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UNIVERSITY OF ALBERTA

RADIATION TRANSPORT

BY

HUMAYON BUTT

(C)

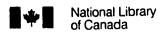
A thesis submitted to the faculty of Graduate Studies and Research in partial fulfilment of the requirement for the degree of Master of Science.

IN

DEPARTMENT OF ELECTRICAL ENGINEERING

EDMONTON, ALBERTA

FALL 1993



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FACULTY OF GRADUATE STUDY

The undersigned certify that they have read and recommended to the faculty of Graduate Studies and Research for acceptance, a thesis entitled RADIATION TRANSPORT FOR THE MEDUSA CODE in partial fulfilment of the requirement for the degree of Master of Science in Laser Plasma interaction.

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ABSTRACT

The main objective of this research is to incorporate the effects of radiation transport into MEDUSA, a code used at the University of Alberta and other research laboratories to study laser plasma interaction phenomena. The effects of radiation transport on ablation pressure and the ablation mass are investigated. When radiation transport is included, the amount of laser energy that is available for ion, kinetic and thermal energies changes. This change in energy is also investigated. The solution of the radiative transfer equation for a one dimensional slab geometry is obtained by using a neutronic transport technique known as DIFFUSION SYNTHETIC ACCELERATION (DSA). The secondary objective of this research is to corroborate the validity of the simplified algorithm developed by Marchand et al at the University of Alberta. The radiation transport algorithm is developed taking into consideration its eventual extension to two dimensional geometries. However, the extension to higher dimensions is not the objective of the present research.

CHAPTER ONE INTRODUCTION

1.1 LASER DRIVEN NUCLEAR FUSION:

In early 1970, many researchers argued that one could use lasers as a mean of igniting thermonuclear fusion^{1/1}. They showed theoretically that a thin shell filled with a deuterium-tritium mixture can be compressed to many times its solid density through laser driven ablative implosion. In an ablative implosion only the exterior of the shell is heated. The shell is shocked, compressed and driven toward the origin by the reaction force produced by the material streaming off. In this way fuel inside the shell can be brought to the densities required for thermonuclear fusion.

During compression, the heated fuel pellet emits electromagnetic radiation which can significantly influence the compression efficiency. These emitted photons can preheat the uncompressed target core, thereby reducing the final target compression. This in turn degrades the pellet gain. Therefore, it is of considerable importance to know the temperature on the inside of the target shell. Such knowledge allows one to choose the proper isentrope for compression calculations as well as to check the predictions of detailed numerical simulations of laser driven implosions. If preheating is sufficiently strong, it is possible that fuel may not ignite. Therefore, it is essential to minimize the fuel preheating during the implosion phase.

When the laser intensity is in the range of 10¹⁶ to 10¹⁸ W m⁻², energy transport due to radiation can exceed heat conduction due to other processes. Experiments^{1/2} have shown that up to 25% of the laser input energy can be lost through radiative emission. From these experiments it can be concluded that by neglecting radiation transport, one may be omitting a significant energy loss mechanism. Therefore, a computer simulation without radiation transport may not yield results that are consistent with experimental observations. Radiation transport is a very complex

process due to its nonlinear nature and because of the dependence of the radiation field on space, angle, frequency and time. A treatment of the interaction of the radiation field with atoms requires a detailed knowledge of various coefficients such as the atomic population densities, the absorption coefficient and emissitivity. Despite its complexity, it is essential to include at least a qualitative analysis of radiation transport in any computer simulation.

1.2 PHYSICS OF LASER PRODUCED PLASMA:

A detailed analysis of all of the processes taking place in a laser produced plasma is beyond the scope of this thesis. In this section, a brief summary of some of the processes which take place when a laser beam is incident on matter are discussed.

When a laser impinges on a target surface, it is initially absorbed by the production of photoelectrons. This leads to electron ionization and heating of the target. The target material evaporates, the vapour is ionized by collisions and a plasma layer is formed. If the intensity of the laser beam is sufficiently high the electronic field of the incident laser beam can lead to noncollisional heating and an outward acceleration of the plasma in an explosive manner. The plasma layer expands mostly in an outward direction while heat is conducted into the solid. This inward heat conduction leads to further evaporation of the target layer. This is called ablation of the target material. The momentum of the ablated plasma is balanced by momentum of the solid target. The momentum transferred by the action of the ablation pressure and the effect of the pondermotive force, launches a shock wave in the solid which after a short time overtakes the front of the heat wave. Assuming classical theory of heat conduction, this time is given as^{1/3}

$$t_o = b \left(\frac{M}{2k}\right)^{\frac{3}{2}} \left(\frac{3}{2}kN\right)^{-2} \phi$$

where ϕ is the flux, N is the ion density, M is the atomic mass of the target, k is the Boltzmann constant and b is 2.0 E-13 If the laser pulse is short compared to t_o the

heated matter has no time to move and energy diffuses into the target by heat conduction. On the other hand, if the laser pulse lasts for a time longer than t_o then expansion is important while laser energy is being absorbed. When the laser pulse is very long compared to t_o the plasma can be divided into three phases. Phase 0 has a mass density ρ_o of the undisturbed solid. Phase 1 has mass density ρ_i and is called the dense phase of opaque ionized matter which is heated by the shock wave. This mass penetrates into phase 0 with the speed of the shock. Phase 2 is composed of plasma subliminated from the boundary of phase 1.

Two thermodynamic quantities, pressure and energy, directly govern the hydrodynamics of the plasma. The energy deposited by the laser pulse can be used to determine the temperature of the plasma and from this one can deduce the pressure. The pressure drives the expansion of the plasma and determines the strength of the recoiled shock launched into the solid and thereby establishes the implosion relocity of the plasma.

A plasma can be considered as either nonideal or ideal. In a nonideal plasma (Q<Z where Q is the ion charge and Z is the atomic number) matter is partially ionized. The coulomb interaction is strong in this case and free electrons can exist in degenerate form. The ideal plasma (Q=Z) is fully ionized and the electrical interaction is weak due to the screening clouds around charges. The screening energy increases as the temperature is reduced and eventually exceeds kT. When this happens a strongly coupled plasma is formed which is nonideal. An approximation for the ionization energy is given as

$$I = 13.6 \; (\frac{Q}{n})^2 \; ev$$

where n is the principle quantum number of the outer most electron. The above expression shows that higher Z plasmas are more difficult to ionize. An ideal plasma emits radiation by bremsstrahlung, radiative recombination and line radiation from hydrogen like or helium like ions. In a magnetically confined plasma with high Z, the bremsstrahlung radiation can become an important mechanism for cooling. For

low density plasma, radiation freely escapes and it can be used to infer parameters such as the plasma density and temperature. In a partially ionized plasma, radiation is strongly absorbed by the bound electrons and the photon population builds up toward a black body distribution.

When a laser beam is incident on a material, the energy that is absorbed by free electrons leads to an increase in their temperature. An increase in temperature increases the Debye length which increases the ion interaction. This forces ions to redistribute so as to reach equilibrium. As plasma is heated, different types of emission spectra are observed. The continuum emission spectrum reflects the energy spectrum of the free electrons. The energetic x-ray signals indicate the presence of super-thermal electrons.

In a plasma, hot regions radiate strongly and emitted photons transport energy to cooler parts of the plasma or permit energy to escape altogether. Since radiation travels rapidly, it plays an important role in plasma hydrodynamics. The radiation that is emitted and absorbed is due to many different processes which take place at a subatomic level. Some of the important processes are discussed below.

Bremsstrahlung Emission: In bremsstrahlung emission, radiation is emitted when electrons are scattered by atoms and ions. As electrons approach a nuclei they are deaccelerated and radiation is emitted.

Free-Free absorption: Absorption of a photon by a free electron is known as free-free absorption. The electron absorption cross-sectional area is obtained by using the principle of balance which states that at thermal equilibrium, the absorption rate is equal to the rate of emission and is given as^{1/3}

$$\sigma^{B} = \frac{8\pi^{3}}{3\sqrt{3}}Z^{2}a_{o}^{5}(\frac{e^{2}}{a_{o}hv})^{3}\frac{e^{2}}{a_{o}\epsilon}$$

where Z is the atomic number, e is the electron charge, h is the Planckian constant, a_o is the radiation constant (=7.5607E-16), ϵ is the permeability constant of the plasma and ν is the frequency.

Radiative Recombination: Radiative recombination occurs when

free electrons radiate more energy than their initial kinetic energy. At negative energies these electrons are trapped in bound states.

Photoelectric Effect: Here, a bound electron absorbs a photon and moves to a higher state.

Line Emission: Line emission occurs when a bound electron in an upper state spontaneously emits a photon of energy hv and falls into a lower state.

In a laser heated plasma, energy is deposited primarily into the electrons and the rate at which the electrons in turn transport this energy to higher density colder plasma determines both the efficiency of implosion and the plasma conditions in the region of deposition.

Mechanisms which are generally associated with the heating of the pellet are:

- 1. Classical electron thermal conduction.
- 2. Radiation transport.
- 3. Super thermal electron transport.
- 4. Shock waves.

Classical conduction is always present, and is modified by anomalous effects from ion and magnetic field fluctuations^{1/4}. When excessive energy is deposited to thermal electrons during an implosion, the classical conduction wave burns through the shell, leading to preheating of the pellet. This condition can be readily avoided with proper pulse shaping. Radiative preheating arises from the reabsorption of bremsstrahlung, recombination and line radiation photons near the ablation surface where plasma electrons are typically in the range of 300 to 500 ev^{1/5}. Super thermal electrons are generated when various thresholds for the absorptive instabilities are exceeded^{1/6}; for example, resonant absorption readily furnishes 100 keV electrons with 10.6 µm laser light intensities of 10²⁰ W m². Shock waves^{1/7} leads to large temperature gradients. They play an important role when thicker targets are used. At intermediate irradiance (10¹⁶ to 10¹⁷ W m²) the dominant heat transport mechanism can be radiation transport.

The effects of radiation transport have been experimentally investigated by

many researchers^{1/80}. In numerous experiments, different pellet materials have been used in order to observe the effects of radiation transport in low and high Z materials. Duston et al^{1/28} used carbon as a target material, and rejected the common notion that for lower Z material radiation transport is negligible. This notion was due to the assumption that for lower Z materials the bound electrons would be easily stripped off and therefore radiation would make a negligible contribution to plastinal dynamics and energy transport in these targets. Yaakobi et al^{1/9} have shown that use of a low Z (plastic) coating reduces the preheating, thus leading to a higher density ablative implosion.

1.3 OBJECTIVE AND ORGANIZATION OF THE THESIS:

When a laser beam is incident on a target, radiation is emitted and then transported and reabsorbed in the target. This can significantly affect the hydrodynamics of the target and ablation parameters. In laser fusion, a precise knowledge of these parameters is crucial for target design. Even though our research does not involve laser induced nuclear fusion, inclusion of radiation transport is useful for a better understanding of radiative effects in other problems, such as use of emitted radiation as a source of x-rays^{1/10} for lithography applications. Therefore, by including radiation transport in MEDUSA, the behavior of laser heated plasma can be better understood. The Diffusion Synthetic Acceleration technique is used to implement the radiative transfer equation in the MEDUSA code. The main objectives of the present research are:

- i. To develop an algorithm which can be extended to solve the radiative transfer equation in two dimensions.
 - ii. To corroborate Marchand's algorithm.

The thesis consists of five chapters. In Chapter One, the importance of the understanding of radiation relevant to laser driven nuclear fusion is discussed, followed by a prologue to the processes involved in laser plasma interactions. In Chapter Two, the derivation and validity of the radiative transfer equation are

discussed. Chapter Three includes a detailed analysis of the Diffusion Synthetic Acceleration Scheme (DSA). Chapter Four includes simulations with the radiation code when a model problem is used to test the validity of the DSA model. Chapter Five contains MEDUSA simulations using Marchand's model and the present model. The main objective is to present a comparison between Marchand's model and the Diffusion Synthetic Acceleration model.

Finally, a detailed analysis of the equations involved in the Diffusion Synthetic Acceleration model is included in Appendix A. This includes a Fourier stability analysis (where possible), the discretization of all equations involved in the algorithm, and a discussion of the boundary conditions. Marchand's model, currently used in MEDUSA to study radiative effects in laser produced plasma is reviewed in Appendix B. In Appendix C, a brief discussion is presented of the atomic physics data used in MEDUSA. A copy of the radiation transport code is included at the end of the thesis in Appendix D.

CHAPTER TWO RADIATIVE TRANSFER EQUATION

2.1 DERIVATION OF RADIATIVE TRANSFER EQUATION:

The radiative transfer equation represents the various processes that take place in a plasma at a sub-atomic level. These processes lead to the generation and transport of radiation, resulting in a change in the number of photons in a given region. The time rate of change of the photons in a volume ΔV is given by

$$\frac{\partial [f(r,v,\Omega,t)\Delta V]}{\partial t} = \Delta V \frac{\partial [f(r,v,\Omega,t)]}{\partial t}$$

(2.1.01)

where $\Delta V = \Delta x \Delta y \Delta z \Delta \mu \Delta \phi$ and f is the distribution function. Physically f is defined such that the number of photons at a given time t at a location in space r in a differential volume element dr with frequency interval dv travelling in direction Ω in a solid angle interval $d\Omega$ is

$$dn = f dr dv d\Omega$$

This time rate of change of photons in a volume element ΔV depends on:

- 1. Net rate of streaming of photons out of a volume through the bounding surface.
- 2. Absorption of photons within the volume element.
- 3. Emission of photons from the volume element.
- 4,5. Scattering into and out of the volume element.

A detailed description of the physical interpretation of the above processes can be found elsewhere^{2/1}. In this section, they are discussed briefly in order to derive the radiative transfer equation.

1. The rate of photon loss through the surface of a cube perpendicular to the x-axis is

$$streaming_x = \dot{x}f(r, v, \Omega, t)]_x^{r+\Delta x} \Delta y \Delta z \Delta v \Delta \mu \Delta \varphi = \Delta V \frac{\partial}{\partial x} [\dot{x}f(r, v, \Omega, t)]$$

(2.1.02)

where x denotes the x-components of the photon velocity and $\Delta y \Delta z \Delta \mu \Delta \phi$ is the appropriate surface area. From this one can determine the net rate of streaming from the cube to be

streaming =
$$\Delta V \left[\frac{\partial (\dot{x}f)}{\partial x} + \frac{\partial (\dot{y}f)}{\partial y} + \frac{\partial (\dot{x}f)}{\partial z} + \frac{\partial (\dot{v}f)}{\partial v} + \frac{\partial (\dot{u}f)}{\partial \mu} + \frac{\partial (\dot{\psi}f)}{\partial \phi} \right]$$

(2.1.03)

where μ and φ derivatives represent the rate of change of photons in the directions μ and φ (the polar angle with respect to z-axis and the azimuthal angle with respect to the horizontal axis), respectively.

2. The rate of absorption is equal to the product of the number of photons in the volume element ΔV and the probability of absorption per photon per unit time

rate of absorption =
$$c\sigma_{\bullet}f\Delta V$$
 (2.1.04)

where σ_* is the absorption coefficient.

3. The photon emission rate is equal to the spontaneous rate of emission divided by the energy of the photon

photon emission rate =
$$S\Delta V/hv$$
 (2.1.05)

where S is the rate of energy emission due to spontaneous processes.

4. The rate of out-scattering from the volume element is

5. The rate of in-scattering to the volume element is

$$c\Delta V\!\!\int_0^n\!\!d\dot{v}\!\int_{4\pi}\!\!d\dot{\Omega}\,\sigma_s(r,\dot{v}\!-\!v,\dot{\Omega}.\Omega,\!t)\,f\,(r,\dot{v},\dot{\Omega},\!t)$$

(2.1.06;07)

In the above equations, σ_{\bullet} is the scattering coefficient and c is the speed of light.

The equation of radiative transfer is obtained by summing the above equations with appropriate signs to designate a loss or gain. The resultant equation is

$$\frac{\partial f(v,\Omega)}{\partial t} + \frac{\partial (xf)}{\partial x} + \frac{\partial (yf)}{\partial y} + \frac{\partial (xf)}{\partial x} + \frac{\partial (vf)}{\partial v} + \frac{\partial (vf)}{\partial x} + \frac{\partial (vf)}{\partial \phi}$$

$$= \frac{S(v)}{hv} - c\sigma_{a}(v)f(v,\Omega) + c\int_{0}^{\infty} d\dot{v} \int_{4\pi} d\dot{\Omega}\sigma_{s}(\dot{v} - v,\dot{\Omega} \cdot \Omega)f(\dot{v},\dot{\Omega})$$

$$-c\int_{0}^{\infty} d\dot{v} \int_{4\pi} d\dot{\Omega}\sigma_{s}(v - \dot{v},\Omega \cdot \dot{\Omega})f(v,\Omega)$$

(2.1.08)

Equation (2.1.08) can be simplified by assuming that photons stream in straight lines. When this assumption is made, $\partial x/\partial t = c\Omega_x$, since photons travel with speed c in a given direction. Similar expressions can be obtained for the y,z axes. Since there is no change in frequency as photons stream, $\partial v/\partial t = 0$. Further, $\partial \mu/\partial t = \partial \phi/\partial t = 0.0$, since these angles are measured with respect to fixed axes in space. The distribution function f is related to the specific intensity as I = chvf. Then with the above assumptions, equation (2.1.08) in terms of the specific intensity reduces to

$$\frac{1}{c} \frac{\partial I(\nu,\Omega)}{\partial t} + \Omega \cdot \nabla I(\nu,\Omega) = S(\nu) - \sigma_a(\nu)I(\nu,\Omega)$$

$$+ \int_0^{\infty} d\dot{\nu} \int_{4\pi} d\dot{\Omega} \left[\frac{\nu}{\dot{\nu}} \sigma_s(\dot{\nu} - \nu, \dot{\Omega} \cdot \Omega)I(\dot{\nu}, \dot{\Omega}) - \sigma_s(\nu - \dot{\nu}, \Omega \cdot \dot{\Omega})I(\nu,\Omega) \right]$$
(2.1.09)

It can be shown^{2/1} that when induced processes are included, the processes of emission and scattering are enhanced by the factor

$$\left[1+\frac{c^2I}{2hv^3}\right]$$

This enhancement leads to nonlinearity (in the form of I2) in the transfer equation

in the following form

$$\frac{1}{c}\frac{\partial I}{\partial t} + \Omega.\nabla I = \dot{\sigma}_a [B-I]$$

$$+ \int_0^{\infty} d\dot{v} \frac{v}{\dot{v}} \int_{4\pi} d\dot{\Omega} \sigma_a \dot{I} \left[1 + \frac{c^2 I}{2hv^3}\right] - \int_0^{\infty} d\dot{v} \int_{4\pi} d\dot{\Omega} \sigma_a I \left[1 + \frac{c^2 \dot{I}}{2h\dot{v}^3}\right]$$

$$where \qquad S = \dot{\sigma}_a B \qquad and \qquad \dot{\sigma}_a = \sigma_a \left[1 + \frac{c^2 B}{2hv^3}\right]$$

$$(2.1.10)$$

Here, for simplicity the notations of I and σ_{\bullet} are given as

$$I = I[r, v, \Omega, t]$$
 and $\hat{I} = I[r, \hat{v}, \hat{\Omega}, t]$

This nonlinearity severely limits one's ability to solve the transfer equation. Therefore, equation (2.1.10) is further simplified by assuming that there is no change in frequency upon scattering. With this assumption the induced in- and outscattering contribution completely cancel each other, and the resulting equation is simply

$$\frac{1}{c}\frac{\partial I}{\partial t} + \Omega \cdot \nabla I = \dot{\sigma}_a[B - I]$$

(2.1.11)

This equation forms the basis of the present research. The goal is to find a technique which can efficiently solve this equation. It is important to briefly discuss the validity of the radiative transfer equation, before we discuss the method used to solve the radiative transfer equation.

2.2 THE VALIDITY OF THE RADIATIVE TRANSFER EQUATION:

Many aspects of radiation transport were ignored when the radiative transfer equation was derived above. Some of them are beyond the scope of the present research and some are irrelevant to the objectives of the present research. In this section, approximations that are used in the derivation of the above transfer equation

are briefly discussed.

There are two classes of approximation: those which are inherent in any radiative transfer equation and those which can be incorporated at the expense of simplicity.

The radiative transfer equation was derived using the assumption that photons are particles. However, it is well known that photons exhibit wave behavior, that is in reality a photon is a wave packet. By treating photons as particles, one intrinsically is neglecting the effects of interference, diffraction and reflection in radiation transport. In the radiative transfer equation, one deals with intensities rather than amplitudes, hence interference is nonexistent. This requires that the density of photons be sufficiently low so that overlap of the tails of the wave packets is negligibly small. Photons of sufficiently different frequencies do not interfere even when they coincide spatially; in other words, photons in the transfer equation are incoherent. It is further assumed that collision and emission processes occur instantaneously. That is, the loss or gain of photons due to these processes is characterized by σ_1 , σ_2 and B (absorption and scattering coefficient and the emissivity respectively) at a given instant of time rather than being dependent upon some sort of time average of these quantities over the collision or emission time. Finally, the diffraction and reflection wave behaviour of photons can not be manifested in any radiative transfer equation; since it requires that scattering centres be correlated as in a crystal and the spatial extent of wave packet be such that several scattering centres are encompassed by a photon. Therefore, in the transfer equation we treat scattering as independent and isolated events; in other words we assume scattering centres are randomly distributed or the wave packets are small compared to the distance between the scattering centres. This further implies that photons have no preferred direction.

The approximations discussed so far are inherent to all transfer equations of photons. The approximations which remain to be discussed are assumed in deriving the radiative transfer equation (2.1.08) and can be incorporated into the equation (2.1.08) at the expense of simplicity.

The two states of polarization of a photon can be added into the radiative transfer equation; this results in four transfer equations which in general are coupled. In practice photons do not move in straight lines since the refractive index is a function of position. If the refractive index is a function of time as well, then a photon changes its frequency as it streams between collisions. One can incorporate^{2/1} refractive and dispersion effects into the streaming term of the transfer equation. Finally, σ_a and S are assumed to be angularly independent in (2.1.08), this implies no inherent preferred direction in the matter. However, in radiative hydrodynamic problems the material in question is normally moving. Therefore, as seen by an inertial frame observer, this motion does introduce a preferred direction, namely the direction of motion of the fluid. These angular dependence properties are not inherent properties of the material, but arise due to relative motion between the fluid and the observer. These are computed using the special theory of relativity. These angular effects are of the order of (u/c), where u is the speed of the fluid and c the speed of light; therefore, one can normally neglect the angular dependence in quantities such as the radiation intensity for nonrelativistic velocities.

CHAPTER THREE DIFFUSION SYNTHETIC ACCELERATION

3.1 INTRODUCTION:

There are many classical methods, such as the Eddington Approximation, Asymptotic Diffusion Theory, the P-N Approximation3/1 and the Monte Carlo Method^{3/2} which have been used in the past to solve the radiative transfer equation. These methods are either too crude or are computationally inefficient. Since the late 1960's, researchers have been investigating other options for solving the radiative transfer equation. One of the most popular techniques is Synthetic Acceleration. This is sometimes used to solve neutronic transport problems, but due to its slow convergence for radiative transport problems it was not attractive. In the late 1970's and early 1980's this technique was greatly improved (by acceleration of the diffusion equation with the grey equation) and today is one of the most efficient methods of solving radiation transport problems in one dimension. The successful implementation of this method for a model problem at Lawrence Livermore National Laboratory was the main motivation for the development of the present code. Diffusion Synthetic Acceleration (DSA) is the main topic of this thesis, since it can have ambiguities in its formulation, a great deal of effort has been made to ensure that important aspects of the DSA technique relevant to one dimensional slab geometry are well explained.

3.2 BRIEF HISTORY:

In 1963, Kopp^{3/3} reported that one can improve the spectral radius of the source iteration technique (also known as power or lambda iteration) by using a synthetic acceleration method. In synthetic acceleration one solves a low order form of the original equation to update the source term of the original equation for the

next iteration. For example, the diffusion equation can be treated as a low order form of the transfer equation; the difficult part is to find the form of the low order equation which reduces the spectral radius and remains stable. The significant improvement and stability issues were not resolved until the late 1970's. In 1977, Alcouffe3/4 reported the cause of instability and proved that the solution for DSA was unstable for cells with large width because the discretized form of the low order equation was not derived from the discretized form of the original equation. In 1985, Alcouffe et al3/5 successfully reported on the implementation of the DSA method for a radiative model problem. The code presented here is similar to the work they published in 1985 with minor modifications. The DSA technique like any other method for radiative problems comes with its limitations. When it works, it is very efficient compared to the source iteration or to other known methods for one dimensional problems. Its efficiency degrades for higher dimensional and curvilinear geometry problems. These instability concerns have been eliminated to a great extent with the use of finite element discretization instead of finite difference discretization of the transfer equation in space.

3.3 DISCRETIZATION OF THE TRANSFER EQUATION:

The radiative transfer equation and the energy balance equation are solved simultaneously (this formulation allows us to test our code against a Marshak Wave Bench Mark). The equations for a one dimensional slab geometry are given by^{3/5}

$$\frac{1}{c}\frac{\partial I}{\partial t}(x,v,\mu,t) + \mu \frac{\partial I}{\partial x}(x,v,\mu,t) + \sigma(x,v)I(x,v,\mu,t) = S(v,T) = \sigma(v,T)B(v,T)$$

$$\frac{\partial u_s(T)}{\partial t} = \beta(T) \left[\int_0^{\infty} \sigma(v,T)I_0(x,v,t)dv - c\sigma_p(T)u_s(T) + S_{ext} \right]$$
where
$$u_s = \frac{c}{4\pi} \int_0^{\infty} B \ dv \qquad \sigma_p = \frac{\int_0^{\infty} \sigma B \ dv}{\int_0^{\infty} B \ dv} \qquad \beta = \frac{4aT^3}{c_v}$$

(3.3.01;02;03a,b,c)

Where I is the specific intensity of radiation, defined as the amount of radiative

energy transferred across a surface element ds with normal n at point x, in frequency range of dv about v, in an angle $d\mu$ about μ in time interval dt about t. The energy emission rate due to spontaneous processes is given by S; B is the emissivity, T is the material temperature, σ is the absorption coefficient defined such that the probability of a photon being absorbed in a distance ds is σds , c, is the material specific heat per unit volume, a is the radiation constant, S_{ex} is the external source in the slab, u_e is the radiative energy density and I_o is the scalar intensity and is defined as

$$I_o(x,v,t) = \int_{-1}^1 I(x,\mu,v,t) \ d\mu \tag{3.3.04}$$

3.3.1 DISCRETIZATION IN TIME:

The radiative transfer equation and the energy balance equation are discretized in time using a backward Euler time differencing scheme in order to ensure stability. The dependence of variables on frequency, angle, space and time is omitted for simplicity. The discretized form of (3.3.01,02,03) in time is given as

$$\frac{1}{c\Delta t^n}(I^{n+1}-I^n) + \mu \frac{\partial I^{n+l}}{\partial x} + \sigma^* I^{n+l} = \sigma^* B^{n+l}$$

$$\frac{1}{\Delta t^n}(u_e^{n+1}-u_e^n) = \beta^* \left[\int_0^\infty \sigma^* I_0^{n+l} dv - c\sigma_p^* u_e^{n+l} + S_{ext} \right]$$

$$u_e^{n+l} = \frac{c}{4\pi} \int_0^\infty B^{n+1} dv$$

(3.3.05;06;07)

The quantities with * superscript are computed using the temperature at time step n, since the temperature at time step (n+1) is not known. In addition, the following approximation to the function B is used^{3/6}

$$B^{n+1} \approx \frac{c}{2} u_e^{n+1} b(v, T^*)$$
 subject to $\int_0^\infty b(v, T) dv = 1$

(3.3.08)

By using (3.3.07) and (3.3.08) and assuming that the external source is zero, the function B reduces to

$$B^{n+1} \approx \frac{cb^*}{2} \frac{\left[\beta^* \Delta t^* \int_0^{\infty} \sigma^* I_o^{n+1} dv + u_e^n\right]}{\left(1 + c\Delta t^n \beta^* \sigma_p^*\right)}$$

$$= \frac{\chi \eta}{2} \left[\int_0^{\infty} \sigma^* I_0^{n+l} + \frac{u_e^n}{\beta^* \Delta t^n} \right]$$
where $\alpha = \frac{1}{\beta^* \sigma_p^*}$, $\tau^n = \frac{1}{c\Delta t^n}$, $\chi = \frac{\sigma^* b^*}{\sigma_p^*}$, $\eta = \frac{1}{(1 + \alpha \tau)}$

With these relations, equations (3.3.06;07) reduce to

$$\mu \frac{\partial I^{n+1}}{\partial x} + (\sigma^* + \tau) I^{n+1} = \frac{\chi \eta}{2} \left[\int_0^{\infty} \sigma^* I_0^{n+1} dv + \frac{u_e^n}{\beta^* \Delta t^n} \right] + \tau^n I^n$$

$$u_e^{n+1} = \frac{\eta}{2} \left[\int_0^{\infty} \sigma^* I_o dv + \frac{u_e^n}{\Delta \beta^*} \right]$$

(3.3.11a,b)

(3.3.09;10a,b,c,d)

If the time index is suppressed in the radiative transfer equation(3.3.11a), it reduces to

$$\mu \frac{\partial I}{\partial x} + (\sigma + \tau)I = \frac{\chi \eta}{2} \int_0^{\infty} \sigma I_0 dv + Q$$

(3.3.12)

where Q contains all the terms evaluated at the previous time step and remains unchanged while the transfer equation is being solved iteratively. Q is given as

$$Q = \frac{\chi^* \eta}{2} \frac{u_t^n}{\beta^* \Delta t^n} + \tau^n I^n$$

(3.3.13)

3.3.2 DISCRETIZATION IN FREQUENCY:

We use equation (3.3.12) to discretize the radiative transfer equation in

frequency. The discretized form of the equation is obtained by integrating (3.3.12) over the frequency interval dv as shown below

$$\int_{\nu_{I}}^{\nu_{A}} \mu \frac{\partial I}{\partial x} dv + \int_{\nu_{I}}^{\nu_{A}} (\sigma + \tau) I dv = \int_{\nu_{I}}^{\nu_{A}} \frac{\chi \eta}{2} \int_{0}^{m} \sigma I_{0} dv + \int_{\nu_{I}}^{\nu_{A}} Q dv$$
(3.3.14)

If we define

$$I_{g} = \int_{v_{I}}^{v_{h}} I \, dv \qquad Q_{g} = \int_{v_{I}}^{v_{h}} Q \, dv \qquad \sigma_{g} = \frac{\int_{v_{I}}^{v_{h}} \sigma I \, dv}{\int_{v_{I}}^{v_{h}} I \, dv} \qquad \chi_{g} = \int_{v_{I}}^{v_{h}} \chi \, dv$$

$$(3.3.15a,b,c,d)$$

then the multi-group transfer equation can be expressed as

$$\mu \frac{\partial I_g}{\partial x} + (\sigma_g + \tau)I_g = \frac{\chi_g \eta}{2} \Sigma_g \ \sigma_g I_{0g} + Q_g$$
(3.3.16)

3.3.3 DISCRETIZATION IN ANGULAR SPACE:

The discretized form of the radiative transfer equation (3.3.16) in angular space is obtained by integrating in angular space as defined below

$$\mu_{m} \frac{\partial I_{mg}}{\partial x} + (\sigma_{g} + \tau)I_{mg} = \frac{\chi_{g}\eta}{2} \Sigma_{g}^{G} \sigma_{g}I_{dg} + Q_{mg}$$

$$where \qquad I_{og} = \Sigma_{m-1}^{M} I_{mg}\omega_{m}$$

$$I_{mg} = \frac{1}{\Delta \omega_{m}} \int_{\omega_{m} - \frac{1}{2}}^{\omega_{m} + \frac{1}{2}} I_{g} d\omega_{m}$$

$$subject \quad to \qquad \Sigma_{m-1}^{M} \omega_{m} = 2$$

(3.3.17a,b,c)

Physically I_{mg} represents the specific intensity in a particular direction with weight distribution of ω_m , μ_m is the cosine angle of the specific intensity with respect to the

x-axis and M is the total number of discretized angles.

3.3.4 DISCRETIZATION IN SPACE:

The spatial discretization of the radiative transfer equation (3.3.17a) is obtained by integrating in space over the cell width, as shown below

$$I_{mgl} = \frac{1}{\Delta x_{l}} \int_{x_{l-\frac{1}{2}}}^{x_{l-\frac{1}{2}}} I_{mg} dx$$

$$\int_{x_{l-\frac{1}{2}}}^{x_{l+\frac{1}{2}}} \mu_{m} \frac{\partial I_{mg}}{\partial x} dx + \int_{x_{l-\frac{1}{2}}}^{x_{l+\frac{1}{2}}} (\sigma_{g} + \tau) I_{mg} dx = \int_{x_{l-\frac{1}{2}}}^{x_{l+\frac{1}{2}}} \frac{\chi_{g} \eta}{2} \Sigma_{g} \sigma_{g} I_{Qg} dx + \int_{x_{l-\frac{1}{2}}}^{x_{l+\frac{1}{2}}} Q_{mg} dx$$

$$(3.3.18)$$

then the transfer equation reduces to

$$\frac{\mu_{m}}{\Delta x_{i}} (I_{mgi+\frac{1}{2}} - I_{mgi-\frac{1}{2}}) + (\sigma_{gi} + \tau)I_{mgi} = \frac{\chi_{gi}\eta_{i}}{2} \Sigma_{gi} \sigma_{gi}I_{0gi} + Q_{mgi}$$
(3.3.19)

3.4 SOURCE ITERATION:

Equation (3.3.19) is simply a set of (M*G) transfer equations corresponding to M angles and G frequency groups. This equation includes three unknowns I_{mg} and $I_{mg+1/2}$, where one of $I_{mg+1/2}$ is obtained from the boundary condition of the cell. Very often one uses a relation known as Diamond Differencing (DD) to equate the number of equations with the number of unknowns. This relation is given as,

$$I_{\text{mgl}} = \frac{1}{2} (I_{\text{mgl} + \frac{1}{2}} + I_{\text{mgl} - \frac{1}{2}})$$

(3.4.01)

This simply states that the intensity at the centre of a cell is equal to the average of the intensity at the cell boundaries. The difficulty in solving the radiative transfer equation arises due to the coupling (summation over the frequency groups) of the specific intensity on the right hand side of (3.3.19). The simplest approach to solve

such types of equations is by the use of the source iteration technique. This involves making an initial guess for the source term in equation (3.3.19) and solving for the intensities. The solution is then taken to be the new initial guess in the source term (the summation term on right hand side) of (3.3.19) for the next iteration and equation (3.3.19) is solved again. This is repeated until the new solution and initial guess have converged to some desired accuracy. The final form of the set of equations involved in the source iteration (SI) method is written as

$$\mu_{m}(I_{mgi+\frac{1}{2}}^{l+\frac{1}{2}} - I_{mgi-\frac{1}{2}}^{l+\frac{1}{2}}) + \hat{\sigma}_{gi}I_{mgi}^{l+\frac{1}{2}} = \frac{\eta \chi_{gi}\Delta x_{i}}{2} \Sigma_{g} \sigma_{gi}I_{0gi}^{l} + \Delta x_{i}Q_{mgi}$$

$$where \qquad \hat{\sigma}_{gi} = (\sigma_{gi} + \tau)\Delta x_{i}$$

$$I_{mgi}^{l+\frac{1}{2}} = \frac{1}{2}[I_{mgi+\frac{1}{2}}^{l+\frac{1}{2}} + I_{mgi-\frac{1}{2}}^{l+\frac{1}{2}}]$$

$$I_{ogi}^{l+\frac{1}{2}} = \Sigma_{m} I_{mgi}^{l+\frac{1}{2}} \omega_{m}$$

(3.4.02a,b,c)

In the SI method one uses (3.4.02) to obtain the intensity as is shown in the appendix (section A.3). A Fourier stability analysis of the transfer equation shows that when $\tau \to 0$ or/and $\sigma > 1$, the spectral radius can be arbitrarily close to unity. In simple terminology, it means that the error reduction per iteration can be extremely slow or that an infinite number of iterations may be required. However, in practice when the radiative transfer equation is fully discretized and one has a finite frequency range rather than from 0 to ∞ , the radius of convergence can shown to be always less than one. This is due to the fact that for a finite system all of the Fourier modes are not present. This slow convergence compels one to look for other methods which can reduce the spectral radius. The next section deals with this issue.

3.5 DIFFUSION SYNTHETIC ACCELERATION OF THE TRANSFER EQUATION:

3.5.1 INTRODUCTION TO SYNTHETIC ACCELERATION:

The idea behind synthetic acceleration can be explained as follows^{3/7}. Suppose

we are given an equation of the form

$$[A-B]f = S$$

where [A-B] is difficult to invert, but A can be inverted relatively easily. We try the following iteration strategy

$$f^{i+1} = A^{i1} Bf^{i} + A^{i1} S$$

where I and I+1 are iterative indices and the eigen value of [A⁻¹B] determines the rate of convergence. The above iteration scheme will converge as long as the spectral radius (the largest eigenvalue) is less than one. It can be shown that one can solve above problem iteratively as

$$[A-B](f-f^{t+1}) = B(f^{t+1}-f^t)$$

where f is the converged solution. The above equation implies that an exact solution can be obtained immediately by inverting [A-B] if the solution to f⁺¹ is known. The inversion of [A-B] is the obstacle we are trying to remove, so we are no closer to the resolution of the problem. If we assume that L is an approximation to [A-B] and if L is easily invertible, then the problem can be solved in two steps as given below

$$f^{+1/2} = A^{-1} Bf^{4} + A^{-1} S$$

 $L(f^{+1} - f^{+1/2}) = B(f^{+1/2} - f^{4})$

This iteration strategy is called synthetic acceleration. In order to elucidate the use of synthetic acceleration, let us consider the radiative transfer equation. The radiative transfer equation and its low order form corresponding to the above set of equations is given by

$$(\mu \frac{\partial}{\partial x} + \sigma) I^{l+\frac{1}{2}} = \frac{\chi \eta}{2} \Sigma_g \Sigma_m \sigma I^l + Q$$

$$L(I^{l+1} - I^{l+\frac{1}{2}}) = \frac{\eta \chi}{2} \Sigma_g \Sigma_m \omega_m \sigma_g (I^{l+\frac{1}{2}} - I^h)$$

It is trivial to identify A and B, but L is not so obvious. The main task in synthetic acceleration is to find the operator L, which reduces the spectral radius and yields a stable solution. We will show by using a systematic approach that the required operator is the diffusion operator. In early 1980, Larsen^{3/8} developed a four step procedure whereby one could derive beginning with virtually any differencing

scheme of the transfer equation a set of linear equations^{3/9}. His approach is applicable to any differencing scheme of the transfer equation without regard to geometry or mesh size. However, equations in P₁ acceleration are algebraically difficult to solve. Hence efficiency remains a serious issue for higher dimensional problems. The approach we have taken to obtain the low order equation is the one proposed by Alcouffe^{3/4} and later improved by Larsen^{3/10}.

The main objective of the DSA scheme is to synthesize a low order form for the radiative transfer equation, which can be used to accelerate the rate of convergence of the transfer equation. In addition, we require the new method to exhibit the following characteristics:

- 1. It offers a solution to the exact transfer equation, rather than just an approximation, such as the diffusion equation.
- 2. It is computationally efficient.
- 3. The method should be extendable to higher dimensions and to curvilinear geometry.
- 4. One should be able to solve more complicated problems, such as problems involving scattering.

From our experience we are able to prove the first two characteristics of the method, proof for the later two is beyond the scope of the present research; however, it has been reported^{3/11,12} that these can also be satisfied.

3.5.2 DIFFUSION SYNTHETIC ACCELERATION:

A Fourier stability analysis of the transfer equation (presented in section A.1 of the appendix) shows that the most slowly converging modes (correspond to $\lambda \approx 0$) are given as

$$D(\lambda,\nu,\mu) = \frac{\chi\eta}{2} \frac{1}{(\sigma+\tau)} \left(1 - \frac{i\lambda\mu}{\sigma+\tau} + O(\lambda^2)\right)$$

(3.5.01)

This equation indicates that the slowly varying modes are linear function of μ . We

use this fact to derive an equation which replaces (3.4.02c) and the end result is a faster convergence of (3.4.02a). Physically, the slowest converging modes correspond to near equilibrium situations. Therefore, in a sense we can guess that the low order form will resemble a diffusion equation.

We will use equation (3.3.12) to illustrate the DSA formulation. Its discretized version is given in Appendix A.3, since its subtle differences are not trivial. The steps that are commonly used to obtain the low order form of the transfer equation are as follows:

- i. The zeroth and first moments of (3.3.12) in angular space are taken, that is equation (3.3.12) is multiplied by the weight functions 1 and ω_m followed by an integration of the resultant equations over angular space.
- ii. I_1 is eliminated from the above two equations.
- iii. The accelerated form of the resultant equation in (ii) is obtained by resetting the index of iteration for the zeroth and first moments of the intensity (that is $1+1/2 \rightarrow 1+1$ for I_o and I_1).

The final result is

$$-\frac{\partial}{\partial x}\frac{1}{3(\sigma+\tau)}\frac{\partial}{\partial x}I_0^{l+1} + (\sigma+\tau)I_0^{l+1} = \eta\chi\int_0^{\infty}\sigma I_0^l dv + Q_0 - \frac{\partial}{\partial x}\frac{1}{3(\sigma+\tau)}Q_1 + \frac{\partial}{\partial x}\frac{2}{3(\sigma+\tau)}\frac{\partial I_2^{l+1/2}}{\partial x}$$

(3.5.02)

This is simply the diffusion equation corresponding to the transfer equation when I is linear in angle, since when I is linear in angle $I_2=0$. It is shown in the appendix (section A.2) that the spectral radius for (3.3.12) with (3.5.02) goes to zero even for those modes for which (3.3.12) with (3.4.02) has spectral radius close to unity. This apparently seems to have solved our problem, but we will see this is not so. In equation (3.5.02) the right hand side contains a coupling term; therefore, we will have to solve this equation using source iteration, as was done for the radiative transfer equation.

3.6 GREY DIFFUSION EQUATION:

A Fourier stability analysis of (3.5.02) with source iteration shows that the spectral radius can be very close to unity. Therefore, to significantly improve the convergence rate of the transfer equation (3.3.12) we must improve the spectral radius of the diffusion equation (3.5.02) by another low order equation or by some other approximation. To accelerate the rate of convergence of the diffusion equation we choose to solve a low order form of diffusion equation, namely the grey diffusion equation, to obtain the new source term for the diffusion equation.

First of all we rewrite (3.5.02) as

$$-\frac{1}{3(\sigma+\tau)}\frac{\partial^{2}}{\partial x^{2}}I_{0}^{k+\frac{1}{2}}+(\sigma+\tau)I_{0}^{k+\frac{1}{2}}=\eta\chi\int_{0}^{\infty}\sigma I_{0}^{k}dv+S$$

(3.6.01)

where S includes all the terms that do not change during the iteration of the diffusion equation. In the source iteration method we take

$$\mathbf{I}^{k+1} = \mathbf{I}^{k+1/2} \tag{3.6.02}$$

A Fourier stability analysis of (3.6;01,02) shows that the diffusion equation can have a radius of convergence that is close to unity. If for simplicity we assume that the opacity is spatially independent in the Fourier stability analysis, then the radius of convergence and the corresponding eigen function are given by

$$\omega = \eta \int_0^{\infty} \frac{3\sigma(\sigma+\tau)\chi}{\lambda^2 + 3(\sigma+\tau)^2} d\nu \qquad \Psi = \eta \frac{3\sigma(\sigma+\tau)\chi}{\lambda^2 + 3(\sigma+\tau)^2} e^{i\lambda x}$$

(3.6.03a,b)

This also shows that the slowest converging modes correspond to modes that are close to equilibrium modes. In order to accelerate the diffusion equation, we solve it by using the synthetic approach. That is, we use a grey equation as the low order equation.

The central idea behind the grey equation is to collapse the continuous energy

dependence in (3.6.01) to one energy group and design this equation such that the near equilibrium situation is treated more accurately than in the source iteration method. This new equation replaces (3.6.02). The steps involved in the derivation of the grey equation are as follows:

i. The first term in equation (3.6.01) is approximated by

$$-\frac{1}{3(\sigma+\tau)}\frac{\partial^{2}}{\partial x^{2}}I_{o}^{k+\frac{1}{2}} - \frac{1}{3(\sigma+\tau)}\frac{\partial^{2}}{\partial x^{2}}\varphi^{k+\frac{1}{2}}\hat{I}_{o}^{k+1} + \frac{1}{3(\sigma+\tau)}\frac{\partial^{2}}{\partial x^{2}}\varphi^{k+\frac{1}{2}}\hat{I}_{o}^{k+\frac{1}{2}}$$

$$-\frac{1}{3(\sigma+\tau)}\frac{\partial^{2}}{\partial x^{2}}I_{o}^{k+\frac{1}{2}}$$
and
$$I_{o}^{k} \text{ or } I_{o}^{k+\frac{1}{2}} - \theta^{k+\frac{1}{2}}\hat{I}_{o}^{k+1} - \theta^{k+\frac{1}{2}}\hat{I}_{o}^{k+\frac{1}{2}} + I_{o}^{k+\frac{1}{2}}$$

$$\hat{I}_{o}^{k+\frac{1}{2}} = \int_{o}^{\infty} \sigma I^{k+\frac{1}{2}} dv$$

(3.6.04)

An important characteristic of this transformation is that it ensures that after convergence, the left side of (3.6.04) is the same as the right side, implying that the converged solution for the source and the accelerated equation are the same. Variables θ and φ will be explained later.

ii. Integrate (3.6.01) over the frequency spectrum.

The final result is

$$\begin{split} &-\int_{0}^{\infty}\left[\frac{1}{3(\sigma+\tau)}\frac{\partial^{2}}{\partial x^{2}}\varphi^{k+\frac{1}{2}}\right]dv\ I_{0}^{k+1}+(\sigma+\tau)I_{0}^{k+1}+\tau\left(\int_{0}^{\infty}\theta^{k+\frac{1}{2}}dv\right)II_{0}^{k+1}\\ &=\eta I_{0}^{k+1}+\int_{0}^{\infty}Sdv+\int_{0}^{\infty}\left[\frac{1}{3(\sigma+\tau)}\frac{\partial^{2}}{\partial x^{2}}\left(I_{0}^{k+\frac{1}{2}}-\varphi^{k+\frac{1}{2}}I_{0}^{k+\frac{1}{2}}\right)\right]dv\\ &\quad\tau\int_{0}^{\infty}\left[I_{0}^{k+\frac{1}{2}}-\theta^{k+\frac{1}{2}}I_{0}^{k+\frac{1}{2}}\right]dv-\eta I_{0}^{k+\frac{1}{2}}+\eta\int_{0}^{\infty}\sigma I_{0}^{k+\frac{1}{2}}dv \end{split}$$

(3.6.05)

 $\theta^{k+1/2}$ and $\phi^{k+1/2}$ are defined^{3/13} such that above equation produces an exact solution without iteration when I_o corresponds to the slowest converging modes. From (3.6.03) we see that the eigenvalue and the eigenfunction corresponding to the

slowest modes are

$$\omega = \eta \int_0^{\infty} \frac{\sigma \chi}{(\sigma + \tau)} d\nu \qquad \Psi = \eta \frac{\chi}{(\sigma + \tau)} e^{i\lambda x}$$

(3.6.06)

We take the spectral functions (in normalized form) to be

$$\theta^{k+\frac{1}{2}} = \varphi^{k+\frac{1}{2}} = \frac{\frac{\chi}{(\sigma+\tau)}}{\left(\int_0^{\infty} \frac{\sigma\chi}{(\sigma+\tau)} dv\right)}$$

(3.6.07)

This choice of spectral function produces the linear grey equation. It is called linear because it leads to an additive correction. The other expressions for θ and ϕ are given by

$$\theta^{k+\frac{1}{2}} = \frac{I_o^{k+\frac{1}{2}}}{I_o^{k+\frac{1}{2}}} \qquad ; \qquad \phi^{k+\frac{1}{2}} = \frac{\left(\frac{\partial I_o^{k+\frac{1}{2}}}{\partial x}\right)}{\left(\frac{\partial I_o^{k+\frac{1}{2}}}{\partial x}\right)}$$

(3.6.08)

Here the correction term is multiplicative, hence it is nonlinear. The main difference between these methods lies in the approximation to the grey spectrum. In the linear case we take it to be the spectrum corresponding to equilibrium, while in the nonlinear case it is the latest spectrum averaged coefficient. This can be rephrased as follows: the linear case grey method is defined by collapsing the cell average flux as the spectral function, while in the nonlinear grey case it is the cell edge flux that is collapsed as the spectral function.

The solution to the radiative transfer equation involves solving the following set of equations (3.3.12), (3.5.02) and (3.6.05). Equation (3.3.12) is solved first, then equation (3.5.02) and (3.6.05) are solved. This form of iteration can be viewed as

inner and outer iteration In the inner iteration equations (3.6.05) and (3.5.02) are repeatedly solved until (3.5.02) is converged. Then equations (3.5.02) and (3.3.12) are solved until (3.3.12) is converged to the desired accuracy. When the above equations are discretized, the consistency in the discretization of the equations and their boundary conditions is crucial for a physically acceptable and stable solution. This is addressed in Appendix (A.4).

CHAPTER FOUR MODEL PROBLEM

The numerical aspects of the technique used to solve the radiative transfer equation are presented in Chapter Three. In this chapter, results are presented for the model problem that is used to test the present code. This chapter also includes a discussion of the issues which often arise with any code - issues such as fixups, stability, efficiency and the validity of the code. A comparison of the source iteration (SI) method and the diffusion synthetic acceleration (DSA) method is presented in this chapter. It will be shown later that when the DSA method is stable, it is always faster than the SI method and yields the same results. The extent to which DSA improves the spectral radius depends on different parameters, such as the time step, convergence criterion and the number of inner/outer iterations.

4.1 FIXUPS AND THE STABILITY OF THE CODE:

It often becomes necessary to incorporate fixups into codes that involve complicated equations and the DSA method is no exception. The main objective of these fixups is to suppress the appearance of nonphysical results. For example, the intensity is a physical quantity which can not be allowed to have a negative value. Therefore, it is important that some fixup should be implemented when negative intensity leads to instability.

The fixups are based on the trial and error approach and hence do not have any real theoretical justification, other than that they prevent nonphysical results from appearing in the simulations. Their presence in the code does not imply that they are used in every simulation. The important rule we have learned for a fixup strategy is that a fixup should be invoked only when the solution has become unstable not because it is becoming unstable. Every effort should be made to ensure

that the transfer equation, the diffusion equation and the grey equation are consistent at all times. A negative value may be physically unacceptable, but mathematically a negative value is as good as a positive value. Hence a negative value should not be modified unless a physically unacceptable solution is obtained or the code has become unstable. In this section we discuss some of the fixups implemented in the code.

The first fixup that is implemented is due to the spatial differencing scheme employed in differencing the radiative transfer equation in space. The Diamond differencing scheme is used to discretize the transfer equation in space, because of the ease of its implementation. Unfortunately, it can lead to a negative specific intensity, which if not corrected can destabilize the code. When a cell edge intensity becomes negative, it is taken to be zero or is set to be the average intensity of the cell. The choice depends on a parameter which is a function of the cell width and the time step (section A.3). Another important fixup which also has been included in our theoretical analysis is the incorporation of the above fixup into the diffusion equation. The Diamond Difference relationship in the diffusion equation is redefined as

$$I_{ogi}^{l+1} = \frac{1}{2} \left[a_{ogi} I_{ogi-\frac{1}{2}}^{l+1} + b_{ogi} I_{ogi+\frac{1}{2}}^{l+1} \right]$$

When a fixup is required in the transfer equation, the coefficients a_{op} and b_{op} are given as

$$a_{\rm ogi} = \frac{I_{\rm ogi}^{1+\frac{1}{2}}}{I_{\rm ogi-\frac{1}{2}}} \qquad , \qquad b_{\rm ogi} = \frac{I_{\rm ogi}^{1+\frac{1}{2}}}{I_{\rm ogi+\frac{1}{2}}}$$

Without the fixup, these coefficients are

$$a_{ogi} = b_{ogi} = 1.0$$

(4.1.01a,b,c)

The choice of these coefficients depends upon the stability of the solution rather than on some theoretical analysis. The main objective is to define these coefficients so that the diffusion matrix yields a stable solution. From equation (A.8.02), we see that the main diagonal element is not always the dominant element. This can lead to a negative solution of the diffusion equation. If a negative solution of the diffusion equation occurs too frequently, the solution for the transfer equation may become unstable or become physically unacceptable. This problem can be eliminated through the use of small time steps so that the gradient opacity is small. One can also modify the algorithm^{4/1} to ensure that the main diagonal element is always dominant, but this modification leads so slower acceleration of the diffusion equation.

In simulations it was observed that when the negative flux fixup is implemented, $I_{ogi=1/2}$ can become zero causing a floating point error in (4.1.01b) when a_{ogi} and b_{ogi} are computed. In order to prevent a floating point error, we take $a_{ogi} = b_{ogi} = 1.0$ whenever $I_{ogi=1/2}$ is zero.

Many switches are added into the code to ensure its stability and to prevent the code from consuming an excessive amount of time on iterations which are extremely slow to converge or start to diverge. If the diffusion equation yields a spectral radius greater than or close to 1.0, then the code automatically resorts to SI for that iteration when switch AUTACC=1. If it occurs too often, then the calculation is terminated. A similar type of switch is included to prevent the grey equation from yielding an unrealistic solution. If the solution of the diffusion or the grey equation becomes unstable too often then the calculation is again terminated. In the event that the integration is not achieved within the required precision or the resultant matrix is ill behaved, then the program is again terminated. The code has been written such that the error messages are written into a file named "analysis" for instabilities which do not cause termination. Error messages appear on the screen for those instabilities which require user input to continue or that require termination of the code. These switches improve the efficiency of the code but do not ensure DSA stability when large time step is used, as was expected in the beginning of the

study.

4.2 THEORETICAL ASPECTS OF THE MODEL PROBLEM:

Often a code is tested against a bench mark problem, before it is used to simulate real problems. The problem we use to test the code is the well known Marshak Wave bench mark^{4/2}. This is the same model problem used by Alcouffe et al^{4/3} and Velarde et al^{4/4} to test their codes. Here a strong source (acting as a laser beam) is placed at one end of the plasma. The temperature (which is changing due to the propagation of the radiation) is computed as a function of space and time. In this section the equations involved in the formulation of the model problem are presented.

