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THERMAL ANALYSIS OF PANSAT
ELECTRIC POWER SUBSYSTEM

by

Eric L. Victor

June, 1994

Thesis Advisor:

I. Michael Ross

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THERMAL ANALYSIS OF PANSAT
ELECTRIC POWER SUBSYSTEM

by

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Submitted in partial fulfillment
of the requirements for the degree of

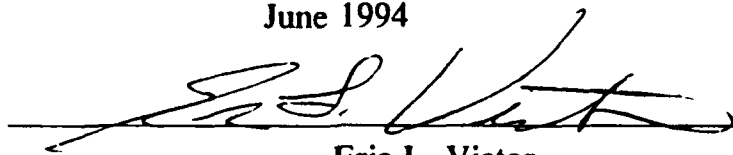
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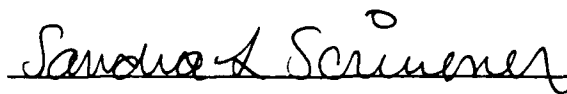
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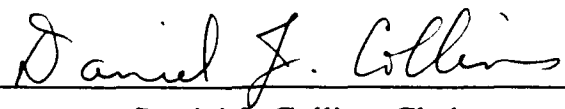
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ABSTRACT

Spacecraft thermal-control subsystems are necessary to maintain all elements of a spacecraft system within their temperature limits for all mission phases. In most instances the heat inputs are highly variable with time, requiring thorough transient-analysis of thermal flow within the spacecraft. Additionally, steady-state thermal profiles are necessary for precise overall thermal-analysis. The objective of this thesis is to develop a steady-state thermal model of the Electric Power Subsystem (EPS) and its associated housing for the Petite Amateur Navy Satellite (PANSAT). This task is undertaken to identify any physical locations within the EPS where temperatures exceed the limits established to protect sensitive electronic components. Software generated steady-state analysis using only contact-conductances for the EPS through the housing attachment is performed. It is shown that given the geometry of the physical model, the conductive relations developed, and the given boundary conditions, the steady-state temperature of the EPS and its associated housing will remain within limits.

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I. INTRODUCTION

In order to maintain all the elements of a spacecraft system within their temperature limits for all mission phases, thermal analysis of individual spacecraft subsystems is necessary for thermal-control subsystem design. Thermal-control designers must account for heat inputs from several sources, such as the Sun, the Earth, and electrical and electronic components on-board the spacecraft. In most instances the heat inputs are highly variable with time, requiring thorough transient-analysis of thermal flow within the spacecraft. Additionally, steady-state thermal profiles are necessary for overall thermal analysis. During the preliminary mission design of a spacecraft there are several thermal issues which must be addressed. A review of these issues bounds the thermal design problem. The first step in the thermal design of a spacecraft is to determine key requirements and constraints, which include the temperature limits and power dissipation of all spacecraft components. Next, spacecraft altitude and orientation relative to the Earth and Sun for all mission phases is determined in order to calculate the minimum and maximum thermal flux from each of these celestial bodies. With this, environmental heat inputs on the exterior surfaces of the spacecraft can be calculated. Once thermal boundary conditions are established, temperature limits defined, software modeling developed, and any other miscellaneous requirements understood, a complete spacecraft thermal subsystem can be developed.

A. THESIS SCOPE

The purpose of this thesis is to develop a steady-state thermal model of the Electric Power Subsystem (EPS) and its associated housing for the Petite Amateur Navy Satellite (PANSAT). This task is undertaken in order to identify any physical locations within the EPS where temperatures exceed the limits established to protect sensitive electronic components. Software generated steady-state analysis using only contact conductances through the housing attachment is studied to pinpoint any physical locations that deviate from the allowable temperature ranges. To generate the data needed for analysis it was necessary to determine circuit board layouts, which

included component locations and board sizes, in addition to power dissipation requirements of individual components. From this information, thermal nodes and thermal conductivities between nodes were calculated. Inward-viewing box geometry was created to physically model the EPS. Finally, the EPS housing was sized for thickness and structural integrity for a dynamic environment with an emphasis on thermal concerns.

B. BACKGROUND

A basic understanding of thermal conductivity and of the Integrated Thermal Analysis System (ITAS) software used to thermally model the EPS is necessary to appreciate the scope of this thesis.

1. Heat Conduction

a. Conduction

Whenever a temperature gradient exists in a solid medium, heat will flow from the higher-temperature to the lower-temperature region. The rate at which heat is transferred by conduction is proportional to the temperature gradient multiplied by the area of flux through which heat is being transferred:

$$q = A \frac{dT}{dx} \quad (1)$$

The actual rate of heat flow depends on the thermal conductivity, k , which is a physical property of the medium. For conduction through a homogeneous medium, the rate of heat transfer is then:

$$q = -kA \frac{dT}{dx} \quad (2)$$

The minus sign is included as a result of the second law of thermodynamics which requires that heat must flow from a higher-temperature region to a lower-temperature region. Equation (2) provides the definition for the thermal conductivity, k , and is called Fourier's Law of Conduction in honor of the French scientist *J.B.J. Fourier*, who proposed it in 1822. The thermal conductivity is a material property that indicates the amount of heat that will flow per unit time across a unit area when the temperature gradient is unity. Although, in general, the thermal conductivity varies

with temperature, in many engineering problems the variation is sufficiently small to be neglected. For engineering calculations, experimentally measured values of thermal conductivity are used [Ref. 1: p 4-8]

The best thermal conductors are metallic solids and the poorest ones are gases. In between lie alloys, nonmetallic solids, and liquids. Solid materials consist of free electrons and of atoms in a periodic lattice arrangement. Thermal energy may thus be conducted by two mechanisms: migration of free electrons and lattice vibration. These two effects are additive, but, in general, the transport due to electrons is more effective than the transport due to vibrational energy in the lattice structure. Since electrons transport electric charge in a manner similar to the way in which they carry thermal energy from a higher-temperature region to a lower-temperature region, good electrical conductors are usually also good heat conductors and good electrical insulators are poor heat conductors. In non-metallic solids there is little or no electronic transport and the conductivity is therefore primarily determined by lattice vibration. This explains why these materials have a lower thermal conductivity than metals. An important group of solid materials for heat transfer design are thermal insulators. These materials are solids, but their structure contains air spaces that are sufficiently small to suppress gaseous motion and thus take advantage of the low thermal conductivity of gases in reducing heat transfer. Although we usually speak of a thermal conductivity of thermal insulators, in reality the transport through an insulator is comprised of conduction as well as radiation across the interstices filled with gas. In good insulators the spaces containing the air are sealed from each other, as in cellular foams made from plastic or glass. The thermal conductivity value of insulation systems is always an effective value that accounts for conduction, radiation, and sometimes also convection within the material. [Ref. 1: p. 10-12]

b. Thermal Conductance

To establish the working equation for thermal conductance that will be used in calculations for this thesis, examine the simple case of steady-state heat flow through a plane wall with a non-varying temperature gradient and non-varying heat flow through a uniform cross-sectional area. Using these assumptions and integrating equation (2) we obtain:

$$q = \frac{T_{\text{hot}} - T_{\text{cold}}}{L / Ak} \quad (3)$$

In this equation, $(T_{\text{hot}} - T_{\text{cold}})$, the difference between the higher-temperature region and the lower-temperature region is the driving potential that causes the flow of heat. The quantity (L/Ak) is equivalent to a thermal resistance, R , that the theoretical wall offers to the flow of heat by conduction, thus:

$$R = L / A k \quad (4)$$

The reciprocal of the thermal resistance is referred to as the thermal conductance, K , defined by [Ref. 1: p. 6.7]

$$K = A k / L \quad (5)$$

c. Contact Resistance

When different conducting surfaces are placed in contact, a thermal resistance is present at the interface of the solids. The interface resistance, frequently called the contact resistance, is developed when two materials will not fit tightly together and a thin layer of fluid is trapped between them. Examination of an enlarged view of the contact between two surfaces shows that the solids touch only at the peaks in the surface and that the valleys in the mating surfaces are occupied by a gas (possibly air), a liquid, or a vacuum. The following parameters are of primary importance:

- Geometry of the contacting material: surface roughness
- Thickness of the gap
- Type of interstitial fluid: gas, liquid, grease, vacuum
- Thermal conductivities of materials
- Microhardness of surface materials
- Contact pressure
- Apparent contact area
- Temperature

At the interface, the mechanism of heat transfer is complex. Conductance takes place through the contact points of the solids, while heat is transferred by convection and radiation across the trapped interstitial fluid. [Ref. 1: p. 12]

It is difficult to determine the surface quality of a material. Surface qualities include its geometry, crystal structure, appearance, color, resistance to corrosion, hardness (microhardness), and size and shape of surface flaws. The surface deviations determine the surface roughness. There are three types of surface deviations: surface flaws, waviness, and roughness. Surface flaws are occasional irregularities; waviness consists of widely spaced irregularities such as feed marks; and roughness consists of finely spaced irregularities (less than 1/32 in.) which determine the 'finish' of a surface. The average height of surface irregularities is a measure of roughness but not a complete specification of the character of the irregularities. A preferred set of roughness classes has been suggested from 1/4 in. to 63,000 microin., as average. [Ref. 2: p.13-65]

Hardness of materials has been variously defined as resistance to local penetration, to scratching, to machining, to wear or abrasions, and to yielding. The multiplicity of definitions and corresponding multiplicity of hardness measuring instruments, together with the lack of a fundamental definition, indicates that hardness may not be a fundamental property of a material but rather a composite one including yield strength, work hardening, true tensile strength, modulus of elasticity, and others. The resistance to localized penetration, or indentation hardness, is widely used industrially as a measure of hardness and is the one measure used for this thesis. [Ref. 2: p.5-15]

There are several indentation tests commonly utilized. The Brinell hardness is determined by forcing a hardened sphere under a known load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell hardness number is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation, in square millimeters. The result is a pressure, but the units are rarely stated. In the standard Brinell test, the diameter of the impression is measured with a low-power hand microscope, but for production work there are available several testing machines which automatically measure the depth of the impression and from this give readings of hardness.

In the Rockwell method of hardness testing, the depth of penetration of an indenter under certain arbitrary conditions of test is determined. The indenter may be either a steel ball of some specified diameter or a spherical-tipped conical diamond of 120 deg. angle and 0.2 mm tip

radius, called a "Brale". A minor load of 10 kg is first applied which causes an initial penetration and holds the indenter in place. Under this condition, the depth-measuring scale is set to its arbitrary maximum value of 130 if any of the balls are used, or to 100 if the Brale is used. A major load of 60, 100, or 150 kg is then applied under dashpot control and then removed, returning to the minor load of 10 kg. The hardness number may then be read directly from the scale which measures penetration, and this scale is so arranged that soft materials with deep penetrations give low-hardness numbers. As compared with the Brinell test, the Rockwell method makes a smaller indentation, may be used on thinner material, and is much more rapid since hardness numbers are read directly and need not be calculated. The relation among the scales of various hardness methods is not exact, since no two measure exactly the same sort of hardness, and a relationship determined on steels of different hardnesses is only approximately true with other materials. The Brinell-Rockwell relation is fairly satisfactory and is shown in Figure 1. [Ref. 2: p. 5-16]

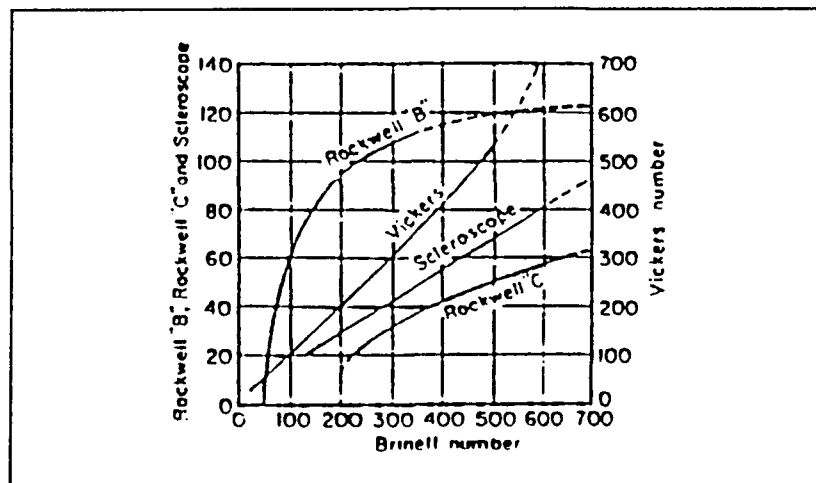


Figure 1. Hardness Scales

d. Joint Conductance

What follows in this section is based on work in thermal contact by Professor M.M. Yovanovich of the University of Waterloo, in Waterloo, Ontario.

Once the microhardness, H , the thermal conductivity, k , and surface roughness, S_r , are determined for both surfaces, and interstitial fluid trapped between the two surfaces, if any, is identified, we can proceed with calculations to determine the joint conductance. Additional

information required includes the contact pressure of the surfaces, P , the apparent contact area of the two surfaces, A_a , and temperature of the surfaces. We define the joint conductance, h , as follows with h_c being the contact conductance and h_g being the gap conductance:

$$h = h_c + h_g \quad (6)$$

(1) Contact Conductance. The first step in calculating the contact conductance is to determine the mean thermal conductivity, k_s , of the two surfaces:

$$k_s = \frac{2(k_1)(k_2)}{k_1 + k_2} \quad (7)$$

The hardness of the softer material is then utilized to find P/H . The value for P/H and the measured readings for surface roughness of the materials are input into the following equation which is then solved for h_c , the contact conductance:

$$h_c = \frac{(1.25)k_s[P/H]^{.95}}{S_r} \quad (8)$$

(2) Gap Conductance. For a complete explanation and derivation for the gap conductance, refer to works by Professor Yovanovich. For the purposes of this thesis, the interstitial space is assumed to be a vacuum and h_g , the gap conductance, is assumed to be zero.

2. Integrated Thermal Analysis System

The Integrated Thermal Analysis System (ITAS) was developed by the Analytix Corporation in 1988. ITAS was developed to assist spacecraft designers in all tasks in thermal design modeling from geometry generation to results post-processing for various engineering computations. These computations include orbital analysis, thermal analysis, contamination evolution, plume impingement, etc. The current interactive version of the code fully supports all capabilities relevant to the spacecraft thermal analysis, namely, view factors (contour integration and ray tracing), shadow factors (blockage), on-orbit incident flux determination for various orientations, radiation interchange factors, on-orbit absorbed heat-rates calculations in addition to steady-state and/or transient temperature computations. There are other capabilities that may be reviewed in the ITAS Users Manual and are not discussed further here.

ITAS is an integrated, interactive, and fairly user-friendly code. Once started, the user may select various options from well designed color menus, depending on the purpose, to calculate or plot various parameters interactively. No special compiler or linker program is necessary to run ITAS, which simplifies the loading and running of the main program. No in-depth knowledge of DOS is required, although an understanding of the basic concepts of heat transfer is necessary for some user provided calculations.

Utilizing ITAS begins with generation of the geometric model. ITAS may be used to interactively generate surface geometry models from "primitives" (basic shapes). These shapes include polygons, boxes, disc's, cones, cylinders, paraboloids, spheres, any generic surface of revolution, generic boxes of any cross-section, and elbows of any angle. All shapes generated are stored in a file called a PARTS file. A PARTS file may consist of 1000 or more parts (the number of parts is limited only by the available disc space) and any number of parts may be chosen for building a geometric model. The parts generated may then be selectively plotted for model building. Once a model is displayed on the screen, surface node numbers and user-assigned thermal node numbers are assigned to the active surfaces in the geometric model.

Once the geometric model is built and surface nodes generated, material properties may be assigned to each surface or node via a reference number from the internal ITAS material property library. Two sets of material property libraries may be accessed from within the ITAS: the optical characteristics library and the physical property library.

The optical library currently contains about four hundred solar absorbtivity and emissivity pairs for coatings and other surfaces and their finishes from white paint to many variations of metallic surfaces. The optical property library may be accessed from different locations within the program, enabling the user to utilize the information within without leaving the main routine. When a material I.D. is entered for a particular surface, the program will automatically assign those optical properties to the surface for all calculations. The contents of the library may be updated by the user.

The physical property library provides information-only data to the user. There are over eleven hundred material entries in this library. The following material properties may be obtained

from this database: thermal conductivity, specific heat, density, latent heat, and maximum or transition temperatures of a specific material. Some of these values are later used in calculations for conductive relationships. Once the geometric model with ITAS generated surface nodes and their associated material properties are entered, then user-defined nodes are entered by the user.

User-nodes are non-geometric nodes and, therefore, do not have any "physical" presence (surface) in ITAS. These nodes are used for mathematically connecting all the surfaces in the geometric model and any other surfaces the user desires. Three types of thermal nodes are allowed in ITAS. First, Diffusion nodes are nodes with finite masses; Second, a Boundary node is a node where the temperature remains fixed at all times; Third, an Arithmetic node is a node with zero mass. The temperature response of an Arithmetic node is instantaneous. Arithmetic nodes exist mathematically in ITAS only, not as physical nodes.

When all user-nodes are entered, conductive values must be calculated and entered for nodal connections. Except for some specialized situations, all conductance values must be pre-calculated by the user. The current version of ITAS will not automatically calculate the conductance between the nodes.

The preceding paragraphs represent the minimum required tasks to be completed in order to execute an ITAS run. Other options are available with the problem dictating option usage.

II. THERMAL MODEL

A. MATERIAL

In order to create the thermal model, the materials for all components and structures must be selected, as well as their geometry. Judicious selection of nodes must be made as well as the following thermal model material parameters determined. [Ref. 3: p. 435]

- Strength
- Stiffness.
- Density (weight)
- Thermal conductivity
- Thermal expansion
- Corrosion resistance
- Cost
- Fracture toughness
- Ease of fabrication
- Versatility of attachment options
- Availability

In addition to the above mentioned mechanical and thermal properties of spacecraft materials, there are other properties of note such as ductility, brittleness, creep, and fatigue strength.

Ductility measures the capacity of a material for inelastic deformation without rupture. Brittleness indicates little capacity for plastic deformation without failure. Ductility is measured by the percentage elongation of tensile test specimen after failure for a specified gauge length. Usually, a material having less than 5% elongation at fracture is said to be brittle and one having more is said to be ductile.

Creep is defined as the time-dependent deformation of a material under an applied load. It is usually regarded as an elevated temperature phenomenon, although some materials also creep at room temperature. The results of tests of materials under a constant load and temperature are usually plotted as strain versus time up to ruptures. The plotted curve exhibits three distinct regions. The first stage includes both elastic and plastic deformities. This stage shows a decreasing creep rate which is due to the strain hardening. The second stage shows a constant minimum creep rate caused by the annealing effect. In the third stage, a considerable reduction in the cross-sectional area occurs, resulting in an increase in stress and creep rate which eventually leads to fracture.

In a tensile test, the load is applied gradually to the failure. Such load condition is known as static condition. A spacecraft is subjected to both static and dynamic loads. In a dynamic load, the stresses are repeated a large number of times, the actual maximum stress is below the ultimate strength of the material and quite frequently even below the yield strength. Such failures are called fatigue failures.

A fatigue failure starts with a small crack. Once a crack has developed, the stress concentration effect becomes greater and the crack progresses more rapidly. As the stress area decreases in size, the stress increases in magnitude until the part fails suddenly. The failure is similar to brittle material fracture.

For ferrous materials, the strength under repeated stresses is often referred to as the endurance limit. Endurance limit stress is the stress that can be repeated an infinite number of times without causing the fracture of the material. Nonferrous materials, such as aluminum alloys, do not have an endurance limit, as they continue to weaken when the stress cycles are repeated. Hence the fatigue strength is the maximum stress that can be repeated for specified number of cycles without producing the failure of the unit.

Stress concentration may be caused by any discontinuity, such as holes, notches, and any abrupt changes in the cross section. Under steady loads, the effect of stress concentration is reduced due to the redistribution of the stresses in the region of the stress concentration, resulting from the plastic flow of the material when the maximum stress reaches the yield point. The effect

of the stress concentration on the brittle material, under a steady load, may be severe since very little plastic flow occurs. Under repeated loads, however, the endurance strength of even ductile material may be greatly reduced due to stress concentration. [Ref. 4: p. 244-248]

1. Material Selection

For structural and component housing designs, the engineer must consider optional materials, types of structures, and construction methods by performing trade studies to compare weight and cost. Most metals are very nearly homogeneous, having constant properties throughout their composition, and isotropic, having the same properties regardless of direction. Non-metals are usually formed with composites, or blends of more than one material. Composite materials can be homogeneous or isotropic, but not generally.

a. EPS Housing

By far the most commonly used metallic material for spacecraft structures and housings is aluminum, of which there are many types and tempers. Aluminum is lightweight, strong, and readily formable. Aluminum and its alloys, numbering in the hundreds, are available in all common commercial forms. The metal does not oxidize progressively because, when exposed to air, a hard, microscopic oxide coating forms on the surface that seals the metal from the environment. The tight chemical bond of oxide is the reason that aluminum is not found in nature; it exists only as a compound.

Aluminum-alloy sheet can be formed, drawn, stamped, or spun. Many wrought or cast aluminum alloys can be welded, brazed, or soldered, and aluminum surfaces readily accept a wide variety of finishes, both mechanical and chemical. Because of their high electrical conductivity, many aluminum alloys are used as electrical conductors. Aluminum reflects radiant energy throughout the entire spectrum, is non-sparking, and non-magnetic.

Commercially pure aluminum has a tensile strength of about 13,000 psi. Cold-working the metal approximately doubles its strength. For greater strength, aluminum is alloyed with other elements such as manganese, silicon, copper, magnesium, or zinc. Like pure aluminum, the alloys can also be strengthened by cold-working. Some alloys are further strengthened and

hardened by heat treatments. At subzero temperatures, aluminum is stronger than at room temperature and is no less ductile. Most aluminum alloys lose strength at elevated temperatures, although some retain significant strength to 500 deg. F. [Ref. 5: p. 48]

For this thesis, Aluminum 6061-T6 was chosen for the EPS housing material. It is a wrought aluminum-alloy containing 61% aluminum, or alloy purity, designated by the third and fourth digits, with a combination of magnesium and silicon as the major alloying elements. The T6 suffix in the designation number indicates that the alloy was solution-heat-treated and artificially aged.

b. Printed Circuit Boards

The printed circuit boards consist of six-layers with alternating levels of copper as the conductor and polyimide as the insulator, as shown in Appendix A. The copper is exposed on the bottom of the printed circuit board and the polyimide is exposed on the top of the circuit board. The top layer of polyimide is 'scratched' to allow for the uppermost layer of copper to be utilized as the signal layer for the components placed on the circuit board. The ground-layer of copper is the fourth layer from the top with the bottom layer of copper acting as the thermal plane.

Copper and copper alloys are fabricated in rod, plate, strip, sheet, tube shapes, forgings, wire, and castings. These alloys are grouped according to composition into several general categories: coppers, high-copper alloys, brasses, leaded brasses, bronzes, aluminum bronzes, silicon bronzes, copper nickels, and nickel silvers. Copper and its alloys form adherent films that are relatively impervious to corrosion and that protect the base metal from further attack. The copper alloys are used where any of the following properties are needed: good thermal or electrical conductivity, corrosion-resistance, ease of forming, ease of joining, and color. On a volume basis, copper has the highest conductivity of any commercial metal. On the other hand, copper and its alloys have relatively low strength-to-weight ratios and low strengths at elevated temperatures. Some alloys are susceptible to stress-corrosion cracking unless they are stress relieved. Copper and its alloys can be hot or cold-worked, although they work-harden. Ductility can be restored by annealing or in heating incident to welding or brazing operations. For our printed circuit board application as well as any application requiring maximum thermal or

electrical conductivity, the most widely used copper is C11000, known as "tough pitch" which contains approximately .03% oxygen and a minimum of 99.9% copper. [Ref. 5: p. 52]

As already stated, polyimide was utilized for printed circuit board fabrication.

Polyimides are a family of some of the most heat and fire-resistant polymers known. Their excellent retention of mechanical and physical properties at high temperatures is due to the nature of the aromatic raw materials that are building blocks of polyimides.

Polyimides are formulated as both thermosets, and thermoplastics. Moldings and laminates are generally based on thermoset resins, although some are made from thermoplastic grades. Unlike most plastics, polyimides are available as laminates and shapes, molded parts, and stock shapes. Thin-film products such as enamel, adhesives, and coatings are usually derived from thermoplastic polyimide resins.

Laminates are based on continuous reinforcements including woven glass and quartz fabrics, or fibers of graphite, boron, quartz, or organic materials. Molding compounds contain discrete fibers such as chopped glass or asbestos, or particulate fillers such as graphite powder, MoS₂, or PTFE.

Polyimide laminates can operate continuously in air at 500 °F; service temperature for intermittent exposure can range from cryogenic to as high as 900 °F. Glass-fiber-reinforced versions retain over 70% of their flexural strength and modulus at 480°F. Creep is almost nonexistent, even at high temperatures, and deformation under load (4,000 psi) is less than .05% at room temperature for 24 hours. These materials have good wear resistance and low coefficients of friction, both of which are further improved by PTFE fillers. Electrical properties of polyimide laminates are outstanding over a wide range of temperature and humidity conditions. [Ref. 5: p. 115]

B. GEOMETRY

1. EPS Housing

The EPS housing encases the Electrical Power System and is located on the -Y side of the upper equipment plate. The EPS will have a maximum mass of 5 lbm. the EPS must remain statically and dynamically within the mounting envelope. Thus, the thickness of the EPS walls must be calculated so as to meet these design criteria. Mounting of the EPS to the upper equipment plate will be by means of stainless steel screws into the upper equipment plate. The EPS housing is to have a mounting surface which is to contact the lower side of the equipment plate with a required flatness to within .002 in. over its length and width. The actual dimensions of the EPS, as well as the EPS housing location within PANSAT, are shown in Appendix B.

The EPS housing is thermally modeled in the ITAS system as a 6-sided box with the dimensions of 9 in. in the X-direction, 8 in. in the Y-direction, and 1.569 in. in the Z-direction. For more precise mathematical construction, the +Y and -Y sides of the EPS housing were divided into four distinct physical and mathematical nodes. This geometry is shown in Figure 2.

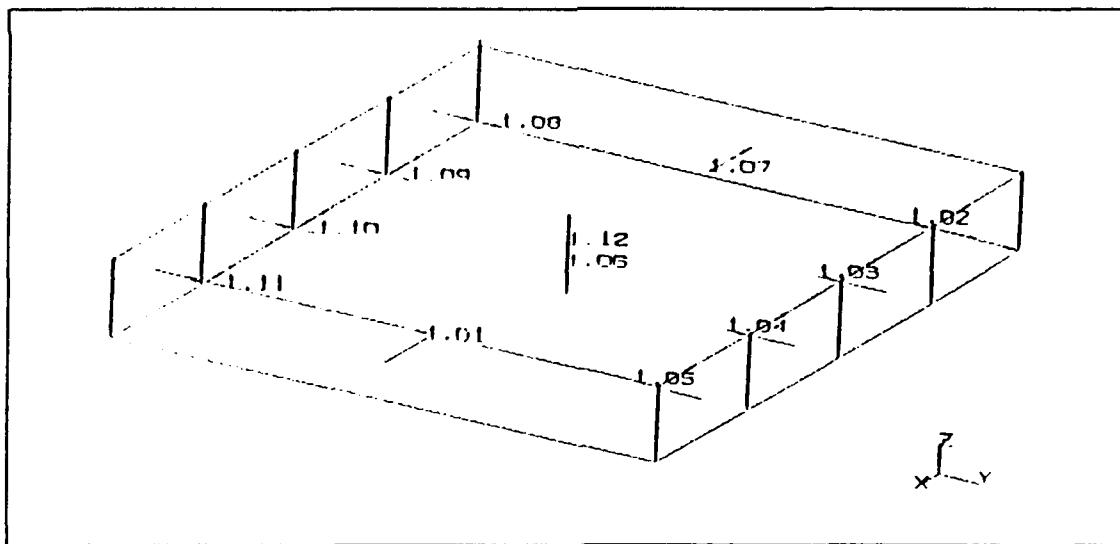


Figure 2. EPS Housing and Nodes

As can be seen in the figure, this results in the EPS housing having 12 physical nodes. It should be noted that these 12 nodes represent the inside-surfaces of the EPS housing since this thesis is concerned only with the inward-viewing geometry. Outside surface nodes would be

required if it were necessary to calculate the radiant thermal flux from other spacecraft components.

