10000.	359.2	358.6	107.1	9.6	6.95	411.1	1555.4	32.7	327.6	1260.5
SIGT=7.00 MR-5.0 MM UP	10000.	357.9	357.4	106.6	9.5	6.94	410.7	1516.1	32.8	325.8	1223.1
SIGT=7.00 MR-10. MM UP	10000.	351.5	351.1	104.0	9.5	6.89	409.2	1320.4	33.4	316.8	1037.0
SIGT=7.00 MR-2.5 MM LEFT	10000.	359.5	358.9	107.2	9.6	6.95	411.2	1564.2	32.7	328.1	1268.8
SIGT=7.00 MR-5.0 MM LEFT	10000.	359.0	358.5	107.1	9.6	6.95	411.1	1550.3	32.8	327.5	1255.6
SIGT=7.00 MR-10. MM LEFT	10000.	354.8	354.3	105.4	9.5	6.92	409.9	1420.3	33.2	321.5	1132.8
SIGT=7.00 MR-TUBE ALIGNED	30000.	334.6	334.1	96.8	9.4	6.74	976.6	1567.4	32.6	292.0	1308.0
SIGT=9.00 MR-TUBE ALIGNED	30000.	333.8	333.3	96.5	9.4	6.74	976.2	1513.1	32.8	291.1	1254.8
SIGT=12.2 MR-TUBE ALIGNED	30000.	331.9	331.4	95.8	9.3	6.72	975.3	1382.3	33.0	288.6	1126.7
SIGT=7.00 MR-2.5 MR TRACK	30000.	334.5	333.9	96.7	9.4	6.74	976.5	1558.5	32.7	291.9	1299.3
SIGT=7.00 MR-5.0 MR TRACK	30000.	334.1	333.5	96.6	9.4	6.74	976.3	1529.9	32.8	291.4	1271.3
SIGT=7.00 MR-10. MR TRACK	30000.	332.1	331.6	95.9	9.3	6.72	975.3	1392.6	33.2	289.0	1136.8
SIGT=7.00 MR-2.5 MM DOWN	30000.	334.5	333.9	96.7	9.4	6.74	976.5	1555.8	32.7	291.9	1296.6
SIGT=7.00 MR-5.0 MM DOWN	30000.	333.9	333.4	96.5	9.4	6.74	976.2	1516.9	32.8	291.2	1258.5
SIGT=7.00 MR-10. MM DOWN	30000.	331.1	330.6	95.5	9.3	6.72	974.8	1324.1	33.4	287.8	1069.7
SIGT=7.00 MR-2.5 MM UP	30000.	334.5	333.9	96.7	9.4	6.74	976.5	1555.4	32.7	291.8	1296.3
SIGT=7.00 MR-5.0 MM UP	30000.	333.9	333.3	96.5	9.4	6.74	976.2	1516.1	32.8	291.1	1257.8
SIGT=7.00 MR-10. MM UP	30000.	331.0	330.6	95.5	9.3	6.71	974.8	1320.4	33.4	287.7	1066.1
SIGT=7.00 MR-2.5 MM LEFT	30000.	334.6	334.0	96.8	9.4	6.74	976.6	1564.2	32.7	292.0	1304.9
SIGT=7.00 MR-5.0 MM LEFT	30000.	334.4	333.8	96.7	9.4	6.74	976.5	1550.3	32.8	291.8	1291.3
SIGT=7.00 MR-10. MM LEFT	30000.	332.5	332.0	96.0	9.4	6.73	975.5	1420.3	33.2	289.5	1164.8
SIGT=7.00 MR-TUBE ALIGNED	50000.	328.4	327.8	94.2	9.3	6.69	1464.7	1567.4	32.6	283.4	1316.6
SIGT=9.00 MR-TUBE ALIGNED	50000.	327.8	327.3	94.0	9.3	6.69	1464.3	1513.1	32.8	282.8	1263.1
SIGT=12.2 MR-TUBE ALIGNED	50000.	326.5	326.0	93.5	9.3	6.68	1463.2	1382.3	33.0	281.3	1134.0
SIGT=7.00 MR-2.5 MR TRACK	50000.	328.3	327.7	94.2	9.3	6.69	1464.6	1558.5	32.7	283.4	1307.8
SIGT=7.00 MR-5.0 MR TRACK	50000.	328.0	327.4	94.1	9.3	6.69	1464.4	1529.9	32.8	283.1	1279.6
SIGT=7.00 MR-10. MR TRACK	50000.	326.6	326.1	93.6	9.3	6.68	1463.3	1392.6	33.2	281.6	1144.2
SIGT=7.00 MR-2.5 MM DOWN	50000.	328.2	327.7	94.2	9.3	6.69	1464.6	1555.8	32.7	283.3	1305.2
SIGT=7.00 MR-5.0 MM DOWN	50000.	327.9	327.3	94.0	9.3	6.69	1464.3	1516.9	32.8	282.9	1266.8
SIGT=7.00 MR-10. MM DOWN	50000.	325.9	325.5	93.4	9.3	6.67	1462.8	1324.1	33.4	280.8	1076.7
SIGT=7.00 MR-2.5 MM UP	50000.	328.2	327.7	94.2	9.3	6.69	1464.6	1555.4	32.7	283.3	1304.8
SIGT=7.00 MR-5.0 MM UP	50000.	327.9	327.3	94.0	9.3	6.69	1464.3	1516.1	32.8	282.9	1266.8
SIGT=7.00 MR-10. MM UP	50000.	325.9	325.4	93.4	9.3	6.67	1462.8	1320.4	33.4	280.8	1073.8
SIGT=7.00 MR-2.5 MM LEFT	50000.	328.3	327.8	94.2	9.3	6.69	1464.7	1564.2	32.7	283.5	1313.4
SIGT=7.00 MR-5.0 MM LEFT	50000.	328.2	327.6	94.2	9.3	6.69	1464.5	1550.3	32.8	283.3	1299.8
SIGT=7.00 MR-10. MM LEFT	50000.	326.9	326.4	93.7	9.3	6.68	1463.5	1420.3	33.2	281.9	1171.6
SIGT=7.00 MR-TUBE ALIGNED	70000.	325.4	324.8	93.0	9.3	6.67	1913.9	1567.4	32.6	279.4	1320.6
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.0	324.4	92.9	9.3	6.66	1913.5	1513.1	32.8	279.0	1266.9
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.0	323.5	92.5	9.3	6.65	1912.4	1382.3	33.0	277.8	1137.5
SIGT=7.00 MR-2.5 MR TRACK	70000.	325.3	324.8	93.0	9.3	6.67	1913.8	1558.5	32.7	279.4	1311.8
SIGT=7.00 MR-5.0 MR TRACK	70000.	325.1	324.5	92.9	9.3	6.66	1913.6	1529.9	32.8	279.2	1283.5
SIGT=7.00 MR-10. MR TRACK	70000.	324.0	323.5	92.6	9.3	6.65	1912.5	1392.6	33.2	278.1	1147.7
SIGT=7.00 MR-2.5 MM DOWN	70000.	325.3	324.7	93.0	9.3	6.67	1913.8	1555.8	32.7	279.4	1309.1
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.0	324.5	92.9	9.3	6.66	1913.5	1516.9	32.8	279.0	1270.7
SIGT=7.00 MR-10. MM DOWN	70000.	323.5	323.0	92.4	9.3	6.65	1911.9	1324.1	33.4	277.5	1080.0
SIGT=7.00 MR-2.5 MM UP	70000.	325.3	324.7	93.0	9.3	6.67	1913.8	1555.4	32.7	279.4	1308.7
SIGT=7.00 MR-5.0 MM UP	70000.	325.0	324.4	92.9	9.3	6.66	1913.5	1516.1	32.8	279.0	1269.9
SIGT=7.00 MR-10. MM UP	70000.	323.5	323.0	92.4	9.3	6.65	1911.9	1320.4	33.4	277.5	1076.3
SIGT=7.00 MR-2.5 MM LEFT	70000.	325.4	324.8	93.0	9.3	6.67	1913.9	1564.2	32.7	279.5	1317.4
SIGT=7.00 MR-5.0 MM LEFT	70000.	325.3	324.7	93.0	9.3	6.66	1913.8	1550.3	32.8	279.4	1303.7
SIGT=7.00 MR-10. MM LEFT	70000.	324.3	323.7	92.7	9.3	6.66	1912.7	1420.3	33.2	278.4	1175.1

Table B-III. 1-D Thermal Model Results - Annular Space Evacuated and Ambient Temperature of 0 C

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	364.0	363.4	84.8	8.6	.00	412.6	1567.4	32.6	198.2	1401.8
SIGT=9.00 MR-TUBE ALIGNED	10000.	362.2	361.6	84.2	8.5	.00	412.0	1513.1	32.8	196.5	1349.4
SIGT=12.2 MR-TUBE ALIGNED	10000.	357.9	357.4	82.7	8.5	.00	410.7	1382.3	33.0	192.1	1223.2
SIGT=7.00 MR-2.5 MR TRACK	10000.	363.7	363.1	84.7	8.5	.00	412.5	1558.5	32.7	198.0	1393.2
SIGT=7.00 MR-5.0 MR TRACK	10000.	362.8	362.2	84.4	8.5	.00	412.2	1529.9	32.8	197.1	1365.6
SIGT=7.00 MR-10. MR TRACK	10000.	358.3	357.7	82.9	8.5	.00	410.8	1392.4	33.2	192.6	1233.1
SIGT=7.00 MR-2.5 MM DOWN	10000.	363.6	363.0	84.6	8.5	.00	412.5	1555.8	32.7	197.9	1390.6
SIGT=7.00 MR-5.0 MM DOWN	10000.	362.3	361.7	84.2	8.5	.00	412.0	1516.9	32.8	196.6	1353.1
SIGT=7.00 MR-10. MM DOWN	10000.	356.0	355.5	82.2	8.5	.00	410.2	1324.1	33.4	190.5	1167.0
SIGT=7.00 MR-2.5 MM UP	10000.	363.6	363.0	84.6	8.5	.00	412.4	1555.4	32.7	197.9	1390.2
SIGT=7.00 MR-5.0 MM UP	10000.	362.3	361.7	84.2	8.5	.00	412.0	1516.1	32.8	196.6	1352.3
SIGT=7.00 MR-10. MM UP	10000.	355.9	355.4	82.2	8.5	.00	410.2	1320.4	33.4	190.3	1163.5
SIGT=7.00 MR-2.5 MM LEFT	10000.	363.9	363.3	84.7	8.5	.00	412.5	1564.2	32.7	198.2	1398.7
SIGT=7.00 MR-5.0 MM LEFT	10000.	363.4	362.8	84.6	8.5	.00	412.4	1530.3	32.8	197.8	1385.3
SIGT=7.00 MR-10. MM LEFT	10000.	359.2	358.6	83.2	8.5	.00	411.1	1420.3	33.2	193.6	1259.9
SIGT=7.00 MR-TUBE ALIGNED	30000.	336.4	335.8	75.4	8.3	.00	977.5	1567.4	32.6	170.2	1429.8
SIGT=9.00 MR-TUBE ALIGNED	30000.	335.6	335.1	75.2	8.3	.00	977.1	1513.1	32.8	169.7	1376.2
SIGT=12.2 MR-TUBE ALIGNED	30000.	333.7	333.2	74.6	8.3	.00	976.1	1382.3	33.0	168.1	1247.2
SIGT=7.00 MR-2.5 MR TRACK	30000.	336.3	335.7	75.3	8.3	.00	977.4	1558.5	32.7	170.2	1421.0
SIGT=7.00 MR-5.0 MR TRACK	30000.	335.9	335.3	75.2	8.3	.00	977.2	1529.9	32.8	169.9	1392.8
SIGT=7.00 MR-10. MR TRACK	30000.	333.9	333.3	74.7	8.3	.00	976.2	1392.6	33.2	168.4	1257.4
SIGT=7.00 MR-2.5 MM DOWN	30000.	336.3	335.7	75.3	8.3	.00	977.4	1555.8	32.7	170.2	1418.3
SIGT=7.00 MR-5.0 MM DOWN	30000.	335.7	335.1	75.2	8.3	.00	977.1	1516.9	32.8	169.7	1380.0
SIGT=7.00 MR-10. MM DOWN	30000.	332.9	332.4	74.5	8.3	.00	975.7	1324.1	33.4	167.6	1189.9
SIGT=7.00 MR-2.5 MM UP	30000.	336.3	335.7	75.3	8.3	.00	977.4	1555.4	32.7	170.2	1417.9
SIGT=7.00 MR-5.0 MM UP	30000.	335.7	335.1	75.2	8.3	.00	977.1	1516.1	32.8	169.7	1379.2
SIGT=7.00 MR-10. MM UP	30000.	332.8	332.3	74.4	8.3	.00	975.7	1320.4	33.4	167.6	1186.2
SIGT=7.00 MR-2.5 MM LEFT	30000.	336.4	335.8	75.4	8.3	.00	977.5	1564.2	32.7	170.3	1426.6
SIGT=7.00 MR-5.0 MM LEFT	30000.	336.2	335.6	75.3	8.3	.00	977.4	1550.3	32.8	170.2	1412.9
SIGT=7.00 MR-10. MM LEFT	30000.	334.3	333.7	74.8	8.3	.00	976.4	1420.3	33.2	168.8	1284.7
SIGT=7.00 MR-TUBE ALIGNED	50000.	329.6	328.9	73.1	8.2	.00	1465.6	1567.4	32.6	163.8	1436.2
SIGT=9.00 MR-TUBE ALIGNED	50000.	329.0	328.4	73.0	8.2	.00	1465.2	1513.1	32.8	163.5	1382.4
SIGT=12.2 MR-TUBE ALIGNED	50000.	327.7	327.2	72.7	8.2	.00	1464.2	1382.3	33.0	162.5	1252.8
SIGT=7.00 MR-2.5 MR TRACK	50000.	329.5	328.9	73.1	8.2	.00	1465.5	1558.5	32.7	163.8	1427.4
SIGT=7.00 MR-5.0 MR TRACK	50000.	329.2	328.6	73.1	8.2	.00	1465.3	1529.9	32.8	163.7	1399.0
SIGT=7.00 MR-10. MR TRACK	50000.	327.8	327.3	72.8	8.2	.00	1464.3	1392.6	33.2	162.8	1263.0
SIGT=7.00 MR-2.5 MM DOWN	50000.	329.5	328.8	73.1	8.2	.00	1465.5	1555.8	32.7	163.8	1424.7
SIGT=7.00 MR-5.0 MM DOWN	50000.	329.1	328.5	73.0	8.2	.00	1465.2	1516.9	32.8	163.5	1386.2
SIGT=7.00 MR-10. MM DOWN	50000.	327.1	326.6	72.6	8.2	.00	1463.7	1324.1	33.4	162.4	1199.1
SIGT=7.00 MR-2.5 MM UP	50000.	329.4	328.8	73.1	8.2	.00	1465.5	1555.4	32.7	163.8	1424.3
SIGT=7.00 MR-5.0 MM UP	50000.	329.1	328.5	73.0	8.2	.00	1465.2	1516.1	32.8	163.5	1385.4
SIGT=7.00 MR-10. MM UP	50000.	327.1	326.6	72.6	8.2	.00	1463.7	1320.4	33.4	162.3	1191.5
SIGT=7.00 MR-2.5 MM LEFT	50000.	329.5	328.9	73.1	8.2	.00	1465.6	1564.2	32.7	163.9	1433.0
SIGT=7.00 MR-5.0 MM LEFT	50000.	329.4	328.8	73.1	8.2	.00	1465.5	1550.3	32.8	163.9	1419.2
SIGT=7.00 MR-10. MM LEFT	50000.	328.1	327.5	72.9	8.2	.00	1464.5	1420.3	33.2	163.0	1290.5
SIGT=7.00 MR-TUBE ALIGNED	70000.	326.3	325.7	72.1	8.2	.00	1914.9	1567.4	32.6	160.9	1439.1
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.9	325.3	72.0	8.2	.00	1914.4	1513.1	32.8	160.7	1385.2
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.9	324.3	71.8	8.2	.00	1913.4	1382.3	33.0	159.9	1255.4
SIGT=7.00 MR-2.5 MR TRACK	70000.	325.2	325.6	72.1	8.2	.00	1914.8	1558.5	32.7	160.9	1430.3
SIGT=7.00 MR-5.0 MR TRACK	70000.	326.0	325.4	72.1	8.2	.00	1914.6	1529.9	32.8	160.8	1401.9
SIGT=7.00 MR-10. MR TRACK	70000.	325.0	324.4	71.9	8.2	.00	1913.5	1392.6	33.2	160.2	1265.6
SIGT=7.00 MR-2.5 MM DOWN	70000.	326.2	325.6	72.1	8.2	.00	1914.8	1555.8	32.7	160.9	1427.6
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.9	325.3	72.0	8.2	.00	1914.5	1516.9	32.8	160.7	1389.0
SIGT=7.00 MR-10. MM DOWN	70000.	324.4	323.9	71.8	8.2	.00	1912.9	1324.1	33.4	159.9	1197.6
SIGT=7.00 MR-2.5 MM UP	70000.	326.2	325.6	72.1	8.2	.00	1914.8	1555.4	32.7	160.9	1427.2
SIGT=7.00 MR-5.0 MM UP	70000.	325.9	325.3	72.0	8.2	.00	1914.5	1516.1	32.8	160.7	1388.2
SIGT=7.00 MR-10. MM UP	70000.	324.4	323.9	71.7	8.2	.00	1912.9	1320.4	33.4	159.9	1193.9
SIGT=7.00 MR-2.5 MM LEFT	70000.	326.3	325.7	72.1	8.2	.00	1914.8	1564.2	32.7	160.9	1436.0
SIGT=7.00 MR-5.0 MM LEFT	70000.	326.2	325.6	72.1	8.2	.00	1914.7	1550.3	32.8	160.9	1422.2
SIGT=7.00 MR-10. MM LEFT	70000.	325.2	324.6	71.9	8.2	.00	1913.7	1420.3	33.2	160.4	1293.1