We start our formulation from equations (3.3.01;02;3a) derived in Chapter Three. These equation are repeated here for convenience

$$\frac{1}{c}\frac{\partial I}{\partial t}(x,\mu,\nu,t) + \mu \frac{\partial I}{\partial x}(x,\mu,\nu,t) + \sigma(\nu,T)I(x,\mu,\nu,t) = S(\nu,T) = \sigma(\nu,T)B(\nu,T)$$

$$\frac{\partial u_e(T)}{\partial t} = \beta(T) \left[\int_0^{\infty} \sigma(\dot{\nu},T)I_0(x,\dot{\nu},t)d\dot{\nu} - c\sigma_p(T)u_e(T) + S_{ext} \right]$$

$$u_e(T) = \frac{c}{4\pi} \int_0^{\infty} B(T,\dot{\nu}) d\dot{\nu}$$

(4.2.01;02;03)

For the model problem, we assume that a local thermodynamic equilibrium (LTE) exists in the plasma. In LTE, it is assumed that properties of the matter are dominated by atomic collisions which establish thermodynamic equilibrium locally at a position x and at time t, and that the radiation field does not affect this equilibrium even when it deviates substantially from the Planckian distribution. That is, at a given instant of time and point in space it is sufficient to specify two thermodynamic quantities, such as the temperature and density in order to compute the source term $S(=\sigma B)$ and the absorption coefficient σ . With the LTE assumption, B becomes the Planckian function and the transfer equation reduces to

$$\frac{1}{c}\frac{\partial I}{\partial t} + \mu \frac{\partial I}{\partial x} = \sigma(B - I)$$

$$\frac{\partial u_e}{\partial t} = \beta \left[\int_0^{\infty} \int_{-1}^1 \sigma I \ d\mu d\nu - c\sigma_p u_e \right]$$

$$u_e = \frac{c}{4\pi} \int_0^{\infty} B \ d\nu = aT^4$$

(4.2.04;05;06)

where σ and B are defined as

$$\sigma = a_1 \frac{[1 - e^{-a_0 v}]}{v^3} \qquad B = \frac{2hv^3}{c^2} [e^{a_0 v} - 1]^{-1}$$
where $a_0 = \frac{h}{KT}$ and $a_1 = 3.8171E55 \ m^{-1}$

(4.2.07)

where T is the material temperature, a (=7.560667E-16 Jm⁻³K⁻⁴) is the Stefan Boltzmann constant, h (=6.626E-34 Js) is the Planckian constant, k (1.3807E-23 JK⁻¹) is the Boltzmann constant. When equation (4.2.04) is discretized in frequency (Chapter Three) it reduces to

$$\mu \frac{\partial I_g}{\partial x} + (\sigma_g + \tau)I_g = \frac{\chi_g \eta}{2} \Sigma_g \sigma_g I_{0g} + Q_g$$

(4.2.08)

For the model problem, the initial intensity in the summation term on the right hand side of the above equation is taken to be Planckian and the absorption coefficient is computed as

$$\sigma_g = \frac{\int_{v_i}^{v_b} \sigma \omega \ dv}{\int_{v_i}^{v_b} \omega \ dv}$$

(4.2.09)

where $\omega(\upsilon)$ is the weight function corresponding to the intensity at that moment. Since this is unknown an approximation is usually made. The choice of this function

is somewhat arbitrary. The weight functions which we have included in the code are known as Planckian and Rossland Mean functions. These functions are given by^{4/5}

$$\omega(v) = B(v) \qquad Planckian$$

$$\omega(v) = \frac{1}{\sigma(v)} \frac{\partial B(v)}{\partial T} \qquad Rossland$$

(4.2.10a,b)

Their justification is based on the following argument^{4/5}. The Planckian function B is a good approximation at thermodynamic equilibrium since the specific intensity is given by a Planckian function, and away from equilibrium the choice of the weight function is of less importance. The Rossland function is a good approximation since the specific intensity can be approximated by the equilibrium diffusion approximation. The choice of these functions becomes less significant if a large number of frequency groups are used.

The Romberg integration approach is used to integrate these functions. Lower-Upper decomposition is implemented to invert the matrices in both the diffusion and the grey equations.

4.3 SIMULATIONS OF THE MODEL PROBLEM:

The main objectives of this section are to test the code against a bench mark problem and make comparison between the two approaches used to solve the transfer equation, namely the Source Iteration (SI) and Diffusion Synthetic Acceleration (DSA) methods. The SI method always yields a stable solution irrespective of the time step involved. The DSA becomes unstable for large time steps, but when it works, it is more efficient than SI and yields the same results as the SI methods.

The model problem we used to test the code involves a slab at uniform temperature with a source at one end. The source is placed at the left boundary and it is assumed to be Planckian. This choice for a source resembles a laser beam incident on a foil. It is assumed that the specific heat of the plasma is constant

during the simulation, that is it is independent of the temperature. The convergence criterion is set to be

$$\left[\frac{I^{n+1}}{I^n} - 1\right] \le 10^{-2} \qquad \left[\frac{T^{n+1}}{T^n} - 1\right] \le 10^{-3}$$

This simply states that the specific intensity of the transfer equation is considered to have been converged when the error between two consecutive solutions is less than 1%. A similar convergence criterion is used for the temperature but a convergence criteria of 0.1% is used instead of 1.0%. If the time step is large (such as in nano seconds) then tighter convergence is essential. Once the intensity has converged we use the so called "parametric iteration" to update the temperature. In parametric iteration we use the new temperature (obtained after solving the energy balance equation) to compute the variables (such as σ and χ) that should have been computed at the advanced time step. This is repeated until the temperature is converged to the desired accuracy. The data set used for the standard model problem is

number of cells (uniform)	20
number of frequency groups	30
number of discretized angles	80

specific heat per unit volume 7.00E+04 JK⁻¹m⁻³

source temperature 1000 ev initial slab temperature 1 ev slab width 0.2 m

frequency range 1.00E-01-1.00E+04 ev

Additional parameters will be mentioned when appropriate.

Many runs were made to explore the performance of the DSA method. In the remainder of this section, we will discuss important aspects related to the efficiency of the code. We have observed that when very small time steps are used (e.g fraction of a picosecond) the DSA method is not very efficient compared to the SI method. When time steps are small, it is more efficient to use the Source Iteration

method, because the time taken to solve the diffusion and grey equation out weighs the efficiency of the DSA method over the SI method. The efficiency of the DSA method improves as we increase the time step. In our simulations, the maximum time step allowed for a stable DSA solution is about 100.0 picoseconds for the model problem. The efficiency of DSA relative to SI depends on the convergence criteria. A tighter convergence criteria with the DSA method results in a small increase in computer time but it significantly increases with the SI method. It is observed that if the number of inner iterations (number of diffusion equations per transfer equation) is not bounded, then not only the efficiency drops but also this can destabilize the code. It is observed that if inner iterations are bounded by 10 then DSA is more efficient and stable compared to when the number of inner iterations is allowed to be unlimited. The solution of the diffusion equation without the grey equation very often increases the computer time for a given simulation (even though it improves the spectral radius) due to slow convergence rate of the SI. However, the time is substantially reduced when the diffusion equation is solved using the grey equation.

Therefore, in order to optimize the efficiency of the code, it is important that the diffusion equation is solved with the grey equation and that a bound is placed on the inner iterations. The remainder of this section includes a graphical representation and a discussion of the following topics:

- i. A comparison between DSA and SI.
- ii. Planckian vs Rossland weight functions.
- iii. Use of exponential temperature as the initial temperature (instead of being uniform).
- iv. Effect of varying the number of cells, number of frequency groups and number of discretized angles.
- v. Marshak Wave Bench Mark

The source code is in a file name "sate.f" (a listing can be found in the appendix) and the input file is called "sate.data" and is given below.

satedata

ENTER 1 FOR RUNS WITH DIFFERENT TIME STEPS OTHERWISE 0	00
ENTER SCR NUM DBXL DBXU TCONT	00 02 0000 9999 01
ENTER T OR F FOR SIMULATIONS OF THE MODEL PROBLEM (SIMRUN)	F
ENTER *0* IF SOURCE IS TO BE DEPENDENT ON TIME (TEMPTD)	01
ENTER *0" IF INITIAL TEMPERATURE DISTRIBUTION IS EXP (TEMEXP)	01
ENTER *0" IF ALWAYS USE NFF (NFMUST)	01
ENTER *0 TO 20* FOR OUTPUT TO BE PRINTED (PRES)	00
ENTER BOUND FOR TRANSPORT AND DIFFUSION EQU (TB DB)	9999 999
ENTER "0" IF (INTB=0) "1" IF (INTB=PINB) "2" IF USE MTSP (NFFC)	02
ENTER IERR AND TERR AND SIER	1.00E-02 2.50E-01 1.00E-02
ENTER # OF OIT AFTER WHICH NEGATIVE FLUX IS ALWAYS USED (INSB)	999999
ENTER ABSORPTION COEFFICIENT 1E? (? = 6 TO 11) (AC)	1.00E+11
ENTER *0 TO 2* FOR CONVERGENCE CRITERION BEST IS *1* (CONVC)	01
ENTER "0" IF INITIAL INTENSITY TO BE PLANCKIAN EACH TIME (TRIN)	01
ENTER "0" IF UNIFORM SPATIAL DISTRIBUTION IS TO BE USED (USC)	00
ENTER TIME INTERVAL AT WHICH TEMPERATURE IS TO SAVED (PRTME)	1.00E-09
ENTER *0 OR 1* DIFFUSION BC (DIFBC)	00
ENTER *0 TO 2* TO OVERCOME NEGATIVE DIFFUSION INTENSITY (NDIT)	03
ENTER MAXIMUM TIME FOR SIMULATION (MAXT)	1.01E-07
ENTER M < 9 G < 61 N < 151	008 030 020
ENTER L LFL UFL TELB ITRB ITSL	
2.00E-01 1.00E+01 1.00E+03 2.00E-02 1.00E+01 1.00E-00	
ENTER *0* IF PLANCKIAN IS TO BE USED AS A WEIGHT (WFN)	00
ENTER SPECIFIC HEAT (SPH)	7.00E+04
ENTER DTIME	1.00E-12
ENTER "0" IF NEGATIVE FLUX FIX UP IS TO BE IMPLEMENTED (NF)	00
ENTER NUMBER OF TEMPERATURE ITERATIONS ALLOWED (TITA)	9999
ENTER NUMBER OF OUTER ITERATIONS ALLOWED (OITA)	999992
ENTER "0" FOR LOWER LIMITS OTHERWISE "1" (SETLIM)	00
ENTER "0" FOR SOURCE = 0 AT RIGHT "1" FOR BOTH ENDS (SETSOU)	02
ENTER "1" IF NEG. FLUX TAKEN IT'S ABSOLUTE VALUE (ABVL)	00
ENTER "1" IF CODE TO BE EXECUTED WITH MEDUSA (MEDUSA)	01
ENTER "1" IF ACCELERATION IS AUTOMATIC (AUTACL)	00 5.00E-01
ENTER "0" IF TRANSPORT EQUATION IS TO BE SOLVED BY SI (TRNACC)	00
ENTER "1" IF DIFFUSION EQUATION IS TO BE ACCELERATED (DIFACC)	02
ENTER "0" FOR LINEAR GREY MODEL OR "1" FOR NONLINEAR (LIN)	00

Figure 4.1 a, b

When finer cells are used the computational time increases significantly, while the solution for the temperature remains very much the same. An increase in the temperature at the left end implies that the closer we move to the left (by making cells more finer), a higher temperature is obtained at the left end of the slab until it reaches the maximum value at the boundary (the value of the source). The difference in temperature can be reduced if a tighter temperature convergence criterion is used in both cases. A decrease in the number of cells has a more noticeable change in the temperature profile than when the number of cells is increased. The difference in the temperature with 50 cells compared to 20 cells (Fig. 4.1a) is relatively small while the computational time is significantly increased. The use of 10 cells (Fig. 4.1b) on the other hand shows a significant difference compared to 20 cells. Therefore, use of 20 cells is sufficient to yield an accurate description of the temperature in the slab for this case.

Figure 4.2 a, b

In the standard model problem 30 frequency groups are used. From Fig. 4.2a, it can be seen that increasing the number of frequency groups has no effect on the temperature profile that is observable. However, if the number of groups (Fig. 4.2b) is decreased then a significant change in the temperature profile is observed. Therefore, 30 frequency groups are sufficient in our simulations of the model problem.

Figure 4.3 a, b

Here it is shown that when the number of discretized angles is reduced (Fig. 4.3) then the entire temperature profile is shifted upward. We did not observe any significant significant change in the temperature profile (Fig. 4.3b) when number of discretized angles is increased to 16. Therefore, we think 8 discretized angles is sufficient to take into consideration the angular dependence of the intensity.

Figure 4.4

This graph represent the Marshak Wave Bench Mark with the present code. The profiles shown here are not exactly as reported by Alcouffe or Honrubia, this is because different weight function profiles are used for the absorption coefficient. This implies that the rate of change of temperature will be different; however we expect that the equilibrium profiles should be very much the same. This is true for all of the results reported by Alcouffe and Honrubia and reported here.

Figure 4.5

Here a comparison of SI and DSA is presented. This graph shows that the accelerated and non accelerated solution are the same. We have observed this consistency for all cases. In this graph a comparison between the linear and nonlinear grey models is also presented. We observed that the linear grey model performs better than the nonlinear model. The comparison of SI and DSA is shown below

	# of transfer equ.	# of diffusion equ	# parametric iteration
SI	1432	0	63
DSA(linear)	148	578	26
DSA(nonline	ar) 148	1893	27

Our present code is not as stable as was expected. There appears to be a discrepancy in our derivation which we have not been able to resolve. The boundary conditions used for the grey equation in the code are the best in a sense that they yield the same result while allowing the use of a larger time step. The cause of this instability will require further investigation in the future. From our experience we think the inconsistency exists between the grey and the diffusion equation boundary conditions.

Figure 4.6 a, b

This graph reflects the effect of the weight functions used for evaluating the absorption coefficient. In Fig. 4.6a the number of groups is 30 and in Fig. 4.6b the

number of groups is 60. This shows that different choice of weight functions can lead to different temperature profiles. This graph also shows that as the number of groups is increased the choice of the weight function becomes less crucial. This conclusion is difficult to corroborate or disapprove because neither Alcouffe nor Honrubia has discussed the choice of the weight functions in their publications.

Figure 4.1 a

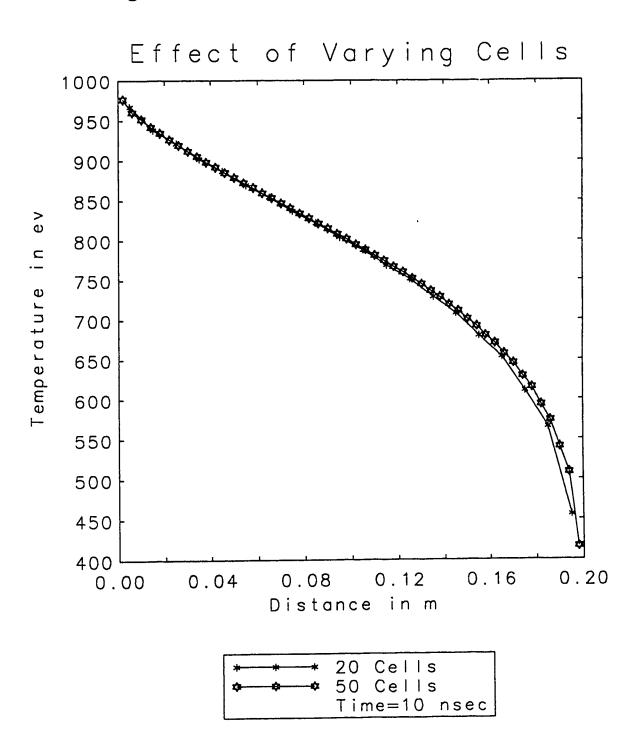


Figure 4.1 b

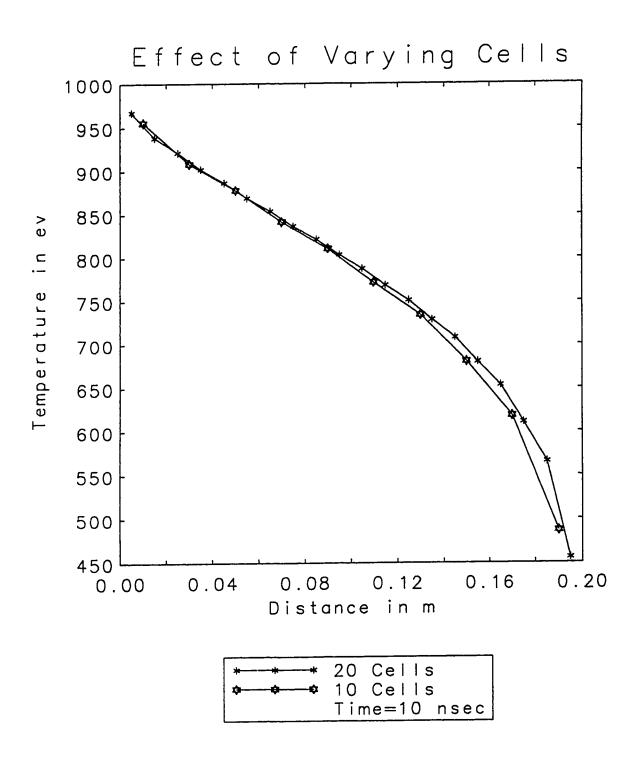


Figure 4.2 a

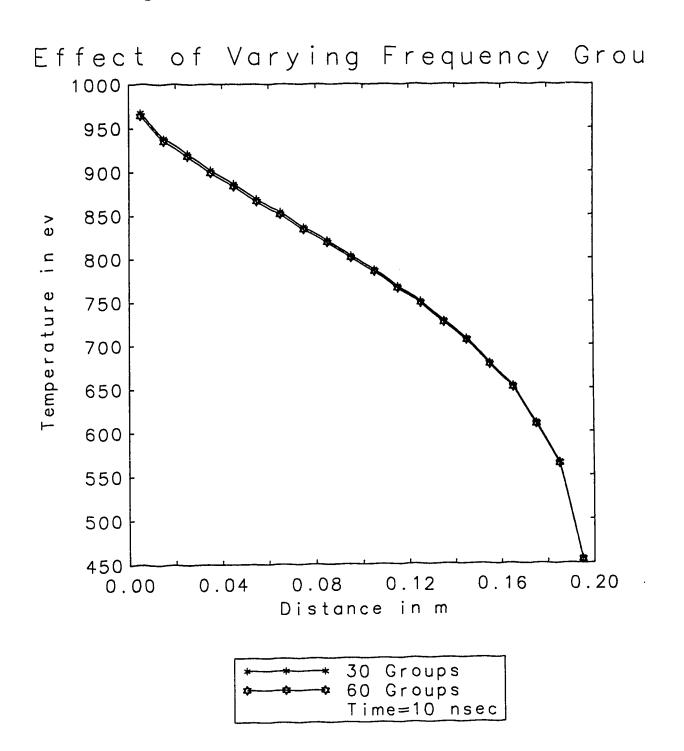


Figure 4.2 b

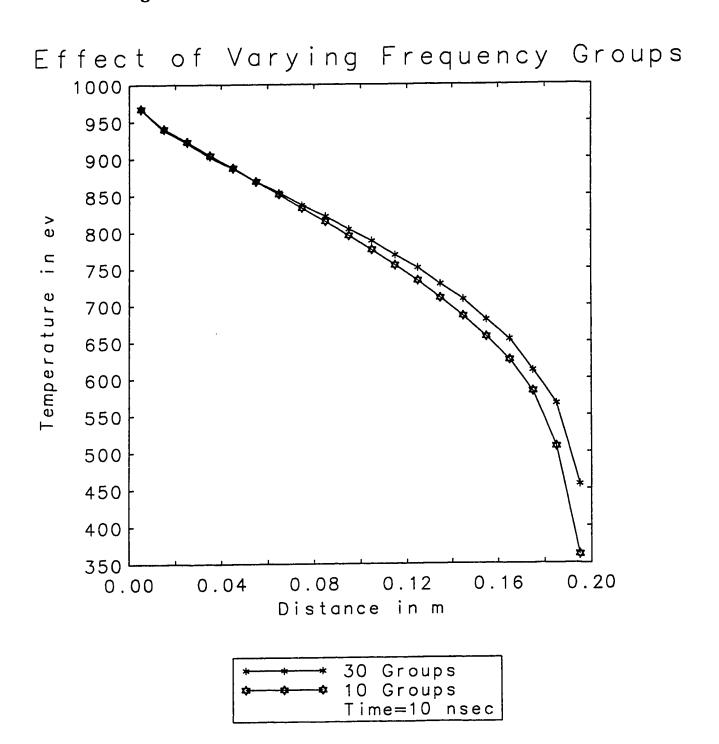


Figure 4.3 a

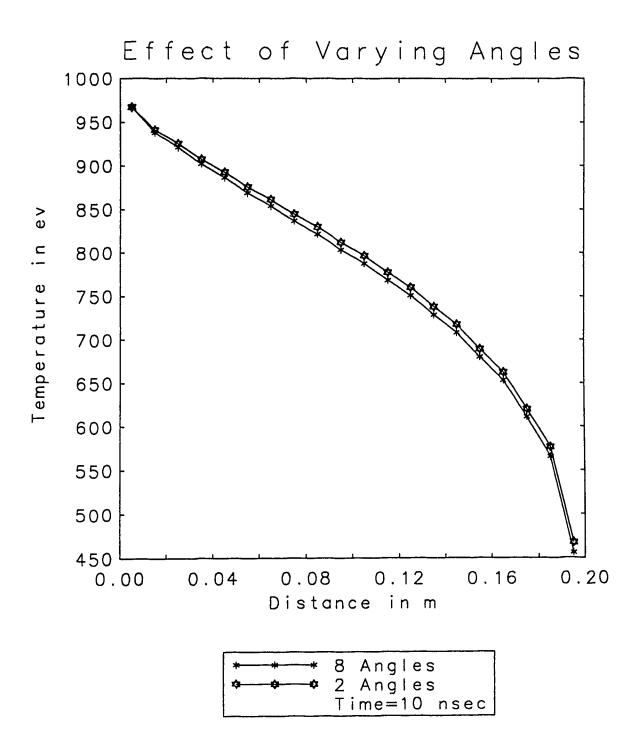


Figure 4.3 b

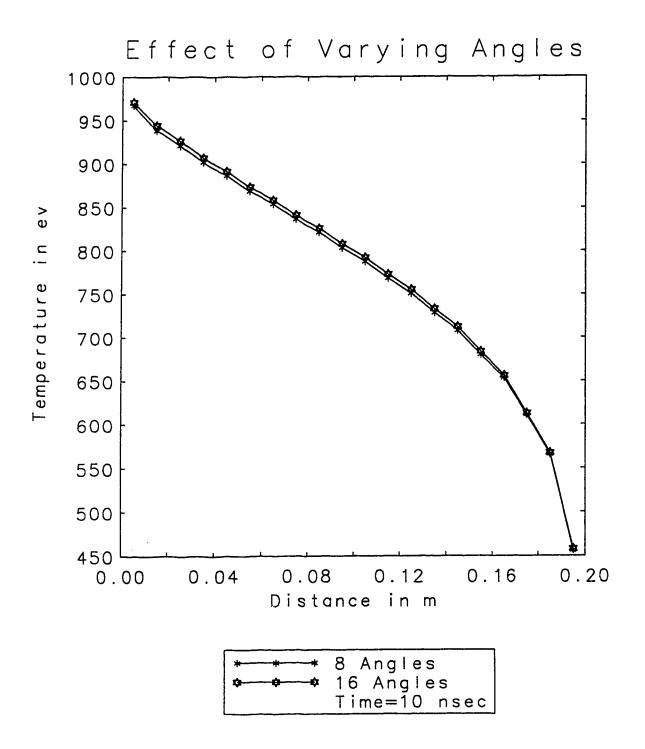


Figure 4.4

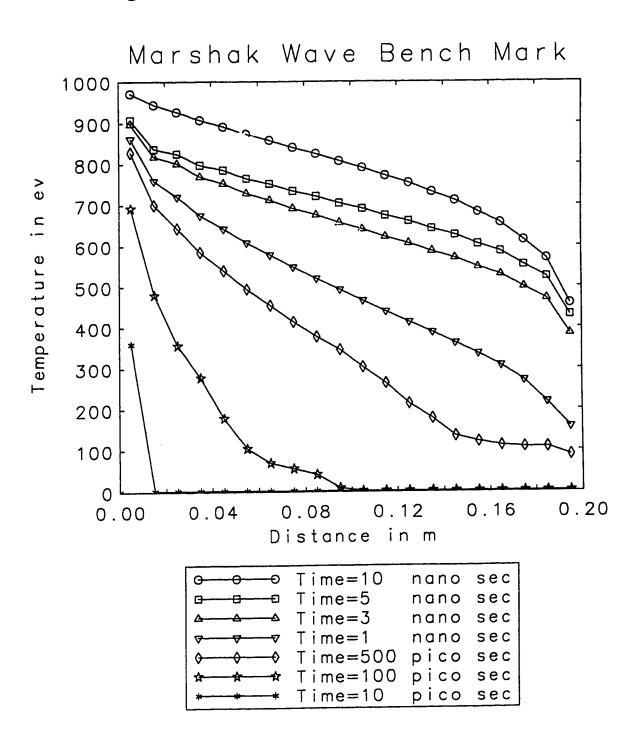


Figure 4.5

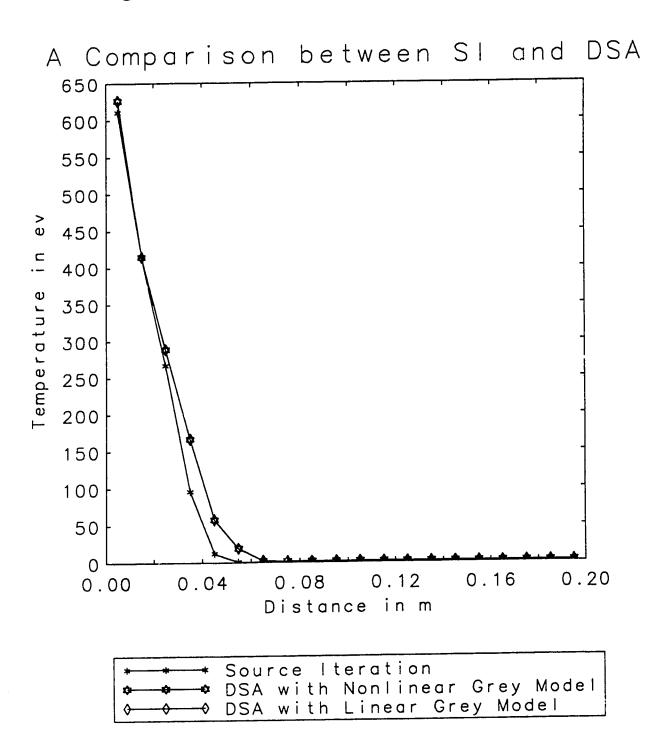
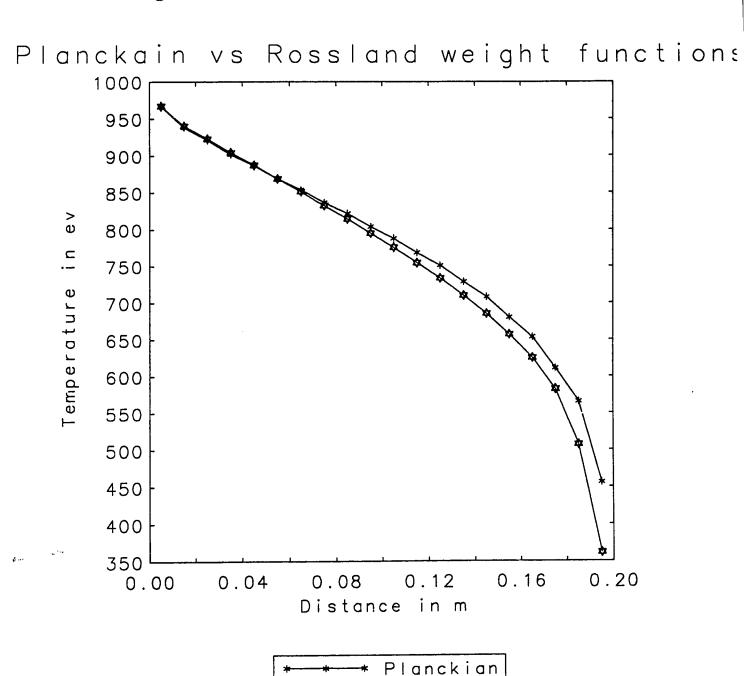
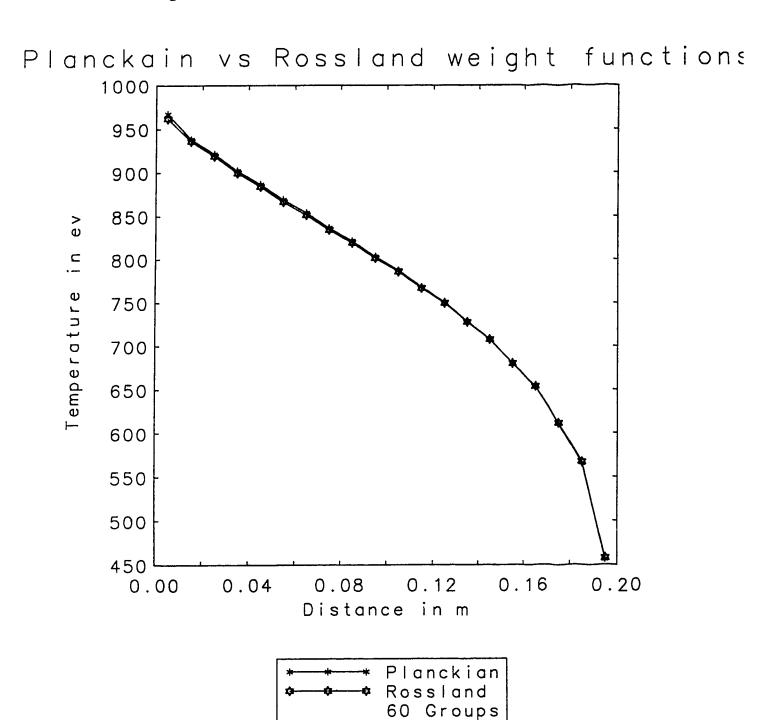


Figure 4.6 a



Rossland 30 Groups

Figure 4.6 b



CHAPTER FIVE MEDUSA SIMULATIONS

The objective of our research has been to study the nature and extent of the effects of radiation in laser produced plasma. We will show through simulations that the radiation plays an important role in the transport of heat in laser produced plasmas. The extent to which radiation affects the hydrodynamics of a plasma very much depends on the time profile and intensity of the laser beam to name few. An exclusion of radiative effects can lead to an erroneous estimate of radiation transported or loss of energy from a plasma. Although the inclusion of radiation transport into a hydrodynamic code is an arduous task, it is important because it gives a more accurate representation of the laser plasma interaction. This chapter has been divided into the following sections:

- i. Introduction to MEDUSA
- iii. Integration of the radiation code into MEDUSA
- iii. Simulations using MEDUSA

This chapter will conclude the objective of our thesis. An extensive appendix is included at the end. The appendix includes the derivation of all of the equations used in the code "sate.f".

5.1 INTRODUCTION TO MEDUSA:

In the mid 1970's a computer code named MEDUSA was written to simulate the laser fusion process. It was written for a one dimensional geometry in order to investigate the hydrodynamics and thermodynamics which take place in a small pellet. MEDUSA was refined later to accurately describe the interaction of laser light with a plasma. The MEDUSA code in its present form differs from the original due to modifications and additions made to it at University of Alberta. The present

version of MEDUSA gives a more realistic simulation compared to the original one. New features included are:

- i. A modified equation of state, which is valid at low temperatures and near solid density.
- ii. A simultaneous solution of electron and ion diffusion and equilibration equations.
- iii. A calculation of the local ionization and x-ray emission from a radiative equilibrium model.
- iv. Addition of the radiation transport.

In this section a brief summary of the equations solved by MEDUSA are outlined, more details can be found elsewhere^{5/1}.

5.1.1 PHYSICAL MODEL:

In MEDUSA, the plasma is assumed to consist of a charge-neutral mixture of electrons and various species of ions (a collective term for atoms, ions and molecules). Thermodynamically, the electrons and ions are treated as two subsystems, each with its own internal energy, temperature and pressure. The two subsystems are coupled via a common velocity which ensures neutrality of the mixture. The exchange of energy is due to electron-ion and electron-atom collisions. Electric fields are ignored. The instantaneous local chemical composition is described by a set of fractions \mathbf{f}_k such that

$$n_k = f_k n_i$$

where f_k is subject to Σ $f_k = 1$, and n_k is the ion density of the kth species. The electron density changes with time due to hydrodynamic expansion and contraction of the moving fluid. The electron and ion densities are related by

$$n_i = n_e / Z m^{-3}$$

where Z is the atomic charge of the matter. The physical density is given as

$$\rho = n_i M m_H \quad Kg m^{-3}$$

where M is the atomic mass (the electron mass is ignored), m_{H} is the hydrogen mass. The average mass and charge is calculated from

$$M = \sum f_k M_k$$
 and $Z = \sum f_k Z_k$

5.1.2 ENERGY EQUATION:

The energy equation is given as

$$C_{\nu} \frac{dT}{dt} + B_{T} \frac{d\rho}{dt} + P \frac{dV}{dt} = S$$
 Jkg^{-1}

where S is the rate per unit mass at which energy enters each system. This is given by the following expressions for electrons and ions

$$S_e = H_e + K + J + X + Y_e$$

$$S_i = H_i - K + Q + Y_i$$

where H: heat flow due to thermal conduction

K: rate of energy exchange between the electron and ion fluids.

J: rate of Bremsstrahlung emission

X: rate of absorption of laser light

Q: rate of viscous shock heating

Y: rate of nuclear energy released (it is switched off in our simulations, since it is irrelevant to our research)

and P is the pressure and C, and B_r are given as

$$C_{\mathbf{y}} = \left(\frac{\partial U}{\partial T}\right)_{\mathbf{p}} \qquad B_{\mathbf{T}} = \left(\frac{\partial U}{\partial \rho}\right)_{\mathbf{T}}$$

5.1.3 HEAT CONDUCTION:

The heat conduction is assumed to be classical and is given as

$$H=\frac{1}{\rho}\nabla\chi\nabla T$$

where the thermal conductivity χ for electrons and ions is

$$\chi_{e} = \frac{1.83E - 10T_{e}^{\frac{5}{2}}}{\log \Lambda Z \overline{Z}^{2}} \qquad W/m \quad K$$

$$\chi_{l} = \frac{4.3E - 12T_{l}^{\frac{5}{2}}}{\log \Lambda \sqrt{M} Z^{\frac{5}{2}} \overline{Z}^{2}} \qquad W/m \quad K$$

$$\Lambda = \frac{1.24E06T_{e}^{\frac{3}{2}} n_{e}}{\sqrt{n_{e}} Z}$$

where Λ is the coulomb logarithm.

5.1.4 ENERGY EXCHANGE:

The exchange of energy between electrons and ions occurs at the rate of

$$\omega = \frac{Z^2 e^4 n \log \Lambda \sqrt{m_o} (kT_o)^{\frac{3}{2}}}{M32\sqrt{2\pi} \epsilon_o^2 m_H}$$
the K term in the energy equation is
$$K = \frac{1}{\rho} \omega n_o k(T_i - T_o)$$

5.1.5 ENERGY EMITTED:

When radiation transport is not included, all of the radiation emitted from the plasma is taken to be via Bremsstrahlung emission by electrons and this emission is treated as a total loss. For a Maxwellian distribution it is given as

$$J = -8.5E - 14 \frac{n_{e}\sqrt{T_{e}Z^{2}}}{M}$$
 WKg⁻¹

5.1.6 ENERGY ABSORBED:

The absorption is assumed to occur via inverse Bremsstrahlung at a density ρ below critical density ρ_c , where ρ_c is given as

$$\rho_c = \frac{\epsilon_o \ M \ m_H \ m_e}{Ze^2} \omega_L^2$$

At $\rho = \rho_c$ the remaining power is deposited in the next adjacent cell and reflection of the laser intensity is neglected. The absorption coefficient is given as

$$\alpha = 13.51 \beta^2 \frac{(5.05 + \log \lambda T_e) Z^{\frac{7}{2}}}{\lambda^2 \sqrt{1 - \beta} T_e^{\frac{3}{2}}} \qquad m^{-1}$$
where β is
$$\beta = \frac{\rho}{\rho_c}$$

If the initial laser intensity is P_o at $r = R_o$, then the power at r is given by

$$P=P_{\bullet}e^{\alpha(R_{\bullet}-r)}$$

5.1.7 MOTION OF THE PLASMA:

The motion of the plasma is governed by the Navier-Stokes equation

$$\rho \frac{du}{dt} = -\nabla P$$

where u is the velocity of the plasma and P is the total pressure, $P = P_i + P_e$.

5.1.8 EQUATION OF STATE:

The equation of state assumes that ions behave as a non-degenerate perfect gas, while electrons behave as being degenerate, non-degenerate or partially degenerate. The most recent EOS package gives a more accurate description of a metal at low temperatures and coincides with the EOS of the original MEDUSA at high temperatures. It is invoked by setting NLOM2(6)=.TRUE., NLOM2(7)=.TRUE. and STATE=-1 (for aluminum).

5.1.9 DIFFERENCING SCHEMES:

The cell edges are free to move, thereby altering the volume of the cell. The

quantities at the centre are obtained by averaging the values at the cell edges. A finite differencing scheme is used to discretize the equations shown above. The cell width varies such that the mass of the cell remains constant during the simulations, since thermonuclear burning is turned off.

5.1.10 TIME DIFFERENCING AND TIME STEP CONTROL:

MEDUSA uses a five level scheme. Levels 1,3,5 correspond to the time step n-1,n,n+1 respectively and levels 2,4 correspond to the time between n-1 & n and n & n+1. If we let r, ρ , $T_{e,i}$, to be the cell coordinate, mass density and temperature (electron and ion) respectively then with known values for $(r, \rho, T_{e,i})^{n-1}$ and $u^{n-1/2}$ $(r, \rho)^n$ we determine T^n , $u^{n+1/2}$, $(r, \rho)^{n+1}$. All basic quantities are thereby advanced one step in time. Due to the non-linearity of the $T_{e,i}$ in the energy equation, this equation is solved by iteration.

Since the temperature equations are solved implicitly, the solution for the temperature is stable for all time steps. However, the time step should be chosen carefully in order to obtain results within a desirable accuracy. The maximum value of Δt is restricted by the Courant-Friedrichs-Lewy conditions and is given as

$$\Delta t^{n+\frac{1}{2}} < \frac{a_1 Min(r_{j+1}^n - r_j^n)}{c_n}$$

The time step is also constrained by the maximum variation allowed in the hydrodynamic velocity and in the ion and electron temperatures.

5.1.11 LASER PROFILE:

In our simulations we use two types of laser beam time profiles. These are gaussian and trapezoid profiles. The maximum power attributed to a given beam ranges from 10¹⁶ Wm⁻² to 10¹⁸ Wm⁻². A detailed description of laser characteristics is given wherever they are used in the simulations sections.

5.2 INTEGRATION OF DSA CODE IN MEDUSA:

The atomic physics tables developed by Lee^{5/2} contain the emissivity and the microscopic cross-section area at a given temperature and ion density. These quantities are in MKS units, watts/ion and m², respectively. For the transfer equation we need the absorption coefficient and the initial intensity. In order to find the relation between given variables and required variables, consider the radiative transfer equation and the energy balance equation

$$\mu \frac{\partial I}{\partial x} + (\sigma + \tau)I = S = \sigma B$$

$$u_e^{n+1} = \frac{\eta}{c\sigma_p^*} \left[\int_0^{\infty} \sigma^* I_0 dv + \frac{u_e^n}{\Delta t \beta^*} \right]$$
where
$$\beta = \frac{4aT^3}{c_v}$$

(5.2.01)

where I is the specific intensity in W m^{-2} , σ is the absorption coefficient in m^{-1} , S is the rate of energy emission due to spontaneous processes, c, is the specific heat per unit volume and c is the speed of light in m/sec and B is the specific intensity.

A careful analysis shows that one can relate the emissivity and the microscopic cross-section area to the specific intensity and absorption coefficient as

$$B = \frac{N_i P \Delta x}{4\pi} \quad and \quad \sigma = N_i A_x$$

(5.2.02)

where

P: is the rate of energy emitted W/ion

A_x: is the microscopic cross-sectional area in m²

N_i: is the ion density per unit volume

The values of the emissivity and cross-section area are obtained through interpolation at a given temperature and density by calling subroutine DINTRP. If the temperature is less than 10 ev then the emissivity is taken to be Planckian, and

the cross-sectional area is obtained by calling the function named CIGMA. When CIGMA is called to obtain the absorption coefficient σ , then

$$\sigma = \frac{M \dot{A}_x}{N_A}$$

(5.2.03)

where A'_x is obtained from CIGMA, N_A is the Avogadro number, and M is the atomic mass. The specific heat is obtained from the EOS subroutine, and is given as

$$c_{\nu} = \rho_3 \frac{[c_{\nu i} + c_{\nu \nu}]}{10.0}$$

(5.2.04)

Where ρ_3 corresponds to mass density at time step 3 and c_m and c_m are the specific heats obtained from EOS at time level 3.

The emitted power is defined as the power loss per unit mass from the plasma; therefore, it is proportional to the difference in the intensity at the adjacent cell boundaries obtained after solving the transfer equation at time level 3. This can be expressed as

$$BREMS_{l} = \frac{2\pi}{\Delta m_{l}} \sum_{g} A_{xg} \left[\sum_{m} \left(I_{mgl}, \frac{1}{2} - I_{mgl}, \frac{1}{2} \right) \omega_{m} \right]$$
(5.2.05)

The present radiation code is invoked by setting SAHA=3.1. In all of the simulations the foil is taken to be aluminium and the flux limiter is taken to be 0.25. Variables such as temperature, pressure, velocity, average Z and mass density as a function of space are stored into file named "out". Quantities such as the ablation pressure, ablated mass, average Z, thermal and kinetic energy and emission to the left and right end of the plasma, as a function of time are stored into "abl.out". The ablated mass is defined as the mass contained between the outside cell and the last cell in the plasma in which an outward velocity is obtained. The ablation pressure

is defined as the pressure of the cell embodied in the ablative surface. The option of a trapezoid time profile for the laser beam has been added. This can be invoked by setting GAUSS =-2.0, PLENTH="rise time (assumed to be same as fall time)". The input file for MEDUSA is "mds.in" and it is given below, this will allow another user to reproduce the results presented here without any uncertainty in the initial conditions that are used. Important variables are bolded.

F0000000 0 1

ENERGY: 1.00 JOULES FOCAL SPOT DIA: 70 MICRONS

TARGET: ALUMINUM 2.0 NS PULSE

	=======================================	
&NEWRUN		
AK0 = 0.10,	AK1 = 0.10,	AK2 = 0.10,
AK3=0.10,	AK4 = 0.10	AK5 = 0.00,
ANABS = 1.0,	ANPULS = 1.0,	
BNEUM = 2.0,	,	
DTEMAX=0.1,	DTIMAX = 0.1,	DUMAX = 0.1,
DTPRNT = 2.5D-10,	DELTAT = 1.0D-12,	DRGLAS=0.0,
DRPLAS=0.0,	DEUTER=0.0	·
FHOT=0.0,	FTHOT=0.0,	FLIMIT = 1.00,
FNE = 1.0,		
GAUSS = -2.0,	GAMMAE=1.66666667,	GAMMAI=1.66666667,
HELIU3=0.0,	HELIU4=0.0,	HYDROG=0.0,
LAMDA1 = 2.48D-06,		
MESH = 40	MXDUMP = 10,	
NITMAX = 50,	NCASE=1,	NRUN=99999,
NLABS=.TRUE.,		NLBURN=.FALSE.,
NLCRI1=.TRUE.,	NLBRMS=.TRUE.,	NLITE=.TRUE.,
NLDEPO=.FALSE.,	NLDUMP=.FALSE.,	NLFUSE = .FALSE.,
NREP=0,	NTRLMS=0.0,	NSLEDG = 9999,
NDUMP=10,	NETRAL=0.0,	NFILM = 1,
NGROUP=5	NHDCPY=100,	NIN=5,
NLCHED = .FALSE.,	NLEDGE=10,	NLEMP=.TRUE.,
NLFILM=.TRUE.,	NLHCPY=.FALSE.,	NLPRNT=.TRUE.,
NLREPT=.FALSE.,	NONLIN=1,	NSHELL=150,
NP1=1,	NP2=40,	NP3=1,
NPRNT = 50000,	NGEOM=1,	NREP=0,
NLECON=.TRUE.,	NLICON=.TRUE.,	NLOMT2(11)=.TRUE.,
NLPFE = .FALSE.,	NLPFI=.TRUE.,	NLX=.TRUE.,
NLOMT2(6) = .TRUE.,	NLOMT2(7) = .TRUE.,	
OUTAMI=1.0,		
PIQ(55) = 2.0,	PONDF = -1.0	PLENTH = 1.0D-10,
PMULT=2.0,	PMAX = 3.16D + 17,	
QSHELL(1)=0.97,	·	
RINI=1.0D-04,	ROGLAS=0.0,	ROPLAS=0.0,
RHOGAS = 2700.0,	RHOINI = 2700.0,	RSHELL=1.0D-04,
RHOT=0.0	•	
SAHA=3.1,	STATE = -1.0,	SIMULT=1.0,
SCR = 1.0,	SCRHO=1.0,	SCTE=1.0,
SCTI=1.0,	SCTIME = 1.0,	SCP=1.0,
TEINI = 3.0D02,	TIINI = 3.0D02,	TINUCL=1.0D+07,
TRITIU = 0.0,	TON=0.0,	TOFF=3.9D-09,
TSTOP = 5.0D-09	·	
XMASS=26.9815,	XTRA=1.0,	XZ=13.0,
ZGLAS=0.0,	ZPLAS=0.0,	
&END	·	
	T TO TT TO (A V - 0000 0	MI EMDA - FAI SE

HNUMIN=8000.0, HNUMAX=9000.0, NLEMRA=.FALSE.

5.3 MEDUSA SIMULATIONS:

This section includes the MEDUSA simulations. The main objective is to validate Marchand's Model with the present code. This is done by comparing the MEDUSA simulations which use Marchand's model and the present code. It will be shown that there are cases where the two algorithms yield different results. These results will be presented followed by a discussion of which algorithm appears to be more accurate. Since Marchand's model was successfully tested against experimental observation, we believe that the present code must also confirm the same experimental observations.

The graphs to be presented in this section reflect the consistency and the differences of the two models. It is observed that Marchand's model works well for a trapezoid profile beam, but appears to give erroneous results when a gaussian profile beam is used. The effects of radiation transport are the subject of this section. The input file for MEDUSA is given on the previous page.

Figure 5.1 a, b, c

This graph represents the electron temperature and normalized mass density of the plasma as a function of space using the DSA model and Marchand's 2-cell simplified model. The laser beam has a trapezoid temporal profile (with RISE TIME=1.0E-10 sec, TOFF=4.0E-09 sec and PMAX=3.16E17 Wm², λ =2.48E-07). These graphs correspond to different time steps and are presented here to show the consistency between the present model and Marchand's model at various time steps.

Figure 5.2 a, b, c

This graph represents the pressure and normalized mass density of the plasma as a function of space with the DSA model and Marchand's model. The laser beam is the same as the one used in Fig. 5.1 (trapezoid). Each graph can be viewed as a snap shot of the pressure and the mass density at different times. Again the consistency between the two models is evident.

Figure 5.3

This graph represents the ablation mass as a function of time with the DSA model and Marchand's model. The laser profile is the same as in Fig. 5.1.

Figure 5.4

This graph represents the ablation pressure as a function of time with the DSA model and Marchand's model. The laser profile is the same as Fig. 5.1.

Figure 5.5 a,b,c

These graphs represent the electron temperature and mass density as a function of space, when a gaussian laser profile (with FWHM=1.7E-09 sec, PMAX=5.0E16 Wm², λ =0.35E-06) is used. This figure shows that when a gaussian profile is used the two models do not give as consistent electron temperature as they did for trapezoid laser profile.

Figure 5.6 a,b,c

Here the pressure and mass density are shown as a function of space, when a gaussian profile for the laser beam is used (same as in Fig. 5.5). Even though the electron temperature was the same for both models, the pressure is not the same. The inconsistency in pressure is quiet conspicuous, the dip in pressure about the ablation surface in Fig. 5.6 b of Marchand's model appears to be nonphysical.

Figure 5.7

This graph represents the ablation mass of the plasma when a laser beam with a gaussian profile is used. Here the inconsistency is so conspicuous that one needs to reject either the DSA model or Marchand's model. It appears that the DSA model is more accurate than Marchand's model, because in Figure 5.3 the intensity is higher than in Fig. 5.7, which implies that the ablation mass in Fig. 5.7 should be less than the ablation mass in Fig. 5.3. This is not true in Marchand's model.

Figure 5.8

This graph represents the ablation pressure of the plasma when a laser beam with a gaussian profile is used. Even though the ablation mass from the two models is quiet different, the ablation pressure is not very different. This reflects the complexity of the radiation transport, that is, consistency in one result does not necessary imply that other parameters are consistent too.

Figure 5.9 a,b,c,d,e

These graphs show the effects of radiation transport on the ablated mass, ablation pressure, kinetic energy, thermal energy and ion energy. The laser profile is a trapezoid (with PLENTH=1.0E-10, PMAX=3.16E17). In these graphs results of MEDUSA with radiation transport (by invoking DSA model or Marchand model) and with no radiation transport (it implies that all radiation emitted is lost rather than being transported) are presented.

Fig. 5.9 a,b show the effect of radiation transport on the ablation mass and ablation pressure. Mora^{5/3A} has shown that the ablation mass and ablation pressure are proportional to intensity and to the critical density of the plasma and are given as

$$m_{abl} \propto I_o^{\frac{1}{2}} n_c^{\frac{1}{4}} \qquad \qquad P_{abl} \propto I_o^{\frac{3}{4}} n_c^{\frac{1}{8}}$$

These relations indicate that ablation pressure is less sensitive to radiation transport compared to ablation mass. The weak dependence of pressure on radiation is due to the fact that with radiation transport the thermal energy is converted into x-rays which can escape the plasma, this conversion reduces the ablation pressure. Radiation transport on the other hand transports energy to higher density plasma which in turn contributes to an increase in ablation pressure. The 2 apple in Fig. 5.9 a,b qualitatively confirm such relations.

When radiation transport is not included, all of the energy emitted due to bremsstrahlung is taken to be a loss. With radiation transport some of the energy

is transported to a colder dense plasma. Therefore, it is expected that when radiation transport is included the kinetic energy, ion energy and thermal energy should be relatively large compared to the case when no radiation is included. This conclusion is qualitatively confirmed from Fig. 5.9 c,d,e.

