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Yucca Mountain Site Characterization Project

HEFF—A User's Manual and Guide for the HEFF Code for Thermal-Mechanical Analysis Using the Boundary-Element Method

Version 4.1

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HEFF—A USER'S MANUAL AND GUIDE FOR THE HEFF CODE FOR THERMAL-MECHANICAL ANALYSIS USING THE BOUNDARY-ELEMENT METHOD

VERSION 4.1

by

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formerly with
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Sandia National Laboratories
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ABSTRACT

The HEFF Code combines a simple boundary-element method of stress analysis with the closed form solutions for constant or exponentially decaying heat sources in an infinite elastic body to obtain an approximate method for analysis of underground excavations in a rock mass with heat generation. This manual describes the theoretical basis for the code, the code structure, model preparation, and steps taken to assure that the code correctly performs its intended functions. The material contained within the report addresses the Software Quality Assurance Requirements for the Yucca Mountain Site Characterization Project.

This work was performed under WBS 1.2.4.2.3.1.

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1. INTRODUCTION

1.1 Description and Use

The computer program HEFF (HEAT with Fictitious Force) is a FORTRAN code based on an indirect formulation of the boundary-element method for plane strain elastic analysis. The initial conditions for such analysis are prescribed boundary tractions or displacements and self-equilibrated initial stress. Through use of a thermoelastic solution to the problem of a line heat source in an infinite elastic, isotropic medium, thermal loading can be treated as additional initial displacements and initial stresses. That allows approximate solution to thermal-mechanical problems in which the heat transfer process is transient, but the process of deformation is considered to be pseudostatic.

It is intended that the HEFF code be used for analysis of relatively simple geometric configurations in circumstances where it may be assumed that the medium is homogeneous, isotropic, linearly elastic, and with material properties that are independent of temperature. Typical applications include scoping analyses of alternative emplacement configurations for a potential nuclear waste repository. This and other applications are illustrated in Figure 1.

By virtue of its boundary-element formulation, the code is particularly well suited to solving problems involving long holes in an infinite media. Semi-infinite problems can also be treated if the appropriate boundary conditions are defined at the free surface through the use of boundary elements and image heat sources.

For the Yucca Mountain Site Characterization Project (YMP), the primary application of the HEFF code has been for performing simple scoping analyses investigating the behavior associated with different waste emplacement options, thermal loading densities, excavation shapes, and panel layout of a potential nuclear waste repository. It is anticipated that it will continue to be used for such purposes due to the simplicity of data preparation and its suitability for use on microcomputers. It is with this use in mind that this documentation, which is intended to meet the Software Quality Assurance Requirements of YMP, has been prepared. However, because HEFF is based on a boundary-element formulation

and incorporates a closed-form solution for heat sources, it represents a significant departure from other thermal and thermal-mechanical modeling capabilities utilized by the YMP. Accordingly, the HEFF may be well suited for use in the verification studies necessary in qualifying the more comprehensive computer models that will be used in the YMP project.

1.2 Background

The program HEFF was developed at the University of Minnesota during studies on numerical modeling of rock stresses within a basaltic nuclear waste repository by Hocking and St. John (1979). The program was constructed by combining the subroutine HEAT with a boundary-element stress analysis code written at the University of Minnesota and subsequently described by Crouch and Starfield (1983). HEAT was developed by Roger Hart at the University of Minnesota and was documented later by Hart (1981) and by Lindner et al. (1984). A user's manual for HEFF was prepared by Brady (1980) as part of the University of Minnesota's subcontract with Rockwell International for the Basalt Waste Isolation Project (BWIP). The present version of the code differs both numerically and cosmetically from the earlier version documented by Brady (1980). Specifically, the HEAT routine has been reprogrammed and tolerances changed significantly, a sign error in the calculation of thermal stresses was corrected, the calculation of out-of-plane stresses has been added, and thermally induced displacements have been accounted for when treating boundary elements with prescribed displacements. The cosmetic changes are intended to improve clarity of both the coding and the output.

The HEFF code has been used in both the BWIP and YMP. One example of the use of HEFF is in SAND86-7005, "Reference Thermal and Thermal/Mechanical Analysis on Drifts for Vertical and Horizontal Emplacement of Nuclear Waste in a Repository in Tuff, St. John (1987)".

1.3 Availability

The version of HEFF documented in this report is available in the public domain by virtue of this publication. An earlier public domain version was documented by Brady (1980). Participants in the YMP project can obtain copies of the code on floppy discs from SNL.

2. DESCRIPTION OF MODELS

This section of the report comprises a general description of the purpose and mathematical basis of the HEFF code. First, the overall solution strategy for thermal-mechanical analysis is described. Subsequently, the boundary-element model and the embedded heat transfer model are described in more detail.

2.1 Nature and Purpose of Analysis

The HEFF code is intended for calculating temperatures, displacements and stresses in a linear, elastic, homogeneous medium. Although finite bodies can be defined by the boundary elements, the primary purpose of the code is to solve problems involving infinite bodies with internal holes or excavations. For the purposes of analysis, such excavations are assumed to be long relative to their other dimensions, which allows a two-dimensional plane strain approximation to be made. For such problems, the initial conditions are usually the initial stress and temperature. The purpose of the analysis is to investigate the excavation-induced and thermally-induced deformation, as well as the total state of stress.

The effect of emplacement of high level nuclear waste in a potential geologic repository is to add a thermal stress to the preexisting initial stress. HEFF was developed with the intention of providing an approximate solution for the temperature, displacements, and stresses in the vicinity of the underground excavations of such a repository. The nature and consequence of the approximations, which derive from the use of a thermal model that is based on the closed-form solution for a line heat source in an infinite medium, are discussed in Sections 2.4.2 and 2.4.3 below.

2.2 Solution Strategy

The HEFF code is based on a boundary-element method that has been referred to as the fictitious stress method (Crouch and Starfield, 1983). The basic characteristics of that method can be illustrated simply by considering the analysis of an underground excavation. The cross section of such an excavation in a stressed medium is illustrated in Figure 2a. The excavation surface S may be subject to imposed tractions t_x, t_y after excavation, or may undergo excavation induced displacements u_x, u_y at any point on the surface. Also shown in Figure 2a is an infinite line heat source of intensity Q embedded in the

isotropic, elastic medium. The effect of the embedded source can be considered as additional initial stresses, and consequently, there will be corresponding induced displacements. Shown in Figure 2b is the surface S' geometrically identical to S, inscribed in a continuum that is stress-free at infinity. S' is subject to tractions, t'_x, t'_y and displacements, u_x, u_y. These quantities represent tractions and displacements that must be induced in an unstressed medium, subject to known thermal loading, to simulate excavation of the opening. If the solution to the problem represented by Figure 2b can be obtained, then the solution to the problem represented by Figure 2a can be obtained directly by addition of the initial stress state.

The solution to the problem represented by Figure 2b is obtained by dividing S' into a number of discrete elements, as shown in Figure 2c. For a representative element i, tractions t'^{i}_x, t'^{i}_y and displacements u^{i}_x, u^{i}_y are assumed constant over the range of the elements. For a properly posed problem, either tractions or displacements are specified on every element i. The requirement is then to use the known boundary conditions (i.e., surface values) to calculate the unknown values.

The general flow of computation within the HEFF code is illustrated schematically in Figure 3. The subroutine INCO2 is called when it is necessary to compute the influence of a boundary force on the stresses and displacements at other locations. It is within the INCO2 routine that the influence coefficients for the boundary-element procedure are developed.

The flowchart also indicates that the TEMCAL subroutine is called when the effect of embedded heat sources is to be determined. This occurs first when computing the boundary tractions equivalent to the thermal loading. Solution of the boundary-element problem leads to computation of a set of displacements and stresses that are induced by those tractions. The total deformation is equal to the sum of the displacements associated with the thermal loads plus the excavation induced displacement (the initial stresses are self-equilibrating). In contrast, the total stress is equal to the sum of the initial, thermal and induced values. Calls to TEMCAL occur whenever the displacements and stresses associated with the heat sources are required.

The assumption made in the formulation of the HEFF solution procedure is that the thermal properties of the material contained within S in Figure 2a are identical to those of the material contained within S' in Figure 2b. This also requires that no heat be extracted from within S', so that the temperature distribution around S is identical to that around S'. The consequence of this assumption is to avoid implicit satisfaction of the thermal boundary conditions on S and to simplify considerably the numerical problem to be solved. However, it also means that it is impossible to simulate heat lost to a ventilating air stream, unless the loss can be approximated by placing a heat sink (negative source) somewhere within the excavation.

Whether or not the thermal boundary conditions on S are satisfied directly, the solution of the coupled thermal-mechanical problem is simplified considerably by noting that the thermal and mechanical processes are, in fact, only semi-coupled. That is, while heat sources generate temperature, strain, displacement, and stress fields, the imposed boundary tractions or displacements generate stress and displacement fields in the medium, but no temperature change. This condition allows the temperature distribution in the medium to be obtained directly from the heat-conduction equations.

2.3 Overall Performance

The HEFF code is based on the use of a fictitious stress method that utilizes straight line elements over which the prescribed tractions or displacements are assumed to be constant. The numerical accuracy of such a procedure is discussed in detail by Crouch and Starfield (1983), who demonstrated that the solutions obtained using constant-strength elements converge to the exact solution as the number of elements is increased. It should be noted that use of constant-strength elements necessarily introduces discontinuities in traction and displacement between adjacent elements.

The numerical solution that is employed in HEFF is generally unreliable at points within a circle of radius equal to one element length, centered at the midpoint of a boundary element. However, the solution on the boundary is accurate at the center of the element and can usually be relied upon for points along the outward normal from the center of the element, providing the other points are no closer to the element than one-half the element length.

The accuracy of thermal calculation is discussed in detail in subsequent sections. The user should be aware of the numerical limitations and approximations of those calculations, but should be more concerned by the physical approximations usually involved. These are first, that any heat source must be idealized as one or more infinite line sources, and second, that the thermoelastic solution for each source is based on the assumption that the body is infinite. The practical implications of these approximations are that the simulated heat source is usually more concentrated than in reality and that the effect of any excavations are completely ignored when computing the temperature and thermally induced stress and displacements.

In view of the inherent physical approximations of the thermal model within the HEFF code, it is generally recommended that the code be used with circumspection when heat sources are emplaced very close to excavations. If an attempt is made to model conditions very soon after emplacement, the results are likely to be in error because the presence of the excavation may significantly perturb heat transfer in the short-term. In the longer term, when temperature gradients in the vicinity of the drift are low, acceptable results are obtained for unventilated excavations even when the sources are close to the excavation boundary. (See comparisons of HEFF and finite-element analyses reported in Section 4.)

2.4 Mechanical Submodel

The mechanical submodel, an indirect form of the boundary-element method, has been referred to as the "fictitious stress method" because it involves development of a set of boundary tractions lacking direct physical significance. The mathematical basis and a numerical implementation of the method are described in detail by Crouch and Starfield (1983). In view of the detailed nature of their presentation and the close similarities between their code TWOFS and HEFF, the description in this section is abbreviated.

2.4.1 Purpose and Scope

The purpose and scope of the mechanical submodel, the heart of the HEFF code, is to solve mixed boundary value problems involving either infinite (unbounded) or finite (bounded) elastic domains. The model is suitable for

solving problems involving creation of a cavity in an initially stressed material.

2.4.2 Mathematical Form

The boundary-element methods are based on the use of elementary solutions to problems in elastostatics. In the case of HEFF, the elementary solution is for a strip segment, in an infinite elastic solid, subjected to uniform tractions. The uniform tractions are designated $t_s = P_s$ and $t_n = P_n$, with s and n corresponding to a local coordinate-scheme with origin at the center of the element. HEFF analyzes only plane sections, so that the strip segment appears as a line and the local coordinates are as illustrated in Figure 4a. Crouch and Starfield (1983, p. 48, 49) give the displacements and stresses due to these tractions as

$$u_s = \frac{P_s}{2G}\left[(3-4\nu)f + nf_{,n}\right] + \frac{P_n}{2G}\left[-nf_{,s}\right] \tag{1}$$

$$u_n = \frac{P_s}{2G}\left[-nf_{,s}\right] + \frac{P_n}{2G}\left[(3-4\nu)f - nf_{,n}\right] \tag{2}$$

$$\sigma_{ss} = P_s\left[(3-2\nu)f_{,s} + nf_{,sn}\right] + P_n\left[2\nu f_{,n} + nf_{,nn}\right] \tag{3}$$

$$\sigma_{nn} = P_s\left[-(1-2\nu)f_{,s} - nf_{,sn}\right] + P_n\left[2(1-\nu)f_{,n} - nf_{,nn}\right] \tag{4}$$

$$\sigma_{sn} = P_s\left[2(1-\nu)f_{,n} + nf_{,nn}\right] + P_n\left[(1-2\nu)f_{,s} - nf_{,sn}\right] \tag{5}$$

in which G and ν are the elastic properties, shear modulus and Poisson's ratio, and the derivatives, $f_{,s}$, $f_{,n}$, $f_{,sn}$, etc., are defined from the following function:

$$f(s,n) = -\frac{1}{4\pi(1-\nu)}\left[n\left(\arctan\frac{n}{s-a} - \arctan\frac{n}{s+a}\right)\right]$$

$$-(s-a)\ln\sqrt{\left[(s-a)^2 + n^2\right]} + (s+a)\ln\sqrt{\left[(s+a)^2 + n^2\right]} \tag{6}$$

Further, because plane strain conditions are assumed

$$u_z = 0 \tag{7}$$

$$\sigma_{zz} = \nu(\sigma_{ss} + \sigma_{nn}) \tag{8}$$

in which z designates the out-of-plane direction.

These equations define the displacements and stresses at any point within the body due to shear and normal tractions applied on the finite segment. Since the body is assumed to be linearly elastic, the effect of applying tractions to several such segments can be obtained by superimposing individual contributions. However, the superimposition requires that the individual contributions first be expressed with reference to an appropriate coordinate system. For points in the interior of a body, that system will usually be the global Cartesian coordinate system, while for points on a specific surface it is convenient to use the local coordinate system defined earlier.

A stress boundary value problem for a cavity in an infinite medium is depicted in Figure 4b. Following the nomenclature introduced earlier, the boundary of the cavity is designated S and the local coordinates s and n are respectively tangent and normal to S. To solve this problem numerically, the boundary S is approximated by N straight line segments (Figure 4c), each of which has a length $2a^i$. If it is assumed that there are prescribed shear and normal stresses σ_s^i and σ_n^i at each segment, the problem is fully defined. In the case illustrated in Figure 4b, the cavity is subjected to an internal pressure p. This is equivalent to prescribing shear and normal tractions that are respectively zero and p.

The sole condition for solution of the static elastic problem is that all the boundary conditions are satisfied. Hence, the real problem of a cavity, or a bounded body, can be replaced by an alternative problem of an imaginary surface subjected to identical boundary conditions. This substitute problem can be solved using the relationship defined above by developing a set of tractions P_s^i and P_n^i that satisfy the stress boundary conditions σ_s^i and σ_n^i along the surface. This process can be expressed mathematically for each segment i as

$$\sigma_s^i = \sum_{j=1}^{N} A_{ss}^{ij} P_s^j + \sum_{j=1}^{N} A_{sn}^{ij} P_n^j \tag{9}$$

$$\sigma_n^i = \sum_{j=1}^{N} A_{ns}^{ij} P_s^j + \sum_{j=i}^{N} A_{nn}^{ij} P_n^j \tag{10}$$

Here, A_{ss}, A_{sn}, A_{ns}, and A_{nn} are the boundary stress influence coefficients that can be derived directly from Equations 3 through 6. Similar relationships can also be derived for the displacements

$$u_s^i = \sum_{j=1}^{N} B_{ss}^{ij} P_s^j + \sum_{j-1}^{N} B_{sn}^{ij} P_n^j \tag{11}$$

$$u_n^i = \sum_{j=1}^{N} B_{ns}^{ij} P_s^j + \sum_{j=1}^{N} B_{nn}^{ij} P_n^j \tag{12}$$

in which B_{ss}, etc. are the boundary displacement influence coefficients derivable from equations 1, 2 and 6.

In any well-posed problem for which either boundary stresses or displacements are defined for all elements, the only unknowns are the tractions P_s^i and P_n^i on the imaginary surface. The problem is reduced to developing a set of simultaneous equations in which P_s^i and P_n^i are the unknown parameters. Once these parameters are determined, equations similar to 9 through 12 can be used to compute the displacements and stresses at any sample point within the body.

2.4.3 Numerical Methods

The boundary-element method relies on development and solution of a set of influence equations. The coefficients of these influence equations are derived directly from the equations given above, with the appropriate derivatives obtained analytically by differentiation of the function f(s,n). (The influence equations are detailed in Crouch and Starfield, 1983.) The influence equations are fully populated and not symmetric. In the HEFF code, the influence functions are assembled as four sets of equations or submatrices; their solution is obtained using Gaussian elimination.

2.5 Temperature and Thermal Stress Submodel

A complete closed-form solution for temperature, stress, and displacement around a continuous line heat source is presented. Both constant and exponentially decaying heat sources are considered. In the latter case, the solution is given in the form of an infinite series, but a good approximation can be obtained by using a limited number of terms. Calculations of the temperature, stresses, and displacement using the line heat source solution as it is performed within the code are also presented.

2.5.1 Purpose and Scope

The purpose and scope of the thermal and thermal stress submodel is to compute the temperatures, displacements, and stresses developed as a result of embedment of a line heat source in an infinite medium. The computed thermal stresses, displacements, or stress and displacements are additional boundary conditions for the mechanical submodel. The computed temperature, displacement, and stress are superimposed on the results of the boundary-element analysis to obtain the total thermal-mechanical response.

2.5.2 Mathematical Formulation for a Continuous Line Heat Source

A continuous line heat source, as described by Carslaw and Jaeger (1959), corresponds to the generation of heat at a prescribed rate per unit time per unit length of line. The consequent temperature changes can be derived by integrating the solution for an instantaneous line heat source. A similar procedure can be used to derive the thermal and thermal-mechanical effects of a line heat source by integrating the following solution for an instantaneous line heat pulse in an infinite medium (Nowacki, 1962)

$$T = Qe^{-r^2/4\kappa t}/(4\pi\kappa t) \tag{13}$$

$$\sigma_{rr} = GmQ(1-e^{-r^2/4\kappa t})/(\pi r^2) \tag{14}$$

$$\sigma_{\theta\theta} = GmQ\left[(1+2r^2/4\kappa t)e^{-r^2/4\kappa t}-1\right]/(\pi r^2) \tag{15}$$

$$u_r = mQ(1-e^{-r^2/4\kappa t})/(2\pi r) \tag{16}$$

Compressive stresses are considered to be positive in these equations, in which:

T = temperature change

Q = heat strength, or heat generation divided by the heat capacity of the medium

κ = diffusivity

t = time

r = radial distance

G = shear modulus

$m = (\frac{1+\nu}{1-\nu})\alpha$

α = thermal expansion coefficient

ν = Poisson's ratio

As for the mechanical submodel, the out-of-plane displacement and stress are derived directly from the plane strain condition, i.e.

$$u_z = 0 \tag{17}$$

$$\sigma_{zz} = \nu(\sigma_{rr} + \sigma_{\theta\theta}) + E\alpha T \tag{18}$$

Upon integration with respect to time, these equations become

$$T = \frac{1}{4\pi\kappa} \int_0^t \phi(\tau) e^{-r^2/4\kappa(t-\tau)}/(t-\tau)d\tau \tag{19}$$

$$\sigma_{rr} = \frac{Gm}{\pi r^2} \int_0^t \phi(\tau)\left[1-e^{-r^2/4\kappa(t-\tau)}\right]d\tau \tag{20}$$

$$\sigma_{\theta\theta} = \frac{Gm}{\pi r^2} \int_0^t \phi(\tau)\left[(1+\frac{2r^2}{4\kappa(t-\tau)})e^{-r^2/4\kappa(t-\tau)}-1\right]d\tau \tag{21}$$

$$u_r = \frac{m}{2\pi r} \int_0^t \phi(\tau)\left[1-e^{-r^2/4\kappa(t-\tau)}\right]d\tau$$

in which $\phi(\tau)$ describes the time dependency of the heat generation.

To solve these equations, for either a constant or time-varying heat source, three integrals must be evaluated

$$I_1 = \int_o^t \phi(\tau)d\tau \tag{22}$$

$$I_2 = \int_o^t \phi(\tau)\frac{e^{-r^2/4\kappa(t-\tau)}}{t-\tau}d\tau \tag{23}$$

$$I_3 = \int_o^t \phi(\tau)e^{-r^2/4\kappa(t-\tau)}d\tau \tag{24}$$

Evaluation of these integrals for a constant strength heat source is straightforward. If the heat is generated at a constant rate, $\phi(\tau)$ is constant and equal to Q_o. Note that Q_o is the heat power per unit length divided by the heat capacity. The integral I_1 is then

$$I_1 = Q_o t \tag{25}$$

Integral I_2, upon making the substitution $u = r^2/4\kappa(t-\tau)$, becomes

$$I_2 = Q_o\int_{\frac{r^2}{4\kappa t}}^{\infty} \frac{e^{-u}}{u}\,du \tag{26}$$

I_2 is now in the form of the exponential integral (Ei(u)) and can be written

$$I_2 = -Q_o Ei(\frac{-r^2}{4\kappa t}) \tag{27}$$

The basic properties of the exponential integral are described by Gautschi and Cahill (1980). Its evaluation within HEFF is described in Section 2.5.4.

The integral I_3 can be obtained in a manner similar to that for I_2. Again substituting $u = r^2/4\kappa(t-\tau)$, I_3 becomes

$$I_3 = \frac{Q_o r^2}{4\kappa}\int_{\frac{r^2}{4\kappa t}}^{\infty} \frac{e^{-u}}{u^2}\,du \tag{28}$$

Integrating by parts and using the solution to I_2

$$I_3 = \frac{Q_o r^2}{4\kappa}\left[\frac{e^{-r^2/4\kappa t}}{r^2/4\kappa t} + Ei(\frac{-r^2}{4\kappa t})\right] \tag{29}$$

Equations 25, 27, and 29 can now be used to give the solutions for temperature, stress, and displacement induced by a constant line heat source.

$$T = \frac{-Q_o}{4\pi\kappa} Ei(\frac{-r^2}{4\kappa t}) \tag{30}$$

$$\sigma_{rr} = \frac{Q_o Gm}{\pi r^2}\left\{t - \frac{r^2}{4\kappa}\left[\frac{e^{-r^2/4\kappa t}}{r^2/4\kappa t} + Ei(\frac{-r^2}{4\kappa t})\right]\right\} \tag{31}$$

$$\sigma_{\theta\theta} = \frac{Q_o Gm}{\pi r^2}\left\{te^{-r^2/4\kappa t} - \frac{r^2}{4\kappa} Ei(\frac{-r^2}{4\kappa t}) - t\right\} \tag{32}$$

$$u_r = \frac{mQ_o}{2\pi r}\left\{t - \frac{r^2}{4\kappa}\left[\frac{e^{-r^2/4\kappa t}}{r^2/4\kappa t} + Ei(\frac{-r^2}{4\kappa t})\right]\right\} \tag{33}$$

2.5.3 Mathematical Formulation for an Exponentially Decaying Heat Source

Within HEFF, the case of a time-varying heat source is defined as the sum of several components, which may be either constant or exponentially decaying. This composition can be expressed by

$$\phi(\tau) = Q_{o_c} + Q_{o_d} \sum_{j=1}^{n} q_j e^{-\lambda_j \tau} \tag{34}$$

in which Q_{o_c} is the strength of the constant part, Q_{o_d} is the initial strength of the decaying part (at time τ = o), and q_j and λ_j are respectively the proportion and decay rate of each of the n decaying components used to describe the time variation. Clearly

$$\sum_{j=1}^{n} q_j = 1 \tag{35}$$

if Q_{o_d} is the initial strength of the combined decaying components.

In this section, the temperature, displacements, and stresses induced by a single decaying component characterized by an initial strength Q_o and decay rate λ are defined. Note that the rate of decay can be alternatively characterized by the half-life of the source. For example, a decay rate of 0.03466/year corresponds to a half-life of 20 years. The number of half-lives a heat source has decayed at a given time t is equal to $\lambda t/\ln 2$.

As for the constant source, derivation of the necessary equations to define the induced temperature, displacement, and stress involves evaluation of the three integrals I_1, I_2, and I_3. As before, the integral I_1 can be evaluated directly. Its solution is:

$$I_1 = Q_o\left(\frac{1-e^{-\lambda t}}{\lambda}\right) \tag{36}$$

The evaluation of integrals I_2 and I_3 is somewhat more involved, but they can be treated as functions of the exponential integral.

Integral I_2 can be written

$$I_2 = Q_o \int_o^t \frac{e^{-\lambda\tau - r^2/4\kappa(t-\tau)}}{t-\tau}\, d\tau \tag{37}$$

Substituting $u = r^2/4\kappa(t-\tau)$, yields

$$I_2 = Q_o e^{-\lambda t} \int_{\frac{r^2}{4\kappa t}}^{\infty} \frac{e^{-u}}{u}\, e^{\lambda r^2/4\kappa u} du \tag{38}$$

By making a Taylor's Series expansion of the exponential term containing $\frac{\lambda r^2}{4\kappa u}$, I_2 becomes

$$I_2 = Q_o e^{-\lambda t} \int_{\frac{r^2}{4\kappa t}}^{\infty} \frac{e^{-u}}{u}\left[1 + \frac{\lambda r^2}{4\kappa}\frac{1}{u} + \lambda^2\left(\frac{r^2}{4\kappa}\right)^2\left(\frac{1}{u^2}\right) + \lambda^3\left(\frac{r^2}{4\kappa}\right)^3\left(\frac{1}{u^3}\right) + \ldots\right] du \tag{39}$$

or

$$I_2 = Q_o e^{-\lambda t} \left[\int_{\frac{r^2}{4\kappa t}}^{\infty} \frac{e^{-u}}{u} du + \sum_{n=2}^{\infty} \frac{\lambda^{n-1} (\frac{r^2}{4\kappa})^{n-1}}{(n-1)!} \int_{\frac{r^2}{4\kappa t}}^{\infty} \frac{e^{-u}}{u^n} du \right] \tag{40}$$

Integration by parts can be performed on each integral in the summation. Gradshteyn and Ryzhik (1980) give a solution to integrals of this form as

$$\int \frac{e^{ax}}{x^n} dx = -e^{ax} \sum_{k=1}^{n-1} \frac{a^{k-1}}{(n-1)(n-2)\cdots(n-k)^{n-k}} + \frac{a^{n-1}}{(n-1)!} Ei(ax) \tag{41}$$

Letting $a = -1$ and solving between the limits of integration $r^2/4\kappa t$ and ∞, I_2 becomes

$$I_2 = Q_o e^{-\lambda t} \left\{ -Ei(\frac{r^2}{4\kappa t}) + \sum_{n=2}^{\infty} A \left[e^{-r^2/4\kappa t} \sum_{k=1}^{n-1} B - \frac{(-1)^{n-1}}{(n-1)!} Ei(\frac{-r^2}{4\kappa t}) \right] \right\} \tag{42}$$

where

$$A = \frac{\lambda^{n-1} (\frac{r^2}{4\kappa})^{n-1}}{(n-1)!} \quad \text{and} \quad B = \frac{(-1)^{k-1}}{(n-1)(n-1)\cdots(n-k)(\frac{r^2}{4\kappa t})^{n-k}}$$

The evaluation of integral I_3 for an exponentially decaying function is solved in the same way as that for integral I_2. Making the same substitution and using a Taylor's Series expansion, as before, I_3 becomes

$$I_3 = Q_o e^{-\lambda t} \sum_{n=2}^{\infty} \frac{\lambda^{n-2} (\frac{r^2}{4\kappa})^{n-1}}{(n-2)!} \int_{\frac{r^2}{4\kappa t}}^{\infty} \frac{e^{-u}}{u^n} du \tag{43}$$

I_3 is now in the same form as I_2

$$I_3 = Q_o e^{-\lambda t} \sum_{n=2}^{\infty} C \left[e^{-r^2/4\kappa t} \sum_{k=1}^{n-1} B - \frac{(-1)^{n-1}}{(n-1)!} Ei(\frac{-r^2}{4\kappa t}) \right] \tag{44}$$

where

$$C = \frac{\lambda^{n-2} (\frac{r^2}{4\kappa})^{n-1}}{(n-2)!}$$

Equations 36, 42, and 44 can now be used to give the solutions for temperature, stress, and displacement induced by a exponentially decaying line heat source.

$$T = \frac{Q_o\, e^{-\lambda t}}{4\pi\kappa} \left\{ -Ei\left(\frac{r^2}{4\kappa t}\right) + \sum_{n=2}^{\infty} A \left[e^{-r^2/4\kappa t} \sum_{k=1}^{n-1} B - \frac{(-1)^{n-1}}{(n-1)!} Ei\left(\frac{-r^2}{4\kappa t}\right) \right] \right\} \tag{45}$$

$$\sigma_{rr} = \frac{Q_o\, Gm}{\pi r^2} \left\{ \frac{1-e^{-\lambda t}}{\lambda} - e^{-\lambda t} \sum_{n=2}^{\infty} C \left[e^{-r^2/4\kappa t} \sum_{k=1}^{n-1} B - \frac{(-1)^{n-1}}{(n-1)!} Ei\left(\frac{-r^2}{4\kappa t}\right) \right] \right\} \tag{46}$$

$$\sigma_{\theta\theta} = \frac{Q_o\, Gm}{\pi r^2} \left\{ -\frac{1-e^{-\lambda t}}{\lambda} - e^{-\lambda t} \frac{2r^2}{4\kappa} Ei\left(\frac{-r^2}{4\kappa t}\right) \right.$$

$$\left. + e^{-\lambda t} \sum_{n=2}^{\infty} \left(C + 2\frac{r^2}{4\kappa} A\right) \left[e^{-r^2/4\kappa t} \sum_{k=1}^{n-1} B - \frac{(-1)^{n-1}}{(n-1)!} Ei\left(\frac{-r^2}{4\kappa t}\right) \right] \right\} \tag{47}$$

$$u_r = \frac{Q_o\, m}{2\pi r} \left\{ \frac{1-e^{-\lambda t}}{\lambda} - e^{-\lambda t} \sum_{n=2}^{\infty} C \left[e^{-r^2/4\kappa t} \sum_{k=1}^{n-1} B - \frac{(-1)^{n-1}}{(n-1)!} Ei\left(\frac{-r^2}{4\kappa t}\right) \right] \right\} \tag{48}$$

The out-of-plane displacement and stress were given by Equations 17 and 18.

2.5.4 Numerical Methods

The solution for both constant and exponentilly decaying heat sources involves the exponential integral. This may be approximated by an infinite series expansion given by Gautschi and Cahill (1980)

$$-Ei(-x) = \gamma + \ln(x) + \sum_{n=1}^{\infty} \frac{(-1)^n x^n}{n.n!} \tag{49}$$

in which γ = Euler's constant (0.5772).

This function is shown graphically in Figure 5, where $XB = r^2/4\kappa t$ is the variable of the exponential integral function Ei(-XB). Ei(-XB) decreases monotonically from the value $Ei(0) = \infty$ to the value $Ei(-\infty) = 0$. Series expansions for Ei(-XB) are also plotted on the figure for 5, 7, and 11 terms in the expansion. For 7 terms in the expansion, for example, the function decreases correctly until $XB \simeq 2$, but then begins to diverge from the correct value. Additional terms are required to provide an acceptable approximation as the argument is increased.

Alternatively, for larger values of x, the following inequality (Gautschi and Cahill, 1980) can be used

$$\frac{1}{2}\ \ln(1+\frac{2}{x}) < -\ e^{x}Ei(-x) < \ln(1+\frac{1}{x})$$

For large x, the inequality approaches

$$-Ei(-x) = \frac{e^{x}}{x} \tag{50}$$

With a correction factor, the approximation to Ei(-x) is

$$-Ei(-x) = \frac{e^{-x}}{x}\left(1-\frac{3}{4x} + \frac{5}{6x^2} - \frac{9}{8x^3} + \frac{17}{10x^4}\right) \tag{51}$$

Values of the function were calculated using Equations 49 and 51 for a given range of the argument and several values of n, the number of terms in the infinite series expansion. Those tests revealed that an acceptable approximation was achieved if Equation 49, with 15 terms, is used in the range $0 < x \leq 4$ and Equation 51 for $x > 4$. Comparison between this numerical approximation and values tabulated in Gautschi and Cahill (1980) is provided in Table 1.

2.5.5 Implementation

A computer subroutine is used to calculate the temperature, stresses, and displacements using the closed-form solutions developed for both the constant and exponentially decaying line heat sources. A flowchart outlining the coding is provided in Figure 6.

The program first checks for excessively large values of the dimensionless parameters $r^2/4\kappa t$. If this exceeds 50, then it is assumed that the induced temperature and stress at the sample point of concern are insignificant. This dimensionless number has been selected based on experience and has been acceptable for most cases. In problems involving many heat sources, their accumulated contribution at a significant distance may be significant, requiring the numerical limit of 50 be increased. There is no known algorithm to test for significance in this case. The exponential integral is evaluated next, using the procedure discussed in Section 2.5.4. Thereafter, either the exponentially decaying heat source solution or the constant heat source solution is selected.

Choice of a zero decay rate will automatically result in use of a constant source. In principal, the same result could be obtained using the exponential solution with a very small value for the decay rate. However, experience has indicated that numerical instabilities can develop in the exponentially decaying heat source solution for values of λt less than 10^{-10}. To avoid such difficulties, the constant source solution is used for λt less than 10^{-10} and appears to provide acceptable results.

For the exponentially decaying heat source solution, individual terms of the series expansion are calculated and then the convergence of the series is checked. A study of the temperature, radial, and tangential stress displacement showed that the radial stress converges slowly and in a more predictable manner than the tangential stress. Therefore, the number of terms used in the series is determined by a tolerance set for the radial stress. For the implementation used in HEFF, a tolerance of $1 * 10^{-6}$ of the initial radial stress terms has been used and appears to provide good accuracy. To eliminate unnecessary calculation and avoid numerical underflow, a check is made to establish when to skip calculations because the influence of the heat source is insignificant. This check is made on the basis of the first term of the temperature calculation. When this falls below a limiting temperature value of 10^{-10}°C, the remainder of the calculations for a decaying heat source are skipped.

The various checks built into the implementation of the line heat source solution limit the range of distances and times over which values of the induced temperatures, stress, and displacement will be computed. Consider the case of a single heat source with strength 1000 m^3°C/yr/m and decay constant 0.1 in an infinite elastic medium with the properties

Thermal Diffusivity (κ)	= 25 m^2/yr
Elastic Modulus (E)	= 10000 MPa
Poisson's Ratio (ν)	= 0.2
Thermal Expansion (α)	= $10*10^{-6}$ °C^{-1}

The results of a series of calculations of the radial stress at different locations and times are listed in Table 2. Note both the obvious limit to the range over which thermally induced stress will be experienced at any time and that the thermally induced stress eventually becomes insignificantly small. Note also that numerical instabilities have been encountered in some circumstances; most

noticeably after long time periods and at close ranges. Every reasonable step has been taken to avoid the numerical problems that cause these instabilities. To prevent them entirely would unnecessarily limit the calculation in most cases of practical significance. Hence, the user should both exercise discretion in selection of sample points when simulating long periods of emplacement and be prepared to make minor changes if instabilities are encountered.

3. USER'S MANUAL

This section comprises documentation for the user of HEFF boundary-element code. First, modeling options offered by the code are described briefly. Second, the input and output files are described and illustrated by a sample problem. Third, the software and hardware resources required for use of the code are defined.

3.1 Function and Invocation of Options

The code offers the user a number of options. In several cases, the use of a particular option has implications of which the user should be aware. Those cases are discussed below. In addition, several features are illustrated schematically in Figure 7.

Geometrical Symmetry - The problem may be geometrically symmetrical about the y axis (i.e., about x = 0). Since this symmetry applies to heat sources, the user should take care to halve the strength of any heat source located on the y axis if this option is used.

Image Heat Sources - Image heat sources (of the same magnitude but opposite sign) are used to enforce an isothermal boundary condition on the plane y = 0. The image heat source also removes any thermally induced normal tractions on that surface, but not the thermally induced shear tractions on the surface. Hence, boundary elements must be placed along the free surface of all half-space problems. The extent of the surface to be defined for any particular application can be determined by simple experimentation.

Heat Source Characteristics - Heat source strength is described by one or more components that can be either constant or exponentially decaying or both. Each component is ascribed some proportion of a separately specified strength and a time at which the component is activated. All sources have identical time-varying characteristics. However, their location, strength at emplacement, and time of emplacement are specified individually. This allows phased emplacement of sources of varied strength.

Heat Sinks - The user is free to specify negative strength heat sources if desired. These might be used to simulate heat loss due to ventilation of an underground excavation, for example. They can also be used to terminate previously activated components of the source. For example, a constant component of strength 1 activated at time zero when combined with a second component of strength -1 activated after one year would be equivalent to emplacing a source of strength 1 for one year and removing it thereafter. To achieve the same effect with decaying components, it is important to note that the magnitude of the negative component (sink) must be equal to the magnitude of the source after decay over the specified period, i.e.

$$Q_o^- = -Q_o^+ e^{-\lambda t}$$

in which Q_o^+ and Q_o^- are the magnitudes of the strengths of the source and sink, respectively, λ is the decay constant describing both source and sink, and t is the time between emplacement and removal.

Mechanical or Thermal-Mechanical Analyses - If the number of heat sources specified in the control data is zero, then all data relating to the thermal and thermal-mechanical properties for the problem are eliminated (including specification of time). In these circumstances, the thermal submodel is never invoked.

Generation of Sample Points - The code allows sample points to be generated either automatically along lines perpendicular to the boundary elements or along independently specified sample lines. In the former case, the user has the option of requesting that sample points are generated for less than the full number of boundary elements. In those circumstances, the user must order the boundary-element segments so that the elements with associated sample lines are generated first. Ordering of the sample lines is particularly important if it is intended that the plot files be postprocessed.

Postprocessing - A postprocessor, POSTHEF, has been developed to display and plot output from the HEFF analysis. If POSTHEF is to be used to contour variables, exterior sample points perpendicular to the boundary elements must be specificied (see input type M2). POSTHEF is described in Appendix C.

3.2 Input and Output Information

3.2.1 Input Data

This summary details the input file for the HEFF code. User specifies names of input and output files during program execution. Except for the first three data lines, free format is used. This means that some value, even if zero, must be entered for every variable to be read. Data items are separated by blanks or commas. Note that an input data set applies for one time only. Hence, output for successive time intervals is obtained by completing a series of independent analyses.

Input A	Plot File Name (10 Characters)
Cols. 1-8	Name of file on which output is to be stored for plotting using POSTHEF (see Appendix C).
Input B	QA Number - A QA number is embedded within the code. Execution is terminated if that number does not correspond with the value specified in the data set, i.e., you are not using the version you think you are?
Input C	Title Input (72 Characters)
Cols. 1-72	Alphanumeric description of job
Input D	Job Execution Data (Free Format)

NUMBS	Number of boundary segments
NUMOS	Number of stress lines (see Input L)
NSORC	Number of components used to describe heat sources
NCOMP	Number of time components defining the heat sources
KSYM	Geometric symmetry identifier
IMAG	Heat source image specifier

Note: (a) The geometric symmetry identifier (KSYM) takes a value of 0 or 1, designating either no symmetry or symmetry about $y = 0$. Remember

that specification of KSYM = 1 (symmetry invoked) will also generate symmetrically located heat sources.

(b) The heat source image specifier (IMAG) takes a value of 0 or 1, designating, respectively, no image sources or the generation of image sources to activate isothermal conditions at y = 0. Remember, selection of an isothermal boundary condition does not result in development of a stress free surface.

Input E — Rock Mass Elastic Constants (Free Format)

PR	Poisson's Ratio
E	Young's Modulus

Input F — Constants to Define Initial State of Stress (Free Format)

AXX	
AYY	Ground surface, pre-mining stresses are:
AXY	
BXX	σ_{yy} = AYY * Y + BYY
BYY	σ_{xx} = AXX * Y + BXX + (CXX + DXX/Y)*σ_{yy}
BXY	σ_{xy} = AXY * Y + BXY
CXX	
DXX	CXX + DXX/Y < RMAX
RMAX	
XZRAT	σ_{zz} = XZRAT * σ_{xx}

Note: The sign convention for stresses is illustrated in Figure 8. Note that compressive stresses are assumed to be positive. This means that the value of the coefficients that describe a dependency on y are usually negative (since y becomes more negative with depth). It is particularly important to conform to this convention if performing thermal-mechanical analyses, since the thermal stress calculations are carried out on that basis.

Input G — TIM — Time at which output is desired (Free Format)

Note: (a) Skip this input and inputs H through K if there are no heat sources (NSORC = 0).

(b) The units of time must be consistent with other units used to define the problem. Any consistent unit can be used, but it is usually convenient to use years for the time unit.

Input H Constants to Determine Initial Rock Temperature VRT (Free Format)

TSURF	Temperature at depth Y = 0
TGRAD	Temperature gradient

where VRT = TGRAD * Y + TSURF.

Note: For the initial rock temperature (VRT) to increase with depth, TGRAD should be negative. (See Note on Input F above.)

Input I Rock Mass Thermal Properties (Free Format)

DIFF	Thermal diffusivity
ALPHA	Coefficient of thermal expansion

Note: The units of diffusivity must be consistent with the time units assumed for Input G. For example, if time is denoted in years, then the units of diffusivity might be m^2/yr.

Input J Definition of Heat Source Components (Free Format), NCOMP records should be input (see Input D)

TOC(I)	Switch-on time for component
PROP(I)	Proportion of strength specified in Input K below (can be negative)
QEXP(I)	Decay constant for component (0 for constant component or a positive value for a decaying component)

Note: (a) All heat sources are assumed to have the same decay characteristics. Only the strength and switch-on time are specified in Input K below.

(b) Time here is the time relative to the switch-on time specified in Input K below.

(c) See Section 2.5.2 for additional discussion.

Input K — Specification of Heat Sources (Free Format), NSORC records should be input (Input D)

XS(I)	x coordinate of source
YS(I)	y coordinate of source
QS(I)	Initial strength of source
TOS(I)	Switch-on time for source

Note: (a) Strength of heat source is the power per unit length of the out-of-plane line heat source (e.g., watts/m) divided by the heat capacity ($J/m^3{}^\circ C$) of the medium. Typical units are $m^3{}^\circ C/yr$ per meter. Take care that a consistent set of units, including those of time, are used.

(b) Switch-on time can be alternatively considered as emplacement time.

Input L — All boundaries are defined as a series of segments. Each segment is then subdivided automatically into the specified number of equal length straight elements. Two alternative means of specification are provided. These allow for straight and curved segments and are illustrated in Figure 9a and b. Both types may be used in any combination.

Type L1 — Specification of a Straight Line Segment (Free Format)

NUM	Number of boundary elements to be generated from segment
KODE	Code describing boundary conditions, as defined below
XBEG	x coordinate of start of segment
YBEG	y coordinate of start of segment
XEND	x coordinate of end of segment
YEND	y coordinate of end of segment
RADIUS	Zero for straight line segment
RATIO	Zero for straight line segment

PSI	Zero for straight line segment
BVS, BVN	Transverse (BVS) and normal (BVN) components of imposed surface traction or displacement (depends on KODE)

Note: See Figure 9a.

Type L2 Specification of a Circular or Elliptical Segment (Free Format)

NUM	Number of boundary elements to be generated from segment
KODE	Code describing boundary conditions, as defined below
XC/YC	Coordinates of center of circular or elliptical segment
THET1, THET2	Angles defining angular range of segment measured counterclockwise from the x-axis (see Figure 9b)
RADIUS	Radius of circular segment or length of one semi-axis (a) of an ellipse
RATIO	Ratio b/a, where (a) and (b) are the lengths of the semi-axes of the ellipse, 0 for a circular segment
PSI	Polar angle of semi-axis (a) measured counterclockwise from the x-axis, 0 for a circular segment
BVS, BVN	Transverse (BVS) and normal (BVN) components of imposed surface traction or displacement (depends on KODE)

Note: See Figure 9b.

General Notes:

(a) When specifying boundary elements, the solid is assumed to be on the right-hand side when moving from the start of the segment to the end.

(b) Apart from as noted in (d) below, the ordering of elements is arbitrary.

(c) If KODE = 1, surface tractions are specified.
= 2, surface displacements are specified.
= 3, normal component of traction, transverse component of displacement are specified.

= 4, normal component of displacement and transverse component of traction are specified.

(d) If the POSTHEF postprocessor is to be used, then the boundary segments must be specified in which the elements will be plotted, with the first element to be plotted first in the sequence.

Input M — Specification of Interior Points

Two alternative means of specification are provided. One or the other, but not both, can be used. If POSTHEF is to be used, the second alternative should be used.

Type M1 — Specification of Points Along Sample Lines

XB(I), YB(I)	x,y coordinates of start of line I
XE(I), YE(I)	x,y coordinates of end of line I
NUMPB(I)	Total number of points along line I, including endpoints

Note: (a) NUMOS records should be input (Input D).
(b) See Figure 9d.

Type M2 — Specification for Generation of Interior Points in Medium (Free Format)

DELN	Distance to first stress point from centroid of each boundary element
RATTY	Multiplier to expand or contract spacing
NUMPT	Number of points generated along each line
NBE	Number of boundary elements where generation is needed (There will be generation normal to the first NBE elements.)

Note: (a) This type is invoked when NUMOS = 0 (Input D).
(b) See Figure 9e.

(c) The variable RATTY defines the spacing between successive sample points along a line normal to each boundary element.

(d) Only one record is required in this case since the sample points are automatically generated for the first NBE elements. This option must be used to generate data for POSTHEF. It is recommended that DELN is not less than 50 percent of the length of the boundary element from which it is generated.

3.2.2 Output Data

Output comprises

- Title, date of creation, and timing information.

- A record of all input information, including generated data for the boundary elements and internal sample points.

- Preexisting stresses at the center of each element, prior to creation of the surfaces defined by the elements. If there are heat sources in the model, then the associated temperature change and thermal stresses are included in this list.

- Computed displacements, stresses, and temperature at each boundary element. Both displacements and stresses are expressed in Cartesian and local (tangential and normal to each element) coordinate frames.

- Computed displacements, stresses, and temperature at each internal sample point. The displacements and stresses are given in Cartesian coordinate frame. In addition, the principal in-plane stresses and their orientations are defined.

- A plot file that can be postprocessed by POSTHEF to obtain graphical output.

The nomenclature used in the output file is defined in Table 3. The complete output for a sample problem is contained within Section 3.2.3.

3.2.3 Sample Problem

The sample problem concerns analysis of a long drift for emplacement of nuclear waste within vertical boreholes drilled along its centerline. For the sake of simplicity, the case of an isolated drift is investigated. The more typical case of a representative drift within a large repository is discussed in Section 4.2.

Geomechanical data required for this problem are

Drift Width	16.0 ft (4.88 m)
Drift Height	22.0 ft (6.71 m)
Radius of Roof Arch	9.0 ft (2.74 m)
Borehole Depth	25.0 ft (7.62 m)
Container Length	18.0 ft (5.49 m)
Depth Below Surface	985.0 ft (300 m)

The material properties and initial conditions required for the analysis are

Specific Gravity	2.34 g/cc
Young's Modulus	15.1 GPa
Poisson's Ratio	0.2
Thermal Conductivity	2.07 W/m°C
Thermal Capacity	2.25 J/cm^3°C
Thermal Expansion	10.7×10^{-6} °C^{-1}
Horizontal/Vertical In-Situ Stress	0.55
Ground Surface Temperature	16.0°C
Temperature Gradient	0.0239°C/m

The waste containers are presumed to be spaced along the drift to achieve an initial thermal loading density of 590.5 W/m, which is assumed to decay in accordance with the following normalized power decay function

$$P(t) = 0.15602\exp(-0.0013539t) + 0.59787\exp(-0.019142t) + 0.15227\exp(-0.005188t) + 0.09384\exp(-0.43768t)$$

in which t is the time in years since emplacement.

To solve this problem, a total of 27 boundary elements were used to define one half of the drift perimeter, the other half being generated automatically by prescribing a vertical plane of symmetry along the centerline. The arrangement of elements is illustrated in Figure 10, on which the location of sample points and heat sources are also marked.

The data set for this problem is reproduced in Figure 11. The following annotation is intended to be read in conjunction with the input data list defined in Section 3.2.1.

Line 1: Name of plot file for subsequent postprocessing.

Line 2: QA number (HEFF 4.1 in this case).

Line 3: Title for problem.

Line 4: Control Information

- o Boundary segments define the problem
- o Sample point generation used
- o Three heat sources used
- o Four decay components for the heat sources
- o Symmetry about x = 0
- o No image heat sources

Line 5: Specification of rock mass elastic constants.

Line 6: Definition of the in-situ stress state. Here a stress gradient of -0.023 MPa/m is defined. The entry is negative, so the calculated in-situ stress is +6.95 MPa (compressive) at an elevation of -300 m below the ground surface. Note that the horizontal stresses are both equal to 0.55 of the vertical stress.

Line 7: Time for which the analysis is to be performed.

Line 8: Definition of initial temperature. Note again that the gradient is negative and that the initial temperature will be positive at some depth below the surface ($y < 0.0$), where the initial temperature is 16 °C.

Line 9: Definition of thermal diffusivity and coefficient of linear thermal expansion. Note that units of thermal diffusivity are m^2/yr. The units of time must be the same as used when

defining the analysis time and the decay characteristics of the waste form.

Lines 10-13: Definition of the four components used to describe the heat generation of the waste form. In this case, the datum for each component is zero years. Here the components have been normalized so that the total strength at 0 years is 1.0.

Lines 14-16: Definition of the location, strength, and timing of the heat sources. In this case, three heat sources are located beneath the center of the drift (i.e., on the line of symmetry, x = 0). These heat sources are intended to simulate the heat generation of a line of containers placed within holes in the floor of the emplacement drift. They are located at the mid-height of the container (-307.335 m) and one-sixth of the container length from each end, with the intention of approximating uniform heat-generation with the volume of the container. Note that the strength of each source is equivalent to one-sixth of the initial thermal output of the containers because the three heat sources are placed on the line of symmetry.

Lines 17-20: Definition of the boundary elements. Note that four boundary segments are used. These define first the floor, then the bottom right-hand corner, the right wall, and a circular roof with radius 2.74 meters. The corner segment, which comprises a single element, is included solely for the purposes of generation of internal sample points.

Line 21: Definition of the generation of sample points. In this case, the first point is 0.3 m from each element. Six points are generated along lines normal to all 27 elements. The ratio of the spacing between adjacent pairs of sample points on a line is 1.5.

Output for the sample problem is shown in Figure 12. The user specifies the output file name during execution. Postprocessing of the output file identified in Line 1 of the input file can be done interactively to produce contours of temperature, stress, and safety factors, as well as the deformed shape of the cavity and tangential stresses around the excavation. Details of the postprocessor POSTHEF are presented in Appendix C.

3.3 Software and Computer System Requirements

The Fortran computer code and executable code has been developed using the Microsoft Fortran 77 compiler and associated linker for IBM-PCs and compatible microcomputers. With the exception of the timing and date routines, which are marked clearly in the code, there are no system-dependent features.

Users wishing to implement the code using an alternative compiler may expect to modify the OPEN statements for units 1 (input), 2 (output), and 3 (plot file) and either remove calls to the date and time functions or replace them with equivalent subroutines.

It is assumed that unit 0 is the monitor and the keyboard, and it is via those devices that the user is prompted for, and responds to requests for, the names of the input and output fields. Under MS-DOS, the user can circumvent these interactions by creating a small batch file in which the names of the input and output files are piped at execution time. However, progress messages will still be sent to unit 0 during execution of the code. Different arrangements may be necessary on other computers or operating systems.

The maximum size of problem that can be analyzed using the HEFF code is determined by the parameter LIMIT in the main program. This is currently set at a value of 100, which is the maximum number of elements, heat sources, or sample lines that can be used in any one problem. There may be as many points as desired on each sample line, although the number of points along lines generated normal to boundary elements should be restricted to 10 if the postprocessor is to be used. The minimum recommended configuration for an IBM-PC or compatible microcomputer is

512K RAM
360K Floppy Disk Drive
8087/80287 Math Coprocessor

The executable version of the code used for the sample and verification problems described in this report was developed using Version 4.1 of the Microsoft Fortran 77 optimizing compiler and run under Version 3.2 of MS-DOS. Execution times given in output reproduced in this report are typical of an IBM PC-AT operating at 8 MHz.

4. VERIFICATION

4.1 Introduction

This section of the documentation describes measures taken to verify the computer software. That is, the measures taken to assure that the mathematical formulation has been correctly translated into computer code are described. Those measures include detailed comparison with four independent analytical solutions for identical or similar problems and also with independent analyses using alternative numerical procedures.

4.2 Code Verification

The purpose of this section is to demonstrate that the mathematical formulations described in Section 2 have been correctly translated into computer code. First, the adequacy of the mechanical model is demonstrated by comparison with the results of closed-form solutions for a thick circular cylinder subjected to external pressure and for a circular hole in an infinite medium with biaxial initial stress. Second, the adequacy of the thermal and thermal-mechanical submodel is demonstrated through detailed comparison with the results of three-dimensional analyses using a computer code based on the closed-form solution for point heat sources. Third, integration of the mechanical and thermal models is demonstrated by comparison with the closed-form solution for a heated thick-walled cylinder and a heat-generating layer within a semi-infinite medium. Finally, the results of analysis of an emplacement drift within a potential nuclear waste repository are compared with those obtained for the same problem using a finite-element model.

4.2.1 Analysis of a Thick-Walled Cylinder Subject to External Pressure

Objective

To verify the mechanical submodel within the HEFF code.

Code Capabilities Exercised

- o Analysis of a finite body defined by two surfaces
- o Definition of plane of symmetry at x = 0
- o Application of boundary traction (pressure)
- o Calculation of displacements and stresses at the boundary and internal sample points

Physical Problem

An initially unstressed thick-walled cylinder is subjected to an external pressure. The cylinder is assumed to be long so plane strain conditions apply. The geometry and material properties for the problem are

Inner Radius (a)	= 4. m
Outer Radius (b)	= 6. m
External Pressure (P)	= 6 MPa
Elastic Modulus (E)	= 60 GPA
Poisson's Ratio (ν)	= 0.25

The physical problem is illustrated in Figure 13a.

Assumptions

The material of the cylinder is homogeneous and isotropic and the strains are small.

Analytical Solution

The solution for the radial (σ_r) and hoop stress (σ_θ) for this problem is provided by Timoshenko and Goodier (1970)

$$\sigma_r = \frac{pa^2b^2}{(b^2-a^2)r^2} - \frac{pb^2}{(b^2-a^2)}$$

$$\sigma_\theta = -\frac{pa^2b^2}{(b^2-a^2)r^2} - \frac{pb^2}{(b^2-a^2)}$$

in which r is the radial coordinate and both σ_r and σ_θ are independent of θ.

The out-of-plane stress can be calculated using the condition that the out-of-plane strain is zero. Specifically

$$\sigma_z = \nu(\sigma_r + \sigma_\theta).$$

The radial displacement (u_r) can be calculated from the relationship

$$u_r = r\epsilon_\theta$$

in which ϵ_θ is the hoop strain, which can be calculated from the stress state using

$$\epsilon_\theta = [\sigma_\theta - \nu(\sigma_r + \sigma_z)]/E$$

$$= [\sigma_\theta(1 - \nu^2) - \nu\ \sigma_r(1 + \nu)]/E$$

Computer Model

The boundary-element model is represented schematically in Figure 13b and input to the HEFF code is reproduced in Figure 14. The model is defined by two semicircular segments, each subdivided into 23 equal length elements. All boundary elements have prescribed shear and normal stresses, i.e., are assigned boundary code KODE = 1. Note that the interior boundary is defined in a counterclockwise sense, while the exterior boundary is defined in a clockwise sense. The solid always lies to the right as the boundary elements are generated.

Results

Complete output for this problem is reproduced in Appendix B. A comparison of computed and "exact" displacements and stresses is provided by Table 4. As indicated by Table 4, agreement between two solutions is generally on the order of 1 to 2 percent for the hoop stress and radial displacement. The radial stresses appear to be relatively inaccurate toward the inner boundary. This is attributed to two factors. First, the stress gradient is relatively high close to the inner surface. Second, the boundary-element mesh generator generates linear segments with center points along an arc of a specified radius. Thus, the average inner radius of the boundary-element model of the cylinder is slightly

greater than assumed in the analytical solution. An improved solution was obtained when additional elements were used to define boundaries.

4.2.2 Analysis of Creation of a Cylindrical Hole in an Initially Stressed Elastic Medium

Objective

To verify the mechanical submodel within the HEFF code.

Code Capabilities Exercised

- o Analysis of a hole in an unbounded medium
- o Relaxation of an initial stress state
- o Definition of a plane of symmetry at x = 0
- o Calculation of displacements and stresses at the boundary and internal sample points

Physical Problem

An infinitely long cylindrical hole is created in an elastic medium with uniform biaxial initial stress. The hole is created in one step and induced displacements and total stresses are calculated. Because the hole is infinitely long, plane strain conditions are assumed. The geometry, initial conditions, and material properties for the problem are

Radius of Hole (a)	= 5 m
Initial Horizontal Stress (σ^{o}_{xx})	= 30 MPa
Initial Vertical Stress (σ^{o}_{yy})	= 15 MPa
Initial Out-of-Plane Stress (σ^{o}_{zz})	= 0 MPa
Elastic Modulus (E)	= 60 GPa
Poisson's Ratio (ν)	= 0.25

The physical problem is illustrated in Figure 15a.

Assumptions

The material in which the hole is created is homogeneous and isotropic and the strains are small.

Analytical Solution

The analytical solution for the total radial (σ_r) and hoop (σ_θ) stresses after excavation is given by Jaeger and Cook (1976)

$$\sigma_r = \frac{\overset{\circ}{\sigma}_x + \overset{\circ}{\sigma}_y}{2}\left(1 - \frac{a^2}{r^2}\right) + \frac{\overset{\circ}{\sigma}_x - \overset{\circ}{\sigma}_y}{2}\left(1 - \frac{4a^2}{r^2} + \frac{3a^4}{r^4}\right)\cos 2\theta$$

$$\sigma_\theta = \frac{\overset{\circ}{\sigma}_x + \overset{\circ}{\sigma}_y}{2}\left(1 + \frac{a^2}{r^2}\right) - \frac{\overset{\circ}{\sigma}_x - \overset{\circ}{\sigma}_y}{2}\left(1 + \frac{3a^4}{r^4}\right)\cos 2\theta$$

in which both σ_r and σ_θ are functions of the radial distance r from the center of the hole and the angle θ, which is measured counterclockwise relative to the positive x-axis. The out-of-plane stress can be calculated, given the condition that the induced out-of-plane strain is zero

$$\sigma_z = \overset{\circ}{\sigma}_z - 2\nu\frac{a^2}{r^2}(\overset{\circ}{\sigma}_x - \overset{\circ}{\sigma}_y)\cos 2\theta$$

The radial displacement that accompanies relaxation of the initial stress state once the hole is created is given by

$$u_r = \frac{(1+\nu)a^2}{2Er}\left[(\overset{\circ}{\sigma}_x + \overset{\circ}{\sigma}_y) + (\overset{\circ}{\sigma}_x - \overset{\circ}{\sigma}_y)(4-4\nu-\frac{a^2}{r^2})\cos 2\theta\right]$$

Computer Model

The boundary-element model is illustrated schematically in Figure 15b, and input for the HEFF code is reproduced in Figure 16. The model is defined by a single semicircular segment, divided into 49 straight line elements of equal length.

Results

Complete output for this problem is reproduced in Appendix B and a comparison of the computed and "exact" displacements and stresses is provided by Table 5. The distribution of stress is illustrated in Figure 17. As indicated, the agreement between the closed-form and boundary-element solutions is good, except for the radial stresses close to the boundary of the hole. As in the case of the thick-walled cylinder, the lack of agreement between the predictions of the radial stress is attributed to the stress gradient and the approximation of a circular profile used in the boundary-element model.

4.2.3 Verification of Temperature and Thermal Stress Calculations

Objective

To verify the thermal submodel within the HEFF Code.

Code Capabilities Exercised

- o Analysis of a single constant strength source
- o Analysis of single decaying source
- o Analysis of general time-varying sources

Physical Problem

A single line source is located within an infinite, linear elastic medium. The physical properties of the medium are

Elastic Modulus (E)	= 15,100 MPa
Poisson's Ratio (ν)	= 0.2
Thermal Expansion Coefficient (α)	= 10.7×10^{-6} °C^{-1}
Thermal Diffusivity (κ)	= 29.03 m^2/yr

The following alternatives for the time-varying characteristics of the sources are considered.

Case A: Constant source, strength 4140 m^3°C/yr/m

Case B: Exponentially decaying source

Initial strength (Q_o) = 4140 m^3°C/yr/m

Decay constant (λ) = 0.025 (half life = 27.7 years)

Case C: Exponentially decaying source

Initial strength (Q_o) = 4140 m^3°C/yr/m

Decay constant (λ) = 0.25 (half life = 2.77 years)

Case D: Arbitrary time varying source

Initial strength (Q_o) = 4140 m^3°C/yr/m

Decay characteristics and proportional contributions

$$
\begin{aligned}
Q(t) = Q_o(&0.15602 \exp(-0.0013539t) \\
&+ 0.59787 \exp(-0.019142t) \\
&+ 0.15227 \exp(-0.051888t) \\
&+ 0.093840 \exp(-0.43768t))
\end{aligned}
$$

Physically, the problem appears as a point source in a cross section normal to the line source.

Assumptions

The material in which the source is embedded is linearly elastic, homogeneous, isotropic, and of infinite extent. The strains are small.

Analytical Solution

The thermal submodel within HEFF is itself a closed-form solution, even though evaluation of the equation does involve numerical approximation. Hence comparison, in the sense used in the previous verification problems, is not possible. Instead, an approximate three-dimensional solution for the infinite line source is constructed by defining, in three dimensions, a large number of point heat sources that lie along the line represented in the two-dimensional model.

The solutions for constant and decaying heat sources in an infinite elastic body is given by Crouch and McClain (1977). Briefly, these are

$$T = \frac{V_3}{\pi^{3/2}}$$

$$\sigma_{rr} = \frac{mG}{\pi r^2}\left\{\frac{V_1}{r} - \frac{2V_2}{\sqrt{\pi}}\right\}$$

$$u_r = -\frac{m}{4\pi r^2}\left\{\frac{V_1}{r} - \frac{2V_2}{\sqrt{\pi}}\right\}$$

in which $m = \alpha(1+\nu)/(1+\nu)$, G is the shear modulus, ν is Poisson's ratio, α the expansion coefficient, and r the radial distance from the source to the sample point. The three functions V_1, V_2, and V_3 differ depending on whether the source is constant or time-varying.

For a constant strength source, the functions are defined by

$$V_1(r,t) = Q_c\left\{t \cdot \mathrm{erf}\frac{r}{\sqrt{4\kappa t}} - \frac{r^2}{2\kappa} \cdot \mathrm{erfc}\frac{r}{\sqrt{4\kappa t}} + \sqrt{\frac{t}{\pi\kappa}} \cdot r \cdot \exp\left(\frac{-r^2}{4\kappa t}\right)\right\}$$

$$V_2(r,t) = Q_c\left\{\sqrt{\frac{t}{\kappa}} \cdot \exp\left(\frac{-r^2}{4\kappa t}\right) - \frac{\sqrt{\pi}}{2\kappa} \cdot r \cdot \mathrm{erfc}\left(\frac{r}{\sqrt{4\kappa t}}\right)\right\}$$

$$V_3(r,t) = Q_c \frac{\sqrt{\pi}}{4\kappa} \cdot \frac{1}{r} \cdot \mathrm{erfc}\left(\frac{r}{\sqrt{4\kappa t}}\right)$$

where $\mathrm{erfc}(z) = 1 - \mathrm{erf}(z)$ is the complementary error function.

