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STRESsOUT—A Data Reduction Program for Inferring Stress State of Rock Having Isotropic Material Properties: A User's Manual

By Mark K. Larson

UNITED STATES DEPARTMENT OF THE INTERIOR

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The background of the development of the program, its capabilities, and its special features are described in this report, as well as the input required. Sample output is also shown in appendix B.

Difficulties associated with numerical calculations of principal stresses and directions are pointed out. Threshold values for detecting these problems are reported; these values may be changed by the user as desired.

Several test problems were set up to verify the computer program and were solved successfully.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

deg	degree	m	meter
ft	foot	mm	millimeter
GPa	gigapascal	m/m	meter per meter
in	inch	MPa	megapascal
in/in	inch per inch	pct	percent
Kb	kilobyte	psi	pound (force) per square inch

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STRESsOUT—A DATA REDUCTION PROGRAM FOR INFERRING STRESS STATE OF ROCK HAVING ISOTROPIC MATERIAL PROPERTIES: A USER'S MANUAL

By Mark K. Larson[1]

ABSTRACT

Researchers at the U.S. Bureau of Mines have developed a FORTRAN computer program that can calculate stress states from overcoring measurements obtained from hollow inclusion cells, triaxial cells, strain gauges installed on the wall of a bored raise, doorstopper gauges, borehole deformation gauges, or a combination of any of these gauges. Such stress states are calculated with reference to global and principal coordinate systems.

The background of the development of the program, its capabilities, and its special features, as well as the input required, are described in this report. Sample output is also shown in appendix C.

Difficulties associated with numerical calculations of principal stresses and directions are pointed out. Threshold values for detecting these problems are reported; these values may be changed by the user as desired.

Several test problems were set up to verify the computer program and were successfully solved.

[1]Mining engineer, Spokane Research Center, U.S. Bureau of Mines, Spokane, WA.

INTRODUCTION

As more difficult ground conditions are encountered during underground mining operations, mining engineers are increasingly integrating the principles of rock mechanics into the design of excavations and mine layouts. To do this, estimates of the stress state in the surrounding rock mass become more important. A vital link to estimating stress-state components is a computer routine that will calculate the best fit stress state given the specific data.

As part of its program to improve mine safety, the U.S. Bureau of Mines has developed and tested such a computer program. STRESsOUT fits the stress state to collected measurements using the least-squares method. This method was demonstrated by Panek (*1*)[2] for overcoring data obtained from a borehole deformation gauge developed by the Bureau.

STRESsOUT is a modification of the program MIMSICELL (*2*), written by D. J. Fitzgerald, which reduces measurements obtained during overcoring with the hollow inclusion stress cell developed by the Commonwealth Scientific and Industrial Research Organization (CSIRO),[3] Mount Waverley, Australia. The analysis was for a continuous, isotropic, linearly elastic rock medium. There were three significant disadvantages in using MIMSICELL.

1. Although MIMSICELL was structured to include the possibility of reducing measurements obtained from doorstopper gauges and other instruments, these routines were never included in the code.

2. Because MIMSICELL was written before the full set of equations for K-factors, which relate an analysis to strains in the instrument's epoxy shell, were derived (*3*), K-factor equations were not included. Instead, constant values for the K-factors were assumed, and the dependence of the K-factors on the properties of the host rock and the cell, the size of the borehole, and the radial position of the strain gauge in the epoxy shell was neglected.

3. MIMSICELL's option to determine fitted elastic rock properties, based on results from a biaxial compression test on overcores, was flawed because it assumed values for the K-factors.

The MIMSICELL program was improved when Jalkanen (*4*) wrote a subroutine to calculate the K-factors and developed a scheme that iteratively determined the elastic properties of the rock and the K-factors when biaxial compression data from tests on the overcores were given. These improvements were incorporated into the STRESsOUT program.

An imperfection was later discovered in the MIMSICELL program. In the code routine, principal stresses and directions are calculated from fitted global stress components according to the equations found in reference 1. This procedure does not guarantee that the principal stresses will be listed in a consistent, algebraic order, nor does it guarantee a right-handed system. In addition, singularities in the calculation routine, which signify nonunique angles or other difficulties, and computer errors created by rounding off generally resulted in flawed calculations of principal directions.

At the suggestion of W. G. Pariseau, McKinnon professor of mining engineering at the University of Utah, changes were made in the code that would force algebraic ordering of the principal stresses from maximum to minimum, force a right-handed principal system, and filter out nonunique principal direction angles (azimuth and inclination).

Other capabilities were added to the program at the request of various users. STRESsOUT can now fit stress states to measurements from hollow inclusion cells, triaxial cells, strain gauges installed on the walls of bored raises, doorstopper gauges, borehole deformation gauges, or any combination of these gauge types as long as the combination of measurements, boreholes, and borehole orientations are sufficient. Finally, STRESsOUT has been revised so that a user can move through the program more easily. Additional comments have been inserted in the code to aid a user in understanding the flow of the program.

In this manual, it is assumed that the user is acquainted with the instruments for which this computer program was written, the redundancies of measurements for each instrument, the overcoring process, and how to screen measurements. The number of measurements and boreholes required for each instrument to determine the stress state is repeated to aid the discussion about using measurements from several instrument types in the same analysis to determine the stress state.

[2]Italic numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

[3]Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

ACKNOWLEDGMENTS

Special thanks are extended to D. J. Fitzgerald of Mindata Pty. Ltd., who permitted the author to publish this modification of MIMSICELL, and to Gerald J. Jalkanen, who permitted inclusion of his work on fitting elastic properties from biaxial compression tests. The author is also grateful for the many hours of discussion with W. G. Pariseau, McKinnon professor of mining engineering, University of Utah, Salt Lake City, UT, and Jeffrey C. Johnson and Jeffrey K. Whyatt, mining engineers at the Spokane Research Center, who contributed immensely to development of STRESsOUT.

PROGRAM PACKAGE AND SYSTEM REQUIREMENTS

The program package consists of one double-sided, double-density IBM PC or IBM-compatible 5-1/4-in floppy diskette and this report. A copy of the diskette can be obtained by sending one double-sided, double-density, 5-1/4-in floppy diskette to the Spokane Research Center, U.S. Bureau of Mines, East 315 Montgomery Ave., Spokane, WA 99207-2291. Requests for the package should reference this report.

STRESsOUT is designed to be used on a computer with a minimum of 256 Kb of random access memory (RAM). Additional RAM may be needed if the user increases the size of the arrays. The user should have a FORTRAN compiler so that PARAMETER statements and threshold values in the code may be changed as desired.

PROGRAM CAPABILITIES

STRESsOUT fits six independent stress-state components to overcoring data using the least-squares method. The stress field near the measurement site is assumed to be constant except for the effect of the boreholes. The rock at each measurement site may be assigned a different set of material properties, but the analysis assumes that material properties of each overcore are isotropic and linearly elastic. The program also fits isotropic elastic properties when data are provided from compressive biaxial tests on an overcore in those cases where a hollow inclusion cell or a triaxial cell is bonded to the wall of the borehole. The kinds of instruments and equations used in the analysis are reviewed here to aid the user and to point out features of STRESsOUT.

OVERCORING MEASUREMENTS

The program reduces measurements to stresses according to

$$M_i = \{C\}_i^T \{\sigma^L\} + e_i, \tag{1}$$

where M_i = local measurement i,

$\{C\}_i^T$ = transposed vector of dimension 1 × 6 of coefficients for measurement i,

$\{\sigma^L\}$ = vector of six independent stress components in local coordinate system (that is, the coordinate system of the particular borehole),

and e_i = error for ith measurement. The stress components are fit by minimizing the sum of the squared error. The stress state is referred to a global coordinate system (fig. 1) by

$$\{\sigma^L\} = \begin{Bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \sigma_{xy} \\ \sigma_{yz} \\ \sigma_{zx} \end{Bmatrix} = [T]\,\{\sigma^G\} = [T] \begin{Bmatrix} \sigma_{NN} \\ \sigma_{EE} \\ \sigma_{VV} \\ \sigma_{NE} \\ \sigma_{EV} \\ \sigma_{VN} \end{Bmatrix}, \tag{2}$$

where σ_{xx} through σ_{zx} = stress state components in local coordinate system,

σ_{NN} through σ_{VN} = stress state components in global coordinate system,

[T] = tranformation matrix,

and $\{\sigma^G\}$ = vector of gobal stress components.

STRESsOUT has built in the various $\{C\}_i^T$ for hollow inclusion cells, triaxial stress cells, strain gauges installed on the wall of a bored raise, doorstopper gauges, and borehole deformation gauges. A menu gives the user the choice of reducing measurements from any one of these

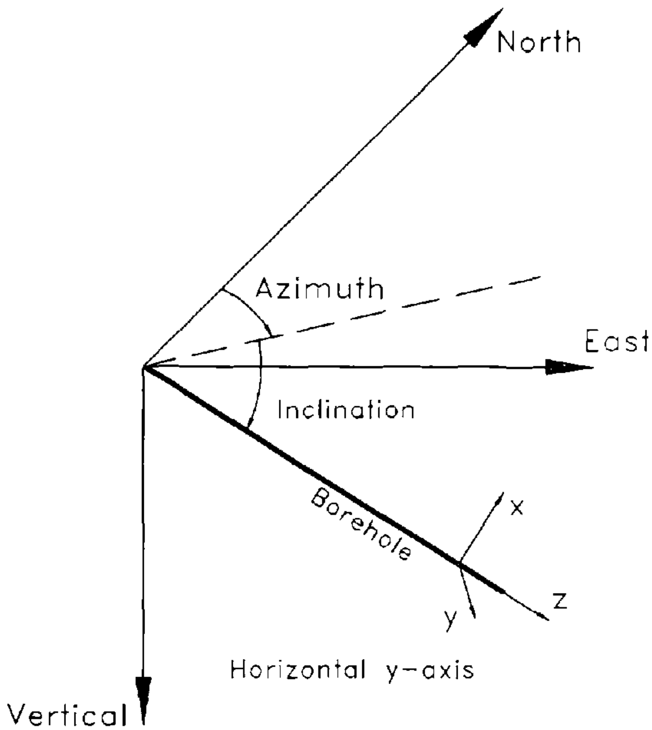

Figure 1.—Local xyz coordinate system with reference to global coordinate system.

gauges or from a combination of any of these gauges. The $\{C\}_i^T$ for each measurement is referenced to the global coordinate system by multiplying $\{C\}_i^T$ by [T]. The resulting coefficients are assembled in an [XX] array—that is, the $\{C\}_i^T$ for one measurement (the *i*th measurement) occupies one row (the *i*th row) in [XX]—and the measurements are assembled in a {YY} array.

In performing the least-squares fit on *N* measurements, the $N \times 6$ matrix [XX] and the $N \times 1$ array [YY] are condensed to the 6×6 coefficient matrix [A] and the 6×1 array {B}, respectively. It is then possible to solve equation 3 for the global stress-state components $\{\sigma^G\}$, that is,

$$[A]\,\{\sigma^G\} = \{B\}. \tag{3}$$

After solving for the global stress state, the program calculates the principal stresses and directions in terms of azimuth and inclination.

The $\{C\}_i^T$ for each instrument is shown next. In the expressions below, α is an angle showing location or orientation of the gauge of interest, and β is the tilt of the gauge. The definition of positive α for hollow inclusion cells, triaxial cells, strain gauges on the wall of a bored raise, doorstopper gauges, and borehole deformation gauges, respectively, are illustrated in figure 2. The former three instruments also require angle β to define the tilt of the strain gauge of interest. Referring to the polar coordinate system, or $r\alpha z$ coordinate system, positive β is defined as the angle from the positive α-direction toward the positive z-axis to the centerline of the strain gauge of interest (fig. 3).[4] The definition of β in MIMSICELL is different than in STRESsOUT (fig. 3).

Hollow Inclusion Cells

The transposed $\{C\}_i^T$ for hollow inclusion cells (*2, 5-6*) is shown in equation 4 below

[4]The angle definition convention adopted for α and β in STRESsOUT is as follows: Let there be a right-handed coordinate system 1,2,3. Let a,b,c also represent that system such that a,b,c represents an even permutation (that is, 1,2,3; 2,3,1; or 3,1,2). Looking from the positive c-direction, the angle is defined as positive from the a-axis counterclockwise to the item of interest.

$$\{C\}_i = \left\{ \begin{array}{l} \dfrac{1}{YM}\left[\dfrac{K_1 - \nu}{2} + \dfrac{K_1 + \nu}{2}\cos(2\beta_i) - (1-\nu^2)\cos(2\alpha_i)\,(1+\cos(2\beta_i))\,K_2\right] \\ \dfrac{1}{YM}\left[\dfrac{K_1 - \nu}{2} + \dfrac{K_1 + \nu}{2}\cos(2\beta_i) + (1-\nu^2)\cos(2\alpha_i)\,(1+\cos(2\beta_i))\,K_2\right] \\ \dfrac{1}{YM}\left[\dfrac{1 - \nu K_4}{2} - \dfrac{1 + \nu K_4}{2}\cos(2\beta_i)\right] \\ \dfrac{1}{YM}\left[2(\nu^2 - 1)\sin(2\alpha_i)\,(1+\cos(2\beta_i))\,K_2\right] \\ \dfrac{1}{YM}\left[2(1+\nu)\cos(\alpha_i)\sin(2\beta_i)\,K_3\right] \\ \dfrac{1}{YM}\left[-2(1+\nu)\sin(\alpha_i)\sin(2\beta_i)\,K_3\right], \end{array} \right\}, \tag{4}$$

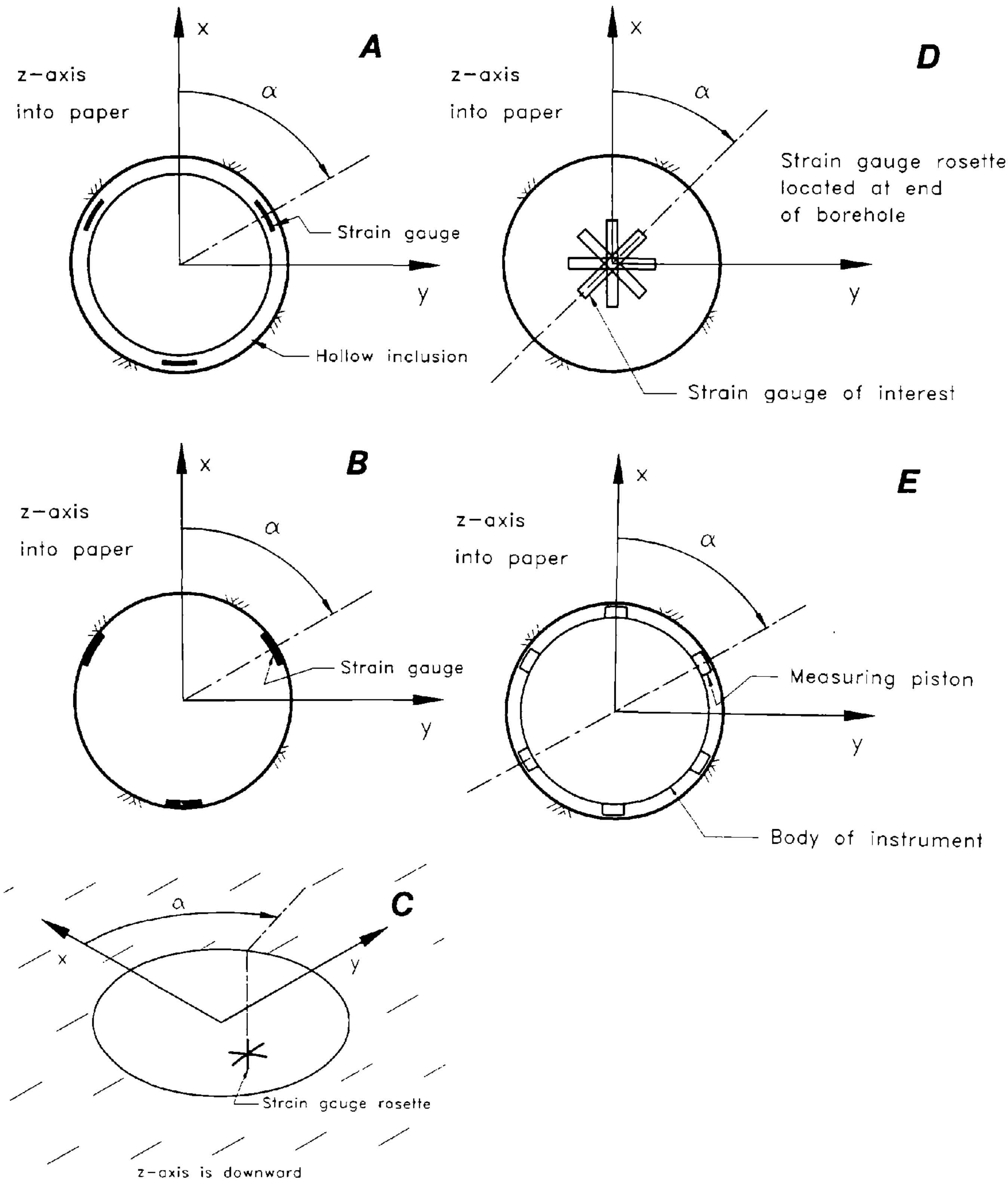

Figure 2.—Definition of angle α. *A*, Hollow inclusion cell; *B*, triaxial cell; *C*, strain gauges bonded to wall of bored raise; *D*, doorstopper gauge; *E*, borehole deformation gauge. *A-B* and *D-E* are views into borehole.

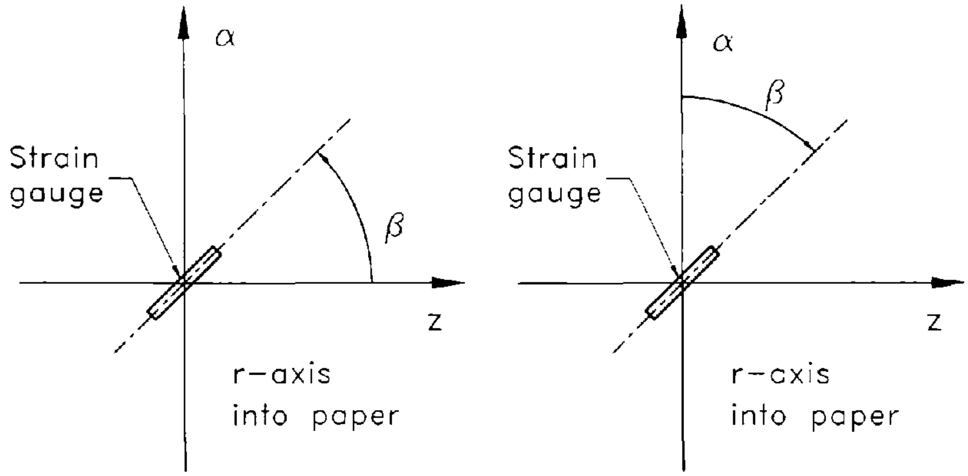

Figure 3.—Definition of angle β with reference to local polar coordinate axes ($r\alpha z$ axes). *A*, Left axes as used in reference 2; *B*, right axes as used in STRESsOUT.

where $\{C\}_i$ = ith vector of coefficients (tranpose of $\{C\}_i^T$),

K_1, K_2, K_3, and K_4 = K-factors that relate strain on the walls of a borehole to the strain at the locations of the strain gauges (*3*),

YM = isotropic Young's modulus,

ν = isotropic Poisson's ratio,

and α = angle between x-axis and centerline of strain gauge (fig. 2).

Triaxial Cells

$\{C\}_i$ for strain gauges in a triaxial cell (*6-7*) is the same as in equation 4, except that K_1, K_2, K_3, and K_4 are set equal to 1.

Strain Gauges on Wall of Bored Raise

$\{C\}_i$ for strain gauges on the wall of a bored raise is found by replacing K_1, K_2, K_3, and K_4 by 1.0 in equation 4 and treating the bored raise in the same way a borehole is treated for a hollow inclusion cell or a triaxial cell.

This method consists of bonding strain gauge rosettes directly to the wall of a bored raise in at least three locations of different orientation (different α). Each rosette is overcored separately.

Doorstopper Gauges

$\{C\}_i$ for strain gauges on a doorstopper (*7-8*) is shown in equation 5,

$$\{C\}_i = \left\{\begin{array}{l} \frac{1}{YM}\left[(a-\nu b)\cos^2(\alpha_i) + (b-\nu a)\sin^2(\alpha_i)\right] \\ \frac{1}{YM}\left[(b-\nu a)\cos^2(\alpha_i) + (a-\nu b)\sin^2(\alpha_i)\right] \\ \frac{1}{YM}\left[c(1-\nu)\right] \\ \frac{1}{YM}\left[2d(1+\nu)\sin(\alpha_i)\cos(\alpha_i)\right] \\ 0 \\ 0 \end{array}\right\}, \quad (5)$$

where a, b, c, d = factors that describe stress concentrations on end of borehole.