Figure 5.1 a

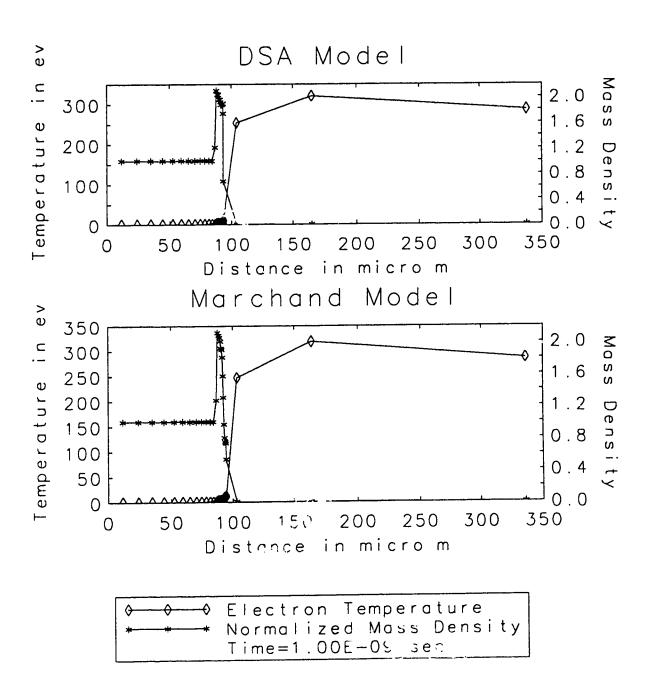


Figure 5.1 b

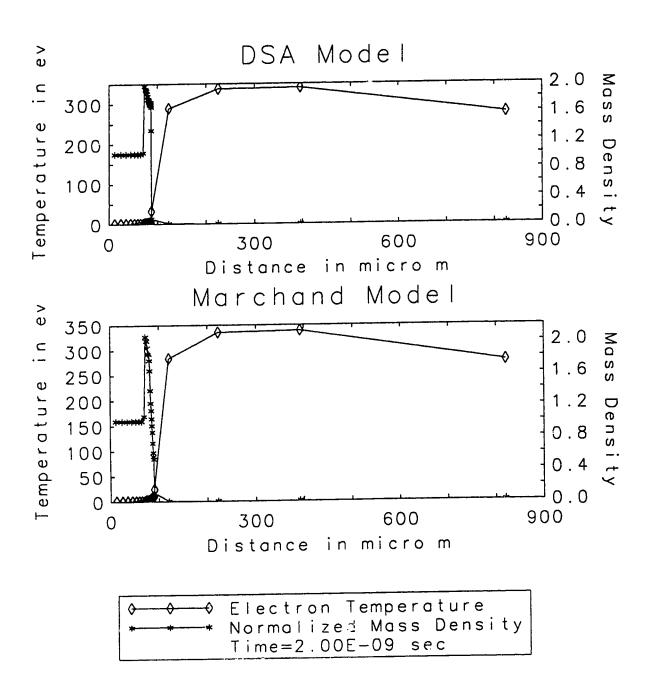


Figure 5.1 c

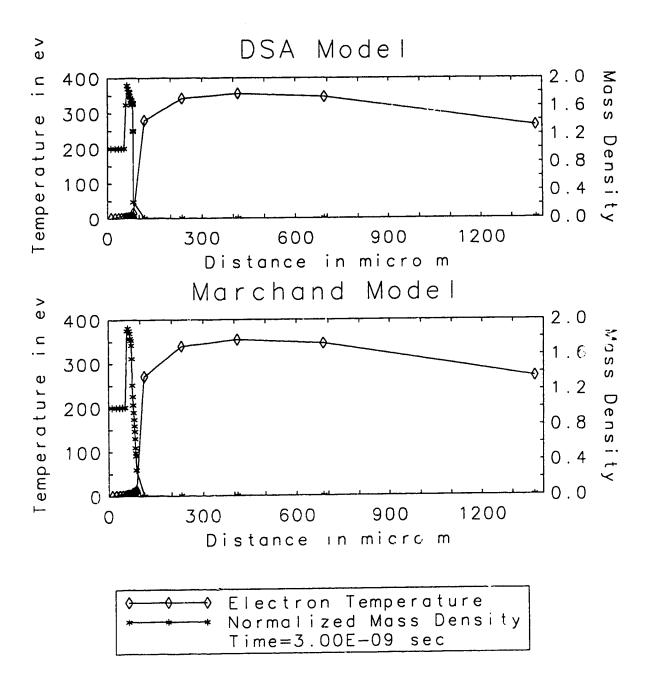


Figure 5.2 a

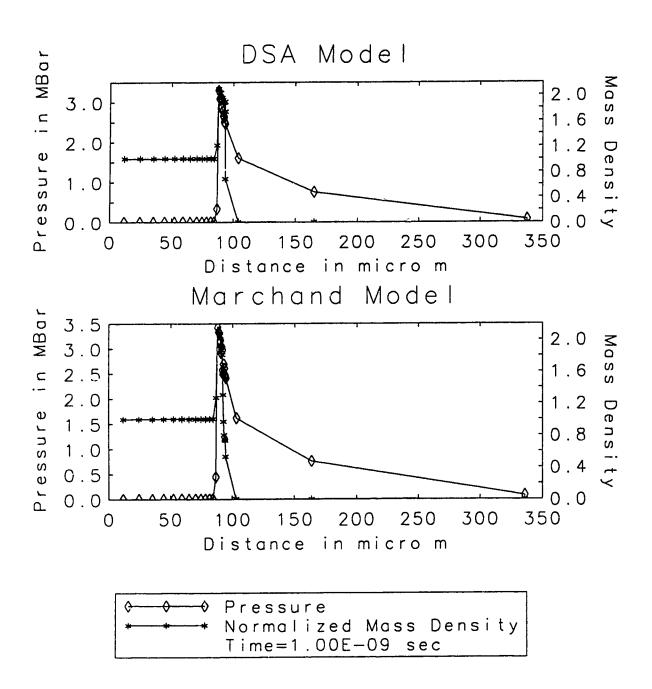


Figure 5.2 b

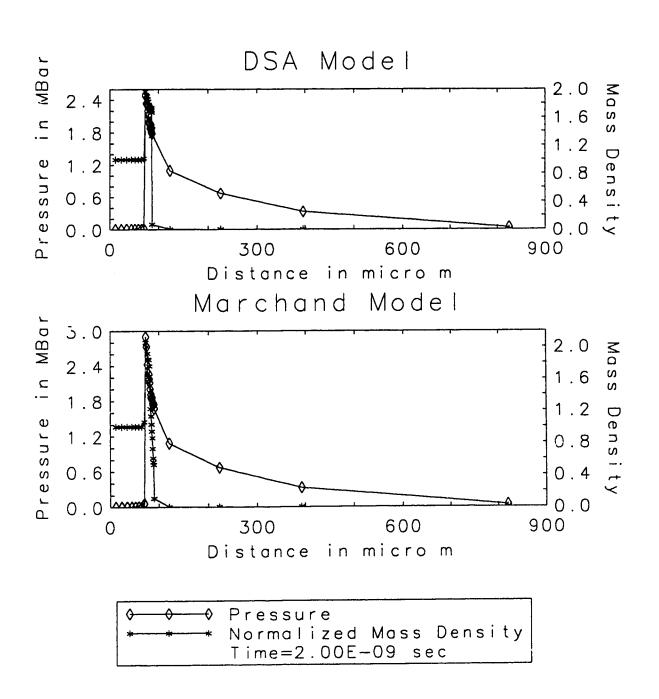


Figure 5.2 c

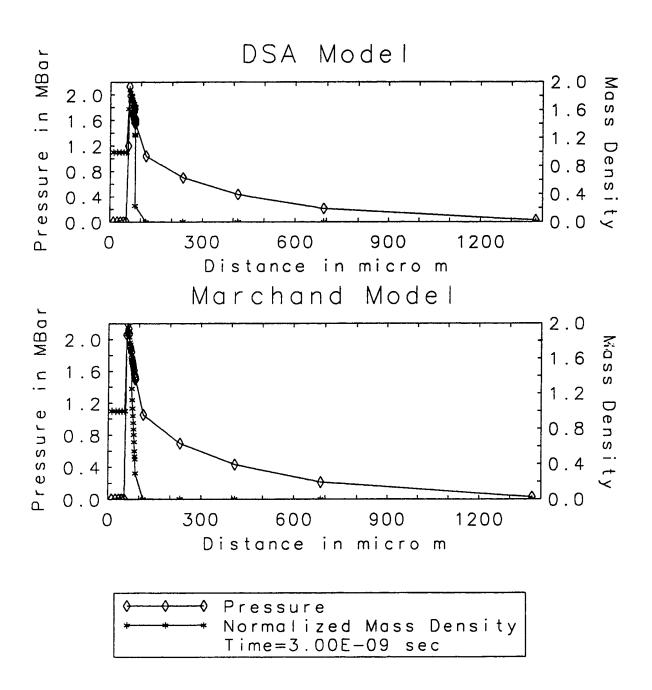


Figure 5.3

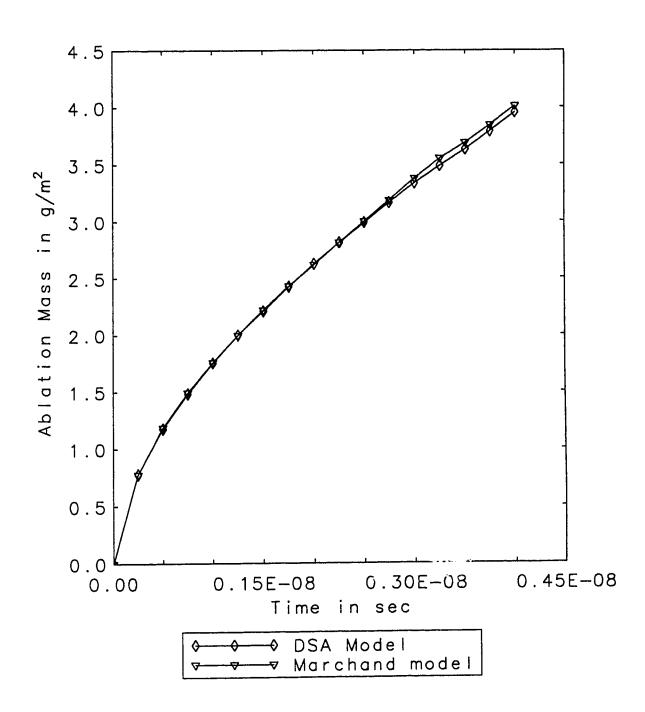


Figure 5.4

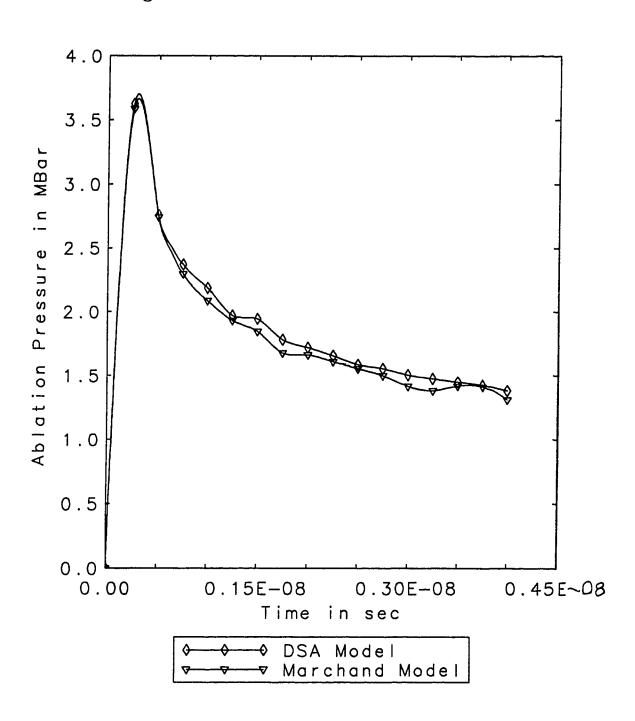


Figure 5.5 a

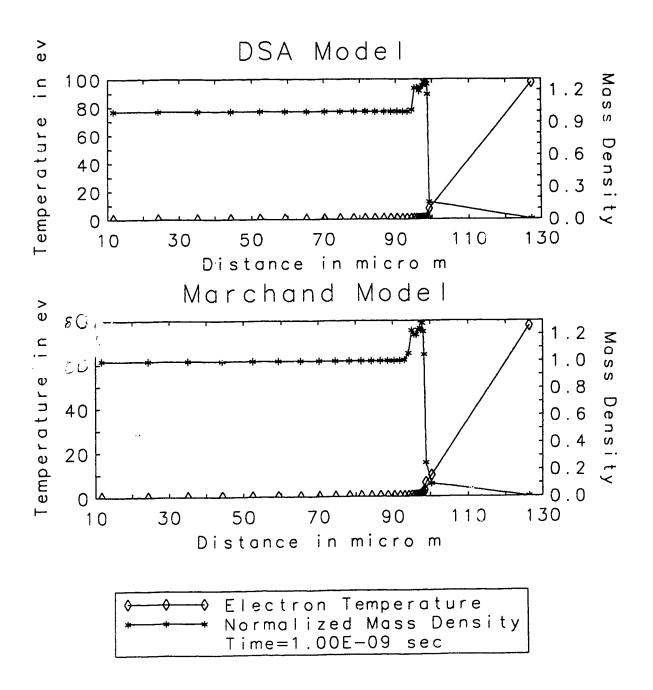


Figure 5.5 b

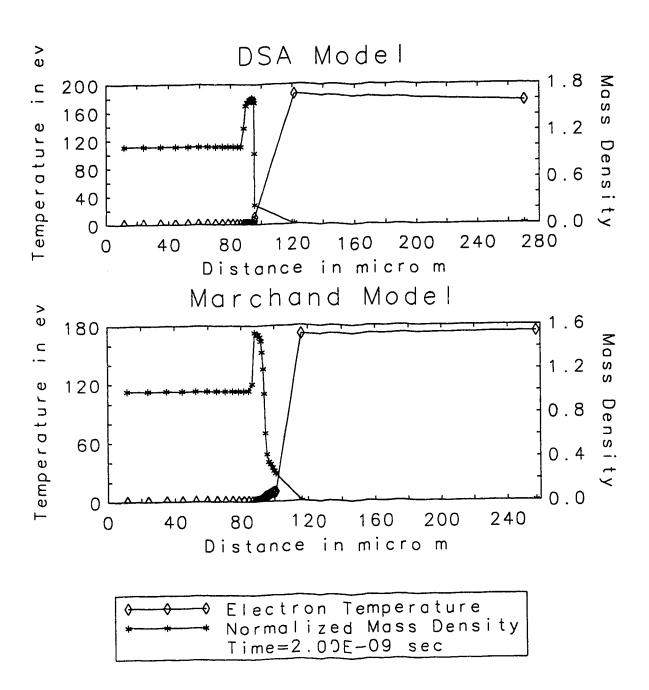


Figure 5.5 c

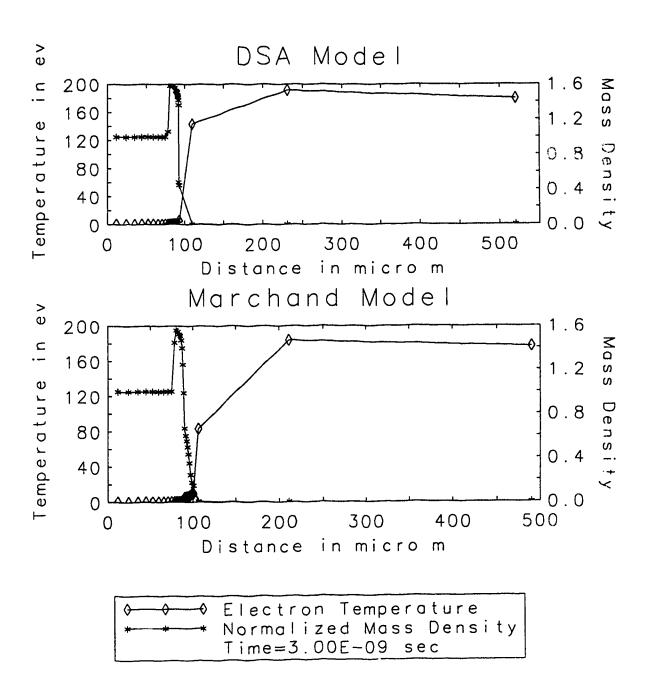


Figure 5.6 a

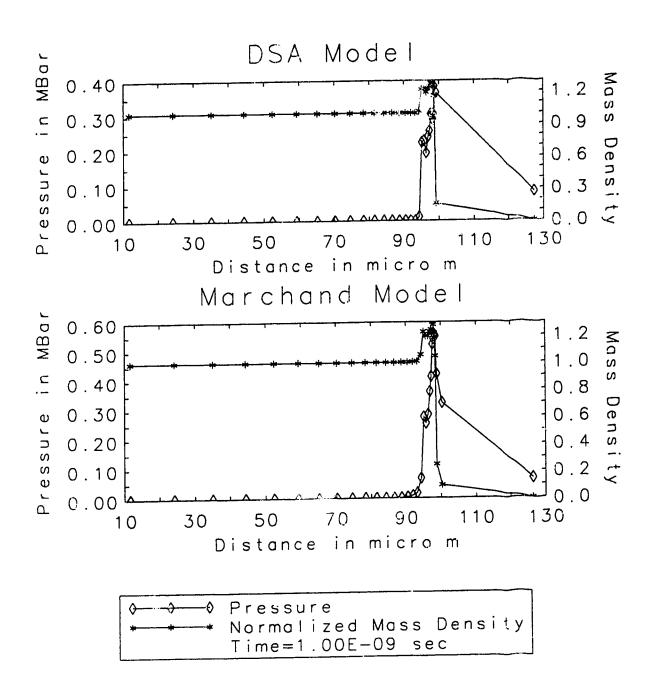


Figure 5.6 b

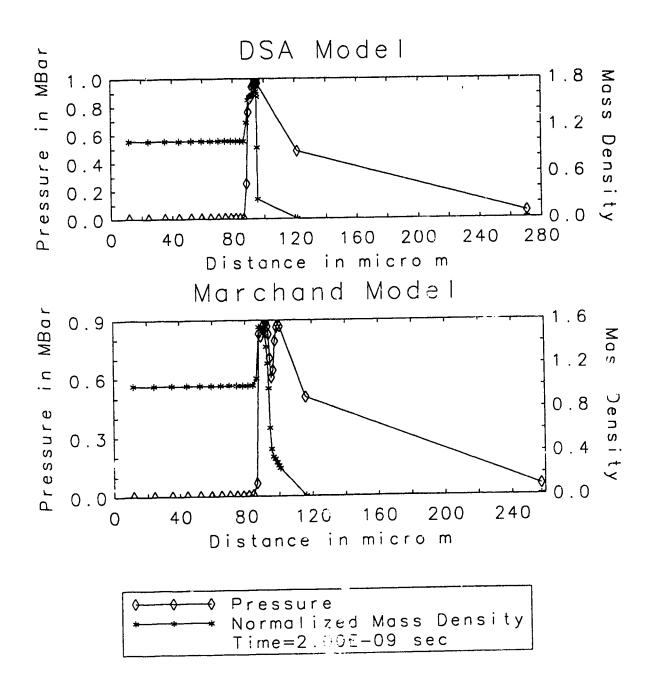


Figure 5.6 c

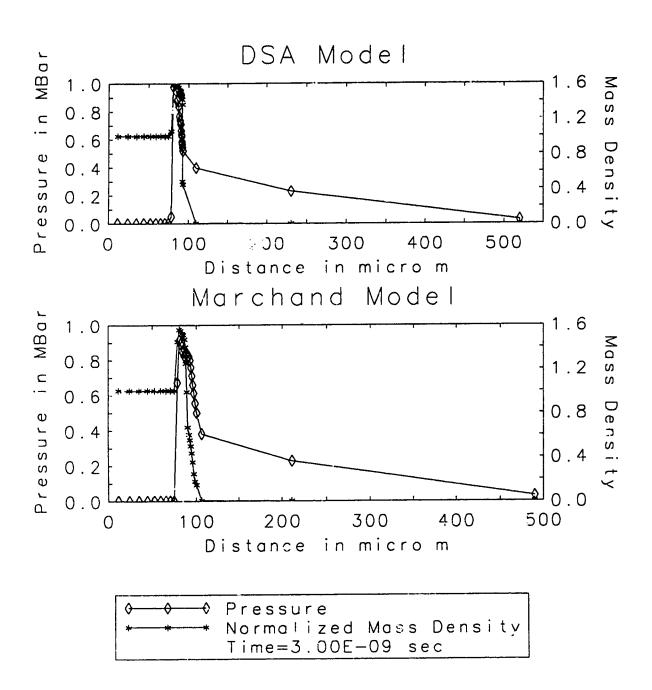


Figure 5.7

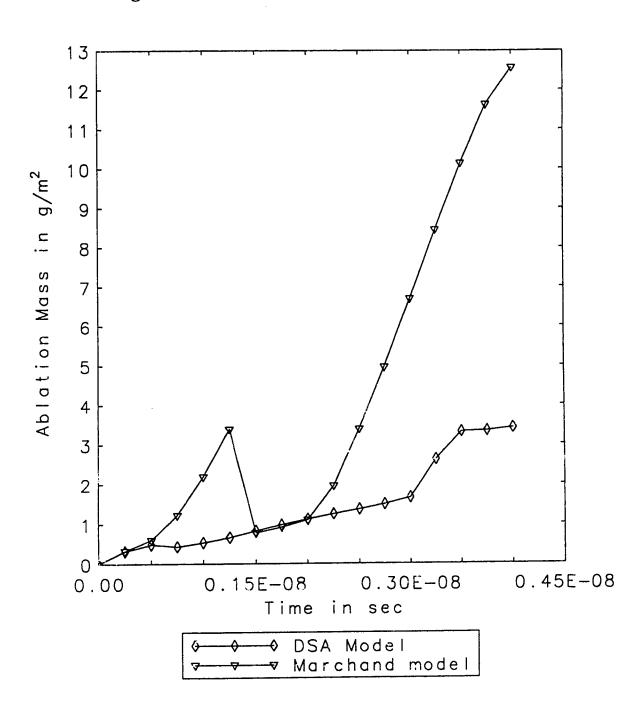


Figure 5.8

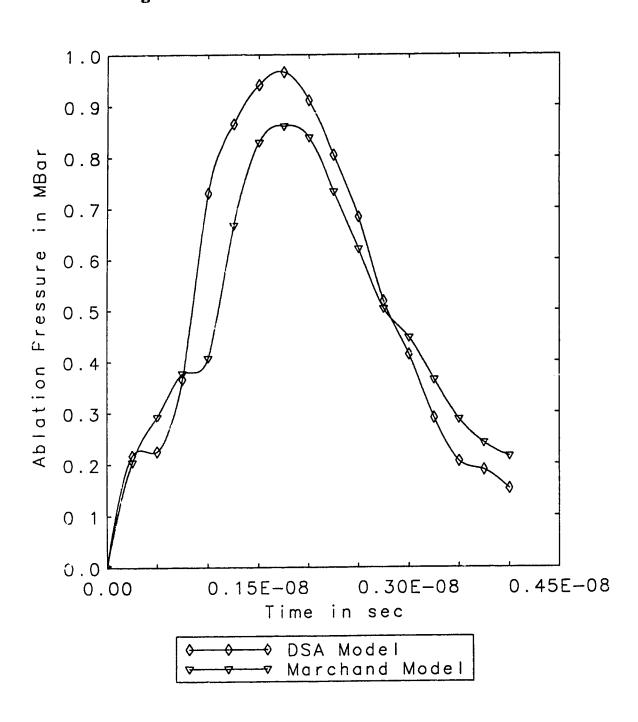


Figure 5.9 a

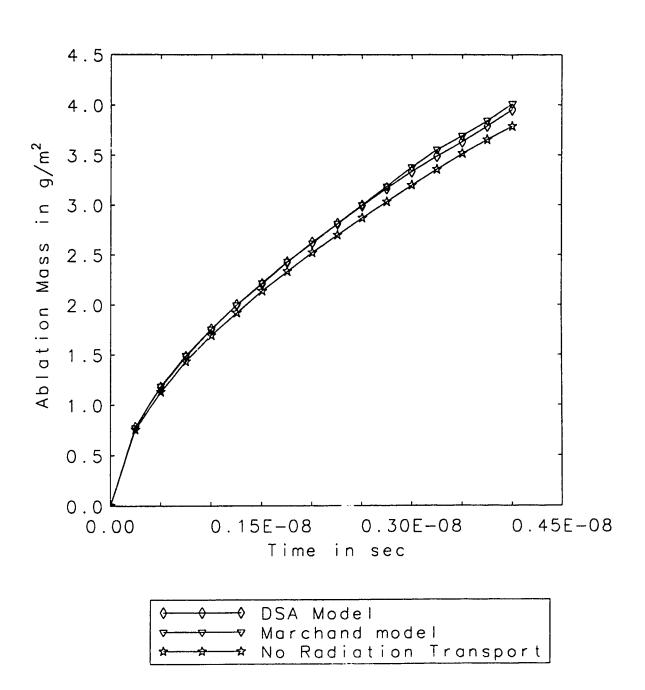


Figure 5.9 b

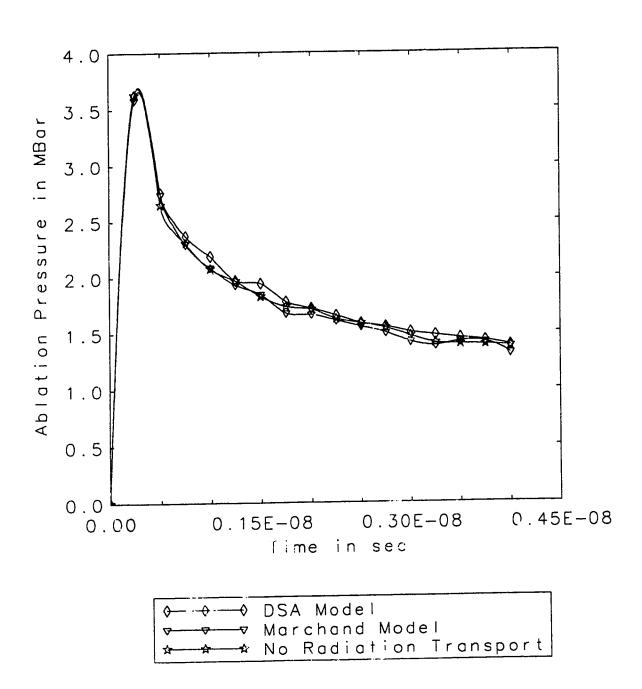


Figure 5.9 c

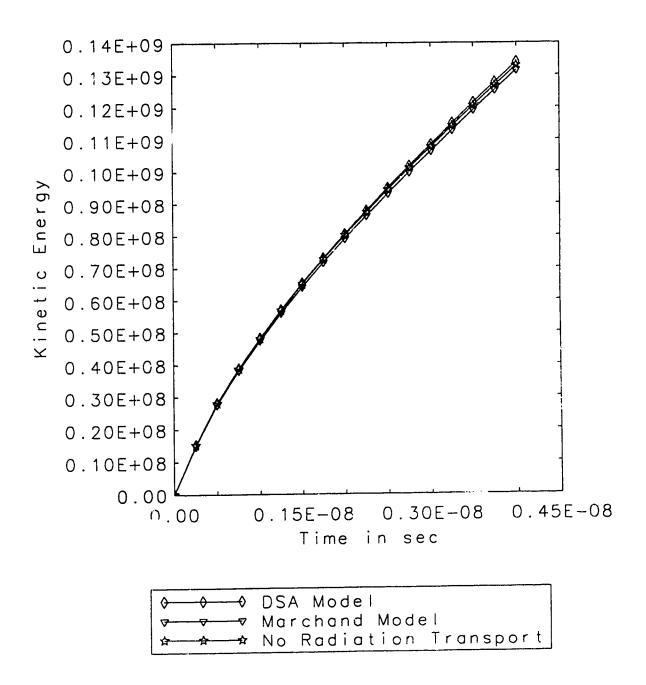


Figure 5.9 d

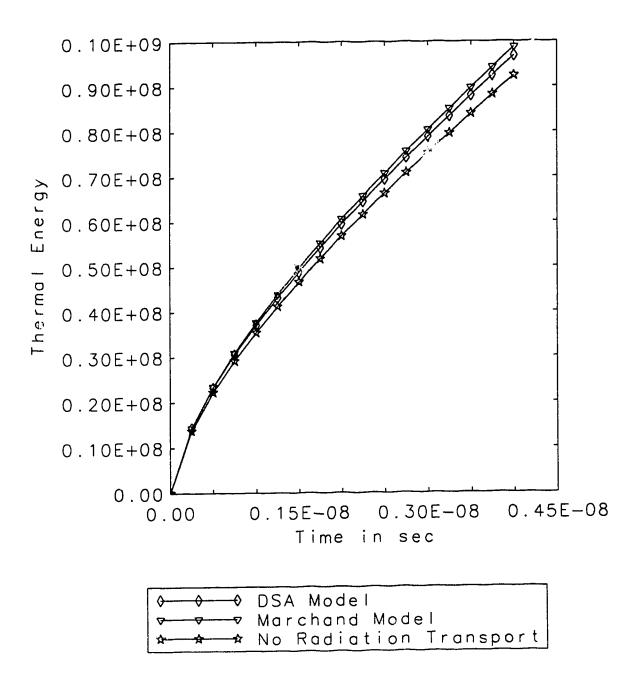
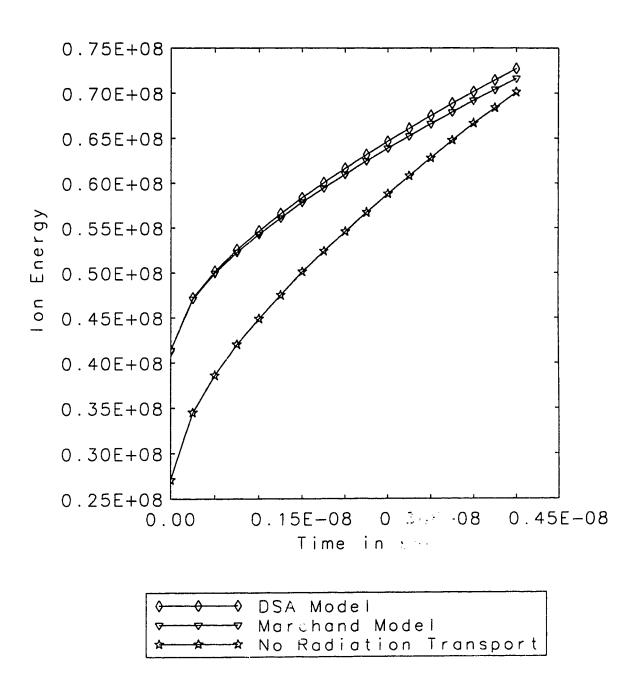
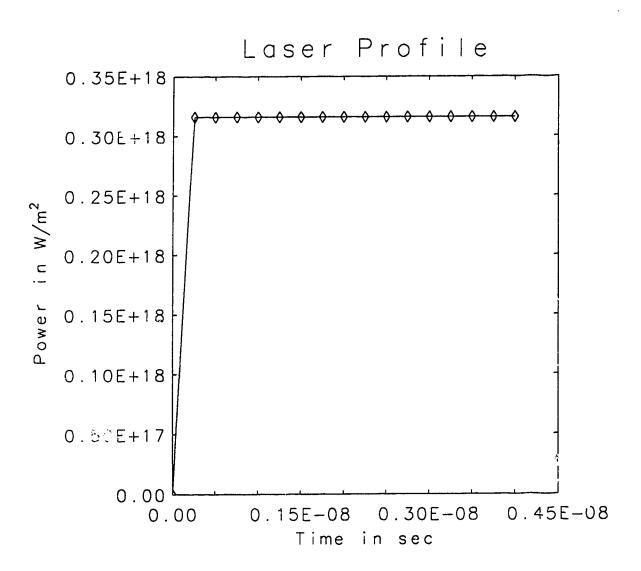
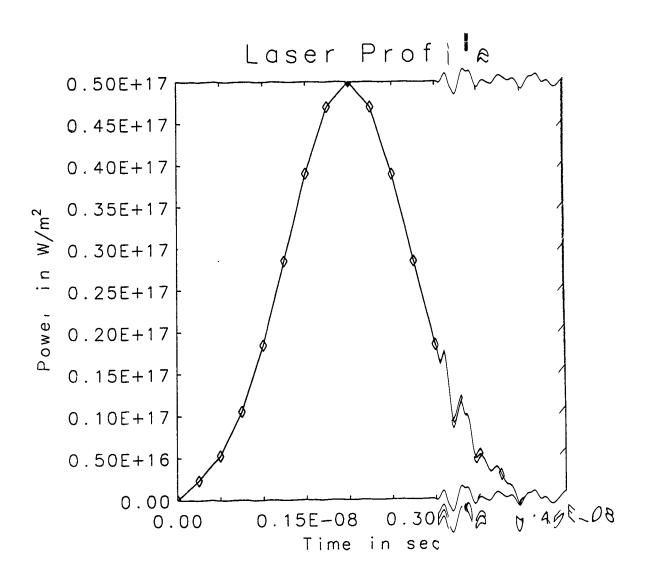


Figure 5.9 e







CONCLUDING REMARKS:

The objective of the research was to solve the radiative transfer equation in one dimension by using a method that can be extended to higher dimensions or curvilinear geometries. Another objective of the pharch was to corroborate Marchand's simplified 2-cell model.

The Diffusion Synthetic Acceleration (D: **) method is chosen to solve the radiative transfer equation. This method has been successfully used to solve neutronic transport problems in higher dimensions, hence it is believed that similar extension should be possible for radiative problems. The Marshak Wave bench mark is used to test the validity of the code. It is observed that Diffusion synthetic Acceleration is very efficient compared to other methods such as SI; however, it becomes unstable at large time steps.

A comparison of DSA and Marchand's model shows that these two models give simila sults when a trapezoid laser pulses are used. However, the results are en a gaussian laser beams are used. Analysis of the results shows not conmodel appears to give erroneous results, the ablated mass obtained that Ma. with Marcha. In model is unrematic, too much mass is being ablated. Therefore, Marchand's model requires further investigation if the above error in the ablation mass is to be rectified. Marchand's model on the other hand is computationally more efficient than DSA, but its disadvantage is its applicability in only one dimensional slab geo: etry problems. Further, in Marchand's model the angular dependence of the intensity is ignored, which is more crucial in higher dimensions. Therefore, Marchand's model is good for nongaussian laser beams in one dimensional slab geometry, while the DSA model can be extended to higher dimensions including curvilinear geometries, though the equations involved become more complicated.

It is observed that the effects of radiation transport is more significant on the ablation mass as compared to the ablation pressure, as predicted by Mora. Inclusion of radiation transport results in an increase in thermal, kinetic and ion energy. This

is due to the fact that when radiation transport is included energy is transported as well rather than being just lost. From the simulations it appears that the increase in energy is about 7 to 10 % for kinetic, thermal and ion energies. More simulations are required to estimate the x-ray conversion efficiency and the effects of radiation transport when different wavelengths or higher intensities are used.

BIBLIOGRAPHY

- 1/1 A. Brueckner and Sieba Jorna; Review of Modern Physics Vol. 46, P.325, Apr 1974.
- 1/2 D. Duston, R.W. Clark and J. Davis; Physical Review A Vol. 31, P. 3220, May 1985.
- 1/3 H. Motz, Physics of Laser Fusion
- 1/4 R.C. Malone, R.L. McCrory and R.L. Morse; Physical Review Letter, Vol. 34, P. 721, 1975.
- 1/5 G.S. Fraley and R.J. Mason; Physical Review Letter, Vol. 35, P. 520, 1975.
- 1/6 D.W. Forslund et al; Physical Review A Vol. 11, P. 679, 1975.
- 1/7 E.A. McLean et al; Physical Review Letters, Vol. 45, P. 1246, 1980.
- 1/8 D. Duston, R.W. Clark, J. Davis and J.P. Apruzese; Physical Review Vol. A27, P. 1441, 1983.
- 1/9 B. Yaakobi, J. Delettrez, L.M. Goldman, R.L. McCroy, W. Seka and J.M. Soures; Optics communications Vol. 41, P. 355, May 1982.
- 1/10 R. Sigel et al; Physics Fluids, Vol. B2, P. 199, 1989.
- 2/1 G. C. Pomraning; Equations of Radiation Hydrodynamics.
- 3/i Same as 2/1.
- 3/2 J.A. Fleck and J.D. Cummings; Journal of Computational Physics, Vol. 08, P. 313, 1971.
- 3/3 H.J. Kopp; Nuclear Science and Enginearing, Vol. 17, P. 65, 1964.
- 3/4 R.E. Alcouffe; Nuclear Sience and Enginearing, Vol. 64, P. 344, 1987.
- 3/5 Multiple Time Scales, Ed. J.U. Brackbill and B.I. Cohen P.74.
- 3/6 E.W. Larsen; Nuclear Science and Enginearing, Vol. 100, P. 255, 1988.
- 3/7 M.L. Adams and W.R. Martin; Nuclear Science and Engineering, Vol. 100, P. 177, 1988.
- 3/8 E.D. Larsen, Personal correspondence.
- 3/9 Same as 2/1.
- 3/10 E.W. Larsen, Nuclear Science and Enginearing, Vol. 82, P. 47, 1981.
- 3/11 Transport and Reactor Report, Ed. R.D. O' Dell and R.E. Alcouffe, P. 29, Aug 1982.
- 3/12 J.E. Morel, Nuclear Science and Enginearing, Vol. 82, P. 34, 1982.
- 3/13 J.E. Morel, E.W. Larsen and M.K. Matzen; Journal of Quan. Spectrosc. Radiat. Transfer. Vol. 34, P. 243, 1985.
- 4/1 B.A. Clark; Nuclear Science and Enginearing, Vol. 90, P. 171, 1984.
- 4/2 R.E. Marshak; Physics of Fluids, Vol. 01, P.24, 1958.
- 4/3 Same as 3/5.
- 4/4 G. Velarde et al; Laser and Particle Beams, Vol. 7, Part 02, 305, 1989.
- 4/5 Same as 2/1.

- 5/1 Notes on MEDUSA from Dr. C.E. Capjack.
- 5/2 Notes on atomic tables from Dr. C.E. Capjack.
- 5/3 P. Mora; Physics Fluids, Vol. 25, P. 1051, 1982.
- 8. Marchand, R. Fedosejevs, C.E. Capjack and Y. T. Lee; Laser and Partoicle Beams, Vol. 6, Part 2, P.183, 1988.
- A/1 same as 3/4.
- A/2 Personal correspodance with M.L. Adams.
- B/1 K. Audenaerde et al; Journal of Computational Physics Vol. 34, P. 510, 1987.
- B/2 R. Marchand, A. Birnboim, C.E. Capjack and D. Salzmann; Canadian Journal of Physics, Vol. 67, P.155, 1989.
- B/3 Same as 5/4.
- C/1 Same as 5/2.

APPENDIX

A. NUMERICAL ASPECTS OF DSA

A.1 FOURIER ANALYSIS OF THE RADIATIVE TRANSFER EQUATION:

We start our Fourier stability analysis of the radiative transfer equation when it is discretized in time. As shown earlier in Chapter Three (3.3.12), this is given as

$$\mu \frac{\partial I}{\partial x} + (\sigma + \tau)I = \frac{\chi \eta}{2} \int_0^{\infty} \sigma I_0 \, d\nu + Q$$
where
$$I_0 = \int_{-1}^{1} I d\mu$$

(A.1.01)

Due to the coupling in frequency on the right hand side, we solve the above equation iteratively. The iteration strategy that is used to solve the radiative transfer equation is known as source iteration. Source iteration (SI) of (A.1.01) is expressed as

$$\mu \frac{\partial I^{l+\frac{1}{2}}}{\partial x} + (\sigma + \tau)I^{l+\frac{1}{2}} = \frac{\chi \eta}{2} \int_0^{\infty} \sigma I_o^l dv + Q$$

$$I_0^{l+1} = I_0^{l+\frac{1}{2}} = \int_{-1}^{1} I^{l+\frac{1}{2}} d\mu$$

(A.1.02a,b)

where the 1/2 index corresponds to the most recent intensity obtained by solving (A.1.02a) with an initial intensity of I_o^1 . For the next iteration, the source term (A.1.02a) is updated by using (A.1.02b). To study the convergence properties of (A.1.02), we define

$$D^{l+\frac{1}{2}} = I^{l+\frac{1}{2}} - I^{l-\frac{1}{2}} = \omega^l D e^{i\lambda x}$$

$$D_0^l = I_0^l - I_0^{l-1} = \omega^l D_0 e^{i\lambda x}$$

where ω is the eigen-value and D_o is subject to the condition

$$\int_0^\infty \sigma \ D_o \ dv = 1$$

(A.1.03a,b,c)

We take σ and χ to be spatially independent for simplicity in the Fourier stability analysis. The following steps are taken to obtain the radius of convergence:

- i. Write (A.1.02a) for l-1 iteration.
- ii. Subtract the above equation from equations (A.1.02a) and substitute (A.1.03a,b) wherever possible.
- iii. Simplify the above result using equation (A.1.03c).
- iv. Repeat the first two steps for equation (A.1.02b).

Since the steps are relatively simple, only the final results are given.

(iii)
$$\rightarrow$$
 (i $\mu\lambda$ + σ + τ) $D = \frac{\chi\eta}{2}$
(iv) \rightarrow $\omega D_0 = \int_{-1}^{1} D d\mu$

(A.1.04a,b)

The radius of convergence is obtained by manipulating (A.1.04a,b) and using (A.1.03c). The steps that are performed are as follows:

- i. Multiply (A.1.04b) by σ and integrate over entire frequency spectrum
- ii. Substitute (A.1.04a) into the above equation
- iii. Simplify the final result by using A.1.03c

The final result after angular integration is

$$\omega = \frac{1}{2} \int_0^{\infty} \sigma \left[\int_{-1}^1 \chi \eta \frac{d\mu}{(i\mu\lambda + \sigma + \tau)} \right] d\nu = \int_0^{\infty} \chi \eta \frac{\sigma}{\lambda} \tan^{-1} \frac{\lambda}{(\sigma + \tau)} d\nu$$

The spectral radius can be viewed as the rate at which both D and D₀ go to zero, which is just the error reduction per iteration. In practice it is taken to be the largest eigen-value. In the source iteration method this occurs when $\lambda = 0$ and $\tau = 0$. When this is true the spectral radius is given by

$$spr = \int_0^\infty \chi dv = \eta$$

where $\eta \to 1$ when $\alpha\tau \to 0$. This is true when $\tau \to 0$ or $\sigma > 1$.

This result shows that the SI method can require an arbitrarily large number of iterations before a converged solution is obtained.

A.2 FOURIER ANALYSIS OF THE RADIATIVE TRANSFER EQUATION USING THE DIFFUSION EQUATION:

A Fourier stability analysis of the transfer equation when it is accelerated using the diffusion equation involves equations (3.3.12;3.3.04;3.5.02) presented earlier

$$\mu \frac{\partial I^{l \cdot \frac{1}{2}}}{\partial x} + (\sigma + \tau)I^{l \cdot \frac{1}{2}} = \frac{\chi \eta}{2} \int_{0}^{\infty} \sigma I_{0}^{l} dv + Q$$

$$I_{0}^{l \cdot \frac{1}{2}} = \int_{-1}^{1} I^{l \cdot \frac{1}{2}}$$

$$-\frac{1}{3(\sigma + \tau)} \frac{\partial^{2} F_{0}^{l \cdot 1}}{\partial x^{2}} + (\sigma + \tau)F_{0}^{l \cdot 1} = \chi \eta \int_{0}^{\infty} \sigma F_{0}^{l \cdot \frac{1}{2}} dv + \chi \eta \int_{0}^{\infty} \sigma (I_{0}^{l \cdot \frac{1}{2}} - I_{0}^{l}) dv$$
(A.2.01;02;03)

Let us define

$$D_{o}^{l+\frac{1}{2}} = I^{l+\frac{1}{2}} - I^{l+\frac{1}{2}} = \omega^{l} D e^{it\lambda}$$

$$D_{o}^{l} = I_{o}^{l} - I_{o}^{l-1} = \omega^{l} D_{o} e^{it\lambda}$$

$$f_{0}^{l+1} = F_{0}^{1+1} - F_{0}^{l} = \omega^{l} f_{0} e^{it\lambda}$$

$$where \qquad F_{0}^{l+1} = I_{0}^{l+1} - I_{0}^{l+1/2}$$

(A.2.04a,b,c,d)

A Fourier analysis of the transfer equation when accelerated with the diffusion equation involves the following steps:

i. Rewrite (A.2.01;02;03) for steps 1-1, and subtract them from (A.2.01;02;03) respectively. After substituting the first equality of (A.2.04), we obtain

$$\mu \frac{\partial D^{l \cdot \frac{1}{2}}}{\partial x} + (\sigma + \tau) D^{l \cdot \frac{1}{2}} = \frac{\chi \eta}{2} \int_{0}^{\infty} \sigma D_{0}^{l} dv$$

$$D_{0}^{l \cdot \frac{1}{2}} = \int_{-1}^{1} D^{l \cdot \frac{1}{2}} d\mu$$

$$- \frac{1}{3(\sigma + \tau)} \frac{\partial^{2} f_{0}^{l \cdot 1}}{\partial x^{2}} + (\sigma + \tau) f_{0}^{l \cdot 1} = \chi \eta \int_{0}^{\infty} \sigma f_{0}^{l \cdot 1}$$

$$+ \chi \eta \int_{0}^{\infty} \left[\sigma \left(\int_{-1}^{l} D^{1 \cdot \frac{1}{2}} d\mu \right) - D_{0}^{l} \right] dv$$

(A.2.06a,b,c)

ii. Substitute the second equality of (A.2.04) (Fourier decomposition) into (A.2.06a), to obtain

$$i\lambda\mu\omega^1 De^{i\lambda\chi} + (\sigma+\tau)\omega^1 De^{i\lambda\chi} = \frac{\chi\eta}{2}\int_{\sigma}^{\pi} \omega^1 D_{\sigma}e^{i\lambda\chi} d\nu$$

From this we have that

$$D = \frac{\chi\eta}{2} \frac{\int_{\sigma}^{\infty} D_{\sigma} dv}{((\sigma+\tau)+i\lambda\mu)} = \frac{((\sigma+\tau)-i\lambda\mu)\chi\eta}{2} \frac{\int_{\sigma}^{\infty} D_{\sigma} dv}{((\sigma+\tau)^2+\lambda^2\mu^2)}$$
$$D_{\sigma}^{l+\frac{1}{2}} = \int_{-1}^{1} \omega^l De^{i\lambda x} d\mu$$

$$\frac{\lambda^2}{3(\sigma+\tau)} \omega^l f_0 e^{i\lambda x} + (\sigma+\tau) \omega^l f_0 e^{i\lambda x} = \chi \eta \int_0^{\infty} \sigma \omega^l f_0 e^{i\lambda x} dv + \chi \eta \int_0^{\infty} \left[\sigma \int_{-1}^1 \omega^l D e^{i\lambda x} d\mu - \omega^1 D_0 e^{i\lambda x} \right] dv$$

After simplification the above results yields

$$\left(\frac{\lambda^2 + 3(\sigma + \tau)^2}{3(\sigma + \tau)}\right) f_o = \chi \eta \int_0^{\infty} \sigma f_o dv + \chi \eta \int_0^{\infty} \left[\sigma \left(\int_{-1}^1 D d\mu\right) - D_o \right) dv\right]$$

(A.2.07a,b,c,d)

iii. From (A.2.04d) we have

$$f_{o}^{l+1} = D_{o}^{l+1} - D_{o}^{l+\frac{1}{2}}$$

$$\omega^{l} f_{o} e^{i\lambda\chi} = \omega^{1+1} D_{o} e^{i\lambda x} - \int_{-1}^{1} D e^{i\lambda x} \omega^{l} d\mu$$

$$f_{o} = \omega D_{o} - \int_{-1}^{1} D d\mu$$

(A.2.08a,b,c)

iv. Substitute f_0 in (A.2.07c) to get

$$\left(\frac{\lambda^{2} + 3(\sigma + \tau)^{2}}{3(\sigma + \tau)}\right) \left(\omega D_{0} - \int_{-1}^{1} D \ d\mu\right) = \chi \eta \int_{0}^{\infty} \left[\sigma(\omega D_{0} - \int_{-1}^{1} D \ d\mu) \ d\nu\right]
+ \chi \eta \int_{0}^{\infty} \sigma \int_{-1}^{1} D d\mu d\nu - \chi \eta \int_{0}^{\infty} \sigma D_{0} d\nu$$

v. Multiply the above equation by σ and divide by

$$\left(\frac{\lambda^2+3(\sigma+\tau)^2}{3(\sigma+\tau)}\right)$$

Then integrate over frequency spectrum, to obtain

$$\omega \left[\int_0^{\infty} \sigma D_0 d\tau - \int_0^{\infty} \frac{\chi \eta \sigma}{\frac{\lambda^2 + 3(\sigma + \tau)^2}{3(\sigma + \tau)}} d\nu \right] = \int_0^{\infty} \sigma \int_{-1}^1 D d\mu d\nu - \int_0^{\infty} \left[\frac{\chi \eta \sigma}{\frac{\lambda^2 + 3(\sigma + \tau)^2}{3(\sigma + \tau)}} \right] d\nu$$
(A.2.09)

vi. Substitute D from (A.2.07) and use the normalization relation

$$\omega = \frac{\int_0^{\infty} \sigma \int_{-1}^1 \chi \eta \frac{((\sigma + \tau) - i\lambda \mu)}{2((\sigma + \tau)^2 + \lambda^2 \mu^2)} d\mu \ d\nu - \int_0^{\infty} \frac{3\chi \eta \sigma (\sigma + \tau)}{(\lambda^2 + 3(\sigma + \tau)^2)} \ d\nu}{\left(1 - \int_0^{\infty} \frac{3\chi \eta \sigma (\sigma + \tau) J\nu}{(3(\sigma + \tau)^2 + \lambda^2)}\right)}$$

(A.2.10)

vii. Simplify the above equation (imaginary parts disappears after $\int d\mu$)

$$\omega = \frac{\int_{\sigma}^{\infty} \frac{\sigma \chi \eta}{2} (\sigma + \tau) d\nu \int_{-1}^{1} \left(\frac{1}{((\sigma + \tau)^{2} + \lambda^{2} \mu^{2})} - \frac{3}{(\lambda^{2} + 3(\sigma + \tau)^{2})} \right) d\mu}{\left(1 - \int_{0}^{\infty} \frac{3 \chi \eta \sigma (\sigma + \tau) d\nu}{\lambda^{2} + 3(\sigma + \tau)^{2}} \right)}$$

viii. After further simplification, the final result is

$$\omega = \frac{\frac{1}{2} \int_0^{\infty} \left[\frac{\sigma \chi(\sigma + \tau)}{(\lambda^2 + \zeta(\sigma + \tau)^2)} \int_{-1}^{1} \left(\frac{\lambda^2 (1 - 3\mu^2)}{((\sigma + \tau)^2 + \lambda^2 \mu^2)} \right) d\mu \right] d\nu}{\left(1 - \int_0^{\infty} \frac{3\chi \eta \sigma(\sigma + \tau)}{(\lambda^2 + 3(\sigma + \tau)^2)} d\nu \right)}$$
(A.2.11)

This shows that in the limit of $\lambda \to 0$ the spectral radius goes to zero for all values of $\tau \ge 0$. Therefore, with the solution of the diffusion equation, the solution of the transfer equation will converge rapidly even for slowly converging modes.

As stated earlier, the diffusion equation itself faces the same problem as the transfer equation, namely slow convergence. It can be shown, by using a Fourier stability analysis similar to that used for the transfer equation with SI (A.1), that the spectral radius for the diffusion equation with the source iteration technique is given by

$$\omega = \eta \int_{\sigma}^{\infty} \frac{3\sigma(\sigma + \tau)\chi}{(\lambda^2 + 3(\sigma + \tau)^2)} d\nu$$

$$spr = \eta \int_{0}^{\infty} d\nu \frac{\sigma\chi}{(\sigma + \tau)} - 1 \quad \text{when} \quad \tau = 0 \text{ and/or } \sigma = \infty$$

This slow convergence can reduce the effectiveness of the diffusion equation in accelerating the transfer equation. Therefore, another equation is derived which is designed such that for slow converging modes a more rapidly converging solution is obtained. Fourier analysis is not presented here due to the complexity in its derivation, but a similar approach can be used to obtain the spectral radius of the transfer equation when it is accelerated using the diffusion equation which in turn has been accelerated by the linear grey equation.

A.3 SOLUTION OF THE RADIATIVE TRANSFER EQUATION:

We rewrite (3.4.02) here for completeness

$$\begin{split} \mu_{m}(I_{mgl+\frac{1}{2}}^{l+\frac{1}{2}} - I_{mgl-\frac{1}{2}}^{l+\frac{1}{2}}) &+ \sigma_{gl}I_{mgl}^{l+\frac{1}{2}} = \frac{\chi_{gl}\Delta x_{l}}{2} \Sigma_{g}\sigma_{gl}I_{0gl}^{l} + \Delta x_{l}Q_{mgl}\\ I_{mgl}^{l+\frac{1}{2}} &= \frac{1}{2}(I_{mgl+\frac{1}{2}}^{l+\frac{1}{2}} + I_{mgl-\frac{1}{2}}^{l+\frac{1}{2}})\\ I_{0gl}^{l+1} &= \Sigma_{m}I_{mgl}^{l+\frac{1}{2}}\omega_{m} \end{split}$$

(A.3.01a,b,c)

The solution to the above equation is obtained by a so called "sweep from left to right" and then "sweep from right to left" method. The intensity incident from the left is computed independent of the intensity going to the right and vice versa.

CASE I. $\mu_{m} > 0$

- i. Substitute (A.3.01b) for $I^{1+1/2}_{mgi+1/2}$ into (A.3.01a) and solve for $I^{1+1/2}_{mgi}$
- ii. Substitute the new value for $I^{1+1/2}_{mgi}$ in (A.3.01b) to obtain $I^{1+1/2}_{mgj+1/2}$ which will be used as $I^{1+1/2}_{mgj-1/2}$ for the next cell, and so on.
- iii. If $I^{1+1/2}_{mgi+1/2}$ is less than zero, let $I^{1+1/2}_{mgp+1/2} = 0$ or $I^{1+1/2}_{mgp+1/2} = I^{1+1/2}_{mg}$ in (A.3.01) and solve again for $I^{1+1/2}_{mgi}$

CASE II. $\mu_{n} < 0$

The procedure is the same as for $\mu_m > 0$ except that $I^{1+1/2}_{mp \ge 1/2}$ is replaced by

I1 · 1/2 mg/ *1/2·

For the next iteration, $I^{1+1/2}_{mp}$ obtained from (A.3.01b) is used to get the new source term for (A.3.01a). The final set of equations for $\mu_m > 0$ is given as

$$I_{mgl}^{l + \frac{1}{2}} = \frac{\left[\frac{\chi_{gl} \eta_{l} \Delta x_{l}}{2} \sum_{g} \sigma_{gl} I_{ogl}^{l} + \Delta x_{l} Q_{mgl} + 2\mu_{m} I_{mgl - \frac{1}{2}}^{l + \frac{1}{2}}\right]}{(\hat{\sigma}_{gl} + 2\mu_{m})}$$

$$I_{mgl + \frac{1}{2}}^{l + \frac{1}{2}} = 2 I_{mgl}^{l + \frac{1}{2}} - I_{mgl - \frac{1}{2}}^{l + \frac{1}{2}}$$

If $I^{1+1/2}_{mp}$ is negative then, according to a parameter ξ (=c Δ t/ Δ x)

$$\xi < 1 \qquad I_{mgt}^{l+\frac{1}{2}} = \frac{\left[\frac{\chi_{gl}\eta_{l}\Delta x_{l}}{2} \sum_{g}\sigma_{gl}I_{ogl}^{1} + \Delta x_{l}Q_{mgl} + \mu_{nl}I_{mgl-\frac{1}{2}}^{1+\frac{1}{2}}\right]}{\hat{\sigma}_{gl}}$$

$$I_{mgl+\frac{1}{2}}^{l+\frac{1}{2}} = 0.0$$

$$\xi \geq 1 \qquad I_{mgl}^{1+\frac{1}{2}} = \frac{\left[\frac{\chi_{gl}\eta_{l}\Delta x_{l}}{2} \sum_{g}\sigma_{gl}I_{ogl}^{1} + \Delta x_{l}Q_{mgl} + \mu_{m}I_{mgl-\frac{1}{2}}^{1+\frac{1}{2}}\right]}{(\hat{\sigma}_{gl} + \mu_{m})}$$
$$I_{mgl+\frac{1}{2}}^{l+\frac{1}{2}} = I_{mgl}^{l+\frac{1}{2}}$$

(A.3.02a,b;03a,b;04a,b)

If $\mu_{\rm m}$ < 0,

$$\begin{split} I_{mgl}^{l+\frac{1}{2}} &= \frac{\left[\frac{\chi_{gl}\eta_{l}\Delta x_{l}}{2} \; \Sigma_{g} \; \sigma_{gl}I_{ogl}^{l} + \Delta\chi_{l} \; Q_{mgl} - 2\mu_{m}I_{mgl+\frac{1}{2}}^{l+\frac{1}{2}}\right]}{(\hat{\sigma}_{gl} - 2\mu_{m})} \\ I_{mgl-\frac{1}{2}}^{l+\frac{1}{2}} &= 2 \; I_{mgl}^{l+\frac{1}{2}} - I_{mgl+\frac{1}{2}}^{l+\frac{1}{2}} \end{split}$$

If I1+1/2 mp is negative then,

$$\xi < 1 \qquad I_{mgi}^{i+\frac{1}{2}} = \frac{\left[\frac{\chi_{gi} \eta_{i} \Delta x_{i}}{2} \sum_{g} \sigma_{gi} I_{ogi}^{1} + \Delta x_{i} Q_{mgi} - \mu_{mi} I_{mgi+\frac{1}{2}}^{1+\frac{1}{2}}\right]}{\hat{\sigma}_{gi}}$$

$$I_{mgi-\frac{1}{2}}^{i+\frac{1}{2}} = 0.0$$

$$\xi \geq 1 \qquad I_{mgi}^{1+\frac{1}{2}} = \frac{\left[\frac{\chi_{gi}\eta_{i}\Delta x_{i}}{2} \sum_{g}\sigma_{gi}I_{ogi}^{1} - \Delta x_{i}Q_{mgi} + \mu_{m}I_{mgi-\frac{1}{2}}^{1+\frac{1}{2}}\right]}{(\hat{\sigma}_{gi} - \mu_{m})}$$

$$I_{mgi-\frac{1}{2}}^{1+\frac{1}{2}} = I_{mgi}^{1+\frac{1}{2}}$$

(A.3.05a,b;06a,b;07a,b)

The new source term is obtained by summing the new specific intensity from the transfer equation as

$$I_{ogi}^{1+1} = I_{ogi}^{1+\frac{1}{2}} = \Sigma_m I_{mgi}^{l+\frac{1}{2}} \omega_m$$

(A.3.08)

Therefore, one complete solution of the transfer equation with source iteration can involve equations (A.3.03;04;05;06;07;08).