For a source described by the relationship $Q(t) = Q_o\exp(-\lambda t)$, the functions are defined by

$$V_1(r,t) = Q_o\left\{-\frac{1}{\lambda} \cdot \exp(-\lambda t) + \frac{1}{\lambda}\left[\mathrm{erf}\left(\frac{r}{\sqrt{4\kappa t}}\right) + \exp\left(\frac{-r^2}{4\kappa t}\right) \cdot \mathrm{Re}\left\{\omega\left(\sqrt{\lambda t} + i\frac{r}{\sqrt{4\kappa t}}\right)\right\}\right]\right\}$$

$$V_2(r,t) = Q_o \cdot \frac{\sqrt{\pi}}{\sqrt{4\kappa\lambda}} \cdot \exp\left(\frac{-r^2}{4\kappa t}\right) \cdot \mathrm{Im}\left\{\omega\left(\sqrt{\lambda t} + i\frac{r}{\sqrt{4\kappa t}}\right)\right\}$$

$$V_3(r,t) = Q_o \cdot \frac{\sqrt{\pi}}{4\kappa r} \cdot \exp\left(\frac{-r^2}{4\kappa t}\right) \cdot \mathrm{Re}\left\{\omega\left(\sqrt{\lambda t} + i\frac{r}{\sqrt{4\kappa t}}\right)\right\}$$

where $\omega(z) = \frac{2iz}{\pi}\int_0^\infty \frac{e^{-t^2}}{z^2-t^2}\,dt$ (with $\mathrm{Im}\{z\} > 0$) is the complex error function, and Re and Im designate real and imaginary parts.

These equations have been incorporated within a computer program, named STRES3D (see Asgian et al., 1991 for Version 4.0), that allows point sources to be distributed according to a user-defined pattern within planes in an infinite elastic body.

Computer Model

For HEFF, the model comprises a single source located anywhere in the medium. This arrangement is approximated using STRES3D by locating 500 heat sources at intervals of 2 m along a line 1000 m in length. The strength of each source at the time of emplacement is 8280 m^3°C/yr (equal to the product of the strength per unit length and the spacing).

Results

Comparison of the temperatures, displacements, and stress computed using the HEFF and STRES3D computer codes is provided in Tables 6 through 9. Generally, correspondence between the two solutions is excellent. Minor differences observed very close to the source are attributed to the finite spacing of the point sources in the three-dimensional model.

Additional details of verification of the thermal and thermal-mechanical submodel in HEFF is provided by Lindner et al. (1984). In particular, several tests on the convergence of the infinite series needed to obtain the solution of exponentially decaying sources are described.

4.2.4 Thermoelastic Response of a Hollow Cylinder

Objective

To verify the thermal-mechanical model within the HEFF code.

Code Capabilities Exercised

- Analysis of a solid body defined by two surfaces
- Definition of a plane of symmetry at x = 0

- Application of thermal stress by means of an out-of-plane line heat source
- Coupling of mechanical submodel to thermal submodel

Physical Problem

An initially unstressed thick-walled cylinder is heated by placing line heat source at its center. The cylinder is assumed to be infinitely long so plane strain conditions apply. The geometry and material properties are

Inner Radius (a)	= 4.0 m
Outer Radius (b)	= 6.0 m
Elastic Modulus (E)	= 6×10^4 MPa
Poisson's Ratio (ν)	= 0.25
Coefficient of Linear Thermal Expansion (α)	= 6×10^{-6} °C^{-1}
Thermal Conductivity (K)	= 1.0 W/m°C
	= 3.156×10^7 J/yr m°C
Specific Heat (c)	= 850 J/kg°C
Density (ρ)	= 2950 kg/m^3
Heat Capacity (ρc)	= 2.51×10^7 J/m^3°C
Thermal Diffusivity (κ)	= 4.0×10^{-7} m^2/s
	= 12.623 m^2/yr
Heat Source Intensity (Q_o)	= 250 W/m
Heat Source Strength	= $\frac{Q_o}{\text{Heat Capacity}}$
	= 3143.0°m^3°C/yr/m

The physical problem is the same as that illustrated in Figure 13, except a line heat source is located at the axis of the cylinder. Clearly, the problem is not entirely realistic since the heat source is actually placed outside the material of the cylinder. However, the purpose of the arrangement is to develop a simple boundary value problem with a prescribed temperature distribution.

Assumptions

The material of the cylinder is homogeneous and isotropic and the strains are small.

Analytical Solution

The solution for the radial (σ_r) and hoop (σ_θ) stresses within a thick cylinder with known temperature distribution is given in Timoshenko and Goodier (1970).

$$\sigma_r = \frac{\alpha E}{(1-\nu)r^2} \left[\frac{r^2-a^2}{b^2-a^2} \int_a^b Trdr - \int_a^r Trdr \right]$$

$$\sigma_\theta = \frac{\alpha E}{(1-\nu)r^2} \left[\frac{r^2+a^2}{b^2-a^2} \int_a^b Trdr + \int_a^r Trdr - Tr^2 \right]$$

$$\sigma_z = \nu(\sigma_r + \sigma_\theta) - E\alpha T$$

where r is the radial coordinate and T is the temperature change from the base temperature and compressive stresses are negative.

Similar to the first verification problem, the radial displacement (u_r) can be calculated from the relationship

$$u_r = r\epsilon_\theta$$

in which ϵ_θ is the hoop strain that can be calculated from the stress state using

$$\epsilon_\theta = (\sigma_\theta - \nu(\sigma_r + \sigma_z))/E + \alpha T$$

Computer Model

The boundary-element model for this problem is the same as for an unheated cylinder, illustrated by Figure 13b; the input file is reproduced in Figure 18. The model is defined by two semicircular segments, each subdivided into 29 equal

length elements. Shear and normal stresses are prescribed for the boundary elements (i.e., KODE = 1).

Results

To derive the closed-form solution, a second order fit to the temperatures computed using the HEFF code was obtained. For the particular sample time (five years) this was

$$T(r) = 95.10 - 16.25\nu + 0.89r^2$$

The closed-form solution was then evaluated by performing the necessary integrations. The results are listed in Table 10, together with the corresponding values obtained using the HEFF code.

When assessing the measure of agreement between the two solutions, it is important to recall the physical approximations assumed in the HEFF analysis. Since the heat source is treated as though it is located within an infinite elastic domain, the thermally induced displacements and stresses are being computed for a problem that is very different from the one we seek to solve. However, the mechanical model within HEFF does ensure that all the mechanical boundary conditions are satisfied.

Despite the approximations of the HEFF model, the agreement between the closed-form and boundary-element solutions is generally satisfactory. Qualitatively, the distributions of displacement and stress (Figure 19) are correct. Thus, the mechanical and thermal models are correctly coupled and the thermally induced displacements and stresses can be computed as though for an infinite elastic domain, even in the extreme circumstances investigated here.

4.2.5 Analysis of Heat Generation Within a Layer in a Semi-Infinite Body

Objective

To verify the coupling between the mechanical and thermal-mechanical submodel.

Code Capabilities Exercised

- Definition of a constant temperature horizontal surface
- Definition of a plane of symmetry about x = 0 for both thermal and mechanical models
- Definition of mixed boundary conditions
- Definition of a free surface by boundary elements
- Calculation of temperatures, displacements, and stresses at boundary and interior points

Physical Problem

Heat is generated at a constant rate within a thin layer of infinite lateral extent that lies parallel to the surface of a half-space. The geometry, material properties, and heat generation for the problem are

Depth of Layer Below Surface (d)	100 m
Thickness of Layer (2L)	5 m
Thermal Diffusivity of Medium (κ)	12.62 m^2/yr
Thermal Expansion Coefficient (α)	$6*10^{-6}/°C$
Elastic Modulus (E)	60 GPa
Poisson's Ratio (ν)	0.25
Heat Generation Per Unit Volume	10 W/m^3

The physical problem is illustrated in Figure 20a. It is assumed that the material properties of half-space are uniform, so the layer differs from the rest of the medium only in that heat is generated uniformly within it.

Assumption

The material of the half-space is homogeneous and isotropic and the strains are small.

Analytical Solution

The temperature distribution within an infinite region due to heat generation within a layer of thickness 2L is given by Carslaw and Jaeger (1959) as

$$T = \frac{2\dot{\kappa}Q_o}{K}\left\{i^2\text{erfc}\,\frac{y-L}{2\sqrt{\kappa t}} - i^2\text{erfc}\,\frac{y+L}{2\sqrt{\kappa t}}\right\} \qquad \text{for } y > L$$

In this equation, the function $i^2\text{erfc}(x)$ is the second repeated integral of the error function and can be evaluated from

$$i^2\text{erfc}(x) = \frac{1}{4}\left[(1+2x^2)\text{erf}(x) - \frac{2}{\sqrt{\pi}}\,x\,\exp(-x^2)\right]$$

in which erfc(x) is the complementary error function and is defined as [1-erf(x)].

The solution for the case of a semi-infinite body with the layer located at depth d below an isothermal surface at y = 0 can be obtained using the method of images.

$$T = \frac{2\kappa Q_o t}{K}\left\{i^2\text{erfc}\,\frac{d+y-L}{2\sqrt{\kappa t}} - i^2\text{erfc}\,\frac{d+y+L}{2\sqrt{\kappa t}} - i^2\text{erfc}\,\frac{d-y-L}{2\sqrt{\kappa t}} + i^2\text{erfc}\,\frac{d-y+L}{2\sqrt{\kappa t}}\right\}$$

Since the layer is infinite and parallel to the free surface, both the thermal and thermal-mechanical problems are one-dimensional. As there is no restriction on the vertical movement of the surface, the vertical stress must remain zero at all times.

$$\sigma_y = 0$$

The corresponding horizontal stresses can be obtained from the condition that there can be no horizontal strain.

$$\sigma_x = \sigma_z = \frac{E\alpha T}{(1-\nu)}$$

Since the distribution of T was defined as a function of depth y and time t, the corresponding distributions of the horizontal stresses can be calculated. The vertical expansion of the column of material between the heat-generating layer and the surface can be shown to be

$$\delta_v = \frac{(1+\nu)\alpha}{(1-\nu)}\int_{-d}^{0} T\,dy$$

The integral can be evaluated numerically.

Computer Model

Several approximations are required before this problem can be analyzed using the HEFF code. First, generation of heat within a layer must be replaced by equivalent line heat sources. In the present instance, these sources were assumed to be located on the midplane of the heat-generating layer, spaced at intervals of 5 meters. The strength of each heat source was 250 W/m, or $3.156*10^8$ J/yr/m. Second, HEFF cannot represent the infinite extent of either the heat-generating layer or the surface of the half-space. In one model, the heat-generating layer was extended to 300 m either side of the centerline and to 2000 m at the surface. Analysis performed using that model revealed a very distinct curvature of the free surface. This was assumed to be a result of the finite extent of the heat-generating layer. As an alternative to attempting a model with greater lateral extent, a vertical boundary 160 m from the model centerline was added. This is analogous to a plane of symmetry, and provides a better approximation to a heated layer of infinite extent. Boundary conditions prescribed for that boundary are zero normal displacement and zero shear stress (i.e., KODE = 4). The revised model, which is illustrated schematically in Figure 20b, provided a better approximation to the exact solution, as well as data for that model which is reproduced in the following section. The heat sources extend beyond the vertical boundary to ensure the temperature, displacements, and stresses due to the heat sources are adequately approximated within the central region of the model. There is no provision within HEFF to prescribe adiabatic vertical boundary for the thermal submodel. Figure 21 shows the HEFF input for this problem.

Results

A comparison of the temperatures and stresses predicted by the two models, after 100 years of heat generation, is provided by Table 11. The displacements could have been listed for either the midplane of the layer or the free surface. Instead, the total expansion of the material between the surface and the layer was calculated. The closed-form solution given above predicts 0.309 m, while a value of 0.308 m was obtained using HEFF.

The data presented in Table 11 indicates that the HEFF solution satisfies both temperature and stress boundary conditions at the free surface and provides an excellent approximation to the temperature field throughout. There are minor

differences in the computed temperature near the heat source, but this can be attributed to real differences in the nature of the heat source. It is reasonable that the temperatures should be slightly lower in the boundary-element solution because all heat is generated in a plane 100 m below the surface. For the closed-form solution, the heat is distributed over a five meter thick layer.

Agreement between the stresses computed from the closed-form solution and by the boundary-element model, as illustrated in Figure 22, is generally considered excellent, particularly near the heat sources. The analytical solution predicts that the horizontal stresses should be equal, whereas there are minor differences between the in-plane and out-of-plane stresses in the results of the HEFF analysis (because the line heat sources used in the HEFF code are infinitely long out of the plane of the section, but only a finite number are defined in the plane of the section). The vertical stresses remain essentially zero, as predicted by the analytical solution.

4.2.6 Near-Field Analysis of an Emplacement Drift

Problem Statement

This problem consists of transient thermal simulation of the near-field single-room region of a hypothetical repository in a tuff rock mass and static stress analysis at specified times. A complete description of the problem and additional results are presented in the report SAND86-7005, entitled "Reference Thermal and Thermal/Mechanical Analysis of Drifts for Vertical and Horizontal Emplacement of Nuclear Waste in a Repository in Tuff (St. John, 1987)". In the interest of brevity, only the results of analysis of the vertical emplacement drift are presented here.

Objectives

The objective of this test problem is to demonstrate that the code provides an acceptable means of modeling heat transfer and the state of stress induced by both the in-situ stress and the thermal loading. The particular case under consideration is that of emplacement of waste containers within vertical holes in the floor of an unventilated drift. Comparison of the results of analysis using the HEFF code with those obtained using a finite-element code

verifies the modeling strategy used and provides a basis for assessing the consequences of the approximate thermal analysis model used by the boundary-element code.

Physical Description

Geometrical data for the emplacement drift and the emplacement boreholes are given in Table 12; thermal and thermal-mechanical data are given in Table 13. The geometrical configuration is also illustrated schematically in Figure 23.

The nuclear waste is assumed to comprise a mix of PWR and BWR spent fuel that has been stored for an average of 8.55 years since removal from the reactors. Its power generation, as a function of time, is defined by the following normalized decay function

$$P(t) = 0.15601\exp(-0.00135t) + 0.59787\exp(-0.01914t) + 0.15227\exp(-0.05188t) + 0.09384\exp(-0.43708t)$$

in which t is time in years since emplacement. For each drift, the thermal loading at the time of emplacement is equivalent to 590.5 W/m.

Assumptions

The problem is solved as one of two-dimensional plane strain. In the case of the finite-element model, the room and pillar centerlines are treated as vertical planes of symmetry, thereby simulating an infinite array of such drifts. In the case of the boundary-element model, the potential repository is assumed to comprise 37 parallel drifts 300 m below the ground surface. A plane of symmetry through the middle of the central drift is imposed, thereby requiring that the location of only 19 drifts be explicitly represented in the model (see Figure 23).

The boundary-element approximation to the real problem is shown in Figure 24. In Figure 24a, the repository scale illustrating the surface and edge boundary elements and the heat source locations is shown. In Figure 24b, the detailed representation of the central room is shown. Boundary elements were used to represent the next adjacent room (illustrated in Figure 23). Drifts further from

the centerline are assumed to have no influence on the state of stress and deformation around the central drift and therefore are not modeled. However, the effect of the emplaced, heat-generating waste at each drift location is considered. The edge boundary elements with the condition of no lateral deformation were imposed, simulating the far-field effect of the free surface as in Example 5. This approach gave superior results to modeling the surface with stress-free boundary elements out to 1000 meters.

The ground surface is assumed to be isothermal; heat equivalent to 590.5 W/m is input at each drift location. For the finite-element model, this input is distributed uniformly over the container as it appears in the cross section of the drift. For the boundary-element model, the emplaced containers are approximated by line heat sources. In the case of the central drift, around which temperature, displacements, and stresses are calculated, the heat generated by the container is approximated by three line heat sources approximately 3.8 m, 5.3 m, and 6.9 m below the centerline of the floor of the drift. The strength of each of those sources is given by

$$\text{Strength} = \frac{1}{3}\frac{Q_o}{\rho c} = \frac{590.5}{3 \cdot 2.25}\frac{\text{W/m}}{\text{J/cm}^3\,^\circ\text{C}} = 2760.7\ \text{m}^3\,^\circ\text{C/yr/m}$$

in which Q_o is the initial thermal loading of the drift and ρ and c are respectively the density and specific heat capacity. At all other locations the emplaced containers are approximated by a single line heat source at midheight.

Since the thermal model in the HEFF code is based on the solution for a line heat source in an infinite medium, the thermal and thermal stress analyses are performed as though the drift is not present. This situation corresponds reasonably closely with that of an unventilated drift. That condition was simulated in the finite-element model by ascribing to the air in the drift an effective thermal conductivity of 80 W/m°C, and density and specific heat capacity of 1.0 kg/m^3 and 1 KJ/kg°C, respectively. The rationale for selection of the value of effective thermal conductivity is discussed by St. John (1987).

Input Specifications

Details of the boundary-element idealization of the model are provided in Figure 24. The second drift, which is located approximately 34 m from the model

centerline, was modeled using 16 elements to define its circumference. The internal sample points marked on Figure 24b are points at which data is generated for postprocessing. The vertical edge was modeled using 20 boundary elements located at x = 324 m and extending from y = 0 to y = -600 meters. The image heat source option has been used to enforce an isothermal boundary at the ground surface. The strengths of the heat sources beneath the central drift have been halved because they lie upon the imposed plane of symmetry (x = 0). A complete listing of input for analysis of conditions 10 years after waste emplacement is reproduced in Figure 25. Data for other sample times is identical, with the exception of the value for the time.

Output

A complete file for the the sample data set is reproduced in Appendix B. A comparison of the results of the boundary-element and finite-element analyses is provided in Table 14. The results of postprocessing output data from both boundary-element and finite-element analyses, using the rock mass strength data listed in Table 13 and a Mohr-Coulomb strength model, are reproduced in Figure 26.

Discussion

In general, the agreement between the results of the two numerical simulations is excellent. Some differences between the predicted temperatures around the drift may be observed. There is almost no temperature gradient across the drift in the case of the finite-element model because the air in the drift was assumed to have a high thermal conductivity and low heat capacity, in contrast to the boundary-element model in which, in effect, the air is assumed to have the same thermal properties as the rock mass. Despite this difference, the predicted temperatures at the midheight of the drift compare very favorably with one another. The stresses and displacements also agree favorably. Postprocessing to determine contours of the ratio of the rock mass strength to the computed stress state provides nearly identical results, even given differences in the location and density of sample points used to develop the plots.

4.2.7 Conclusion From Verification Studies

The verification studies described in this section provide definitive evidence of the accuracy of the HEFF code when performing mechanical stress analyses. These findings are consistent with reports of other investigators, including Crouch and Starfield (1983). It is concluded that HEFF is appropriate for mechanical stress analyses, providing the assumptions of linear elasticity, homogeneity, and elastic isotropy are justifiable. In addition to assuring that these assumptions are justifiable, the user should assure that an adequate number of elements are used to define the boundary of the structure analyzed, by performing sample analyses using different element densities.

The verification studies also serve to clarify the numerical and physical approximations inherent in the thermal and thermal-mechanical models. Despite these approximations, the computed values for temperature, displacement, and stress appear to be in good agreement with both closed-form solutions and an independent finite-element analysis. Accordingly, the code is recommended for simple thermal-mechanical analyses. However, any such analysis should be primarily of a scoping nature and the user should carefully evaluate the possible consequences of the physical approximations imposed by the code.

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TABLE 1

COMPARISON OF TABULATED AND COMPUTED VALUES OF THE EXPONENTIAL INTEGRAL

x	-Ei(-x)	Equation (51)	Equation (49) Terms in Series 11	13	15
0.01	4.03793[1]	$0.1672*10^{11}$	4.03793	4.03793	4.03793
0.10	1.82292[1]	$0.1443*10^{6}$	1.82292	1.82292	1.82292
0.30	0.90568[1]	$0.4345*10^{3}$	0.90568	0.90568	0.90568
0.50	0.55977[2]	$0.2551*10^{2}$	0.55977	0.55977	0.55977
0.80	0.31059[2]	$0.1863*10^{1}$	0.31060	0.31060	0.31060
1.00	0.21938[2]	0.61077	0.21938	0.21938	0.21938
2.00	0.04890[2]	0.05064	0.04890	0.04890	0.04890
3.00	0.01305[3]	0.01364	0.01312	0.01305	0.01305
3.20	0.01013[3]	0.01056	0.01030	0.01014	0.01013
3.40	0.00789[3]	0.00820	0.00822	0.00791	0.00789
3.60	0.00616[3]	0.00639	0.00682	0.00620	0.00616
3.80	0.00482[3]	0.00499	0.00658	0.00491	0.00482
4.00	0.00378[3]	0.00391	0.00604	0.00396	0.00379
5.00	0.00115[3]	0.00118	0.03234	0.00495	0.00150
9.00	0.00001[2]	0.00001	29.65	11.92	3.67

Notes: 1: Derived from tabulated values of $x^{-1}\left[E_1(x) + \ln x + \gamma\right]$

2: Tabulated as $E_1(x)$

3: Derived from tabulated values of $xe^{x}E_1(x)$

Reference: Gautschi and Cahill, 1980

TABLE 2

COMPUTED VALUES OF THE RADIAL STRESS (MPa)
FOR VARIOUS SAMPLE POINTS AND AT VARIOUS TIMES

Time (yrs)	Sample Point 0.1	1.0	10.0	Distance (m) From Source 100.0	500.0
1	1.753	0.924	0.16	---	---
10	0.970	0.633	0.288	0.013	---
50	0.069	0.063	0.056	0.018	---
100	0.024	0.023	0.022	0.013	0.0008
200	0.014	0.011	0.010	0.008	0.0008
300	o.f.	0.007	0.006	0.006	---
400	o.f.	o.f.	0.005	0.005	---
500	---	---	---	---	---

Note: o.f. indicates numerical overflow

TABLE 3

OUTPUT FILE NOMENCLATURE

Name	Meaning
UX/UY	x/y displacements for element center or sample point
US/UN	Shear/normal displacements of element center
SIGXX/YY	Normal stress in xx/yy direction
SIGXY	Shear stress acting on the plane normal to the x-axis
SIGZZ	Out-of-plane normal stress
SIGMA-S	Shear traction on boundary element
SIGMA-N	Normal traction on boundary element
SIGMA-T	Tangential stress, parallel to element surface
SIG1	More compressive, in-plane principal stress
SIG2	Less compressive, in-plane principal stress
ALPHA	Angle of SIG1, measured counterclockwise from x

Note: See Figure 4 for a definition of global and local coordinate frames. Displacements, stress, and tractions are treated as positive if acting against the positive coordinate direction. These sign conventions are illustrated in Figure 8.

TABLE 4

COMPARISON OF ANALYTIC AND HEFF ANALYSES FOR DISPLACEMENTS AND STRESSES IN A THICK-WALLED CYLINDER SUBJECT TO EXTERNAL PRESSURE

	Analytical Solution				HEFF							
Radial Distance (m)	Radial Displacement (mm)	Radial Stress (MPa)	Hoop Stress (MPa)	Out-of-Plane Stress (MPa)	Radial Displacement (mm)	E*	Radial Stress (MPa)	E	Hoop Stress (MPa)	E	Out-of-Plane Stress (MPa)	E
4.0	1.350	0.00	21.60	5.40	1.370	+1.16	0.00	0	21.58	-0.09	5.40	0
4.4	1.313	1.87	19.73	5.40	1.334	+1.16	1.64	-12.3	19.94	+1.06	5.40	0
4.8	1.290	3.30	18.30	5.40	1.309	+1.5	3.09	- 6.36	18.49	+1.04	5.40	0
5.2	1.277	4.41	17.19	5.40	1.295	+1.4	4.23	- 4.08	17.35	+0.93	5.40	0
5.6	1.273	5.29	16.31	5.40	1.289	+1.3	5.15	- 2.65	16.43	+0.74	5.40	0
6.0	1.275	6.00	15.60	5.40	1.287	+1.2	6.00**	0	15.58	-0.13	5.40	0

* E = Percent Difference Between Solutions
** Results for Element 74, See Appendix B, Point (6.0) is Outside HEFF Model

TABLE 5

COMPARISON OF ANALYTIC AND HEFF ANALYSIS FOR DISPLACEMENTS AND STRESSES AROUND A CIRCULAR HOLE IN AN ELASTIC PLATE WITH BIAXIAL INITIAL STRESS STATE

	Analytical Solution*				HEFF*							
Radial Distance (m)	Radial Dis-place-ment (m)	Radial Stress (MPa)	Hoop Stress (MPa)	Out-of-Plane Stress (MPa)	Radial Displacement (m)	E**	Radial Stress (MPa)	E	Hoop Stress (MPa)	E	Out-of-Plane Stress (MPa)	E
5.00	-3.906	0.00	15.00	-7.50	-3.960	+1.41	0.00	0.0	15.00	0.0	-7.50	0.0
5.40	-3.720	1.53	17.75	-6.43	-3.774	+1.45	1.19	-22.2	17.69	-0.34	-6.53	+1.56
5.80	-3.540	3.41	19.29	-5.58	-3.592	+1.47	3.07	+9.97	19.28	-0.05	-5.66	+1.43
6.20	-3.370	5.37	20.12	-4.88	-3.420	+1.48	5.05	+5.96	20.14	-0.1	-4.95	+1.43
6.60	-3.211	7.28	20.50	-4.31	-3.259	+1.49	6.97	-4.3	20.54	-0.2	-4.37	+1.39
7.00	-3.064	9.07	20.62	-3.83	-3.109	+1.47	8.78	-3.2	20.67	-0.24	-3.89	+1.57
7.40	-2.926	10.72	20.58	-3.43	-2.970	+1.5	10.45	-2.5	20.64	-0.29	-3.48	+1.46

* Data is Presented for a Radial Line Parallel to the Maximum Principal Initial Stress
** E = Percent Difference Between Solutions

TABLE 6

COMPARISON OF STRES3D AND HEFF ANALYSIS FOR TEMPERATURE, STRESS, AND DISPLACEMENTS FOR SINGLE LINE HEAT SOURCE IN AN INFINITE MEDIUM - CASE A, CONSTANT STRENGTH SOURCE

STRES3D

Radial Distance (m)	Temperature (°C) 1	10	100	Radial Stress (MPa) 1	10	100	Radial Displacement (mm) 1	10	100
1	92.41	144.50	196.74	10.69	15.97	21.29	-9.22	-13.41	-17.57
11	4.65	40.53	90.72	1.89	6.28	11.49	-16.54	-54.76	-99.55
21	0.11	16.74	61.99	0.60	3.60	8.56	-10.03	-60.00	-141.10
51	0.00	0.80	25.67	0.10	1.00	4.70	-4.13	-40.13	-186.10
101	0.00	0.00	6.13	0.03	0.27	2.19	-2.05	-20.55	-168.00
151	0.00	0.00	1.17	0.01	0.12	1.17	-1.34	-13.41	-128.60
201	0.00	0.00	0.16	0.01	0.07	0.69	-0.97	-9.76	-96.99

HEFF

Radial Distance (m)	Temperature (°C) 1	10	100	Radial Stress (MPa) 1	10	100	Radial Displacement (mm) 1	10	100
1	95.01	147.10	199.30	11.88	17.15	22.42	-9.44	-13.63	-17.82
11	4.64	40.53	90.73	1.89	6.27	11.44	-16.54	-54.81	-100.00
21	0.11	16.74	61.99	0.60	3.60	8.51	-10.03	-60.00	-142.00
51	0.00	0.80	25.67	0.10	1.00	4.65	-5.16	-40.33	-188.30
101	0.00	0.00	6.13	0.00	0.26	2.14	0.00	-20.94	-172.10
151	0.00	0.00	1.17	0.00	0.12	1.12	0.00	-14.01	-134.60
201	0.00	0.00	0.16	0.00	0.07	0.65	0.00	-10.52	-104.60

TABLE 7

COMPARISON OF STRES3D AND HEFF ANALYSIS FOR TEMPERATURE, STRESS, AND DISPLACEMENTS FOR SINGLE LINE HEAT SOURCE IN AN INFINITE MEDIUM - CASE B, DECAYING SOURCE, λ = 0.025

STRES3D

Radial Distance (m)	Temperature (°C) 1	10	100	Radial Stress (MPa) 1	10	100	Radial Displacement (mm) 1	10	100
1	90.66	117.22	26.54	10.48	12.91	2.81	-0.90	-1.08	-0.23
11	4.61	34.97	17.50	1.87	5.29	1.99	-1.63	-4.61	-1.70
21	0.11	14.98	14.48	0.59	3.10	1.71	-0.99	-5.16	-2.79
51	0.00	0.76	8.70	0.10	0.88	1.23	-0.41	-3.54	-4.82
101	0.00	0.00	2.98	0.03	0.23	0.72	-0.20	-1.82	-5.45
151	0.00	0.00	0.70	0.01	0.11	0.41	-0.13	-1.19	-4.57
201	0.00	0.00	0.11	0.00	0.06	0.25	-0.09	-0.86	-3.54

HEFF

Radial Distance (m)	Temperature (°C) 1	10	100	Radial Stress (MPa) 1	10	100	Radial Displacement (mm) 1	10	100
1	93.20	119.20	26.75	11.64	13.83	2.89	-0.92	-1.10	-0.23
11	4.61	34.97	17.50	1.87	5.28	1.97	-1.63	-4.62	-1.72
21	1.09	14.98	14.48	0.59	3.10	1.69	-0.99	-5.17	-2.82
51	0.00	0.76	8.70	0.10	0.88	1.20	-0.41	-3.56	-4.89
101	0.00	0.00	2.98	0.00	0.23	0.70	0.00	-1.85	-5.60
151	0.00	0.00	0.70	0.00	0.10	0.40	0.00	-1.24	-4.78
201	0.00	0.00	0.11	0.00	0.06	0.24	0.00	-0.93	-3.82

TABLE 8

COMPARISON OF STRES3D AND HEFF ANALYSIS FOR TEMPERATURE, STRESS, AND DISPLACEMENTS FOR SINGLE LINE HEAT SOURCE IN AN INFINITE MEDIUM - CASE C, DECAYING SOURCE, λ = 0.25

STRES3D

Radial Distance (m)	Temperature (°C) 1	10	100	Radial Stress (MPa) 1	10	100	Radial Displacement (mm) 1	10	100
1	76.48	22.22	0.95	8.79	2.36	0.10	-0.76	-0.19	-0.01
11	4.29	11.51	0.94	1.66	1.44	0.10	-1.45	-1.26	-0.08
21	0.11	6.49	0.91	0.53	1.03	0.10	-0.89	-1.71	-0.15
51	0.00	0.50	0.75	0.24	0.36	0.09	-0.36	-1.44	-0.34
101	0.00	0.00	0.38	0.09	0.09	0.06	-0.18	-0.75	-0.49
151	0.00	0.00	0.12	0.02	0.04	0.04	-0.12	-0.49	-0.46
201	0.00	0.00	0.03	0.01	0.03	0.03	-0.09	-0.36	-0.38

HEFF

Radial Distance (m)	Temperature (°C) 1	10	100	Radial Stress (MPa) 1	10	100	Radial Displacement (mm) 1	10	100
1	78.50	22.40	0.00	9.71	2.45	0.00	-0.77	-0.20	0.00
11	4.29	11.50	0.00	1.65	1.44	0.00	-1.45	-1.26	0.00
21	0.11	6.49	0.00	0.53	1.02	0.00	-0.88	-1.71	0.00
51	0.00	0.49	0.00	0.09	0.36	0.00	-0.37	-1.45	0.00
101	0.00	0.00	0.00	0.00	0.10	0.00	0.00	-0.77	0.00
151	0.00	0.00	0.00	0.00	0.04	0.00	0.00	-0.51	0.00
201	0.00	0.00	0.00	0.00	0.02	0.00	0.00	-0.39	0.00

TABLE 9

COMPARISON OF STRES3D AND HEFF ANALYSIS FOR TEMPERATURE, STRESS, AND DISPLACEMENTS FOR SINGLE LINE HEAT SOURCE IN AN INFINITE MEDIUM - CASE D, 4 COMPONENT, DECYAING SOURCE

STRES3D

Radial Distance (m)	Temperature (°C) 1	10	100	Radial Stress (MPa) 1	10	100	Radial Displacement (mm) 1	10	100
1	88.61	110.93	52.45	10.23	12.22	5.62	-0.88	-1.02	-0.46
11	4.56	33.03	28.30	1.84	4.99	3.41	-1.60	-4.36	-2.94
21	0.11	14.18	21.28	0.58	2.93	2.72	-0.97	-4.88	-4.46
51	0.00	0.73	10.85	0.10	0.84	1.71	-0.40	-3.36	-6.74
101	0.00	0.00	3.26	0.03	0.22	0.90	-0.20	-1.72	-6.91
151	0.00	0.00	0.72	0.02	0.10	0.51	-0.13	-1.12	-5.58
201	0.00	0.00	0.11	0.01	0.06	0.31	-0.09	-0.82	-4.28

HEFF

Radial Distance (m)	Temperature (°C) 1	10	100	Radial Stress (MPa) 1	10	100	Radial Displacement (mm) 1	10	100
1	91.08	112.90	53.02	11.36	13.10	5.87	-0.90	-1.04	-0.47
11	4.56	33.04	28.27	1.84	4.99	3.38	-1.61	-4.36	-2.96
21	0.11	14.19	21.24	0.58	2.93	2.69	-0.97	-4.89	-4.49
51	0.00	0.73	10.82	0.10	0.83	1.68	-0.40	-3.96	-6.82
101	0.00	0.00	3.24	0.00	0.22	0.88	0.00	-1.76	-7.07
151	0.00	0.00	0.71	0.00	0.10	0.48	0.00	-1.17	-5.83
201	0.00	0.00	0.11	0.00	0.06	0.28	0.00	-0.88	-4.60

TABLE 10

COMPARISON OF ANALYTIC AND HEFF ANALYSIS OF DISPLACEMENTS AND STRESSES THROUGH A HEATED THICK CYLINDER

	Analytical Solution			HEFF					
Radial Distance	Radial Displacement (mm)	Radial Stress (MPa)	Hoop Stress (MPa)	Radial Displacement (mm)	E*	Radial Stress (MPa)	E	Hoop Stress (MPa)	E
4.0	-1.08	0.00	4.05	-1.031	-4.54	0.00	0.00	4.63	+14.32
4.33	-1.19	0.24	2.40	-1.147	-3.61	0.15	-37.50	3.05	+27.08
4.67	-1.29	0.34	0.96	-1.251	-3.02	0.30	-11.76	1.60	+66.67
5.0	-1.38	0.35	-0.25	-1.345	-2.54	0.34	0.00	0.35	---
5.33	-1.47	0.28	-1.30	-1.431	-2.65	0.31	+10.71	-0.72	-44.62
5.67	-1.54	0.15	-2.23	-1.510	-1.95	0.22	+46.67	-1.65	-26.01
6.0	-1.61	0.00	-3.01	-1.581	-1.80	0.00	0.00	-2.36**	-21.59

* E = Percent Difference Between Solutions
** Result for Element 74, See Appendix B, Point (6.0,0) is Outside HEFF Model

TABLE 11

COMPARISON OF ANALYTIC AND HEFF TEMPERATURES AND STRESSES IN A SEMI-INFINITE REGION WITH HEATED LAYER

Depth Below Surface (m)	Analytic Solution			HEFF Analysis						
	Temp. (°C)	Horiz. Stress (MPa)	Vert. Stress (MPa)	Temp. (°C)	E*	In-Plane Horiz. Stress	E	Out-of-Plane Horiz. Stress	E	Vert. Stress
0	0.00	0.0	0.0	0.0	0.00	0.70	---	0.21	---	0.0
10	24.05	11.54	0.0	23.91	-0.58	11.91	-3.2	11.68	0.34	0.04
20	52.48	25.19	0.0	52.18	-0.57	25.37	0.71	25.28	-0.27	-0.03
30	89.84	43.12	0.0	89.31	-0.59	43.11	0.02	43.12	-0.49	-0.08
40	140.8	67.60	0.0	140.10	-0.50	67.38	-0.33	67.43	-0.54	-0.14
50	210.5	101.05	0.0	209.4	-0.52	100.6	-0.45	100.7	-0.54	-0.19
60	303.9	145.85	0.0	302.4	-0.49	145.1	-0.51	145.3	-0.61	-0.22
70	425.9	204.41	0.0	423.8	-0.49	203.3	-0.54	203.5	-0.54	-0.25
80	580.9	278.86	0.0	578.2	-0.46	277.2	-0.59	277.6	-0.52	-0.25
90	772.2	370.64	0.0	768.9	-0.42	368.5	-0.58	369.0	-0.47	-0.24
95	882.7	423.72	0.0	878.6	-0.46	421.9	-0.61	421.7	-0.52	0.34

* E = Percent Difference Between Solutions

TABLE 12

GEOMETRICAL DATA FOR ANALYSIS OF A VERTICAL EMPLACEMENT DRIFT

	Feet	
Drift Dimensions		
Width	6.0	(4.88 m)
Height	22.0	(6.71 m)
Radius of Roof Arch	9.0	(2.74 m)
Emplacement Drift Spacing	112.0	(34.14 m)
Depth Below Ground Surface	984.3	(300.0 m)
Container Borehole Dimensions		
Depth	25.00	(7.62 m)
Diameter	2.42	(0.74 m)

TABLE 13

THERMAL AND THERMAL-MECHANICAL DATA FOR ANALYSIS OF A VERTICAL EMPLACEMENT DRIFT

Rock Mass	
Specific Gravity	2.34 g/cc
Young's Modulus	15.1 GPa
Poisson's Ratio	0.2
Thermal Conductivity	
(25 to 100°C temp. range)	2.07 W/m°K
Thermal Capacitance	2.25 J/cm^{3}K
Thermal Expansion(*10^6)	
(25 to 200°C temp. range)	$10.7 * 10^{-6} C^{-1}$
Horiz./Vert. In-Situ Stress	0.55
Ground Surface Temperature	16.0°C
Temperature Gradient	0.0239°C/m
Rock Matrix (for postprocessing only)	
Unconfined Compressive Rock Strength	75.4 MPa
Tensile Strength	-9.0 MPa
Angle of Internal Friction	29.2°

TABLE 14

COMPARISON OF RESULTS OF BOUNDARY-ELEMENT AND FINITE-ELEMENT ANALYSES OF A VERTICAL EMPLACEMENT DRIFT

Model Types and Time	Boundary Element (HEFF)				Finite Element (VISCOT)			
	t=0 yr	10 yr	35 yr	100 yr	t=0 yr	10 yr	35 yr	100 yr
Temperature °C								
Crown (27)	NC	61.65	93.17	104.9	23.0	73.4	101.8	108.5
Midfloor (1)	NC	90.34	114.0	115.3	23.0	75.9	103.6	109.3
Midwall (14)	NC	73.75	102.5	109.7	23.0	74.7	102.8	109.0
Uy Displacement (cm)								
Crown (27)	-0.2967	-1.721	-2.003	+0.743	+0.191	-2.330	-5.826	-10.382
Midfloor (1)	-0.7253	-1.843	-1.602	+1.473	-0.235	-2.341	-5.299	-9.332
Closure	+0.4286	+0.122	-0.401	-0.730	+0.426	+0.011	-0.527	-1.050
Ux Displacement (cm)								
Midwall	0.1161	0.3687	0.7381	0.833	+0.113	+0.399	+0.687	+0.791
Closure	0.2322	0.7374	1.476	1.666	0.226	0.800	1.374	1.582
σ_T Stress (MPa)								
Crown (27)	5.724	27.08	44.38	55.92	5.75	28.48	47.78	54.28
Midfloor (1)	0.7264	10.50	22.72	29.51	0.80	10.38	23.13	28.30
Midwall (14)	8.437	6.572	0.9031	-3.538	8.16	4.99	-1.24	-3.84

The following supplemental information is provided to clarify the meaning of various response measures.

Displacements are considered positive if in the negative coordinate direction.

Closure is negative if the dimension increases.

Compressive stresses are positive.

Note that in the case of finite-element analyses, the stresses are extrapolated to the nodal points using computed values at the element Gauss points and assuming a linear variation of stress within the element.

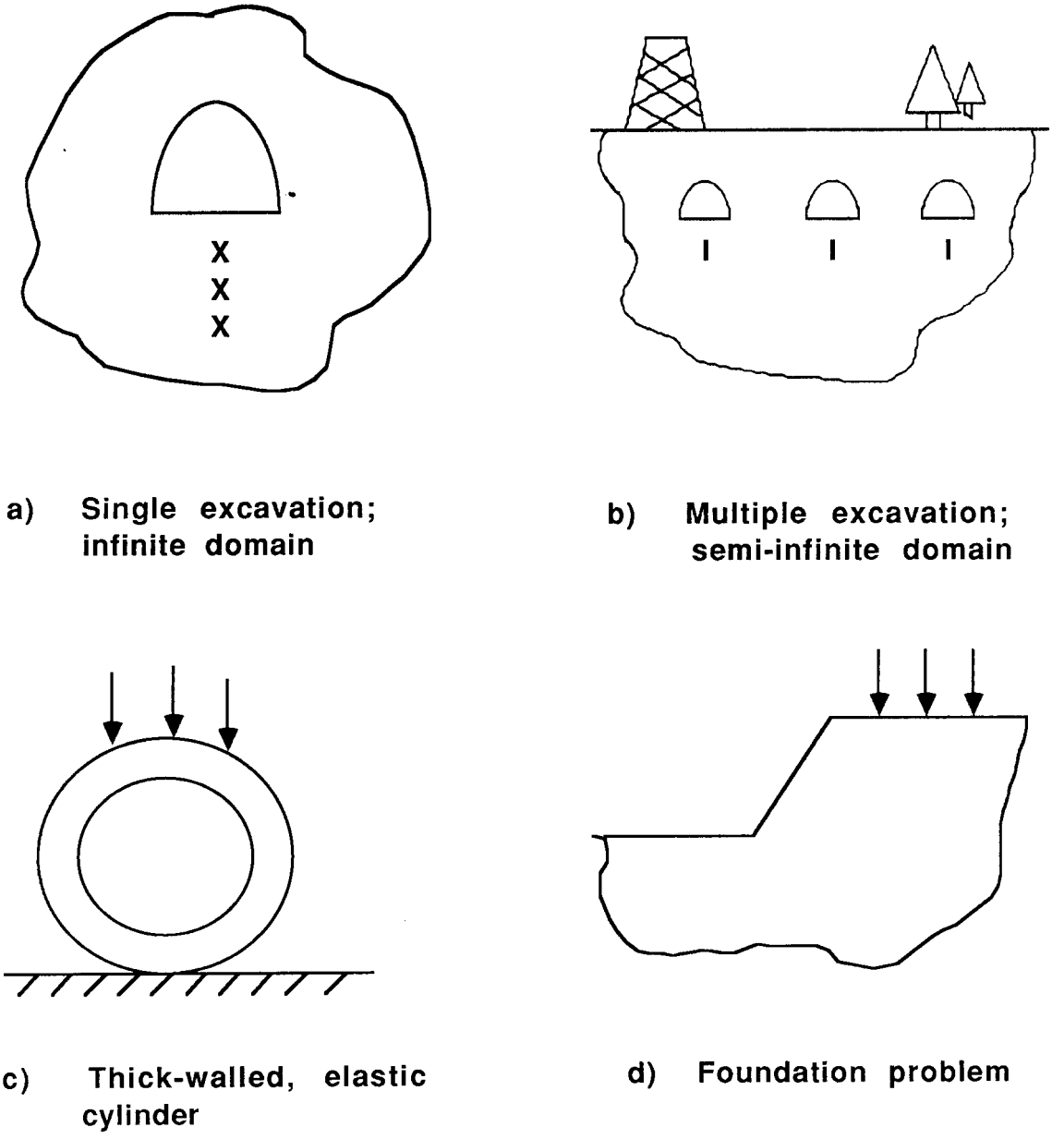
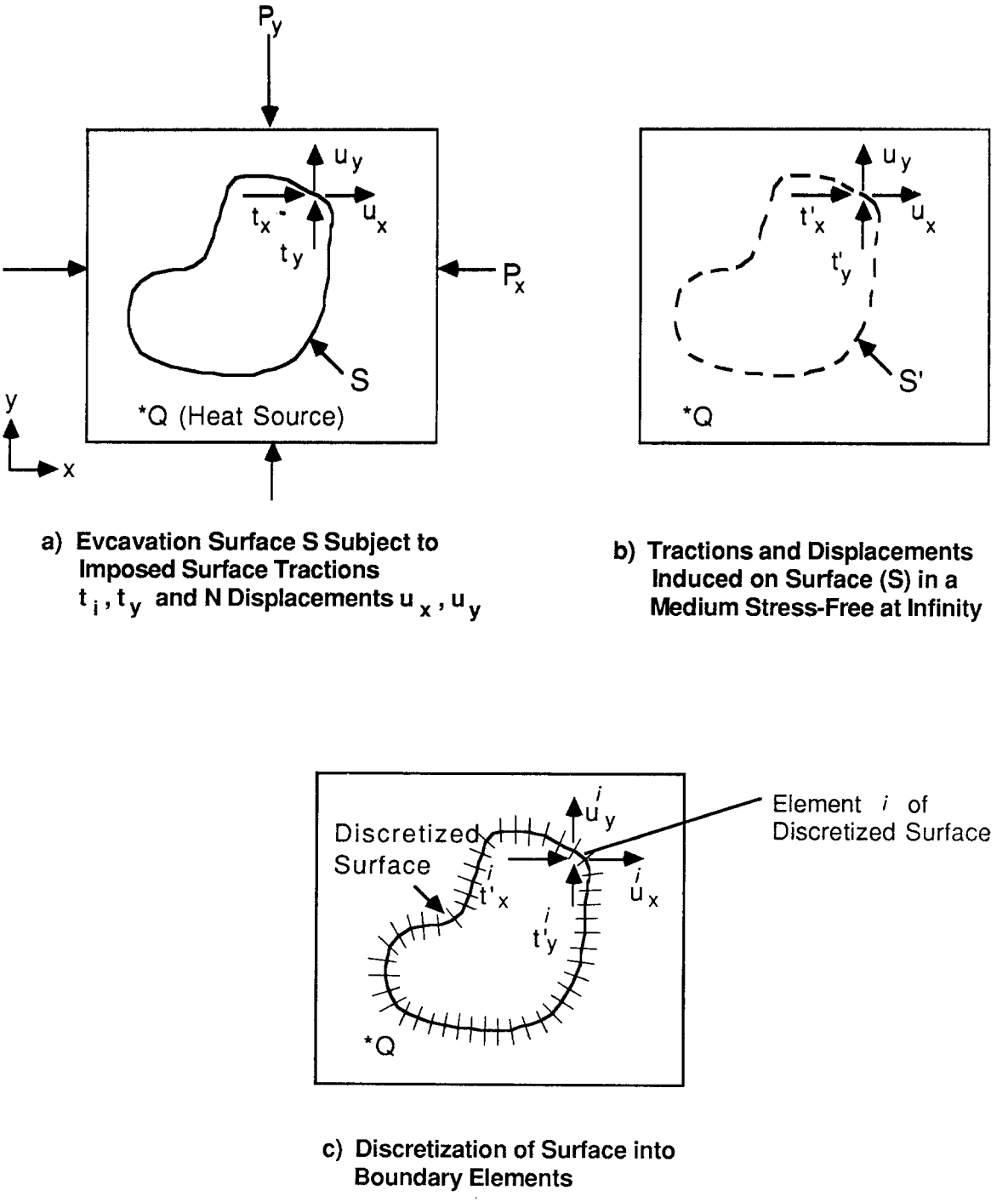


Figure 1. Classes of Problems That Can Be Analyzed Using The HEFF Boundary-Element Code



a) Evcavation Surface S Subject to Imposed Surface Tractions t_i, t_y and N Displacements u_x, u_y

b) Tractions and Displacements Induced on Surface (S) in a Medium Stress-Free at Infinity

c) Discretization of Surface into Boundary Elements

Figure 2. Schematic Interpretation of Boundary-Element Idealization

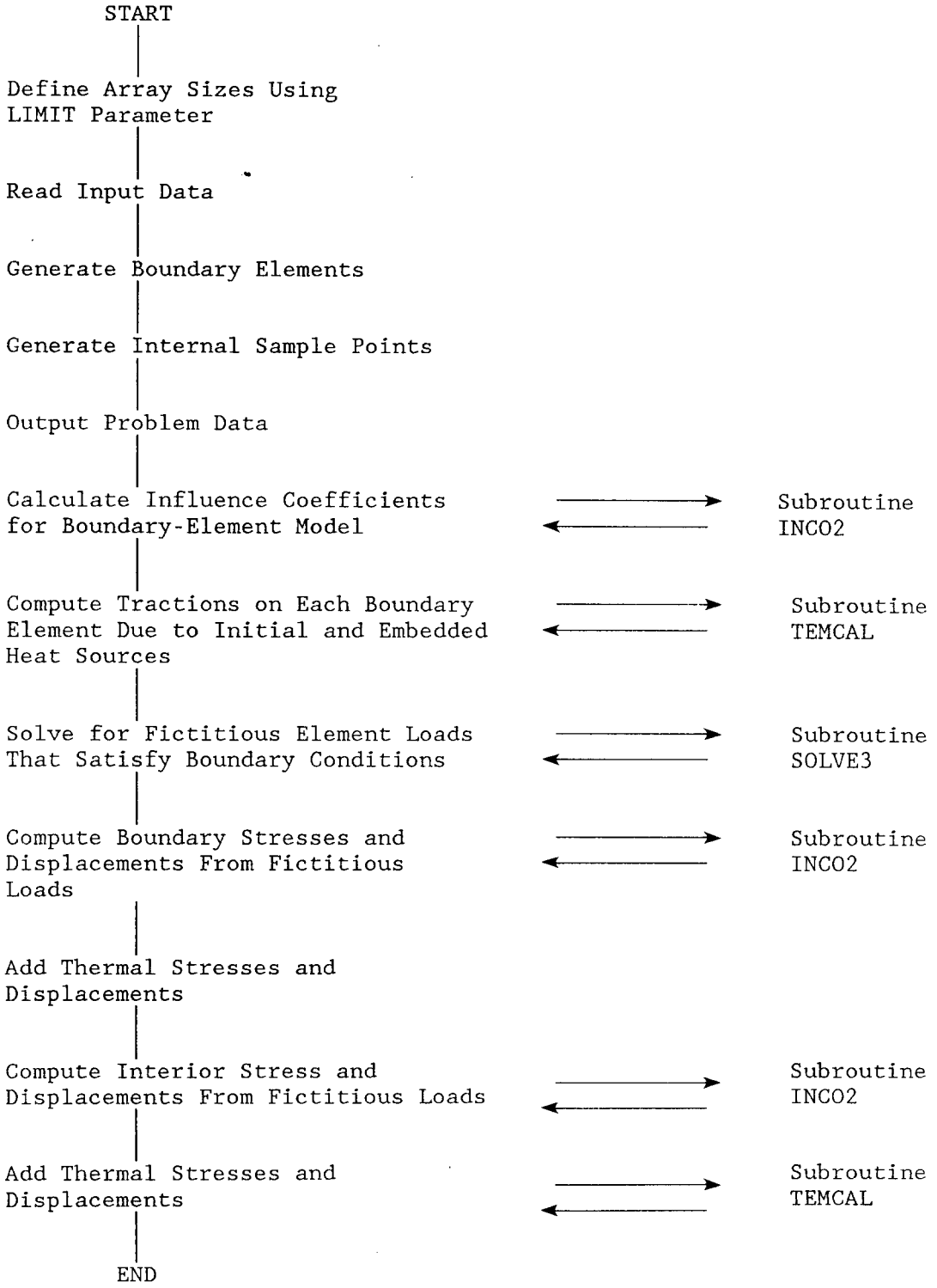
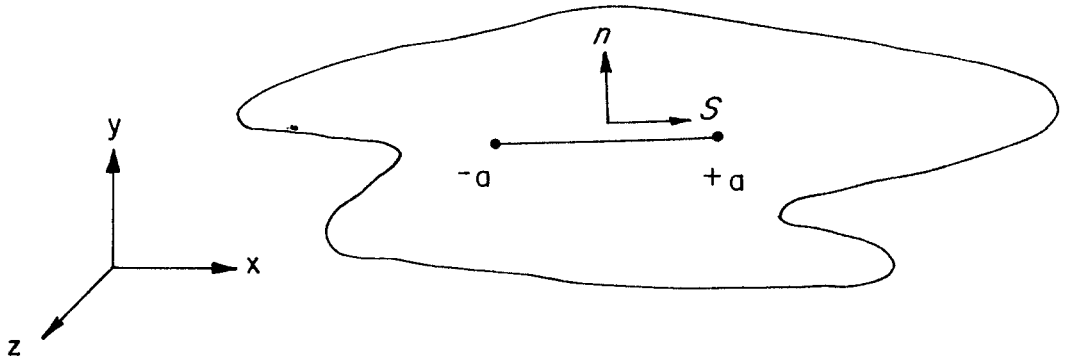
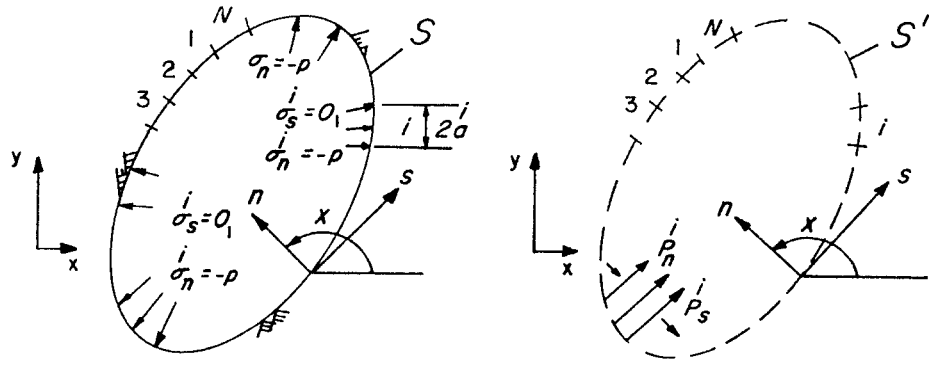


Figure 3. Flowchart for the HEFF Code



a) Cross Section Through an Infinite Body



b) Physical Problem

c) Numerical Model

Figure 4. The Boundary-Element Method for a Cavity Problem

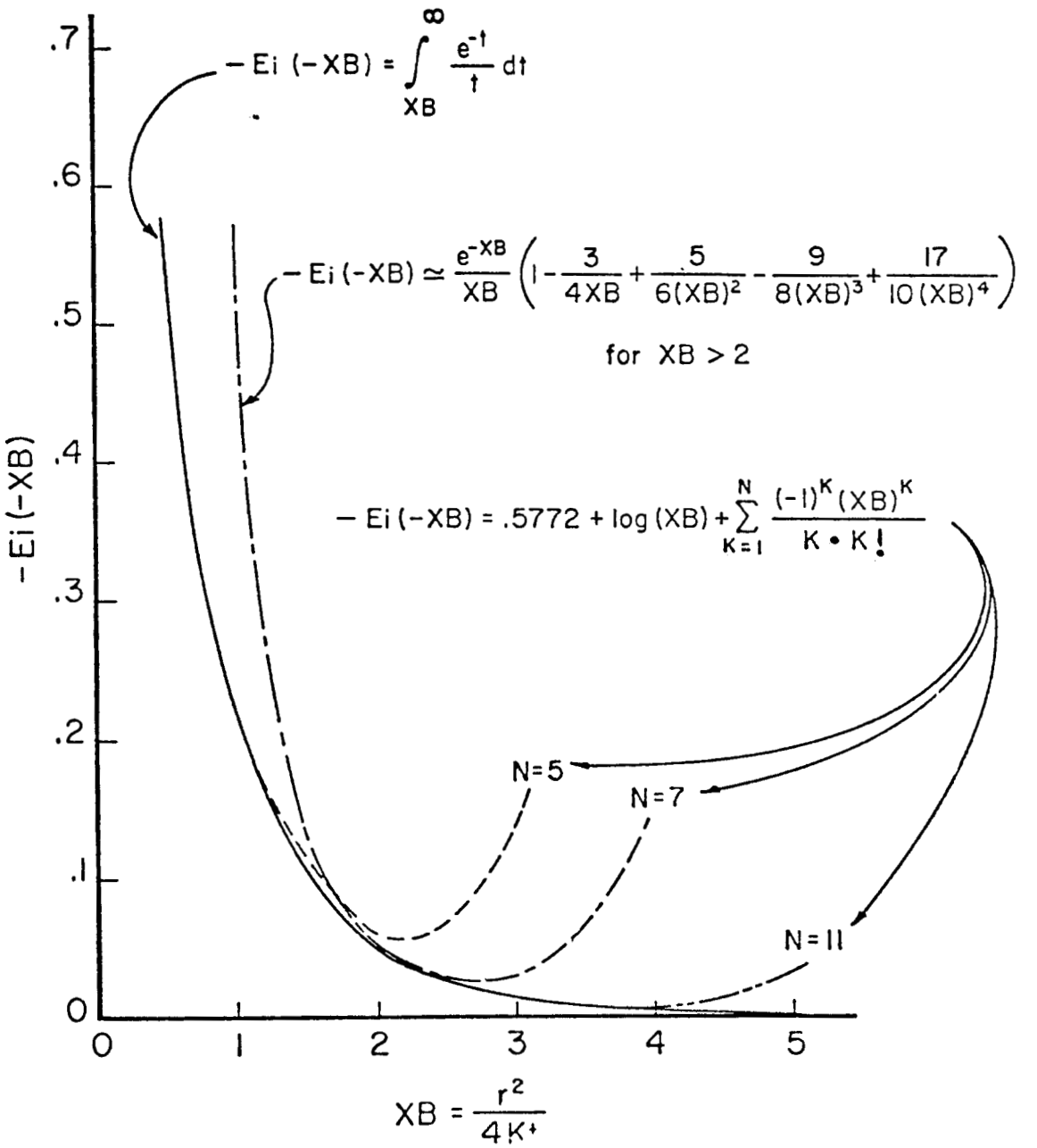


Figure 5. Exponential Integral Function (Hart, 1981)

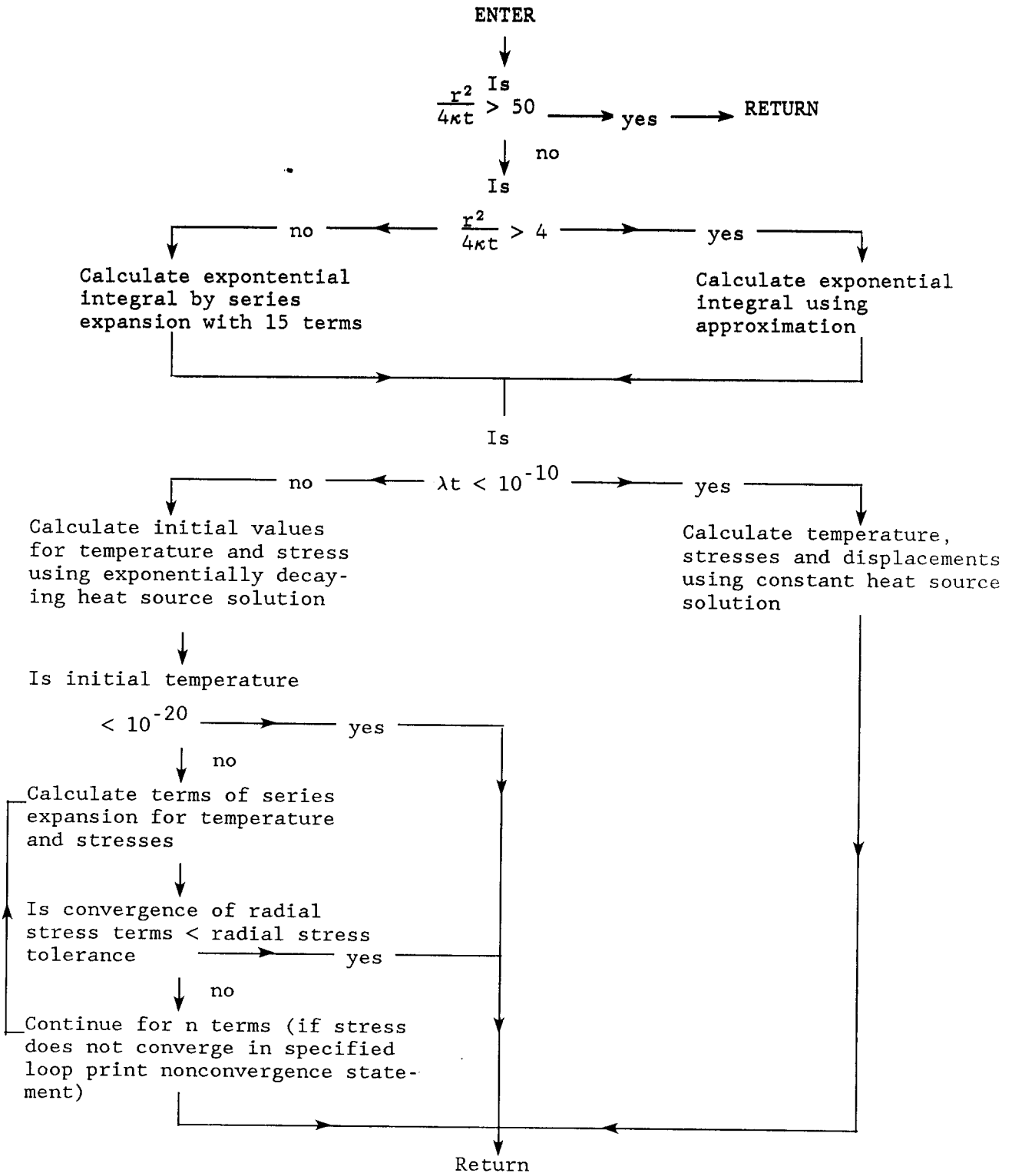


Figure 6. Evaluation of Temperature, Displacement, and Stress by the Thermal and Thermal-Mechanical Submodel

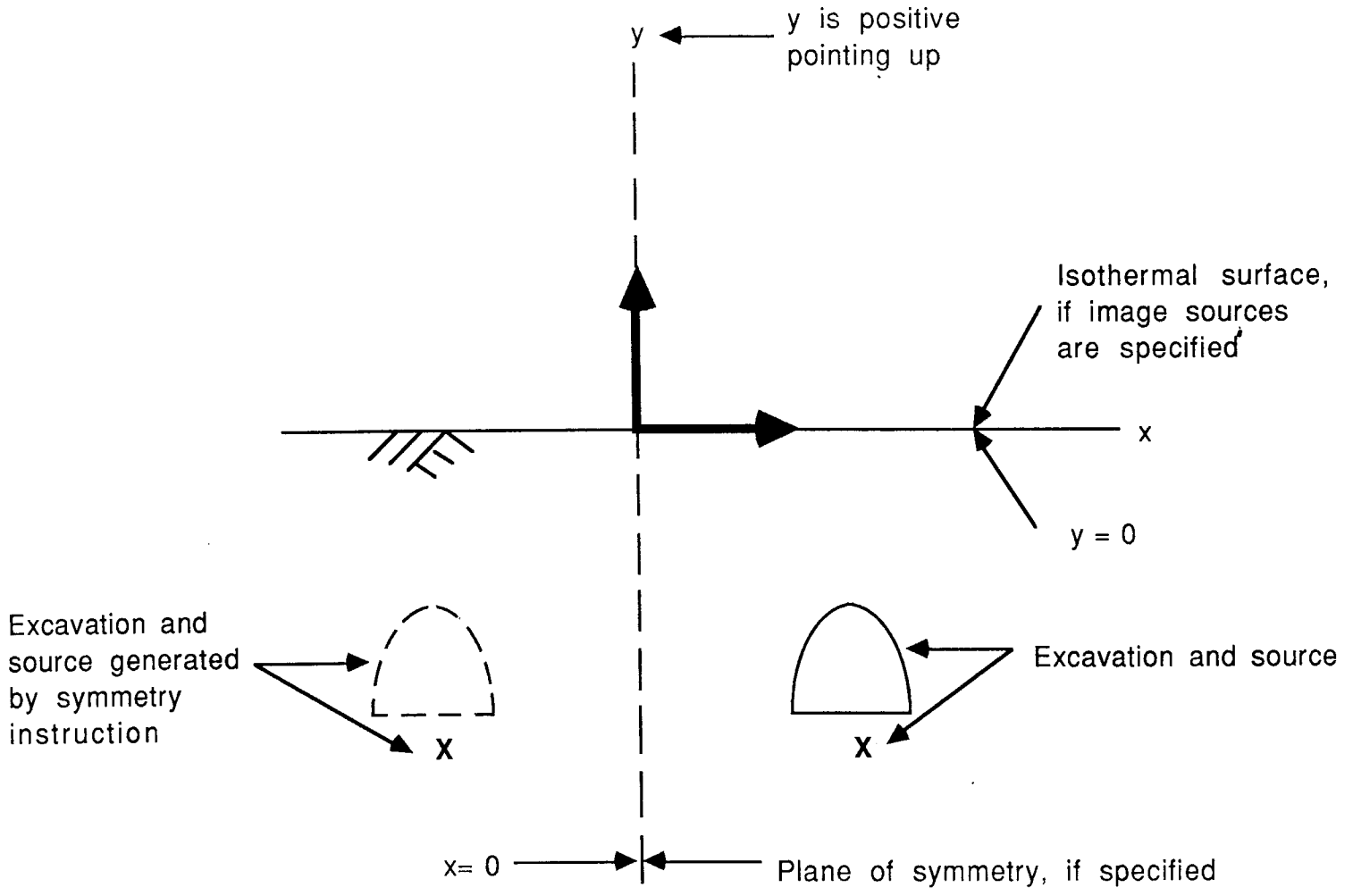
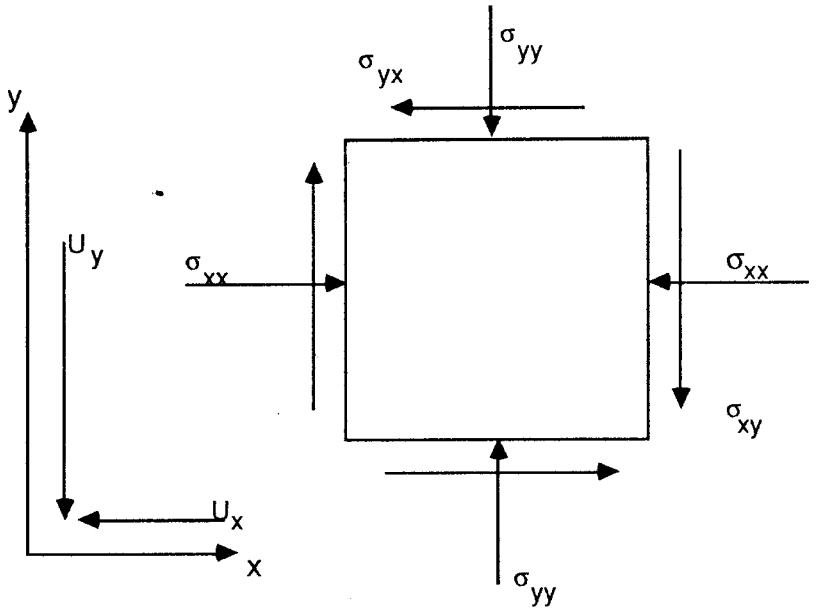
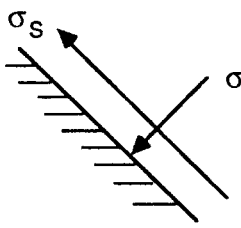


Figure 7. Drawing Showing Reference Coordinates and Illustrating Symmetry and Image Options

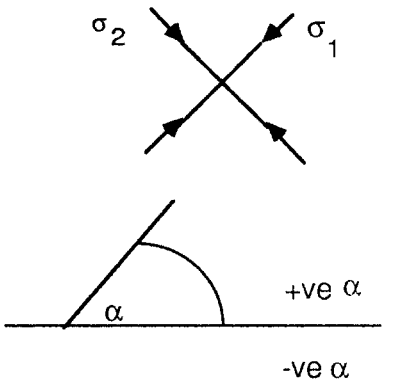


a) Displacements and Stresses in the Interior: Normal stresses are positive if compressive. The sign convention for displacements corresponds (i.e., displacements are positive if directed toward the origin).