Table B-IV. 1-D Thermal Model Results - Annular Space Maintained at Atmospheric Pressure and Ambient Temperature of 0 C

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES		GLASS TEMP.	CONVECTION COEFFICIENTS			ABSORBED SOLAR ENERGY		RECEIVER HEAT LOSS	ENERGY ABSORBED BY FLUID
		I.D.	O.D.		HAIR	HGAP	H FLUID	QTUBE	QGLASS		
	(--)	(C)	(C)	(C)	(UNITS OF W/M**2-K)			(W)	(W)	(W)	(W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	359.9	359.4	120.4	9.3	6.96	411.3	1567.4	32.6	318.0	1281.9
SIGT=9.00 MR-TUBE ALIGNED	10000.	358.2	357.6	119.8	9.3	6.94	410.8	1513.1	32.8	315.6	1230.3
SIGT=12.2 MR-TUBE ALIGNED	10000.	353.9	353.4	118.1	9.3	6.91	409.7	1382.3	33.0	309.4	1105.9
SIGT=7.00 MR-2.5 MR TRACK	10000.	359.6	359.1	120.3	9.3	6.96	411.2	1558.5	32.7	317.7	1273.5
SIGT=7.00 MR-5.0 MR TRACK	10000.	358.7	358.2	120.0	9.3	6.95	411.0	1529.9	32.8	316.4	1246.3
SIGT=7.00 MR-10. MR TRACK	10000.	354.2	353.8	118.2	9.3	6.91	409.8	1392.6	33.2	310.1	1115.7
SIGT=7.00 MR-2.5 MM DOWN	10000.	359.5	359.0	120.3	9.3	6.95	411.2	1555.8	32.7	317.6	1270.9
SIGT=7.00 MR-5.0 MM DOWN	10000.	358.3	357.8	119.8	9.3	6.94	410.8	1516.9	32.8	315.8	1233.9
SIGT=7.00 MR-10. MM DOWN	10000.	352.0	351.5	117.4	9.3	6.89	409.3	1324.1	33.4	306.9	1050.6
SIGT=7.00 MR-2.5 MM UP	10000.	359.5	359.0	120.3	9.3	6.95	411.2	1555.4	32.7	317.5	1270.5
SIGT=7.00 MR-5.0 MM UP	10000.	358.3	357.7	119.8	9.3	6.94	410.8	1516.1	32.8	315.7	1233.2
SIGT=7.00 MR-10. MM UP	10000.	351.9	351.4	117.3	9.3	6.89	409.2	1320.4	33.4	306.7	1047.1
SIGT=7.00 MR-2.5 MM LEFT	10000.	359.8	359.3	120.4	9.3	6.96	411.3	1564.2	32.7	318.0	1278.9
SIGT=7.00 MR-5.0 MM LEFT	10000.	359.4	358.8	120.2	9.3	6.95	411.2	1550.3	32.8	317.4	1265.7
SIGT=7.00 MR-10. MM LEFT	10000.	355.1	354.7	118.6	9.3	6.92	410.0	1420.3	33.2	311.4	1142.1
SIGT=7.00 MR-TUBE ALIGNED	30000.	334.8	334.2	110.3	9.1	6.75	976.7	1567.4	32.6	281.8	1318.2
SIGT=9.00 MR-TUBE ALIGNED	30000.	334.0	333.4	110.0	9.1	6.74	976.3	1513.1	32.8	280.0	1265.1
SIGT=12.2 MR-TUBE ALIGNED	30000.	332.1	331.6	109.3	9.1	6.72	975.3	1382.3	33.0	278.4	1136.9
SIGT=7.00 MR-2.5 MR TRACK	30000.	334.7	334.1	110.3	9.1	6.75	976.6	1558.5	32.7	281.7	1309.5
SIGT=7.00 MR-5.0 MR TRACK	30000.	334.2	333.7	110.1	9.1	6.74	976.4	1529.9	32.8	281.2	1281.5
SIGT=7.00 MR-10. MR TRACK	30000.	332.2	331.7	109.4	9.1	6.72	975.4	1392.6	33.2	278.7	1147.1
SIGT=7.00 MR-2.5 MM DOWN	30000.	334.6	334.1	110.3	9.1	6.74	976.6	1555.8	32.7	281.6	1306.9
SIGT=7.00 MR-5.0 MM DOWN	30000.	334.0	333.5	110.1	9.1	6.74	976.3	1516.9	32.8	280.9	1268.8
SIGT=7.00 MR-10. MM DOWN	30000.	331.2	330.8	109.1	9.1	6.72	974.9	1324.1	33.4	277.5	1080.0
SIGT=7.00 MR-2.5 MM UP	30000.	334.6	334.0	110.3	9.1	6.74	976.6	1555.4	32.7	281.6	1306.5
SIGT=7.00 MR-5.0 MM UP	30000.	334.0	333.5	110.1	9.1	6.74	976.3	1516.1	32.8	280.9	1268.0
SIGT=7.00 MR-10. MM UP	30000.	331.2	330.7	109.1	9.1	6.72	974.9	1320.4	33.4	277.5	1076.3
SIGT=7.00 MR-2.5 MM LEFT	30000.	334.7	334.2	110.3	9.1	6.75	976.6	1564.2	32.7	281.8	1315.1
SIGT=7.00 MR-5.0 MM LEFT	30000.	334.5	334.0	110.2	9.1	6.74	976.5	1550.3	32.8	281.6	1301.5
SIGT=7.00 MR-10. MM LEFT	30000.	332.6	332.1	109.6	9.1	6.73	975.6	1420.3	33.2	279.3	1174.2
SIGT=7.00 MR-TUBE ALIGNED	50000.	329.5	327.9	107.8	9.1	6.69	1464.8	1567.4	32.6	273.1	1326.9
SIGT=9.00 MR-TUBE ALIGNED	50000.	327.9	327.4	107.7	9.1	6.69	1464.3	1513.1	32.8	272.6	1273.3
SIGT=12.2 MR-TUBE ALIGNED	50000.	326.6	326.1	107.2	9.1	6.68	1463.3	1382.3	33.0	271.0	1144.3
SIGT=7.00 MR-2.5 MR TRACK	50000.	328.4	327.8	107.8	9.1	6.69	1464.7	1558.5	32.7	273.1	1316.1
SIGT=7.00 MR-5.0 MR TRACK	50000.	328.1	327.5	107.7	9.1	6.69	1464.5	1529.9	32.8	272.8	1289.9
SIGT=7.00 MR-10. MR TRACK	50000.	326.7	326.2	107.3	9.1	6.68	1463.4	1392.6	33.2	271.3	1154.5
SIGT=7.00 MR-2.5 MM DOWN	50000.	328.4	327.8	107.8	9.1	6.69	1464.7	1555.8	32.7	273.0	1315.4
SIGT=7.00 MR-5.0 MM DOWN	50000.	328.0	327.4	107.7	9.1	6.69	1464.4	1516.9	32.8	272.6	1277.1
SIGT=7.00 MR-10. MM DOWN	50000.	326.0	325.6	107.1	9.1	6.67	1462.9	1324.1	33.4	270.5	1087.0
SIGT=7.00 MR-2.5 MM UP	50000.	328.3	327.8	107.8	9.1	6.69	1464.7	1555.4	32.7	273.0	1315.1
SIGT=7.00 MR-5.0 MM UP	50000.	328.0	327.4	107.7	9.1	6.69	1464.4	1516.1	32.8	272.6	1276.8
SIGT=7.00 MR-10. MM UP	50000.	326.0	325.5	107.0	9.1	6.67	1462.8	1320.4	33.4	270.5	1083.3
SIGT=7.00 MR-2.5 MM LEFT	50000.	328.4	327.9	107.8	9.1	6.69	1464.7	1564.2	32.7	273.2	1323.7
SIGT=7.00 MR-5.0 MM LEFT	50000.	328.3	327.7	107.8	9.1	6.69	1464.6	1550.3	32.8	273.1	1310.0
SIGT=7.00 MR-10. MM LEFT	50000.	327.0	326.5	107.4	9.1	6.68	1463.6	1420.3	33.2	271.6	1181.9
SIGT=7.00 MR-TUBE ALIGNED	70000.	325.5	324.9	106.6	9.1	6.67	1914.0	1567.4	32.6	269.1	1330.9
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.0	324.5	106.5	9.1	6.66	1913.6	1513.1	32.8	268.7	1277.2
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.0	323.5	106.2	9.0	6.65	1912.5	1382.3	33.0	267.5	1147.8
SIGT=7.00 MR-2.5 MR TRACK	70000.	325.4	324.8	106.6	9.1	6.67	1913.9	1558.5	32.7	269.1	1322.1
SIGT=7.00 MR-5.0 MR TRACK	70000.	325.2	324.6	106.6	9.1	6.66	1913.7	1529.9	32.8	268.9	1295.8
SIGT=7.00 MR-10. MR TRACK	70000.	324.1	323.6	106.3	9.1	6.66	1912.6	1392.6	33.2	267.8	1158.0
SIGT=7.00 MR-2.5 MM DOWN	70000.	325.4	324.8	106.6	9.1	6.67	1913.9	1555.8	32.7	269.1	1319.4
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.1	324.5	106.5	9.1	6.66	1913.6	1516.9	32.8	268.7	1281.0
SIGT=7.00 MR-10. MM DOWN	70000.	323.6	323.1	106.1	9.0	6.65	1912.0	1324.1	33.4	267.2	1090.3
SIGT=7.00 MR-2.5 MM UP	70000.	325.4	324.8	106.6	9.1	6.67	1913.9	1555.4	32.7	269.1	1319.0
SIGT=7.00 MR-5.0 MM UP	70000.	325.1	324.5	106.5	9.1	6.66	1913.6	1516.1	32.8	268.7	1280.2
SIGT=7.00 MR-10. MM UP	70000.	323.6	323.1	106.1	9.0	6.65	1912.0	1320.4	33.4	267.2	1086.6
SIGT=7.00 MR-2.5 MM LEFT	70000.	325.4	324.9	106.7	9.1	6.67	1914.0	1564.2	32.7	269.1	1327.8
SIGT=7.00 MR-5.0 MM LEFT	70000.	325.3	324.8	106.6	9.1	6.67	1913.9	1550.3	32.8	269.1	1314.0
SIGT=7.00 MR-10. MM LEFT	70000.	324.3	323.8	106.3	9.1	6.66	1912.8	1420.3	33.2	268.1	1185.4

Table B-V. 1-D Thermal Model Results - Annular Space Evacuated and Ambient Temperature of 25 C