A.4 DERIVATION OF DISCRETIZED FORM OF THE DIFFUSION EQUATION:

In order to obtain a diffusion equation which is consistent with the transfer equation just solved, one must start with (3.5.02) instead of (3.3.12). Alcouffe showed^{A/1} that the diffusion obtain equation from (3.7.27) leads to unstable solutions. The following steps are taken in order to obtain the discretized diffusion equation from the transfer equation.

i. Multiply equation (A.3.01) by ω_m and $\omega_m \mu_m$ and sum over the angular space to obtain the zeroth and first order moment in angular

space. This yields

$$(I_{1gi+\frac{1}{2}}^{1+\frac{1}{2}}-I_{1gi-\frac{1}{2}}^{1+\frac{1}{2}})+\hat{\sigma}_{gi}I_{ogi}^{1+\frac{1}{2}}=\chi_{gi}\eta_{i}\Delta x_{i}\Sigma_{g}\sigma_{gi}I_{ogi}^{1}+\Delta x_{i}Q_{ogi}$$

$$\frac{2}{3} (I_{2gl,\frac{1}{2}}^{l+\frac{1}{2}} - I_{2gl,\frac{1}{2}}^{l+\frac{1}{2}}) + \frac{1}{3} (I_{ogl,\frac{1}{2}}^{l+\frac{1}{2}} - I_{ogl,\frac{1}{2}}^{l+\frac{1}{2}}) + \hat{\sigma}_{gl}^{l+\frac{1}{2}} = Q_{1gl} \Delta x_{l}$$

$$(A.4.01;02)$$

Here we used the facts that

$$I_{2gt}^{l+\frac{1}{2}} = \sum_{m} I_{mgt}^{1+\frac{1}{2}} \omega_{m} \left(\frac{3\mu_{m}^{2}-1}{2}\right) = \frac{3}{2} \sum_{m} \mu_{m}^{2} \omega_{m} I_{mgt}^{1+\frac{1}{2}} - \frac{1}{2} I_{ogt}^{l+\frac{1}{2}}$$

$$\Sigma_{m} \omega_{m} \mu_{m} = 0$$

$$Q_{ogi} = \frac{\chi_{gi} \eta_{i} u_{\sigma}^{n}}{\beta_{i} \Delta t^{n}} + \tau^{n} I_{ogi}^{n}$$

$$Q_{lgi} = \tau^{n} I_{i} gi$$

(A.4.04a,b,c)

ii. The accelerated form of the diffusion equation is obtained by accelerating only the first two moments, as given below

$$(I_{1gl+\frac{1}{2}}^{l+1}-I_{1gl-\frac{1}{2}}^{l+1}) + \hat{\sigma}_{gl} \ I_{ogl}^{l+1} = \chi_{gl} \ \eta_{l} \ \Delta x_{l} \ \Sigma_{g} \ \sigma_{gl} \ I_{ogl}^{l+1} + \Delta x_{l} \ Q_{ogl}$$

$$\frac{2}{3} \left(I_{2gl + \frac{1}{2}}^{l + \frac{1}{2}} - I_{2gl - \frac{1}{2}}^{l + \frac{1}{2}} \right) + \frac{1}{3} \left(I_{ogl + \frac{1}{2}}^{l + 1} - I_{ogl - \frac{1}{2}}^{l + 1} \right) + \hat{\sigma}_{gl} I_{lgl}^{l + 1} = Q_{lgl} \Delta x_{l}$$

$$(A.4.05;06)$$

The DD relationship is redefined in order to eliminate the instability due to the negative flux fix up in the transfer equation, as

$$I_{ngi}^{1+1} = \frac{1}{2} \left[a_{ogi} I_{ogi+\frac{1}{2}}^{i+1} + b_{ogi} I_{ogi-\frac{1}{2}}^{i+1} \right] \qquad n = 0, 1$$

(A.4.07)

where the choice of a_{op} and b_{op} is somewhat based on trial and error approach.

To obtain the diffusion equation in the form of a tridiagonal matrix, the following manipulative steps are taken

- i. Equate (A.4.02) and (A.4.06).
- ii. Substitute (A.4.07) in it for n=1 with $a_{1\mu}=b_{1\mu}=1$.
- iii. Write the resultant for i+1.
- iv. Divide (ii) and (iii) by σ_p and σ_{p+1} respectively.
- v. Eliminate (A.4.05) for $I^{l+1}_{1g_{l-1}/2}$.
- vi. Rewrite (A.4.05) for i=i+1 and eliminate for $I^{(+1/2)}_{101-3/2}$.
- vii. Substitute $I_{1gi-1/2}^{1+1}$ and $I_{1gi-3/2}^{1+1}$ from v and vi into step iv.
- viii. Substitute (A.4.07) for n=0 in (vii).
- ix. Subtract the resulting two equation from the two equations obtained in step vii.

The final result is

$$\begin{split} &-\frac{1}{3\hat{\sigma}_{gl+1}} \left[I_{ogl+\frac{3}{2}}^{l+1} - I_{ogl+\frac{1}{2}}^{l+1}\right] + \frac{1}{3\hat{\sigma}_{gl}} \left[I_{ogl+\frac{1}{2}}^{l+1} - I_{ogl-\frac{1}{2}}^{l+1}\right] \\ &+ \frac{\hat{\sigma}_{gl+1}}{4} \left[a_{ogl+1}I_{ogl+\frac{3}{2}}^{l+1} + b_{ogl+1}I_{ogl+\frac{1}{2}}^{l+1}\right] + \frac{\hat{\sigma}_{gl}}{4} \left[a_{ogl}I_{ogl+\frac{1}{2}}^{l+1} + b_{ogl}I_{ogl-\frac{1}{2}}^{l+1}\right] \\ &= \frac{1}{4} \left[\chi_{gl+1}\eta_{l+1}\Delta x_{l+1}\Sigma_{gl}\sigma_{gl+1}(a_{0gl+1}I_{ogl+\frac{3}{2}}^{l+1} + b_{0gl+1}I_{ogl+\frac{1}{2}}^{l+1})\right] \\ &+ \frac{1}{4} \left[\chi_{gl}\eta_{l}\Delta x_{l}\Sigma_{gl}\sigma_{gl}(a_{0gl}I_{ogl+\frac{1}{2}}^{l+1} + b_{0gl}I_{ogl-\frac{1}{2}}^{l+1})\right] + S_{gl}^{l+\frac{1}{2}} \end{split}$$

(A.4.08)

Where $S_{g}^{1+1/2}$ consists of variables which do not change during iteration of the diffusion equation, and is given as

$$S_{gl}^{1 + \frac{1}{2}} = \frac{\Delta x_{l} Q_{0gl}}{2} + \frac{\Delta x_{l+1} Q_{0gl+1}}{2} - \frac{1}{3\dot{\sigma}_{gl+1}} \begin{bmatrix} I_{ogl}^{1 + \frac{1}{2}} - I_{ogl+\frac{1}{2}}^{1 + \frac{1}{2}} \\ I_{ogl}^{1 + \frac{1}{2}} - I_{ogl+\frac{1}{2}}^{1 + \frac{1}{2}} \end{bmatrix} + \frac{1}{2} \begin{bmatrix} I_{ogl+\frac{1}{2}}^{1 + \frac{1}{2}} - I_{1gl-\frac{1}{2}}^{1 + \frac{1}{2}} \\ I_{1gl+\frac{3}{2}} - I_{1gl-\frac{1}{2}}^{1 + \frac{1}{2}} \end{bmatrix}$$

(A.4.09)

A.5 DERIVATION OF THE DISCRETIZED FORM OF THE GREY EQUATION:

A discretized form of the diffusion equation was obtained from the discretized transfer equation to ensure stability. The grey diffusion equation is derived from the discretized form of the diffusion equation, namely equation (A.4.08).

The accelerated form of the diffusion equation is obtained by summing the frequency groups with a particular weight function. The following substitution is made in (A.4.08) before summing over the frequency groups in order to obtain the grey equation.

Consider the following transformation to be used in the diffusion equation

$$\begin{split} f_{gl}^{k^*} &= (a_{ogl}I_{ogl^*}^{k^*}\frac{1}{2} + b_{ogl}I_{ogl^*}^{k^*}\frac{1}{2}) &\rightarrow \theta_{gl}^{k^*}\frac{1}{2} (a_{ol}I_{ol^*}^{k^*1}\frac{1}{2} + b_{ol}I_{ol^*}^{k^*1}\frac{1}{2}) \\ &+ f_{gl}^{k^*} - \theta_{gl}^{k^*1}(a_{ol}I_{ol^*}\frac{1}{2} + b_{ol}I_{ol^*}\frac{1}{2}) \end{split}$$

$$\begin{split} g_{gi}^{k*\frac{1}{2}} &= (I_{ogi*\frac{1}{2}}^{k*\frac{1}{2}} - I_{ogi-\frac{1}{2}}^{k*\frac{1}{2}}) \rightarrow \phi_{gi}^{k*\frac{1}{2}} (I_{oi*\frac{1}{2}}^{k*1} - I_{oi-\frac{1}{2}}^{k*1}) \\ &+ g_{gi}^{k*\frac{1}{2}} - \phi_{gi}^{k*\frac{1}{2}} (I_{oi*\frac{1}{2}}^{k*\frac{1}{2}} - I_{oi-\frac{1}{2}}^{k*\frac{1}{2}}) \end{split}$$

(A.5.01a,b)

$$a_{oi} = \frac{\Sigma_{g}(a_{ogi} I_{ogi+\frac{1}{2}}^{k+\frac{1}{2}})}{I_{oi+\frac{1}{2}}^{k+\frac{1}{2}}}, \quad b_{oi} = \frac{\Sigma_{g}(b_{ogi} I_{ogi+\frac{1}{2}}^{k+\frac{1}{2}})}{I_{oi+\frac{1}{2}}^{k+\frac{1}{2}}}, \quad I_{oi+\frac{1}{2}}^{k+\frac{1}{2}} = \Sigma_{g} I_{ogi+\frac{1}{2}}^{k+\frac{1}{2}}$$

(A.5.02a,b,c)

k' can be k or k+1/2 corresponding to values before and after acceleration. The resultant equation is

$$\begin{split} &-\Sigma_{g}\frac{1}{3\hat{\sigma}_{gl+1}}\left[\varphi_{gl+1}^{k+l/2}\left(J_{ol+\frac{3}{2}}^{k+1}-J_{ol+\frac{1}{2}}^{k+1}\right)^{61} + \left(J_{ogl+\frac{3}{2}}^{k+\frac{1}{2}}-J_{ogl+\frac{1}{2}}^{k+\frac{1}{2}}\right)^{62} - \varphi_{gl+1}^{k+l/2}\left(J_{ol+\frac{3}{2}}^{k+\frac{1}{2}}-J_{ol+\frac{1}{2}}^{k+\frac{1}{2}}\right)^{63}\right] \\ &+\Sigma_{g}\frac{1}{3\hat{\sigma}_{gl}}\left[\varphi_{gl}^{k+l/2}\left(J_{ol+\frac{1}{2}}^{k+1}-J_{ol+\frac{1}{2}}^{k+1}\right)^{64} + \left(J_{ogl+\frac{1}{2}}^{k+\frac{1}{2}}-J_{ol+\frac{1}{2}}^{k+\frac{1}{2}}\right)^{65} - \varphi_{gl}^{k+l/2}\left(J_{ol+\frac{1}{2}}^{k+\frac{1}{2}}-J_{ol+\frac{1}{2}}^{k+\frac{1}{2}}\right)^{66}\right] \\ &+\Sigma_{g}\frac{\hat{\sigma}_{gl+1}}{4}\left[\theta_{gl+1}^{k+l/2}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+1}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{67} + f_{gl+1}^{k+\frac{1}{2}}-\theta_{gl+1}^{k+\frac{1}{2}}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+\frac{1}{2}}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+\frac{1}{2}}\right)^{69}\right] \\ &+\Sigma_{g}\frac{\hat{\sigma}_{gl}}{4}\left[\theta_{gl}^{k+\frac{1}{2}}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+1}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{610} + f_{gl}^{k+\frac{1}{2}}-\theta_{gl}^{k+\frac{1}{2}}\left(\alpha_{ol+1}I_{ol+\frac{1}{2}}^{k+\frac{1}{2}}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{612}\right] \\ &=\Sigma_{g}\frac{1}{4}\chi_{gl+1}\eta_{l+1}\Delta x_{l}\Sigma_{g}\sigma_{gl+1}\left[\theta_{gl+1}^{k+1}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+1}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{613} + f_{gl+1}^{k+1}\right]^{613} + f_{gl+1}^{k+1}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+\frac{1}{2}}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{615}\right] \\ &+\Sigma_{g}S_{gl}^{1}\eta_{l}\Delta x_{l}\Sigma_{g}\sigma_{ogl}\left[\theta_{ogl}^{k+1}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+1}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{615}\right] \\ &+\Sigma_{g}S_{gl}^{1}\eta_{l}\Delta x_{l}\Sigma_{g}\sigma_{ogl}\left[\theta_{ogl}^{k+1}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+1}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{615}\right] \\ &+\Sigma_{g}S_{gl}^{1}\eta_{l}\Delta x_{l}\Sigma_{g}\sigma_{ogl}\left[\theta_{ogl}^{k+1}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+1}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{615}\right] \\ &+\Sigma_{g}S_{gl}^{1}\eta_{l}\Delta x_{l}\Sigma_{g}\sigma_{ogl}\left[\theta_{ogl}^{k+1}\left(\alpha_{ol+1}I_{ol+\frac{3}{2}}^{k+1}+b_{ol+1}I_{ol+\frac{1}{2}}^{k+1}\right)^{615}\right] \\ &+\Sigma_{g}S_{gl}^{1}\eta_{l}\Delta x_{l}\Sigma_{gl}^{1}\sigma_{l}\Delta x_{l}\Sigma_{gl}^{1}\sigma_{l}\Delta$$

(A.5.04)

These relations simply reflect that a correction term is added to both sides of (A.4.08) in order that the accelerated form of the new equation yields the solution more rapidly by projecting out the slow converging modes. Before the final form of the Grey equation is presented, consider the following manipulative steps taken to obtain the final form of the grey equation.

Suppose we have an arbitrary function ψ_p which is a function of frequency and space. Consider the two terms (#7 & #13) from (A.5.04)

$$\Sigma_{R} \left[\hat{\sigma}_{Rl} \; \psi_{Rl} - \Delta x_{l} \; \chi_{Rl} \; \eta_{l} \; \Sigma_{A} \; \sigma_{A} \psi_{Rl} \right]$$

where other variables are as previously defined

$$= \Sigma_{g} \left[(\sigma_{gi} + \tau) \Delta x_{i} \psi_{gi} - \Delta x_{i} \chi_{gi} \eta_{i} \Sigma_{g} \sigma_{gi} \psi_{gi} \right]$$

$$= \Sigma_{g} \left[\sigma_{gi} \Delta x_{i} + \tau \Delta x_{i} - \frac{\Delta x_{i} \chi_{gi}}{(1 + \alpha_{i} \tau)} \Sigma_{g} \sigma_{gi} \right] \psi_{gi}$$

$$\begin{split} &= \Sigma_g \left[\begin{array}{cccc} \sigma_{gi} & \Delta x_i + \tau \Delta x_i - \frac{\Delta x_i \sigma_{gi}}{(1 + \alpha_i \tau)} & \Sigma_g & \chi_{gi} \right] \psi_{gi} \\ &= \Sigma_g \left[\begin{array}{cccc} \hat{\sigma}_{gi} & \psi_{gi} - \Delta x_i \chi_{gi} \eta_i \Sigma_g \sigma_{gi} \psi_{gi} \right] \\ &= \Sigma_g \left[\tau \Delta x_i + \frac{\alpha_i \sigma_{gi} \tau \Delta x_i}{(1 + \alpha_i \tau)} \right] \psi_{gi} \\ &= \Sigma_g \left[1 + \alpha_i \sigma_{gi} \eta_i \right] \psi_{gi} \tau \Delta x_i \\ &= \xi_{gi} = (1 + \alpha_i \sigma_{gi} \eta_i) \tau \Delta x_i \end{split}$$

(A.5.05)

If ψ_{ν} is taken to be $\theta^{k+1/2}$, then above result can be written as

$$\xi_i = \Sigma_g \ \xi_{gi} \ \theta_{gi}^{k \cdot \frac{1}{2}}$$

With the above manipulation and keeping only k+1 terms on left side of equation (A.5.04), it reduces to

$$\begin{split} &-\sum_{g} \frac{\varphi_{gi-1}}{3\hat{\sigma}_{gi+1}} \left(I_{oi + \frac{3}{2}}^{k+1} - I_{oi + \frac{1}{2}}^{k+1} \right) + \sum_{g} \frac{\varphi_{gi}}{3\hat{\sigma}_{gi}} \left(I_{oi + \frac{1}{2}}^{k+1} - I_{oi - \frac{1}{2}}^{k+1} \right) \\ &+ \frac{\xi_{i+1}}{4} \left(a_{oi+1} I_{oi+\frac{3}{2}}^{k+1} + b_{oi+1} I_{oi+\frac{1}{2}}^{k+1} \right) + \frac{\xi_{i}}{4} \left(a_{oi} I_{oi+\frac{1}{2}}^{k+1} + b_{oi} I_{oi-\frac{1}{2}}^{k+1} \right) \\ &= \sum_{g} \left[\frac{1}{3\hat{\sigma}_{gi+1}} \left(I_{ogi+\frac{3}{2}}^{k+\frac{1}{2}} - I_{ogi+\frac{1}{2}}^{k+\frac{1}{2}} \right) - \frac{1}{3\hat{\sigma}_{gi}} \left(I_{ogi+\frac{1}{2}}^{k+\frac{1}{2}} - I_{ogi-\frac{1}{2}}^{k+\frac{1}{2}} \right) \right] \\ &- \sum_{g} \left[\frac{\varphi_{gi+1}}{3\hat{\sigma}_{gi+1}} \left(I_{oi+\frac{3}{2}}^{k+\frac{1}{2}} - I_{oi+\frac{1}{2}}^{k+\frac{1}{2}} \right) - \frac{\varphi_{gi}}{3\hat{\sigma}_{gi}} \left(I_{oi+\frac{1}{2}}^{k+\frac{1}{2}} - I_{oi-\frac{1}{2}}^{k+\frac{1}{2}} \right) \right] \\ &- \frac{1}{4} \sum_{g} \left(\xi_{gi+1} f_{gi+1}^{k+\frac{1}{2}} + \xi_{g} f_{gi} \right) \\ &+ \frac{1}{4} \left[\xi_{i+1} \left(a_{oi+1} I_{oi+\frac{3}{2}}^{k+\frac{1}{2}} + b_{oi+1} I_{oi+\frac{1}{2}}^{k+\frac{1}{2}} \right) + \xi_{i} \left(a_{oi} I_{oi+\frac{1}{2}}^{k+\frac{1}{2}} + b_{oi} I_{oi-\frac{1}{2}}^{k+\frac{1}{2}} \right) \right] \\ &+ \sum_{g} S_{gi}^{k+\frac{1}{2}} \end{split}$$

(A.5.06)

The solution of the grey equation depends on the choice of the spectral functions θ and φ . One expression for θ and φ corresponds to the spectral function causing slowest convergence. In this case θ and φ are taken to be same and are given as

$$\theta_{gi}^{k+\frac{1}{2}} = \varphi_{gi}^{k+\frac{1}{2}} = \frac{\chi_{gi}/(\sigma_{gi}+\tau)}{\Sigma_{g}[\chi_{gi}/(\sigma_{gi}+\tau)]}$$

(A.5.07)

This is known as the linear case. The other expression for θ and ϕ is known as the non linear case and is given as

$$\theta_{gt}^{k+\frac{1}{2}} = \frac{f_{gt}^{k+\frac{1}{2}}}{\left(a_{0t} I_{0t+\frac{1}{2}} + b_{0t} I_{0t-\frac{1}{2}}\right)}, \quad \phi_{gt}^{k+\frac{1}{2}} = \frac{g_{gt}^{k+\frac{1}{2}}}{\left(I_{0t+\frac{1}{2}}^{k+\frac{1}{2}} - I_{0t-\frac{1}{2}}^{k+\frac{1}{2}}\right)}$$
(A.5.08a,b)

When the nonlinear expression is substituted in (A.5.06), it reduces to

$$\begin{split} & - \Sigma_{g} \frac{1}{3\hat{\sigma}_{g^{l+1}}} \left[\varphi_{g^{l+1}}^{k+\frac{1}{2}} \Big(I_{0l+\frac{3}{2}}^{k+1} - I_{0l+\frac{1}{2}}^{k+1} \Big) \right] + \Sigma_{g} \frac{1}{3\hat{\sigma}_{g^{l}}} \left[\varphi_{g^{l}}^{k+\frac{1}{2}} \Big(I_{0l+\frac{1}{2}}^{k+1} - I_{g^{l-\frac{1}{2}}}^{k+1} \Big) \right] \\ & + \frac{1}{4} \Big[\xi_{l+1} \Big(a_{0l+1} I_{0l+\frac{3}{2}}^{k+1} + b_{0l+1} I_{0g^{l+\frac{1}{2}}}^{k+1} \Big) \Big] + \frac{1}{4} \Big[\xi_{l} \Big(a_{0l} I_{0l+\frac{1}{2}}^{k+1} + b_{0l} I_{0l-\frac{1}{2}}^{k+1} \Big) \Big] = \Sigma_{g} S_{g^{l}}^{g^{l+\frac{1}{2}}} \end{split}$$

(A.5.09)

The following steps are utilized to obtain above equation. Consider the following expression from right side of (A.5.06)

$$\Sigma_{g} \frac{\varphi_{gt}^{k \cdot \frac{1}{2}}}{\mathring{\sigma}_{gt}} (I_{ot \cdot \frac{1}{2}}^{k \cdot \frac{1}{2}} - I_{ot \cdot \frac{1}{2}}^{k \cdot \frac{1}{2}}) + \xi_{l}(a_{ot} I_{ot \cdot \frac{1}{2}}^{k \cdot \frac{1}{2}} - b_{ot} I_{ot \cdot \frac{1}{2}}^{k \cdot \frac{1}{2}})$$
(A.5.10)

If we substitute the nonlinear expression (A.5.08a,b) in (A.5.10)

$$\sum_{g} \frac{1}{\hat{o}_{gl}} \frac{(I_{0gl}^{k+\frac{1}{2}} - I_{0gl-\frac{1}{2}}^{k+\frac{1}{2}})(I_{0l+\frac{1}{2}}^{k+\frac{1}{2}} - I_{0l+\frac{1}{2}}^{k+\frac{1}{2}})}{(I_{0l+\frac{1}{2}}^{k+\frac{1}{2}} - I_{0l+\frac{1}{2}}^{k+\frac{1}{2}})}$$

$$+ \sum_{g} \frac{\xi_{gfgl}^{k+\frac{1}{2}} (a_{0l}I_{0l+\frac{1}{2}}^{k+\frac{1}{2}} + b_{0l}I_{0l-\frac{1}{2}}^{k+\frac{1}{2}})}{(a_{0l}I_{0l+\frac{1}{2}}^{k+\frac{1}{2}} + b_{0l}I_{0l-\frac{1}{2}}^{k+\frac{1}{2}})}$$

$$= \sum_{g} \frac{1}{\hat{o}_{gl}} (I_{0gl+\frac{1}{2}}^{k+\frac{1}{2}} - I_{0gl-\frac{1}{2}}^{k+\frac{1}{2}}) + \sum_{g} \xi_{gfgl}^{k+\frac{1}{2}}$$

(A.5.11)

Here we have used (A.5.01) and (A.5.05).

Now it is trivial to see how all terms except S_{gi} on the right hand side of (A.5.06) cancel each other.

A.6 BOUNDARY CONDITIONS OF THE DIFFUSION EQUATION:

The boundary conditions^{A/2} are obtained by adding a term into the flux (scalar intensity) at cell boundaries in order to make it consistent with the scalar intensity inside the slab. Conventionally, a quantity known as the one-way flux must be conserved between the accelerated and non-accelerated equations.

The one way flux at the left and right boundaries is given as,

$$J_{\frac{1}{2}}^{l+\frac{1}{2}} = \Sigma_{\mu_{m}>0} \omega_{m} \mu_{m} I_{\frac{mq}{2}}^{l+\frac{1}{2}}$$

$$J_{l+\frac{1}{2}}^{l+\frac{1}{2}} = \Sigma_{\mu_{m}<0} \omega_{m} \mu_{m} I_{\frac{mq}{2}l+\frac{1}{2}}^{l+\frac{1}{2}}$$

(A.6.01)

The diffusion equation derived here is based on the fact that if the specific intensity is linear in angular space, then the exact solution of the diffusion equation is obtained without iteration (assuming no negative flux fixup is implemented). The specific intensity at the boundaries is defined as

$$I_{\text{mg}}^{l+\frac{1}{2}} = \frac{1}{2}I_{0g}^{l+\frac{1}{2}} + \frac{3}{2}\mu_{\text{m}}I_{1g}^{l+\frac{1}{2}}$$

(A.6.02)

The one way flux becomes

$$J_{\frac{1}{2}}^{l \cdot \frac{1}{2}} = \Sigma_{\mu_{m} > 0} \omega_{m} \mu_{m} \left[\frac{1}{2} J_{0g\frac{1}{2}}^{l \cdot \frac{1}{2}} + \frac{3}{2} \mu_{m} J_{1g\frac{1}{2}}^{l \cdot \frac{1}{2}} \right]$$

$$J_{l \cdot \frac{1}{2}}^{l \cdot \frac{1}{2}} = \Sigma_{\mu_{m} < 0} \omega_{m} \mu_{m} \left[\frac{1}{2} J_{0gl \cdot \frac{1}{2}}^{l \cdot \frac{1}{2}} + \frac{3}{2} \mu_{m} J_{1gl \cdot \frac{1}{2}}^{l \cdot \frac{1}{2}} \right]$$

(A.6.03a,b)

It's accelerated form is given as

$$\begin{split} J_{\frac{1}{2}}^{l+1} &= \Sigma_{\mu_{m} \geq 0} \ \omega_{m} \mu_{m} [\frac{1}{2} I_{0g\frac{1}{2}}^{l+1} \ + \ \frac{3}{2} \mu_{m} I_{1g\frac{1}{2}}^{l+1}] \\ J_{l+\frac{1}{2}}^{l+1} &= \Sigma_{\mu_{m} < 0} \ \omega_{m} \mu_{m} [\frac{1}{2} I_{0gl+\frac{1}{2}}^{l+1} \ + \ \frac{3}{2} \mu_{m} I_{1gl+\frac{1}{2}}^{l+1}] \end{split}$$

(A.6.04a,b)

By subtracting (A.6.03) from (A.6.04), and using the condition that $J^{1+1/2} = J^{1+1}$, we obtain the following accelerated diffusion intensity at the boundaries after summing over all angles

$$\begin{split} I_{\text{Og}\frac{1}{2}}^{l+1} \Sigma_{\mu_{m} > 0} \ \omega_{m} \mu_{m} &= I_{\text{Og}\frac{1}{2}}^{l+\frac{1}{2}} \Sigma_{\mu_{m} > 0} \ \omega_{m} \ \mu_{m} \ + I_{\text{Ig}\frac{1}{2}}^{l+\frac{1}{2}} - I_{\text{Ig}\frac{1}{2}}^{l+1} \\ I_{\text{Og}l+\frac{1}{2}}^{l+1} \Sigma_{\mu_{m} < 0} \omega_{m} \mu_{m} &= I_{\text{Og}l+\frac{1}{2}}^{l+\frac{1}{2}} \Sigma_{\mu_{m} < 0} \ \omega_{m} \mu_{m} \ + I_{\text{Ig}l+\frac{1}{2}}^{l+\frac{1}{2}} - I_{\text{Ig}l+\frac{1}{2}}^{l+1} \\ since \ \Sigma_{m} \ \omega_{m} \mu_{m}^{2} &= \frac{1}{3} \end{split}$$

(A.6.05a,b)

However $I^{l+1}_{lgl/2}$ and $I^{l+1}_{lgl+1/2}$ are unknown. To find expressions for these variables in terms of $I^{l+1}_{ogi\pm 1/2}$ quantities we go back to the original equation used to derive the diffusion equation within the slab.

 $I^{l+1}_{lg1/2}$ and $I^{l+1}_{lgJ+1/2}$ are computed as follows

- A. $I^{l+1}_{1g1/2}$
- i. Divide (A.4.06) by σ_{ti}
- ii. Substitute (A.4.07) in above for n=1
- iii. Multiply (A.4.05) by (-1/2) and add the resultant into above
- iv. Substitute (A.4.06) for n=0 into iv
- v. Solve for $I^{l+1}_{lg1/2}$ by taking i = 1
- B. $I^{l+1}_{1gl+1/2}$

A similar procedure is used, except that we now multiply by 1/2 (instead of - 1/2) and solve for $I^{k\cdot 1}_{1gl+1/2}$ by taking i = I (instead of i=1), The final result is

$$\begin{split} I_{1g_{\frac{1}{2}}}^{l+1} &= \frac{\hat{\sigma}_{g_{l}}}{4} (a_{0g_{l}} I_{0g_{\frac{3}{2}}}^{l+1} + b_{0g_{l}} I_{0g_{\frac{1}{2}}}^{l+1}) - \frac{\chi_{g_{l}} \eta_{1} \Delta x_{1}}{4} \Sigma_{g_{l}} \sigma_{g_{l}} (a_{0g_{l}} I_{0g_{\frac{3}{2}}}^{l+1} + b_{0g_{l}} I_{0g_{\frac{1}{2}}}^{l+1}) \\ &- \frac{\Delta x_{1} Q_{0g_{l}}}{2} + \frac{Q_{1g_{l}} \Delta x_{1}}{\hat{\sigma}_{g_{l}}} - \frac{1}{3\hat{\sigma}_{g_{l}}} (I_{0g_{\frac{3}{2}}}^{l+1} - I_{0g_{\frac{1}{2}}}^{l+1}) - \frac{2}{3\hat{\sigma}_{g_{l}}} (I_{2g_{\frac{3}{2}}}^{l+\frac{1}{2}} - I_{2g_{\frac{1}{2}}}^{l+\frac{1}{2}}) \\ I_{1g_{l}+\frac{1}{2}}^{l+1} &= -\frac{\hat{\sigma}_{g_{l}}}{4} (a_{0g_{l}} I_{0g_{l}+\frac{1}{2}}^{l+1} + b_{0g_{l}} I_{0g_{l}-\frac{1}{2}}^{l+1}) + \frac{\chi_{g_{l}} \eta_{l} \Delta x_{l}}{4} \Sigma_{g_{l}} \sigma_{g_{l}} (a_{0g_{l}} I_{0g_{l}+\frac{1}{2}}^{l+1} + b_{0g_{l}} I_{0g_{l}-\frac{1}{2}}^{l+1}) \\ &+ \frac{\Delta x_{l} Q_{0g_{l}}}{2} + \frac{Q_{1g_{l}} \Delta x_{l}}{\hat{\sigma}_{g_{l}}} - \frac{1}{3\sigma_{g_{l}}} (I_{0g_{l}+\frac{1}{2}}^{l+1} - I_{0g_{l}-\frac{1}{2}}^{l+1}) - \frac{2}{3\hat{\sigma}_{g_{l}}} (I_{2g_{l}+\frac{1}{2}}^{l+\frac{1}{2}} - I_{2g_{l}-\frac{1}{2}}^{l+\frac{1}{2}}) \\ &+ \frac{\Delta x_{l} Q_{0g_{l}}}{2} + \frac{Q_{1g_{l}} \Delta x_{l}}{\hat{\sigma}_{g_{l}}} - \frac{1}{3\sigma_{g_{l}}} (I_{0g_{l}+\frac{1}{2}}^{l+1} - I_{0g_{l}-\frac{1}{2}}^{l+1}) - \frac{2}{3\hat{\sigma}_{g_{l}}} (I_{2g_{l}+\frac{1}{2}}^{l+\frac{1}{2}} - I_{2g_{l}-\frac{1}{2}}^{l+\frac{1}{2}}) \end{split}$$

$$(A.6.06a,b)$$

After substituting (A.6.06) in (A.6.05), we rewrite these equations in similar form as the diffusion equation. The final form of the accelerated diffusion equation at the boundaries is given as

$$\begin{split} &(\Sigma_{\mu_{m}>0}\ \omega_{m}\mu_{m}+\frac{\hat{\sigma}_{gl}}{4}b_{0gl}+\frac{1}{3\hat{\sigma}_{gl}})I_{0g\frac{1}{2}}^{l+1}+(\frac{\hat{\sigma}_{gl}}{4}a_{0gl}-\frac{1}{3\hat{\sigma}_{0gl}})I_{0g\frac{3}{2}}^{l+1}\\ &=I_{0g\frac{1}{2}}^{l+\frac{1}{2}}\Sigma_{\mu_{m}>0}\ \omega_{m}\mu_{m}+I_{1g\frac{1}{2}}^{l+\frac{1}{2}}+\frac{\chi_{gl}\eta_{1}\Delta\chi_{1}}{4}\Sigma_{g}\ \sigma_{gl}(a_{0gl}I_{0g\frac{3}{2}}^{l+1}+b_{0gl}I_{0g\frac{1}{2}}^{l+1})\\ &+\frac{\Delta\chi_{1}Q_{0gl}}{2}-\frac{Q_{1gl}\Delta\chi_{1}}{\hat{\sigma}_{gl}}+\frac{2}{3\hat{\sigma}_{gl}}(I_{2g\frac{3}{2}}^{l+\frac{1}{2}}-I_{2g\frac{1}{2}}^{l+\frac{1}{2}}) \end{split}$$

$$\begin{split} &(-\Sigma_{\mu_{m} < 0} \ \omega_{m} \mu_{m} + \frac{\hat{\sigma}_{gl}}{4} a_{0gl} + \frac{1}{3\hat{\sigma}_{gl}}) I_{ogl}^{l+1} + (\frac{\hat{\sigma}_{gl}}{4} b_{0gl} - \frac{1}{3\hat{\sigma}_{gl}}) I_{0gl-\frac{1}{2}}^{l+1} \\ &= -I_{0gl+\frac{1}{2}}^{l+\frac{1}{2}} \Sigma_{\mu_{m} < 0} \omega_{m} \mu_{m} - I_{1gl+\frac{1}{2}}^{l+\frac{1}{2}} + \frac{\chi_{gl} \eta_{l} \Delta x_{l}}{4} \Sigma_{\frac{1}{2}} \ \sigma_{gl} (a_{0gl} I_{0gl+\frac{1}{2}}^{l+1} + b_{0gl} I_{0gl-\frac{1}{2}}^{l+1}) \\ &+ \frac{\Delta x_{l} Q_{0gl}}{2} + \frac{Q_{1gl} \Delta x_{l}}{\hat{\sigma}_{gl}} - \frac{2}{3\hat{\sigma}_{gl}} I_{0g} (I_{2gl+\frac{1}{2}}^{l+\frac{1}{2}} - I_{2gl-\frac{1}{2}}^{l+\frac{1}{2}}) \end{split}$$

(A.6.07a,b)

A.7 BOUNDARY CONDITIONS OF THE GREY EQUATION:

The boundary conditions for the grey equation are obtained from the diffusion boundary conditions using the transformation (A.5.02) that was used to obtain the grey equation from the diffusion equation inside the slab. The following steps are used:

- i. Substitute (A.5.01) in (A.6.06).
- ii. Sum over frequency groups.
- iii. Use similar simplification as was done to obtain (A.5.06) from (A.5.04). The final form of the grey equation at the boundaries can then be expressed as

$$\begin{array}{l} (\ \Sigma_{\mu_{m} \succ 0} \ \omega_{m} \mu_{m} \ + \ \Sigma_{g} \ \frac{\phi_{gl}}{3 \hat{\sigma}_{gl}} \ + \ \frac{1}{4} \xi_{1} b_{01}) I_{0\frac{1}{2}}^{k+1} \ + \ (\frac{1}{4} \xi_{1} a_{01} \ - \ \Sigma_{g} \frac{1}{3 \hat{\sigma}_{gl}} \phi_{gl}) I_{0\frac{3}{2}}^{k+1} \\ = \ I_{0\frac{1}{2}}^{l+\frac{1}{2}} \Sigma_{\mu_{m} \succ 0} \omega_{m} \mu_{m} \ + \ I_{1\frac{1}{2}}^{l+\frac{1}{2}} \ - \ \frac{1}{4} \Sigma_{g} \xi_{g} f_{gl}^{k+\frac{1}{2}} \ + \ \frac{\xi_{1}}{4} (a_{01} I_{0\frac{3}{2}}^{k+\frac{1}{2}} \ + b_{01} I_{0\frac{1}{2}}^{k+\frac{1}{2}}) \\ + \ \frac{\Delta x_{1}}{2} \Sigma_{g} Q_{0gl} \ - \ \Sigma_{g} \frac{Q_{1gl} \Delta x_{1}}{\hat{\sigma}_{gl}} \ + \ \Sigma_{g} \frac{2}{3 \hat{\sigma}_{gl}} (I_{2e\frac{3}{2}}^{l+\frac{1}{2}} \ - \ I_{2e\frac{1}{2}}^{l+\frac{1}{2}}) \\ - \frac{1}{3} \Sigma \frac{\phi_{gl}^{l+\frac{1}{2}}}{\hat{\sigma}_{gl}} (I_{0\frac{3}{2}}^{k+\frac{1}{2}} - I_{0\frac{1}{2}}^{k+\frac{1}{2}}) + \frac{1}{3} \Sigma (\frac{1}{\hat{\sigma}_{gl}} (I_{0e\frac{3}{2}}^{k+\frac{1}{2}} - I_{0e\frac{1}{2}}^{k+\frac{1}{2}}) \end{array}$$

(A.7.01;02)

A.8 SOLUTION OF THE DIFFUSION AND GREY EQUATIONS:

To obtain the solution for the diffusion equation, we rewrite (A.4.08) and (A.6.07) in a tridiagonal form, and invert the matrix. In matrix form (A.4.08) is written as

$$a_{gi}I_{Qgi-\frac{1}{2}}^{l+1} + b_{gi}I_{Qgi+\frac{1}{2}}^{l+1} + c_{gi}I_{Qgi+\frac{3}{2}}^{l+1} = R_{gi}^{l+1}$$

(A.8.01)

where coefficients from (A.4.08) for i=2..I are given as

$$a_{gi} = -\frac{1}{3\hat{\sigma}_{gi-1}} + \frac{\hat{\sigma}_{gi-1}}{4} b_{0gi-1}$$

$$b_{gi} = \frac{1}{3\hat{\sigma}_{gi}} + \frac{1}{3\hat{\sigma}_{gi-1}} + \frac{\hat{\sigma}_{gi}b_{0gi}}{4} + \frac{\hat{\sigma}_{gi-1}a_{0gi-1}}{4}$$

$$c_{gi} = -\frac{1}{3\hat{\sigma}_{gi}} + \frac{\hat{\sigma}_{gi}a_{0gi}}{4}$$

$$R_{gi}^{l+1} = \frac{1}{4} \Sigma_{i}^{+} \left[\chi_{gi-1} \eta_{i-1} \Delta x_{i-1} \Sigma_{gi} \sigma_{gi-1} (a_{0gi-1}I_{0gi-\frac{1}{2}}^{l+1} + b_{0gi}I_{gi-\frac{3}{2}}^{l+1}) \right] + S_{gi-1}^{l+\frac{1}{2}}$$

$$(A.8.02a,b,c,d)$$

The expression for left and right boundaries from (A.6.07) are

$$\begin{split} a_{gl} &= 0.0 \\ b_{gl} &= \Sigma_{\mu_{m}>0} \omega_{m} \mu_{m} + \frac{1}{3\hat{\sigma}_{gl}} + \frac{1}{4} \hat{\sigma}_{gl} b_{0gl} \\ c_{gl} &= -\frac{1}{3\hat{\sigma}_{gl}} + \frac{1}{4} \hat{\sigma}_{gl} a_{0gl} \\ R_{gl}^{l} &= I_{0g\frac{1}{2}}^{l+\frac{1}{2}} \Sigma_{\mu_{m}>0} \omega_{m} \mu_{m} + I_{1g\frac{1}{2}}^{l+\frac{1}{2}} + \frac{\Delta x_{1} Q_{0gl}}{2} - \frac{\Delta x_{1} Q_{1gl}}{\hat{\sigma}_{gl}} \\ &+ \frac{2}{3\hat{\sigma}_{gl}} (I_{2g\frac{3}{2}}^{l+\frac{1}{2}} - I_{2g\frac{1}{2}}^{l+\frac{1}{2}}) + \frac{1}{4} \chi_{gl} \eta_{1} \Delta x_{1} \Sigma_{gl} \sigma_{gl} (a_{0gl} I_{0g\frac{1}{2}}^{l+1} + b_{0gl} I_{0g\frac{1}{2}}^{l+1}) \end{split}$$

(A.8.03a,b,c,d)

$$\begin{split} a_{gl+1} &= \frac{1}{4} \hat{\sigma}_{gl} b_{0gl-1} - \frac{1}{3 \hat{\sigma}_{gl-1}} \\ b_{gl+1} &= -\Sigma_{\mu_m < 0} \omega_m \mu_m + \frac{1}{3 \hat{\sigma}_{gl-1}} + \frac{1}{4} \hat{\sigma}_{gl-1} a_{0gl-1} \\ c_{gl+1} &= 0.0 \\ R_{gl+1} &= -I_{0gl+\frac{1}{2}}^{l+\frac{1}{2}} \Sigma_{\mu_m < 0} \omega_m \mu_m - I_{1gl+\frac{1}{2}}^{l+\frac{1}{2}} + \frac{\Delta x_l Q_{0gl}}{2} + \frac{\Delta x_l Q_{1gl}}{\hat{\sigma}_{gl}} \\ -\frac{2}{3 \hat{\sigma}_{gl}} (I_{2gl+\frac{1}{2}}^{l+\frac{1}{2}} - I_{2gl-\frac{1}{2}}^{l+\frac{1}{2}}) + \frac{1}{4} \chi_{gl} \eta_l \Delta x_l \Sigma_{\frac{1}{2}} \sigma_{gl} (a_{0gl} I_{0gl+\frac{1}{2}}^{l+1} + b_{0gl} I_{gl-\frac{1}{2}}^{l+1}) \end{split}$$

(A.8.04a,b,c,d)

In the source iteration method a new solution is substituted in (A.8.02d;3d) and the matrix is inverted again for the new solution. This is repeated until some desired convergence is achieved. To accelerate the diffusion equation we solve the

grey equation instead of substituting the new solution on the right side of the diffusion equation. The Grey equation is solved in like manner to the diffusion equation. The set of equations is given as

$$a_{l}^{k,\frac{1}{2}}_{0l-\frac{1}{2}} + b_{l}^{k,\frac{1}{2}}_{0l,\frac{1}{2}} + c_{l}^{k,\frac{1}{2}}_{0l,\frac{3}{2}} = R_{l}^{k}$$
(A.8.05)

where coefficients from (A.5.04) for i=2..N are given as,

$$a_{l} = -\frac{1}{3} \sum_{g} \frac{\varphi_{gl-1}}{\partial_{gl-1}} + \frac{1}{4} \xi_{l-1} b_{0l-1}$$

$$b_{l} = \frac{1}{3} \sum_{g} \left[\frac{\varphi_{gl}}{\partial_{gl}} + \frac{\varphi_{gl-1}}{\partial_{gl-1}} \right] + \frac{1}{4} \left[\xi_{l} b_{0l} + \xi_{l-1} a_{0l-1} \right]$$

$$c_{l} = -\frac{1}{3} \sum_{g} \frac{\varphi_{gl}}{\partial_{gl}} + \frac{1}{4} \xi_{l} a_{0l}$$
For linear case
$$R_{l}^{k+\frac{1}{2}} = \sum_{g} \frac{1}{3 \hat{\sigma}_{gl+1}} (I_{0gl+\frac{3}{2}-l}^{k+\frac{1}{2}} - I_{0gl+\frac{1}{2}}^{k+\frac{1}{2}}) - \sum_{g} \frac{1}{3 \hat{\sigma}_{gl}} (I_{0gl+\frac{1}{2}}^{k+\frac{1}{2}} - I_{0gl-\frac{1}{2}}^{k+\frac{1}{2}})$$

$$- \frac{1}{3} \sum_{g} \frac{\varphi_{gl+1}}{\hat{\sigma}_{gl+1}} (I_{0l+\frac{3}{2}-l}^{k+\frac{1}{2}} - I_{0l+\frac{1}{2}}^{k+\frac{1}{2}}) + \frac{1}{3} \sum_{g} \frac{\varphi_{gl}}{\hat{\sigma}_{gl}} (I_{0l+\frac{1}{2}-l}^{k+\frac{1}{2}} - I_{0l-\frac{1}{2}}^{k+\frac{1}{2}})$$

$$- \frac{1}{4} \sum_{g} [\xi_{gl+1} f_{gl+1}^{k+\frac{1}{2}} + \xi_{g} f_{gl}^{k+\frac{1}{2}}] + \frac{1}{4} \xi_{l} [a_{0l} I_{0l+\frac{1}{2}}^{k+\frac{1}{2}} + b_{0l} I_{0l-\frac{1}{2}}^{k+\frac{1}{2}}]$$

$$+ \frac{1}{4} \xi_{l+1} [a_{0l+1} I_{0l+\frac{3}{2}}^{k+\frac{1}{2}} + b_{0l+1} I_{0l+\frac{1}{2}}^{k+\frac{1}{2}}] + \sum_{g} S_{gl}^{k+\frac{1}{2}}$$

For non linear case
$$R^{\frac{k+\frac{1}{2}}{2}} = \sum S_{-k}^{\frac{k+\frac{1}{2}}{2}}$$

(A.8.06a,b,c,d)

At the left and right boundaries from (A.7.01;02) we have

$$a_{1} = 0.0$$

$$b_{1} = \frac{1}{3} \Sigma_{g} \frac{\varphi_{gl}}{\hat{\sigma}_{gl}} + \frac{1}{4} \xi_{1} b_{01} + \Sigma_{\mu_{m} > 0} \omega_{m} \mu_{m}$$

$$c_{1} = -\frac{1}{3} \Sigma_{g} \frac{\varphi_{gl}}{\hat{\sigma}_{gl}} + \frac{1}{4} \xi_{1} a_{01}$$

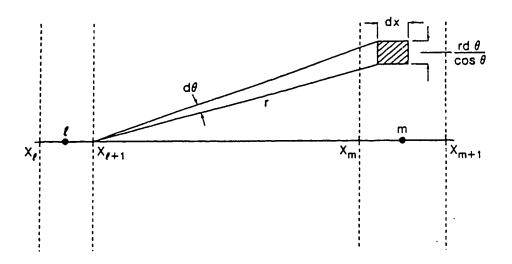
For linear case $R_{1}^{k} = I_{0\frac{1}{2}}^{l \cdot \frac{1}{2}} \Sigma_{\mu_{m} > 0} \omega_{m} \mu_{m} + I_{1\frac{1}{2}}^{l \cdot \frac{1}{2}} + \Sigma_{g} \frac{1}{3 \hat{\sigma}_{gl}} (I_{0g}^{k \cdot \frac{1}{2}} - I_{0g\frac{1}{2}}^{k \cdot \frac{1}{2}})$ $- \frac{1}{3} \Sigma_{g} \frac{\varphi_{gl}}{\hat{\sigma}_{gl}} (I_{0\frac{3}{2}}^{k \cdot \frac{1}{2}} - I_{0\frac{1}{2}}^{k \cdot \frac{1}{2}}) + \Sigma_{g} \frac{2}{3 \hat{\sigma}_{gl}} (I_{2g\frac{3}{2}}^{l \cdot \frac{1}{2}} - I_{2g\frac{1}{2}}^{l \cdot \frac{1}{2}}) + \frac{\Delta x_{1}}{2} \Sigma_{Q_{0gl}}$ $- \Delta x_{1} \Sigma_{g} \frac{Q_{1gl}}{\hat{\sigma}_{gl}} - \frac{1}{4} \Sigma_{g} \xi_{g} f_{gl}^{k \cdot \frac{1}{2}} + \frac{1}{4} \xi_{1} (a_{0l} I_{0\frac{3}{2}}^{k \cdot \frac{1}{2}} + b_{0l} I_{0\frac{1}{2}}^{k \cdot \frac{1}{2}})$ For non linear case $R_{1}^{k} = I_{0\frac{1}{2}}^{l \cdot \frac{1}{2}} \Sigma_{\mu_{m} > 0} \omega_{m} \mu_{m} + I_{1\frac{1}{2}}^{l \cdot \frac{1}{2}} + \Sigma_{g} \frac{2}{3 \hat{\sigma}_{gl}} (I_{2g\frac{3}{2}}^{l \cdot \frac{1}{2}} - I_{2g\frac{1}{2}}^{l \cdot \frac{1}{2}})$ $+ \frac{\Delta x_{1}}{2} \Sigma_{g} Q_{0gl} - \Delta x_{1} \Sigma_{g} \frac{Q_{1gl}}{\hat{\sigma}_{-1}}$

$$\begin{split} a_{l+1} &= -\frac{1}{3} \sum_{s} \frac{\phi_{gl}}{\hat{\sigma}_{gl}} + \frac{1}{4} \xi_{l} b_{0l} \\ b_{l+1} &= \frac{1}{3} \sum_{g} \frac{\phi_{gl}}{\hat{\sigma}_{gl}} + \frac{1}{4} \xi_{l} a_{0l} - \sum_{\mu_{m} < 0} \omega_{m} \mu_{m} \\ c_{l+1} &= 0.0 \\ For \ linear \ case \\ R_{l+1}^{k+\frac{1}{2}} &= -I_{0l+\frac{1}{2}}^{l+\frac{1}{2}} \sum_{\mu_{m} < 0} \omega_{m} \mu_{m} - I_{1l+\frac{1}{2}}^{l+\frac{1}{2}} - \sum_{g} \frac{1}{3 \hat{\sigma}_{gl}} (I_{0gl+\frac{1}{2}}^{k+\frac{1}{2}} - I_{0gl-\frac{1}{2}}^{k+\frac{1}{2}}) \\ &+ \sum_{g} \frac{\phi_{gl}}{3 \hat{\sigma}_{gl}} (I_{0l+\frac{1}{2}}^{k+\frac{1}{2}} - I_{0l-\frac{1}{2}}^{k+\frac{1}{2}}) - \sum_{g} \frac{2}{3 \hat{\sigma}_{gl}} (I_{2gl+\frac{1}{2}}^{l+\frac{1}{2}} - I_{2gl-\frac{1}{2}}^{l+\frac{1}{2}}) + \frac{\Delta x_{l}}{2} \sum_{Q_{0gl}} Q_{0gl} \\ &+ \Delta x_{l} \sum_{g} \frac{Q_{1gl}}{\hat{\sigma}_{gl}} - \frac{1}{4} \sum_{g} \xi_{g} \xi_{gl}^{k+\frac{1}{2}} + \frac{1}{4} \xi_{l} (a_{0l} I_{0l+\frac{1}{2}}^{k+\frac{1}{2}} + b_{0l} I_{0l-\frac{1}{2}}^{k+\frac{1}{2}}) \\ &\quad For \ non \ linear \ case \\ R_{l+1}^{k+\frac{1}{2}} &= -I_{0l+\frac{1}{2}}^{l+\frac{1}{2}} \sum_{\mu_{m} < 0} \omega_{m} \mu_{m} - I_{1l+\frac{1}{2}}^{l+\frac{1}{2}} - \sum_{g} \frac{2}{3 \hat{\sigma}_{gl}} (I_{2gl+\frac{1}{2}}^{l+\frac{1}{2}} - I_{2gl-\frac{1}{2}}^{l+\frac{1}{2}}) \\ &+ \frac{\Delta x_{l}}{2} \sum_{g} Q_{0gl} + \Delta x_{l} \sum_{g} \frac{Q_{1gl}}{\hat{\sigma}_{gl}} \end{aligned}$$

B. MARCHAND'S MODEL

Conceptually Marchand's approach is quite similar to the approach used by Audenaerde et al^{8/1} to solve the neutron particle transport problem. The details of the mathematics involved can be found elsewhere^{8/2}. The following discussion emphasises the conceptual understanding of Marchand's model in it's exact form and then the two-cell simplified model.

In order to elucidate Marchand's algorithm, consider the geometry shown in the figure below.



Using the analogy of the Andemaerde analysis, the radiation power intensity that originates from a ring of radius R of thickness dx in cell m and is incident on the right boundary of lth cell is

$$dP_{i+1}^{m}(\mu,\nu)d\mu d\nu = (2\pi R dR dx) d\nu \ n_{m} I_{m} \frac{\mu}{r^{2}} e^{-\tau(x_{i-1},x)^{2}\mu}$$

(B.01)

where $\mu = \cos\theta$ and τ is the optical depth between x_{t+1} and x_t , and can be expressed as

$$\tau(x_{l+1},x) = \tau(x_{l+1},x_m) + \tau(x_m,x) = \tau_{lm} + \frac{\tau(x-x_m)}{\Delta x_m}$$
(B.02)

where $\tau_m = n_m \sigma_m \Delta x_m$, n_m is the ion density, and I_m is the power radiated per atom, per unit frequency interval dv per unit solid angle in cell m.