Several researchers have proposed values of, or equations for, finding the stress concentration factors (table 1). STRESsOUT has three options for determining the stress concentration factors. The first option is to calculate the factors with the equations proposed by Rahn (*9*), which he obtained from results of a finite-element analysis using axisymmetric elements.

$$a = 1.32 + 0.08\nu\,(1+\nu),$$
$$b = -0.12 + 0.18\nu\,(1 + 2.55\nu),$$
$$c = -1.09 \times (0.33 + \nu),$$

and
$$d = a - b. \quad (6)$$

Table 1.—Stress concentration factors at flat end of borehole in isotropic rocks (after Rahn (9))

Method	ν	a	b	c	Source
Photoelastic experiment.	0.48	1.55	0	NM	
	.29	1.51	0	NM	Leeman, 1964 (8).
	.26	1.53	0	NM	
Do.	.47	1.56	0	NM	Galle and Wilhiot, 1966 (*10*).
Experiment . . .	.22	1.56	0	NM	Hoskins, 1967 (*11*).
Do.	.44	1.42	-.06	-1.10	
	.37	1.39	-.20	-.98	Hiramatsu and Oka, 1968 (*12*).
	.29	1.32	-.29	-.82	
Photoelastic experiment.	.48	1.25	-.07	-.85	
	.35	1.28	-.02	-.74	
	.30	1.24	-.07	-.71	Van Heerden, 1969 (*13*).
	.26	1.22	-.10	-.67	
FEM (axisymmetric).	.4	1.45	0	-.91	
	.3	1.41	-.04	-.84	Coates and Yu, 1970 (*14*).
	.2	1.40	-.08	-.75	
	0	1.36	-.12	-.52	
Experiment . . .	.38	1.25	0	NM	Bonnechere and Fairhurst, 1971 (*15*).
Dynamic relaxation.	.45	1.45	NM	-.85	
	.4	1.35	NM	-.81	
	.3	1.28	NM	-.71	Hiltscher, 1971 (*16*).
	.2	1.25	NM	-.60	
	.1	1.21	NM	-.51	
	0	1.19	NM	-.41	
BIEM (3-D)	.475	1.39	.08	-.91	
	.4	1.38	.03	-.82	
	.3	1.36	-.03	-.70	
	.25	1.36	-.05	-.64	Hocking, 1976 (*17*).
	.2	1.35	-.07	-.58	
	.1	1.34	-.10	-.48	
	0	1.33	-.13	-.37	
FEM (annual or elements).	.475	1.37	.06	-.86	
	.4	1.36	.02	-.80	
	.3	1.35	-.03	-.68	
	.2	1.34	-.07	-.57	Rahn, 1981 (*18*).
	.1	1.33	-.10	-.47	
	0	1.32	-.13	-.37	

BIEM Boundary-integral-element method.
FEM Finite-element method.
NM Not measured.

NOTE.—Data arranged in chronological order.

The second option uses a series of equations that were fit to results from a three-dimensional, boundary-element analysis performed by Hocking (*17*), in which:

$$a = 1.3302 + 0.085290\nu + 0.087445\nu^2,$$

$$b = -0.12745 + 0.17342\nu + 0.54919\nu^2,$$

$$c = -0.37140 - 1.0139\nu - 0.25717\nu^2,$$

and $$d = a - b. \tag{7}$$

The third option is a series of user-supplied values for a, b, c, and d.

The Rahn and Hocking options give stress concentration factors that are state of the art. Values from both options are very similar. However, if the user wants to use other values, table 1 may be used as a guide.

Borehole Deformation Gauges

The $\{C\}_i$ that relates the change in stress state to the change in borehole diameter measured with a borehole deformation gauge is shown in equation 8 (*19*).

$$\{C\}_i = \left\{\begin{array}{l} \dfrac{DIAM}{YM}\left[1 + 2(1 - \nu^2)\cos(2\alpha_i)\right] \\ \dfrac{DIAM}{YM}\left[1 - 2(1 - \nu^2)\cos(2\alpha_i)\right] \\ \dfrac{DIAM}{YM}\left[-\nu\right] \\ \dfrac{DIAM}{YM}\left[4(1 - \nu^2)\sin(2\alpha_i)\right] \\ 0 \\ 0 \end{array}\right\}, \tag{8}$$

where DIAM = diameter of borehole.

The instrument and the measurement method are described in Merrill (*20*) and Leeman (*21*), while the overcoring method is described in Hooker and Bickel (*22*).

Combination of Instruments

The use of this option may be better demonstrated with an example.

Suppose that an engineer desires to measure the stress state in some area of an underground mine and so selects a site at the end of a drift or crosscut. Suppose also that a hollow inclusion cell is overcored in the first borehole, a borehole deformation gauge is overcored in the second borehole, and a doorstopper is overcored in the third borehole (fig. 4).

Examination of the overcore of the hollow inclusion gauge reveals poor bonding or air bubbles in the epoxy near two of the rosettes, thus requiring the elimination of six of the nine strain gauges when determining the stress state. Assuming that there is reason for confidence in the other three readings from the hollow inclusion cell and that there is no reason to discount the three measurements from the borehole deformation gauge or the four measurements from the doorstopper gauge, then the measurements from all three instrument types may be used together to determine the stress state even though the measurements

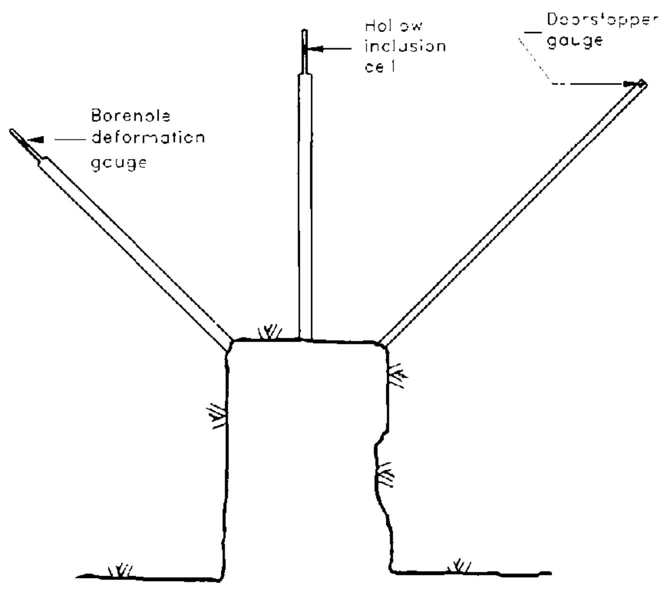

Figure 4.—Location of instruments at measurement site in example scenario for which measurements from combination of instrument types are used to infer stress state.

of each gauge type are insufficient in themselves to make the determination.[5]

In combining these readings, the [XX] array contains the $\{C\}_i^T$ transformed to the global coordinate system corresponding to each measurement. For example, the first three rows of the array would contain the transformed $\{C\}_i^T$ shown in equation 4 for the hollow inclusion cell, which corresponds to the three good strain measurements. According to equation 8, the next three rows would have the transformed $\{C\}_i^T$ for the three borehole deformation gauge measurements. The final four rows of [XX] would contain the $\{C\}_i^T$ shown in equation 5 transformed to the global coordinate system, which corresponds to the four doorstopper measurements.

The {YY} array contains the three hollow inclusion cell measurements, the three borehole deformation gauge measurements, and finally, the four doorstopper measurements.

BIAXIAL TEST MEASUREMENTS

STRESsOUT solves for the isotropic Young's modulus and Poisson's ratio using data from a biaxial compression test on an overcore obtained with a hollow inclusion stress cell or a triaxial cell. Only Young's modulus can be determined from biaxial compression test data of an overcore collected with a borehole deformation gauge; this routine, found in Kim and Franklin (*6*), was not included in STRESsOUT.

STRESsOUT has two options for biaxial test data. The first option is for measurements taken with a hollow inclusion cell. The program must determine K-factors through a predictor-corrector scheme proposed by Jalkanen (*4*). Initial estimates of K_1 and C1 factors[6] provide a beginning point, after which the program fits the rock elastic properties and calculates new K-factors. It then corrects rock properties by calculating the least-squares fit on the basis of the latest K-factors. This iterative process continues until improvements in both K_1 and C1 are less than a tolerance specified by the user. A suggested tolerance is given in the section "Input Data."

The second biaxial test data option is for measurements taken with a triaxial cell. In this calculation, the K-factors are set equal to 1.0, so that the program calculates the material properties directly using the least-squares method.

MODIFICATIONS

Several modifications to MIMSICELL in STRESsOUT were incorporated to enhance the program. These changes are described as follows:

1. Angle β (fig. 3), which describes the tilt of strain gauges for hollow inclusion cells, triaxial cells, or strain gauges on the wall of a bored raise, is defined differently in this manual than in the installation manual for the CSIRO HICell (2) and in MIMSICELL. In STRESsOUT, β is defined (with reference to the polar coordinate system $r\alpha z$) as positive from the positive α-axis counterclockwise to the axis of the gauge when looking from the positive r-axis toward the negative r-direction.[7] The equations in the hollow inclusion cell subroutine have been adjusted to

[5]To determine the stress state from borehole deformation gauge measurements, the user is referred to Moody (*23*), who points out that Leeman's assertion (*21*) that three nonparallel measurements in each of two boreholes are required to determine the six independent stress components is false. Instead, Moody states that a total of six measurements from three nonparallel boreholes is required. The same requirements apply for doorstopper gauge measurements. Gray and Toews (*24*) discuss required measurements from doorstopper gauges in addition to the borehole deformation gauges.

For strain measurements obtained with hollow inclusion cells, triaxial cells, or gauges on the wall of a bored raise, a total of at least six measurements from more than two locations on the wall of the borehole or bored raise are needed (*11*).

[6]This C1 is not the C_1 described by Duncan Fama and Pender (*3*), but that C_1 without the radii squared. In the STRESsOUT program, C1 is a variable used in subroutine MODCAL to set up the system of equations to solve for the material properties of an overcore.

[7]See footnote 4.

reflect this change. Angle α, the local coordinate system, and the global coordinate system are unchanged.

2. The user designates whether input is entered from a keyboard or from a file.

3. All input is in free format, except input for character variables.

4. The user may enter material properties or applied stresses from biaxial tests in either English or metric units. The program prompts the user to designate which system is desired.

5. All floating point variables are of the REAL*8 type. Having all variables involved in the least-squares summation and the matrix-solving routine in double precision achieves greater accuracy.

6. Six COMMON blocks minimize storage requirements. MEAS includes arrays having information about the measurements. BH contains arrays of angles describing orientation of boreholes. LS contains matrices with assembled equations that will provide the fitted least-squares solution when solved. The MP block contains the material properties, and BIAX includes a pointer and a flag used in the biaxial test data routine. FILE has the parameter IFL, which designates whether the input comes from a keyboard or a file.

7. The number of maximum measurements (currently 98) can be changed easily by setting NDIM[8] equal to another value (other than 99) in all FORTRAN PARAMETER statements in the code.

8. The program can handle measurements from several boreholes in the same analysis. The maximum number of boreholes is currently set at 10. This number is easily altered by setting NBHL to the desired value in all appropriate PARAMETER statements.

9. The program can handle multiple sets of isotropic properties in the same analysis. The maximum number of sets of properties is currently set at 10. This number is easily altered by setting NMTYP to the desired value in all appropriate PARAMETER statements.

10. The program can handle multiple values of borehole diameter in the borehole deformation gauge analysis. This capability should be used when the borehole diameter differs among overcores. The maximum number of different borehole diameters is currently set at 10. This number is easily altered by setting NDIA to the desired value in all appropriate PARAMETER statements.

11. MIMSICELL calculates a least-squares fit based on all measurements and calculates successive fittings after eliminating that measurement with the greatest absolute difference from the fitted strain. This process continues until the number of measurements is one more than the number required to determine the stress state. STRESsOUT goes through the same procedure, but the program prompts the user to designate the number of successive measurements to be eliminated in this fashion. The prompt informs the user as to the maximum number of measurements that can be eliminated but that will still yield an overdetermined system of equations so that the program can determine a solution and perform a statistical analysis.

12. The program can combine measurements from various gauge types for fitting the stress state. However, care must be taken to satisfy the necessary conditions for determining the stress state.

13. To aid in determining whether sufficient conditions for determining the stress state have been met (that is, whether six independent equations of the form of equation 1 are established by the selection of measurements), the determinant of the 6×6 coefficient matrix [A] (the coefficient matrix formed in the least-squares fit) is calculated and displayed. The analysis proceeds no further if the determinant shows that the matrix is singular, which indicates that there are less than six independent equations.

CODE STRUCTURE

STRESsOUT consists of a mainline program, nine subroutines, and two functions. The mainline program, SO-MAIN, acts as a menu and calls up appropriate subroutines according to input (figs. 5-6).

[8]NDIM = maximum number of measurements + 1, which gives room to enter a dummy measurement that fulfills the escape clause for exiting from the measurement input routine.

MAINLINE PROGRAM (SO-MAIN)

Selects type of input (keyboard or file) and output file.

Selects type of data (overcore or biaxial).

Calls **READ1**.

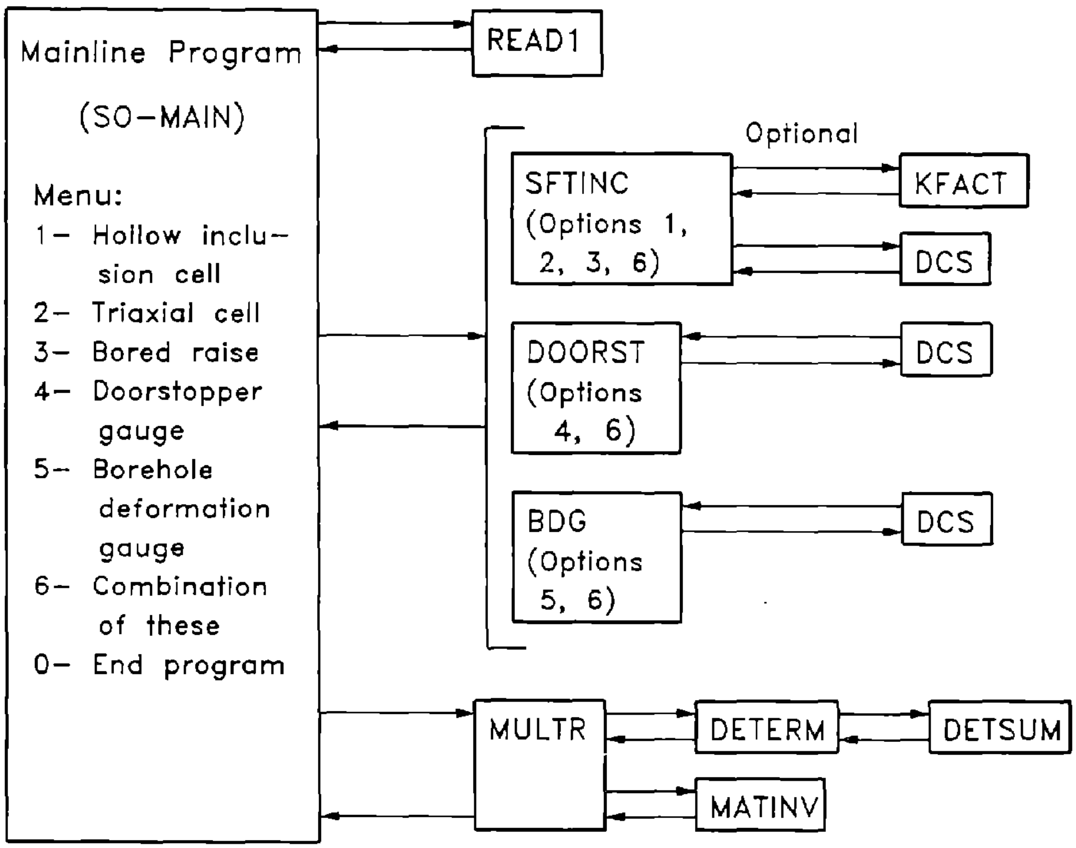

Figure 5.—Diagram of overcoring options for STRESsOUT.

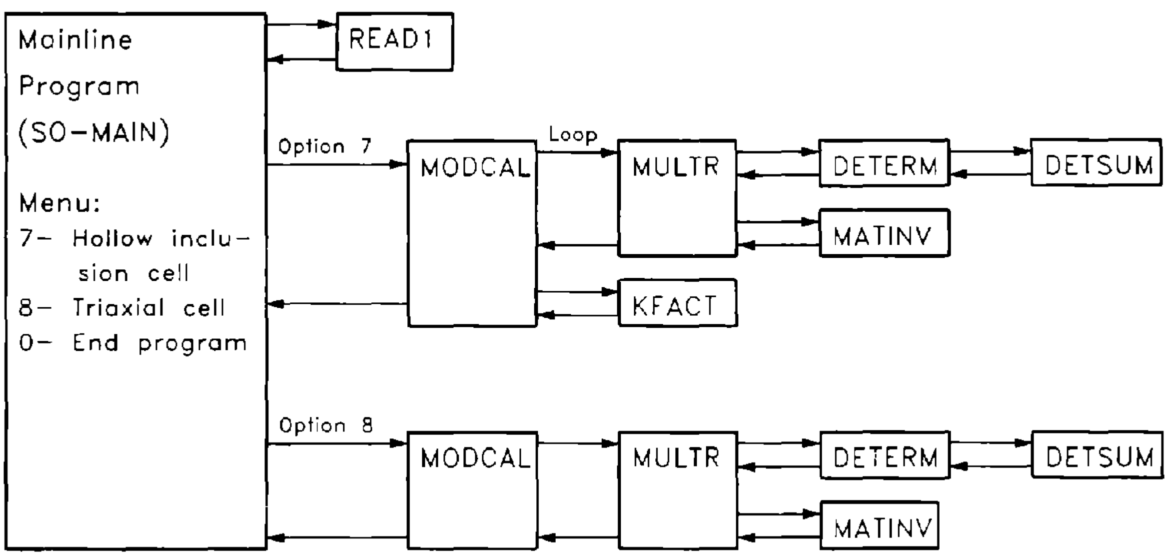

Figure 6.—Diagram of biaxial test options for STRESsOUT.

Calls appropriate subroutine for type of data:

SFTINC for hollow inclusion, triaxial, or bored raise data,

DOORST for doorstopper data,

BDG for Bureau borehole deformation gauge data,

MODCAL for biaxial test data.

Subroutines **SFTINC**, **DOORST**, and **BDG** assemble the matrices, except where measurements from different instrument types are combined. In this case, **SO-MAIN** assembles the coefficient matrix and the measurement matrix. For biaxial data, **MODCAL** runs the appropriate analysis.

Calls **MULTR** for overcoring data.

SUBROUTINES

READ1 Reads and writes information about instruments, their location, elastic properties, and borehole orientations to the output file.

SFTINC Reads or calculates K-factors for hollow inclusion cell; calls **KFACT** to calculate K-factors if indicated; sets K-factors to 1.0 for triaxial cells or bored raise data (fig. 5).

Reads measurements, angles, borehole numbers, and material types.

Calculates coefficient matrix elements.

Calls **DCS** to calculate direction cosines.

If indicated, writes local and global coefficients to output file.

DOORST Reads stress concentration factor option.

Computes or reads in stress concentration factors.

Reads doorstopper gauge measurements, orientation angles, borehole numbers, and material types.

Calculates coefficient matrix elements.

Calls **DCS** to calculate direction cosines.

If indicated, writes local and global coefficients to output file.

BDG Reads diameters of boreholes.

Reads measurements obtained from borehole deformation gauges, orientation angles, borehole numbers, material types, and borehole diameter designations.

Calculates coefficient matrix elements.

Calls **DCS** to calculate direction cosines.

If indicated, writes local and global coefficients to output file.

MODCAL Reads inner and outer diameters of overcores.

Reads biaxial test data, that is, strain, stress, and tilt angle of gauges.

Assembles coefficients of equations in matrices.

For hollow inclusion cells:

Reads properties and geometries of cells and reads estimates for correction factors.

Executes iterative cycle to determine rock properties and K-factors:

Calls **MULTR** to fit rock properties.

Calls **KFACT** to calculate K-factors with current rock properties.

Checks improvement; if below tolerance, stops iteration cycle.

Recalculates coefficients.

For triaxial cells:

Calls **MULTR** to fit rock properties.

KFACT Calculates K-factors for given geometries and material properties of overcores and hollow inclusion cells.

DCS Calculates direction cosines relating local and global coordinate systems.

MULTR Reads number of additional analytical runs in which the measurements farthest from the fitted solution are eliminated.

Assembles least-squares coefficient matrix and vector.