2. Printed Circuit Boards

There were several questions to address in the modeling of the printed circuit boards. The first question was whether or not to model the two circuit boards within the EPS as one-sided or two-sided for purposes of ITAS calculated view factors. The second question dealt with the determination of the number of physical nodes each circuit board would require for precise measurements. Once the number of nodes were determined, in what shapes would these nodes be? Lastly, once the overall thickness of the circuit boards was determined, how would each layer of a circuit board be modeled in relation to the other layers of the same board?

It was determined that for the most accurate measurements, the circuit boards would be modeled as 2-sided for view-factor and shadow-factor computations. After examination of both the upper and lower circuit board layouts and the power dissipation for each component on each board, a physical breakdown into nodes was completed. The printed circuit board layouts, power dissipation requirements, and nodal breakdowns for both boards can be found in Appendix A. The upper circuit board was modeled as two separate polygons with a total number of 18 physical nodes while the lower board was modeled as a single polygon and divided into 12 physical nodes. Nodal breakdowns for both boards was based on attempting to maximize the number of nodes for the sake of accuracy, while striving to minimize the number of nodes for sake of convenience and ease of calculation. These two somewhat contradictory approaches yielded the results shown. For both circuit boards, all physical nodes were rectangular, a construct which greatly reduces the number of user calculations.

The overall thickness of both circuit boards was determined to be .062 in. The copper layers were of the 1 ounce type which means that the thickness would be that of 1 ounce of copper over a 1 sq. ft. area. Using the density of copper at 20 °C, yielding 8.96 g/cm³, and converting to oz/ft³ resulted in a density of 8,949 oz/ft³. Solving for the volume, and thus the thickness:

$$t = \frac{M}{DLW} = \frac{1oz}{(8949oz / ft^3)(1ft)(1ft)} = .00011 ft$$

$$t = .00134 in.$$

This is the thickness for one layer of the copper. Multiplying by 3 yielded the thickness for all copper layers. Subtracting this from .062 and dividing that number by 3 yielded a thickness for each polyimide layer of .01933 in. These thicknesses will be used later in calculation of flux areas for thermal conductivity between nodes.

For the modeling of the circuit board layers, each layer was given the identical geometry. For the top printed circuit board, the bottom layer of thermal plane copper was numbered from 601 to 618 with next layer up being a polyimide layer with node numbers of 501 to 518. This numbering system was continued with each subsequently higher layer numbering in the 400's, 300's, 200's, and 100's. This same numbering technique was used in the bottom board as well with the layers numbered from the 1600's to 1100.

C. THERMAL NODES

1. Node Definitions

Appendix C contains a listing of all ITAS generated surface numbers and the user-generated node numbers that were assigned to them. These user node assignments are made in order to create a mathematical node for each surface for thermal calculations. All EPS housing thermal nodes were given 900 series numbers, from 901 to 912. Node no. -913 was input as the thermal node for the bottom of the upper equipment plate. Thus, the EPS housing-PANSAT thermal interface will be between the 906 and -913 nodes. Recall that the minus sign in front of 913 indicates that particular node will have a constant temperature.

In addition to the physical nodes that were created geometrically in ITAS, several more mathematical nodes were created in order to more effectively model the overall system. The inside geometry of the model can be seen in Appendix D. What this will show is a simple line schematic of a box with two flat (thin) surfaces representing the printed circuit boards. This model is constructed this way, as mentioned earlier, to calculate the view and shadow factors internal to

the EPS. However, the actual physical contact between the printed circuit boards and the housing occurs along ledges that the printed circuit boards rest upon along the +Y and -Y sides of the housing. In addition to these ledges, there are mechanical devices which, when screwed down, wedge against the top of the printed circuit boards and the housing overhang to secure the printed circuit board. These rails were assigned node numbers as follows:

- +Y bottom rail: 921
- +Y middle rail: 922
- +Y top rail: 923
- -Y bottom rail: 924
- -Y middle rail: 925
- -Y top rail: 926

These nodes will provide a means of calculating the conductance from the bottom portion of both PCB's copper thermal planes to the EPS housing. There will also be some conductance from the top layer of polyimide on both PCB's to the railing nodes via the screw attachments wedged against the top of the board, though these values would be expected to be very small.

2. Node Conductance Calculations

There were 8 different node calculation variations: Housing to housing; housing to PANSAT upper-equipment plate; railing to housing; PCB copper thermal-layer to railing; PCB top polyimide-layer to railing; PCB copper-layer; PCB polyimide-layer; PCB copper-layer to polyimide-layer. For the purposes of calculations, thermal nodes are physically located in the 3-dimensional center of each physical surface. A general description of each calculation variation is included below, and a listing of ITAS conductance entries is included as Appendix E.

Recall that the general formula for the calculation of conductivity between two nodes in a solid medium is:

$$K = \frac{kA}{L}$$

The general method for calculating the conductance between 2 nodes where 2 surfaces are in contact is as follows: First, calculate the conductance from 1 node to the surface interface.

This is calculated using equation (5). Repeat this for the second node to surface interface, then calculate the contact conductance for the two surfaces as discussed in the background section. Once these 3 conductance's are calculated, solve the following equation for the overall conductance between the 2 nodes:

$$K_o = \frac{1}{\frac{1}{K_1} + \frac{1}{h_c} + \frac{1}{K_2}} \quad (9)$$

a. Housing to Housing Node Calculations [Ref. Table 1]

Conductances were calculated using equation (5) and the following thermal conductivity of aluminum:

$$k = 170 \frac{W}{m^\circ C} = 4.31 \frac{W}{in^\circ C}$$

b. EPS Housing to PANSAT Upper Equipment Plate

To calculate the conductance through the equipment plate, it was assumed that the equipment plate thickness was .125 in. yielding a value for L of .0625. With a total area of contact of 72 in.². Using the same thermal conductivity of k as from part a., we obtain $K_1 = 4965 W/^\circ C$.

To calculate the conductance through the top of the EPS housing, $A = 72 \text{ in}^2$ and $L = .0995 \text{ in.}$ were used, yielding $K_2 = 3118.79 W/^\circ C$. To solve for the contact conductance, the following parameters were assumed: $P = 10 \text{ psi}$; $H = 1180 \times 10^6 \text{ n/m}^2$; $S_r = 7 \text{ microm.}$ These values yielded $h_c = 134.136 W/^\circ C$. Now, solving for K_o :

$$K_o = 125 W/^\circ C$$

c. Railing to Housing Conductances [Ref. Table 2]

Although the railing nodes are mathematically distinct from the housing nodes, the physical reality is that the railings are not separate from those walls. Thus, the conductance calculations do not include contact conductances.

TABLE 1. HOUSING TO HOUSING NODE CONDUCTANCES

FROM NODE	TO NODE	AREA (in ²)	LENGTH (in)	K (W/°C)
901	905	0.3138	5.1250	0.2638
901	906	1.5440	5.2845	1.2592
901	911	0.3138	5.1250	0.2638
901	912	1.5440	5.2845	1.2592
902	903	0.3138	2.2500	0.6011
902	906	0.4342	4.7845	0.3911
902	907	0.3138	5.1250	0.2638
902	912	0.4342	4.7845	0.3911
903	904	0.3138	2.2500	0.6011
903	906	0.4342	4.7845	0.3911
903	912	0.4342	4.7845	0.3911
904	905	0.3138	2.2500	0.6011
904	906	0.4342	4.7845	0.3911
904	912	0.4342	4.7845	0.3911
905	906	0.4342	4.7845	0.3911
905	912	0.4342	4.7845	0.3911
908	906	0.4342	4.7845	0.3911
908	909	0.3138	2.2500	0.6011
908	912	0.4342	4.7845	0.3911
909	906	0.4342	4.7845	0.3911
909	910	0.3138	2.2500	0.6011
909	912	0.4342	4.7845	0.3911
910	906	0.4342	4.7845	0.3911
910	911	0.3138	2.2500	0.6011
910	912	0.4342	4.7845	0.3911
911	906	0.4342	4.7845	0.3911
911	912	0.4342	4.7845	0.3911

TABLE 2. RAILING TO HOUSING NODE CONDUCTANCES

From Node	To Node	Area (in ²)	Length (in)	K (W/°C)
921	901	0.0625	4.6000	0.0585
921	902	0.0625	4.6000	0.0585
921	903	0.5625	0.2250	10.7750
921	904	0.5625	0.2250	10.7750
921	905	0.5625	0.2250	10.7750
921	906	0.5625	0.2250	10.7750

921	912	2.2500	0.2440	39.7438
922	901	0.1720	4.6000	0.1611
922	902	0.1720	4.6000	0.1611
922	903	1.5480	0.2250	29.6528
922	904	1.5480	0.2250	29.6528
922	905	1.5480	0.2250	29.6528
922	906	1.5480	0.2250	29.6528
923	901	0.1252	4.6000	0.1173
923	907	0.1252	4.6000	0.1173
923	902	1.1272	0.2250	21.5921
923	903	1.1272	0.2250	21.5921
923	904	1.1272	0.2250	21.5921
923	905	1.1272	0.2250	21.5921
923	906	2.2500	0.3470	27.9466
924	901	0.0625	4.6000	0.0585
924	907	0.0625	4.6000	0.0585
924	908	0.5625	0.2250	10.7750
924	909	0.5625	0.2250	10.7750
924	910	0.5625	0.2250	10.7750
924	911	0.5625	0.2250	10.7750
924	912	2.2500	0.2440	39.7438
925	901	0.1720	4.6000	0.1611
925	907	0.1720	4.6000	0.1611
925	908	1.5480	0.2250	29.6528
925	909	1.5480	0.2250	29.6528
925	910	1.5480	0.2250	29.6528
925	911	1.5480	0.2250	29.6528
926	901	0.1252	4.6000	0.1173
926	907	0.1252	4.6000	0.1173
926	908	1.1272	0.2250	21.5921
926	909	1.1272	0.2250	21.5921
926	910	1.1272	0.2250	21.5921
926	911	1.1272	0.2250	21.5921
926	906	2.2500	0.3470	27.9466

d. PCB Copper to Railing Conductances

(1) Top PCB Thermal Plane Copper to Railing. Assumptions:

$P = 10 \text{ psi}$

$S_r (\text{both}) = 7 \text{ microm}$

$H_{al} = 1180 \times 10^6 \text{ n/m}^2$

$$L_{cu} = .00067 \text{ in.}$$

$$L_{rail} = .344 \text{ in.}$$

$$k_{cu} = 9.65 \text{ W/in}^{\circ}\text{C}$$

$$k_{al} = 4.31 \text{ W/in}^{\circ}\text{C}$$

$$\text{Thus: } h_c = 2.574 \text{ W/in}^2\text{C}$$

TABLE 3. TOP PCB THERMAL PLANE COPPER TO RAILING COPPER TO RAILING CONDUCTANCES

FROM NODE	TO NODE	AREA (in ²)	h_c	$K_1(\text{Cu})$	$K_2(\text{A1})$	K_o
601	925	0.3750	0.9652	5,401	4.6984	0.8007
602	925	0.6000	1.5444	8,641	7.5174	1.2811
603	925	0.6062	1.5604	8,731	7.5957	1.2945
604	925	0.9187	2.3648	13,232	11.5110	1.9620
614	922	0.1875	0.4826	2,700	2.3490	0.4003
615	922	0.2500	0.6435	3,600	3.1320	0.5338
616	922	0.3437	0.8848	4,951	4.3068	0.7340
617	922	0.6550	1.6859	9,433	8.2065	1.3986
618	922	0.8125	2.0913	11,702	10.1798	1.7351

(2) Bottom PCB Thermal Plane Copper to Railing. Assumptions are the same as in (1), above.

TABLE 4. BOTTOM PCB THERMAL PLANE COPPER TO RAILING CONDUCTANCES

FROM NODE	TO NODE	AREA (in ²)	h_c	$K_1(\text{Cu})$	$K_2(\text{A1})$	K_o
1601	924	0.6250	1.6087	9,007	21.5500	1.4967
1602	924	0.7187	1.8500	10,352	24.7825	1.7123
1603	924	0.5625	1.4478	8,101	19.3950	1.3470
1604	924	0.3437	0.8848	4,951	11.8525	0.8232
1609	921	0.6250	1.6087	9,001	21.5500	1.4967
1610	921	0.7187	1.8500	10,352	24.7825	1.7213
1611	921	0.5625	1.4478	8,101	19.3950	1.3470
1612	921	0.3437	0.8848	4,951	11.8525	0.8232

e. PCB Polyimide to Railing Conductances

(1) Top PCB. Assumptions:

$$P = 10 \text{ psi}$$

$$S_r (\text{both}) = 7 \text{ microm}$$

$$H_{\text{poly}} = 1537 \times 10^6 \text{ N/m}^2$$

$$L_{\text{rail}} = .344 \text{ in.}$$

$$L_{\text{poly}} = .00966 \text{ in.}$$

$$k_{\text{poly}} = .2 \text{ W/m}^\circ\text{C}$$

$$\text{Thus, } h_c = .004378 \text{ W/in}^{2^\circ}\text{C}$$

TABLE 5. TOP PCB POLYIMIDE LAYER TO RAILING CONDUCTANCES

FROM NODE	TO NODE	AREA(in ²)	h_c	$K_1(\text{Poly})$	$K_2(\text{Al})$	K_0
101	926	0.3750	0.0016	0.1940	6.4520	0.0016
102	926	0.6000	0.0026	0.3100	10.3233	0.0026
103	926	0.6062	0.0026	0.3130	10.4308	0.0026
104	926	0.9187	0.0040	0.4750	15.8076	0.0039
114	923	0.1875	0.0008	0.0970	3.2260	0.0008
115	923	0.2500	0.0011	0.1290	4.3013	0.0010
116	923	0.3437	0.0015	0.1770	5.9144	0.0014
117	923	0.6550	0.0028	0.3390	11.2696	0.0028
118	923	0.8125	0.0035	0.4200	13.9775	0.0035

(2) Bottom PCB. Assumptions are the same as above.

TABLE 6. BOTTOM PCB POLYIMIDE LAYER TO RAILING CONDUCTANCES

FROM NODE	TO NODE	AREA (in ²)	h_c	$K_1(\text{Poly})$	$K_2(\text{Al})$	K_0
1101	925	0.6250	0.0027	0.3234	7.8306	0.0027
1102	925	0.7187	0.0031	0.3720	9.0052	0.0031
1103	925	0.5625	0.0024	0.2911	7.0476	0.0024
1104	925	0.3437	0.0015	0.1779	4.3068	0.0014
1109	922	0.6285	0.0027	0.3234	7.8306	0.0027
1110	922	0.7187	0.0031	0.3720	9.0052	0.0031
1111	922	0.5625	0.0024	0.2911	7.0476	0.0024
1112	922	0.3437	0.0015	0.1779	4.3068	0.0014

f. PCB Copper-layer Conductances

(1) Top PCB.

TABLE 7. TOP PCB COPPER-LAYER CONDUCTANCES

FROM NODE	TO NODE	AREA (in ²)	LENGTH (in)	K (W/°C)
601	602	0.0033	1.9500	0.0165
601	605	0.0020	2.6250	0.0073
602	603	0.0033	2.4125	0.0134
602	606	0.0033	2.6250	0.0118
603	604	0.0033	2.5500	0.0126
603	607	0.0032	2.6250	0.0119
604	608	0.0035	2.6250	0.0131
605	606	0.0036	1.9500	0.0182
605	609	0.0010	2.0312	0.0030
605	610	0.0010	2.0312	0.0030
606	607	0.0036	2.4125	0.0148
606	610	0.0003	2.0312	0.0015
606	611	0.0018	2.0312	0.0087
606	612	0.0010	2.0312	0.0049
607	608	0.0036	2.5500	0.0139
607	612	0.0024	2.0312	0.0117
607	613	0.0007	2.0312	0.0036
608	613	0.0035	2.0312	0.0170
609	610	0.0017	0.8750	0.0194
609	614	0.0010	1.3750	0.0045
610	611	0.0017	1.1875	0.0143
610	615	0.0013	1.3750	0.0094
611	612	0.0017	2.0000	0.0085
611	616	0.0018	1.3750	0.0129
612	613	0.0017	2.9375	0.0057
612	617	0.0035	2.9375	0.0115
613	618	0.0043	1.3750	0.0305
614	615	0.0019	0.8750	0.0212
615	616	0.0019	1.1875	0.0182
616	617	0.0019	2.0000	0.0108
617	618	0.0019	1.3750	0.0157

These conductances were utilized for all three copper layers of the top printed circuit board.

(2) Bottom PCB.

TABLE 8. BOTTOM PCB COPPER-LAYER CONDUCTANCES

FROM NODE	TO NODE	AREA (in ²)	LENGTH (in)	K (W/°C)
1601	1602	0.0033	2.3750	0.0136
1601	1604	0.0046	2.6875	0.0168
1602	1603	0.0033	2.2500	0.0143
1602	1605	0.0016	2.6875	0.0060
1603	1606	0.0043	2.6875	0.0156
1604	1605	0.0038	2.3750	0.0156
1604	1607	0.0046	2.5625	0.0176
1605	1606	0.0038	2.2500	0.0165
1605	1608	0.0016	2.5625	0.0063
1606	1609	0.0043	2.5625	0.0164
1607	1608	0.0030	2.3750	0.0122
1607	1610	0.0046	1.8125	0.0249
1608	1609	0.0030	2.2500	0.0129
1608	1611	0.0016	1.8125	0.0089
1609	1612	0.0043	1.8125	0.0231
1610	1611	0.0018	2.3750	0.0074
1611	1612	0.0018	2.2500	0.0079

These conductances were utilized for all three copper-layers of the bottom printed circuit board.

g. PCB Polyimide-layer Conductances

(1) Top PCB.

TABLE 9. TOP PCB POLYIMIDE-LAYER CONDUCTANCES

FROM NODE	TO NODE	AREA (in ²)	LENGTH (in)	K (W/°C)
501	502	0.0483	1.9500	0.00012
501	505	0.0289	2.6250	0.00005
502	503	0.0483	2.4125	0.00010
502	506	0.0463	2.6250	0.00008
503	504	0.0483	2.5500	0.00009
503	507	0.0468	2.6250	0.00009
504	508	0.0517	2.6250	0.00009
505	506	0.0531	1.9500	0.00013
505	509	0.0145	2.0312	0.00003
505	510	0.0145	2.0312	0.00003

506	507	0.0531	2.4125	0.00011
506	510	0.0048	2.0312	0.00001
506	511	0.0265	2.0312	0.00006
506	512	0.0149	2.0312	0.00003
507	508	0.0531	2.5500	0.00010
507	512	0.0357	2.0312	0.00008
507	513	0.0111	2.0312	0.00002
508	513	0.0517	2.0312	0.00012
509	510	0.0253	0.8750	0.00014
509	514	0.0144	1.3750	0.00005
510	511	0.0253	1.1875	0.00010
510	515	0.0193	1.3750	0.00007
511	512	0.0253	2.0000	0.00006
511	516	0.0265	1.3750	0.00009
512	513	0.0253	2.9375	0.00004
512	517	0.0507	2.9375	0.00008
513	518	0.0628	1.3750	0.00023
514	515	0.0277	0.8750	0.00016
515	516	0.0277	1.1875	0.00011
516	517	0.0277	2.0000	0.00007
517	518	0.0277	1.3750	0.00010

These conductances were utilized for all three polyimide-layers of the top printed circuit board.

(2) Bottom PCB.

TABLE 10. BOTTOM PCB POLYIMIDE-LAYER CONDUCTANCES

FROM NODE	TO NODE	AREA (in ²)	LENGTH (in)	K (W/°C)
1101	1102	0.0483	2.3750	0.00010
1101	1104	0.0676	2.6875	0.00012
1102	1103	0.0483	2.2500	0.00010
1102	1105	0.0241	2.6875	0.00004
1103	1106	0.0628	2.6875	0.00011
1104	1105	0.0676	2.5625	0.00013
1104	1107	0.0555	2.3750	0.00011
1105	1106	0.0555	2.2500	0.00012
1105	1108	0.0241	2.5625	0.00004

1106	1109	0.0628	2.5625	0.00012
1107	1108	0.0676	1.8125	0.00018
1107	1110	0.0434	2.3750	0.00009
1108	1109	0.0434	2.2500	0.00009
1108	1111	0.0241	1.8125	0.00006
1109	1112	0.0628	1.8125	0.00017
1110	1111	0.0265	2.3750	0.00005
1111	1112	0.0265	2.2500	0.00005

These conductance's were utilized for all three polyimide-layers of the bottom printed circuit board.

h. PCB Copper-layer to Polyimide-layer Conductances

(1) Top PCB. Assumptions are as follows:

$$\begin{aligned}
 P &= 10 \text{ psi} \\
 H_{\text{poly}} &= 1537 \times 10^6 \text{ N/m}^2 \\
 S_r &= 7 \text{ microm.} \\
 L_{\text{cu}} &= .00067 \text{ in.} \\
 L_{\text{poly}} &= .00966 \text{ in.} \\
 k_{\text{cu}} &= 4.31 \text{ W/in}^\circ\text{C} \\
 k_{\text{poly}} &= .2 \text{ W/in}^\circ\text{C}
 \end{aligned}$$

$$\text{Yields: } h^c = .0034 \text{ W/in}^{20}\text{C}$$

These conductances are listed in Table 11 and were utilized for all copper-layer to polyimide-layer conductance relationships for the top PCB.

TABLE 11. TOP PCB COPPER-LAYER TO POLYIMIDE-LAYER CONDUCTANCES

FROM NODE	TO NODE	AREA(in ²)	h_c	$K_1(\text{Cu})$	$K_2(\text{A1})$	K_o
601	501	3.7500	0.0127	54,011	1.9400	0.0126
602	502	6.0000	0.0204	86,417	3.1000	0.0202
603	503	6.0620	0.0206	87,310	3.1370	0.0204
604	504	6.6780	0.0227	96,312	3.4610	0.0225
605	505	4.1250	0.0140	59,412	2.1350	0.0139
606	506	6.6000	0.0224	95,059	3.4160	0.0222
607	507	6.6680	0.0226	96,039	3.4510	0.0225
608	508	7.3560	0.0250	105,948	3.8070	0.0071
609	509	0.9840	0.0033	14,172	0.5090	0.0033
610	510	1.3125	0.0044	18,903	0.6790	0.0044

611	511	1.8040	0.0061	25,982	0.9330	0.0060
612	512	3.4780	0.0118	50,093	1.8000	0.0117
613	513	4.2650	0.0145	61,428	2.2070	0.0144
614	514	1.0780	0.0036	15,526	0.5570	0.0036
615	515	1.4375	0.0048	20,704	0.7440	0.0048
616	516	1.9760	0.0067	28,460	1.0220	0.0066
617	517	3.8090	0.0129	54,860	1.9710	0.0128
618	518	1.8040	0.0061	25,982	0.9330	0.0060

(2) Bottom PCB. Assumptions made were the same as above in (1).

TABLE 12. BOTTOM PCB COPPER-LAYER TO POLYIMIDE-LAYER CONDUCTANCES

From node	To Node	Area (in ²)	h_c	$K_1(\text{Cu})$	$K_2(\text{A1})$	K_0
1601	1501	8.7500	0.0297	126,026	4.5200	0.0295
1602	1502	3.1250	0.0106	45,009	1.6174	0.0105
1603	1503	8.1250	0.0276	117,024	4.2054	0.0274
1604	1504	10.0625	0.0342	144,930	5.2083	0.0339
1605	1505	3.5937	0.0122	51,760	1.8601	0.0121
1606	1506	9.3437	0.0317	134,577	4.8363	0.0315
1607	1507	7.8750	0.0267	113,423	4.0760	0.0266
1608	1508	2.8125	0.0095	40,508	1.4559	0.0095
1609	1509	7.3125	0.0248	105,321	3.7849	0.0247
1610	1510	4.8125	0.0163	69,314	2.4909	0.0162
1611	1511	1.7187	0.0058	24,755	0.8896	0.0058
1612	1512	4.4687	0.0151	64,363	2.3130	0.0150

These conductances were utilized for all copper-layer to polyimide-layer conductance relationships for the bottom printed circuit board.

D. THERMAL MODEL PARAMETERS

1. Boundary Conditions

The boundary conditions for this steady-state thermal model involved both the temperature of the PANSAT upper-equipment plate and the amount of heat dissipated by printed circuit board electronic components. Boundary conditions were established for worst-case cold and worst-case hot conditions. For both cases, a starting temperature of 20°C was assigned to each surface node in the model.

a. Cold-Case

For the cold-case, the thermal node for the upper equipment plate, node number -913, was set equal to a constant 0°C. For power dissipation in the printed circuit boards, it was assumed that any component with less than a 100% duty cycle would be off. Further, the amount of heat dissipated would be for the eclipse period of the orbit.

b. Hot-Case

For the hot-case, the thermal node for the upper equipment plate, node number -913, was set equal to a constant 40°C. For power dissipation in the printed circuit boards, it was assumed that every component would be on, with the amount of heat dissipated being that for the sunlit portion of the orbit.

2. ITAS Inputs

a. Cold-Case

ITAS cold-case data entries and inputs are given in Appendix F.

b. Hot-Case

ITAS hot-case data entries and inputs are given in Appendix G. Note that the hot-case data entry Appendix G contains only the changes to the cold-case data entry Appendix F.

III. RESULTS AND ANALYSIS

A. ITAS OUTPUT

Actual running time for ITAS modeling for both the hot and cold cases was less than 2 minutes. By examining Appendices F and G it can be seen that ITAS first calculates the view-factor for each surface, then the radiated energy intercepted by that surface. Finally, the heat conduction for the model is calculated. Cold-case outputs can be found at the end of Appendix H, and hot-case outputs are located at the end of Appendix I.

B. ANALYSIS

1. Cold-Case

Examination of the ITAS calculated steady-state temperature for surfaces in the cold-case shows that temperatures range from a low of $.12^{\circ}\text{C}$ at the top of the EPS housing to a high of 20°C in the PCB's. This would seem to be a valid result since the largest possible heat transfer for this model should occur between nodes 906 and -913, the top of the EPS housing and the PANSAT upper equipment plate, respectively. With a constant temperature of 0°C for node -913, this node will act as a heat sink drawing heat away from the EPS housing due to the higher starting temperature of 20°C for the EPS surfaces and the heat being dissipated in the PCB's which will seek a conductive path to the heat sink. Since the conductive paths will allow only a finite amount of heat to be transferred in any given time, the relative temperatures of the surfaces illustrates a decreasing trend as a function of conductive path nearness to the upper-equipment plate. A complete listing of steady-state temperatures for each thermal node is given at the end of Appendix H, with a graphical representation of the temperature gradient utilizing selected nodes given in Figure 3. For both the cold-case and hot-case temperature gradient graphs, the paths selected represent worst-case paths for both the top and bottom printed circuit boards. This means that for the cold-case, starting at 0°C for node -913 to $.12^{\circ}\text{C}$ for node 906, the thermal path for the top and bottom printed circuit boards then diverge to different nodes with the top printed circuit board

thermal path proceeding to node 925 and the bottom printed circuit board thermal path proceeding to node 924. For the hot-case, the procedure is similar.

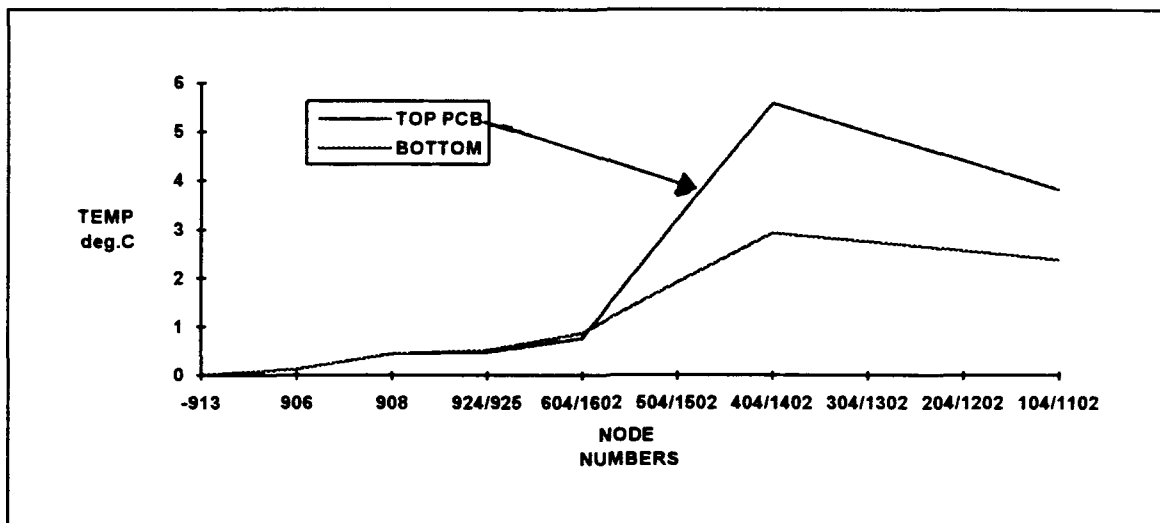


Figure 3. Cold-Case Temperature Gradient for Selected Nodes

2. Hot-Case

Examination of the ITAS calculated steady-state temperatures for surfaces in the hot case shows that temperatures range from a low of 20°C within the PCB's to a high of 39.91°C for the top of the EPS housing at node 906, the interface with the upper-equipment plate. The explanation for these results is similar to that described above for the cold-case, except that in the hot-case the upper-equipment plate is acting as a heat source for the EPS housing and PCB's. A complete listing of steady-state temperatures for each thermal node is given at the end of Appendix I, with a graphical representation of the temperature gradient utilizing selected nodes given in Figure 4.