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	364.1	363.5	101.8	8.3	.00	412.6	1567.4	32.6	194.6	1405.4
SIGT=9.00 MR-TUBE ALIGNED	10000.	362.3	361.7	101.2	8.3	.00	412.0	1513.1	32.8	192.9	1353.0
SIGT=12.2 MR-TUBE ALIGNED	10000.	358.0	357.5	99.9	8.3	.00	410.8	1382.3	33.0	188.5	1226.8
SIGT=7.00 MR-2.5 MR TRACK	10000.	363.8	363.2	101.7	8.3	.00	412.5	1558.5	32.7	194.4	1396.8
SIGT=7.00 MR-5.0 MR TRACK	10000.	362.9	362.3	101.4	8.3	.00	412.2	1529.9	32.8	193.5	1369.2
SIGT=7.00 MR-10. MR TRACK	10000.	358.4	357.8	100.1	8.3	.00	410.9	1392.6	33.2	189.1	1236.7
SIGT=7.00 MR-2.5 MM DOWN	10000.	363.7	363.1	101.7	8.3	.00	412.5	1555.8	32.7	194.3	1394.2
SIGT=7.00 MR-5.0 MM DOWN	10000.	362.5	361.9	101.3	8.3	.00	412.1	1516.9	32.8	193.0	1356.7
SIGT=7.00 MR-10. MM DOWN	10000.	355.1	355.6	99.4	8.3	.00	410.3	1324.1	33.4	186.9	1170.6
SIGT=7.00 MR-2.5 MM UP	10000.	363.7	363.1	101.7	8.3	.00	412.5	1555.4	32.7	194.3	1393.8
SIGT=7.00 MR-5.0 MM UP	10000.	362.4	361.8	101.3	8.3	.00	412.1	1516.1	32.8	193.0	1355.9
SIGT=7.00 MR-10. MM UP	10000.	356.0	355.5	99.3	8.3	.00	410.2	1320.4	33.4	186.8	1167.0
SIGT=7.00 MR-2.5 MM LEFT	10000.	364.0	363.4	101.8	8.3	.00	412.6	1564.2	32.7	194.6	1402.3
SIGT=7.00 MR-5.0 MM LEFT	10000.	363.5	362.9	101.6	8.3	.00	412.4	1550.3	32.8	194.2	1388.9
SIGT=7.00 MR-10. MM LEFT	10000.	359.3	358.7	100.4	8.3	.00	411.1	1420.3	33.2	190.0	1263.5
SIGT=7.00 MR-TUBE ALIGNED	30000.	336.5	335.9	92.9	8.1	.00	977.5	1567.4	32.6	166.7	1433.3
SIGT=9.00 MR TUBE ALIGNED	30000.	335.7	335.1	92.7	8.1	.00	977.1	1513.1	32.8	166.2	1379.7
SIGT=12.2 MR-TUBE ALIGNED	30000.	333.8	333.2	92.2	8.1	.00	976.2	1382.3	33.0	164.5	1250.8
SIGT=7.00 MR-2.5 MR TRACK	30000.	336.4	335.7	92.9	8.1	.00	977.4	1558.5	32.7	166.7	1424.5
SIGT=7.00 MR-5.0 MR TRACK	30000.	335.9	335.3	92.8	8.1	.00	977.2	1529.9	32.8	166.4	1396.3
SIGT=7.00 MR-10. MR TRACK	30000.	333.9	333.4	92.3	8.1	.00	976.2	1392.6	33.2	164.9	1260.9
SIGT=7.00 MR-2.5 MM DOWN	30000.	336.3	335.7	92.9	8.1	.00	977.4	1555.8	32.7	166.6	1421.9
SIGT=7.00 MR-5.0 MM DOWN	30000.	335.7	335.2	92.8	8.1	.00	977.1	1516.9	32.8	166.2	1383.5
SIGT=7.00 MR-10. MM DOWN	30000.	332.9	332.4	92.1	8.1	.00	975.8	1324.1	33.4	164.1	1193.4
SIGT=7.00 MR-2.5 MM UP	30000.	336.3	335.7	92.9	8.1	.00	977.4	1555.4	32.7	166.6	1421.5
SIGT=7.00 MR-5.0 MM UP	30000.	335.7	335.1	92.7	8.1	.00	977.1	1516.1	32.8	166.2	1382.7
SIGT=7.00 MR-10. MM UP	30000.	332.9	332.4	92.1	8.1	.00	975.7	1320.4	33.4	164.1	1189.7
SIGT=7.00 MR-2.5 MM LEFT	30000.	336.4	335.8	92.9	8.1	.00	977.5	1564.2	32.7	166.8	1430.1
SIGT=7.00 MR-5.0 MM LEFT	30000.	336.2	335.6	92.9	8.1	.00	977.4	1550.3	32.8	166.7	1416.4
SIGT=7.00 MR-10. MM LEFT	30000.	334.3	333.8	92.4	8.1	.00	976.5	1420.3	33.2	165.2	1288.2
SIGT=7.00 MR-TUBE ALIGNED	50000.	329.6	329.0	90.8	8.0	.00	1465.6	1567.4	32.6	160.3	1439.7
SIGT=9.00 MR-TUBE ALIGNED	50000.	329.1	328.5	90.7	8.0	.00	1465.2	1513.1	32.8	160.0	1385.9
SIGT=12.2 MR-TUBE ALIGNED	50000.	327.8	327.2	90.4	8.0	.00	1464.2	1382.3	33.0	159.0	1256.3
SIGT=7.00 MR-2.5 MR TRACK	50000.	329.5	328.9	90.8	8.0	.00	1465.6	1558.5	32.7	160.3	1430.9
SIGT=7.00 MR-5.0 MR TRACK	50000.	329.2	328.6	90.8	8.0	.00	1465.3	1529.9	32.8	160.2	1402.5
SIGT=7.00 MR-10. MR TRACK	50000.	327.9	327.3	90.5	8.0	.00	1464.3	1392.6	33.2	159.3	1266.5
SIGT=7.00 MR-2.5 MM DOWN	50000.	329.5	328.9	90.8	8.0	.00	1465.5	1555.8	32.7	160.3	1428.2
SIGT=7.00 MR-5.0 MM DOWN	50000.	329.1	328.5	90.7	8.0	.00	1465.2	1516.9	32.8	160.0	1389.7
SIGT=7.00 MR-10. MM DOWN	50000.	327.2	326.7	90.3	8.0	.00	1463.8	1324.1	33.4	158.9	1198.6
SIGT=7.00 MR-2.5 MM UP	50000.	329.5	328.9	90.8	8.0	.00	1465.5	1555.4	32.7	160.3	1427.8
SIGT=7.00 MR-5.0 MM UP	50000.	329.1	328.5	90.7	8.0	.00	1465.2	1516.1	32.8	160.0	1388.9
SIGT=7.00 MR-10. MM UP	50000.	327.1	326.6	90.3	8.0	.00	1463.7	1320.4	33.4	158.8	1195.0
SIGT=7.00 MR-2.5 MM LEFT	50000.	329.6	329.0	90.8	8.0	.00	1465.6	1564.2	32.7	160.4	1436.5
SIGT=7.00 MR-5.0 MM LEFT	50000.	329.4	328.8	90.8	8.0	.00	1465.5	1550.3	32.8	160.3	1422.7
SIGT=7.00 MR-10. MM LEFT	50000.	328.1	327.6	90.6	8.0	.00	1464.5	1420.3	33.2	159.5	1294.0
SIGT=7.00 MR-TUBE ALIGNED	70000.	326.3	325.7	89.8	8.0	.00	1914.9	1567.4	32.6	157.4	1442.6
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.9	325.3	89.8	8.0	.00	1914.5	1513.1	32.8	157.2	1388.7
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.9	324.4	89.5	8.0	.00	1913.4	1382.3	33.0	156.5	1258.8
SIGT=7.00 MR-2.5 MR TRACK	70000.	326.3	325.7	89.9	8.0	.00	1914.8	1558.5	32.7	157.4	1433.8
SIGT=7.00 MR-5.0 MR TRACK	70000.	326.1	325.4	89.8	8.0	.00	1914.6	1529.9	32.8	157.3	1405.4
SIGT=7.00 MR-10. MR TRACK	70000.	325.0	324.4	89.6	8.0	.00	1913.5	1392.6	33.2	156.7	1269.1
SIGT=7.00 MR-2.5 MM DOWN	70000.	326.3	325.6	89.8	8.0	.00	1914.8	1555.8	32.7	157.4	1431.1
SIGT=7.00 MR-5.0 MM DOWN	70000.	326.0	325.4	89.8	8.0	.00	1914.5	1516.9	32.8	157.2	1392.5
SIGT=7.00 MR-10. MM DOWN	70000.	324.5	323.9	89.5	8.0	.00	1912.9	1324.1	33.4	156.4	1201.1
SIGT=7.00 MR-2.5 MM UP	70000.	326.3	325.6	89.8	8.0	.00	1914.8	1555.4	32.7	157.4	1430.7
SIGT=7.00 MR-5.0 MM UP	70000.	325.9	325.3	89.8	8.0	.00	1914.5	1516.1	32.8	157.2	1391.7
SIGT=7.00 MR-10. MM UP	70000.	324.4	323.9	89.5	8.0	.00	1912.9	1320.4	33.4	156.4	1197.4
SIGT=7.00 MR-2.5 MM LEFT	70000.	326.3	325.7	89.9	8.0	.00	1914.9	1564.2	32.7	157.4	1439.5
SIGT=7.00 MR-5.0 MM LEFT	70000.	326.2	325.6	89.9	8.0	.00	1914.8	1550.3	32.8	157.4	1425.7
SIGT=7.00 MR-10. MM LEFT	70000.	325.2	324.6	89.7	8.0	.00	1913.7	1420.3	33.2	156.9	1296.6

Table B-VI. 1-D Thermal Model Results - Annular Space Maintained at Atmospheric Pressure and Ambient Temperature of 25 C

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES		GLASS TEMP.	CONVECTION COEFFICIENTS			ABSORBED SOLAR ENERGY		RECEIVER HEAT LOSS	ENERGY ABSORBED BY FLUID
		I.D.	O.D.		HAIR	HGAP	HFLUID	QTUBE	QGLASS		
	(--)	(C)	(C)	(C)	(UNITS OF W/M**2-C)			(W)	(W)	(W)	(W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	360.3	359.7	133.8	9.1	6.96	411.4	1567.4	32.6	307.5	1292.5
SIGT=9.00 MR-TUBE ALIGNED	10000.	358.5	358.0	133.1	9.1	6.95	410.9	1513.1	32.8	305.0	1240.9
SIGT=12.2 MR-TUBE ALIGNED	10000.	354.3	353.8	131.5	9.1	6.91	409.8	1382.3	33.0	298.9	1116.4
SIGT=7.00 MR-2.5 MR TRACK	10000.	360.0	359.4	133.7	9.1	6.96	411.3	1558.5	32.7	307.1	1284.1
SIGT=7.00 MR-5.0 MR TRACK	10000.	359.1	358.5	133.3	9.1	6.95	411.1	1529.9	32.8	305.8	1256.9
SIGT=7.00 MR-10. MR TRACK	10000.	354.6	354.1	131.7	9.1	6.91	409.9	1392.6	33.2	299.5	1126.3
SIGT=7.00 MR-2.5 MM DOWN	10000.	359.9	359.4	133.6	9.1	6.96	411.3	1555.8	32.7	307.0	1281.5
SIGT=7.00 MR-5.0 MM DOWN	10000.	358.6	358.1	133.2	9.1	6.95	410.9	1516.9	32.8	305.2	1244.5
SIGT=7.00 MR-10. MM DOWN	10000.	352.4	351.9	130.9	9.0	6.90	409.3	1334.1	33.4	296.4	1061.1
SIGT=7.00 MR-2.5 MM UP	10000.	359.9	359.3	133.6	9.1	6.96	411.3	1555.8	32.7	307.0	1281.1
SIGT=7.00 MR-5.0 MM UP	10000.	358.6	358.1	133.2	9.1	6.95	410.9	1516.1	32.8	305.2	1243.7
SIGT=7.00 MR-10. MM UP	10000.	352.2	351.8	130.8	9.0	6.89	409.3	1330.4	33.4	296.2	1057.6
SIGT=7.00 MR-2.5 MM LEFT	10000.	360.2	359.6	133.8	9.1	6.96	411.4	1564.2	32.7	307.4	1289.5
SIGT=7.00 MR-5.0 MM LEFT	10000.	359.7	359.2	133.5	9.1	6.96	411.3	1550.3	32.8	306.8	1276.3
SIGT=7.00 MR-10. MM LEFT	10000.	355.5	355.0	132.0	9.1	6.92	410.1	1420.3	33.2	300.9	1152.6
SIGT=7.00 MR-TUBE ALIGNED	30000.	334.9	334.4	124.0	8.9	6.75	976.7	1567.4	32.6	271.0	1329.0
SIGT=9.00 MR-TUBE ALIGNED	30000.	334.1	333.6	123.8	8.9	6.74	976.4	1513.1	32.8	270.1	1278.8
SIGT=12.2 MR-TUBE ALIGNED	30000.	332.2	331.7	123.1	8.9	6.72	975.4	1382.3	33.0	267.6	1147.7
SIGT=7.00 MR-2.5 MR TRACK	30000.	334.8	334.2	124.0	8.9	6.75	976.7	1558.5	32.7	270.9	1320.3
SIGT=7.00 MR-5.0 MR TRACK	30000.	334.4	333.8	123.9	8.9	6.74	976.5	1529.9	32.8	270.4	1292.3
SIGT=7.00 MR-10. MR TRACK	30000.	332.4	331.9	123.2	8.9	6.73	975.5	1392.6	33.2	268.0	1157.8
SIGT=7.00 MR-2.5 MM DOWN	30000.	334.8	334.2	124.0	8.9	6.75	976.7	1555.8	32.7	270.8	1317.7
SIGT=7.00 MR-5.0 MM DOWN	30000.	334.2	333.7	123.8	8.9	6.74	976.4	1516.9	32.8	270.2	1279.5
SIGT=7.00 MR-10. MM DOWN	30000.	331.4	330.9	122.9	8.9	6.72	975.0	1334.1	33.4	266.8	1090.7
SIGT=7.00 MR-2.5 MM UP	30000.	334.8	334.2	124.0	8.9	6.75	976.7	1555.8	32.7	270.8	1317.3
SIGT=7.00 MR-5.0 MM UP	30000.	334.2	333.6	123.8	8.9	6.74	976.4	1516.1	32.8	270.1	1278.8
SIGT=7.00 MR-10. MM UP	30000.	331.3	330.9	122.8	8.9	6.72	975.0	1330.4	33.4	266.7	1087.1
SIGT=7.00 MR-2.5 MM LEFT	30000.	334.9	334.3	124.0	8.9	6.75	976.7	1564.2	32.7	271.0	1325.9
SIGT=7.00 MR-5.0 MM LEFT	30000.	334.7	334.1	124.0	8.9	6.75	976.6	1550.3	32.8	270.8	1312.3
SIGT=7.00 MR-10. MM LEFT	30000.	332.8	332.3	123.3	8.9	6.73	975.7	1420.3	33.2	268.6	1184.9
SIGT=7.00 MR-TUBE ALIGNED	50000.	328.6	328.0	121.6	8.8	6.69	1464.8	1567.4	32.6	262.3	1337.7
SIGT=9.00 MR-TUBE ALIGNED	50000.	328.0	327.5	121.5	8.8	6.69	1464.4	1513.1	32.8	261.8	1284.1
SIGT=12.2 MR-TUBE ALIGNED	50000.	326.7	326.2	121.0	8.8	6.68	1463.4	1382.3	33.0	260.2	1155.1
SIGT=7.00 MR-2.5 MR TRACK	50000.	328.5	327.9	121.6	8.8	6.69	1464.8	1558.5	32.7	262.3	1328.9
SIGT=7.00 MR-5.0 MR TRACK	50000.	328.2	327.6	121.5	8.8	6.69	1464.6	1529.9	32.8	262.0	1300.7
SIGT=7.00 MR-10. MR TRACK	50000.	326.8	326.3	121.1	8.8	6.68	1463.5	1392.6	33.2	260.5	1165.3
SIGT=7.00 MR-2.5 MM DOWN	50000.	328.5	327.9	121.6	8.8	6.69	1464.8	1555.8	32.7	262.3	1326.2
SIGT=7.00 MR-5.0 MM DOWN	50000.	328.1	327.5	121.5	8.8	6.69	1464.5	1516.9	32.8	261.8	1287.9
SIGT=7.00 MR-10. MM DOWN	50000.	326.2	325.7	120.9	8.8	6.67	1463.0	1334.1	33.4	259.7	1097.8
SIGT=7.00 MR-2.5 MM UP	50000.	328.5	327.9	121.6	8.8	6.69	1464.8	1555.8	32.7	262.3	1325.8
SIGT=7.00 MR-5.0 MM UP	50000.	328.1	327.5	121.5	8.8	6.69	1464.5	1516.1	32.8	261.8	1287.1
SIGT=7.00 MR-10. MM UP	50000.	326.1	325.6	120.9	8.8	6.67	1462.9	1320.4	33.4	259.7	1094.1
SIGT=7.00 MR-2.5 MM LEFT	50000.	328.5	328.0	121.6	8.8	6.69	1464.8	1564.2	32.7	262.4	1334.5
SIGT=7.00 MR-5.0 MM LEFT	50000.	328.4	327.8	121.6	8.8	6.69	1464.7	1550.3	32.8	262.3	1320.8
SIGT=7.00 MR-10. MM LEFT	50000.	327.1	326.6	121.2	8.8	6.68	1463.7	1420.3	33.2	260.9	1192.6
SIGT=7.00 MR-TUBE ALIGNED	70000.	325.6	325.0	120.5	8.8	6.67	1314.1	1567.4	32.6	258.3	1341.7
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.1	324.6	120.4	8.8	6.66	1913.7	1513.1	32.8	257.9	1286.0
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.1	323.6	120.1	8.8	6.66	1912.6	1382.3	33.0	256.7	1158.6
SIGT=7.00 MR-2.5 MR TRACK	70000.	325.5	324.9	120.5	8.8	6.67	1914.0	1558.5	32.7	258.3	1332.9
SIGT=7.00 MR-5.0 MR TRACK	70000.	325.3	324.7	120.4	8.8	6.67	1913.8	1529.9	32.8	258.1	1304.6
SIGT=7.00 MR-10. MR TRACK	70000.	324.2	323.7	120.1	8.8	6.66	1912.7	1392.6	33.2	257.0	1168.8
SIGT=7.00 MR-2.5 MM DOWN	70000.	325.5	324.9	120.5	8.8	6.67	1914.0	1555.8	32.7	258.3	1330.2
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.2	324.6	120.4	8.8	6.66	1913.7	1516.9	32.8	257.9	1291.8
SIGT=7.00 MR-10. MM DOWN	70000.	323.7	323.2	120.0	8.8	6.65	1912.1	1334.1	33.4	256.5	1101.1
SIGT=7.00 MR-2.5 MM UP	70000.	325.5	324.9	120.5	8.8	6.67	1914.0	1555.8	32.7	258.3	1329.9
SIGT=7.00 MR-5.0 MM UP	70000.	325.2	324.6	120.4	8.8	6.66	1913.7	1516.1	32.8	257.9	1291.0
SIGT=7.00 MR-10. MM UP	70000.	323.6	323.2	120.0	8.8	6.65	1912.1	1320.4	33.4	256.4	1097.4
SIGT=7.00 MR-2.5 MM LEFT	70000.	325.5	325.0	120.5	8.8	6.67	1914.1	1564.2	32.7	258.3	1338.6
SIGT=7.00 MR-5.0 MM LEFT	70000.	325.4	324.9	120.5	8.8	6.67	1913.9	1550.3	32.8	258.3	1324.8
SIGT=7.00 MR-10. MM LEFT	70000.	324.4	323.9	120.2	8.8	6.66	1912.9	1420.3	33.2	257.3	1196.2

Table B-VII. 1-D Thermal Model Results - Annular Space Evacuated and Ambient Temperature of 50 C