Runs output cycle:

If indicated, writes coefficients of equations to be solved to output file.

Calls **DETERM** to calculate determinant of coefficient matrix.

If matrix is singular, makes no attempt to solve for the global stresses or rock properties; instead, returns to calling program or subroutine.

Calls **MATINV** to invert coefficient matrix and calculate global stresses (or rock properties, if these are biaxial test data); writes results to output file.

Performs analysis of variance of results; writes results to output file.

Calculates principal stresses and directions in the case of overcoring data; writes results to output file.

DETERM Calculates the determinant of a matrix passed as an argument.

Enters a loop to sum the product of the elements. In doing so, it calls **DETSUM** to calculate products of the elements it designates.

DETSUM Calculates the product of designated elements of the matrix.

MATINV Inverts coefficient matrix and solves matrix equation, storing the result in the one-dimensional array B(6,1).

ASIN External function that determines the arc sine of the variable X.

ACOS External function that determines the arc cosine of the variable X.

INPUT DATA

The information presented here will assist the user in preparing input for the program. Terminal prompts are listed and required input is described.

STRESsOUT is designed as an interactive program, but it is likely that the user will want to gather all input data into a file, because the task of entering data from a keyboard is very tedious. Reviewing sample input files listed in appendix B may be of some help.

The general information to be entered depends on whether an overcoring or a biaxial test option is selected. For any option, prompts differ according to instrument type. Below, the prompts and input data will be handled according to the instrument option selected. (The line-by-line prompts shown on the computer screen are indicated by bold lettering.)

Step 1

ENTER 0 TO INPUT DATA FROM A KEYBOARD

1 TO ACCEPT INPUT FROM A DATA FILE

The variable read is IFL. The user should enter either 0 or 1 and press Return. The prompt will be repeated if any character other than 0 or 1 is entered. Here, 0 and 1 are the unit numbers of input devices, but they can be changed to be compatible with various systems or compilers. If a change in unit numbers is desired, the changes must be made in the following lines of code of the mainline program:

1. 11 FORMAT (etc.).
2. The IF statement immediately following the READ(*,*) IFL statement.
3. OPEN (UNIT=1, etc.).

Step 2

If the user enters 1 for IFL, the next prompt is

ENTER INPUT DATA FILE NAME

The variable name is IOUTPI. Up to 36 characters can be entered for the file name, including the path.

Step 3

HELLO, YOU ARE RUNNING PROGRAM

```
**********************
*    STRESsOUT       *
*  (Version 1.00)    *
**********************
```

A MULTIPLE LINEAR REGRESSION PROGRAM FOR DETERMINING STRESS

COMPONENTS FROM STRAIN GAUGE OR DISPLACEMENT READINGS.

TYPE IN THE CODE APPROPRIATE TO YOUR DATA:

0-STOP...NO MORE DATA

OVERCORING DATA

1-HOLLOW INCLUSION CELL

2-TRIAXIAL CELL

3-STRAIN GAUGES ON WALL OF BORED RAISE

4-DOORSTOPPER GAUGE

5-BOREHOLE DEFORMATION GAUGE

6-COMBINATION OF THE ABOVE

BIAXIAL COMPRESSION DATA ON OVERCORE

7-HOLLOW INCLUSION CELL

8-TRIAXIAL CELL

The variable is IDTYPE. The user should enter the code for the appropriate option. Option 0 ends the program. Option 6 allows the user to use measurements from various types of instruments (soft inclusion cell, strain gauge on wall of bored raise, doorstopper gauge, borehole deformation gauge) in fitting the stress state.

Step 4

TYPE IN OUTPUT FILE NAME

The variable name is IOUTPT. Up to 36 characters may be entered for the file name. To protect existing output files, the program searches for the file name. If that name already exists, the statement **FILE ALREADY EXISTS** appears on the screen and the program ends without the file being replaced.

Step 5

DO YOU WANT MATRIX COEFFICIENTS PRINTED? (Y/N)

The variable is ANS. The input must be Y or N in either uppercase or lowercase. The matrix coefficients are the elements of the $N \times 6$ matrix in both local and global coordinate systems. Generally, the user will not want these coefficients in the output file. The program will repeat the prompt if the user does not supply acceptable characters.

Step 6

The program now enters READ1.

TYPE IN LABEL DESCRIBING INSTRUMENT TYPE(S)

The variable is CTYPE. The user may enter 1 line of up to 80 characters.

Step 7

TYPE IN TEST SITE LOCATION INFORMATION

The variable is CLOC. The user may enter 1 line of up to 80 characters.

Step 8

For options 1 through 6, the prompt is

TYPE IN NORTHING, EASTING, AND ELEVATION OF TEST SITE

The variables are NORT, EAST, and ELEV, entered in free format. If option 7 or 8 was selected, skip this step and proceed to step 9.

Step 9

For overcoring options 1 through 6, the prompt is

TYPE IN DATE OF INSTALLATION INFORMATION

For biaxial test options, the prompt is

TYPE IN DATE OF BIAXIAL TEST

The variable in either case is DATI. The user may enter 1 line of up to 80 characters.

Step 10

For overcoring options 1 through 6, the prompt is

TYPE IN DATE OF OVERCORING INFORMATION

The variable is DATO. The user may enter 1 line of up to 80 characters. If biaxial test option 7 or 8 was selected, skip this step and proceed to step 11.

Step 11

For overcoring options 1 through 6, the prompt is

TYPE IN 5 LINES OF 80 CHARACTERS OR LESS DESCRIBING

SETTING DEPTH INFORMATION FOR EACH INSTRUMENT

(Return after each line)

The variables (one per line) are CLAB1, CLAB2, CLAB3, CLAB4, and CLAB5. As indicated in the prompt, each line may contain as many as 80 characters.

For biaxial test option 7 or 8, the prompt is

TYPE IN LINES OF 80 CHARACTERS OR LESS DESCRIBING

OVERCORE (LENGTH, ROCK TYPE, CONDITION, ETC.)

(Return after each line)

Step 12

ENTER NUMBER OF MATERIAL TYPES

The variable is NMAT, which must be entered as an integer.

Step 13

The program allows the user to enter Young's modulus in either English or metric units. The next prompt asks the user to designate which one.

ENTER E IF ROCK MODULUS WILL BE INPUT IN ENGLISH UNITS (psi)

M IF ROCK MODULUS WILL BE INPUT IN METRIC UNITS (GPa)

The variable is IMPMET, which accepts one character. The prompt will be repeated if a character other than E, e, M, or m is entered.

Step 13.A

If E or e is selected, the next prompt is

ENTER THE ELASTIC PROPERTIES FOR MATERIAL ##:

POISSON'S RATIO (in/in) AND YOUNG'S MODULUS (*106 psi)**

is a counter supplied by the program and ranges from 1 to NMAT. The variables PR (isotropic Poisson's ratio) and YM are entered in free format. The prompt repeats if the user enters 0. for Young's modulus. The value of Young's modulus in metric units (YMM in gigapascals) is calculated in the program (YMM = YM × 6.895).

The calculations of the program are in English units. However, the answers are written to the output file in both English and metric units.

Step 13.B

If M or m is selected, the next prompt is

ENTER THE ELASTIC PROPERTIES FOR MATERIAL ##:

POISSON'S RATIO (m/m) AND YOUNG'S MODULUS (GPa)

is a counter supplied by the program and ranges from 1 to NMAT. The variables PR and YMM are entered in free format. The prompt repeats if the user enters 0. for Young's modulus. The value of Young's modulus in English units (YM in pounds of force per square inch) is calculated in the program (YM = YMM/6.895).[9]

Step 14

ENTER NUMBER OF BOREHOLES (OR BORED RAISES)

[9] After the material properties input loop is finished, three warnings may be written to the output file following the material properties table if unusual or unreasonable values of material properties have been entered. See appendix A for specific warnings and conditions under which these warnings appear.

The variable is NUMBH, which must be entered as an integer.

Step 15

ENTER AZIMUTH (DEGREES CLOCKWISE FROM NORTH)

AND INCLINATION (DEGREES POS. DOWN, NEG. UP)

FOR BOREHOLE (OR BORED RAISE) ##

This prompt and format is repeated NUMBH times, and input must be supplied after each prompt. The azimuths and inclinations are stored in the arrays AZ(NBHL) and DP(NBHL), where NBHL is the dimension of the array. NBHL can be altered by changing the appropriate number in the FORTRAN PARAMETER statements. NBHL is currently set at 10. AZ(##) and DP(##) (where ## represents the value of the DO loop counter) are entered in free format.

The borehole azimuth as defined in the program is the angle clockwise from north to the vertical plane containing the centerline of the borehole, such that the line of sight from the vertex of the angle is into the borehole. The borehole inclination is the smallest angle from the horizontal plane to the centerline of the borehole and is defined as positive down. Thus, a vertical borehole downward has an inclination of 90.0° and a vertical borehole upward has an inclination of -90.0°.

The local x-axis (fig. 1) is (1) the direction in a plane perpendicular to the z-axis (which is the centerline of the borehole) that forms the largest angle with and above the horizontal plane, and (2) the direction north if the borehole is vertically up or down. The azimuth of a borehole that is vertical is nonunique, but as a result of the definition of the local x-axis, the azimuth must be entered as 0.0 for a vertical borehole, whether that borehole is up or down.

Step 16

At this point, different subroutines are called, depending on which option the user selected in step 3 of the SO-MAIN menu. Under the options for overcoring data, the program may call one or more of the three subroutines SFTINC, DOORST, or BDG. For example, if option 1, hollow inclusion cell, was chosen, then the program calls up the subroutine appropriate for that option, in this case SFTINC (fig. 5). Under the options for biaxial data, the program calls MODCAL, which performs the appropriate analysis for a hollow inclusion cell or a triaxial cell as selected in step 3 (fig. 6).

OPTIONS—OVERCORING DATA

Step 16: Option 1—Hollow Inclusion Cell

To analyze measurements taken with a hollow inclusion cell, subroutine SFTINC is called.

Option 1, I

ENTER 1 IF K-FACTORS ARE TO BE INPUT

2 IF K-FACTORS ARE TO BE CALCULATED

The variable, KFFLAG, is an integer. If KFFLAG is set to 1, the user must supply the K-factors. If KFFLAG is set to 2, the program will call subroutine KFACT to calculate the K-factors using cell properties supplied by the user.

Option 1, II.1

If KFFLAG is 1, the prompt is

ENTER K1, K2, K3, AND K4 FOR MATERIAL ##

The factors (variables) K1##, K2##, K3##, and K4## (where ## represents the value of the DO loop counter) are entered in free format. These factors compensate for the fact that the strain gauges are embedded in a hollow inclusion stress cell rather than bonded directly to the wall. If strain gauges are bonded to the borehole wall, each of the K-factors should be set to 1. (See reference 3 for the derivation of the equations for calculating these variables.)

Option 1, II.2

If KFFLAG is 2, the series of prompts is

ENTER E IF EPOXY CELL MODULUS WILL BE INPUT IN ENGLISH UNITS (psi)

M IF EPOXY CELL MODULUS WILL BE INPUT IN METRIC UNITS (GPa)

The variable is IMPMET, which accepts one character. The prompt repeats if a character other than E, e, M, or m is entered.

Option 1, II.2.a

If E or e is selected, the next prompt is

FOR HOLLOW INCLUSION CELL, ENTER:

POISSON'S RATIO OF EPOXY,

YOUNG'S MODULUS OF EPOXY (*106 psi),**

INNER RADIUS OF CELL,

OUTER RADIUS OF EPOXY OR HOLE,

AND RADIUS OF STRAIN GAUGES.

The variables are V1, E1, R1, R2, and P, entered in free format. The program will convert Young's modulus of the epoxy to metric units for later output (E1M = E1 × 6.895).

Option 1, II.2.b

If M or m is selected, the next prompt is

FOR HOLLOW INCLUSION CELL, ENTER:

POISSON'S RATIO OF EPOXY,

YOUNG'S MODULUS OF EPOXY (GPa),

INNER RADIUS OF CELL,

OUTER RADIUS OF EPOXY OR HOLE,

AND RADIUS OF STRAIN GAUGES.

The variables are V1, E1M, R1, R2, and P, entered in free format. The program will convert Young's modulus of the epoxy to English units for later output (E1 = E1M/6.895).

The variables R1, R2, and P may be entered in any unit of measure as long as each variable is entered in that same unit. This is because the variables only appear as ratios in the calculation of K-factors.

Option 1, III

ENTER MICROSTRAIN,

ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),

BETA (TILT OF GAUGE),

BOREHOLE NUMBER,

AND MATERIAL TYPE.

ENTER 0 FOR BOREHOLE NUMBER OR MATERIAL TYPE TO END MEASUREMENT INPUT LOOP.

TYPE IN MICROSTRAIN, ALPHA, BETA, BOREHOLE NUMBER,

AND MATERIAL TYPE FOR READING ###.

is a counter supplied by the program. Microstrain (the measurement in microlength per length), alpha (in degrees), and beta (in degrees) are real numbers, while the borehole number and the material type are integers. These variables are stored in arrays STR(NDIM), ALP (NDIM), BET(NDIM), NBH(NDIM), and MT(NDIM), respectively, whereas NDIM is the maximum size of the arrays. The last two lines of the prompt repeat until 0 is entered for borehole number or material type, which forces an exit from the loop.

The maximum number of measurements that can be analyzed is NDIM - 1, since there must be one level left to enter a dummy measurement line, such as 0. 0. 0. 0 0, to leave the measurement input loop. NDIM is currently set at 99, but this number can be altered by changing the value in all FORTRAN PARAMETER statements.

Option 1, IV and V

At this point, the program returns to SO-MAIN (IV) and subroutine MULTR (V) is called.

ENTER NUMBER OF RUN PASSES TO BE EXECUTED

IN WHICH SUCCESSIVELY WORST READINGS ARE ELIMINATED;

NUMBER MUST BE EQUAL TO OR LESS THAN (MAXDEL).

MAXDEL is a number supplied by the program and is equal to the number of measurements minus the number of independent parameters minus 1. Here, it is equal to 7 less than the number of measurements. The variable input is NDEL, an integer. If NDEL exceeds MAXDEL, the prompt will be repeated.

NDEL indicates how many runs should be executed so that the measurement with the greatest absolute difference from the "fitted measurement" (calculated using the fitted stresses) will be eliminated. For example, in a series of nine measurements, MAXDEL is 2. If the user enters 2 for NDEL, the program will perform three analytical runs. The first run will fit the stresses to all nine measurements. The next two runs will fit stresses to all measurements used in the previous run except the measurement with the greatest absolute difference.

After assembling the coefficient matrix [A] and the vector {B} (equation 3) in each analysis run, DETERM is called to calculate the determinant of [A]. If the absolute value of the determinant is less than a threshold value, the matrix is considered to be singular and the program will abort the analysis runs (see paragraphs 4 through 6 in the "Threshold Values for Numerical Problem Identification" section). Go to step 3.

Option 1, VI

Return to SO-MAIN menu (step 3).

Step 16: Option 2—Triaxial Cell

To analyze measurements of strain obtained from overcored triaxial cells, subroutine SFTINC is called. The program goes directly to the prompts in option 1, III, and proceeds through IV, V, and VI.

Step 16: Option 3—Bored Raise Gauge

To analyze measurements of strain obtained from overcored gauges bonded to the wall of a bored raise, subroutine SFTINC is called. The program goes directly to the prompts in option 1, III, and proceeds through IV, V, and VI.

Step 16: Option 4—Doorstopper Gauge

To analyze measurements taken from overcored doorstopper gauges, subroutine DOORST is called.

Option 4, I

SELECT OPTION FOR STRESS CONCENTRATION FACTORS

1 - FACTORS ACCORDING TO RAHN (1984) (AXISYMMETRIC ELEMENTS)

2 - FACTORS BASED ON HOCKING (1976) (3-D BEM)

3 - SELECT OWN FACTORS

The variable is IFTYPE, of integer type. If the user does not supply an input of 1, 2, or 3, the prompt will repeat. The program computes the stress concentration factors, which are attempts to take into account the effect of stress concentration at the end of the hole for 1 and 2.

Option 4, II

If 3 is selected, the user must supply the stress concentration factors a, b, c, and d. The next prompt will be

ENTER STRESS CONCENTRATION FACTORS a, b, c, AND d

FOR MATERIAL ##

The variables are A1##, B1##, C1##, and D1## (where ## represents the value of the DO loop counter). The purpose of 1 in the variable names is to prevent confusion with the arrays A, B, C, and D.

Table 1 is a summary of stress concentration values for isotropic rock obtained by several researchers. The user may refer to this information as a guide for selecting values. The factor d is determined by the difference a - b.

Option 4, III

ENTER MICROSTRAIN,

ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),

BOREHOLE NUMBER,

AND MATERIAL TYPE.

ENTER 0 FOR BOREHOLE NUMBER OR MATERIAL TYPE

TO END MEASUREMENT INPUT LOOP.

TYPE IN MICROSTRAIN, ALPHA, BOREHOLE NUMBER, AND MATERIAL TYPE

FOR READING ###.

Input continues as in option 1, IV, V, and VI.

Step 16: Option 5—Borehole Deformation Gauge

To analyze measurements obtained with a borehole deformation gauge, subroutine BDG is called.

Option 5, I

ENTER NUMBER OF DIFFERENT VALUES OF BOREHOLE DIAMETER

The variable is NDIAM, which must be entered as an integer.

Option 5, II

ENTER E IF BOREHOLE DIAMETER WILL BE INPUT IN ENGLISH UNITS (in)

M IF BOREHOLE DIAMETER WILL BE INPUT IN METRIC UNITS (mm)

The variable is IMPMET, which accepts one character. The prompt will be repeated if a character other than E, e, M, or m is entered.

Option 5, II.1

If E or e is selected, the next prompt is

ENTER BOREHOLE DIAMETER (in) # ??

?? is a counter supplied by the program and ranges from 1 to NDIAM. The variable is DIAM, which is real. The program will compute the metric equivalent for later output.

Option 5, II.2

If M or m is selected, the next prompt is

ENTER BOREHOLE DIAMETER (mm) # ??

?? is a counter supplied by the program and ranges from 1 to NDIAM. The variable is DIAMM, which is real. The program will compute the English equivalent for later output.

Option 5, III

ENTER MICROINCHES,

ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),

BOREHOLE NUMBER,

MATERIAL TYPE,

AND BOREHOLE DIAMETER DESIGNATION.

ENTER 0 FOR BOREHOLE NUMBER, MATERIAL TYPE, OR

BOREHOLE DIAMETER DESIGNATION TO END MEASUREMENT INPUT LOOP.

TYPE IN MICROINCHES, ALPHA, BOREHOLE NUMBER, MATERIAL TYPE,

AND BOREHOLE DIAMETER DESIGNATION FOR READING ###.

is a counter supplied by the program. Microinches (the measurement in inches × 10^6) and alpha (in degrees) are real numbers, while borehole number, material type, and borehole diameter designation are integers. These variables are stored in arrays STR(NDIM), ALP (NDIM), NBH(NDIM), MT(NDIM), and NDD(NDIM), respectively, where NDIM is the maximum size of the arrays. The maximum number of measurements that can be analyzed is NDIM - 1, because there must be one level left to enter a dummy measurement line, such as 0. 0. 0 0 0, to leave the measurement input loop. NDIM is currently set at 99, but this number can be altered by changing the value in all FORTRAN PARAMETER statements.

At this point, the user proceeds as in option 1, IV, V, and VI.

Step 16: Option 6—Combination of Gauge Types

For this option, the program is driven from SO-MAIN, and subroutines SFTINC, DOORST, and BDG are called according to the type of measurements involved. The program prompts the user to (1) select the type of instrument and (2) indicate how many measurements of that type of instrument are to be entered.

Option 6, I

SELECT THE CODE APPROPRIATE TO YOUR DATA

1-HOLLOW INCLUSION CELL

2-TRIAXIAL CELL

3-STRAIN GAUGES ON WALL OF BORED RAISE

4-DOORSTOPPER GAUGES

5-BOREHOLE DEFORMATION GAUGE

0-STOP...NO MORE DATA

The variable is ICOMB, an integer. ICOMB designates the type of the next group of measurements. The prompt repeats after measurements from that group have been entered.

If the measurements entered are not sufficient to determine the stress state, one of the following situations may result:

1. A division-by-zero condition, which stops the program, or
2. One of infinitely many stress states that could cause the measured strains or displacements is calculated and written to the output file.

When combining measurements from various gauge types for fitting the stress state, the user must select measurements so that the coefficient matrix [XX] and therefore [A] has a rank of 6, for six independent equations. This number is required to determine uniquely the six stress-state components. The coefficient matrix will have the required rank if any of its submatrices have that rank. Therefore, the user may guarantee a rank of 6 by ensuring that one of the subsets (that is, the coefficients for measurements from one instrument type) has a rank of 6.