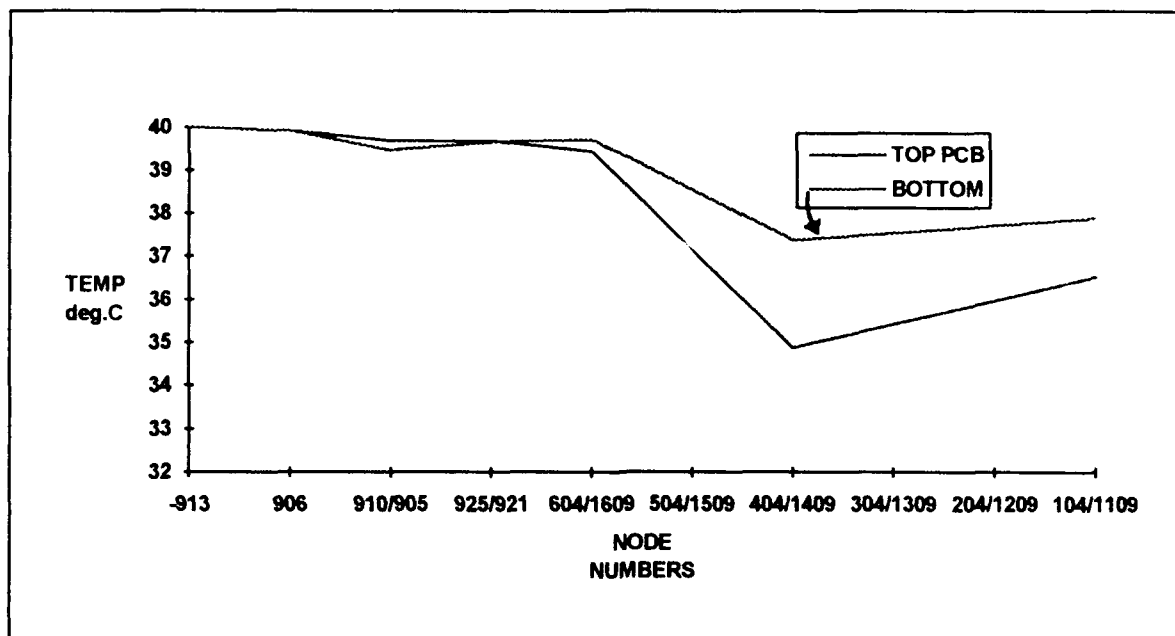


Figure 4. Hot-Case Temperature Gradient for Selected Nodes

C. CONCLUSIONS

It seems clear, given the results of this thermal model, that if only inward-viewing geometry and conductance relationships were taken into consideration that the thermal profile of the EPS housing and its associated electronic components on the PCB's would be at the mercy of the upper-equipment plate temperature. So large is the conductive path between the EPS housing and the upper equipment plate in comparison with all other conductive relationships, and given that the upper-equipment plate temperature is determined by the overall PANSAT temperature, it is critical that the normal on-orbit operating temperature limits of PANSAT be determined to within 10° of accuracy to preclude the possibility of electronic component failure. A reasonable first-order estimate of spacecraft temperature extremes can be obtained by the process given in Reference 3, page 425. If it proves to be too difficult to determine the temperature extremes to within the desired accuracy range, additional measures might be necessary to ensure EPS thermal integrity. Such measures might include the application of grease to the EPS-housing / upper-equipment plate interface, EPS specific heaters (mounted to the upper-equipment plate or the EPS housing itself),

additional insulation for the housing, or an increase in the active control of the overall PANSAT thermal environment.

D. RECOMMENDATIONS

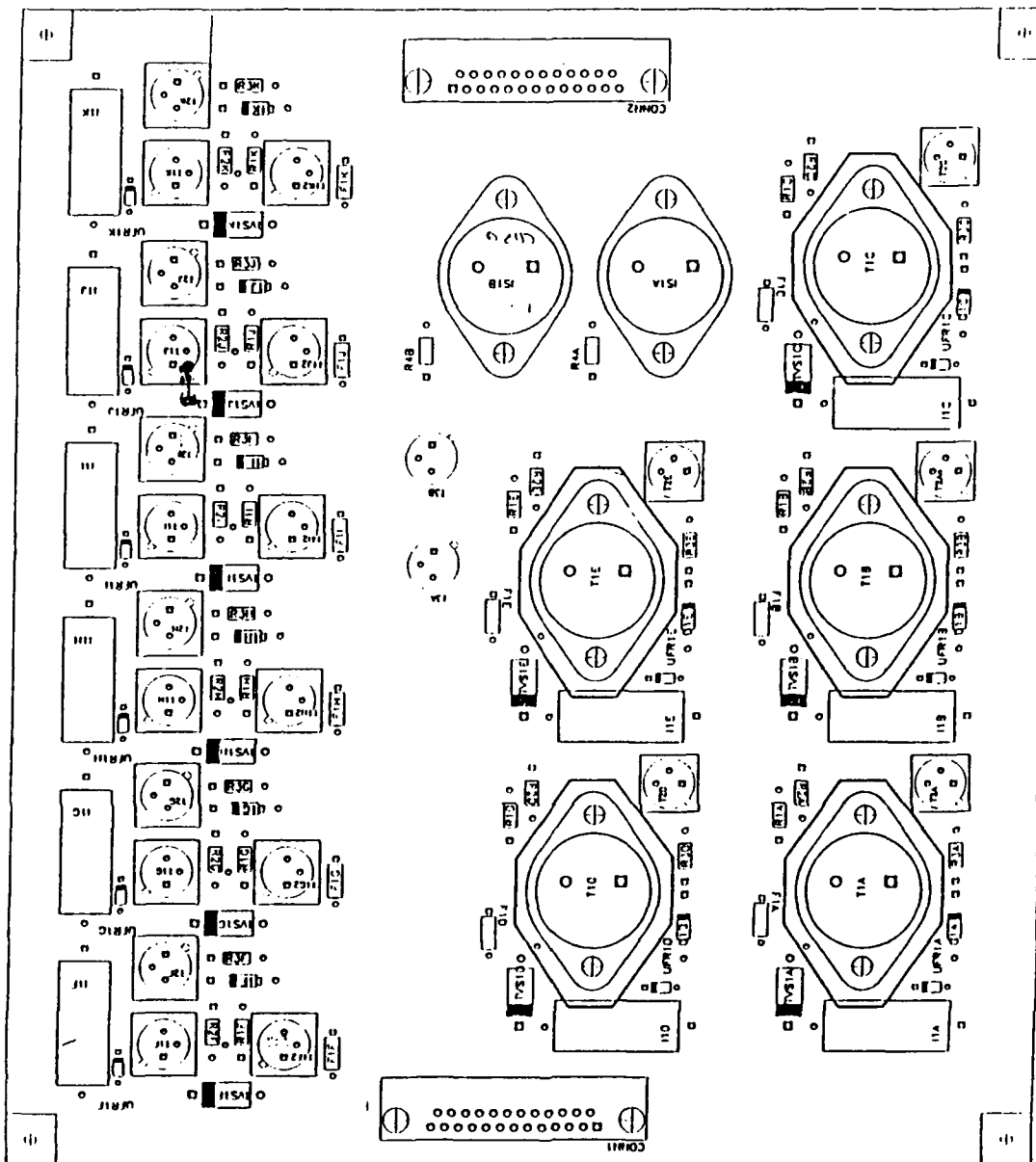
It is recommended that this thermal model be incorporated into the larger overall thermal model of the PANSAT. This could be accomplished most efficiently by utilizing this model as one of many modules with each module representing the major subsystems and components of the PANSAT. Further, it is desirable that a thermal test of the EPS system hardware be conducted in a vacuum chamber to test the closeness of the software modeling results to a "real-world" test of a physical system.

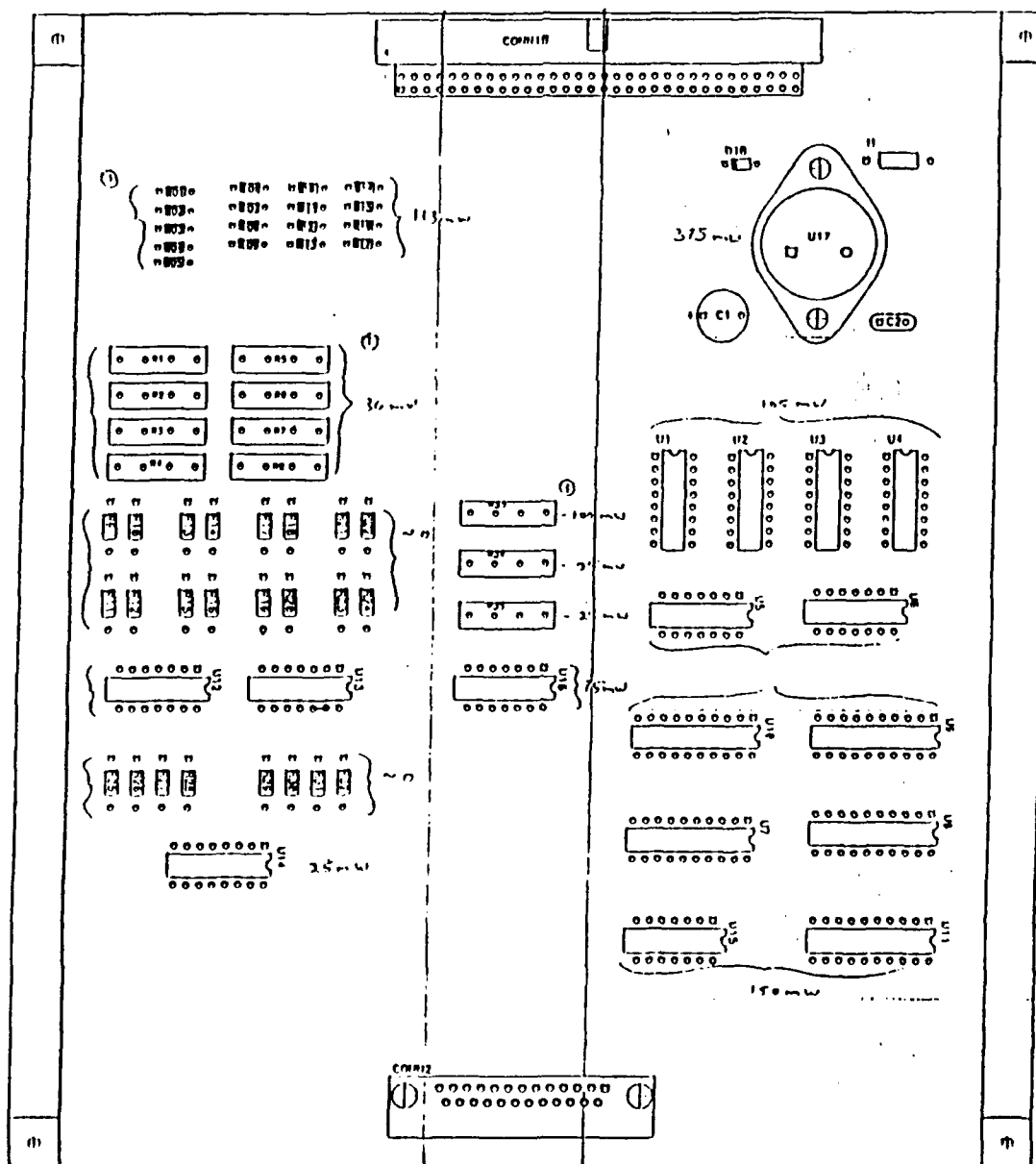
APPENDIX A

PCB Layer-Layer

Polyimide fiberglass
Signal layer - Traces very little copper
Polyimide fiberglass
Ground Layer copper
Polyimide fiberglass
Thermal Plane Copper

PRINTED CIRCUIT BOARD LAYOUTS





Power Dissipation needs only in Center Portion of Board

EPS Switch Board

Component	Designator	Subcircuit	Duty cycle	Power Dissipation, Bus = 15V (Sunlit)	Power Dissipation, Bus = 12V (Eclipse)	X-Coord	Y-Coord
Inductor	I1A	DCSA Power Switch	100	0.039	0.061	2.200	8.900
Transient Voltage Suppressor	TVS1A	"	-0			2.925	8.637
Ultra Fast Recovery Diode	IUR1A	"	-0			1.825	8.600
12v Zener Bi-Directional	ID1A	"	-0			1.650	8.125
PMOSFET Gate Bias Resistor	IR1A	"	100	0.002	0.001	3.025	7.250
PMOSFET Gate Bias Resistor	IR2A	"	100	0.000	0.000	2.850	7.075
NMOSFET Gate Protection Resistor	IR3A	"	100	0.003	0.003	1.650	7.575
PMOSFET	IT1A	"	100	0.006	0.009	2.375	7.850
NMOSFET	IT2A	"	100	0.000	0.000	1.775	7.000
Pico Fuse	IF1A	"				3.150	8.075
Inductor	I1B	DCSB Power Switch	100	0.039	0.061	2.200	6.475
Transient Voltage Suppressor	TVS1B	"	-0			2.925	6.212
Ultra Fast Recovery Diode	IUR1B	"	-0			1.825	6.175
12v Zener Bi-Directional	ID1B	"	-0			1.650	5.700
PMOSFET Gate Bias Resistor	IR1B	"	100	0.002	0.001	3.025	4.825
PMOSFET Gate Bias Resistor	IR2B	"	100	0.000	0.000	2.850	4.650
NMOSFET Gate Protection Resistor	IR3B	"	100	0.003	0.003	1.650	5.150
PMOSFET	IT1B	"	100	0.006	0.009	2.375	5.425
NMOSFET	IT2B	"	100	0.000	0.000	1.775	4.575
Pico Fuse	IF1B	"				3.150	5.650
Inductor	I1C	IRF Power Switch - Rx only	70	0.010	0.015	2.200	4.050
Transient Voltage Suppressor	TVS1C	"	-0			2.925	3.787
Ultra Fast Recovery Diode	IUR1C	"	-0			1.825	3.750
12v Zener Bi-Directional	ID1C	"	-0			1.650	3.275
PMOSFET Gate Bias Resistor	IR1C	"	100	0.002	0.001	3.025	2.400
PMOSFET Gate Bias Resistor	IR2C	"	100	0.000	0.000	2.850	2.225
NMOSFET Gate Protection Resistor	IR3C	"	70	0.003	0.003	1.650	2.725
PMOSFET	IT1C	"	70	0.006	0.009	2.375	3.000
NMOSFET	IT2C	"	70	0.000	0.000	1.775	2.150
Pico Fuse	IF1C	"				3.150	3.225
Inductor	I1C	IRF Power Switch - Rx and Tx	30	0.088	0.138		
Transient Voltage Suppressor	TVS1C	"	-0				
Ultra Fast Recovery Diode	IUR1C	"	-0				
12v Zener Bi-Directional	ID1C	"	-0				
PMOSFET Gate Bias Resistor	IR1C	"	30	0.002	0.001		

EPS Switch Board

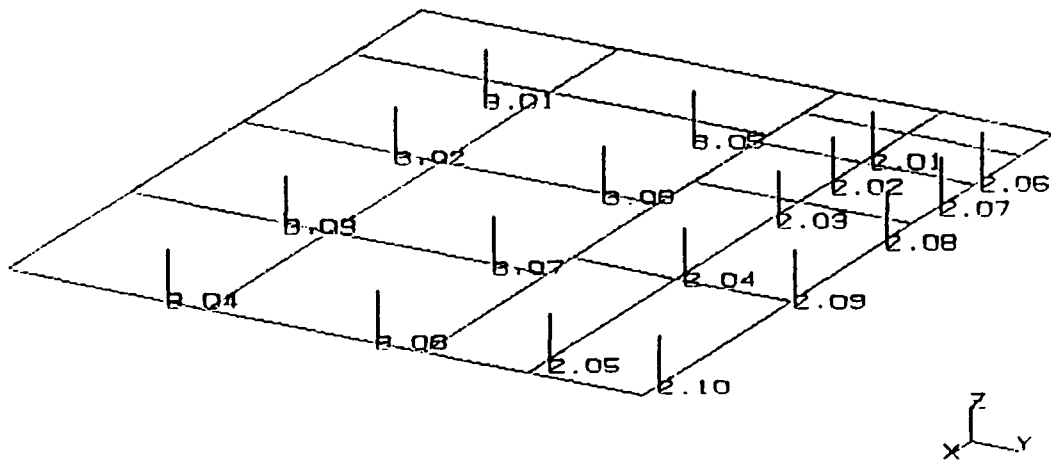
Component	Designator	Subcircuit	Duty cycle	Power Dissipation, Bus = 15V (Sunlit)	Power Dissipation, Bus = 12V (Eclipse)	X-Coord	Y-Coord
PMOSFET Gate Bias Resistor	R2C	"	30	0.000	0.000		
NMOSFET Gate Protection Resistor	R3C	"	30	0.003	0.003		
PMOSFET	T1C	"	30	0.014	0.021		
NMOSFET	T2C	"	30	0.000	0.000		
Pico Fuse	F1C	"					
Inductor	L1D	CHARG Battery A Power Switch	60	0.012	N/A	4.300	8.900
Transient Voltage Suppressor	TVS1D	"	-0		"	5.025	8.637
Ultra Fast Recovery Diode	UFR1D	"	-0		"	3.925	8.600
12v Zener Bi-Directional	D1D	"	-0		"	3.750	8.125
PMOSFET Gate Bias Resistor	R1D	"	60	0.002	"	5.125	7.250
PMOSFET Gate Bias Resistor	R2D	"	60	0.000	"	4.950	7.075
NMOSFET Gate Protection Resistor	R3D	"	60	0.003	0.003	3.750	7.575
PMOSFET	T1D	"	60	0.008	"	4.475	7.850
NMOSFET	T2D	"	60	0.000	"	3.875	7.000
Pico Fuse	F1D	"			"	5.250	8.175
Inductor	L1E	CHARG Battery B Power Switch	60	0.050	N/A	4.300	6.475
Transient Voltage Suppressor	TVS1E	"	-0		"	5.025	6.212
Ultra Fast Recovery Diode	UFR1E	"	-0		"	3.925	6.175
12v Zener Bi-Directional	D1E	"	-0		"	3.750	5.700
PMOSFET Gate Bias Resistor	R1E	"	60	0.002	"	5.125	4.825
PMOSFET Gate Bias Resistor	R2E	"	60	0.000	"	4.950	4.650
NMOSFET Gate Protection Resistor	R3E	"	60	0.003	0.003	3.750	5.150
PMOSFET	T1E	"	60	0.008	"	4.475	5.425
NMOSFET	T2E	"	60	0.000	"	3.875	4.575
Pico Fuse	F1E	"			"	5.250	5.650
Inductor	L1F	MUX A	30	0.006	0.009	8.400	8.875
Transient Voltage Suppressor	TVS1F	"	-0		"	7.297	9.450
Ultra Fast Recovery Diode	UFR1F	"	-0		"	8.125	9.225
12v Zener Bi-Directional	D1F	"	-0		"	7.175	8.550
PMOSFET Gate Bias Resistor	R1F	"	30	0.002	0.001	7.175	8.950
PMOSFET Gate Bias Resistor	R2F	"	30	0.000	0.000	7.400	8.950
NMOSFET Gate Protection Resistor	R3F	"	30	0.003	0.003	7.225	8.375
PMOSFET	T1F	"	30	0.003	0.004	7.775	9.050
PMOSFET	T1F2	"	30	0.003	0.004	6.850	9.050
NMOSFET	T2F	"	30	0.000	0.000	7.775	8.450
Pico Fuse	F1F	"	100		"	6.475	9.125

EPS Switch Board

Component	Designator	Subcircuit	Duty cycle	Power Dissipation, Bus = 15V (Sunlit)	Power Dissipation, Bus = 12V (Eclipse)	X-Coord	Y-Coord
Inductor	I1G	MUX B	30	0.006	0.009	8.400	7.525
Transient Voltage Suppressor	TVS1G	"	-0			7.297	8.100
Ultra Fast Recovery Diode	UFR1G	"	-0			8.125	7.875
12v Zener Bi-Directional	D1G	"	-0			7.175	7.200
PMOSFET Gate Bias Resistor	R1G	"	30	0.002	0.001	7.175	7.600
PMOSFET Gate Bias Resistor	R2G	"	30	0.000	0.000	7.400	7.600
NMOSFET Gate Protection Resistor	R3G	"	30	0.003	0.003	7.225	7.025
PMOSFET	T1G	"	30	0.003	0.004	7.775	7.700
PMOSFET	T1G2	"	30	0.003	0.004	6.850	7.700
NMOSFET	T2G	"	30	0.000	0.000	7.775	7.100
Pico Fuse	F1G	"	100			6.475	7.775
Inductor	I1H	MASS A	30	0.001	0.002	8.400	6.175
Transient Voltage Suppressor	TVS1H	"	-0			7.297	6.750
Ultra Fast Recovery Diode	UFR1H	"	-0			8.125	6.525
12v Zener Bi-Directional	D1H	"	-0			7.175	5.850
PMOSFET Gate Bias Resistor	R1H	"	30	0.002	0.001	7.175	6.250
PMOSFET Gate Bias Resistor	R2H	"	30	0.000	0.000	7.400	6.250
NMOSFET Gate Protection Resistor	R3H	"	30	0.003	0.003	7.225	5.675
PMOSFET	T1H	"	30	0.001	0.001	7.775	6.350
PMOSFET	T1H2	"	30	0.001	0.001	6.850	6.350
NMOSFET	T2H	"	30	0.000	0.000	7.775	5.750
Pico Fuse	F1H	"	100			6.475	6.425
Inductor	I1I	MASS B	30	0.001	0.002	8.400	4.825
Transient Voltage Suppressor	TVS1I	"	-0			7.297	5.400
Ultra Fast Recovery Diode	UFR1I	"	-0			8.125	5.175
12v Zener Bi-Directional	D1I	"	-0			7.175	4.500
PMOSFET Gate Bias Resistor	R1I	"	30	0.002	0.001	7.175	4.900
PMOSFET Gate Bias Resistor	R2I	"	30	0.000	0.000	7.400	4.900
NMOSFET Gate Protection Resistor	R3I	"	30	0.003	0.003	7.225	4.325
PMOSFET	T1I	"	30	0.001	0.001	7.775	5.000
PMOSFET	T1I2	"	30	0.001	0.001	6.850	5.000
NMOSFET	T2I	"	30	0.000	0.000	7.775	4.400
Pico Fuse	F1I	"	100			6.475	5.075
Inductor	I1J	TRICKLE A	-0			8.400	3.475
Transient Voltage Suppressor	TVS1J	"	-0			7.297	4.050

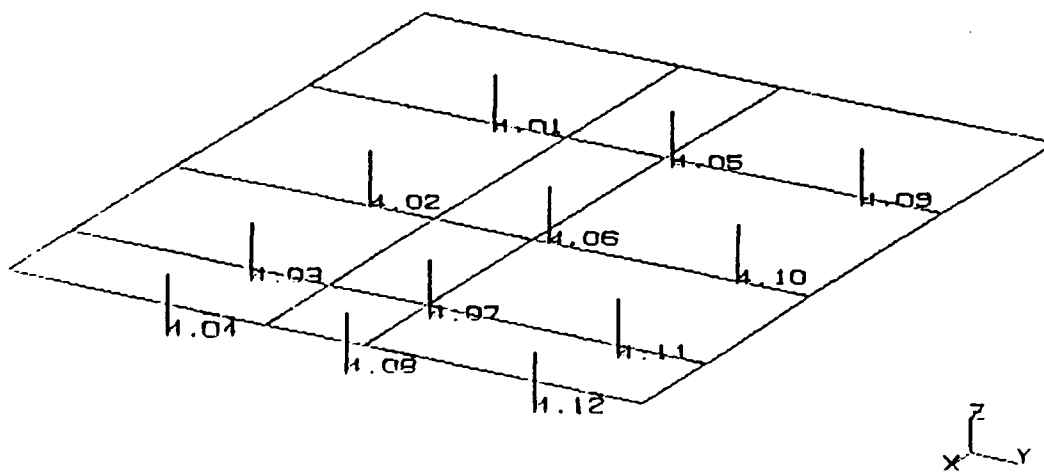
EPS Switch Board

Component	Designator	Subcircuit	Duty cycle	Power Dissipation, Bus = 15V (Sunlit)	Power Dissipation, Bus = 12V (Eclipse)	X-Coord	Y-Coord
Ultra Fast Recovery Diode	UFR1J	"	~0			8.125	3.825
12v Zener Bi-Directional	ID1J	"	~0			7.175	3.150
PMOSFET Gate Bias Resistor	IR1J	"	~0			7.175	3.550
PMOSFET Gate Bias Resistor	IR2J	"	~0			7.400	3.550
PMOSFET Gate Protection Resistor	IR3J	"	~0			7.225	3.975
PMOSFET	IT1J	"	~0			7.775	3.650
PMOSFET	IT1J2	"	~0			6.850	3.650
PMOSFET	IT2J	"	~0			7.775	3.050
Pico Fuse	IF1J	"	~0			6.475	3.725
Inductor	II1K	TRICKLE B	~0				
Transient Voltage Suppressor	TVS1K	"	~0			8.400	2.100
Ultra Fast Recovery Diode	UFR1K	"	~0			7.297	2.675
12v Zener Bi-Directional	ID1K	"	~0			8.125	2.450
PMOSFET Gate Bias Resistor	IR1K	"	~0			7.175	2.775
PMOSFET Gate Bias Resistor	IR2K	"	~0			7.400	2.175
PMOSFET Gate Bias Resistor	IR3K	"	~0			7.225	2.600
PMOSFET	IT1K	"	~0			7.775	2.275
PMOSFET	IT1K2	"	~0			6.850	2.275
PMOSFET	IT2K	"	~0			7.775	1.675
Pico Fuse	IF1K	"	~0			6.475	2.350
NMOSFET	IT3A	Discharge Battery A				5.750	5.300
NMOSFET	IT3B	Discharge Battery B				5.775	3.650
LM150	IS1A	Constant Current Source				3.975	3.092
LM150	IS1B	Constant Current Source				5.225	3.092
			Total Power	0.211W	0.238W		