(b)

b) Boundary Stresses: Normal stresses are positive if compressive, while shear stresses are positive if to the left with respect to the outward normal.



(c)

c) Principal Stresses: The major principal stress calculated for interior points is the most compressive stress and is oriented at an angle measured counter-clockwise from the positive direction.

Figure 8. Sign Conventions for the HEFF Code

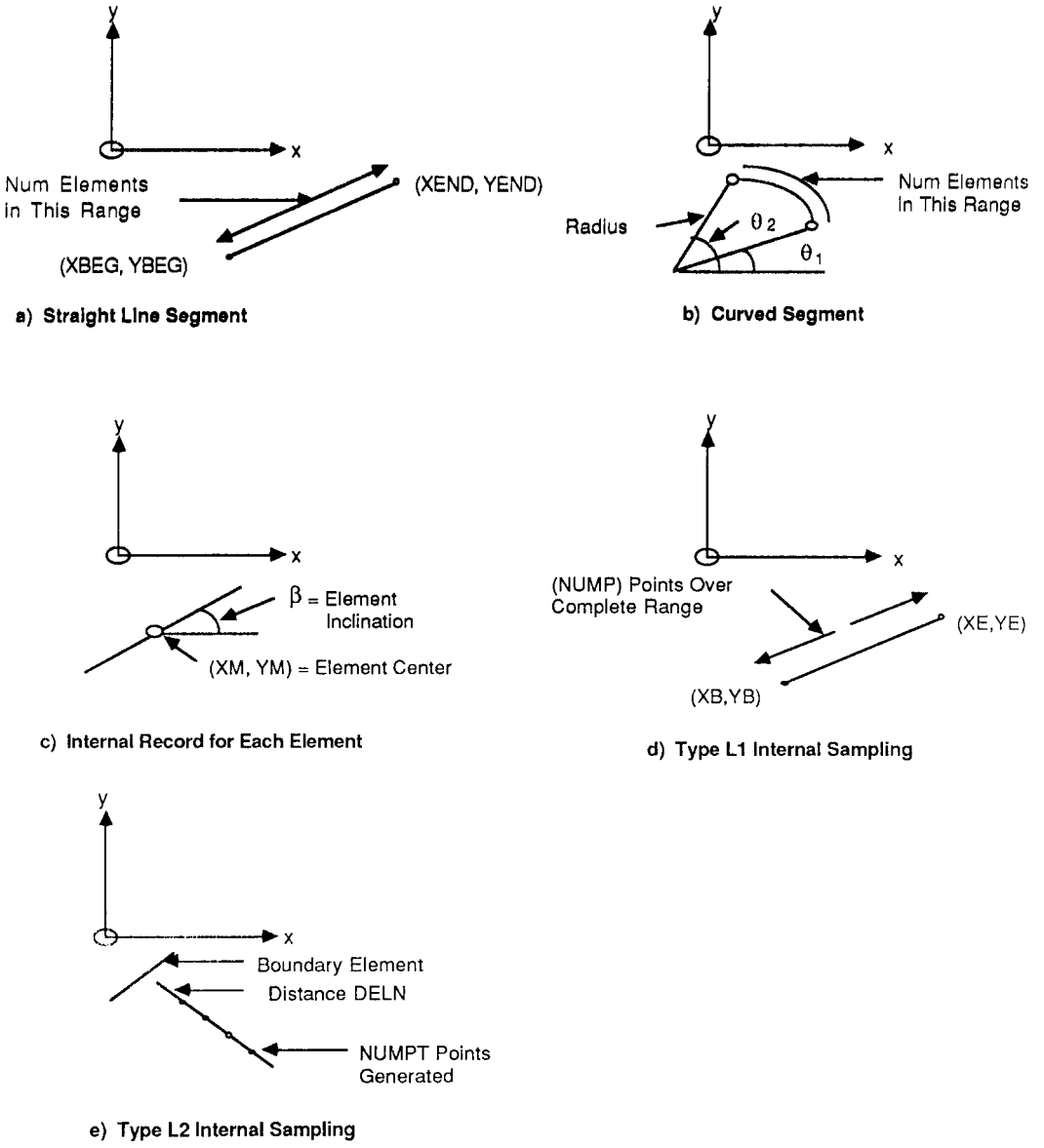


Figure 9. Designation of Variables Defining Segments, Elements, and Internal Sample Points

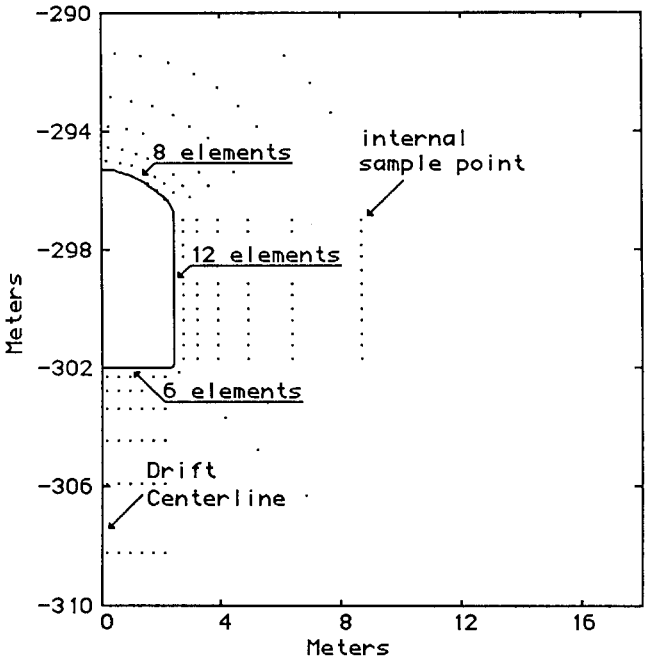


Figure 10. Boundary-Element Model for Analysis of Vertical Emplacement

```
VERT10S
HEFF 4 1
VERTICAL EMPLACEMENT - OUTPUT AT T=10 YRS.
4  0  3  4  1  1
0.2    15100.
0  -0.023  0  0  0  0  0.55  0  0.55  1
10.
-0.0239  16.9
29.03   10.7E-6
0  .15602    .0013539
0  .59787    .019142
0  .15227    .051888
0  .09384    .43768
  0.0     -305.812   1380.328    0.0
  0.0     -307.335   1380.328    0.0
  0.0     -308.858   1380.328    0.0
6  1   0.     -302.     2.34    -302.     0.    0.   0.   0.   0.
1  1   2.34   -302.     2.44    -301.9    0.    0.   0.   0.   0.
12 1   2.44   -301.9    2.44    -296.78   0.    0.   0.   0.   0.
8  1   0.     -298.03   27.13     90.0    2.74  0.   0.   0.   0.
.3  1.50  6  27
```

Figure 11. Input to the HEFF Code for the Sample Problem

(Please find attached output data)

Figure 12. Output From Sample Problem

```
*****************************************************************************************
*                                                                                       *
*                                    H  E  F  F                                         *
*                                                                                       *
*                              A BOUNDARY ELEMENT CODE                                  *
*                       FOR TWO-DIMENSIONAL THERMOELASTIC ANALYSIS                      *
*                                  OF A ROCK MASS                                       *
*                          SUBJECT TO CONSTANT OR DECAYING                              *
*                                THERMAL LOADING                                        *
*                       VERSION DATED: DEC. 6 1987 (MS-FORTRAN 77)                      *
*                                                                                       *
*                                    VERSION 4.1                                        *
*                                                                                       *
*****************************************************************************************
```

VERTICAL EMPLACEMENT - OUTPUT AT T=10 YRS. OUTPUT CREATED ON 12/ 7/1987

```
NUMBER OF BOUNDARY SEGMENTS . . . . . . . =  4
NUMBER OF STRESS LINES  . . . . . . . . . =  0
NUMBER OF HEAT SOURCES  . . . . . . . . . =  3
NUMBER OF EXP. DECAYING COMPONENTS . . . =  4
```

THE LINE X=0.0 IS A LINE OF SYMMETRY.
IMAGE BOUNDARY ELEMENTS AND HEAT SOURCES WILL BE GENERATED WITH RESPECT TO THIS LINE.

CONSTANT TEMPERATURE B.C. IMPOSED AT SURFACE

```
POISSONS RATIO OF BODY . . . . . . . . . =   .20
MODULUS OF ELASTICITY OF BODY . . . . . . =   .1510E+05
SHEAR MODULUS OF BODY . . . . . . . . . . =   .6292E+04
```

```
XX-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00 + ( .5500E+00 +  .0000E+00 / Y ) * SIGYY
YY-COMPONENT OF FIELD STRESS =-.2300E-01Y + .0000E+00
XY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
MAXIMUM VALUE FOR CXX + DXX / Y = .5500E+00
RATIO OF ZZ STRESS TO XX STRESS = .1000E+01
```

TIME FOR OUTPUT
.100E+02

TEMPERATURE VARIATION WITH DEPTH= -.0239Y + 16.9000

```
THERMAL DIFFUSIVITY . . . . . . . . . . . =   .2903E+02
THERMAL EXPANSION COEFFICIENT . . . . . . =   .1070E-04
STRESS COEFFICIENT  VE  . . . . . . . . . =   .1010E+00
```

PROPERTIES OF HEAT SOURCES - CONSTANT OR DECAYING

TIME ON	PROPORTION	DECAY CONST.
.00	.15602E+00	.13539E-02
.00	.59787E+00	.19142E-01
.00	.15227E+00	.51888E-01
.00	.93840E-01	.43768E+00

SOURCE DATA

X-COORD	Y-COORD	STRENGTH	TIME ON
.000	-305.812	1380.328	.000
.000	-307.335	1380.328	.000
.000	-308.858	1380.328	.000

IN THE LIST BELOW, THE VALUE ASSIGNED TO KODE DENOTES BOUNDARY CONDITIONS AS FOLLOWS.
KODE= 1 NORMAL AND SHEAR STRESSES PRESCRIBED
KODE= 2 NORMAL AND SHEAR DISPL. PRESCRIBED
KODE= 3 NORMAL STRESS AND SHEAR DISPL. PRESCRIBED
KODE= 4 NORMAL DISPL. AND SHEAR STRESS PRESCRIBED

ELEMENT	KODE	X(CENTER)	Y(CENTER)	HALF-WIDTH	SIN BETA	COS BETA	B-VALUE (S)	B-VALUE (N)
1	1	.1950	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
2	1	.5850	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
3	1	.9750	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
4	1	1.3650	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
5	1	1.7550	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
6	1	2.1450	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
7	1	2.3900	-301.9500	.0707	.7071	.7071	.0000E+00	.0000E+00
8	1	2.4400	-301.6866	.2133	1.0000	.0000	.0000E+00	.0000E+00
9	1	2.4400	-301.2600	.2133	1.0000	.0000	.0000E+00	.0000E+00
10	1	2.4400	-300.8333	.2133	1.0000	.0000	.0000E+00	.0000E+00
11	1	2.4400	-300.4067	.2133	1.0000	.0000	.0000E+00	.0000E+00
12	1	2.4400	-299.9800	.2133	1.0000	.0000	.0000E+00	.0000E+00
13	1	2.4400	-299.5533	.2133	1.0000	.0000	.0000E+00	.0000E+00
14	1	2.4400	-299.1266	.2133	1.0000	.0000	.0000E+00	.0000E+00
15	1	2.4400	-298.7000	.2133	1.0000	.0000	.0000E+00	.0000E+00
16	1	2.4400	-298.2733	.2133	1.0000	.0000	.0000E+00	.0000E+00
17	1	2.4400	-297.8467	.2133	1.0000	.0000	.0000E+00	.0000E+00
18	1	2.4400	-297.4200	.2133	1.0000	.0000	.0000E+00	.0000E+00
19	1	2.4400	-296.9933	.2133	1.0000	.0000	.0000E+00	.0000E+00
20	1	2.3417	-296.6197	.1878	.6566	-.5159	.0000E+00	.0000E+00
21	1	2.1268	-296.3127	.1878	.7780	-.6282	.0000E+00	.0000E+00
22	1	1.8721	-296.0381	.1878	.6848	-.7287	.0000E+00	.0000E+00
23	1	1.5821	-295.8008	.1878	.5788	-.8155	.0000E+00	.0000E+00
24	1	1.2625	-295.6054	.1878	.4618	-.8870	.0000E+00	.0000E+00
25	1	.9191	-295.4556	.1878	.3362	-.9418	.0000E+00	.0000E+00
26	1	.5584	-295.3541	.1878	.2043	-.9789	.0000E+00	.0000E+00
27	1	.1873	-295.3029	.1878	.0685	-.9977	.0000E+00	.0000E+00

LINES DEFINING STRESS POINTS

XBEG	YBEG	XEND	YEND	NUMPB
.1950	-302.3000	.1950	-308.2344	0
.5850	-302.3000	.5850	-308.2344	0
.9750	-302.3000	.9750	-308.2344	0
1.3650	-302.3000	1.3650	-308.2344	0
1.7550	-302.3000	1.7550	-308.2344	0
2.1450	-302.3000	2.1450	-308.2344	0
2.6021	-302.1621	6.7985	-306.3582	0
2.7400	-301.6866	8.6744	-301.6866	0
2.7400	-301.2600	8.6744	-301.2600	0
2.7400	-300.8333	8.6744	-300.8333	0
2.7400	-300.4067	8.6744	-300.4067	0

2.7400	-299.9800	8.6744	-299.9800	0
2.7400	-299.5533	8.6744	-299.5533	0
2.7400	-299.1266	8.6744	-299.1266	0
2.7400	-298.7000	8.6744	-298.7000	0
2.7400	-298.2733	8.6744	-298.2733	0
2.7400	-297.8467	8.6744	-297.8467	0
2.7400	-297.4200	8.6744	-297.4200	0
2.7400	-296.9933	8.6744	-296.9933	0
2.5986	-296.4649	7.6822	-293.4032	0
2.3602	-296.1243	6.9774	-292.3962	0
2.0775	-295.8195	6.1416	-291.4951	0
1.7557	-295.5562	5.1904	-290.7167	0
1.4010	-295.3393	4.1417	-290.0757	0
1.0199	-295.1730	3.0151	-289.5841	0
.6197	-295.0604	1.8321	-289.2512	0
.2079	-295.0036	.6144	-289.0831	0

TIME REQUIRED TO COMPUTE INFLUENCE COEFFICIENTS= 8.62 SECONDS.

* *

OUTPUT FOR TIME= .1000E+02

PRE-EXISTING STRESS AT EACH ELEMENT

ELEMENT	TEMP	SIGMAXX	SIGMAYY	SIGMAXY	SIGMAZZ	NORM-STR	SHEAR-STR	NORM-DIS	SHEAR-D
1	.8181E+02	.7961E+01	.1446E+02	.1307E+00	.1547E+02	.1446E+02	.1307E+00	-.3107E-02	-.1165E-03
2	.8161E+02	.7983E+01	.1439E+02	.3867E+00	.1543E+02	.1439E+02	.3867E+00	-.3099E-02	-.3485E-03
3	.8119E+02	.8022E+01	.1427E+02	.6271E+00	.1535E+02	.1427E+02	.6271E+00	-.3083E-02	-.5776E-03
4	.8060E+02	.8075E+01	.1410E+02	.8442E+00	.1523E+02	.1410E+02	.8442E+00	-.3060E-02	-.8021E-03
5	.7985E+02	.8135E+01	.1389E+02	.1033E+01	.1508E+02	.1389E+02	.1033E+01	-.3031E-02	-.1021E-02
6	.7896E+02	.8198E+01	.1364E+02	.1192E+01	.1490E+02	.1364E+02	.1192E+01	-.2997E-02	-.1232E-02
7	.7808E+02	.8198E+01	.1347E+02	.1270E+01	.1472E+02	.9562E+01	.2633E+01	-.1155E-02	-.3073E-02
8	.7660E+02	.8015E+01	.1334E+02	.1246E+01	.1442E+02	.8015E+01	-.1246E+01	.1355E-02	-.3075E-02
9	.7451E+02	.7728E+01	.1319E+02	.1185E+01	.1399E+02	.7728E+01	-.1185E+01	.1314E-02	-.3212E-02
10	.7251E+02	.7463E+01	.1304E+02	.1126E+01	.1359E+02	.7463E+01	-.1126E+01	.1275E-02	-.3341E-02
11	.7062E+02	.7218E+01	.1289E+02	.1071E+01	.1320E+02	.7218E+01	-.1071E+01	.1238E-02	-.3460E-02
12	.6882E+02	.6991E+01	.1274E+02	.1020E+01	.1283E+02	.6991E+01	-.1020E+01	.1202E-02	-.3573E-02
13	.6711E+02	.6779E+01	.1259E+02	.9727E+00	.1248E+02	.6779E+01	-.9727E+00	.1168E-02	-.3677E-02
14	.6548E+02	.6581E+01	.1245E+02	.9286E+00	.1215E+02	.6581E+01	-.9286E+00	.1136E-02	-.3775E-02
15	.6393E+02	.6396E+01	.1231E+02	.8875E+00	.1183E+02	.6396E+01	-.8875E+00	.1105E-02	-.3867E-02
16	.6245E+02	.6221E+01	.1217E+02	.8494E+00	.1153E+02	.6221E+01	-.8494E+00	.1076E-02	-.3953E-02
17	.6103E+02	.6056E+01	.1204E+02	.8139E+00	.1124E+02	.6056E+01	-.8139E+00	.1048E-02	-.4033E-02
18	.5967E+02	.5900E+01	.1191E+02	.7808E+00	.1097E+02	.5900E+01	-.7808E+00	.1021E-02	-.4108E-02
19	.5838E+02	.5752E+01	.1178E+02	.7498E+00	.1070E+02	.5752E+01	-.7498E+00	.9947E-03	-.4178E-02
20	.5735E+02	.5623E+01	.1169E+02	.6982E+00	.1049E+02	.7855E+01	-.3008E+01	.2989E-02	-.3151E-02
21	.5660E+02	.5513E+01	.1164E+02	.6218E+00	.1034E+02	.8538E+01	-.3125E+01	.3350E-02	-.2818E-02
22	.5596E+02	.5417E+01	.1160E+02	.5384E+00	.1021E+02	.9236E+01	-.3051E+01	.3664E-02	-.2447E-02
23	.5543E+02	.5334E+01	.1157E+02	.4489E+00	.1010E+02	.9902E+01	-.2793E+01	.3930E-02	-.2045E-02
24	.5501E+02	.5267E+01	.1154E+02	.3544E+00	.1001E+02	.1049E+02	-.2367E+01	.4144E-02	-.1617E-02
25	.5470E+02	.5216E+01	.1152E+02	.2560E+00	.9945E+01	.1097E+02	-.1799E+01	.4307E-02	-.1169E-02
26	.5449E+02	.5182E+01	.1151E+02	.1547E+00	.9902E+01	.1131E+02	-.1124E+01	.4415E-02	-.7072E-03
27	.5438E+02	.5165E+01	.1151E+02	.5177E-01	.9880E+01	.1148E+02	-.3822E+00	.4470E-02	-.2366E-03

TIME REQUIRED TO COMPUTE PRE-EXISTING STRESSES = 36.97 SECONDS.

TIME REQUIRED TO SOLVE EQUATIONS= 4.78 SECONDS.

BOUNDARY STRESSES AND DISPLACEMENTS AT TIME = .100E+02

ELM	X-COORD	Y-COORD	UX	UY	US	UN		
	SIGXX	SIGYY	SIGXY	SIGZZ	SIGMA-S	SIGMA-N	SIGMA-T	TEMP
1	.1950E+00	-.3020E+03	-.1910E-03	-.8887E-02	-.1910E-03	-.8887E-02		
	-.7568E+00	-.2980E-06	-.8400E-07	.1084E+02	-.8400E-07	-.2980E-06	-.7568E+00	.8181E+02
2	.5850E+00	-.3020E+03	-.5667E-03	-.8765E-02	-.5667E-03	-.8765E-02		
	-.2451E+00	.2384E-05	-.6124E-06	.1091E+02	-.6124E-06	.2384E-05	-.2451E+00	.8161E+02
3	.9750E+00	-.3020E+03	-.9233E-03	-.8515E-02	-.9233E-03	-.8515E-02		
	.8773E+00	.1252E-05	.8331E-06	.1106E+02	.8331E-06	.1252E-05	.8773E+00	.8119E+02
4	.1365E+01	-.3020E+03	-.1244E-02	-.8121E-02	-.1244E-02	-.8121E-02		
	.2935E+01	-.1848E-05	.1522E-05	.1138E+02	.1522E-05	-.1848E-05	.2935E+01	.8060E+02
5	.1755E+01	-.3020E+03	-.1500E-02	-.7543E-02	-.1500E-02	-.7543E-02		
	.7118E+01	.7153E-06	-.2719E-05	.1209E+02	-.2719E-05	.7153E-06	.7118E+01	.7985E+02
6	.2145E+01	-.3020E+03	-.1597E-02	-.6661E-02	-.1597E-02	-.6661E-02		
	.2106E+02	-.2027E-05	-.1842E-05	.1474E+02	-.1842E-05	-.2027E-05	.2106E+02	.7896E+02
7	.2390E+01	-.3020E+03	-.1209E-02	-.5645E-02	-.4846E-02	-.3137E-02		
	.4157E+02	.4158E+02	.4157E+02	.2702E+02	.1875E-05	.3741E-05	.8315E+02	.7808E+02
8	.2440E+01	-.3017E+03	-.5409E-03	-.4844E-02	-.4844E-02	.5409E-03		
	.7078E-05	.3910E+02	-.2090E-06	.1797E+02	.2090E-06	.7078E-05	.3910E+02	.7660E+02
9	.2440E+01	-.3013E+03	.1263E-04	-.4579E-02	-.4579E-02	-.1263E-04		
	.2474E-05	.2351E+02	-.2738E-06	.1451E+02	.2738E-06	.2474E-05	.2351E+02	.7451E+02
10	.2440E+01	-.3008E+03	.3580E-03	-.4484E-02	-.4484E-02	-.3580E-03		
	.3785E-05	.1916E+02	.6666E-06	.1332E+02	-.6666E-06	.3785E-05	.1916E+02	.7251E+02
11	.2440E+01	-.3004E+03	.5926E-03	-.4445E-02	-.4445E-02	-.5926E-03		
	.6706E-07	.1709E+02	.1096E-05	.1260E+02	-.1096E-05	.6706E-07	.1709E+02	.7062E+02
12	.2440E+01	-.3000E+03	.7509E-03	-.4430E-02	-.4430E-02	-.7509E-03		
	-.1147E-05	.1593E+02	-.1153E-05	.1207E+02	.1153E-05	-.1147E-05	.1593E+02	.6882E+02
13	.2440E+01	-.2996E+03	.8491E-03	-.4425E-02	-.4425E-02	-.8491E-03		
	-.1505E-05	.1528E+02	-.1312E-06	.1167E+02	.1312E-06	-.1505E-05	.1528E+02	.6711E+02
14	.2440E+01	-.2991E+03	.8960E-03	-.4422E-02	-.4422E-02	-.8960E-03		
	.3302E-05	.1499E+02	.6633E-06	.1134E+02	-.6633E-06	.3302E-05	.1499E+02	.6548E+02
15	.2440E+01	-.2987E+03	.8961E-03	-.4412E-02	-.4412E-02	-.8961E-03		
	-.2779E-05	.1500E+02	.7513E-06	.1109E+02	-.7513E-06	-.2779E-05	.1500E+02	.6393E+02
16	.2440E+01	-.2983E+03	.8507E-03	-.4389E-02	-.4389E-02	-.8507E-03		
	.9313E-06	.1537E+02	.6264E-07	.1093E+02	-.6264E-07	.9313E-06	.1537E+02	.6245E+02

17	.2440E+01	-.2978E+03	.7576E-03	-.4341E-02	-.4341E-02	-.7576E-03		
	-.1788E-05	.1629E+02	-.2617E-06	.1088E+02	.2617E-06	-.1788E-05	.1629E+02	.5103E+02
18	.2440E+01	-.2974E+03	.6093E-03	-.4250E-02	-.4250E-02	-.6093E-03		
	-.1252E-05	.1836E+02	-.2941E-06	.1108E+02	.2941E-06	-.1252E-05	.1836E+02	.5967E+02
19	.2440E+01	-.2970E+03	.3898E-03	-.4059E-02	-.4059E-02	-.3898E-03		
	-.8047E-06	.2492E+02	.4197E-06	.1218E+02	-.4197E-06	-.8047E-06	.2492E+02	.5838E+02
20	.2342E+01	-.2966E+03	.1771E-03	-.3560E-02	-.3141E-02	.1685E-02		
	.7483E+01	.2063E+02	-.1242E+02	.1265E+02	.1991E-05	-.5093E-06	.2811E+02	.5735E+02
21	.2127E+01	-.2963E+03	.1211E-03	-.3207E-02	-.2571E-02	.1921E-02		
	.8590E+01	.1318E+02	-.1064E+02	.1126E+02	-.2124E-05	-.2891E-05	.2177E+02	.5660E+02
22	.1872E+01	-.2960E+03	.8837E-04	-.2927E-02	-.2069E-02	.2073E-02		
	.9635E+01	.8510E+01	-.9055E+01	.1043E+02	.1227E-05	.2023E-05	.1814E+02	.5596E+02
23	.1582E+01	-.2958E+03	.6418E-04	-.2698E-02	-.1614E-02	.2163E-02		
	.1011E+02	.5092E+01	-.7174E+01	.9757E+01	-.6147E-06	.6695E-05	.1520E+02	.5543E+02
24	.1262E+01	-.2956E+03	.4526E-04	-.2514E-02	-.1201E-02	.2209E-02		
	.1001E+02	.2714E+01	-.5212E+01	.9193E+01	.2464E-06	.3901E-05	.1272E+02	.5501E+02
25	.9191E+00	-.2955E+03	.2994E-04	-.2375E-02	-.8266E-03	.2227E-02		
	.9541E+01	.1216E+01	-.3406E+01	.8748E+01	-.2993E-05	.1138E-05	.1076E+02	.5470E+02
26	.5584E+00	-.2954E+03	.1703E-04	-.2282E-02	-.4829E-03	.2230E-02		
	.8996E+01	.3919E+00	-.1878E+01	.8440E+01	.5206E-06	-.4372E-06	.9388E+01	.5449E+02
27	.1873E+00	-.2953E+03	.5521E-05	-.2235E-02	-.1586E-03	.2230E-02		
	.8642E+01	.4075E-01	-.5934E+00	.8282E+01	-.3157E-06	-.3395E-05	.8683E+01	.5438E+02

TIME REQUIRED TO COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS= 9.77 SECONDS.

INTERIOR STRESSES AND DISPLACEMENTS AT TIME = .100E+02

POINT	X-COORD	Y-COORD	UX	UY				
	SIGXX	SIGYY	SIGXY	SIGZZ	SIG1	SIG2	ALPHA	TEMP
1	.1950E+00	-.3023E+03	-.1486E-03	-.8549E-02				
	.2290E+01	.3512E+00	.1948E+00	.1185E+02	.2309E+01	.3318E+00	.5681E+01	.8387E+02
2	.1950E+00	-.3028E+03	-.1039E-03	-.8009E-02				
	.6796E+01	.1194E+01	.5255E+00	.1346E+02	.6845E+01	.1145E+01	.5313E+01	.8724E+02
3	.1950E+00	-.3034E+03	-.7753E-04	-.7184E-02				
	.1070E+02	.3666E+01	.8334E+00	.1569E+02	.1079E+02	.3568E+01	.6669E+01	.9309E+02
4	.1950E+00	-.3044E+03	-.9197E-04	-.6016E-02				
	.1305E+02	.8218E+01	.8752E+00	.1897E+02	.1320E+02	.8065E+01	.9963E+01	.1049E+03
5	.1950E+00	-.3060E+03	-.1604E-03	-.4302E-02				
	.1653E+02	.1431E+02	.1841E-01	.2614E+02	.1653E+02	.1431E+02	.4747E+00	.1373E+03
6	.1950E+00	-.3082E+03	-.1720E-03	-.1885E-02				
	.1464E+02	.1697E+02	.1280E+00	.2558E+02	.1698E+02	.1463E+02	.8687E+02	.1329E+03
7	.5850E+00	-.3023E+03	-.4382E-03	-.8426E-02				
	.2882E+01	.3841E+00	.6177E+00	.1194E+02	.3026E+01	.2398E+00	.1316E+02	.8363E+02
8	.5850E+00	-.3028E+03	-.3049E-03	-.7886E-02				
	.7323E+01	.1369E+01	.1651E+01	.1356E+02	.7751E+01	.9419E+00	.1451E+02	.8693E+02
9	.5850E+00	-.3034E+03	-.2304E-03	-.7073E-02				
	.1086E+02	.4032E+01	.2518E+01	.1572E+02	.1169E+02	.3204E+01	.1821E+02	.9264E+02
10	.5850E+00	-.3044E+03	-.2739E-03	-.5933E-02				
	.1300E+02	.8356E+01	.2518E+01	.1881E+02	.1411E+02	.7253E+01	.2365E+02	.1038E+03
11	.5850E+00	-.3060E+03	-.4306E-03	-.4269E-02				
	.1582E+02	.1287E+02	.1319E+01	.2389E+02	.1632E+02	.1236E+02	.2088E+02	.1261E+03
12	.5850E+00	-.3082E+03	-.4932E-03	-.1876E-02				
	.1486E+02	.1576E+02	.1751E+00	.2458E+02	.1579E+02	.1483E+02	.7928E+02	.1279E+03
13	.9750E+00	-.3023E+03	-.7031E-03	-.8173E-02				
	.4191E+01	.4819E+00	.1175E+01	.1214E+02	.4532E+01	.1413E+00	.1617E+02	.8316E+02
14	.9750E+00	-.3028E+03	-.4860E-03	-.7635E-02				
	.8376E+01	.1858E+01	.3037E+01	.1377E+02	.9571E+01	.6624E+00	.2149E+02	.8635E+02
15	.9750E+00	-.3034E+03	-.3786E-03	-.6853E-02				
	.1108E+02	.4896E+01	.4237E+01	.1580E+02	.1323E+02	.2743E+01	.2694E+02	.9178E+02
16	.9750E+00	-.3044E+03	-.4522E-03	-.5776E-02				
	.1283E+02	.8756E+01	.3901E+01	.1855E+02	.1519E+02	.6391E+01	.3122E+02	.1019E+03
17	.9750E+00	-.3060E+03	-.6675E-03	-.4191E-02				
	.1520E+02	.1222E+02	.2228E+01	.2247E+02	.1639E+02	.1103E+02	.2811E+02	.1189E+03
18	.9750E+00	-.3082E+03	-.7749E-03	-.1863E-02				
	.1480E+02	.1460E+02	.1817E+00	.2331E+02	.1491E+02	.1449E+02	.3032E+02	.1216E+03
19	.1365E+01	-.3023E+03	-.9215E-03	-.7774E-02				
	.6567E+01	.7750E+00	.2132E+01	.1257E+02	.7267E+01	.7480E-01	.1818E+02	.8249E+02
20	.1365E+01	-.3028E+03	-.6367E-03	-.7247E-02				
	.9847E+01	.3077E+01	.4953E+01	.1417E+02	.1246E+02	.4628E+00	.2783E+02	.8552E+02
21	.1365E+01	-.3034E+03	-.5251E-03	-.6532E-02				
	.1114E+02	.6484E+01	.5905E+01	.1593E+02	.1516E+02	.2464E+01	.3424E+02	.9059E+02
22	.1365E+01	-.3044E+03	-.6301E-03	-.5558E-02				
	.1246E+02	.9497E+01	.4943E+01	.1825E+02	.1614E+02	.5819E+01	.3666E+02	.9953E+02
23	.1365E+01	-.3060E+03	-.8841E-03	-.4080E-02				
	.1462E+02	.1191E+02	.2856E+01	.2136E+02	.1642E+02	.1010E+02	.3229E+02	.1131E+03
24	.1365E+01	-.3082E+03	-.1024E-02	-.1846E-02				

	.1452E+02	.1374E+02	.2587E+00	.2213E+02	.1460E+02	.1366E+02	.1667E+02	.1157E+03
25	.1755E+01	-.3023E+03	-.1060E-02	-.7188E-02				
	.1076E+02	.1962E+01	.4426E+01	.1351E+02	.1260E+02	.1208E+00	.2259E+02	.8164E+02
26	.1755E+01	-.3028E+03	-.7587E-03	-.6713E-02				
	.1113E+02	.6080E+01	.7556E+01	.1486E+02	.1657E+02	.6369E+00	.3577E+02	.8449E+02
27	.1755E+01	-.3034E+03	-.6808E-03	-.6129E-02				
	.1079E+02	.8945E+01	.7205E+01	.1612E+02	.1713E+02	.2603E+01	.4136E+02	.8916E+02
28	.1755E+01	-.3044E+03	-.8127E-03	-.5298E-02				
	.1192E+02	.1052E+02	.5579E+01	.1794E+02	.1685E+02	.5600E+01	.4143E+02	.9703E+02
29	.1755E+01	-.3060E+03	-.1087E-02	-.3945E-02				
	.1403E+02	.1182E+02	.3254E+01	.2042E+02	.1636E+02	.9488E+01	.3563E+02	.1081E+03
30	.1755E+01	-.3082E+03	-.1248E-02	-.1822E-02				
	.1416E+02	.1312E+02	.3710E+00	.2107E+02	.1427E+02	.1300E+02	.1775E+02	.1104E+03
31	.2145E+01	-.3023E+03	-.1089E-02	-.6337E-02				
	.1571E+02	.9288E+01	.1070E+02	.1580E+02	.2367E+02	.1332E+01	.3664E+02	.8064E+02
32	.2145E+01	-.3028E+03	-.8888E-03	-.6065E-02				
	.1077E+02	.1213E+02	.9469E+01	.1581E+02	.2094E+02	.1954E+01	.4706E+02	.8330E+02
33	.2145E+01	-.3034E+03	-.8605E-03	-.5686E-02				
	.1002E+02	.1195E+02	.7592E+01	.1631E+02	.1864E+02	.3329E+01	.4862E+02	.8757E+02
34	.2145E+01	-.3044E+03	-.1004E-02	-.5016E-02				
	.1130E+02	.1166E+02	.5768E+01	.1763E+02	.1725E+02	.5711E+01	.4588E+02	.9447E+02
35	.2145E+01	-.3060E+03	-.1282E-02	-.3796E-02				
	.1344E+02	.1188E+02	.3455E+01	.1960E+02	.1620E+02	.9114E+01	.3864E+02	.1037E+03
36	.2145E+01	-.3082E+03	-.1454E-02	-.1793E-02				
	.1375E+02	.1266E+02	.4861E+00	.2012E+02	.1394E+02	.1247E+02	.2083E+02	.1056E+03
37	.2602E+01	-.3022E+03	-.1227E-02	-.5313E-02				
	.1624E+02	.2603E+02	.7025E+01	.1893E+02	.2970E+02	.1257E+02	.6244E+02	.7862E+02
38	.2920E+01	-.3025E+03	-.1311E-02	-.5050E-02				
	.1131E+02	.1975E+02	.4545E+01	.1679E+02	.2173E+02	.9324E+01	.6645E+02	.7926E+02
39	.3398E+01	-.3030E+03	-.1535E-02	-.4679E-02				
	.9772E+01	.1654E+02	.3835E+01	.1593E+02	.1827E+02	.8040E+01	.6570E+02	.7983E+02
40	.4114E+01	-.3037E+03	-.1932E-02	-.4128E-02				
	.9608E+01	.1434E+02	.3289E+01	.1545E+02	.1603E+02	.7923E+01	.6287E+02	.7974E+02
41	.5188E+01	-.3047E+03	-.2499E-02	-.3323E-02				
	.9952E+01	.1251E+02	.2463E+01	.1482E+02	.1400E+02	.8455E+01	.5871E+02	.7771E+02
42	.6799E+01	-.3064E+03	-.3157E-02	-.2233E-02				
	.9972E+01	.1092E+02	.1250E+01	.1360E+02	.1178E+02	.9109E+01	.5535E+02	.7208E+02
43	.2740E+01	-.3017E+03	-.8492E-03	-.5031E-02				
	.8419E+01	.2738E+02	.9336E+01	.1719E+02	.3121E+02	.4594E+01	.6772E+02	.7587E+02
44	.3190E+01	-.3017E+03	-.1093E-02	-.4924E-02				
	.9779E+01	.1969E+02	.7151E+01	.1573E+02	.2344E+02	.6034E+01	.6236E+02	.7469E+02
45	.3865E+01	-.3017E+03	-.1402E-02	-.4705E-02				
	.8882E+01	.1636E+02	.5203E+01	.1458E+02	.1902E+02	.6212E+01	.6284E+02	.7280E+02
46	.4878E+01	-.3017E+03	-.1852E-02	-.4403E-02				
	.8134E+01	.1437E+02	.3835E+01	.1355E+02	.1619E+02	.6309E+01	.6455E+02	.6981E+02
47	.6396E+01	-.3017E+03	-.2459E-02	-.4029E-02				
	.7803E+01	.1266E+02	.2772E+01	.1241E+02	.1392E+02	.6547E+01	.6562E+02	.6531E+02
48	.8674E+01	-.3017E+03	-.3178E-02	-.3605E-02				
	.7658E+01	.1093E+02	.1970E+01	.1102E+02	.1186E+02	.6734E+01	.6486E+02	.5901E+02
49	.2740E+01	-.3013E+03	-.3135E-03	-.4797E-02				
	.1727E+01	.2348E+02	.3741E+01	.1474E+02	.2410E+02	.1101E+01	.8051E+02	.7386E+02
50	.3190E+01	-.3013E+03	-.7184E-03	-.4856E-02				
	.4893E+01	.2056E+02	.5927E+01	.1463E+02	.2255E+02	.2904E+01	.7144E+02	.7282E+02
51	.3865E+01	-.3013E+03	-.1166E-02	-.4728E-02				
	.6639E+01	.1714E+02	.5213E+01	.1402E+02	.1929E+02	.4491E+01	.6761E+02	.7113E+02
52	.4878E+01	-.3013E+03	-.1701E-02	-.4468E-02				
	.7105E+01	.1479E+02	.3891E+01	.1320E+02	.1642E+02	.5479E+01	.6733E+02	.6841E+02
53	.6396E+01	-.3013E+03	-.2361E-02	-.4119E-02				
	.7299E+01	.1287E+02	.2774E+01	.1218E+02	.1402E+02	.6154E+01	.6757E+02	.6424E+02
54	.8674E+01	-.3013E+03	-.3111E-02	-.3710E-02				
	.7402E+01	.1102E+02	.1984E+01	.1087E+02	.1190E+02	.6526E+01	.6620E+02	.5829E+02
55	.2740E+01	-.3008E+03	.4906E-04	-.4650E-02				
	.6585E+00	.1984E+02	.1731E+01	.1349E+02	.1999E+02	.5035E+00	.8488E+02	.7195E+02
56	.3190E+01	-.3008E+03	-.3859E-03	-.4755E-02				
	.2348E+01	.1968E+02	.3863E+01	.1365E+02	.2051E+02	.1526E+01	.7799E+02	.7102E+02
57	.3865E+01	-.3008E+03	-.9219E-03	-.4709E-02				
	.4570E+01	.1755E+02	.4444E+01	.1342E+02	.1892E+02	.3194E+01	.7280E+02	.6950E+02
58	.4878E+01	-.3008E+03	-.1544E-02	-.4506E-02				
	.5999E+01	.1519E+02	.3669E+01	.1284E+02	.1647E+02	.4713E+01	.7069E+02	.6703E+02
59	.6396E+01	-.3008E+03	-.2261E-02	-.4194E-02				
	.6769E+01	.1308E+02	.2690E+01	.1194E+02	.1407E+02	.5778E+01	.6977E+02	.6317E+02
60	.8674E+01	-.3008E+03	-.3042E-02	-.3807E-02				
	.7139E+01	.1111E+02	.1972E+01	.1072E+02	.1192E+02	.6326E+01	.6760E+02	.5756E+02
61	.2740E+01	-.3004E+03	.2976E-03	-.4564E-02				
	.3718E+00	.1776E+02	.9413E+00	.1272E+02	.1781E+02	.3210E+00	.8691E+02	.7012E+02
62	.3190E+01	-.3004E+03	-.1338E-03	-.4664E-02				
	.1292E+01	.1846E+02	.2419E+01	.1291E+02	.1880E+02	.9577E+00	.8213E+02	.6929E+02

63	.3865E+01	-.3004E+03	-.7071E-03	-.4665E-02	.1826E+02	.2375E+01	.7734E+02	.6793E+02
	.3138E+01	.1750E+02	.3397E+01	.1287E+02				
64	.4878E+01	-.3004E+03	-.1392E-02	-.4521E-02	.1637E+02	.4094E+01	.7423E+02	.6568E+02
	.5000E+01	.1546E+02	.3209E+01	.1247E+02				
65	.6396E+01	-.3004E+03	-.2161E-02	-.4254E-02	.1406E+02	.5442E+01	.7213E+02	.6210E+02
	.6253E+01	.1325E+02	.2517E+01	.1170E+02				
66	.8674E+01	-.3004E+03	-.2973E-02	-.3895E-02	.1192E+02	.6138E+01	.6903E+02	.5681E+02
	.6879E+01	.1118E+02	.1933E+01	.1056E+02				
67	.2740E+01	-.3000E+03	.4669E-03	-.4511E-02	.1656E+02	.2419E+00	.8813E+02	.6837E+02
	.2594E+00	.1655E+02	.5336E+00	.1218E+02				
68	.3190E+01	-.3000E+03	.4581E-04	-.4589E-02	.1761E+02	.7042E+00	.8496E+02	.6763E+02
	.8346E+00	.1748E+02	.1479E+01	.1236E+02				
69	.3865E+01	-.3000E+03	-.5369E-03	-.4610E-02	.1759E+02	.1904E+01	.8114E+02	.6640E+02
	.2276E+01	.1722E+02	.2387E+01	.1239E+02				
70	.4878E+01	-.3000E+03	-.1259E-02	-.4516E-02	.1615E+02	.3647E+01	.7770E+02	.6435E+02
	.4214E+01	.1558E+02	.2602E+01	.1212E+02				
71	.6396E+01	-.3000E+03	-.2066E-02	-.4300E-02	.1399E+02	.5163E+01	.7455E+02	.6104E+02
	.5790E+01	.1336E+02	.2267E+01	.1146E+02				
72	.8674E+01	-.3000E+03	-.2904E-02	-.3975E-02	.1190E+02	.5966E+01	.7047E+02	.5605E+02
	.6629E+01	.1124E+02	.1870E+01	.1040E+02				
73	.2740E+01	-.2996E+03	.5741E-03	-.4474E-02	.1585E+02	.2030E+00	.8902E+02	.6671E+02
	.2076E+00	.1585E+02	.2669E+00	.1176E+02				
74	.3190E+01	-.2996E+03	.1641E-03	-.4525E-02	.1684E+02	.5919E+00	.8713E+02	.6604E+02
	.6326E+00	.1680E+02	.8120E+00	.1192E+02				
75	.3865E+01	-.2996E+03	-.4145E-03	-.4550E-02	.1702E+02	.1664E+01	.8438E+02	.6493E+02
	.1811E+01	.1687E+02	.1496E+01	.1199E+02				
76	.4878E+01	-.2996E+03	-.1150E-02	-.4499E-02	.1586E+02	.3369E+01	.8099E+02	.6305E+02
	.3675E+01	.1556E+02	.1933E+01	.1180E+02				
77	.6396E+01	-.2996E+03	-.1980E-02	-.4336E-02	.1387E+02	.4951E+01	.7694E+02	.5998E+02
	.5406E+01	.1342E+02	.1963E+01	.1122E+02				
78	.8674E+01	-.2996E+03	-.2836E-02	-.4048E-02	.1186E+02	.5810E+01	.7189E+02	.5528E+02
	.6394E+01	.1128E+02	.1787E+01	.1023E+02				
79	.2740E+01	-.2991E+03	.6283E-03	-.4440E-02	.1552E+02	.1878E+00	.8980E+02	.6512E+02
	.1880E+00	.1552E+02	.5288E-01	.1143E+02				
80	.3190E+01	-.2991E+03	.2290E-03	-.4466E-02	.1642E+02	.5629E+00	.8904E+02	.6452E+02
	.5674E+00	.1641E+02	.2667E+00	.1159E+02				
81	.3865E+01	-.2991E+03	-.3383E-03	-.4489E-02	.1659E+02	.1592E+01	.8731E+02	.6350E+02
	.1625E+01	.1656E+02	.7020E+00	.1166E+02				
82	.4878E+01	-.2991E+03	-.1069E-02	-.4473E-02	.1555E+02	.3247E+01	.8409E+02	.6178E+02
	.3377E+01	.1542E+02	.1261E+01	.1151E+02				
83	.6396E+01	-.2991E+03	-.1904E-02	-.4363E-02	.1370E+02	.4808E+01	.7924E+02	.5894E+02
	.5118E+01	.1339E+02	.1631E+01	.1099E+02				
84	.8674E+01	-.2991E+03	-.2770E-02	-.4115E-02	.1180E+02	.5673E+01	.7326E+02	.5452E+02
	.6181E+01	.1129E+02	.1689E+01	.1007E+02				
85	.2740E+01	-.2987E+03	.6343E-03	-.4403E-02	.1551E+02	.1924E+00	-.8938E+02	.6360E+02
	.1942E+00	.1551E+02	-.1659E+00	.1118E+02				
86	.3190E+01	-.2987E+03	.2448E-03	-.4406E-02	.1628E+02	.6065E+00	-.8905E+02	.6306E+02
	.6108E+00	.1628E+02	-.2611E+00	.1133E+02				
87	.3865E+01	-.2987E+03	-.3056E-03	-.4428E-02	.1629E+02	.1667E+01	-.8984E+02	.6213E+02
	.1668E+01	.1629E+02	-.4020E-01	.1139E+02				
88	.4878E+01	-.2987E+03	-.1016E-02	-.4445E-02	.1522E+02	.3265E+01	.8700E+02	.6055E+02
	.3297E+01	.1519E+02	.6254E+00	.1125E+02				
89	.6396E+01	-.2987E+03	-.1840E-02	-.4384E-02	.1350E+02	.4730E+01	.8138E+02	.5791E+02
	.4926E+01	.1330E+02	.1299E+01	.1077E+02				
90	.8674E+01	-.2987E+03	-.2706E-02	-.4176E-02	.1172E+02	.5553E+01	.7455E+02	.5375E+02
	.5990E+01	.1128E+02	.1582E+01	.9903E+01				
91	.2740E+01	-.2983E+03	.5931E-03	-.4353E-02	.1586E+02	.2254E+00	-.8836E+02	.6215E+02
	.2382E+00	.1585E+02	-.4466E+00	.1102E+02				
92	.3190E+01	-.2983E+03	.2135E-03	-.4339E-02	.1641E+02	.7483E+00	-.8682E+02	.6165E+02
	.7964E+00	.1637E+02	-.8668E+00	.1116E+02				
93	.3865E+01	-.2983E+03	-.3132E-03	-.4368E-02	.1607E+02	.1903E+01	-.8692E+02	.6081E+02
	.1944E+01	.1603E+02	-.7614E+00	.1118E+02				
94	.4878E+01	-.2983E+03	-.9887E-03	-.4417E-02	.1487E+02	.3408E+01	.8970E+02	.5935E+02
	.3409E+01	.1487E+02	.5928E-01	.1101E+02				
95	.6396E+01	-.2983E+03	-.1786E-02	-.4401E-02	.1326E+02	.4707E+01	.8331E+02	.5690E+02
	.4823E+01	.1315E+02	.9894E+00	.1055E+02				
96	.8674E+01	-.2983E+03	-.2646E-02	-.4232E-02	.1162E+02	.5450E+01	.7575E+02	.5298E+02
	.5824E+01	.1125E+02	.1472E+01	.9738E+01				
97	.2740E+01	-.2978E+03	.5023E-03	-.4281E-02	.1671E+02	.3205E+00	-.8681E+02	.6076E+02
	.3714E+00	.1666E+02	-.9116E+00	.1099E+02				
98	.3190E+01	-.2978E+03	.1353E-03	-.4261E-02	.1678E+02	.1072E+01	-.8392E+02	.6031E+02
	.1249E+01	.1661E+02	-.1055E+01	.1108E+02				
99	.3865E+01	-.2978E+03	-.3558E-03	-.4310E-02	.1586E+02	.2332E+01	-.8383E+02	.5953E+02
	.2488E+01	.1571E+02	-.1446E+01	.1102E+02				
100	.4878E+01	-.2978E+03	-.9825E-03	-.4394E-02	.1449E+02	.3658E+01	-.8787E+02	.5819E+02
	.3673E+01	.1447E+02	-.4030E+00	.1079E+02				
101	.6396E+01	-.2978E+03	-.1743E-02	-.4418E-02	.1300E+02	.4726E+01	.8498E+02	.5591E+02
	.4789E+01	.1294E+02	.7214E+00	.1034E+02				

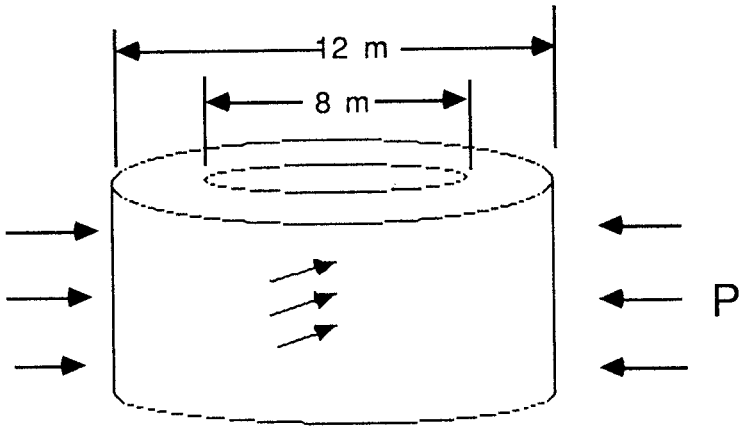
102	.8674E+01	-.2978E+03	-.2588E-02	-.4283E-02	.1151E+02	.5361E+01	.7683E+02	.5222E+02
	.5680E+01	.1119E+02	.1364E+01	.9575E+01				
103	.2740E+01	-.2974E+03	.3543E-03	-.4172E-02	.1834E+02	.6332E+00	-.8383E+02	.5943E+02
	.8375E+00	.1814E+02	-.1891E+01	.1116E+02				
104	.3190E+01	-.2974E+03	.1251E-04	-.4175E-02	.1722E+02	.1779E+01	-.7993E+02	.5901E+02
	.2251E+01	.1675E+02	-.2658E+01	.1110E+02				
105	.3865E+01	-.2974E+03	-.4241E-03	-.4261E-02	.1555E+02	.2975E+01	-.8077E+02	.5830E+02
	.3299E+01	.1523E+02	-.1992E+01	.1089E+02				
106	.4878E+01	-.2974E+03	-.9908E-03	-.4378E-02	.1407E+02	.3975E+01	-.8585E+02	.5706E+02
	.4028E+01	.1402E+02	-.7285E+00	.1059E+02				
107	.6396E+01	-.2974E+03	-.1707E-02	-.4435E-02	.1273E+02	.4770E+01	.8635E+02	.5494E+02
	.4803E+01	.1270E+02	.5058E+00	.1014E+02				
108	.8674E+01	-.2974E+03	-.2533E-02	-.4331E-02	.1139E+02	.5282E+01	.7779E+02	.5146E+02
	.5555E+01	.1112E+02	.1263E+01	.9412E+01				
109	.2740E+01	-.2970E+03	.1423E-03	-.4017E-02	.2064E+02	.1961E+01	-.7728E+02	.5815E+02
	.2868E+01	.1974E+02	-.4014E+01	.1168E+02				
110	.3190E+01	-.2970E+03	-.1365E-03	-.4094E-02	.1718E+02	.3071E+01	-.7541E+02	.5777E+02
	.3966E+01	.1628E+02	-.3440E+01	.1115E+02				
111	.3865E+01	-.2970E+03	-.5017E-03	-.4226E-02	.1505E+02	.3739E+01	-.7833E+02	.5711E+02
	.4201E+01	.1459E+02	-.2240E+01	.1075E+02				
112	.4878E+01	-.2970E+03	-.1006E-02	-.4370E-02	.1363E+02	.4301E+01	-.8442E+02	.5597E+02
	.4390E+01	.1354E+02	-.9030E+00	.1039E+02				
113	.6396E+01	-.2970E+03	-.1677E-02	-.4453E-02	.1246E+02	.4822E+01	.8740E+02	.5399E+02
	.4838E+01	.1244E+02	.3455E+00	.9942E+01				
114	.8674E+01	-.2970E+03	-.2480E-02	-.4376E-02	.1127E+02	.5210E+01	.7863E+02	.5072E+02
	.5445E+01	.1103E+02	.1170E+01	.9252E+01				
115	.2599E+01	-.2965E+03	-.1168E-04	-.3759E-02	.2094E+02	.3010E+01	-.6769E+02	.5674E+02
	.5594E+01	.1836E+02	-.6298E+01	.1172E+02				
116	.2984E+01	-.2962E+03	-.2354E-03	-.3931E-02	.1638E+02	.4185E+01	-.7095E+02	.5583E+02
	.5484E+01	.1508E+02	-.3763E+01	.1089E+02				
117	.3562E+01	-.2959E+03	-.5129E-03	-.4127E-02	.1389E+02	.4585E+01	-.7508E+02	.5447E+02
	.5201E+01	.1327E+02	-.2314E+01	.1026E+02				
118	.4430E+01	-.2954E+03	-.8704E-03	-.4342E-02	.1236E+02	.4742E+01	-.8083E+02	.5249E+02
	.4935E+01	.1216E+02	-.1198E+01	.9659E+01				
119	.5731E+01	-.2946E+03	-.1320E-02	-.4547E-02	.1129E+02	.4764E+01	-.8768E+02	.4965E+02
	.4774E+01	.1128E+02	-.2637E+00	.8990E+01				
120	.7682E+01	-.2934E+03	-.1845E-02	-.4694E-02	.1040E+02	.4644E+01	.8528E+02	.4576E+02
	.4683E+01	.1036E+02	.4722E+00	.8159E+01				
121	.2360E+01	-.2961E+03	.4188E-05	-.3491E-02	.1901E+02	.1855E+01	-.5836E+02	.5594E+02
	.6576E+01	.1429E+02	-.7660E+01	.1097E+02				
122	.2710E+01	-.2958E+03	-.1747E-03	-.3761E-02	.1582E+02	.3424E+01	-.6535E+02	.5497E+02
	.5580E+01	.1366E+02	-.4698E+01	.1049E+02				
123	.3236E+01	-.2954E+03	-.4149E-03	-.4024E-02	.1350E+02	.4220E+01	-.7144E+02	.5354E+02
	.5160E+01	.1256E+02	-.2801E+01	.9955E+01				
124	.4023E+01	-.2948E+03	-.7287E-03	-.4289E-02	.1199E+02	.4565E+01	-.7788E+02	.5149E+02
	.4893E+01	.1166E+02	-.1524E+01	.9388E+01				
125	.5205E+01	-.2938E+03	-.1123E-02	-.4544E-02	.1096E+02	.4647E+01	-.8504E+02	.4860E+02
	.4694E+01	.1091E+02	-.5435E+00	.8730E+01				
126	.6977E+01	-.2924E+03	-.1583E-02	-.4749E-02	.1015E+02	.4509E+01	.8777E+02	.4471E+02
	.4517E+01	.1015E+02	.2199E+00	.7911E+01				
127	.2078E+01	-.2958E+03	.2473E-04	-.3235E-02	.1655E+02	.1395E+01	-.4998E+02	.5527E+02
	.7663E+01	.1028E+02	-.7464E+01	.1028E+02				
128	.2386E+01	-.2955E+03	-.1031E-03	-.3561E-02	.1460E+02	.2816E+01	-.5797E+02	.5425E+02
	.6130E+01	.1128E+02	-.5296E+01	.1001E+02				
129	.2848E+01	-.2950E+03	-.3025E-03	-.3887E-02	.1283E+02	.3823E+01	-.6568E+02	.5276E+02
	.5351E+01	.1130E+02	-.3380E+01	.9614E+01				
130	.3541E+01	-.2943E+03	-.5752E-03	-.4209E-02	.1149E+02	.4394E+01	-.7349E+02	.5065E+02
	.4968E+01	.1092E+02	-.1935E+01	.9118E+01				
131	.4581E+01	-.2932E+03	-.9192E-03	-.4517E-02	.1056E+02	.4577E+01	-.8177E+02	.4772E+02
	.4699E+01	.1044E+02	-.8485E+00	.8494E+01				
132	.6142E+01	-.2915E+03	-.1317E-02	-.4778E-02	.9873E+01	.4431E+01	-.8966E+02	.4384E+02
	.4431E+01	.9872E+01	-.3259E-01	.7698E+01				
133	.1756E+01	-.2956E+03	.4022E-04	-.3006E-02	.1431E+02	.1137E+01	-.4200E+02	.5471E+02
	.8412E+01	.7036E+01	-.6551E+01	.9688E+01				
134	.2016E+01	-.2952E+03	-.4263E-04	-.3359E-02	.1314E+02	.2464E+01	-.5005E+02	.5365E+02
	.6866E+01	.8738E+01	-.5256E+01	.9548E+01				
135	.2407E+01	-.2946E+03	-.1983E-03	-.3731E-02	.1190E+02	.3600E+01	-.5855E+02	.5212E+02
	.5859E+01	.9639E+01	-.3693E+01	.9278E+01				
136	.2993E+01	-.2938E+03	-.4268E-03	-.4107E-02	.1082E+02	.4357E+01	-.6792E+02	.4996E+02
	.5270E+01	.9907E+01	-.2251E+01	.8864E+01				
137	.3872E+01	-.2926E+03	-.7186E-03	-.4469E-02	.1006E+02	.4614E+01	-.7810E+02	.4701E+02
	.4845E+01	.9832E+01	-.1099E+01	.8285E+01				
138	.5190E+01	-.2907E+03	-.1054E-02	-.4784E-02	.9546E+01	.4429E+01	-.8722E+02	.4314E+02
	.4441E+01	.9534E+01	-.2478E+00	.7517E+01				
139	.1401E+01	-.2953E+03	.4693E-04	-.2813E-02	.1237E+02	.9643E+00	-.3382E+02	.5426E+02
	.8836E+01	.4499E+01	-.5275E+01	.9194E+01				
140	.1609E+01	-.2949E+03	-.1386E-05	-.3174E-02				

	.7591E+01	.6416E+01	-.4675E+01	.9151E+01	.1172E+02	.2292E+01	-.4142E+02	.5317E+02
141	.1921E+01	-.2943E+03	-.1154E-03	-.3577E-02				
	.6555E+01	.7864E+01	-.3565E+01	.8980E+01	.1083E+02	.3585E+01	-.5020E+02	.5161E+02
142	.2388E+01	-.2934E+03	-.2959E-03	-.3998E-02				
	.5764E+01	.8737E+01	-.2302E+01	.8641E+01	.9991E+01	.4510E+01	-.6142E+02	.4942E+02
143	.3090E+01	-.2921E+03	-.5308E-03	-.4410E-02				
	.5122E+01	.9132E+01	-.1201E+01	.8109E+01	.9465E+01	.4790E+01	-.7454E+02	.4644E+02
144	.4142E+01	-.2901E+03	-.7999E-03	-.4773E-02				
	.4538E+01	.9153E+01	-.3805E+00	.7370E+01	.9184E+01	.4507E+01	-.8532E+02	.4259E+02
145	.1020E+01	-.2952E+03	.4338E-04	-.2660E-02				
	.9016E+01	.2644E+01	-.3819E+01	.8804E+01	.1080E+02	.8561E+00	-.2508E+02	.5393E+02
146	.1171E+01	-.2947E+03	.1863E-04	-.3021E-02				
	.8211E+01	.4512E+01	-.3665E+01	.8837E+01	.1047E+02	.2256E+01	-.3161E+02	.5282E+02
147	.1398E+01	-.2941E+03	-.5805E-04	-.3443E-02				
	.7271E+01	.6255E+01	-.2967E+01	.8740E+01	.9773E+01	.3754E+01	-.4014E+02	.5123E+02
148	.1739E+01	-.2932E+03	-.1881E-03	-.3898E-02				
	.6329E+01	.7605E+01	-.2002E+01	.8462E+01	.9068E+01	.4866E+01	-.5384E+02	.4902E+02
149	.2249E+01	-.2917E+03	-.3607E-03	-.4350E-02				
	.5461E+01	.8442E+01	-.1091E+01	.7971E+01	.8798E+01	.5105E+01	-.7190E+02	.4603E+02
150	.3015E+01	-.2896E+03	-.5582E-03	-.4755E-02				
	.4683E+01	.8778E+01	-.3986E+00	.7257E+01	.8817E+01	.4644E+01	-.8449E+02	.4218E+02
151	.6197E+00	-.2951E+03	.3042E-04	-.2554E-02				
	.9052E+01	.1440E+01	-.2298E+01	.8535E+01	.9692E+01	.8004E+00	-.1556E+02	.5371E+02
152	.7117E+00	-.2946E+03	.1981E-04	-.2911E-02				
	.8663E+01	.3160E+01	-.2334E+01	.8619E+01	.9519E+01	.2304E+01	-.2015E+02	.5258E+02
153	.8496E+00	-.2940E+03	-.2403E-04	-.3343E-02				
	.7852E+01	.5042E+01	-.1964E+01	.8573E+01	.8861E+01	.4033E+01	-.2721E+02	.5098E+02
154	.1056E+01	-.2930E+03	-.1024E-03	-.3822E-02				
	.6814E+01	.6712E+01	-.1363E+01	.8338E+01	.8127E+01	.5399E+01	-.4393E+02	.4875E+02
155	.1367E+01	-.2915E+03	-.2080E-03	-.4303E-02				
	.5765E+01	.7887E+01	-.7625E+00	.7876E+01	.8132E+01	.5519E+01	-.7215E+02	.4576E+02
156	.1832E+01	-.2893E+03	-.3289E-03	-.4737E-02				
	.4823E+01	.8477E+01	-.2986E+00	.7182E+01	.8502E+01	.4799E+01	-.8536E+02	.4192E+02
157	.2079E+00	-.2950E+03	.1092E-04	-.2499E-02				
	.9042E+01	.8504E+00	-.7652E+00	.8397E+01	.9113E+01	.7796E+00	-.5292E+01	.5360E+02
158	.2387E+00	-.2946E+03	.8127E-05	-.2854E-02				
	.8901E+01	.2459E+01	-.8009E+00	.8507E+01	.8999E+01	.2361E+01	-.6982E+01	.5247E+02
159	.2849E+00	-.2939E+03	-.6099E-05	-.3291E-02				
	.8176E+01	.4390E+01	-.6867E+00	.8487E+01	.8296E+01	.4270E+01	-.9972E+01	.5086E+02
160	.3543E+00	-.2929E+03	-.3225E-04	-.3780E-02				
	.7093E+01	.6221E+01	-.4833E+00	.8274E+01	.7308E+01	.6006E+01	-.2397E+02	.4862E+02
161	.4584E+00	-.2914E+03	-.6782E-04	-.4277E-02				
	.5943E+01	.7577E+01	-.2738E+00	.7828E+01	.7622E+01	.5898E+01	-.8074E+02	.4562E+02
162	.6144E+00	-.2891E+03	-.1085E-03	-.4726E-02				
	.4909E+01	.8309E+01	-.1104E+00	.7143E+01	.8313E+01	.4906E+01	-.8814E+02	.4178E+02

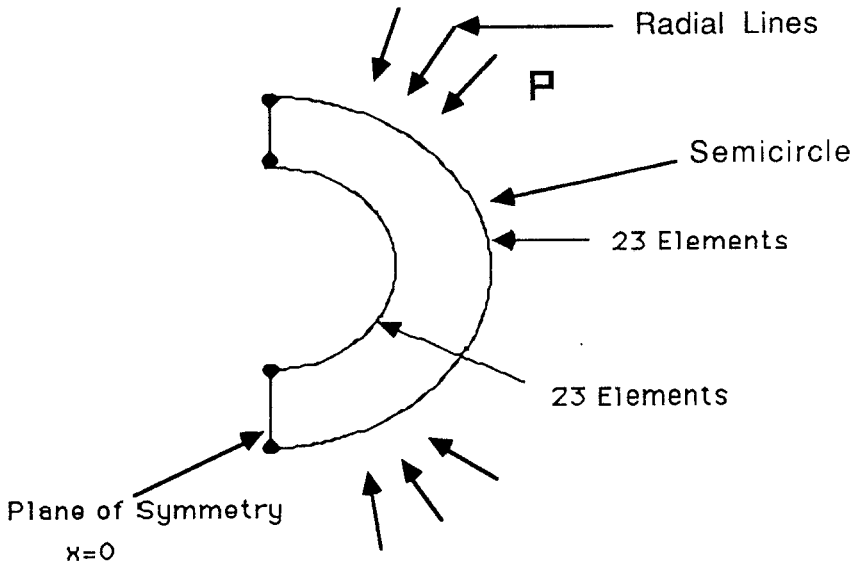
TIME REQUIRED TO COMPUTE STRESSES AND DISPLACEMENTS AT STRESS POINTS= 277.38 SECONDS.