The coefficient matrix rank may still be 6 even if none of the instrument type subsets has that rank. The program later checks this by calculating the determinant of the least-squares coefficient matrix [A] and writing it to the output file. If the determinant is less than or equal to a tolerance about zero (set currently at 1.0×10^{-6}), then the following message is written to the output file and is displayed on the screen.

!!!

THE COEFFICIENT MATRIX, A, MAY BE SINGULAR. THE MEASUREMENTS MAY NOT BE SUFFICIENT TO DETERMINE A UNIQUE STRESS STATE.

!!!

The rest of the analytical runs on that set of data are skipped.

The value of the determinant is written to the output file before this warning. When the warning appears, further analysis of measurements is halted, and the program returns to SO-MAIN and displays the SO-MAIN menu in step 3.

Option 6, II

HOW MANY READINGS OF THIS KIND?

The variable is ICOMBN, an integer, which indicates the number of measurements in the group that will be read next. The next prompt depends on the value of ICOMB. Go to the appropriate step according to the value of ICOMB.

Option 6, III.1

ICOMB = 1 (hollow inclusion cell measurements). Proceed as in option 1, I, II, and III. The last two lines of prompt III are repeated ICOMBN times, after which the program returns to SO-MAIN (IV). Proceed as in option 6, I.

Option 6, III.2

ICOMB = 2 (triaxial cell measurements). Proceed as in option 1, III. The last two lines of the prompt are repeated ICOMBN times, after which the program returns to SO-MAIN (IV). Proceed as in option 6, I.

Option 6, III.3

ICOMB = 3 (bored raise measurements). Proceed as in option 1, III. The last two lines of the prompt are repeated ICOMBN times, after which the program returns to SO-MAIN (IV). Proceed as in option 6, I.

Option 6, III.4

ICOMB = 4 (doorstopper gauge measurements). Proceed as in option 4, I, II, and III. The last two lines of prompt III are repeated ICOMBN times, after which the program returns to SO-MAIN (IV). Continue as in option 6, I.

Option 6, III.5

ICOMB = 5 (borehole deformation gauge measurements). Proceed as in option 5, I, II, and III. The last two lines of prompt III are repeated ICOMBN times, after which the program returns to SO-MAIN (IV). Continue as in option 6, I.

Option 6, III.6

When there are no more measurements, enter 0 to exit. After leaving the loop, the program calls subroutine MULTR (V) and returns to the SO-MAIN menu (VI). Press 0 to exit.

Figure 7 summarizes the procedures for analyzing overcoring data.

OPTIONS—BIAXIAL TEST DATA

To fit isotropic rock elastic properties to strain measurements obtained with a hollow inclusion cell or a triaxial cell, the user should select option 7 (hollow inclusion cell) or 8 (triaxial cell) from the SO-MAIN menu (step 3). MODCAL is called (fig. 6).

Step 16: Option 7—Hollow Inclusion Cell

The user must furnish some information for calculation of K-factors, so that the next prompt is the same as in option 1, II.2.

Option 7, I

ENTER E IF EPOXY CELL MODULUS WILL BE INPUT IN ENGLISH UNITS (psi)

M IF EPOXY CELL MODULUS WILL BE INPUT IN METRIC UNITS (GPa)

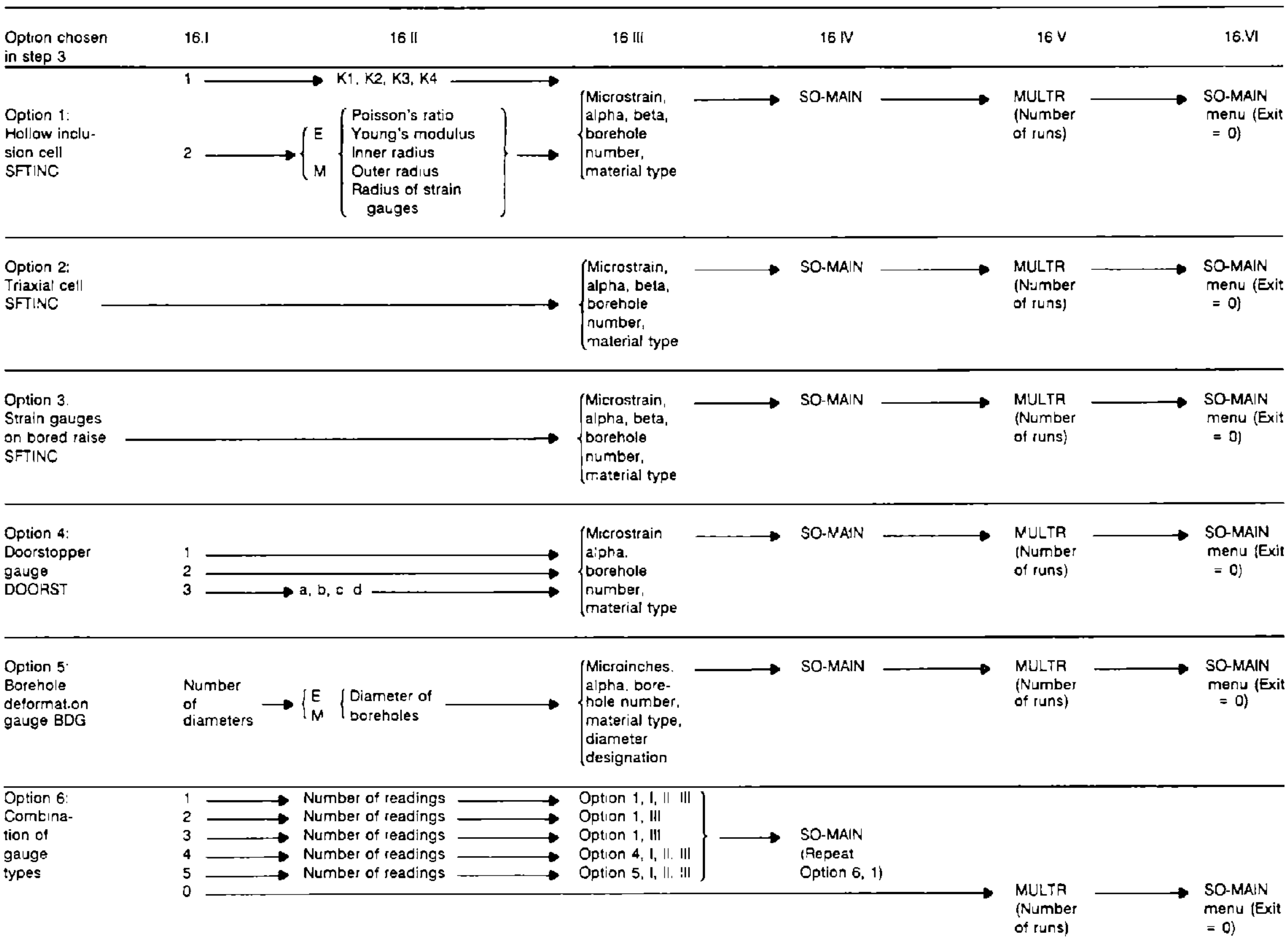

Figure 7.—Procedures for overcoring data in STRESsOUT.

The variable is IMPMET, which accepts one character. The prompt will be repeated if a character other than E, e, M, or m is entered.

Option 7, I.1

If E or e is selected, the next prompt is

FOR HOLLOW INCLUSION CELL, ENTER:

POISSON'S RATIO OF EPOXY,

YOUNG'S MODULUS OF EPOXY (*10**6 psi)

INNER RADIUS OF CELL,

OUTER RADIUS OF EPOXY OF HOLE,

AND RADIUS OF STRAIN GAUGES.

The variables are V1, E1, R1, R2, and P, entered in free format. The program will convert Young's modulus of the epoxy to metric units for later output (E1M = E1 × 6.895).

Option 7, I.2

If M or m is selected, the next prompt is

FOR HOLLOW INCLUSION CELL, ENTER:

POISSON'S RATIO OF EPOXY,

YOUNG'S MODULUS OF EPOXY (GPa),

INNER RADIUS OF CELL,

OUTER RADIUS OF EPOXY OR HOLE,

AND RADIUS OF STRAIN GAUGES.

The variables are V1, E1, R1, R2, or P, entered in free format. The program will convert Young's modulus of the epoxy to English units for later output (E1 = E1M/6.895).

Option 7, II

ENTER INITIAL ESTIMATES FOR K1 AND C1 FACTORS,

MAXIMUM NUMBER OF ITERATIONS FOR ROUTINE,

AND TOLERANCE FACTOR ON BOTH K1 AND C1.

The variables to be entered are K11, C11, MNIT, and TF. K11, C11, and TF are real variables and MNIT is an integer variable. Estimates ranging between 0.9 and 1.1 are usually sufficient for K1 and C1 factors (K11 and C11).

MNIT and TF are values that the program uses to determine when to discontinue the iteration process. When the improvements in values of both K11 and C11 are both less than TF from one iteration to the next, the iteration process halts. In case the input tolerance is too small, the integer entered for MNIT specifies the maximum number of iterations that will be executed. Reasonable numbers for MNIT and TF are 0.0001 and 20, respectively.

Option 7, III

ENTER INNER AND OUTER DIAMETER OF ROCK OVERCORE

(ENGLISH OR METRIC UNITS)

The variables are AA and BB. The real numbers are used as a ratio in the program, so any system of units is acceptable.

Option 7, IV

ENTER BIAXIAL HYDROSTATIC TEST DATA AS REQUESTED.

TO FINISH...SET BETA=777.0.

ENTER E IF APPLIED STRESS WILL BE INPUT IN ENGLISH UNITS (psi)

M IF APPLIED STRESS WILL BE INPUT IN METRIC UNITS (MPa)

The variable is IMPMET, which accepts one character. The program repeats the prompt if a character other than E, e, M, or m is entered. The unit selected here is for applied stress from the biaxial test data.

Option 7, V

ENTER VALUES OF STRAIN, STRESS, AND BETA FOR READING ###

The variables are the arrays STR(NDIM), STRES(NBIAX), and BET(NDIM), which are additional arrays needed for the biaxial routine. ### is a counter supplied by the program. The prompt repeats itself for each successive reading until the user supplies data in which BET(###) is read as 777. The maximum size of arrays is currently set at 99 for NDIM and, because the maximum number of strain readings likely for biaxial tests is 12, 13 for NBIAX. These numbers may be altered by making the appropriate changes in the FORTRAN PARAMETER statements.

Option 7, VI

At this point, the iteration loop begins. A message on the screen tells the user the number of the iteration loop.

******* BEGIN ITERATION # ??**

?? is the counter. During the iteration procedure, subroutine MULTR is called to fit the elastic properties and run an analysis of variance.

Option 7, VII

Upon entering MULTR, the user is prompted with

ENTER NUMBER OF RUN PASSES TO BE EXECUTED

IN WHICH SUCCESSIVELY WORST READINGS ARE ELIMINATED;

NUMBER MUST BE EQUAL TO OR LESS THAN (MAXDEL)

MAXDEL is a number supplied by the program and is equal to 3 less than the number of measurements. The variable is NDEL, an integer variable. If NDEL exceeds MAXDEL, the prompt will be repeated.

In each iteration, NDEL indicates how many runs should be executed in which the measurement or factor with the greatest absolute difference from the "fitted factor" (calculated using the fitted material properties) will be eliminated. For example, in a series of nine measurements, MAXDEL is 2. If the user 2 for NDEL, the program will perform three analytical runs. The first run will fit the material properties to all nine measurements. The following two runs will fit the material properties to all measurements used in the previous run except the measurement whose associated factor has the greatest absolute difference. This prompt is only given the first time MULTR is called; the flag NDFLAG suppresses the prompt when MULTR is called subsequently.

Option 7, VIII

Another screen message tells the user in which analytical run the program is during each iteration.

RUN NUMBER ?

? is the counter.

Upon meeting the "stop iterations" criteria, the program leaves MODCAL and returns to SO-MAIN. The menu in step 3 appears on the screen. Enter 0 to leave the program.

Step 16: Option 8—Triaxial Cell

The K-factors are all set to 1.0 for the triaxial cell. Therefore, I and II, which deal with K-factors in option 7, are not needed. Proceed to III.

Option 8, III

Proceed as in option 7, III.

Option 8, IV

Proceed as in option 7, IV.

Option 8, V

Proceed as in option 7, V.

The program does not enter an iteration loop here, but calculates the rock elastic properties directly. Skip VI and continue with VII.

Option 8, VII

The program continues as in option 7, VII.

VIII is skipped, and after performing the analysis runs, the program leaves MODCAL and returns to SO-MAIN. The menu in step 3 appears on the screen. Enter 0 to leave the program.

OUTPUT DATA

The program writes output to unit 4, which is identified in the code as a file. The user supplies the name of the output file as part of the input.

The following outline describes the output:

1. Echo of general information, such as instrument type, location, date of installation, material properties, orientation of boreholes, etc.
2. Echo of measurements and gauge orientation angles.
3. Analytical runs, including—

   a. Determinant of coefficient matrix, [A].
   b. Table of measurements, fitted measurements, and differences.
   c. Fitted global stresses or material properties, standard deviations, and correlation coefficients.
   d. Analysis-of-variance table.
   e. When stress states are being fitted, table of principal stresses and principal directions calculated from the fitted global stress state.

Output for several sample problems can be found in appendix C.

CALCULATION OF PRINCIPAL STRESSES

Solving for principal stresses and directions is a problem in solving for the eigenvalues (principal stresses) and their eigenvectors (direction cosines l_i, m_i, and n_i). Equations 12 through 14 are used in STRESsOUT to calculate the direction cosines directly from the stress state.[10] In the equations below, B, C, D, E, F, and G are auxiliary variables used to calculate the principal stresses, as are auxiliary variables FFEE and BC below, and AD_i, BD_i, CD_i, DDD_i, $DEN1_i$, $DEN2_i$, and $DEN3_i$ are auxiliary variables used to calculate direction cosines.

The eigenvalues (principal stresses) are the three roots of the cubic equation

$$\sigma_i^3 + 3B\sigma_i^2 + 3C\sigma_i + D = 0, \qquad (9)$$

[10]Equations 9, 10, 11, and 12 appear as equations 52, 53, 54, and 55 in Panek (*1*) and are discussed by Timoshenko and Goodier (*25*) and Eshbach (*26*).

where $B = -(\sigma_{NN} + \sigma_{EE} + \sigma_{VV})/3$,

$$C = (\sigma_{NN}\sigma_{EE} + \sigma_{EE}\sigma_{VV} + \sigma_{VV}\sigma_{NN} - \sigma_{NE}^2 - \sigma_{EV}^2 - \sigma_{VN}^2)/3,$$

and $$D = -\sigma_{NN}\sigma_{EE}\sigma_{VV} - 2\sigma_{NE}\sigma_{EV}\sigma_{VN} + \sigma_{NN}\sigma_{EV}^2 + \sigma_{EE}\sigma_{VN}^2 + \sigma_{VV}\sigma_{NE}^2. \quad (10)$$

The three roots, σ_1, σ_2, and σ_3, of equation 9 are found by

$$E = (B^2 - C)^{1/2},$$

$$F = -B^3 + (3BC - D)/2,$$

$$\cos(3G) = \pm F/E^3,$$

$$\sigma_1 = -B \pm 2E\cos(G),$$

$$\sigma_2 = -B \pm 2E\cos(G + \pi/3),$$

and $$\sigma_3 = -B \pm 2E\cos(G + 2\pi/3)\ (22). \quad (11)$$

Where $\pm$ appears, use + if F is positive and − if F is negative.

Direction cosines l_i, m_i, and n_i for principal direction $_i$ with respect to the global coordinate system may be found from solving

$$(\sigma_i - \sigma_{NN})l_i - \sigma_{NE}m_i - \sigma_{VN}n_i = 0,$$

$$-\sigma_{NE}l_i + (\sigma_i - \sigma_{EE})m_i - \sigma_{EV}n_i = 0,$$

$$-\sigma_{VN}l_i - \sigma_{EV}m_i + (\sigma_i - \sigma_{VV})n_i = 0,$$

and $$l_i^2 + m_i^2 + n_i^2 = 1, \quad (12)$$

but are directly calculated from

$$l_i = AD_i \times DDD_i,$$

$$m_i = BD_i \times DDD_i,$$

and $$n_i = CD_i \times DDD_i, \quad (13)$$

where

$$AD_i = \frac{1}{DEN1_i} = \frac{1}{(\sigma_i - \sigma_{NN}) \times \sigma_{EV} + \sigma_{NE} \times \sigma_{VN}},$$

$$BD_i = \frac{1}{DEN2_i} = \frac{1}{(\sigma_i - \sigma_{EE}) \times \sigma_{VN} + \sigma_{EV} \times \sigma_{NE}},$$

$$CD_i = \frac{1}{DEN3_i} = \frac{1}{(\sigma_i - \sigma_{VV}) \times \sigma_{NE} + \sigma_{VN} \times \sigma_{EV}},$$

and

$$DDD_i = \frac{1}{(AD_i^2 + BD_i^2 + CD_i^2)}. \quad (14)$$

Equations 9 through 11 do not guarantee that the principal stresses will be calculated in algebraic order. Neither can these equations guarantee a right-handed system. Therefore, after calculation of stresses, the principal stresses and their directions are written to the output file in algebraic descending order. The direction cosines associated with the first principal stress are then modified to guarantee a right-handed system. For example, the sign of each component of that set of direction cosines may have to be changed to reflect the opposite direction.

There are additional numerical conditions that may result in calculations of nonunique principal directions, as described in the following section. The discussion of threshold values used to detect difficulties may serve as a guide if the user desires to change the values.

IDENTIFICATION OF NUMERICAL PROBLEMS

Division by Zero

Nonunique principal directions are detected in STRESsOUT so that they are not written to the output file. Difficulties arise when a division-by-zero (or by a number close to zero) situation arises when calculating the principal stresses and direction cosines associated with the principal directions. Rounding-off errors associated with a particular computer permits this mathematical operation to take place, resulting in specific values for azimuths or inclinations that do not reflect nonuniqueness of the angles.

An examination of the equations for determining the principal stresses (equations 9, 10, and 11), direction cosines (equations 12, 13, and 14), and azimuth and inclination angles (equation 15) will help identify the possibilities for division by zero. The azimuth and inclination are calculated by

$$Az_i = \tan^{-1}(m_i/l_i),$$

and $$\delta_i = \tan^{-1}(n_i), \quad (15)$$

where Az_i = azimuth,

δ_i = inclination,

and l_i, m_i, n_i = direction cosines of ith principal direction.

Several conditions could cause division by zero or by a very small number in the calculation of Az_i and δ_i. These are—

1. In the process of calculating principal stresses, the variable E may be very small for certain stress states. Because it appears in the denominator of the calculation of FFEE,[11] a check prevents a spurious solution. The program compares the value of E to a threshold value. If E is not above the threshold value, then the principal stresses and directions are not calculated. Instead, the following messages are written to the output file:

PRINCIPAL STRESSES WERE NOT CALCULATED DUE TO NUMERICAL PROBLEMS.

THE VARIABLE E (VALUE = XX.XXXXXXE-XXX) IS CLOSE TO ZERO.

BECAUSE E OCCURS IN THE DENOMINATOR OF THE EQUATION FOR

CALCULATING PRINCIPAL STRESSES, CONTINUING WILL RESULT

IN DIVISION BY ZERO OR SPURIOUS VALUES OF PRINCIPAL STRESS.

In the messages above, XX.XXXXXXE-XXX represents a numeric field in which the value of E is written.

2. If the stress state is hydrostatic, then $DEN1_i$, $DEN2_i$, and $DEN3_i$ in equation 14 are zero or very close to zero. Principal directions are nonunique, and therefore the output flags for azimuths and inclinations are set so that they are not printed.

3. If two of the principal stresses are equal, then a plane exists in which the stress is the same in any direction. There are an infinite number of solutions for the principal stress directions in that plane. The azimuth and inclination of the out-of-plane principal direction are written to the output file, but the in-plane principal direction flags are set so that azimuth and inclination are ignored and dashed lines appear.

4. If a combination of stress-state component values exists in which $DEN1_i$, $DEN2_i$, or $DEN3_i$ equals zero, then division by zero occurs. For example, $DEN1_i$ will be zero if (1) either (σ_i - σ_{NN}) or σ_{EV} is zero <u>and</u> (2) σ_{NE} or σ_{VN} is zero. In these instances, the program takes advantage of rounding-off error and machine word length to calculate the direction cosines. In all but one case, the ratios are preserved in the calculations so that the resulting values for l_i, m_i, and n_i are accurate. The exception is when there are two global shear stresses and one principal stress that are zero. In that case, numerical difficulty is experienced in calculating one of the variables $DEN1_i$, $DEN2_i$, or $DEN3_i$. The effect is that one of the calculated principal directions is incorrect. This condition can be detected and the principal direction correctly determined given the other two principal directions.