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	364.2	363.6	118.9	8.1	.00	412.7	1567.4	32.6	190.4	1409.6
SIGT=9.00 MR-TUBE ALIGNED	10000.	362.5	361.9	118.4	8.1	.00	412.1	1513.1	32.8	188.7	1357.2
SIGT=12.2 MR-TUBE ALIGNED	10000.	358.2	357.7	117.1	8.1	.00	410.8	1382.3	33.0	184.4	1230.9
SIGT=7.00 MR-2.5 MR TRACK	10000.	363.9	363.3	118.8	8.1	.00	412.6	1568.5	32.7	190.2	1401.0
SIGT=7.00 MR-5.0 MR TRACK	10000.	363.0	362.4	118.6	8.1	.00	412.3	1529.9	32.8	189.3	1373.4
SIGT=7.00 MR-10. MR TRACK	10000.	358.5	358.0	117.3	8.1	.00	410.9	1392.6	33.2	184.9	1240.8
SIGT=7.00 MR-2.5 MM DOWN	10000.	363.9	363.3	118.8	8.1	.00	412.5	1565.8	32.7	190.1	1398.4
SIGT=7.00 MR-5.0 MM DOWN	10000.	362.6	362.0	118.4	8.1	.00	412.1	1516.9	32.8	188.7	1360.8
SIGT=7.00 MR-10. MM DOWN	10000.	356.3	355.8	116.6	8.1	.00	410.3	1324.1	33.4	182.8	1174.7
SIGT=7.00 MR-2.5 MM UP	10000.	363.8	363.2	118.8	8.1	.00	412.5	1565.4	32.7	190.1	1398.0
SIGT=7.00 MR-5.0 MM UP	10000.	362.6	362.0	118.4	8.1	.00	412.1	1516.1	32.8	188.8	1360.0
SIGT=7.00 MR-10. MM UP	10000.	356.1	355.6	116.6	8.1	.00	410.3	1320.4	33.4	182.7	1171.1
SIGT=7.00 MR-2.5 MM LEFT	10000.	364.1	363.5	118.9	8.1	.00	412.6	1564.2	32.7	190.4	1406.5
SIGT=7.00 MR-5.0 MM LEFT	10000.	363.7	363.1	118.8	8.1	.00	412.5	1550.3	32.8	190.0	1393.1
SIGT=7.00 MR-10. MM LEFT	10000.	359.4	358.9	117.5	8.1	.00	411.2	1420.3	33.2	185.9	1267.6
SIGT=7.00 MR-TUBE ALIGNED	30000.	336.5	335.9	110.5	7.9	.00	977.5	1567.4	32.6	162.6	1437.4
SIGT=9.00 MR-TUBE ALIGNED	30000.	335.8	335.2	110.4	7.9	.00	977.1	1513.1	32.8	162.1	1383.8
SIGT=12.2 MR-TUBE ALIGNED	30000.	333.8	333.3	109.9	7.8	.00	976.2	1382.3	33.0	160.5	1254.8
SIGT=7.00 MR-2.5 MR TRACK	30000.	336.4	335.9	110.5	7.9	.00	977.5	1568.5	32.7	162.6	1426.6
SIGT=7.00 MR-5.0 MR TRACK	30000.	336.0	335.4	110.5	7.9	.00	977.3	1529.9	32.8	162.3	1400.4
SIGT=7.00 MR-10. MR TRACK	30000.	334.0	333.4	110.0	7.8	.00	976.3	1392.6	33.2	160.8	1265.0
SIGT=7.00 MR-2.5 MM DOWN	30000.	336.4	335.8	110.5	7.9	.00	977.5	1565.8	32.7	162.6	1423.9
SIGT=7.00 MR-5.0 MM DOWN	30000.	335.8	335.2	110.4	7.9	.00	977.2	1516.9	32.8	162.1	1387.6
SIGT=7.00 MR-10. MM DOWN	30000.	333.0	332.5	109.8	7.8	.00	976.8	1324.1	33.4	160.0	1197.5
SIGT=7.00 MR-2.5 MM UP	30000.	336.4	335.8	110.5	7.9	.00	977.4	1565.4	32.7	162.6	1425.5
SIGT=7.00 MR-5.0 MM UP	30000.	335.8	335.2	110.4	7.9	.00	977.2	1516.1	32.8	162.1	1386.8
SIGT=7.00 MR-10. MM UP	30000.	332.9	332.4	109.8	7.8	.00	976.8	1320.4	33.4	160.0	1193.6
SIGT=7.00 MR-2.5 MM LEFT	30000.	336.5	335.9	110.5	7.9	.00	977.5	1564.2	32.7	162.7	1434.2
SIGT=7.00 MR-5.0 MM LEFT	30000.	336.3	335.7	110.5	7.9	.00	977.4	1550.3	32.8	162.6	1420.5
SIGT=7.00 MR-10. MM LEFT	30000.	334.4	333.8	110.1	7.9	.00	976.5	1420.3	33.2	161.2	1292.3
SIGT=7.00 MR-TUBE ALIGNED	50000.	329.6	329.0	108.6	7.8	.00	1463.7	1567.4	32.6	156.2	1443.8
SIGT=9.00 MR-TUBE ALIGNED	50000.	329.1	328.5	108.5	7.8	.00	1462.2	1513.1	32.8	155.9	1390.0
SIGT=12.2 MR-TUBE ALIGNED	50000.	327.8	327.3	108.2	7.8	.00	1464.2	1382.3	33.0	154.9	1260.4
SIGT=7.00 MR-2.5 MR TRACK	50000.	329.6	329.0	108.6	7.8	.00	1465.6	1568.5	32.7	156.3	1434.9
SIGT=7.00 MR-5.0 MR TRACK	50000.	329.3	328.7	108.5	7.8	.00	1465.4	1529.9	32.8	156.1	1406.6
SIGT=7.00 MR-10. MR TRACK	50000.	327.9	327.4	108.3	7.8	.00	1464.3	1392.6	33.2	155.2	1278.6
SIGT=7.00 MR-2.5 MM DOWN	50000.	329.5	328.9	108.5	7.8	.00	1465.6	1565.8	32.7	156.2	1432.3
SIGT=7.00 MR-5.0 MM DOWN	50000.	329.1	328.5	108.5	7.8	.00	1465.3	1516.9	32.8	156.0	1393.7
SIGT=7.00 MR-10. MM DOWN	50000.	327.2	326.7	108.1	7.8	.00	1463.8	1324.1	33.4	154.8	1202.7
SIGT=7.00 MR-2.5 MM UP	50000.	329.5	328.9	108.5	7.8	.00	1465.6	1565.4	32.7	156.2	1431.9
SIGT=7.00 MR-5.0 MM UP	50000.	329.1	328.5	108.5	7.8	.00	1465.3	1516.1	32.8	156.0	1392.9
SIGT=7.00 MR-10. MM UP	50000.	327.2	326.7	108.1	7.8	.00	1463.8	1320.4	33.4	154.8	1199.8
SIGT=7.00 MR-2.5 MM LEFT	50000.	329.6	329.0	108.6	7.8	.00	1465.6	1564.2	32.7	156.3	1440.6
SIGT=7.00 MR-5.0 MM LEFT	50000.	329.5	328.9	108.6	7.8	.00	1465.5	1550.3	32.8	156.3	1426.8
SIGT=7.00 MR-10. MM LEFT	50000.	328.2	327.6	108.4	7.8	.00	1464.5	1420.3	33.2	155.5	1298.0
SIGT=7.00 MR-TUBE ALIGNED	70000.	326.4	325.8	107.7	7.8	.00	1914.9	1567.4	32.6	153.3	1446.7
SIGT=9.00 MR-TUBE ALIGNED	70000.	326.0	325.4	107.6	7.8	.00	1914.5	1513.1	32.8	153.1	1392.8
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.9	324.4	107.4	7.8	.00	1913.4	1382.3	33.0	152.4	1262.9
SIGT=7.00 MR-2.5 MR TRACK	70000.	326.3	325.7	107.7	7.8	.00	1914.9	1568.5	32.7	153.3	1437.9
SIGT=7.00 MR-5.0 MR TRACK	70000.	326.1	325.5	107.7	7.8	.00	1914.6	1529.9	32.8	153.2	1409.5
SIGT=7.00 MR-10. MR TRACK	70000.	325.0	324.5	107.5	7.8	.00	1913.5	1392.6	33.2	152.7	1275.1
SIGT=7.00 MR-2.5 MM DOWN	70000.	326.3	325.7	107.7	7.8	.00	1914.8	1565.8	32.7	153.3	1436.2
SIGT=7.00 MR-5.0 MM DOWN	70000.	326.0	325.4	107.6	7.8	.00	1914.5	1516.9	32.8	153.1	1396.6
SIGT=7.00 MR-10. MM DOWN	70000.	324.5	324.0	107.4	7.8	.00	1913.0	1324.1	33.4	152.0	1206.1
SIGT=7.00 MR-2.5 MM UP	70000.	326.3	325.7	107.7	7.8	.00	1914.8	1565.4	32.7	153.3	1434.8
SIGT=7.00 MR-5.0 MM UP	70000.	326.0	325.4	107.6	7.8	.00	1914.5	1516.1	32.8	153.1	1395.8
SIGT=7.00 MR-10. MM UP	70000.	324.5	323.9	107.4	7.8	.00	1912.9	1320.4	33.4	152.0	1205.5
SIGT=7.00 MR-2.5 MM LEFT	70000.	326.4	325.7	107.7	7.8	.00	1914.9	1564.2	32.7	153.4	1443.5
SIGT=7.00 MR-5.0 MM LEFT	70000.	326.2	325.6	107.7	7.8	.00	1914.8	1550.3	32.8	153.3	1429.7
SIGT=7.00 MR-10. MM LEFT	70000.	325.0	324.4	107.5	7.8	.00	1913.8	1420.3	33.2	152.8	1300.7

Table B-VIII. 1-D Thermal Model Results - Annular Space Maintained at Atmospheric Pressure and Ambient Temperature of 50 C

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
	(--)										
SIGT=7.00 MR-TUBE ALIGNED	10000.	360.7	360.1	147.4	8.9	6.96	411.5	1567.4	32.6	296.3	1303.7
SIGT=9.00 MR-TUBE ALIGNED	10000.	358.9	358.4	146.8	8.9	6.95	411.0	1513.1	32.8	293.8	1252.0
SIGT=12.2 MR-TUBE ALIGNED	10000.	354.6	354.2	145.2	8.8	6.91	409.9	1382.3	33.0	287.7	1127.6
SIGT=7.00 MR-2.5 MR TRACK	10000.	360.4	359.8	147.3	8.9	6.96	411.4	1558.5	32.7	296.0	1295.2
SIGT=7.00 MR-5.0 MR TRACK	10000.	359.4	358.9	147.0	8.9	6.95	411.2	1529.9	32.8	294.7	1266.0
SIGT=7.00 MR-10. MR TRACK	10000.	355.0	354.5	145.4	8.9	6.92	410.0	1392.6	33.2	288.4	1137.4
SIGT=7.00 MR-2.5 MM DOWN	10000.	360.3	359.7	147.3	8.9	6.96	411.4	1555.8	32.7	295.8	1292.7
SIGT=7.00 MR-5.0 MM DOWN	10000.	359.3	358.8	146.9	8.9	6.95	411.1	1526.9	32.8	294.3	1263.7
SIGT=7.00 MR-10. MM DOWN	10000.	352.7	352.3	144.6	8.8	6.90	409.4	1329.1	33.4	285.2	1072.3
SIGT=7.00 MR-2.5 MM UP	10000.	360.3	359.7	147.3	8.9	6.96	411.4	1555.4	32.7	295.8	1292.3
SIGT=7.00 MR-5.0 MM UP	10000.	359.0	358.5	146.8	8.9	6.95	411.0	1516.1	32.8	294.0	1254.9
SIGT=7.00 MR-10. MM UP	10000.	352.6	352.2	144.6	8.8	6.90	409.4	1328.4	33.4	285.1	1066.7
SIGT=7.00 MR-2.5 MM LEFT	10000.	360.6	360.0	147.4	8.9	6.96	411.5	1564.2	32.7	296.2	1300.7
SIGT=7.00 MR-5.0 MM LEFT	10000.	360.1	359.6	147.2	8.9	6.96	411.4	1550.3	32.8	295.6	1287.4
SIGT=7.00 MR-10. MM LEFT	10000.	355.9	355.4	145.7	8.9	6.92	410.2	1420.3	33.2	289.7	1163.6
SIGT=7.00 MR-TUBE ALIGNED	30000.	335.1	334.5	138.0	8.5	6.75	976.8	1567.4	32.6	259.6	1340.4
SIGT=9.00 MR-TUBE ALIGNED	30000.	334.3	333.8	137.8	8.5	6.74	976.4	1513.1	32.8	258.7	1287.2
SIGT=12.2 MR-TUBE ALIGNED	30000.	332.4	331.9	137.1	8.5	6.73	975.5	1382.3	33.0	256.3	1159.0
SIGT=7.00 MR-2.5 MR TRACK	30000.	335.0	334.4	138.0	8.5	6.75	976.8	1558.5	32.7	259.5	1331.7
SIGT=7.00 MR-5.0 MR TRACK	30000.	334.6	334.0	137.9	8.5	6.74	976.6	1529.9	32.8	259.0	1303.7
SIGT=7.00 MR-10. MR TRACK	30000.	332.6	332.1	137.2	8.5	6.73	975.6	1392.6	33.2	256.6	1176.2
SIGT=7.00 MR-2.5 MM DOWN	30000.	334.9	334.4	138.0	8.5	6.75	976.7	1555.8	32.7	259.5	1329.0
SIGT=7.00 MR-5.0 MM DOWN	30000.	334.4	333.8	137.8	8.5	6.74	976.5	1516.9	32.8	258.8	1290.9
SIGT=7.00 MR-10. MM DOWN	30000.	331.6	331.1	136.9	8.5	6.72	975.1	1324.1	33.4	255.4	1102.1
SIGT=7.00 MR-2.5 MM UP	30000.	334.9	334.4	138.0	8.5	6.75	976.7	1555.4	32.7	259.5	1328.6
SIGT=7.00 MR-5.0 MM UP	30000.	334.4	333.8	137.8	8.5	6.74	976.5	1516.1	32.8	258.8	1290.1
SIGT=7.00 MR-10. MM UP	30000.	331.5	331.0	136.9	8.5	6.72	975.0	1320.4	33.4	255.4	1098.4
SIGT=7.00 MR-2.5 MM LEFT	30000.	335.1	334.5	138.0	8.5	6.75	976.8	1564.2	32.7	259.6	1337.3
SIGT=7.00 MR-5.0 MM LEFT	30000.	334.9	334.3	138.0	8.5	6.75	976.7	1550.3	32.8	259.4	1323.7
SIGT=7.00 MR-10. MM LEFT	30000.	333.0	332.5	137.4	8.5	6.73	975.8	1420.3	33.2	257.2	1196.3
SIGT=7.00 MR-TUBE ALIGNED	50000.	328.7	328.1	135.7	8.5	6.69	1464.9	1567.4	32.6	250.9	1349.1
SIGT=9.00 MR-TUBE ALIGNED	50000.	328.1	327.6	135.6	8.5	6.69	1464.5	1513.1	32.8	250.4	1295.5
SIGT=12.2 MR-TUBE ALIGNED	50000.	326.8	326.3	135.1	8.6	6.68	1463.5	1382.3	33.0	248.8	1166.5
SIGT=7.00 MR-2.5 MR TRACK	50000.	328.6	328.0	135.7	8.5	6.69	1464.9	1558.5	32.7	250.9	1340.3
SIGT=7.00 MR-5.0 MR TRACK	50000.	328.3	327.8	135.6	8.5	6.69	1464.6	1529.9	32.8	250.6	1312.1
SIGT=7.00 MR-10. MR TRACK	50000.	327.0	326.4	135.2	8.5	6.68	1463.6	1392.6	33.2	249.1	1176.7
SIGT=7.00 MR-2.5 MM DOWN	50000.	328.6	328.0	135.7	8.5	6.69	1464.8	1555.8	32.7	250.8	1337.7
SIGT=7.00 MR-5.0 MM DOWN	50000.	328.2	327.6	135.6	8.5	6.69	1464.5	1516.9	32.8	250.4	1299.3
SIGT=7.00 MR-10. MM DOWN	50000.	326.3	325.8	135.0	8.5	6.67	1463.0	1324.1	33.4	248.3	1109.2
SIGT=7.00 MR-2.5 MM UP	50000.	328.5	328.0	135.7	8.6	6.69	1464.8	1555.4	32.7	250.8	1337.3
SIGT=7.00 MR-5.0 MM UP	50000.	328.2	327.6	135.6	8.5	6.69	1464.5	1516.1	32.8	250.4	1298.5
SIGT=7.00 MR-10. MM UP	50000.	326.2	325.8	135.0	8.6	6.67	1463.0	1320.4	33.4	248.3	1105.5
SIGT=7.00 MR-2.5 MM LEFT	50000.	328.7	328.1	135.7	8.5	6.69	1464.9	1564.2	32.7	251.0	1345.9
SIGT=7.00 MR-5.0 MM LEFT	50000.	328.5	327.9	135.7	8.5	6.69	1464.8	1550.3	32.8	250.9	1332.8
SIGT=7.00 MR-10. MM LEFT	50000.	327.2	326.7	135.3	8.5	6.68	1463.8	1420.3	33.2	249.5	1204.0
SIGT=7.00 MR-TUBE ALIGNED	70000.	325.6	325.1	134.5	8.5	6.67	1914.2	1567.4	32.6	246.9	1353.1
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.2	324.7	134.5	8.5	6.66	1913.7	1513.1	32.8	246.5	1299.4
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.2	323.7	134.2	8.5	6.66	1912.7	1382.3	33.0	245.3	1170.0
SIGT=7.00 MR-2.5 MR TRACK	70000.	325.6	325.0	134.6	8.5	6.67	1914.1	1558.5	32.7	246.6	1345.4
SIGT=7.00 MR-5.0 MR TRACK	70000.	325.4	324.8	134.6	8.5	6.67	1913.9	1529.9	32.8	246.6	1316.1
SIGT=7.00 MR-10. MR TRACK	70000.	324.3	323.8	134.3	8.5	6.66	1912.8	1392.6	33.2	245.5	1180.2
SIGT=7.00 MR-2.5 MM DOWN	70000.	325.6	325.0	134.6	8.5	6.67	1914.1	1555.8	32.7	246.8	1341.7
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.3	324.7	134.5	8.5	6.66	1913.8	1516.9	32.8	246.5	1303.2
SIGT=7.00 MR-10. MM DOWN	70000.	323.8	323.3	134.1	8.5	6.65	1912.2	1324.1	33.4	245.0	1112.5
SIGT=7.00 MR-2.5 MM UP	70000.	325.6	325.0	134.6	8.5	6.67	1914.1	1555.4	32.7	246.8	1341.3
SIGT=7.00 MR-5.0 MM UP	70000.	325.2	324.7	134.5	8.5	6.66	1913.8	1516.1	32.8	246.5	1302.4
SIGT=7.00 MR-10. MM UP	70000.	323.7	323.3	134.1	8.5	6.65	1912.2	1320.4	33.4	245.0	1110.8
SIGT=7.00 MR-2.5 MM LEFT	70000.	325.6	325.0	134.6	8.5	6.67	1914.2	1564.2	32.7	246.9	1350.0
SIGT=7.00 MR-5.0 MM LEFT	70000.	325.5	324.9	134.6	8.5	6.67	1914.0	1550.3	32.8	246.8	1336.3
SIGT=7.00 MR-10. MM LEFT	70000.	324.5	324.0	134.3	8.5	6.66	1913.0	1420.3	33.2	245.8	1207.7