The total radiation specific intensity from cell m incident on interface x_{i+1} is

$$P_{l+1}^{m}(\mu,\nu) = \int_{0}^{\Delta x} dP_{l+1}^{m}(\mu,\nu) dx$$
(B.03)

By using equation (B.01;02) in (B.03), (B.03) reduces to

$$P_{l+1}^{m} d\mu dv = \frac{2\pi I_{m}}{\sigma_{m}} \mu d\mu dv \left\{ e^{-\frac{\tau_{lm}}{\mu}} \right\} \left\{ 1 - e^{-\frac{\tau_{m}}{\mu}} \right\}$$
(B.04)

We can represent the contribution due to all cells left of cell I as

$$P_{l+1}^{m} d\mu = \sum_{m>l} \frac{2\pi I_{m}}{\sigma_{m}} \mu d\mu \ \{e^{-\frac{\tau_{lm}}{\mu}}\} \{1 - e^{-\frac{\tau_{m}}{\mu}}\}$$
(B.05)

To compute the total intensity reaching position x_{i+1} (the right side of the cell) from all directions, we integrate over μ

$$Q_{l+1}^{R} = \int_{0}^{1} d\mu P_{l+1}^{R}$$

$$Q_{l+1}^{R} = \sum_{m>l} \frac{2\pi I_{m}}{\sigma_{m}} \mu [E_{3}(\tau_{l,m}) - E_{3}(\tau_{l,m} + \tau_{m})]$$
where
$$E_{3}(\tau) = \int_{1}^{\infty} \frac{dz}{z^{3}} e^{-iz}$$
(B.06)

where E₃ is the exponential integral of order three. Similarly, the contribution from all directions at the left boundary of the cell is

$$Q_{l+1}^{L} = \sum_{m \le l} \frac{2\pi I_m}{\sigma_m} \mu[E_3(\tau_{l+1,m}) - E_3(\tau_{l+1,m} + \tau_m)]$$

(B.07)

Then using the fact that energy is conserved, the net gain/loss of energy per unit volume and per unit energy in lth cell is

$$W_{l} = \frac{[Q_{l+1}^{R} - Q_{l}^{R} + Q_{l}^{L} - Q_{l+1}^{L}]}{\Delta x}$$

$$W_{l} = -\{\frac{4\pi I_{l}}{\Delta x \sigma_{l}} [\frac{1}{2} - E_{3}(\tau_{l})]\} + \sum_{m \neq l} \frac{2\pi I_{m}}{\sigma_{l} \Delta x} \{E_{3}(\tau_{lm}) - E_{3}(\tau_{lm} + \tau_{l}) - E_{3}(\tau_{lm} + \tau_{m}) + E_{3}(\tau_{lm} + \tau_{l} + \tau_{m})\}$$
(B.08)

Here the first term represents the power emitted out of cell l and the second term represents the power (emitted from all other cells and) absorbed by the lth cell. Unfortunately, due to coupling of each zone with other neighbouring zones, the simulation run times are significantly larger than those in which radiation is neglected.

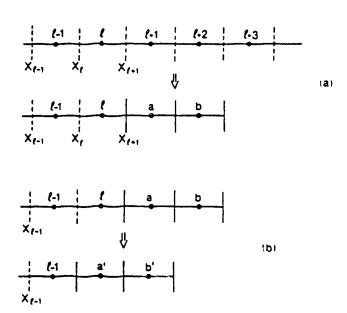
In order to reduce the radiation time, Marchand developed an intuitive approach to solve the above problem. He claimed that one can approximate the plasma as being either optically thin or optically thick. In the limit where the plasma is optically thin, the intensity coming from the right (or left) of a given cell is the same as that produced by a single cell of luminosity equal to the sum of intensities emitted from all cells (since nothing is absorbed), that is

$$P_{l+1}=2\pi Z$$
 where $Z=\sum_{m}I_{m}\Delta x_{m}$ (B.09)

For the optically thick case, one treats it as if it is comprised of two cells, one optically thick (emission is negligible) and the other optically thin (here absorption is negligible), then the intensity emitted out of the original cell is

$$P(\mu) = 2\pi Z_b e^{-\frac{\tau_a}{\mu}} \qquad \text{where} \qquad Z_b = l_b \Delta x_b$$
(B.10)

where cell "a" is non-radiating with optical thickness τ_* and cell "b" is optically thin and radiates with luminosity Z_b . Marchand called this approach of reducing n cells into two effective cells the recursive approach. The figure below illustrate what is meant by recursive approach.



In the recursive approach one assumes that the radiation intensity everywhere in the plasma can be approximated by the intensity generated by a combination of two cells, one optically thick and one optically thin. Following the preceding analysis, the intensity incident on the right boundary of the lth cell from the right is

$$P_{l}^{R} \approx 2\pi Z_{l} e^{-\frac{\tau_{l}}{B}} \approx 2\pi \mu \frac{I_{l}}{\sigma_{l}} (1 - e^{-\frac{\tau_{l}}{B}}) + Z_{b} e^{-\frac{(\tau_{c} - \tau_{b})}{B}}$$
(B.11)

here the unknowns Z_{s} and τ_{s} are chosen so that the dominant angular dependence

of the specific intensity is around $|\mu| = 1$; because in the cold region the specific intensity is strongly peaked around $|\mu| = 1$. With this simplification the number of computational operations is proportional to the number of cells N rather than N^2 as it is for the exact model.

To physically justify the applicability of his algorithm Marchand made some assumptions^{8/3}. He assumed that for problems in consideration, the time scale which characterizes macroscopic changes of the medium is long compared to the typical photon transit time; hence to a good approximation radiation transport can be considered as a stationary problem. The range of energies is restricted to 30 ev < hv < 10 Kev for which photon scattering mean free paths are typically much longer than the absorption mean free path, implying scattering is negligible. In this limit, it is possible to describe the radiation transport in terms of photons being produced isotropically and propagating in straight lines until they are absorbed. The absorption probability is prescribed by the local absorption cross-section. Therefore, Marchand's model is applicable for problems in which time dependence or scattering can be ignored. The angular dependence of the intensity is ignored. Although our present radiation transport code also ignores scattering, the technique that is used to solve the radiative transfer equation can be made applicable, with appropriate modification, to problems involving scattering.

C. LEE'S RADIATIVE TABLES

Spectral-line intensities from laser produced plasmas are useful as temperature and density diagnostics. These emission spectra allow one to test the accuracy of the theoretical rate coefficients. However, before one can predict the emission spectra, one needs to know the plasma's charge state distribution and ion-level population as a function of it's electron temperature and density.

The tables of emission spectra used in MEDUSA are produced by Y.T. Lee et al at Lawrence Livermore National Laboratory. A detailed description of the model used for Lee's table can be found elsewhere^{C/1}. Here the formulation and regions of validity of these tables is briefly discussed.

Since the laser produced plasmas of interest are produced with electron density ranging from 10¹⁷ to 10²¹ cm³, neither the coronal nor the Saha-Boltzmann equilibrium models are applicable. The coronal model gives ionization balance for ions in their ground states, hence it's valid for plasmas with electron densities less than 10¹⁶ cm³. On the other hand, Saha-Boltzmann equation is only valid for higher density plasmas. The coronal model assumes that all ions in the plasma are in their ground state. The local thermodynamic equilibrium (LTE) model significantly over estimates the average ionization state at all temperature and the coronal model underestimates the ionization state at low temperature by neglecting excited sate ionization. Lee uses a kinetic model injunction with coronal and Saha-Boltzmann model to calculate the time dependent ionization balance and ion-level populations of the non-LTE plasma in the electron density range of interest. This model reduces to coronal equilibrium at low density and Saha-Boltzmann equilibrium at high density.

The ground-state and excited-state energy levels for each ionization stage are generated from screening constant calculated by W. Lokke et al and R. More. There is one energy level per principal quantum number, and quantum lowering is obtained from a modified Stewart and Pyatt formula to account for dense plasma effects. The following atomic process are included in the model

- i. excitation and de-excitation collisions
- ii. Radiative spontaneous emission
- iii. Ionization due to collision
- iv. Radiative recombination
- v. Three body recombination
- vi. Dielectronic recombination

The model assumes that each energy level couples with every level of the same ionization stage, but only to the ground state of the next ionization stage. The contribution of electron-impact ionization from excited levels is also taken into account.

The results of ionization balance model are used to normalized the relative populations that are determined by the balance of collisions and spontaneous radiative transitions to calculate spectral line intensity (of L shell transition) as a function of electron temperature and density. In the calculation, it is assumed that the effects of ionization and radiative recombination on the excited-state population are negligible, since electron collision rates are very large (of the order of 2) compare to both the ionization and radiative recombination rates at the temperatures and densities under consideration.

The model assumes that the plasma has small temperature and density gradients, and the effect of radiation transport is neglected. In situations where radiation transport and gradients are not negligible, the model is still useful in setting an upper bound for experimental data.

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REAL™ CU(NCI.), CW, CH(NFONCI.)
REAL™ DISTINCI.), DITME, DEPR
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           OF (BCSL.NE. 0) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           Place output in "material" instead of on the across
OPEN (UNIT"-4,ITLE-material, STATUS-COLO?)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           OPEN (UNI) "ALF HAD" many 2000.

END IF

"" read initial data for the radiation code
                                                       REAL® ETANCL)

REAL® FINITIONAL + 1), FOUNTO, FORMEO

REAL® FROMO + 1), FOUNTO, FORMEO

REAL® HILM
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           CALL DATAIN
                                                     REAL** FRANGO** 1), FQOYGUNCL)

REAL** BILENYOU, RUBENYOU, TISL, ERREDONCL, ERR

REAL** BILENYOU, RUBENYOU, TISL, ERREDONCL, EZINOMFOUNCL)

REAL** BITREN, ITEROMFOUNCL)

REAL** BITREN, ITEROMFOUNCL)

REAL** BITREN, ITEROMFOUNCL, NOROMFOUNCL, *1), NZENOMFOUNCL,

REAL** BITREN, BITROMANOUMFOUNCL, RETURE

REAL** PARCINCL, PRITINANOUMFOUNCL, PRITIME

REAL** PRONOCL, PROGNAC + 1), PLANKOMFOUNCL)

REAL** PARONCL, PROGNAC + 1), PLANKOMFOUNCL)

REAL** BORNOCL, PROGNAC + 1), PLANKOMFOUNCL)

REAL** BORNOCL, STR.

REAL** SOLUNNOL** STR.

REAL** SOLUNNOL** 1), SPEB

REAL** SOLUNNOL** 1)

REAL** SINTOMFOUNCL** 1)

REAL** SINTOMFOUNCL** 1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       PRNT - PRES
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           NCPI = NC+I
NCMI = NC+I
NAD2 = NA/2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           SOCIET - FALSE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            PRNTM = 1.005-12
read legandre polys
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ale's serve and weight func
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           CALLLPL
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            C**** initialize the staration counters
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         111=0
Off=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           # = 0
TOIT = 0
                                                                                                                                                                                                                                                                                                                                                                                                                                  173
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           THE - O
                                                       REAL SINT(NFO,NCL + 1)
REAL STIME, TOU, TERR, TELB
REAL STRAFFURINCL), TEMP(NCL)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            COUNT = 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       DCOUNT = 0
NEXCHT = 0
                                                                                                                                                                                                                                                                                                                                                                                                                                  175
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177
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181
                                                         REAL SUFL
                                                         REAL WY(NANG)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       IT-0
                                                         REAL® ZLP(NANO), ZINT(NPO,NCL), ZQ(NPO,NCL), DEER
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                50 TTIME = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     19' (25:56:UN) THEN

19' (25:56:UN) THEN

10' (25:56:UN) THEN

10' (25:56:UN) THEN

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                                                       COMMON /ROI! ALFA, AC, ATMASS, DAF, ATEM
COMMON /RO2! ABC, AB, AO
COMMON /RO2! BETA, BO
COMMON /RO4! CV, CW, CH
COMMON /RO5 DL, DBNT, PRINTM
COMMON /RO5 DE, DBNT, PRINTM
COMMON /RO5 DBT, DTME, DGPR
                                                                                                                                                                                                                                                                                                                                                                                                                                  182
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initial made of accoluration.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         TRNACC = 0
DEFACC = 0
                                                       COMMON / (100 PET, D'ITME, DEP'R.
COMMON / (1071 PETA.
COMMON / (1071 PETA. PETA.
COMMON / (100 PE. P.)
COMMON / (100 PETA.
COMMON / (110 PETA.
COMMON / (110 PETA.)
                                                                                                                                                                                                                                                                                                                                                                                                                                  100
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           TRN - FALSE.
DEFF - FALSE.
LOR - FALSE.
                                                       COMMON /R.I./ INTB, INTI, IZIN
COMMON /R.I./ ITEB, ITER
COMMON /R.I.V.L LFL, LOWLIM
COMMON /R.I.V.L LFL, LOWLIM
                                                                                                                                                                                                                                                                                                                                                                                                                                  192
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           NLOR - FALSE
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           CALL RUNTET(IT)
                                                      COMMON /R14 / MAXT
COMMON /R15 / NATE, NBNT
COMMON /R15 / NFFT, NDRN, NZBN
COMMON /R17 / PMACC, PRNT, PRTIME
COMMON /R18 / PGBN, PFGE, PLANK
COMMON /R18 / PGBN, PTGE, PLANK
COMMON /R18 / PGBN, PTGE, PZBN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                         C**** esta above ain
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        en 2467
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     DOF
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                CONT = 0
40 CONTINUE
70 OF (MEDULA, BQ. 1) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     OF (MERLURA, ES), 1) armore 
put data microscopy for makes sensulation 
MDT exts as a switch to essentie a pert of tables natureation 
this nativestim reads the restation to tables and evaluation the 
versibles for the RTE, it's flunctions to some as the model 
*** adventum for the model problem.
                                                         COMMON /R182/ PAB
                                                       COMMON /R19/ Q
COMMON /R19/ Q
COMMON /R29/ SPH, SIRC, SPR,
COMMON /R21/ SIGM, GRS1
COMMON /R22/ SOLU, SPRB
                                                      COMMON (R23/ S, SUM1, SUM2, GR.FQ, GR.ZQ
COMMON (R231/ SINT
COMMON (R24/ TTIME, TOU, TERR, TELB
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         MOT-0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           CALL TABLES
                                                      COMMON /R25/ TRNIFVR, TEMP
 103
                                                       COMMON /R26/ UFL
                                                      COMMON /R27/ WF
COMMON /R29/ ZLP, ZINT, ZQ, DEEK
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        IF (NETT NE. 1.OR. ( NOT. RTEON)) RETURN
```

213	Cours define the model problem	123 319	WRITE (99.140) TOIT, TIIT, OIT, TIT
214 215	CVIT WODET	320 321	140 FORMAT (1X, 'toke'', IB, 1X, 'tuke'', 14, 1X, 'toke'', 14, 1
216	Corassassassassassassassassas	322	END IF
217 21 9	END #	323 324	NDZI = 0 DO 170 J = 1, NO
219	Coose RT used to resul parameter for computation of spectral reliate of	325	DO 160 K = 1, NC
220 221	C the transfer equation C arguet used to prevent the code from fulling sport, these switches	326 327	22x7((J,K) = (AO(J,K)*NDBN(J,K + 1) + BO(J,K)*NDBN(J,K)) / 1 2
222	C stop further computation of an equation when it appears to be	328	IF (ZINT(JJK) LE. 0.0) THEN
223 224	C**** fulling to converge of starts to diverge. RT = 0	329 330	ND21 = ND21 + 1 WRITE (99.150) J, K., ZENT(J,K), TOIT, TIT
223	#0 SMTETT = 0	331	150 FORMAT (1X, 'zint from diff is nog. j k zint toit tit',
226 227	SMT8T2 = 0 SMT8T3 = 0	332	1 2(12,1X), 1PE10.3, 2(1X,12)) END IF
228	2M(213 - 0	333 334	160 CONTENUE
229	SM(IST) = 0	335	170 CONTINUE
230 231	TOTT = TOTT + 1	336 337	C**** WRITE (8,7)zies neg. from diff this often indzi DO 190 K = 1, NC
232	TE (TOIT OT, OITA) THEN	338	AB(IC) = 0.0
233 234	Coordinate Like Filiabetaphile	319 340	DO 180 J = 1, NO AB(K) = AB(K) + ABC(JJK) * ZENT(JJK)
235	CALL TEMPER	341	180 CONTINUE
236 237	CALL CTUTM	342 343	190 CONTINUE IF (ABVL.EQ. 1) THEN
238	WRITE (R. ") program stoped because only exceeded, TOIT, OITA	344	Cooos take absolute value of converged ratin when it is negative
239 240	STOP BND IP	345 346	DO 210 K = 1, NC DO 200 J = 1, NO
241	NT = 0	347	P (NDON(JJC) LE 0.0) THEN
242 243	Conne DRT used as reset parameter for computation of spectral radius Conne of the diffusion aspectos.	348	NDRN(JJC) = ABS(NDRN(JJC)) BND BF
244	DRT=0	349 350	200 CONTINUE
245	Consession of the contract of	331	210 CONTINUE
246 247	C**** paive radiative transfer equation CALL TRNPRT	352 353	END # DO 230 K = 1, NC
248	Constitutions	354	F (AB(IC) LE 0.0) THEN
249 250	Off = Off + 1 Cooo check if radiative transfer equation is converged.	355 356	WRITE (99,220) K, AB(K), TOIT, THT. OIT, TIT 220 FORMAT (1X, 'ab(k) from diff is neg, may cause instability
251		357	1', 12, 1X, 1PE11.3, 4(1X,B))
252 253	CALL TROUNV	358 359	END IF 230 CONTINUE
254	DO 110 J = 1, NO	360	00 70 80
255 256	DO 100 K = 1, NC DO 901 = 1, NA	361 362	END IF 240 IF (DIFACC LE. 1) THEN
257	PRITICULO = NEUTROLIO	363	Cooos solve diffusion equation using source iteration
258 259	90 CONTINUE	364 345	CALL DEFE
260	110 CONTINUE	346	Creecessessessessessesses
261 262	IF (CONV.BQ. 0. OR. OT. OE. TB. OR. (SMISTI) THEN	367	ELSE IF (DIFACC EQ. 2) THEN
263	Cores transport intensity is converged or transport bound is exceeded or Cores make in true	348 369	Consequences execution of the control of the contro
264 265	IF (SMTST) THEN	370	CALL GRDE
266	WRITE (99, "Youter iteration terminated due to opr.ge. 1,00 t to other?"	371 372	BND ₽
267	MITST - FALSE	373	NECED = 0
26 8 269	BND IF GO TO 290	374 375	DO 260 K = 1, NCP1 DO 250 J = 1, NG
270	END #	376	F (NDM(I,K) LE 0) THEN
271 272	IF (TRNACC BQ. 0) THEN	377 378	NEOD = NEOD + 1 END IF
273	CALL TRACE	379	250 CONTENUE
274 275	Canonessessessessessessessesses Conne topping contraction mend between partitions	380 381	260 CONTINUE C**** write(8,**)**rdin neg this often/,negd
276	00 TO 80	382	DO 280 J = 1, NO
277 278	PLES IF (TRNACC EQ. 1) THEN IT = 0	383 384	DO 270 K = 1, NCP1 DB/T(JJC) = NDB/K/JC)
279	120 THT = THT + 1	385	270 CONTINUE
280 281	DCOUNT - DCOUNT + NDICNT	386	280 CONTINUE
282	NDSCNT = 0 Coses solve stablish-squary diffusion equation	387 388	GO TO 120 END F
283	Commencementarions	389	Coose confinte ma purbecaptus
294 285	CALL MPDE	390 391	390 III = III + 1
286	Coordinate of multifrequency different reportion in converged	392	DO 320 K = 1, NC
287 286	CALL DECONV	393 394	DO 310 J ~ 1, NO ZBNTUJO = 0.0
289	Casteranianassassassassassassassassassassassassas	395	DO 300 I = 1, NA
290 291	ET = HT + L DF CHT (OEL DEL CORV DEC. 0 OFL (SENTETT)) THESE	396 397	ZENTUJO = ZENTUJO + NENTUJO * WF(I) 300 CONTINUE
292	Cooos diffusion counties is consumed or diffusion bound in surrented or	398	310 CONTINUE
293 294	Coose metal is true BY (NUM JBQ, 1) THEIN	399 400	320 CONTINUE IF (NUM LEO, 0) THEN
295	Cooks hand to company converged accelerated and unaccelerated diffusion	401	Cooper used to compare converged accelerated and unccelerated zink
296 297	C intensity, LL (that is) she relation of diffusion equation with. Common SI and with gray diffusion equation.	402 403	C**** Li. solution of the RTE with SI and with diffusion equation WRITE (8,7); k zint, TOIT, TET, OIT, ITT, TIT
298	WRITE (R. Their tile ell in ter, TOIT, TRT, OIT, ET,	404	WRITE (98,330) ((J.K.ZENTUJK),K=1,NC),J=1,NO)
299 300	1 TIT WRITE (98,130) ((J.K.NOON(J.SO.K=1,NCF1).D=1,NO)	405 406	330 FORMAT (3(1X,12,1X,12,1X,1PB10.3,1X))
301	130 PORMAT (3(1XZ-1XZ-1XX-130-130)	407	CALL CPUTM
302	WRITE (".") 'unter I to continue"	408	Commence
303 304	READ (5.º) NUM BY (NUM JOE, 1) THEN	409 410	WRITE (*, "yenter 0 to continue" READ (5, ") NUM
305	atos	411	IF (NUM NE. 0) THEN
306 307	END F	412 413	510P END F
300	IF (INITAL) THEON	414	END F
309 310	SACTST = FALSE. IF (SACTST2, CIE, NOTNC=0,05) THEN	415 416	DO 350 K = 1, NC ABGO = 0.0
311	WRITE (99, "Visual deration terremented due to too often i	417	DO 340 J = 1, NG
312	11 volution of	418	AB(IC) = AB(IC) + ABC(IJC) * ZINT(IJC)
313 314	SMTTT = 0 Blee if (SMTTT) .GE NO?NC*0.01) THEN	419 420	340 CONTRACE 350 CONTRACE
315	WRITE (99, "Yigger statution terminated due to days ge. 0	421	DO 370 K = 1, NC
316 317	1.99 too offer! SN(TST3 = 0	422 423	IF (AB(K), LE, 0) THEN WRITE (8,560) K, TOIT, OIT, TIT, AB(K)
318	BND F	424	360 FORMAT (1X, home may become mag. It toit out tit ab(k)',
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                                                            I 4(IXE), IX IIPE10.3)
END IF
J70 CONTINUE
C**** WEIT*
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               INTEGER USC, WFN, CONV. DBXL, DBXU, NUM
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             COMMON (I) ABYL, AUTACL, CONVC, COURT, CONT, TOURT, DR, DESKINT COMMON (I) DRT, DUPBC, DEFACE, IT, TITA COMMON (I) DRSB, BUN, LIN, MEDUJAA COMMON (I) DRSB, BUN, LIN, MEDUJAA COMMON (I) DRSB, BUN, LIN, MEDUJAA COMMON (I) OTT, DTA, PRES, RT, SETSOU, STR., TRINACC COMMON (I) OTT, DTA, PRES, RT, SETSOU, STR., TRINACC COMMON (II) TR. TRISHOTT, TIT, TOTT, TRIN COMMON (II) USC, WIN, CONV, DRSG, DRSU, NUM.
                                                                                                               WALTE ( " "Yest tilk tie", TOST, TITT, TIT
                                                                 IF (MEDUSA BQ. 0) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      336
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351
352
353
353
                                                                   CALL TEMPER
                                                                   Coose check if new temperature is converged
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           REAL® ALFA(NCL), AC, ATMASS, DAF(NFG,NCL), ATEMENT,)
REAL® DET(NCL), DTDM: DOPR
REAL® DET(NCL), DTDM: DOPR
REAL® DET(NCN), DR.BONFG), ITSI, ERJEXINCL), BERR
REAL® DET(RNANG), NO.NCL + 1), BOTTONANG,NFG,NCL, BERLS
REAL® ITSI, ITSIA(NFG,NCL)
REAL® ITSIA, ITSIA(NFG,NCL)
REAL® MAST
REAL® DET(R), SPR
REAL® SOU(NCL + 1), SPR
REAL® SOU(NCL + 1), SPR
REAL® TOUTERS, TELB
REAL® UT,
REAL® ZUP(NANG), ZINTINFG,NCL), ZO(NFG,NCL), DER
                                                                 CALL TEMCON
                                                                                      IF (SIMPLUN) THEIN
IF (CONT.EQ. 0) THEN
       440
441
442
443
444
445
                                                                                                 CALL CPUTM
                                                            CALL RUNTST(IT)
                                                                                                 GO TO 60
       446
447
448
449
                                                                                              END IF
                                                                                        END IF
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             COMMON /ROI! ALFA, AC, ATMASS, DAF, ATEM COMMON /ROM DETT, DTDAGS, DEPR COMMON /ROM DETT, DTDAGS, DEPR COMMON /ROM PALBA (COMMON /RII! PATB, IRRS, ITSL, IERED, IERR COMMON /RII! PATB, IRTS, IERD, IERR COMMON /RII! PATB, ITSL
COMMON /RII! L. LIPL, LOWILM COMMON /RI! L. LIPL, LOWILM COMMON /RI! PATB, PRT. PRTIME COMMON /RI! PATB, PRT. PRTIME COMMON /RIO SPIL, SIRC, SPR COMMON /RIO SPIL SIRC, SP
                                                                                      ENDIE (CONT. EQ. 0.0R. TIT. OE. TITA) THEN IF (CONT. EQ. 0.0R. TITA) THEN IF (TIT. OE. TITA) THEN WILTE (E.180) TIME

O PORMAT (I.X. Inconverged temperature
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                                                                                                                                                                                                                                       arged temperature at times, (PE11.4)
                                                                                        | FUNDAME | STATE | ST
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                                                                                            IF (NIKUN .EQ. 0) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 COMMON /R24/ TTIME, TOU, TERR, TELLS
                                                                                          F (NEUN.EQ. 0) THEN
STOP
PAO F
NCNT - NCNT + 1
F (NCNT.EQ. 1) THEN
DTIME = 1.00E.11
ELSE F (NCNT.EQ. 2) THEN
DTIME = 1.00E.10
ELSE F (NCNT.EQ. 3) THEN
DTIME = 2.00E.10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               COMMON /R26/ UPL
COMMON /R26/ ZLP, ZB/T, ZQ, DESK
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               WHITE (& SYNNTER NO IF SOUCHE IS TO HE DEPENDENT ON TIME!
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    WRITE (A. TEMPTER TO BE DUCKE IN THE DEPENDENT ON TIME:

READ (4.10) TEMPTER

20 FORMAT (ASX. E)

WRITE (A.20) TEMPTER = '. (2)

WRITE (A.79ENTER TO BE INITIAL TEMPERATURE IX.REBUTION IS EXICH

WRITE (A.79ENTER TO BE INITIAL TEMPERATURE IX.REBUTION IS EXICH

LOCATIAL:
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    372
373
574
375
576
                                                                                                 DTIME = 2.00E-10
                                                                                            ELSE IF (NCNT .EQ. 4) THEN
DTIME = 4.00E-10
ELSE IF (NCNT .EQ. 5) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             IANTIAL'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      (RATIOL:
READ (4,30) TEMEXP
30 PORMAT (46%, IZ)
WRITE (R,40) TEMEXP
40 PORMAT (1X, TEMEXP = ', IZ)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ELSE IF (NCNT EQ. 3) THEN
DTIME = 0.008-10
ELSE IF (NCNT EQ. 6) THEN
DTIME = 1.008-09
ELSE IF (NCNT EQ. 7) THEN
DTIME = 1.608-09
ELSE IF (NCNT EQ. 8) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            WHITE (4.9) TRUE = '. IZ)

READ (4.50) NIPAURT

SO FORMAT (1X. TENEODY ='. IZ)

READ (4.50) NIPAURT

SO FORMAT (46X. IZ)

WRITE (8.60) NIPAURT ='. IZ)

WRITE (8.60) NIPAURT ='. IZ)

WRITE (8.70) PRES

TO FORMAT (46X. IZ)

WRITE (8.00) FRES

SO FORMAT (40X. IZ)

WRITE (8.70) TR. IZ

SO FORMAT (40X. IL, IZ)

WRITE (8.70) TR. IZ

SO FORMAT (40X. IL, IZ)

WRITE (8.70) TR. IZ

SO FORMAT (40X. IL, IZ)

WRITE (8.70) TR. IZ

SO FORMAT (1X. TELE ='. IX. IZ)

WRITE (8.70) TR. IZ

SO FORMAT (1X. TELE ='. IX. IZ)

WRITE (8.70) TR. IZ

SO FORMAT (1X. TELE ='. IX. IZ))
 DTIME = 2.00E-09
ELSE IF (NCNT EQ. 9) THEN
DTIME = 3.00E-09
ELSE IF (NCNT EQ. 10) THEN
                                                                                          ELSE IF (NCNT EQ. 10) THEN
DTIME = 5.00E-09
ELSE IF (NCNT EQ. 11) THEN
DTIME = 1.00E-00
ELSE IF (NCNT EQ. 12) THEN
DTIME = 1.00E-07
                                                                                            ELSE.
                                                                                          STOP
END IF
TIT = 0
OTT = 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   WILTE (6, 972BILO OR ")" IF IT IS TO BE CELL AVERAGE INTENSITY OR
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            WILLE (6, "year if hits paper crietrion is to be used?

READ (6,110) NPFC

10 FORMAT (66X, II)

WRITE (8, 120) NPFC = ', II)

WRITE (8, 120) NPFC = ', III)

WRITE (8, "YENTER BERR AND THEIR AND DIER!

READ (4,130) SERR, TERR, DERR

130 FORMAT (61X, XIX, FERR, DER

WRITE (8, 140) SERR, TERR, DERR

140 FORMAT (1X, XIX, FERR, DERR

150 FORMAT (1X, XIX, FERR, DERR)

WRITE (8, 140) SERR, TERR, DERR

1 DERR = ', 1PE10.3)

WRITE (6, "YENTER 60Y OUT AFTER WHICH NEGATIVE FLUX IS ALWAYS US 1ED?"
                                                                                          IT = 0
TOIT = 0
TIIT = 0
COUNT = 0
                                                                                      DCOUNT = 0
NDICNT = 0
GO TO 50
ELSE
                                                                                        * notice that in
                                                                             OO TO 70
END #
ELSE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          1ED'
READ (4.150) INE
                                                                                  CALL TABLES
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              READ (4.150) INSIGNATION (125X, IS)
WRITE (8.160) RNB
169 FORMAT (1X, TRNB = *, IS)
WRITE (4, *YRNTER ABSORPTION COEFFICIENT 127 (7 = 4 TO 117
READ (4.170) AC
179 FORMAT (407X, IPER 27)
                                                                             END #
END
 511
512
513
514
515
                                                                             • read that impact
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             WRITE (LIBO AC
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  WILLE (C. A.M. OWLL-MALL) BE LOST VAN SALES OF A SALES 
516
517
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519
                                                                             SUBBOUTINE DATAIN
                                                                             PARAMETER (NANO-24 NFO-64 NCL=151)
PARAMETER (RK-7.5606/TE-167/K-6,6261E-34)
PARAMETER (RK=1.3807E-25,8F=3.0E06,EVE-1,6022E-19)
PARAMETER (TCF=EVE/BCF=3.141393,A0=PK/RK-TCF))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          INDEMALEY
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            INORMALEY
READ (4.199 CONVC
199 FORMAT (65C, ID)
WEITE (R.200) CONVC
200 FORMAT (1.X, "CONVC = ", IZ)
READ (4.210) TEIN
210 FORMAT (65C, IZ)
WEITE (R.220) TEIN
220 FORMAT (1.X, "TEIN = ", IZ)
WEITE (R.270) TEIN
200 FORMAT (1.X, "TEIN = ", IZ)
WEITE (6, "YENTER "O" IF UNIFORM SPATIAL DURIBUTION IS TO BE USEZY
 520
 521
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523
524
525
526
527
528
                                                                             INTEGER ABVIL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT
                                                                           INTEGER ABY, DUTACL CONVI, COUNT, CONT, TONT, NEW TONT, TEMPTO, TIT, TILN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  633
634
635
636
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              READ (4,230) USC
230 FORMAT (66%, E2)
```

```
125
743
                                                                  WRITE (8,240) USC
240 FORMAT (1 X, USC = 1, I2)
READ (4,250) PRITIME
250 FORMAT (1 X, PRITIME = 1, IPE11.2)
WRITE (8,240) PRITIME = 1, IPE11.2)
WRITE (8,700) PROTO 2° FOR DEPUSION BC*
READ (4,270) DEPO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          620 WRITE (6, "YENTER "O" FOR LINEAR GREY MODEL OR "1" FOR NONLINEAR O
                637
              618
639
640
641
642
643
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  READ (4.630) LIN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    744
745
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       READ (4,630) LIN
630 FORMAT (66X, I2)
WRITE (8,640) LIN
640 FORMAT (1X, ILIN = 1, I2)
IF (SETLIM.EQ. 0) THEN
LOWLIM = 60.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             READ (4,370) DEPSC.
270 PORMAT (1645, I2)
WRITE (8,280) DEPSC.
280 PORMAT (13, "DEPSC. = ', I2)
WRITE (4, "PENTER." ")" IP NEW DEPUSION INTENSITY IS NEGATIVE IT!
15
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       HTT DM = 70.0
                643
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649
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  HILIM = 7020 BQ. 1) THEN LOWLIM = 90.0 HILIM = 100.0 ELSE IF (SETLIM EQ. 2) THEN
                                                                                 ...
Write (6.°Ytaken to be zero")" of it is taken to be the previou
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       LOWLIM = 140.0
         651
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 PLISE F (SETLIM EQ. 3) THEN
LOWISM = 190.0
HISLIM = 200.0
ELSE F (SETLIM EQ. 4) THEN
                                                                                  WRITE (6. ") TO TENSITY FOR THAT GROUP & CELL!
                                                                WRITE (6, "YENTENSI
READ (4,290) NDIT
290 FORMAT (66%, I2)
WRITE (8,500) NDIT
                                                              WRITE (8,300) NDIT
SOP PORMAT (12, TODT = 1,12)
WRITE (6,"TENTER MAXIMUM TIME FOR SIMULATION OF MODEL PROBLEM
READ (4,310) MAXT
310 FORMAT (40X, IPER 2)
WRITE (8,320) MAXT
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       LOWLD4 = 290.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       HT .TM = 100 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  HILE IF (SETLIM .EQ. 5) THEN
LOWLIM = 250.0
HILM = 300.0
                                                           WRITE (4,120) MAXT

310 FORMAT (1X, "MAXT = ', IPE11.2)

WRITE (4,79N TER NA < 24 NO < 64 NC < 131 '

READ (4,319) NA, NO, NC

310 FORMAT (1X, "NA = ', B, 3X, NO = ', B, 5X, NC = ', B)

WRITE (4,340) NA, NO, NC

404 FORMAT (1X, "NA = ', B, 3X, NO = ', B, 5X, NC = ', B)

WRITE (4,79N TER L LFL, UFL TELS ITES ITES

READ (4,350) L LFL, UFL, TELS, ITES, ITES,

350 FORMAT (1X, 4X, E1, E1, E2, 1)

WRITE (4,560)

960 FORMAT (1X, 4X, L, EX, 1, EL, 6X, 3, EL, 5X, 3, EL, 5X, 5X, EL, 
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  ELSE IF (SETLIM EQ. 6) THEN
      661
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675
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 LOWILDA = 690.0
HELDA = 700.0
END IF
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     END SF
WRITE (R.650) LOWLIN, HILIM
650 FORDMAT (IX, Towling, IPE10.3, IX, Talling, IPE10.3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               RETURN
END
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               this subrousine defines the modal problem used to test the code snotper user can modify the modal by changing the variables in the subrousine, my change in other subrousine will result in altertation of the method isset?
                                                              360 FORMAT (1X 4X T. 8X LFL: 6X UFL: 5X TELE: 5X TIRE:
                                                           360 PORMAT (1X, XX, XX, ELFL, 0X, UPL), 3X, TELD, 3X, TELD, 1 3X, 
                                                    WILTE (6, "PFUNCTION OR "1" IF ROSSLAND P
READ (4,180) WINN
180 FORMAT (65X, 12)
WRITE (8,190) WFN
190 FORMAT (11X, "WFN = ',12)
WRITE (8,490) WFH
400 FORMAT (60X, 1PER 2)
WRITE (8,410) WFH
410 FORMAT (11X, "SPECIFIC HEAT = ',1PE10.3)
WRITE (8,410) WFH
410 FORMAT (11X, "SPECIFIC HEAT = ',1PE10.3)
WRITE (8,470) DTIME
READ (4,420) DTIME
READ (4,420) DTIME
430 FORMAT (40X, 1PER 2)
WRITE (8,430) DTIME
430 FORMAT (40X, 1PER 2)
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             SURBOUTING MODEL
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            PARAMETER (NANO-24,NFO-64)NC1=151)
PARAMETER (RK=7.560667E-16,PK=6.6261E-34)
PARAMETER (RK=1.3807E-23,SP=9.0808,EVB=1.6022E-19)
PARAMETER (RK=1.3807E-23,SP=9.0808,EVB=1.6022E-19)
PARAMETER (RK=8.3807E-23,SP=3.0808,EVB=1.41593,A0=PK/(BK*TCF))
PARAMETER (A1=3.8171E+35)
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REAL® FFORTO + 1.NCL), ITLB
REAL® LLFL, LFR\ LFR\00000 + 1), LITLB, LUFL
REAL® REAL
REAL® TRNFV
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           793
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802
                                                         430 PURBANT (1.X, TYTIBME = ", 19210.3)
NF = 0
WRITE (4.440) NF
440 PURBANT (1.X, NF = ", 12)
WRITE (4.450) NT
READ (4.450) TITA
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             INTEGER ABVL, AUTACL, CONVC, COUNT, CONT. TCONT, DB, DCOUNT
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          RITEGER ABVL, AUTACL, CONVC, COUNT, CONT. TCONT 
NYTEGER DRIT, DIFBC, DIFACC, IIT, TITA 
NYTEGER DRIB, BUN, LB., MEDURA 
NYTEGER NA, NO, NC, NF, NOTT, NFPC, NDICNT, NFMUST 
NYTEGER OT, OTA, PERS, RT, SETSOU, SCR, TRNACC 
NYTEGER TO, OTA, PERS, RT, SETSOU, SCR, TRNACC 
NYTEGER USC, WFNL CONV. DEXIL, DEXIL, NUM 
NYTEGER NCPI, NCMI, NAD2 
NYTEGER NCPI, NCMI, NAD2 
NYTEGER SMYSTI, SMYSTS, SMYSTS, SMYSTS, SMYSTS
                                                         450 PORMAT (/64%, 14)
                                                         WRITE (4.40) TITA

400 FORMAT (1X, TITA = ', M)

WRITE (4, "PENTER NUMER OF OUTER ITERATIONS ALLOWED'

READ (4.470) OITA
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          903
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909
810
811
                                                      READ (4.479) OTTA
470 PORMAT (42X, Is)
WRITE (R.480) OTTA
480 FORMAT (11X, 'OTTA =', Is)
READ (4.490) SETLIM
490 FORMAT (45X, I2)
WRITE (8.500) SETLIM
500 PORMAT (11X, 'SETLIM' =', I2)
SETIOU = 2
WRITE (8.47ENTER 0 FF PLUX AT RIGHT BOUNDAR IS 0, 1 IF BOTH END S
1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            LOCKCAL TRN, DEFF, LOB, NLOB, SDARUN, SLATST
COMMON /L.I/ TRN, DEFF, LOR, NLOB, SDARUN, SMTST
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         COMMON /ILI ABVIL AUTACIL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT COMMON /IZI DRTD, DRTDC, DRTACC, RT, TITA COMMON /IZI PRSB, BRUN, LBN, MEDUSA COMMON /IZI PRSB, BRUN, LBN, MEDISA RTCOMMON /IZI PRSB, BRUN, LBN, MEDISA RTCO, MONTH, NPMUST COMMON /IZI OTT, OTTA, PRES, RT, SETSOU, SCR, TRNACC COMMON /IZI PR, TBMESP, TRT, TOTT, TEMPROPT, TIT, TINN COMMON /IZI PS, TRENCY, DRXIL, DBXU, NUM COMMON /IZI MCS, WPN, CONV, DBXIL, DBXU, NUM COMMON /IZI NCPI, NCAIL NADZ COMMON /IZI NCPI, SMTSTI, SMTSTI, SMTSTI, SMTSTI, SMTSTI, SMTSTI
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          816
                                                                   READ (4.510) SETBOU
                                                        STO FORMAT (640), E2)
WRITE (8,320) SETSOU
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        819
819
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    REAL*8 ALFANCI, AC, ATMASS, DAFNYTONCI, ATEMNYCI,

REAL*8 ABCOMPONCI, ARRYCI, ACOMPONCI,

REAL*8 BETANCI, BOOMFONCI,

REAL*8 CYNCI, CW, CHROMPONCI,

REAL*8 DETROCI, DWINGONCI,

REAL*8 DETROCI, DWINGONCI,

REAL*8 DETROCI, DWINGONCI,

REAL*8 TANKI,

REAL*8 FROWO+1), POOMFONCI,

REAL*8 FROWO+1), POOMFONCI,

REAL*8 REAL
                                                      WRITE (CLEAD SERIOU = ', IZ)

SEP PORMAT (1X, 'METBOU = ', IZ)

WRITE (4, "YENTER "1" FOR A & B TO BE I AT BOUNDARIES'
RRAD (4,310) ABVL

330 FORMAT (60X, IZ)

WRITE (8,340) ABVL
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        820
821
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825
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829
                                                      WRITE (8,540) MEDUSA:

WRITE (6,7) ENTIER "1" IF CODE TO BE RUN WITH MEDUSA:
READ (4,350) MEDUSA
350 FORMAT (MED. 2)

WRITE (8,540) MEDUSA
720
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727
                                                      WRITE (8,360) MEDICAN

WRITE (6,79ENTER I IF CRITERIAN IS AUTOMATICALLY DECIDED DEPENDIN

10 ON THE SPR OF

WRITE (6,77ENAMEORT BOD, ALSO ENTER THE VALEU FOR SPR FOR AUTOMA

1TIC ACCELERATION (<,5)*
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      830
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         REAL & NATIONALL NINTONANO NEGLICIA
   728
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        834
                                                        11 II: ACCELERATION (C.)7

READ (4.570) AUTACL. SPEB
570 PORMAT (56X, IZ, 2X, 1PER.2)

WITH (6.79ENTER 0° IP TRANSFORT EQUATION IS TO BE SOLVED BY SP
WRITE (6.79ENTER 0° IP TRANSFORT EQUATION IS TO BE SOLVED BY SP
WRITE (6.79ENTER 0° IP TRANSFORT EQUATION IS TO BE SOLVED BY SP
READ (4.580) TRINACC
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         REAL ** PRITTINANGLEGINCL), NDBN/PGJNCL, + 1), NZIN/PGJNCL)
REAL ** PRACONCL, PRITTINANGLEGINCL), PRITINE
REAL ** PORN/NCL + 1), PROB/NCL + 1), PLANK/NFGJNCL)
REAL ** PORN/NCL + 1), PROB/NCL + 1), PLANK/NFGJNCL)
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REAL® SOMEONICI, GREGNICI.+1)
REAL® SOMEONICI, GREGNICI.+1)
REAL® SOMEONICI. (SPES
REAL® SOMEONICI.)
REAL® SOMEONICI. (SPES
REAL® SOMEONICI.)
                                                    READ (4.360) TRINACC
350 PORMAT (46X, I2)
WRITE (1.370) TRINACC = 1, I2)
WRITE (1.370) TRINACC = 1, I2)
WRITE (4.70) TRINACC = 1, I2)
WRITE (4.70) TRINACC = 1, I2)
WRITE (4.60) DEFACC
600 PORMAT (46X, I2)
WRITE (4.610) DEFACC
100 PORMAT (46X, I2)
WRITE (4.610) DEFACC
100 PORMAT (46X, I2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         real = treverous, temponel,
real = upl
real = wp(nano)
real = zlp(nano), zentopponel, zoopponel), dier
738
739
740
741
742
                                                    610 FORMAT (1X, TOFFACC = 1.12)
```

849	COMMON /ROLL ALFA, AC, ATMASS, DAF, ATEM	126 955	ELLE IF (NFFC BQ. 1) THEN
850 851	COMMON (ROL) ABC, AB, AO COMMON (ROL) BETA, BO	936 957	Cooos when it is resultive
852	COMMON /ROW CV, CW, CHI	958	DO 90 K = 1, NC
853 854	COMMAON /ROS/ DEL DENT, PRINTM COMMON /ROS/ DEST, DTIME, DEPR	939 960	TRNFVRIK) = 2.0 90 CONTENUE
855	COMMON /R07/ ETA	961	TRNEV = (SPOTDME) / DL(1)
856 857	CONGMON /ROW FIL FQ CONGMON /ROW HILIM	962 963	REAR BY (NOTIC BQ. 2) THEN Connect implement regarine flux fixup as whoven in the these
858 859	COMMON /R10/ INUE, INVES, ITSL, TERED, TERR COMMON /R11/ INVES, INVE, IZZN	964 945	DO 100 K = 1, NC TRNPVN(K) = (SP*DTIME) / DL(K)
860	COMMON /R12/ ITRB, ITER	966	100 CONTINUE
861 862	COMMON /R13/ L, LPL LOWLIM COMMON /R14/ MAXT	967 968	END OF
963	COMMON /RLS/ NATE, NINT	969	DE (CONT BQ 0) THEN
864 865	COMMON /R16/ NEFT, NDON, NZIN COMMON /R17/ PMAC, PINT, PRTIME	970 971	F(TT: OE 1) THEN DO 110 K = 1. NC
866	COMMON /RLB/ POIN, PPOIL PLANK	972 973	TEMP(IC) = NATE(IC) 110 CONTINUE
967 968	COMMON /R19/ Q COMMON /R20/ SPH, SDR.C, SPR	974	25-00 pr
869 870	COMMON /R21/ SIGM, GR.SI COMMON /R22/ SOLU, SPRB	975 976	DO 130 K = 1, NC DO 120 J = 1, NO + 1
871	COMMON /R23/ 8, SUM1, SUM2, ORFQ, ORZQ	977	FF(J,K) = FR(J) / TEMP(K)
872 873	COMMON /R24/ TTIME, TOU, TERR, TELB COMMON /R25/ TRNPVR, TEMP	978 979	120 CONTENUE 130 CONTENUE
874	COMMON /R26/ UFL	980	IF (TRUN .BQ. 0 .OR. TOIT BQ. 0) TREN
875 876	COMMON /R27/ W/F COMMON /R28/ ZZLP, ZZNT, ZQ, DIESK	981 983	EF (WPN .BQ. 0) THEN Coose calculate initial intensity managing plantitum distribution
877		963	DO 160 K = 1, NC DO 150 J = 1, NO
878 879	real-spink(ncl), abb(ncl), dprd(ncl) real-sumchi(ncl), chir(ncl), ressio, respin	984 985	D=FF(3X)
200	REAL TO PLANNING INCL.), SIGNATURE ONCL.), SCHLENNEO, NCL.)	986 987	名=FFU + 1JC) 〒 (D.OT. LCWLING THEN
891 882	EXTERNAL PPLNK, F2, F3, F860 INTRINSIC ALOGIO, EXP	986	D=LOWLIM
983 884	C CL C28 NON-LTE DATA FOR AVRG-ZRADIATIVE COOLING ETC	989 990	END OF UP (E.OT. HOLING THEN
885	C VERSION JUNE 1986 Y.T. LEB	991	E = 1427M
896 887	COMMON /LEEDRY/HNUFDO(64), DTEMP(19), DDENS(22), ENION(19,22), 1 TBLZ(19,22), TBLZSQ(19,22), POWER(19,22,64),	992 993	END IF CALL ROMB(FPLNK, D. E. RESPLN)
202	2 SIGMA(19,22,64), HNÜMEN, HNÜMAX, ZATOM, NT, NR, NGHIGH,	994	Coose WRITE (4, ") will ", RESPLN
889 890	3 NOLOW, NORMAX, NTMAX C	995 996	PLANKU.K) = (2/(EP**2)) * (TEMP(K)**4) * (BK*TCP) * 1 RESPLN / (A0**3)
891	UF (TOTT .EQ. 0) THEN	997	DO 1401=1, NA WYT(LJK) = (2/(SP**2)) * (TEMP(K)**4) * (BK*TCF) *
892 893	C**** define the frequency groups and the cell width initial temp- C**** grature, specific heat for the model problem - only once	998 999	1 RESPLN / (A0**3)
894	D18 = 0.0 IF (USC EO. 0) THEN	1000 1001	PRYTUJIO = ENTUJIO 140 CONTINUE
895 896	tr (USC 15Q, 0) (15514 C**** take uniformly spaced spatial cells	1002	150 CONTINUE
897 898	CW=L/NC DBT(1)=CW/2	1003 1004	160 CONTINUE ELSE
899	DO 10 K = 2, NC	1005	Coord calculate initial intensity samening Rossland distribution
900 901	DEST(K) = DEST(K - 1) + CW 10 CONTINUE	1006 1007	DO 190 K = 1, NC DO 180 J = 1, NO
902	DO 20 K = 1, NC	1008	D = FFUJO
903 904	DLAC) = CW 20 CONTINUE	1009 1010	B = FFU + 1.X) Br (D.OT. LOWLING THEN
905	END F	1011	D=LOWLIM BND #
906 907	C**** Breatery spectrum is logarithmically grouped LLPL = LOO(LPL)	1013	P (B .OT. HELDO THEN
908	LUTL = LOQ(UFL) LTD = (LUTL - LLTL) / NO	1014 1015	g = 101.04 END 0"
910	LPR(1) = LLPL	1016	C>>> CALL ROMM(F2, D, E, RES2)
911 912	DO 30 J = 2, NG + 1 LPR(J) = LPR(J - 1) + LPIN	1017 101 8	CALL ROMB(F3, D, E, RESS) C**** CALL ROMB(FFLNIC, D, E, RESPLN)
913	30 CONTINUE	1019	PLANKUJO = 1.60652E-20 * AC * RESS * (TEMP(K) **6) C**** WRITE (6, *)res2 and res3 *, RES2, RES3 , PLANKUJK)
914 915	DO 40 J = 1, NG + 1 FR(I) = EXP(LFR(I))	1020 1021	DO 1701=1, NA
916	40 CONTINUE	1022 1023	BATTUJA) — BATKUJA) PRATTUJA) — BATKUJA)
917 91 8	DO 50 K = 1, NC C**** specific best is taken to be uniform in the model	1024	170 CONTINUE
919 920	CV(K) = SPH 50 CONTINUE	1025 1026	180 CONTINUE
921	C**** deline initial temperature distribution	1027	END #
922 923	IF (TEMEOR .EQ. 0) THEN C**** Let initial become the exponential from left to right from	1028 1029	Coose take initial intensity to be the intensity from transfer equation
924	Coood Key to 1 ey	1030	DO 230 K = 1, NC
925 926	LITLB = LOO(TELB) DO 60 K = 1, NC	1031 1032	DO 210 J = 1, NO DO 200 I = 1, NA
927	TEMP(IC) = TELB * EXP((-LITLB*(DENT(IC) - DENT(IC)/2))/(L - (1033 1034	1977(U.K) = 1977(U.K) 1977(U.K) = 1977(U.K)
92 8 929	1 DEST(IC)(2))) 60 CONTINUE	1035	200 CONTRUE
930	ELSE	103 6 1037	210 CONTINUE 220 CONTINUE
931 932	C**** take initial temperature to be uniform DO 70 K = 1, NC	1038	8P4D ₽
933 934	TEMPON = ITEL 70 CONTRACE	1039 1040	DO 250 J = 1, NG DO 240 K = 1, NC
935	END #	1041	ZP/T(J,K) = 0.0
936 937	END of If (CONT. BQ. 0) THEN	1042 1043	DO 230 (= 1, NA ZBNTUJK) = ZBNTUJK) + IBNTUJK) * WP(II)
938	IF (NOT. SEMEKUN) THEN	1044	230 CONTINUE
939 940	TTIME = TTIME + DTIME P (TTIME .OT. MAXT .AND. TOIT .NE. 0) THEN	1045 1046	ZZNUJK) = ZZNTUJK) 240 CONTENZE
941	WRITE (".") Tripes remained, TTDAE - DTDAE, SEARUN	1047	250 CONTENUE DO 270 K = 1, NC
942 943	WRITE (6, "yprogram terminated, must reached" STOP	1049	SPLNCOO = 0.0
944	PAO F	1050 1051	DO 266 J = 1, NO D = FT (J,K)
945 946	END # TOU = 1 / (#P*DTD4E)	1052	E-F7()+1.K)
947	IF (NEFFC EQ. 0) THESH	1053 1054	BY OD OT. LOWLING THEIN D = LOWLING
948 949	Correcting intensity at cell boundary to be zero when it in regative C TREFVR determines the type of modification to be used for	1055	20 F
950 951	Cooos the negative flex fix up DO 80 K = 1, NC	105 6 1057	17 (E. (77. HELDA) THEN E = HELDA
952	TRNFVROK) = 0.5	1058	20 p
953 954	80 CONTINUE TRUEV = (SP*DTIME) / DL(1)	1059 1060	CALL ROMB(PPLNK, D, E, RESPLN) SPLNK(K) = SPLNK(K) + RESPLN
***	and so a few the summer of parts.	124	•