5. If a principal direction is vertical, the azimuth is meaningless. If the inclination is within a certain tolerance of +90° or −90°, then the program sets the output flag so that the azimuth will not be written to the output file.

[11]FFEE = ABS(F)/E^3 (see equation 11). FFEE is used so that the program can correctly identify the sign in calculating the principal stress.

Improper Range for Variables Used in Internal Functions

Experience with STRESsOUT has uncovered other possible difficulties with the range of values of variables used in internal functions. STRESsOUT detects the following situations in MULTR:

1. In order to prevent taking the arc cosine of FFEE when FFEE is slightly outside the range -1.0 to 1.0, a tolerance is given; if FFEE is within the tolerance of that range, then the program sets FFEE equal to 1.0 (or -1.0). Otherwise, the principal stresses and their directions are not calculated, and the program writes the following message to the output file:

PRINCIPAL STRESSES WERE NOT CALCULATED DUE TO NUMERICAL PROBLEMS.

THE VARIABLE FFEE (VALUE = XX.XXXXXXE-XXX) IS OUTSIDE THE RANGE

FOR WHICH THE ARC COSINE FUNCTION IS DEFINED.

In the messages above, XX.XXXXXXE-XXX represents a numeric field in which the value of FFEE is written.

2. If the variable BC (BC = B^2 - C) is less than zero (it can only be slightly less than zero), an error condition results in the calculation of E = SQRT (BC). To correct that problem, the program sets E equal to zero if BC is less than or equal to zero. In this case, however, the check described in item 1 in the section "Division by Zero" does not need to be done. Instead, the program sets AB to 0.0 and skips calculation of FFEE.

Last Check for Nonorthogonal Principal Directions

After the principal stresses and their direction cosines have been calculated, it is possible that the checks performed have not caught numerical problems in the calculation of direction cosines. Therefore, if no previous output flags have been set, a check is performed to see if the principal directions are all orthogonal. The principal stress table is written to the output file, but if the principal directions are not mutually orthogonal, the message **PRINCIPAL DIRECTIONS ARE NOT ORTHOGONAL** appears beneath the table. This check is primarily aimed at the hydrostatic case to detect nonorthogonal principal directions that were not detected earlier and flagged.

THRESHOLD VALUES FOR NUMERICAL PROBLEM IDENTIFICATION

To avoid numerical problems, such as division by a very small number, and to detect some of the conditions described above, STRESsOUT has several IF statements in which a variable is compared with a threshold value. The threshold value represents a limit or tolerance that allows detection of a potential problem.

The author determined threshold values mostly through trial and error when running the verification test problems. In practical, real-world calculations, the user may never encounter any of the numerical difficulties some of the threshold values were designed to detect. However, the user may find it necessary to change some of the threshold values if the computer used has a different word length or for some other reason. The statements containing the threshold values can be identified by four-digit labels, starting at 1000, found in subroutine MULTR.

Statement numbers, variable compared, and threshold values as given in the code are listed in table 2. An explanation of each comparison and threshold value follows.

Table 2.—Threshold values for detection of numerical problems in subroutine MULTR

Statement	Variable	Threshold value
1000	ABS(DETR)	1.0E-06
1001	ABS(DETR)	1.0E-06
1010	SST	1.0E-08
1011	SST	1.0E-08
1020	GF	1.0E-00
1030	ABS(E)	1.0E-08
1031	ABS(E)	1.0E-08
1040	ABS(1.-FFEE)	1.0E-05
1041	ABS(1.-FFEE)	1.0E-05
1050	DEN1, DEN2, DEN3	1.0E-21
1060	ABS(CX/S1)	1.0E-05
1070	S4, S5, S6	1.0E-05
	ABS(C(K,1))	5.0E-01
1080	ABS(ABS(CN(K))-1.)	3.8E-05
1090	ABS(CL(K))	1.0E-15
1091	ABS(CL(K))	1.0E-15
1100	BR(K)	-5.0E-02
1110	ABS(ABS(DET4)-1.)	1.0E-02

Statements 1000 and 1001 are attempts to identify whether the coefficient matrix [A] is singular. A singular matrix would indicate that there are not enough independent equations, that is, that there are not enough different borehole or instrument orientations and/or instrument readings to determine the stress state. The variable DETR is the value of the determinant of [A]. If the absolute value of DETR is less than or equal to the threshold value, the following warning is written to the output file and the screen:

!!
THE COEFFICIENT MATRIX, A, MAY BE SINGULAR. THE MEASUREMENTS MAY NOT BE SUFFICIENT TO DETERMINE A UNIQUE STRESS STATE.
!!

The value of the determinant is written to the output file before this warning. Further analysis is halted and the program returns to the SO-MAIN menu (step 3).

The user must be aware that this check cannot correctly judge the singularity of matrix [A]. Computer word length and rounding-off error cause the calculated determinant for a singular matrix to be small, but often nonzero. However, poor selection of borehole or gauge orientations may result in an ill-conditioned matrix so that a small determinant may be calculated. There is no unique threshold value that will distinguish singular matrices from those with some degree of ill-conditioning in these cases. Therefore, the user must use the information accordingly and adjust the threshold value according to his or her needs.

In **statements 1010** and **1011**, the variable SST will be small if error in the measurements is negligible. If SST is less than or equal to the threshold value, the program does not run an analysis of variance. The user will generally want the analysis of variance performed and printed, so the user needs to set the threshold value for SST so that it is very small, yet sufficiently large to prevent division by zero in the statement R2 = SSR/SST.

In **statement 1020**, the value 1.0 should not be changed. The statement is labeled to call the user's attention to the fact that an F-value of 1000 in the output reflects an exact solution (that is, there is no error in measurement). The user could rewrite this statement and the one preceding so that 1000.0 is written to the output file for a certain tolerance about 1.0 for the variable GF.

Statements 1030 and 1031 are checks on variable E to avoid division by a very small number when FFEE is being calculated. These variables are used in the calculation of principal stress. Therefore, if ABS(E) is less than or equal to the threshold value, the program does not calculate the principal stresses or directions and writes the message shown in item 1 in the section "Division by Zero" to the output file.

The purpose of **statements 1040** and **1041** is to avoid taking the arc cosine of a number greater than 1.0 or less than -1.0. The threshold value represents a tolerance about 1.0 or -1.0 in which the program will set FFEE to 1.0 or -1.0 if FFEE is outside this range. If FFEE is outside the tolerance, the program will stop because of an error condition (that is, trying to compute the arc cosine of a number outside the defined range) and write the message shown in item 1 in the section "Improper Range for Variables Used in Internal Functions" to the output file.

Statement 1050 is a check for the hydrostatic stress condition. It was found that if any of the values of $DEN1_i$, $DEN2_i$, or $DEN3_i$ are less than the threshold value, a division-by-zero error condition occurs. In this case, the flags of all principal direction angles are set so that they are not written to the output file (that is, they are nonunique in a hydrostatic state). If the user finds that the angles are written to the output file, but that they are nonunique or are not orthogonal (the program checks for this; if not orthogonal, a message appears in the output file stating so), then it may be desirable to raise the threshold value.

Statement 1060 is a check for equality of two principal stresses. If any two principal stresses are equal, there is an infinite number of solutions for their principal directions, which lie in a plane perpendicular to the other principal direction. If the difference between two of the principal directions is less than or equal to the threshold value, then flags are set so that the azimuth and inclination of those two principal directions are not written to the output file. The threshold value may be adjusted according to the user's needs.

Statement 1070 is an attempt to detect the condition where one calculated principal direction may be in error because of numerical problems. The variables S4, S5, and S6 are the absolute values of the ratios of the three global shear stress components σ_{NE}, σ_{EV}, and σ_{VN}, respectively, with reference to the largest magnitude of the principal stresses. When any of these ratios is small and the current principal stress (the one designated in the code by first the index K) is also small, then the condition is present. The two threshold values were determined by trial and error, but may need adjustment.

In **statement 1080**, the threshold value represents a tolerance around the vertical direction, up or down (-90° or 90°), within which the azimuth is determined to be meaningless; therefore, a flag is set so that it is not written to the output file. The current threshold value of 3.8E-5 causes the azimuth to be flagged if the absolute value of the inclination is greater than or equal to 89.5° (that is, the threshold value is a tolerance about 1.0 or -1.0).

Statements 1090 and **1091** are attempts to avoid division by zero when the principal stress direction is east-west. In statement 1090, the azimuth is set to 90°. The user should be aware that the system of principal stresses may not be right handed if the azimuth is always set to 90°; however, a left-handed system has not been encountered during problem verification.

Statement 1100 is an attempt to eliminate any negative angles as azimuths. Presently, angles are rounded to the nearest 10th of a degree in the output file, so an angle could be less than zero but displayed as 0.0 if 360° was not added to it. An angle of 0.0 instead of 360.0 is preferable for an azimuth, and therefore the threshold value was set at -0.05. The user may prefer a threshold value of 0.0.

In **statement 1110**, the threshold value represents a tolerance such that if the determinant of the principal direction cosines (DET4) falls inside the range (-1.0 + tolerance) < DET4 < (1.0 - tolerance), then the principal directions are considered not to be orthogonal. If DET4 is inside that range, the message **PRINCIPAL DIRECTIONS ARE NOT ORTHOGONAL** appears in the output file beneath the principal stresses and directions table.

CODE VERIFICATION PROBLEMS

Several test problems were devised to check STRESsOUT thoroughly. These problems were formulated from 12 different stress states and 11 different borehole orientations. The "measurements" were back calculated from the stress state, given the borehole orientation(s) and material type(s) of the particular test problem.

The 12 stress states used in the test problems are designated by number and listed in tables 3 and 4. The stress states listed provide several numerical difficulties in the calculation of principal stresses and directions so that threshold values in subroutine MULTR can be tested.

The 11 borehole orientations used in the test cases are listed in table 5. These include four horizontal directions, two vertical directions, and five inclined directions.

The combinations of stress state and borehole orientation that make up the test problems for each instrument are listed in table 6. Test problems were run to verify the hollow inclusion cell; the doorstopper gauge in which a, b, c, and d were set according to Rahn (*9*); the doorstopper gauge in which a, b, c, and d were set according to equations based on Hocking (*17*); and borehole deformation gauge options. In addition, one problem was run to verify the triaxial cell option, one problem was run to verify the option for strain gauges bonded to the wall of a bored raise, and three problems were run to verify the combination-of-instruments option. Three problems were run to verify the biaxial data option, two for the hollow inclusion cell, and one for the triaxial cell.

Three problems were devised to test warning messages that may appear in the output files. The first problem tests for a condition that results in a spurious K_4 factor for the hollow inclusion cell (that is, when Poisson's ratio is at or near zero). The second problem tests for conditions insufficient to determine the stress state. The third problem tests for the condition in which Poisson's ratio is outside its usual isotropic range. Input files of these test problems are found in the program package diskette.

Table 3.—Global stress state of verification problems

Case	Component	Stress, psi	Case	Component	Stress, psi
1	σ_{NN}	1,000	7	σ_{NN}	1,000
	σ_{EE}	0		σ_{EE}	1,000
	σ_{VV}	0		σ_{VV}	0
	σ_{NE}	0		σ_{NE}	0
	σ_{EV}	0		σ_{EV}	0
	σ_{VN}	0		σ_{VN}	0
2	σ_{NN}	0	8	σ_{NN}	-1,000
	σ_{EE}	-1,000		σ_{EE}	0
	σ_{VV}	0		σ_{VV}	1,000
	σ_{NE}	0		σ_{NE}	0
	σ_{EV}	0		σ_{EV}	0
	σ_{VN}	0		σ_{VN}	0
3	σ_{NN}	0	9	σ_{NN}	1,000
	σ_{EE}	0		σ_{EE}	1,000
	σ_{VV}	1,000		σ_{VV}	1,000
	σ_{NE}	0		σ_{NE}	0
	σ_{EV}	0		σ_{EV}	0
	σ_{VN}	0		σ_{VN}	0
4	σ_{NN}	0	10	σ_{NN}	1,000
	σ_{EE}	0		σ_{EE}	-1,500
	σ_{VV}	0		σ_{VV}	3,000
	σ_{NE}	-1,000		σ_{NE}	0
	σ_{EV}	0		σ_{EV}	0
	σ_{VN}	0		σ_{VN}	0
5	σ_{NN}	0	11	σ_{NN}	0
	σ_{EE}	0		σ_{EE}	0
	σ_{VV}	0		σ_{VV}	0
	σ_{NE}	0		σ_{NE}	500
	σ_{EV}	1,000		σ_{EV}	0
	σ_{VN}	0		σ_{VN}	-1,000
6	σ_{NN}	0	12	σ_{NN}	-500
	σ_{EE}	0		σ_{EE}	-1,680
	σ_{VV}	0		σ_{VV}	1,200
	σ_{NE}	0		σ_{NE}	300
	σ_{EV}	0		σ_{EV}	-700
	σ_{VN}	-1,000		σ_{VN}	-900

Table 4.—Principal stresses and directions of verification problems

Case	Component	Stress, psi	Azimuth, deg	Inclination, deg
1	σ_1	1,000	0	0
	σ_2	0	UD	UD
	σ_3	0	UD	UD
2	σ_1	0	UD	UD
	σ_2	0	UD	UD
	σ_3	-1,000	90	0
3	σ_1	1,000	UD	90
	σ_2	0	UD	UD
	σ_3	0	UD	UD
4	σ_1	1,000	135	0
	σ_2	0	UD	90
	σ_3	-1,000	45	0
5	σ_1	1,000	90	45
	σ_2	0	0	0
	σ_3	-1,000	90	-45
6	σ_1	1,000	0	-45
	σ_2	0	90	0
	σ_3	-1,000	0	45
7	σ_1	1,000	UD	UD
	σ_2	1,000	UD	UD
	σ_3	0	UD	90
8	σ_1	1,000	UD	90
	σ_2	0	90	0
	σ_3	-1,000	180	0
9	σ_1	1,000	UD	UD
	σ_2	1,000	UD	UD
	σ_3	1,000	UD	UD
10	σ_1	3,000	UD	90
	σ_2	1,000	0	0
	σ_3	-1,500	90	0
11	σ_1	1,118.03	204.1	39.2
	σ_2	0	90	26.6
	σ_3	-1,118.03	155.9	-39.2
12	σ_1	1,756.71	29.2	-63.7
	σ_2	-887.94	359.9	23.3
	σ_3	-1,848.77	274.9	-11.5

UD Undefined.

Table 5.—Borehole orientations used in test cases

Orientation designator	Azimuth, deg	Inclination, deg
A	0	0
B	90	0
C	180	0
D	270	0
E	0	90
F	0	-90
G	60	30
H	45	-45
I	150	25
J	255	-75
K	300	60

CALCULATION OF INPUT DATA

Measurements for the input files were calculated with the aid of a spreadsheet program. This facilitated calculation of each stress state in the local coordinate system for each borehole orientation. The local stress states were then used to calculate measurements for each gauge type.

Various material properties were chosen for the verification problems. For overcoring verification test problems not involving a combination of instrument types, Young's modulus was kept constant at 1×10^6 psi (6.895 GPa), and Poisson's ratio values were 0.05, 0.15, 0.25, 0.35, and 0.45. The biaxial test problems were determined using 2×10^6 psi (13.790 GPa) for Young's modulus and 0.25 for Poisson's ratio. For the combination of instruments overcoring problems, Young's moduli selected were 1×10^6 (6.895 GPa), 2×10^6 psi (13.790 GPa), 3×10^6 psi (20.685 GPa), 4×10^6 psi (27.580 GPa), and 5×10^6 psi (34.475 GPa); and Poisson's ratios were 0.05, 0.15, 0.25, 0.35, and 0.45.

The hollow inclusion cell properties were assumed to be 0.40 for Poisson's ratio and 0.384×10^6 psi (2.65 GPa) for Young's modulus. For these problems, standard CSIRO HICell and borehole dimensions were assumed; that is, inner radius of the hollow inclusion cell = 0.639 in (16 mm), hole radius = 0.75 in (19.05 mm), and radius of strain gauges = 0.689 (17.5 mm).[12]

[12]In using STRESsOUT to analyze measurements with a hollow inclusion cell, the user should check the cell properties and dimensions currently given by the manufacturer of the particular instrument at the time.

Table 6.—Stress states and borehole orientations used in test cases for code verification

Type of measurement	Designation in file names	Test problems by stress state case number and borehole orientation
HiCell (K-factors calculated for hollow inclusion cell).	HK	1A 1E 1G 2B 2F 2H
		3C 3E 3I 4D 4F 4J
		5A 5E 5K 6B 6F 6G
		7C 7E 7H 8D 8F 8I
		9A 9E 9J 10B 10F 10K
		11C 11E 11G 12D 12F 12H
Triaxial cell	T	12H
Overcored strain gauges on wall of bored raise.	BR	12H
Doorstopper [(using Rahn (*9*) stress concentration factors)].	DR	1ABJ 1BFK 1CEI 2AEI 2DGJ 2HJK
		3CFG 3DEH 3GHI 4ABJ 4BFK 4CEI
		5AEI 5DGJ 5HJK 6CFG 6DEH 6GHI
		7ABJ 7BFK 7CEI 8AEI 8DGJ 8HJK
		9CFG 9DEH 9GHI 10ABJ 10BFK 10CEI
		11AEI 11DGJ 11HJK 12CFG 12DEH 12GHI
Doorstopper [(using Hocking (*17*) stress concentration factors)].	DH	1ABJ 1BFK 1CEI 2AEI 2DGJ 2HJK
		3CFG 3DEH 3GHI 4ABJ 4BFK 4CEI
		5AEI 5DGJ 5HJK 6CFG 6DEH 6GHI
		7ABJ 7BFK 7CEI 8AEI 8DGJ 8HJK
		9CFG 9DEH 9GHI 10ABJ 10BFK 10CEI
		11AEI 11DGJ 11HJK 12CFG 12DEH 12GHI
Borehole deformation gauge . .	BDG	1ABJ 1BFK 1CEI 2AEI 2DGJ 2HJK
		3CFG 3DEH 3GHI 4ABJ 4BFK 4CEI
		5AEI 5DGJ 5HJK 6CFG 6DEH 6GHI
		7ABJ 7BFK 7CEI 8AEI 8DGJ 8HJK
		9CFG 9DEH 9GHI 10ABJ 10BFK 10CEI
		11AEI 11DGJ 11HJK 12CFG 12DEH 12GHI
Combination of gauge types . .	HDB	12CFG 12GHI
	HTD	12DEH
Biaxial test with hollow inclusion cell.	BIAX	2 3
Biaxial test with triaxial cell	BIAX	1
Miscellaneous (warning test) . . .	WARN	1 2 3

NOTE.—The format of file names is XXX##YYY.ZZZ, where XXX represents the designation of type of measurement (up to three characters), ## represents the stress-state case designation (up to two digits), YYY represents the borehole orientation(s) (up to three characters), and ZZZ distinguishes between an input file (INP) and an output file (OUT).

Measurements from the spreadsheet were assembled in files. A listing of some of the input files is in appendix B. Also, the input files, the STRESsOUT FORTRAN listing, and the executable file can be obtained on floppy diskette from the program package.

RESULTS

Results of the verification runs are not reproduced here because of their size. However, appendix C lists sample outputs, one for each type of measurement.

The difference between the stress output (global and principal systems) for the test problems and those listed in table 3 are less than 0.005 psi, or 0.0005 pct[13] of the largest magnitude of principal stress in each case. The error involved depends mostly on the precision of the calculated strains in the input.

The principal directions as written to the output file coincided to those given in table 3. However, the positive directions (as defined by the azimuth and inclination) may not coincide with the values in the table since there is more than one way to define a positive principal direction. Numerical differences, even between output runs (for example, output runs 1, 2, or 3 in the same output file), may cause differences in the definition of the positive principal axes, but the principal directions are the same. The user may recall that the program forces the output to list the principal system as a right-handed system.

CONCLUSIONS

The U.S. Bureau of Mines computer program STRESsOUT calculates stress state, given reliable measurements with instruments such as a hollow inclusion cell, a triaxial cell, strain gauges on the wall of a bored raise, a doorstopper gauge, a borehole deformation gauge, or a combination of any of these. In addition, the program fits the isotropic material properties of an overcore, given biaxial test measurements with a hollow inclusion cell or rosettes of a triaxial cell bonded to the wall of the smaller hole.

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APPENDIX A.—WARNINGS FOLLOWING UNREASONABLE VALUES OF MATERIAL PROPERTIES

First, if the user enters a value for Poisson's ratio that is outside of the usual range of isotropic values ($0 \leq PR \leq 0.5$), the pro-gram writes the following message to the output file:

WARNING: POISSON'S RATIO FOR THE FOLLOWING MATERIALS IS

OUTSIDE OF THE USUAL RANGE OF ISOTROPIC VALUES (0. TO 0.5).