APPENDIX C

ONE-DIMENSIONAL THERMAL MODEL RESULTS FOR VARIED WIND CONDITIONS

One-dimensional thermal modeling results are presented in tabulated form for four wind velocity (0, 2.5, 5.0, and 10.0 m/s) and two annulus gas pressure conditions (10^5 Pa and 10^{-3} Pa). All other conditions modeled in this work are fixed by Table I. A summary of the tabulated results is given below.

Wind Velocity (m/s)	Table Presenting Results	
	Evacuated (10^{-3} Pa)	Atmospheric Pressure (10^5 Pa)
0.0	B-V	B-VI
2.5	C-I	C-II
5.0	C-III	C-IV
10.0	C-V	C-VI

Table C-I. 1-D Thermal Model Results - Annular Space Evacuated and Wind Velocity of 2.5 m/s

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	363.9	363.3	68.1	23.4	.00	412.5	1567.4	32.6	201.2	1398.7
SIGT=9.00 MR-TUBE ALIGNED	10000.	362.1	361.5	67.7	23.4	.00	412.0	1513.1	32.8	199.5	1346.4
SIGT=12.2 MR-TUBE ALIGNED	10000.	357.8	357.3	66.7	23.4	.00	410.7	1382.3	33.0	195.0	1220.3
SIGT=7.00 MR-2.5 MR TRACK	10000.	363.6	363.0	68.0	23.4	.00	412.4	1558.5	32.7	201.0	1390.2
SIGT=7.00 MR-5.0 MR TRACK	10000.	362.7	362.1	67.8	23.4	.00	412.1	1529.9	32.8	200.1	1362.6
SIGT=7.00 MR-10. MR TRACK	10000.	358.2	357.6	66.9	23.4	.00	410.8	1392.6	33.2	195.6	1230.2
SIGT=7.00 MR-2.5 MM DOWN	10000.	363.5	362.9	68.0	23.4	.00	412.4	1555.8	32.7	200.9	1387.6
SIGT=7.00 MR-5.0 MM DOWN	10000.	362.2	361.6	67.7	23.4	.00	412.0	1516.9	32.8	199.6	1350.1
SIGT=7.00 MR-10. MM DOWN	10000.	355.9	355.4	66.4	23.4	.00	410.2	1324.1	33.4	193.3	1164.2
SIGT=7.00 MR-2.5 MM UP	10000.	363.5	362.9	68.0	23.4	.00	412.4	1555.4	32.7	200.9	1387.2
SIGT=7.00 MR-5.0 MM UP	10000.	362.2	361.6	67.7	23.4	.00	412.0	1516.1	32.8	199.6	1349.3
SIGT=7.00 MR-10. MM UP	10000.	355.8	355.3	66.4	23.4	.00	410.2	1320.4	33.4	193.2	1160.6
SIGT=7.00 MR-2.5 MM LEFT	10000.	363.8	363.2	68.1	23.4	.00	412.5	1564.2	32.7	201.2	1395.7
SIGT=7.00 MR-5.0 MM LEFT	10000.	363.3	362.7	68.0	23.4	.00	412.4	1550.3	32.8	200.8	1382.3
SIGT=7.00 MR-10. MM LEFT	10000.	359.1	358.5	67.1	23.4	.00	411.1	1420.3	33.2	196.5	1256.9
SIGT=7.00 MR-TUBE ALIGNED	30000.	336.4	335.8	62.0	23.4	.00	977.5	1567.4	32.6	172.6	1427.5
SIGT=9.00 MR-TUBE ALIGNED	30000.	335.6	335.0	61.9	23.4	.00	977.1	1513.1	32.8	172.0	1374.0
SIGT=12.2 MR-TUBE ALIGNED	30000.	333.7	333.2	61.5	23.5	.00	976.1	1382.3	33.0	170.3	1245.0
SIGT=7.00 MR-2.5 MR TRACK	30000.	336.3	335.7	62.0	23.4	.00	977.4	1558.5	32.7	172.6	1418.7
SIGT=7.00 MR-5.0 MR TRACK	30000.	335.9	335.3	61.9	23.4	.00	977.2	1529.9	32.8	172.2	1390.5
SIGT=7.00 MR-10. MR TRACK	30000.	333.8	333.3	61.6	23.5	.00	976.2	1392.6	33.2	170.7	1255.2
SIGT=7.00 MR-2.5 MM DOWN	30000.	336.2	335.6	62.0	23.4	.00	977.4	1555.8	32.7	172.5	1416.0
SIGT=7.00 MR-5.0 MM DOWN	30000.	335.7	335.1	61.9	23.4	.00	977.1	1516.9	32.8	172.1	1377.7
SIGT=7.00 MR-10. MM DOWN	30000.	332.8	332.3	61.4	23.5	.00	975.7	1324.1	33.4	169.9	1187.7
SIGT=7.00 MR-2.5 MM UP	30000.	336.2	335.6	62.0	23.4	.00	977.4	1555.4	32.7	172.5	1415.7
SIGT=7.00 MR-5.0 MM UP	30000.	335.7	335.1	61.9	23.4	.00	977.1	1516.1	32.8	172.0	1376.9
SIGT=7.00 MR-10. MM UP	30000.	332.8	332.3	61.4	23.5	.00	975.7	1320.4	33.4	169.9	1184.0
SIGT=7.00 MR-2.5 MM LEFT	30000.	336.4	335.7	62.0	23.4	.00	977.4	1564.2	32.7	172.6	1424.3
SIGT=7.00 MR-5.0 MM LEFT	30000.	336.2	335.6	62.0	23.4	.00	977.3	1550.3	32.8	172.5	1410.6
SIGT=7.00 MR-10. MM LEFT	30000.	334.2	333.7	61.7	23.4	.00	976.4	1420.3	33.2	171.1	1282.5
SIGT=7.00 MR-TUBE ALIGNED	50000.	329.5	328.9	60.6	23.5	.00	1465.6	1567.4	32.6	166.0	1434.1
SIGT=9.00 MR-TUBE ALIGNED	50000.	329.0	328.4	60.5	23.5	.00	1465.2	1513.1	32.8	165.7	1380.3
SIGT=12.2 MR-TUBE ALIGNED	50000.	327.7	327.2	60.3	23.5	.00	1464.2	1382.3	33.0	164.6	1250.7
SIGT=7.00 MR-2.5 MR TRACK	50000.	329.5	328.8	60.6	23.5	.00	1465.5	1558.5	32.7	166.0	1425.3
SIGT=7.00 MR-5.0 MR TRACK	50000.	329.2	328.6	60.5	23.5	.00	1465.3	1529.9	32.8	165.8	1396.9
SIGT=7.00 MR-10. MR TRACK	50000.	327.8	327.3	60.3	23.5	.00	1464.2	1392.6	33.2	164.9	1260.9
SIGT=7.00 MR-2.5 MM DOWN	50000.	329.4	328.8	60.6	23.5	.00	1465.5	1555.8	32.7	166.0	1422.6
SIGT=7.00 MR-5.0 MM DOWN	50000.	329.0	328.4	60.5	23.5	.00	1465.2	1516.9	32.8	165.7	1384.1
SIGT=7.00 MR-10. MM DOWN	50000.	327.1	326.6	60.2	23.5	.00	1463.7	1324.1	33.4	164.5	1193.1
SIGT=7.00 MR-2.5 MM UP	50000.	329.4	328.8	60.6	23.5	.00	1465.5	1555.4	32.7	166.0	1422.2
SIGT=7.00 MR-5.0 MM UP	50000.	329.0	328.4	60.5	23.5	.00	1465.2	1516.1	32.8	165.7	1383.3
SIGT=7.00 MR-10. MM UP	50000.	327.1	326.6	60.2	23.5	.00	1463.7	1320.4	33.4	164.5	1189.4
SIGT=7.00 MR-2.5 MM LEFT	50000.	329.5	328.9	60.6	23.5	.00	1465.6	1564.2	32.7	166.1	1430.9
SIGT=7.00 MR-5.0 MM LEFT	50000.	329.4	328.8	60.6	23.5	.00	1465.5	1550.3	32.8	166.0	1417.1
SIGT=7.00 MR-10. MM LEFT	50000.	328.1	327.5	60.4	23.5	.00	1464.5	1420.3	33.2	165.2	1288.4
SIGT=7.00 MR-TUBE ALIGNED	70000.	326.3	325.7	59.9	23.5	.00	1914.8	1567.4	32.6	163.0	1437.1
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.9	325.3	59.9	23.5	.00	1914.4	1513.1	32.8	162.8	1383.2
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.9	324.3	59.7	23.5	.00	1913.4	1382.3	33.0	162.0	1253.4
SIGT=7.00 MR-2.5 MR TRACK	70000.	326.2	325.6	59.9	23.5	.00	1914.8	1558.5	32.7	163.0	1428.3
SIGT=7.00 MR-5.0 MR TRACK	70000.	326.0	325.4	59.9	23.5	.00	1914.6	1529.9	32.8	162.9	1399.9
SIGT=7.00 MR-10. MR TRACK	70000.	324.9	324.4	59.8	23.5	.00	1913.5	1392.6	33.2	162.3	1263.6
SIGT=7.00 MR-2.5 MM DOWN	70000.	326.2	325.6	59.9	23.5	.00	1914.8	1555.8	32.7	163.0	1425.6
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.9	325.3	59.9	23.5	.00	1914.4	1516.9	32.8	162.8	1387.0
SIGT=7.00 MR-10. MM DOWN	70000.	324.4	323.9	59.7	23.5	.00	1912.9	1324.1	33.4	162.0	1195.6
SIGT=7.00 MR-2.5 MM UP	70000.	326.2	325.6	59.9	23.5	.00	1914.8	1555.4	32.7	163.0	1425.2
SIGT=7.00 MR-5.0 MM UP	70000.	325.9	325.3	59.9	23.5	.00	1914.4	1516.1	32.8	162.8	1386.2
SIGT=7.00 MR-10. MM UP	70000.	324.4	323.9	59.7	23.5	.00	1912.9	1320.4	33.4	162.0	1191.9
SIGT=7.00 MR-2.5 MM LEFT	70000.	326.3	325.7	59.9	23.5	.00	1914.8	1564.2	32.7	163.0	1434.0
SIGT=7.00 MR-5.0 MM LEFT	70000.	326.2	325.6	59.9	23.5	.00	1914.7	1550.3	32.8	163.0	1420.2
SIGT=7.00 MR-10. MM LEFT	70000.	325.2	324.6	59.8	23.5	.00	1913.7	1420.3	33.2	162.5	1291.1

Table C-II. 1-D Thermal Model Results - Annular Space Maintained at Atmospheric Pressure and Wind Velocity of 2.5 m/s