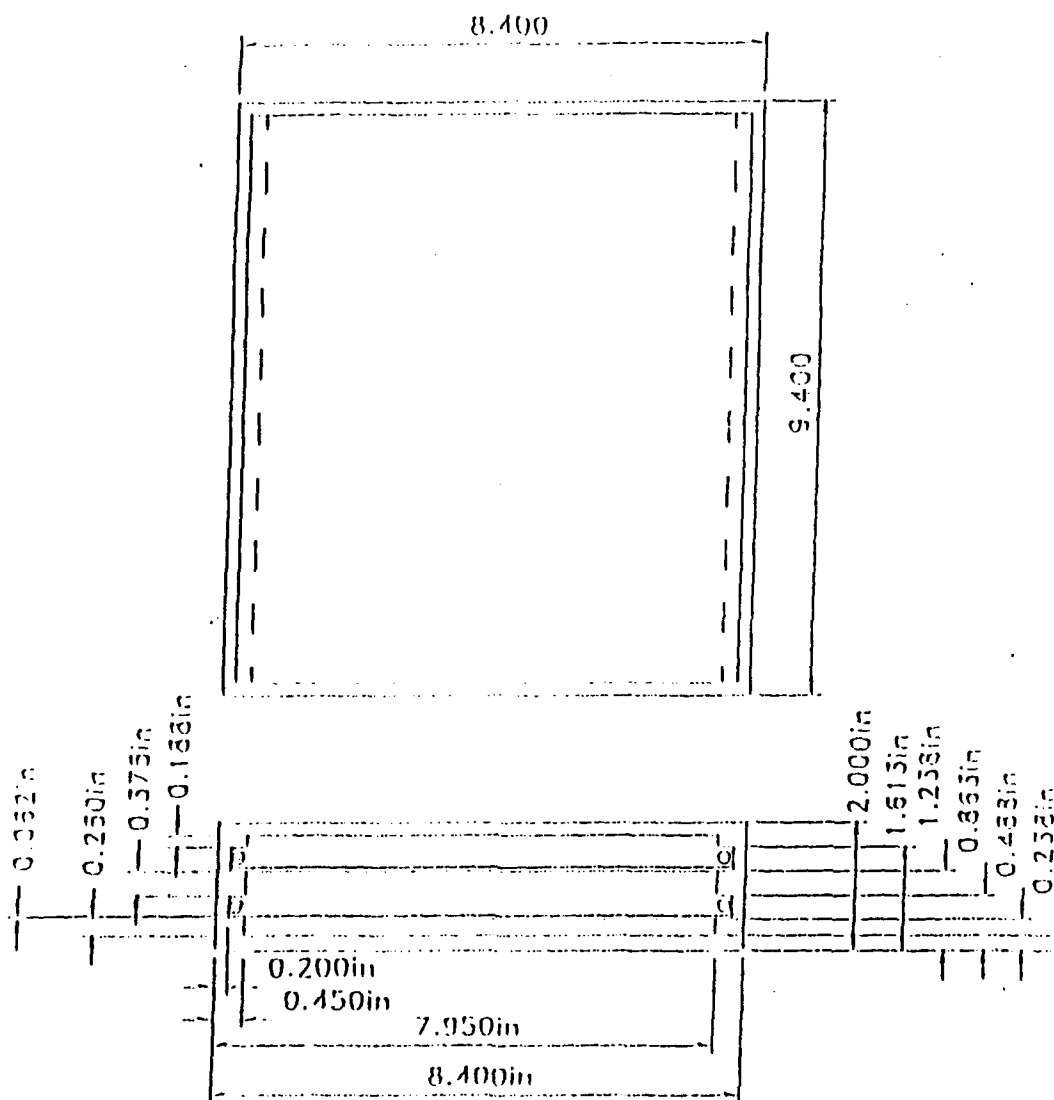
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21.11.88 08/08/84

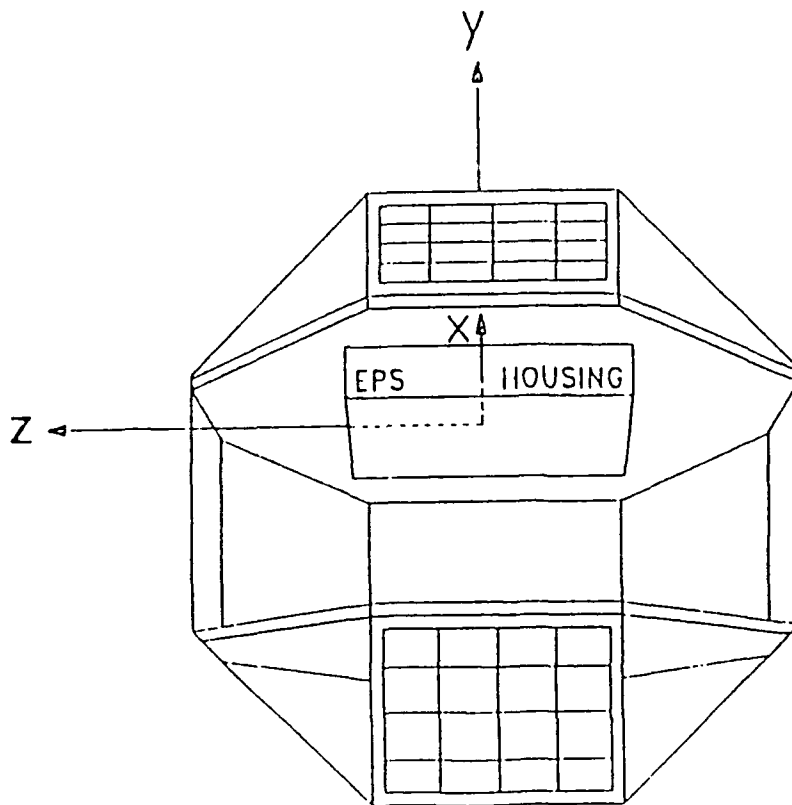


APPENDIX B

EPS HOUSING



EPS HOUSING LOCATION



APPENDIX C ITAS SURFACE-NODE NUMBERS

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n 2 1.02 2 .4 .8 1. 0. EPS HOUSING n
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n 6 1.06 6 .4 .8 1. 0. EPS HOUSING n
n 7 1.07 7 .4 .8 1. 0. EPS HOUSING n
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n 9 1.09 9 .4 .8 1. 0. EPS HOUSING n
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n 14 2.02 14 0 .01 1. 0. PCB 1-1 n
n 15 2.03 15 0 .01 1. 0. PCB 1-1 n
n 16 2.04 16 0 .01 1. 0. PCB 1-1 n
n 17 2.05 17 0 .01 1. 0. PCB 1-1 n
n 18 2.06 18 0 .01 1. 0. PCB 1-1 n
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
S-F1Load/Save All S-F4Auto TM UDC Allowed ESCQuit
F1Load/Save Page F3PropLib F4AutoGen F5ImportPropFmt F6NewPropFile F10Search

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PgDn PgUp Home End                                     F2Help
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n 21 2.09 21 0 .01 1. 0. PCB 1-1 n
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n 23 3.01 23 0 .01 1. 0. PCB 1-2 n
n 24 3.02 24 0 .01 1. 0. PCB 1-2 n
n 25 3.03 25 0 .01 1. 0. PCB 1-2 n
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n 34 4.04 34 0 .01 1. 0. PCB 2 (BOTTOM) n
n 35 4.05 35 0 .01 1. 0. PCB 2 (BOTTOM) n
n 36 4.06 36 0 .01 1. 0. PCB 2 (BOTTOM) n
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
S-F1Load/Save All S-F4Auto TM UDC Allowed ESCQuit
F1Load/Save Page F3PropLib F4AutoGen F5ImportPropFmt F6NewPropFile F10Search

```

PgDn PgUp Home End

F2Help

Ctrl : Copy (See F2) ITAS Property Data Entry

Seq	Surface	No	NodeNo	Alpha	Emiss	T/Mass	Dissip	MID	Comments
25	3.03		25	0	.01	1.	0.		PCB 1-2
26	3.04		26	0	.01	1.	0.		PCB 1-2
27	3.05		27	0	.01	1.	0.		PCB 1-2
28	3.06		28	0	.01	1.	0.		PCB 1-2
29	3.07		29	0	.01	1.	0.		PCB 1-2
30	3.08		30	0	.01	1.	0.		PCB 1-2
31	4.01		31	0	.01	1.	0.		PCB 2 (BOTTOM)
32	4.02		32	0	.01	1.	0.		PCB 2 (BOTTOM)
33	4.03		33	0	.01	1.	0.		PCB 2 (BOTTOM)
34	4.04		34	0	.01	1.	0.		PCB 2 (BOTTOM)
35	4.05		35	0	.01	1.	0.		PCB 2 (BOTTOM)
36	4.06		36	0	.01	1.	0.		PCB 2 (BOTTOM)
37	4.07		37	0	.01	1.	0.		PCB 2 (BOTTOM)
38	4.08		38	0	.01	1.	0.		PCB 2 (BOTTOM)
39	4.09		39	0	.01	1.	0.		PCB 2 (BOTTOM)
40	4.10		40	0	.01	1.	0.		PCB 2 (BOTTOM)
41	4.11		41	0	.01	1.	0.		PCB 2 (BOTTOM)
42	4.12		42	0	.01	1.	0.		PCB 2 (BOTTOM)

S-FileLoad/Save All

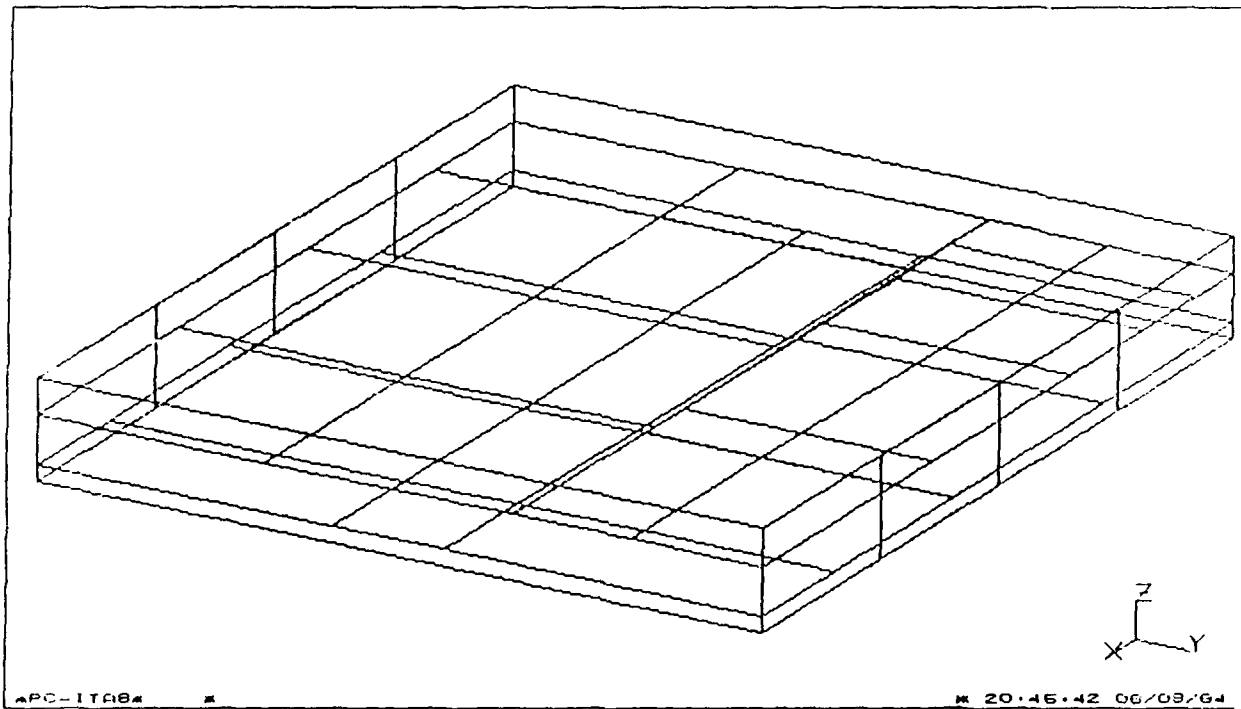
S-F4Auto TM

UDC Allowed

ESCQuit

F11load/Save Page F3PropLib F4AutoGen F5ImportPropFmt F6NewPropFile F10Search

APPENDIX D EPS THERMAL MODEL SCHEMATIC



APPENDIX E ITAS NODE CONDUCTANCES

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		1	901	1000	L	GEO NODES-THERM NODES(HOUS) 1X
2		2	902	1000	L	+Y
3		3	903	1000	L	+Y
4		4	904	1000	L	+Y
5		5	905	1000	L	+Y
6		6	906	1000	L	+Z
7		7	907	1000	L	-X
8		8	908	1000	L	-Y
9		9	909	1000	L	-Y
10		10	910	1000	L	-Y
11		11	911	1000	L	-Y
12		12	912	1000	L	-Z
13		13	609	1000	L	GEO NODES TO TOP PCB THERM LAYER
14		14	610	1000	L	
15		15	611	1000	L	
16		16	612	1000	L	
17		17	613	1000	L	
18		18	614	1000	L	

Ctrl-F1 Import ITAS_NC ALT-F3 AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1 Import Column Shift-F3 AutoCHT Shift-F5 Del/Pur End
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
19		19	615	1000	L	
20		20	616	1000	L	
21		21	617	1000	L	
22		22	618	1000	L	
23		23	601	1000	L	
24		24	602	1000	L	
25		25	603	1000	L	
26		26	604	1000	L	
27		27	605	1000	L	
28		28	606	1000	L	
29		29	607	1000	L	
30		30	608	1000	L	
31		31	1601	1000	L	GEO NODES TO BOTTOM PCB THERM LAYER
32		32	1602	1000	L	
33		33	1603	1000	L	
34		34	1604	1000	L	
35		35	1605	1000	L	
36		36	1606	1000	L	

Ctrl-F1 Import ITAS_NC ALT-F3 AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1 Import Column Shift-F3 AutoCHT Shift-F5 Del/Pur End
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
37	1	37	1607	1000	L	
38	1	38	1608	1000	L	
39	1	39	1609	1000	L	
40	1	40	1610	1000	L	
41	1	41	1611	1000	L	
42	1	42	1612	1000	L	
43	1	-913	906	125.366	L	EPS HOUSING TO EQUIP PLATE
44	1	901	905	.2638	L	HOUSING NODES TO HOUSING NODES
45	1	901	906	1.2592	L	
46	1	901	911	.2638	L	
47	1	901	912	1.2592	L	
48	1	902	903	.6011	L	
49	1	902	906	.3911	L	
50	1	902	907	.2638	L	
51	1	902	912	.3911	L	
52	1	903	904	.6011	L	
53	1	903	906	.3911	L	
54	1	903	912	.3911	L	

Ctrl-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		904	905	.6011	L	
1		904	906	.3911	L	
1		904	912	.3911	L	
1		905	906	.3911	L	
1		905	912	.3911	L	
1		907	906	.3911	L	
1		907	908	.2638	L	
1		907	912	.3911	L	
1		908	906	.3911	L	
1		908	909	.6011	L	
1		908	912	.3911	L	
1		909	906	.3911	L	
1		909	910	.6011	L	
1		909	912	.3911	L	
1		910	906	.3911	L	
1		910	911	.6011	L	
1		910	912	.3911	L	
1		911	906	.3911	L	

Ctrl-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		911	912	.3911	L	
1		921	901	.5855	L	+Y BOTTOM RAIL TO HOUSING
1		921	907	.5855	L	
1		921	908	10.775	L	
1		921	909	10.775	L	
1		921	910	10.775	L	
1		921	911	10.775	L	
1		921	912	39.7438	L	
1		922	901	.1611	L	+Y MIDDLE RAIL TO HOUSING
1		922	907	.1611	L	
1		922	908	29.6528	L	
1		922	909	29.6528	L	
1		922	910	29.6528	L	
1		922	911	29.6528	L	
1		923	901	.1173	L	+Y TOP RAIL TO HOUSING
1		923	907	.1173	L	
1		923	908	21.5921	L	
1		923	909	21.5921	L	

Ctrl-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		923	910	21.5921	L	
1		923	911	21.5921	L	
1		923	906	27.9466	L	
1		924	901	.05855	L	-Y BOTTOM RAIL TO HOUSING
1		924	907	.05855	L	
1		924	908	10.775	L	
1		924	909	10.775	L	
1		924	910	10.775	L	
1		924	911	10.775	L	
1		924	912	39.7438	L	
1		925	901	.1611	L	-Y MIDDLE RAIL TO HOUSING
1		925	907	.1611	L	
1		925	908	29.6528	L	
1		925	909	29.6528	L	
1		925	910	29.6528	L	
1		925	911	29.6528	L	
1		926	901	.1173	L	-Y TOP RAIL TO HOUSING
1		926	907	.1173	L	

Ctrl-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		116	923	.0014	L	
1		117	923	.0028	L	
1		118	923	.0035	L	
1		601	602	.01657	L	TOP PCB THRM LYR NODE TO NODE
1		601	605	.00738	L	
1		602	603	.0134	L	
1		602	606	.01183	L	
1		603	604	.01267	L	
1		603	607	.01194	L	
1		604	608	.01315	L	
1		605	606	.01825	L	
1		605	609	.00306	L	
1		605	610	.00306	L	
1		606	607	.01475	L	
1		606	610	.00159	L	
1		606	611	.00874	L	
1		606	612	.00493	L	
1		607	608	.01396	L	

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		607	612	.01177	L	
1		607	613	.00366	L	
1		608	613	.01702	L	
1		609	610	.0194	L	
1		609	614	.00452	L	
1		610	611	.0143	L	
1		610	615	.0094	L	
1		611	612	.00849	L	
1		611	616	.0129	L	
1		612	613	.00578	L	
1		612	617	.01156	L	
1		613	618	.03059	L	
1		615	614	.02128	L	
1		615	616	.01826	L	
1		617	616	.01084	L	
1		617	618	.01577	L	
1		401	402	.01657	L	TOP PCB GROUND LYR NODE TO NODE
1		401	405	.00738	L	

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		402	403	.0134	L	
1		402	406	.01183	L	
1		403	404	.01267	L	
1		403	407	.01194	L	
1		404	408	.01315	L	
1		405	406	.01825	L	
1		405	409	.00306	L	
1		405	410	.00306	L	
1		406	407	.01475	L	
1		406	410	.00159	L	
1		406	411	.00874	L	
1		406	412	.00493	L	
1		407	408	.01396	L	
1		407	412	.01177	L	
1		407	413	.00366	L	
1		408	413	.01702	L	
1		409	410	.0194	L	
1		409	414	.00452	L	

Ctrl-F Import ITAS_NC ALT-F3 AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F Import Column Shift-F3 AutoCHT Shift-F5 Del/Pur End
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		410	411	.0143	L	
1		410	415	.0094	L	
1		411	412	.00849	L	
1		411	416	.01291	L	
1		412	413	.00578	L	
1		412	417	.01156	L	
1		413	418	.03059	L	
1		415	414	.02128	L	
1		415	416	.01826	L	
1		417	416	.01084	L	
1		417	418	.01577	L	
1		501	502	.0001	L	TOP PCB 5TH LYR NODE
1		501	505	.0001	L	TONODE-POLY
1		502	503	.0001	L	
1		502	506	.0001	L	
1		503	504	.0001	L	
1		503	507	.0001	L	
1		504	508	.0001	L	

Ctrl-F Import ITAS_NC ALT-F3 AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F Import Column Shift-F3 AutoCHT Shift-F5 Del/Pur End
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1		613	513	.0144	L	
1		614	514	.0036	L	
1		615	515	.0048	L	
1		616	516	.0066	L	
1		617	517	.0128	L	
1		618	518	.0157	L	
1		501	401	.0126	L	
1		502	402	.0202	L	
1		503	403	.0204	L	
1		504	404	.0225	L	
1		505	405	.0139	L	
1		506	406	.0222	L	
1		507	407	.0225	L	
1		508	408	.0071	L	
1		509	409	.0033	L	
1		510	410	.0044	L	
1		511	411	.006	L	
1		512	412	.0117	L	

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
271	1	513	413	.0144	L	
272	1	514	414	.0036	L	
273	1	515	415	.0048	L	
274	1	516	416	.0066	L	
275	1	517	417	.0128	L	
276	1	518	418	.0157	L	
277	1	401	301	.0126	L	
278	1	402	302	.0202	L	
279	1	403	303	.0204	L	
280	1	404	304	.0225	L	
281	1	405	305	.0139	L	
282	1	406	306	.0222	L	
283	1	407	307	.0225	L	
284	1	408	308	.0071	L	
285	1	409	309	.0033	L	
286	1	410	310	.0044	L	
287	1	411	311	.006	L	
288	1	412	312	.0117	L	

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
289	1	413	313	.0144	L	
290	1	414	314	.0036	L	
291	1	415	315	.0048	L	
292	1	416	316	.0066	L	
293	1	417	317	.0128	L	
294	1	418	318	.0157	L	
295	1	301	201	.0126	L	
296	1	302	202	.0202	L	
297	1	303	203	.0204	L	
298	1	304	204	.0225	L	
299	1	305	205	.0139	L	
300	1	306	206	.0222	L	
301	1	307	207	.0225	L	
302	1	308	208	.0071	L	
303	1	309	209	.0033	L	
304	1	310	210	.0044	L	
305	1	311	211	.006	L	
306	1	312	212	.0117	L	

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
307	1	313	213	.0144	L	
308	1	314	214	.0036	L	
309	1	315	215	.0048	L	
310	1	316	216	.0066	L	
311	1	317	217	.0128	L	
312	1	318	218	.0157	L	
313	1	201	101	.0126	L	
314	1	202	102	.0202	L	
315	1	203	103	.0204	L	
316	1	204	104	.0225	L	
317	1	205	105	.0139	L	
318	1	206	106	.0222	L	
319	1	207	107	.0225	L	
320	1	208	108	.0071	L	
321	1	209	109	.0033	L	
322	1	210	110	.0044	L	
323	1	211	111	.006	L	
324	1	212	112	.0117	L	

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
325	1	213	113	.0144	L	
326	1	214	114	.0036	L	
327	1	215	115	.0144	L	
328	1	216	116	.0066	L	
329	1	217	117	.0128	L	
330	1	218	118	.0157	L	
331	1	1601	1602	.0168	L	BOT PCB THRM LYR NODE TO NODE
332	1	1601	1605	.0136	L	
333	1	1602	1603	.0176	L	
334	1	1602	1606	.0156	L	
335	1	1603	1604	.0249	L	
336	1	1603	1607	.0122	L	
337	1	1604	1608	.0074	L	
338	1	1605	1606	.006	L	
339	1	1605	1609	.0143	L	
340	1	1606	1607	.0063	L	
341	1	1606	1610	.0165	L	
342	1	1607	1608	.0089	L	

Ctrl-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
343	1	1607	1611	.0129	L	
344	1	1608	1612	.0079	L	
345	1	1609	1610	.0156	L	
346	1	1610	1611	.0164	L	
347	1	1611	1612	.0231	L	
348	1	1401	1402	.0168	L	BOT PCB GROUND LYR NODE TO NODE
349	1	1401	1405	.0136	L	
350	1	1402	1403	.0176	L	
351	1	1402	1406	.0156	L	
352	1	1403	1404	.0249	L	
353	1	1403	1407	.0122	L	
354	1	1404	1408	.0074	L	
355	1	1405	1406	.006	L	
356	1	1405	1409	.0143	L	
357	1	1406	1407	.0063	L	
358	1	1406	1410	.0165	L	
359	1	1407	1408	.0089	L	
360	1	1407	1411	.0129	L	

Ctrl-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
397	1	1504	1404	.0162	L	
398	1	1505	1405	.0105	L	
399	1	1506	1406	.0121	L	
400	1	1507	1407	.0095	L	
401	1	1508	1408	.0058	L	
402	1	1509	1409	.0274	L	
403	1	1510	1410	.0315	L	
404	1	1511	1411	.0247	L	
405	1	1512	1412	.015	L	
406	1	1401	1301	.0295	L	
407	1	1402	1302	.0339	L	
408	1	1403	1303	.0266	L	
409	1	1404	1304	.0162	L	
410	1	1405	1305	.0105	L	
411	1	1406	1306	.0121	L	
412	1	1407	1307	.0095	L	
413	1	1408	1308	.0058	L	
414	1	1409	1309	.0274	L	

Ctrl-F1 Import ITAS_NC ALT-F3 AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1 Import Column Shift-F3 AutoCHT Shift-F5 Del/Pur End
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
415	1	1410	1310	.0315	L	
416	1	1411	1311	.0247	L	
417	1	1412	1312	.015	L	
418	1	1301	1201	.0295	L	
419	1	1302	1202	.0339	L	
420	1	1303	1203	.0266	L	
421	1	1304	1204	.0162	L	
422	1	1305	1205	.0105	L	
423	1	1306	1206	.0121	L	
424	1	1307	1207	.0095	L	
425	1	1308	1208	.0058	L	
426	1	1309	1209	.0274	L	
427	1	1310	1210	.0315	L	
428	1	1311	1211	.0247	L	
429	1	1312	1212	.015	L	
430	1	1201	1101	.0295	L	
431	1	1202	1102	.0339	L	
432	1	1203	1103	.0266	L	

Ctrl-F1 Import ITAS_NC ALT-F3 AutoMLI UDC Allowed PgDn PgUp Home
 Shift-F1 Import Column Shift-F3 AutoCHT Shift-F5 Del/Pur End
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

```

##### Ctrl:Copy##### ITAS Conductor Data Entry ##### ESC:Quit f

```

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
433	1	1204	1104	.0162	L	
434	1	1205	1105	.0105	L	
435	1	1206	1106	.0121	L	
436	1	1207	1107	.0095	L	
437	1	1208	1108	.0058	L	
438	1	1209	1109	.0274	L	
439	1	1210	1110	.0315	L	
440	1	1211	1111	.0247	L	
441	1	1212	1112	.015	L	
1					L	
1					L	
1					L	
1					L	
1					L	
1					L	
1					L	
1					L	
1					L	

```

#####
CTRL-F1Import ITAS_NC      ALT-F3AutoMLI    UDC Allowed      PgDn PgUp Home
SHIFT-F1Import Column      Shift-F3AutoCHT  Shift-F5Del/Pur   End
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete  F7Mark/UnMark F10Search

```

APPENDIX F ITAS NODE DATA FOR COLD-CASE

```

Ctrl:Copy##### ITAS Node Data Entry For Thermal Analysis #####ESC:Quit
"
" SEQ#   NodeNo   Temp-C   ThrMass   Dissip   Comment
"       901       20           0       EPS HOUSING WALLS 4X
"       902       20           0       4Y
"       903       20           0       4Y
"       904       20           0       4Y
"       905       20           0       4Y
"       906       20           0       4Z
"       907       20           0       -X
"       908       20           0       -Y
"       909       20           0       -Y
"       910       20           0       -Y
"       911       20           0       -Y
"       912       20           0       -Z
"       -913       0           0       BOUNDARY NODE TO 906
"       921       20           0       HOUSING 4Y BOTTOM RAIL
"       922       20           0       4Y MIDDLE RAIL
"       923       20           0       4Y TOP RAIL
"       924       20           0       -Y BOTTOM RAIL
"       925       20           0       -Y MIDDLE RAIL
#####
CTRL-F Import ITAS_NC   UDC Allowed                               PgDn PgUp Home End
SHIFT-F Import Column
          F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete      F7Mark/UnMark F10Search

```

```

A6Ctrl:Copy##### ITAS Node Data Entry For Thermal Analysis #####ESC:QuitE
n
n SEQ#      NodeNo      Temp-C      ThrMass      Dissip      Comment
n          926          20              0          -Y TOP RAIL
n          601          20          .058      TOP PCB THERMAL PLANE
n          602          20          .070
n          603          20          .026
n          604          20          .001
n          605          20              0
n          606          20              0
n          607          20              0
n          608          20              0
n          609          20              0
n          610          20              0
n          611          20              0
n          612          20              0
n          613          20              0
n          614          20              0
n          615          20              0
n          616          20              0
n          617          20              0
A#####
CTRL-F1Import ITAS_NC      UDC Allowed      PgDn PgUp Home End
SHIFT-F1Import Column      Shift-F5del/Pur
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
37	618	20		0	
38	501	20		0	5TH LAYER POLYIMIDE
39	502	20		0	
40	503	20		0	
41	504	20		0	
42	505	20		0	
43	506	20		0	
44	507	20		0	
45	508	20		0	
46	509	20		0	
47	510	20		0	
48	511	20		0	
49	512	20		0	
50	513	20		0	
51	514	20		0	
52	515	20		0	
53	516	20		0	
54	517	20		0	

Ctrl-F1 Import ITAS_NC UDC Allowed PgDn PgUp Home End
 Shift-F1 Import Column Shift-F5 Del/Pur
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
	518	20			
401		20		.003	GROUND LAYER COPPER
402		20		.004	
403		20		.001	
404		20		.001	
405		20		0	
406		20		0	
407		20		0	
408		20		0	
409		20		0	
410		20		0	
411		20		0	
412		20		0	
413		20		0	
414		20		0	
415		20		0	
416		20		0	
417		20		0	

Ctrl-F1 Import ITAS_NC UDC Allowed PgDn PgUp Home End
 Shift-F1 Import Column Shift-F5 Del/Pur
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
	418	20		0	
	301	20		0	3RD LAYER POLYIMIDE
	302	20		0	
	303	20		0	
	304	20		0	
	305	20		0	
	306	20		0	
	307	20		0	
	308	20		0	
	309	20		0	
	310	20		0	
	311	20		0	
	312	20		0	
	313	20		0	
	314	20		0	
	315	20		0	
	316	20		0	
	317	20		0	

Ctrl-F1 Import ITAS_NC UDC Allowed PgDn PgUp Home End
Shift-F1 Import Column Shift-F5 Del/Pur
F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
	318	20		0	
	201	20		0	SIGNAL LEVEL (VERY LITTLE CU)
	202	20		0	
	203	20		0	
	204	20		0	
	205	20		0	
	206	20		0	
	207	20		0	
	208	20		0	
	209	20		0	
	210	20		0	
	211	20		0	
	212	20		0	
	213	20		0	
	214	20		0	
	215	20		0	
	216	20		0	
	217	20		0	