##, ##

The symbols *##, ##* are the material types with Poisson's ratios outside of the usual range of values.

Second, if the magnitude of Poisson's ratio is close to zero, the calculation of one of the K-factors (K_4) for the hollow inclusion cell causes numerical problems because the denominator is very small (*3*).[1] Therefore, if the user selects options 1 or 6 in step 3 and any entered Poisson's ratio falls within a program-specified tolerance of zero, the program writes the following to the output file:

WARNING: THE VALUE OF POISSON'S RATIO FOR THE FOLLOWING MATERIALS MAY CAUSE CALCULATION OF UNREASONABLE VALUES

FOR HOLLOW INCLUSION CELL K-FACTORS.

##, ##

The symbols *##, ##* are the material types whose Poisson's ratios are less than or equal to the tolerance. The tolerance is currently set at 0.01 and may be changed in the code if the user desires. (The IF statement with the tolerance is identified by statement 1000 in subroutine **READ1**.)

Third, if Young's modulus is entered as a negative value, the program writes the following to the output file:

WARNING: YOUNG'S MODULUS FOR THE FOLLOWING MATERIALS IS NEGATIVE.

##, ##

The symbols *##, ##* are material types whose Young's moduli are negative.

[1]Italic numbers in parentheses refer to items in the list of references preceding this appendix.

APPENDIX B.—SAMPLE INPUT FROM VERIFICATION TEST PROBLEMS

Hollow Inclusion Cell:

Filename: HK12H.INP

```
1
HK12H.OUT
N
Verification test of HICell with
K-factors
Case 12H
0. 0. 0.
This test conducted July 1989
(Six blank lines here)
1
E
.05 1.
1
45. -45.
2
E
.4 .384 16. 19.05 17.5
1452.19 323. 90. 1 1
-1022.65 300. 0. 1 1
1513.58 300. 45. 1 1
-87.72 163.5 45. 1 1
-1006.42 163.5 135. 1 1
-3323.04 180. 0. 1 1
1452.19 83. 90. 1 1
-3053.15 60. 0. 1 1
-3213.09 60. 45. 1 1
0. 0. 0. 0 0
2
0
```

Triaxial Cell:

Filename: TR12H.INP

```
2
TR12H.OUT
N
Triaxial Cell
Case 12H
0. 0. 0.
This test conducted December 1990
(Six blank lines here)
1
E
.25 1.
1
45. -45.
1915.46 300. 90. 1 1
-1185.69 300. 0. 1 1
1872.63 300. 45. 1 1
490.83 180. 45. 1 1
-2095.13 180. 135. 1 1
-3519.76 180. 0. 1 1
1915.46 60. 90. 1 1
-3245.92 60. 0. 1 1
-3465.96 60. 45. 1 1
0. 0. 0. 0 0
2
0
```

Bored Raise:

Filename: BR12H.INP

```
3
BR12H.OUT
N
Verification test of Bored Raise
Option
Case 12H
0. 0. 0.
This test conducted December 1990
(Six blank lines here)
1
E
.25 1.
1
45. -45.
1915.46 300. 90. 1 1
-1185.69 300. 0. 1 1
1872.63 300. 45. 1 1
490.83 180. 45. 1 1
-2095.13 180. 135. 1 1
-3519.76 180. 0. 1 1
1915.46 60. 90. 1 1
-3245.92 60. 0. 1 1
-3465.96 60. 45. 1 1
0. 0. 0. 0 0
2
0
```

Doorstopper gauge (Rahn):

Filename: DR10ABJ.INP

```
4
DR10ABJ.OUT
N
Doorstopper gauges--Rahn
Case 10ABJ
0. 0. 0.
```

```
This test conducted August 1989
(Six blank lines here)
1
E
.25 1.
3
0. 0.
90. 0.
255. -75.
1
4169.43 0. 1 1
-3656.70 90. 1 1
256.36 45. 1 1
256.36 -45. 1 1
4398.40 0. 2 1
920.12 90. 2
2659.26 45. 2 1
2659.26 -45. 2 1
-3017.31 0. 3 1
243.30 90. 3 1
-337.08 45. 3 1
-2436.93 -45. 3 1
0. 0. 0 0
2
0
```

Doorstopper gauge (Hocking):

Filename: DH9CFG.INP

```
4
DH9CFG.OUT
N
Doorstopper gauges--Hocking
Case 9CFG
0. 0. 0.
This test conducted August 1989
(Six blank lines here)
1
E
.45 1.
3
180. 0.
0. -90.
60. 30.
2
312.59 0. 1 1
312.59 90. 1 1
312.59 45. 1 1
312.59 -45. 1 1
312.59 0. 2 1
312.59 90. 2 1
312.59 45. 2 1
312.59 -45. 2 1
312.59 0. 3 1
312.59 90. 3 1
312.59 45. 3 1
312.59 -45. 3 1
0. 0. 0 0
2
0
```

Borehole Deformation Gauge:

Filename: BDG8HJK.INP

```
5
BDG8HJK.OUT
N
Borehole deformation gauges
Case 8HJK
0. 0. 0.
This test conducted August 1989
(Six blank lines here)
1
E
.35 1.
3
45. -45.
255. -75.
300. 60.
1
E
1.5
118.63 -60. 1 1 1
1468.12 0. 1 1 1
-3105.50 60. 1 1 1
-2013.18 -60. 2 1 1
587.70 0. 2 1 1
-4215.31 60. 2 1 1
-751.78 -60. 3 1 1
746.72 0. 3 1 1
-4171.49 60. 3 1 1
0. 0. 0 0 0
2
0
```

Combination of gauges:

Filename: HTD12DEH.INP

```
6
HTD12DEH.OUT
N
Combination--HICell, triaxial cell, doorstopper gauge, and BDG
Case 12deh
0. 0. 0.
This test conducted December 1990

Borehole 1 -- HICell installed at 16 ft 10 in.
Borehole 1 -- Triaxial cell installed at 18 ft 9 in.
Borehole 2 -- Doorstopper at 20 ft 8 in -- Rahn
Borehole 3 -- Doorstopper at 16 ft 3 in -- Hocking.
Borehole 3 -- Borehole Def. Gauge installed at 18 ft 9 in.
5
E
.05 5.
.15 4.
.25 3.
.35 2.
.45 1.
3
270. 0.
0. 90.
45. -45.
1
6
2
E
.4 .384 16. 19.05 17.5
-618.33 323. 90. 1 3
1991.19 300. 0. 1 3
21.16 300. 45. 1 3
163.58 163.5 45. 1 3
-692.32 163.5 135. 1 3
-746.28 180. 0. 1 3
2
3
-1995.00 83. 90. 1 5
325.39 60. 0. 1 5
488.23 60. 45. 1 5
4
4
1
-168.25 0. 2 1
-523.61 90. 2 1
-255.58 45. 2 1
-436.27 -45. 2 1
4
```

```
4
2
-630.87 0. 3 4
-1059.68 90. 3 4
-551.90 45. 3 4
-1138.65 -45. 3 4
5
6
2
E
1.5
2.
-1516.53 -60. 3 2 1
-603.91 0. 3 2 1
-710.98 60. 3 2 1
-2022.04 -60. 3 2 2
-805.22 0. 3 2 2
-947.98 60. 3 2 2
0
5
0
```

<u>Biaxial Test on Overcore with Hollow Inclusion Cell</u>:

Filename: BIAX2.INP

```
7
BIAX2.OUT
N
Hollow Inclusion Cell
SRC
August 1990
The strains here are nearly exact for a biaxial test with pressure
placed at a radius of 2.875 in. (5.75 diameter).
The strain gauges are embedded in a hollow inclusion cell.
The strains should converge to
    Poisson's ratio = 0.25        Young's modulus = 2.00 * 1.e6 psi
E
.4 .5 16. 19.05 17.5
1.01 1.01 10 .00001
1.5 5.75
E
-532.72 2000. 90.
2258.72 2000. 0.
863.00 2000. 45.
863.00 2000. 45.
863.00 2000. 135.
2258.72 2000. 0.
-532.72 2000. 90.
2258.72 2000. 0.
863.00 2000. 45.
0. 0. 777.
```

```
2
0
```

<u>Biaxial Test on Overcore with Triaxial Cell:</u>

Filename: BIAX1.INP

```
8
BIAX1.OUT
N
Triaxial cell
SRC
August 1990
The strains here are nearly exact for a biaxial test with pressure
placed at a radius of infinity (7.5e6 in. radius).
The strain gauges are on the wall of the hole.
The results should converge to
    Poisson's ratio = 0.25       Young's = 2.00 * 1.e6 psi
1.5 15000000.
E
-500. 2000. 90.
2000. 2000. 0.
750. 2000. 45.
750. 2000. 45.
750. 2000. 135.
2000. 2000. 0.
-500. 2000. 90.
2000. 2000. 0.
750. 2000. 45.
0. 0. 777.
2
0
```

APPENDIX C.—SAMPLE OUTPUT FROM VERIFICATION TEST PROBLEMS

Overcoring Data -- Hollow Inclusion Cell:

Filename: HK12H.OUT

```
**************************************************
*                                                *
*                   STRESsOUT                    *
*                                                *
*                 (Version 1.00)                 *
*                                                *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM   *
*                                                *
**************************************************
```

```
GENERAL INFORMATION
--------------------
     INSTRUMENT TYPE:      Verification test of HICell with K-factors
     INSTRUMENT LOCATION:  Case 12H
                NORTHING:      .00
                EASTING:       .00
                ELEVATION:     .00
     DATE OF INSTALLATION: This test conducted July 1989
     DATE OF OVERCORING:

SETTING DEPTH INFORMATION:
```

ROCK ELASTIC PROPERTIES:

MATERIAL TYPE	POISSON'S RATIO (m/m)	YOUNG'S MODULUS (*10**6 psi)	YOUNG'S MODULUS (GPa)
1	.0500	1.0000	6.8950

BOREHOLE ORIENTATIONS:

BOREHOLE NUMBER	AZIMUTH (deg)	INCLINATION (deg)
1	45.00	-45.00

PROPERTIES OF HOLLOW INCLUSION CELL:

POISSON'S RATIO (m/m)	YOUNG'S MODULUS (psi)	YOUNG'S MODULUS (GPa)	INNER RADIUS	HOLE RADIUS	RADIUS OF GAUGES
.40000	.38400	2.64768	16.000	19.050	17.500

CORRECTION FACTORS FOR HOLLOW INCLUSION CELL:

MATERIAL	K1	K2	K3	K4
1	1.04518	.92629	1.02550	.67726

READINGS:
-THE READINGS REFLECT THE CHANGE IN STRAIN OR DISPLACEMENT AT THE GAUGE

DUE TO OVERCORING. SIGN CONVENTION: TENSILE STRAIN OR EXTENSION IS POSITIVE. BECAUSE THE READINGS ARE DUE TO STRESS RELIEF, THE SIGN CONVENTION FOR STRESS IS OPPOSITE -- COMPRESSIVE STRESS IS POSITIVE.

-ALPHA IS THE ANGLE IN DEGREES DESCRIBING THE POSITION OF THE MIDPOINT OF THE GAUGE ON THE CIRCUMFERENCE OF THE BOREHOLE OR RAISE. (LOOKING INTO THE BOREHOLE, IT IS MEASURED CLOCKWISE FROM NORTH OR UP.)

-BETA IS THE ANGLE IN DEGREES DESCRIBING THE TILT OF THE GAUGE. LOOKING ALONG THE POSITIVE R-AXIS (R-ALPHA-Z SYSTEM), BETA IS MEASURED POSITIVE FROM THE ALPHA-AXIS CLOCKWISE TO THE AXIS OF THE STRAIN GAUGE.

MICROSTRAIN OR MICROINCHES	ALPHA	BETA	BOREHOLE NUMBER	MATERIAL TYPE	DIAMETER NUMBER	INSTRUMENT
1452.19	323.00	90.00	1	1		Hollow Inclusion Cell
-1022.65	300.00	.00	1	1		Hollow Inclusion Cell
1513.58	300.00	45.00	1	1		Hollow Inclusion Cell
-87.72	163.50	45.00	1	1		Hollow Inclusion Cell
-1006.42	163.50	135.00	1	1		Hollow Inclusion Cell
-3323.04	180.00	.00	1	1		Hollow Inclusion Cell
1452.19	83.00	90.00	1	1		Hollow Inclusion Cell
-3053.15	60.00	.00	1	1		Hollow Inclusion Cell
-3213.09	60.00	45.00	1	1		Hollow Inclusion Cell

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .49993699E+06

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
1452.19	1452.19	.00
-1022.65	-1022.65	.00
1513.58	1513.58	.00
-87.72	-87.72	.00
-1006.42	-1006.42	.00
-3323.04	-3323.04	.00
1452.19	1452.19	.00
-3053.15	-3053.15	.00
-3213.09	-3213.09	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 3 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	-1680.00	-11.584

STANDARD ERROR	.000	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.001	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	33361453.56	6	5560242.26	************
DEVIATION	.00	3	.00	
TOTAL VARIATION	33361453.56	9		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.71	12.113	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .16006964E+06

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
1452.19	1452.19	.00
-1022.65	-1022.65	.00
1513.58	1513.58	.00
4 DISCARD NO. 1		
-1006.42	-1006.42	.00
-3323.04	-3323.04	.00
1452.19	1452.19	.00
-3053.15	-3053.15	.00

-3213.09	-3213.09	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 2 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.827
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	32774895.34	6	5462482.56	************
DEVIATION	.00	2	.00	
TOTAL VARIATION	32774895.34	8		

PRINCIPAL STRESSES (psi)	PRINCIPAL STRESSES (MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.71	12.113	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .55780071E+05

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
1452.19	1452.19	.00
-1022.65	-1022.65	.00
3 DISCARD NO. 2		
4 DISCARD NO. 1		
-1006.42	-1006.42	.00
-3323.04	-3323.04	.00
1452.19	1452.19	.00
-3053.15	-3053.15	.00
-3213.09	-3213.09	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 1 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	(MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.827
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	26117062.49	6	4352843.75	************
DEVIATION	.00	1	.00	
TOTAL VARIATION	26117062.49	7		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.71	12.113	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

Overcoring Data -- Triaxial Cell:

Filename: TR12H.OUT

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**************************************************
*                                                *
*                   STRESSOUT                    *
*                                                *
*                (Version 1.00)                  *
*                                                *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM   *
*                                                *
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GENERAL INFORMATION

INSTRUMENT TYPE: Triaxial Cell
INSTRUMENT LOCATION: Case 12H
NORTHING: .00
EASTING: .00
ELEVATION: .00
DATE OF INSTALLATION: This test conducted December 1990
DATE OF OVERCORING:

SETTING DEPTH INFORMATION:

ROCK ELASTIC PROPERTIES:

MATERIAL TYPE	POISSON'S RATIO (m/m)	YOUNG'S MODULUS (*10**6 psi)	YOUNG'S MODULUS (GPa)
1	.2500	1.0000	6.8950

BOREHOLE ORIENTATIONS:

BOREHOLE NUMBER	AZIMUTH (deg)	INCLINATION (deg)
1	45.00	-45.00

READINGS:

-THE READINGS REFLECT THE CHANGE IN STRAIN OR DISPLACEMENT AT THE GAUGE DUE TO OVERCORING. SIGN CONVENTION: TENSILE STRAIN OR EXTENSION IS POSITIVE. BECAUSE THE READINGS ARE DUE TO STRESS RELIEF, THE SIGN CONVENTION FOR STRESS IS OPPOSITE -- COMPRESSIVE STRESS IS POSITIVE.
-ALPHA IS THE ANGLE IN DEGREES DESCRIBING THE POSITION OF THE MIDPOINT OF THE GAUGE ON THE CIRCUMFERENCE OF THE BOREHOLE OR RAISE. (LOOKING INTO THE BOREHOLE, IT IS MEASURED CLOCKWISE FROM NORTH OR UP.)
-BETA IS THE ANGLE IN DEGREES DESCRIBING THE TILT OF THE GAUGE. LOOKING ALONG THE POSITIVE R-AXIS (R-ALPHA-Z SYSTEM), BETA IS MEASURED POSITIVE FROM THE ALPHA-AXIS CLOCKWISE TO THE AXIS OF THE STRAIN GAUGE.

MICROSTRAIN OR MICROINCHES	ALPHA	BETA	BOREHOLE NUMBER	MATERIAL TYPE	DIAMETER NUMBER	INSTRUMENT

1915.46	300.00	90.00	1	1	Triaxial Cell
-1185.69	300.00	.00	1	1	Triaxial Cell
1872.63	300.00	45.00	1	1	Triaxial Cell
490.83	180.00	45.00	1	1	Triaxial Cell
-2095.13	180.00	135.00	1	1	Triaxial Cell
-3519.76	180.00	.00	1	1	Triaxial Cell
1915.46	60.00	90.00	1	1	Triaxial Cell
-3245.92	60.00	.00	1	1	Triaxial Cell
-3465.96	60.00	45.00	1	1	Triaxial Cell

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .82490500E+06

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
1915.46	1915.46	.00
-1185.69	-1185.69	.00
1872.63	1872.63	.00
490.83	490.83	.00
-2095.13	-2095.13	.00
-3519.76	-3519.76	.00
1915.46	1915.46	.00
-3245.92	-3245.92	.00
-3465.96	-3465.96	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 3 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	S T R E S S E S (psi)	(MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.001	.0000
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.001	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.001	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS.

CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	45868170.34	6	7644695.06	************
DEVIATION	.00	3	.00	
TOTAL VARIATION	45868170.34	9		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.77	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .24059730E+06

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
1915.46	1915.46	.00
-1185.69	-1185.69	.00
1872.63	1872.63	.00
490.83	490.83	.00
-2095.13	-2095.13	.00
-3519.76	-3519.76	.00
1915.46	1915.46	.00
-3245.92	-3245.92	.00

9 DISCARD NO. 1

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 2 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	S T R E S S E S (psi)	(MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	37950915.26	6	6325152.54	************
DEVIATION	.00	2	.00	
TOTAL VARIATION	37950915.26	8		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .13748417E+06

DEVIATIONS:

STRAIN COMPUTED STRAIN DIFFERENCE

1915.46	1915.46	.00
-1185.69	-1185.69	.00
1872.63	1872.63	.00
490.83	490.83	.00
-2095.13	-2095.13	.00
-3519.76	-3519.76	.00
7 DISCARD NO. 2		
-3245.92	-3245.92	.00
9 DISCARD NO. 1		

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 1 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	(MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	31384641.95	6	5230773.66	************
DEVIATION	.00	1	.00	
TOTAL VARIATION	31384641.95	7		

PRINCIPAL STRESSES AZIMUTH INCLINATION

(psi)	(MPa)	(deg)	(deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

Overcoring Data -- Strain Gauges on Wall of Bored Raise:

Filename: BR12H.OUT

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*************************************************
*                                               *
*                  STRESSsOUT                   *
*                                               *
*                (Version 1.00)                 *
*                                               *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM  *
*                                               *
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GENERAL INFORMATION

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     INSTRUMENT TYPE:      Verification test of Bored Raise Option
     INSTRUMENT LOCATION:  Case 12H
                NORTHING:       .00
                EASTING:        .00
                ELEVATION:      .00
     DATE OF INSTALLATION: This test conducted December 1990
     DATE OF OVERCORING:
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SETTING DEPTH INFORMATION:

ROCK ELASTIC PROPERTIES:

MATERIAL TYPE	POISSON'S RATIO (m/m)	YOUNG'S MODULUS (*10**6 psi)	YOUNG'S MODULUS (GPa)
1	.2500	1.0000	6.8950

BOREHOLE ORIENTATIONS:

BOREHOLE NUMBER	AZIMUTH (deg)	INCLINATION (deg)
1	45.00	-45.00

READINGS:

-THE READINGS REFLECT THE CHANGE IN STRAIN OR DISPLACEMENT AT THE GAUGE DUE TO OVERCORING. SIGN CONVENTION: TENSILE STRAIN OR EXTENSION IS POSITIVE. BECAUSE THE READINGS ARE DUE TO STRESS RELIEF, THE SIGN CONVENTION FOR STRESS IS OPPOSITE -- COMPRESSIVE STRESS IS POSITIVE.

-ALPHA IS THE ANGLE IN DEGREES DESCRIBING THE POSITION OF THE MIDPOINT OF THE GAUGE ON THE CIRCUMFERENCE OF THE BOREHOLE OR RAISE. (LOOKING INTO THE BOREHOLE, IT IS MEASURED CLOCKWISE FROM NORTH OR UP.)