		127	
1041	260 CONTINUE	1167	DO 440 J = 1, NO
1062	270 CONTINUE	1168	D=F7(JA)
1063 1064	DIO 280 K = 1, NC (EREDIK) = 4 ° FI ° 5 03343E+07 ° SPLNK(IC) / SP	1169 1170	E = FF() + 1.K) IF (D. (JT. LOWLIN) THEN
1065	280 CONTINUE	1171	D = LOWLIM
1046	IF (PRES OR 5 AND TOTT OR DESC. AND TOTT LE DEXU)	1172	END OF
1967 1968	I THEN WILTE (8,290) (K,DLOC),CV(IC),TEMP(IC)(11604,EERED(IC),K=1,NC)	1173 1174	I' (E.OT. HILIM) THEN E = HILIM
1069	290 FORMAT (2/1/12,1X/d=1,1PE10.3,1X/cv=1,1PE10.3.1X,1amp=1	1175	END F
1070	1 (PE10.3.1X-U,1PE10.3,1X))	1176	CALL ROMB(FPLNK, D, E, RESPLN)
1071 1072	WRITE (8,77fbq group limits model* WRITE (8,300) (J.FR.(J.)=1.NG + 1)	1177 1178	CALL ROMB(PSIG, D, E, RESSIG) PLNINT(J.K) = RESPLN
1073	100 FORMAT (BCg,12,1 X,F11.4,1 X))	1179	SIGNT(JJK) = RESPIZA SIGNT(JJK) = RESSIG
1974	WRITE (8,771) is list as model?	1180	SPLNKAC = SPLNKAC + PLNENT(IJK)
1075 1076	WRITE (8,310) (((IJ,K,IBHT(IJ,K),K=1,NC),J=1,NC),J=1,NA) 310	1181 1182	ABB(K) = ABB(K) + PI.NINT(J,K) * SKIRYT(J,K) SCPLIN(J,K) = (EXP(-D) - EXP(-E))
1077	WRITE (8,7) k zer model	1183	440 CONTINUE
1078	WRITE (8,320) ((J.K.Z2NT(J.K),K=1,NC),J=1,NO)	1184	450 CONTINUE
1079 10 8 0	320 FORMAT (BIZ.) X.I.PE(0.3,1XI)	1105 1106	DO 470 K = 1, NC DO 460 J = 1, NG
1081	WRITE (8,7)) k integration limits model* WRITE (8,330) ((J.K.FF(J.K),K=1,NC),J=1,NC) + 1)	1107	CHB(J)C) = SIGBNT(JJC) = PLNINT(JJC) / ABB(IC)
1002	330 FORMAT (BIZ.1X,1X,1PE10.3))	1186	$ABC(JJC) = 27.0 \circ AC \circ SOP(JN(JJC) / ((ATEM(IC) \circ \circ \circ)) \circ P(JNINT(J, IC)) / ((ATEM(IC) \circ \circ \circ)) \circ P(JNINT(J, IC)) / ((ATEM(IC) \circ \circ)) \circ P(JNINT(J, IC)) / ((ATEM($
10 83 10 8 4	砂心 ず 2×D ず	11 89 1190	1 K)) 460 CONTINUE
1025	EF (CONT. BQ. 1) THEEN	1191	470 CONTINUE
1006	C**** poive opacity at new tamp.	1192	ELSE
1007 1000	00 TO 400 END ₽	1193	DO 490 K = 1, NC
1009	EF (TTEME: (NE. 1.0005E-10 AND), TORT INE. 0) THEEN	1194 1195	SPLNIK(K) = 0.0 ABB(K) = 0.0
1090	C**** no need to calculate intensity at the boundary, sence temperature	1196	DO 480 J = 1, NO
1091 1092	C**** remains constant after 0.1 m for time dependent case. (IO TO 400	1197	D=17(JX)
1093	800 B	1198 1199	E = FP() + 1.K) IF (D. OT. LOWLING THEN
1094	EF (TEMPTD), BQ. 0) THEEN	1200	D = LOWLIM
1095 1096	Cases express temperature on left and as linear function of time	1201	POF
1097	C**** untill it reaches its measurem value (1000 ev) IF (TIDAE, LT, 1.0000)E-10) THEN	1202 1203	IF (E.OT. HILDO) THEN E = HILDA
1098	ITLB = ((TELB - 1)*TTDs@/1.08-10 + 1)	1204	65vD 14
1099	12.48	1205	CH(J,C) = (EDP(-D) - EDP(-E))
1100	ILB = TAIB BND &	1206 1207	CALL ROMB(F2, D, E, RES2) CALL ROMB(F3, D, E, RES3)
1102	74.19 84.19	1208	CALL ROMB(FPLNK, D. E. RESPLN)
1103	mlb = Telb	1209	CALL ROMB(PEIG, D. E. RESSKI)
1104 1105	END IP WRITE (4, "YEB IN"), ITEB, ITEB	1210 1211	PLNINT(J,K) = RESPLN
1106	DO 340 J = 1, NO	1212	SIGNITUJK) = RESSIG SPLNKJK) = SPLNKJK) + PLNINTUJK)
1107	D = FR(I) / ITLB	1213	ABB(K) = ABB(K) + PLNINT(J,K) * SIGINT(J,K)
1108	E = FR(J + 1) / ITLB	1214	SCPLINGUK = (EXP(-D) - EXP(-E))
1109 1110	IF (D.OT. LOWLIN) THEN D=LOWLIM	1215 121 6	C WRITE (6, ") truz and rus3", RES2, RES3 480 CONTENUE
1111	BND ₽	1217	490 CONTRIUE
1112	pr (B.OT. Howard) THEN	1218	DO 510 K = 1, NC
1113 1114	E = HILIM END #	1219 1220	DO 500 J = 1, NO CHB(J)() = SIGENT(J)() * PLNENT(J)() / ABB(K)
1113	CALL ROMB(FPLNK, D, E, RESPLN)	1221	ABC(J,K) = 27.0 ° (AC) ° REB2 / ((ATEM(K)°°3)°RES3)
1116	C WRITE (6,280) J. RESPLN	1222	300 CONTINUE
1117 1118	C 280 FORMAT (1X.'J=', 12, 2X, TNTEGRAL INLB=', 1FE10.3) PALB(J) = (2/(SP**2)) * (TTLB**4) * (BK*TCF) * RESPLN / (A0**3)	1223 1224	510 CONTINUE ENDIF
1119	340 CONTINUE	1225	DO 520 K = 1, NC
1120	DO 350 J = 1, NO	1226	PMAC(K) = 27.0 ° AC ° ABB(K) / ((ATEM(K) **3) *SPLNK(K))
1121 1122	D = FR(J) / (TRB E = FR(J + 1) / (TRB	1227 1228	BETACK) = 4 * RK * ((ATEMOX)*TCF)**3) / CV(K)
1123	IF (D.GT. LOWLING THEN	1229	ALFARC = 1 / (PMAC(IC)*BETA(IC)) 520 CONTINUE
1124	D = LOWLIM	1230	DO 530 K = 1, NC
1125		1231	ETAGO = 1 / (1 + ALPAGO TOU)
1126 1127	IF (B. OT. HELDA) THEN E = HELDA	1232 1233	DETRIDIK) = SPLNIK(K) * 4 * PI / SP 330 CONTINUE
1128	150 F	1234	\$\$C=0.0
1129	CALL ROMB(PFLNK, D. E. REMPLN)	1235	DO 540 K = 1, NC
1130 1131	C WRITE (4,300) J. REMPLN C 300 FORMAT (1X, 'J = ', I2, 2X, 'BNTEGRAL INRB = ', 1PE10.3)	123 6 1237	SEC = SEC + ETA(IC) 540 CONTINUE
1132	INRB(I) = (2/(EP**2)) * (ITRB**4) * (BK*TCF) * RESPLN / (A0 **3)	1238	SEC = SEC/NC
1133	350 CONTINUE	1239	IF (PRES.OE, 2 AND, TOIT OR, DEXI, AND, TOIT LE, DEXU)
1134 1135	EF (SETROU BQ. 0) THEN Cooo no source on the right boundary	1240 1241	1 THEN
1136	DO 3401 = 1, NO	1342	WEITE (8, ") bets princ alth in model" WEITE (8,550) (K.BETA(K), PMAC(K), ALPA(K), K=1,NC)
1137	PARIO = 0.0	1243	550 PORMAT (3(2,1%3(1PE10.3,1%)))
113 8 1139	140 CONTINUE BLAST F (RETROU.BQ. I) THEIN	1244 1245	END # DO 580 J = 1, NG
1140	Coose an interest on the felt or right boundary	1246	DO 570 K = 1, NC
1141	DO 370 J = 1, NO	1247	PQUA)=0.0
1142 1143	patb(n = 0,0	1248 1249	DO 560 (= 1, NA
1144	370 CONTRUE	1250	Q(UJA) = CHA(UA) + EDRED(K) + ETA(K) / (2*DTIME*BETA(K)) 1 + TOU + ENT(UJA)
1143	end f	1251	PQ(JJC) = PQ(JJC) + ENT(LJJC) * WP(I) * ZLP(I)
1146 1147	IF (PRES) OB. 16. AND, TOIT OB. DEXIL AND, TOIT LE. DEXIL)	1252	560 CONTINUE
1148	WELTE (8.300) ITLA, ITRA	1253 1254	SIGNUJU) = (ABCUJU) + TOU) + DLUK) ZQUJU) = (RBUJU) + EREDU) + ETAK) / (DTIME*BETAK)) +
1149	380 FORMAT (1X, TTLB = ', 1PE10.3, 1X, TTRB = ', 1PE10.3)	1255	1 TOU • IZEN(J,K)
1150	WILTE (ELINO) (LEALE(I), EARE(I), I—I, NOI)	1256	570 CONTENUE
1151 1152	390 PORMAT (4(f*,121,131,2)(1PE10.3,130)) END F	1257 1258	\$40 CONTRIUS DO 600 K = 1, NC
1133	400 F (TIT LT, 1) THEN	1259	GRZQ(K) = 0.0
1134	DO 410 K = 1, NC	1260	GRFQ(K) = 0.0
1155 1156	ATEMANO = TEMP(N) 410 CONTRAINE	1261 1262	SUNCTROX) = 0.0 DO 590 J = 1, NG
1157	END F	1262 1263	DO 590 J = 1, NO GRZOGO = GRZOGO + ZOGJO
1158	DO 430 K = 1, NC	1264	CRUPQOO = CRUPQOO + PQCJAO / SYCHAUJAO
1159 1160	DO 420 J = 1, NG + 1	1265 1266	SUMCHBIO - SUMCHBIO + CHBIO XO
1161	FP(LIK) = PR(J) / ATEM(K) 420 CONTINUE	1266 1267	590 CONTENUE 600 CONTENUE
1162	430 CONTINUE	1268	EF (FRES .CRE. 2 .AND. TOIT .CRE, DEXIZ .AND. TOIT .LE. DEXU)
1143	EF (WYN .BQ. 0) THEN	1269	1 THEN
1164 1163	DO 450 K = 1, NC SPLNK(IQ = 0.0	1270 1271	WRITE (R,7) num of this and abbels model* WRITE (R,610) (K,5U)(CHIK), ABB(K), K=1,NC)
1166	ABB(R) = 0.0	1272	610 PORMAT (5(22,1%,2(1PE11.4,1%)))
		127	and the second s

1273	WRITE (8, ")'] k chi she plank st model"	128 1379	COMMON /REW Q
1274	WRITE (8.620) ((J.K.CHR(JK), ABC(J,K), PLANK(J,K), J=1,NG), K=1,NC)	13 8 0	COMMON /R21/ SIGM, ORSE
1275	620 FORMAT (3(32,1%,12,1%,3(1PB10.3,1%)))	1381	COMMON /R23/ S, SUM1, SUM2, GRPQ, GRZQ
1276	WRITE (R, "Y i j k q mode"	1382	COMMON (R231/ SINT
1277	WRITE (R.630) (((LJX,Q(LJX),X=1,NC),I=1,NG),I=1,NA)	13 83	COMMON /R24/ TYDME, TOU, YERR, TELB
127 8	630 FORMAT (6(IZ,1X,IZ,1X,IZ,1X,IPE10.3,1X))	13 84	COMMON /R23/ TRNPVR, TEMP
1279	PAUSE	1385	COMMON /R27/ WP
12 9 0	END IF	1386	COMMON /R26/ ZLP, ZINT, ZQ, DIER
1281	EF (TIT. OE. 1) THEN	1387	
1282	DO 660 J = 1, NG	13 88	COMMON /IMT/ J, N
1283	DO 650 K = 1, NC	13 89	
1284	ZENT(J,K) = 0.0	1390	DO 60 I = 1, NAD2
1285	DO 640 I = 1, NA	1391	DO 50 J = 1, NO
1286	Z2NT(1,K) = Z2NT(1,K) + N2NT(U,K) + WF(1)	1392	DO 40 K = 1, NC
1287	640 CONTINUE	1393	NTB(U,I) = 0.0
1288	650 CONTINUE	13 94	
1289	660 CONTINUE	1395	NDNT(UJK) = ((CHB(JJK)*ETA(K)*AB(K)*2 + Q(UJK))*D(4K) +
1290	END IF	1396	1 2*ZLP(D*RNTB(UJK)) / (BIGN4(JK) + 2*ZLP(D)
1291	DO 680 K = 1, NC	1397	$INTB(IJ,K+1)=2*NINT(IJ,K)\cdot INTB(IJ,K)$
1292	AB(IC) = 0.0	1398	IF (PRESI GE. 13 AND, TOIT GE, DEXEL AND, TOIT LE, DEXU) 1 THEN
1293	DO 670 J = 1, NO	1399	
1294	AB(IC) = AB(IC) + ABC(J.IC) * ZZNT(J.IC)	1400	WRITE (8,10) L.J., K., PENT(UJK), NENT(UJK), 1. NENT(UJK) / PENT(UJK), ENTE(UJK + 1)
1295	670 CONTENUE	1401	
1296	680 CONTINUE	1402	10 PORMAT (13, 13 K PINENUP INTB-, 3(12,13).
1297	IF (PRES.GB. 2 .AND. TOIT.GE. DBXL .AND. TOIT.LE. DBXU) 1 THEN	1403	1 4(IPE10.3,1X))
1298		1404	END F
1299	WRITE (8, 7) k zist zą modsł	1405	C**** regative flux fix up criterion is selected (63), according C**** to TRNIVE value
1300	WRITE (8,690) ((J,K,ZENT(J,K),ZQ(J,K),J=1,NG),K=1,NC)	1406	
1301	690 FORMAT (5(12,1X,12,1X,1PE10.3,1X,1PE10.3))	1407	EF (NF .BQ. 0) THEEN
1302	end of	1408	EF (INTE(LUK + 1) LT. 0) THEN NEFT(LUK) = 1.0
1303	Return	1409	
1304	END	1410	COUNT = COUNT + 1 IF (TRINFVR(K)_LT. 1) THEN
1305	C	1411	
1305	C ************************	1412	MINT(LJ,K) = ((CHI(J,K) "ETA(K) "AB(K)/2 + Q(LJ,K))"
1307	C * this subroutine solves the RTE equation and evaluates the * C * the varieties needed for solving the diffusion equation *	1413	1 DL(K) + ZLP(0*PNTB(L),K) / SIGM(J,K)
1308		1414	NTB(L),K + 1) = 0.0
1309	C	1415	IF (PRES. GE. 15 .AND. TOTT GEL DEXIL .AND. TOTT LEL
1310	C	141 6	1 DBXU) THEN WHITE (R,20) L J, K, PENT(LJJK), NENT(LJJK),
1311	SUBROUTINE TRAPRT	1417	
1312 1313	PARAMETER (NANO=24.NPO=64.NCL=151)	141 8 1419	1 NRYT(U,K) / PRYT(U,K), RYTB(U,K + 1) 20 FORMAT (1X, 13 K P1NI NVP RYTB=', 3(12,1X),
1314	PARAMETER (SP=3.0800)	1420	1 4(1PE10.3,1X))
1315	INTEGER ABVL, AUTACL, CONVC, COUNT, CONT, TCONT, DB. DCOUNT	1421	END (F
1316		1422	ELSE
1317	INTEGER DET, DIFBC, DIFACC, BT, TITA	1423	NENT(LJ.K) = ((CEBUJK) "ETA(K)" AB(K)/2 + Q(LJ.K))" 1 DL(K) + ZLP(I)"NTB(LJ.K)) / (SIGMUJK) + ZLP(I))
1318	INTEGER INSE, IRUN, LIN, MEDUSA	1424	
1319	INTEGER NA, NG, NC, NF, NDIT, NFFC, NDICNT, NFMUST	1425	OLU)TIMIN = (I + XLU)ETM
1320	INTEGER OIT, OITA, PRES, RT, SETSOU, SCR, TRNACC	1426	IF (PREE OE, 15 AND, TOFT OE, DEXT, AND, TOFT LE. 1 DEXU) THEN
1321	INTEGER TB, TEMEOP, TIT, TOIT, TEMPTO, TIT, TRIN	1427	
1322	INTEGER USC, WFN, CONV, DEXIL, DEXU, NUM	142 8	WRITE (8,30) L.J. K., PENT(UJK), NENT(UJK),
1323	INTEGER NCP1, NCM1, NAD2	142 9	1. NENT(UJK) / PENT(UJK), ENTE(UJK + 1)
1324		1430	30 FORMAT (LX, T.J.K.PI NI NVP INTB→, 3(12, LX),
1325	COMMON /II / ABVL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT COMMON /IZ/ DRT, DEFBC, DEFACC, ITT, TITA	1431	1 4(IPE10.3,1X))
1326		1432	950 F
1327	COMMON /IS/ INSIB, IRUN, LIN, MEDUSA	1433	500 F 500 F
1328	COMMON NA/ NA, NG, NG, NF, NDIT, NFFC, NDICNT, NFMUST	1434	END IF
1329	COMMON NS/ ORT, ORTA, FRES, RT, SETSOU, SCR, TRNACC	1435	
1330	COMMON /M/ TB, TEMEOP, THT, TOIT, TEMPTO, THT, TREN	1436	40 CONTINUE
1331	COMMON /T/ UNC, WYN, CONV, DBXL, DBXU, NUM	1437	50 CONTINUE
1332	COMMON /M/ NCPI, NCMI, NAD2	1438 1439	60 CONTINUE
1333 1334	REAL® ALFA(NCL), AC, ATMARS, DAF(NFG,NCL), ATEM(NCL)	1440	DO 1201=NAD2+1, NA DO 1101=1, NG
1335	REAL® ABCOPPONCI.), ABONCI.), ACOPPONCI.)	1441	DO 100 K = NC, 1, -1
1336	REAL® BETA(NCI.), BOONFONCI.)	1442	INTB(J,NCP1) = INTB(J)
1337	REAL'S CV(NCL), CW, CHRNFQ,NCL)	1443	NFFT(LJ,K) = 0.0
133 8	REAL® DL(NCL), DDNT(NFO,NCL + 1), PRNTM	1444	NOVITUJK) = ((CHB(J,K)*BTA(K)*AB(K)/2 + Q(U,JK)*DL(K) +
1339	REAL® DEST(NCL), DTDME, DEPR	1445	1 2*ZLIY(D*BYTB(U,JK + 1)) / (BK/BA(J,K) + 2*ZLIY(I))
1340 1341	real-seta(ncl) real-seta(ncl) real-seta(ncl+1), freapped, fracquo	1446 1447	INTE(U,IC) = 2 * NENT(U,IC) - INTE(U,IC + 1) IF (PRES OR, 15 ,AND, TOIT OR, DRAW, AND, TOIT LE, DRAW)
1342	REAL® FROWG + 1), PQOWG.NCL)	1448	i THEN
1343	REAL'S INLEGATO), INBEGATO), ITEL, ERED(NCL), ERR	1449	WRITE (8,70) I, J, K, PRITUJK), NRHTUJK),
1344	REAL'S INTEGNANG, INCLAS 1), ENTINANG, APONCL), IZIN(NTO, NCL)	1450	1 NRHTUJK) / PRITUJK), BNTBUJK)
1345	REAL® ITER, ITEROFONCL)	1451	70 FORMAT (1X, 1 J K P1 N1 NUP INTID=1, 3(12.1 X),
1346	REAL'S NATE(NCL), NENT(NANG,NGLNCL) REAL'S NATE(NANG,NGLNCL), NOBNORG,NCL + 1), NZIN(NFG,NCL)	1452	1 4(1PE10.3,1X))
1347		1453	END F
134 8	REAL** PMACOCIL), PRYTONANO, NYONCL), PRYTME	1454	Coose regative flux fix up criterion is selected, according to Coose TRNFVR value.
1349	REAL** PORNOCL + 1), PFORNCL + 1), PLANKONYONCL)	1455	
1350	REAL'S FORMOTONICL + 1), PITEOPGINCL), PZNOTGINCL)	1456	F (NF EQ. 0) THEN F (NTBCLIC) LT. 0) THEN
1351	real's parokel)	1457	NPPT(LJ.K) = 1.0
1352	Real's Ocknowegnel)	145 8	
1353	REAL® SCHOOLD, GREENCL+ 1) REAL® SCHOOLD, STAIL, STAIL, GREQUICL, GREQUICL)	1459 1460	COUNT = COUNT + 1 IF (TRNFVR.GC L.T. 1) THEIN
1354 1355	REAL'S SINTON CLICL + 1)	1461	NENT(LJ,K) = ((CHRU JC)"ETARC)"ABRC)2 + Q(LJ,K))"
1356	REAL'STIME, TOU, TEAR, TELB	1462	1 DLOG - ZUPOJ TRITBOJ,K + 1)) / SIOMUJO
1357	REAL'STRIMVENCIA TEMPONCIA	1463	BITBOJ,O = 0.0
1358	REAL*8 WPOLANG)	1464 1465	IF (PRES. OR. 15 AND, TOIT OR. DEXIC. AND, TOIT LE. 1 DEXIC) THEN
1359 1360	real o zepovano), zentopolnce), zoopos nce), deer	1466	WRITE (R,BO) L J. K., PEYTOUJK), NEYTOUJK),
1361	COMMON /BDI / ALEA, AC, ATMASS, DAE, ATEM	1467	t NENT(UJA) / PENT(UJA), BNTB(UJA)
1362	COMMON /BDZ / ABC, AB, AO	1468	BO PORMAT (1X. 1 J K PI NENTP ENTE~, 3(2,13).
1363	COMMON /ROS/ BETA, BO	1469	1 4(IPE10.3,130))
1364	COMBAON /ROA/ CV, CW, CHE	1470	570g
1365	COMBAON /ROA/ DIL, DINT, PROVIM	1471	570g
1366	COMMON /ROM/ DIST, DTDME, DEPR.	1472	NB/T(L)() = ((CHBU)()*ETA(()*ABG()/2 + Q(L)())* 1 DL(() - ZL*(()*B/TB(L)(K + 1))/(BIG((L)(L) - ZL*(()))
1367	COMMON /RO71/ ETA	1473	DATE(CALC) = NEWTOLAR)
13 68	COMMON /RO71/ FINT, FINT., FINT.	1474	
1369	COMMON /ROW FR., PQ COMMON /R10/ INLE, INRE, ITHE, ERED, IERR	1475 1476	F (PRES. CIE. 15 .AND. TOIT CIE. DEXIL .AND. TOIT LE. 1 DEXIL) THEN
1370 1371	COMMON /RL1 / INTIB, IENT, IZEN	1477	WRITE (8,90) L J, K, PB/TGJ,K), NB/TGJ,K).
1372	COMMON /R12/ ITRB, ITBR	1478	1 NENTOJIO / FENTOJIO, ENTEOJIO
1373	COMMON /R15/ NATE, NINT	1479	90 FORMAT (1X, 1J K F1 NI NGP ENTE=1, 3(12,1X),
1374	COMMON /R.14/ NEPT, NORL, NZIN	1480	1 4(IFE)0.3,1X))
1375	COMMON /RL17/ PMAC, PINT, PRTDME	1481	90 #
1376	COMMON /RL19/ POIN, PFOIL PLANK	1482	
1377	COMMON /R.181/ PDRI, PITE, PZIN	1483	200 F
1378	COMMON /R.182/ PAB		200 F
13/8	COMMUNICATION FOR	128	_ • •

```
129
                                                                                                                                                                                                                                                                                                                                 1591
1392
                                                                                                                                                                                                                                                                                                                                                                                  WRITE ($,360) (K,AB(K),K=1,NC)
FORMAT (4(1X,Y,IZ,1X,1PE10.3))
                                          100 CONTINUE
110 CONTINUE
120 CONTINUE
DO 150 J = 1, NO
DO 140 K = 1, NOPI
     1485
1486
1487
                                                                                                                                                                                                                                                                                                                                                                      360 FORMAT (4(1)
2ND IF
DO 380 J = 1, NO
                                                                                                                                                                                                                                                                                                                                 1593
                                                                                                                                                                                                                                                                                                                                 1594
       1486
                                                                                                                                                                                                                                                                                                                                                                                  DO 380 I = 1, NO

DO 370 K = 1, NCM1

SUJO = (DLICO*ZQUJK) + DLIK + 11*ZQUJK + 11)/ 2 - (

FRITUJK + 2) - FRITUJK + 2) - DRITUJK +

1)/ (19*BGBWUJK + 1)) + (DRITUJK + 1) - DRITUJK) / (19*

SIGMUJO)

CONTRUUE
                                                                                                                                                                                                                                                                                                                                 1595
1596
1597
1598
1599
1600
      1485
                                         DO 140 K = 1, NCP1
DO 140 K = 1, NCP1
DO 1501 = 1, NA
DB THUS = DBNTUJK) * BNTB(UJK) * WF(I)
DO CONTRAUB
130 CONTRAUB
130 CONTRAUB
130 CONTRAUB
     1490
1491
1492
1493
1494
                                                                                                                                                                                                                                                                                                                                                                     370 CONTINUE
D0 400 K = 1, NC
D0 390 1 = 1, NC
HERUJA) = DLIA) * CHEUJA) * ETA(K) * AB(K) / 4
HTEUJA) = DLIA) * CHEUJA) * ETA(K) * AB(K) / 4
390 CONTINUE
                                                                                                                                                                                                                                                                                                                                 1601
1602
1603
1604
1605
1606
1607
1608
1609
     1496
1497
1498
1499
                                                 OF (PRES. CE. 2) THEN
WRITE (8,140) (((U,K,PNT(U,K),NNT(U,K,L=1,NA,L=1,NG),
                                           1 K=1.NC)
160 FORMAT (3(3(12,130,3(1PE10.3,130)))
PND IF
                                                                                                                                                                                                                                                                                                                                                                       390
400
     1500
                                                                                                                                                                                                                                                                                                                                                                               OF CONTINUE
OF (PRESIGE 7 AND. TOIT GE DEXIL AND TOIT LE DEXU)
                                                 EF (TRINACC IEQ. 1) THESY
     1501
                                                   DO 190 J = 1, NO
DO 190 J = 1, NO
DO 180 K = 1, NOP1
DOTTUJK) = 0.0
FINITUJK) = 0.0
SBITUJK) = 0.0
    1502
1503
1504
1505
1506
1507
1508
1509
                                                                                                                                                                                                                                                                                                                                                                                   WRITE (8,") took door, TOIT
                                                                                                                                                                                                                                                                                                                                                                                WRITE (R.*) Took door, TOTT
WRITE (R.*) Is so but fy
PORMAT (IX, 2(2,1 X,2,1 X,3,1 PE10.3,1 X0))
WRITE (R.*) (J.X.,2(J.X.), K-1, NCM1), J-1, NO)
PORMAT (IX, 4(2,1 X,2,1 X,1 PE10.3,1 X))
WRITE (R.*) Is juiging
WRITE (R.*) Is juiging
WRITE (R.*) (J.X.,2(J,X,3,5) MJ,X,K-1,NC,J-1,NO)
PORMAT (2(2,1 X,2,2,2,1 PE10.3,1 X0))
WRITE (R.*) Is fire pain and
WRITE (R.*) Is fire pain and
WRITE (R.*) Is fire pain and
                                                                                                                                                                                                                                                                                                                                 1611
1612
1613
1614
                                                          DO 1701=1. NA
                                                            DBATUJO, = DBATUJO, + BATB(LJJO, * WF(I)
FRATUJO, = PBATUJO, + BATB(LJJO, * ZLJP(I) * WF(I)
SBATUJO, = WF(I) + BATB(LJJO, * WF(II) * WF(II)
                                                                                                                                                                                                                                                                                                                                 1613
                                                                                                                                                                                                                                                                                                                                1616
1617
1618
1619
                                       1311
    1512
1513
1514
1514
1515
                                                                                                                                                                                                                                                                                                                                 1620
1621
                                                                                                                                                                                                                                                                                                                                1622
1623
1624
1625
                                                                                                                                                                                                                                                                                                                                                                                       FORMAT (1X, 12, 1X, 12, 1X, 1PE10.3, 1X, 1PE10.3, 1X, 1PE10.3)
     1517
                                                                                                                                                                                                                                                                                                                                                                           END IF
   1518
1519
1520
1521
                                                                                                                                                                                                                                                                                                                                                                             RETURN
                                                                                                                                                                                                                                                                                                                                 1626
                                                                                                                                                                                                                                                                                                                                1627
1628
1629
                                                                                                                                                                                                                                                                                                                                                                             PND
     1322
   1323
1324
1325
                                                              CONTINUE
                                                                                                                                                                                                                                                                                                                                                                           * this subroutine computes the spectral radius and determines if *
* the intensity is converged.
                                                 O CONTINUE
O CONTINUE
O CONTINUE
DO 240 K = 1, NC
PAB(K) = 0.0
                                                                                                                                                                                                                                                                                                                                 1630
                                                                                                                                                                                                                                                                                                                                 1631
                                                                                                                                                                                                                                                                                                                               1632
1633
1634
1635
    1526
    1327
                                        DO 230 J = 1, NO
PAB(K) = PAB(K) + ABC(J,K) * PZZN(J,K)
230 CONTENUE
240 CONTENUE
                                                                                                                                                                                                                                                                                                                                                                           SUBROUTINE TROONV
  1528
1529
1530
1531
                                                                                                                                                                                                                                                                                                                                                                          PARAMETER (NANO=24.NFO=64.NCL=151)
                                                                                                                                                                                                                                                                                                                                 1636
                                                                                                                                                                                                                                                                                                                               1637
1638
1639
                                                                                                                                                                                                                                                                                                                                                                           REAL® DEFF
REAL® NOS
REAL® POS
   1512
                                     DO 250 K = 1, NCP1
PFOR(C) = 0.0
PGRN(C) = 0.0
DO 250 J = 1, NO
PFOR(C) = PFOR(C) + PRITUJIC)
PGRN(C) = PGRN(C) + DRITUJIC)
250 CONTRIVE
250 CONTRIVE
DO 250 K = 1, NC
GRIG(C) = 0.0
DO 270 J = 1, NG
GRIG(C) = 0.0
DO 270 J = 1, NG
CRESCO = GRISQ(C) + (RRITUJIC + 1) - SRITUJIC) / SIGM(UJIC)
270 CONTRIVES
270 CONTRIVES
                                                  DO 260 K = 1, NCF1
  1533
1534
1535
                                                                                                                                                                                                                                                                                                                                 1640
1641
                                                                                                                                                                                                                                                                                                                                                                           REAL*S SNIN(NCL), SPIN(NCL)
                                                                                                                                                                                                                                                                                                                               1642
1643
1644
1645
1646
1647
1648
1649
1650
                                                                                                                                                                                                                                                                                                                                                                           REAL*S TINT
  1534
                                                                                                                                                                                                                                                                                                                                                                         INTEGER ABVI., AUTACI., CONVC, COUNT, CONT, TCONT, DB, DCOUNT INTEGER DRT, DEPOC. DEFACC, IIT, TITA
RYTEGER DRED, BLIN, LEN, MEDURA
RYTEGER DRED, BLIN, LEN, MEDURA
RYTEGER DRED, GOTA, PAES, RT, SETSOU, SCR, TRANCC
RYTEGER DRED, DEFACE, DRED, TOTT, TEMPTD, TIT, TRIN
RYTEGER LICE, WIPL, CONV, DEAL, DEXU, NUM
RYTEGER LICE, WIPL, CONV, DEAL, DEXU, NUM
RYTEGER DRED, NCMI, NADZ
RYTEGER SATISTI, SMITSTS, SMITSTS
   1337
   1538
  1539
1540
1541
1542
 1543
1544
1543
1546
1547
1548
1549
1550
1551
                                       270 CONTINUE
280 CONTINUE
DF (PRES, OE. 5 AND. TOST, OT. DEXIL, AND. TOST, LE. DEXIL)
                                                                                                                                                                                                                                                                                                                               1632
1633
1634
1635
                                       1 THEN
WRITE (R, "7t plu) pair
WRITE (R, "7t plu) pair
WRITE (R, 200) (K, PFGRIC, PGB-IG), K-1, NCP1)
200 PORMAT (1X, 3/t; Z, 1X, 2(1PE10.3), 1X))
WRITE (R, 300) (K, GRESDO, K-1, NC)
WRITE (R, 300) (K, GRESDO, K-1, NC)
                                                                                                                                                                                                                                                                                                                                                                          LOGICAL TEN, DEFF, LOR, NLGR, SEARUN, SMITST
COMMON /L.I/TEN, DEFF, LOR, NLGR, SEARUN, SMITST
                                                                                                                                                                                                                                                                                                                               1656
                                                                                                                                                                                                                                                                                                                                                                           COMMON /II/ ABVL. AUTACL. CONVC. COUNT. CONT. TCONT, DB, DCOUNT
                                                                                                                                                                                                                                                                                                                               1637
1638
1639
1660
1661
1662
1663
1664
                                                                                                                                                                                                                                                                                                                                                                          COMMON 1/2 DRT, DIPPC, DEPACC, ST, TITA
COMMON 1/2 DRT, DEPC, DEPACC, ST, TITA
COMMON 1/2 PRES, SEUN, LEN, MEDUSA
COMMON 1/4 NA, NG, NC, NF, NDIT, NPFC, NDICNT, NFMUST
COMMON 1/2 OTT, OTTA, PRES, RT, SETSOU, SCR, TRNACC
  1332
 1553
1554
1555
                                                       PORMAT (1X, 5(Y,IZ,1X,1FE10.3,1X))
                                               *** magazive flux flx up cristarion is saled
UF (NF .BQ. 0) THEN
                                                                                                                                                                                                                                                                                                                                                                          COMMON NO TR. TEMEDIO, TET, TOT, TEMETID, TIT, TRIN
COMMON IT! USC, WFN, CONV. DEXIL, DEXIU, NUM
COMMON IN NCP!, NCM!, NAD2
COMMON IN NET! SMITT!, SMITTS, SMITTS, SMITTS,
  1336
                                                  IF (NF BQ, 0) THEIN

DO 3301 = 1, NO

DO 320 K = 1, NO

DO 3101 = 1, NA

IF (NFFT(LLIC), OT. 0.5) THEIN

IF (ORTT(LK 1), BQ, 0.0) THEIN
 1337
1338
1339
                                                                                                                                                                                                                                                                                                                               1643
1646
1647
1648
1669
  1540
                                                                                                                                                                                                                                                                                                                                                                         REAL® ABCOPGINCL), ABONCL, ACOPGINCL)
REAL® DILINCL), DRITORGINCL +1), FRNTM
REAL® DESTONCL), DTIME, DEPR
REAL® FROWG + 1), FQOPGINCL)
 1562
1563
1564
1564
                                                               AO(UIC) = 1.0
EL.EE
AO(UIC) = 22NT(UIC) / DENT(UIC + 1)
END EF
                                                                                                                                                                                                                                                                                                                               1670
1671
1672
1673
                                                                                                                                                                                                                                                                                                                                                                           REAL OF INCHOSO), INRIBOSTO), ITSL, STRED(NCL.), ERR
                                                                                                                                                                                                                                                                                                                                                                         REAL*8 NAE(NO), NREGOTO, ITSL, EREDINCL), ES
REAL*8 NATE(NCL), NRTI(NANO.NTC.NCL)
REAL*8 SOLU(NCL+1), EPRB
REAL*8 SOLU(NCL+1), EPRB
REAL*8 SOLU(NCL+1), EPRB
REAL*8 STH, SEC. EPR
REAL*8 WF(NANO)
                                                               SHO F
F (DRITCUIC), EQ. 0.0) THEN
BOOUL) = 1.0
ELME
BOOUL) = ZENTOJC/ DRITCUIC
SHO F
GO TO 320
1366
1367
1368
1369
1370
                                                                                                                                                                                                                                                                                                                               1674
                                                                                                                                                                                                                                                                                                                               1675
1676
1677
  1571
 1572
1573
                                                              70.5E
                                                                                                                                                                                                                                                                                                                               1678
1679
1680
1681
1682
1683
                                                                AO(JJC) = 1.0
BO(JJC) = 1.0
                                                                                                                                                                                                                                                                                                                                                                           COMMON /R02/ ABC, AB, AO
COMMON /R03/ DL, DONT, PRNTM
                                                                                                                                                                                                                                                                                                                                                                        COMMON ROS/ DIL DOTT, PRITTM
COMMON ROS/ DIL DOTT, PRITTM
COMMON ROS/ PIL PQ
COMMON ROS/ PIL PQ
COMMON ROS/ PIL DA
COMMON RIS/ NATE, RRIN, TISL, EDIED, ERR
COMMON RIS/ NATE, RRIN,
COMMON RIS/ NATE, RRIN,
COMMON RIS/ NATE, RRIN,
COMMON RIS/ SATE, PRITTME
COMMON RIS/ SATE, SER,
COMMON RIS/ SATE, SER
  1374
                                                      END IF
CONTINUE
CONTINUE
  1575
1576
1577
1378
1579
                                      310
                                      320 CONTINUE
330 CONTINUE
END IF
                                                                                                                                                                                                                                                                                                                               1684
1685
1686
1687
1688
                                                 DO 350 K = 1, NC
  1380
  1581
1582
1583
                                                   AB(C) = 0.6
DO $40.1 = 1, NO
AB(C) = AB(C) + ABC(JIC) * (AO(JIC)*DENT(JIC + 1) + BO(JIC)*
DENT(JIC)
                                                                                                                                                                                                                                                                                                                              1689
1690
1691
1692
1693
1694
1695
                                                                                                                                                                                                                                                                                                                                                                           COMMON /B27/ WF
  1564
 1585
1586
1587
1588
1589
                                     340 CONTINUE
PARIQU = 2 * PARIQU
350 CONTINUE
IP (PRIES LOE 5 ANID. TOIT LOE DEXID. ANID. TOIT LE DEXIU)
                                                                                                                                                                                                                                                                                                                                                                           IF (RT LT. 1) THEN
                                                                                                                                                                                                                                                                                                                                                                           DO 30 K = 1, NC

SNINOC = 0.0

SPINOC = 0.0

DO 20 J = 1, NO

DO 10 I = 1, NA
                                                            THEN
                                                   WRITE (R. ") & de for dell'
```

```
130
   1697
1698
1699
1700
                                                                                       SPIN(IC) = SPIN(IC) + (ABC(IJC)^{optivT(IJJC)^{optivT(IJJC)}} (I)^{optivT(IJJC)^{optivT(IJJC)}} (I)^{optivT(IJJC)^{optivT(IJJC)}} (I)^{optivT(IJJC)^{optivT(IJJC)}} (I)^{optivT(IJJC)^{optivT(IJJC)}} (I)^{optivT(IJJC)^{optivT(IJJC)}} (I)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)}}} (I)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)}}} (I)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(IJC)^{optivT(
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1803
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           ENTEGER TB. TEMEOP, TET, TOIT, TEMPTD. TIT, TRIN
ENTEGER USC, WEN, CONV, DBXL, DBXU, NUM
ENTEGER NCP1, NCM1, NAD2
                                                                                          STEACH STANDARD * (ABC(I)(C)*NEWT(LIX)*WF(I)*(FR(I + 1)

*FR(I)))

- FR(I)))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1804
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           1805
1806
1807
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           COMMON /III / ABVIL, AUTACEL, CONVC, CUN'NT, CONT, TOWNT, THE UNIN'NT COMMON /III / AUTOCOMMON / AU
                                                                                 CONTINUE
   1701
 1702
1703
1704
1705
1706
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1808
                                                                         DEFF. = DEFF. + (((ZMPA(K) - 25DPA(K))A3)...3) . DPA(K)
DEFF. = 0.0
DA (K = 1' NG
DEFF. = 0.0
COMMON
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1809
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1810
   1707
                                                            40 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1813
1708
1709
1710
                                                                         PDIF = SQRT(DIFFF/4)
NDIF = PDIF
RT = 2
GO TO 110
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1814
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1815
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1816
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            REAL® ABCONFOLNCL), ABONCL), AUNTOINCL)
REAL® NATEONCL), ABTINANOINFOLNCL)
REAL® WOONANOI
REAL® ZLPONANOI, ZBYTONFOLNCL), ZQNIFOLNCL), DEDA
 1711
 1712
                                                                    PLSE
DO 70 K = 1, NC
 1713
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1819
                                                                             1820
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1821
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               COMMON /RO2/ ABC, AB, AO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1822
1823
1824
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               COMMON /RIS/ NATE, NEXT
   1716
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            COMMON /R27/ WF
COMMON /R28/ ZLP, ZENT, ZQ, DIER
 1717
 1718
                                                                                          ·FR(J)))
                                                                            CONTINUE
CONTINUE
CONTINUE
1719
1720
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1825
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1826
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            DO 30 J = 1, NO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               DO 30 # = 1, NO
22NT(J,K) = 0.0
DO 10 1= 1, NA
22NT(J,K) = 2NT(J,K) + NENT(LJ,K) * WF(I)
DO 30 K = 100 **
CONTRAUB
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1827
1828
1829
 1721
                                                                      O CONTROUS

DO SO K = 1, NC

DOFFF = DOFFF + ((SNIN(K) - SPIN(K))2)**2) * DL(K)

O CONTROUS

NDDF = SQRT(DOFFF/4)

END TO SORT(DOFFF/4)
 1722
   1773
 1724
1725
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1830
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1231
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1832
1833
1834
1834
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       CONTINUE
                                                        NOR = SQRT(DEFF/4)
END B
SPR = NOB / PDB
PDF = NOB
WRITE (6,90) TOTT, TUT, TIT
OF FORMAT (1X, TOTT = R, 3X, TUT = R, 3X, TIT = R)
WRITE (6,100) NOB , SPR, SBRC, DSPR
100 FORMAT (1X, TOTE ERR = 1, TPE10.3, 3X, TRAN SPR = 1, TPE10.3, 3X, 13X, TRAN SPR = 1, TPE10.3, 3X, END
END B
PDF (SPR, GR, 1,00) THEN
   1726
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    20 CONTRIUE
D0 50 K = 1, NC
AB(C) = 0.0
D0 40 J = 1, NO
AB(C) = AB(C) + AB(C)J(C) * ZENTIJJC)
40 CONTRIUE
50 CONTRIUE
80 CONTRIUE
 1727
 1728
 1729
1730
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1834
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1838
1839
 1731
 1732
 1733
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1735
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              RETURN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1840
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1841
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               END.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           1842
1843
1844
1844
 1736
                                                                    IF (SPR.OE. 1.00) THEN
 1737
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  * this subroutine solves the diffeon equation
1738
1739
1740
1741
                                                                      IP (SPK (OE 1:00) HEN
SMISTI = SMISTI + 1
IP (SMISTI (OE 5) THEN
WRITE (R.*Transport term
SMIST = TRUE
END IP
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1944
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           1847
1848
1849
1830
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               SUBMOUTINE MFDE
 1742
 1743
1744
1745
                                                                    PND IF
                                                        END IF
110 DO 120 K = 1, NC
SPINIC) = SNINGC)
120 CONTENUE
IF (CONVC.EQ. 0) THEN
IF (NDIF. OE. IERR) OO TO 210
CONV = 1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              PARAMETER (NANO-24,NFG-64,NCL-151)
PARAMETER (Ph-3,141593)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1851
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1853
1854
 1746
1747
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               REAL® A(NCL + 1)
REAL® B(NCL + 1)
REAL® C(NCL + 1)
REAL® R(NCL + 1)
1748
1749
1750
1751
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1835
                                                                  CONV = 1
ELSE IF (CONVC.EQ. 1) THEN
DD 150 J = 1, NO
DD 140 K = 1, NC
DD 150 J = 1, NA
IF (ABS((NINTUL)C) - PINTUL(X))/PINTUL(X)). GE.
10
CONTINUE
10
CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1856
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1857
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              COMMON/MT/1 N
1752
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               COMMON /RMT/ A, B, C, R
 1753
1754
1755
1756
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1960
1961
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              LOGICAL TRN, DEPT, LOR, NLOR, SMRUN, SMITH
COMMON /LI/ TRN, DEPT, LOR, NLOR, SMRUN, SMITH
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1963
1964
1965
 1757
                                                           140 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            INTEGER ABYL, AUTACL, CONVC, COUNT, CONT. TONT. DR. DCOUNT
PITSGER DRT, DEPIC, DEPACC, IST. TITA
PITSGER NESS, BUN. CEN, MEDURA
PITSGER NESS, BUN. CEN, MEDURA
PITSGER NA, NO, NC, NY, NNYT, NPPC, NDECNT, NPMUST
PITSGER DR, OTA, PEEZ, RT, SETTIOU, SCR. TRANCC
PITSGER TR. TREBEST, TET, TET, TESPTD, TIT. TEN
PITSGER USC, WPM, COPY DRIEL, DRIVE, NUM
PITSGER USC, WPM, COPY DRIEL, DRIVE, NUM
PITSGER USC, WPM, COPY DRIEL, DRIVE, NUM
1758
1759
1760
1761
                                                                  ELSE IP (CONVC.EQ. 2) THEN
DO 200 K = 1, NC
TENT = 0.0
DO 170 J = 1, NG
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1864
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1967
1968
1969
 1762
1763
1764
1765
                                                        DO 1601=1, NA
TINT = TINT + PINTILIDO
160 CONTINUE
170 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1870
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1871
1872
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               INTROFFE NOP! NOM! HAD?
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               INTEGER SMIST), SMIST2, SMIST3, SMIST4, SMIST3
1766
                                                        1767
1768
1769
1770
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            COMMON /III / ABYL, AUTACL, CONVC, COUNT, CONT, TCUNT, DR. DCYUNT COMMON /II / DRT, DEPBC, DEPACC, ET. TITA COMMON /IV / DRT, DEPBC, DEPACC, ET. TITA COMMON /IV / DRB, BUUN, LIN, MEDURA COMMON /IV / DRB, BUUN, LIN, MEDURA COMMON /IV / DRB, DRT, NOT, NEW, DRT, TRANCC COMMON /IV / DRB, TDMEDU, TET, TOTT, TEMPTO, TIT, TUPN COMMON /IV / DR, TEMEDU, TET, TOTT, TEMPTO, TIT, TUPN COMMON /IV / DRC, VONV, DEST., DESTU, MUM COMMON /IV / NCPI, NCMI, NADZ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1873
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1981
1982
1983
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               COMMON /SMT/ SMTST1, SMTST2, SMTST3, SMTST4, SMTST5
1776
1777
1778
1779
                                                                    RETURN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            REAL® ALFACACIA, AC, ATMARS, DAFAWONCIA, ATEMANCIA
REAL® ABCONFONCIA, ABONCIA, ACOMPONCIA
REAL® BETACACIA, BOOMFONCIA
REAL® CVONCIA, CW, CHOMFONCIA
REAL® DIEDNICIA, DINTOWONCIA + 1), PRINTM
REAL® DIETNICIA, DITME, DEPR
                                                                  IF (AUTACL_BQ, 1) THEN

IF (SPR, OT, SPRB_AND, DEPR_LY, 0.80) THEN

TRNACC = 1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1964
1965
1986
1987
 1780
1781
1782
1783
                                                                            DEFACC = 2
                                                                         ELSE
TRINACC = 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1900
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1890
1891
1892
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1794
                                                                       END IF
1785
1786
1787
                                                                    END IF
                                                                  RETURN
END
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1893
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            REAL'S BYTBOUND INFONCL; 1), SYTOUND SY ONCL. IZENDY O'N

REAL'S INAT BOYCE, INSTITUTION ON O'N CL.)

REAL'S NAT BOYCE, INSTITUTION ON O'N CL.)

REAL'S PRACONCL; PRITO AND O'N CL.) PRITO SY

REAL'S PRACONCL; PRITO AND O'N CL.) PRITOS

REAL'S PRACONCL; RESONCL; PRITOS O'N CL. INSTITUTION O'N CL.)

REAL'S SOMO O'N CL.; O'N RESONCL; PROPOSITION CL.)

REAL'S SOMO O'N CL.; O'N RESONCL; O'N CL.)

REAL'S SOMO O'N CL.; O'N RESONCL; O'N CL.)

REAL'S SOMO O'N CL.; O'N C.; O'N
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1900
1901
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                                                                 SUPPROLUTING TRANSP
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            1902
1903
1904
1905
1906
                                                                  PARAMETER (NANO-24 NFO-64 NCL-151)
1796
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              REAL'S SMIOWOJNCL+ 1)
REAL'S WYOLANO)
REAL'S ZIPONANO), ZENTOWOJNCLI, ZQOWOJNCLI, DIER
1797
                                                                  INTEGER ABUL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT
                                                                  INTEGER DRT, DIFFIC, DIFFACC, ITT. TITTA
INTEGER INSIR, IRUN, LIN, MEDUSIA
INTEGER NA, NO, NC, NP, NOIT, NPPC, NDICHT, NPMUST
INTEGER OIT, OITA, PREIR, RT, SETSOU, SCR, TRINACC
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              COMMON (BOL) ALFA, AC, ATHAMS, DAF, ATEM
COMMON (BD2) ABC, AB, AO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      1907
1908
130
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COMMENTATION BETA, BO
COMMENTATION CV, CW, CHI
COMMENTATION CV, CW, CHI
COMMENTATION COMPT, PENTIN
COMMENTATION COMPT.
PENTINE, DEPT.
COMMENTATION FETA.
COMMENTATION FETA.
PORT.
COMMENTATION FETA. PORT.
COMMENTATION FETA.
PORT.
COMMENTATION FETA.
PORT.
COMMENTATION FETA.
COMMENTATION COMPT.
COMMENTATION COMPT.
COMMENTATION COMPT.
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COMMENTATION PORT.
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COMMENTATION PORT.
COMMENTAT
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   2015
2016
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        COMMON /LI/ TRN, DIPF, LOR, NLOR, SIMRUN, SMTST
              1910
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     BYTEGER ABVL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT BYTEGER DRT, DUPBC, DIPACC, IIT, TITA
BYTEGER BNB, BUN, LEN, MCDUSA
BYTEGER NN, NO, NC, NY, NDT, NPPC, NDIGNT, NPMUST
BYTEGER NT, NOT, N, PREB, RT, SETSOU, SCR, TRNACC
BYTEGER OT, OTTA, PREB, RT, SETSOU, SCR, TRNACC
BYTEGER TB, TEMEDY, TIT, TOTT, TEMPTD, TIT, TRIN
BYTEGER ING, WPN, CONV, DBXL, DBXU, NUM
BYTEGER NCPL, NCML, NAD2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   2017
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   2018
2019
2020
2021
                1914
                1915
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   2022
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   2023
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2023
2024
2024
2027
2028
2029
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        INTEGER SMISTI, SMISTS, SMISTS, SMISTA, SMISTS
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     COMMON /II / ABVL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT COMMON /IJ / DRT, DIFBC, DIFACC, IIT, TITA COMMON /IJ / DRSB, BLUN, LBN, MEDUSA COMMON /IJ / DRSB, BLUN, LBN, MEDUSA COMMON /IJ / DRSB, BLUN, LBN, MEDUSA COMMON /IJ / DRSB, RT, SETSOU, SCR, TRNACC COMMON /IJ / DRSB, TT, SETSOU, SCR, TRNACC COMMON /IJ / TB, TBRBCP, TIT, TOT, TEMPTO, TIT, TILDN COMMON /IJ / USC, WIN, CONV, DBSQ, DBSQ, NUTM COMMON /IJ / MICEL, NCAIL, NAD2 COMMON /IJ / NCCI, NCAIL, NAD2
              1920
              1921
           1922
1923
1924
1925
                                                                                COMMON RE21 SOM, ORSI
COMMON RE22 SOLU, SPRB
COMMON RE22 SOLU, SPRB
COMMON RE23 S, SUMI, SUMZ, ORPQ, ORZQ
COMMON R231/SBNT
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               2030
2031
2032
2033
2034
             1924
             1927
                                                                                  COMMON /R27/ WF
             1928
                                                                                  COMBNON /R28/ ZLP, ZINT. ZQ, DREB
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2015
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        COMMON /SMT/ SMTST1, SMTST2, SMTST3, SMTST4, SMTST5
                                                                                SF (PRES GE 3 AND TOST GE DEXT. AND TOST LE DEXU)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               2036
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      REAL® ABO(NFO.NCL), AB(NCL), AO(NFO.NCL)
REAL® DL(NCL), DB/T(NFO.NCL + 1), PR/NTM
REAL® DB/T(NCL), DTD/E, DB/R
             1931
                                                                             I THEN
WRITE (8,19) is the paid
WRITE (8,10) (U.K.TERU.K.).PTEU.K.).K-I.NC).J-I.NG)
10 FORMAT (IX, IZ, IX, IZ, IX, IPE10.3, IX, IPE10.3)
END IP

ON A IN TO SERVICE OF THE PROPERTY OF THE PRO
         1932
1933
1934
1933
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2038
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2039
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     REAL-1 PRINTO + 1), POINTOINCL)
REAL-19 INTETNAMOLIPOINCL), NORWITTOINCL + 1), NZINNIFOINCL)
REAL-19 WITTOMANO), ZENTOITOINCL), ZOONFOINCL), DER
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       DO 60 J = 1, NO
           1934
                                                                      DO 40.1-1, NO
DO 20 K = 1, NCP1
DY (K BQ, 1) THEN
A(K) = 0.0
B(K) = 8UMI + SKIMKUK) * BO(JJC) / 4 + 1 / (3*SIGM(JJC))
C(K) = SIGM(JJC) * AO(JJC) / 4 + 1 / (3*SIGM(JJC))
ELSE BY (K BQ, NCP1) THEN
A(K) = 8UMI JK - 1) * BO(JJC - 1) / 4 + 1 / (3*SIGM(JJC))

| 1))
B(K) = -8UMI Z + SIGM(JK - 1) * AO(JJC - 1) / 4 + 1 / (3*SIGM(JJC))
C(K) = 0.0
ELSE
         1917
        1938
1939
1940
1941
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   COMMON /R/02/ ABC, AB, AO
COMMON /R/03/ DL, DINT, PRINTM
COMMON /R/03/ DIST, DTIME, DSPR
COMMON /R/03/ FR, PC
COMMON /R/03/ FR, DDIN, NZIN
         1942
        1943
1944
1945
1944
1947
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     COMMON /R27/ WP
COMMON /R28/ ZZ.P, ZZNT, ZQ, DEER
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     IF (DRT LT. 1) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      In (URL 13.1) THEY
DO 20 K = 1, INC
DEPRINC = 0.0
DEPRINC = 0.0
DO 10 I = 1, INO
DEPRINC = DEPRINC + ABCUJO * DENTUJO * (FRU + 1) -
         1948
                                                                                       F1.55
        1949
1950
1951
                                                                                               A(K) = $50M(J,K - I) * BO(J,K - I) / 4 - I / (3*$10M(J,K -
                                                                                         1))
BOX) = (SIGMALUK - 1)*AGULK - 1) * SIGMALUK * 10*AGULK - 1) * SIGMALUK * 10*AGULK - 10 * SIGMALUK * 10*AGULK + 10*AGU
         1952
    1953
1954
1955
1956
1957
1959
1960
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1962
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1967
1971
1972
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1974
1975
1975
                                                                             FE(D)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  DENINGO = DENINGO + ABC(JJO * NORN(JJO * (FR(J + 1) -
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       DENIN(I) = DENIN(I) + ABC(J,K) * NDIN(J,K) * (FR(I+1

FR(J))

10 CONTINUE

20 CONTINUE

DORF = 00

DO 30 K = 1, NC

DOUTF = DORF + (((DRNIN(I) - DEPIN(K))/2)**2) * DL(I)

30 CONTINUE

DPDF = SQRTIDDEF/4)

DET = 2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        DRT=2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         DO 40 K = 1, NC
DEPENIC = DSNENIC
40 CONTENUE
GO TO 120
                                                                                         RACO = FTERCUK - 1) + FTERCUSO + SCJK - 1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 ELSE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        DO 60 K = 1. NO
                                                                               CONTINUE
OF (PRES OE. 7 AND. TOIT OE. DEXIL AND. TOIT LE. DEXU)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           DO SO J = 1, NO
DO SO J = 1, NO
DO SO J = DENDNIK) + ABCUJA; * NDDNIJA; * (FRUJ + 1) -
                                                                                  THEN THE 7 AND TOT US DISAL AND TOT US DISAL THEN THEN WAITE (R-40) (K-A(K-BOK-CIK)-RICK-I-NCPI)
PORMAT(IX, Y., Z., IX, IPEI0.3, IX, IPEI0.3, IX, IPEI0.3, IX, IPEI0.3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  FR(D)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         1 FIG.))
60 CONTINUE
60 CONTINUE
DDBF = 0.0
DD 70 K = 1,1-1C
DDBF = DDBF + (((DBNBNK) - DDPN(K)/2)**2) * DL(K)
                                                                               END F
                                                                               N - NCTI
                                                                             WHITE SECTION AND A SECTION ASSESSMENT OF THE SECTION ASSESSMENT OF TH
1978
1979
1979
1981
1982
1984
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1997
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2001
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2006
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2007
2007
2008
                                                           c
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           70 CONTINUE
DNOW = SQRT(DDW7/4)
END #
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              END IF
DIFFE = DNDIF / DPDIF
DFDIF = DNDIF
DFDIF = DNDIF
IF (FRUIT, GE, 3 AND, TOIT, GE, DBXL, AND, TOIT, LE, DBXU)
                                                                     SO CONTINUE
                                                                  60 CONTINUE
CONTINUE
CONTINUE
DO 80 J = 1, NO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         WRITE (8,80) DNDW, DSPR
80 POMAT (13, 'DRYT ERR'+, 1PE10.3, 5%, 'DWF SPR'+, 1PE10.3)
                                                                               DO 70 K = 1, NCP1
                                                                                  EF (NDENCUQ LT. 0) THEN
NOIGHT = NDIGHT + 1
END EF
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              IO FORMAT (13, DENT ENU=, IPE10.3, 53, DEFF SER=, IPE10.3
END #
OO TO 110
DO 100 J = 1, NO
DO 90 K = 1, NO
# (NDRVIJK)/DENTUJK).GT. 100 0.OR. NDRVIJK//DENTUJK).
1 LE. 001) THEN
SMITT4 = SMITST4 + 1
                                                                     70 CONTINUE
                                                                      SF (PRES OR 6 AND TOIT OR DEXIL AND TOIT LE DEXU)

1 THEN
                                                                   SO CONTINUE
                                                                  I THEN
WRITE (R. YMM MEY, TOIT, TET, OIT, ET, TIT
WRITE (R.SM) (U.K.DENTU.ICLNORMUJALKH JNCP133-13NO)
90 PORMAT (RIX.T.JZ.JX.Y.JZ.JKTE10.3.JXM)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         2101
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ENDIF
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         90 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         2102
                                                                        END IF
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2103
2104
2105
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      IO CONTINUE

BY (BACTST4 .OT. (NG*NC)*0.05) THEN

SAITST = .TRUE.

WRITE (99,7) inner iteration terminated d
                                                                        END.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         2106
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                nted due to unphysical excre

    the advocates computes the spectral radius and determine
    if diffusion equation

                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    WRITE (99, "Please" iteration terminated du-
les in calif.
PAD F
10 9F (089R. GE. 1.00) THEN
SMISTS = SMISTS + 1
F (SMISTS - SMOPNC=0.01)) THEN
WRITE (99, "Please" ferration terminated du
10 toe offert
SMIST = TRUE.
IND SMIST = TRUE.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2107
2108
2109
2110
2111
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2112
2113
                                                                        SUBROUTINE DECONV
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             and show to show become > 1
                                                                      PARAMETER (NANO-24 NFO-44 NCL-151)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2114
2115
2010
2011
2012
                                                                      REAL** DOWN, DPDW, DNOW
REAL** DRYNINGLY, DWANINGLY
REAL** TRYT
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2116
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              120 DO 130 K = 1, NC
DSPRIGO = DIENTRIGO
130 CONTENUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2117
2118
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2119
                                                                     LO 4CAL TRN DRY, LOR, NLOR, SDARUN, SMTST
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2120
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              EF (CONVC .EQ. 0) THEN
```

```
132
                                          IF (DNDIF GE DIER) GO TO 190
ELSE IF (CONVC EQ. 1) THEN
DO 150 J = 1, NO
                                                                                                                                                                                                                                                                                               2227
2228
2229
2230
                                                                                                                                                                                                                                                                                                                                        RETURN
 2123
                                   DO 190 # = 1, NO
DO 190 K = 1, NCP1
IF (ABSINDING)X)/DINTUX() - 1) GE DERN GO TO 190
140 CONTRIUE
150 CONTRIUE
ELSE IF (CONNC EQ. 2) THEN
 2124
2125
2126
2127
2128
                                                                                                                                                                                                                                                                                               2231
                                                                                                                                                                                                                                                                                                                                          * the subrouting computes temperature in each cell
                                                                                                                                                                                                                                                                                               2232
                                                                                                                                                                                                                                                                                               2233
2234
2235
2235
2236
                                                                                                                                                                                                                                                                                                                                       SUBROUTINE TEMPER
                                             DO 180 J = 1, NO
 2129
                                 TINT = 0.0
DO 160 K = 1, NCP1
TINT = TENT + NDBK(J.K)
160 CONTRUE
DO 170 K = 1, NCP1
IF (ABSI(NDBK/J.K) - DENT(J.K)/YIENT) GE DEER)
170 CONTRUE
180 CONTRUE
END IF
CONTRUE
END IF
RETUREN
                                                                                                                                                                                                                                                                                                                                       PARAMETER (NANO=14.NFO=64.NCL=151)
PARAMETER (RK=7.5606/TF.16.PK=4.526/E-14)
PARAMETER (RK=7.5606/TF.16.PK=2.06/E-14)
PARAMETER (TC=EVE/BK.CK=4.3144.PF-1.141593.40=9K:1HK=TCF))
2130
2131
2132
2133
2134
                                                                                                                                                                                                                                                                                               2237
                                                                                                                                                                                                                                                                                               2239
2239
2240
2241
2241
                                                                                                                                                                                                                                                                                                                                        REAL*I NEREDINCL)
 2135
2136
2137
2138
2139
                                                                                                                                                                                                                                                                                                                                      INTEGER BRID, BLUN, LEN, MEDUSA
INTEGER NA, NO, NC, NF, NDIT, NFFC, NDICNT, NFMUST
INTEGER OFF, OFFA, PRES, RT, SETSOU, SCR, TRANSCO
INTEGER TR. TEMBOR, TET, TOTT, TEMPTD, TIT, TREN
INTEGER USC, WITH, CONV., DEXIL, DEXIL, NUM
                                                                                                                                                                                                                                                                                               2243
                                                                                                                                                                                                                                                                                               2244
2245
2246
2247
2248
 2140
 2141
                                          RETURN
2142
2143
2144
2144
2145
                                     190 CONV = 1
                                                                                                                                                                                                                                                                                                                                       COMMON /IU INSIA, IRUN, LIN, MEDUSIA
COMMON /IU INA, NO, NC, NF, NDIT, NFFC, NDICNT, NEMUST
COMMON /IU OIT, OITA, PRES, RT, SETSOU, SCR, TRNACC
COMMON /IU ITS, TEMESO, TIST, TOT, TEMESTO, TIT, TRIN
COMMON /IT/ USIC, WFN, CONV. DEXIL, PEXU, NUM
                                          RETURN
END
                                                                                                                                                                                                                                                                                               2249
                                                                                                                                                                                                                                                                                               2230
2231
2232
2146
2147
2148
2149
2150
                                            * this subrouting solves the diffusion equation using SI **
                                                                                                                                                                                                                                                                                               2253
                                                                                                                                                                                                                                                                                               2254
                                                                                                                                                                                                                                                                                               2255
2254
2257
                                                                                                                                                                                                                                                                                                                                        REAL*8 ABC(NFO,NCL), AB(NCL), AO(NFO,NCL)
REAL*8 BETAINCL), BOINFO,NCL)
REAL*8 DETI(NCL), DTIME, DEPR
REAL*8 ETAINCL)
                                          SUBROUTINE DEFFSI
 2151
 2152
                                          PARAMETER (NANG=24 NFO=64 NCL=151)
                                                                                                                                                                                                                                                                                               225
                                                                                                                                                                                                                                                                                               2259
2260
2261
2262
                                                                                                                                                                                                                                                                                                                                        REAL OF INTERNATION INTERNATION ITSELEPTION CLASSES
 2153
2154
                                        INTEGER ABVI., AUTACI., CONVC, COUNT, CONT, TCONT, DB, DCOUNT INTEGER DRT, DIPBC, DIPACC, IT, TITA
INTEGER RNSB, BUN, LIN, MEDUSA
INTEGER NA, BO, NC, NP, DOTT, NPFC, NDECNT, NFMUST
INTEGER OT, OTTA, PRES, RT, SETSOU, SCR, TRINACC
INTEGER OT, TITA, PRES, RT, SETSOU, SCR, TRINACC
INTEGER NE, TEMESER, TIT, TOTT, TEMPTD, TIT, TURN
INTEGER NCB, WPN, CONV, DBXL, DBXU, NUM
INTEGER NCPI, NCMI, NAD2
                                                                                                                                                                                                                                                                                                                                        REAL TO MATERIAL DI WITCHING TO THE EMBADICAL DE REAL TO MATERIAL DE MATERIAL DE PRINCE PRINCE PRITIME REAL TO TIME, TOU, TERR, TELB
 2153
2156
2157
2158
2159
2160
                                                                                                                                                                                                                                                                                               2263
                                                                                                                                                                                                                                                                                               1264
2263
1264
1266
1267
                                                                                                                                                                                                                                                                                                                                        COMMON /B02/ ARC. AR. AO
                                                                                                                                                                                                                                                                                                                                        CORMON /ROY / ABC, AB, AO
COMMON /ROY BETA, BO
COMMON /ROY BETA, BO
COMMON /ROY DETA, DTDME, DEPR.
COMMON /ROY BTA
COMMON /ROY BTA
COMMON /ROY PARA, DRIRK, TITEL, BERED, BERR
COMMON /ROY NATE, NENT
COMMON /ROY NATE, NENT
 2161
2162
2163
2164
2164
2165
                                          INTEGER SMISTI, SMIST2, SMIST3, SMIST4, SMIST3
                                                                                                                                                                                                                                                                                               2244
                                                                                                                                                                                                                                                                                               2264
                                        COMMON /II / ABYL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT COMMON /IJ / DRT, DUPBC, DEPACC, IIT, TITA COMMON /IJ / DRSD, RUN, LEN, MEDUSA COMMON /IJ / DRSD, RUN, LEN, MEDUSA COMMON /IJ / DRSD, RUN, LEN, MEDUSA COMMON /IJ / DRT, OTTA, PRES, RT, SETSOU, SCR, TRNACC COMMON /IJ / DRSD, TIT, TOT, TEMPO, TIT, TRIN COMMON /IJ / DRSD, PROM, DSSD, DSSD, NUM COMMON /IJ / NCC, WYN, CONV, DSSD, DSSD, NUM COMMON /IJ / NCC, WYN, CONV, DSSD, DSSD, NUM COMMON /IJ / NCC, WAS AUTACL AUTST).
                                                                                                                                                                                                                                                                                                                                        COMMON /R24/ TTIME, TOU, TENR, TELB
                                                                                                                                                                                                                                                                                               2272
 2166
                                                                                                                                                                                                                                                                                                                                 DO 10 K = 1, NC
NERED(K) = (ETAGC/(EP*PMAC(IC))) * (2*PI*ABIC) * BERED(K/(I
1 DTIME*BETAGC))
NATE(IC) = ((NEREEDGC/RIC)**0.23)
10 CONTRIVE
15 (AEDULA EQ. 0) THEN
DO 20 K = 1, NC
NATE(IC) = NATE(IC) / TCF
20 CONTRIVE
15 (PRES. GE. 1. AND. TOIT. OE. DBJG. AND. TOIT LE. DBJCU)
1 THEN
1
2167
2168
2169
2170
                                                                                                                                                                                                                                                                                               2273
                                                                                                                                                                                                                                                                                               2274
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 2171
2172
2173
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2175
                                           COMMON /SMT/ SMTST1, SMTST2, SMTST3, SMTST4, SMTST3
                                                                                                                                                                                                                                                                                               2275
                                         REAL® ALFA(NCL), AC, ATMASS, DAF(NFG)NCL), ATEM(NCL)
REAL® ABC(NFG)NCL), ABCNCL), ACOPFG)NCL)
REAL® BETA(NCL), BO(NFG)NCL)
REAL® CV(NCL), CW. CHS(NFG)NCL)
REAL® DL(NCL), DNT(NFG)NCL+1), PRNTM
REAL® DET(NCL), DTME, DSPR
                                                                                                                                                                                                                                                                                               2280
2281
2282
2283
2176
2177
2178
2179
                                                                                                                                                                                                                                                                                                                                                       THEON
                                                                                                                                                                                                                                                                                                                                             WALTE (6,30) TIDAR, TOIT, TUT, TIT
                                                                                                                                                                                                                                                                                               2284
2285
2286
2287
                                                                                                                                                                                                                                                                                                                                             FORMAT (IX, hump int, 1PE10.3, 3X, host tist tert, 3(1X15))
WILTE (6,40) (DETTIC),NATE(IC),IX-1,NC)
FORMAT (3(1PE10.3,1X,1PE10.3,1X))
 2180
                                          REAL® ETA(NCL)
2181
                                           REAL SITER ITEROFONCE)
                                          REAL 19 NEFT (NANOLYGLNCL), NDBNNFGNCL + 1), NZDNNFGNCL)
REAL 18 ZLP(NANO), ZDNTNFGNCL), ZQNFGNCL), DER
                                                                                                                                                                                                                                                                                               2280
                                                                                                                                                                                                                                                                                               2289
                                                                                                                                                                                                                                                                                                                                         END #
 2183
                                                                                                                                                                                                                                                                                               2290
2291
2292
                                                                                                                                                                                                                                                                                                                                        END F
RETURN
END
 2184
2185
2186
2187
                                          COMMON /ROL/ ALFA, AC. ATMASS, DAF, ATEM
                                          COMMON /R02/ ABC, AB, AO
COMMON /R02/ ABC, AB, AO
COMMON /R03/ BETA, BO
COMMON /R03/ CV, CW, CHI
COMMON /R03/ DL, DINT, PRINTM
                                                                                                                                                                                                                                                                                               2293
                                                                                                                                                                                                                                                                                               2294
2295
2296
2296
2297
 21 60
                                                                                                                                                                                                                                                                                                                                             determine of temperature as converged
 2189
                                         COMMON /ROS/ DIL DINT, PRINTM
COMMON /ROS/ DIST, DITME, DEPR.
COMMON /ROS/ DITME, TIME,
COMMON /RIS/ MPTI, NDIN, NZIN
                                                                                                                                                                                                                                                                                               2290
2299
2300
2301
2302
                                                                                                                                                                                                                                                                                                                                        SURBOUTING TEMCON
 2192
 2193
                                                                                                                                                                                                                                                                                                                                        PARAMETER (NANO-2434/0-443NCL-151)
2194
2195
2196
2197
                                                                                                                                                                                                                                                                                                                                        DYFEREN ABYL, AUTACL, CONVC, COUNT, CONT, TOORT, DB, DCOUNT
                                          DO 20 K = 1, NC
AB(IC) = 0.0
DO 10 J = 1, NG
                                                                                                                                                                                                                                                                                               2303
2304
2305
2306
2307
                                                                                                                                                                                                                                                                                                                                        INTEGER NA, NO, NC, NP, NDIT, NPPC, NDICNY, NPMURT
INTEGER TB, TEMEXP, TRY, TOIT, TEMPTD, TIT, TRIN
 2190
                                               ABOQ = ABOQ + ABCUJQ * (AOUJQ PEDNUJK + 1) + BOUJQ)*
2199
2200
2201
2202
                                                                                                                                                                                                                                                                                                                                        COMMON /II/ ABYL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCYUNT
COMMON /IV NA, NO, NC, NF, NOIT, NFPC, NDICNT, NFMURT
COMMON /IV/ TB, TEMEZO, THT, TOTT, TEMETO, TIT, TRIN
                                     I NORVIJO)
10 CONTRAUS
20 CONT
                                                                                                                                                                                                                                                                                               2308
2309
2310
2311
2203
2204
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2207
                                                                                                                                                                                                                                                                                                                                       REAL'S ALFAONCI, AC, ATMARK, DAFOFGINCI, ATEMONCI.)
REAL'S DISTONCI, DTORE, DIFFE
REAL'S NATEONCI, NANTONANGINFOINCI.)
REAL'S ITIME, TOU, TERR, TELB
                                     1 ITEM WRITE (8.7% iddf WRITE (8.3%) (6.48%),K=1.NC)
30 PORMAT (13, 4(13,512 | 3.18%), (13, 512 | 3.18%))
                                                                                                                                                                                                                                                                                                2312
                                                                                                                                                                                                                                                                                               2313
2314
2315
2316
                                         END F
                                                                                                                                                                                                                                                                                                                                        COMMON /ROL/ ALFA, AC, ATMARR, DAF, ATEM
COMMON /ROL/ DEST, DTEME, DRFR
COMMON /RLS/ NATE, NENT
COMMON /RLS/ TTEME, TOU, TERR, TELB
                                         DO 30 K = 1, NC
DO 40 J = 1, NO
ITERUJO = DUGO * CHRUJO * ETAGO * ABGO / 4
2209
2210
                                                                                                                                                                                                                                                                                               2317
2318
2319
2211
 2212
                                      40 CONTINUE
                                   40 CONTRAUE
50 CONTRAUE
57 (DEFACE BQ. 1 AND, BT . GE. 2) THEN
DO TOK = 1, NC
DO 60 = 1, NC
DAFULO = (AOCLIC)**NDBNUK + 1) + BOULC)**NDBNUK)/(
AOCLIC)**DRTUK + 1) + BOULC)**NDBNUK)/(
60 CONTRAUE
70 CONTRAUE
DOBB (6 - 1, NC)**
2213
2214
2215
                                                                                                                                                                                                                                                                                                                                        LOCICAL TEN, DEFF, LOR, NLOR, SEARUN, SMITT COMMON /LI/TEN, DEFF, LOR, NLOR, SEARUN, SMITT
                                                                                                                                                                                                                                                                                               2320
                                                                                                                                                                                                                                                                                               2321
2323
2324
 2216
                                                                                                                                                                                                                                                                                                                                          00 TO 30
                                                                                                                                                                                                                                                                                               2325
                                                                                                                                                                                                                                                                                                                                        END F
 2219
                                                                                                                                                                                                                                                                                                                                        DO 90 K = 1, NC
DO 80 J = 1, NG
ITERUJO = (TERUJO) * DAFUJO
CONTINUE
 2221
2223
                                                                                                                                                                                                                                                                                                2328
                                                                                                                                                                                                                                                                                                2329
                                                                                                                                                                                                                                                                                               2330
                                                                                                                                                                                                                                                                                                                                           1940 #
2224
                                                                                                                                                                                                                                                                                               2331
2332
                                                                                                                                                                                                                                                                                                                                     10 CONTENUE
CONT = 0
 2225
                                     90 CONTINUE
                                          END IF
                                                                                                                                                                                                                                                                                             132
```