Ctrl-F1 Import ITAS_NC UDC Allowed PgDn PgUp Home End
Shift-F1 Import Column Shift-F5 Del/Pur
F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
218		20		0	
101		20		0	TOP LAYER POLYIMIDE
102		20		0	
103		20		0	
104		20		0	
105		20		0	
106		20		0	
107		20		0	
108		20		0	
109		20		0	
110		20		0	
111		20		0	
112		20		0	
113		20		0	
114		20		0	
115		20		0	
116		20		0	
117		20		0	

Ctrl-F1Import ITAS_NC UDC Allowed PgDn PgUp Home End
 Shift-F1Import Column Shift-F5Del/Pur
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
118		20		0	
1601		20		0	BOTTOM PCB THERMAL PLANE COPPER
1602		20		0	
1603		20		0	
1604		20		0	
1605		20		0	
1606		20		0	
1607		20		0	
1608		20		0	
1609		20		0	
1610		20		0	
1611		20		0	
1612		20		0	
1613		20		0	
1614		20		0	
1615		20		0	
1616		20		0	
1617		20		0	

Ctrl-F1Import ITAS_NC UDC Allowed PgDn PgUp Home End
 Shift-F1Import Column Shift-F5Del/Pur
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis; ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
	1618	20		0	
	1501	20		0	5TH LAYER POLYIMIDE
	1502	20		0	
	1503	20		0	
	1504	20		0	
	1505	20		0	
	1506	20		0	
	1507	20		0	
	1508	20		0	
	1509	20		0	
	1510	20		0	
	1511	20		0	
	1512	20		0	
	1513	20		0	
	1514	20		0	
	1515	20		0	
	1516	20		0	
	1517	20		0	

Ctrl-F1 Import ITAS_NC UDC Allowed PgDn PgUp Home End
Shift-F1 Import Column Shift-F5 Del/Pur
F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis; ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
	1518	20		0	
	1401	20		0	GROUND LAYER COPPER
	1402	20		0	
	1403	20		0	
	1404	20		0	
	1405	20		0	
	1406	20		0	
	1407	20		0	
	1408	20		0	
	1409	20		0	
	1410	20		0	
	1411	20		0	
	1412	20		0	
	1413	20		0	
	1414	20		0	
	1415	20		0	
	1416	20		0	
	1417	20		0	

Ctrl-F1 Import ITAS_NC UDC Allowed PgDn PgUp Home End
Shift-F1 Import Column Shift-F5 Del/Pur
F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
	1418	20		0	
	1301	20		0	3RD LAYER POLYIMIDE
	1302	20		0	
	1303	20		0	
	1304	20		0	
	1305	20		0	
	1306	20		0	
	1307	20		0	
	1308	20		0	
	1309	20		0	
	1310	20		0	
	1311	20		0	
	1312	20		0	
	1313	20		0	
	1314	20		0	
	1315	20		0	
	1316	20		0	
	1317	20		0	

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

Ctrl: F1Import ITAS_NC UDC Allowed PgDn PgUp Home End
Shift: F1Import Column Shift-F5Del/Pur
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
	1318	20		0	
	1201	20		0	SIGNAL LAYER COPPER
	1202	20		0	
	1203	20		0	
	1204	20		0	
	1205	20		0	
	1206	20		0	
	1207	20		0	
	1208	20		0	
	1209	20		0	
	1210	20		0	
	1211	20		0	
	1212	20		0	
	1213	20		0	
	1214	20		0	
	1215	20		0	
	1216	20		0	
	1217	20		0	

Ctrl: F1Import ITAS_NC UDC Allowed PgDn PgUp Home End

Shift: F1Import Column Shift-F5Del/Pur
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

SEQ#	NodeNo	Temp-C	ThrMass	Dissip	Comment
1218	20			0	
1101	20			0	TOP LAYER POLYIMIDE
1102	20			0	
1103	20			0	
1104	20			0	
1105	20			0	
1106	20			0	
1107	20			0	
1108	20			0	
1109	20			0	
1110	20			0	
1111	20			0	
1112	20			0	
1113	20			0	
1114	20			0	
1115	20			0	
1116	20			0	
1117	20			0	

```

    eESCrl:CopyeITAS Node Data Entry For Thermal Analysis eESC:Quit

```

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
1118	20		0		

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APPENDIX G ITAS NODE DATA FOR HOT-CASE

9

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
1	901	20		0	EPS HOUSING WALLS +X
2	902	20		0	+Y
3	903	20		0	+Y
4	904	20		0	+Y
5	905	20		0	+Y
6	906	20		0	+Z
7	907	20		0	-X
8	908	20		0	-Y
9	909	20		0	-Y
10	910	20		0	-Y
11	911	20		0	-Y
12	912	20		0	-Z
13	-913	40		0	BOUNDARY NODE TO 906
14	921	20		0	HOUSING +Y BOTTOM RAIL
15	922	20		0	+Y MIDDLE RAIL
16	923	20		0	+Y TOP RAIL
17	924	20		0	-Y BOTTOM RAIL
18	925	20		0	-Y MIDDLE RAIL

Ctrl:Import ITAS_NC UDC Allowed PgDn PgUp Home End

Shift-F1Import Column Shift-F5Del/Pur
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
19	926	20		0	-Y TOP RAIL
20	601	20		.037	TOP PCB THERMAL PLANE
21	602	20		.0475	
22	603	20		.01995	
23	604	20		.01	
24	605	20		.011	
25	606	20		.060	
26	607	20		.011	
27	608	20		0	
28	609	20		0	
29	610	20		.008	
30	611	20		.008	
31	612	20		.011	
32	613	20		0	
33	614	20		0	
34	615	20		.009	
35	616	20		.009	
36	617	20		.004	

Ctrl:Import ITAS_NC UDC Allowed PgDn PgUp Home End

Shift-F1Import Column Shift-F5Del/Pur
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
127	118	20		0	
128	1601	20		.113	BOTTOM PCB THERMAL PLANE COPPER
129	1602	20		.086	
130	1603	20		.025	
131	1604	20		0	
132	1605	20		0	
133	1606	20		.175	
134	1607	20		0	
135	1608	20		0	
136	1609	20		.375	
137	1610	20		.105	
138	1611	20		.15	
139	1612	20		0	
140	1613	20		0	
141	1614	20		0	
142	1615	20		0	
143	1616	20		0	
144	1617	20		0	

CTRL-F1 Import ITAS_NC UDC Allowed PgDn PgUp Home End
 SHIFT-F1 Import Column Shift-F5 Del/Pur
 F1 Save/Purge F2 Help F3 AutoGen F4 Purge F5 Delete F7 Mark/UnMark F10 Search

APPENDIX H ITAS OUTPUT FOR COLD-CASE

TOTAL SURFACES IN THIS MODEL= 42
TOTAL SURFACES IN THIS MODEL= 42

PC-ITAS Summary of Input Parameters

These parameters reflect the latest values assigned to them
prior to any computation

TOTAL SURFACES IN THIS MODEL= 42

Date: 05/20/94

Time: 14:35:32.10

Thermal Analysis Parameters

=====

1. Solution Method:1.Steady-State 2.Transient 3. (1&2).....	1
2. Solution Time Step(minutes).....	0.10
3. Final Time (minutes);if <0 then no of orbs.....	-1.00
4. Starting Temperature(Kelvin).....	300.00
5. Temperature Print Interval (minutes).....	20
6. No. of Iterations For Convergence (NLOOP).....	9999
7. Temperature Unit 1:K, 2:C, 3:F, 4:R.....	2
8. Solution Accuracy Parameter (not used).....	130
9. Solution Convergence Parameter (not used).....	1.30
10. Solution Tolerance (ARLXCA, DRLXCA).....	0.00100
11. Transient Solution Stability Factor (not used).....	0.850
12. Include User-Defined Network.....(Y/N).....	Y
13. Print RADK, POWER.....(Y/N).....	N
14. Print Transient Time/Temperature...(Y/N).....	N
15. Starting Temperatures Forced (No.4)(Y/N).....	N
16. Thermal Analyses Without Orbital Loads (Y/N).....	Y
17. Stand-Alone Thermal Analyzer (ITAS-Format Models).....	Y
18. No. of Isolated Cavities (RADK files).....	0

=====

ITAS THERMAL ANALYSIS

////////////////////////////////////

ITAS THERMAL ANALYZER:

*ERROR*DATA ERROR ENCOUNTERED

ERROR FOR CODE=

END OF RADIATION CONDUCTANCE & POWER PROCESSING

THERMAL DATA PREP ERROR CODE= 1

Date: 05/20/94

Time: 14:38:44.10

Thermal Analysis Parameters

=====

1. Solution Method:1.Steady-State 2.Transient 3. (1&2).....	1
2. Solution Time Step(minutes).....	0.10
3. Final Time (minutes);if <0 then no of orbs.....	-1.00
4. Starting Temperature(Kelvin).....	300.00
5. Temperature Print Interval (minutes).....	20
6. No. of Iterations For Convergence (NLOOP).....	9999
7. Temperature Unit 1:K, 2:C, 3:F, 4:R.....	2
8. Solution Accuracy Parameter (not used).....	130
9. Solution Convergence Parameter (not used).....	1.30
10. Solution Tolerance (ARLXCA, DRLXCA).....	0.00100
11. Transient Solution Stability Factor (not used).....	0.850

[illegible]

```

1. View Factor Accuracy Parameter.....2
2. Engineering Units of the Geometry Data:
   1:inch, 2:feet, 3:centimeter, 4:meter.....1
3. View Factor Computation Without Blockage (Y/N).....N
4. Print Control Parameters:
   0:Do Not Print; 1:Print All; 2:Print All & Intervener List.0
5. View-Factor Re-Start File.....

```

```

INPUT IS IN  INCHES
OUTPUT IS IN CENTIMETERS
TOTAL SURFACES IN THIS MODEL=  42

```

SURFACE	1.-FACT	KEY
1.01	0.3965	(3)
1.02	0.3648	(25)
1.03	0.3930	(26)
1.04	0.3858	(27)
1.05	0.3524	(28)
1.06	0.8752	(1)
1.07	0.3811	(4)
1.08	0.3527	(29)
1.09	0.3855	(30)
1.10	0.3854	(31)
1.11	0.3524	(32)
1.12	-0.0024	(2)
2.01	0.6859	(42)
2.02	0.8949	(40)
2.03	0.9450	(37)
2.04	0.9497	(33)
2.05	0.8709	(20)

ACTIVE SURFACES IN OUTPUT- 42

VIEW FACTOR CALC CPU TIME (second) = 34.7100

** END OF PC-ITAS VIEW FACTOR CALCULATIONS **

Date: 05/20/94 Time: 14:39:19.10

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8	1.08	8	0.40	0.80	1.00	0.00	0
9	1.09	9	0.40	0.80	1.00	0.00	0
10	1.10	10	0.40	0.80	1.00	0.00	0
11	1.11	11	0.40	0.80	1.00	0.00	0
12	1.12	12	0.40	0.80	1.00	0.00	0
13	2.01	13	0.00	0.01	1.00	0.00	0
14	2.02	14	0.00	0.01	1.00	0.00	0
15	2.03	15	0.00	0.01	1.00	0.00	0
16	2.04	16	0.00	0.01	1.00	0.00	0
17	2.05	17	0.00	0.01	1.00	0.00	0
18	2.06	18	0.00	0.01	1.00	0.00	0
19	2.07	19	0.00	0.01	1.00	0.00	0
20	2.08	20	0.00	0.01	1.00	0.00	0
21	2.09	21	0.00	0.01	1.00	0.00	0
22	2.10	22	0.00	0.01	1.00	0.00	0
23	3.01	23	0.00	0.01	1.00	0.00	0
24	3.02	24	0.00	0.01	1.00	0.00	0
25	3.03	25	0.00	0.01	1.00	0.00	0
26	3.04	26	0.00	0.01	1.00	0.00	0
27	3.05	27	0.00	0.01	1.00	0.00	0
28	3.06	28	0.00	0.01	1.00	0.00	0
29	3.07	29	0.00	0.01	1.00	0.00	0
30	3.08	30	0.00	0.01	1.00	0.00	0
31	4.01	31	0.00	0.01	1.00	0.00	0
32	4.02	32	0.00	0.01	1.00	0.00	0
33	4.03	33	0.00	0.01	1.00	0.00	0
34	4.04	34	0.00	0.01	1.00	0.00	0
35	4.05	35	0.00	0.01	1.00	0.00	0
36	4.06	36	0.00	0.01	1.00	0.00	0
37	4.07	37	0.00	0.01	1.00	0.00	0
38	4.08	38	0.00	0.01	1.00	0.00	0
39	4.09	39	0.00	0.01	1.00	0.00	0
40	4.10	40	0.00	0.01	1.00	0.00	0
41	4.11	41	0.00	0.01	1.00	0.00	0
42	4.12	42	0.00	0.01	1.00	0.00	0

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 ITAS SCRIPT-F (RADK) COMPUTATIONS
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PC-ITAS SCRIPT-F CALCULATION SEGMENT:

Writing ITAS-format RADK for future use

Node#,	Temp.,	TherMass,	Power
1	10.00	1.00	0.00 EPS HOUSING
2	10.00	1.00	0.00 EPS HOUSING
3	10.00	1.00	0.00 EPS HOUSING
4	10.00	1.00	0.00 EPS HOUSING
5	10.00	1.00	0.00 EPS HOUSING
6	10.00	1.00	0.00 EPS HOUSING
7	10.00	1.00	0.00 EPS HOUSING
8	10.00	1.00	0.00 EPS HOUSING
9	10.00	1.00	0.00 EPS HOUSING
10	10.00	1.00	0.00 EPS HOUSING
11	10.00	1.00	0.00 EPS HOUSING
12	10.00	1.00	0.00 EPS HOUSING
13	10.00	1.00	0.00 PCB 1-1
14	10.00	1.00	0.00 PCB 1-1
15	10.00	1.00	0.00 PCB 1-1
16	10.00	1.00	0.00 PCB 1-1
17	10.00	1.00	0.00 PCB 1-1
18	10.00	1.00	0.00 PCB 1-1
19	10.00	1.00	0.00 PCB 1-1

20	10.00	1.00	0.00	PCB 1-1
21	10.00	1.00	0.00	PCB 1-1
22	10.00	1.00	0.00	PCB 1-1
23	10.00	1.00	0.00	PCB 1-2
24	10.00	1.00	0.00	PCB 1-2
25	10.00	1.00	0.00	PCB 1-2
26	10.00	1.00	0.00	PCB 1-2
27	10.00	1.00	0.00	PCB 1-2
28	10.00	1.00	0.00	PCB 1-2
29	10.00	1.00	0.00	PCB 1-2
30	10.00	1.00	0.00	PCB 1-2
31	10.00	1.00	0.00	PCB 2 (BOTTOM)
32	10.00	1.00	0.00	PCB 2 (BOTTOM)
33	10.00	1.00	0.00	PCB 2 (BOTTOM)
34	10.00	1.00	0.00	PCB 2 (BOTTOM)
35	10.00	1.00	0.00	PCB 2 (BOTTOM)
36	10.00	1.00	0.00	PCB 2 (BOTTOM)
37	10.00	1.00	0.00	PCB 2 (BOTTOM)
38	10.00	1.00	0.00	PCB 2 (BOTTOM)
39	10.00	1.00	0.00	PCB 2 (BOTTOM)
40	10.00	1.00	0.00	PCB 2 (BOTTOM)
41	10.00	1.00	0.00	PCB 2 (BOTTOM)
42	10.00	1.00	0.00	PCB 2 (BOTTOM)
RAD	00	0.1295000000E+01	1	4
RAD	00	0.3408000000E+01	1	5
RAD	00	0.1231900000E+02	1	6
RAD	00	0.1441000000E+01	1	7
RAD	00	0.1166000000E+01	1	10
RAD	00	0.3754000000E+01	1	11
RAD	00	0.9037000000E+01	1	12
RAD	00	0.5500000000E+00	2	3
RAD	00	0.3313000000E+01	2	6
RAD	00	0.3342000000E+01	2	7
RAD	00	0.2634000000E+01	2	12
RAD	00	0.9950000000E+00	3	4
RAD	00	0.3602000000E+01	3	6
RAD	00	0.9060000000E+00	3	7
RAD	00	0.2767000000E+01	3	12
RAD	00	0.7580000000E+00	4	5
RAD	00	0.3602000000E+01	4	6
RAD	00	0.2770000000E+01	4	12
RAD	00	0.3314000000E+01	5	6
RAD	00	0.2622000000E+01	5	12
RAD	00	0.1230000000E+02	6	7
RAD	00	0.3314000000E+01	6	8
RAD	00	0.3600000000E+01	6	9
RAD	00	0.3601000000E+01	6	10
RAD	00	0.3314000000E+01	6	11
RAD	00	0.1643000000E+01	6	12
RAD	00	0.3619000000E+01	7	8
RAD	00	0.1020000000E+01	7	9
RAD	00	0.9591000000E+01	7	12
RAD	00	0.7800000000E+00	8	9
RAD	00	0.2629000000E+01	8	12
RAD	00	0.7910000000E+00	9	10
RAD	00	0.2762000000E+01	9	12
RAD	00	0.2766000000E+01	10	12
RAD	00	0.2615000000E+01	11	12
RAD	00	0.5660000000E+00	12	12
RAD	00	0.5110000000E+00	12	39

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*****
#OF RADIATION CONDUCTANCES GENERATED=      38
*****
SCRIPT-F CALC CPU TIME (second)      =      2.58000
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RECORD	5022=	1	901	20	0	EPS HOUSING WALLS +X
RECORD	5023=	2	902	20	0	+Y
RECORD	5024=	3	903	20	0	+Y
RECORD	5025=	4	904	20	0	+Y
RECORD	5026=	5	905	20	0	+Y
RECORD	5027=	6	906	20	0	+Z
RECORD	5028=	7	907	20	0	-X
RECORD	5029=	8	908	20	0	-Y
RECORD	5030=	9	909	20	0	-Y
RECORD	5031=	10	910	20	0	-Y
RECORD	5032=	11	911	20	0	-Y
RECORD	5033=	12	912	20	0	-Z
RECORD	5034=	13	-913	0	0	BOUNDARY NODE TO 906
RECORD	5035=	14	921	20	0	HOUSING +Y BOTTOM RAIL
RECORD	5036=	15	922	20	0	+Y MIDDLE RAIL
RECORD	5037=	16	923	20	0	+Y TOP RAIL
RECORD	5038=	17	924	20	0	-Y BOTTOM RAIL
RECORD	5039=	18	925	20	0	-Y MIDDLE RAIL
RECORD	5040=	19	926	20	0	-Y TOP RAIL
RECORD	5041=	20	601	20	.058	TOP PCB THERMAL PLANE
RECORD	5042=	21	602	20	.070	
RECORD	5043=	22	603	20	.026	
RECORD	5044=	23	604	20	.001	
RECORD	5045=	24	605	20	0	
RECORD	5046=	25	606	20	0	
RECORD	5047=	26	607	20	0	
RECORD	5048=	27	608	20	0	
RECORD	5049=	28	609	20	0	
RECORD	5050=	29	610	20	0	
RECORD	5051=	30	611	20	0	
RECORD	5052=	31	612	20	0	
RECORD	5053=	32	613	20	0	
RECORD	5054=	33	614	20	0	
RECORD	5055=	34	615	20	0	
RECORD	5056=	35	616	20	0	
RECORD	5057=	36	617	20	0	
RECORD	5058=	37	618	20	0	
RECORD	5059=	38	501	20	0	5TH LAYER POLYIMIDE
RECORD	5060=	39	502	20	0	
RECORD	5061=	40	503	20	0	
RECORD	5062=	41	504	20	0	
RECORD	5063=	42	505	20	0	
RECORD	5064=	43	506	20	0	
RECORD	5065=	44	507	20	0	
RECORD	5066=	45	508	20	0	
RECORD	5067=	46	509	20	0	
RECORD	5068=	47	510	20	0	
RECORD	5069=	48	511	20	0	
RECORD	5070=	49	512	20	0	
RECORD	5071=	50	513	20	0	
RECORD	5072=	51	514	20	0	

RECORD	5073=	52	515	20	0	
RECORD	5074=	53	516	20	0	
RECORD	5075=	54	517	20	0	
RECORD	5076=	55	518	20		
RECORD	5077=	56	401	20	.003	GROUND LAYER COPPER
RECORD	5078=	57	402	20	.004	
RECORD	5079=	58	403	20	.001	
RECORD	5080=	59	404	20	.001	
RECORD	5081=	60	405	20	0	
RECORD	5082=	61	406	20	0	
RECORD	5083=	62	407	20	0	
RECORD	5084=	63	408	20	0	
RECORD	5085=	64	409	20	0	
RECORD	5086=	65	410	20	0	
RECORD	5087=	66	411	20	0	
RECORD	5088=	67	412	20	0	
RECORD	5089=	68	413	20	0	
RECORD	5090=	69	414	20	0	
RECORD	5091=	70	415	20	0	
RECORD	5092=	71	416	20	0	
RECORD	5093=	72	417	20	0	
RECORD	5094=	73	418	20	0	
RECORD	5095=	74	301	20	0	3RD LAYER POLYIMIDE
RECORD	5096=	75	302	20	0	
RECORD	5097=	76	303	20	0	
RECORD	5098=	77	304	20	0	
RECORD	5099=	78	305	20	0	
RECORD	5100=	79	306	20	0	
RECORD	5101=	80	307	20	0	
RECORD	5102=	81	308	20	0	
RECORD	5103=	82	309	20	0	
RECORD	5104=	83	310	20	0	
RECORD	5105=	84	311	20	0	
RECORD	5106=	85	312	20	0	
RECORD	5107=	86	313	20	0	
RECORD	5108=	87	314	20	0	
RECORD	5109=	88	315	20	0	
RECORD	5110=	89	316	20	0	
RECORD	5111=	90	317	20	0	
RECORD	5112=	91	318	20	0	
RECORD	5113=	92	201	20	0	SIGNAL LEVEL (VERY LITTLE CU)
RECORD	5114=	93	202	20	0	
RECORD	5115=	94	203	20	0	
RECORD	5116=	95	204	20	0	
RECORD	5117=	96	205	20	0	
RECORD	5118=	97	206	20	0	
RECORD	5119=	98	207	20	0	
RECORD	5120=	99	208	20	0	
RECORD	5121=	100	209	20	0	
RECORD	5122=	101	210	20	0	
RECORD	5123=	102	211	20	0	
RECORD	5124=	103	212	20	0	
RECORD	5125=	104	213	20	0	
RECORD	5126=	105	214	20	0	
RECORD	5127=	106	215	20	0	
RECORD	5128=	107	216	20	0	
RECORD	5129=	108	217	20	0	
RECORD	5130=	109	218	20	0	
RECORD	5131=	110	201	20	0	TOP LAYER POLYIMIDE
RECORD	5132=	111	102	20	0	

RECORD	5133=	112	103	20	0
RECORD	5134=	113	104	20	0
RECORD	5135=	114	105	20	0
RECORD	5136=	115	106	20	0
RECORD	5137=	116	107	20	0
RECORD	5138=	117	108	20	0
RECORD	5139=	118	109	20	0
RECORD	5140=	119	110	20	0
RECORD	5141=	120	111	20	0
RECORD	5142=	121	112	20	0
RECORD	5143=	122	113	20	0
RECORD	5144=	123	114	20	0
RECORD	5145=	124	115	20	0
RECORD	5146=	125	116	20	0
RECORD	5147=	126	117	20	0
RECORD	5148=	127	118	20	0
RECORD	5149=	128	1601	20	0
RECORD	5150=	129	1602	20	0
RECORD	5151=	130	1603	20	0
RECORD	5152=	131	1604	20	0
RECORD	5153=	132	1605	20	0
RECORD	5154=	133	1606	20	0
RECORD	5155=	134	1607	20	0
RECORD	5156=	135	1608	20	0
RECORD	5157=	136	1609	20	0
RECORD	5158=	137	1610	20	0
RECORD	5159=	138	1611	20	0
RECORD	5160=	139	1612	20	0
RECORD	5161=	140	1613	20	0
RECORD	5162=	141	1614	20	0
RECORD	5163=	142	1615	20	0
RECORD	5164=	143	1616	20	0
RECORD	5165=	144	1617	20	0
RECORD	5166=	145	1618	20	0
RECORD	5167=	146	1501	20	0
RECORD	5168=	147	1502	20	0
RECORD	5169=	148	1503	20	0
RECORD	5170=	149	1504	20	0
RECORD	5171=	150	1505	20	0
RECORD	5172=	151	1506	20	0
RECORD	5173=	152	1507	20	0
RECORD	5174=	153	1508	20	0
RECORD	5175=	154	1509	20	0
RECORD	5176=	155	1510	20	0
RECORD	5177=	156	1511	20	0
RECORD	5178=	157	1512	20	0
RECORD	5179=	158	1513	20	0
RECORD	5180=	159	1514	20	0
RECORD	5181=	160	1515	20	0
RECORD	5182=	161	1516	20	0
RECORD	5183=	162	1517	20	0
RECORD	5184=	163	1518	20	0
RECORD	5185=	164	1401	20	0
RECORD	5186=	165	1402	20	0
RECORD	5187=	166	1403	20	0
RECORD	5188=	167	1404	20	0
RECORD	5189=	168	1405	20	0
RECORD	5190=	169	1406	20	0
RECORD	5191=	170	1407	20	0
RECORD	5192=	171	1408	20	0

BOTTOM PCB THERMAL PLANE COPPER

5TH LAYER POLYIMIDE

GROUND LAYER COPPER

RECORD	5193=	172	1409	20	0	
RECORD	5194=	173	1410	20	0	
RECORD	5195=	174	1411	20	0	
RECORD	5196=	175	1412	20	0	
RECORD	5197=	176	1413	20	0	
RECORD	5198=	177	1414	20	0	
RECORD	5199=	178	1415	20	0	
RECORD	5200=	179	1416	20	0	
RECORD	5201=	180	1417	20	0	
RECORD	5202=	181	1418	20	0	
RECORD	5203=	182	1301	20	0	3RD LAYER POLYIMIDE
RECORD	5204=	183	1302	20	0	
RECORD	5205=	184	1303	20	0	
RECORD	5206=	185	1304	20	0	
RECORD	5207=	186	1305	20	0	
RECORD	5208=	187	1306	20	0	
RECORD	5209=	188	1307	20	0	
RECORD	5210=	189	1308	20	0	
RECORD	5211=	190	1309	20	0	
RECORD	5212=	191	1310	20	0	
RECORD	5213=	192	1311	20	0	
RECORD	5214=	193	1312	20	0	
RECORD	5215=	194	1313	20	0	
RECORD	5216=	195	1314	20	0	
RECORD	5217=	196	1315	20	0	
RECORD	5218=	197	1316	20	0	
RECORD	5219=	198	1317	20	0	
RECORD	5220=	199	1318	20	0	
RECORD	5221=	200	1201	20	0	SIGNAL LAYER COPPER
RECORD	5222=	201	1202	20	0	
RECORD	5223=	202	1203	20	0	
RECORD	5224=	203	1204	20	0	
RECORD	5225=	204	1205	20	0	
RECORD	5226=	205	1206	20	0	
RECORD	5227=	206	1207	20	0	
RECORD	5228=	207	1208	20	0	
RECORD	5229=	208	1209	20	0	
RECORD	5230=	209	1210	20	0	
RECORD	5231=	210	1211	20	0	
RECORD	5232=	211	1212	20	0	
RECORD	5233=	212	1213	20	0	
RECORD	5234=	213	1214	20	0	
RECORD	5235=	214	1215	20	0	
RECORD	5236=	215	1216	20	0	
RECORD	5237=	216	1217	20	0	
RECORD	5238=	217	1218	20	0	
RECORD	5239=	218	1101	20	0	TOP LAYER POLYIMIDE
RECORD	5240=	219	1102	20	0	
RECORD	5241=	220	1103	20	0	
RECORD	5242=	221	1104	20	0	
RECORD	5243=	222	1105	20	0	
RECORD	5244=	223	1106	20	0	
RECORD	5245=	224	1107	20	0	
RECORD	5246=	225	1108	20	0	
RECORD	5247=	226	1109	20	0	
RECORD	5248=	227	1110	20	0	
RECORD	5249=	228	1111	20	0	
RECORD	5250=	229	1112	20	0	
RECORD	5251=	230	1113	20	0	
RECORD	5252=	231	1114	20	0	

RECORD 5253= 232 1115 20 0
 RECORD 5254= 233 1116 20 0
 RECORD 5255= 234 1117 20 0
 RECORD 5256= 235 1118 20 0

~~~~~ END OF USER NODES ~~~~~