JOB COMPLETED AT 8: 6 HOURS

DATA FOR PLOTTING WILL BE STORED IN FILE NAMED VERT10S



a) Infinite Thick-Walled Cylinder With External Pressure

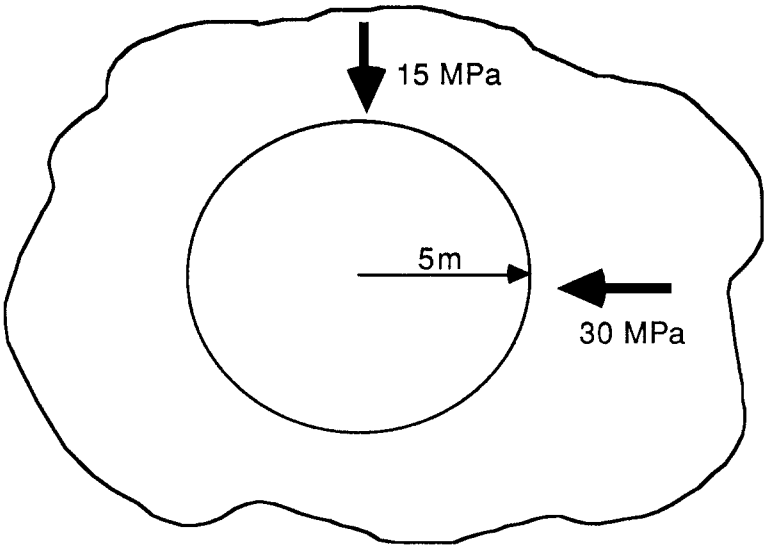


b) Idealization for Plane Strain Model

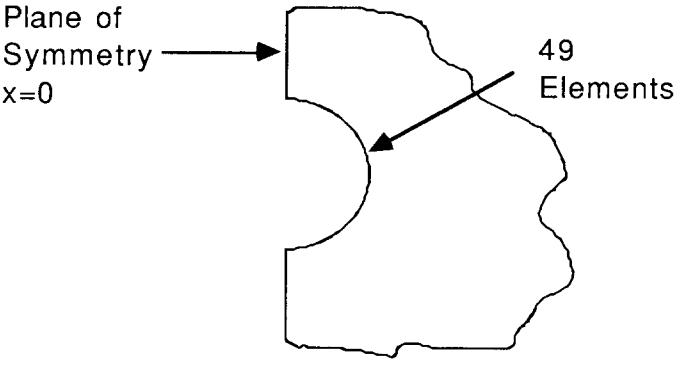
Figure 13. Verification Problem 1: Thick-Walled Cylinder

```
VERIF1
HEFF 4.1
THICK WALLED CYLINDER SUBJECTED TO EXTERNAL PRESSURE
2 1 0 0 1 0
0.25 60000.0
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
23 1 0. 0. -90. 90. 4. 0. 0. 0. 0.
23 1 0. 0. 90. -90. 6. 0. 0. 0. 6.
4.0 0.0 6.0 0. 6
```

Figure 14. Input to the HEFF Code for Analysis of a Thick-Walled Cylinder Subject to External Pressure



a) Infinite Length Cylindrical Hole in Initially Stressed Medium

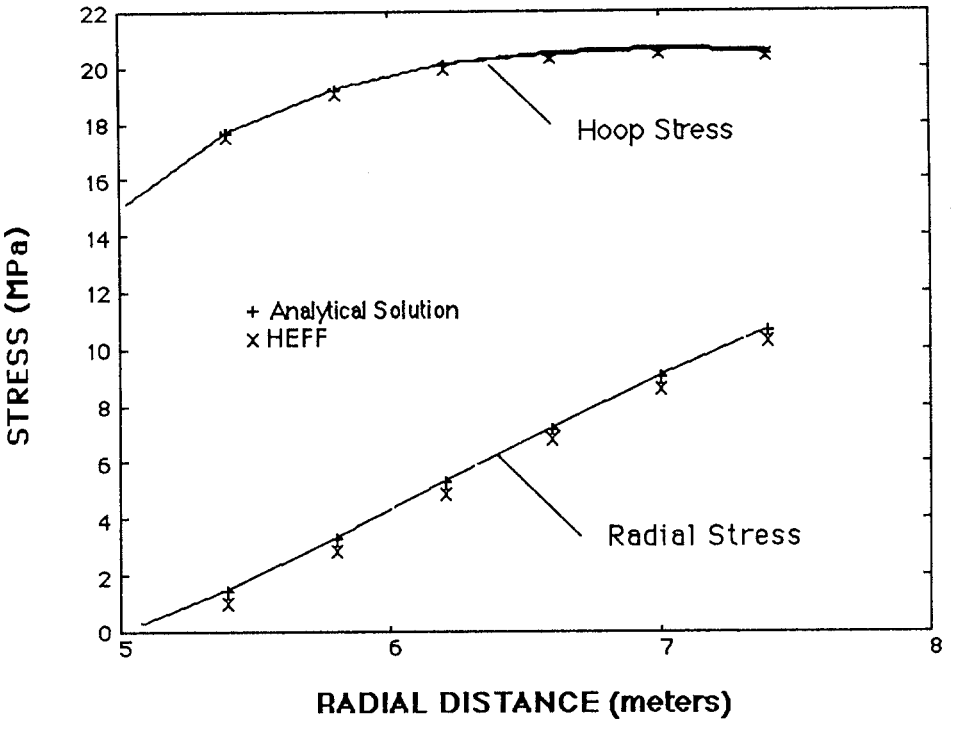


b) Idealization for Plane Strain Model

Figure 15. Verification Problem 2: Hole in Biaxially Stressed Plate

```
VERIF2
HEFF 4.1
EXCAVATION OF A CIRCULAR HOLE IN A BI-AXIALLY STRESSED PLATE
1 1 0 0 1 0
0.25 60000.0
0. 0. 0. 30. 15. 0. 0. 0. 0. 0.
49 1 0. 0. -90. 90. 5.005 0. 0. 0. 0.
5. 0. 10.2 0. 14
```

Figure 16. Input to the HEFF Code for Analysis of a Circular Hole in a Material with Biaxial Initial Stress State



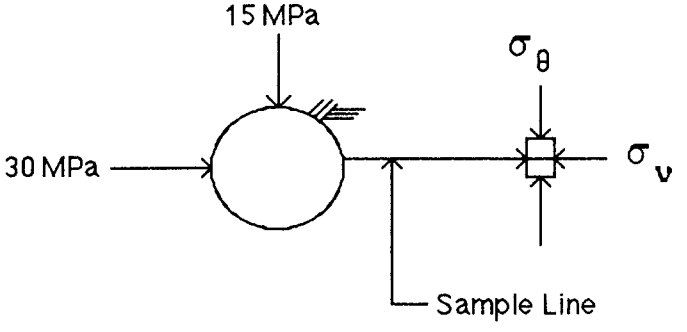


Figure 17. Distribution of Radial and Tangential Stress Along a Line $\theta = 0$, for a Cylindrical Hole in an Elastic Plate, With Biaxial Initial Stress State

```
VERIF3
HEFF 4.1
THERMO-ELASTIC RESPONSE OF A HOLLOW CYLINDER
2 1 1 1 0
0.25 60000.
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
5.
0. 0.
12.62 6.0E-06
0. 1.0 0.
0. 0. 1573.16 0.
29 1 0. 0. -90.  90. 4. 0. 0. 0. 0.
29 1 0. 0.  90. -90. 6. 0. 0. 0. 0.
4.0 0. 6.0 0. 7
```

Figure 18. Input to the HEFF Code for Analysis of a Heated Thick-Walled Cylinder

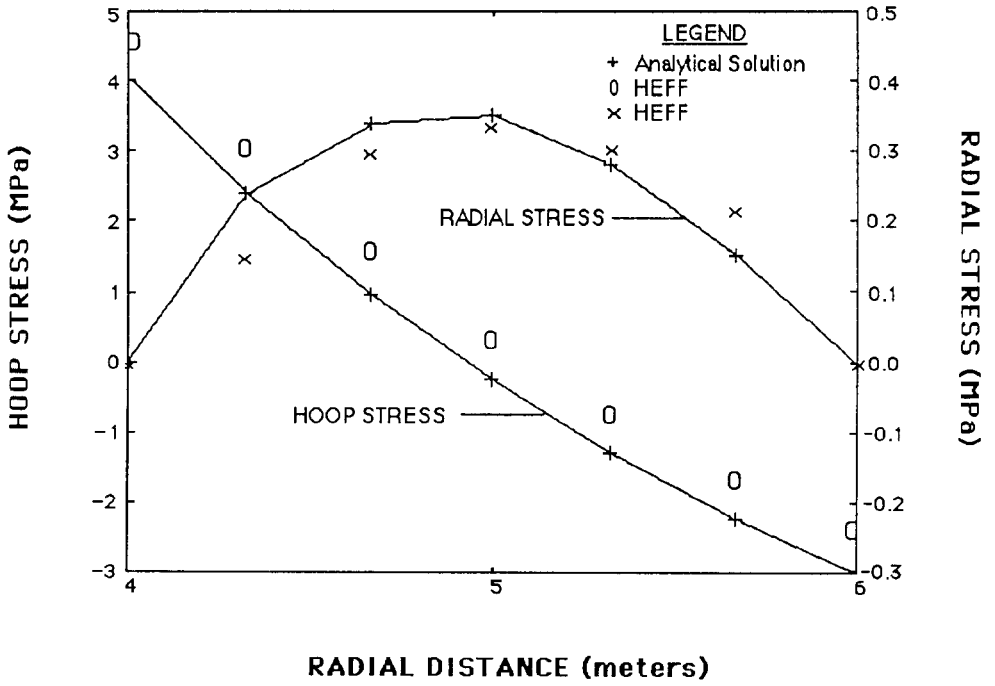
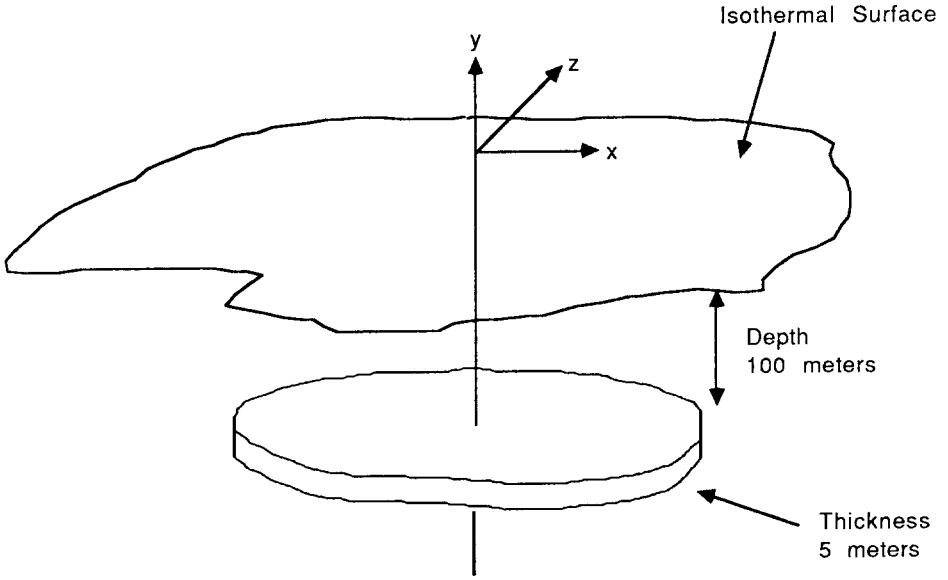
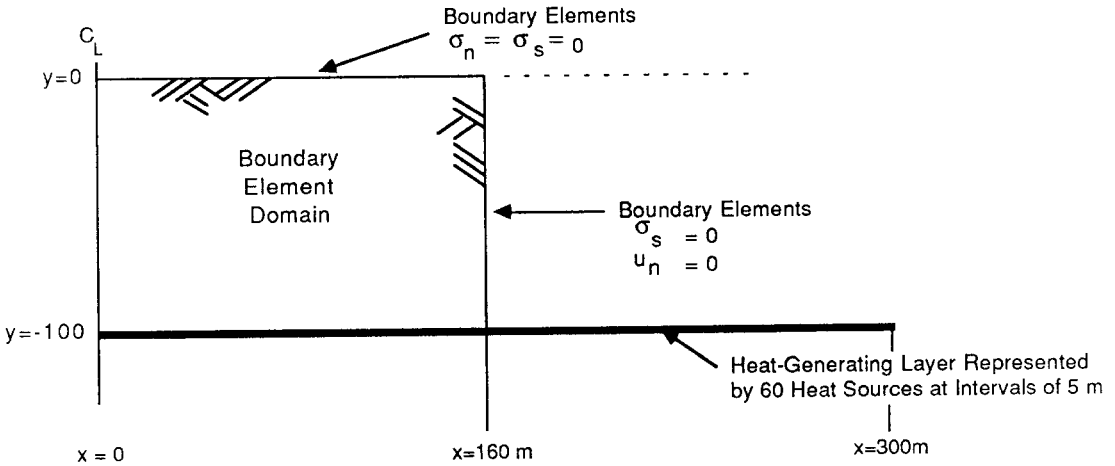


Figure 19. Comparison of Results of HEFF and "Exact" Analyses of a Heated Thick-Walled Cylinder



a) Heat-Generating Horizontal Layer in a Half-Space



b) Idealization for Plane Strain Model

Figure 20. Illustration of the Boundary-Element Model Used for Analysis of a Heat-Generating Layer in an Elastic Half-Space

```
VERIF4
HEFF 4.1
UNIFORM HEAT GENERATION IN SEMI-INFINITE MEDIUM
2 1 60 1 1 1
0.25 60000.
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
100.0
0. 0.
12.623 6.0E-06
0. 1. 0.
2.5  -100. 3143. 0.
7.5  -100. 3143. 0.
12.5  -100. 3143. 0.
17.5  -100. 3143. 0.
22.5  -100. 3143. 0.
27.5  -100. 3143. 0.
32.5  -100. 3143. 0.
37.5  -100. 3143. 0.
42.5  -100. 3143. 0.
47.5  -100. 3143. 0.
52.5  -100. 3143. 0.
57.5  -100. 3143. 0.
62.5  -100. 3143. 0.
67.5  -100. 3143. 0.
72.5  -100. 3143. 0.
77.5  -100. 3143. 0.
82.5  -100. 3143. 0.
87.5  -100. 3143. 0.
92.5  -100. 3143. 0.
97.5  -100. 3143. 0.
102.5  -100. 3143. 0.
107.5  -100. 3143. 0.
112.5  -100. 3143. 0.
117.5  -100. 3143. 0.
122.5  -100. 3143. 0.
127.5  -100. 3143. 0.
132.5  -100. 3143. 0.
137.5  -100. 3143. 0.
142.5  -100. 3143. 0.
147.5  -100. 3143. 0.
152.5  -100. 3143. 0.
157.5  -100. 3143. 0.
162.5  -100. 3143. 0.
167.5  -100. 3143. 0.
172.5  -100. 3143. 0.
177.5  -100. 3143. 0.
182.5  -100. 3143. 0.
187.5  -100. 3143. 0.
192.5  -100. 3143. 0.
197.5  -100. 3143. 0.
202.5  -100. 3143. 0.
207.5  -100. 3143. 0.
212.5  -100. 3143. 0.
217.5  -100. 3143. 0.
222.5  -100. 3143. 0.
227.5  -100. 3143. 0.
232.5  -100. 3143. 0.
237.5  -100. 3143. 0.
242.5  -100. 3143. 0.
247.5  -100. 3143. 0.
252.5  -100. 3143. 0.
257.5  -100. 3143. 0.
262.5  -100. 3143. 0.
267.5  -100. 3143. 0.
272.5  -100. 3143. 0.
277.5  -100. 3143. 0.
282.5  -100. 3143. 0.
287.5  -100. 3143. 0.
292.5  -100. 3143. 0.
297.5  -100. 3143. 0.
20 1  0. 0.0  160.0 0.0  0.  0.  0.  0.  0.
15 4 160.0 0.0 160.0 -150.0 0. 0. 0. 0. 0.
5.0  0.0  5.0  -100.0  21
```

Figure 21. Input to the HEFF Code for Analysis of a Heat-Generating Layer

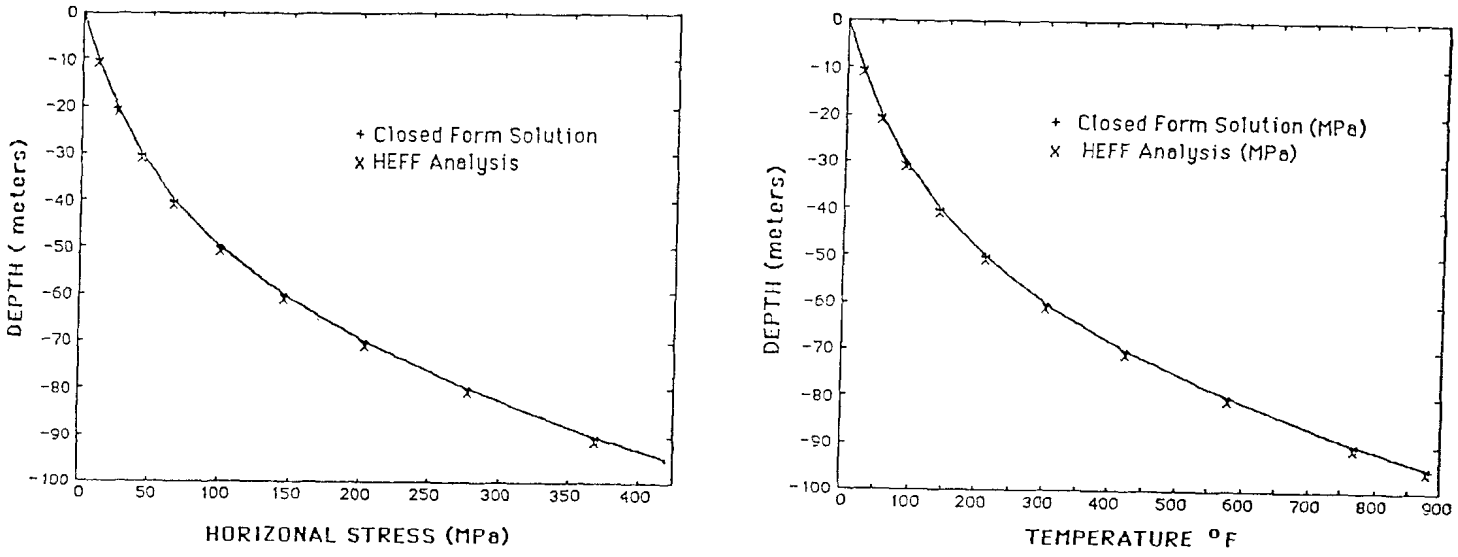


Figure 22. Comparison of Closed Form and HEFF Analyses for Heat-Generating Layer

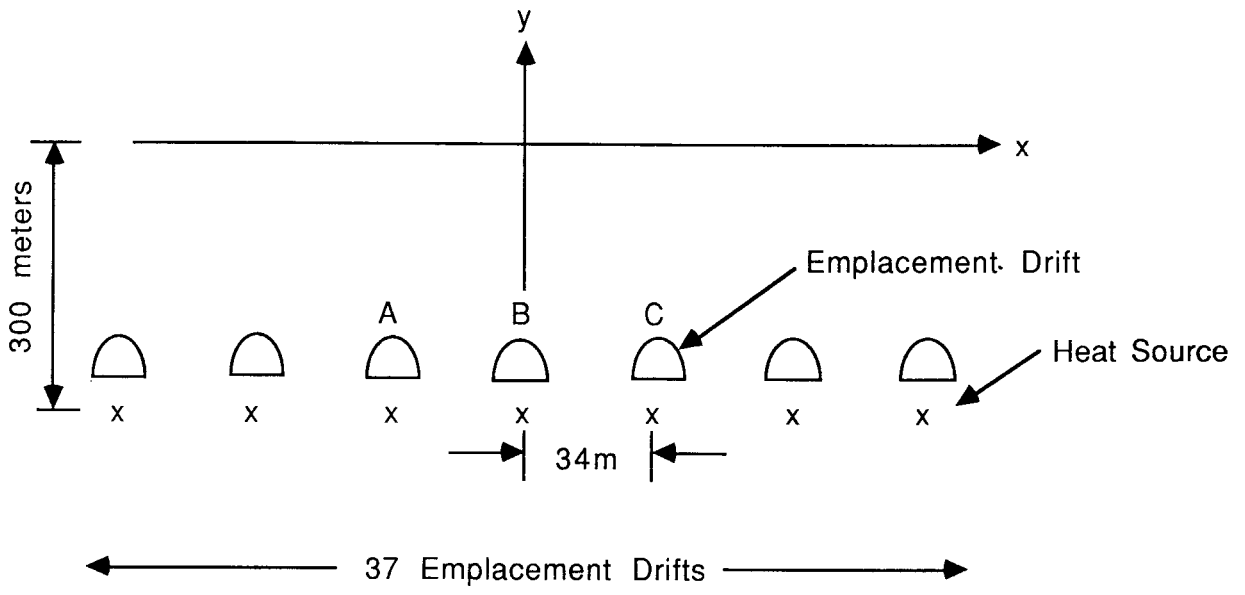
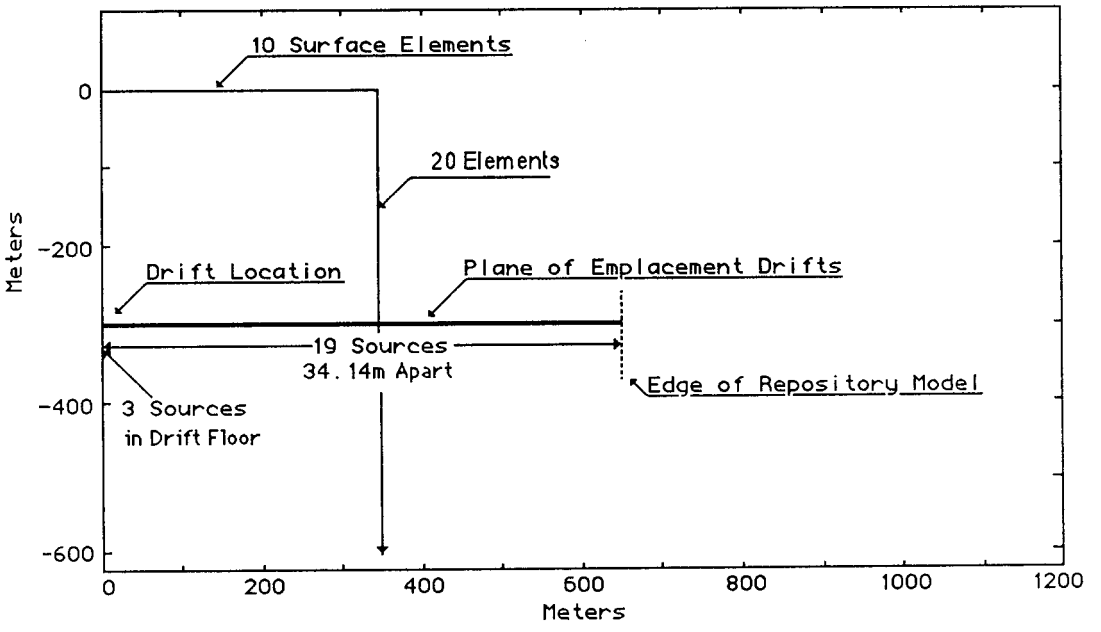
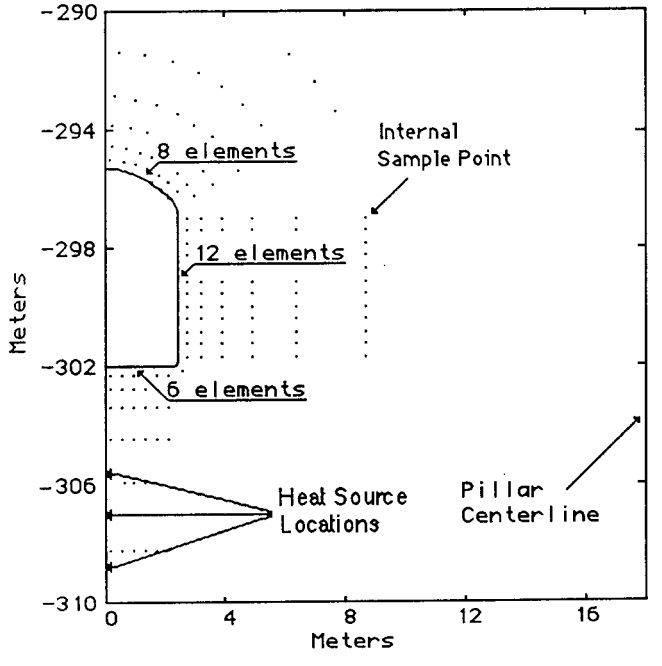


Figure 23. Idealized Cross Section of a Repository with Parallel Drifts for Vertical Emplacement of Waste (Note That Only Drifts A, B and C Were Modeled Using Boundary Elements)



a) Repository Model



b) Drift Detail and Sample Points

Figure 24. Details of Boundary-Element Model for Analysis of Vertical Emplacement

```
VERT10
HEFF 4.1
VERTICAL EMPLACEMENT - OUTPUT AT T=10 YRS.
10  0   22  4   1  1
0.2   15100.
0  -0.023  0  0  0  0  0.55  0  0.55  1
10.
-0.0239  16.9
29.03   10.7E-6
0  .15602    .0013539
0  .59787    .019142
0  .15227    .051888
0  .09384    .43768
  0.0     -305.812   1380.328    0.0
  0.0     -307.335   1380.328    0.0
  0.0     -308.858   1380.328    0.0
 34.138   -307.335   8281.97     0.0
 68.276   -307.335   8281.97     0.0
102.414   -307.335   8281.97     0.0
136.552   -307.335   8281.97     0.0
170.690   -307.335   8281.97     0.0
204.828   -307.335   8281.97     0.0
238.966   -307.335   8281.97     0.0
273.104   -307.335   8281.97     0.0
307.242   -307.335   8281.97     0.0
341.380   -307.335   8281.97     0.0
375.518   -307.335   8281.97     0.0
409.656   -307.335   8281.97     0.0
443.794   -307.335   8281.97     0.0
477.932   -307.335   8281.97     0.0
512.070   -307.335   8281.97     0.0
546.208   -307.335   8281.97     0.0
580.346   -307.335   8281.97     0.0
614.484   -307.335   8281.97     0.0
648.622   -307.335   8281.97     0.0
6  1   0.      -302.     2.34    -302.     0.    0.   0.   0.   0.
1  1   2.34   -302.     2.44    -301.9    0.    0.   0.   0.   0.
12 1   2.44   -301.9    2.44    -296.78   0.    0.   0.   0.   0.
8  1   0.      -298.03  27.13     90.0    2.74  0.   0.   0.   0.
4  1  31.698  -302.    36.578   -302.     0.    0.   0.   0.   0.
4  1  36.578  -302.    36.578   -296.78   0.    0.   0.   0.   0.
4  1  34.138  -298.03  27.13     152.87   2.74  0.   0.   0.   0.
4  1  31.698  -296.78  31.698   -302.0    0.    0.   0.   0.   0.
10 1   0.       0.    324.3       0.      0.    0.   0.   0.   0.
20 4   324.3    0.0   324.3    -600.      0.    0.   0.   0.   0.
.3  1.50  6  27
```

Figure 25. Input to the HEFF Code for the Near-Field Analysis of the Emplacement Drift

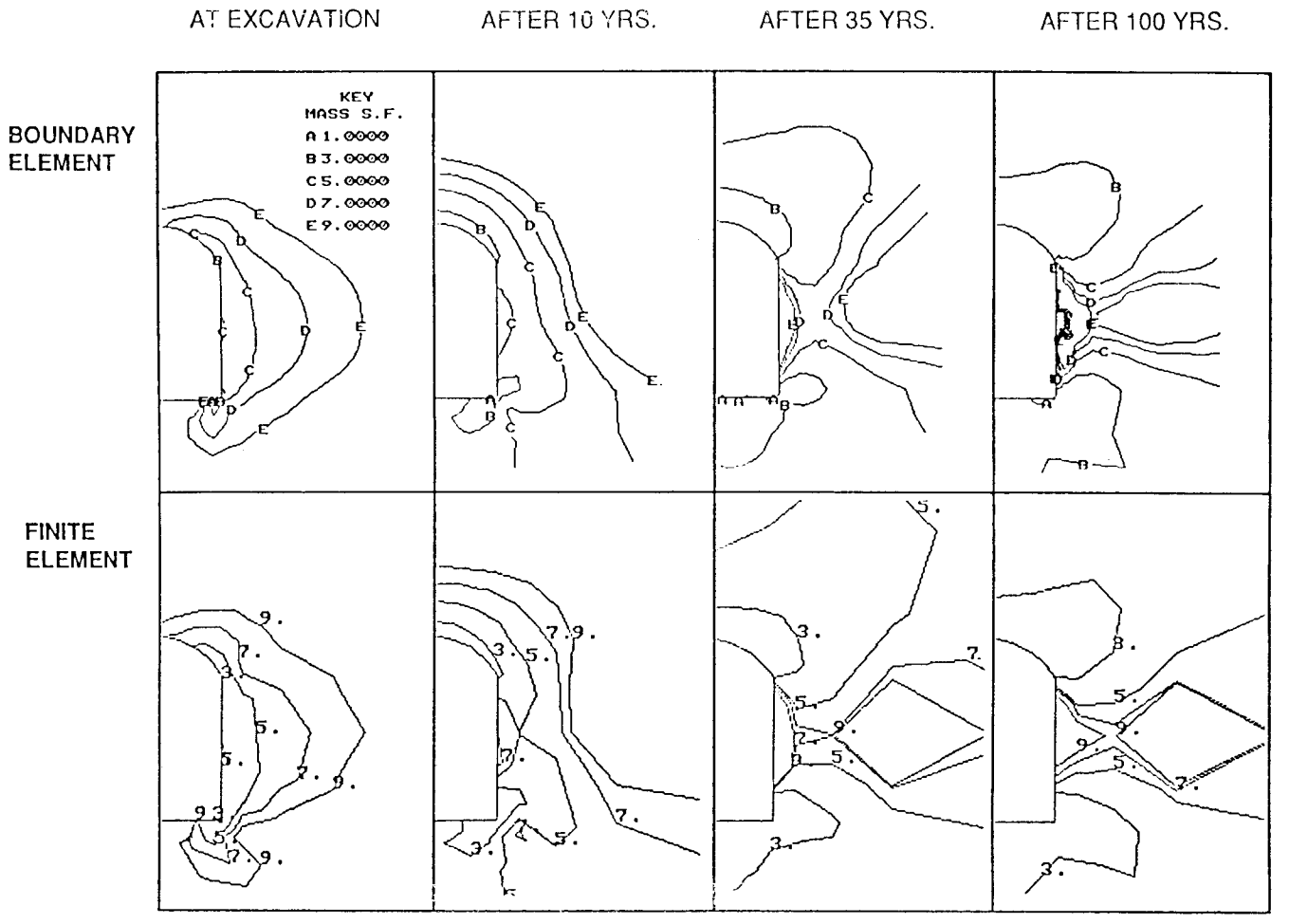


Figure 26. Comparison of HEFF and Finite Element Predictions of Ratio Between Matrix Strength and Stress Around Vertical Emplacement Drift at Times Up to 100 Years After Waste Emplacement

APPENDIX A

Listing of HEFF Version 4.1

```
SLARGE
      PROGRAM HEFF                                                      HEF  1
C     - IMPLEMENTED UNDER MS FORTRAN 77 VERSION 4.01 - DECEMBER 6 1987
C     VERSION 4.1 - DECEMBER 6 1987
C
C     THIS VERSION DIFFERS FROM EARLIER VERSIONS ONLY IN THE HEAT
C     ROUTINE  WHERE MINOR CHANGES HAVE BEEN MADE TO IMPROVE
C     ACCURACY AND AVOID MATHEMATICAL DIFFICULTIES
C     ****************************************************************
C
C     HEFF IS AN INDIRECT FORMULATION OF THE BOUNDARY ELEMENT
C     METHOD. IT IS A COMBINATION OF PROGRAM "BEP2D" WHICH USES
C     STRIP LOAD SINGULARITIES, AND A ROUTINE MODELLING
C     EXPONENTIALLY DECAYING HEAT SOURCES
C     ORIGINAL CODING OF HEFF WAS BY B.H.G.BRADY USING THE MECHANICAL
C     MODEL OF S.L.CROUCH AND THERMAL MODEL OF R.D.HART
C
C     THIS VERSION CLEANED-UP BY : CHRIS ST. JOHN (DEC. 9, 1987)
C                                  J.F.T.AGAPITO AND ASSOCIATES
C                                  (303) 242-4220
C
C     ----------  CONTROL VARIABLES  ----------------------------------
C
C     NUMBS : NUMBER OF LINE SEGMENTS DEFINING EXCAVATIONS
C     NUMOS : NUMBER OF LINE SEGMENTS DEFINING STRESS POINTS
C     NSORC : NUMBER OF EXPONENTIALLY DECAYING HEAT SOURCES
C     NCOMP : NUMBER OF EXPONENTIALLY DECAYING COMPONENTS
C     KSYM  : CODE DEFINING SYMMETRY CONDITIONS
C             = 1   NO SYMMETRY
C             = 2   XS=X=0 IS A LINE OF SYMMETRY
C     IMAG  : CODE DEFINING USE OF IMAGE HEAT SOURCES
C             = 0   NO IMAGE HEAT SOURCES
C             = 1   IMAGE HEAT SOURCES
C
C     ----------  LOGICAL UNIT DEFINITIONS  ---------------------------
C
C     UNIT 0 : MONITOR AND KEYBOARD
C     UNIT 1 : INPUT FILE NAMED BY THE USER
C     UNIT 2 : OUTPUT FILE NAMED BY THE USER
C     UNIT 3 : FILE CONTAINING DATA FOR PLOTTING
C
C     ----------  DIMENSIONS OF ARRAYS  -------------------------------
C
C     ARRAY SIZES ARE SPECIFIED BY  THE PARAMETER 'LIMIT'
C
C     NUMBER OF ELEMENTS : NUMBE --- CSS,CSN,CNS,CNN,RS,RN,PS,PN,XM,YM,
C                                    A,COSBET,SINBET,KOD,SS,SN,BS,BN
C     NUMBER OF STRESS LINES : NUMOS --- XB,YB,XE,YE,NUMPB
C     NUMBER OF EXP. DECAYING COMPONENTS : NCOMP --- TOC,PROP,QEXP
C     NUMBER OF HEAT SOURCES : NSORC --- XS,YS,QS,TOS
C
C     ----------  VARIABLE DEFINITIONS  -------------------------------
C
C     PR : POISSONS RATIO
C     E  : YOUNGS MODULUS
C     G  : SHEAR MODULUS
C     DIFF : THERMAL DIFFUSIVITY
C     ALPHA : THERMAL EXPANSION COEFFICIENT
C     TGRAD : TEMPERATURE GRADIENT
C     TSURF : INITIAL SURFACE TEMPERATURE
C
C     AXX,AYY : CONSTANTS DEFINING IN SITU STRESSES
C     AXY,BXX : CONSTANTS DEFINING IN SITU STRESSES
C     BYY,BXY : CONSTANTS DEFINING IN SITU STRESSES
C     CXX,DXX,RMAX : CONSTANTS DEFINING VERTICAL STRESS
C     XZRAT : CONSTANT DEFINING OUT OF PLANE STRESS
C
C     TOC(I) : TIME ON FOR COMPONENT I
C     PROP(I) : PROPORTION OF COMPONENT I
C     QEXP(I) : DECAY CONSTANT FOR COMPONENT I
C
C     XS(J) : X-COORDINATE OF SOURCE J
C     YS(J) : Y-COORDINATE OF SOURCE J
C     QS(J) : INITIAL STRENGTH OF SOURCE J
C     TOS(J) : TIME ON FOR SOURCE J
C
C     XB(K) : BEGINNING X-COORDINATE OF STRESS LINE K
C     YB(K) : BEGINNING Y-COORDINATE OF STRESS LINE K
C     XE(K) : ENDING X-COORDINATE OF STRESS LINE K
C     YE(K) : ENDING Y-COORDINATE OF STRESS LINE K
C     NUMPB(K) : NUMBER OF STRESS POINTS ALONG STRESS LINE K
C
C     -------------  USER NOTES  ----------------------------------------
C
C     SURFACE BOUNDARY CONDITIONS
C      AS CURRENTLY CODED, THE PROGRAM DOES NOT PLACE IMAGE BOUNDARY
C      ELEMENTS ABOVE THE SURFACE.  IF THE EXCAVATIONS ARE SUFFICIENTLY
C      FAR FROM THE SURFACE TO HAVE NO EFFECT, THESE IMAGE BOUNDARY
C      ELEMENTS ARE NOT NECCESSARY.  IMAGE HEAT SOURCES CAN BE USED TO
C      YIELD A ZERO NORMAL STRESS, ZERO HEAT FLOW BOUNDARY CONDITION AT
C      THE SURFACE. THE PROGRAM DOES NOT REMOVE THE SURFACE SHEARS.
C
C     ****************************************************************
C
      PARAMETER (LIMIT =100)                                            HEF  2
C
C
      REAL     CSS(LIMIT,LIMIT),CSN(LIMIT,LIMIT),CNS(LIMIT,LIMIT)       HEF  3
      REAL     CNN(LIMIT,LIMIT),RS(LIMIT),RN(LIMIT),PS(LIMIT),PN(LIMIT) HEF  4
      REAL     XS(LIMIT),YS(LIMIT),QS(LIMIT),TOS(LIMIT),TOC(5),PROP(5)  HEF  5
      REAL     AA(6),XM(LIMIT),YM(LIMIT),A(LIMIT),COSBET(LIMIT)         HEF  6
      REAL     SINBET(LIMIT),STORE(7,LIMIT),BN(LIMIT),BS(LIMIT)         HEF  7
      REAL     XB(LIMIT),YB(LIMIT),XE(LIMIT),YE(LIMIT),QEXP(5),TIM,SS,SN HEF  8
      INTEGER NUMPB(LIMIT),KOD(LIMIT)                                   HEF  9
      CHARACTER*72 ITITLE                                               HEF 10
      CHARACTER*10 NAME,QACIN,QANUM,QANUM1                              HEF 11
C
      DATA QANUM /'HEFF 4.1  '/                                         HEF 12
      DATA QANUM1 /'heff 4.1  '/                                        HEF 13
C
C     DEFINE ARRAY SIZE
C     -----------------
      NIFL = LIMIT                                                      HEF 14
C
C     OPEN INPUT AND OUTPUT FILES
```

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C     ---------------------------
C     POSSIBLE SYSTEM DEPENDENCE BELOW IN OPENING FILES AND CALLS TO
C     GETTIM,GETDAT
C
      WRITE(0,'(A\)') ' Enter name of input file '                      HEF 15
      READ (0,'(A)') NAME                                               HEF 16
      OPEN(1,FILE=NAME,FORM='FORMATTED',STATUS='OLD')                   HEF 17
      WRITE(0,'(A\)') ' Enter name of output file '                     HEF 18
      READ (0,'(A)') NAME                                               HEF 19
      OPEN(2,FILE=NAME,FORM='FORMATTED',STATUS='UNKNOWN')               HEF 20
C
C     READ NAME OF PLOT FILE
C     ----------------------
      READ (1,'(A10)') NAME                                             HEF 21
C
C
      OPEN (3,FILE=NAME,FORM='FORMATTED',STATUS='UNKNOWN',              HEF 22
     1 ACCESS='SEQUENTIAL')                                             HEF 23
C
C
C     CHECK QA NUMBER
C     ---------------
C
      READ(1,'(A10)') QACIN                                             HEF 24
      IF (QACIN.NE.QANUM.AND.QACIN.NE.QANUM1) THEN                      HEF 25
          WRITE(0,'(50A)')'  WRONG QA NUMBER'                           HEF 26
          WRITE(2,'(50A)')'WRONG QA NUMBER. JOB ABORTED'                HEF 27
          STOP                                                          HEF 28
      ENDIF                                                             HEF 29
C
C     COMPLETE FILE OPENING
C     ---------------------
C
      READ (1,'(A72)') ITITLE                                           HEF 30
      WRITE (2,1000)                                                    HEF 31
C
C     FIRST SCREEN MESSAGE : READ INPUT
C     ---------------------------------
C
      WRITE (0,2000)                                                    HEF 32
C
C     CALL BUILT-IN ROUTINE FOR DATE TO RECORD ON OUTPUT
C     --------------------------------------------------
C     (MS FORTRAN 4.0 ONLY)
C      -------------------
C
      CALL GETDAT(IY,IM,ID)                                             HEF 33
      WRITE (2,1010)'ITITLE,IM,ID,IY                                    HEF 34
C
      READ (1,*) NUMBS,NUMOS,NSORC,NCOMP,KSYM,IMAG                      HEF 35
      READ (1,*) PR,E                                                   HEF 36
      READ (1,*) AXX,AYY,AXY,BXX,BYY,BXY,CXX,DXX,RMAX,XZRAT             HEF 37
      WRITE (2,1030) NUMBS,NUMOS,NSORC,NCOMP                            HEF 38
      IF (KSYM.EQ.0) WRITE (2,1040)                                     HEF 39
      IF (KSYM.EQ.1) WRITE (2,1050)                                     HEF 40
      IF (IMAG.EQ.0) WRITE (2,1060)                                     HEF 41
      IF (IMAG.NE.0) WRITE (2,1070)                                     HEF 42
C
      G=E/(2.0*(1.0+PR))                                                HEF 43
      WRITE (2,1080) PR,E,G                                             HEF 44
      WRITE (2,1090) AXX,BXX,CXX,DXX,AYY,BYY,AXY,BXY,RMAX,XZRAT         HEF 45
C
      PI=4.*ATAN(1.)                                                    HEF 46
      CON=1./(4.*PI*(1.-PR))                                            HEF 47
      CFAC=PI/180.0                                                     HEF 48
C
      ALFAE=0.0                                                         HEF 49
      IF (NSORC.NE.0) THEN                                              HEF 50
          READ (1,*) TIM                                                HEF 51
          WRITE (2,1110)TIM                                             HEF 52
          READ (1,*) TGRAD,TSURF                                        HEF 53
          WRITE (2,1100) TGRAD,TSURF                                    HEF 54
          READ (1,*) DIFF,ALPHA                                         HEF 55
          VE=(1.0+PR)*ALPHA*G/(1.0-PR)                                  HEF 56
          ALFAE=ALPHA*E                                                 HEF 57
          WRITE (2,1120) DIFF,ALPHA,VE                                  HEF 58
          WRITE (2,1130)                                                HEF 59
C
          DO 10  I=1,NCOMP                                              HEF 60
           READ (1,*)  TOC(I),PROP(I),QEXP(I)                           HEF 61
           WRITE (2,1140) TOC(I),PROP(I),QEXP(I)                        HEF 62
10        CONTINUE                                                      HEF 63
C
          WRITE (2,1150)                                                HEF 64
C
          DO 20  I=1,NSORC                                              HEF 65
           READ (1,*)  XS(I),YS(I),QS(I),TOS(I)                         HEF 66
           WRITE (2,1160) XS(I),YS(I),QS(I),TOS(I)                      HEF 67
20        CONTINUE                                                      HEF 68
C
      ENDIF                                                             HEF 69
C
C     DEFINE LOCATIONS, SIZES, ORIENTATIONS AND BOUNDARY CONDITIONS OF
C     ----------------------------------------------------------------
C     BOUNDARY ELEMENTS.
C     ------------------
C
      WRITE (2,1170)                                                    HEF 70
      WRITE (2,1180)                                                    HEF 71
      NUMBE=0                                                           HEF 72
C
      DO 80  N=1,NUMBS                                                  HEF 73
        READ (1,*) NUM,KODE,XBEG,YBEG,XEND,YEND,RADIUS,RATIO,PSI,BVS,   HEF 74
     1  BVN                                                             HEF 75
        IF (RADIUS.LE.0.0) THEN                                         HEF 76
            XD=(XEND-XBEG)/NUM                                          HEF 77
            YD=(YEND-YBEG)/NUM                                          HEF 78
            SW=SQRT(XD*XD+YD*YD)                                        HEF 79
C
            DO 30 JA=1,NUM                                              HEF 80
              NUMBE=NUMBE+1                                             HEF 81
              M=NUMBE                                                   HEF 82
              XM(M)=XBEG+0.5*(2.*JA-1.)*XD                              HEF 83
              YM(M)=YBEG+0.5*(2.*JA-1.)*YD                              HEF 84
              A(M)=0.5*SW                                               HEF 85
              SINBET(M)=YD/SW                                           HEF 86
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              COSBET(M)=XD/SW                                           HEF 87
              KOD(M)=KODE                                               HEF 88
              BS(M)=BVS                                                 HEF 89
              BN(M)=BVN                                                 HEF 90
30          CONTINUE                                                    HEF 91
        ELSE                                                            HEF 92
            NELG=0                                                      HEF 93
            RELG=NELG                                                   HEF 94
            RELR=NUM                                                    HEF 95
            IF(RATIO.EQ.0.0) RATIO=1.0                                  HEF 96
            SINPSI=SIN(PSI*PI/180.)                                     HEF 97
            COSPSI=COS(PSI*PI/180.)                                     HEF 98
            GD=.1E-10                                                   HEF 99
            GA=RATIO*COS((XEND-PSI)*PI/180.0)                           HEF100
            IF (ABS(GA).LT.GD) GA=GD                                    HEF101
            GB=RATIO*COS((YEND-PSI)*PI/180.0)                           HEF102
            IF (ABS(GB).LT.GD) GB=GD                                    HEF103
            CHI1=ATAN2(SIN((XEND-PSI)*PI/180.0),GA)                     HEF104
            CHI2=ATAN2(SIN((YEND-PSI)*PI/180.0),GB)                     HEF105
            DCHI=(CHI2-CHI1)/RELR                                       HEF106
            IF (ABS(DCHI).GE.GD) THEN                                   HEF107
              GC=DCHI/ABS(DCHI)                                         HEF108
            ELSE                                                        HEF109
              GC=-1.0                                                   HEF110
            ENDIF                                                       HEF111
            DCHI=DCHI+((YEND-XEND)/ABS(YEND-XEND)-GC)*PI/RELR           HEF112
70          NUMBE=NUMBE+1                                               HEF113
            M=NUMBE                                                     HEF114
            CHI=CHI1+RELG*DCHI                                          HEF115
            EY1=RADIUS*(COS(CHI)*SINPSI+SIN(CHI)*COSPSI*RATIO)+YBEG     HEF116
            EX1=RADIUS*(COS(CHI)*COSPSI-SIN(CHI)*SINPSI*RATIO)+XBEG     HEF117
            CHI=CHI+DCHI                                                HEF118
            EY2=RADIUS*(COS(CHI)*SINPSI+SIN(CHI)*COSPSI*RATIO)+YBEG     HEF119
            EX2=RADIUS*(COS(CHI)*COSPSI-SIN(CHI)*SINPSI*RATIO)+XBEG     HEF120
            DX=EX2-EX1                                                  HEF121
            DY=EY2-EY1                                                  HEF122
            IF (ABS(DX).LT.(.1E-13)*RADIUS) DX=0.0                      HEF123
            IF (ABS(DY).LT.(.1E-13)*RADIUS) DY=0.0                      HEF124
            SW=SQRT(DX*DX+DY*DY)                                        HEF125
            XM(M)=0.5*(EX1+EX2)                                         HEF126
            YM(M)=0.5*(EY1+EY2)                                         HEF127
            COSBET(M)=DX/SW                                             HEF128
            SINBET(M)=DY/SW                                             HEF129
            A(M)=0.5*SW                                                 HEF130
            KOD(M)=KODE                                                 HEF131
            BS(M)=BVS                                                   HEF132
            BN(M)=BVN                                                   HEF133
            NELG=NELG+1                                                 HEF134
            RELG=NELG                                                   HEF135
            IF (NELG.LT.NUM) GO TO 70                                   HEF136
        ENDIF                                                           HEF137
C
80      CONTINUE                                                        HEF138
C
      WRITE (2,1190) (M,KOD(M),XM(M),YM(M),A(M),SINBET(M),COSBET(M),BS(M HEF139
     1),BN(M),M=1,NUMBE)                                                HEF140
      WRITE (2,1200)                                                    HEF141
      IF (NUMOS.NE.0) THEN                                              HEF142
        DO 90  I=1,NUMOS                                                HEF143
          READ (1,*)  XB(I),YB(I),XE(I),YE(I),NUMPB(I)                  HEF144
          WRITE (2,1210) XB(I),YB(I),XE(I),YE(I),NUMPB(I)               HEF145
90      CONTINUE                                                        HEF146
      ELSE                                                              HEF147
100     READ (1,*) DELN,RATTY,NUMPT,NBE                                 HEF148
C
C       SET UP LENGTH OF LINES TO BE GENERATED NORMAL TO BOUNDARY
C       ---------------------------------------------------------
C
        DELS=DELN                                                       HEF149
        RLINE=0.0                                                       HEF150
        IF(NUMPT.LT.2) NUMPT=2                                          HEF151
        NUMP=NUMPT-1                                                    HEF152
C
        DO 110  I=1,NUMP                                                HEF153
          DELS=DELS*RATTY                                               HEF154
          RLINE=RLINE+DELS                                              HEF155
110     CONTINUE                                                        HEF156
        DO 120  M=1,NBE                                                 HEF157
          SB=-COSBET(M)                                                 HEF158
          CB= SINBET(M)                                                 HEF159
          XC=XM(M)                                                      HEF160
          YC=YM(M)                                                      HEF161
          XB(M)=XC+CB*DELN                                              HEF162
          YB(M)=YC+SB*DELN                                              HEF163
          XE(M)=XB(M)+CB*RLINE                                          HEF164
          YE(M)=YB(M)+SB*RLINE                                          HEF165
          NUMPB(M)=0                                                    HEF166
120     CONTINUE                                                        HEF167
        WRITE (2,1210) (XB(I),YB(I),XE(I),YE(I),NUMPB(I),I=1,NBE)       HEF168
        NUMOS=NBE                                                       HEF169
      ENDIF                                                             HEF170
C
C
C     START RECORD ON PLOT FILE
C     -------------------------
      WRITE (3,3000) NAME,NUMBE,NUMPT,IY,IM,ID,IH,IM                    HEF171
C
C     COMPUTE INFLUENCE COEFFICIENTS AND SET UP SYSTEM OF ALGEBRAIC
C     -------------------------------------------------------------
C     EQUATIONS.
C     ---------
C
      CALL SECOND (TIMO)                                                HEF172
C
C     SECOND SCREEN MESSAGE : COMPUTE INFLUENCE COEFFICIENTS
C     ------------------------------------------------------
C
      WRITE (0,2100)                                                    HEF173
C
      DO 200  I=1,NUMBE                                                 HEF174
        XI=XM(I)                                                        HEF175
        YI=YM(I)                                                        HEF176
        COSBI=COSBET(I)                                                 HEF177
        SINBI=SINBET(I)                                                 HEF178
        KODE=KOD(I)                                                     HEF179
C
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      DO 190  J=1,NUMBE                                                 HEF180
        CALL INITL(SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)       HEF181
        XJ=XM(J)                                                        HEF182
        YJ=YM(J)                                                        HEF183
        COSBJ=COSBET(J)                                                 HEF184
        SINBJ=SINBET(J)                                                 HEF185
        AJ=A(J)                                                         HEF186
        CALL INCO2 (XI,YI,XJ,YJ,AJ,COSBJ,SINBJ,+1,PR,E,CON,PI,          HEF187
     1   SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)                 HEF188
C
        IF (KSYM.NE.0) THEN                                             HEF189
            XJ=-XM(J)                                                   HEF190
            CALL INCO2 (XI,YI,XJ,YJ,AJ,COSBJ,-SINBJ,-1,PR,E,CON,PI,     HEF191
     1      SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)              HEF192
        ENDIF                                                           HEF193
C
C
        GO TO (150,160,170,180), KODE                                   HEF194
C
C
150     CSN(I,J)=(SYYN-SXXN)*SINBI*COSBI+SXYN*(COSBI*COSBI-SINBI*SINBI  HEF195
     1  )                                                               HEF196
        CSS(I,J)=(SYYS-SXXS)*SINBI*COSBI+SXYS*(COSBI*COSBI-SINBI*SINBI  HEF197
     1  )                                                               HEF198
        CNS(I,J)=SXXS*SINBI*SINBI-2.*SXYS*SINBI*COSBI+SYYS*COSBI*COSBI  HEF199
        CNN(I,J)=SXXN*SINBI*SINBI-2.*SXYN*SINBI*COSBI+SYYN*COSBI*COSBI  HEF200
        GO TO 190                                                       HEF201
C
160     CSN(I,J)= DXN*COSBI+DYN*SINBI                                   HEF202
        CSS(I,J)= DXS*COSBI+DYS*SINBI                                   HEF203
        CNS(I,J)=-DXS*SINBI+DYS*COSBI                                   HEF204
        CNN(I,J)=-DXN*SINBI+DYN*COSBI                                   HEF205
        GO TO 190                                                       HEF206
C
170     CSN(I,J)=DXN*COSBI+DYN*SINBI                                    HEF207
        CSS(I,J)=DXS*COSBI+DYS*SINBI                                    HEF208
        CNS(I,J)=SXXS*SINBI*SINBI-2.*SXYS*SINBI*COSBI+SYYS*COSBI*COSBI  HEF209
        CNN(I,J)=SXXN*SINBI*SINBI-2.*SXYN*SINBI*COSBI+SYYN*COSBI*COSBI  HEF210
        GO TO 190                                                       HEF211
C
180     CSN(I,J)=(SYYN-SXXN)*SINBI*COSBI+SXYN*(COSBI*COSBI-SINBI*SINBI  HEF212
     1  )                                                               HEF213
        CSS(I,J)=(SYYS-SXXS)*SINBI*COSBI+SXYS*(COSBI*COSBI-SINBI*SINBI  HEF214
     1  )                                                               HEF215
        CNS(I,J)=-DXS*SINBI+DYS*COSBI                                   HEF216
        CNN(I,J)=-DXN*SINBI+DYN*COSBI                                   HEF217
C
190   CONTINUE                                                          HEF218
200 CONTINUE                                                            HEF219
C
C
      CALL SECOND (TIME)                                                HEF220
      TIME=TIME-TIMO                                                    HEF221
      TIMO=TIMO+TIME                                                    HEF222
      WRITE (2,1220) TIME                                               HEF223
C
C     COMPUTE OUTPUT AT DESIRED TIME
C     ------------------------------
C
      WRITE (2,1230)                                                    HEF224
      WRITE (2,1240) TIM                                                HEF225
C
C     COMPUTE PRE-EXISTING STRESSES AND SET BOUNDARY CONDITIONS
C     ---------------------------------------------------------
C
C     THIRD SCREEN MESSAGE: COMPUTE PRE-EXISTING STRESSES
C     ---------------------------------------------------
C
      WRITE (0,2200) TIM                                                HEF226
C
      DO 260  N=1,NUMBE                                                 HEF227
        YT=YM(N)                                                        HEF228
        PYY=AYY*YT+BYY                                                  HEF229
        RK=CXX                                                          HEF230
        IF (YT.NE.0.) RK=CXX+DXX/YT                                     HEF231
        IF(RK.GT.RMAX) RK=RMAX                                          HEF232
        PXX=AXX*YT+BXX+RK*PYY                                           HEF233
        PXY=AXY*YT+BXY                                                  HEF234
        PZZ=XZRAT*PXX                                                   HEF235
        TP=0.0                                                          HEF236
        IF (NSORC.NE.0) THEN                                            HEF237
           TP=TGRAD*YT+TSURF                                            HEF238
           CALL TEMCAL (XM(N),YM(N),TIM,DIFF,G,VE,                      HEF239
     1     TOC,PROP,QEXP,NCOMP,XS,YS,QS,TOS,KSYM,NSORC,IMAG,AA)         HEF240
           TP=TP+AA(1)                                                  HEF241
           PXX=PXX+AA(2)                                                HEF242
           PYY=PYY+AA(3)                                                HEF243
           PXY=PXY+AA(4)                                                HEF244
           PZZ=PZZ+PR*(AA(2)+AA(3))+ALFAE*AA(1)                         HEF245
        ENDIF                                                           HEF246
        COSB=COSBET(N)                                                  HEF247
        SINB=SINBET(N)                                                  HEF248
C
C       THERMALLY INDUCED INITIAL STRESSES
C       ----------------------------------
C
        SS=(PYY-PXX)*SINB*COSB+PXY*(COSB*COSB-SINB*SINB)                HEF249
        SN=PXX*SINB*SINB-2.0*PXY*SINB*COSB+PYY*COSB*COSB                HEF250
C
C       THERMALLY INDUCED DISPLACEMENTS
C       -------------------------------
C
        UX=AA(5)                                                        HEF251
        UY=AA(6)                                                        HEF252
        DS=UX*COSB + UY*SINB                                            HEF253
        DN=-UX*SINB + UY*COSB                                           HEF254
C
C       STORE OUTPUT FROM THERMAL SOLUTION FOR EACH BOUNDARY ELEMENT
C       ------------------------------------------------------------
C
        STORE(1,N)=TP                                                   HEF255
        STORE(2,N)=PXX                                                  HEF256
        STORE(3,N)=PYY                                                  HEF257
        STORE(4,N)=PXY                                                  HEF258
        STORE(5,N)=PZZ                                                  HEF259
        STORE(6,N)=UX                                                   HEF260
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      STORE(7,N)=UY                                                     HEF261
C
      WRITE (2,1250) N,TP,PXX,PYY,PXY,PZZ,SN,SS,DN,DS                   HEF262
C
      KODE=KOD(N)                                                       HEF263
      GO TO (220,230,240,250), KODE                                     HEF264
220   RN(N)=BN(N)-SN                                                    HEF265
      RS(N)=BS(N)-SS                                                    HEF266
      GO TO 260                                                         HEF267
230   RN(N)=BN(N)-DN                                                    HEF268
      RS(N)=BS(N)-DS                                                    HEF269
      GO TO 260                                                         HEF270
240   RN(N)=BN(N)-SN                                                    HEF271
      RS(N)=BS(N)-DS                                                    HEF272
      GO TO 260                                                         HEF273
250   RS(N)=BS(N)-SS                                                    HEF274
      RN(N)=BN(N)-DN                                                    HEF275
260 CONTINUE                                                            HEF276
C
    CALL SECOND (TIME)                                                  HEF277
    TIME=TIME-TIMO                                                      HEF278
    TIMO=TIMO+TIME                                                      HEF279
    WRITE (2,1260) TIME                                                 HEF280
C
C   SOLVE SYSTEM OF ALGEBRAIC EQUATIONS.
C   ------------------------------------
C
    CALL SOLVE3 (NUMBE,CSS,CSN,CNS,CNN,RS,RN,PS,PN,NIFL)                HEF281
    CALL SECOND (TIME)                                                  HEF282
    TIME=TIME-TIMO                                                      HEF283
    TIMO=TIMO+TIME                                                      HEF284
    WRITE (2,1270) TIME                                                 HEF285
C
C   COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS.
C   --------------------------------------------
C
C   FOURTH SCREEN MESSAGE : COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS
C   -------------------------------------------------------------------
C
    WRITE (0,2300)                                                      HEF286
    WRITE (2,1280)                                                      HEF287
    WRITE (2,1290) TIM                                                  HEF288
C
    DO 300  I=1,NUMBE                                                   HEF289
      XI=XM(I)                                                          HEF290
      YI=YM(I)                                                          HEF291
      COSBI=COSBET(I)                                                   HEF292
      SINBI=SINBET(I)                                                   HEF293
C
C     SET INITIAL CONDITIONS, INCLUDING THERMAL EFFECT
C     ------------------------------------------------
      TP=STORE(1,I)                                                     HEF294
      SIGXX=STORE(2,I)                                                  HEF295
      SIGYY=STORE(3,I)                                                  HEF296
      SIGXY=STORE(4,I)                                                  HEF297
      SIGZZ=STORE(5,I)                                                  HEF298
      UX=STORE(6,I)                                                     HEF299
      UY=STORE(7,I)                                                     HEF300
C
      DO 280  J=1,NUMBE                                                 HEF301
        CALL INITL(SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)       HEF302
        XJ=XM(J)                                                        HEF303
        YJ=YM(J)                                                        HEF304
        AJ=A(J)                                                         HEF305
        COSBJ=COSBET(J)                                                 HEF306
        SINBJ=SINBET(J)                                                 HEF307
        CALL INCO2 (XI,YI,XJ,YJ,AJ,COSBJ,SINBJ,+1,PR,E,CON,PI,          HEF308
     1   SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)                 HEF309
C
        IF (KSYM.NE.0) THEN                                             HEF310
            XJ=-XM(J)                                                   HEF311
            CALL INCO2 (XI,YI,XJ,YJ,AJ,COSBJ,-SINBJ,-1,PR,E,CON,PI,     HEF312
     1      SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)              HEF313
        ENDIF                                                           HEF314
C
        DIGXX=SXXS*PS(J)+SXXN*PN(J)                                     HEF315
        DIGYY=SYYS*PS(J)+SYYN*PN(J)                                     HEF316
        SIGXX=SIGXX+DIGXX                                               HEF317
        SIGYY=SIGYY+DIGYY                                               HEF318
        SIGXY=SIGXY+SXYS*PS(J)+SXYN*PN(J)                               HEF319
        SIGZZ=SIGZZ+PR*(DIGXX+DIGYY)                                    HEF320
        UX=UX+DXS*PS(J)+DXN*PN(J)                                       HEF321
        UY=UY+DYS*PS(J)+DYN*PN(J)                                       HEF322
280   CONTINUE                                                          HEF323
C
C
      US=UX*COSBI+UY*SINBI                                              HEF324
      UN=-UX*SINBI+UY*COSBI                                             HEF325
      SIGS=(SIGYY-SIGXX)*SINBI*COSBI+SIGXY*(COSBI*COSBI-SINBI*SINBI)    HEF326
      SIGN=SIGXX*SINBI*SINBI-2.*SIGXY*SINBI*COSBI+SIGYY*COSBI*COSBI     HEF327
      SIGT=SIGXX*COSBI*COSBI+2.*SIGXY*SINBI*COSBI+SIGYY*SINBI*SINBI     HEF328
      WRITE (2,1300) I,XM(I),YM(I),UX,UY,US,UN,SIGXX,SIGYY,SIGXY,SIGZZ  HEF329
     1  SIGS,SIGN,SIGT,TP                                               HEF330
      WRITE (3,3001) I,XM(I),YM(I),UX,UY,A(I),SINBI,COSBI,SIGS,SIGN,    HEF331
     1  SIGT,SIGZZ,TP                                                   HEF332
C
300   CONTINUE                                                          HEF333
C
      CALL SECOND (TIME)                                                HEF334
      TIME=TIME-TIMO                                                    HEF335
      TIMO=TIMO+TIME                                                    HEF336
      WRITE (2,1310) TIME                                               HEF337
C
C     COMPUTE STRESSES AND DISPLACEMENTS AT SPECIFIED POINTS IN BODY.
C     ---------------------------------------------------------------
C     FIFTH SCREEN MESSAGE : COMPUTE INTERIOR POINT VALUES
C     ----------------------------------------------------
C
      WRITE (0,2400)                                                    HEF338
      IF (NUMOS.LE.0) GO TO 400                                         HEF339
      WRITE (2,1280)                                                    HEF340
      WRITE (2,1320) TIM                                                HEF341
      NPOINT=0                                                          HEF342
C
      DO 370  N=1,NUMOS                                                 HEF343
        NUMP=NUMPB(N)-1                                                 HEF344
```