-BETA IS THE ANGLE IN DEGREES DESCRIBING THE TILT OF THE GAUGE. LOOKING ALONG THE POSITIVE R-AXIS (R-ALPHA-Z SYSTEM), BETA IS MEASURED POSITIVE FROM THE ALPHA-AXIS CLOCKWISE TO THE AXIS OF THE STRAIN GAUGE.

MICROSTRAIN OR MICROINCHES	ALPHA	BETA	BOREHOLE NUMBER	MATERIAL TYPE	DIAMETER NUMBER	INSTRUMENT

1915.46	300.00	90.00	1	1	Gauges on Wall of Bored Raise
-1185.69	300.00	.00	1	1	Gauges on Wall of Bored Raise
1872.63	300.00	45.00	1	1	Gauges on Wall of Bored Raise
490.83	180.00	45.00	1	1	Gauges on Wall of Bored Raise
-2095.13	180.00	135.00	1	1	Gauges on Wall of Bored Raise
-3519.76	180.00	.00	1	1	Gauges on Wall of Bored Raise
1915.46	60.00	90.00	1	1	Gauges on Wall of Bored Raise
-3245.92	60.00	.00	1	1	Gauges on Wall of Bored Raise
-3465.96	60.00	45.00	1	1	Gauges on Wall of Bored Raise

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .82490500E+06

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
1915.46	1915.46	.00
-1185.69	-1185.69	.00
1872.63	1872.63	.00
490.83	490.83	.00
-2095.13	-2095.13	.00
-3519.76	-3519.76	.00
1915.46	1915.46	.00
-3245.92	-3245.92	.00
-3465.96	-3465.96	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 3 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	S T R E S S E S (psi)	(MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.001	.0000
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.001	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.001	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS.

CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	45868170.34	6	7644695.06	************
DEVIATION	.00	3	.00	
TOTAL VARIATION	45868170.34	9		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.77	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .24059730E+06

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
1915.46	1915.46	.00
-1185.69	-1185.69	.00
1872.63	1872.63	.00
490.83	490.83	.00
-2095.13	-2095.13	.00
-3519.76	-3519.76	.00
1915.46	1915.46	.00
-3245.92	-3245.92	.00

9 DISCARD NO. 1

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 2 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	(MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	37950915.26	6	6325152.54	************
DEVIATION	.00	2	.00	
TOTAL VARIATION	37950915.26	8		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .13748417E+06

DEVIATIONS:

STRAIN COMPUTED STRAIN DIFFERENCE

1915.46	1915.46	.00
-1185.69	-1185.69	.00
1872.63	1872.63	.00
490.83	490.83	.00
-2095.13	-2095.13	.00
-3519.76	-3519.76	.00
7 DISCARD NO. 2		
-3245.92	-3245.92	.00
9 DISCARD NO. 1		

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 1 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	31384641.95	6	5230773.66	************
DEVIATION	.00	1	.00	
TOTAL VARIATION	31384641.95	7		

PRINCIPAL STRESSES AZIMUTH INCLINATION

(psi)	(MPa)	(deg)	(deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

Overcoring Data -- Doorstopper (Rahn):

Filename: DR10ABJ.OUT

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**************************************************
*                                                *
*                   STRESSOUT                    *
*                                                *
*                (Version 1.00)                  *
*                                                *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM   *
*                                                *
**************************************************
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GENERAL INFORMATION

INSTRUMENT TYPE: Doorstopper gauges--Rahn
INSTRUMENT LOCATION: Case 10ABJ
NORTHING: .00
EASTING: .00
ELEVATION: .00
DATE OF INSTALLATION: This test conducted August 1989
DATE OF OVERCORING:

SETTING DEPTH INFORMATION:

ROCK ELASTIC PROPERTIES:

MATERIAL TYPE	POISSON'S RATIO (m/m)	YOUNG'S MODULUS (*10**6 psi)	YOUNG'S MODULUS (GPa)
1	.2500	1.0000	6.8950

BOREHOLE ORIENTATIONS:

BOREHOLE NUMBER	AZIMUTH (deg)	INCLINATION (deg)
1	.00	.00
2	90.00	.00
3	255.00	-75.00

STRESS CONCENTRATION FACTORS (RAHN):

MATERIAL	a	b	c	d
1	1.345000	-.046312	-.632200	1.391313

READINGS:
-THE READINGS REFLECT THE CHANGE IN STRAIN OR DISPLACEMENT AT THE GAUGE DUE TO OVERCORING. SIGN CONVENTION: TENSILE STRAIN OR EXTENSION IS POSITIVE. BECAUSE THE READINGS ARE DUE TO STRESS RELIEF, THE SIGN CONVENTION FOR STRESS IS OPPOSITE -- COMPRESSIVE STRESS IS POSITIVE.
-ALPHA IS THE ANGLE IN DEGREES DESCRIBING THE POSITION OF THE MIDPOINT OF THE GAUGE ON THE CIRCUMFERENCE OF THE BOREHOLE OR RAISE. (LOOKING INTO THE BOREHOLE, IT IS MEASURED CLOCKWISE FROM NORTH OR UP.)
-BETA IS THE ANGLE IN DEGREES DESCRIBING THE TILT OF THE GAUGE.

LOOKING ALONG THE POSITIVE R-AXIS (R-ALPHA-Z SYSTEM), BETA IS MEASURED POSITIVE FROM THE ALPHA-AXIS CLOCKWISE TO THE AXIS OF THE STRAIN GAUGE.

MICROSTRAIN OR MICROINCHES	ALPHA	BETA	BOREHOLE NUMBER	MATERIAL TYPE	DIAMETER NUMBER	INSTRUMENT
4169.43	.00		1	1		Doorstopper--Rahn
-3656.70	90.00		1	1		Doorstopper--Rahn
256.36	45.00		1	1		Doorstopper--Rahn
256.36	-45.00		1	1		Doorstopper--Rahn
4398.40	.00		2	1		Doorstopper--Rahn
920.12	90.00		2	1		Doorstopper--Rahn
2659.26	45.00		2	1		Doorstopper--Rahn
2659.26	-45.00		2	1		Doorstopper--Rahn
-3017.31	.00		3	1		Doorstopper--Rahn
243.30	90.00		3	1		Doorstopper--Rahn
-337.08	45.00		3	1		Doorstopper--Rahn
-2436.93	-45.00		3	1		Doorstopper--Rahn

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .14218843E+05

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
4169.43	4169.43	.00
-3656.70	-3656.71	.01
256.36	256.36	.00
256.36	256.36	.00
4398.40	4398.40	.00
920.12	920.12	.00
2659.26	2659.26	.00
2659.26	2659.26	.00
-3017.31	-3017.31	.00
243.30	243.30	.00
-337.08	-337.08	.00
-2436.93	-2436.93	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 6 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	1000.00	6.895
STANDARD ERROR	.003	.0000
NORMAL EAST-WEST	-1500.00	-10.342
STANDARD ERROR	.003	.0000

NORMAL VERTICAL	3000.00	20.685
STANDARD ERROR	.002	.0000
SHEAR N-S/E-W	.00	.000
STANDARD ERROR	.002	.0000
SHEAR E-W/VERT	.00	.000
STANDARD ERROR	.002	.0000
SHEAR VERT/N-S	.00	.000
STANDARD ERROR	.002	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	77322956.51	6	12887159.42	************
DEVIATION	.00	6	.00	
TOTAL VARIATION	77322956.51	12		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
3000.00	20.685	--	90.0
1000.00	6.895	180.0	.0
-1500.00	-10.342	270.0	.0

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .85824065E+04

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
4169.43	4169.43	.00
2 DISCARD NO. 1		
256.36	256.36	.00
256.36	256.36	.00
4398.40	4398.40	.00
920.12	920.12	.00
2659.26	2659.26	.00
2659.26	2659.26	.00
-3017.31	-3017.31	.00
243.30	243.30	.00

-337.08	-337.08	.00
-2436.93	-2436.93	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 5 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	(MPa)
NORMAL NORTH-SOUTH	1000.00	6.895
STANDARD ERROR	.002	.0000
NORMAL EAST-WEST	-1500.00	-10.343
STANDARD ERROR	.002	.0000
NORMAL VERTICAL	3000.00	20.685
STANDARD ERROR	.002	.0000
SHEAR N-S/E-W	.00	.000
STANDARD ERROR	.001	.0000
SHEAR E-W/VERT	.00	.000
STANDARD ERROR	.001	.0000
SHEAR VERT/N-S	.00	.000
STANDARD ERROR	.001	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	58387448.74	6	9731241.46	************
DEVIATION	.00	5	.00	
TOTAL VARIATION	58387448.74	11		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
3000.00	20.685	--	-90.0
1000.00	6.895	180.0	.0

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-1500.00  -10.343        90.0        .0

NOTE:  (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
       (2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
       (3) "--" INDICATES VALUE IS NOT UNIQUE.
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OUTPUT RESULTS:  RUN NUMBER  3
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THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS    .49223328E+04


DEVIATIONS:

  STRAIN        COMPUTED STRAIN     DIFFERENCE
 4169.43           4169.43             .00
    2  DISCARD NO.  1
  256.36            256.36             .00
  256.36            256.36             .00
 4398.40           4398.40             .00
  920.12            920.12             .00
 2659.26           2659.26             .00
 2659.26           2659.26             .00
-3017.31          -3017.31             .00
   10  DISCARD NO.  2
 -337.08           -337.08             .00
-2436.93          -2436.93             .00

  STANDARD DEVIATION OF DIFFERENCES IS     .00 ON  4 DEGREES OF FREEDOM.
  GOODNESS OF FIT =1.00
  CORRELATION COEFFICIENT =1.00


  THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD
  WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES
  METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM.  THE MAGNITUDE AND
  DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.


**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

  COMPONENT              S T R E S S E S
  DESIGNATION            (psi)       (MPa)
 ------------------------------------------