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES		GLASS TEMP.	CONVECTION COEFFICIENTS			ABSORBED SOLAR ENERGY		RECEIVER HEAT LOSS	ENERGY ABSORBED BY FLUID
		I.D.	O.D.		HAIR	HGAP	HFLUID	QTUBE	QGLASS		
	(--)	(C)	(C)	(C)	(UNITS OF W/M**2-K)			(W)	(W)	(W)	(W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	359.3	358.7	95.9	23.2	6.95	411.1	1567.4	32.6	336.6	1263.4
SIGT=9.00 MR-TUBE ALIGNED	10000.	357.5	357.0	95.4	23.2	6.94	410.6	1513.1	32.8	333.9	1212.0
SIGT=12.2 MR-TUBE ALIGNED	10000.	353.3	352.8	94.1	23.2	6.90	409.6	1382.3	33.0	327.3	1087.9
SIGT=7.00 MR-2.5 MR TRACK	10000.	359.0	358.5	95.8	23.2	6.95	411.0	1558.5	32.7	336.2	1255.0
SIGT=7.00 MR-5.0 MR TRACK	10000.	358.1	357.6	95.6	23.2	6.94	410.8	1529.9	32.8	334.8	1227.9
SIGT=7.00 MR-10. MR TRACK	10000.	353.6	353.1	94.2	23.2	6.91	409.6	1392.6	33.2	328.0	1097.7
SIGT=7.00 MR-2.5 MM DOWN	10000.	358.9	358.4	95.8	23.2	6.95	411.0	1555.8	32.7	336.0	1252.4
SIGT=7.00 MR-5.0 MM DOWN	10000.	357.7	357.1	95.4	23.2	6.94	410.7	1516.9	32.8	334.1	1215.6
SIGT=7.00 MR-10. MM DOWN	10000.	351.4	350.9	93.5	23.2	6.89	409.1	1324.1	33.4	324.7	1032.8
SIGT=7.00 MR-2.5 MM UP	10000.	358.9	358.4	95.8	23.2	6.95	411.0	1555.4	32.7	336.0	1252.1
SIGT=7.00 MR-5.0 MM UP	10000.	357.6	357.1	95.4	23.2	6.94	410.7	1516.1	32.8	334.1	1214.8
SIGT=7.00 MR-10. MM UP	10000.	351.3	350.8	93.5	23.2	6.89	409.1	1320.4	33.4	324.5	1029.3
SIGT=7.00 MR-2.5 MM LEFT	10000.	359.2	358.6	95.9	23.2	6.95	411.1	1564.2	32.7	336.5	1260.4
SIGT=7.00 MR-5.0 MM LEFT	10000.	358.7	358.2	95.8	23.2	6.95	411.0	1550.3	32.8	335.8	1247.2
SIGT=7.00 MR-10. MM LEFT	10000.	354.5	354.0	94.5	23.2	6.91	409.9	1420.3	33.2	329.5	1124.0
SIGT=7.00 MR-TUBE ALIGNED	30000.	334.5	334.0	88.2	23.3	6.74	976.5	1567.4	32.6	238.3	1301.7
SIGT=9.00 MR-TUBE ALIGNED	30000.	333.7	333.2	88.0	23.3	6.74	976.2	1513.1	32.8	297.3	1248.6
SIGT=12.2 MR-TUBE ALIGNED	30000.	331.8	331.4	87.5	23.3	6.72	975.2	1382.3	33.0	294.7	1120.6
SIGT=7.00 MR-2.5 MR TRACK	30000.	334.4	333.8	88.2	23.3	6.74	976.5	1558.5	32.7	298.2	1293.0
SIGT=7.00 MR-5.0 MR TRACK	30000.	334.0	333.4	88.1	23.3	6.74	976.3	1529.9	32.8	297.7	1265.0
SIGT=7.00 MR-10. MR TRACK	30000.	332.0	331.5	87.6	23.3	6.72	975.3	1392.6	33.2	295.1	1130.7
SIGT=7.00 MR-2.5 MM DOWN	30000.	334.4	333.8	88.2	23.3	6.74	976.5	1555.8	32.7	298.2	1290.3
SIGT=7.00 MR-5.0 MM DOWN	30000.	333.8	333.3	88.0	23.3	6.74	976.2	1516.9	32.8	297.4	1252.3
SIGT=7.00 MR-10. MM DOWN	30000.	331.0	330.5	87.3	23.3	6.71	974.8	1324.1	33.4	293.8	1063.7
SIGT=7.00 MR-2.5 MM UP	30000.	334.4	333.8	88.2	23.3	6.74	976.5	1555.4	32.7	298.1	1289.9
SIGT=7.00 MR-5.0 MM UP	30000.	333.8	333.3	88.0	23.3	6.74	976.2	1516.1	32.8	297.4	1251.5
SIGT=7.00 MR-10. MM UP	30000.	330.9	330.5	87.3	23.3	6.71	974.8	1320.4	33.4	293.7	1060.1
SIGT=7.00 MR-2.5 MM LEFT	30000.	334.5	333.9	88.2	23.3	6.74	976.5	1564.2	32.7	298.3	1298.5
SIGT=7.00 MR-5.0 MM LEFT	30000.	334.3	333.7	88.2	23.3	6.74	976.4	1550.3	32.8	298.1	1285.0
SIGT=7.00 MR-10. MM LEFT	30000.	332.4	331.9	87.7	23.3	6.73	975.5	1420.3	33.2	295.7	1157.8
SIGT=7.00 MR-TUBE ALIGNED	50000.	328.3	327.7	86.3	23.3	6.69	1464.6	1567.4	32.6	289.2	1310.8
SIGT=9.00 MR-TUBE ALIGNED	50000.	327.8	327.2	86.2	23.3	6.69	1464.2	1513.1	32.8	288.6	1257.3
SIGT=12.2 MR-TUBE ALIGNED	50000.	326.5	326.0	85.9	23.3	6.68	1463.2	1382.3	33.0	286.9	1128.4
SIGT=7.00 MR-2.5 MR TRACK	50000.	328.2	327.7	86.3	23.3	6.69	1464.6	1558.5	32.7	289.1	1302.0
SIGT=7.00 MR-5.0 MR TRACK	50000.	327.9	327.4	86.3	23.3	6.69	1464.3	1529.9	32.8	288.8	1273.9
SIGT=7.00 MR-10. MR TRACK	50000.	326.6	326.1	85.9	23.3	6.68	1463.3	1392.6	33.2	287.2	1138.6
SIGT=7.00 MR-2.5 MM DOWN	50000.	328.2	327.6	86.3	23.3	6.69	1464.5	1555.8	32.7	289.1	1299.4
SIGT=7.00 MR-5.0 MM DOWN	50000.	327.8	327.3	86.2	23.3	6.69	1464.2	1516.9	32.8	288.6	1261.1
SIGT=7.00 MR-10. MM DOWN	50000.	325.9	325.4	85.8	23.3	6.67	1462.7	1324.1	33.4	286.4	1071.1
SIGT=7.00 MR-2.5 MM UP	50000.	328.2	327.6	86.3	23.3	6.69	1464.5	1555.4	32.7	289.1	1299.0
SIGT=7.00 MR-5.0 MM UP	50000.	327.8	327.3	86.2	23.3	6.69	1464.2	1516.1	32.8	288.6	1260.3
SIGT=7.00 MR-10. MM UP	50000.	325.8	325.4	85.8	23.3	6.67	1462.7	1320.4	33.4	286.3	1067.5
SIGT=7.00 MR-2.5 MM LEFT	50000.	328.3	327.7	86.4	23.3	6.69	1464.6	1564.2	32.7	289.2	1307.7
SIGT=7.00 MR-5.0 MM LEFT	50000.	328.1	327.6	86.3	23.3	6.69	1464.5	1550.3	32.8	289.1	1294.0
SIGT=7.00 MR-10. MM LEFT	50000.	326.8	326.3	86.0	23.3	6.68	1463.5	1420.3	33.2	287.6	1165.9
SIGT=7.00 MR-TUBE ALIGNED	70000.	325.3	324.8	85.5	23.3	6.67	1913.9	1567.4	32.6	284.9	1315.1
SIGT=9.00 MR-TUBE ALIGNED	70000.	324.9	324.4	85.4	23.3	6.66	1913.4	1513.1	32.8	284.5	1261.4
SIGT=12.2 MR-TUBE ALIGNED	70000.	323.9	323.4	85.1	23.3	6.65	1912.4	1382.3	33.0	283.2	1132.1
SIGT=7.00 MR-2.5 MR TRACK	70000.	325.3	324.7	85.5	23.3	6.67	1913.8	1558.5	32.7	284.9	1306.3
SIGT=7.00 MR-5.0 MR TRACK	70000.	325.1	324.5	85.4	23.3	6.66	1913.6	1529.9	32.8	284.7	1278.0
SIGT=7.00 MR-10. MR TRACK	70000.	324.0	323.5	85.2	23.3	6.65	1912.5	1392.6	33.2	283.5	1142.3
SIGT=7.00 MR-2.5 MM DOWN	70000.	325.3	324.7	85.5	23.3	6.66	1913.8	1555.8	32.7	284.9	1303.5
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.0	324.4	85.4	23.3	6.66	1913.5	1516.9	32.8	284.5	1265.2
SIGT=7.00 MR-10. MM DOWN	70000.	323.5	323.0	85.1	23.3	6.65	1911.9	1324.1	33.4	282.9	1074.6
SIGT=7.00 MR-2.5 MM UP	70000.	325.3	324.7	85.5	23.3	6.66	1913.9	1555.4	32.7	284.9	1303.2
SIGT=7.00 MR-5.0 MM UP	70000.	324.9	324.4	85.4	23.3	6.66	1913.5	1516.1	32.8	284.5	1264.9
SIGT=7.00 MR-10. MM UP	70000.	323.4	323.0	85.1	23.3	6.65	1911.9	1320.4	33.4	282.9	1070.9
SIGT=7.00 MR-2.5 MM LEFT	70000.	325.3	324.8	85.5	23.3	6.67	1913.8	1564.2	32.7	285.0	1311.9
SIGT=7.00 MR-5.0 MM LEFT	70000.	325.2	324.7	85.5	23.3	6.66	1913.7	1550.3	32.8	284.9	1298.2
SIGT=7.00 MR-10. MM LEFT	70000.	324.2	323.7	85.2	23.3	6.66	1912.7	1420.3	33.2	283.8	1169.7

Table C-III. 1-D Thermal Model Results - Annular Space Evacuated and Wind Velocity of 5.0 m/s

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	363.8	363.2	56.0	36.1	.00	412.5	1567.4	32.6	203.2	1396.8
SIGT=9.00 MR-TUBE ALIGNED	10000.	362.0	361.5	55.7	36.1	.00	411.9	1513.1	32.8	201.4	1344.5
SIGT=12.2 MR-TUBE ALIGNED	10000.	357.8	357.2	55.0	36.1	.00	410.7	1382.3	33.0	196.9	1218.4
SIGT=7.00 MR-2.5 MR TRACK	10000.	363.5	362.9	55.9	36.1	.00	412.4	1558.5	32.7	203.0	1388.2
SIGT=7.00 MR-5.0 MR TRACK	10000.	362.6	362.0	55.8	36.1	.00	412.1	1529.9	32.8	202.0	1360.7
SIGT=7.00 MR-10. MR TRACK	10000.	358.1	357.6	55.1	36.1	.00	410.	1392.6	33.2	197.4	1228.3
SIGT=7.00 MR-2.5 MM DOWN	10000.	363.4	362.8	55.9	36.1	.00	412.4	1555.8	32.7	202.9	1385.6
SIGT=7.00 MR-5.0 MM DOWN	10000.	362.2	361.6	55.7	36.1	.00	412.0	1516.9	32.8	201.6	1348.1
SIGT=7.00 MR-10. MM DOWN	10000.	355.8	355.3	54.7	36.1	.00	410.2	1324.1	33.4	195.2	1162.3
SIGT=7.00 MR-2.5 MM UP	10000.	363.4	362.8	55.9	36.1	.00	412.4	1555.4	32.7	202.9	1385.2
SIGT=7.00 MR-5.0 MM UP	10000.	362.1	361.6	55.7	36.1	.00	412.0	1516.1	32.8	201.5	1347.4
SIGT=7.00 MR-10. MM UP	10000.	355.7	355.2	54.7	36.1	.00	410.2	1320.4	33.4	195.0	1158.7
SIGT=7.00 MR-2.5 MM LEFT	10000.	363.7	363.1	55.9	36.1	.00	412.5	1564.2	32.7	203.2	1393.7
SIGT=7.00 MR-5.0 MM LEFT	10000.	363.2	362.7	55.9	36.1	.00	412.3	1550.3	32.8	202.8	1380.3
SIGT=7.00 MR-10. MM LEFT	10000.	359.0	358.5	55.2	36.1	.00	411.0	1420.3	33.2	198.4	1255.0
SIGT=7.00 MR-TUBE ALIGNED	30000.	336.4	335.8	51.5	36.1	.00	977.5	1567.4	32.6	174.2	1425.8
SIGT=9.00 MR-TUBE ALIGNED	30000.	335.6	335.0	51.4	36.1	.00	977.1	1513.1	32.8	173.7	1372.3
SIGT=12.2 MR-TUBE ALIGNED	30000.	333.7	333.1	51.1	36.1	.00	976.1	1382.3	33.0	172.0	1243.4
SIGT=7.00 MR-2.5 MR TRACK	30000.	336.2	335.6	51.5	36.1	.00	977.4	1558.5	32.7	174.2	1417.1
SIGT=7.00 MR-5.0 MR TRACK	30000.	335.8	335.2	51.4	36.1	.00	977.2	1529.9	32.8	173.9	1388.9
SIGT=7.00 MR-10. MR TRACK	30000.	333.8	333.3	51.2	36.1	.00	976.2	1392.6	33.2	172.3	1253.5
SIGT=7.00 MR-2.5 MM DOWN	30000.	336.2	335.6	51.5	36.1	.00	977.4	1555.8	32.7	174.2	1414.4
SIGT=7.00 MR-5.0 MM DOWN	30000.	335.6	335.0	51.4	36.1	.00	977.1	1516.9	32.8	173.7	1376.1
SIGT=7.00 MR-10. MM DOWN	30000.	332.8	332.3	51.1	36.1	.00	975.7	1324.1	33.4	171.5	1186.0
SIGT=7.00 MR-2.5 MM UP	30000.	336.2	335.6	51.5	36.1	.00	977.4	1555.4	32.7	174.2	1414.8
SIGT=7.00 MR-5.0 MM UP	30000.	335.6	335.0	51.4	36.1	.00	977.1	1516.1	32.8	173.7	1375.3
SIGT=7.00 MR-10. MM UP	30000.	332.8	332.3	51.1	36.1	.00	975.7	1320.4	33.4	171.5	1182.4
SIGT=7.00 MR-2.5 MM LEFT	30000.	336.5	335.7	51.5	36.1	.00	977.4	1564.2	32.7	174.3	1422.7
SIGT=7.00 MR-5.0 MM LEFT	30000.	336.1	335.5	51.5	36.1	.00	977.3	1550.3	32.8	174.2	1409.0
SIGT=7.00 MR-10. MM LEFT	30000.	334.2	333.7	51.2	36.1	.00	976.4	1420.3	33.2	172.7	1280.9
SIGT=7.00 MR-TUBE ALIGNED	50000.	329.5	328.9	50.5	36.1	.00	1465.6	1567.4	32.6	167.6	1432.5
SIGT=9.00 MR-TUBE ALIGNED	50000.	329.0	328.4	50.4	36.1	.00	1465.2	1513.1	32.8	167.3	1378.7
SIGT=12.2 MR-TUBE ALIGNED	50000.	327.7	327.1	50.2	36.1	.00	1464.2	1382.3	33.0	166.2	1249.2
SIGT=7.00 MR-2.5 MR TRACK	50000.	329.4	328.8	50.5	36.1	.00	1465.5	1558.5	32.7	167.6	1423.7
SIGT=7.00 MR-5.0 MR TRACK	50000.	329.2	328.6	50.4	36.1	.00	1465.3	1529.9	32.8	167.4	1395.4
SIGT=7.00 MR-10. MR TRACK	50000.	327.8	327.2	50.3	36.1	.00	1464.2	1392.6	33.2	166.5	1259.4
SIGT=7.00 MR-2.5 MM DOWN	50000.	329.4	328.8	50.5	36.1	.00	1465.5	1555.8	32.7	167.6	1421.8
SIGT=7.00 MR-5.0 MM DOWN	50000.	329.0	328.4	50.4	36.1	.00	1465.2	1516.9	32.8	167.3	1382.5
SIGT=7.00 MR-10. MM DOWN	50000.	327.1	326.6	50.2	36.1	.00	1463.7	1324.1	33.4	166.1	1191.5
SIGT=7.00 MR-2.5 MM UP	50000.	329.4	328.8	50.5	36.1	.00	1465.5	1555.4	32.7	167.6	1420.6
SIGT=7.00 MR-5.0 MM UP	50000.	329.0	328.4	50.4	36.1	.00	1465.2	1516.1	32.8	167.3	1381.7
SIGT=7.00 MR-10. MM UP	50000.	327.1	326.6	50.2	36.1	.00	1463.7	1320.4	33.4	166.0	1187.9
SIGT=7.00 MR-2.5 MM LEFT	50000.	329.5	328.9	50.5	36.1	.00	1465.6	1564.2	32.7	167.7	1429.3
SIGT=7.00 MR-5.0 MM LEFT	50000.	329.4	328.8	50.5	36.1	.00	1465.4	1550.3	32.8	167.6	1415.6
SIGT=7.00 MR-10. MM LEFT	50000.	328.1	327.5	50.3	36.1	.00	1464.4	1420.3	33.2	166.8	1286.8
SIGT=7.00 MR-TUBE ALIGNED	70000.	326.3	325.7	50.0	36.1	.00	1914.8	1567.4	32.6	164.5	1435.6
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.9	325.3	50.0	36.1	.00	1914.4	1513.1	32.8	164.3	1381.7
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.9	324.3	49.8	36.1	.00	1913.4	1382.3	33.0	163.6	1251.8
SIGT=7.00 MR-2.5 MR TRACK	70000.	326.2	325.6	50.0	36.1	.00	1914.8	1558.5	32.7	164.6	1426.7
SIGT=7.00 MR-5.0 MR TRACK	70000.	326.0	325.4	50.0	36.1	.00	1914.5	1529.9	32.8	164.4	1398.4
SIGT=7.00 MR-10. MR TRACK	70000.	324.9	324.4	49.9	36.1	.00	1913.4	1392.6	33.2	163.8	1262.1
SIGT=7.00 MR-2.5 MM DOWN	70000.	326.2	325.6	50.0	36.1	.00	1914.7	1555.8	32.7	164.5	1424.1
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.9	325.3	50.0	36.1	.00	1914.4	1516.9	32.8	164.3	1385.5
SIGT=7.00 MR-10. MM DOWN	70000.	324.4	323.9	49.8	36.1	.00	1912.9	1324.1	33.4	163.5	1194.1
SIGT=7.00 MR-2.5 MM UP	70000.	326.2	325.6	50.0	36.1	.00	1914.7	1555.4	32.7	164.5	1423.7
SIGT=7.00 MR-5.0 MM UP	70000.	325.9	325.3	50.0	36.1	.00	1914.4	1516.1	32.8	164.3	1384.7
SIGT=7.00 MR-10. MM UP	70000.	324.4	323.9	49.8	36.1	.00	1912.9	1320.4	33.4	163.5	1190.4
SIGT=7.00 MR-2.5 MM LEFT	70000.	326.3	325.6	50.0	36.1	.00	1914.8	1564.2	32.7	164.6	1432.4
SIGT=7.00 MR-5.0 MM LEFT	70000.	326.2	325.5	50.0	36.1	.00	1914.7	1550.3	32.8	164.6	1418.6
SIGT=7.00 MR-10. MM LEFT	70000.	325.1	324.6	49.9	36.1	.00	1913.7	1420.3	33.2	164.0	1289.6