```
      IF (NUMP.NE.-1) THEN                                              HEF345
          DELX=(XE(N)-XB(N))/NUMP                                       HEF346
          DELY=(YE(N)-YB(N))/NUMP                                       HEF347
          NUMPT=NUMP+1                                                  HEF348
          RATTY=1.0                                                     HEF349
      ELSE                                                              HEF350
          DELX=DELN*(XE(N)-XB(N))/RLINE                                 HEF351
          DELY=DELN*(YE(N)-YB(N))/RLINE                                 HEF352
      ENDIF                                                             HEF353
      XP=XB(N)-DELX                                                     HEF354
      YP=YB(N)-DELY                                                     HEF355
C
      DO 360  NI=1,NUMPT                                                HEF356
        NPOINT=NPOINT+1                                                 HEF357
        XP=XP+DELX                                                      HEF358
        YP=YP+DELY                                                      HEF359
        DELX=DELX*RATTY                                                 HEF360
        DELY=DELY*RATTY                                                 HEF361
        TP=TGRAD*YP+TSURF                                               HEF362
        SIGYY=AYY*YP+BYY                                                HEF363
        RK=CXX                                                          HEF364
        IF (YP.NE.0.) RK=CXX+DXX/YP                                     HEF365
        IF (RK.GT.RMAX) RK=RMAX                                         HEF366
        SIGXX=AXX*YP+BXX+RK*SIGYY                                       HEF367
        SIGXY=AXY*YP+BXY                                                HEF368
        SIGZZ=XZRAT*SIGXX                                               HEF369
        UX=0.                                                           HEF370
        UY=0.                                                           HEF371
C
        DO 340  J=1,NUMBE                                               HEF372
          CALL INITL(SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)     HEF373
          XJ=XM(J)                                                      HEF374
          YJ=YM(J)                                                      HEF375
          AJ=A(J)                                                       HEF376
          COSBJ=COSBET(J)                                               HEF377
          SINBJ=SINBET(J)                                               HEF378
          CALL INCO2 (XP,YP,XJ,YJ,AJ,COSBJ,SINBJ,+1,PR,E,CON,PI,        HEF379
     1     SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)               HEF380
C
          IF (KSYM.NE.0) THEN                                           HEF381
              XJ=-XM(J)                                                 HEF382
              CALL INCO2 (XP,YP,XJ,YJ,AJ,COSBJ,-SINBJ,-1,PR,E,CON,PI,   HEF383
     1        SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)            HEF384
          ENDIF                                                         HEF385
C
          DIGXX=SXXS*PS(J)+SXXN*PN(J)                                   HEF386
          DIGYY=SYYS*PS(J)+SYYN*PN(J)                                   HEF387
          SIGXX=SIGXX+DIGXX                                             HEF388
          SIGYY=SIGYY+DIGYY                                             HEF389
          SIGXY=SIGXY+SXYS*PS(J)+SXYN*PN(J)                             HEF390
          SIGZZ=SIGZZ+PR*(DIGXX+DIGYY)                                  HEF391
          UX=UX+DXS*PS(J)+DXN*PN(J)                                     HEF392
          UY=UY+DYS*PS(J)+DYN*PN(J)                                     HEF393
340     CONTINUE                                                        HEF394
        IF (NSORC.NE.0) THEN                                            HEF395
C           ADD THERMAL EFFECT
C           -------------------
            CALL TEMCAL (XP,YP,TIM,DIFF,G,VE,                           HEF396
     1       TOC,PROP,QEXP,NCOMP,XS,YS,QS,TOS,KSYM,NSORC,IMAG,AA)       HEF397
            TP=TP+AA(1)                                                 HEF398
            SIGXX=SIGXX+AA(2)                                           HEF399
            SIGYY=SIGYY+AA(3)                                           HEF400
            SIGXY=SIGXY+AA(4)                                           HEF401
            SIGZZ=SIGZZ+PR*(AA(2)+AA(3))+ALFAE*AA(1)                    HEF402
            UX=UX+AA(5)                                                 HEF403
            UY=UY+AA(6)                                                 HEF404
        ENDIF                                                           HEF405
C
        CENT=(SIGXX+SIGYY)/2.0                                          HEF406
        DIFF1=SIGXX-CENT                                                HEF407
        TAUM=SQRT(SIGXY*SIGXY+DIFF1*DIFF1)                              HEF408
        SIG1=CENT+TAUM                                                  HEF409
        SIG3=CENT-TAUM                                                  HEF410
        IF (SIGXY.EQ.0.0) SIGXY=0.0001                                  HEF411
        ALPHA2=ATAN2(SIGXY,DIFF1)                                       HEF412
        ALPHA=0.5*ALPHA2/CFAC                                           HEF413
C
C       OUTPUT RESULTS FOR PLOTTING
C       ---------------------------
        WRITE (3,3002) NPOINT,XP,YP,UX,UY,SIG1,SIG3,ALPHA,SIGZZ,TP      HEF414
        WRITE (2,1330) NPOINT,XP,YP,UX,UY,SIGXX,SIGYY,SIGXY,SIGZZ,SIG1  HEF415
     1                 ,SIG3,ALPHA,TP                                   HEF416
360   CONTINUE                                                          HEF417
370   CONTINUE                                                          HEF418
C
      CALL SECOND (TIME)                                                HEF419
      TIME=TIME-TIMO                                                    HEF420
      TIMO=TIMO+TIME                                                    HEF421
      WRITE (2,1340) TIME                                               HEF422
C
C     CALL BUILT-IN ROUTINE FOR TIME (MS FORTRAN 4.0 ONLY)
C     ----------------------------------------------------
C
      CALL GETTIM(IH,IMIN,ISEC,IHUN)                                    HEF423
      WRITE(2,1350)IH,IMIN                                              HEF424
C
400   CONTINUE                                                          HEF425
C
C     CLOSE ALL FILES
C     ---------------
      CLOSE(3)                                                          HEF426
      WRITE(*,*)                                                        HEF427
      WRITE(*,*)                                                        HEF428
      WRITE(0,1360)NAME                                                 HEF429
      WRITE(2,1360)NAME                                                 HEF430
C
C     FORMAT STATEMENTS - FOR OUTPUT FILE
C     -----------------------------------
C
1000  FORMAT (//,2X,100('*'),/,2X,'*',98X,'*',/,                        HEF431
     12X,'*',44X,'H  E  F  F',44X,'*',/,2X,'*',98X,'*',/,               HEF432
     22X,'*',28X,'          A BOUNDARY ELEMENT CODE          ',28X,'*',/, HEF433
     32X,'*',28X,'FOR TWO-DIMENSIONAL THERMOELASTIC ANALYSIS',28X,'*',/, HEF434
     42X,'*',28X,'              OF A ROCK MASS               ',28X,'*',/, HEF435
     52X,'*',28X,'     SUBJECT TO CONSTANT OR DECAYING       ',28X,'*',/, HEF436
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      62X,'*',28X,'                THERMAL LOADING                ',28X,'*',/,
      72X,'*',28X,'VERSION DATED: DEC. 6 1987 (MS-FORTRAN 77)',28X,'*',/,
      72X,'*',28X,'                                               ',28X,'*',/,
      72X,'*',28X,'                VERSION 4.1                    ',28X,'*',/,
      82X,'*',98X,'*',/,2X,100('*'),//)
1010  FORMAT (2X,A63,' OUTPUT CREATED ON',I10,'/',I2,'/',I4,///)
1030  FORMAT ( /,' NUMBER OF BOUNDARY SEGMENTS . . . . . . . =',I3,
     1         /,' NUMBER OF STRESS LINES  . . . . . . . . . =',I3,
     3         /,' NUMBER OF HEAT SOURCES  . . . . . . . . . =',I3,
     4         /,' NUMBER OF EXP. DECAYING COMPONENTS  . . . =',I3,/)
1040  FORMAT ( /,' NO SYMMETRY CONDITIONS IMPOSED')
1050  FORMAT ( /,' THE LINE X=0.0 IS A LINE OF SYMMETRY.'
     1         /,' IMAGE BOUNDARY ELEMENTS AND HEAT SOURCES WILL BE',
     2          ' GENERATED WITH RESPECT TO THIS LINE.')
1060  FORMAT ( /,' EFFECT OF IMAGE HEAT SOURCES NOT COMPUTED')
1070  FORMAT ( /,' CONSTANT TEMPERATURE B.C. IMPOSED AT SURFACE')
1080  FORMAT ( /,' POISSONS RATIO OF BODY . . . . . . . . . =',F6.2
     1         /,' MODULUS OF ELASTICITY OF BODY . . . . . . =',E12.4,
     2         /,' SHEAR MODULUS OF BODY . . . . . . . . . . =',E12.4/)
1090  FORMAT ( /,' XX-COMPONENT OF FIELD STRESS =',E10.4,'Y +',E10.4,
     1          + (',E10.4,' + ',E10.4,' / Y ) * SIGYY'
     2         /,' YY-COMPONENT OF FIELD STRESS =',E10.4,'Y +',E10.4,
     3         /,' XY-COMPONENT OF FIELD STRESS =',E10.4,'Y +',E10.4,
     4         /,' MAXIMUM VALUE FOR CXX + DXX / Y =',E10.4,
     5         /,' RATIO OF ZZ STRESS TO XX STRESS =',E10.4)
1100  FORMAT ( /,' TEMPERATURE VARIATION WITH DEPTH=',F10.4,'Y +',F10.4)
1110  FORMAT ( /,' TIME FOR OUTPUT',/,(5(E10.3)))
1120  FORMAT ( /,' THERMAL DIFFUSIVITY . . . . . . . . . . =',E12.4,/,
     1          ' THERMAL EXPANSION COEFFICIENT . . . . . . =',E12.4,/,
     2          ' STRESS COEFFICIENT  VE . . . . . . . . . =',E12.4)
1130  FORMAT ( /,' PROPERTIES OF HEAT SOURCES - CONSTANT OR DECAYING',
     1         //,'  TIME ON      PROPORTION     DECAY CONST.')
1140  FORMAT (F10.2,2E15.5)
1150  FORMAT ( /,' SOURCE DATA',/
     1          '  X-COORD    Y-COORD  STRENGTH   TIME ON')
1160  FORMAT (8F10.3)
1170  FORMAT ( /,' IN THE LIST BELOW, THE VALUE ASSIGNED TO KODE',
     1          ' DENOTES BOUNDARY CONDITIONS AS FOLLOWS.'
     2         /,'   KODE= 1 NORMAL AND SHEAR STRESSES PRESCRIBED',
     3         /,'   KODE= 2 NORMAL AND SHEAR DISPL. PRESCRIBED',
     4         /,'   KODE= 3 NORMAL STRESS AND SHEAR DISPL. PRESCRIBED',
     5         /,'   KODE= 4 NORMAL DISPL. AND SHEAR STRESS PRESCRIBED')
1180  FORMAT ( /,' ELEMENT KODE   X(CENTER)   Y(CENTER)  HALF'
     1          '-WIDTH    SIN BETA    COS BETA  B-VALUE (S) ',
     2          ' B-VALUE (N)')
1190  FORMAT (2I6,5F12.4,1X,2E13.4)
1200  FORMAT ( /,' LINES DEFINING STRESS POINTS',/,12X,
     1          'XBEG          YBEG          XEND          YEND      NUMPB')
1210  FORMAT (4X,4F12.4,4X,I4)
1220  FORMAT ( /,' TIME REQUIRED TO COMPUTE INFLUENCE COEFFICIENTS='
     1                                                  F7.2,' SECONDS.')
1230  FORMAT ( /,65('*'))
1240  FORMAT ( /,' OUTPUT FOR TIME=',E12.4,///
     1          ' PRE-EXISTING STRESS AT EACH ELEMENT',//,
     2          ' ELEMENT   TEMP     SIGMAXX     SIGMAYY     SIGMAXY'
     3          '    SIGMAZZ     NORM-STR    SHEAR-STR',5X,'NORM-DIS'
     4         4X,'SHEAR-DIS')
1250  FORMAT (I5,9E12.4)
1260  FORMAT ( /,' TIME REQUIRED TO COMPUTE PRE-EXISTING STRESSES  =',
     1          F7.2,' SECONDS.')
1270  FORMAT ( /,' TIME REQUIRED TO SOLVE EQUATIONS=', F7.2,' SECONDS.')
1280  FORMAT (///)
1290  FORMAT (///,' BOUNDARY STRESSES AND DISPLACEMENTS AT TIME =',E12.3,
     1        //,' ELM X-COORD      Y-COORD      UX          UY',  ',
     2'US          UN',/ ,  SIGXX       SIGYY       ',
     3'SIGXY       SIGZZ       SIGMA-S     SIGMA-N',
     4'     SIGMA-T     TEMP' )
1300  FORMAT (/,I3,2E12.4,4E12.4/5X,8E12.4)
1310  FORMAT ( /,' TIME REQUIRED TO COMPUTE BOUNDARY STRESSES',
     1          ' AND DISPLACEMENTS='                   F7.2,' SECONDS.')
1320  FORMAT (//,' INTERIOR STRESSES AND DISPLACEMENTS AT TIME =',E10.3,
     1        //,' POINT X-COORD      Y-COORD      UX          UY',/,
     2'      SIGXX       SIGYY       SIGXY       SIGZZ       SIG1',
     3'      SIG2        ALPHA       TEMP ')
1330  FORMAT (/,I3,2E12.4,2E12.4/5X,8E12.4)
1340  FORMAT ( /,' TIME REQUIRED TO COMPUTE STRESSES AND DISPLACEMENTS',
     1          ' AT STRESS POINTS='                    F7.2,' SECONDS.')
1350  FORMAT (//,'JOB COMPLETED AT ',I2,':',I2,' HOURS')
1360  FORMAT (///,' DATA FOR PLOTTING WILL BE STORED IN FILE NAMED ',A8
     1,)
C
C
C     SCREEN MESSAGE FORMATS
C     ----------------------
C
C
2000  FORMAT (////,
     18X,'                H  E  F  F                    ',/,
     1'                                                  ',/,
     28X,'          A BOUNDARY ELEMENT CODE             ',/,
     38X,'FOR TWO-DIMENSIONAL THERMOELASTIC ANALYSIS',/,
     48X,'              OF A ROCK MASS                  ',/,
     58X,'      SUBJECT TO CONSTANT OR DECAYING         ',/,
     68X,'              THERMAL LOADING                 ',/,
     78X,'         DEC. 6 1987 (MS-FORTRAN 77)          ',/,
     78X,'                                              ',/,
     78X,'              VERSION 4.1                     ',/,////,
     2          ,        READ INPUT DATA')
2100  FORMAT ('      COMPUTE INFLUENCE COEFFICIENTS')
2200  FORMAT (/,'      COMPUTE PRE-EXISTING STRESSES AT TIME =', E10.3)
2300  FORMAT ('      COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS')
2400  FORMAT ('      COMPUTE INTERIOR STRESSES AND DISPLACEMENTS')
C
C
C     PLOT FILE FORMATS
C     -----------------
C
C
3000  FORMAT(A8,2I5,5I5)
3001  FORMAT(I5,2E14.6,10E12.4)
3002  FORMAT(I5,2E14.6,7E12.4)
C
      STOP
      END
```

```
C ***********************************************************************
C       SYSTEM DEPENDENT FEATURES- THE FOLLOWING INTERFACE ROUTINES
C       AND SUBROUTINES GETTIM AND GETDAT ARE SYSTEM DEPENDENT
C
C       THESE ARE NOT NEEDED FOR MS FORTRAN 4.0
C
C       ACCESS DATE AND TIME
C       --------------------
C
C      INTERFACE TO SUBROUTINE TIME (N,STR)
C      CHARACTER*10 STR [NEAR,REFERENCE]
C      INTEGER*2 N [VALUE]
C      END
C      INTERFACE TO SUBROUTINE DATE (N,STR)
C      CHARACTER*10 STR [NEAR,REFERENCE]
C      INTEGER*2 N [VALUE]
C      END
C
C
C
C
C      SUBROUTINE GETTIM (IH,IMIN,ISEC,IF)
C      -----------------------------------
C      CHARACTER*10 TSTR
C
C  CALL TIME (NOTE THAT THE STRING LENGTH IS PASSED
C  AS THE FIRST ARGUMENT)
C
C      CALL TIME (10,TSTR)
C      READ(TSTR,'(3(I2,1X))') IH,IMIN,ISEC
C      IF=0
C      RETURN
C      END
C
C
C      SUBROUTINE GETDAT (IY,IM,ID)
C      ----------------------------
C      CHARACTER*10 TSTR
C
C  CALL DATE (NOTE THAT THE STRING LENGTH IS PASSED
C  AS THE FIRST ARGUMENT)
C
C      CALL DATE (10,TSTR)
C      READ(TSTR,'(3(I2,1X))') IY,IM,ID
C      IF=0
C      RETURN
C      END
C***********************************************************************
C
C     THIS CALLS THE BUILT-IN LIBRARY ROUTINE (ONLY FOR MS FORTRAN 4.0)-
C     GETTIM
C
      SUBROUTINE SECOND(TIME)                                           SEC  1
C     -----------------------
      INTEGER*2 IH,IM,IS,IF                                             SEC  2
      CALL GETTIM(IH,IM,IS,IF)                                          SEC  3
      TIME=FLOAT(3600*IH + 60*IM + IS) + FLOAT(IF)/100                  SEC  4
      RETURN                                                            SEC  5
      END                                                               SEC  6
C
C***********************************************************************
C
      SUBROUTINE SOLVE3 (N,CSS,CSN,CNS,CNN,RS,RN,PS,PN,NIFL)            SOL  1
C     ------------------------------------------------------------
C     SOLUTION OF CX=Y BY GAUSSIAN ELIMINATION.
C       MATRIX C IS PARTITIONED INTO FOUR N BY N SUBMATRICES (CSS,CSN,
C         CNS AND CNN).
C       VECTORS X AND Y ARE DIVIDED INTO VECTORS PS, PN AND RS, RN EACH
C         OF LENGTH N.
C     ------------------------------------------------------------
      DIMENSION CSS(NIFL,1),CSN(NIFL,1),CNS(NIFL,1),CNN(NIFL,1),        SOL  2
     1 RS(1),RN(1),PS(1),PN(1)                                          SOL  3
C
      NB=N-1                                                            SOL  4
C
      DO 1070 J=1,NB                                                    SOL  5
C FOR MICROSOFT
C -------------
       IF (CSS(J,J).EQ.0.) CSS(J,J)=1.E-20                              SOL  6
        L=J+1                                                           SOL  7
        DO 1030 JJ=L,N                                                  SOL  8
          XM=CSS(JJ,J)/CSS(J,J)                                         SOL  9
          DO 1010 I=J,N                                                 SOL 10
1010        CSS(JJ,I)=CSS(JJ,I)-XM*CSS(J,I)                             SOL 11
          DO 1020 I=1,N                                                 SOL 12
1020        CSN(JJ,I)=CSN(JJ,I)-XM*CSN(J,I)                             SOL 13
1030      RS(JJ)=RS(JJ)-XM*RS(J)                                        SOL 14
C
        DO 1060 JJ=1,N                                                  SOL 15
          XM=CNS(JJ,J)/CSS(J,J)                                         SOL 16
          DO 1040 I=1,N                                                 SOL 17
1040        CNN(JJ,I)=CNN(JJ,I)-XM*CSN(J,I)                             SOL 18
          DO 1050 I=J,N                                                 SOL 19
1050        CNS(JJ,I)=CNS(JJ,I)-XM*CSS(J,I)                             SOL 20
1060      RN(JJ)=RN(JJ)-XM*RS(J)                                        SOL 21
1070    CONTINUE                                                        SOL 22
C
C FOR MICROSOFT
C -------------
      IF (CSS(N,N).EQ.0.) CSS(N,N)=1.E-20                               SOL 23
      DO 1090 JJ=1,N                                                    SOL 24
        XM=CNS(JJ,N)/CSS(N,N)                                           SOL 25
        DO 1080 I=1,N                                                   SOL 26
          CNS(JJ,I)=CNS(JJ,I)-XM*CSS(N,I)                               SOL 27
1080      CNN(JJ,I)=CNN(JJ,I)-XM*CSN(N,I)                               SOL 28
1090    RN(JJ)=RN(JJ)-XM*RS(N)                                          SOL 29
C
      DO 1110 J=1,NB                                                    SOL 30
C FOR MICROSOFT
C -------------
        IF (CNN(J,J).EQ.0.) CNN(J,J)=1.E-20                             SOL 31
        L=J+1                                                           SOL 32
        DO 1110 JJ=L,N                                                  SOL 33
        XM=CNN(JJ,J)/CNN(J,J)                                           SOL 34
```

```
      DO 1100 I=J,N                                                     SOL 35
1100    CNN(JJ,I)=CNN(JJ,I)-XM*CNN(J,I)                                 SOL 36
1110  RN(JJ)=RN(JJ)-XM*RN(J)                                            SOL 37
C
C FOR MICROSOFT
C -------------
      IF (CNN(N,N).EQ.0.) CNN(N,N)=1.E-20                               SOL 38
      PN(N)=RN(N)/CNN(N,N)                                              SOL 39
      DO 1130 J=1,NB                                                    SOL 40
        JJ=N-J                                                          SOL 41
        L=JJ+1                                                          SOL 42
        SUM=0.                                                          SOL 43
        DO 1120 I=L,N                                                   SOL 44
1120      SUM=SUM+CNN(JJ,I)*PN(I)                                       SOL 45
1130    PN(JJ)=(RN(JJ)-SUM)/CNN(JJ,JJ)                                  SOL 46
C
      SUM=0.                                                            SOL 47
      DO 1140 I=1,N                                                     SOL 48
1140    SUM=SUM+CSN(N,I)*PN(I)                                          SOL 49
      PS(N)=(RS(N)-SUM)/CSS(N,N)                                        SOL 50
      DO 1170 J=1,NB                                                    SOL 51
        JJ=N-J                                                          SOL 52
        L=JJ+1                                                          SOL 53
        SUM=0.                                                          SOL 54
        DO 1150 I=1,N                                                   SOL 55
1150      SUM=SUM+CSN(JJ,I)*PN(I)                                       SOL 56
        DO 1160 I=L,N                                                   SOL 57
1160      SUM=SUM+CSS(JJ,I)*PS(I)                                       SOL 58
1170    PS(JJ)=(RS(JJ)-SUM)/CSS(JJ,JJ)                                  SOL 59
C
      RETURN                                                            SOL 60
      END                                                               SOL 61
C
C
      SUBROUTINE INCO2 (X,Y,CX,CY,A,COSB,SINB,MSYM,PR,E,CON,PI,         INC  1
     1 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)                   INC  2
C     ------------------------------------------------------------
C
C     INFLUENCE COEFFICIENTS
C
C     ------------------------------------------------------------
C
      COND=(1.+PR)/E                                                    INC  3
      PR1=1.-2.*PR                                                      INC  4
      PR2=2.*(1.-PR)                                                    INC  5
      PR3=3.-4.*PR                                                      INC  6
      COS2B=COSB*COSB-SINB*SINB                                         INC  7
      SIN2B=2.*SINB*COSB                                                INC  8
C
      XB= (X-CX)*COSB+(Y-CY)*SINB                                       INC  9
      YB=-(X-CX)*SINB+(Y-CY)*COSB                                       INC 10
C
C     COMPUTE FUNCTION F(XB,YB) AND ITS REQUIRED DERIVATIVES.
C     -------------------------------------------------------
C
      R1S=(XB-A)*(XB-A)+YB*YB                                           INC 11
      R2S=(XB+A)*(XB+A)+YB*YB                                           INC 12
      FL1=0.5*ALOG(R1S)                                                 INC 13
      FL2=0.5*ALOG(R2S)                                                 INC 14
      FB2=CON*(FL1-FL2)                                                 INC 15
      IF (YB.NE.0.) GO TO 1010                                          INC 16
      FB3=0                                                             INC 17
      IF (ABS(XB).GT.A) GO TO 1020                                      INC 18
      FB3=CON*PI                                                        INC 19
      GO TO 1020                                                        INC 20
1010  FB3=-CON*(ATAN((XB+A)/YB)-ATAN((XB-A)/YB))                        INC 21
1020  FB1=YB*FB3+CON*((XB-A)*FL1-(XB+A)*FL2)                            INC 22
      FB4=CON*(YB/R1S-YB/R2S)                                           INC 23
      FB5=CON*((XB-A)/R1S-(XB+A)/R2S)                                   INC 24
C
C     COMPUTE COEFFICIENTS FOR DISPLACEMENTS.
C     ---------------------------------------
      DXPS=COND*( PR3*COSB*FB1+YB*(COSB*FB3+SINB*FB2))                  INC 25
      DXPN=COND*(-PR3*SINB*FB1+YB*(SINB*FB3-COSB*FB2))                  INC 26
      DYPS=COND*( PR3*SINB*FB1+YB*(SINB*FB3-COSB*FB2))                  INC 27
      DYPN=COND*( PR3*COSB*FB1-YB*(COSB*FB3+SINB*FB2))                  INC 28
C
C     COMPUTE COEFFICIENTS FOR STRESSES.
C     ----------------------------------
      SXXPS=FB2+PR2*(COS2B*FB2-SIN2B*FB3)+YB*(SIN2B*FB5+COS2B*FB4)      INC 29
      SXXPN=FB3-PR1*(COS2B*FB3+SIN2B*FB2)+YB*(SIN2B*FB4-COS2B*FB5)      INC 30
      SYYPS=FB2-PR2*(COS2B*FB2-SIN2B*FB3)-YB*(SIN2B*FB5+COS2B*FB4)      INC 31
      SYYPN=FB3+PR1*(COS2B*FB3+SIN2B*FB2)-YB*(SIN2B*FB4-COS2B*FB5)      INC 32
      SXYPS=     PR2*(SIN2B*FB2+COS2B*FB3)+YB*(SIN2B*FB4-COS2B*FB5)     INC 33
      SXYPN=     PR1*(COS2B*FB2-SIN2B*FB3)-YB*(COS2B*FB4+SIN2B*FB5)     INC 34
C
      DXS=DXS+MSYM*DXPS                                                 INC 35
      DXN=DXN+DXPN                                                      INC 36
      DYS=DYS+MSYM*DYPS                                                 INC 37
      DYN=DYN+DYPN                                                      INC 38
      SXXS=SXXS+MSYM*SXXPS                                              INC 39
      SXXN=SXXN+SXXPN                                                   INC 40
      SYYS=SYYS+MSYM*SYYPS                                              INC 41
      SYYN=SYYN+SYYPN                                                   INC 42
      SXYS=SXYS+MSYM*SXYPS                                              INC 43
      SXYN=SXYN+SXYPN                                                   INC 44
C
      RETURN                                                            INC 45
      END                                                               INC 46
C
C
      SUBROUTINE INITL(SXXS,SXXN,SYYS,SYYN,SXYS,SXYN,DXS,DXN,DYS,DYN)   INI  1
C     ---------------------------------------------------------------
C
C     THIS SUBROUTINE INITIALIZES VARIABLES
C
      SXXS=0.                                                           INI  2
      SXXN=0.                                                           INI  3
      SYYS=0.                                                           INI  4
      SYYN=0.                                                           INI  5
      SXYS=0.                                                           INI  6
      SXYN=0.                                                           INI  7
      DXS=0.                                                            INI  8
      DXN=0.                                                            INI  9
      DYS=0.                                                            INI 10
      DYN=0.                                                            INI 11
C
```

```
      RETURN                                                            INI 12
      END                                                               INI 13
C
C*********************************************************************
C
      SUBROUTINE TEMCAL (XP,YP,TIM,DIFF,G,VE,                           TEM  1
     1 TOC,PROP,QEXP,NCOMP,XS,YS,QS,TOS,KSYM,NSORC,IMAG,AA)             TEM  2
C
C-----------------------------------------------------------------
C
C     COMPUTE THERMAL EFFECT AT (XP,YP) FOR TIME = TIM
C
C-----------------------------------------------------------------
      DIMENSION DD(6),AA(1),TOC(1),PROP(1),QEXP(1),XS(1),YS(1),QS(1),   TEM  3
     1 TOS(1)                                                           TEM  4
C
C     VECTORS DD AND AA CONTAIN TEMP, STRESS, AND DISPLACEMENT DATA
C
C     DD(1) / AA(1) :- INDUCED TEMPERATURE  (EACH SOURCE/TOTAL)
C     DD(2) / AA(2) :- INDUCED XX STRESS
C     DD(3) / AA(3) :- INDUCED YY STRESS
C     DD(4) / AA(4) :- INDUCED XY STRESS
C     DD(5) / AA(5) :- INDUCED  X DISPLACEMENT
C     DD(6) / AA(6) :- INDUCED  Y DISPLACEMENT
C
      DO 1010 I=1,6                                                     TEM  5
        AA(I)=0.0                                                       TEM  6
1010  CONTINUE                                                          TEM  7
C
      IMSIGN=-1                                                         TEM  8
1020  IMSIGN=-IMSIGN                                                    TEM  9
      SNCH=-1.0                                                         TEM 10
1030  SNCH=-SNCH                                                        TEM 11
C
      DO 1070 I=1,NSORC                                                 TEM 12
        IF (TIM.LT.TOS(I)) GO TO 1070                                   TEM 13
        X=XP-XS(I)*SNCH                                                 TEM 14
        Y=YP-YS(I)*IMSIGN                                               TEM 15
C
        DO 1060 J=1,NCOMP                                               TEM 16
          TIME=TIM-TOS(I)-TOC(J)                                        TEM 17
          IF (TIME.LE.0.0) GO TO 1060                                   TEM 18
          IF (TIME*QEXP(J)/0.7.GT.20.0) GO TO 1060                      TEM 19
          QC=QS(I)*PROP(J)*IMSIGN                                       TEM 20
          DO 1040 II=1,6                                                TEM 21
1040        DD(II)=0.0                                                  TEM 22
C
          CALL HEAT (QC,QEXP(J),TIME,X,Y,DD(1),DD(2),DD(3),DD(4),DD(5), TEM 23
     1    DD(6),DIFF,G,VE)                                              TEM 24
C
          DO 1050 K=1,6                                                 TEM 25
            AA(K)=AA(K)+DD(K)                                           TEM 26
1050      CONTINUE                                                      TEM 27
1060    CONTINUE                                                        TEM 28
1070  CONTINUE                                                          TEM 29
C
      IF (KSYM.EQ.1.AND.SNCH.GT.0) GO TO 1030                           TEM 30
      IF (IMAG.NE.0.AND.IMSIGN.GT.0) GO TO 1020                         TEM 31
      RETURN                                                            TEM 32
      END                                                               TEM 33
C
      SUBROUTINE HEAT (A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,              HEA  1
     1 DIFF,G,VE)                                                       HEA  2
C-----------------------------------------------------------------
C       THIS SUBROUTINE WAS ORIGINALLY CODED BY R.D.HART (UNIVERSITY
C       OF MINNESOTA).  IMPROVEMENTS AND DOUBLE PRECISION MODIFICATIONS
C       BY S.KEY (RE/SPEC).
C-----------------------------------------------------------------
C
      LOGICAL B
      DOUBLE PRECISION QC,QEXP,TM,X,Z,R,XA,XB,XC,XAEXP,XBEXP,CON1,CON2, HEA  3
     1                 EI,FRL,SUM,RS,TS,TOL,FAC,Y,TSUM,XN,TEMP1,        HEA  4
     2                 TEMP2,EXFCT,TP,FCT,SNEW,SOLD,S1,S2,TEST,         HEA  5
     3                 SINTH,COSTH,UR,UX,UZ,S,C,TX,TZ,TXZ,XBI,DPI,      HEA  6
     4                 XBK,XCN,QP2,QP1,SG1,XBN,XBNK,CEUL,CON3           HEA  7
C                                                                       HEA  8
C
      DATA              CEUL /0.57721566490153D0/                       HEA  9
      DATA              DPI  /3.14159265358979D0/                       HEA 10
      DATA              CON3 /0.83333333333333D0/                       HEA 11
C
      QC =DBLE(A1)                                                      HEA 12
      QEXP =DBLE(A2)                                                    HEA 13
      TM =DBLE(A3)                                                      HEA 14
      X =DBLE(A4)                                                       HEA 15
      Z =DBLE(A5)                                                       HEA 16
C
C     HEAT SOURCE - CLOSED FORM SOLUTION
C     ----------------------------------
      TP = 0.D0                                                         HEA 17
      TX = 0.D0                                                         HEA 18
      TZ = 0.D0                                                         HEA 19
      TXZ = 0.D0                                                        HEA 20
      UX = 0.D0                                                         HEA 21
      UZ = 0.D0                                                         HEA 22
      IFLAG=0                                                           HEA 23
      R =DSQRT(X*X+Z*Z)                                                 HEA 24
C
C     AVOID CALCULATIONS TOO CLOSE TO SOURCE
C
      IF(R.LT.1.0D-2) THEN                                              HEA 25
        R = 1.0D-2                                                      HEA 26
        X = 1.0D-2                                                      HEA 27
        Z = 0.0D0                                                       HEA 28
      ENDIF                                                             HEA 29
      XA = -QEXP*TM                                                     HEA 30
      XB = R*R/(4.0D0*DBLE(DIFF)*TM)                                    HEA 31
C
C     AVOID VERY SMALL NUMBERS - EXPONENTIAL INTEGRAL
C     IS STABLE WITHIN THIS LIMIT
C
      IF (XB.GT.50.0D0) GO TO 1110                                      HEA 32
      XC = XB*TM                                                        HEA 33
      XBI = 1.0D0/XB                                                    HEA 34
      XAEXP =DEXP(XA)                                                   HEA 35
      XBEXP = DEXP(-XB)                                                 HEA 36
```

```
      CON1 = QC/(4.0D0*DPI*DBLE(DIFF))                                  HEA 37
      CON2 = QC*DBLE(VE)/(DPI*R*R)                                      HEA 38
C
C     EXPONENTIAL INTEGRAL
C     --------------------
      IF (XB .GT. 4.0D0) THEN                                           HEA 39
        EI = -XBEXP*XBI*                                                HEA 40
     1  (1.0D0 - XBI*(0.75D0 - XBI*(CON3-XBI*(1.125D0-XBI*1.7D0))))    HEA 41
      ELSE                                                              HEA 42
        XBK = 1.0D0                                                     HEA 43
        SUM = 0.0D0                                                     HEA 44
        FRL = 1.0D0                                                     HEA 45
        DO 1030 K=1,15                                                  HEA 46
           XBK = XBK*(-XB)                                              HEA 47
           FRL = DBLE(FLOAT(K))*FRL                                     HEA 48
           SUM = SUM+ XBK/(DBLE(FLOAT(K))*FRL)                          HEA 49
1030    CONTINUE                                                        HEA 50
        EI = CEUL + DLOG(XB) + SUM                                      HEA 51
      ENDIF                                                             HEA 52
C
C     SET LIMIT ON DECAY CONSTANT - USE CONSTANT SOURCE
C     FOR SMALLER VALUES
C
1040  IF (DABS(XA).LT.1.0D-10) GO TO 1090                               HEA 53
C
C     DECAYING SOURCE
C     ---------------
      TP = -XAEXP*EI                                                    HEA 54
      IF (DABS(TP).LT.1.0D-20) GO TO 1110                               HEA 55
      RS = (1.0D0-XAEXP)/QEXP                                           HEA 56
      TS =((XAEXP-1.0D0)/QEXP-2.0D0*XAEXP*XC*EI)                        HEA 57
      TOL = (1.0D-6)*DABS(RS)                                           HEA 58
      S1 = 0.0D0                                                        HEA 59
      SNEW = 0.0D0                                                      HEA 60
      FAC = 1.0D0                                                       HEA 61
      QP1 = 1.0D0                                                       HEA 62
      XCN = 1.0D0                                                       HEA 63
      XBN = XB                                                          HEA 64
      SG1 = 1.0D0                                                       HEA 65
      B = .FALSE.                                                       HEA 66
      DO 1080 N=2,80                                                    HEA 67
        N1 = N-1                                                        HEA 68
        FAC = DBLE(FLOAT(N1))*FAC                                       HEA 69
        QP2 = QP1                                                       HEA 70
        QP1 = QP1*QEXP                                                  HEA 71
        XCN = XCN*XC                                                    HEA 72
        SG1 = -SG1                                                      HEA 73
C
C     EXPONENTIAL FUNCTION
C     --------------------
        Y = -1.0D0                                                      HEA 74
        XBN = XBN*XB                                                    HEA 75
        XBNK = XBN                                                      HEA 76
        TSUM = 0.0D0                                                    HEA 77
        DO 1060 K=1,N1                                                  HEA 78
          XN = 1.0D0                                                    HEA 79
          DO 1050 L=1,K                                                 HEA 80
             XN = XN*DBLE(FLOAT(N-L))                                   HEA 81
1050      CONTINUE                                                      HEA 82
          Y = -Y                                                        HEA 83
          XBNK = XBNK*XBI                                               HEA 84
          TSUM = TSUM+Y/(XN*XBNK)                                       HEA 85
1060    CONTINUE                                                        HEA 86
        TEMP1 =XBEXP*TSUM                                               HEA 87
        TEMP2 = SG1/FAC*EI                                              HEA 88
        EXFCT = TEMP1-TEMP2                                             HEA 89
C
C     TEMPERATURE
C     -----------
        TP = TP+XAEXP*QP1*XCN/FAC*EXFCT                                 HEA 90
C
C     STRESSES
C     --------
        FCT = FAC/(DBLE(FLOAT(N1)))                                     HEA 91
        SOLD = SNEW                                                     HEA 92
        S1 = XAEXP*QP2*XCN/FCT*EXFCT                                    HEA 93
        SNEW = S1                                                       HEA 94
        S2 = 2.0D0*XAEXP*QP1*XCN*XC/FAC*EXFCT                           HEA 95
        RS = RS-SNEW                                                    HEA 96
        TS = TS+(S1+S2)                                                 HEA 97
        TEST =DABS(SOLD)-DABS(SNEW)                                     HEA 98
        IF (TEST.GE.0.0D0.AND.TEST.LT.TOL)THEN                          HEA 99
           IF (B) GO TO 1100                                            HEA100
           B = .TRUE.                                                   HEA101
        ENDIF                                                           HEA102
1080  CONTINUE                                                          HEA103
      WRITE (6,1120)                                                    HEA104
      GO TO 1100                                                        HEA105
C
C     CONSTANT SOURCE :
C     -----------------
C
C     TEMPERATURE
C     -----------
C
1090  TP=-EI                                                            HEA106
C
C     STRESSES
C     --------
      RS = (TM-XC*(XBEXP/XB+EI))                                        HEA107
      TS = (XBEXP*TM-XC*EI-TM)                                          HEA108
1100  SINTH = X/R                                                       HEA109
      COSTH = Z/R                                                       HEA110
      TP = TP * CON1                                                    HEA111
      RS = RS * CON2                                                    HEA112
      TS = TS * CON2                                                    HEA113
      UR = RS*R/(DBLE(G)+DBLE(G))                                       HEA114
      UX =-UR*SINTH                                                     HEA115
      UZ =-UR*COSTH                                                     HEA116
      S = SINTH*SINTH                                                   HEA117
      C = COSTH*COSTH                                                   HEA118
      TX = RS*S+TS*C                                                    HEA119
      TZ = RS*C+TS*S                                                    HEA120
      TXZ = (RS-TS)*SINTH*COSTH                                         HEA121
C
1110  CONTINUE                                                          HEA122
```

```
      A6 = SNGL(TP)                                                     HEA123
      A7 = SNGL(TX)                                                     HEA124
      A8 = SNGL(TZ)                                                     HEA125
      A9 = SNGL(TXZ)                                                    HEA126
      A10 = SNGL(UX)                                                    HEA127
      A11 = SNGL(UZ)                                                    HEA128
C
      RETURN                                                            HEA129
C
 1120 FORMAT (48H RADIAL STRESS DOES NOT CONVERGE WITHIN 80 TERMS)      HEA130
      END                                                               HEA131
```

APPENDIX B

Output for Verification Analyses