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133
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2440
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2453
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  EF (I LT. 20) GO TO 10
WRITE (6, Trequired pre
         2333
2334
2335
                                                                                DO 20 K = 1, NC
                                                                                         DO 20 K = 1, NC
B' (ABBINATERCYATEMIC) - 1) GT 001) THEN
GU TO 30
END B'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           STOP
40 RES = Z(LI)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                RETURN
END
         2337
                                                                        20 CONTINUE
         2339
2340
2341
2342
                                                                                  DIDME - 3 . DIDME
                                                                               PADD
                                                                        30 DO 40 K = 1, NC
ATEM(K) = NATE(K)
40 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          this subrouture enverte the tradingoral matrix by LU
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     * decomposition
         2343
2344
                                                                               RETURN
        2345
2346
2347
2348
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                1'ARAMETER (NANO=24 NFO=64 NCL=151)
                                                              C**** f) function is used for computing plancking absorption C**** and initial intensity (which is secured to be plancking)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      24/34
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    EGOICAL TEN, DEFF, LOR, NLOR, SEMRUN, SMTST
COMMON /LI/ TRN, DEFF, LOR, NLOR, SEMRUN, SMTST
         2349
         2110
                                                                           PUNCTION PPLNKOO
        2351
2352
2353
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               BYTEGER DRT, DEFEC, DEFACC, IIT, TITA
INTEGER NA, NO, NC, NF, NDIT, NFFC, NDICNT, NFMUST
RYTEGER OIT, OITA, PRES, RT, SETSOU, SCR, TRNACC
NYTEGER TB, TEMEDY, TET, TOIT, TEMPTD, TIT, TRN
RYTZ-TR USC, WPN, CONV. DEXIL, DEXU, NUM
RYTEGER NG, NCM, NDIST, SMISTA, SMISTA, SMISTS
                                                                           REAL S X FPLNK
                                                                           INTRINSIC EXP
         2354
         2155
      2356
2357
2358
                                                                           IF (ABSOX) LT. I E-06) THEN
                                                                           FPLNK = X * X
ELSE
FPLNK = (X**3) / (EXP(X) - 1.0)
      2359
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             COMBION (IZ) DRT, DBFBC, DBFACC, BT, TITA
COMBION (AV NA, NG, NC, NP, NDIT, NFFC, NDICHT, NFMUST
COMBION (IZ) OTT, OTTA, PREB, RT, SETSOU, SCR, TRNACC
COMBION (IZ) OTT, OTTA, PREB, RT, SETSOU, SCR, TRNACC
COMBION (IZ) TR, TEMEDO, TITT, TOTT, TEMETID, TIT, TRIN
COMBION (IZ) (IZ)
COMBION (IZ) NCPI, NCMI, NAD2
COMBION (IZ)
COMBINE 
                                                                           END #
    2361
2362
2363
2364
2364
2365
                                                                           RETURN
                                                           C**** (2 and (3 functions are used for computing resuland at C**** (on conficient
    2366
2367
2364
2369
                                                                        FUNCTION F2(X)
REAL*0 X, F2
RYTHENRIC EXP
(*ABB(X) LT. 1.E-0) THEN
F2 = X * X * EDP(X)
ELLE
ELLE
F1 = ((X**4)*EXP(X))/((EXP(X) - 1.0)**2)
END #
RETTION
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                COMMON /RMT/ A. B. C. R.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               REAL® DLONCL), DENTONYO,NCL + 1), PRINTM
COMMON /ROS/ DL, DENT, PRINTM
   2370
2371
2373
2373
2374
2375
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             REAL*8 A(NCL + 1), B(NCL + 1), C(NCL + 1), R(NCL + 1)
REAL*8 SO(LUNCL + 1), BPRB
REAL*8 O(A(NCL + 1), DENCAL* 1), OC(NCL + 1)
REAL*8 O(A(NCL + 1)
REAL*8 O(A(NCL + 1), BRIGNCL + 1)
REAL*8 NO(A(NCL + 1), BRIGNCL + 1)
REAL*8 NO(A(NCL + 1), BRIGNCL + 1)
                                                                          RETURN
   2376
2377
2378
2379
                                                                           END
                                                         c
                                                                        FUNCTION F3(X)
REAL® X, F3
INTRINSIC DEOP
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               COMMON /R22/ SOLUL SPRIN
   2380
                                                                      INTRINGIC DESCP
IP (ABS(X) .LT. 1.8-6) THEN
F3 = X ** 4 * EXP(2.*X)
   2381
 2382
2383
2384
2385
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             IF (PRES. GE. 6 AND, TOIT GE. DBXL AND, TOIT LE DBXU)
                                                                        F3 = ((X**7)*EXP(2.*X))/((EXP(X) - 1.0)**3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     RND IF
RETURN
 2104
2387
2388
2389
                                                        c
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      1PE11.4)
                                                                        FUNCTION PSIO(X)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               END I
 2390
2391
2392
2393
                                                                        REAL T X FRIO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             DO 20 K = 1. N
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  OA(IC) = A(IC)
OC(IC) = C(IC)
OB(IC) = B(IC)
OB(IC) = R(IC)
 23P4
2393
                                                                        DF (ABBOD) LT. 1.E-06) THEN
2396
2397
2398
2399
                                                                        ELSE
PSIO = (1 - EXP(-X)) / X ** 3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     20 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           F (RS(), BC, 0.0) THEN

WRITE (R, "7SOLVE SOLU(2) BY ELEMENATION, LEAVING N-1 EQUATION"

PAUME

PAUME

BND F
                                                                        END #
                                                                        RETURN
 2400
2401
                                                                        END
 2402
2403
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2508
2509
2510
2511
2511
2512
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             BET = B(1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   BET = B(1) S(1) FET DO 30 K = 2, N QAM(C) = C(K - 1) / BET BET = B(C) - A(C) * GAM(C) S(U,K) + 1) S(U,K) - A(C) 
                                                                                    following subroutine computes the integral of a given flav-
 2404
2405
 2406
2407
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2409
2410
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2513
2514
2515
2516
2516
2517
                                                                        SUBROUTINE ROMB(P, D, E, RES)
                                                                      REAL SD, DEL, DEP
REAL SER
REAL SR, F
REAL SR, E
REAL SR, Z(20,20)
2411
2412
2413
2414
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          (0 CONTRUES

DO 30 K = 1, N

DF (K :BQ. 1) THEN

NR(Q) = 0 B(Q) * 30 LLU(K) + 0 C((Q) * 30 LLU(K + 1)

ELER EF (G :BQ. N) THEN

NR(Q) = 0 A((Q) * 30 LLU(K - 1) + 0 B(Q) * 30 LLU(K)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2518
2519
2520
2521
 2415
2416
2417
                                                                        EXTERNAL P
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2522
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      223
                                                                      # (D.BQ. 6) THEN
D=1.05-06
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       NBUBO = OABO * SOLU(K - 1) + OB(BO * SOLU(BO + OC(K) * SOLU(
 2418
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          1 K+1)
 2419
 2420
2421
                                                                        END #
ERR = 1.05-04 * ((D/E)**4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  DO F
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2524
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2527
2528
2529
2539
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ELSE

ERROR = -999.9999

ELSE

ERROR = 1 - OROR / NROR
                                                                        I=I
DEL=E-D
 2422
2423
                                                              178L = 8 · D

Z(1,1) = 0.5 ° DBL ° (F(D) + F(B))

10 J = 2 ° (1 · 1)

DBL = DBL / 2

1 = 1 + 1

Z(1,1) = 0.5 ° Z(1 · 1,1)
2424
2425
2426
2427
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2531
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  END #
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   END #

50 CONTINUE

DO 60 K = 1, N

# (ABS(ERRAC)) .GT. 0.01) GO TO 70

60 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2532
2533
2534
 2425
2429
2430
2431
2431
2432
                                                                      DO 30 K = 1, J
X = D + ((2.4K) - 1) * DEL
Z(L1) = Z(L1) + DEL * F(O)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2535
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                RETURN
70 IF (NPR. EQ. 0) THEN
WINTE (6.7) sols is ill behaved for group, J. TOTT, ET, TIT
WINTE (6.90) (X.AQ), BQQ, C(Q), BQQ, X=1,N)
90 FORMAT (1X, Z1, 1X, "+1, IPE10.3, 1X, "+1, IPE10.3, 1X, "+1, IPE10.3, 1X, "+1, IPE10.3, IX, "+1, IPE10.3, IX, "+1, IPE10.3, IX, "+1, IPE10.3, IX, "sols,", IPE10.3, IX, "s
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2534
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          RETURN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2537
2538
                                                                20 CONTINUE
2433
2434
2435
                                                                     DO 30 K = 2, I
Z(JK) = (4.00(K - 1)"Z(JK - 1) - Z(J - 1,K - 1))/(4.00(K -
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2539
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2541
                                                                1 1)+1.)
30 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2542
2543
2544
133
 2437
                                                                      DEFF = ABS(Z(LD - Z(LI - 1))
                                                                        IF (DEFF LT. ESUR) GO TO 40
```

```
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  2545
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2547
                                       SMTST2 = SMTST2 + 1
BY (SMTST2.CT. BYTY(NO*NC)*.05)) THEN
WRITE (4.**) program terminated as LU antat2*
SMTST = .TRUE.
                                                                                                                                                                                                                                                                                          WF(7) = 0.083277
WF(E) = 0.062672
WF(9) = 0.040601
WF(10) = 0.017614
    2548
  2549
2549
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2554
                                        FOAT) DP
                                                                                                                                                                                                                                                                                          23.241) = 0.07412
                                                                                                                                                                                                                                                                                         ZLP(1) = 0.074327
ZLP(2) = 0.227784
ZLP(3) = 0.373704
ZLP(4) = 0.510867
ZLP(5) = 0.634054
ZLP(6) = 0.744332
                                    END IF
WRITE (6, "Yunter 1 if above message to be ren
READ (5,") NPR
END IF
RETURN
                                     END
                                                                                                                                                                                                                                                                                        ZLP(1) = 0.744332
ZLP(1) = 0.839117
ZLP(8) = 0.912234
ZLP(9) = 0.943972
ZLP(10) = 0.993129
ELSE BY (NA. ISQ. 34) THESN
WP(1) = 0.127938
  2555
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2558
2559
                                                                                                                                                                                                                                                      2661
                                                                                                                                                                                                                                                     2643
2643
2644
2445
2646
                                     * following subroutine provides zeroes and weight functions *
* of Lagandre Polynomial
                                                                                                                                                                                                                                                     2647
2668
2669
2670
  2361
                                    SUBMOUTING LPL
                                                                                                                                                                                                                                                                                          WF(2) = 0.125837
                                                                                                                                                                                                                                                                                         WP(2) = 0.123837
WP(3) = 0.121670
WP(4) = 0.115306
WP(5) = 0.107464
WP(6) = 0.097619
WP(7) = 0.086190
WP(7) = 0.073346
WP(10) = 0.04237
WP(11) = 0.022331
WP(12) = 0.012341
  2362
2363
2364
2363
                                    PARAMETER (NANG-24,NFO-64,NCL-151)
                                    INTEGER NA, NG, NC, NF, NDIT, NFFC, NDICNT, NFMUIT
INTEGER NCP1, NCM1, NAD2
COMMON /BF NCP1, NCM1, NAD2
                                                                                                                                                                                                                                                      2471
2672
 2566
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                                                                                                                                                                                                                                                     2673
2674
2675
2676
                                    REAL® S(NFG,NCL), SUM1, SUM2, GRFQ(NCL), GRZQ(NCL)
                                    REAL WEINAND
                                                                                                                                                                                                                                                     2676
2678
2678
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2681
                                                                                                                                                                                                                                                                                        ZIP(1) = 0.01234;
ZIP(1) = 0.044037
ZIP(2) = 0.191119
ZIP(3) = 0.313043
ZIP(4) = 0.433794
ZIP(5) = 0.543421
  2571
2572
2573
                                    REAL® ZLP(NANO), ZINT(NFG,NCL), ZQ(NFG,NCL), DER
                                    COMMON /44 NA, NG, NC, NF, NDIT, NFFC, NDICNT, NFMUST
  2574
                                    COMMON /R23/ S, SUM1, SUM2, GRFQ, ORZQ
COMMON /R23/ WF
COMMON /R23/ ZLP, ZNT, ZQ, DIER
  2575
                                                                                                                                                                                                                                                                                        71.P(6) = 0.543909

71.P(7) = 0.740124

71.P(9) = 0.886416

71.P(10) = 0.938273

71.P(11) = 0.974729
  2576
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2578
                                                                                                                                                                                                                                                     2683
2683
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2683
2686
                                   EF (NA .EQ. 2) THEN
WF(1) = 1.000000
  2579
  2580
2581
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2583
2583
2584
                                    ZLP(1) = 0.577393
ELSE IF (NA .EQ. 4) THEN
WF(1) = 0.652142
WF(2) = 0.347858
                                                                                                                                                                                                                                                     2687
2488
2489
2690
2691
2492
                                                                                                                                                                                                                                                                                         ZLP(12) = 0.995187
                                                                                                                                                                                                                                                                                    WRITE (4,10)

10 PORMAT (1X, THA CAN NOT BE EQUAL TO ODD # OR 14,18 OR 22, CHANGE
1 THE VALUE FOR NA)
                                    WF(2) = 0.347658
ZLP(1) = 0.339981
ZLP(2) = 0.861136
ELSE IF (NA. BQ. 6) THEN
WF(1) = 0.467914
WF(2) = 0.360762
WF(3) = 0.171325
  2585
 2585
2587
2588
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2589
                                                                                                                                                                                                                                                                                        570P
                                                                                                                                                                                                                                                     2693
2694
2693
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2700
2701
                                                                                                                                                                                                                                                                                    DO 20 [= 1, NAD2
WF(NA + 1 - 0) = WF(0)
ZLP(NA + 1 - 0) = -ZLP(0)
20 CONTRIUE
 2591
2592
2593
2594
                                      21.P(1) = 0.238619
                                    ZI_P(2) = 0.661209
ZI_P(3) = 0.932470
ELSE IF (NA . EQ. 8) THEN
WF(1) = 0.362484
                                                                                                                                                                                                                                                                                       SUM1 = 0.0
                                                                                                                                                                                                                                                                                   SUMI = 0.0
DO 30 I = 1, NAD2
SUMI = SUMI + SUP(I) * WF(I)
30 CONTENUE
  2595
                                      WF(2) = 0.313707
WF(3) = 0.222381
WF(4) = 0.101229
  2596
                                                                                                                                                                                                                                                     2702
                                                                                                                                                                                                                                                                                   30 CUNTENUE
DO 40 I = NAD2 + I, NA
SUM2 = SUM2 + ZLP(I) * WF(I)
40 CONTINUE
RETURN
 2597
2598
2598
2599
                                                                                                                                                                                                                                                    2703
2704
2705
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2711
                                      ZLP(1) = 0.183435
ZLP(2) = 0.525532
                                    ZLP(3) = 0.796667
ZLP(4) = 0.960290
ELSE IF (NA BQ. 10) THEN
2601
2602
2603
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                                                                                                                                                                                                                                                                                       END

    this subrestime runs this code for the model problem for 
    cases.

                                    WF(1) = 0.295524

WF(2) = 0.269267

WF(3) = 0.219086

WF(4) = 0.149451

WF(5) = 0.066671

ZZP(1) = 0.148874
                                                                                                                                                                                                                                                    2712
2713
2714
2715
2716
                                                                                                                                                                                                                                                                                       SUBROUTINE RUNTST(TT)
                                 ZLP(1) = 0.148674

ZLP(2) = 0.433395

ZLP(3) = 0.679410

ZLP(4) = 0.85903

ZLP(5) = 0.973907

ELSE IF (NA. EQ. 12) THEN

WF(1) = 0.249147

WF(2) = 0.233493

WF(3) = 0.203167

WF(4) = 0.160078

WF(5) = 0.160078

WF(5) = 0.07175
                                                                                                                                                                                                                                                                                       PARAMETER (NANO=243/PO=643/CL=151)
                                                                                                                                                                                                                                                     2717
                                                                                                                                                                                                                                                                                      INTEGER ABYL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT
INTEGER DRT, DEPG, DEPACC, ET, TITA
INTEGER DRT, BUN, LIN, MEDURA
INTEGER DIT, OTTA, PERB, RT, INTEGU, BCR, TRIVACC
                                                                                                                                                                                                                                                     2721
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2730
                                                                                                                                                                                                                                                                                       COMMON /II/ ABVIL AUTACL CONVC, COUNT, CONT, TOONT, DB, DCOUNT
                                                                                                                                                                                                                                                                                       COMMON MY DRY, DEFEC, DEFACE, ET, TITA
COMMON MY PASE, BUUN, LIN, MEDURA
COMMON MY PASE, SUUN, LIN, MEDURA
COMMON MY OTT, OTTA, PRES, RT, SETSOU, SCR, TENACC
                                     WF(6) = 0.047175
ZLP(1) = 0.125233
ZLP(2) = 0.367832
                                                                                                                                                                                                                                                                                       LOGICAL TRIN, DIEF, LOR, NLOR, SEARUN, SHITST
COMMON /LI/TEIN, DIEF, LOR, NLOR, SEARUN, SHITST
                                     ZLP(3) = 0.587318
                                  ZLP(4) = 0.769903
ZLP(5) = 0.904117
ZLP(6) = 0.901561
ELEE F (NA.BQ. 16) THEN
                                                                                                                                                                                                                                                    2731
2732
2733
                                                                                                                                                                                                                                                                                       INTEGER NORTH, IT
                                                                                                                                                                                                                                                                                      REAL® THER(16)
REAL® MAXT
REAL® TIME, TOU, TERR, TELB
REAL® DETONCL), DTME, DEPR
                                                                                                                                                                                                                                                    2734
2735
2736
2737
2625
                                     WF(1) = 0.189451
                                     WP(2) = 0.182403
WP(3) = 0.149157
WP(4) = 0.149396
WP(5) = 0.124629
2639
2630
2631
2632
2633
2634
2635
2636
2637
                                                                                                                                                                                                                                                                                      COMMON /RI4/ MAXT
COMMON /RI4/ TIME, TOU, TERR, TELB
COMMON /RI0/ DEST, DTEME, DEPR
                                    WF(6) = 0.095159
WF(7) = 0.062254
WF(8) = 0.027152
ZLP(1) = 0.095013
                                                                                                                                                                                                                                                    2739
                                                                                                                                                                                                                                                    2740
2741
2742
2743
                                                                                                                                                                                                                                                                                     E" (IT .BQ. 0) THEN
NDB(1) = 2
NDB(2) = 5
NDB(3) = 10
NDB(4) = 20
NDB(5) = 50
NDB(6) = 100
NDB(7) = 500
NDB(8) = 1000
                                    ZLP(2) = 0.281604
ZLP(3) = 0.458017
ZLP(4) = 0.617876
ZLP(5) = 0.755404
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2641
2642
2643
2644
2645
2646
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2649
                                                                                                                                                                                                                                                    2745
2746
2747
                                     ZLP(6) = 0.865631
                                  ZIP(7) = 0.944575
ZIP(8) = 0.969401
ELSE IF (NA .EQ. 20) THEN
WP(1) = 0.152753
                                                                                                                                                                                                                                                    2748
2749
2750
2751
                                                                                                                                                                                                                                                                                        NDB(8) = 1000
TMES(1) = 1.00E-12
TMES(2) = 2.00E-12
TMES(3) = 5.00E-12
TMES(4) = 1.00E-11
TMES(5) = 2.00E-11
                                     WF(2) = 0.149173
                                                                                                                                                                                                                                                    2752
                                    WF(3) = 0.142096
WF(4) = 0.131689
WF(5) = 0.118193
WF(6) = 0.101930
                                                                                                                                                                                                                                                    2753
                                                                                                                                                                                                                                                    2755
2756
```

```
TM(E2(8) = 2 006-10
TM(E2(9) = 3 006-10
TM(E2(10) = 1 006-09
TM(E2(11) = 2 006-09
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                2845.1
2864.2
2864.2
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         REAL® AAO(NCL), ANCL + 1)

REAL® BAO(NCL), BONCL + 1)

REAL® BOONCL), BONCL + 1)

REAL® CINCL + 1)

REAL® FUNANCL), FUNONCL), FUNDONCL), FUNENCL)

REAL® GONTINCL + 1), GREIONCL + 1)

REAL® GONTINCL + 1), GREIONCL + 1)

REAL® ROBONCL + 1), GREIONCL + 1)

REAL® NORMONCL + 1), DENONFONCL + 1), NZIN(NFONCL)

REAL® NORMONCL + 1), DENONFONCL + 1), NZIN(NFONCL)

REAL® NORMONCL + 1)

REAL® NORMONCL + 1)

REAL® NORMONCL + 1)

REAL® ROBONCL + 1)
                 2759
                                                                                       TMEX(1) = 2.00E-09
TMEX(1) = 1.00E-08
TMEX(1) = 1.00E-08
TMEX(1) = 5.00E-08
TMEX(1) = 5.00E-08
                2761
2762
2763
                2764
2763
                2766
              2768
2768
2769
2770
2770
                                                                                    PNDF
                                                                                  END OF
WRITE (B. Yhm & R.Y., TRN, DB, IT + )
OF ( NOT TRN) THEN
IT = IT + 1
ITIME = TIMERIT)
TIME = OTIMER
TRN = TRUE.
              2772
            2773
2774
2775
                                                                                       DR = NDB(1)

IF (TTIME OR, MAXT) THEN

WILLE (6,7) unifying in comple
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              REAL® ZETANFONCL)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           COMMON /IMT/ J, N
COMMON /RMT/ A, B, C, R
            2776
            2777
                                                                                          STOP
            2778
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       REAL® ALFA(NCL), AC, ATMASS, DAF(NFO,NCL), ATEM(NCL)
REAL® ASCONGINCL), ABINCL), AO(NFO,NCL)
REAL® BETA(NCL), BOONFO,NCL)
REAL® DEO(NCL), CW, CRENFO,NCL)
REAL® DLONCL), CW, CRENFO,NCL
REAL® TRANCL)
REAL® TRANCL)
REAL® FROWO + 1), PQOPO,NCL)
REAL® FROWO + 1), PQOPO,NCL)
REAL® TRANCHONCL + 1), FNAUDPO), FNROPO
REAL® TRANCHONCL + 1), FNAUDPO), FNROPO
REAL® TRANCHONCL + 1), PROMICL + 1), PLANKOPO,NCL), IZIN(NFO,NCL)
REAL® PORNOCL + 1), PFGONCL + 1), PLANKOPO,NCL), REAL® ROMNOCL + 1), PROMICL + 1), PROMICL PROMINGUNCL)
REAL® ROMNOCL + 1), PROMICL + 1), PLANKOPO,NCL), REAL® PORNOCL + 1), PROMICL PROMIPO,NCL)
           2779
2780
2781
                                                                                RETURN
END IF
END IF
                                                                       10 IF (.NOT. DOTF) THEN
TRNACC = 1
DOFACC = 0
IF (DB. OT. 500) THEN
           2782
           2783
2784
2785
2786
2787
                                                                                          K = 0
DOFF = .TRUE.
                                                                                       D0FACC = 2
D6 = NDB(1)
LIN = 0
OO TO 10
         2788
2789
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2791
2792
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2797
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       Real** Podnoki, + 1), Pfornci, + 1), Plank(nfonci)
Real** Podnoronci, + 1), Pitenfonci, Pzdnofonci,
Real** Paroci,
Real** Signoronci, Orskoci, + 1)
Real** Signoronci, Orskoci, + 1)
Real** Signoronci, Signoronci,
Real** Signoronci, Signoronci,
Real** Signoronci, Signoronci,
Real** Signoronci, Signoronci, Signoronci,
Real** Signoronci, Signoronci, Signoronci, Orzonci,
Real** Tiber, Tou, Terr, Telb
Real** Ziponano, Zdnoronci, Zonoronci, Der
                                                                                        K = K + 1
                                                                             DB = NDB(R)
RETURN
END #F
ELAE B* (.NOT. LOR) THEN
        2798
2799
2800
2801
2802
                                                                                  IF (DB .OT. 500) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         COMMON /ROL/ ALFA, AC, ATMASS, DAF, ATEM
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       COMMON /RO! / ALPA, AC, ATMAS
COMMON /RO! / ABC, AB, AO
COMMON /RO! / BETA, BO
COMMON /RO! CV, CW, CHE
COMMON /RO! / DRIT, PRINTM
COMMON /RO! / BTA
                                                                                     K = 0
LOR = TRUE
DB = NDB(1)
                                                                                       LIN-I
        2803
2804
2805
2806
2807
                                                                                       00 TO 10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       COMMON /RUF! / FINT, FINE, FINE,
COMMON /RUF! / FINT, FINE, FINE
COMMON /RUF! / FITE, ENT, IZIN
COMMON /RUF! / ITER, ITER
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   2910
                                                                                  FILER.
                                                                                    K = K + 1
DB = NDB(K)
AETURN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  2911
2912
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2917
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   COMMON /R13/ ITRB, ITRB, COMMON /R13/ ITRB, ITRB, COMMON /R13/ PGIN, IPON, PZIN COMMON /R13/ PGIN, IPON, PTIZ, PZIN COMMON /R13/ PGIN PGIN, IPON, PTIZ, PZIN COMMON /R21/ SGIM, GRSI COMMON /R21/ SGIM, SUMI, SUMI, GRPQ, GRZQ COMMON /R23/ S, SUMI, SUMI, GRPQ, GRZQ COMMON /R23/ S, SUMI, SUMI, CRPQ, GRZQ COMMON /R23/ ZSINT COMMON /R23/ ZSINT COMMON /R23/ ZSINT, ZQ, DESK
         2808
2809
                                                                                  END IF
WRITE (IL "Value div. DEFF. D6
      2810
2811
2812
                                                                            ELSE IF ( NOT, NLOR) THEN
IF (DB .GT. 500) THEN
                                                                                       K = 0
NLOR = .TRUE.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  2918
2919
        2813
                                                                                NLOR = TRUI
DB = NDB(I)
GO TO 10
ELSE
K = K + I
DB = NDB(K)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                2920
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        2814
      2815
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        2818
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2926
2927
                                                                                    RETURN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      DO 20 K = 1, NOP1
                                                                        REJORY
BAD BY
BLUE
WRITE (8,79m Hill by salay dv, TRN, DUFF, LOR, NLOR, SEMRUN,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ORNTOX) = 0.0
DO 10 J = 1, NO
        2821
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            DO 40 K = 1, NO

ORNTIC) = ORNTIC) + NDRNOJO

10 CONTRNUE

20 CONTRNUE

DO 40 K = 1, NO

AAO(10 = 10
                                                                     WRITE (R. "Pirm of
DB
TEN = FALSE
DBF = FALSE
LOR = FALSE
NLOR = FALSE
DB = NDB(1)
OO TO 10
END F
END
      2822
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                2925
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    2823
2834
2825
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BBO(IQ = 0.0
DO 30 J = 1, NG
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    2827
   2828
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2951
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AAOQO = AAOQO = AOQUO = NDENQUE + 1)
BBOQO = BBOQO = BOQUO = NDENQUE
AAOQO = AAOQO = ORTICE + 1)
BBOQO = BBOQO = ORTICE + 1)
BBOQO = BBOQO = ORTICE = 1
BF (PRES .GE 3 AND. TOIT .GE .DBXC .AND. TOIT .LE .DBXU)
   2831
2832
   2833
2834
2835
                                                                             * this asbroutine solves the grey equation
                                                                                                                                                                                                                                                                                                                ٠
   2834
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         WRITE (IL "Year blo"
   2837
 2838
2839
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2844
2845
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            WRITE (8.90) (X.AAO(Q.BBO(X),K=1,NC)
50 PORMAT (1X 2(Y.IZ,1X2(1PE10.3,1X)))
END #
                                                                       SUBROUTINE ORDE
                                                                        PARAMETER (NANO-24,NFO-64,NCL=151)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   DO 70 K = 1, NCM1
                                                                       PARAMETER (PD-1.141593)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            GRACK = 0.0
DO 60 J = 1, NG
GRACK = GRACK + S(J.K)
60 CONTENUE
                                                                       LOGICAL TEN. DEFF, LOR, NLOR, SEMEUN, SMITST
COMMON /LI/ TEN, DEFF, LOR, NLOR, SEMEUN, SMITST
                                                                  INTEGER ABVI., AUTACI., CONVC, COUNT, CONT, TCONT, DB, DCOUNT INTEGER DRIT, DIFFEC, DIFFACC, ST, TITA
INTEGER RRIB, SUN, LEN, MEDIZAR
INTEGER NA, NO, NC, NC, PROTT, NPFC, NDICNIT, NPAUSIT
INTEGER OTT, OTTA, PREE, RT, SETSOU, SCR, TRNACC
INTEGER TE, TEMEDY, TET, TOIT, TEMETID, TIT, TURN
INTEGER INC, WIPN, CONV, DEXIL, DEXIU, NUM
INTEGER INC, WIPN, CONV, DEXIL, DEXIU, NUM
INTEGER INC. WIPN, CONV, DEXIL, DEXIU, NUM
INTEGER INC. WIPN, CONV, DEXIL, DEXIU, NUM
INTEGER INC. WIPN, CONV.)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             2952
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 2544
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              70 CONTINUE
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 DO 90 K = 1, NO
DO 90 K = 1, NO
ZETAJJO) = (1 + ALFAJO-ABC(JO-ETAJO) * TOU * DLJO
FUNÇUJO = AOCIJO * NOBN(JK + 1) * BOUJO * NOBN(JK)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        2956
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135
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90 CONTINUE
F (PRES. GE. 4 AND. TOIT. GE. DEXIL AND. TOIT LE. DEXIL)
1 THEN
 2851
2852
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2854
                                                                     COMMON /II/ ABVIL, AUTACIL CONVC, COUNT, CONT, TCONT, DB, DCOUNT
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       WRITE (R. ")=
 2855
                                                                   COMBINENTI/ AUTACL. CONVC; COUNT; CONT; CONT; CONT; CONT; CONT; CONT, CO
 2856
2857
2857
2858
2859
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         WRITE (K.* /W WRITE (K.* /W WRITE (K.* /W K.* I. NCMI)