Table C-IV. 1-D Thermal Model Results - Annular Space Maintained at Atmospheric Pressure and Wind Velocity of 5.0 m/s

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES		GLASS TEMP.	CONVECTION COEFFICIENTS			ABSORBED SOLAR ENERGY		RECEIVER HEAT LOSS	ENERGY ABSORBED BY FLUID
		I.D.	O.D.		HAIR	HGAP	HFLUID	QTUBE	QGLASS		
	(--)	(C)	(C)	(C)	(UNITS OF W/M**2-K)			(W)	(W)	(W)	(W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	358.9	358.3	78.1	35.8	6.95	411.0	1567.4	32.6	349.3	1250.7
SIGT=9.00 MR-TUBE ALIGNED	10000.	357.1	356.6	77.7	35.8	6.93	410.5	1513.1	32.8	346.6	1199.3
SIGT=12.2 MR-TUBE ALIGNED	10000.	352.9	352.4	76.7	35.8	6.90	409.5	1382.3	33.0	339.7	1075.6
SIGT=7.00 MR-2.5 MR TRACK	10000.	358.6	358.0	78.1	35.8	6.95	410.9	1558.5	32.7	348.9	1242.3
SIGT=7.00 MR-5.0 MR TRACK	10000.	357.6	357.1	77.9	35.8	6.94	410.7	1529.9	32.8	347.5	1215.2
SIGT=7.00 MR-10. MR TRACK	10000.	353.2	352.7	76.8	35.8	6.90	409.5	1392.6	33.2	340.4	1085.3
SIGT=7.00 MR-2.5 MM DOWN	10000.	358.5	357.9	78.1	35.8	6.95	410.9	1555.8	32.7	348.8	1239.7
SIGT=7.00 MR-5.0 MM DOWN	10000.	357.2	356.7	77.8	35.8	6.94	410.6	1516.9	32.8	346.8	1202.9
SIGT=7.00 MR-10. MM DOWN	10000.	351.0	350.5	76.3	35.8	6.88	409.0	1324.1	33.4	336.9	1020.5
SIGT=7.00 MR-2.5 MM UP	10000.	358.5	357.9	78.1	35.8	6.95	410.9	1555.4	32.7	348.7	1239.3
SIGT=7.00 MR-5.0 MM UP	10000.	357.2	356.7	77.8	35.8	6.94	410.6	1516.1	32.8	346.7	1202.2
SIGT=7.00 MR-10. MM UP	10000.	350.8	350.4	76.3	35.8	6.88	409.0	1320.4	33.4	336.7	1017.0
SIGT=7.00 MR-2.5 MM LEFT	10000.	358.8	358.2	78.1	35.8	6.95	411.0	1564.2	32.7	349.2	1247.7
SIGT=7.00 MR-5.0 MM LEFT	10000.	358.3	357.8	78.0	35.8	6.94	410.9	1550.3	32.8	348.6	1234.5
SIGT=7.00 MR-10. MM LEFT	10000.	354.1	353.6	77.0	35.8	6.91	409.8	1420.3	33.2	341.9	1111.6
SIGT=7.00 MR-TUBE ALIGNED	30000.	334.4	333.8	72.2	35.9	6.74	976.5	1567.4	32.6	309.8	1290.3
SIGT=9.00 MR-TUBE ALIGNED	30000.	333.6	333.0	72.0	35.9	6.74	976.1	1513.1	32.8	308.7	1237.2
SIGT=12.2 MR-TUBE ALIGNED	30000.	331.7	331.2	71.6	35.9	6.72	975.1	1382.3	33.0	306.0	1109.3
SIGT=7.00 MR-2.5 MR TRACK	30000.	334.2	333.7	72.2	35.9	6.74	976.4	1558.5	32.7	309.7	1281.6
SIGT=7.00 MR-5.0 MR TRACK	30000.	333.8	333.3	72.1	35.9	6.74	976.2	1529.9	32.8	309.1	1253.6
SIGT=7.00 MR-10. MR TRACK	30000.	331.8	331.3	71.7	35.9	6.72	975.2	1392.6	33.2	306.4	1119.4
SIGT=7.00 MR-2.5 MM DOWN	30000.	334.2	333.6	72.2	35.9	6.74	976.4	1555.8	32.7	309.6	1278.9
SIGT=7.00 MR-5.0 MM DOWN	30000.	333.6	333.1	72.1	35.9	6.74	976.1	1516.9	32.8	308.8	1240.9
SIGT=7.00 MR-10. MM DOWN	30000.	330.8	330.4	71.5	35.9	6.71	974.7	1324.1	33.4	305.1	1052.5
SIGT=7.00 MR-2.5 MM UP	30000.	334.2	333.6	72.2	[illegible]	[illegible]	976.4	1555.4	32.7	309.6	1278.5
SIGT=7.00 MR-5.0 MM UP	30000.	333.6	333.1	72.1	[illegible]	[illegible]	976.1	1516.1	32.8	308.8	1240.1
SIGT=7.00 MR-10. MM UP	30000.	330.8	330.3	71.5	[illegible]	[illegible]	974.7	1320.4	33.4	305.0	1048.9
SIGT=7.00 MR-2.5 MM LEFT	30000.	334.3	333.8	72.2	35.9	6.74	976.4	1564.2	32.7	309.8	1287.1
SIGT=7.00 MR-5.0 MM LEFT	30000.	334.1	333.6	72.2	35.9	6.74	976.3	1550.3	32.8	309.6	1273.6
SIGT=7.00 MR-10. MM LEFT	30000.	332.2	331.7	71.8	35.9	6.72	975.4	1420.3	33.2	307.0	1146.5
SIGT=7.00 MR-TUBE ALIGNED	50000.	328.2	327.6	70.8	35.9	6.69	1464.5	1567.4	32.6	300.3	1299.7
SIGT=9.00 MR-TUBE ALIGNED	50000.	327.7	327.1	70.7	35.9	6.69	1464.1	1513.1	32.8	299.7	1246.2
SIGT=12.2 MR-TUBE ALIGNED	50000.	326.4	325.9	70.4	35.9	6.67	1463.1	1382.3	33.0	297.9	1117.4
SIGT=7.00 MR-2.5 MR TRACK	50000.	328.1	327.5	70.8	35.9	6.69	1464.5	1558.5	32.7	300.3	1291.0
SIGT=7.00 MR-5.0 MR TRACK	50000.	327.8	327.3	70.7	35.9	6.69	1464.3	1529.9	32.8	299.9	1262.8
SIGT=7.00 MR-10. MR TRACK	50000.	326.5	326.0	70.5	35.9	6.68	1463.2	1392.6	33.2	298.2	1127.6
SIGT=7.00 MR-2.5 MM DOWN	50000.	328.1	327.5	70.8	35.9	6.69	1464.5	1555.8	32.7	300.2	1288.3
SIGT=7.00 MR-5.0 MM DOWN	50000.	327.7	327.2	70.7	35.9	6.69	1464.2	1516.9	32.8	299.7	1250.0
SIGT=7.00 MR-10. MM DOWN	50000.	325.8	325.3	70.3	35.9	6.67	1462.7	1324.1	33.4	297.4	1060.1
SIGT=7.00 MR-2.5 MM UP	50000.	328.1	327.5	70.8	35.9	6.69	1464.5	1555.4	32.7	300.2	1287.9
SIGT=7.00 MR-5.0 MM UP	50000.	327.7	327.1	70.7	35.9	6.69	1464.2	1516.1	32.8	299.7	1249.2
SIGT=7.00 MR-10. MM UP	50000.	325.7	325.3	70.3	35.9	6.67	1462.6	1320.4	33.4	297.4	1056.6
SIGT=7.00 MR-2.5 MM LEFT	50000.	328.2	327.6	70.8	35.9	6.69	1464.[illegible]	1564.2	32.7	300.4	1296.6
SIGT=7.00 MR-5.0 MM LEFT	50000.	328.0	327.5	70.8	35.9	6.69	1464.4	1550.3	32.8	300.3	1282.9
SIGT=7.00 MR-10. MM LEFT	50000.	326.7	326.2	70.5	35.9	6.68	1463.4	1420.3	33.2	298.7	1154.9
SIGT=7.00 MR-TUBE ALIGNED	70000.	325.3	324.7	70.1	35.9	6.67	1913.8	1567.4	32.6	295.9	1304.1
SIGT=9.00 MR-TUBE ALIGNED	70000.	324.[illegible]	324.3	70.0	35.9	6.66	1913.3	1513.1	32.8	295.5	1250.5
SIGT=12.2 MR-TUBE ALIGNED	70000.	323.8	323.3	69.8	35.9	6.65	1912.3	1382.3	33.0	294.1	1121.2
SIGT=7.00 MR-2.5 MR TRACK	70000.	325.2	324.6	70.1	35.9	6.66	1913.7	1558.5	32.7	295.9	1295.3
SIGT=7.00 MR-5.0 MR TRACK	70000.	325.0	324.4	70.1	35.9	6.66	1913.5	1529.9	32.8	295.7	1267.1
SIGT=7.00 MR-10. MR TRACK	70000.	323.9	323.4	69.9	35.9	6.65	1912.4	1392.6	33.2	294.4	1131.4
SIGT=7.00 MR-2.5 MM DOWN	70000.	325.2	324.6	70.1	35.9	6.66	1913.7	1555.8	32.7	295.9	1292.7
SIGT=7.00 MR-5.0 MM DOWN	70000.	324.9	324.3	70.0	35.9	6.66	1913.4	1516.9	32.8	295.5	1254.2
SIGT=7.00 MR-10. MM DOWN	70000.	323.4	322.9	69.8	35.9	6.65	1911.8	1324.1	33.4	293.8	1063.7
SIGT=7.00 MR-2.5 MM UP	70000.	325.2	324.6	70.1	35.9	6.66	1913.7	1555.4	32.7	295.9	1292.3
SIGT=7.00 MR-5.0 MM UP	70000.	324.9	324.3	70.0	35.9	6.66	1913.4	1516.1	32.8	295.5	1253.4
SIGT=7.00 MR-10. MM UP	70000.	323.3	322.9	69.8	35.9	6.65	1911.8	1320.4	33.4	293.8	1063.1
SIGT=7.00 MR-2.5 MM LEFT	70000.	325.2	324.7	70.1	35.9	6.66	1913.8	1564.2	32.7	296.0	1301.0
SIGT=7.00 MR-5.0 MM LEFT	70000.	325.1	324.6	70.1	35.9	6.66	1913.6	1550.3	32.8	295.9	1287.3
SIGT=7.00 MR-10. MM LEFT	70000.	324.1	323.6	69.9	35.9	6.66	1912.6	1420.3	33.2	294.7	1158.8

Table C-V. 1-D Thermal Model Results - Annular Space Evacuated and Wind Velocity of 10.0 m/s