```
*****************************************************************************************
*                                                                                       *
*                                    H  E  F  F                                         *
*                                                                                       *
*                          A BOUNDARY ELEMENT CODE                                      *
*                   FOR TWO-DIMENSIONAL THERMOELASTIC ANALYSIS                          *
*                              OF A ROCK MASS                                           *
*                        SUBJECT TO CONSTANT OR DECAYING                                *
*                              THERMAL LOADING                                          *
*                   VERSION DATED: DEC. 6 1987 (MS-FORTRAN 77)                          *
*                                                                                       *
*                                  VERSION 4.1                                          *
*                                                                                       *
*****************************************************************************************
```

THICK WALLED CYLINDER SUBJECTED TO EXTERNAL PRESSURE OUTPUT CREATED ON 12/ 6/1987

NUMBER OF BOUNDARY SEGMENTS . . . . = 2
NUMBER OF STRESS LINES . . . . = 1
NUMBER OF HEAT SOURCES . . . . = 0
NUMBER OF EXP. DECAYING COMPONENTS . . . = 0

THE LINE X=0.0 IS A LINE OF SYMMETRY.
IMAGE BOUNDARY ELEMENTS AND HEAT SOURCES WILL BE GENERATED WITH RESPECT TO THIS LINE.

EFFECT OF IMAGE HEAT SOURCES NOT COMPUTED

POISSONS RATIO OF BODY . . . . . = .25
MODULUS OF ELASTICITY OF BODY . . . . . = .6000E+05
SHEAR MODULUS OF BODY . . . . . = .2400E+05

XX-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00 + (.0000E+00 + .0000E+00 / Y) * SIGYY
YY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
XY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
MAXIMUM VALUE FOR CXX + DXX / Y = .0000E+00
RATIO OF ZZ STRESS TO XX STRESS = .0000E+00

IN THE LIST BELOW, THE VALUE ASSIGNED TO KODE DENOTES BOUNDARY CONDITIONS AS FOLLOWS.
KODE= 1 NORMAL AND SHEAR STRESSES PRESCRIBED
KODE= 2 NORMAL AND SHEAR DISPL. PRESCRIBED
KODE= 3 NORMAL STRESS AND SHEAR DISPL. PRESCRIBED
KODE= 4 NORMAL DISPL. AND SHEAR STRESS PRESCRIBED

ELEMENT	KODE	X(CENTER)	Y(CENTER)	HALF-WIDTH	SIN BETA	COS BETA	B-VALUE (S)	B-VALUE (N)
1	1	.1281	-3.9959	.1282	.0321	.9995	.0000E+00	.0000E+00
2	1	.3839	-3.9795	.1282	.0960	.9954	.0000E+00	.0000E+00
3	1	.6381	-3.9467	.1282	.1596	.9872	.0000E+00	.0000E+00
4	1	.8896	-3.8977	.1282	.2225	.9749	.0000E+00	.0000E+00
5	1	1.1375	-3.8327	.1282	.2845	.9587	.0000E+00	.0000E+00
6	1	1.3808	-3.7519	.1282	.3454	.9385	.0000E+00	.0000E+00
7	1	1.6183	-3.6558	.1282	.4048	.9144	.0000E+00	.0000E+00
8	1	1.8492	-3.5446	.1282	.4625	.8866	.0000E+00	.0000E+00
9	1	2.0725	-3.4188	.1282	.5184	.8551	.0000E+00	.0000E+00
10	1	2.2873	-3.2790	.1282	.5721	.8202	.0000E+00	.0000E+00
11	1	2.4927	-3.1257	.1282	.6235	.7818	.0000E+00	.0000E+00
12	1	2.6878	-2.9596	.1282	.6723	.7403	.0000E+00	.0000E+00
13	1	2.8719	-2.7813	.1282	.7183	.6957	.0000E+00	.0000E+00
14	1	3.0442	-2.5916	.1282	.7614	.6482	.0000E+00	.0000E+00
15	1	3.2040	-2.3912	.1282	.8014	.5981	.0000E+00	.0000E+00
16	1	3.3506	-2.1810	.1282	.8381	.5455	.0000E+00	.0000E+00
17	1	3.4835	-1.9619	.1282	.8713	.4907	.0000E+00	.0000E+00
18	1	3.6020	-1.7346	.1282	.9010	.4339	.0000E+00	.0000E+00
19	1	3.7058	-1.5003	.1282	.9269	.3753	.0000E+00	.0000E+00
20	1	3.7943	-1.2598	.1282	.9491	.3151	.0000E+00	.0000E+00
21	1	3.8672	-1.0141	.1282	.9673	.2537	.0000E+00	.0000E+00
22	1	3.9242	-.7642	.1282	.9816	.1912	.0000E+00	.0000E+00
23	1	3.9651	-.5112	.1282	.9918	.1279	.0000E+00	.0000E+00
24	1	3.9897	-.2561	.1282	.9979	.0641	.0000E+00	.0000E+00
25	1	3.9979	.0000	.1282	1.0000	.0000	.0000E+00	.0000E+00
26	1	3.9897	.2561	.1282	.9979	-.0641	.0000E+00	.0000E+00
27	1	3.9651	.5112	.1282	.9918	-.1279	.0000E+00	.0000E+00
28	1	3.9242	.7642	.1282	.9816	-.1912	.0000E+00	.0000E+00
29	1	3.8672	1.0141	.1282	.9673	-.2537	.0000E+00	.0000E+00
30	1	3.7943	1.2598	.1282	.9491	-.3151	.0000E+00	.0000E+00
31	1	3.7058	1.5003	.1282	.9269	-.3753	.0000E+00	.0000E+00
32	1	3.6020	1.7346	.1282	.9010	-.4339	.0000E+00	.0000E+00
33	1	3.4835	1.9619	.1282	.8713	-.4907	.0000E+00	.0000E+00
34	1	3.3506	2.1810	.1282	.8381	-.5455	.0000E+00	.0000E+00
35	1	3.2040	2.3912	.1282	.8014	-.5981	.0000E+00	.0000E+00
36	1	3.0442	2.5916	.1282	.7614	-.6482	.0000E+00	.0000E+00
37	1	2.8719	2.7813	.1282	.7183	-.6957	.0000E+00	.0000E+00
38	1	2.6878	2.9596	.1282	.6723	-.7403	.0000E+00	.0000E+00
39	1	2.4927	3.1257	.1282	.6235	-.7818	.0000E+00	.0000E+00
40	1	2.2873	3.2790	.1282	.5721	-.8202	.0000E+00	.0000E+00
41	1	2.0725	3.4188	.1282	.5184	-.8551	.0000E+00	.0000E+00
42	1	1.8492	3.5446	.1282	.4625	-.8866	.0000E+00	.0000E+00
43	1	1.6183	3.6558	.1282	.4048	-.9144	.0000E+00	.0000E+00
44	1	1.3808	3.7519	.1282	.3454	-.9385	.0000E+00	.0000E+00
45	1	1.1375	3.8327	.1282	.2845	-.9587	.0000E+00	.0000E+00
46	1	.8896	3.8977	.1282	.2225	-.9749	.0000E+00	.0000E+00
47	1	.6381	3.9467	.1282	.1596	-.9872	.0000E+00	.0000E+00
48	1	.3839	3.9795	.1282	.0960	-.9954	.0000E+00	.0000E+00
49	1	.1281	3.9959	.1282	.0321	-.9995	.0000E+00	.0000E+00
50	1	.1922	5.9938	.1923	-.0321	.9995	.0000E+00	.6000E+01
51	1	.5758	5.9692	.1923	-.0960	.9954	.0000E+00	.6000E+01
52	1	.9571	5.9200	.1923	-.1596	.9872	.0000E+00	.6000E+01
53	1	1.3344	5.8466	.1923	-.2225	.9749	.0000E+00	.6000E+01
54	1	1.7063	5.7491	.1923	-.2845	.9587	.0000E+00	.6000E+01
55	1	2.0711	5.6279	.1923	-.3454	.9385	.0000E+00	.6000E+01
56	1	2.4275	5.4837	.1923	-.4048	.9144	.0000E+00	.6000E+01
57	1	2.7738	5.3169	.1923	-.4625	.8866	.0000E+00	.6000E+01
58	1	3.1088	5.1282	.1923	-.5184	.8551	.0000E+00	.6000E+01
59	1	3.4309	4.9185	.1923	-.5721	.8202	.0000E+00	.6000E+01
60	1	3.7390	4.6886	.1923	-.6235	.7818	.0000E+00	.6000E+01
61	1	4.0317	4.4394	.1923	-.6723	.7403	.0000E+00	.6000E+01
62	1	4.3079	4.1720	.1923	-.7183	.6957	.0000E+00	.6000E+01
63	1	4.5663	3.8874	.1923	-.7614	.6482	.0000E+00	.6000E+01
64	1	4.8060	3.5868	.1923	-.8014	.5981	.0000E+00	.6000E+01

65	1	5.0259	3.2715	.1923	-.8381	.5455	.0000E+00	.6000E+01
66	1	5.2252	2.9428	.1923	-.8713	.4907	.0000E+00	.6000E+01
67	1	5.4030	2.6020	.1923	-.9010	.4339	.0000E+00	.6000E+01
68	1	5.5586	2.2504	.1923	-.9269	.3753	.0000E+00	.6000E+01
69	1	5.6914	1.8897	.1923	-.9491	.3151	.0000E+00	.6000E+01
70	1	5.8008	1.5211	.1923	-.9673	.2537	.0000E+00	.6000E+01
71	1	5.8863	1.1464	.1923	-.9816	.1912	.0000E+00	.6000E+01
72	1	5.9477	.7669	.1923	-.9918	.1279	.0000E+00	.6000E+01
73	1	5.9846	.3842	.1923	-.9979	.0641	.0000E+00	.6000E+01
74	1	5.9969	.0000	.1923	-1.0000	.0000	.0000E+00	.6000E+01
75	1	5.9846	-.3842	.1923	-.9979	-.0641	.0000E+00	.6000E+01
76	1	5.9477	-.7669	.1923	-.9918	-.1279	.0000E+00	.6000E+01
77	1	5.8863	-1.1464	.1923	-.9816	-.1912	.0000E+00	.6000E+01
78	1	5.8008	-1.5211	.1923	-.9673	-.2537	.0000E+00	.6000E+01
79	1	5.6914	-1.8897	.1923	-.9491	-.3151	.0000E+00	.6000E+01
80	1	5.5586	-2.2504	.1923	-.9269	-.3753	.0000E+00	.6000E+01
81	1	5.4030	-2.6020	.1923	-.9010	-.4339	.0000E+00	.6000E+01
82	1	5.2252	-2.9428	.1923	-.8713	-.4907	.0000E+00	.6000E+01
83	1	5.0259	-3.2715	.1923	-.8381	-.5455	.0000E+00	.6000E+01
84	1	4.8060	-3.5868	.1923	-.8014	-.5981	.0000E+00	.6000E+01
85	1	4.5663	-3.8874	.1923	-.7614	-.6482	.0000E+00	.6000E+01
86	1	4.3079	-4.1720	.1923	-.7183	-.6957	.0000E+00	.6000E+01
87	1	4.0317	-4.4394	.1923	-.6723	-.7403	.0000E+00	.6000E+01
88	1	3.7390	-4.6886	.1923	-.6235	-.7818	.0000E+00	.6000E+01
89	1	3.4309	-4.9185	.1923	-.5721	-.8202	.0000E+00	.6000E+01
90	1	3.1088	-5.1282	.1923	-.5184	-.8551	.0000E+00	.6000E+01
91	1	2.7738	-5.3169	.1923	-.4625	-.8866	.0000E+00	.6000E+01
92	1	2.4275	-5.4837	.1923	-.4048	-.9144	.0000E+00	.6000E+01
93	1	2.0711	-5.6279	.1923	-.3454	-.9385	.0000E+00	.6000E+01
94	1	1.7063	-5.7491	.1923	-.2845	-.9587	.0000E+00	.6000E+01
95	1	1.3344	-5.8466	.1923	-.2225	-.9749	.0000E+00	.6000E+01
96	1	.9571	-5.9200	.1923	-.1596	-.9872	.0000E+00	.6000E+01
97	1	.5758	-5.9692	.1923	-.0960	-.9954	.0000E+00	.6000E+01
98	1	.1922	-5.9938	.1923	-.0321	-.9995	.0000E+00	.6000E+01

LINES DEFINING STRESS POINTS

XBEG	YBEG	XEND	YEND	NUMPB
4.0000	.0000	6.0000	.0000	6

TIME REQUIRED TO COMPUTE INFLUENCE COEFFICIENTS= 133.42 SECONDS.

* *

OUTPUT FOR TIME= .0000E+00

PRE-EXISTING STRESS AT EACH ELEMENT

ELEMENT	TEMP	SIGMAXX	SIGMAYY	SIGMAXY	SIGMAZZ	NORM-STR	SHEAR-STR	NORM-DIS	SHEAR-DIS
1	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
2	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
3	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
4	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
5	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
6	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
7	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
8	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
9	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
10	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
11	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
12	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
13	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
14	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
15	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
16	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
17	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
18	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
19	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
20	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
21	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
22	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
23	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
24	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
25	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
26	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
27	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
28	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
29	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
30	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
31	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
32	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
33	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
34	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
35	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
36	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
37	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
38	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
39	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
40	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
41	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
42	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
43	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
44	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
45	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
46	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
47	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
48	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
49	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
50	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
51	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
52	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
53	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
54	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
55	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
56	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
57	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
58	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
59	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
60	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
61	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
62	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
63	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
64	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
65	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
66	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
67	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00

68	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
69	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
70	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
71	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
72	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
73	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
74	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
75	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
76	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
77	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
78	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
79	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
80	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
81	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
82	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
83	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
84	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
85	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
86	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
87	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
88	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
89	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
90	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
91	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
92	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
93	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
94	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
95	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
96	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
97	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
98	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00

TIME REQUIRED TO COMPUTE PRE-EXISTING STRESSES = 1.15 SECONDS.

TIME REQUIRED TO SOLVE EQUATIONS= 239.53 SECONDS.

BOUNDARY STRESSES AND DISPLACEMENTS AT TIME = .000E+00

ELM	X-COORD SIGXX	Y-COORD SIGYY	UX SIGXY	UY SIGZZ	US SIGMA-S	UN SIGMA-N	SIGMA-T	TEMP
1	.1281E+00	-.3996E+01	.4362E-04	-.1360E-02	.4045E-08	-.1361E-02		
	.2156E+02	.2216E-01	.6913E+00	.5395E+01	-.3938E-06	-.5599E-05	.2158E+02	.0000E+00
2	.3839E+00	-.3979E+01	.1307E-03	-.1355E-02	.1092E-07	-.1361E-02		
	.2136E+02	.1990E+00	.2063E+01	.5395E+01	.1055E-05	-.4827E-06	.2158E+02	.0000E+00
3	.6381E+00	-.3947E+01	.2172E-03	-.1343E-02	.1934E-07	-.1361E-02		
	.2103E+02	.5497E+00	.3400E+01	.5395E+01	-.7192E-06	-.5451E-06	.2158E+02	.0000E+00
4	.8896E+00	-.3898E+01	.3028E-03	-.1327E-02	.2627E-07	-.1361E-02		
	.2051E+02	.1069E+01	.4681E+01	.5395E+01	.5409E-06	-.3977E-05	.2158E+02	.0000E+00
5	.1136E+01	-.3833E+01	.3872E-03	-.1305E-02	.3422E-07	-.1361E-02		
	.1983E+02	.1747E+01	.5886E+01	.5395E+01	.4062E-06	-.1133E-05	.2158E+02	.0000E+00
6	.1381E+01	-.3752E+01	.4700E-03	-.1277E-02	.4176E-07	-.1361E-02		
	.1901E+02	.2574E+01	.6994E+01	.5395E+01	-.2692E-05	-.3260E-05	.2158E+02	.0000E+00
7	.1618E+01	-.3656E+01	.5509E-03	-.1244E-02	.4852E-07	-.1361E-02		
	.1804E+02	.3536E+01	.7987E+01	.5395E+01	.1829E-05	-.4318E-06	.2158E+02	.0000E+00
8	.1849E+01	-.3545E+01	.6295E-03	-.1206E-02	.5421E-07	-.1361E-02		
	.1696E+02	.4617E+01	.8849E+01	.5395E+01	-.1042E-05	.3304E-06	.2158E+02	.0000E+00
9	.2073E+01	-.3419E+01	.7055E-03	-.1164E-02	.6011E-07	-.1361E-02		
	.1578E+02	.5799E+01	.9566E+01	.5395E+01	.2394E-05	-.3865E-05	.2158E+02	.0000E+00
10	.2287E+01	-.3279E+01	.7766E-03	-.1116E-02	.6670E-07	-.1361E-02		
	.1452E+02	.7063E+01	.1013E+02	.5395E+01	-.3487E-05	.2673E-05	.2158E+02	.0000E+00
11	.2493E+01	-.3126E+01	.8485E-03	-.1064E-02	.7160E-07	-.1361E-02		
	.1319E+02	.8389E+01	.1052E+02	.5395E+01	.1380E-05	-.4638E-05	.2158E+02	.0000E+00
12	.2688E+01	-.2960E+01	.9149E-03	-.1007E-02	.7626E-07	-.1361E-02		
	.1183E+02	.9754E+01	.1074E+02	.5395E+01	.1804E-06	-.3931E-05	.2158E+02	.0000E+00
13	.2872E+01	-.2781E+01	.9776E-03	-.9467E-03	.8182E-07	-.1361E-02		
	.1044E+02	.1114E+02	.1078E+02	.5395E+01	-.3823E-06	-.2441E-05	.2158E+02	.0000E+00
14	.3044E+01	-.2592E+01	.1036E-02	-.8821E-03	.8574E-07	-.1361E-02		
	.9068E+01	.1251E+02	.1065E+02	.5395E+01	.2073E-05	.3424E-05	.2158E+02	.0000E+00
15	.3204E+01	-.2391E+01	.1091E-02	-.8139E-03	.8882E-07	-.1361E-02		
	.7720E+01	.1386E+02	.1034E+02	.5395E+01	-.9586E-06	-.2213E-05	.2158E+02	.0000E+00
16	.3351E+01	-.2181E+01	.1141E-02	-.7423E-03	.9222E-07	-.1361E-02		
	.6422E+01	.1516E+02	.9866E+01	.5395E+01	-.1772E-05	-.1109E-04	.2158E+02	.0000E+00
17	.3483E+01	-.1962E+01	.1186E-02	-.6677E-03	.9507E-07	-.1361E-02		
	.5196E+01	.1638E+02	.9227E+01	.5395E+01	-.2932E-05	-.4083E-05	.2158E+02	.0000E+00
18	.3602E+01	-.1735E+01	.1226E-02	-.5904E-03	.9612E-07	-.1361E-02		
	.4062E+01	.1752E+02	.8436E+01	.5395E+01	-.1222E-05	.3762E-05	.2158E+02	.0000E+00
19	.3706E+01	-.1500E+01	.1261E-02	-.5106E-03	.9799E-07	-.1361E-02		
	.3039E+01	.1854E+02	.7506E+01	.5395E+01	-.1301E-05	-.5132E-05	.2158E+02	.0000E+00
20	.3794E+01	-.1260E+01	.1292E-02	-.4287E-03	.9929E-07	-.1361E-02		
	.2143E+01	.1944E+02	.6453E+01	.5395E+01	-.4149E-07	.4596E-05	.2158E+02	.0000E+00
21	.3867E+01	-.1014E+01	.1316E-02	-.3451E-03	.9980E-07	-.1361E-02		
	.1388E+01	.2019E+02	.5295E+01	.5395E+01	.8139E-06	.1930E-05	.2158E+02	.0000E+00
22	.3924E+01	-.7642E+00	.1336E-02	-.2600E-03	.1010E-06	-.1361E-02		
	.7885E+00	.2079E+02	.4049E+01	.5395E+01	-.3055E-06	-.4155E-05	.2158E+02	.0000E+00
23	.3965E+01	-.5112E+00	.1350E-02	-.1739E-03	.1014E-06	-.1361E-02		
	.3529E+00	.2123E+02	.2737E+01	.5395E+01	-.2231E-06	.2564E-05	.2158E+02	.0000E+00
24	.3990E+01	-.2561E+00	.1358E-02	-.8709E-04	.1005E-06	-.1361E-02		

	.8859E-01	.2149E+02	.1380E+01	.5395E+01	.1600E-05	.7023E-05	.2158E+02	.0000E+00
25	.3998E+01	.8941E-07	.1361E-02	.9878E-07	.9894E-07	-.1361E-02		
	.1954E-05	.2158E+02	.3184E-05	.5395E+01	-.6659E-06	.1954E-05	.2158E+02	.0000E+00
26	.3990E+01	.2561E+00	.1358E-02	.8729E-04	.9792E-07	-.1361E-02		
	.8858E-01	.2149E+02	-.1380E+01	.5395E+01	.5838E-06	.1683E-05	.2158E+02	.0000E+00
27	.3965E+01	.5112E+00	.1350E-02	.1741E-03	.9570E-07	-.1361E-02		
	.3529E+00	.2123E+02	-.2737E+01	.5395E+01	.1670E-05	-.4467E-05	.2158E+02	.0000E+00
28	.3924E+01	.7642E+00	.1336E-02	.2602E-03	.9406E-07	-.1361E-02		
	.7885E+00	.2079E+02	-.4049E+01	.5395E+01	.5601E-06	.4963E-06	.2158E+02	.0000E+00
29	.3867E+01	.1014E+01	.1316E-02	.3453E-03	.9034E-07	-.1361E-02		
	.1388E+01	.2019E+02	-.5295E+01	.5395E+01	.1279E-05	.4211E-05	.2158E+02	.0000E+00
30	.3794E+01	.1260E+01	.1292E-02	.4289E-03	.8906E-07	-.1361E-02		
	.2143E+01	.1944E+02	-.6453E+01	.5395E+01	.3770E-06	-.8469E-06	.2158E+02	.0000E+00
31	.3706E+01	.1500E+01	.1261E-02	.5108E-03	.8604E-07	-.1361E-02		
	.3039E+01	.1854E+02	-.7506E+01	.5395E+01	-.3785E-06	.3384E-05	.2158E+02	.0000E+00
32	.3602E+01	.1735E+01	.1226E-02	.5906E-03	.8230E-07	-.1361E-02		
	.4062E+01	.1752E+02	-.8436E+01	.5395E+01	-.1170E-05	-.7792E-05	.2158E+02	.0000E+00
33	.3483E+01	.1962E+01	.1186E-02	.6679E-03	.7750E-07	-.1361E-02		
	.5196E+01	.1638E+02	-.9227E+01	.5395E+01	.4203E-06	-.1690E-05	.2158E+02	.0000E+00
34	.3351E+01	.2181E+01	.1141E-02	.7425E-03	.7400E-07	-.1361E-02		
	.6422E+01	.1516E+02	-.9866E+01	.5395E+01	.5220E-06	-.2762E-05	.2158E+02	.0000E+00
35	.3204E+01	.2391E+01	.1091E-02	.8141E-03	.7022E-07	-.1361E-02		
	.7720E+01	.1386E+02	-.1034E+02	.5395E+01	-.1791E-05	.4207E-06	.2158E+02	.0000E+00
36	.3044E+01	.2592E+01	.1036E-02	.8823E-03	.6604E-07	-.1361E-02		
	.9068E+01	.1251E+02	-.1065E+02	.5395E+01	.3357E-05	-.4806E-05	.2158E+02	.0000E+00
37	.2872E+01	.2781E+01	.9776E-03	.9469E-03	.6169E-07	-.1361E-02		
	.1044E+02	.1114E+02	-.1076E+02	.5395E+01	-.1303E-05	-.3750E-06	.2158E+02	.0000E+00
38	.2688E+01	.2960E+01	.9149E-03	.1008E-02	.5649E-07	-.1361E-02		
	.1183E+02	.9754E+01	-.1074E+02	.5395E+01	-.1426E-05	-.5213E-05	.2158E+02	.0000E+00
39	.2493E+01	.3126E+01	.8485E-03	.1064E-02	.5335E-07	-.1361E-02		
	.1319E+02	.8389E+01	-.1052E+02	.5395E+01	.1616E-05	-.4970E-05	.2158E+02	.0000E+00
40	.2287E+01	.3279E+01	.7786E-03	.1116E-02	.4750E-07	-.1361E-02		
	.1452E+02	.7063E+01	-.1013E+02	.5395E+01	-.1460E-06	-.3824E-06	.2158E+02	.0000E+00
41	.2073E+01	.3419E+01	.7055E-03	.1164E-02	.4228E-07	-.1361E-02		
	.1578E+02	.5799E+01	-.9566E+01	.5395E+01	-.2318E-05	-.5973E-05	.2158E+02	.0000E+00
42	.1849E+01	.3545E+01	.6295E-03	.1207E-02	.3809E-07	-.1361E-02		
	.1696E+02	.4617E+01	-.8849E+01	.5395E+01	-.6861E-07	-.2773E-05	.2158E+02	.0000E+00
43	.1618E+01	.3656E+01	.5509E-03	.1245E-02	.3275E-07	-.1361E-02		
	.1804E+02	.3536E+01	-.7987E+01	.5395E+01	-.3778E-05	.4467E-05	.2158E+02	.0000E+00
44	.1381E+01	.3752E+01	.4700E-03	.1277E-02	.2777E-07	-.1361E-02		
	.1901E+02	.2574E+01	-.6994E+01	.5395E+01	-.2390E-05	-.4655E-05	.2158E+02	.0000E+00
45	.1138E+01	.3833E+01	.3872E-03	.1305E-02	.2258E-07	-.1361E-02		
	.1983E+02	.1747E+01	-.5886E+01	.5395E+01	.9783E-07	-.4208E-05	.2158E+02	.0000E+00
46	.8896E+00	.3898E+01	.3028E-03	.1327E-02	.1852E-07	-.1361E-02		
	.2051E+02	.1069E+01	-.4681E+01	.5395E+01	-.1921E-06	-.3381E-05	.2158E+02	.0000E+00
47	.6381E+00	.3947E+01	.2172E-03	.1344E-02	.1365E-07	-.1361E-02		
	.2103E+02	.5497E+00	-.3400E+01	.5395E+01	-.7893E-06	.7344E-05	.2158E+02	.0000E+00
48	.3839E+00	.3979E+01	.1307E-03	.1355E-02	.8707E-08	-.1361E-02		
	.2138E+02	.1990E+00	-.2063E+01	.5395E+01	-.3832E-06	-.3996E-06	.2158E+02	.0000E+00
49	.1281E+00	.3996E+01	.4362E-04	.1360E-02	.2778E-08	-.1361E-02		
	.2156E+02	.2217E-01	-.6913E+00	.5395E+01	-.1473E-06	.2964E-05	.2158E+02	.0000E+00
50	.1922E+00	.5994E+01	.4109E-04	.1281E-02	-.3818E-08	.1282E-02		
	.1557E+02	.6010E+01	-.3069E+00	.5395E+01	.2182E-06	.6000E+01	.1558E+02	.0000E+00
51	.5758E+00	.5969E+01	.1231E-03	.1276E-02	-.7946E-08	.1282E-02		
	.1549E+02	.6088E+01	-.9156E+00	.5395E+01	.2582E-06	.6000E+01	.1558E+02	.0000E+00
52	.9571E+00	.5920E+01	.2046E-03	.1266E-02	-.1371E-07	.1282E-02		
	.1534E+02	.6244E+01	-.1509E+01	.5395E+01	.1873E-06	.6000E+01	.1558E+02	.0000E+00
53	.1334E+01	.5847E+01	.2853E-03	.1250E-02	-.2204E-07	.1282E-02		
	.1510E+02	.6474E+01	-.2078E+01	.5395E+01	-.8316E-06	.6000E+01	.1558E+02	.0000E+00
54	.1706E+01	.5749E+01	.3647E-03	.1229E-02	-.2734E-07	.1282E-02		
	.1480E+02	.6775E+01	-.2613E+01	.5395E+01	-.2767E-06	.6000E+01	.1558E+02	.0000E+00
55	.2071E+01	.5628E+01	.4427E-03	.1203E-02	-.3279E-07	.1282E-02		
	.1444E+02	.7143E+01	-.3105E+01	.5395E+01	-.2627E-08	.6000E+01	.1558E+02	.0000E+00
56	.2427E+01	.5484E+01	.5189E-03	.1172E-02	-.3722E-07	.1282E-02		
	.1401E+02	.7570E+01	-.3546E+01	.5395E+01	.2514E-05	.6000E+01	.1558E+02	.0000E+00
57	.2774E+01	.5317E+01	.5929E-03	.1137E-02	-.4298E-07	.1282E-02		
	.1353E+02	.8049E+01	-.3928E+01	.5395E+01	-.9682E-06	.6000E+01	.1558E+02	.0000E+00
58	.3109E+01	.5128E+01	.6645E-03	.1096E-02	-.4841E-07	.1282E-02		
	.1300E+02	.8574E+01	-.4246E+01	.5395E+01	.1830E-05	.6000E+01	.1558E+02	.0000E+00
59	.3431E+01	.4919E+01	.7334E-03	.1052E-02	-.5423E-07	.1282E-02		
	.1244E+02	.9135E+01	-.4495E+01	.5395E+01	-.5482E-06	.6000E+01	.1558E+02	.0000E+00
60	.3739E+01	.4689E+01	.7993E-03	.1002E-02	-.6029E-07	.1282E-02		
	.1186E+02	.9724E+01	-.4670E+01	.5395E+01	-.8289E-06	.6000E+01	.1558E+02	.0000E+00
61	.4032E+01	.4439E+01	.8618E-03	.9491E-03	-.6399E-07	.1282E-02		
	.1125E+02	.1033E+02	-.4767E+01	.5395E+01	.1387E-05	.6000E+01	.1558E+02	.0000E+00
62	.4308E+01	.4172E+01	.9209E-03	.8919E-03	-.6875E-07	.1282E-02		
	.1064E+02	.1094E+02	-.4787E+01	.5395E+01	-.9121E-06	.6000E+01	.1558E+02	.0000E+00

63	.4566E+01	.3887E+01	.9761E-03	.8311E-03	-.7235E-07	.1282E-02		
	.1003E+02	.1155E+02	-.4728E+01	.5395E+01	.3096E-07	.6000E+01	.1558E+02	.0000E+00
64	.4806E+01	.3587E+01	.1027E-02	.7666E-03	-.7598E-07	.1282E-02		
	.9427E+01	.1215E+02	-.4592E+01	.5395E+01	.1526E-05	.6000E+01	.1558E+02	.0000E+00
65	.5026E+01	.3272E+01	.1074E-02	.6994E-03	-.7946E-07	.1282E-02		
	.8851E+01	.1273E+02	-.4360E+01	.5395E+01	.1082E-05	.6000E+01	.1558E+02	.0000E+00
66	.5225E+01	.2943E+01	.1117E-02	.6292E-03	-.8322E-07	.1282E-02		
	.8307E+01	.1327E+02	-.4096E+01	.5395E+01	-.2801E-07	.6000E+01	.1558E+02	.0000E+00
67	.5403E+01	.2602E+01	.1155E-02	.5563E-03	-.8581E-07	.1282E-02		
	.7803E+01	.1378E+02	-.3745E+01	.5395E+01	-.1422E-05	.6000E+01	.1558E+02	.0000E+00
68	.5559E+01	.2250E+01	.1188E-02	.4812E-03	-.8933E-07	.1282E-02		
	.7349E+01	.1423E+02	-.3332E+01	.5395E+01	.1020E-05	.6000E+01	.1558E+02	.0000E+00
69	.5691E+01	.1890E+01	.1217E-02	.4040E-03	-.9337E-07	.1282E-02		
	.6951E+01	.1463E+02	-.2865E+01	.5395E+01	.3781E-06	.6000E+01	.1558E+02	.0000E+00
70	.5801E+01	.1521E+01	.1240E-02	.3253E-03	-.9336E-07	.1282E-02		
	.6616E+01	.1496E+02	-.2350E+01	.5395E+01	.2192E-06	.6000E+01	.1558E+02	.0000E+00
71	.5886E+01	.1146E+01	.1258E-02	.2452E-03	-.9811E-07	.1282E-02		
	.6350E+01	.1523E+02	-.1797E+01	.5395E+01	-.5502E-06	.6000E+01	.1558E+02	.0000E+00
72	.5948E+01	.7669E+00	.1271E-02	.1640E-03	-.9807E-07	.1282E-02		
	.6157E+01	.1542E+02	-.1215E+01	.5395E+01	-.1239E-05	.6000E+01	.1558E+02	.0000E+00
73	.5985E+01	.3842E+00	.1279E-02	.8224E-04	-.1006E-06	.1282E-02		
	.6039E+01	.1554E+02	-.6125E+00	.5395E+01	-.9466E-06	.6000E+01	.1558E+02	.0000E+00
74	.5997E+01	-.1341E-06	.1282E-02	.1009E-06	-.1007E-06	.1282E-02		
	.6000E+01	.1558E+02	-.1401E-05	.5395E+01	.2832E-06	.6000E+01	.1558E+02	.0000E+00
75	.5985E+01	-.3842E+00	.1279E-02	-.8203E-04	-.9995E-07	.1282E-02		
	.6039E+01	.1554E+02	.6125E+00	.5395E+01	-.1359E-05	.6000E+01	.1558E+02	.0000E+00
76	.5948E+01	-.7669E+00	.1271E-02	-.1638E-03	-.1003E-06	.1282E-02		
	.6157E+01	.1542E+02	.1215E+01	.5395E+01	-.1163E-05	.6000E+01	.1558E+02	.0000E+00
77	.5886E+01	-.1146E+01	.1258E-02	-.2450E-03	-.9817E-07	.1282E-02		
	.6350E+01	.1523E+02	.1797E+01	.5395E+01	-.7123E-06	.6000E+01	.1558E+02	.0000E+00
78	.5801E+01	-.1521E+01	.1240E-02	-.3251E-03	-.9812E-07	.1282E-02		
	.6616E+01	.1496E+02	.2350E+01	.5395E+01	-.4138E-06	.6000E+01	.1558E+02	.0000E+00
79	.5691E+01	-.1890E+01	.1217E-02	-.4039E-03	-.9629E-07	.1282E-02		
	.6951E+01	.1463E+02	.2865E+01	.5395E+01	-.6795E-06	.6000E+01	.1558E+02	.0000E+00
80	.5559E+01	-.2250E+01	.1188E-02	-.4810E-03	-.9142E-07	.1282E-02		
	.7349E+01	.1423E+02	.3332E+01	.5395E+01	-.1276E-05	.6000E+01	.1558E+02	.0000E+00
81	.5403E+01	-.2602E+01	.1155E-02	-.5561E-03	-.9161E-07	.1282E-02		
	.7803E+01	.1378E+02	.3745E+01	.5395E+01	.2016E-05	.6000E+01	.1558E+02	.0000E+00
82	.5225E+01	-.2943E+01	.1117E-02	-.6290E-03	-.9064E-07	.1282E-02		
	.8307E+01	.1327E+02	.4096E+01	.5395E+01	-.9246E-06	.6000E+01	.1558E+02	.0000E+00
83	.5026E+01	-.3272E+01	.1074E-02	-.6992E-03	-.8692E-07	.1282E-02		
	.8851E+01	.1273E+02	.4380E+01	.5395E+01	.2767E-05	.6000E+01	.1558E+02	.0000E+00
84	.4806E+01	-.3587E+01	.1027E-02	-.7666E-03	-.8474E-07	.1282E-02		
	.9427E+01	.1215E+02	.4592E+01	.5395E+01	.2271E-05	.6000E+01	.1558E+02	.0000E+00
85	.4566E+01	-.3887E+01	.9761E-03	-.8309E-03	-.7700E-07	.1282E-02		
	.1003E+02	.1155E+02	.4728E+01	.5395E+01	.1467E-05	.6000E+01	.1558E+02	.0000E+00
86	.4308E+01	-.4172E+01	.9209E-03	-.8917E-03	-.7369E-07	.1282E-02		
	.1064E+02	.1094E+02	.4787E+01	.5395E+01	.7298E-06	.6000E+01	.1558E+02	.0000E+00
87	.4032E+01	-.4439E+01	.8618E-03	-.9489E-03	-.6950E-07	.1282E-02		
	.1125E+02	.1033E+02	.4767E+01	.5395E+01	-.2625E-07	.6000E+01	.1558E+02	.0000E+00
88	.3739E+01	-.4689E+01	.7993E-03	-.1002E-02	-.6488E-07	.1282E-02		
	.1186E+02	.9724E+01	.4670E+01	.5395E+01	-.7113E-06	.6000E+01	.1558E+02	.0000E+00
89	.3431E+01	-.4919E+01	.7334E-03	-.1051E-02	-.6041E-07	.1282E-02		
	.1244E+02	.9135E+01	.4495E+01	.5395E+01	.5385E-06	.6000E+01	.1558E+02	.0000E+00
90	.3109E+01	-.5128E+01	.6645E-03	-.1096E-02	-.5287E-07	.1282E-02		
	.1300E+02	.8574E+01	.4246E+01	.5395E+01	.6387E-06	.6000E+01	.1558E+02	.0000E+00
91	.2774E+01	-.5317E+01	.5929E-03	-.1136E-02	-.4769E-07	.1282E-02		
	.1353E+02	.8049E+01	.3928E+01	.5395E+01	-.7350E-07	.6000E+01	.1558E+02	.0000E+00
92	.2427E+01	-.5484E+01	.5189E-03	-.1172E-02	-.4263E-07	.1282E-02		
	.1401E+02	.7570E+01	.3546E+01	.5395E+01	-.3493E-06	.6000E+01	.1558E+02	.0000E+00
93	.2071E+01	-.5628E+01	.4427E-03	-.1203E-02	-.3628E-07	.1282E-02		
	.1444E+02	.7143E+01	.3105E+01	.5395E+01	-.1425E-06	.6000E+01	.1558E+02	.0000E+00
94	.1706E+01	-.5749E+01	.3647E-03	-.1229E-02	-.3016E-07	.1282E-02		
	.1480E+02	.6775E+01	.2613E+01	.5395E+01	-.1269E-05	.6000E+01	.1558E+02	.0000E+00
95	.1334E+01	-.5847E+01	.2853E-03	-.1250E-02	-.2267E-07	.1282E-02		
	.1510E+02	.6474E+01	.2078E+01	.5395E+01	-.2430E-06	.6000E+01	.1558E+02	.0000E+00
96	.9571E+00	-.5920E+01	.2046E-03	-.1265E-02	-.1807E-07	.1282E-02		
	.1534E+02	.6244E+01	.1509E+01	.5395E+01	-.5956E-06	.6000E+01	.1558E+02	.0000E+00
97	.5758E+00	-.5969E+01	.1231E-03	-.1276E-02	-.1107E-07	.1282E-02		
	.1549E+02	.6088E+01	.9156E+00	.5395E+01	-.1050E-06	.6000E+01	.1558E+02	.0000E+00
98	.1922E+00	-.5994E+01	.4109E-04	-.1281E-02	-.2894E-08	.1282E-02		
	.1557E+02	.6010E+01	.3069E+00	.5395E+01	-.1201E-06	.6000E+01	.1558E+02	.0000E+00

TIME REQUIRED TO COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS= 136.65 SECONDS.

INTERIOR STRESSES AND DISPLACEMENTS AT TIME = .000E+00

POINT	X-COORD SIGXX	Y-COORD SIGYY	UX SIGXY	UY SIGZZ	SIG1	SIG2	ALPHA	TEMP
1	.4000E+01 .5549E-02	.0000E+00 .2157E+02	.1361E-02 .1297E-05	.9767E-07 .5395E+01	.2157E+02	.5550E-02	.9000E+02	.0000E+00
2	.4400E+01 .1752E+01	.0000E+00 .1983E+02	.1323E-02 .2277E-05	.9887E-07 .5395E+01	.1983E+02	.1752E+01	.9000E+02	.0000E+00
3	.4800E+01 .3196E+01	.0000E+00 .1838E+02	.1299E-02 .6381E-06	.9953E-07 .5395E+01	.1838E+02	.3196E+01	.9000E+02	.0000E+00
4	.5200E+01 .4319E+01	.0000E+00 .1726E+02	.1285E-02 .1074E-05	.9981E-07 .5395E+01	.1726E+02	.4319E+01	.9000E+02	.0000E+00
5	.5600E+01 .5211E+01	.0000E+00 .1637E+02	.1280E-02 .3311E-05	.9852E-07 .5395E+01	.1637E+02	.5211E+01	.9000E+02	.0000E+00
6	.6000E+01 -.1018E+02	.0000E+00 .1018E+02	.1281E-02 .2007E-03	.1003E-06 -.2807E-04	.1018E+02	-.1018E+02	.9000E+02	.0000E+00

TIME REQUIRED TO COMPUTE STRESSES AND DISPLACEMENTS AT STRESS POINTS= 8.41 SECONDS.

JOB COMPLETED AT 16:10 HOURS

DATA FOR PLOTTING WILL BE STORED IN FILE NAMED VERIF1

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*****************************************************************************
*                                                                           *
*                                H  E  F  F                                 *
*                                                                           *
*                          A BOUNDARY ELEMENT CODE                          *
*                  FOR TWO-DIMENSIONAL THERMOELASTIC ANALYSIS               *
*                            OF A ROCK MASS                                 *
*                       SUBJECT TO CONSTANT OR DECAYING                     *
*                              THERMAL LOADING                              *
*                  VERSION DATED: DEC. 6 1987 (MS-FORTRAN 77)               *
*                                                                           *
*                                VERSION 4.1                                *
*                                                                           *
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EXCAVATION OF A CIRCULAR HOLE IN A BI-AXIALLY STRESSED PLATE OUTPUT CREATED ON 12/ 6/1987

NUMBER OF BOUNDARY SEGMENTS . . . . = 1
NUMBER OF STRESS LINES . . . . = 1
NUMBER OF HEAT SOURCES . . . . = 0
NUMBER OF EXP. DECAYING COMPONENTS . . . = 0

THE LINE X=0.0 IS A LINE OF SYMMETRY.
IMAGE BOUNDARY ELEMENTS AND HEAT SOURCES WILL BE GENERATED WITH RESPECT TO THIS LINE.

EFFECT OF IMAGE HEAT SOURCES NOT COMPUTED

POISSONS RATIO OF BODY . . . . = .25
MODULUS OF ELASTICITY OF BODY . . . . . . = .6000E+05
SHEAR MODULUS OF BODY . . . . = .2400E+05

XX-COMPONENT OF FIELD STRESS = .0000E+00Y + .3000E+02 + (.0000E+00 + .0000E+00 / Y) * SIGYY
YY-COMPONENT OF FIELD STRESS = .0000E+00Y + .1500E+02
XY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
MAXIMUM VALUE FOR CXX + DXX / Y = .0000E+00
RATIO OF ZZ STRESS TO XX STRESS = .0000E+00

IN THE LIST BELOW, THE VALUE ASSIGNED TO KODE DENOTES BOUNDARY CONDITIONS AS FOLLOWS.
KODE= 1 NORMAL AND SHEAR STRESSES PRESCRIBED
KODE= 2 NORMAL AND SHEAR DISPL. PRESCRIBED
KODE= 3 NORMAL STRESS AND SHEAR DISPL. PRESCRIBED
KODE= 4 NORMAL DISPL. AND SHEAR STRESS PRESCRIBED

ELEMENT	KODE	X(CENTER)	Y(CENTER)	HALF-WIDTH	SIN BETA	COS BETA	B-VALUE (S)	B-VALUE (N)
1	1	.1603	-4.9999	.1604	.0321	.9995	.0000E+00	.0000E+00
2	1	.4803	-4.9793	.1604	.0960	.9954	.0000E+00	.0000E+00
3	1	.7984	-4.9383	.1604	.1596	.9872	.0000E+00	.0000E+00
4	1	1.1131	-4.8770	.1604	.2225	.9749	.0000E+00	.0000E+00
5	1	1.4233	-4.7957	.1604	.2845	.9587	.0000E+00	.0000E+00
6	1	1.7277	-4.6946	.1604	.3454	.9385	.0000E+00	.0000E+00
7	1	2.0249	-4.5743	.1604	.4048	.9144	.0000E+00	.0000E+00
8	1	2.3138	-4.4352	.1604	.4625	.8866	.0000E+00	.0000E+00
9	1	2.5932	-4.2778	.1604	.5184	.8551	.0000E+00	.0000E+00
10	1	2.8620	-4.1029	.1604	.5721	.8202	.0000E+00	.0000E+00
11	1	3.1190	-3.9111	.1604	.6235	.7818	.0000E+00	.0000E+00
12	1	3.3631	-3.7032	.1604	.6723	.7403	.0000E+00	.0000E+00
13	1	3.5935	-3.4801	.1604	.7183	.6957	.0000E+00	.0000E+00
14	1	3.8091	-3.2427	.1604	.7614	.6482	.0000E+00	.0000E+00
15	1	4.0090	-2.9920	.1604	.8014	.5981	.0000E+00	.0000E+00
16	1	4.1925	-2.7290	.1604	.8381	.5455	.0000E+00	.0000E+00
17	1	4.3587	-2.4548	.1604	.8713	.4907	.0000E+00	.0000E+00
18	1	4.5070	-2.1705	.1604	.9010	.4339	.0000E+00	.0000E+00
19	1	4.6368	-1.8772	.1604	.9269	.3753	.0000E+00	.0000E+00
20	1	4.7476	-1.5763	.1604	.9491	.3151	.0000E+00	.0000E+00
21	1	4.8388	-1.2689	.1604	.9673	.2537	.0000E+00	.0000E+00
22	1	4.9102	-.9563	.1604	.9816	.1912	.0000E+00	.0000E+00
23	1	4.9614	-.6397	.1604	.9918	.1279	.0000E+00	.0000E+00
24	1	4.9922	-.3205	.1604	.9979	.0641	.0000E+00	.0000E+00
25	1	5.0024	.0000	.1604	1.0000	.0000	.0000E+00	.0000E+00
26	1	4.9922	.3205	.1604	.9979	-.0641	.0000E+00	.0000E+00
27	1	4.9614	.6397	.1604	.9918	-.1279	.0000E+00	.0000E+00
28	1	4.9102	.9563	.1604	.9816	-.1912	.0000E+00	.0000E+00
29	1	4.8388	1.2689	.1604	.9673	-.2537	.0000E+00	.0000E+00
30	1	4.7476	1.5763	.1604	.9491	-.3151	.0000E+00	.0000E+00
31	1	4.6368	1.8772	.1604	.9269	-.3753	.0000E+00	.0000E+00
32	1	4.5070	2.1705	.1604	.9010	-.4339	.0000E+00	.0000E+00
33	1	4.3587	2.4548	.1604	.8713	-.4907	.0000E+00	.0000E+00
34	1	4.1925	2.7290	.1604	.8381	-.5455	.0000E+00	.0000E+00
35	1	4.0090	2.9920	.1604	.8014	-.5981	.0000E+00	.0000E+00
36	1	3.8091	3.2427	.1604	.7614	-.6482	.0000E+00	.0000E+00
37	1	3.5935	3.4801	.1604	.7183	-.6957	.0000E+00	.0000E+00
38	1	3.3631	3.7032	.1604	.6723	-.7403	.0000E+00	.0000E+00
39	1	3.1190	3.9111	.1604	.6235	-.7818	.0000E+00	.0000E+00
40	1	2.8620	4.1029	.1604	.5721	-.8202	.0000E+00	.0000E+00
41	1	2.5932	4.2778	.1604	.5184	-.8551	.0000E+00	.0000E+00
42	1	2.3138	4.4352	.1604	.4625	-.8866	.0000E+00	.0000E+00
43	1	2.0249	4.5743	.1604	.4048	-.9144	.0000E+00	.0000E+00
44	1	1.7277	4.6946	.1604	.3454	-.9385	.0000E+00	.0000E+00
45	1	1.4233	4.7957	.1604	.2845	-.9587	.0000E+00	.0000E+00
46	1	1.1131	4.8770	.1604	.2225	-.9749	.0000E+00	.0000E+00
47	1	.7984	4.9383	.1604	.1596	-.9872	.0000E+00	.0000E+00
48	1	.4803	4.9793	.1604	.0960	-.9954	.0000E+00	.0000E+00
49	1	.1603	4.9999	.1604	.0321	-.9995	.0000E+00	.0000E+00

LINES DEFINING STRESS POINTS

XBEG	YBEG	XEND	YEND	NUMPB
5.0000	.0000	10.2000	.0000	14

TIME REQUIRED TO COMPUTE INFLUENCE COEFFICIENTS= 33.40 SECONDS.

* *

OUTPUT FOR TIME= .0000E+00

PRE-EXISTING STRESS AT EACH ELEMENT

ELEMENT	TEMP	SIGMAXX	SIGMAYY	SIGMAXY	SIGMAZZ	NORM-STR	SHEAR-STR	NORM-DIS	SHEAR-DIS

1	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1502E+02	-.4805E+00	.0000E+00	.0000E+00
2	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1514E+02	-.1434E+01	.0000E+00	.0000E+00
3	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1538E+02	-.2363E+01	.0000E+00	.0000E+00
4	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1574E+02	-.3254E+01	.0000E+00	.0000E+00
5	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1621E+02	-.4092E+01	.0000E+00	.0000E+00
6	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1679E+02	-.4862E+01	.0000E+00	.0000E+00
7	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1746E+02	-.5552E+01	.0000E+00	.0000E+00
8	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1821E+02	-.6151E+01	.0000E+00	.0000E+00
9	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1903E+02	-.6649E+01	.0000E+00	.0000E+00
10	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1991E+02	-.7039E+01	.0000E+00	.0000E+00
11	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2083E+02	-.7312E+01	.0000E+00	.0000E+00
12	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2178E+02	-.7465E+01	.0000E+00	.0000E+00
13	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2274E+02	-.7496E+01	.0000E+00	.0000E+00
14	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2370E+02	-.7404E+01	.0000E+00	.0000E+00
15	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2463E+02	-.7190E+01	.0000E+00	.0000E+00
16	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2554E+02	-.6858E+01	.0000E+00	.0000E+00
17	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2639E+02	-.6414E+01	.0000E+00	.0000E+00
18	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2718E+02	-.5864E+01	.0000E+00	.0000E+00
19	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2789E+02	-.5218E+01	.0000E+00	.0000E+00
20	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2851E+02	-.4486E+01	.0000E+00	.0000E+00
21	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2903E+02	-.3680E+01	.0000E+00	.0000E+00
22	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2945E+02	-.2815E+01	.0000E+00	.0000E+00
23	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2975E+02	-.1902E+01	.0000E+00	.0000E+00
24	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2994E+02	-.9591E+00	.0000E+00	.0000E+00
25	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.3000E+02	-.4255E-05	.0000E+00	.0000E+00
26	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2994E+02	.9591E+00	.0000E+00	.0000E+00
27	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2975E+02	.1902E+01	.0000E+00	.0000E+00
28	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2945E+02	.2815E+01	.0000E+00	.0000E+00
29	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2903E+02	.3680E+01	.0000E+00	.0000E+00
30	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2851E+02	.4486E+01	.0000E+00	.0000E+00
31	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2789E+02	.5218E+01	.0000E+00	.0000E+00
32	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2718E+02	.5864E+01	.0000E+00	.0000E+00
33	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2639E+02	.6414E+01	.0000E+00	.0000E+00
34	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2554E+02	.6858E+01	.0000E+00	.0000E+00
35	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2463E+02	.7190E+01	.0000E+00	.0000E+00
36	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2370E+02	.7404E+01	.0000E+00	.0000E+00
37	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2274E+02	.7496E+01	.0000E+00	.0000E+00
38	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2178E+02	.7465E+01	.0000E+00	.0000E+00
39	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.2083E+02	.7312E+01	.0000E+00	.0000E+00
40	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1991E+02	.7039E+01	.0000E+00	.0000E+00
41	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1903E+02	.6650E+01	.0000E+00	.0000E+00
42	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1821E+02	.6151E+01	.0000E+00	.0000E+00
43	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1746E+02	.5552E+01	.0000E+00	.0000E+00
44	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1679E+02	.4862E+01	.0000E+00	.0000E+00
45	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1621E+02	.4092E+01	.0000E+00	.0000E+00
46	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1574E+02	.3254E+01	.0000E+00	.0000E+00
47	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1538E+02	.2363E+01	.0000E+00	.0000E+00
48	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1514E+02	.1434E+01	.0000E+00	.0000E+00
49	.0000E+00	.3000E+02	.1500E+02	.0000E+00	.0000E+00	.1502E+02	.4805E+00	.0000E+00	.0000E+00

TIME REQUIRED TO COMPUTE PRE-EXISTING STRESSES = .82 SECONDS.

TIME REQUIRED TO SOLVE EQUATIONS= 31.03 SECONDS.

BOUNDARY STRESSES AND DISPLACEMENTS AT TIME = .000E+00

ELM	X-COORD	Y-COORD	UX	UY	US	UN		
	SIGXX	SIGYY	SIGXY	SIGZZ	SIGMA-S	SIGMA-N	SIGMA-T	TEMP
1	.1603E+00	-.5000E+01	.1274E-03	-.7961E-03	.1018E-03	-.7998E-03		
	.7486E+02	.7698E-01	.2401E+01	.7485E+01	.5888E-06	-.2849E-05	.7494E+02	.0000E+00
2	.4803E+00	-.4979E+01	.3818E-03	-.7927E-03	.3039E-03	-.8257E-03		
	.7376E+02	.6864E+00	.7116E+01	.7362E+01	-.2832E-06	.3028E-06	.7445E+02	.0000E+00
3	.7984E+00	-.4938E+01	.6345E-03	-.7859E-03	.5009E-03	-.8771E-03		
	.7160E+02	.1871E+01	.1158E+02	.7118E+01	-.3797E-05	-.3408E-05	.7347E+02	.0000E+00
4	.1113E+01	-.4877E+01	.8845E-03	-.7758E-03	.6897E-03	-.9532E-03		
	.6846E+02	.3567E+01	.1563E+02	.6757E+01	.2328E-05	-.7224E-05	.7203E+02	.0000E+00
5	.1423E+01	-.4796E+01	.1131E-02	-.7624E-03	.8672E-03	-.1053E-02		
	.6446E+02	.5678E+01	.1913E+02	.6286E+01	-.4072E-05	-.3928E-05	.7014E+02	.0000E+00
6	.1728E+01	-.4695E+01	.1372E-02	-.7458E-03	.1030E-02	-.1174E-02		
	.5975E+02	.8092E+01	.2199E+02	.5711E+01	.1274E-06	-.2210E-05	.6784E+02	.0000E+00
7	.2025E+01	-.4574E+01	.1608E-02	-.7260E-03	.1177E-02	-.1315E-02		
	.5449E+02	.1068E+02	.2412E+02	.5042E+01	.4256E-05	-.3095E-05	.6517E+02	.0000E+00
8	.2314E+01	-.4435E+01	.1837E-02	-.7033E-03	.1304E-02	-.1473E-02		
	.4886E+02	.1330E+02	.2549E+02	.4291E+01	.3920E-05	.6074E-05	.6216E+02	.0000E+00
9	.2593E+01	-.4278E+01	.2059E-02	-.6776E-03	.1409E-02	-.1647E-02		
	.4305E+02	.1582E+02	.2610E+02	.3469E+01	-.6923E-06	-.2692E-05	.5888E+02	.0000E+00
10	.2862E+01	-.4103E+01	.2272E-02	-.6492E-03	.1492E-02	-.1832E-02		
	.3724E+02	.1812E+02	.2598E+02	.2590E+01	.1344E-06	.7695E-05	.5536E+02	.0000E+00
11	.3119E+01	-.3911E+01	.2475E-02	-.6181E-03	.1550E-02	-.2026E-02		
	.3159E+02	.2009E+02	.2519E+02	.1669E+01	.1585E-05	.7232E-05	.5168E+02	.0000E+00
12	.3363E+01	-.3703E+01	.2668E-02	-.5845E-03	.1582E-02	-.2227E-02		
	.2624E+02	.2164E+02	.2383E+02	.7202E+00	-.1084E-05	.3297E-05	.4788E+02	.0000E+00
13	.3593E+01	-.3480E+01	.2850E-02	-.5486E-03	.1589E-02	-.2429E-02		
	.2131E+02	.2272E+02	.2201E+02	-.2404E+00	-.2049E-05	-.1179E-04	.4404E+02	.0000E+00
14	.3809E+01	-.3243E+01	.3021E-02	-.5106E-03	.1569E-02	-.2631E-02		
	.1690E+02	.2331E+02	.1985E+02	-.1197E+01	-.1105E-05	.5381E-05	.4021E+02	.0000E+00
15	.4009E+01	-.2992E+01	.3178E-02	-.4705E-03	.1524E-02	-.2829E-02		
	.1304E+02	.2342E+02	.1748E+02	-.2134E+01	-.4460E-05	-.5260E-05	.3646E+02	.0000E+00
16	.4192E+01	-.2729E+01	.3323E-02	-.4287E-03	.1454E-02	-.3019E-02		
	.9778E+01	.2308E+02	.1502E+02	-.3036E+01	.8245E-06	-.2589E-05	.3286E+02	.0000E+00
17	.4359E+01	-.2455E+01	.3454E-02	-.3852E-03	.1359E-02	-.3199E-02		
	.7091E+01	.2236E+02	.1259E+02	-.3868E+01	.4976E-07	-.6891E-06	.2945E+02	.0000E+00
18	.4507E+01	-.2170E+01	.3571E-02	-.3402E-03	.1243E-02	-.3365E-02		

	.4950E+01	.2135E+02	.1028E+02	-.4676E+01	.1019E-05	.4974E-05	.2630E+02	.0000E+00
19	.4637E+01	-.1877E+01	.3673E-02	-.2940E-03	.1106E-02	-.3515E-02		
	.3302E+01	.2015E+02	.8157E+01	-.5388E+01	-.1950E-05	-.6316E-05	.2345E+02	.0000E+00
20	.4748E+01	-.1576E+01	.3760E-02	-.2467E-03	.9508E-03	-.3646E-02		
	.2081E+01	.1888E+02	.6268E+01	-.6011E+01	.4888E-05	-.2530E-05	.2096E+02	.0000E+00
21	.4839E+01	-.1269E+01	.3832E-02	-.1984E-03	.7801E-03	-.3757E-02		
	.1214E+01	.1765E+02	.4628E+01	-.6535E+01	-.1407E-05	.5805E-05	.1886E+02	.0000E+00
22	.4910E+01	-.9563E+00	.3888E-02	-.1494E-03	.5965E-03	-.3845E-02		
	.6282E+00	.1656E+02	.3226E+01	-.6952E+01	.3363E-06	-.8016E-05	.1719E+02	.0000E+00
23	.4961E+01	-.6397E+00	.3928E-02	-.9993E-04	.4032E-03	-.3909E-02		
	.2613E+00	.1572E+02	.2027E+01	-.7255E+01	-.1214E-05	.4959E-05	.1598E+02	.0000E+00
24	.4992E+01	-.3205E+00	.3952E-02	-.5006E-04	.2033E-03	-.3948E-02		
	.6260E-01	.1518E+02	.9748E+00	-.7438E+01	.3140E-07	.1756E-04	.1525E+02	.0000E+00
25	.5002E+01	.1118E-06	.3961E-02	.2084E-09	.1332E-08	-.3961E-02		
	.7033E-05	.1500E+02	.4784E-05	-.7500E+01	-.5282E-06	.7033E-05	.1500E+02	.0000E+00
26	.4992E+01	.3205E+00	.3952E-02	.5006E-04	-.2033E-03	-.3948E-02		
	.6260E-01	.1518E+02	-.9748E+00	-.7438E+01	.7252E-06	.1806E-04	.1525E+02	.0000E+00
27	.4961E+01	.6397E+00	.3928E-02	.9993E-04	-.4032E-03	-.3909E-02		
	.2613E+00	.1572E+02	-.2027E+01	-.7255E+01	.1063E-05	.7925E-05	.1598E+02	.0000E+00
28	.4910E+01	.9563E+00	.3888E-02	.1494E-03	-.5965E-03	-.3845E-02		
	.6282E+00	.1656E+02	-.3226E+01	-.6952E+01	-.1985E-05	-.1373E-04	.1719E+02	.0000E+00
29	.4839E+01	.1269E+01	.3832E-02	.1984E-03	-.7801E-03	-.3757E-02		
	.1213E+01	.1765E+02	-.4628E+01	-.6535E+01	.6539E-06	-.1556E-04	.1886E+02	.0000E+00
30	.4748E+01	.1576E+01	.3760E-02	.2467E-03	-.9508E-03	-.3646E-02		
	.2081E+01	.1888E+02	-.6268E+01	-.6011E+01	-.1520E-05	-.8682E-05	.2096E+02	.0000E+00
31	.4637E+01	.1877E+01	.3673E-02	.2940E-03	-.1106E-02	-.3515E-02		
	.3302E+01	.2015E+02	-.8157E+01	-.5388E+01	.1345E-05	.1323E-05	.2345E+02	.0000E+00
32	.4507E+01	.2170E+01	.3571E-02	.3402E-03	-.1243E-02	-.3365E-02		
	.4950E+01	.2135E+02	-.1028E+02	-.4676E+01	.5232E-09	-.4593E-05	.2630E+02	.0000E+00
33	.4359E+01	.2455E+01	.3454E-02	.3852E-03	-.1359E-02	-.3199E-02		
	.7091E+01	.2236E+02	-.1259E+02	-.3888E+01	.9292E-06	-.8269E-06	.2945E+02	.0000E+00
34	.4192E+01	.2729E+01	.3323E-02	.4287E-03	-.1454E-02	-.3019E-02		
	.9778E+01	.2308E+02	-.1502E+02	-.3036E+01	.4157E-05	.6445E-06	.3286E+02	.0000E+00
35	.4009E+01	.2992E+01	.3178E-02	.4705E-03	-.1524E-02	-.2829E-02		
	.1304E+02	.2342E+02	-.1748E+02	-.2134E+01	.3316E-05	.1218E-04	.3646E+02	.0000E+00
36	.3809E+01	.3243E+01	.3021E-02	.5106E-03	-.1569E-02	-.2631E-02		
	.1690E+02	.2331E+02	-.1965E+02	-.1197E+01	.1821E-05	-.9424E-05	.4021E+02	.0000E+00
37	.3593E+01	.3480E+01	.2850E-02	.5486E-03	-.1589E-02	-.2429E-02		
	.2131E+02	.2272E+02	-.2201E+02	-.2404E+00	.8533E-06	-.3422E-05	.4404E+02	.0000E+00
38	.3363E+01	.3703E+01	.2668E-02	.5845E-03	-.1582E-02	-.2227E-02		
	.2624E+02	.2164E+02	-.2383E+02	.7202E+00	.1364E-05	.9271E-06	.4788E+02	.0000E+00
39	.3119E+01	.3911E+01	.2475E-02	.6181E-03	-.1550E-02	-.2026E-02		
	.3159E+02	.2009E+02	-.2519E+02	.1669E+01	.1705E-05	.6356E-06	.5168E+02	.0000E+00
40	.2862E+01	.4103E+01	.2272E-02	.6492E-03	-.1492E-02	-.1832E-02		
	.3724E+02	.1812E+02	-.2598E+02	.2590E+01	.2621E-05	.9513E-05	.5536E+02	.0000E+00
41	.2593E+01	.4278E+01	.2059E-02	.6776E-03	-.1409E-02	-.1647E-02		
	.4305E+02	.1582E+02	-.2610E+02	.3469E+01	.1429E-05	.6065E-06	.5888E+02	.0000E+00
42	.2314E+01	.4435E+01	.1837E-02	.7033E-03	-.1304E-02	-.1473E-02		
	.4886E+02	.1330E+02	-.2549E+02	.4291E+01	-.6989E-05	.2869E-05	.6216E+02	.0000E+00
43	.2025E+01	.4574E+01	.1608E-02	.7260E-03	-.1177E-02	-.1315E-02		
	.5449E+02	.1068E+02	-.2412E+02	.5042E+01	-.5315E-05	.6927E-05	.6517E+02	.0000E+00
44	.1728E+01	.4695E+01	.1372E-02	.7458E-03	-.1030E-02	-.1174E-02		
	.5975E+02	.8092E+01	-.2199E+02	.5711E+01	.5589E-05	.1199E-04	.6784E+02	.0000E+00
45	.1423E+01	.4796E+01	.1131E-02	.7624E-03	-.8672E-03	-.1053E-02		
	.6446E+02	.5678E+01	-.1913E+02	.6286E+01	.2955E-05	.1422E-04	.7014E+02	.0000E+00
46	.1113E+01	.4877E+01	.8845E-03	.7758E-03	-.6897E-03	-.9532E-03		
	.6846E+02	.3567E+01	-.1563E+02	.6757E+01	.1132E-05	-.1185E-04	.7203E+02	.0000E+00
47	.7984E+00	.4938E+01	.6345E-03	.7859E-03	-.5009E-03	-.8771E-03		
	.7160E+02	.1871E+01	-.1158E+02	.7118E+01	-.2721E-06	-.3421E-06	.7347E+02	.0000E+00
48	.4803E+00	.4979E+01	.3818E-03	.7927E-03	-.3039E-03	-.8257E-03		
	.7376E+02	.6864E+00	-.7116E+01	.7362E+01	.7724E-06	-.1036E-05	.7445E+02	.0000E+00
49	.1603E+00	.5000E+01	.1274E-03	.7961E-03	-.1018E-03	-.7998E-03		
	.7486E+02	.7700E-01	-.2401E+01	.7485E+01	-.2504E-06	.9098E-05	.7494E+02	.0000E+00

TIME REQUIRED TO COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS= 35.38 SECONDS.

INTERIOR STRESSES AND DISPLACEMENTS AT TIME = .000E+00

POINT	X-COORD SIGXX	Y-COORD SIGYY	UX SIGXY	UY SIGZZ	SIG1	SIG2	ALPHA	TEMP
1	.5000E+01	.0000E+00	.3959E-02	-.2168E-09				
	.9112E+02	.4536E+02	-.6745E-05	.2287E+02	.9112E+02	.4536E+02	-.8447E-05	.0000E+00
2	.5400E+01	.0000E+00	.3774E-02	.1326E-08				
	.1187E+01	.1769E+02	-.8931E-06	-.6530E+01	.1769E+02	.1187E+01	-.9000E+02	.0000E+00
3	.5800E+01	.0000E+00	.3592E-02	-.5127E-09				
	.3072E+01	.1928E+02	-.2354E-06	-.5661E+01	.1928E+02	.3072E+01	-.9000E+02	.0000E+00

4	.6200E+01	.0000E+00	.3420E-02	-.4790E-09				
	.5047E+01	.2014E+02	.3010E-06	-.4954E+01	.2014E+02	.5047E+01	.9000E+02	.0000E+00
5	.6600E+01	.0000E+00	.3259E-02	-.2886E-09				
	.6972E+01	.2054E+02	.3629E-05	-.4372E+01	.2054E+02	.6972E+01	.9000E+02	.0000E+00
6	.7000E+01	.0000E+00	.3109E-02	-.4656E-09				
	.8781E+01	.2067E+02	.4692E-05	-.3886E+01	.2067E+02	.8781E+01	.9000E+02	.0000E+00
7	.7400E+01	.0000E+00	.2970E-02	.2190E-08				
	.1045E+02	.2064E+02	-.6486E-06	-.3477E+01	.2064E+02	.1045E+02	-.9000E+02	.0000E+00
8	.7800E+01	.0000E+00	.2841E-02	-.1206E-08				
	.1197E+02	.2051E+02	-.1083E-05	-.3130E+01	.2051E+02	.1197E+02	-.9000E+02	.0000E+00
9	.8200E+01	.0000E+00	.2722E-02	.1990E-08				
	.1335E+02	.2032E+02	.3514E-07	-.2832E+01	.2032E+02	.1335E+02	.9000E+02	.0000E+00
10	.8600E+01	.0000E+00	.2611E-02	.1521E-08				
	.1460E+02	.2010E+02	-.3345E-05	-.2575E+01	.2010E+02	.1460E+02	-.9000E+02	.0000E+00
11	.9000E+01	.0000E+00	.2508E-02	.1910E-08				
	.1573E+02	.1986E+02	-.2777E-05	-.2351E+01	.1986E+02	.1573E+02	-.9000E+02	.0000E+00
12	.9400E+01	.0000E+00	.2412E-02	.1148E-08				
	.1675E+02	.1962E+02	.2331E-05	-.2155E+01	.1962E+02	.1675E+02	.9000E+02	.0000E+00
13	.9800E+01	.0000E+00	.2323E-02	-.9433E-09				
	.1768E+02	.1939E+02	-.3057E-05	-.1983E+01	.1939E+02	.1768E+02	-.9000E+02	.0000E+00
14	.1020E+02	.0000E+00	.2240E-02	.2661E-08				
	.1852E+02	.1916E+02	-.4871E-05	-.1830E+01	.1916E+02	.1852E+02	-.9000E+02	.0000E+00

TIME REQUIRED TO COMPUTE STRESSES AND DISPLACEMENTS AT STRESS POINTS= 10.05 SECONDS.

JOB COMPLETED AT 16:25 HOURS

DATA FOR PLOTTING WILL BE STORED IN FILE NAMED VERIF2

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*****************************************************************************************
*                                                                                       *
*                                    H  E  F  F                                         *
*                                                                                       *
*                              A BOUNDARY ELEMENT CODE                                  *
*                       FOR TWO-DIMENSIONAL THERMOELASTIC ANALYSIS                      *
*                                   OF A ROCK MASS                                      *
*                          SUBJECT TO CONSTANT OR DECAYING                              *
*                                  THERMAL LOADING                                      *
*                       VERSION DATED: DEC. 6 1987 (MS-FORTRAN 77)                      *
*                                                                                       *
*                                     VERSION 4.1                                       *
*                                                                                       *
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UNIFORM HEAT GENERATION IN SEMI-INFINITE MEDIUM OUTPUT CREATED ON 12/ 7/1987

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NUMBER OF BOUNDARY SEGMENTS . . . . . . . =  2
NUMBER OF STRESS LINES  . . . . . . . . . =  1
NUMBER OF HEAT SOURCES  . . . . . . . . . = 60
NUMBER OF EXP. DECAYING COMPONENTS  . . . =  1

THE LINE X=0.0 IS A LINE OF SYMMETRY.
IMAGE BOUNDARY ELEMENTS AND HEAT SOURCES WILL BE GENERATED WITH RESPECT TO THIS LINE.

CONSTANT TEMPERATURE B.C. IMPOSED AT SURFACE

POISSONS RATIO OF BODY . . . . . . . . . =   .25
MODULUS OF ELASTICITY OF BODY . . . . . . =   .6000E+05
SHEAR MODULUS OF BODY . . . . . . . . . . =   .2400E+05

XX-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00 + ( .0000E+00 +  .0000E+00 / Y ) * SIGYY
YY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
XY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
MAXIMUM VALUE FOR CXX + DXX / Y = .0000E+00
RATIO OF ZZ STRESS TO XX STRESS = .0000E+00

TIME FOR OUTPUT
 .100E+03

TEMPERATURE VARIATION WITH DEPTH=     .0000Y +     .0000

THERMAL DIFFUSIVITY . . . . . . . . . . . =   .1262E+02
THERMAL EXPANSION COEFFICIENT . . . . . . =   .6000E-05
STRESS COEFFICIENT  VE  . . . . . . . . . =   .2400E+00

EXPONENTIALLY DECAYING COMPONENTS
  TIME ON      PROPORTION     DECAY CONST.
     .00      .10000E+01      .00000E+00

SOURCE DATA
  X-COORD    Y-COORD  STRENGTH   TIME ON
    2.500   -100.000  3143.000      .000
    7.500   -100.000  3143.000      .000
   12.500   -100.000  3143.000      .000
   17.500   -100.000  3143.000      .000
   22.500   -100.000  3143.000      .000
   27.500   -100.000  3143.000      .000
   32.500   -100.000  3143.000      .000
   37.500   -100.000  3143.000      .000
   42.500   -100.000  3143.000      .000
   47.500   -100.000  3143.000      .000
   52.500   -100.000  3143.000      .000
   57.500   -100.000  3143.000      .000
   62.500   -100.000  3143.000      .000
   67.500   -100.000  3143.000      .000
   72.500   -100.000  3143.000      .000
   77.500   -100.000  3143.000      .000
   82.500   -100.000  3143.000      .000
   87.500   -100.000  3143.000      .000
   92.500   -100.000  3143.000      .000
   97.500   -100.000  3143.000      .000
  102.500   -100.000  3143.000      .000
  107.500   -100.000  3143.000      .000
  112.500   -100.000  3143.000      .000
  117.500   -100.000  3143.000      .000
  122.500   -100.000  3143.000      .000
  127.500   -100.000  3143.000      .000
  132.500   -100.000  3143.000      .000
  137.500   -100.000  3143.000      .000
  142.500   -100.000  3143.000      .000
  147.500   -100.000  3143.000      .000
  152.500   -100.000  3143.000      .000
  157.500   -100.000  3143.000      .000
  162.500   -100.000  3143.000      .000
  167.500   -100.000  3143.000      .000
  172.500   -100.000  3143.000      .000
  177.500   -100.000  3143.000      .000
  182.500   -100.000  3143.000      .000
  187.500   -100.000  3143.000      .000
  192.500   -100.000  3143.000      .000
  197.500   -100.000  3143.000      .000
  202.500   -100.000  3143.000      .000
  207.500   -100.000  3143.000      .000
  212.500   -100.000  3143.000      .000
  217.500   -100.000  3143.000      .000
  222.500   -100.000  3143.000      .000
  227.500   -100.000  3143.000      .000
  232.500   -100.000  3143.000      .000
  237.500   -100.000  3143.000      .000
  242.500   -100.000  3143.000      .000
  247.500   -100.000  3143.000      .000
  252.500   -100.000  3143.000      .000
  257.500   -100.000  3143.000      .000
  262.500   -100.000  3143.000      .000
  267.500   -100.000  3143.000      .000
  272.500   -100.000  3143.000      .000
  277.500   -100.000  3143.000      .000
```

282.500	-100.000	3143.000	.000
287.500	-100.000	3143.000	.000
292.500	-100.000	3143.000	.000
297.500	-100.000	3143.000	.000

IN THE LIST BELOW, THE VALUE ASSIGNED TO KODE DENOTES BOUNDARY CONDITIONS AS FOLLOWS.
KODE= 1 NORMAL AND SHEAR STRESSES PRESCRIBED
KODE= 2 NORMAL AND SHEAR DISPL. PRESCRIBED
KODE= 3 NORMAL STRESS AND SHEAR DISPL. PRESCRIBED
KODE= 4 NORMAL DISPL. AND SHEAR STRESS PRESCRIBED

ELEMENT	KODE	X(CENTER)	Y(CENTER)	HALF-WIDTH	SIN BETA	COS BETA	B-VALUE (S)	B-VALUE (N)
1	1	4.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
2	1	12.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
3	1	20.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
4	1	28.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
5	1	36.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
6	1	44.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
7	1	52.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
8	1	60.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
9	1	68.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
10	1	76.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
11	1	84.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
12	1	92.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
13	1	100.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
14	1	108.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
15	1	116.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
16	1	124.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
17	1	132.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
18	1	140.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
19	1	148.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
20	1	156.0000	.0000	4.0000	.0000	1.0000	.0000E+00	.0000E+00
21	4	160.0000	-5.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
22	4	160.0000	-15.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
23	4	160.0000	-25.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
24	4	160.0000	-35.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
25	4	160.0000	-45.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
26	4	160.0000	-55.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
27	4	160.0000	-65.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
28	4	160.0000	-75.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
29	4	160.0000	-85.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
30	4	160.0000	-95.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
31	4	160.0000	-105.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
32	4	160.0000	-115.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
33	4	160.0000	-125.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
34	4	160.0000	-135.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00
35	4	160.0000	-145.0000	5.0000	-1.0000	.0000	.0000E+00	.0000E+00

LINES DEFINING STRESS POINTS

XBEG	YBEG	XEND	YEND	NUMPB
5.0000	.0000	5.0000	-100.0000	21

TIME REQUIRED TO COMPUTE INFLUENCE COEFFICIENTS= 15.16 SECONDS.

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OUTPUT FOR TIME= .1000E+03

PRE-EXISTING STRESS AT EACH ELEMENT

ELEMENT	TEMP	SIGMAXX	SIGMAYY	SIGMAXY	SIGMAZZ	NORM-STR	SHEAR-STR	NORM-DIS	SHEAR-DIS
1	.7753E-05	-.7153E-06	.1258E-04	.4611E+00	.5757E-05	.1258E-04	.4611E+00	-.4924E+00	-.1746E-08
2	.1264E-05	-.9939E-05	.5171E-05	.1386E+01	-.7372E-06	.5171E-05	.1386E+01	-.4922E+00	.6752E-08
3	-.5367E-05	.4873E-05	.1445E-05	.2320E+01	-.3525E-06	.1445E-05	.2320E+01	-.4919E+00	.5588E-08
4	.5594E-06	-.7659E-05	.8732E-05	.3267E+01	.4695E-06	.8732E-05	.3267E+01	-.4914E+00	-.1793E-07
5	-.1777E-05	-.1013E-05	-.7093E-05	.4236E+01	-.2666E-05	-.7093E-05	.4236E+01	-.4908E+00	-.3411E-07
6	-.3454E-05	-.2533E-06	.1146E-04	.5231E+01	.1558E-05	.1146E-04	.5231E+01	-.4900E+00	.4179E-07
7	.1032E-04	-.1620E-04	.7138E-05	.6259E+01	.1451E-05	.7138E-05	.6259E+01	-.4891E+00	.7218E-08
8	-.4413E-05	-.4843E-05	-.3025E-05	.7327E+01	-.3556E-05	-.3025E-05	.7327E+01	-.4880E+00	-.3956E-08
9	.4401E-06	.1293E-04	.1329E-04	.8443E+01	.6715E-05	.1329E-04	.8443E+01	-.4866E+00	-.4342E-07
10	-.2253E-05	.1612E-04	.1043E-05	.9615E+01	.3480E-05	.1043E-05	.9615E+01	-.4851E+00	-.1548E-07
11	-.7126E-06	-.2772E-05	.7302E-05	.1085E+02	.8759E-06	.7302E-05	.1085E+02	-.4834E+00	-.5472E-08
12	.3707E-05	.1177E-05	.1265E-04	.1216E+02	.4791E-05	.1265E-04	.1216E+02	-.4815E+00	.2596E-07
13	-.4681E-05	-.1390E-04	-.6124E-05	.1356E+02	-.6692E-05	-.6124E-05	.1356E+02	-.4794E+00	.1618E-07
14	.6401E-05	.1490E-05	.6616E-05	.1505E+02	.4331E-05	.6616E-05	.1505E+02	-.4770E+00	-.1607E-07
15	.1666E-05	.1410E-04	.2593E-05	.1665E+02	.4772E-05	.2593E-05	.1665E+02	-.4743E+00	-.8149E-08
16	-.3648E-05	-.6609E-05	.2317E-05	.1838E+02	-.2386E-05	.2317E-05	.1838E+02	-.4714E+00	.2352E-07
17	-.1352E-05	.5901E-05	.2205E-05	.2024E+02	.1540E-05	.2205E-05	.2024E+02	-.4682E+00	.2247E-07
18	-.4754E-05	-.6020E-05	-.2086E-05	.2226E+02	-.3738E-05	-.2086E-05	.2226E+02	-.4647E+00	-.5821E-08
19	.2072E-05	-.2354E-05	.1666E-04	.2445E+02	.4322E-05	.1666E-04	.2445E+02	-.4608E+00	-.1770E-07
20	.3057E-05	.8911E-05	-.2235E-05	.2683E+02	.2769E-05	-.2235E-05	.2683E+02	-.4565E+00	-.9197E-08
21	.1167E+02	.3984E+01	.1619E+01	.2805E+02	.5602E+01	.3984E+01	-.2805E+02	-.2925E-02	.4540E+00
22	.3719E+02	.1301E+02	.4835E+01	.2770E+02	.1785E+02	.1301E+02	-.2770E+02	-.8740E-02	.4523E+00
23	.6929E+02	.2527E+02	.7986E+01	.2700E+02	.3326E+02	.2527E+02	-.2700E+02	-.1444E-01	.4484E+00
24	.1126E+03	.4302E+02	.1102E+02	.2595E+02	.5404E+02	.4302E+02	-.2595E+02	-.1997E-01	.4414E+00
25	.1720E+03	.6864E+02	.1390E+02	.2456E+02	.8254E+02	.6864E+02	-.2456E+02	-.2524E-01	.4299E+00
26	.2525E+03	.1046E+03	.1657E+02	.2286E+02	.1212E+03	.1046E+03	-.2286E+02	-.3018E-01	.4121E+00
27	.3591E+03	.1534E+03	.1896E+02	.2086E+02	.1723E+03	.1534E+03	-.2086E+02	-.3474E-01	.3854E+00
28	.4964E+03	.2173E+03	.2104E+02	.1861E+02	.2383E+03	.2173E+03	-.1861E+02	-.3886E-01	.3471E+00
29	.6686E+03	.2982E+03	.2274E+02	.1617E+02	.3209E+03	.2982E+03	-.1617E+02	-.4248E-01	.2937E+00
30	.8783E+03	.3977E+03	.2392E+02	.1360E+02	.4216E+03	.3977E+03	-.1360E+02	-.4559E-01	.2216E+00
31	.8783E+03	.3968E+03	.2482E+02	.1099E+02	.4216E+03	.3968E+03	-.1099E+02	-.4815E-01	.1329E+00
32	.6686E+03	.2956E+03	.2538E+02	.8328E+01	.3210E+03	.2956E+03	-.8328E+01	-.5106E-01	.6074E-01
33	.4966E+03	.2129E+03	.2543E+02	.5768E+01	.2384E+03	.2129E+03	-.5768E+01	-.5342E-01	.7642E-02
34	.3594E+03	.1474E+03	.2515E+02	.3369E+01	.1725E+03	.1474E+03	-.3369E+01	-.5525E-01	-.3006E-01
35	.2532E+03	.9694E+02	.2458E+02	.1181E+01	.1215E+03	.9694E+02	-.1181E+01	-.5660E-01	-.5574E-01

TIME REQUIRED TO COMPUTE PRE-EXISTING STRESSES = 54.38 SECONDS.

TIME REQUIRED TO SOLVE EQUATIONS= 11.15 SECONDS.