~~~~~ END OF FLUID ~~~~~

TOTAL THERMAL MASS ENCOUNTERED (W-MIN/C)= 1329.04

TOTAL THERMAL MASS ENCOUNTERED (BTU /F)= 42.0002

~~~~~ END OF FLUID ~~~~~

NODE 1 (REL NODE 1 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 2 (REL NODE 2 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 3 (REL NODE 3 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 4 (REL NODE 4 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 5 (REL NODE 5 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 6 (REL NODE 6 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 7 (REL NODE 7 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 8 (REL NODE 8 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 9 (REL NODE 9 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 10 (REL NODE 10 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 11 (REL NODE 11 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 12 (REL NODE 12 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 13 (REL NODE 13 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 14 (REL NODE 14 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 15 (REL NODE 15 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 16 (REL NODE 16 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 17 (REL NODE 17 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 18 (REL NODE 18 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 19 (REL NODE 19 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 20 (REL NODE 20 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 21 (REL NODE 21 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 22 (REL NODE 22 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 23 (REL NODE 23 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 24 (REL NODE 24 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 25 (REL NODE 25 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 26 (REL NODE 26 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 27 (REL NODE 27 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 28 (REL NODE 28 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 29 (REL NODE 29 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 30 (REL NODE 30 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 31 (REL NODE 31 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 32 (REL NODE 32 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 33 (REL NODE 33 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 34 (REL NODE 34 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 35 (REL NODE 35 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 36 (REL NODE 36 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 37 (REL NODE 37 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 38 (REL NODE 38 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 39 (REL NODE 39 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 40 (REL NODE 40 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 41 (REL NODE 41 ) IS BEING ADDED TO THE CURRENT LIST  
 NODE 42 (REL NODE 42 ) IS BEING ADDED TO THE CURRENT LIST

END OF RADIATION CONDUCTANCE & POWER PROCESSING

ITAS THERMAL ANALYSIS:

CHECKOUT PHASE OF PC-ITAS THERMAL ANALYSIS

TOTAL CARDS ENCOUNTERED: 1760  
 TOTAL THERMAL MASSES USED (W-MIN/C)= 1366.04  
 TOTAL THERMAL MASSES USED (BTU/F )= 43.1695

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NO. OF THERMAL NODES=

277

ITAS STEADY-STATE SOLUTION ALGORITHM (SUCCESSIVE POINT ITERATION) PARAMETERS:  
 ARLXCA=0.10000E-02, DRLXCA=0.10000E-02 NLOOP= 9999

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ITAS STEADY-STATE SOLUTION (SUCCESSIVE POINT ITERATION)

NO. OF ITERATIONS= 2588 TOTAL INPUT ENERGY (W)= 0.16400

SYSTEM ENERGY BALANCE (W)= -8.0523 ( 4909.9 %)

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|   |       |       |   |       |       |   |       |       |   |       |       |
|---|-------|-------|---|-------|-------|---|-------|-------|---|-------|-------|
| T | 1=    | 0.43  | T | 2=    | 0.80  | T | 3=    | 0.83  | T | 4=    | 0.83  |
| T | 5=    | 0.77  | T | 6=    | 0.12  | T | 7=    | 0.56  | T | 8=    | 0.44  |
| T | 9=    | 0.44  | T | 10=   | 0.44  | T | 11=   | 0.44  | T | 12=   | 0.51  |
| T | 13=   | 19.79 | T | 14=   | 19.59 | T | 15=   | 19.39 | T | 16=   | 19.33 |
| T | 17=   | 18.55 | T | 18=   | 3.13  | T | 19=   | 2.51  | T | 20=   | 1.55  |
| T | 21=   | 0.87  | T | 22=   | 0.97  | T | 23=   | 1.38  | T | 24=   | 1.03  |
| T | 25=   | 0.97  | T | 26=   | 0.75  | T | 27=   | 19.60 | T | 28=   | 19.24 |
| T | 29=   | 19.25 | T | 30=   | 19.27 | T | 31=   | 0.88  | T | 32=   | 0.86  |
| T | 33=   | 0.97  | T | 34=   | 1.30  | T | 35=   | 18.46 | T | 36=   | 18.33 |
| T | 37=   | 18.87 | T | 38=   | 19.28 | T | 39=   | 0.88  | T | 40=   | 0.86  |
| T | 41=   | 0.96  | T | 42=   | 1.26  | T | 901=  | 0.43  | T | 902=  | 0.80  |
| T | 903=  | 0.83  | T | 904=  | 0.83  | T | 905=  | 0.77  | T | 906=  | 0.12  |
| T | 907=  | 0.56  | T | 908=  | 0.44  | T | 909=  | 0.44  | T | 910=  | 0.44  |
| T | 911=  | 0.44  | T | 912=  | 0.51  | T | 913=  | 0.00  | T | 921=  | 0.50  |
| T | 922=  | 0.47  | T | 923=  | 0.36  | T | 924=  | 0.50  | T | 925=  | 0.46  |
| T | 926=  | 0.36  | T | 601=  | 1.38  | T | 602=  | 1.03  | T | 603=  | 0.97  |
| T | 604=  | 0.75  | T | 605=  | 19.60 | T | 606=  | 19.24 | T | 607=  | 19.25 |
| T | 608=  | 19.26 | T | 609=  | 19.79 | T | 610=  | 19.59 | T | 611=  | 19.39 |
| T | 612=  | 19.33 | T | 613=  | 18.55 | T | 614=  | 3.13  | T | 615=  | 2.51  |
| T | 616=  | 1.54  | T | 617=  | 0.87  | T | 618=  | 0.97  | T | 501=  | 4.19  |
| T | 502=  | 3.89  | T | 503=  | 3.62  | T | 504=  | 3.19  | T | 505=  | 15.90 |
| T | 506=  | 15.62 | T | 507=  | 15.37 | T | 508=  | 14.53 | T | 509=  | 15.54 |
| T | 510=  | 15.32 | T | 511=  | 15.20 | T | 512=  | 15.29 | T | 513=  | 14.24 |
| T | 514=  | 5.94  | T | 515=  | 5.68  | T | 516=  | 5.08  | T | 517=  | 4.29  |
| T | 518=  | 4.44  | T | 401=  | 6.91  | T | 402=  | 6.69  | T | 403=  | 6.21  |
| T | 404=  | 5.58  | T | 405=  | 12.30 | T | 406=  | 12.05 | T | 407=  | 11.54 |
| T | 408=  | 9.94  | T | 409=  | 11.44 | T | 410=  | 11.26 | T | 411=  | 11.16 |
| T | 412=  | 11.34 | T | 413=  | 10.08 | T | 414=  | 8.62  | T | 415=  | 8.66  |
| T | 416=  | 8.47  | T | 417=  | 7.62  | T | 418=  | 7.77  | T | 301=  | 6.31  |
| T | 302=  | 6.10  | T | 303=  | 5.67  | T | 304=  | 4.99  | T | 305=  | 12.30 |
| T | 306=  | 12.06 | T | 307=  | 11.54 | T | 308=  | 9.94  | T | 309=  | 11.44 |
| T | 310=  | 11.26 | T | 311=  | 11.17 | T | 312=  | 11.34 | T | 313=  | 10.08 |
| T | 314=  | 7.52  | T | 315=  | 7.50  | T | 316=  | 7.42  | T | 317=  | 6.66  |
| T | 318=  | 6.78  | T | 201=  | 5.70  | T | 202=  | 5.51  | T | 203=  | 5.13  |
| T | 204=  | 4.39  | T | 205=  | 12.30 | T | 206=  | 12.06 | T | 207=  | 11.54 |
| T | 208=  | 9.94  | T | 209=  | 11.44 | T | 210=  | 11.26 | T | 211=  | 11.17 |
| T | 212=  | 11.34 | T | 213=  | 10.07 | T | 214=  | 6.42  | T | 215=  | 6.34  |
| T | 216=  | 6.36  | T | 217=  | 5.70  | T | 218=  | 5.79  | T | 101=  | 5.10  |
| T | 102=  | 4.93  | T | 103=  | 4.59  | T | 104=  | 3.80  | T | 105=  | 12.30 |
| T | 106=  | 12.06 | T | 107=  | 11.54 | T | 108=  | 9.94  | T | 109=  | 11.44 |
| T | 110=  | 11.26 | T | 111=  | 11.17 | T | 112=  | 11.34 | T | 113=  | 10.07 |
| T | 114=  | 5.32  | T | 115=  | 5.95  | T | 116=  | 5.31  | T | 117=  | 4.74  |
| T | 118=  | 4.80  | T | 1601= | 0.88  | T | 1602= | 0.86  | T | 1603= | 0.97  |
| T | 1604= | 1.30  | T | 1605= | 18.46 | T | 1606= | 18.33 | T | 1607= | 18.87 |
| T | 1608= | 19.28 | T | 1609= | 0.88  | T | 1610= | 0.86  | T | 1611= | 0.96  |
| T | 1612= | 1.26  | T | 1613= | 20.00 | T | 1614= | 20.00 | T | 1615= | 20.00 |
| T | 1616= | 20.00 | T | 1617= | 20.00 | T | 1618= | 20.00 | T | 1501= | 1.90  |
| T | 1502= | 1.90  | T | 1503= | 2.00  | T | 1504= | 2.22  | T | 1505= | 11.83 |
| T | 1506= | 11.79 | T | 1507= | 12.10 | T | 1508= | 12.28 | T | 1509= | 1.97  |
| T | 1510= | 1.97  | T | 1511= | 2.07  | T | 1512= | 2.27  | T | 1513= | 20.00 |

|         |       |         |       |         |       |         |       |
|---------|-------|---------|-------|---------|-------|---------|-------|
| T 1514= | 20.00 | T 1515= | 20.00 | T 1516= | 20.00 | T 1517= | 20.00 |
| T 1518= | 20.00 | T 1401= | 2.89  | T 1402= | 2.91  | T 1403= | 3.00  |
| T 1404= | 3.08  | T 1405= | 5.39  | T 1406= | 5.41  | T 1407= | 5.55  |
| T 1408= | 5.63  | T 1409= | 3.03  | T 1410= | 3.05  | T 1411= | 3.14  |
| T 1412= | 3.22  | T 1413= | 20.00 | T 1414= | 20.00 | T 1415= | 20.00 |
| T 1416= | 20.00 | T 1417= | 20.00 | T 1418= | 20.00 | T 1301= | 2.72  |
| T 1302= | 2.74  | T 1303= | 2.82  | T 1304= | 2.90  | T 1305= | 5.39  |
| T 1306= | 5.41  | T 1307= | 5.55  | T 1308= | 5.63  | T 1309= | 2.83  |
| T 1310= | 2.85  | T 1311= | 2.94  | T 1312= | 3.02  | T 1313= | 20.00 |
| T 1314= | 20.00 | T 1315= | 20.00 | T 1316= | 20.00 | T 1317= | 20.00 |
| T 1318= | 20.00 | T 1201= | 2.54  | T 1202= | 2.56  | T 1203= | 2.64  |
| T 1204= | 2.72  | T 1205= | 5.39  | T 1206= | 5.41  | T 1207= | 5.55  |
| T 1208= | 5.63  | T 1209= | 2.64  | T 1210= | 2.66  | T 1211= | 2.74  |
| T 1212= | 2.82  | T 1213= | 20.00 | T 1214= | 20.00 | T 1215= | 20.00 |
| T 1216= | 20.00 | T 1217= | 20.00 | T 1218= | 20.00 | T 1101= | 2.37  |
| T 1102= | 2.38  | T 1103= | 2.46  | T 1104= | 2.54  | T 1105= | 5.39  |
| T 1106= | 5.41  | T 1107= | 5.55  | T 1108= | 5.63  | T 1109= | 2.44  |
| T 1110= | 2.46  | T 1111= | 2.54  | T 1112= | 2.62  | T 1113= | 20.00 |
| T 1114= | 20.00 | T 1115= | 20.00 | T 1116= | 20.00 | T 1117= | 20.00 |
| T 1118= | 20.00 | T       |       |         |       |         |       |

# ASCENDING NODE NUMBER : TEMPERATURE

\*\*\*\*\*  
 ITAS STEADY-STATE SOLUTION (SUCCESSIVE POINT ITERATION)  
 NO. OF ITERATIONS= 2588 TOTAL INPUT ENERGY (W)= 0.16400  
 SYSTEM ENERGY BALANCE (W)= -8.0523 ( 4909.9 %)  
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|        |        |        |        |        |        |        |        |
|--------|--------|--------|--------|--------|--------|--------|--------|
| T 1=   | 0.433  | T 2=   | 0.796  | T 3=   | 0.832  | T 4=   | 0.832  |
| T 5=   | 0.770  | T 6=   | 0.124  | T 7=   | 0.563  | T 8=   | 0.438  |
| T 9=   | 0.437  | T 10=  | 0.437  | T 11=  | 0.438  | T 12=  | 0.508  |
| T 13=  | 19.791 | T 14=  | 19.587 | T 15=  | 19.386 | T 16=  | 19.329 |
| T 17=  | 18.549 | T 18=  | 3.130  | T 19=  | 2.511  | T 20=  | 1.545  |
| T 21=  | 0.869  | T 22=  | 0.968  | T 23=  | 1.381  | T 24=  | 1.030  |
| T 25=  | 0.969  | T 26=  | 0.754  | T 27=  | 19.596 | T 28=  | 19.236 |
| T 29=  | 19.254 | T 30=  | 19.265 | T 31=  | 0.876  | T 32=  | 0.858  |
| T 33=  | 0.966  | T 34=  | 1.298  | T 35=  | 18.463 | T 36=  | 18.326 |
| T 37=  | 18.872 | T 38=  | 19.277 | T 39=  | 0.885  | T 40=  | 0.858  |
| T 41=  | 0.958  | T 42=  | 1.260  | T 101= | 5.103  | T 102= | 4.925  |
| T 103= | 4.595  | T 104= | 3.798  | T 105= | 12.301 | T 106= | 12.056 |
| T 107= | 11.542 | T 108= | 9.940  | T 109= | 11.437 | T 110= | 11.260 |
| T 111= | 11.166 | T 112= | 11.344 | T 113= | 10.075 | T 114= | 5.318  |
| T 115= | 5.949  | T 116= | 5.314  | T 117= | 4.742  | T 118= | 4.804  |
| T 201= | 5.705  | T 202= | 5.513  | T 203= | 5.134  | T 204= | 4.393  |
| T 205= | 12.301 | T 206= | 12.056 | T 207= | 11.542 | T 208= | 9.940  |
| T 209= | 11.437 | T 210= | 11.260 | T 211= | 11.166 | T 212= | 11.344 |
| T 213= | 10.075 | T 214= | 6.419  | T 215= | 6.337  | T 216= | 6.365  |
| T 217= | 5.700  | T 218= | 5.795  | T 301= | 6.307  | T 302= | 6.100  |
| T 303= | 5.674  | T 304= | 4.989  | T 305= | 12.301 | T 306= | 12.055 |
| T 307= | 11.542 | T 308= | 9.939  | T 309= | 11.438 | T 310= | 11.260 |
| T 311= | 11.165 | T 312= | 11.344 | T 313= | 10.075 | T 314= | 7.521  |
| T 315= | 7.501  | T 316= | 7.415  | T 317= | 6.658  | T 318= | 6.785  |
| T 401= | 6.908  | T 402= | 6.687  | T 403= | 6.213  | T 404= | 5.584  |
| T 405= | 12.301 | T 406= | 12.055 | T 407= | 11.542 | T 408= | 9.939  |
| T 409= | 11.438 | T 410= | 11.260 | T 411= | 11.165 | T 412= | 11.344 |
| T 413= | 10.075 | T 414= | 8.622  | T 415= | 8.664  | T 416= | 8.465  |
| T 417= | 7.615  | T 418= | 7.775  | T 501= | 4.190  | T 502= | 3.888  |
| T 503= | 3.620  | T 504= | 3.195  | T 505= | 15.904 | T 506= | 15.618 |
| T 507= | 15.370 | T 508= | 14.526 | T 509= | 15.540 | T 510= | 15.318 |
| T 511= | 15.195 | T 512= | 15.285 | T 513= | 14.240 | T 514= | 5.939  |
| T 515= | 5.684  | T 516= | 5.080  | T 517= | 4.288  | T 518= | 4.443  |

|   |       |        |   |       |        |   |       |        |   |       |        |
|---|-------|--------|---|-------|--------|---|-------|--------|---|-------|--------|
| T | 601=  | 1.381  | T | 602=  | 1.030  | T | 603=  | 0.969  | T | 604=  | 0.754  |
| T | 605=  | 19.596 | T | 606=  | 19.235 | T | 607=  | 19.254 | T | 608=  | 19.265 |
| T | 609=  | 19.791 | T | 610=  | 19.587 | T | 611=  | 19.386 | T | 612=  | 19.328 |
| T | 613=  | 18.549 | T | 614=  | 3.129  | T | 615=  | 2.510  | T | 616=  | 1.545  |
| T | 617=  | 0.868  | T | 618=  | 0.968  | T | 901=  | 0.432  | T | 902=  | 0.796  |
| T | 903=  | 0.832  | T | 904=  | 0.831  | T | 905=  | 0.769  | T | 906=  | 0.124  |
| T | 907=  | 0.562  | T | 908=  | 0.438  | T | 909=  | 0.437  | T | 910=  | 0.437  |
| T | 911=  | 0.437  | T | 912=  | 0.508  | T | 913=  | 0.000  | T | 921=  | 0.501  |
| T | 922=  | 0.474  | T | 923=  | 0.362  | T | 924=  | 0.501  | T | 925=  | 0.460  |
| T | 926=  | 0.362  | T | 1101= | 2.367  | T | 1102= | 2.385  | T | 1103= | 2.463  |
| T | 1104= | 2.544  | T | 1105= | 5.390  | T | 1106= | 5.409  | T | 1107= | 5.550  |
| T | 1108= | 5.629  | T | 1109= | 2.444  | T | 1110= | 2.462  | T | 1111= | 2.539  |
| T | 1112= | 2.620  | T | 1113= | 20.000 | T | 1114= | 20.000 | T | 1115= | 20.000 |
| T | 1116= | 20.000 | T | 1117= | 20.000 | T | 1118= | 20.000 | T | 1201= | 2.542  |
| T | 1202= | 2.561  | T | 1203= | 2.644  | T | 1204= | 2.724  | T | 1205= | 5.390  |
| T | 1206= | 5.409  | T | 1207= | 5.550  | T | 1208= | 5.629  | T | 1209= | 2.638  |
| T | 1210= | 2.657  | T | 1211= | 2.740  | T | 1212= | 2.820  | T | 1213= | 20.000 |
| T | 1214= | 20.000 | T | 1215= | 20.000 | T | 1216= | 20.000 | T | 1217= | 20.000 |
| T | 1218= | 20.000 | T | 1301= | 2.716  | T | 1302= | 2.736  | T | 1303= | 2.824  |
| T | 1304= | 2.904  | T | 1305= | 5.390  | T | 1306= | 5.409  | T | 1307= | 5.549  |
| T | 1308= | 5.629  | T | 1309= | 2.832  | T | 1310= | 2.853  | T | 1311= | 2.940  |
| T | 1312= | 3.020  | T | 1313= | 20.000 | T | 1314= | 20.000 | T | 1315= | 20.000 |
| T | 1316= | 20.000 | T | 1317= | 20.000 | T | 1318= | 20.000 | T | 1401= | 2.890  |
| T | 1402= | 2.912  | T | 1403= | 3.004  | T | 1404= | 3.083  | T | 1405= | 5.389  |
| T | 1406= | 5.410  | T | 1407= | 5.549  | T | 1408= | 5.628  | T | 1409= | 3.025  |
| T | 1410= | 3.048  | T | 1411= | 3.140  | T | 1412= | 3.220  | T | 1413= | 20.000 |
| T | 1414= | 20.000 | T | 1415= | 20.000 | T | 1416= | 20.000 | T | 1417= | 20.000 |
| T | 1418= | 20.000 | T | 1501= | 1.900  | T | 1502= | 1.900  | T | 1503= | 2.004  |
| T | 1504= | 2.221  | T | 1505= | 11.831 | T | 1506= | 11.788 | T | 1507= | 12.104 |
| T | 1508= | 12.278 | T | 1509= | 1.973  | T | 1510= | 1.969  | T | 1511= | 2.070  |
| T | 1512= | 2.272  | T | 1513= | 20.000 | T | 1514= | 20.000 | T | 1515= | 20.000 |
| T | 1516= | 20.000 | T | 1517= | 20.000 | T | 1518= | 20.000 | T | 1601= | 0.875  |
| T | 1602= | 0.858  | T | 1603= | 0.965  | T | 1604= | 1.298  | T | 1605= | 18.463 |
| T | 1606= | 18.325 | T | 1607= | 18.871 | T | 1608= | 19.277 | T | 1609= | 0.884  |
| T | 1610= | 0.858  | T | 1611= | 0.958  | T | 1612= | 1.260  | T | 1613= | 20.000 |
| T | 1614= | 20.000 | T | 1615= | 20.000 | T | 1616= | 20.000 | T | 1617= | 20.000 |
| T | 1618= | 20.000 | T |       |        |   |       |        |   |       |        |

ASCENDING NODE NUMBER : IMPRESSED Q

|   |      |       |   |      |       |   |      |       |   |      |       |
|---|------|-------|---|------|-------|---|------|-------|---|------|-------|
| Q | 1=   | 0.000 | Q | 2=   | 0.000 | Q | 3=   | 0.000 | Q | 4=   | 0.000 |
| Q | 5=   | 0.000 | Q | 6=   | 0.000 | Q | 7=   | 0.000 | Q | 8=   | 0.000 |
| Q | 9=   | 0.000 | Q | 10=  | 0.000 | Q | 11=  | 0.000 | Q | 12=  | 0.000 |
| Q | 13=  | 0.000 | Q | 14=  | 0.000 | Q | 15=  | 0.000 | Q | 16=  | 0.000 |
| Q | 17=  | 0.000 | Q | 18=  | 0.000 | Q | 19=  | 0.000 | Q | 20=  | 0.000 |
| Q | 21=  | 0.000 | Q | 22=  | 0.000 | Q | 23=  | 0.000 | Q | 24=  | 0.000 |
| Q | 25=  | 0.000 | Q | 26=  | 0.000 | Q | 27=  | 0.000 | Q | 28=  | 0.000 |
| Q | 29=  | 0.000 | Q | 30=  | 0.000 | Q | 31=  | 0.000 | Q | 32=  | 0.000 |
| Q | 33=  | 0.000 | Q | 34=  | 0.000 | Q | 35=  | 0.000 | Q | 36=  | 0.000 |
| Q | 37=  | 0.000 | Q | 38=  | 0.000 | Q | 39=  | 0.000 | Q | 40=  | 0.000 |
| Q | 41=  | 0.000 | Q | 42=  | 0.000 | Q | 101= | 0.000 | Q | 102= | 0.000 |
| Q | 103= | 0.000 | Q | 104= | 0.000 | Q | 105= | 0.000 | Q | 106= | 0.000 |
| Q | 107= | 0.000 | Q | 108= | 0.000 | Q | 109= | 0.000 | Q | 110= | 0.000 |
| Q | 111= | 0.000 | Q | 112= | 0.000 | Q | 113= | 0.000 | Q | 114= | 0.000 |
| Q | 115= | 0.000 | Q | 116= | 0.000 | Q | 117= | 0.000 | Q | 118= | 0.000 |
| Q | 201= | 0.000 | Q | 202= | 0.000 | Q | 203= | 0.000 | Q | 204= | 0.000 |
| Q | 205= | 0.000 | Q | 206= | 0.000 | Q | 207= | 0.000 | Q | 208= | 0.000 |
| Q | 209= | 0.000 | Q | 210= | 0.000 | Q | 211= | 0.000 | Q | 212= | 0.000 |
| Q | 213= | 0.000 | Q | 214= | 0.000 | Q | 215= | 0.000 | Q | 216= | 0.000 |
| Q | 217= | 0.000 | Q | 218= | 0.000 | Q | 301= | 0.000 | Q | 302= | 0.000 |
| Q | 303= | 0.000 | Q | 304= | 0.000 | Q | 305= | 0.000 | Q | 306= | 0.000 |
| Q | 307= | 0.000 | Q | 308= | 0.000 | Q | 309= | 0.000 | Q | 310= | 0.000 |

|         |       |         |       |         |       |         |       |
|---------|-------|---------|-------|---------|-------|---------|-------|
| Q 311=  | 0.000 | Q 312=  | 0.000 | Q 313=  | 0.000 | Q 314=  | 0.000 |
| Q 315=  | 0.000 | Q 316=  | 0.000 | Q 317=  | 0.000 | Q 318=  | 0.000 |
| Q 401=  | 0.003 | Q 402=  | 0.004 | Q 403=  | 0.001 | Q 404=  | 0.001 |
| Q 405=  | 0.000 | Q 406=  | 0.000 | Q 407=  | 0.000 | Q 408=  | 0.000 |
| Q 409=  | 0.000 | Q 410=  | 0.000 | Q 411=  | 0.000 | Q 412=  | 0.000 |
| Q 413=  | 0.000 | Q 414=  | 0.000 | Q 415=  | 0.000 | Q 416=  | 0.000 |
| Q 417=  | 0.000 | Q 418=  | 0.000 | Q 501=  | 0.000 | Q 502=  | 0.000 |
| Q 503=  | 0.000 | Q 504=  | 0.000 | Q 505=  | 0.000 | Q 506=  | 0.000 |
| Q 507=  | 0.000 | Q 508=  | 0.000 | Q 509=  | 0.000 | Q 510=  | 0.000 |
| Q 511=  | 0.000 | Q 512=  | 0.000 | Q 513=  | 0.000 | Q 514=  | 0.000 |
| Q 515=  | 0.000 | Q 516=  | 0.000 | Q 517=  | 0.000 | Q 518=  | 0.000 |
| Q 601=  | 0.058 | Q 602=  | 0.070 | Q 603=  | 0.026 | Q 604=  | 0.001 |
| Q 605=  | 0.000 | Q 606=  | 0.000 | Q 607=  | 0.000 | Q 608=  | 0.000 |
| Q 609=  | 0.000 | Q 610=  | 0.000 | Q 611=  | 0.000 | Q 612=  | 0.000 |
| Q 613=  | 0.000 | Q 614=  | 0.000 | Q 615=  | 0.000 | Q 616=  | 0.000 |
| Q 617=  | 0.000 | Q 618=  | 0.000 | Q 901=  | 0.000 | Q 902=  | 0.000 |
| Q 903=  | 0.000 | Q 904=  | 0.000 | Q 905=  | 0.000 | Q 906=  | 0.000 |
| Q 907=  | 0.000 | Q 908=  | 0.000 | Q 909=  | 0.000 | Q 910=  | 0.000 |
| Q 911=  | 0.000 | Q 912=  | 0.000 | Q 913=  | 0.000 | Q 921=  | 0.000 |
| Q 922=  | 0.000 | Q 923=  | 0.000 | Q 924=  | 0.000 | Q 925=  | 0.000 |
| Q 926=  | 0.000 | Q 1101= | 0.000 | Q 1102= | 0.000 | Q 1103= | 0.000 |
| Q 1104= | 0.000 | Q 1105= | 0.000 | Q 1106= | 0.000 | Q 1107= | 0.000 |
| Q 1108= | 0.000 | Q 1109= | 0.000 | Q 1110= | 0.000 | Q 1111= | 0.000 |
| Q 1112= | 0.000 | Q 1113= | 0.000 | Q 1114= | 0.000 | Q 1115= | 0.000 |
| Q 1116= | 0.000 | Q 1117= | 0.000 | Q 1118= | 0.000 | Q 1201= | 0.000 |
| Q 1202= | 0.000 | Q 1203= | 0.000 | Q 1204= | 0.000 | Q 1205= | 0.000 |
| Q 1206= | 0.000 | Q 1207= | 0.000 | Q 1208= | 0.000 | Q 1209= | 0.000 |
| Q 1210= | 0.000 | Q 1211= | 0.000 | Q 1212= | 0.000 | Q 1213= | 0.000 |
| Q 1214= | 0.000 | Q 1215= | 0.000 | Q 1216= | 0.000 | Q 1217= | 0.000 |
| Q 1218= | 0.000 | Q 1301= | 0.000 | Q 1302= | 0.000 | Q 1303= | 0.000 |
| Q 1304= | 0.000 | Q 1305= | 0.000 | Q 1306= | 0.000 | Q 1307= | 0.000 |
| Q 1308= | 0.000 | Q 1309= | 0.000 | Q 1310= | 0.000 | Q 1311= | 0.000 |
| Q 1312= | 0.000 | Q 1313= | 0.000 | Q 1314= | 0.000 | Q 1315= | 0.000 |
| Q 1316= | 0.000 | Q 1317= | 0.000 | Q 1318= | 0.000 | Q 1401= | 0.000 |
| Q 1402= | 0.000 | Q 1403= | 0.000 | Q 1404= | 0.000 | Q 1405= | 0.000 |
| Q 1406= | 0.000 | Q 1407= | 0.000 | Q 1408= | 0.000 | Q 1409= | 0.000 |
| Q 1410= | 0.000 | Q 1411= | 0.000 | Q 1412= | 0.000 | Q 1413= | 0.000 |
| Q 1414= | 0.000 | Q 1415= | 0.000 | Q 1416= | 0.000 | Q 1417= | 0.000 |
| Q 1418= | 0.000 | Q 1501= | 0.000 | Q 1502= | 0.000 | Q 1503= | 0.000 |
| Q 1504= | 0.000 | Q 1505= | 0.000 | Q 1506= | 0.000 | Q 1507= | 0.000 |
| Q 1508= | 0.000 | Q 1509= | 0.000 | Q 1510= | 0.000 | Q 1511= | 0.000 |
| Q 1512= | 0.000 | Q 1513= | 0.000 | Q 1514= | 0.000 | Q 1515= | 0.000 |
| Q 1516= | 0.000 | Q 1517= | 0.000 | Q 1518= | 0.000 | Q 1601= | 0.000 |
| Q 1602= | 0.000 | Q 1603= | 0.000 | Q 1604= | 0.000 | Q 1605= | 0.000 |
| Q 1606= | 0.000 | Q 1607= | 0.000 | Q 1608= | 0.000 | Q 1609= | 0.000 |
| Q 1610= | 0.000 | Q 1611= | 0.000 | Q 1612= | 0.000 | Q 1613= | 0.000 |
| Q 1614= | 0.000 | Q 1615= | 0.000 | Q 1616= | 0.000 | Q 1617= | 0.000 |
| Q 1618= | 0.000 |         |       |         |       |         |       |

\*\*\*\*\*  
THERMAL CALC CPU TIME (second) = 98.8100  
\*\*\*\*\*

# APPENDIX I ITAS OUTPUT FOR HOT-CASE

\*\*\*\*\*  
Date: 05/20/94 Time: 15:04:24.10  
\*\*\*\*\*

## Thermal Analysis Parameters