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
SIGT=7.00 MR-TUBE ALIGNED	10000.	363.8	363.2	46.5	55.5	.00	412.5	1567.4	32.6	204.6	1395.4
SIGT=9.00 MR-TUBE ALIGNED	10000.	362.0	361.4	46.3	55.5	.00	411.9	1513.1	32.8	202.8	1343.1
SIGT=12.2 MR-TUBE ALIGNED	10000.	357.7	357.2	45.8	55.5	.00	410.7	1382.3	33.0	198.2	1217.1
SIGT=7.00 MR-2.5 MR TRACK	10000.	363.5	362.9	46.5	55.5	.00	412.4	1558.5	32.7	204.4	1386.8
SIGT=7.00 MR-5.0 MR TRACK	10000.	362.5	362.0	46.4	55.5	.00	412.1	1529.9	32.8	203.4	1359.3
SIGT=7.00 MR-10. MR TRACK	10000.	358.0	357.5	45.9	55.5	.00	410.8	1392.6	33.2	198.8	1227.0
SIGT=7.00 MR-2.5 MM DOWN	10000.	363.4	362.8	46.4	55.5	.00	412.4	1555.8	32.7	204.3	1384.2
SIGT=7.00 MR-5.0 MM DOWN	10000.	362.1	361.5	46.3	55.5	.00	412.0	1516.9	32.8	202.9	1346.8
SIGT=7.00 MR-10. MM DOWN	10000.	355.8	355.3	45.6	55.5	.00	410.2	1324.1	33.4	196.5	1161.0
SIGT=7.00 MR-2.5 MM UP	10000.	363.4	362.8	46.4	55.5	.00	412.4	1555.4	32.7	204.2	1383.8
SIGT=7.00 MR-5.0 MM UP	10000.	362.1	361.5	46.3	55.5	.00	412.0	1516.1	32.8	202.9	1346.0
SIGT=7.00 MR-10. MM UP	10000.	355.7	355.2	45.6	55.5	.00	410.2	1320.4	33.4	196.4	1157.4
SIGT=7.00 MR-2.5 MM LEFT	10000.	363.7	363.1	46.5	55.5	.00	412.5	1564.2	32.7	204.6	1392.3
SIGT=7.00 MR-5.0 MM LEFT	10000.	363.2	362.6	46.4	55.5	.00	412.3	1550.3	32.8	204.2	1378.9
SIGT=7.00 MR-10. MM LEFT	10000.	359.0	358.4	46.0	55.5	.00	411.0	1420.3	33.2	199.8	1253.7
SIGT=7.00 MR-TUBE ALIGNED	30000.	336.4	335.7	43.4	55.6	.00	977.4	1567.4	32.6	175.4	1424.6
SIGT=9.00 MR-TUBE ALIGNED	30000.	335.6	335.0	43.3	55.6	.00	977.1	1513.1	32.8	174.8	1371.1
SIGT=12.2 MR-TUBE ALIGNED	30000.	333.7	333.1	43.1	55.6	.00	976.1	1382.3	33.0	173.1	1242.2
SIGT=7.00 MR-2.5 MR TRACK	30000.	336.2	335.6	43.4	55.6	.00	977.4	1558.5	32.7	175.4	1415.9
SIGT=7.00 MR-5.0 MR TRACK	30000.	335.8	335.2	43.3	55.6	.00	977.2	1529.9	32.8	175.1	1387.7
SIGT=7.00 MR-10. MR TRACK	30000.	333.8	333.3	43.1	55.6	.00	976.2	1392.6	33.2	173.5	1252.4
SIGT=7.00 MR-2.5 MM DOWN	30000.	336.2	335.6	43.3	55.6	.00	977.4	1555.8	32.7	175.3	1413.2
SIGT=7.00 MR-5.0 MM DOWN	30000.	335.6	335.0	43.3	55.6	.00	977.1	1516.9	32.8	174.9	1374.9
SIGT=7.00 MR-10. MM DOWN	30000.	332.8	332.3	43.1	55.6	.00	975.7	1324.1	33.4	172.7	1184.9
SIGT=7.00 MR-2.5 MM UP	30000.	336.2	335.6	43.3	55.6	.00	977.4	1555.4	32.7	175.3	1412.8
SIGT=7.00 MR-5.0 MM UP	30000.	335.6	335.0	43.3	55.6	.00	977.1	1516.1	32.8	174.9	1374.1
SIGT=7.00 MR-10. MM UP	30000.	332.7	332.2	43.1	55.6	.00	975.7	1320.4	33.4	172.6	1181.2
SIGT=7.00 MR-2.5 MM LEFT	30000.	336.3	335.7	43.4	55.6	.00	977.4	1564.2	32.7	175.5	1421.5
SIGT=7.00 MR-5.0 MM LEFT	30000.	336.1	335.5	43.4	55.6	.00	977.3	1550.3	32.8	175.4	1407.8
SIGT=7.00 MR-10. MM LEFT	30000.	334.2	333.7	43.2	55.6	.00	976.4	1420.3	33.2	173.9	1279.7
SIGT=7.00 MR-TUBE ALIGNED	50000.	329.5	329.0	42.6	55.6	.00	1465.6	1567.4	32.6	168.7	1431.4
SIGT=9.00 MR-TUBE ALIGNED	50000.	329.0	328.4	42.6	55.6	.00	1465.2	1513.1	32.8	168.4	1377.6
SIGT=12.2 MR-TUBE ALIGNED	50000.	327.7	327.1	42.5	55.6	.00	1464.1	1382.3	33.0	167.3	1248.0
SIGT=7.00 MR-2.5 MR TRACK	50000.	329.4	328.8	42.6	55.6	.00	1465.5	1558.5	32.7	168.7	1422.6
SIGT=7.00 MR-5.0 MR TRACK	50000.	329.1	328.5	42.6	55.6	.00	1465.3	1529.9	32.8	168.6	1394.2
SIGT=7.00 MR-10. MR TRACK	50000.	327.8	327.2	42.5	55.6	.00	1464.2	1392.6	33.2	167.6	1258.3
SIGT=7.00 MR-2.5 MM DOWN	50000.	329.4	328.8	42.6	55.6	.00	1465.5	1555.8	32.7	168.7	1419.9
SIGT=7.00 MR-5.0 MM DOWN	50000.	329.0	328.4	42.6	55.6	.00	1465.2	1516.9	32.8	168.4	1381.4
SIGT=7.00 MR-10. MM DOWN	50000.	327.1	326.6	42.5	55.6	.00	1463.7	1324.1	33.4	167.2	1190.4
SIGT=7.00 MR-2.5 MM UP	50000.	329.4	328.8	42.6	55.6	.00	1465.5	1555.4	32.7	168.7	1419.5
SIGT=7.00 MR-5.0 MM UP	50000.	329.0	328.4	42.6	55.6	.00	1465.2	1516.1	32.8	168.4	1380.6
SIGT=7.00 MR-10. MM UP	50000.	327.1	326.5	42.5	55.6	.00	1463.7	1320.4	33.4	167.1	1186.7
SIGT=7.00 MR-2.5 MM LEFT	50000.	329.5	328.9	42.6	55.6	.00	1465.5	1564.2	32.7	168.8	1428.2
SIGT=7.00 MR-5.0 MM LEFT	50000.	329.3	328.7	42.6	55.6	.00	1465.4	1550.3	32.8	168.8	1414.4
SIGT=7.00 MR-10. MM LEFT	50000.	328.1	327.5	42.5	55.6	.00	1464.4	1420.3	33.2	167.9	1285.7
SIGT=7.00 MR-TUBE ALIGNED	70000.	326.3	325.7	42.3	55.6	.00	1914.8	1567.4	32.6	165.6	1434.5
SIGT=9.00 MR-TUBE ALIGNED	70000.	325.9	325.3	42.3	55.6	.00	1914.4	1513.1	32.8	165.4	1380.6
SIGT=12.2 MR-TUBE ALIGNED	70000.	324.8	324.3	42.2	55.6	.00	1913.3	1382.3	33.0	164.7	1250.7
SIGT=7.00 MR-2.5 MR TRACK	70000.	326.2	325.6	42.3	55.6	.00	1914.8	1558.5	32.7	165.7	1425.6
SIGT=7.00 MR-5.0 MR TRACK	70000.	326.0	325.4	42.3	55.6	.00	1914.5	1529.9	32.8	165.5	1397.3
SIGT=7.00 MR-10. MR TRACK	70000.	324.9	324.4	42.2	55.6	.00	1913.4	1392.6	33.2	164.9	1261.8
SIGT=7.00 MR-2.5 MM DOWN	70000.	326.2	325.6	42.3	55.6	.00	1914.7	1555.8	32.7	165.6	1423.0
SIGT=7.00 MR-5.0 MM DOWN	70000.	325.9	325.3	42.3	55.6	.00	1914.4	1516.9	32.8	165.5	1384.3
SIGT=7.00 MR-10. MM DOWN	70000.	324.4	323.9	42.2	55.6	.00	1912.9	1324.1	33.4	164.6	1193.0
SIGT=7.00 MR-2.5 MM UP	70000.	326.2	325.6	42.3	55.6	.00	1914.7	1555.4	32.7	165.6	1422.6
SIGT=7.00 MR-5.0 MM UP	70000.	325.9	325.3	42.3	55.6	.00	1914.4	1516.1	32.8	165.4	1383.6
SIGT=7.00 MR-10. MM UP	70000.	324.4	323.9	42.2	55.6	.00	1912.8	1320.4	33.4	164.6	1189.3
SIGT=7.00 MR-2.5 MM LEFT	70000.	326.3	325.8	42.3	55.6	.00	1914.8	1564.2	32.7	165.7	1431.3
SIGT=7.00 MR-5.0 MM LEFT	70000.	326.1	325.5	42.3	55.6	.00	1914.7	1550.3	32.8	165.7	1417.5
SIGT=7.00 MR-10. MM LEFT	70000.	325.1	324.6	42.3	55.6	.00	1913.7	1420.3	33.2	165.1	1288.5

Table C-VI. 1-D Thermal Model Results - Annular Space Maintained at Atmospheric Pressure and Wind Velocity of 10.0 m/s

CASE DESIGNATION	REYNOLDS NUMBER	RECEIVER TUBE TEMPERATURES I.D. (C)	RECEIVER TUBE TEMPERATURES O.D. (C)	GLASS TEMP. (C)	CONVECTION COEFFICIENTS HAIR (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HGAP (UNITS OF W/M**2-K)	CONVECTION COEFFICIENTS HFLUID (UNITS OF W/M**2-K)	ABSORBED SOLAR ENERGY QTUBE (W)	ABSORBED SOLAR ENERGY QGLASS (W)	RECEIVER HEAT LOSS (W)	ENERGY ABSORBED BY FLUID (W)
	(---)										
SIGT=7.00 MR-TUBE ALIGNED	10000.	358.5	358.0	63.0	55.2	6.95	410.9	1567.4	32.6	359.8	1240.2
SIGT=9.00 MR-TUBE ALIGNED	10000.	356.7	356.2	62.7	55.2	6.93	410.4	1513.1	32.8	356.9	1169.0
SIGT=12.2 MR-TUBE ALIGNED	10000.	352.5	352.1	62.0	55.2	6.90	409.4	1382.3	33.0	349.8	1065.5
SIGT=7.00 MR-2.5 MR TRACK	10000.	358.2	357.7	63.0	55.2	6.94	410.8	1558.5	32.7	359.4	1231.8
SIGT=7.00 MR-5.0 MR TRACK	10000.	357.3	356.8	62.8	55.2	6.94	410.6	1529.9	32.8	357.8	1204.8
SIGT=7.00 MR-10. MR TRACK	10000.	352.8	352.4	62.1	55.2	6.90	409.5	1392.6	33.2	350.6	1075.2
SIGT=7.00 MR-2.5 MM DOWN	10000.	358.1	357.6	63.0	55.2	6.94	410.8	1555.8	32.7	359.2	1229.3
SIGT=7.00 MR-5.0 MM DOWN	10000.	356.9	356.4	62.8	55.2	6.93	410.5	1516.9	32.8	357.1	1192.6
SIGT=7.00 MR-10. MM DOWN	10000.	350.6	350.2	61.7	55.2	6.88	408.9	1324.1	33.4	347.0	1010.5
SIGT=7.00 MR-2.5 MM UP	10000.	358.1	357.6	63.0	55.2	6.94	410.8	1555.4	32.7	359.2	1228.9
SIGT=7.00 MR-5.0 MM UP	10000.	356.8	356.3	62.7	55.2	6.93	410.5	1516.1	32.8	357.1	1191.8
SIGT=7.00 MR-10. MM UP	10000.	350.5	350.1	61.7	55.2	6.88	408.9	1320.4	33.4	346.7	1007.0
SIGT=7.00 MR-2.5 MM LEFT	10000.	358.4	357.9	63.0	55.2	6.95	410.9	1564.2	32.7	359.7	1237.2
SIGT=7.00 MR-5.0 MM LEFT	10000.	357.9	357.4	63.0	55.2	6.94	410.8	1550.3	32.8	359.0	1224.1
SIGT=7.00 MR-10. MM LEFT	10000.	353.7	353.3	62.2	55.2	6.91	409.7	1420.3	33.2	352.1	1101.4
SIGT=7.00 MR-TUBE ALIGNED	30000.	334.2	333.7	58.7	55.3	6.74	976.4	1567.4	32.6	319.1	1280.9
SIGT=9.00 MR-TUBE ALIGNED	30000.	333.4	332.9	58.6	55.3	6.73	976.0	1513.1	32.8	318.1	1227.9
SIGT=12.2 MR-TUBE ALIGNED	30000.	331.5	331.1	58.3	55.3	6.72	975.1	1382.3	33.0	315.2	1100.1
SIGT=7.00 MR-2.5 MR TRACK	30000.	334.1	333.6	58.7	55.3	6.74	976.3	1558.5	32.7	319.0	1272.2
SIGT=7.00 MR-5.0 MR TRACK	30000.	333.7	333.1	58.6	55.3	6.74	976.1	1529.9	32.8	318.5	1244.3
SIGT=7.00 MR-10. MR TRACK	30000.	331.7	331.2	58.3	55.3	6.72	975.1	1392.6	33.2	315.6	1110.2
SIGT=7.00 MR-2.5 MM DOWN	30000.	334.1	333.5	58.7	55.3	6.74	976.3	1555.8	32.7	319.0	1269.6
SIGT=7.00 MR-5.0 MM DOWN	30000.	333.5	333.0	58.6	55.3	6.74	976.0	1516.9	32.8	318.1	1231.6
SIGT=7.00 MR-10. MM DOWN	30000.	330.7	330.2	58.2	55.3	6.71	974.6	1324.1	33.4	314.2	1043.3
SIGT=7.00 MR-2.5 MM UP	30000.	334.1	333.5	58.7	55.3	6.74	976.3	1555.4	32.7	319.0	1269.2
SIGT=7.00 MR-5.0 MM UP	30000.	333.5	333.0	58.6	55.3	6.74	976.0	1516.1	32.8	318.1	1230.2
SIGT=7.00 MR-10. MM UP	30000.	330.6	330.2	58.2	55.3	6.71	974.6	1320.4	33.4	314.2	1039.7
SIGT=7.00 MR-2.5 MM LEFT	30000.	334.2	333.6	58.7	55.3	6.74	976.4	1564.2	32.7	319.2	1277.8
SIGT=7.00 MR-5.0 MM LEFT	30000.	334.0	333.4	58.7	55.3	6.74	976.3	1550.3	32.8	318.9	1264.2
SIGT=7.00 MR-10. MM LEFT	30000.	332.1	331.6	58.4	55.3	6.72	975.3	1420.3	33.2	316.3	1137.3
SIGT=7.00 MR-TUBE ALIGNED	50000.	328.1	327.5	57.7	55.3	6.68	1464.5	1567.4	32.6	309.4	1290.7
SIGT=9.00 MR-TUBE ALIGNED	50000.	327.6	327.0	57.6	55.3	6.68	1464.1	1513.1	32.8	308.7	1237.2
SIGT=12.2 MR-TUBE ALIGNED	50000.	326.3	325.8	57.4	55.3	6.67	1463.0	1382.3	33.0	306.9	1108.5
SIGT=7.00 MR-2.5 MR TRACK	50000.	328.0	327.5	57.7	55.3	6.69	1464.4	1558.5	32.7	309.4	1281.9
SIGT=7.00 MR-5.0 MR TRACK	50000.	327.7	327.2	57.6	55.3	6.69	1464.2	1529.9	32.8	309.0	1253.8
SIGT=7.00 MR-10. MR TRACK	50000.	326.4	325.9	57.4	55.3	6.67	1463.1	1392.6	33.2	307.2	1118.6
SIGT=7.00 MR-2.5 MM DOWN	50000.	328.0	327.4	57.7	55.3	6.69	1464.4	1555.8	32.7	309.3	1279.3
SIGT=7.00 MR-5.0 MM DOWN	50000.	327.6	327.1	57.6	55.3	6.69	1464.1	1516.9	32.8	308.8	1241.0
SIGT=7.00 MR-10. MM DOWN	50000.	325.7	325.2	57.4	55.3	6.67	1462.6	1324.1	33.4	306.4	1051.2
SIGT=7.00 MR-2.5 MM UP	50000.	328.0	327.4	57.7	55.3	6.69	1464.4	1555.4	32.7	309.3	1278.9
SIGT=7.00 MR-5.0 MM UP	50000.	327.6	327.1	57.6	55.3	6.69	1464.1	1516.1	32.8	308.8	1240.2
SIGT=7.00 MR-10. MM UP	50000.	325.6	325.2	57.5	55.3	6.67	1462.6	1320.4	33.4	306.3	1047.6
SIGT=7.00 MR-2.5 MM LEFT	50000.	328.1	327.5	57.7	55.3	6.69	1464.5	1564.2	32.7	309.4	1287.5
SIGT=7.00 MR-5.0 MM LEFT	50000.	327.9	327.4	57.7	55.3	6.69	1464.3	1550.3	32.8	309.3	1273.9
SIGT=7.00 MR-10. MM LEFT	50000.	326.6	326.1	57.5	55.3	6.68	1463.3	1420.3	33.2	307.7	1145.9
SIGT=7.00 MR-TUBE ALIGNED	70000.	325.2	324.6	57.2	55.3	6.66	1913.7	1567.4	32.6	304.9	1295.2
SIGT=9.00 MR-TUBE ALIGNED	70000.	324.8	324.2	57.1	55.3	6.66	1913.3	1513.1	32.8	304.4	1241.6
SIGT=12.2 MR-TUBE ALIGNED	70000.	323.8	323.3	57.0	55.3	6.65	1912.2	1382.3	33.0	303.0	1112.4
SIGT=7.00 MR-2.5 MR TRACK	70000.	325.1	324.6	57.2	55.3	6.66	1913.6	1558.5	32.7	304.8	1286.4
SIGT=7.00 MR-5.0 MR TRACK	70000.	324.9	324.4	57.2	55.3	6.66	1913.4	1529.9	32.8	304.6	1258.2
SIGT=7.00 MR-10. MR TRACK	70000.	323.8	323.4	57.0	55.3	6.65	1912.3	1392.6	33.2	303.3	1122.6
SIGT=7.00 MR-2.5 MM DOWN	70000.	325.1	324.6	57.2	55.3	6.66	1913.6	1555.8	32.7	304.8	1283.8
SIGT=7.00 MR-5.0 MM DOWN	70000.	324.8	324.3	57.1	55.3	6.66	1913.3	1516.9	32.8	304.4	1245.5
SIGT=7.00 MR-10. MM DOWN	70000.	323.3	322.9	57.0	55.3	6.65	1911.7	1324.1	33.4	302.7	1054.9
SIGT=7.00 MR-2.5 MM UP	70000.	325.1	324.5	57.2	55.3	6.66	1913.6	1555.4	32.7	304.8	1283.4
SIGT=7.00 MR-5.0 MM UP	70000.	324.8	324.3	57.1	55.3	6.66	1913.3	1516.1	32.8	304.4	1244.8
SIGT=7.00 MR-10. MM UP	70000.	323.3	322.8	57.0	55.3	6.65	1911.7	1320.4	33.4	302.6	1054.2
SIGT=7.00 MR-2.5 MM LEFT	70000.	325.2	324.6	57.2	55.3	6.66	1913.7	1564.2	32.7	304.9	1292.1
SIGT=7.00 MR-5.0 MM LEFT	70000.	325.1	324.5	57.2	55.3	6.66	1913.6	1550.3	32.8	304.8	1278.3
SIGT=7.00 MR-10. MM LEFT	70000.	324.1	323.6	57.1	55.3	6.65	1912.5	1420.3	33.2	303.6	1149.9

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