BOUNDARY STRESSES AND DISPLACEMENTS AT TIME = .100E+03

ELM	X-COORD / SIGXX	Y-COORD / SIGYY	UX / SIGXY	UY / SIGZZ	US / SIGMA-S	UN / SIGMA-N	SIGMA-T	TEMP
1	.4000E+01	.0000E+00	.3653E-04	-.3170E-02	.3653E-04	-.3170E-02		
	.7062E+00	.3576E-06	.4989E-07	.1766E+00	.4989E-07	.3576E-06	.7062E+00	.7753E-05
2	.1200E+02	.0000E+00	.1085E-03	-.3187E-02	.1085E-03	-.3187E-02		

	.6897E+00	-.5364E-06	-.8851E-07	.1724E+00	-.8851E-07	-.5364E-06	.6897E+00	.1264E-05
3	.2000E+02	.0000E+00	.1772E-03	-.3226E-02	.1772E-03	-.3226E-02		
	.6566E+00	.3576E-06	-.5428E-07	.1642E+00	-.5428E-07	.3576E-06	.6566E+00	-.5367E-05
4	.2800E+02	.0000E+00	.2402E-03	-.3278E-02	.2402E-03	-.3278E-02		
	.6069E+00	.5364E-06	.3264E-06	.1517E+00	.3264E-06	.5364E-06	.6069E+00	.5594E-06
5	.3600E+02	.0000E+00	.2955E-03	-.3350E-02	.2955E-03	-.3350E-02		
	.5404E+00	-.1669E-05	.9064E-06	.1351E+00	.9064E-06	-.1669E-05	.5404E+00	-.1777E-05
6	.4400E+02	.0000E+00	.3407E-03	-.3433E-02	.3407E-03	-.3433E-02		
	.4571E+00	-.2384E-06	.2191E-06	.1143E+00	.2191E-06	-.2384E-06	.4571E+00	-.3454E-05
7	.5200E+02	.0000E+00	.3734E-03	-.3526E-02	.3734E-03	-.3526E-02		
	.3574E+00	-.2384E-06	-.1063E-05	.6935E-01	-.1063E-05	-.2384E-06	.3574E+00	.1032E-04
8	.6000E+02	.0000E+00	.3916E-03	-.3630E-02	.3916E-03	-.3630E-02		
	.2417E+00	-.4172E-06	-.5402E-07	.6043E-01	-.5402E-07	-.4172E-06	.2417E+00	-.4413E-05
9	.6800E+02	.0000E+00	.3929E-03	-.3733E-02	.3929E-03	-.3733E-02		
	.1112E+00	-.3576E-06	-.4812E-07	.2781E-01	-.4812E-07	-.3576E-06	.1112E+00	.4401E-06
10	.7600E+02	.0000E+00	.3755E-03	-.3838E-02	.3755E-03	-.3836E-02		
	-.3256E-01	-.2742E-05	.3536E-07	-.8142E-02	.3536E-07	-.2742E-05	-.3256E-01	-.2253E-05
11	.8400E+02	.0000E+00	.3376E-03	-.3933E-02	.3376E-03	-.3933E-02		
	-.1875E+00	.1192E-06	-.1101E-05	-.4688E-01	-.1101E-05	.1192E-06	-.1875E+00	-.7126E-06
12	.9200E+02	.0000E+00	.2774E-03	-.4012E-02	.2774E-03	-.4012E-02		
	-.3511E+00	-.5960E-06	.1427E-06	-.8777E-01	.1427E-06	-.5960E-06	-.3511E+00	.3707E-05
13	.1000E+03	.0000E+00	.1938E-03	-.4071E-02	.1938E-03	-.4071E-02		
	-.5207E+00	-.8345E-06	.1553E-05	-.1302E+00	.1553E-05	-.8345E-06	-.5207E+00	-.4681E-05
14	.1080E+03	.0000E+00	.8567E-04	-.4092E-02	.8567E-04	-.4092E-02		
	-.6947E+00	.1252E-05	-.2615E-05	-.1737E+00	-.2615E-05	.1252E-05	-.6947E+00	.6401E-05
15	.1160E+03	.0000E+00	-.4797E-04	-.4071E-02	-.4797E-04	-.4071E-02		
	-.8740E+00	-.4232E-05	-.3770E-05	-.2185E+00	-.3770E-05	-.4232E-05	-.8740E+00	.1666E-05
16	.1240E+03	.0000E+00	-.2089E-03	-.3982E-02	-.2089E-03	-.3982E-02		
	-.1067E+01	.1311E-05	.3012E-05	-.2668E+00	.3012E-05	.1311E-05	-.1067E+01	-.3648E-05
17	.1320E+03	.0000E+00	-.4018E-03	-.3798E-02	-.4018E-03	-.3798E-02		
	-.1304E+01	.4172E-05	-.1812E-05	-.3259E+00	-.1812E-05	.4172E-05	-.1304E+01	-.1352E-05
18	.1400E+03	.0000E+00	-.6401E-03	-.3468E-02	-.6401E-03	-.3468E-02		
	-.1684E+01	-.7749E-06	.2662E-05	-.4210E+00	.2662E-05	-.7749E-06	-.1684E+01	-.4754E-05
19	.1480E+03	.0000E+00	-.9711E-03	-.2827E-02	-.9711E-03	-.2827E-02		
	-.2564E+01	-.2086E-05	.3322E-05	-.6411E+00	.3322E-05	-.2086E-05	-.2564E+01	.2072E-05
20	.1560E+03	.0000E+00	-.1489E-02	-.9656E-03	-.1489E-02	-.9656E-03		
	.1036E+00	.6586E-05	-.1145E-05	.2591E-01	-.1145E-05	.6586E-05	.1036E+00	.3057E-05
21	.1600E+03	-.5000E+01	-.4410E-08	.1954E-03	-.1954E-03	-.4410E-08		
	.7282E+01	.2657E+02	.2396E-05	.1267E+02	-.2396E-05	.7282E+01	.2657E+02	.1167E+02
22	.1600E+03	-.1500E+02	-.2494E-08	.5468E-03	-.5468E-03	-.2494E-08		
	.1653E+02	.8600E+01	-.1086E-05	.1967E+02	.1086E-05	.1653E+02	.8600E+01	.3719E+02
23	.1600E+03	-.2500E+02	-.3507E-08	.4914E-02	-.4914E-02	-.3507E-08		
	.3248E+02	.4910E+01	.1816E-05	.3429E+02	-.1816E-05	.3248E+02	.4910E+01	.6929E+02
24	.1600E+03	-.3500E+02	-.1722E-09	.1332E-01	-.1332E-01	-.1722E-09		
	.5344E+02	.3588E+01	-.3600E-06	.5479E+02	.3600E-06	.5344E+02	.3588E+01	.1126E+03
25	.1600E+03	-.4500E+02	.6049E-08	.2696E-01	-.2696E-01	.6049E-08		
	.8210E+02	.2979E+01	.1137E-05	.8317E+02	-.1137E-05	.8210E+02	.2979E+01	.1720E+03
26	.1600E+03	-.5500E+02	.8130E-08	.4765E-01	-.4765E-01	.8130E-08		
	.1209E+03	.2694E+01	.2888E-05	.1218E+03	-.2888E-05	.1209E+03	.2694E+01	.2525E+03
27	.1600E+03	-.6500E+02	-.5107E-08	.7770E-01	-.7770E-01	-.5107E-08		
	.1722E+03	.2568E+01	.1152E-04	.1729E+03	-.1152E-04	.1722E+03	.2568E+01	.3591E+03
28	.1600E+03	-.7500E+02	-.1751E-07	.1199E+00	-.1199E+00	-.1751E-07		
	.2383E+03	.2524E+01	-.3777E-05	.2389E+03	.3777E-05	.2383E+03	.2524E+01	.4964E+03
29	.1600E+03	-.8500E+02	-.2548E-08	.1776E+00	-.1776E+00	-.2548E-08		
	.3210E+03	.2504E+01	.2065E-05	.3216E+03	-.2065E-05	.3210E+03	.2504E+01	.6686E+03
30	.1600E+03	-.9500E+02	-.2784E-08	.2544E+00	-.2544E+00	-.2784E-08		
	.4220E+03	.2230E+01	.9937E-06	.4223E+03	-.9937E-06	.4220E+03	.2230E+01	.8783E+03
31	.1600E+03	-.1050E+03	.1341E-07	.3479E+00	-.3479E+00	.1341E-07		
	.4205E+03	.1737E+01	-.5045E-06	.4218E+03	.5045E-06	.4205E+03	.1737E+01	.8783E+03
32	.1600E+03	-.1150E+03	-.3050E-08	.4252E+00	-.4252E+00	-.3050E-08		
	.3237E+03	.3908E+01	-.3398E-05	.3226E+03	.3398E-05	.3237E+03	.3908E+01	.6686E+03
33	.1600E+03	-.1250E+03	.4244E-08	.4831E+00	-.4831E+00	.4244E-08		
	.2441E+03	.6041E+01	.2252E-05	.2413E+03	-.2252E-05	.2441E+03	.6041E+01	.4966E+03
34	.1600E+03	-.1350E+03	.5037E-08	.5254E+00	-.5254E+00	.5037E-08		
	.1822E+03	.1002E+02	.1320E-05	.1774E+03	-.1320E-05	.1822E+03	.1002E+02	.3594E+03
35	.1600E+03	-.1450E+03	.1332E-07	.5550E+00	-.5550E+00	.1332E-07		
	.1636E+03	.1603E+02	.2313E-05	.1360E+03	-.2313E-05	.1636E+03	.1603E+02	.2532E+03

TIME REQUIRED TO COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS= 16.86 SECONDS.

INTERIOR STRESSES AND DISPLACEMENTS AT TIME = .100E+03

POINT	X-COORD SIGXX	Y-COORD SIGYY	UX SIGXY	UY SIGZZ	SIG1	SIG2	ALPHA	TEMP
1	.5000E+01	.0000E+00	.4749E-04	-.3172E-02				
	.6928E+00	.5754E-02	.3864E-01	.1746E+00	.6950E+00	.3588E-02	.3209E+01	-.6319E-05

2	.5000E+01	-.5000E+01	.3927E-04	-.2868E-02	.6113E+01	.1955E-01	-.1005E+00	.1168E+02
	.6113E+01	.1957E-01	-.1069E-01	.5739E+01				
3	.5000E+01	-.1000E+02	.3408E-04	-.1969E-02	.1191E+02	.4016E-02	-.5764E-01	.2391E+02
	.1191E+02	.4033E-02	-.1406E-01	.1159E+02				
4	.5000E+01	-.1500E+02	.2980E-04	-.4353E-03	.1824E+02	-.1264E-01	-.5750E-01	.3722E+02
	.1824E+02	-.1263E-01	-.1832E-01	.1796E+02				
5	.5000E+01	-.2000E+02	.2620E-04	.1799E-02	.2537E+02	-.3295E-01	-.4909E-01	.5218E+02
	.2537E+02	-.3293E-01	-.2176E-01	.2512E+02				
6	.5000E+01	-.2500E+02	.2306E-04	.4840E-02	.3357E+02	-.5622E-01	-.4128E-01	.6935E+02
	.3357E+02	-.5620E-01	-.2423E-01	.3334E+02				
7	.5000E+01	-.3000E+02	.2037E-04	.8802E-02	.4311E+02	-.8353E-01	-.3417E-01	.8931E+02
	.4311E+02	-.8351E-01	-.2575E-01	.4291E+02				
8	.5000E+01	-.3500E+02	.1788E-04	.1385E-01	.5428E+02	-.1094E+00	-.2781E-01	.1127E+03
	.5428E+02	-.1094E+00	-.2640E-01	.5411E+02				
9	.5000E+01	-.4000E+02	.1538E-04	.2016E-01	.6738E+02	-.1385E+00	-.2224E-01	.1401E+03
	.6738E+02	-.1385E+00	-.2621E-01	.6723E+02				
10	.5000E+01	-.4500E+02	.1280E-04	.2795E-01	.8271E+02	-.1654E+00	-.1741E-01	.1721E+03
	.8271E+02	-.1654E+00	-.2518E-01	.8258E+02				
11	.5000E+01	-.5000E+02	.9970E-05	.3749E-01	.1006E+03	-.1869E+00	-.1330E-01	.2094E+03
	.1006E+03	-.1869E+00	-.2339E-01	.1005E+03				
12	.5000E+01	-.5500E+02	.6782E-05	.4904E-01	.1213E+03	-.2064E+00	-.9812E-02	.2526E+03
	.1213E+03	-.2064E+00	-.2080E-01	.1212E+03				
13	.5000E+01	-.6000E+02	.3029E-05	.6291E-01	.1451E+03	-.2237E+00	-.6887E-02	.3024E+03
	.1451E+03	-.2237E+00	-.1747E-01	.1451E+03				
14	.5000E+01	-.6500E+02	-.1408E-05	.7944E-01	.1723E+03	-.2390E+00	-.4463E-02	.3592E+03
	.1723E+03	-.2390E+00	-.1344E-01	.1724E+03				
15	.5000E+01	-.7000E+02	-.6551E-05	.9900E-01	.2033E+03	-.2492E+00	-.2454E-02	.4238E+03
	.2033E+03	-.2492E+00	-.8715E-02	.2033E+03				
16	.5000E+01	-.7500E+02	-.1270E-04	.1220E+00	.2381E+03	-.2547E+00	-.7911E-03	.4967E+03
	.2381E+03	-.2547E+00	-.3292E-02	.2383E+03				
17	.5000E+01	-.8000E+02	-.1972E-04	.1488E+00	.2772E+03	-.2545E+00	.5699E-03	.5782E+03
	.2772E+03	-.2545E+00	.2759E-02	.2774E+03				
18	.5000E+01	-.8500E+02	-.2789E-04	.1800E+00	.3206E+03	-.2483E+00	.1683E-02	.6688E+03
	.3206E+03	-.2482E+00	.9423E-02	.3209E+03				
19	.5000E+01	-.9000E+02	-.3733E-04	.2159E+00	.3685E+03	-.2355E+00	.2581E-02	.7689E+03
	.3685E+03	-.2355E+00	.1661E-01	.3689E+03				
20	.5000E+01	-.9500E+02	-.4798E-04	.2570E+00	.4211E+03	-.3437E+00	.3305E-02	.8786E+03
	.4211E+03	-.3437E+00	.2431E-01	.4215E+03				
21	.5000E+01	-.1000E+03	-.5995E-04	.3039E+00	.4717E+03	-.6779E+01	.3882E-02	.9707E+03
	.4717E+03	-.6779E+01	.3242E-01	.4657E+03				

TIME REQUIRED TO COMPUTE STRESSES AND DISPLACEMENTS AT STRESS POINTS= 42.18 SECONDS.

JOB COMPLETED AT 5:41 HOURS

DATA FOR PLOTTING WILL BE STORED IN FILE NAMED VERIF4

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*****************************************************************************************
*                                                                                       *
*                                    H  E  F  F                                         *
*                                                                                       *
*                              A BOUNDARY ELEMENT CODE                                  *
*                       FOR TWO-DIMENSIONAL THERMOELASTIC ANALYSIS                      *
*                                   OF A ROCK MASS                                      *
*                            SUBJECT TO CONSTANT OR DECAYING                            *
*                                  THERMAL LOADING                                      *
*                       VERSION DATED: DEC. 6 1987 (MS-FORTRAN 77)                      *
*                                                                                       *
*                                     VERSION 4.1                                       *
*                                                                                       *
*****************************************************************************************

 THERMO-ELASTIC RESPONSE OF A HOLLOW CYLINDER                    OUTPUT CREATED ON        12/ 6/1987


NUMBER OF BOUNDARY SEGMENTS . . . . . . . =  2
NUMBER OF STRESS LINES  . . . . . . . . . =  1
NUMBER OF HEAT SOURCES  . . . . . . . . . =  1
NUMBER OF EXP. DECAYING COMPONENTS  . . . =  1


THE LINE X=0.0 IS A LINE OF SYMMETRY.
IMAGE BOUNDARY ELEMENTS AND HEAT SOURCES WILL BE GENERATED WITH RESPECT TO THIS LINE.

EFFECT OF IMAGE HEAT SOURCES NOT COMPUTED

POISSONS RATIO OF BODY . . . . . . . . . =    .25
MODULUS OF ELASTICITY OF BODY . . . . . . =   .6000E+05
SHEAR MODULUS OF BODY . . . . . . . . . . =   .2400E+05


XX-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00 + ( .0000E+00 +  .0000E+00 / Y ) * SIGYY
YY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
XY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
MAXIMUM VALUE FOR CXX + DXX / Y = .0000E+00
RATIO OF ZZ STRESS TO XX STRESS = .0000E+00

TIME FOR OUTPUT
 .500E+01

TEMPERATURE VARIATION WITH DEPTH=     .0000Y +     .0000

THERMAL DIFFUSIVITY . . . . . . . . . . . =   .1262E+02
THERMAL EXPANSION COEFFICIENT . . . . . . =   .6000E-05
STRESS COEFFICIENT  VE  . . . . . . . . . =   .2400E+00

EXPONENTIALLY DECAYING COMPONENTS
  TIME ON      PROPORTION     DECAY CONST.
     .00      .10000E+01      .00000E+00

SOURCE DATA
  X-COORD   Y-COORD  STRENGTH   TIME ON
     .000      .000  1573.160      .000

IN THE LIST BELOW, THE VALUE ASSIGNED TO KODE DENOTES BOUNDARY CONDITIONS AS FOLLOWS.
  KODE= 1 NORMAL AND SHEAR STRESSES PRESCRIBED
  KODE= 2 NORMAL AND SHEAR DISPL. PRESCRIBED
  KODE= 3 NORMAL STRESS AND SHEAR DISPL. PRESCRIBED
  KODE= 4 NORMAL DISPL. AND SHEAR STRESS PRESCRIBED
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ELEMENT	KODE	X(CENTER)	Y(CENTER)	HALF-WIDTH	SIN BETA	COS BETA	B-VALUE (S)	B-VALUE (N)
1	1	.2162	-3.9883	.2166	.0541	.9985	.0000E+00	.0000E+00
2	1	.6462	-3.9415	.2166	.1618	.9868	.0000E+00	.0000E+00
3	1	1.0685	-3.8485	.2166	.2675	.9635	.0000E+00	.0000E+00
4	1	1.4784	-3.7105	.2166	.3701	.9290	.0000E+00	.0000E+00
5	1	1.8709	-3.5289	.2166	.4684	.8835	.0000E+00	.0000E+00
6	1	2.2415	-3.3059	.2166	.5612	.8277	.0000E+00	.0000E+00
7	1	2.5857	-3.0442	.2166	.6474	.7622	.0000E+00	.0000E+00
8	1	2.8997	-2.7468	.2166	.7260	.6877	.0000E+00	.0000E+00
9	1	3.1797	-2.4171	.2166	.7961	.6052	.0000E+00	.0000E+00
10	1	3.4224	-2.0592	.2166	.8569	.5156	.0000E+00	.0000E+00
11	1	3.6250	-1.6771	.2166	.9076	.4199	.0000E+00	.0000E+00
12	1	3.7851	-1.2753	.2166	.9477	.3193	.0000E+00	.0000E+00
13	1	3.9008	-.8586	.2166	.9766	.2150	.0000E+00	.0000E+00
14	1	3.9707	-.4318	.2166	.9941	.1081	.0000E+00	.0000E+00
15	1	3.9941	.0000	.2166	1.0000	.0000	.0000E+00	.0000E+00
16	1	3.9707	.4318	.2166	.9941	-.1081	.0000E+00	.0000E+00
17	1	3.9008	.8586	.2166	.9766	-.2150	.0000E+00	.0000E+00
18	1	3.7851	1.2753	.2166	.9477	-.3193	.0000E+00	.0000E+00
19	1	3.6250	1.6771	.2166	.9076	-.4199	.0000E+00	.0000E+00
20	1	3.4224	2.0592	.2166	.8569	-.5156	.0000E+00	.0000E+00
21	1	3.1797	2.4171	.2166	.7961	-.6052	.0000E+00	.0000E+00
22	1	2.8997	2.7468	.2166	.7260	-.6877	.0000E+00	.0000E+00
23	1	2.5857	3.0442	.2166	.6474	-.7622	.0000E+00	.0000E+00
24	1	2.2415	3.3059	.2166	.5612	-.8277	.0000E+00	.0000E+00
25	1	1.8709	3.5289	.2166	.4684	-.8835	.0000E+00	.0000E+00
26	1	1.4784	3.7105	.2166	.3701	-.9290	.0000E+00	.0000E+00
27	1	1.0685	3.8485	.2166	.2675	-.9635	.0000E+00	.0000E+00
28	1	.6462	3.9415	.2166	.1618	-.9868	.0000E+00	.0000E+00
29	1	.2162	3.9883	.2166	.0541	-.9985	.0000E+00	.0000E+00
30	1	.3244	5.9824	.3248	-.0541	.9985	.0000E+00	.0000E+00
31	1	.9693	5.9123	.3248	-.1618	.9868	.0000E+00	.0000E+00
32	1	1.6028	5.7728	.3248	-.2675	.9635	.0000E+00	.0000E+00
33	1	2.2176	5.5657	.3248	-.3701	.9290	.0000E+00	.0000E+00
34	1	2.8063	5.2933	.3248	-.4684	.8835	.0000E+00	.0000E+00
35	1	3.3622	4.9589	.3248	-.5612	.8277	.0000E+00	.0000E+00
36	1	3.8786	4.5663	.3248	-.6474	.7622	.0000E+00	.0000E+00
37	1	4.3496	4.1201	.3248	-.7260	.6877	.0000E+00	.0000E+00
38	1	4.7696	3.6257	.3248	-.7961	.6052	.0000E+00	.0000E+00
39	1	5.1336	3.0888	.3248	-.8569	.5156	.0000E+00	.0000E+00
40	1	5.4375	2.5156	.3248	-.9076	.4199	.0000E+00	.0000E+00
41	1	5.6776	1.9130	.3248	-.9477	.3193	.0000E+00	.0000E+00
42	1	5.8511	1.2879	.3248	-.9766	.2150	.0000E+00	.0000E+00
43	1	5.9561	.6478	.3248	-.9941	.1081	.0000E+00	.0000E+00
44	1	5.9912	.0000	.3248	-1.0000	.0000	.0000E+00	.0000E+00
45	1	5.9561	-.6478	.3248	-.9941	-.1081	.0000E+00	.0000E+00
46	1	5.8511	-1.2879	.3248	-.9766	-.2150	.0000E+00	.0000E+00
47	1	5.6776	-1.9130	.3248	-.9477	-.3193	.0000E+00	.0000E+00

48	1	5.4375	-2.5156	.3248	-.9076	-.4199	.0000E+00	.0000E+00
49	1	5.1336	-3.0888	.3248	-.8569	-.5156	.0000E+00	.0000E+00
50	1	4.7696	-3.6257	.3248	-.7961	-.6052	.0000E+00	.0000E+00
51	1	4.3496	-4.1201	.3248	-.7260	-.6877	.0000E+00	.0000E+00
52	1	3.8766	-4.5663	.3248	-.6474	-.7622	.0000E+00	.0000E+00
53	1	3.3622	-4.9589	.3248	-.5612	-.8277	.0000E+00	.0000E+00
54	1	2.8063	-5.2933	.3248	-.4684	-.8835	.0000E+00	.0000E+00
55	1	2.2176	-5.5657	.3248	-.3701	-.9290	.0000E+00	.0000E+00
56	1	1.6028	-5.7728	.3248	-.2675	-.9635	.0000E+00	.0000E+00
57	1	.9693	-5.9123	.3248	-.1618	-.9868	.0000E+00	.0000E+00
58	1	.3244	-5.9824	.3248	-.0541	-.9985	.0000E+00	.0000E+00

LINES DEFINING STRESS POINTS

XBEG	YBEG	XEND	YEND	NUMPB
4.0000	.0000	6.0000	.0000	7

TIME REQUIRED TO COMPUTE INFLUENCE COEFFICIENTS= 46.68 SECONDS.

* *

OUTPUT FOR TIME= .5000E+01

PRE-EXISTING STRESS AT EACH ELEMENT

ELEMENT	TEMP	SIGMAXX	SIGMAYY	SIGMAXY	SIGMAZZ	NORM-STR	SHEAR-STR	NORM-DIS	SHEAR-DIS
1	.4457E+02	.6109E+01	.1528E+02	-.4989E+00	.2139E+02	.1531E+02	.1033E-05	.1274E-02	.1432E-09
2	.4457E+02	.6323E+01	.1507E+02	-.1473E+01	.2139E+02	.1531E+02	-.3183E-06	.1274E-02	-.5730E-10
3	.4457E+02	.6742E+01	.1465E+02	-.2379E+01	.2139E+02	.1531E+02	.1361E-05	.1274E-02	.1732E-09
4	.4457E+02	.7346E+01	.1405E+02	-.3173E+01	.2139E+02	.1531E+02	-.2469E-05	.1274E-02	-.3212E-09
5	.4457E+02	.8107E+01	.1329E+02	-.3819E+01	.2139E+02	.1531E+02	-.1184E-05	.1274E-02	-.1852E-09
6	.4457E+02	.8988E+01	.1240E+02	-.4286E+01	.2139E+02	.1531E+02	.1718E-05	.1274E-02	.2105E-09
7	.4457E+02	.9950E+01	.1144E+02	-.4553E+01	.2139E+02	.1531E+02	-.1798E-05	.1274E-02	-.2353E-09
8	.4457E+02	.1095E+02	.1045E+02	-.4607E+01	.2139E+02	.1531E+02	-.3010E-05	.1274E-02	-.4102E-09
9	.4457E+02	.1193E+02	.9462E+01	-.4446E+01	.2139E+02	.1531E+02	-.1453E-05	.1274E-02	-.2030E-09
10	.4457E+02	.1286E+02	.8535E+01	-.4077E+01	.2139E+02	.1531E+02	.4785E-06	.1274E-02	.1252E-09
11	.4457E+02	.1368E+02	.7709E+01	-.3517E+01	.2139E+02	.1531E+02	-.1935E-05	.1274E-02	-.2719E-09
12	.4457E+02	.1437E+02	.7023E+01	-.2792E+01	.2139E+02	.1531E+02	-.7116E-06	.1274E-02	-.1237E-09
13	.4457E+02	.1488E+02	.6508E+01	-.1937E+01	.2139E+02	.1531E+02	-.1968E-05	.1274E-02	-.2804E-09
14	.4457E+02	.1520E+02	.6190E+01	-.9919E+00	.2139E+02	.1531E+02	.1194E-05	.1274E-02	.1707E-09
15	.4457E+02	.1531E+02	.6082E+01	.2754E-06	.2139E+02	.1531E+02	.1055E-05	.1274E-02	.1457E-09
16	.4457E+02	.1520E+02	.6190E+01	.9919E+00	.2139E+02	.1531E+02	.1365E-05	.1274E-02	.1961E-09
17	.4457E+02	.1488E+02	.6508E+01	.1937E+01	.2139E+02	.1531E+02	.1535E-05	.1274E-02	.2236E-09
18	.4457E+02	.1437E+02	.7023E+01	.2792E+01	.2139E+02	.1531E+02	-.6253E-06	.1274E-02	-.6369E-10
19	.4457E+02	.1368E+02	.7709E+01	.3517E+01	.2139E+02	.1531E+02	.6873E-06	.1274E-02	.1182E-09
20	.4457E+02	.1286E+02	.8535E+01	.4077E+01	.2139E+02	.1531E+02	.1142E-05	.1274E-02	.1376E-09
21	.4457E+02	.1193E+02	.9462E+01	.4446E+01	.2139E+02	.1531E+02	.1786E-05	.1274E-02	.2489E-09
22	.4457E+02	.1095E+02	.1045E+02	.4607E+01	.2139E+02	.1531E+02	-.1001E-06	.1274E-02	-.1924E-10
23	.4457E+02	.9950E+01	.1144E+02	.4553E+01	.2139E+02	.1531E+02	.2573E-05	.1274E-02	.3047E-09
24	.4457E+02	.8988E+01	.1240E+02	.4286E+01	.2139E+02	.1531E+02	.2655E-06	.1274E-02	-.5025E-10
25	.4457E+02	.8107E+01	.1329E+02	.3819E+01	.2139E+02	.1531E+02	.5222E-06	.1274E-02	.3087E-10
26	.4457E+02	.7346E+01	.1405E+02	.3173E+01	.2139E+02	.1531E+02	.2725E-05	.1274E-02	.3555E-09
27	.4457E+02	.6742E+01	.1465E+02	.2379E+01	.2139E+02	.1531E+02	-.1361E-05	.1274E-02	-.1732E-09
28	.4457E+02	.6323E+01	.1507E+02	.1473E+01	.2139E+02	.1531E+02	.3183E-06	.1274E-02	.5730E-10
29	.4457E+02	.6109E+01	.1528E+02	.4989E+00	.2139E+02	.1531E+02	-.2129E-05	.1274E-02	-.2957E-09
30	.2997E+02	.2780E+01	.1160E+02	.4799E+00	.1438E+02	.1163E+02	-.2608E-05	-.1452E-02	.4222E-09
31	.2997E+02	.2986E+01	.1140E+02	.1417E+01	.1438E+02	.1163E+02	.5210E-05	-.1452E-02	-.6441E-09
32	.2997E+02	.3389E+01	.1100E+02	.2288E+01	.1438E+02	.1163E+02	-.1292E-05	-.1452E-02	.2213E-09
33	.2997E+02	.3970E+01	.1041E+02	.3052E+01	.1438E+02	.1163E+02	-.3487E-05	-.1452E-02	.5289E-09
34	.2997E+02	.4702E+01	.9683E+01	.3674E+01	.1438E+02	.1163E+02	-.2664E-05	-.1452E-02	.4601E-09
35	.2997E+02	.5550E+01	.8835E+01	.4123E+01	.1438E+02	.1163E+02	.1465E-05	-.1452E-02	-.2620E-09
36	.2997E+02	.6474E+01	.7910E+01	.4380E+01	.1438E+02	.1163E+02	-.2451E-05	-.1452E-02	.3920E-09
37	.2997E+02	.7433E+01	.6952E+01	.4432E+01	.1438E+02	.1163E+02	.3752E-07	-.1452E-02	.1157E-10
38	.2997E+02	.8380E+01	.6005E+01	.4277E+01	.1438E+02	.1163E+02	.1244E-05	-.1452E-02	-.1381E-09
39	.2997E+02	.9271E+01	.5113E+01	.3921E+01	.1438E+02	.1163E+02	-.1325E-05	-.1452E-02	.2086E-09
40	.2997E+02	.1007E+02	.4319E+01	.3383E+01	.1436E+02	.1163E+02	.1621E-05	-.1452E-02	-.2647E-09
41	.2997E+02	.1073E+02	.3659E+01	.2686E+01	.1438E+02	.1163E+02	.2157E-05	-.1452E-02	-.3510E-09
42	.2997E+02	.1122E+02	.3164E+01	.1864E+01	.1438E+02	.1163E+02	-.8427E-06	-.1452E-02	.1507E-09
43	.2997E+02	.1153E+02	.2858E+01	.9541E+00	.1438E+02	.1163E+02	.2179E-05	-.1452E-02	-.3524E-09
44	.2997E+02	.1163E+02	.2754E+01	-.2649E-06	.1438E+02	.1163E+02	.6136E-06	-.1452E-02	-.1004E-09
45	.2997E+02	.1153E+02	.2858E+01	-.9541E+00	.1438E+02	.1163E+02	.4854E-06	-.1452E-02	-.6771E-10
46	.2997E+02	.1122E+02	.3164E+01	-.1864E+01	.1438E+02	.1163E+02	.1267E-05	-.1452E-02	-.1903E-09
47	.2997E+02	.1073E+02	.3659E+01	-.2686E+01	.1438E+02	.1163E+02	-.2146E-05	-.1452E-02	.3092E-09
48	.2997E+02	.1007E+02	.4319E+01	-.3383E+01	.1438E+02	.1163E+02	.1040E-05	-.1452E-02	-.1386E-09
49	.2997E+02	.9271E+01	.5113E+01	-.3921E+01	.1438E+02	.1163E+02	-.9546E-06	-.1452E-02	.1415E-09
50	.2997E+02	.8380E+01	.6005E+01	-.4277E+01	.1438E+02	.1163E+02	.3050E-05	-.1452E-02	-.5145E-09
51	.2997E+02	.7433E+01	.6952E+01	-.4432E+01	.1438E+02	.1163E+02	-.3281E-05	-.1452E-02	.5967E-09
52	.2997E+02	.6474E+01	.7910E+01	-.4380E+01	.1438E+02	.1163E+02	.2988E-05	-.1452E-02	-.4901E-09
53	.2997E+02	.5550E+01	.8835E+01	-.4123E+01	.1438E+02	.1163E+02	-.1440E-05	-.1452E-02	.2627E-09
54	.2997E+02	.4702E+01	.9683E+01	-.3674E+01	.1438E+02	.1163E+02	-.2657E-05	-.1452E-02	.4807E-09
55	.2997E+02	.3970E+01	.1041E+02	-.3052E+01	.1438E+02	.1163E+02	.3487E-05	-.1452E-02	-.5289E-09
56	.2997E+02	.3389E+01	.1100E+02	-.2288E+01	.1438E+02	.1163E+02	.1292E-05	-.1452E-02	-.2213E-09
57	.2997E+02	.2986E+01	.1140E+02	-.1417E+01	.1438E+02	.1163E+02	-.5210E-05	-.1452E-02	.8441E-09
58	.2997E+02	.2780E+01	.1160E+02	-.4799E+00	.1438E+02	.1163E+02	-.2814E-05	-.1452E-02	.4672E-09

TIME REQUIRED TO COMPUTE PRE-EXISTING STRESSES = 2.26 SECONDS.

TIME REQUIRED TO SOLVE EQUATIONS= 50.75 SECONDS.

BOUNDARY STRESSES AND DISPLACEMENTS AT TIME = .500E+01

ELM	X-COORD SIGXX	Y-COORD SIGYY	UX SIGXY	UY SIGZZ	US SIGMA-S	UN SIGMA-N	SIGMA-T	TEMP
1	.2162E+00	-.3988E+01	-.5581E-04	.1029E-02	-.8546E-09	.1031E-02		
	.4635E+01	.1362E-01	.2513E+00	.1721E+02	.7642E-07	-.4576E-05	.4648E+01	.4457E+02
2	.6462E+00	-.3942E+01	-.1668E-03	.1017E-02	-.2104E-08	.1031E-02		
	.4527E+01	.1217E+00	.7421E+00	.1721E+02	.8781E-06	-.8235E-06	.4648E+01	.4457E+02
3	.1069E+01	-.3849E+01	-.2758E-03	.9932E-03	-.3344E-08	.1031E-02		
	.4316E+01	.3327E+00	.1198E+01	.1721E+02	-.1173E-05	.8738E-07	.4648E+01	.4457E+02
4	.1478E+01	-.3710E+01	-.3815E-03	.9576E-03	-.5604E-08	.1031E-02		
	.4011E+01	.6368E+00	.1598E+01	.1721E+02	-.3058E-06	.5343E-06	.4648E+01	.4457E+02
5	.1871E+01	-.3529E+01	-.4828E-03	.9107E-03	-.6402E-08	.1031E-02		
	.3628E+01	.1020E+01	.1924E+01	.1721E+02	.7069E-06	.1634E-05	.4648E+01	.4457E+02
6	.2241E+01	-.3306E+01	-.5785E-03	.8532E-03	-.7132E-08	.1031E-02		
	.3184E+01	.1464E+01	.2159E+01	.1721E+02	.3526E-06	-.6900E-07	.4648E+01	.4457E+02

7	.2586E+01	-.3044E+01	-.6673E-03	.7856E-03	-.8299E-08	.1031E-02		
	.2700E+01	.1946E+01	.2294E+01	.1721E+02	-.3213E-06	.6737E-06	.4648E+01	.4457E+02
8	.2900E+01	-.2747E+01	-.7484E-03	.7069E-03	-.9985E-08	.1031E-02		
	.2196E+01	.2450E+01	.2321E+01	.1721E+02	-.8850E-06	.7453E-06	.4648E+01	.4457E+02
9	.3180E+01	-.2417E+01	-.8206E-03	.6236E-03	-.1131E-07	.1031E-02		
	.1702E+01	.2946E+01	.2239E+01	.1721E+02	-.1636E-05	.4034E-05	.4648E+01	.4457E+02
10	.3422E+01	-.2059E+01	-.8833E-03	.5314E-03	-.1074E-07	.1031E-02		
	.1235E+01	.3413E+01	.2053E+01	.1721E+02	-.1216E-05	.1729E-05	.4648E+01	.4457E+02
11	.3625E+01	-.1677E+01	-.9355E-03	.4328E-03	-.1230E-07	.1031E-02		
	.8195E+00	.3829E+01	.1771E+01	.1721E+02	.1367E-05	-.3986E-05	.4648E+01	.4457E+02
12	.3785E+01	-.1275E+01	-.9769E-03	.3291E-03	-.1264E-07	.1031E-02		
	.4739E+00	.4174E+01	.1407E+01	.1721E+02	-.1480E-05	.3233E-05	.4648E+01	.4457E+02
13	.3901E+01	-.8586E+00	-.1007E-02	.2216E-03	-.1260E-07	.1031E-02		
	.2148E+00	.4433E+01	.9759E+00	.1721E+02	-.1864E-06	.1467E-05	.4648E+01	.4457E+02
14	.3971E+01	-.4316E+00	-.1025E-02	.1114E-03	-.1229E-07	.1031E-02		
	.5434E-01	.4594E+01	.4996E+00	.1721E+02	-.2927E-06	.8588E-06	.4648E+01	.4457E+02
15	.3994E+01	.1192E-06	-.1031E-02	-.1191E-07	-.1176E-07	.1031E-02		
	.2043E-05	.4648E+01	-.9849E-06	.1721E+02	.3146E-06	.2043E-05	.4648E+01	.4457E+02
16	.3971E+01	.4318E+00	-.1025E-02	-.1115E-03	-.1110E-07	.1031E-02		
	.5434E-01	.4594E+01	-.4996E+00	.1721E+02	-.3074E-06	-.9252E-06	.4648E+01	.4457E+02
17	.3901E+01	.8586E+00	-.1007E-02	-.2216E-03	-.1141E-07	.1031E-02		
	.2148E+00	.4433E+01	-.9759E+00	.1721E+02	-.1330E-06	-.2360E-05	.4648E+01	.4457E+02
18	.3785E+01	.1275E+01	-.9769E-03	-.3292E-03	-.1074E-07	.1031E-02		
	.4739E+00	.4174E+01	-.1407E+01	.1721E+02	-.6040E-06	-.4046E-05	.4648E+01	.4457E+02
19	.3625E+01	.1677E+01	-.9355E-03	-.4328E-03	-.1085E-07	.1031E-02		
	.8195E+00	.3829E+01	-.1771E+01	.1721E+02	-.1626E-06	-.2025E-05	.4648E+01	.4457E+02
20	.3422E+01	.2059E+01	-.8833E-03	-.5315E-03	-.9610E-08	.1031E-02		
	.1235E+01	.3413E+01	-.2053E+01	.1721E+02	-.1059E-05	.2132E-05	.4648E+01	.4457E+02
21	.3180E+01	.2417E+01	-.8206E-03	-.6236E-03	-.9365E-08	.1031E-02		
	.1702E+01	.2946E+01	-.2239E+01	.1721E+02	.1637E-05	.1429E-05	.4648E+01	.4457E+02
22	.2900E+01	.2747E+01	-.7484E-03	-.7069E-03	-.8631E-08	.1031E-02		
	.2196E+01	.2450E+01	-.2321E+01	.1721E+02	.6791E-06	-.9722E-05	.4648E+01	.4457E+02
23	.2586E+01	.3044E+01	-.6673E-03	-.7857E-03	-.7186E-08	.1031E-02		
	.2700E+01	.1946E+01	-.2294E+01	.1721E+02	.8825E-06	.1337E-05	.4648E+01	.4457E+02
24	.2241E+01	.3306E+01	-.5785E-03	-.8532E-03	-.6524E-08	.1031E-02		
	.3184E+01	.1464E+01	-.2159E+01	.1721E+02	.4429E-06	-.2829E-05	.4648E+01	.4457E+02
25	.1871E+01	.3529E+01	-.4826E-03	-.9108E-03	-.5625E-08	.1031E-02		
	.3626E+01	.1020E+01	-.1924E+01	.1721E+02	-.9652E-07	-.5660E-07	.4648E+01	.4457E+02
26	.1476E+01	.3710E+01	-.3815E-03	-.9576E-03	-.3979E-08	.1031E-02		
	.4011E+01	.6366E+00	-.1596E+01	.1721E+02	.8831E-06	-.4454E-05	.4648E+01	.4457E+02
27	.1069E+01	.3849E+01	-.2758E-03	-.9933E-03	-.3396E-08	.1031E-02		
	.4316E+01	.3327E+00	-.1196E+01	.1721E+02	.2238E-05	-.7329E-05	.4648E+01	.4457E+02
28	.6462E+00	.3942E+01	-.1666E-03	-.1017E-02	-.2106E-08	.1031E-02		
	.4527E+01	.1217E+00	-.7421E+00	.1721E+02	.6597E-06	.5026E-05	.4648E+01	.4457E+02
29	.2162E+00	.3966E+01	-.5581E-04	-.1029E-02	-.9729E-09	.1031E-02		
	.4635E+01	.1362E-01	-.2513E+00	.1721E+02	-.6016E-07	-.1670E-05	.4648E+01	.4457E+02
30	.3244E+00	.5982E+01	-.8554E-04	-.1578E-02	.9110E-09	-.1580E-02		
	-.2352E+01	-.6917E-02	.1275E+00	.1020E+02	.9711E-07	-.2285E-05	-.2359E+01	.2997E+02
31	.9693E+00	.5912E+01	-.2556E-03	-.1559E-02	.8167E-09	-.1580E-02		
	-.2297E+01	-.6175E-01	.3766E+00	.1020E+02	.1432E-06	-.6707E-06	-.2359E+01	.2997E+02
32	.1603E+01	.5773E+01	-.4227E-03	-.1522E-02	.3732E-08	-.1580E-02		
	-.2190E+01	-.1688E+00	.6081E+00	.1020E+02	.3612E-07	-.1104E-05	-.2359E+01	.2997E+02
33	.2216E+01	.5566E+01	-.5848E-03	-.1468E-02	.4302E-08	-.1580E-02		
	-.2036E+01	-.3232E+00	.8112E+00	.1020E+02	-.4702E-06	.4367E-05	-.2359E+01	.2997E+02
34	.2806E+01	.5293E+01	-.7401E-03	-.1396E-02	.6152E-08	-.1580E-02		
	-.1842E+01	-.5176E+00	.9763E+00	.1020E+02	.1137E-05	.4570E-05	-.2359E+01	.2997E+02
35	.3362E+01	.4959E+01	-.8866E-03	-.1306E-02	.6082E-08	-.1580E-02		
	-.1616E+01	-.7430E+00	.1096E+01	.1020E+02	.1241E-06	.1435E-05	-.2359E+01	.2997E+02
36	.3879E+01	.4566E+01	-.1023E-02	-.1204E-02	.7950E-08	-.1580E-02		
	-.1370E+01	-.9887E+00	.1164E+01	.1020E+02	-.1817E-05	.3385E-05	-.2359E+01	.2997E+02
37	.4350E+01	.4120E+01	-.1147E-02	-.1087E-02	.8363E-08	-.1580E-02		
	-.1116E+01	-.1243E+01	.1178E+01	.1020E+02	.9262E-06	.1864E-05	-.2359E+01	.2997E+02
38	.4770E+01	.3626E+01	-.1256E-02	-.9561E-03	.9694E-08	-.1580E-02		
	-.8640E+00	-.1495E+01	.1137E+01	.1020E+02	-.3877E-06	-.1311E-05	-.2359E+01	.2997E+02
39	.5134E+01	.3089E+01	-.1354E-02	-.8146E-03	.1137E-07	-.1580E-02		
	-.6270E+00	-.1732E+01	.1042E+01	.1020E+02	.1087E-05	-.4750E-05	-.2359E+01	.2997E+02
40	.5437E+01	.2516E+01	-.1434E-02	-.6634E-03	.1072E-07	-.1580E-02		
	-.4159E+00	-.1943E+01	.8990E+00	.1020E+02	-.3892E-06	.1194E-05	-.2359E+01	.2997E+02
41	.5678E+01	.1913E+01	-.1497E-02	-.5045E-03	.1048E-07	-.1580E-02		
	-.2405E+00	-.2119E+01	.7136E+00	.1020E+02	-.9529E-06	-.1097E-05	-.2359E+01	.2997E+02
42	.5851E+01	.1286E+01	-.1543E-02	-.3397E-03	.1246E-07	-.1580E-02		
	-.1090E+00	-.2250E+01	.4953E+00	.1020E+02	-.1002E-05	.2920E-06	-.2359E+01	.2997E+02
43	.5956E+01	.6478E+00	-.1571E-02	-.1706E-03	.1112E-07	-.1580E-02		
	-.2756E-01	-.2332E+01	.2536E+00	.1020E+02	-.3346E-06	.4236E-07	-.2359E+01	.2997E+02
44	.5991E+01	-.1786E-06	-.1580E-02	-.1195E-07	.1189E-07	-.1580E-02		
	-.1453E-05	-.2359E+01	.3486E-06	.1020E+02	-.2560E-06	-.1453E-05	-.2359E+01	.2997E+02
45	.5956E+01	-.6478E+00	-.1571E-02	.1706E-03	.1226E-07	-.1580E-02		

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      -.2758E-01  -.2332E+01  -.2536E+00   .1020E+02   .6406E-06  -.7430E-06  -.2359E+01   .2997E+02

46    .5851E+01  -.1288E+01  -.1543E-02   .3396E-03   .1197E-07  -.1580E-02
      -.1090E+00  -.2250E+01  -.4953E+00   .1020E+02   .1199E-06   .7869E-06  -.2359E+01   .2997E+02

47    .5678E+01  -.1913E+01  -.1497E-02   .5045E-03   .1174E-07  -.1580E-02
      -.2405E+00  -.2119E+01  -.7138E+00   .1020E+02   .1035E-06  -.2996E-05  -.2359E+01   .2997E+02

48    .5437E+01  -.2516E+01  -.1434E-02   .6634E-03   .1067E-07  -.1580E-02
      -.4159E+00  -.1943E+01  -.8990E+00   .1020E+02  -.1340E-06   .1359E-05  -.2359E+01   .2997E+02

49    .5134E+01  -.3069E+01  -.1354E-02   .8145E-03   .1076E-07  -.1580E-02
      -.6271E+00  -.1732E+01  -.1042E+01   .1020E+02   .9968E-06  -.4075E-05  -.2359E+01   .2997E+02

50    .4770E+01  -.3626E+01  -.1258E-02   .9561E-03   .9889E-08  -.1580E-02
      -.8640E+00  -.1495E+01  -.1137E+01   .1020E+02  -.2132E-06   .3027E-05  -.2359E+01   .2997E+02

51    .4350E+01  -.4120E+01  -.1147E-02   .1067E-02   .1029E-07  -.1580E-02
      -.1116E+01  -.1243E+01  -.1178E+01   .1020E+02   .6881E-07   .1047E-05  -.2359E+01   .2997E+02

52    .3879E+01  -.4566E+01  -.1023E-02   .1204E-02   .8152E-08  -.1580E-02
      -.1370E+01  -.9887E+00  -.1164E+01   .1020E+02  -.1305E-05   .7708E-06  -.2359E+01   .2997E+02

53    .3362E+01  -.4959E+01  -.8866E-03   .1308E-02   .7684E-08  -.1580E-02
      -.1616E+01  -.7430E+00  -.1096E+01   .1020E+02   .6144E-06   .3507E-05  -.2359E+01   .2997E+02

54    .2806E+01  -.5293E+01  -.7401E-03   .1396E-02   .6297E-08  -.1580E-02
      -.1842E+01  -.5176E+00  -.9763E+00   .1020E+02   .6426E-06   .1414E-06  -.2359E+01   .2997E+02

55    .2218E+01  -.5566E+01  -.5846E-03   .1468E-02   .4888E-08  -.1580E-02
      -.2036E+01  -.3232E+00  -.8112E+00   .1020E+02   .5191E-06  -.1147E-05  -.2359E+01   .2997E+02

56    .1603E+01  -.5773E+01  -.4227E-03   .1522E-02   .3385E-08  -.1580E-02
      -.2190E+01  -.1686E+00  -.6081E+00   .1020E+02   .3272E-06   .2519E-06  -.2359E+01   .2997E+02

57    .9693E+00  -.5912E+01  -.2556E-03   .1559E-02   .2956E-08  -.1580E-02
      -.2297E+01  -.6175E-01  -.3766E+00   .1020E+02   .1074E-07  -.6200E-06  -.2359E+01   .2997E+02

58    .3244E+00  -.5982E+01  -.8554E-04   .1578E-02   .1746E-08  -.1580E-02
      -.2352E+01  -.6917E-02  -.1275E+00   .1020E+02  -.6133E-07  -.1961E-05  -.2359E+01   .2997E+02
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TIME REQUIRED TO COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS= 48.94 SECONDS.

INTERIOR STRESSES AND DISPLACEMENTS AT TIME = .500E+01

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POINT X-COORD      Y-COORD      UX           UY
      SIGXX        SIGYY        SIGXY        SIGZZ        SIG1         SIG2         ALPHA        TEMP

 1    .4000E+01    .0000E+00   -.1033E-02   -.1238E-07
      -.3343E-02    .4625E+01   -.5378E-06    .1718E+02    .4625E+01   -.3343E-02   -.9000E+02    .4451E+02

 2    .4333E+01    .0000E+00   -.1147E-02   -.1209E-07
       .1481E+00    .3051E+01    .1295E-05    .1576E+02    .3051E+01    .1481E+00    .9000E+02    .4155E+02

 3    .4667E+01    .0000E+00   -.1250E-02   -.1213E-07
       .3003E+00    .1596E+01    .3153E-06    .1445E+02    .1596E+01    .3003E+00    .9000E+02    .3883E+02

 4    .5000E+01    .0000E+00   -.1344E-02   -.1234E-07
       .3442E+00    .3540E+00    .3448E-05    .1326E+02    .3540E+00    .3442E+00    .8998E+02    .3634E+02

 5    .5333E+01    .0000E+00   -.1430E-02   -.1270E-07
       .3103E+00   -.7180E+00    .3709E-06    .1215E+02    .3103E+00   -.7180E+00    .2066E-04    .3403E+02

 6    .5667E+01    .0000E+00   -.1509E-02   -.1269E-07
       .2159E+00   -.1648E+01   -.1717E-06    .1113E+02    .2159E+00   -.1646E+01   -.5278E-05    .3190E+02