100 FORMAT (IX. 40*, Z.IX. IPEIO.3))

WRITE (R.* // with first
WRITE (R.* // with first
WRITE (R.* I/ 0) (JULZETAGJIC, FUNGJIC, K.* I. NC), J= 1.NO)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       110 FORMAT (1X, 20, Z.1X Y.Z.2(1PE10.3,1X)))
END F
DO 130 K = 1, NC
 2040
 2061
2062
```

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136
3075
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        2969
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2972
                                                                                                         Funhin = 0 0
Do 120 I = 1, NG
Funhin = Funhin + Abruja * (Aaoks*orntk + 1) + Bboks*
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               R(K) = SUM1 * PORNICI + PPORKO + DIAK) * GRZQKK) 2 - DIAK) * GRZQKG + 2 * GRSRKC / 3
BLASE B* (DOPBC JSQ 1) THEN
                                                                                                                   ONTHO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      3078
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        R(K) = 0.0
DO 310 J = 1, NO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      DO 310 ** 1, NO

R(K) ** R(K) ** SUM1 ** PDIN(J.K) ** FNT(J.K) ** 2 * (SINT(
J.K * 1) ** SNT(J.K)) * (J*SK)M(J.K) ** TOR(J.K)

/* ** PQ(J.K) ** D(J.K) ** SIGM(J.K) ** TOR(J.K)

CONTINUE

ELSE IF (DIPBC BQ 2) THEN

R(O ** ETA(K) ** D(J.K) ** PUNH(K) / 4 ** SI.

END IF

ELSE IF (K EQ. NCP1) THEN

IF (DIPBC EQ. 0) THEN

R(O ** SUM2 ** PODN(G) ** PYNH(K) ** D(J.K ** 1) ** GRZQ(K ** 1)

/* ** D(J.K ** 1) ** GRZQ(K ** 1) ** 2 ** CRSR(K ** 1) / 3

R(S) ** SUM2 ** PODN(G) ** PYNH(J.K) ** CRSR(K ** 1) / 3

R(S) ** SUM2 ** PODN(G) ** PNH(J.K) ** SIR K)

R(O ** OD DO 320 J** = 1, NO

R(K) ** R(G) ** SUM2 ** PDDN(JJ.K) ** FNH(JJ.K) ** 2 ** (SINH(J.K) ** J** ** SINH(J.K) ** J** SINH(
    2973
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                                                                                   120 CONTINUE

SIL = PODN(1) * SUM1 + DL(1) * GRZQ(1)/2 - DL(1) * GRFQ(1) + 2 *

IGRSM(1)/3 + PFGM(1)

SR = PODN(NCP)) * SUM2 - DL(NC) * GRZQ(NC)/2 - DL(NC) * GRFQ(NC)

1 + 2 * GRSM(NC)/3 + PFGM(NCP1)

Fr (LIN.EQ. 0) THEN

C***** Qualition

DO 150 K = 1, NC

DN DM(20, 0, 0)
                                                                                 DO 150 K = 1, NC
DUMP(IC) = 0.0
DO 140 J = 1, NO
DUMP(IC) = DUMP(IC) + CHI(J,C) / (ABC(J,C) + TOU)

140 CONTINUE
150 CONTINUE
DO 170 K = 1, NC
DO 160 J = 1, NO
THETA(J,C) = CHI(J,C) / ((ABC(J,C) + TOU)*DUMP(IC))
PHI(J,C) = THETA(J,C)

160 CONTINUE
170 CONTINUE
DO 190 K = 1, NC
    2984
2983
2986
2987
2989
2990
2991
2992
2993
2996
2996
2999
3000
3001
3002
3003
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               DO 330 3 = 1, NO
RIGG = RIGG - SURG * PDBN(J.K) - PRIT(J.K) - 2 * (SINT(J.K) - 1) * (SINT(J.K) - 1) * (SINT(J.K) - 1) * (SINT(J.K) - 1) * (SIGN(J.K - 1)) * (SIGN(J.K) * (SIGN(J.K) - 1) * (SIGN(J.K) - 1) * (SIGN(J.K) * (SIGN(J.K) - 1) * (SIGN(J.K) - 1
                                                                                                  70 CONTINUE
DD 190 K = 1, NC
FUNAIG) = 0.0
SUMZIG) = 0.0
DD 190 J = 1, NG
FUNAIG) = FUNAIG) + PHEIJG / SIGMIJG)
SUMZIGO = SUMZIGO + ZETAIJG) * THETAIJG)
DO CONTINUE
DD 210 K = 1, NG
SDDDIGO = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3101
3102
3103
3104
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   R(K) = OR5(K - 1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               END BY
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3105
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3106
3107
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              END IF
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             (PRES. GE. 3 AND. TOIT GE. DBXL AND. TOIT LE DBXL)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  THEN
DO 350 K = 1, NO
                                                                                                             SDD100 = 0.0
                                                                                                           DO 200 J = 1, NG
DO 200 J = 1, NG
SDOR(O = SDDR(O + (NDRK(J.K + 1) - NDRK(J.K)) / SIGM(J.K)
PUNCO(O = FUNCO(O + ZETA(J.K) * FUNR(I.K)
CONTRUE
    3004
3005
3006
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3008
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           SUMTHOO = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         SUMPH(K) = 0.0
DO 340 J = 1, NO
SUMTH(K) = SUMTH(K) + THETA(J,K)
SUMTH(K) = SUMPH(K) + PH((J,K)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3111
3112
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3113
                                                                               FUNCION = FUNCION - 2-221A(X) * FUNCION - 2-
    3009
3010
3011
3012
3013
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3115
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               340 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3116
3117
3118
3119
3120
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           350 CONTINUE
WAITE (B. Yahanf
WAITE (B. Yahanf
WAITE (B. S40) (K.DUMP(K),K.F.I.N.C)
$40 PORMAT (A(I,X.Y.L.I,X.) [PEI 0.3))
WAITE (B. Yahata jahr
WAITE (B.
      3014
    3015
3016
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3018
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3121
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3122
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      3019
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    3021
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3023
      3024
                                                                                                             END IF
ESSE IF (K. BQ. NCP1) THEN
IF (DIFFIC. EQ. 0) THEN
LIG1 = SUNAC * PERING) - PFORK) - SDDI(K - 1)/3 + FUND
(K. 1)/3 - FORSIGC. 1)/3 + DL(K - 1) * GRZQ(K - 1)
/2 + DL(K - 1) * GRFQ(K - 1) - FUNCOK - 1)/4 + FUNE(K
    3025
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3028
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                3131
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3140
3141
3142
3143
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          1 IPE(0.3)
END #
DO 450 K = 1, NCP1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              DO 430 K. P.I., NCFI

#F (K. BQ. 1) THEN

#F (DEPBC. BQ. 0) THEN

A(Q. = 0.0

B(Q. = RUMI + FUNA(K)/3 + SUNZ/K) * BBO(K)/4

C(Q. = FUNA(K)/3 + SUNZ/K) * AAO(K)/4

ELSE #F (DEPBC. BQ. 1) THEN
      1029
                                                                                                               /2 + DL(K - 1) * GRPQ(K - 1) - FUNCOK - 1) / 4 + FUNE(K - 1) / 4
ELSE IF (DEFBC .EQ. 1) THEN
R(G) = SUN2 * (GRPT(K) - POPN(K)) - PFOR(K) - SUDP(K - 1)
/ 3 + FUND(K - 1) / 3 - POL(K - 1)
GRZQ(K - 1) / 2 + DL(K - 1) * GRPQ(K - 1) - FUNCOK - 1) /
4 + FUNE(K - 1) / 4
ELSE IF (DEFBC .EQ. 2) THEN
R(G) = ETA(K - 1) * DL(K - 1) * FUNH(K - 1) / 4 + SR
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3031
3032
3033
    3034
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               AOC = 0.0
BOC = 0.0
COC = 0.0
DO 410 J = 1, NO
    3036
    3037
  3038
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3041
3042
                                                                                                                   3144
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   DO 4103 **1, NO
BO() = B(0, 6 B(0, 4 
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                3145
3146
3147
3148
                                                                                                               ELLAB

R(IC) = (SDDB(IC) - SDDB(IC - 1)) / 3 - (FUND(IC) - FUND(IC - 1))

//3 - (FUND(IC) - FUND(IC - 1)) / 4 + (FUNE(IC) + FUNE(IC - 1))

//4 + CRES(IC - 1)
3043
3044
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3046
3047
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3049
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3051
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3149
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      CUNTENUE
B(0) = B(0) + $UM1
ELSE IF (DB*BC .BQ. 2) THEN
A(0) = 0.0
B(0) = 0.0
C(0) = 0.0
                                                                               220 CONTENUE
ELSE
Cooss use the nonlin
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                3150
3151
3152
3153
                                                                                                                                                                                                our grey model for accelerating the differ
                                                                                                  DO 240 K = 1, NC
DO 240 J = 1, NO
FUNDOJO = NDRNOJK + 1) - NDRNOJK)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3154
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                3155
3156
3157
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               DO 420 J = 1, NO
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | BOQ = BOQ + (BIOM(J)Q*BO(J)()4 + 1/(3*BIOM(J)())) *
| NDBN(J)Q
| CQQ = CQQ + (BIOM(J)Q*AO(J)()4 + 1/(3*BIOM(J)())) *
                                                                                 230 CONTINUE
  3052
                                                                                   240 CONTINUES
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                3158
3053
3054
3055
                                                                                                  DO 2401 = 1, NO
DO 250 K = 1, NC
THETAUJQ = FUNE(UJQ) / (AAO(K)*GENT(K + 1) + BBO(K)*GENT(
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  3159
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        NDBNUK+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                3160
3161
3162
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           BOQ = BOQ / OBYTOQ + SUM1
COQ = COQ / OBYTOK + 1)
3056
3057
3058
3059
3060
3061
3062
3063
3064
3065
3066
3067
3068
3069
                                                                               PHUJIC) = FUNO(CIC) / (CENTO(C+1) - CENTO(C)
250 CONTINUE
260 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                3163
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      DOF
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                END IF
ELSE IF OL BQ, NCP1) THEN
IF (DIFFIC EQ, 9) THEN
AG() = FUNAQ(L-1)/3 + SUNEQ(L-1) * BBO(K-1)/4
EG() = FUNAQ(L-1)/3 + SUNEQ(L-1) * AAG(L-1)/4 - SUNEQ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             3164
3163
3166
3166
                                                                                                  DO 280 K = 1, NC
                                                                             DO 280 K * 1, NC
SUMZ(0) = 0.0
DO 270 J = 1, NO
SUMZ(0) = SUMZ(0) + ZETA(J,C) * THETA(J,C)
270 CONTINUE
280 CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             3168
3169
3170
3171
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               COC = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ELSE F (DEBC BQ. 1) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           ELSE # (OPRIC BQ. 1) THEN
AGC =0.0
BGC =0.0
DG 430 J = 1, NG
AGC = AGC + (SIGMUJK - 1)*BOUJK - 1)4 - 1/13*BIGMUJK
K - 1))) * NORMUJK) / ORTGO
BGC = BGC + BGGG # K - 1)*AOUJK - 1)4 + 1/13*BIGMUJK
K - 1))) * NORMUJK) / ORTGO
CONTINUE / CONTINUE / CONTINUE / 1)4 + 1/13*BIGMUJK
K - 1))) * NORMUJK) / ORTGO
                                                                                                  DO 300 K = 1, NC
FUNA(K) = 0.0
DO 290 J = 1, NG
FUNA(K) = FUNA(K) + PHS(J,K) / SIGN(J,K)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             3172
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             3173
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             3174
3175
  3070
                                                                                                                   CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             3176
                                                                               300 CONTINUE
DO 330 K = 1, NCP1
IF (K.EQ. 1) THEN
IF (DIFFIC .EQ. 0) THEN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             3177
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               430
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           3178
3179
3180
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           BOX) = BOX) - SUM2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      COC) = 0.0
ELSE IF (DIFFIC EQ. 2) THEN
  3073
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       134
```

```
WRITE (99,10) TOIT, THT, TIT, OIT, BT

10 FORMAT (1X, "TOT" | B, 1X, "TIT", B, 1X, "TIT", IA, 1X,

1 "OIT", IA, 1X, "TIT", IB)

WRITE (99,20) (BETICK), ANTEK(, K=1, NC)

20 FORMAT (2(1X, IPE10,3))

C" CALL GETTIMETR, INGN, ISEC, 1100SEC)

CRINTM = FITME - STIME

WRITE (99,40) TRINACC, DPIACC, LIN, DITME

40 FORMAT (1X, "THEOS", IZ, 1X, "deface", IZ, 1X, "firs", IZ, 1X,

1 "demen", IPE11,4)

WRITE (99,30) RUNTM / 100

WRITE (8,50) RUNTM / 100

VICTOR (1X, "THEOS", IZ, 12, "sec")
                                                                                                                                                                                                                                                                                                                                                           3287
3288
3289
             3181
                                                                      ARC) = 0 0
B(K) = 0 0
            3183
3184
3184
3185
                                                                      BBA1=00

DO 440 |= 1, NO

A(K) = A(K) - (BIOMEJK - 1)*BO(JK - 1)/4 - 1/(3*BIGMEJ,

K - 1)(3)* *PODA(JK - 1)

B(K) = B(K) - (SIOMEJK - 1)*AO(JK - 1)/4 + 1/(3*BIGMEJ,
                                                                                                                                                                                                                                                                                                                                                           3290
3291
3292
3293
3294
            1167
                                                                          K - I))) * NDBN(J,K)
CONTINUE
          3188
3189
3190
3191
                                                   440
                                                               . CUM LINUS
AG() = AG() / OBYT(K - 1)
BG() = BG() / OBYT(G) + SUM2
C(K) = 0 0
END IF
                                                                                                                                                                                                                                                                                                                                                          3295
3296
3297
3298
3299
3300
3301
3302
3303
3304
3303
           3192
           1191
                                                            PLSE
                                                                                                                                                                                                                                                                                                                                                                                                   WHITE (0.90) RUNTM / 100
S PORMAT (1X, 'matime =', F12.2, 'ser')
IF (RUNTM / 100, OT, 1000.0) THEN
WRITE (99,60) RUNTM / 6000.0
60 FORMAT (1X, 'matime =', F12.2, 'min')
ELSE IF (RUNTM / 100, OT, 10000.0) THEN
WRITE (99,70) RUNTM / 36000.0
70 FORMAT (1X, 'matime =', F12.2, 'hr')
FRID IF
                                                              72.55.
AIC) = -FUNACK - 1) / 3 + SUNZCK - 1) * BBOCK - 1) / 4
BIC) = (FUNACK - 1) + FUNACK) / 3 + (SUNZCK - 1) *AAO(K - 1) +
SUNZCK - 10 AAO(K) / 3 + SUNZCK + AAO(K) / 4
CRC) = -FUNACK) / 3 + SUNZCK + AAO(K) / 4
           3194
          3195
          3190
                                                            END F
                                                  450 CONTINUE
          1199
       3200
3201
3202
3203
3204
                                                       PECONTINOS
PE (PRES DE 4 AND. TOTT. GB. DBXL, AND TOTT LE. DBXU)
1 THEN
P(LD. 20, 0) THEN
WRITE (R. 7) s b c m lin grey
                                                                                                                                                                                                                                                                                                                                                          3306
3307
3308
3309
3310
                                                                                                                                                                                                                                                                                                                                                                                                         END F
        1205
1206
1207
                                                                                                                                                                                                                                                                                                                                                         3311
3312
3313
3314

    this subroutine reads the tables and evaluates all the "variables needed for the simulation of this code with MEDGUA" this naturation is equivalent of eubroutien model, this A"
    over rides say predefined variables, which are redesthe here.

                                                               WRITE (B,")'s b c r in nonlin grey'
                                                 EMD IF

WILITE (IL,440) (IC,AIC),B(IC),C(IC),B(IC),K=1,N)

460 FORMAT (IX, Yr, IZ, IX, IPE10.3, IX, IPE10.3, IX, IPE10.3, IX,
        3200
        3209
                                                                        1PE10.3)
                                                                                                                                                                                                                                                                                                                                                          3315
       3210
3211
3211
3212
3213
3214
                                                       END I
                                                                                                                                                                                                                                                                                                                                                        3316
3317
3318
3318
                                                     N=NCPI
CALLLU3
DO 470 K=1, NCPI
NOBNIO=SOLUIO
                                                                                                                                                                                                                                                                                                                                                                                                         SUBROUTINE TABLES
                                                                                                                                                                                                                                                                                                                                                                                                        PARAMETER (NANO=24.NFO=64.NCL=151)
PARAMETER (RK=1.5066TE-16.FK=6.261E-34)
PARAMETER (RK=1.3078-21.3F=).000EV9=1.6021E-19)
PARAMETER (TCP=EVE/BK,P=3.141593,A0=PK/(BK*TCP))
                                                                                                                                                                                                                                                                                                                                                          3320
       3215
3216
3217
                                                                                                                                                                                                                                                                                                                                                         3323
3323
3324
3325
                                                 470 CONTINUE
                                                      IF (PRES. OE. 3 .AND. TOIT .CE. DEXIL .AND. TOIT .LE. DEXIL)
                                                                                                                                                                                                                                                                                                                                                                                                     ENTEGER ABYL, AUTACL, CONVC, COUNT, CONT, TOONT, DB, DCOUNT BYTBGER DRT, DEPSC, DEFACC, BT, TITA
RYTEGER RNB, BLUN, LEN, MEDUBA
BYTEGER RN, NO, NC, NP, NDTI, NPFC, NDICNT, NFMUST
INTEGER OT, OTTA, PRER, BT, SETSOU, SCR, TRNACC
RYTEGER TB, TEMESOP, TBT, TOTT, TEMPTO, TIT, TRIN
RYTEGER LIBC, WPN, CONV, DBXL, DBXU, NUM
BYTEGER NCP, INCHI, NAD2
BYTEGER NCP, INCHI, NAD2
                                               3218
        3219
        1220
                                                                                                                                                                                                                                                                                                                                                          1126
                                                     END IF
IF (PRES. GE. 5. AND. TOIT GE. DBXL AND. TOIT LE. DBXU)
        1721
                                                                                                                                                                                                                                                                                                                                                         1127
                                                                                                                                                                                                                                                                                                                                                        3328
3329
3330
3331
       3222
3223
                                                   I THEN
WRITE (R.490) ((K.J.THETAUJC)*(AAO(K)*NORN(K + 1) + BBO(K)*ORNT(K),FUNF(
I NORN(K),THETAUJC)*(AAO(K)*ORNT(K + 1) + BBO(K)*ORNT(K),FUNF(
      3224
3223
                                                                                                                                                                                                                                                                                                                                                        3332
3333
3334
3335
3336
                                                                                                                                                                                                                                                                                                                                                                                                        INTEGER SMISTI, SMISTS, SMISTS, SMISTA, SMISTS
      1226
                                                    2 JIO JEL NO KOL NO
                                               4 3.8.1=1,740,1X=1,740,1
490 PORMAT (2(1X\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}{2}\),1\(\frac{1}\),2\(\frac{1}\),2\(\frac{1}{2}\),1\(\fr
     3227
3228
3229
3230
                                                                                                                                                                                                                                                                                                                                                                                                        INTEGER MOT. NITT
                                                         ABOX) = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                    COMMON /IJ / ABVI., AUTACI., CONVC, COUNT, CONT, TCONT, DB, DCOUNT COMMON /IJ / DRT, DDFBC, DBYACC, BT, TITA COMMON /IJ / DRT, DDFBC, DBYACC, BT, TITA COMMON /IV PABB, BUUN, LIN, MEDURA COMMON /IV NA, NO, NC, NC, NEDT, NOFC, NDICNT, NEMUST COMMON /IV OTF, OTFA, PABS, RT, SETSOU, SCR, TRINACC COMMON /IV OTF, OTFA, PABS, RT, SETSOU, SCR, TRINACC COMMON /IV TB, TBMBCOY, TRIT, TOTT, TRAPPID, TIT, TRIN COMMON /IT / UBC, WPN, CONV, DBJGL, DBJGL, NUM COMMON /IV UBC, WPN, CONV, DBJGL, DBJGL, NUM COMMON /IV NCPI, NCMI, NADZ SCROBNON /IV NCPI, NCMI, NADZ SCROBNON /IV SMITTS, SMITTS, SMITTS, SMITTS, SMITTS, SMITTS, COMMON /IMPO MEDT, NITT, RTEON
                                                       ARKI, TUV
DO 300 J = 1, NO
AB(G) = AB(G) + ABCJJK) * (THETA(JJK)*(AAO(K)*NGRYK + 1) +
BBO(G)*NGRYK(K) + FUNR(JJG) - THETA(JJK)*(AAO(K)*ORNT(K + 1) +
BBO(G)*GRYT(G)))
     3231
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                                                                                                                                                                                                                                                                                                                                                        3337
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                                                                                                                                                                                                                                                                                                                                                        3340
3341
                                              500 CONTINUE
     1216
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1219
                                                                                                                                                                                                                                                                                                                                                       3342
3343
3344
3345
                                            STO CONTINUE
IF (PRES OB. 3 AND, TOIT OR, DBXL AND, TOIT LE, DBXU)
                                            WRITE (R. "Yab groy"
WRITE (R. 320) (K.AB(K),K=1,NC)
520 FORMAT (4(1X,Y,IZ,1X,1PE10.3))
    3240
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                                                                                                                                                                                                                                                                                                                                                     3346
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                                                 REAL-M ALFAONCI, AC, ATMARE, DAF(NYO,NCI.), ATEM(NCI.)
REAL-M ABC(NYO,NCI.), AB(NCI.), AO(NYO,NCI.)
REAL-M BETA(NCI.), BOONYO,NCI.)
REAL-M C(NOCI.), CW. CHONYO,NCI.)
REAL-M C(NOCI.), CW. CHONYO,NCI.)
REAL-M C(NOCI.), CW. CHONYO,NCI.)
   3246
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3250
                                                                                                                                                                                                                                                                                                                                                     3352
3353
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3354
                                             530 CONTENUE
                                                                                                                                                                                                                                                                                                                                                                                                   REAL® DICÍNCIA, DEPROPOJNCI. + 1), PRINTM
REAL® DESTINACI.), DITME, DEPR
REAL® ETANICI.)
REAL® FRITOWONICI. + 1), FRILOWO, FRIROWO
REAL® HELM
REAL® HELM
REAL® ROBOMO, NEBOWO, ITEL, EREDINCI.), ERR
REAL® ROBOMO, ITEL, EREDINCI.)
                                             340 CONTINUE
RETURN
END
                                                                                                                                                                                                                                                                                                                                                    3356
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3361
3363
3364
3366
3367
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3369
  3231
3232
3233
3234

    prints time of simulation on a pe with microsoft compiler
    8UT "C" community must be removed before time can be obtain

                                                                                                                                                                                                                                                                                                                                                                                                REAL*# ITER, ITEROPOINCL)

REAL*# IL LPL, LOWIDM

REAL*# NATE(NCL), NENTOWNONFOINCL)

REAL*# NATE(NCL), NENTOWNONFOINCL)

REAL*# PRETOWNONFOINCL, NDENOPOINCL** 1), NZIN(NFOINCL)

REAL*# PRETOWNOCH** 1), FPTOWNOC** 1), PLANK(NFOINCL)

REAL*# PRENOPOINCL** 1), PTTOWNOC** 1), PZEN(NFOINCL)

REAL*# PRENOPOINCL** 1), PTTOWNOC** 1), PZEN(NFOINCL)

REAL*# PRENOPOINCL** 1), REAL*# 2 GOMMONOLNCL, ORSINCL** 1)

REAL*# 2 GOMMONOLNCL**, ORSINCL** 1)

REAL*# 2 SOMMONOLNCL**, SIMI, SUM2, ORPO(NCL), ORZQ(NCL)

REAL*# 3 SOMMONOLNCL** 1)

REAL*# 3 SOMMONOLNCL** 1)
   1255
  3236
3237
3238
3238
3239
                                                   SUBROUTINE CPUTM
                                                   PARAMETER (NANO-24 NPO-64 NCL-151)
 3260
3261
3262
                                                 INTEGER ABYL, AUTACL, CONVC, COUNT, CONT, TCONT, DB, DCOUNT
INTEGER DRT, DEPIC, DEFACC, BT, TITA
INTEGER RIBB, BUNI, LIN, MEDURA
INTEGER NA, NO, NC, NF, NDIT, NPPC, NDICNT, NPMUST
  3263
                                                                                                                                                                                                                                                                                                                                                     3370
3371
3372
                                                 INTEGER OIT, OTTA, PRES, RT, SETEOU, SCR. TRNACC
INTEGER TB, TEMEOP, THT, TOIT, TEMPTO, TIT, TRIN
 3263
3266
3267
                                                 COMMON /TL/ ABVE, AUTACE, CONVC, COUNT, CONT, TCONT, DB, DCOUNT
                                                                                                                                                                                                                                                                                                                                                     3373
                                               COMMON 72/ DRT, DEPIC, DEFACE, ST, TITA
COMMON 72/ DRB, RUN, LEN, MEDURA
COMMON 72/ DRB, DRB, RT, SETMOU, SCR. TRNACC
COMMON 72/ TR, TEMEDIP, TET, TOIT, TEMPTD, TIT, TRIN
 1265
                                                                                                                                                                                                                                                                                                                                                   3374
3375
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3382
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                                                                                                                                                                                                                                                                                                                                                                                                   REAL'S TIME, TOU, TERR, TELB
REAL'S TRINFVENCL), TEMP(NCL)
REAL'S UPL
                                                                                                                                                                                                                                                                                                                                                                                                  REAL® WF(NANO)
REAL® ZLP(NANO), ZP/T(NFG,NCL), ZQ(NFG,NCL), DIER
 3273
 3274
3273
                                                 REAL® NATEONCL), NEVTONANO, NPO, NCL)
                                               REAL'S DIST(NCL), DITME, DEPR.
REAL'S TIME, TOU, TEAR, TELB
                                                                                                                                                                                                                                                                                                                                                                                                  COMMON /R01/ ALFA, AC, ATMARR, DAF, ATEM
COMMON /R02/ ABC, AB, AO
COMMON /R03/ BETA, BO
 3276
 3277
                                                                                                                                                                                                                                                                                                                                                    3383
                                                                                                                                                                                                                                                                                                                                                  3384
3385
3386
3387
3388
                                                                                                                                                                                                                                                                                                                                                                                                  COMMON /ROA/ CV, CW, CHE
COMMON /ROA/ DL, DENT, PENTIM
COMMON /ROA/ DEST, DTEME, DEPR
COMMON /ROA/ ETA
 3278
                                                 COMMON /ROS/ DEST, DYBMS, DEPR
3279
3280
                                                 COMMON /R.I.S/ NATE, NENT
COMMON /R.SA/ TTEME, TOU, TERR, TELB
 3281
3282
                                                 LOGICAL TRN, DIFF, LOB, NLOB, SEMIUN, SMITT
COMMON /LI/TEN, DIFF, LOB, NLOB, SEMIUN, SMITT
RRAL-18 STEME, FITME, RUNTM
COMMON /THEV STEME, FITME, RUNTM
                                                                                                                                                                                                                                                                                                                                                                                                   COMMON /ROTI/ FINT, FINE, FINE
                                                                                                                                                                                                                                                                                                                                                                                                   COMMON /ROW FR. FQ
COMMON /ROW HELDA
COMMON /RIO/ INLB, INRB, ITSE, IERED, ERR
COMMON /RIO/ INTB, ENT, IZIN
 3283
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37

3393	COMMON /R12/ TTRB, ITER	3499 3 NOLOW, NORMAX, NTMAX
3394	COMMON /R13/ L, LFL, LOWLIM	3500 C
3395 3396	COMMON /R14/ MAXT COMMON /R15/ NATE, NINT	3501 C. CO.O. AUXILIARY X-RAY TRANSPORT ARRAYS FOR USE WITH LEE'S TABLES
3397 3398	COMMON (R.14) NEFT, NDIN, NZIN COMMON (R.17) PMAC, PINT, PRITIME	3503 C 3504 REAL*S NEB
3399	COMMON /RIS/ POIN, PFOL PLANK	3505 COMMON /LEEDING/ RADTL, RADTR, PPL1, PPR1, DT2R, PRDLL1(64),
3400 3401	COMMON /R181/ PDIN, PITE, PZIN COMMON /R182/ PAB	3506 1 PRDLR1(64), PRADLL(64), PRADLR(64), RADLL(64), RADLR(64), 3507 2 TEIB(151), NEB(151), REDOES
3402	COMMON /R19/ Q	3500 C
3403 3404	COMMON /R20/ SPH, SIRC, SPR COMMON /R21/ SIGN, GRSI	3509 CL C3.2 MESH AND NUMERICAL METHODS 3510 C VERSION 1A 1/8/73 JPC CULHAM
3405	COMMON /IL22/ SOLU, SPRB	3511 COMBMON /COMBIUM/ AR, AL BE, BL, CE, CE, DE, DE, F, F, GE, GE, Q2,
3406 3407	COMMON /R23/ S, SUM1, SUM2, GR/PQ, GR/ZQ COMMON /R231/ SINT	3912 1 Q4, TETTE, TETE, UTTE, MESH, NJ, NJM1, NJP1, NL, NLM1, 3913 2 NLP1
3408	COMMON /R24/ TTIME, TOU, TERR, TELB	3514 DOMENSION AE(151), AI(151), BE(151), BI(151), CE(151), CI(151),
3409 3410	COMMON /R25/ TRNT/VR, TEMP COMMON /R26/ UFL	3919 1 DE(151), DE(151), E(151), F(151), GE(151), GE(151), G(151), 3916 2 Q2(151), Q4(151), TETE(151), TETE(151), UTE(151)
3411	COMMON /R27/ WIF	3317 C
3412 3413	COMMON /IC21/ ZLP, ZINT, ZQ, DIER	3518 CL C2.9 RADIATION REABSORPTION 3519 C VERSION JUNE 1984, D. SALZMANN
3414	INTEGER IFL. NIR	3520 COMMON /COMABB/ YDRS(151), DO(20,15)
3415	EXTERNAL FPLNK, F2, F3	3521 C 3522 CL C2.7 PHYSICS CONTROL
3416 3417	INTEGER NRN, NCODE, NCOUNT, PRNT	3523 C VERSION IA 1/8/73 IPC CULHAM
3418	COMMON /RDC/ NRN, NCODE, NCOUNT, PRNT	3524 CORDINON /CORICON/ PINEN, ILHONEN, TEMEN, TIMEN, UMEN, METEP, NCASE, 3523 I NOBOR, MILIERAM, MIBCON, MILTURE, MILICON, MILK, NILARS, NILHUMS,
3419 3420	REAL® ABB(NCL)	3526 2 NLBURN, NLCRUI, NLDEPO, NLBCON, NLFUSE, NLJCON, NLAUVE,
3421	REAL® DD, DMDN	3527 3 NEPPE, NEPPE, NEX 3528 LOGICAL MERRIMS, MERCON, MERUSE, MERCON, MEX, NEARS, NERHANS,
3422 3423	real & er, energl(npg), energr(npg) real & inibr(ncl)	3529 I NEBURN, NECREI, NEDEPO, NEBCON, NEPUSE, NEICON, NEMOVE.
3424	REAL® JUNK(NFO,NCL), JUNK2(NFO,NCL), SUMINK(NCL)	3530 2 NEPTE, NEPTE NEX 3531 C
3425 3426	REAL® PV, POVER(NFG,NCL), PLNKN(NFG,NCL) REAL® RESPLN	3532 CL C3.1 NUMERICAL CONTROL PARAMETERS
3427	REAL® SPLAN(NCL), SUMCHI(NCL)	3533 C VERISION 1A 1/8/73 JPC CULHAM 3534 COMMON /COMPIC/ AKO, AK1, AK2, AK3, AK4, AK5, BRIEUM, DELTAT, DT2,
3428 3429	REAL® TAIN REAL® XA, XBA(NFG,NCL), XAA	3335 I DT3, DT4, DTEMAX, DTMAX, DTMAX, DTMIN, DUMAX, RDT2, RDT3,
3430	REAL® ZFAC, ZFAC1, ZTMAX	3536 2 RDT4, NCBLDT, NCONDT, NIT, NTMAX, BREAK, NLGOON, NLITE 3537 LOGICAL BREAK, NLGOON, NLITE
3431 3432	REAL® NIO(151) REAL® REPH(150)	3534 C
3433	COMMON /RCV/ RSPH	3339 CL C4.1 ADMINISTRATIVE VARIABLES 3340 C VERSION IA 1/8/73 JPC CULHAM
3434 3431	IMPLICIT REAL®(A - H,O - Z) C**** beginning of medium common blocks	3541 COMMON /COMMON PIQ, TSTOP, MAXDAM, MAXRUN, NDUMP, NREP, NLDUM
3436	c	3542 1 NLEMP
3437 343 8	CL C2.1 HYDRODYNAMICS C VERSION IA 178/73 JPC CULHAM	3543 LOOKAL NLDUMP, NLEMP 3544 DIRENBON PIQ(100)
3439	COMMON /COMHYD/ DM, P3, PINI, R1, R3, R5, RHO1, RHO3, RHO5,	3545 C
3440 3441	1 RHORU, RHOR, RINI, TIME, UZ, U4, UEDOE, V1, V3, V5 DIMENSION DM(151), P3(151), R1(151), R3(151), R5(151), RHO1(151),	3546 COBBON /COMUTI/ ZWHARI (151), ZWHARZ (1
3442	1 RHOS(151), RHOS(151), U2(151), U4(151), V1(151),	3548 2 ZWMARR(151), ZWMAR9(151), ZWMA10(151), ZWMA11(151),
3443 3444	2 V3(151), V5(151) C	3549 3 ZWMAI2(151), ZWMAI3(151), ZWMAI4(151), ZWMAI3(151), 3550 4 ZWMAI6(151)
3445	CL C2.2 THERMODYNAMICS	3551 C
3446 3447	C VERSION IA 1/8/73 JPC CULHAM COMMON (COMTH) DDROES, DDROES, DDROES, DDROES, DDTES,	3553 CORGMON/SHEELL/RENEELL, QUHELL, NEMEELL, NEMEXX 3553 CORGMON/SHEELL/RENEELL/RENEELL, NEMEXIL, NEMEXX
3448	1 DOTTI, DOTTS, GAMMAE, GAMMAI, KAPPAE, KAPPAI, PEI, PEJ,	3554 DOMONOUN REPORT(11), QUARTA(11), NEW 2011(11)
3449	2 PII, PD, TEI, TEJ, TEM, TII, TD, TIM REAL® KAPPAE, KAPPAI	3555 EQUIVALENCE (PIQ(63),ZPLAII), (PIQ(63),ROPLAII), (PIQ(61),DRPLAS), 3556 I (PIQ(59),BTATIS), (PIQ(58),BAHA), (PIQ(56),PONDP),
3450 3451	DBAGENSION DDROEI (151), DDROE3 (151), DDROEI (151), DDROEI (151),	3557 2 (PIQ(57),BHOT), (PIQ(37),GAUSS), (PIQ(52),ANABS),
3452	1 DOTEI(151), DOTEI(151), DOTEI(151), DOTEI(151),	3558 3 (PIQ(22),PTHOT), (PIQ(21),PHOT), (PIQ(14),PNB), 3559 4 (PIQ(13),ZGLAS), (PIQ(12),BOGLAS), (PIQ(11),DRGLAS),
3453 3434	2 KAPPAR(151), KAPPAR(151), PEI(151), PEI(151), PII(151), 3 '45(151), TEI(151), TE3(151), TII(151), TEX(151)	3560 5 (PIQ(10), FLIMIT), (R.HORVERHOGAE), (I.ASER1(1), TON),
3455	C	156 6 (LÁBER 1(2), PHULT), (LABER 1(3), ANFULS), (LABER 1(4), 1562 7 PLENTH), (LABER 1(5), TOPP), (LABER 1(6), PMAX),
3456 3457	CL C2.3 IONS AND ELECTRONS C VERSION 1A 1/8/73 JPC CULHAM	3563 8 (PIQ(60),EDMULT), (PIQ(64),OUTAMI), (PIQ(66),DTPRNT)
3458	REAL*O LC, MIEFF, NE, NI	3564 EQUIVALENCE (PIQ(67),NELEDO) 3565 C
3459 3460	COMMON /COME/ BREMSI, BREMSI, DECEN, DECEMAX, DECEMIN, EFFZ, 1 EDICHE, LC, MEETF, NI, NE, OMEGAI, FZI, FZI, FZIQI, FZIQI,	1366 CL C1.1. BASIC SYSTEM PARAMETERS
3461	2 DDZI, DDZI, PIDASH, PMASS	3547 C VERSION 2B 14.8.73 KVRANH CULHAM 3540 C
3462 3463	DOMENSION BREMSI (151), BREMSI (151), DECIEN (151), EFFZ (151), 1 EDICHE (151), LC (151), MEEP (151), NE (151), NI (151),	3569 CL C1.1. BARIC SYSTEM PARAMETERS
3464	2 FZ1(151), FZ3(151), FZ3Q1(151), FZ3Q3(151), DDZ1(151).	3570 C VERBION 2B 14.8.73 KVR/MHH CULHAM 3571 COMMON /COMBAN ALTEME, CPTIME, NLEDGE, NLEND, NLRES, NONLIN,
3465 3466	3 DDZ3(151), PEDASH(151), OMBQAL(151) C	3572 1 NOUT, NIPRINT, NIBEAD, NIRESUM, NIFTEP, STIME, LASELI.
3467	CL C2.4 LASER VARIABLES	3573 2 LABELS, LABELS, LABELS, LABELS, LABELS, LABELS, LABELS
346 8 3469	C VERSION IA 1/8/73 JPC CULHAM C REAL® LAMDAI, LABERI, NBCRII	1574 3 NDIARY, NIN, NPUNCH, NRUN 3575 LOGICAL NUMBER, NEWES
3470	COMMON /COMLAS/ ALPHAI, ELASI, LAMDAI, LASERI, PLASI, RABSI,	3576 DESCRIPTION LABEL 1(12), LABEL 2(12), LABEL 3(13), LABEL 4(13),
3471 3472	1 ROCKII, XLI, XLI, NECRII, FRACLS, NABEI DIMENMON ALPHAI(151), LAMERI(100), XLI(151), XLI(151)	3577 1 LABELS(12), LABELS(12), LABELS(12), LABELS(12) 3570
3473	C	3579 Cooos and of medium common blocks
3474	CL C2.5 THERMONUCLEAR REACTIONS C VERSION IA 1/8/73 JPC CULHAM	3580 SF (MDT 18Q. 0) THEN 3581 C**** initialization of the variables
3475 3476	COMMON /COMPUS/ DELITER, FID, F3D, F1H, F3H, F1HE3, F3HE3, F1HE4,	3585 Coose helt je set to 3 conts give septantians tateran pe many explorities
3477 3478	1 F1H54, F1NEU, F1NEU, F1NTRL, F1NTRL, F1T, F3T, F1X, F3X, 2 HELRIS, HELRIA, HYDROO, NETRAL, NTRLMS, PNEUT1, PNEUT3,	3583 DATA NTR. M/, AN M.022E2M/, EPR, EPR1, EPR2 /1:E-9, 1:E-3, 1:E- 3584 t 1/
3479	3 RIDD, RSDD, RIDHES, RSDHES, RIDT, RSDT, RNEUTS, RNEUTS.	3585 EF (NTR. BQ. 0) THEIN
3480 3481	4 TENUCI, TOTNEU, TRITIU, XMASS, XTRA, XZ, YEI, YES, YII, 5 YEI, YELD, XTRAI, XTRAZ, XTRAS, XZI, XZZ, XZS, XMASSI,	3586 NTR = 1 3587 NC = NL
3482	6 XMAREZ, XMARES, XTRAN, XZA, XMAREN, FIXI, FIXZ, FIXS, F3XI,	3588 NCP1 = NC + 1
3483	7 F3X2, F3X3, F1X4, F3X4 REAL® NETRAL, NTRLME	3589 NCMI = NC - I 3590 NG = NGHBOH - NGLOW
3484 3485	DIMENSION FID(151), F3D(151), F1H(151), F3H(151), F1HE3(151),	3591 There = 0.5 * (10.0***DTEX#(1))
3486	1 F3HES(151), F1HE4(151), F3HE4(151), F1NEU(151),	3592 DMM = 10.0 ™ DDENM(1) 3593 1221 = 2ATOM+1.
3487 3488	3 F3T(151), F1X(151), F3X(151), F1X1(151), F1X2(151),	3594 F (TBAE BQ. 0.0) TIET!
3489	4 F1X3(151), F1X4(151), F3X1(151), F3X3(151), F3X3(151).	3595 DT28 = DT2 3596 DO 10 K = 1, NC
3490 3491	5	3597 NTB(X) = NB(X)
3492	7 YII(151), YI3(151)	3998 TEIBOX) - TEIOX) 3999 10 CONTENUE
3493	C CL C28 NON-LITE DATA FOR AVRG-ZRADIATIVE COOLING ETC	3600 REDGES = R:(NCP1)
3494	C VERSION JUNE 1966 Y.T. LEE CONGAON /LEEDINY/ HNUEDO(64), DTEMP(19), DDENS(22), ENSIGN (19,22).	3401 RADTL = 0.0 3402 RADTR = 0.0
3494 3495		3603 PFLI = 0.0
3494	1 TBLZ(19,22), TBLZSQ(19,22), POWER(19,22,64).	3404 PFR.1 = 0.0

3605	DO 20.J = 1, NO + 1	139 3711	CALL ROMBIFPLNK, DD, EE, RESPLN) PLANK(I,K) = (2*PK/SP**2) * ((BK*TE3/K/PK)**4) * RESPLN
3606 3607	PRADLA() = 0 0 PRADLA() = 0 0	3712 3713	110 CONTINUE
1608	PRINLLI(I) = 0 0	3714	END IF
3609	PRDLR1(I) = 0 0	3715	120 CONTINUE
1610	RADILITY = 0.0	3716 3717	DO 150 K = 1, NC AB(K) = 0.0
3611	RADLEU) = 0.0 20 CONTENUE	3710	DO 140 J = 1, NG
1612 3613	SAD & COMINOR	3719	ZDNT(J,K) = 0.0
3614	END F	3720	DO 1301 = 1, NA
3615	DTIME - DT2	3721	PONTICUJO = PLANKCIJO
3616	ATMARE - XMARE	3722 3723	INT(LJ.K) = PLANK(J.K) ZINT(J.K) = ZINT(J.K) + INT(LJ.K) * WF(I)
3617 3618	TOU = 1 / (8P*D7DAE) NTT = NT	3724	130 CONTINUE
3619	IF (NIT NE 1) RETURN	3725	IZINUJO = ZINTUJO
1620	Coose estrupolate tall using the slope of the provious step	3726	AB(K) = AB(K) + ABC(J,K) * ZINT(J,K)
3621	DO 30 K = 1, NC	3727	140 CONTINUE 150 CONTINUE
3622	Z.I = (TE10K) - TE180K)) * DTZ / DT28 bf (ABB(Z1) .CT. 0.5*TE30K)) Z1 = 0.0	372# 3729	IF (PRESI OR 3 AND, TOIT OR DEXT. AND, TOIT LE DEXU)
3623 3624	TE3(K) = TE1(K) + Z1	3730	1 THEN
1425	NIO(IC) = NIQC)	3731	WRITE (8,160) (K,DL(K),CV(K),ATEM(K)/11604,EERED(K),K=1,NC)
3626	ZI = (NICK) - NIBCK)) * DT2 / DT2B	3732	160 PORMAT (2(Y,12,1X'4-,1PE10.3,1X'c-,1PE10.3,1X'4mp-,
3627	P (ABS(Z1) .OT. 0.5"\100() Z1 = 0.0	3733 3734	1 1PE10.3,1X,"Ue=",1PE10.3,1X()) WRITE (R,")"See group limits in tables ', DTIME
3628 3629	MICC = NICC + ZI 30 CONTENUE	3733	WRITE (8,170) (J.FR(J),J=1,NG + 1)
3630	ZI = (RI(NCPI) - REDOEB) * DT2 / DT2B	3736	170 FORMAT (B(g/,2,1X,F11.4,1X))
3631	IF (ABS(Z1) .GT. 0.5*R1(NCP1)) Z1 = 0.0	3737	WRITE (B, ")'i j k iden in tables"
3632	REDOEB = RI(NCPI) + ZI	3738	WRITE (8,100) (((UJKJEVIT(UJK)K=1,NC),J=1,NG),J=1,NA)
3633	DO 40 K = 1, NC	3739 3740	180 PORMAT (6(*12.1X,*12.1X,*12.1X,1PE10.3,1X)) WRITE (8, *7) k zint in tables '
3634 3633	BREMBACC = 0.0 40 CONTINUE	3741	WRITE (8,190) ((J.K.ZINT(J.K),K=1,NC),J=1,NG)
3636	DO 50 J = 1, NO + 1	3742	190 PORMAT (8(12,1X,12,1X,1PE10.3,1X))
3637	PRADLL(J) = 0.0	3743	END IF
3638	PRADUJU) = 0.0	3744	DO 210 K = 1, NC
3639	50 CONTINUE	3745 3746	ABB(K) = 0.0 SPLAN(K) = 0.0
3640 3641	ZTMAX = TE3(NABSI) DO 60 K = NABSI, NC	3747	DO 200 J = 1, NG
3642	ZTMAX = DMAXI(ZTMAX,TES(K))	3748	ABB(IC) = ABB(IC) + ABC(IJC) * PLANK(IJC)
3643	60 CONTENUE	3749	SPLAN(K) = SPLAN(K) + PLANKUJK)
3644	IF (ZTMAX LE TMIN) THEN	3750	200 CONTINUE
3645	C**** skip radiation code	3751 3752	2:0 CONTINUE DO 230 K = 1, NC
3646 3647	RTEON = .FALSE. WRITE (4,70) NCOUNT, TIT, TIME	3753	SUI4CHE(K) = 0.0
1648	70 PORMAT (multition code skipped due to low tump in rts.f.,	3754	DO 220 J = 1, NO
3649	1 2(1X,14), 1X, 1PE11.4)	3755	CHILLIC) = ABC(IJC) * PLANK(IJC) / ABB(IC)
3650	OO TO 670	3756	SUMCHBOO = SUMCHBOO + CHBOUG
3651	FLSE	3757 375 8	ERLED(IC) = 4 ° FI ° SPLAN(IC) / SP 220 CONTINUE
3452 3453	RTEON = .TRUE. END IP	3759	· 230 CONTINUE
3454	DO 80 K = 1, NC	3760	IF (PRES.GE. 1) THEN
3633	ATEMOS) = TESOS)	3761	WRITE (R,240) TE3(1), DDTE3(1), DDTE3(1), RHO3(1), CV(1),
3656	Coose righ is obtained from EOS subrestim in MEDUSA	3762	1 REPH(1), DM(1), DL(1), ATMASE, V3(1)
3637	CV(IC) = RSPH(IC) * RHO3(IC) / 10.0	3763 37 64	240 FORMAT (13 dec deiro cv op den distan 121°, 10(13X,1PE10.3)) END 2F
363 8 3639	DST(K) = RI(K) DL(K) = ABB(RI(K + 1) - RI(K))	3763	IF (PRES.GE, 21) THEN
3660	SO CONTENUE	3766	WRITE (8, "Ysuenchi in tables "
3661	C**** define the frequency groups	3767	WRITE (8,250) (C,SUMCHEOC),K=1,NC)
3662	DO 90 JJ = NOLOW, NORBOH	3760	250 FORMAT (8(22,1X,1PE11.4,1X))
3663 3664	J = 1J - NOLOW + 1 FR(J) = HNUEDO(IJ)	37 69 3770	END IF DO 260 K = 1, NC
3445	90 CONTINUE	3771	BETA(IC) = 4 ° BK ° (TES(IC) **3) / CV(IC)
3666	Coose find the power and x-excitored area at given temperature	3772	PMAC(IC) = ABB(IC) / SPLAN(IC)
3467	C**** and density by interpolation. (power=W/m**2, x-erem=m**2 and	3773	ALFA(K) = 1 / (PMAC(K) TBETA(K))
3668	Cooos she cosh-1/m)	3774	TRINFVRIO = SP * DTIME / DL(IC)
3449 3470	DO 120 K = 1, NC EF (TE3(K), OE, TMEN) THEIN	3775 377 6	ETA(K)=1/(1+ALFA(K)*TOU) 260 CONTINUE
367L	DO 100 TI = NOTOM' NOTBOH	3777	SEC = 0.0
3672	1 = 11 - NGLOW + 1	3778	DO 270 K = 1, NC
3673	XAA = CIOMA(DLOG10(0.9*(HNUEDG(J) + HNUEDG(J + 1))),ZATOM)	3779	SQLC = SQLC + ETA(K)
3674	1 ATMARE/AN	3780	270 CONTINUE
3675	C**** zfiz) = 0.0 if ic3 < torin, otherwise zfiz! = 1.0	3781 3782	SBIC = SBIC / NC DO 300 J = 1, NG
3676 3677	ZPACI = DMAXI(0.0D0,DMM1(1.0D0,(TESQC) - TMM//TMM)) C**** zfic = 0.0 if le3 < tmin, otherwise affic =< 1.0	3783	DO 390 K = 1, NC
3678	ZFAC - ZFAC1 * DMEN1(1.0DQ,NICQ/DMEN)	3784	FQ(J,Q) = 0.0
3479	CALL DENTRE(DLOGIO(TES(IC)), DLOGIO(NI(IC)), SIGMA(1,1,II),	3785	DO 280 I = 1, NA
3680	l XA, FL)	3786	Q(LUIC) = CHR(LUC) * ERMED(RC) * BTA(RC) / (2*DTIME*BETA(RC)
3681	XSA(LIC) = (1.0 - ZFAC1) * XAA + ZFAC1 * 10.0 ** XA	3787 3786	1)+ TOU * INT(LJ.K) FQ(JK) = PQ(JK) + INT(LJ.K) * WF(I) * ZLP(I)
3482 3483	XIA(JJ) = 10.0 ™ XA ABC(JJ) = NB(K) * XIA(JJ)	37 89	280 CONTINUE
3684	CC ABCUJO = (RHOJOR)*ANYORA(JJO) / ATMARS	3790	SIGNA(JJC) = (ABC(JJC) + TOU) * DLOC)
3685	CALL INTERPOWER(1,1,17), PV)	3791	ZQ(JJC) = CFB(JJC) * ESRED(IC) * ETA(IC) / (DTIME*BETA(IC)) +
3686	PLANK(JJQ = ZPAC * 10.0 ** PV * NIOO * DLOO / (4*PI)	3792	1 TOU · EZNUJO
3487	CC PLANKULO = ZFAC*10.0**PV/(4*F1*XBA(JA))	3793 1794	290 CONTINUE
36 86 36 89	100 CONTINUE C**** residen	3794 3795	300 CONTENUE IF (PRES JEE, 5 LAND, TORT JOE, DEXE, JAND, TORT LE, DEXU)
3690	51.55	3796	1 THEN
3691	DO 110 II = NGLOW, NGHIGH	3797	WRITE (R.") sum of chie and aboth in tables '
3692	J = JJ - NOLOW + 1	3798	WRITE (R.310) (K,SUMCHRIK),SUMPRK(K),K*1.NC)
3493	XAA = CIGNA(DLOG10(0.5°(FR/UEDG(J) + FR/UEDG(J + 1))),ZATOM)	3799	310 FORMAT (5(12,1 X,2(1 FE11.4,1 X)))
3694	* ATMARE / AN TRACT = DMANT (0.000 DMM) (1.000 (TRAC) - TMN) (TMN))	3800 3801	WRITE (8,7)] & chi she phash in tables ' WRITE (8,320) (J.K.CHEUJK),ABCUJK),FLANKUJK),J=1,NU),K=1.
3695 3696	ZFAC1 = DMAXI (0.0D0,DM2H1(1.0D0,(TES(IX) - TMEH)/TMEH)) ZFAC = ZFAC1 * DM2H1(1.0D0,M3(IX)10.0***********************************	3801 3802	WILLE (#220) (#2402##4###############################
3497	CALL DENTRP(DLOGIO(TES(IC)), DLOGIO(PRIC), SIGMA(1,1,1,1),	3803	320 PORMAT (3(12,1X,12,1X,3(1PE10.3,1X0)))
3698	1 XA,FL)	3804	WRITE (R.") i j k q in tables '
3699	X3A(J,X) = (1.0 - 7FAC1) * XAA + 2FAC1 * 10.0 ** XA	3805	WRITE (B.330) (((LLK,QCLJK),K=1,NC),J=1,NG),J=1,NA)
3700	C XSA(JX) = XAA	3806	330 FORMAT (6(12,1 X,12,1 X,12,1 X,1 PE1 0.3,1 X))
3701	ABOULO = NBOO * XBAULO	3807 3808	PAUME END IF
3702 3703	CC ABCUJO = (RH03(IQ)*AN*/XIA(JJQ) / ATMARS DD = HNUEDQ(J) * 11604.0 / TE3(IQ)	3809	DO 350 K = 1, NC
3703 3704	EE = HNUEDG(J) * (1604.0 / TES(K)	3810	GRZQ00 = 0.0
3705	F (DD.GT. LOWLING THEN	3811	CBUPQDC) = 0.0
5706	DD = LOWLIM	3812	DO 340 J = 1, NG
3707	BAD IF	3813	ORZQOO = ORZQOO + ZQUUO
3708	EF (ESE.OT. HELD-O THEIN	3814 3815	CREPQ(IC) = CREPQ(IC) + PQ(IJIC) / SIGNATUC) 340 CONTENUE
3709 3710	RE - HELDA END F	3815 3816	350 CONTINUE

3817	DO 360 J = 1, NO
3818	DVLB() = 0.0
3819	D/RE(J) = 0.0
3820	360 CONTINUE
3821	EF (NFFC EQ. 0) THEN
3822	DO 370 K = 1, NC
3823	TRNFVR(K) = 0.5
3824	370 CONTINUE
3825 3826	TRNFV = (SP*DTDAE) / DL(1)
3827	ELSE IF (NFFC .EQ. 1) THEN DO 380 K = 1, NC
3828	TRNFVR(K) = 2.0
3829	380 CONTENUE
3830	TRNFV = (3P*DTIME) / DL(1)
3831	ELSE IF (NFFC .EQ. 2) THEN
3832	DO 390 K = 1, NC
3833	TRNFVR(IC) = (SP*DTIME) / DL(IC)
3834	390 CONTINUE
3835	END IF
3836	DO 410 K = 1, NC
3837 3838	INTERICIC) = 0.0 DO 400 J = 1, NG
3839	INIBR(K) = INIBR(K) + 4 * PI * PLANK(J,K) / DM(K)
3840	400 CONTINUE
3841	410 CONTINUE
3842	RETURN
3843	end f
3844	IF (PRES.OE. 4) THEN
3845	WRITE (8,7%) it int mint mint/lint in tubler
3846	WRITE (0.420) (((U.)K.DVT(U.)K.)XDVT(U.)K)XDVT
3847	1 LUXUHINAUHINOUKHIC - SNC)
3848	420 FORMAT (3(°,D,1X,°,D,1X,°,D,1X,3(1PE10.3.1X)))
3849 3850	END F
	Coose brams - power emitted per unit mass watts/Kg
3851 3852	DO 450 K = 1, NCP1 DO 440 J = 1, NG
3832	DO 440 J = 1, NO DENT(J,K) = 0.0
3834	DO 430 I = 1, NA
3855	DINT(J,K) = DINT(J,K) + INTB(J,J,K) + WF(I) + ZZ_P(I)
3856	430 CONTINUE
3857	440 CONTINUE
3858	450 CONTINUE
3859	DC 480 K = 1, NC
3860	BRU: M\$3(IC) = 0.0
3861	DO 470 J = 1, NG
3862	DO 460 (= 1, NA
3963	BREMISOR) = BREMISOR(K) + (24PVDM(R)) * (EVTB(LJ,K + 1) -
3864	1 INTB(LUX)) • WF(I)
3863	460 CONTINUE
3866 3867	470 CONTINUE
3868	480 CONTINUE Coose flux emitted from right and of the plants watcher?
3869	DO 510 J = 1, NG
3870	PRADLR(I) = 0.0
3871	DO 500 K = NC, NC
3872	DO 490 I = 1, NAD2
3873	PRADER(J) = PRADER(J) + (2*Pf) * INTB(LJ,K + 1) * WP(I) *
3874	l ZLP(I)
3875	490 CONTINUE
3876	500 CONTINUE
3877	FLUXR = FLUXR + PRADLR(J)
3878	510 CONTENUE C**** flux emisted from left end of the plantes westerin*2
3879 3880	DO 540 J = 1, NG
3881	PRADLIC) = 0.0
3882	DO 530 K = 1, 1
3863	DO 3201 = NAD2, NA
3884	PRADEL(I) = PRADEL(I) + (2°PI) * INTB(LJK) * WP(I) * AB8(
3885	1 ZLP(0)
3806	520 CONTINUE
3887	530 CONTINUE
3888	FLUXL = FLUXL + PRADLL(I)
3889	540 CONTINUE
3890	DUMME - DUMME + THE
3891	E (DUMINE OR, DIPRNT/2.5) THEN
3 892	DUMINE = 0.0
3893 3894	WRITE (7,550) TIME, FLUXE, FLUXE, 550 PORMAT (find & fluor in ris.f = ', 3(1PE11.4,1X))
3895	DO 500 J = 1, NO
3896	EN-ED/GL(J) = 0.0
3897	ENERGE(J) = 0.0
3896	DO 570 I=1, NA
3899	DO 360 K = NABS1, NABS1
3900	ENERGLA) = ENERGLA) + NENT(LJ,K - 2)
3901	ENERGRAD) = ENERGRAD + NENT(LJ,K + 2)
3902	SÃO CONTINUE
3903	570 CONTRACE
3904	SEC CONTINUE
3905 3906	WRITE (11,590) (HNUEDG/),ENERGL(),ENERGR(I),I=1,NG)
3906 3907	590 FORMAT (3(1PE12.5,1X)) END IF
3907 3908	END IF IF (PRES.CIE. 2) THEN
390 0 3909	CALL TEMPER
3910	WRITE (6,97sher solving rise to 3 to 1 male brunns infler in rise.f
3911	WRITE (6,600) (IC,TE1(IC),TE3(IC),NATE(IC),BREMIS(IC),NIBR(IC),K=1.
3912	i NC)
3913	600 FORMAT (2(12,1X,5(1FE10.3,1X)))
3914	IF (PRES.OE. 2) THEN
3915	DO 620 K = 1, NC
3916	DO 610 JJ = NOLOW, NOHIGH
3917	J=IJ-NGLOW+1
391 8 3919	DD = HNUEDG(I) * 11604.0 / NATE(IC)
3919 3920	EE = HNUEDG(3) + 1) * 11604.0 / NATE(K)
3920 3921	EF (DD .GT. LOWLIN) THEN DD = LOWLIN
3922	END IF
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| 140 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1972 | 1
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