```
=====
1. Solution Method:1.Steady-State 2.Transient 3. (1&2)..... 1
2. Solution Time Step .....(minutes)..... 0.10
3. Final Time (minutes);if <0 then no of orbs..... -1.00
4. Starting Temperature .....(Kelvin )..... 300.00
5. Temperature Print Interval (minutes)..... 20
6. No. of Iterations For Convergence (NLOOP)..... 9999
7. Temperature Unit 1:K, 2:C, 3:F, 4:R..... 2
8. Solution Accuracy Parameter (not used)..... 130
9. Solution Convergence Parameter (not used)..... 1.30
10. Solution Tolerance (ARLXCA, DRLXCA)..... 0.00100
11. Transient Solution Stability Factor (not used)..... 0.850
12. Include user-Defined Network.....(Y/N)..... Y
13. Print RADK, POWER.....(Y/N)..... N
14. Print Transient Time/Temperature...(Y/N)..... N
15. Starting Temperatures Forced (No.4)(Y/N)..... N
16. Thermal Analyses Without Orbital Loads (Y/N)..... Y
17. Stand-Alone Thermal Analyzer (ITAS-Format Models)..... N
18. No. of Isolated Cavities (RADK files)..... 0
=====
```

## \*ITAS THERMAL ANALYSIS\*

\*\*\*\*\*  
Date: 05/20/94 Time: 15:04:24.10  
\*\*\*\*\*

## View Factor Computation Parameters

```
=====
1. View Factor Accuracy Parameter.....2
2. Engineering Units of the Geometry Data:
   1:inch, 2:feet, 3:centimeter, 4:meter.....1
3. View Factor Computation Without Blockage (Y/N).....N
4. Print Control Parameters:
   0:Do Not Print; 1:Print All; 2:Print All & Intervener List.0
5. View-Factor Re-Start File.....
=====
```

## \*ITAS VIEW FACTOR COMPUTATIONS\*

\*\*\*\*\*  
INPUT IS IN INCHES  
OUTPUT IS IN CENTIMETERS  
TOTAL SURFACES IN THIS MODEL= 42

UNITY MINUS THE SUM OF THE FACTORS  
(VIEW FACTOR -to- SPACE)

SURFACE 1.-FACT KEY

ACTIVE SURFACES IN OUTPUT- 42

VIEW FACTOR CALC CPU TIME (second) = 33.4500

\*\* END OF PC-ITAS VIEW FACTOR CALCULATIONS \*\*

Date: 05/20/94 Time: 15:04:58.10

.....

[illegible]

84

```

6. SINDA-format RADK file to be generated (Y/N)..... N
7. SINDA Radiation Conductor Number At Start..... 100000
8. Print control: 0:No,do not print, 1:Yes, print all..... 0
9. File name to store RADKS.....EPS.RAD
=====

```

```

=====
Seq      Surface No      Node No      Alpha      Emiss      T/Mass      Dissip      Matr ID
=====
1         1.01         1         0.40         0.80         1.00         0.00         0
2         1.02         2         0.40         0.80         1.00         0.00         0
3         1.03         3         0.40         0.80         1.00         0.00         0
4         1.04         4         0.40         0.80         1.00         0.00         0
5         1.05         5         0.40         0.80         1.00         0.00         0
6         1.06         6         0.40         0.80         1.00         0.00         0
7         1.07         7         0.40         0.80         1.00         0.00         0
8         1.08         8         0.40         0.80         1.00         0.00         0
9         1.09         9         0.40         0.80         1.00         0.00         0
10        1.10        10        0.40         0.80         1.00         0.00         0
11        1.11        11        0.40         0.80         1.00         0.00         0
12        1.12        12        0.40         0.80         1.00         0.00         0
13        2.01        13        0.00         0.01         1.00         0.00         0
14        2.02        14        0.00         0.01         1.00         0.00         0
15        2.03        15        0.00         0.01         1.00         0.00         0
16        2.04        16        0.00         0.01         1.00         0.00         0
17        2.05        17        0.00         0.01         1.00         0.00         0
18        2.06        18        0.00         0.01         1.00         0.00         0
19        2.07        19        0.00         0.01         1.00         0.00         0
20        2.08        20        0.00         0.01         1.00         0.00         0
21        2.09        21        0.00         0.01         1.00         0.00         0
22        2.10        22        0.00         0.01         1.00         0.00         0
23        3.01        23        0.00         0.01         1.00         0.00         0
24        3.02        24        0.00         0.01         1.00         0.00         0
25        3.03        25        0.00         0.01         1.00         0.00         0
26        3.04        26        0.00         0.01         1.00         0.00         0
27        3.05        27        0.00         0.01         1.00         0.00         0
28        3.06        28        0.00         0.01         1.00         0.00         0
29        3.07        29        0.00         0.01         1.00         0.00         0
30        3.08        30        0.00         0.01         1.00         0.00         0
31        4.01        31        0.00         0.01         1.00         0.00         0
32        4.02        32        0.00         0.01         1.00         0.00         0
33        4.03        33        0.00         0.01         1.00         0.00         0
34        4.04        34        0.00         0.01         1.00         0.00         0
35        4.05        35        0.00         0.01         1.00         0.00         0
36        4.06        36        0.00         0.01         1.00         0.00         0
37        4.07        37        0.00         0.01         1.00         0.00         0
38        4.08        38        0.00         0.01         1.00         0.00         0
39        4.09        39        0.00         0.01         1.00         0.00         0
40        4.10        40        0.00         0.01         1.00         0.00         0
41        4.11        41        0.00         0.01         1.00         0.00         0
42        4.12        42        0.00         0.01         1.00         0.00         0
=====

```

\*\*\*\*\*ITAS SCRIPT-F (RADK) COMPUTATIONS\*\*\*\*\*

PC-ITAS SCRIPT-F CALCULATION SEGMENT:

Writing ITAS-format RADK for future use

| Node# | Temp., | TherMass, | Power            |
|-------|--------|-----------|------------------|
| 1     | 10.00  | 1.00      | 0.00 EPS HOUSING |
| 2     | 10.00  | 1.00      | 0.00 EPS HOUSING |

|     |       |                  |                     |
|-----|-------|------------------|---------------------|
| 3   | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 4   | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 5   | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 6   | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 7   | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 8   | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 9   | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 10  | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 11  | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 12  | 10.00 | 1.00             | 0.00 EPS HOUSING    |
| 13  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 14  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 15  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 16  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 17  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 18  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 19  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 20  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 21  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 22  | 10.00 | 1.00             | 0.00 PCB 1-1        |
| 23  | 10.00 | 1.00             | 0.00 PCB 1-2        |
| 24  | 10.00 | 1.00             | 0.00 PCB 1-2        |
| 25  | 10.00 | 1.00             | 0.00 PCB 1-2        |
| 26  | 10.00 | 1.00             | 0.00 PCB 1-2        |
| 27  | 10.00 | 1.00             | 0.00 PCB 1-2        |
| 28  | 10.00 | 1.00             | 0.00 PCB 1-2        |
| 29  | 10.00 | 1.00             | 0.00 PCB 1-2        |
| 30  | 10.00 | 1.00             | 0.00 PCB 1-2        |
| 31  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 32  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 33  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 34  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 35  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 36  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 37  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 38  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 39  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 40  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 41  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| 42  | 10.00 | 1.00             | 0.00 PCB 2 (BOTTOM) |
| RAD | 00    | 0.1295000000E+01 | 1 4                 |
| RAD | 00    | 0.3408000000E+01 | 1 5                 |
| RAD | 00    | 0.1231900000E+02 | 1 6                 |
| RAD | 00    | 0.1441000000E+01 | 1 7                 |
| RAD | 00    | 0.1166000000E+01 | 1 10                |
| RAD | 00    | 0.3754000000E+01 | 1 11                |
| RAD | 00    | 0.9037000000E+01 | 1 12                |
| RAD | 00    | 0.5500000000E+00 | 2 3                 |
| RAD | 00    | 0.3313000000E+01 | 2 6                 |
| RAD | 00    | 0.3342000000E+01 | 2 7                 |
| RAD | 00    | 0.2634000000E+01 | 2 12                |
| RAD | 00    | 0.9950000000E+00 | 3 4                 |
| RAD | 00    | 0.3602000000E+01 | 3 6                 |
| RAD | 00    | 0.9060000000E+00 | 3 7                 |
| RAD | 00    | 0.2767000000E+01 | 3 12                |
| RAD | 00    | 0.7580000000E+00 | 4 5                 |
| RAD | 00    | 0.3602000000E+01 | 4 6                 |
| KAD | 00    | 0.2770000000E+01 | 4 12                |
| KAD | 00    | 0.3314000000E+01 | 5 6                 |
| KAD | 00    | 0.2622000000E+01 | 5 12                |

```

#OF RADIATION CONDUCTANCES GENERATED= 38
*****
SCRIPT-F CALC CPU TIME (second) = 2.64000
*****

```

vvvvvvvvvvvvvvvvvvvvvvvvv' ADDING USER NODES vvvvvvvvvvvvv

87

|        |       |    |     |    |      |                               |
|--------|-------|----|-----|----|------|-------------------------------|
| RECORD | 5056= | 35 | 616 | 20 | .009 |                               |
| RECORD | 5057= | 36 | 617 | 20 | .004 |                               |
| RECORD | 5058= | 37 | 618 | 20 | 0    |                               |
| RECORD | 5059= | 38 | 501 | 20 | 0    | 5TH LAYER POLYIMIDE           |
| RECORD | 5060= | 39 | 502 | 20 | 0    |                               |
| RECORD | 5061= | 40 | 503 | 20 | 0    |                               |
| RECORD | 5062= | 41 | 504 | 20 | 0    |                               |
| RECORD | 5063= | 42 | 505 | 20 | 0    |                               |
| RECORD | 5064= | 43 | 506 | 20 | 0    |                               |
| RECORD | 5065= | 44 | 507 | 20 | 0    |                               |
| RECORD | 5066= | 45 | 508 | 20 | 0    |                               |
| RECORD | 5067= | 46 | 509 | 20 | 0    |                               |
| RECORD | 5068= | 47 | 510 | 20 | 0    |                               |
| RECORD | 5069= | 48 | 511 | 20 | 0    |                               |
| RECORD | 5070= | 49 | 512 | 20 | 0    |                               |
| RECORD | 5071= | 50 | 513 | 20 | 0    |                               |
| RECORD | 5072= | 51 | 514 | 20 | 0    |                               |
| RECORD | 5073= | 52 | 515 | 20 | 0    |                               |
| RECORD | 5074= | 53 | 516 | 20 | 0    |                               |
| RECORD | 5075= | 54 | 517 | 20 | 0    |                               |
| RECORD | 5076= | 55 | 518 | 20 |      |                               |
| RECORD | 5077= | 56 | 401 | 20 | .003 | GROUND LAYER COPPER           |
| RECORD | 5078= | 57 | 402 | 20 | .004 |                               |
| RECORD | 5079= | 58 | 403 | 20 | .001 |                               |
| RECORD | 5080= | 59 | 404 | 20 | .001 |                               |
| RECORD | 5081= | 60 | 405 | 20 | 0    |                               |
| RECORD | 5082= | 61 | 406 | 20 | 0    |                               |
| RECORD | 5083= | 62 | 407 | 20 | 0    |                               |
| RECORD | 5084= | 63 | 408 | 20 | 0    |                               |
| RECORD | 5085= | 64 | 409 | 20 | 0    |                               |
| RECORD | 5086= | 65 | 410 | 20 | 0    |                               |
| RECORD | 5087= | 66 | 411 | 20 | 0    |                               |
| RECORD | 5088= | 67 | 412 | 20 | 0    |                               |
| RECORD | 5089= | 68 | 413 | 20 | 0    |                               |
| RECORD | 5090= | 69 | 414 | 20 | 0    |                               |
| RECORD | 5091= | 70 | 415 | 20 | 0    |                               |
| RECORD | 5092= | 71 | 416 | 20 | 0    |                               |
| RECORD | 5093= | 72 | 417 | 20 | 0    |                               |
| RECORD | 5094= | 73 | 418 | 20 | 0    |                               |
| RECORD | 5095= | 74 | 301 | 20 | 0    | 3RD LAYER POLYIMIDE           |
| RECORD | 5096= | 75 | 302 | 20 | 0    |                               |
| RECORD | 5097= | 76 | 303 | 20 | 0    |                               |
| RECORD | 5098= | 77 | 304 | 20 | 0    |                               |
| RECORD | 5099= | 78 | 305 | 20 | 0    |                               |
| RECORD | 5100= | 79 | 306 | 20 | 0    |                               |
| RECORD | 5101= | 80 | 307 | 20 | 0    |                               |
| RECORD | 5102= | 81 | 308 | 20 | 0    |                               |
| RECORD | 5103= | 82 | 309 | 20 | 0    |                               |
| RECORD | 5104= | 83 | 310 | 20 | 0    |                               |
| RECORD | 5105= | 84 | 311 | 20 | 0    |                               |
| RECORD | 5106= | 85 | 312 | 20 | 0    |                               |
| RECORD | 5107= | 86 | 313 | 20 | 0    |                               |
| RECORD | 5108= | 87 | 314 | 20 | 0    |                               |
| RECORD | 5109= | 88 | 315 | 20 | 0    |                               |
| RECORD | 5110= | 89 | 316 | 20 | 0    |                               |
| RECORD | 5111= | 90 | 317 | 20 | 0    |                               |
| RECORD | 5112= | 91 | 318 | 20 | 0    |                               |
| RECORD | 5113= | 92 | 201 | 20 | 0    | SIGNAL LEVEL (VERY LITTLE CU) |
| RECORD | 5114= | 93 | 202 | 20 | 0    |                               |
| RECORD | 5115= | 94 | 203 | 20 | 0    |                               |

|        |       |     |      |    |      |                                 |
|--------|-------|-----|------|----|------|---------------------------------|
| RECORD | 5116= | 95  | 204  | 20 | 0    |                                 |
| RECORD | 5117= | 96  | 205  | 20 | 0    |                                 |
| RECORD | 5118= | 97  | 206  | 20 | 0    |                                 |
| RECORD | 5119= | 98  | 207  | 20 | 0    |                                 |
| RECORD | 5120= | 99  | 208  | 20 | 0    |                                 |
| RECORD | 5121= | 100 | 209  | 20 | 0    |                                 |
| RECORD | 5122= | 101 | 210  | 20 | 0    |                                 |
| RECORD | 5123= | 102 | 211  | 20 | 0    |                                 |
| RECORD | 5124= | 103 | 212  | 20 | 0    |                                 |
| RECORD | 5125= | 104 | 213  | 20 | 0    |                                 |
| RECORD | 5126= | 105 | 214  | 20 | 0    |                                 |
| RECORD | 5127= | 106 | 215  | 20 | 0    |                                 |
| RECORD | 5128= | 107 | 216  | 20 | 0    |                                 |
| RECORD | 5129= | 108 | 217  | 20 | 0    |                                 |
| RECORD | 5130= | 109 | 218  | 20 | 0    |                                 |
| RECORD | 5131= | 110 | 101  | 20 | 0    | TOP LAYER POLYIMIDE             |
| RECORD | 5132= | 111 | 102  | 20 | 0    |                                 |
| RECORD | 5133= | 112 | 103  | 20 | 0    |                                 |
| RECORD | 5134= | 113 | 104  | 20 | 0    |                                 |
| RECORD | 5135= | 114 | 105  | 20 | 0    |                                 |
| RECORD | 5136= | 115 | 106  | 20 | 0    |                                 |
| RECORD | 5137= | 116 | 107  | 20 | 0    |                                 |
| RECORD | 5138= | 117 | 108  | 20 | 0    |                                 |
| RECORD | 5139= | 118 | 109  | 20 | 0    |                                 |
| RECORD | 5140= | 119 | 110  | 20 | 0    |                                 |
| RECORD | 5141= | 120 | 111  | 20 | 0    |                                 |
| RECORD | 5142= | 121 | 112  | 20 | 0    |                                 |
| RECORD | 5143= | 122 | 113  | 20 | 0    |                                 |
| RECORD | 5144= | 123 | 114  | 20 | 0    |                                 |
| RECORD | 5145= | 124 | 115  | 20 | 0    |                                 |
| RECORD | 5146= | 125 | 116  | 20 | 0    |                                 |
| RECORD | 5147= | 126 | 117  | 20 | 0    |                                 |
| RECORD | 5148= | 127 | 118  | 20 | 0    |                                 |
| RECORD | 5149= | 128 | 1601 | 20 | .113 | BOTTOM PCB THERMAL PLANE COPPER |
| RECORD | 5150= | 129 | 1602 | 20 | .086 |                                 |
| RECORD | 5151= | 130 | 1603 | 20 | .025 |                                 |
| RECORD | 5152= | 131 | 1604 | 20 | 0    |                                 |
| RECORD | 5153= | 132 | 1605 | 20 | 0    |                                 |
| RECORD | 5154= | 133 | 1606 | 20 | .175 |                                 |
| RECORD | 5155= | 134 | 1607 | 20 | 0    |                                 |
| RECORD | 5156= | 135 | 1608 | 20 | 0    |                                 |
| RECORD | 5157= | 136 | 1609 | 20 | .375 |                                 |
| RECORD | 5158= | 137 | 1610 | 20 | .105 |                                 |
| RECORD | 5159= | 138 | 1611 | 20 | .15  |                                 |
| RECORD | 5160= | 139 | 1612 | 20 | 0    |                                 |
| RECORD | 5161= | 140 | 1613 | 20 | 0    |                                 |
| RECORD | 5162= | 141 | 1614 | 20 | 0    |                                 |
| RECORD | 5163= | 142 | 1615 | 20 | 0    |                                 |
| RECORD | 5164= | 143 | 1616 | 20 | 0    |                                 |
| RECORD | 5165= | 144 | 1617 | 20 | 0    |                                 |
| RECORD | 5166= | 145 | 1618 | 20 | 0    |                                 |
| RECORD | 5167= | 146 | 1501 | 20 | 0    | 5TH LAYER POLYIMIDE             |
| RECORD | 5168= | 147 | 1502 | 20 | 0    |                                 |
| RECORD | 5169= | 148 | 1503 | 20 | 0    |                                 |
| RECORD | 5170= | 149 | 1504 | 20 | 0    |                                 |
| RECORD | 5171= | 150 | 1505 | 20 | 0    |                                 |
| RECORD | 5172= | 151 | 1506 | 20 | 0    |                                 |
| RECORD | 5173= | 152 | 1507 | 20 | 0    |                                 |
| RECORD | 5174= | 153 | 1508 | 20 | 0    |                                 |
| RECORD | 5175= | 154 | 1509 | 20 | 0    |                                 |

|        |       |     |      |    |   |                     |
|--------|-------|-----|------|----|---|---------------------|
| RECORD | 5176= | 155 | 1510 | 20 | 0 |                     |
| RECORD | 5177= | 156 | 1511 | 20 | 0 |                     |
| RECORD | 5178= | 157 | 1512 | 20 | 0 |                     |
| RECORD | 5179= | 158 | 1513 | 20 | 0 |                     |
| RECORD | 5180= | 159 | 1514 | 20 | 0 |                     |
| RECORD | 5181= | 160 | 1515 | 20 | 0 |                     |
| RECORD | 5182= | 161 | 1516 | 20 | 0 |                     |
| RECORD | 5183= | 162 | 1517 | 20 | 0 |                     |
| RECORD | 5184= | 163 | 1518 | 20 | 0 |                     |
| RECORD | 5185= | 164 | 1401 | 20 | 0 | GROUND LAYER COPPER |
| RECORD | 5186= | 165 | 1402 | 20 | 0 |                     |
| RECORD | 5187= | 166 | 1403 | 20 | 0 |                     |
| RECORD | 5188= | 167 | 1404 | 20 | 0 |                     |
| RECORD | 5189= | 168 | 1405 | 20 | 0 |                     |
| RECORD | 5190= | 169 | 1406 | 20 | 0 |                     |
| RECORD | 5191= | 170 | 1407 | 20 | 0 |                     |
| RECORD | 5192= | 171 | 1408 | 20 | 0 |                     |
| RECORD | 5193= | 172 | 1409 | 20 | 0 |                     |
| RECORD | 5194= | 173 | 1410 | 20 | 0 |                     |
| RECORD | 5195= | 174 | 1411 | 20 | 0 |                     |
| RECORD | 5196= | 175 | 1412 | 20 | 0 |                     |
| RECORD | 5197= | 176 | 1413 | 20 | 0 |                     |
| RECORD | 5198= | 177 | 1414 | 20 | 0 |                     |
| RECORD | 5199= | 178 | 1415 | 20 | 0 |                     |
| RECORD | 5200= | 179 | 1416 | 20 | 0 |                     |
| RECORD | 5201= | 180 | 1417 | 20 | 0 |                     |
| RECORD | 5202= | 181 | 1418 | 20 | 0 |                     |
| RECORD | 5203= | 182 | 1301 | 20 | 0 | 3RD LAYER POLYIMIDE |
| RECORD | 5204= | 183 | 1302 | 20 | 0 |                     |
| RECORD | 5205= | 184 | 1303 | 20 | 0 |                     |
| RECORD | 5206= | 185 | 1304 | 20 | 0 |                     |
| RECORD | 5207= | 186 | 1305 | 20 | 0 |                     |
| RECORD | 5208= | 187 | 1306 | 20 | 0 |                     |
| RECORD | 5209= | 188 | 1307 | 20 | 0 |                     |
| RECORD | 5210= | 189 | 1308 | 20 | 0 |                     |
| RECORD | 5211= | 190 | 1309 | 20 | 0 |                     |
| RECORD | 5212= | 191 | 1310 | 20 | 0 |                     |
| RECORD | 5213= | 192 | 1311 | 20 | 0 |                     |
| RECORD | 5214= | 193 | 1312 | 20 | 0 |                     |
| RECORD | 5215= | 194 | 1313 | 20 | 0 |                     |
| RECORD | 5216= | 195 | 1314 | 20 | 0 |                     |
| RECORD | 5217= | 196 | 1315 | 20 | 0 |                     |
| RECORD | 5218= | 197 | 1316 | 20 | 0 |                     |
| RECORD | 5219= | 198 | 1317 | 20 | 0 |                     |
| RECORD | 5220= | 199 | 1318 | 20 | 0 |                     |
| RECORD | 5221= | 200 | 1201 | 20 | 0 | SIGNAL LAYER COPPER |
| RECORD | 5222= | 201 | 1202 | 20 | 0 |                     |
| RECORD | 5223= | 202 | 1203 | 20 | 0 |                     |
| RECORD | 5224= | 203 | 1204 | 20 | 0 |                     |
| RECORD | 5225= | 204 | 1205 | 20 | 0 |                     |
| RECORD | 5226= | 205 | 1206 | 20 | 0 |                     |
| RECORD | 5227= | 206 | 1207 | 20 | 0 |                     |
| RECORD | 5228= | 207 | 1208 | 20 | 0 |                     |
| RECORD | 5229= | 208 | 1209 | 20 | 0 |                     |
| RECORD | 5230= | 209 | 1210 | 20 | 0 |                     |
| RECORD | 5231= | 210 | 1211 | 20 | 0 |                     |
| RECORD | 5232= | 211 | 1212 | 20 | 0 |                     |
| RECORD | 5233= | 212 | 1213 | 20 | 0 |                     |
| RECORD | 5234= | 213 | 1214 | 20 | 0 |                     |
| RECORD | 5235= | 214 | 1215 | 20 | 0 |                     |

|        |       |     |      |    |   |                     |
|--------|-------|-----|------|----|---|---------------------|
| RECORD | 5236= | 215 | 1216 | 20 | 0 |                     |
| RECORD | 5237= | 216 | 1217 | 20 | 0 |                     |
| RECORD | 5238= | 217 | 1218 | 20 | 0 |                     |
| RECORD | 5239= | 218 | 1101 | 20 | 0 | TOP LAYER POLYIMIDE |
| RECORD | 5240= | 219 | 1102 | 20 | 0 |                     |
| RECORD | 5241= | 220 | 1103 | 20 | 0 |                     |
| RECORD | 5242= | 221 | 1104 | 20 | 0 |                     |
| RECORD | 5243= | 222 | 1105 | 20 | 0 |                     |
| RECORD | 5244= | 223 | 1106 | 20 | 0 |                     |
| RECORD | 5245= | 224 | 1107 | 20 | 0 |                     |
| RECORD | 5246= | 225 | 1108 | 20 | 0 |                     |
| RECORD | 5247= | 226 | 1109 | 20 | 0 |                     |
| RECORD | 5248= | 227 | 1110 | 20 | 0 |                     |
| RECORD | 5249= | 228 | 1111 | 20 | 0 |                     |
| RECORD | 5250= | 229 | 1112 | 20 | 0 |                     |
| RECORD | 5251= | 230 | 1113 | 20 | 0 |                     |
| RECORD | 5252= | 231 | 1114 | 20 | 0 |                     |
| RECORD | 5253= | 232 | 1115 | 20 | 0 |                     |
| RECORD | 5254= | 233 | 1116 | 20 | 0 |                     |
| RECORD | 5255= | 234 | 1117 | 20 | 0 |                     |
| RECORD | 5256= | 235 | 1118 | 20 | 0 |                     |

~~~~~ END OF USER NODES ~~~~~

~~~~~ END OF FLUID ~~~~~

TOTAL THERMAL MASS ENCOUNTERED (W-MIN/C)= 1329.04

TOTAL THERMAL MASS ENCOUNTERED (BTU /F)= 42.0002

~~~~~ END OF FLUID ~~~~~

| | | | | |
|------|----|-----------|----|--------------------------------------|
| NODE | 1 | (REL NODE | 1 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 2 | (REL NODE | 2 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 3 | (REL NODE | 3 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 4 | (REL NODE | 4 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 5 | (REL NODE | 5 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 6 | (REL NODE | 6 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 7 | (REL NODE | 7 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 8 | (REL NODE | 8 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 9 | (REL NODE | 9 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 10 | (REL NODE | 10 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 11 | (REL NODE | 11 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 12 | (REL NODE | 12 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 13 | (REL NODE | 13 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 14 | (REL NODE | 14 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 15 | (REL NODE | 15 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 16 | (REL NODE | 16 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 17 | (REL NODE | 17 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 18 | (REL NODE | 18 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 19 | (REL NODE | 19 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 20 | (REL NODE | 20 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 21 | (REL NODE | 21 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 22 | (REL NODE | 22 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 23 | (REL NODE | 23 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 24 | (REL NODE | 24 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 25 | (REL NODE | 25 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 26 | (REL NODE | 26 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 27 | (REL NODE | 27 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 28 | (REL NODE | 28 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 29 | (REL NODE | 29 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 30 | (REL NODE | 30 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 31 | (REL NODE | 31 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 32 | (REL NODE | 32 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 33 | (REL NODE | 33 |) IS BEING ADDED TO THE CURRENT LIST |
| NODE | 34 | (REL NODE | 34 |) IS BEING ADDED TO THE CURRENT LIST |