 7    .6000E+01    .0000E+00   -.1580E-02   -.1195E-07
       .1255E+02    .1812E+01   -.2388E-04    .1436E+02    .1255E+02    .1812E+01   -.1274E-03    .2992E+02
```

TIME REQUIRED TO COMPUTE STRESSES AND DISPLACEMENTS AT STRESS POINTS= 6.15 SECONDS.

JOB COMPLETED AT 16:43 HOURS

DATA FOR PLOTTING WILL BE STORED IN FILE NAMED VERIF3

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*****************************************************************************
*                                                                           *
*                                  H  E  F  F                               *
*                                                                           *
*                          A BOUNDARY ELEMENT CODE                          *
*                   FOR TWO-DIMENSIONAL THERMOELASTIC ANALYSIS              *
*                              OF  A ROCK MASS                              *
*                       SUBJECT TO CONSTANT OR DECAYING                     *
*                              THERMAL LOADING                              *
*                   VERSION DATED: DEC. 6 1987 (MS-FORTRAN 77)              *
*                                                                           *
*                                 VERSION 4.1                               *
*                                                                           *
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VERTICAL EMPLACEMENT - OUTPUT AT T=10 YRS. OUTPUT CREATED ON 12/ 7/1987

NUMBER OF BOUNDARY SEGMENTS . . . . = 9
NUMBER OF STRESS LINES . . . . = 0
NUMBER OF HEAT SOURCES . . . . = 22
NUMBER OF EXP. DECAYING COMPONENTS . . . = 4

THE LINE X=0.0 IS A LINE OF SYMMETRY.
IMAGE BOUNDARY ELEMENTS AND HEAT SOURCES WILL BE GENERATED WITH RESPECT TO THIS LINE.

CONSTANT TEMPERATURE B.C. IMPOSED AT SURFACE

POISSONS RATIO OF BODY . . . . . = .20
MODULUS OF ELASTICITY OF BODY . . . . . = .1510E+05
SHEAR MODULUS OF BODY . . . . . = .6292E+04

XX-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00 + (.5500E+00 + .0000E+00 / Y) * SIGYY
YY-COMPONENT OF FIELD STRESS =-.2300E-01Y + .0000E+00
XY-COMPONENT OF FIELD STRESS = .0000E+00Y + .0000E+00
MAXIMUM VALUE FOR CXX + DXX / Y = .5500E+00
RATIO OF ZZ STRESS TO XX STRESS = .1000E+01

TIME FOR OUTPUT
.100E+02

TEMPERATURE VARIATION WITH DEPTH= -.0239Y + 16.9000

THERMAL DIFFUSIVITY . . . . . = .2903E+02
THERMAL EXPANSION COEFFICIENT . . . . . = .1070E-04
STRESS COEFFICIENT VE . . . . . = .1010E+00

PROPERTIES OF HEAT SOURCES - CONSTANT OR DECAYING

TIME ON	PROPORTION	DECAY CONST.
.00	.15602E+00	.13539E-02
.00	.59787E+00	.19142E-01
.00	.15227E+00	.51886E-01
.00	.93840E-01	.43766E+00

SOURCE DATA

X-COORD	Y-COORD	STRENGTH	TIME ON
.000	-305.612	1360.328	.000
.000	-307.335	1360.328	.000
.000	-308.658	1360.328	.000
34.138	-307.335	8281.970	.000
68.276	-307.335	8281.970	.000
102.414	-307.335	8281.970	.000
136.552	-307.335	8281.970	.000
170.690	-307.335	8281.970	.000
204.828	-307.335	8281.970	.000
238.966	-307.335	8281.970	.000
273.104	-307.335	8281.970	.000
307.242	-307.335	8281.970	.000
341.380	-307.335	8281.970	.000
375.518	-307.335	8281.970	.000
409.656	-307.335	8281.970	.000
443.794	-307.335	8281.970	.000
477.932	-307.335	8281.970	.000
512.070	-307.335	8281.970	.000
546.208	-307.335	8281.970	.000
580.346	-307.335	8281.970	.000
614.484	-307.335	8281.970	.000
648.622	-307.335	8281.970	.000

IN THE LIST BELOW, THE VALUE ASSIGNED TO KODE DENOTES BOUNDARY CONDITIONS AS FOLLOWS.
KODE= 1 NORMAL AND SHEAR STRESSES PRESCRIBED
KODE= 2 NORMAL AND SHEAR DISPL. PRESCRIBED
KODE= 3 NORMAL STRESS AND SHEAR DISPL. PRESCRIBED
KODE= 4 NORMAL DISPL. AND SHEAR STRESS PRESCRIBED

ELEMENT	KODE	X(CENTER)	Y(CENTER)	HALF-WIDTH	SIN BETA	COS BETA	B-VALUE (S)	B-VALUE (N)
1	1	.1950	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
2	1	.5850	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
3	1	.9750	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
4	1	1.3650	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
5	1	1.7550	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
6	1	2.1450	-302.0000	.1950	.0000	1.0000	.0000E+00	.0000E+00
7	1	2.3900	-301.9500	.0707	.7071	.7071	.0000E+00	.0000E+00
8	1	2.4400	-301.6866	.2133	1.0000	.0000	.0000E+00	.0000E+00
9	1	2.4400	-301.2600	.2133	1.0000	.0000	.0000E+00	.0000E+00
10	1	2.4400	-300.8333	.2133	1.0000	.0000	.0000E+00	.0000E+00
11	1	2.4400	-300.4067	.2133	1.0000	.0000	.0000E+00	.0000E+00
12	1	2.4400	-299.9800	.2133	1.0000	.0000	.0000E+00	.0000E+00
13	1	2.4400	-299.5533	.2133	1.0000	.0000	.0000E+00	.0000E+00
14	1	2.4400	-299.1266	.2133	1.0000	.0000	.0000E+00	.0000E+00
15	1	2.4400	-298.7000	.2133	1.0000	.0000	.0000E+00	.0000E+00
16	1	2.4400	-298.2733	.2133	1.0000	.0000	.0000E+00	.0000E+00
17	1	2.4400	-297.8467	.2133	1.0000	.0000	.0000E+00	.0000E+00
18	1	2.4400	-297.4200	.2133	1.0000	.0000	.0000E+00	.0000E+00
19	1	2.4400	-296.9933	.2133	1.0000	.0000	.0000E+00	.0000E+00
20	1	2.3417	-296.6197	.1878	.8566	-.5159	.0000E+00	.0000E+00
21	1	2.1268	-296.3127	.1878	.7780	-.6282	.0000E+00	.0000E+00
22	1	1.8721	-296.0361	.1878	.6848	-.7287	.0000E+00	.0000E+00

23	1	1.5821	-295.8008	.1878	.5788	-.8155	.0000E+00	.0000E+00
24	1	1.2625	-295.6054	.1878	.4618	-.8870	.0000E+00	.0000E+00
25	1	.9191	-295.4556	.1878	.3362	-.9418	.0000E+00	.0000E+00
26	1	.5584	-295.3541	.1878	.2043	-.9789	.0000E+00	.0000E+00
27	1	.1873	-295.3029	.1878	.0685	-.9977	.0000E+00	.0000E+00
28	1	32.3080	-302.0000	.6100	.0000	1.0000	.0000E+00	.0000E+00
29	1	33.5280	-302.0000	.6100	.0000	1.0000	.0000E+00	.0000E+00
30	1	34.7480	-302.0000	.6100	.0000	1.0000	.0000E+00	.0000E+00
31	1	35.9680	-302.0000	.6100	.0000	1.0000	.0000E+00	.0000E+00
32	1	36.5780	-301.3475	.6525	1.0000	.0000	.0000E+00	.0000E+00
33	1	36.5780	-300.0425	.6525	1.0000	.0000	.0000E+00	.0000E+00
34	1	36.5780	-298.7375	.6525	1.0000	.0000	.0000E+00	.0000E+00
35	1	36.5780	-297.4325	.6525	1.0000	.0000	.0000E+00	.0000E+00
36	1	36.0718	-296.2363	.7422	.7332	-.6801	.0000E+00	.0000E+00
37	1	34.8525	-295.4911	.7422	.2709	-.9626	.0000E+00	.0000E+00
38	1	33.4235	-295.4911	.7422	-.2709	-.9626	.0000E+00	.0000E+00
39	1	32.2042	-296.2363	.7422	-.7332	-.6801	.0000E+00	.0000E+00
40	1	31.6980	-297.4325	.6525	-1.0000	.0000	.0000E+00	.0000E+00
41	1	31.6980	-298.7375	.6525	-1.0000	.0000	.0000E+00	.0000E+00
42	1	31.6980	-300.0425	.6525	-1.0000	.0000	.0000E+00	.0000E+00
43	1	31.6980	-301.3475	.6525	-1.0000	.0000	.0000E+00	.0000E+00
44	1	50.0000	.0000	50.0000	.0000	.0000	.0000E+00	.0000E+00
45	1	150.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00
46	1	250.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00
47	1	350.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00
48	1	450.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00
49	1	550.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00
50	1	650.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00
51	1	750.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00
52	1	850.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00
53	1	950.0000	.0000	50.0000	.0000	1.0000	.0000E+00	.0000E+00

LINES DEFINING STRESS POINTS

XBEG	YBEG	XEND	YEND	NUMPB
.1950	-302.3000	.1950	-308.2344	0
.5850	-302.3000	.5850	-308.2344	0
.9750	-302.3000	.9750	-308.2344	0
1.3650	-302.3000	1.3650	-308.2344	0
1.7550	-302.3000	1.7550	-308.2344	0
2.1450	-302.3000	2.1450	-308.2344	0
2.6021	-302.1621	6.7985	-306.3582	0
2.7400	-301.6866	8.6744	-301.6866	0
2.7400	-301.2600	8.6744	-301.2600	0
2.7400	-300.8333	8.6744	-300.8333	0
2.7400	-300.4067	8.6744	-300.4067	0
2.7400	-299.9800	8.6744	-299.9800	0
2.7400	-299.5533	8.6744	-299.5533	0
2.7400	-299.1266	8.6744	-299.1266	0
2.7400	-298.7000	8.6744	-298.7000	0
2.7400	-298.2733	8.6744	-298.2733	0
2.7400	-297.8467	8.6744	-297.8467	0
2.7400	-297.4200	8.6744	-297.4200	0
2.7400	-296.9933	8.6744	-296.9933	0
2.5866	-296.4649	7.6822	-293.4032	0
2.3602	-296.1243	6.9774	-292.3962	0
2.0775	-295.8195	6.1416	-291.4951	0
1.7557	-295.5562	5.1904	-290.7167	0
1.4010	-295.3393	4.1417	-290.0757	0
1.0199	-295.1730	3.0151	-289.5841	0
.6197	-295.0604	1.8321	-289.2512	0
.2079	-295.0036	.6144	-289.0831	0

TIME REQUIRED TO COMPUTE INFLUENCE COEFFICIENTS= 33.34 SECONDS.

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OUTPUT FOR TIME= .1000E+02

PRE-EXISTING STRESS AT EACH ELEMENT

ELEMENT	TEMP	SIGMAXX	SIGMAYY	SIGMAXY	SIGMAZZ	NORM-STR	SHEAR-STR	NORM-DIS	SHEAR-D
1	.9034E+02	.1286E+02	.1126E+02	.1222E+00	.1719E+02	.1126E+02	.1222E+00	-.5246E-02	-.6880E-04
2	.9014E+02	.1290E+02	.1120E+02	.3611E+00	.1715E+02	.1120E+02	.3611E+00	-.5238E-02	-.2005E-03
3	.8975E+02	.1294E+02	.1108E+02	.5845E+00	.1708E+02	.1108E+02	.5845E+00	-.5223E-02	-.3305E-03
4	.8919E+02	.1300E+02	.1091E+02	.7845E+00	.1695E+02	.1091E+02	.7845E+00	-.5202E-02	-.4560E-03
5	.8846E+02	.1306E+02	.1070E+02	.9564E+00	.1682E+02	.1070E+02	.9564E+00	-.5175E-02	-.5750E-03
6	.8764E+02	.1313E+02	.1046E+02	.1098E+01	.1665E+02	.1046E+02	.1098E+01	-.5143E-02	-.6880E-03
7	.8680E+02	.1313E+02	.1029E+02	.1164E+01	.1648E+02	.1055E+02	-.1423E+01	-.3118E-02	-.4178E-02
8	.8529E+02	.1293E+02	.1018E+02	.1134E+01	.1617E+02	.1293E+02	-.1134E+01	.7398E-03	-.5346E-02
9	.8313E+02	.1261E+02	.1005E+02	.1065E+01	.1573E+02	.1261E+02	-.1065E+01	.7024E-03	-.5650E-02
10	.8108E+02	.1231E+02	.9921E+01	.9990E+00	.1531E+02	.1231E+02	-.9990E+00	.6674E-03	-.5944E-02
11	.7911E+02	.1203E+02	.9793E+01	.9373E+00	.1492E+02	.1203E+02	-.9373E+00	.6346E-03	-.6227E-02
12	.7724E+02	.1177E+02	.9668E+01	.8796E+00	.1453E+02	.1177E+02	-.8796E+00	.6038E-03	-.6502E-02
13	.7546E+02	.1151E+02	.9546E+01	.8257E+00	.1417E+02	.1151E+02	-.8257E+00	.5749E-03	-.6766E-02
14	.7375E+02	.1127E+02	.9428E+01	.7754E+00	.1382E+02	.1127E+02	-.7754E+00	.5478E-03	-.7026E-02
15	.7211E+02	.1104E+02	.9315E+01	.7285E+00	.1349E+02	.1104E+02	-.7285E+00	.5223E-03	-.7276E-02
16	.7055E+02	.1082E+02	.9205E+01	.6847E+00	.1317E+02	.1082E+02	-.6847E+00	.4983E-03	-.7519E-02
17	.6904E+02	.1061E+02	.9100E+01	.6439E+00	.1286E+02	.1061E+02	-.6439E+00	.4758E-03	-.7754E-02
18	.6759E+02	.1041E+02	.8999E+01	.6058E+00	.1256E+02	.1041E+02	-.6058E+00	.4546E-03	-.7983E-02
19	.6620E+02	.1021E+02	.8903E+01	.5702E+00	.1226E+02	.1021E+02	-.5702E+00	.4347E-03	-.8205E-02
20	.6506E+02	.1003E+02	.8840E+01	.5220E+00	.1205E+02	.1018E+02	.2831E+00	.4678E-02	-.6986E-02
21	.6423E+02	.9884E+01	.8809E+01	.4592E+00	.1188E+02	.9908E+01	.4286E+00	.5653E-02	-.6435E-02
22	.6350E+02	.9751E+01	.8785E+01	.3932E+00	.1173E+02	.9631E+01	.5063E+00	.6549E-02	-.5734E-02
23	.6289E+02	.9637E+01	.8766E+01	.3249E+00	.1160E+02	.9366E+01	.5174E+00	.7339E-02	-.4897E-02
24	.6239E+02	.9544E+01	.8756E+01	.2546E+00	.1150E+02	.9132E+01	.4688E+00	.8002E-02	-.3941E-02
25	.6202E+02	.9473E+01	.8747E+01	.1828E+00	.1142E+02	.8945E+01	.3712E+00	.8517E-02	-.2888E-02
26	.6177E+02	.9425E+01	.8742E+01	.1101E+00	.1137E+02	.8815E+01	.2374E+00	.8870E-02	-.1763E-02
27	.6165E+02	.9400E+01	.8740E+01	.3676E-01	.1135E+02	.8748E+01	.8158E-01	.9049E-02	-.5923E-03
28	.8765E+02	.1296E+02	.1064E+02	-.9596E+00	.1665E+02	.1064E+02	-.9596E+00	-.5210E-02	.5924E-03
29	.8919E+02	.1280E+02	.1111E+02	-.3570E+00	.1696E+02	.1111E+02	-.3570E+00	-.5275E-02	.2083E-03
30	.8919E+02	.1280E+02	.1111E+02	.3533E+00	.1696E+02	.1111E+02	.3533E+00	-.5275E-02	-.2007E-03
31	.8765E+02	.1296E+02	.1064E+02	.9559E+00	.1665E+02	.1064E+02	.9559E+00	-.5210E-02	-.5847E-03
32	.8310E+02	.1258E+02	.1008E+02	.1059E+01	.1573E+02	.1258E+02	-.1059E+01	.6977E-03	-.5625E-02
33	.7714E+02	.1174E+02	.9676E+01	.8702E+00	.1451E+02	.1174E+02	-.8702E+00	.5980E-03	-.6490E-02
34	.7195E+02	.1102E+02	.9311E+01	.7182E+00	.1346E+02	.1102E+02	-.7182E+00	.5159E-03	-.7277E-02
35	.6739E+02	.1036E+02	.8989E+01	.5955E+00	.1252E+02	.1038E+02	-.5955E+00	.4460E-03	-.7994E-02
36	.6386E+02	.9811E+01	.8805E+01	.4081E+00	.1180E+02	.9752E+01	.4711E+00	.6092E-02	-.6102E-02
37	.6195E+02	.9456E+01	.8748E+01	.1384E+00	.1141E+02	.8872E+01	.3034E+00	.8685E-02	-.2331E-02
38	.6195E+02	.9456E+01	.8748E+01	-.1443E+00	.1141E+02	.8875E+01	-.3085E+00	.8666E-02	.2326E-02
39	.6386E+02	.9811E+01	.8604E+01	-.4140E+00	.1180E+02	.9758E+01	-.4705E+00	.6096E-02	.6097E-02
40	.6739E+02	.1038E+02	.8989E+01	-.6013E+00	.1252E+02	.1038E+02	.6013E+00	.4539E-03	.7993E-02
41	.7195E+02	.1102E+02	.9311E+01	-.7236E+00	.1346E+02	.1102E+02	.7236E+00	.5224E-03	.7276E-02
42	.7713E+02	.1174E+02	.9676E+01	-.8750E+00	.1451E+02	.1174E+02	.8750E+00	.6050E-03	.6490E-02
43	.8310E+02	.1258E+02	.1008E+02	-.1063E+01	.1573E+02	.1258E+02	.1063E+01	.7052E-03	.5624E-02
44	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00

45	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
46	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
47	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
48	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
49	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
50	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
51	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
52	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
53	.1690E+02	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00

TIME REQUIRED TO COMPUTE PRE-EXISTING STRESSES = 149.89 SECONDS.

TIME REQUIRED TO SOLVE EQUATIONS= 34.60 SECONDS.

BOUNDARY STRESSES AND DISPLACEMENTS AT TIME = .100E+02

ELM	X-COORD SIGXX	Y-COORD SIGYY	UX SIGXY	UY SIGZZ	US SIGMA-S	UN SIGMA-N	SIGMA-T	TEMP
1	.1950E+00 .1052E+02	-.3020E+03 .3301E-05	-.7415E-04 .1914E-07	-.1399E-01 .1447E+02	-.7415E-04 .1914E-07	-.1399E-01 .3301E-05	.1052E+02	.9034E+02
2	.5850E+00 .1111E+02	-.3020E+03 .3631E-05	-.2162E-03 .3303E-07	-.1389E-01 .1456E+02	-.2162E-03 .3303E-07	-.1389E-01 .3631E-05	.1111E+02	.9014E+02
3	.9750E+00 .1241E+02	-.3020E+03 .1453E-06	-.3355E-03 .1364E-05	-.1369E-01 .1475E+02	-.3355E-03 .1364E-05	-.1369E-01 .1453E-06	.1241E+02	.8975E+02
4	.1365E+01 .1481E+02	-.3020E+03 .2265E-05	-.4134E-03 -.7182E-06	-.1337E-01 .1514E+02	-.4134E-03 -.7182E-06	-.1337E-01 .2265E-05	.1481E+02	.8919E+02
5	.1755E+01 .1972E+02	-.3020E+03 -.5633E-06	-.4154E-03 .1234E-05	-.1290E-01 .1601E+02	-.4154E-03 .1234E-05	-.1290E-01 -.5633E-06	.1972E+02	.8648E+02
6	.2145E+01 .3624E+02	-.3020E+03 -.8529E-05	-.2287E-03 .4054E-05	-.1217E-01 .1916E+02	-.2287E-03 .4054E-05	-.1217E-01 -.8529E-05	.3624E+02	.8764E+02
7	.2390E+01 .4516E+02	-.3020E+03 .4517E+02	.4949E-03 .4516E+02	-.1133E-01 .2986E+02	-.7665E-02 -.3383E-06	.8364E-02 .9457E-05	.8033E+02	.8680E+02
8	.2440E+01 .6399E-05	-.3017E+03 .2983E+02	.1493E-02 -.6747E-05	-.1079E-01 .1752E+02	-.1079E-01 .6747E-05	-.1493E-02 .6399E-05	.2983E+02	.8529E+02
9	.2440E+01 .6227E-05	-.3013E+03 .1438E+02	.2334E-02 -.1824E-05	-.1083E-01 .1408E+02	-.1083E-01 .1824E-05	-.2334E-02 .6227E-05	.1438E+02	.8313E+02
10	.2440E+01 .1671E-05	-.3008E+03 .1020E+02	.2868E-02 .1006E-05	-.1103E-01 .1291E+02	-.1103E-01 -.1006E-05	-.2868E-02 .1671E-05	.1020E+02	.8108E+02
11	.2440E+01 .8109E-05	-.3004E+03 .8285E+01	.3233E-02 -.3068E-05	-.1128E-01 .1221E+02	-.1128E-01 .3068E-05	-.3233E-02 .8109E-05	.8285E+01	.7911E+02
12	.2440E+01 .1466E-05	-.3000E+03 .7273E+01	.3477E-02 .1328E-05	-.1155E-01 .1170E+02	-.1155E-01 -.1328E-05	-.3477E-02 .1466E-05	.7273E+01	.7724E+02
13	.2440E+01 -.5630E-05	-.2996E+03 .6747E+01	.3626E-02 .1336E-05	-.1182E-01 .1131E+02	-.1182E-01 -.1336E-05	-.3626E-02 -.5630E-05	.6747E+01	.7546E+02
14	.2440E+01 .3877E-05	-.2991E+03 .6562E+01	.3692E-02 .1265E-05	-.1209E-01 .1099E+02	-.1209E-01 -.1265E-05	-.3692E-02 .3877E-05	.6562E+01	.7375E+02
15	.2440E+01 -.8643E-05	-.2987E+03 .6670E+01	.3681E-02 .3199E-06	-.1235E-01 .1075E+02	-.1235E-01 -.3199E-06	-.3681E-02 -.8643E-05	.6670E+01	.7211E+02
16	.2440E+01 -.3493E-05	-.2983E+03 .7110E+01	.3597E-02 -.6610E-06	-.1260E-01 .1058E+02	-.1260E-01 .6610E-06	-.3597E-02 -.3493E-05	.7110E+01	.7055E+02
17	.2440E+01 -.2202E-06	-.2978E+03 .8035E+01	.3436E-02 -.1222E-05	-.1282E-01 .1053E+02	-.1282E-01 .1222E-05	-.3436E-02 -.2202E-06	.8035E+01	.6904E+02
18	.2440E+01 .1293E-05	-.2974E+03 .9940E+01	.3189E-02 -.2879E-06	-.1299E-01 .1067E+02	-.1299E-01 .2879E-06	-.3189E-02 .1293E-05	.9940E+01	.6759E+02
19	.2440E+01 .1046E-05	-.2970E+03 .1496E+02	.2841E-02 -.1796E-05	-.1308E-01 .1145E+02	-.1308E-01 .1796E-05	-.2841E-02 .1046E-05	.1496E+02	.6620E+02
20	.2342E+01 .5980E+01	-.2966E+03 .1648E+02	.2450E-02 -.9928E+01	-.1296E-01 .1277E+02	-.1236E-01 .3051E-05	.4566E-02 .2417E-05	.2246E+02	.6508E+02
21	.2127E+01 .8324E+01	-.2963E+03 .1277E+02	.2161E-02 -.1031E+02	-.1290E-01 .1236E+02	-.1139E-01 -.2342E-05	.6422E-02 .2063E-05	.2109E+02	.6423E+02
22	.1872E+01 .1143E+02	-.2960E+03 .1010E+02	.1867E-02 -.1074E+02	-.1286E-01 .1233E+02	-.1017E-01 .7984E-06	.6096E-02 -.3765E-05	.2153E+02	.6350E+02
23	.1582E+01 .1480E+02	-.2958E+03 .7455E+01	.1556E-02 -.1050E+02	-.1284E-01 .1237E+02	-.8699E-02 .3696E-06	.9569E-02 .2965E-05	.2226E+02	.6289E+02
24	.1262E+01 .1807E+02	-.2956E+03 .4899E+01	.1228E-02 -.9408E+01	-.1282E-01 .1243E+02	-.7009E-02 .1535E-05	.1080E-01 .4485E-05	.2297E+02	.6239E+02
25	.9191E+00 .2089E+02	-.2955E+03 .2663E+01	.8879E-03 -.7459E+01	-.1280E-01 .1249E+02	-.5140E-02 -.9577E-06	.1176E-01 -.2874E-06	.2356E+02	.6202E+02
26	.5584E+00 .2297E+02	-.2954E+03 .1001E+01	.5368E-03 -.4794E+01	-.1279E-01 .1253E+02	-.3138E-02 -.1418E-05	.1241E-01 .7528E-07	.2397E+02	.6177E+02
27	.1873E+00 .2407E+02	-.2953E+03 .1135E+00	.1796E-03 -.1653E+01	-.1278E-01 .1256E+02	-.1055E-02 -.3493E-06	.1274E-01 .3339E-05	.2418E+02	.6165E+02
28	.3231E+02 .2710E+02	-.3020E+03 .1135E-05	.9140E-03 -.2603E-05	-.1264E-01 .1735E+02	.9140E-03 -.2603E-05	-.1264E-01 .1135E-05	.2710E+02	.8765E+02
29	.3353E+02 .1338E+02	-.3020E+03 .6565E-06	.8067E-03 .5533E-06	-.1371E-01 .1486E+02	.8067E-03 .5533E-06	-.1371E-01 .6565E-06	.1338E+02	.8919E+02
30	.3475E+02 .1342E+02	-.3020E+03 -.3354E-06	.3869E-03 .3567E-07	-.1371E-01 .1486E+02	.3869E-03 .3567E-07	-.1371E-01 -.3354E-06	.1342E+02	.8919E+02
31	.3597E+02 .2726E+02	-.3020E+03 -.2167E-05	.2861E-03 .2516E-05	-.1264E-01 .1739E+02	.2861E-03 .2516E-05	-.1264E-01 -.2167E-05	.2726E+02	.8765E+02

32	.3656E+02	-.3013E+03	.2747E-02	-.1076E-01	-.1076E-01	-.2747E-02		
	.2878E-05	.2243E+02	-.7951E-06	.1566E+02	.7951E-06	.2878E-05	.2243E+02	.8310E+02
33	.3656E+02	-.3000E+03	.4044E-02	-.1139E-01	-.1139E-01	-.4044E-02		
	-.2106E-06	.8934E+01	.3538E-05	.1202E+02	-.3538E-05	-.2106E-06	.8934E+01	.7714E+02
34	.3656E+02	-.2987E+03	.4324E-02	-.1219E-01	-.1219E-01	-.4324E-02		
	.3636E-05	.7771E+01	-.9592E-06	.1094E+02	.9592E-06	.3636E-05	.7771E+01	.7195E+02
35	.3656E+02	-.2974E+03	.3923E-02	-.1280E-01	-.1280E-01	-.3923E-02		
	-.4770E-05	.1120E+02	-.1325E-06	.1089E+02	.1325E-06	-.4770E-05	.1120E+02	.6739E+02
36	.3607E+02	-.2962E+03	.2870E-02	-.1276E-01	-.1131E-01	.6574E-02		
	.9590E+01	.1115E+02	-.1034E+02	.1223E+02	-.2532E-05	.3114E-05	.2074E+02	.6386E+02
37	.3485E+02	-.2955E+03	.1405E-02	-.1266E-01	-.4782E-02	.1181E-01		
	.2266E+02	.1795E+01	-.6377E+01	.1266E+02	.4691E-06	.1942E-05	.2446E+02	.6195E+02
38	.3342E+02	-.2955E+03	-.2060E-03	-.1264E-01	.3623E-02	.1211E-01		
	.2248E+02	.1780E+01	.6325E+01	.1262E+02	-.1765E-05	.2546E-05	.2426E+02	.6195E+02
39	.3220E+02	-.2962E+03	-.1648E-02	-.1272E-01	.1045E-01	.7440E-02		
	.9469E+01	.1101E+02	.1021E+02	.1217E+02	-.2924E-05	-.4370E-05	.2047E+02	.6386E+02
40	.3170E+02	-.2974E+03	-.2679E-02	-.1276E-01	.1276E-01	-.2679E-02		
	-.6984E-05	.1130E+02	-.1306E-05	.1091E+02	.1306E-05	-.6984E-05	.1130E+02	.6739E+02
41	.3170E+02	-.2987E+03	-.3075E-02	-.1216E-01	.1216E-01	-.3075E-02		
	.1831E-05	.7916E+01	-.3284E-06	.1097E+02	.3284E-06	.1831E-05	.7916E+01	.7195E+02
42	.3170E+02	-.3000E+03	-.2800E-02	-.1138E-01	.1138E-01	-.2800E-02		
	.2890E-05	.9085E+01	.2094E-05	.1205E+02	-.2094E-05	.2890E-05	.9085E+01	.7713E+02
43	.3170E+02	-.3013E+03	-.1521E-02	-.1076E-01	.1076E-01	-.1521E-02		
	-.7647E-05	.2252E+02	.6910E-05	.1570E+02	-.6910E-05	-.7647E-05	.2252E+02	.8310E+02
44	.5000E+02	.0000E+00	.1235E-03	-.5821E-02	.1235E-03	-.5821E-02		
	.3468E-01	-.1197E-07	-.6733E-08	.6936E-02	-.6733E-08	-.1197E-07	.3468E-01	.1690E+02
45	.1500E+03	.0000E+00	.3291E-03	-.5956E-02	.3291E-03	-.5956E-02		
	.2439E-01	.5036E-07	.2180E-08	.4879E-02	.2180E-08	.5036E-07	.2439E-01	.1690E+02
46	.2500E+03	.0000E+00	.4461E-03	-.6159E-02	.4461E-03	-.6159E-02		
	.1202E-01	-.4635E-08	-.7309E-08	.2405E-02	-.7309E-08	-.4635E-08	.1202E-01	.1690E+02
47	.3500E+03	.0000E+00	.4693E-03	-.6364E-02	.4693E-03	-.6364E-02		
	.3376E-02	-.1688E-08	.7774E-08	.6756E-03	.7774E-08	-.1688E-08	.3376E-02	.1690E+02
48	.4500E+03	.0000E+00	.4900E-03	-.6543E-02	.4900E-03	-.6543E-02		
	-.1290E-02	.3922E-08	-.1842E-08	-.2579E-03	-.1842E-08	.3922E-08	-.1290E-02	.1690E+02
49	.5500E+03	.0000E+00	.4696E-03	-.6693E-02	.4696E-03	-.6693E-02		
	-.3556E-02	-.3056E-09	.1824E-08	-.7112E-03	.1824E-08	-.3056E-09	-.3556E-02	.1690E+02
50	.6500E+03	.0000E+00	.4406E-03	-.6819E-02	.4406E-03	-.6819E-02		
	-.4644E-02	.2925E-08	.1023E-07	-.8288E-03	.1023E-07	.2925E-08	-.4644E-02	.1690E+02
51	.7500E+03	.0000E+00	.4065E-03	-.6924E-02	.4065E-03	-.6924E-02		
	-.5257E-02	.6403E-09	.1084E-08	-.1051E-02	.1084E-08	.6403E-09	-.5257E-02	.1690E+02
52	.8500E+03	.0000E+00	.3696E-03	-.7013E-02	.3696E-03	-.7013E-02		
	-.5812E-02	-.1048E-08	.3167E-08	-.1162E-02	.3167E-08	-.1048E-08	-.5812E-02	.1690E+02
53	.9500E+03	.0000E+00	.3281E-03	-.7087E-02	.3281E-03	-.7087E-02		
	-.6819E-02	-.1979E-08	.1359E-08	-.1364E-02	.1359E-08	-.1979E-08	-.6819E-02	.1690E+02

TIME REQUIRED TO COMPUTE BOUNDARY STRESSES AND DISPLACEMENTS= 35.38 SECONDS.

INTERIOR STRESSES AND DISPLACEMENTS AT TIME = .100E+02

POINT	X-COORD SIGXX	Y-COORD SIGYY	UX SIGXY	UY SIGZZ	SIG1	SIG2	ALPHA	TEMP
1	.1950E+00	-.3023E+03	-.4072E-04	-.1357E-01				
	.1273E+02	.3971E+00	.2134E+00	.1533E+02	.1274E+02	.3935E+00	.9909E+00	.9243E+02
2	.1950E+00	-.3028E+03	-.9928E-05	-.1291E-01				
	.1613E+02	.1282E+01	.5390E+00	.1674E+02	.1615E+02	.1262E+01	.2076E+01	.9585E+02
3	.1950E+00	-.3034E+03	-.1631E-05	-.1193E-01				
	.1858E+02	.3714E+01	.7949E+00	.1867E+02	.1862E+02	.3672E+01	.3053E+01	.1018E+03
4	.1950E+00	-.3044E+03	-.3299E-04	-.1052E-01				
	.1955E+02	.7892E+01	.7817E+00	.2162E+02	.1960E+02	.7840E+01	.3819E+01	.1136E+03
5	.1950E+00	-.3060E+03	-.1101E-03	-.8424E-02				
	.2217E+02	.1324E+02	-.6932E-01	.2848E+02	.2217E+02	.1324E+02	-.4450E+00	.1462E+03
6	.1950E+00	-.3082E+03	-.1244E-03	-.5335E-02				
	.1986E+02	.1511E+02	.7923E-01	.2769E+02	.1986E+02	.1511E+02	.9556E+00	.1418E+03
7	.5850E+00	-.3023E+03	-.1149E-03	-.1347E-01				
	.1335E+02	.4353E+00	.6769E+00	.1542E+02	.1336E+02	.3999E+00	.2992E+01	.9220E+02
8	.5850E+00	-.3028E+03	-.2436E-04	-.1281E-01				
	.1661E+02	.1465E+01	.1689E+01	.1683E+02	.1680E+02	.1279E+01	.6284E+01	.9556E+02
9	.5850E+00	-.3034E+03	-.4239E-05	-.1184E-01				
	.1867E+02	.4055E+01	.2390E+01	.1869E+02	.1905E+02	.3674E+01	.9056E+01	.1013E+03
10	.5850E+00	-.3044E+03	-.9550E-04	-.1046E-01				
	.1949E+02	.7961E+01	.2234E+01	.2145E+02	.1991E+02	.7543E+01	.1059E+02	.1125E+03
11	.5850E+00	-.3060E+03	-.2780E-03	-.8404E-02				
	.2147E+02	.1174E+02	.1059E+01	.2623E+02	.2158E+02	.1162E+02	.6141E+01	.1350E+03
12	.5850E+00	-.3082E+03	-.3487E-03	-.5333E-02				
	.2010E+02	.1386E+02	.3064E-01	.2666E+02	.2010E+02	.1386E+02	.2820E+00	.1366E+03
13	.9750E+00	-.3023E+03	-.1630E-03	-.1326E-01				

	.1471E+02	.5466E+00	.1287E+01	.1565E+02	.1483E+02	.4308E+00	.5150E+01	.9175E+02
14	.9750E+00	-.3028E+03	-.2006E-04	-.1261E-01				
	.1756E+02	.1966E+01	.3084E+01	.1703E+02	.1815E+02	.1380E+01	.1079E+02	.9499E+02
15	.9750E+00	-.3034E+03	-.3666E-05	-.1166E-01				
	.1876E+02	.4850E+01	.3960E+01	.1873E+02	.1982E+02	.3792E+01	.1489E+02	.1005E+03
16	.9750E+00	-.3044E+03	-.1545E-03	-.1034E-01				
	.1929E+02	.8213E+01	.3420E+01	.2115E+02	.2026E+02	.7242E+01	.1585E+02	.1107E+03
17	.9750E+00	-.3060E+03	-.4117E-03	-.6351E-02				
	.2067E+02	.1096E+02	.1606E+01	.2479E+02	.2119E+02	.1066E+02	.1003E+02	.1278E+03
18	.9750E+00	-.3082E+03	-.5329E-03	-.5332E-02				
	.2006E+02	.1267E+02	-.5297E-01	.2542E+02	.2006E+02	.1267E+02	-.4105E+00	.1305E+03
19	.1365E+01	-.3023E+03	-.1633E-03	-.1294E-01				
	.1715E+02	.8746E+00	.2326E+01	.1610E+02	.1748E+02	.5486E+00	.7976E+01	.9111E+02
20	.1365E+01	-.3028E+03	.1059E-04	-.1229E-01				
	.1882E+02	.3198E+01	.4961E+01	.1739E+02	.2026E+02	.1755E+01	.1621E+02	.9420E+02
21	.1365E+01	-.3034E+03	-.4700E-05	-.1141E-01				
	.1864E+02	.6272E+01	.5451E+01	.1881E+02	.2070E+02	.4213E+01	.2069E+02	.9933E+02
22	.1365E+01	-.3044E+03	-.2124E-03	-.1016E-01				
	.1890E+02	.8711E+01	.4263E+01	.2061E+02	.2045E+02	.7163E+01	.1995E+02	.1084E+03
23	.1365E+01	-.3060E+03	-.5235E-03	-.8277E-02				
	.2033E+02	.1050E+02	.2290E+01	.2366E+02	.2084E+02	.9992E+01	.1249E+02	.1220E+03
24	.1365E+01	-.3082E+03	-.6837E-03	-.5333E-02				
	.1981E+02	.1174E+02	-.5735E-01	.2423E+02	.1981E+02	.1174E+02	-.4069E+00	.1246E+03
25	.1755E+01	-.3023E+03	-.8332E-04	-.1246E-01				
	.2134E+02	.2172E+01	.4757E+01	.1706E+02	.2245E+02	.1056E+01	.1320E+02	.9030E+02
26	.1755E+01	-.3028E+03	.6248E-04	-.1187E-01				
	.1971E+02	.6116E+01	.7361E+01	.1800E+02	.2293E+02	.2693E+01	.2365E+02	.9321E+02
27	.1755E+01	-.3034E+03	-.1811E-04	-.1111E-01				
	.1811E+02	.8369E+01	.6477E+01	.1869E+02	.2135E+02	.5136E+01	.2653E+02	.9795E+02
28	.1755E+01	-.3044E+03	-.2737E-03	-.9998E-02				
	.1837E+02	.9386E+01	.4720E+01	.2044E+02	.2039E+02	.7362E+01	.2322E+02	.1059E+03
29	.1755E+01	-.3060E+03	-.6197E-03	-.8190E-02				
	.1979E+02	.1020E+02	.2572E+01	.2270E+02	.2044E+02	.9552E+01	.1409E+02	.1171E+03
30	.1755E+01	-.3082E+03	-.8067E-03	-.5333E-02				
	.1948E+02	.1102E+02	-.1450E-01	.2316E+02	.1948E+02	.1102E+02	-.9822E-01	.1193E+03
31	.2145E+01	-.3023E+03	.9856E-04	-.1176E-01				
	.2557E+02	.9753E+01	.1088E+02	.1927E+02	.3112E+02	.4209E+01	.2699E+02	.8936E+02
32	.2145E+01	-.3028E+03	.9651E-04	-.1138E-01				
	.1887E+02	.1152E+02	.8740E+01	.1872E+02	.2467E+02	.5710E+01	.3359E+02	.9207E+02
33	.2145E+01	-.3034E+03	-.5641E-04	-.1080E-01				
	.1724E+02	.1069E+02	.6593E+01	.1894E+02	.2132E+02	.6605E+01	.3180E+02	.9641E+02
34	.2145E+01	-.3044E+03	-.3411E-03	-.9808E-02				
	.1778E+02	.1007E+02	.4782E+01	.2005E+02	.2006E+02	.7778E+01	.2556E+02	.1034E+03
35	.2145E+01	-.3060E+03	-.7044E-03	-.8097E-02				
	.1926E+02	.1000E+02	.2690E+01	.2185E+02	.1999E+02	.9280E+01	.1508E+02	.1127E+03
36	.2145E+01	-.3082E+03	-.9133E-03	-.5332E-02				
	.1912E+02	.1046E+02	.4505E-01	.2222E+02	.1912E+02	.1046E+02	.2980E+00	.1146E+03
37	.2602E+01	-.3022E+03	.2947E-03	-.1114E-01				
	.2478E+02	.2125E+02	.7599E+01	.2110E+02	.3081E+02	.1521E+02	.3846E+02	.8740E+02
38	.2920E+01	-.3025E+03	.1384E-03	-.1091E-01				
	.1685E+02	.1501E+02	.4802E+01	.1876E+02	.2210E+02	.1176E+02	.3408E+02	.8814E+02
39	.3398E+01	-.3030E+03	-.1046E-03	-.1049E-01				
	.1664E+02	.1204E+02	.3952E+01	.1787E+02	.1891E+02	.9768E+01	.2990E+02	.8867E+02
40	.4114E+01	-.3037E+03	-.4489E-03	-.9788E-02				
	.1595E+02	.1016E+02	.3313E+01	.1738E+02	.1746E+02	.8652E+01	.2440E+02	.8905E+02
41	.5188E+01	-.3047E+03	-.8599E-03	-.8674E-02				
	.1590E+02	.8648E+01	.2427E+01	.1662E+02	.1664E+02	.7911E+01	.1689E+02	.8749E+02
42	.6799E+01	-.3064E+03	-.1192E-02	-.7033E-02				
	.1568E+02	.7377E+01	.1205E+01	.1575E+02	.1585E+02	.7206E+01	.8088E+01	.8267E+02
43	.2740E+01	-.3017E+03	.1192E-02	-.1121E-01				
	.9413E+01	.2156E+02	.1065E+02	.1764E+02	.2776E+02	.3234E+01	.5987E+02	.8461E+02
44	.3190E+01	-.3017E+03	.9886E-03	-.1132E-01				
	.1218E+02	.1458E+02	.8986E+01	.1662E+02	.2244E+02	.4312E+01	.4880E+02	.8353E+02
45	.3865E+01	-.3017E+03	.7720E-03	-.1129E-01				
	.1164E+02	.1169E+02	.6880E+01	.1569E+02	.1865E+02	.4884E+01	.4469E+02	.8180E+02
46	.4878E+01	-.3017E+03	.4729E-03	-.1115E-01				
	.1131E+02	.1026E+02	.5163E+01	.1487E+02	.1597E+02	.5596E+01	.4211E+02	.7912E+02
47	.6396E+01	-.3017E+03	.1064E-03	-.1088E-01				
	.1117E+02	.9177E+01	.3610E+01	.1399E+02	.1392E+02	.6426E+01	.3729E+02	.7522E+02
48	.8674E+01	-.3017E+03	-.2923E-03	-.1055E-01				
	.1137E+02	.8002E+01	.2225E+01	.1298E+02	.1248E+02	.6896E+01	.2643E+02	.7016E+02
49	.2740E+01	-.3013E+03	.2014E-02	-.1120E-01				
	.1843E+01	.1639E+02	.3969E+01	.1475E+02	.1740E+02	.8298E+00	.7569E+02	.8254E+02
50	.3190E+01	-.3013E+03	.1615E-02	-.1145E-01				
	.5708E+01	.1512E+02	.6928E+01	.1512E+02	.1879E+02	.2039E+01	.6210E+02	.8159E+02
51	.3865E+01	-.3013E+03	.1201E-02	-.1151E-01				
	.8393E+01	.1254E+02	.6566E+01	.1489E+02	.1735E+02	.3580E+01	.5376E+02	.8006E+02

52	.4878E+01	-.3013E+03	.7539E-03	-.1139E-01	.1531E+02	.5049E+01	.4860E+02	.7765E+02
	.9537E+01	.1082E+02	.5090E+01	.1439E+02				
53	.6396E+01	-.3013E+03	.2793E-03	-.1114E-01	.1342E+02	.6337E+01	.4204E+02	.7408E+02
	.1024E+02	.9513E+01	.3524E+01	.1369E+02				
54	.8674E+01	-.3013E+03	-.1960E-03	-.1082E-01	.1209E+02	.6992E+01	.2895E+02	.6935E+02
	.1090E+02	.8186E+01	.2159E+01	.1279E+02				
55	.2740E+01	-.3008E+03	.2566E-02	-.1130E-01	.1253E+02	.4276E+00	.8156E+02	.8056E+02
	.6874E+00	.1227E+02	.1754E+01	.1338E+02				
56	.3190E+01	-.3008E+03	.2133E-02	-.1156E-01	.1523E+02	.1170E+01	.7111E+02	.7973E+02
	.2643E+01	.1375E+02	.4305E+01	.1393E+02				
57	.3865E+01	-.3008E+03	.1604E-02	-.1167E-01	.1567E+02	.2727E+01	.6210E+02	.7837E+02
	.5561E+01	.1284E+02	.5353E+01	.1411E+02				
58	.4876E+01	-.3008E+03	.1026E-02	-.1160E-01	.1451E+02	.4610E+01	.5534E+02	.7620E+02
	.7812E+01	.1131E+02	.4630E+01	.1390E+02				
59	.6396E+01	-.3008E+03	.4454E-03	-.1138E-01	.1289E+02	.6278E+01	.4719E+02	.7293E+02
	.9331E+01	.9835E+01	.3295E+01	.1339E+02				
60	.8674E+01	-.3008E+03	-.1039E-03	-.1108E-01	.1166E+02	.7101E+01	.3158E+02	.6852E+02
	.1043E+02	.8358E+01	.2045E+01	.1260E+02				
61	.2740E+01	-.3004E+03	.2945E-02	-.1147E-01	.1014E+02	.2972E+00	.8468E+02	.7866E+02
	.3816E+00	.1005E+02	.9082E+00	.1256E+02				
62	.3190E+01	-.3004E+03	.2515E-02	-.1168E-01	.1276E+02	.8309E+00	.7720E+02	.7793E+02
	.1417E+01	.1220E+02	.2581E+01	.1308E+02				
63	.3865E+01	-.3004E+03	.1939E-02	-.1181E-01	.1411E+02	.2230E+01	.6933E+02	.7672E+02
	.3710E+01	.1263E+02	.3923E+01	.1343E+02				
64	.4878E+01	-.3004E+03	.1269E-02	-.1178E-01	.1368E+02	.4292E+01	.6210E+02	.7477E+02
	.6347E+01	.1162E+02	.3861E+01	.1344E+02				
65	.6396E+01	-.3004E+03	.5977E-03	-.1160E-01	.1234E+02	.6253E+01	.5273E+02	.7178E+02
	.8466E+01	.1011E+02	.2934E+01	.1308E+02				
66	.8674E+01	-.3004E+03	-.1826E-04	-.1132E-01	.1127E+02	.7224E+01	.3434E+02	.6767E+02
	.9984E+01	.8512E+01	.1885E+01	.1240E+02				
67	.2740E+01	-.3000E+03	.3200E-02	-.1166E-01	.8843E+01	.2354E+00	.8679E+02	.7685E+02
	.2623E+00	.8816E+01	.4807E+00	.1200E+02				
68	.3190E+01	-.3000E+03	.2781E-02	-.1183E-01	.1124E+02	.6798E+00	.8177E+02	.7620E+02
	.8964E+00	.1103E+02	.1497E+01	.1246E+02				
69	.3865E+01	-.3000E+03	.2193E-02	-.1194E-01	.1287E+02	.1955E+01	.7562E+02	.7512E+02
	.2628E+01	.1219E+02	.2625E+01	.1287E+02				
70	.4878E+01	-.3000E+03	.1469E-02	-.1194E-01	.1291E+02	.4084E+01	.6879E+02	.7336E+02
	.5239E+01	.1175E+02	.2975E+01	.1302E+02				
71	.6396E+01	-.3000E+03	.7300E-03	-.1179E-01	.1181E+02	.6260E+01	.5868E+02	.7063E+02
	.7760E+01	.1031E+02	.2464E+01	.1279E+02				
72	.8674E+01	-.3000E+03	.5902E-04	-.1155E-01	.1086E+02	.7358E+01	.3723E+02	.6681E+02
	.9577E+01	.8639E+01	.1686E+01	.1220E+02				
73	.2740E+01	-.2996E+03	.3357E-02	-.1189E-01	.8156E+01	.2017E+00	.8853E+02	.7511E+02
	.2070E+00	.8151E+01	.2041E+00	.1157E+02				
74	.3190E+01	-.2996E+03	.2950E-02	-.1199E-01	.1033E+02	.6096E+00	.8559E+02	.7453E+02
	.6672E+00	.1027E+02	.7461E+00	.1200E+02				
75	.3865E+01	-.2996E+03	.2364E-02	-.1207E-01	.1199E+02	.1817E+01	.8132E+02	.7356E+02
	.2049E+01	.1176E+02	.1518E+01	.1241E+02				
76	.4878E+01	-.2996E+03	.1616E-02	-.1208E-01	.1226E+02	.3970E+01	.7541E+02	.7198E+02
	.4496E+01	.1173E+02	.2020E+01	.1264E+02				
77	.6396E+01	-.2996E+03	.8373E-03	-.1198E-01	.1132E+02	.6292E+01	.5505E+02	.6948E+02
	.7166E+01	.1042E+02	.1922E+01	.1251E+02				
78	.8674E+01	-.2996E+03	.1263E-03	-.1177E-01	.1045E+02	.7500E+01	.4028E+02	.6593E+02
	.9216E+01	.8734E+01	.1456E+01	.1201E+02				
79	.2740E+01	-.2991E+03	.3430E-02	-.1211E-01	.7883E+01	.1850E+00	-.8989E+02	.7344E+02
	.1850E+00	.7883E+01	-.1429E-01	.1124E+02				
80	.3190E+01	-.2991E+03	.3033E-02	-.1215E-01	.9886E+01	.5665E+00	.8910E+02	.7292E+02
	.5886E+00	.9864E+01	.1456E+00	.1164E+02				
81	.3865E+01	-.2991E+03	.2459E-02	-.1219E-01	.1145E+02	.1776E+01	.8672E+02	.7206E+02
	.1807E+01	.1142E+02	.5521E+00	.1205E+02				
82	.4878E+01	-.2991E+03	.1713E-02	-.1221E-01	.1176E+02	.3937E+01	.8201E+02	.7063E+02
	.4066E+01	.1161E+02	.1076E+01	.1232E+02				
83	.6396E+01	-.2991E+03	.9166E-03	-.1215E-01	.1089E+02	.6342E+01	.7189E+02	.6834E+02
	.6781E+01	.1045E+02	.1342E+01	.1225E+02				
84	.8674E+01	-.2991E+03	.1822E-03	-.1198E-01	.1006E+02	.7646E+01	.4356E+02	.6505E+02
	.8913E+01	.8791E+01	.1204E+01	.1182E+02				
85	.2740E+01	-.2987E+03	.3425E-02	-.1233E-01	.7962E+01	.1818E+00	-.8826E+02	.7184E+02
	.1890E+00	.7955E+01	-.2356E+00	.1100E+02				
86	.3190E+01	-.2987E+03	.3038E-02	-.1231E-01	.9830E+01	.6043E+00	-.8736E+02	.7137E+02
	.6239E+00	.9810E+01	-.4248E+00	.1136E+02				
87	.3865E+01	-.2987E+03	.2480E-02	-.1232E-01	.1121E+02	.1819E+01	-.8790E+02	.7060E+02
	.1831E+01	.1120E+02	-.3442E+00	.1176E+02				
88	.4876E+01	-.2987E+03	.1754E-02	-.1234E-01	.1141E+02	.3976E+01	.8863E+02	.6930E+02
	.3980E+01	.1140E+02	.1779E+00	.1204E+02				
89	.6396E+01	-.2987E+03	.9666E-03	-.1231E-01	.1053E+02	.6401E+01	.7916E+02	.6721E+02
	.6547E+01	.1038E+02	.7622E+00	.1201E+02				
90	.8674E+01	-.2987E+03	.2261E-03	-.1219E-01	.9684E+01	.7793E+01	.4718E+02	.6417E+02
	.8667E+01	.8811E+01	.9426E+00	.1163E+02				

91	.2740E+01	-.2983E+03	.3345E-02	-.1253E-01	.8419E+01	.1964E+00	-.8642E+02	.7030E+02
	.2285E+00	.8387E+01	-.5128E+00	.1085E+02				
92	.3190E+01	-.2983E+03	.2967E-02	-.1247E-01	.1014E+02	.6766E+00	-.8347E+02	.6986E+02
	.7992E+00	.1002E+02	-.1070E+01	.1122E+02				
93	.3865E+01	-.2983E+03	.2432E-02	-.1244E-01	.1122E+02	.1955E+01	-.8231E+02	.6919E+02
	.2121E+01	.1106E+02	-.1226E+01	.1156E+02				
94	.4878E+01	-.2983E+03	.1743E-02	-.1246E-01	.1119E+02	.4083E+01	-.8472E+02	.6801E+02
	.4143E+01	.1113E+02	-.6516E+00	.1181E+02				
95	.6396E+01	-.2983E+03	.9877E-03	-.1247E-01	.1025E+02	.6461E+01	.8676E+02	.6610E+02
	.6473E+01	.1023E+02	.2122E+00	.1179E+02				
96	.8674E+01	-.2983E+03	.2576E-03	-.1238E-01	.9336E+01	.7936E+01	.5145E+02	.6326E+02
	.8480E+01	.8792E+01	.6824E+00	.1144E+02				
97	.2740E+01	-.2976E+03	.3186E-02	-.1270E-01	.9390E+01	.2460E+00	-.8395E+02	.6862E+02
	.3478E+00	.9269E+01	-.9590E+00	.1081E+02				
98	.3190E+01	-.2976E+03	.2820E-02	-.1260E-01	.1085E+02	.8493E+00	-.7879E+02	.6845E+02
	.1227E+01	.1047E+02	-.1906E+01	.1116E+02				
99	.3865E+01	-.2976E+03	.2319E-02	-.1257E-01	.1144E+02	.2213E+01	-.7634E+02	.6782E+02
	.2728E+01	.1092E+02	-.2118E+01	.1145E+02				
100	.4878E+01	-.2976E+03	.1686E-02	-.1259E-01	.1109E+02	.4257E+01	-.7805E+02	.6675E+02
	.4550E+01	.1079E+02	-.1363E+01	.1162E+02				
101	.6396E+01	-.2976E+03	.9816E-03	-.1262E-01	.1004E+02	.6516E+01	-.8541E+02	.6500E+02
	.6539E+01	.1002E+02	-.2812E+00	.1156E+02				
102	.8674E+01	-.2976E+03	.2773E-03	-.1258E-01	.9020E+01	.8068E+01	.5714E+02	.6239E+02
	.8348E+01	.8740E+01	.4336E+00	.1126E+02				
103	.2740E+01	-.2974E+03	.2940E-02	-.1283E-01	.1119E+02	.4108E+00	-.7996E+02	.6739E+02
	.7364E+00	.1086E+02	-.1851E+01	.1097E+02				
104	.3190E+01	-.2974E+03	.2595E-02	-.1272E-01	.1191E+02	.1234E+01	-.7276E+02	.6706E+02
	.2173E+01	.1097E+02	-.3023E+01	.1123E+02				
105	.3865E+01	-.2974E+03	.2149E-02	-.1269E-01	.1177E+02	.2625E+01	-.6989E+02	.6649E+02
	.3706E+01	.1069E+02	-.2952E+01	.1136E+02				
106	.4878E+01	-.2974E+03	.1589E-02	-.1273E-01	.1105E+02	.4492E+01	-.7143E+02	.6552E+02
	.5157E+01	.1036E+02	-.1979E+01	.1146E+02				
107	.6396E+01	-.2974E+03	.9521E-03	-.1276E-01	.9906E+01	.6564E+01	-.7766E+02	.6392E+02
	.6717E+01	.9756E+01	-.6979E+00	.1136E+02				
108	.8674E+01	-.2974E+03	.2855E-03	-.1277E-01	.8745E+01	.8179E+01	.6678E+02	.6150E+02
	.8267E+01	.8657E+01	.2049E+00	.1106E+02				
109	.2740E+01	-.2970E+03	.2593E-02	-.1291E-01	.1414E+02	.9976E+00	-.7241E+02	.6602E+02
	.2196E+01	.1294E+02	-.3785E+01	.1146E+02				
110	.3190E+01	-.2970E+03	.2300E-02	-.1283E-01	.1305E+02	.2004E+01	-.6513E+02	.6572E+02
	.3957E+01	.1110E+02	-.4215E+01	.1139E+02				
111	.3865E+01	-.2970E+03	.1935E-02	-.1282E-01	.1208E+02	.3198E+01	-.6317E+02	.6520E+02
	.5008E+01	.1027E+02	-.3577E+01	.1135E+02				
112	.4878E+01	-.2970E+03	.1463E-02	-.1286E-01	.1104E+02	.4775E+01	-.6498E+02	.6432E+02
	.5696E+01	.9920E+01	-.2402E+01	.1132E+02				
113	.6396E+01	-.2970E+03	.9028E-03	-.1294E-01	.9825E+01	.6606E+01	-.7022E+02	.6286E+02
	.6974E+01	.9457E+01	-.1025E+01	.1120E+02				
114	.8674E+01	-.2970E+03	.2832E-03	-.1295E-01	.8550E+01	.8227E+01	.6948E+02	.6062E+02
	.8227E+01	.8550E+01	.2945E-02	.1081E+02				
115	.2599E+01	-.2965E+03	.2138E-02	-.1299E-01	.1727E+02	.2281E+01	-.5875E+02	.6447E+02
	.6315E+01	.1324E+02	-.6648E+01	.1209E+02				
116	.2984E+01	-.2962E+03	.1783E-02	-.1306E-01	.1452E+02	.3590E+01	-.5249E+02	.6356E+02
	.7642E+01	.1047E+02	-.5280E+01	.1165E+02				
117	.3562E+01	-.2959E+03	.1390E-02	-.1323E-01	.1276E+02	.4626E+01	-.4701E+02	.6223E+02
	.8419E+01	.8990E+01	-.4066E+01	.1130E+02				
118	.4430E+01	-.2954E+03	.9668E-03	-.1351E-01	.1131E+02	.5662E+01	-.4268E+02	.6031E+02
	.8715E+01	.8258E+01	-.2815E+01	.1090E+02				
119	.5731E+01	-.2946E+03	.5531E-03	-.1392E-01	.9975E+01	.6583E+01	-.3797E+02	.5761E+02
	.8690E+01	.7867E+01	-.1645E+01	.1038E+02				
120	.7682E+01	-.2934E+03	.1402E-03	-.1446E-01	.8872E+01	.7125E+01	-.2853E+02	.5403E+02
	.8474E+01	.7523E+01	-.7332E+00	.9665E+01				
121	.2360E+01	-.2961E+03	.1877E-02	-.1302E-01	.1841E+02	.1893E+01	-.5026E+02	.6356E+02
	.8644E+01	.1166E+02	-.8119E+01	.1209E+02				
122	.2710E+01	-.2958E+03	.1540E-02	-.1316E-01	.1544E+02	.3757E+01	-.4623E+02	.6257E+02
	.9346E+01	.9848E+01	-.5835E+01	.1171E+02				
123	.3236E+01	-.2954E+03	.1175E-02	-.1342E-01	.1323E+02	.4992E+01	-.4077E+02	.6113E+02
	.9715E+01	.8503E+01	-.4072E+01	.1126E+02				
124	.4023E+01	-.2948E+03	.7949E-03	-.1376E-01	.1151E+02	.5921E+01	-.3569E+02	.5906E+02
	.9606E+01	.7822E+01	-.2646E+01	.1079E+02				
125	.5205E+01	-.2938E+03	.4379E-03	-.1424E-01	.1006E+02	.6637E+01	-.3062E+02	.5619E+02
	.9173E+01	.7525E+01	-.1501E+01	.1017E+02				
126	.6977E+01	-.2924E+03	.8508E-04	-.1487E-01	.8862E+01	.7029E+01	-.2329E+02	.5240E+02
	.8576E+01	.7315E+01	-.6659E+00	.9398E+01				
127	.2076E+01	-.2958E+03	.1607E-02	-.1304E-01	.1910E+02	.1765E+01	-.4190E+02	.6276E+02
	.1137E+02	.9497E+01	-.8619E+01	.1208E+02				
128	.2386E+01	-.2955E+03	.1301E-02	-.1328E-01	.1618E+02	.3741E+01	-.3906E+02	.6171E+02
	.1124E+02	.8680E+01	-.6086E+01	.1171E+02				
129	.2846E+01	-.2950E+03	.9702E-03	-.1359E-01				

	.1093E+02	.7924E+01	-.3954E+01	.1125E+02	.1366E+02	.5197E+01	-.3458E+02	.6017E+02
130	.3541E+01	-.2943E+03	.6350E-03	-.1400E-01				
	.1034E+02	.7481E+01	-.2374E+01	.1069E+02	.1168E+02	.6147E+01	-.2951E+02	.5799E+02
131	.4581E+01	-.2932E+03	.3110E-03	-.1454E-01				
	.9531E+01	.7318E+01	-.1261E+01	.1001E+02	.1010E+02	.6747E+01	-.2437E+02	.5497E+02
132	.6142E+01	-.2915E+03	.3662E-04	-.1523E-01				
	.8620E+01	.7207E+01	-.5241E+00	.8156E+01	.8793E+01	.7033E+01	-.1828E+02	.5099E+02
133	.1756E+01	-.2956E+03	.1327E-02	-.1307E-01				
	.1412E+02	.7402E+01	-.8333E+01	.1210E+02	.1974E+02	.1775E+01	-.3403E+02	.6212E+02
134	.2016E+01	-.2952E+03	.1061E-02	-.1336E-01				
	.1315E+02	.7364E+01	-.5805E+01	.1172E+02	.1675E+02	.3773E+01	-.3175E+02	.6100E+02
135	.2407E+01	-.2946E+03	.7756E-03	-.1374E-01				
	.1208E+02	.7283E+01	-.3625E+01	.1123E+02	.1403E+02	.5335E+01	-.2825E+02	.5938E+02
136	.2993E+01	-.2938E+03	.4902E-03	-.1421E-01				
	.1094E+02	.7231E+01	-.2030E+01	.1062E+02	.1164E+02	.6337E+01	-.2376E+02	.5709E+02
137	.3872E+01	-.2926E+03	.2208E-03	-.1461E-01				
	.9768E+01	.7225E+01	-.9878E+00	.9870E+01	.1011E+02	.6887E+01	-.1892E+02	.5395E+02
138	.5190E+01	-.2907E+03	.1255E-05	-.1555E-01				
	.8603E+01	.7189E+01	-.3604E+00	.8957E+01	.8689E+01	.7103E+01	-.1351E+02	.4981E+02
139	.1401E+01	-.2953E+03	.1039E-02	-.1309E-01				
	.1667E+02	.5467E+01	-.7360E+01	.1214E+02	.2032E+02	.1819E+01	-.2637E+02	.6159E+02
140	.1609E+01	-.2949E+03	.8218E-03	-.1344E-01				
	.1489E+02	.6145E+01	-.5044E+01	.1173E+02	.1719E+02	.3841E+01	-.2455E+02	.6042E+02
141	.1921E+01	-.2943E+03	.5902E-03	-.1386E-01				
	.1309E+02	.6685E+01	-.3067E+01	.1120E+02	.1432E+02	.5453E+01	-.2188E+02	.5874E+02
142	.2368E+01	-.2934E+03	.3610E-03	-.1439E-01				
	.1142E+02	.7033E+01	-.1626E+01	.1055E+02	.1195E+02	.6496E+01	-.1826E+02	.5637E+02
143	.3090E+01	-.2921E+03	.1478E-03	-.1503E-01				
	.9909E+01	.7211E+01	-.7204E+00	.9762E+01	.1009E+02	.7031E+01	-.1405E+02	.5313E+02
144	.4142E+01	-.2901E+03	-.3915E-04	-.1582E-01				
	.6540E+01	.7236E+01	-.2136E+00	.8800E+01	.8574E+01	.7202E+01	-.9081E+01	.4886E+02
145	.1020E+01	-.2952E+03	.7465E-03	-.1311E-01				
	.1882E+02	.3827E+01	-.5770E+01	.1217E+02	.2078E+02	.1863E+01	-.1880E+02	.6119E+02
146	.1171E+01	-.2947E+03	.5851E-03	-.1349E-01				
	.1630E+02	.5141E+01	-.3897E+01	.1174E+02	.1753E+02	.3915E+01	-.1746E+02	.5999E+02
147	.1398E+01	-.2941E+03	.4144E-03	-.1396E-01				
	.1369E+02	.6201E+01	-.2321E+01	.1119E+02	.1453E+02	.5555E+01	-.1556E+02	.5826E+02
148	.1739E+01	-.2932E+03	.2459E-03	-.1452E-01				
	.1177E+02	.6896E+01	-.1181E+01	.1051E+02	.1204E+02	.6625E+01	-.1294E+02	.5583E+02
149	.2249E+01	-.2917E+03	.9156E-04	-.1520E-01				
	.9980E+01	.7241E+01	-.4794E+00	.9662E+01	.1006E+02	.7160E+01	-.9646E+01	.5251E+02
150	.3015E+01	-.2896E+03	-.4208E-04	-.1602E-01				
	.8455E+01	.7315E+01	-.1064E+00	.8684E+01	.8465E+01	.7305E+01	-.5289E+01	.4816E+02
151	.6197E+00	-.2951E+03	.4493E-03	-.1312E-01				
	.2037E+02	.2631E+01	-.3680E+01	.1220E+02	.2110E+02	.1896E+01	-.1127E+02	.6093E+02
152	.7117E+00	-.2946E+03	.3499E-03	-.1353E-01				
	.1730E+02	.4427E+01	-.2459E+01	.1175E+02	.1775E+02	.3973E+01	-.1045E+02	.5970E+02
153	.8496E+00	-.2940E+03	.2453E-03	-.1403E-01				
	.1444E+02	.5868E+01	-.1443E+01	.1118E+02	.1467E+02	.5631E+01	-.9307E+01	.5794E+02
154	.1056E+01	-.2930E+03	.1430E-03	-.1462E-01				
	.1199E+02	.6814E+01	-.7143E+00	.1048E+02	.1209E+02	.6718E+01	-.7712E+01	.5547E+02
155	.1367E+01	-.2915E+03	.4949E-04	-.1532E-01				
	.1001E+02	.7282E+01	-.2706E+00	.9629E+01	.1004E+02	.7255E+01	-.5613E+01	.5210E+02
156	.1832E+01	-.2893E+03	-.3082E-04	-.1616E-01				
	.8379E+01	.7391E+01	-.4211E-01	.8606E+01	.8381E+01	.7389E+01	-.2436E+01	.4769E+02
157	.2079E+00	-.2950E+03	.1500E-03	-.1313E-01				
	.2119E+02	.1999E+01	-.1264E+01	.1222E+02	.2127E+02	.1916E+01	-.3754E+01	.6080E+02
158	.2387E+00	-.2946E+03	.1164E-03	-.1355E-01				
	.1782E+02	.4056E+01	-.8401E+00	.1176E+02	.1787E+02	.4005E+01	-.3481E+01	.5956E+02
159	.2849E+00	-.2939E+03	.8117E-04	-.1407E-01				
	.1472E+02	.5699E+01	-.4893E+00	.1118E+02	.1474E+02	.5672E+01	-.3097E+01	.5778E+02
160	.3543E+00	-.2929E+03	.4678E-04	-.1467E-01				
	.1210E+02	.6777E+01	-.2387E+00	.1046E+02	.1211E+02	.6766E+01	-.2561E+01	.5529E+02
161	.4584E+00	-.2914E+03	.1547E-04	-.1538E-01				
	.1002E+02	.7310E+01	-.8702E-01	.9603E+01	.1002E+02	.7307E+01	-.1839E+01	.5190E+02
162	.6144E+00	-.2891E+03	-.1133E-04	-.1623E-01				
	.8334E+01	.7436E+01	-.1007E-01	.8570E+01	.8334E+01	.7436E+01	-.6420E+00	.4745E+02

TIME REQUIRED TO COMPUTE STRESSES AND DISPLACEMENTS AT STRESS POINTS= 652.35 SECONDS.

JOB COMPLETED AT 7: 7 HOURS

DATA FOR PLOTTING WILL BE STORED IN FILE NAMED VERT10

APPENDIX C

Description of the POSTHEF Code for Postprocessing Results of HEFF Analyses

DESCRIPTION OF THE POSTHEF CODE FOR POST-PROCESSING RESULTS OF HEFF ANALYSES

POSTHEF is a special purpose post-processor intended to plot output from a run of HEFF, during which the output has been generated for a single time step. On-screen graphics are generated using the HALO Graphics Perimitives (Media Cybernetics, 800-446-HALO), and plots are generated by performing screen dumps using the HALO instruction GPRINT. POSTHEF also uses one routine coded in PASCAL. This reads data directly from the keyboard, allowing the user to determine whether or not the graphics image generated on the screen is to be plotted.

The use of POSTHEF is almost entirely self-explanatory since the program interrogates the user. However, the following notes may be helpful.

1) Plot options offered are:
   - Factors of Safety
   - Temperature Contours
   - Deformed Boundary
   - Boundary (or Tangential) Stress
   - Principal Stress Vectors
   - Stress Contours
   - Extensile Strain

2) For the factor of safety plots, the strength of the rock matrix has been defined using a Mohr-Coulomb failure criterion. Specifically, if the computed major and minor principal stresses at a point are S1 and S3, respectively, the factor of safety against matrix failure is defined as:

$$FSM = \frac{(S1+S3)\ \sin FM + Q\ (1-\sin FM)}{(S1-S3)}: \quad S3 > \text{tensile strength} \qquad (1)$$

$$FSM = 0 \text{ for } S3 \leq \text{tensile strength} \qquad (2)$$

in which Q and FM are, respectively, the uniaxial compressive strength and the friction angle for the matrix of the rock mass. S1 and S3 are the major

Note that the user of POSTHEF can force the code to assume that the out-of-plane stress is always intermediate. To select this option, enter "N" when requested whether out-of-plane stresses are to be considered.

The shear strength of preexisting joints is defined by a Coulomb-Navier criterion. Specifically, if SS and SN are the computed shear and normal stresses on a plane of a given orientation, the factor of safety against slip is defined as:

$$FSJ = \frac{CJ + SN \tan FJ}{SS}: \quad SN \geq 0 \tag{3}$$

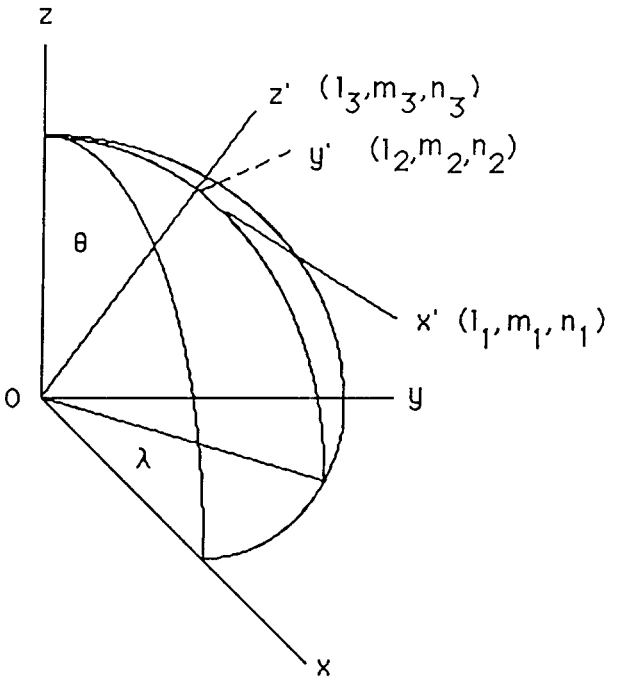
$$FSJ = 0.0 \qquad SN < 0 \tag{4}$$

in which CJ and FJ are, respectively, the cohesion and friction angle of the joint. Since joints do not usually possess any strength in tension, the factor of safety is assumed to be zero if the normal stress, SN, is tensile.

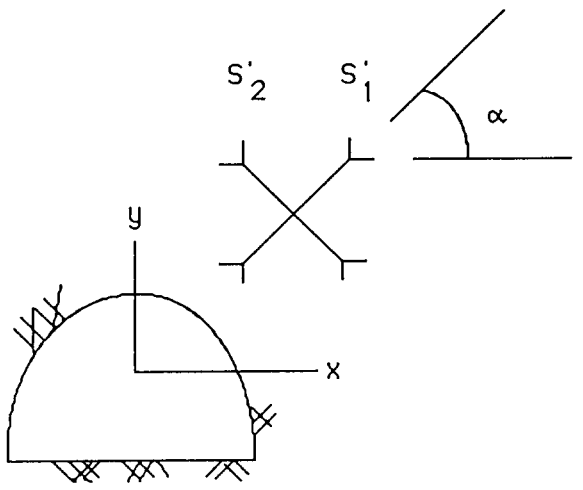
The joint can be oriented in any direction relative to the plane of the analysis. Accordingly, general transformation equations are required to calculate the shear and normal stresses. If we assume that the orientation of the joint plane relative to the plane of the analysis is defined by the angles (L) and (T), then the direction cosines or mutually perpendicular axes in the joint plane and normal to it are (Jaeger and Cook, 1976):

$L_1 = \cos(T)\cos(L-A)$	$M_1 = \cos(T)\sin(L-A)$	$N_1 = -\sin(T)$
$L_2 = -\sin(L-A)$	$M_2 = \cos(L-A)$	$N_2 = 0$
$L_3 = \sin(T)\cos(L-A)$	$M_3 = \sin(T)\sin(L-A)$	$N_3 = \cos(T)$

L and T are defined by Figure 2.5 of Jaeger and Cook, which is reproduced as Figure 1. (L is the orientation of the trace of the



(a) Orientation of Principal Stress in the Plane of the Drift Section



(b) Definition of the Local Coordinate Axes for the Joint Planes

Figure 1

normal to the joint plane in the xy plane, relative to the x axis, and T is the orientation of the normal relative to the z axis. Hence, for a joint that is vertical and perpendicular to the plane of the section, L = 0 and T = 90 degrees.) A is the orientation of the most compressive principal stress in the plane of the analysis, measured relative to the x axis.

The normal and maximum shear stress on the joint plane are now given by (Jaeger and Cook, 1976):

$$SN = L_3^2 S1' + M_3^2 S2' + N_3^2 S3'$$

$$SS = SQRT((L_2L_3S1'+M_2M_3S2'+N_2N_3S3')^2+(L_3L_1S1'+M_3M_1S2'+N_3N_1S3')^2)$$

in which the S1' and S2' are the in-plane principal stresses and S3' is the out-of-plane stress, SZZ.

Note that the code calculates the factor of safety using either the matrix criterion or the joint criterion or both and selects the lesser of the two on a point by point basis, for contouring.

3) For the extensile strain plots, the extensile strain is defined as

$$\epsilon_3 = 100\left[S_3 - \nu\left(S_1 + S_2\right)\right]/EMOD$$

where EMOD is the Poisson ratio ν of the rock mass, S_1, S_2, and S_3 are the principal stresses, and the extensile strain ϵ_3 is expressed as a percentage. Both EMOD and ν are input following screen requests.

4) POSTHEF will only function correctly for data points generated normal to a sequence of boundary elements that define a continuous, and ordered, contour. The user may elect to plot data for fewer than the total number of elements along which output was generated using HEFF. In that case, data at the end of the records generated by HEFF is discarded. Hence, when setting up the data for the HEFF analysis, the user must take care in ordering the boundary elements, and ensure that the elements for which plotting is to be performed are defined first.

5) The program asks for the name of the output file. This will contain an echo of the data processed and output from the calculation of factor of safety, if performed.

6) Once a plot has been generated on the screen, the user has two choices; press "P," in which case the contents of the screen are redrawn and copied to the printer, or press return or space if additional plots are required. Any other keyboard entry will cause the bell to ring. Note: there is no user prompt to act as a reminder that a keyboard entry is required.

7) When creating an executable version of POSTHEF, it is necessary to use compatible versions of FORTRAN, PASCAL, and HALO. The current version of POSTHEF is written for Microsoft 3.3 Fortran, so the code should be linked with the Microsoft Pascal Library and the Microsoft compatible version of HALO. As of this date, the most recent version of HALO is version 2.26.

To create an executable file POSTHEF.EXE from the compiled source codes (source.OBJ), type:

```
\path\LINK @POSTHEF.LNK,,, \path\8087 \path\FORTRAN \path\PASCAL \ path\HALOF
```

where \path\ is the DOS path to the LINK program or libraries, and the file POSTHEF.LNK looks like this:

```
POSTHEF + UTILG + UTILP + UTILC + \path\HALODVXX + \path\TOOL
```

HALODVXX is the HALO graphics object file, and TOOL is the PASCAL routine for getting a character from the keyboard while in graphics mode. For example, if the program LINK.EXE and PASCAL module TOOL.OBJ are in directory c:\comp3\, along with the libraries 8087.LIB, FORTRAN-.LIB and PASCAL.LIB, and if the HALO library HALOF.LIB and object file HALODVXX.OBJ are in directory c:\HALO\, then file POSTHEF.LNK would be:

```
POSTHEF + UTILG + UTILP + UTILC + \HALO\HALODVXX + \comp3\TOOL
```

and the LINK command line would be:

```
\comp3\LINK @POSTHEF,,, \comp3\8087 \comp3\FORTRAN \comp3\PASCAL \HALO\ HALOF
```

8) At run time, POSTHEF requires that a file called DEVICE exists in the current directory. Lines 1 and 2 of this file must contain the name of the HALO graphics card driver and printer driver file names, respectively. The path to these device drivers must also be present unless they reside in the current directory. Line 3 contains the XRANGE and YRANGE parameters for the screen and printer being used. Line 4 contains the HALO mode number and two color numbers for plotting on an EGA monitor. The following is an example of the file DEVICE for plotting on a HERCULES monographics monitor and printing to an HP Laserjet:

```
$haloherc.dev$
$halolasr.prn$
8.307,6.100,7.00,3.34
1,1,1
```

The first two numbers on line 3 are used to plot undistorted on the screen, and the second two are used for undistorted printer plots. These four numbers may need to be adjusted when using other graphics cards and printers. POSTHEF will tell the user if any syntax errors occur in file DEVICE at run time.

APPENDIX D

RIB and SEPDB Appendix

RIB AND SEPDB APPENDIX

No RIB or SEPDB data were used in this report because the results are generic in nature and, thus, are not contingent upon specific input parameters.

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