NODE 35 (REL NODE 35) IS BEING ADDED TO THE CURRENT LIST
 NODE 36 (REL NODE 36) IS BEING ADDED TO THE CURRENT LIST
 NODE 37 (REL NODE 37) IS BEING ADDED TO THE CURRENT LIST
 NODE 38 (REL NODE 38) IS BEING ADDED TO THE CURRENT LIST
 NODE 39 (REL NODE 39) IS BEING ADDED TO THE CURRENT LIST
 NODE 40 (REL NODE 40) IS BEING ADDED TO THE CURRENT LIST
 NODE 41 (REL NODE 41) IS BEING ADDED TO THE CURRENT LIST
 NODE 42 (REL NODE 42) IS BEING ADDED TO THE CURRENT LIST
 END OF RADIATION CONDUCTANCE & POWER PROCESSING
 ITAS THERMAL ANALYSIS:

CHECKOUT PHASE OF PC-ITAS THERMAL ANALYSIS

TOTAL CARDS ENCOUNTERED: 1776
 TOTAL THERMAL MASSES USED (W-Min/C)= 1366.04
 TOTAL THERMAL MASSES USED (BTU/F)= 43.1695

=====

NO. OF THERMAL NODES= 277

ITAS STEADY-STATE SOLUTION ALGORITHM (SUCCESSIVE POINT ITERATION) PARAMETERS:
 ARLXCA=0.10000E-02, DRLXCA=0.10000E-02 NLOOP= 9999

ITAS STEADY-STATE SOLUTION (SUCCESSIVE POINT ITERATION)
 NO. OF ITERATIONS= 2805 TOTAL INPUT ENERGY (W)= 1.2830
 SYSTEM ENERGY BALANCE (W)= 7.1385 (556.39 %)

| | | | | | | | |
|--------|-------|--------|-------|--------|-------|--------|-------|
| T 1= | 39.68 | T 2= | 39.43 | T 3= | 39.39 | T 4= | 39.40 |
| T 5= | 39.46 | T 6= | 39.91 | T 7= | 39.61 | T 8= | 39.68 |
| T 9= | 39.68 | T 10= | 39.68 | T 11= | 39.68 | T 12= | 39.64 |
| T 13= | 20.18 | T 14= | 20.43 | T 15= | 20.66 | T 16= | 20.73 |
| T 17= | 21.65 | T 18= | 37.01 | T 19= | 38.08 | T 20= | 38.64 |
| T 21= | 39.26 | T 22= | 39.17 | T 23= | 39.02 | T 24= | 39.28 |
| T 25= | 39.27 | T 26= | 39.43 | T 27= | 20.59 | T 28= | 21.00 |
| T 29= | 20.89 | T 30= | 20.74 | T 31= | 39.39 | T 32= | 39.42 |
| T 33= | 39.28 | T 34= | 38.92 | T 35= | 21.45 | T 36= | 22.58 |
| T 37= | 21.48 | T 38= | 20.84 | T 39= | 39.71 | T 40= | 39.43 |
| T 41= | 39.44 | T 42= | 38.89 | T 901= | 39.68 | T 902= | 39.43 |
| T 903= | 39.39 | T 904= | 39.40 | T 905= | 39.46 | T 906= | 39.91 |
| T 907= | 39.61 | T 908= | 39.68 | T 909= | 39.68 | T 910= | 39.68 |
| T 911= | 39.68 | T 912= | 39.64 | T 913= | 40.00 | T 921= | 39.65 |
| T 922= | 39.65 | T 923= | 39.74 | T 924= | 39.54 | T 925= | 39.67 |
| T 926= | 39.74 | T 601= | 39.02 | T 602= | 39.28 | T 603= | 39.27 |
| T 604= | 39.43 | T 605= | 20.59 | T 606= | 21.00 | T 607= | 20.89 |
| T 608= | 20.74 | T 609= | 20.18 | T 610= | 20.43 | T 611= | 20.66 |
| T 612= | 20.73 | T 613= | 21.65 | T 614= | 37.01 | T 615= | 38.08 |
| T 616= | 38.64 | T 617= | 39.26 | T 618= | 39.17 | T 501= | 36.53 |
| T 502= | 36.72 | T 503= | 36.78 | T 504= | 37.12 | T 505= | 24.43 |
| T 506= | 24.72 | T 507= | 24.88 | T 508= | 25.64 | T 509= | 24.60 |
| T 510= | 24.85 | T 511= | 24.98 | T 512= | 24.88 | T 513= | 25.99 |
| T 514= | 34.27 | T 515= | 34.75 | T 516= | 35.15 | T 517= | 35.89 |
| T 518= | 35.74 | T 401= | 34.13 | T 402= | 34.21 | T 403= | 34.35 |
| T 404= | 34.85 | T 405= | 28.19 | T 406= | 28.39 | T 407= | 28.81 |
| T 408= | 30.38 | T 409= | 28.86 | T 410= | 29.04 | T 411= | 29.13 |
| T 412= | 28.93 | T 413= | 30.18 | T 414= | 31.66 | T 415= | 31.63 |
| T 416= | 31.80 | T 417= | 32.62 | T 418= | 32.45 | T 301= | 34.64 |
| T 302= | 34.73 | T 303= | 34.85 | T 304= | 35.41 | T 305= | 28.19 |
| T 306= | 28.39 | T 307= | 28.81 | T 308= | 30.38 | T 309= | 28.86 |
| T 310= | 29.04 | T 311= | 29.13 | T 312= | 28.93 | T 313= | 30.18 |
| T 314= | 32.73 | T 315= | 32.76 | T 316= | 32.83 | T 317= | 33.56 |

| | | | | | | | |
|---------|-------|---------|-------|---------|-------|---------|-------|
| T 318= | 33.43 | T 201= | 35.16 | T 202= | 35.24 | T 203= | 35.34 |
| T 204= | 35.97 | T 205= | 28.19 | T 206= | 28.39 | T 207= | 28.81 |
| T 208= | 30.38 | T 209= | 28.86 | T 210= | 29.04 | T 211= | 29.13 |
| T 212= | 28.93 | T 213= | 30.18 | T 214= | 33.81 | T 215= | 33.90 |
| T 216= | 33.86 | T 217= | 34.50 | T 218= | 34.40 | T 101= | 35.68 |
| T 102= | 35.75 | T 103= | 35.84 | T 104= | 36.53 | T 105= | 28.19 |
| T 106= | 28.39 | T 107= | 28.81 | T 108= | 30.38 | T 109= | 28.86 |
| T 110= | 29.04 | T 111= | 29.13 | T 112= | 28.93 | T 113= | 30.18 |
| T 114= | 34.89 | T 115= | 34.28 | T 116= | 34.89 | T 117= | 35.44 |
| T 118= | 35.37 | T 1601= | 39.39 | T 1602= | 39.42 | T 1603= | 39.28 |
| T 1604= | 38.92 | T 1605= | 21.45 | T 1606= | 22.58 | T 1607= | 21.48 |
| T 1608= | 20.84 | T 1609= | 39.71 | T 1610= | 39.43 | T 1611= | 39.44 |
| T 1612= | 38.89 | T 1613= | 20.00 | T 1614= | 20.00 | T 1615= | 20.00 |
| T 1616= | 20.00 | T 1617= | 20.00 | T 1618= | 20.00 | T 1501= | 38.37 |
| T 1502= | 38.38 | T 1503= | 38.25 | T 1504= | 38.02 | T 1505= | 28.27 |
| T 1506= | 28.85 | T 1507= | 28.23 | T 1508= | 27.91 | T 1509= | 38.52 |
| T 1510= | 38.34 | T 1511= | 38.28 | T 1512= | 37.94 | T 1513= | 20.00 |
| T 1514= | 20.00 | T 1515= | 20.00 | T 1516= | 20.00 | T 1517= | 20.00 |
| T 1518= | 20.00 | T 1401= | 37.38 | T 1402= | 37.38 | T 1403= | 37.26 |
| T 1404= | 37.17 | T 1405= | 34.89 | T 1406= | 34.97 | T 1407= | 34.75 |
| T 1408= | 34.63 | T 1409= | 37.36 | T 1410= | 37.28 | T 1411= | 37.17 |
| T 1412= | 37.04 | T 1413= | 20.00 | T 1414= | 20.00 | T 1415= | 20.00 |
| T 1416= | 20.00 | T 1417= | 20.00 | T 1418= | 20.00 | T 1301= | 37.55 |
| T 1302= | 37.54 | T 1303= | 37.43 | T 1304= | 37.34 | T 1305= | 34.89 |
| T 1306= | 34.97 | T 1307= | 34.75 | T 1308= | 34.63 | T 1309= | 37.53 |
| T 1310= | 37.46 | T 1311= | 37.35 | T 1312= | 37.23 | T 1313= | 20.00 |
| T 1314= | 20.00 | T 1315= | 20.00 | T 1316= | 20.00 | T 1317= | 20.00 |
| T 1318= | 20.00 | T 1201= | 37.71 | T 1202= | 37.71 | T 1203= | 37.60 |
| T 1204= | 37.51 | T 1205= | 34.89 | T 1206= | 34.97 | T 1207= | 34.75 |
| T 1208= | 34.63 | T 1209= | 37.71 | T 1210= | 37.64 | T 1211= | 37.54 |
| T 1212= | 37.42 | T 1213= | 20.00 | T 1214= | 20.00 | T 1215= | 20.00 |
| T 1216= | 20.00 | T 1217= | 20.00 | T 1218= | 20.00 | T 1101= | 37.88 |
| T 1102= | 37.87 | T 1103= | 37.77 | T 1104= | 37.68 | T 1105= | 34.89 |
| T 1106= | 34.97 | T 1107= | 34.75 | T 1108= | 34.63 | T 1109= | 37.88 |
| T 1110= | 37.82 | T 1111= | 37.73 | T 1112= | 37.61 | T 1113= | 20.00 |
| T 1114= | 20.00 | T 1115= | 20.00 | T 1116= | 20.00 | T 1117= | 20.00 |
| T 1118= | 20.00 | T | | | | | |

ASCENDING NODE NUMBER : TEMPERATURE

 ITAS STEADY-STATE SOLUTION (SUCCESSIVE POINT ITERATION)
 NO. OF ITERATIONS= 2805 TOTAL INPUT ENERGY (W)= 1.2830
 SYSTEM ENERGY BALANCE (W)= 7.1385 (556.39 %)

| | | | | | | | |
|--------|--------|--------|--------|--------|--------|--------|--------|
| T 1= | 39.676 | T 2= | 39.432 | T 3= | 39.392 | T 4= | 39.400 |
| T 5= | 39.458 | T 6= | 39.911 | T 7= | 39.012 | T 8= | 39.684 |
| T 9= | 39.684 | T 10= | 39.684 | T 11= | 39.684 | T 12= | 39.642 |
| T 13= | 20.181 | T 14= | 20.433 | T 15= | 20.655 | T 16= | 20.725 |
| T 17= | 21.649 | T 18= | 37.012 | T 19= | 38.079 | T 20= | 38.644 |
| T 21= | 39.257 | T 22= | 39.168 | T 23= | 39.018 | T 24= | 39.276 |
| T 25= | 39.272 | T 26= | 39.428 | T 27= | 20.586 | T 28= | 20.996 |
| T 29= | 20.890 | T 30= | 20.740 | T 31= | 39.393 | T 32= | 39.417 |
| T 33= | 39.280 | T 34= | 38.924 | T 35= | 21.450 | T 36= | 22.584 |
| T 37= | 21.483 | T 38= | 20.843 | T 39= | 39.710 | T 40= | 39.425 |
| T 41= | 39.436 | T 42= | 38.892 | T 101= | 35.675 | T 102= | 35.753 |
| T 103= | 35.841 | T 104= | 36.526 | T 105= | 28.187 | T 106= | 28.391 |
| T 107= | 28.807 | T 108= | 30.378 | T 109= | 28.861 | T 110= | 29.042 |
| T 111= | 29.133 | T 112= | 28.932 | T 113= | 30.184 | T 114= | 34.890 |
| T 115= | 34.280 | T 116= | 34.889 | T 117= | 35.438 | T 118= | 35.374 |
| T 201= | 35.159 | T 202= | 35.240 | T 203= | 35.344 | T 204= | 35.969 |

| | | | | | | | | | | | |
|---|-------|--------|---|-------|--------|---|-------|--------|---|-------|--------|
| T | 205= | 28.187 | T | 206= | 28.391 | T | 207= | 28.807 | T | 208= | 30.378 |
| T | 209= | 28.861 | T | 210= | 29.042 | T | 211= | 29.133 | T | 212= | 28.932 |
| T | 213= | 30.184 | T | 214= | 33.812 | T | 215= | 33.901 | T | 216= | 33.860 |
| T | 217= | 34.498 | T | 218= | 34.400 | T | 301= | 34.643 | T | 302= | 34.727 |
| T | 303= | 34.847 | T | 304= | 35.412 | T | 305= | 28.188 | T | 306= | 28.391 |
| T | 307= | 28.808 | T | 308= | 30.378 | T | 309= | 28.861 | T | 310= | 29.042 |
| T | 311= | 29.133 | T | 312= | 28.932 | T | 313= | 30.184 | T | 314= | 32.735 |
| T | 315= | 32.764 | T | 316= | 32.831 | T | 317= | 33.557 | T | 318= | 33.427 |
| T | 401= | 34.127 | T | 402= | 34.214 | T | 403= | 34.351 | T | 404= | 34.855 |
| T | 405= | 28.188 | T | 406= | 28.391 | T | 407= | 28.808 | T | 408= | 30.378 |
| T | 409= | 28.861 | T | 410= | 29.042 | T | 411= | 29.133 | T | 412= | 28.932 |
| T | 413= | 30.185 | T | 414= | 31.658 | T | 415= | 31.627 | T | 416= | 31.803 |
| T | 417= | 32.616 | T | 418= | 32.454 | T | 501= | 36.526 | T | 502= | 36.716 |
| T | 503= | 36.783 | T | 504= | 37.115 | T | 505= | 24.432 | T | 506= | 24.721 |
| T | 507= | 24.878 | T | 508= | 25.637 | T | 509= | 24.597 | T | 510= | 24.847 |
| T | 511= | 24.976 | T | 512= | 24.881 | T | 513= | 25.989 | T | 514= | 34.275 |
| T | 515= | 34.749 | T | 516= | 35.149 | T | 517= | 35.891 | T | 518= | 35.740 |
| T | 601= | 39.019 | T | 602= | 39.278 | T | 603= | 39.272 | T | 604= | 39.428 |
| T | 605= | 20.586 | T | 606= | 20.996 | T | 607= | 20.891 | T | 608= | 20.740 |
| T | 609= | 20.181 | T | 610= | 20.433 | T | 611= | 20.656 | T | 612= | 20.726 |
| T | 613= | 21.650 | T | 614= | 37.013 | T | 615= | 38.079 | T | 616= | 38.644 |
| T | 617= | 39.259 | T | 618= | 39.168 | T | 901= | 39.676 | T | 902= | 39.432 |
| T | 903= | 39.392 | T | 904= | 39.401 | T | 905= | 39.458 | T | 906= | 39.911 |
| T | 907= | 39.612 | T | 908= | 39.685 | T | 909= | 39.685 | T | 910= | 39.685 |
| T | 911= | 39.684 | T | 912= | 39.642 | T | 913= | 40.000 | T | 921= | 39.649 |
| T | 922= | 39.650 | T | 923= | 39.739 | T | 924= | 39.642 | T | 925= | 39.667 |
| T | 926= | 39.740 | T | 1101= | 37.875 | T | 1102= | 37.871 | T | 1103= | 37.773 |
| T | 1104= | 37.683 | T | 1105= | 34.893 | T | 1106= | 34.966 | T | 1107= | 34.751 |
| T | 1108= | 34.628 | T | 1109= | 37.882 | T | 1110= | 37.822 | T | 1111= | 37.727 |
| T | 1112= | 37.613 | T | 1113= | 20.000 | T | 1114= | 20.000 | T | 1115= | 20.000 |
| T | 1116= | 20.000 | T | 1117= | 20.000 | T | 1118= | 20.000 | T | 1201= | 37.711 |
| T | 1202= | 37.707 | T | 1203= | 37.603 | T | 1204= | 37.511 | T | 1205= | 34.893 |
| T | 1206= | 34.966 | T | 1207= | 34.751 | T | 1208= | 34.628 | T | 1209= | 37.708 |
| T | 1210= | 37.642 | T | 1211= | 37.540 | T | 1212= | 37.423 | T | 1213= | 20.000 |
| T | 1214= | 20.000 | T | 1215= | 20.000 | T | 1216= | 20.000 | T | 1217= | 20.000 |
| T | 1218= | 20.000 | T | 1301= | 37.547 | T | 1302= | 37.543 | T | 1303= | 37.432 |
| T | 1304= | 37.340 | T | 1305= | 34.894 | T | 1306= | 34.966 | T | 1307= | 34.751 |
| T | 1308= | 34.629 | T | 1309= | 37.533 | T | 1310= | 37.462 | T | 1311= | 37.353 |
| T | 1312= | 37.233 | T | 1313= | 20.000 | T | 1314= | 20.000 | T | 1315= | 20.000 |
| T | 1316= | 20.000 | T | 1317= | 20.000 | T | 1318= | 20.000 | T | 1401= | 37.384 |
| T | 1402= | 37.379 | T | 1403= | 37.261 | T | 1404= | 37.169 | T | 1405= | 34.894 |
| T | 1406= | 34.967 | T | 1407= | 34.752 | T | 1408= | 34.629 | T | 1409= | 37.359 |
| T | 1410= | 37.283 | T | 1411= | 37.167 | T | 1412= | 37.043 | T | 1413= | 20.000 |
| T | 1414= | 20.000 | T | 1415= | 20.000 | T | 1416= | 20.000 | T | 1417= | 20.000 |
| T | 1418= | 20.000 | T | 1501= | 38.371 | T | 1502= | 38.383 | T | 1503= | 38.252 |
| T | 1504= | 38.016 | T | 1505= | 28.272 | T | 1506= | 28.850 | T | 1507= | 28.225 |
| T | 1508= | 27.912 | T | 1509= | 38.516 | T | 1510= | 38.339 | T | 1511= | 38.280 |
| T | 1512= | 37.936 | T | 1513= | 20.000 | T | 1514= | 20.000 | T | 1515= | 20.000 |
| T | 1516= | 20.000 | T | 1517= | 20.000 | T | 1518= | 20.000 | T | 1601= | 39.393 |
| T | 1602= | 39.417 | T | 1603= | 39.280 | T | 1604= | 38.925 | T | 1605= | 21.450 |
| T | 1606= | 22.585 | T | 1607= | 21.484 | T | 1608= | 20.844 | T | 1609= | 39.711 |
| T | 1610= | 39.426 | T | 1611= | 39.436 | T | 1612= | 38.893 | T | 1613= | 20.000 |
| T | 1614= | 20.000 | T | 1615= | 20.000 | T | 1616= | 20.000 | T | 1617= | 20.000 |
| T | 1618= | 20.000 | T | | | | | | | | |

ASCENDING NODE NUMBER : IMPRESSED Q

| | | | | | | | | | | | |
|---|-----|-------|---|-----|-------|---|-----|-------|---|-----|-------|
| Q | 1= | 0.000 | Q | 2= | 0.000 | Q | 3= | 0.000 | Q | 4= | 0.000 |
| Q | 5= | 0.000 | Q | 6= | 0.000 | Q | 7= | 0.000 | Q | 8= | 0.000 |
| Q | 9= | 0.000 | Q | 10= | 0.000 | Q | 11= | 0.000 | Q | 12= | 0.000 |
| Q | 13= | 0.000 | Q | 14= | 0.000 | Q | 15= | 0.000 | Q | 16= | 0.000 |
| Q | 17= | 0.000 | Q | 18= | 0.000 | Q | 19= | 0.000 | Q | 20= | 0.000 |

| | | | | | | | | |
|---|-------|---------|-------|---------|-------|---------|-------|-------|
| Q | 21= | 0.000 Q | 22= | 0.000 Q | 23= | 0.000 Q | 24= | 0.000 |
| Q | 25= | 0.000 Q | 26= | 0.000 Q | 27= | 0.000 Q | 28= | 0.000 |
| Q | 29= | 0.000 Q | 30= | 0.000 Q | 31= | 0.000 Q | 32= | 0.000 |
| Q | 33= | 0.000 Q | 34= | 0.000 Q | 35= | 0.000 Q | 36= | 0.000 |
| Q | 37= | 0.000 Q | 38= | 0.000 Q | 39= | 0.000 Q | 40= | 0.000 |
| Q | 41= | 0.000 Q | 42= | 0.000 Q | 101= | 0.000 Q | 102= | 0.000 |
| Q | 103= | 0.000 Q | 104= | 0.000 Q | 105= | 0.000 Q | 106= | 0.000 |
| Q | 107= | 0.000 Q | 108= | 0.000 Q | 109= | 0.000 Q | 110= | 0.000 |
| Q | 111= | 0.000 Q | 112= | 0.000 Q | 113= | 0.000 Q | 114= | 0.000 |
| Q | 115= | 0.000 Q | 116= | 0.000 Q | 117= | 0.000 Q | 118= | 0.000 |
| Q | 201= | 0.000 Q | 202= | 0.000 Q | 203= | 0.000 Q | 204= | 0.000 |
| Q | 205= | 0.000 Q | 206= | 0.000 Q | 207= | 0.000 Q | 208= | 0.000 |
| Q | 209= | 0.000 Q | 210= | 0.000 Q | 211= | 0.000 Q | 212= | 0.000 |
| Q | 213= | 0.000 Q | 214= | 0.000 Q | 215= | 0.000 Q | 216= | 0.000 |
| Q | 217= | 0.000 Q | 218= | 0.000 Q | 301= | 0.000 Q | 302= | 0.000 |
| Q | 303= | 0.000 Q | 304= | 0.000 Q | 305= | 0.000 Q | 306= | 0.000 |
| Q | 307= | 0.000 Q | 308= | 0.000 Q | 309= | 0.000 Q | 310= | 0.000 |
| Q | 311= | 0.000 Q | 312= | 0.000 Q | 313= | 0.000 Q | 314= | 0.000 |
| Q | 315= | 0.000 Q | 316= | 0.000 Q | 317= | 0.000 Q | 318= | 0.000 |
| Q | 401= | 0.003 Q | 402= | 0.004 Q | 403= | 0.001 Q | 404= | 0.001 |
| Q | 405= | 0.000 Q | 406= | 0.000 Q | 407= | 0.000 Q | 408= | 0.000 |
| Q | 409= | 0.000 Q | 410= | 0.000 Q | 411= | 0.000 Q | 412= | 0.000 |
| Q | 413= | 0.000 Q | 414= | 0.000 Q | 415= | 0.000 Q | 416= | 0.000 |
| Q | 417= | 0.000 Q | 418= | 0.000 Q | 501= | 0.000 Q | 502= | 0.000 |
| Q | 503= | 0.000 Q | 504= | 0.000 Q | 505= | 0.000 Q | 506= | 0.000 |
| Q | 507= | 0.000 Q | 508= | 0.000 Q | 509= | 0.000 Q | 510= | 0.000 |
| Q | 511= | 0.000 Q | 512= | 0.000 Q | 513= | 0.000 Q | 514= | 0.000 |
| Q | 515= | 0.000 Q | 516= | 0.000 Q | 517= | 0.000 Q | 518= | 0.000 |
| Q | 601= | 0.037 Q | 602= | 0.047 Q | 603= | 0.020 Q | 604= | 0.010 |
| Q | 605= | 0.011 Q | 606= | 0.060 Q | 607= | 0.011 Q | 608= | 0.000 |
| Q | 609= | 0.000 Q | 610= | 0.008 Q | 611= | 0.008 Q | 612= | 0.011 |
| Q | 613= | 0.000 Q | 614= | 0.000 Q | 615= | 0.009 Q | 616= | 0.009 |
| Q | 617= | 0.004 Q | 618= | 0.000 Q | 901= | 0.000 Q | 902= | 0.000 |
| Q | 903= | 0.000 Q | 904= | 0.000 Q | 905= | 0.000 Q | 906= | 0.000 |
| Q | 907= | 0.000 Q | 908= | 0.000 Q | 909= | 0.000 Q | 910= | 0.000 |
| Q | 911= | 0.000 Q | 912= | 0.000 Q | 913= | 0.000 Q | 921= | 0.000 |
| Q | 922= | 0.000 Q | 923= | 0.000 Q | 924= | 0.000 Q | 925= | 0.000 |
| Q | 926= | 0.000 Q | 1101= | 0.000 Q | 1102= | 0.000 Q | 1103= | 0.000 |
| Q | 1104= | 0.000 Q | 1105= | 0.000 Q | 1106= | 0.000 Q | 1107= | 0.000 |
| Q | 1108= | 0.000 Q | 1109= | 0.000 Q | 1110= | 0.000 Q | 1111= | 0.000 |
| Q | 1112= | 0.000 Q | 1113= | 0.000 Q | 1114= | 0.000 Q | 1115= | 0.000 |
| Q | 1116= | 0.000 Q | 1117= | 0.000 Q | 1118= | 0.000 Q | 1201= | 0.000 |
| Q | 1202= | 0.000 Q | 1203= | 0.000 Q | 1204= | 0.000 Q | 1205= | 0.000 |
| Q | 1206= | 0.000 Q | 1207= | 0.000 Q | 1208= | 0.000 Q | 1209= | 0.000 |
| Q | 1210= | 0.000 Q | 1211= | 0.000 Q | 1212= | 0.000 Q | 1213= | 0.000 |
| Q | 1214= | 0.000 Q | 1215= | 0.000 Q | 1216= | 0.000 Q | 1217= | 0.000 |
| Q | 1218= | 0.000 Q | 1301= | 0.000 Q | 1302= | 0.000 Q | 1303= | 0.000 |
| Q | 1304= | 0.000 Q | 1305= | 0.000 Q | 1306= | 0.000 Q | 1307= | 0.000 |
| Q | 1308= | 0.000 Q | 1309= | 0.000 Q | 1310= | 0.000 Q | 1311= | 0.000 |
| Q | 1312= | 0.000 Q | 1313= | 0.000 Q | 1314= | 0.000 Q | 1315= | 0.000 |
| Q | 1316= | 0.000 Q | 1317= | 0.000 Q | 1318= | 0.000 Q | 1401= | 0.000 |
| Q | 1402= | 0.000 Q | 1403= | 0.000 Q | 1404= | 0.000 Q | 1405= | 0.000 |
| Q | 1406= | 0.000 Q | 1407= | 0.000 Q | 1408= | 0.000 Q | 1409= | 0.000 |
| Q | 1410= | 0.000 Q | 1411= | 0.000 Q | 1412= | 0.000 Q | 1413= | 0.000 |
| Q | 1414= | 0.000 Q | 1415= | 0.000 Q | 1416= | 0.000 Q | 1417= | 0.000 |
| Q | 1418= | 0.000 Q | 1501= | 0.000 Q | 1502= | 0.000 Q | 1503= | 0.000 |
| Q | 1504= | 0.000 Q | 1505= | 0.000 Q | 1506= | 0.000 Q | 1507= | 0.000 |
| Q | 1508= | 0.000 Q | 1509= | 0.000 Q | 1510= | 0.000 Q | 1511= | 0.000 |
| Q | 1512= | 0.000 Q | 1513= | 0.000 Q | 1514= | 0.000 Q | 1515= | 0.000 |
| Q | 1516= | 0.000 Q | 1517= | 0.000 Q | 1518= | 0.000 Q | 1601= | 0.113 |

| | | | | | | | |
|---------|-------|---------|-------|---------|-------|---------|-------|
| Q 1602= | 0.086 | Q 1603= | 0.025 | Q 1604= | 0.000 | Q 1605= | 0.000 |
| Q 1606= | 0.175 | Q 1607= | 0.000 | Q 1608= | 0.000 | Q 1609= | 0.375 |
| Q 1610= | 0.105 | Q 1611= | 0.150 | Q 1612= | 0.000 | Q 1613= | 0.000 |
| Q 1614= | 0.000 | Q 1615= | 0.000 | Q 1616= | 0.000 | Q 1617= | 0.000 |
| Q 1618= | 0.000 | Q | | | | | |

THERMAL CALC CPU TIME (second) = 100.790

LIST OF REFERENCES

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