  NORMAL NORTH-SOUTH   1000.00      6.895
  STANDARD ERROR           .001      .0000

  NORMAL EAST-WEST    -1500.00    -10.343
  STANDARD ERROR           .002      .0000

  NORMAL VERTICAL      3000.00     20.685
  STANDARD ERROR           .001      .0000

  SHEAR N-S/E-W            .00       .000
  STANDARD ERROR           .001      .0000

  SHEAR E-W/VERT           .00       .000
  STANDARD ERROR           .001      .0000

  SHEAR VERT/N-S           .00       .000
  STANDARD ERROR           .001      .0000


  NOTE:  THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS.
  CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S
```

T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	57929838.01	6	9654973.00	*************
DEVIATION	.00	4	.00	
TOTAL VARIATION	57929838.01	10		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
3000.00	20.685	--	-90.0
1000.00	6.895	180.0	.0
-1500.00	-10.343	90.0	.0

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

Overcoring Data -- Doorstopper (Hocking):

Filename: DH9CFG.OUT

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**************************************************
*                                                *
*                    STRESSOUT                   *
*                                                *
*                 (Version 1.00)                 *
*                                                *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM   *
*                                                *
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GENERAL INFORMATION

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INSTRUMENT TYPE:      Doorstopper gauges--Hocking
INSTRUMENT LOCATION:  Case 9CFG
          NORTHING:       .00
          EASTING:        .00
          ELEVATION:      .00
DATE OF INSTALLATION: This test conducted August 1989
DATE OF OVERCORING:
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SETTING DEPTH INFORMATION:

ROCK ELASTIC PROPERTIES:

MATERIAL TYPE	POISSON'S RATIO (m/m)	YOUNG'S MODULUS (*10**6 psi)	YOUNG'S MODULUS (GPa)
1	.4500	1.0000	6.8950

BOREHOLE ORIENTATIONS:

BOREHOLE NUMBER	AZIMUTH (deg)	INCLINATION (deg)
1	180.00	.00
2	.00	-90.00
3	60.00	30.00

STRESS CONCENTRATION FACTORS (HOCKING):

MATERIAL	a	b	c	d
1	1.386288	.061800	-.879732	1.324488

READINGS:

-THE READINGS REFLECT THE CHANGE IN STRAIN OR DISPLACEMENT AT THE GAUGE DUE TO OVERCORING. SIGN CONVENTION: TENSILE STRAIN OR EXTENSION IS POSITIVE. BECAUSE THE READINGS ARE DUE TO STRESS RELIEF, THE SIGN CONVENTION FOR STRESS IS OPPOSITE -- COMPRESSIVE STRESS IS POSITIVE.

-ALPHA IS THE ANGLE IN DEGREES DESCRIBING THE POSITION OF THE MIDPOINT OF THE GAUGE ON THE CIRCUMFERENCE OF THE BOREHOLE OR RAISE. (LOOKING INTO THE BOREHOLE, IT IS MEASURED CLOCKWISE FROM NORTH OR UP.)

-BETA IS THE ANGLE IN DEGREES DESCRIBING THE TILT OF THE GAUGE.

LOOKING ALONG THE POSITIVE R-AXIS (R-ALPHA-Z SYSTEM), BETA IS MEASURED POSITIVE FROM THE ALPHA-AXIS CLOCKWISE TO THE AXIS OF THE STRAIN GAUGE.

MICROSTRAIN OR MICROINCHES	ALPHA	BETA	BOREHOLE NUMBER	MATERIAL TYPE	DIAMETER NUMBER	INSTRUMENT
312.59	.00		1	1		Doorstopper--Hocking
312.59	90.00		1	1		Doorstopper--Hocking
312.59	45.00		1	1		Doorstopper--Hocking
312.59	-45.00		1	1		Doorstopper--Hocking
312.59	.00		2	1		Doorstopper--Hocking
312.59	90.00		2	1		Doorstopper--Hocking
312.59	45.00		2	1		Doorstopper--Hocking
312.59	-45.00		2	1		Doorstopper--Hocking
312.59	.00		3	1		Doorstopper--Hocking
312.59	90.00		3	1		Doorstopper--Hocking
312.59	45.00		3	1		Doorstopper--Hocking
312.59	-45.00		3	1		Doorstopper--Hocking

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .80140549E+04

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	S T R E S S E S (psi)	(MPa)
NORMAL NORTH-SOUTH	999.98	6.895
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	999.98	6.895
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	999.98	6.895
STANDARD ERROR	.000	.0000

SHEAR N-S/E-W	.00	.000
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	.00	.000
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	.00	.000
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF RESIDUALS WAS NOT DONE BECAUSE OF NEGLIGIBLE ERROR IN MEASUREMENTS.

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
999.98	6.895	--	--
999.98	6.895	--	--
999.98	6.895	--	--

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .36764751E+04

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
5 DISCARD NO. 1		
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	999.98	6.895
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	999.98	6.895
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	999.98	6.895
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	.00	.000
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	.00	.000
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	.00	.000
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF RESIDUALS WAS NOT DONE BECAUSE OF NEGLIGIBLE ERROR IN MEASUREMENTS.

PRINCIPAL STRESSES (psi)	PRINCIPAL STRESSES (MPa)	AZIMUTH (deg)	INCLINATION (deg)
999.98	6.895	--	--
999.98	6.895	--	--
999.98	6.895	--	--

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .21865281E+04

DEVIATIONS:

STRAIN	COMPUTED STRAIN	DIFFERENCE
312.59	312.59	.00
2 DISCARD NO. 2		
312.59	312.59	.00
312.59	312.59	.00
5 DISCARD NO. 1		
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00
312.59	312.59	.00

312.59	312.59	.00
312.59	312.59	.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	999.98	6.895
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	999.98	6.895
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	999.98	6.895
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	.00	.000
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	.00	.000
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	.00	.000
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF RESIDUALS WAS NOT DONE BECAUSE OF NEGLIGIBLE ERROR IN MEASUREMENTS.

PRINCIPAL STRESSES (psi)	PRINCIPAL STRESSES (MPa)	AZIMUTH (deg)	INCLINATION (deg)
999.98	6.895	--	--
999.98	6.895	--	--
999.98	6.895	--	--

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

Borehole deformation gauge:

Filename: BDG8HJK.OUT

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**************************************************
*                                                *
*                   STRESSOUT                    *
*                                                *
*                 (Version 1.00)                 *
*                                                *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM   *
*                                                *
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GENERAL INFORMATION
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     INSTRUMENT TYPE:      Borehole deformation gauges
     INSTRUMENT LOCATION:  Case 8HJK
                NORTHING:       .00
                EASTING:        .00
                ELEVATION:      .00
     DATE OF INSTALLATION: This test conducted August 1989
     DATE OF OVERCORING:

SETTING DEPTH INFORMATION:
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ROCK ELASTIC PROPERTIES:

MATERIAL TYPE	POISSON'S RATIO (m/m)	YOUNG'S MODULUS (*10**6 psi)	YOUNG'S MODULUS (GPa)
1	.3500	1.0000	6.8950

BOREHOLE ORIENTATIONS:

BOREHOLE NUMBER	AZIMUTH (deg)	INCLINATION (deg)
1	45.00	-45.00
2	255.00	-75.00
3	300.00	60.00

BOREHOLE DIAMETER:

DIAMETER NUMBER	* * DIAMETER * * (in)	(mm)
1	1.5000	38.1000

READINGS:
- THE READINGS REFLECT THE CHANGE IN STRAIN OR DISPLACEMENT AT THE GAUGE DUE TO OVERCORING. SIGN CONVENTION: TENSILE STRAIN OR EXTENSION IS POSITIVE. BECAUSE THE READINGS ARE DUE TO STRESS RELIEF, THE SIGN CONVENTION FOR STRESS IS OPPOSITE -- COMPRESSIVE STRESS IS POSITIVE.
- ALPHA IS THE ANGLE IN DEGREES DESCRIBING THE POSITION OF THE MIDPOINT OF THE GAUGE ON THE CIRCUMFERENCE OF THE BOREHOLE OR RAISE. (LOOKING INTO THE BOREHOLE, IT IS MEASURED CLOCKWISE FROM NORTH OR UP.)

-BETA IS THE ANGLE IN DEGREES DESCRIBING THE TILT OF THE GAUGE. LOOKING ALONG THE POSITIVE R-AXIS (R-ALPHA-Z SYSTEM), BETA IS MEASURED POSITIVE FROM THE ALPHA-AXIS CLOCKWISE TO THE AXIS OF THE STRAIN GAUGE.

MICROSTRAIN OR MICROINCHES	ALPHA	BETA	BOREHOLE NUMBER	MATERIAL TYPE	DIAMETER NUMBER	INSTRUMENT
118.63	-60.00		1	1	1	Borehole Deformation Gauge
1468.12	.00		1	1	1	Borehole Deformation Gauge
-3105.50	60.00		1	1	1	Borehole Deformation Gauge
-2013.18	-60.00		2	1	1	Borehole Deformation Gauge
587.70	.00		2	1	1	Borehole Deformation Gauge
-4215.31	60.00		2	1	1	Borehole Deformation Gauge
-751.78	-60.00		3	1	1	Borehole Deformation Gauge
746.72	.00		3	1	1	Borehole Deformation Gauge
-4171.49	60.00		3	1	1	Borehole Deformation Gauge

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .28348450E+09

DEVIATIONS:

DISPL.	COMPUTED DISPL.	DIFFERENCE
118.63	118.63	.00
1468.12	1468.12	.00
-3105.50	-3105.50	.00
-2013.18	-2013.18	.00
587.70	587.70	.00
-4215.31	-4215.31	.00
-751.78	-751.78	.00
746.72	746.72	.00
-4171.49	-4171.49	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 3 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	-1000.00	-6.895
STANDARD ERROR	.001	.0000
NORMAL EAST-WEST	.00	.000
STANDARD ERROR	.001	.0000
NORMAL VERTICAL	1000.00	6.895
STANDARD ERROR	.003	.0000
SHEAR N-S/E-W	.00	.000

STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	.00	.000
STANDARD ERROR	.001	.0000
SHEAR VERT/N-S	.00	.000
STANDARD ERROR	.001	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	38226247.31	6	6371041.22	************
DEVIATION	.00	3	.00	
TOTAL VARIATION	38226247.31	9		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1000.00	6.895	--	-90.0
.00	.000	270.0	.0
-1000.00	-6.895	180.0	.0

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .14020382E+09

DEVIATIONS:

DISPL.	COMPUTED DISPL.	DIFFERENCE
118.63	118.63	.00
1468.12	1468.12	.00
-3105.50	-3105.50	.00
-2013.18	-2013.18	.00
587.70	587.70	.00
6 DISCARD NO. 1		
-751.78	-751.78	.00
746.72	746.72	.00
-4171.49	-4171.49	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 2 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	-1000.00	-6.895
STANDARD ERROR	.001	.0000
NORMAL EAST-WEST	.00	.000
STANDARD ERROR	.001	.0000
NORMAL VERTICAL	1000.00	6.895
STANDARD ERROR	.002	.0000
SHEAR N-S/E-W	.00	.000
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	.00	.000
STANDARD ERROR	.001	.0000
SHEAR VERT/N-S	.00	.000
STANDARD ERROR	.001	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	28397768.93	6	4732961.49	************
DEVIATION	.00	2	.00	
TOTAL VARIATION	28397768.93	8		

PRINCIPAL STRESSES (psi)	PRINCIPAL STRESSES (MPa)	AZIMUTH (deg)	INCLINATION (deg)
1000.00	6.895	--	-90.0
.00	.000	270.0	.0
-1000.00	-6.895	180.0	.0

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .58953669E+08

DEVIATIONS:

DISPL.	COMPUTED DISPL.	DIFFERENCE
118.63	118.63	.00
1468.12	1468.12	.00
-3105.50	-3105.50	.00
-2013.18	-2013.18	.00
587.70	587.70	.00
6 DISCARD NO. 1		
-751.78	-751.78	.00
8 DISCARD NO. 2		
-4171.49	-4171.49	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 1 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	S T R E S S E S (psi)	(MPa)
NORMAL NORTH-SOUTH	-1000.00	-6.895
STANDARD ERROR	.000	.0000
NORMAL EAST-WEST	.00	.000
STANDARD ERROR	.000	.0000
NORMAL VERTICAL	1000.00	6.895
STANDARD ERROR	.000	.0000
SHEAR N-S/E-W	.00	.000
STANDARD ERROR	.000	.0000
SHEAR E-W/VERT	.00	.000
STANDARD ERROR	.000	.0000
SHEAR VERT/N-S	.00	.000
STANDARD ERROR	.000	.0000

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST

REGRESSION	25335858.62	6	4222643.10
			*************
DEVIATION	.00	1	.00
TOTAL VARIATION	25335858.62	7	

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1000.00	6.895	--	90.0
.00	.000	270.0	.0
-1000.00	-6.895	.0	.0

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

Combination of instrument types:

Filename: HTD12DEH.OUT

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*                                                *
*                   STRESsOUT                    *
*                                                *
*                (Version 1.00)                  *
*                                                *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM   *
*                                                *
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GENERAL INFORMATION

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     INSTRUMENT TYPE:      Combination--HICell, triaxial cell, doorstopper gauge, and BDG
     INSTRUMENT LOCATION:  Case 12deh
                NORTHING:      .00
                EASTING:       .00
                ELEVATION:     .00
     DATE OF INSTALLATION: This test conducted December 1990
     DATE OF OVERCORING:
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SETTING DEPTH INFORMATION:

Borehole 1 -- HICell installed at 16 ft 10 in.
Borehole 1 -- Triaxial cell installed at 18 ft 9 in.
Borehole 2 -- Doorstopper at 20 ft 8 in -- Rahn
Borehole 3 -- Doorstopper at 16 ft 3 in -- Hocking.
Borehole 3 -- Borehole Def. Gauge installed at 18 ft 9 in.

ROCK ELASTIC PROPERTIES:

MATERIAL TYPE	POISSON'S RATIO (m/m)	YOUNG'S MODULUS (*10**6 psi)	YOUNG'S MODULUS (GPa)
1	.0500	5.0000	34.4750
2	.1500	4.0000	27.5800
3	.2500	3.0000	20.6850
4	.3500	2.0000	13.7900
5	.4500	1.0000	6.8950

BOREHOLE ORIENTATIONS:

BOREHOLE NUMBER	AZIMUTH (deg)	INCLINATION (deg)
1	270.00	.00
2	.00	90.00
3	45.00	-45.00

PROPERTIES OF HOLLOW INCLUSION CELL:

POISSON'S RATIO (m/m)	YOUNG'S MODULUS (psi)	YOUNG'S MODULUS (GPa)	INNER RADIUS	HOLE RADIUS	RADIUS OF GAUGES
.40000	.38400	2.64768	16.000	19.050	17.500

CORRECTION FACTORS FOR HOLLOW INCLUSION CELL:

MATERIAL	K1	K2	K3	K4

1	1.12062	1.09632	1.06591	.13845
2	1.10858	1.08421	1.06205	.80749
3	1.09280	1.06598	1.05568	.93813
4	1.06805	1.03325	1.04316	.98870
5	1.01070	.94935	1.00732	1.00145

STRESS CONCENTRATION FACTORS (RAHN):

MATERIAL	a	b	c	d
1	1.324200	-.109852	-.414200	1.434053
2	1.333800	-.082672	-.523200	1.416473
3	1.345000	-.046312	-.632200	1.391313
4	1.357800	-.000772	-.741200	1.358573
5	1.372200	.053948	-.850200	1.318253

STRESS CONCENTRATION FACTORS (HOCKING):

MATERIAL	a	b	c	d
1	1.334683	-.117406	-.422738	1.452089
2	1.344961	-.089080	-.529271	1.434041
3	1.356988	-.049771	-.640948	1.406758
4	1.370763	.000523	-.757768	1.370241
5	1.386288	.061800	-.879732	1.324488

BOREHOLE DIAMETER:

DIAMETER NUMBER	* * DIAMETER * * (in)	(mm)
1	1.5000	38.1000
2	2.0000	50.8000

READINGS:

-THE READINGS REFLECT THE CHANGE IN STRAIN OR DISPLACEMENT AT THE GAUGE DUE TO OVERCORING. SIGN CONVENTION: TENSILE STRAIN OR EXTENSION IS POSITIVE. BECAUSE THE READINGS ARE DUE TO STRESS RELIEF, THE SIGN CONVENTION FOR STRESS IS OPPOSITE -- COMPRESSIVE STRESS IS POSITIVE.

-ALPHA IS THE ANGLE IN DEGREES DESCRIBING THE POSITION OF THE MIDPOINT OF THE GAUGE ON THE CIRCUMFERENCE OF THE BOREHOLE OR RAISE. (LOOKING INTO THE BOREHOLE, IT IS MEASURED CLOCKWISE FROM NORTH OR UP.)

-BETA IS THE ANGLE IN DEGREES DESCRIBING THE TILT OF THE GAUGE. LOOKING ALONG THE POSITIVE R-AXIS (R-ALPHA-Z SYSTEM), BETA IS MEASURED POSITIVE FROM THE ALPHA-AXIS CLOCKWISE TO THE AXIS OF THE STRAIN GAUGE.

MICROSTRAIN OR MICROINCHES	ALPHA	BETA	BOREHOLE NUMBER	MATERIAL TYPE	DIAMETER NUMBER	INSTRUMENT
-618.33	323.00	90.00	1	3		Hollow Inclusion Cell
1991.19	300.00	.00	1	3		Hollow Inclusion Cell
21.16	300.00	45.00	1	3		Hollow Inclusion Cell
163.58	163.50	45.00	1	3		Hollow Inclusion Cell
-692.32	163.50	135.00	1	3		Hollow Inclusion Cell
-746.28	180.00	.00	1	3		Hollow Inclusion Cell
-1995.00	83.00	90.00	1	5		Triaxial Cell
325.39	60.00	.00	1	5		Triaxial Cell
488.23	60.00	45.00	1	5		Triaxial Cell
-168.25	.00		2	1		Doorstopper--Rahn
-523.61	90.00		2	1		Doorstopper--Rahn
-255.58	45.00		2	1		Doorstopper--Rahn

-436.27	-45.00	2	1		Doorstopper--Rahn
-630.87	.00	3	4		Doorstopper--Hocking
-1059.68	90.00	3	4		Doorstopper--Hocking
-551.90	45.00	3	4		Doorstopper--Hocking
-1138.65	-45.00	3	4		Doorstopper--Hocking
-1516.53	-60.00	3	2	1	Borehole Deformation Gauge
-603.91	.00	3	2	1	Borehole Deformation Gauge
-710.98	60.00	3	2	1	Borehole Deformation Gauge
-2022.04	-60.00	3	2	2	Borehole Deformation Gauge
-805.22	.00	3	2	2	Borehole Deformation Gauge
-947.98	60.00	3	2	2	Borehole Deformation Gauge

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .30616166E+05

DEVIATIONS:

MEASUREMENT	COMPUTED MEASUREMENT	DIFFERENCE
-618.33	-618.33	.00
1991.19	1991.19	.00
21.16	21.16	.00
163.58	163.58	.00
-692.32	-692.32	.00
-746.28	-746.28	.00
-1995.00	-1995.00	.00
325.39	325.39	.00
488.23	488.23	.00
-168.25	-168.25	.00
-523.61	-523.61	.00
-255.58	-255.58	.00
-436.27	-436.27	.00
-630.87	-630.87	.00
-1059.68	-1059.68	.00
-551.90	-551.90	.00
-1138.65	-1138.65	.00
-1516.53	-1516.53	.00
-603.91	-603.91	.00
-710.98	-710.98	.00
-2022.04	-2022.04	.00
-805.22	-805.22	.00
-947.98	-947.97	-.01

STANDARD DEVIATION OF DIFFERENCES IS .93 ON 17 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.561	.0039
NORMAL EAST-WEST	-1680.00	-11.584

STANDARD ERROR	.643	.0044
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.574	.0040
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.394	.0027
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.355	.0024
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.351	.0024

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	15499026.30	6	2583171.05	3018781.7622
DEVIATION	14.55	17	.86	
TOTAL VARIATION	15499040.85	23		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .19803146E+05

DEVIATIONS:

MEASUREMENT	COMPUTED MEASUREMENT	DIFFERENCE
-618.33	-618.33	.00
1991.19	1991.19	.00
21.16	21.16	.00
163.58	163.58	.00
-692.32	-692.32	.00
-746.28	-746.28	.00
-1995.00	-1995.00	.00
325.39	325.39	.00

488.23	488.23	.00
-168.25	-168.25	.00
-523.61	-523.61	.00
-255.58	-255.58	.00
-436.27	-436.27	.00
-630.87	-630.87	.00
-1059.68	-1059.68	.00
-551.90	-551.90	.00
-1138.65	-1138.65	.00
-1516.53	-1516.53	.00
-603.91	-603.91	.00
-710.98	-710.98	.00
-2022.04	-2022.04	.00
-805.22	-805.22	.00

23 DISCARD NO. 1

STANDARD DEVIATION OF DIFFERENCES IS .81 ON 16 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	(MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.547	.0038
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.564	.0039
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.505	.0035
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.350	.0024
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.311	.0021
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.311	.0021

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	15325530.14	6	2554255.02	
				3880609.0983
DEVIATION	10.53	16	.66	

TOTAL VARIATION 15325540.67 22

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .17484004E+05

DEVIATIONS:

MEASUREMENT	COMPUTED MEASUREMENT	DIFFERENCE
-618.33	-618.33	.00
1991.19	1991.19	.00
21.16	21.16	.00
163.58	163.58	.00
-692.32	-692.32	.00
-746.28	-746.28	.00
-1995.00	-1995.00	.00
325.39	325.39	.00
488.23	488.23	.00
-168.25	-168.25	.00
-523.61	-523.61	.00
-255.58	-255.58	.00
-436.27	-436.27	.00
-630.87	-630.87	.00
-1059.68	-1059.68	.00
-551.90	-551.90	.00
17 DISCARD NO. 2		
-1516.53	-1516.53	.00
-603.91	-603.91	.00
-710.98	-710.98	.00
-2022.04	-2022.04	.00
-805.22	-805.22	.00
23 DISCARD NO. 1		

STANDARD DEVIATION OF DIFFERENCES IS .69 ON 15 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	S T R E S S E S (psi)	(MPa)

NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.471	.0033
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.484	.0033
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.433	.0030
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.303	.0021
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.275	.0019
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.268	.0018

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	14927278.54	6	2487879.76	
				5157175.6509
DEVIATION	7.24	15	.48	
TOTAL VARIATION	14927285.77	21		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.93	-6.122	359.9	23.3
-1848.76	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 4

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .14780991E+05

DEVIATIONS:

MEASUREMENT	COMPUTED MEASUREMENT	DIFFERENCE
-618.33	-618.33	.00
1991.19	1991.19	.00

```
  21.16           21.16            .00
 163.58          163.58            .00
-692.32         -692.32            .00
-746.28         -746.28            .00
-1995.00        -1995.00           .00
 325.39          325.39            .00
 488.23          488.23            .00
-168.25         -168.25            .00
-523.61         -523.61            .00
-255.58         -255.58            .00
-436.27         -436.27            .00
-630.87         -630.87            .00
   15  DISCARD NO.  3
-551.90         -551.90            .00
   17  DISCARD NO.  2
-1516.53        -1516.53           .00
-603.91         -603.91            .00
-710.98         -710.98            .00
-2022.04        -2022.04           .00
-805.22         -805.22            .00
   23  DISCARD NO.  1
```

STANDARD DEVIATION OF DIFFERENCES IS .58 ON 14 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	(MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.393	.0027
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.403	.0028
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.366	.0025
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.267	.0018
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.234	.0016
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.226	.0016

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	14589770.93	6	2431628.49	7262211.3253
DEVIATION	4.69	14	.33	
TOTAL VARIATION	14589775.62	20		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.77	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 5

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .14058658E+05

DEVIATIONS:

MEASUREMENT	COMPUTED MEASUREMENT	DIFFERENCE
-618.33	-618.33	.00
1991.19	1991.19	.00
21.16	21.16	.00
163.58	163.58	.00
-692.32	-692.32	.00
-746.28	-746.28	.00
-1995.00	-1995.00	.00
325.39	325.39	.00
488.23	488.23	.00
-168.25	-168.25	.00
-523.61	-523.61	.00
12 DISCARD NO. 4		
-436.27	-436.27	.00
-630.87	-630.87	.00
15 DISCARD NO. 3		
-551.90	-551.90	.00
17 DISCARD NO. 2		
-1516.53	-1516.53	.00
-603.91	-603.91	.00
-710.98	-710.98	.00
-2022.04	-2022.04	.00
-805.22	-805.22	.00
23 DISCARD NO. 1		

STANDARD DEVIATION OF DIFFERENCES IS .47 ON 13 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND

DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.323	.0022
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.333	.0023
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.298	.0021
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.221	.0015
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.192	.0013
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.184	.0013

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	14543882.01	6	2423980.34	************
DEVIATION	2.88	13	.22	
TOTAL VARIATION	14543884.90	19		

PRINCIPAL STRESSES (psi)	PRINCIPAL STRESSES (MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.77	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

1

OUTPUT RESULTS: RUN NUMBER 6

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .11076066E+05

DEVIATIONS:

MEASUREMENT	COMPUTED MEASUREMENT	DIFFERENCE
-618.33	-618.33	.00
1991.19	1991.19	.00
21.16	21.16	.00
163.58	163.58	.00
-692.32	-692.32	.00
-746.28	-746.28	.00
-1995.00	-1995.00	.00
325.39	325.39	.00
488.23	488.23	.00
-168.25	-168.25	.00
-523.61	-523.61	.00
12 DISCARD NO. 4		
-436.27	-436.27	.00
-630.87	-630.87	.00
15 DISCARD NO. 3		
-551.90	-551.90	.00
17 DISCARD NO. 2		
-1516.53	-1516.53	.00
19 DISCARD NO. 5		
-710.98	-710.98	.00
-2022.04	-2022.04	.00
-805.22	-805.22	.00
23 DISCARD NO. 1		

STANDARD DEVIATION OF DIFFERENCES IS .46 ON 12 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE STRESSES IN THE ROCK ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH GIVES VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY LEAST SQUARES METHOD) OF THE STRESS COMPONENTS IN THE GLOBAL SYSTEM. THE MAGNITUDE AND DIRECTION OF PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS COMPONENTS.

**** STRESS COMPONENTS IN REFERENCE SYSTEM ****

COMPONENT DESIGNATION	STRESSES (psi)	STRESSES (MPa)
NORMAL NORTH-SOUTH	-500.00	-3.447
STANDARD ERROR	.316	.0022
NORMAL EAST-WEST	-1680.00	-11.584
STANDARD ERROR	.332	.0023
NORMAL VERTICAL	1200.00	8.274
STANDARD ERROR	.292	.0020
SHEAR N-S/E-W	300.00	2.068
STANDARD ERROR	.223	.0015
SHEAR E-W/VERT	-700.00	-4.826
STANDARD ERROR	.186	.0013
SHEAR VERT/N-S	-900.00	-6.205
STANDARD ERROR	.179	.0012

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE STRESS COMPONENTS. CONFIDENCE LIMITS FOR THE STRESS COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF

THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	14526440.94	6	2421073.49	************
DEVIATION	2.50	12	.21	
TOTAL VARIATION	14526443.45	18		

PRINCIPAL STRESSES (psi)	(MPa)	AZIMUTH (deg)	INCLINATION (deg)
1756.70	12.112	29.2	-63.7
-887.94	-6.122	359.9	23.3
-1848.77	-12.747	274.9	-11.5

NOTE: (1) AZIMUTH IS THE ANGLE IN DEGREES POSITIVE CLOCKWISE FROM NORTH.
(2) INCLINATION IS THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.
(3) "--" INDICATES VALUE IS NOT UNIQUE.

Biaxial Data -- Hollow Inclusion Cell:

Filename: BIAX2

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**************************************************
*                                                *
*                   STRESsOUT                    *
*                                                *
*                (Version 1.00)                  *
*                                                *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM   *
*                                                *
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     GENERAL INFORMATION
    ---------------------
          INSTRUMENT TYPE:      Hollow Inclusion Cell
          INSTRUMENT LOCATION:  SRC
          DATE OF BIAXIAL TEST: August 1990

     OVERCORE INFORMATION:
The strains here are nearly exact for a biaxial test with pressure
placed at a radius of 2.875 in. (5.75 diameter).
The strain gauges are embedded in a hollow inclusion cell.
The strains should converge to
    Poisson's ratio = 0.25        Young's modulus = 2.00 * 1.e6 psi


     PROPERTIES OF HOLLOW INCLUSION CELL:
          POISSON'S RATIO OF CELL OR EPOXY =    .40000
          YOUNG'S MODULUS OF CELL OR EPOXY =    .50000 * 10**6 psi  OR     3.44750 GPa
          INNER RADIUS =      16.00000
          OUTER RADIUS =      19.05000
          RADIUS OF GAUGES =  17.50000

     INITIAL ESTIMATE FOR K1 =   1.01000
     INITIAL ESTIMATE FOR C1 =   1.01000
     MAXIMUM NUMBER OF ITERATIONS FOR ROUTINE =   10
     TOLERANCE FACTOR ON K1 AND C1 =    .00001

     INNER RADIUS OF OVERCORE =       1.50
     OUTER RADIUS OF OVERCORE =       5.75
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1

***** BEGIN ITERATION # 1

BIAXIAL HYDROSTATIC TEST DATA / X FACTORS FOR TEST DATA

STRAIN	STRESS (psi)	STRESS (MPa)	BETA	XX(1)	XX(2)	YY(1)	INSTRUMENT
-532.72	2000.00	13.790	90.00	141.8953	-1144.0763	.0000	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	4899.3647	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	926.6949	935.9619	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	926.6949	935.9619	Hollow Inclusion Cell
863.00	2000.00	13.790	135.00	372.3845	926.6950	935.9619	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	4899.3647	Hollow Inclusion Cell
-532.72	2000.00	13.790	90.00	141.8953	-1144.0763	.0000	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	4899.3647	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	926.6949	935.9619	Hollow Inclusion Cell

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .12064729E+15

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
4899.36	4899.36	.00
935.96	935.96	.00
935.96	935.96	.00
935.96	935.96	.00
4899.36	4899.36	.00
.00	.00	.00
4899.36	4899.36	.00
935.96	935.96	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 7 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS 1.9206 * 10**6 psi OR 13.2428 GPa
STANDARD ERROR .00000 * 10**6 psi OR .00000 GPa

POISSON'S RATIO .2382 in/in (m/m)
STANDARD ERROR .0000 in/in (m/m)

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	37725953.64	2	18862976.82	1000.0000
DEVIATION	.00	7	.00	
TOTAL VARIATION	37725953.64	9		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .10326135E+15

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
4899.36	4899.36	.00
935.96	935.96	.00
935.96	935.96	.00
5 DISCARD NO. 1		
4899.36	4899.36	.00
.00	.00	.00
4899.36	4899.36	.00
935.96	935.96	.00

STANDARD DEVIATION OF DIFFERENCES IS .16 ON 6 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS	1.9206 * 10**6 psi	OR	13.2428 GPa
STANDARD ERROR	.00004 * 10**6 psi	OR	.00024 GPa
POISSON'S RATIO	.2382 in/in (m/m)		
STANDARD ERROR	.0001 in/in (m/m)		

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	36331981.13	2	18165990.56	************
DEVIATION	-.15	6	.02	
TOTAL VARIATION	36331980.98	8		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .76777066E+14

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
1 DISCARD NO. 2		
4899.36	4899.36	.00
935.96	935.96	.00
935.96	935.96	.00
5 DISCARD NO. 1		
4899.36	4899.36	.00

.00	.00	.00
4899.36	4899.36	.00
935.96	935.96	.00

STANDARD DEVIATION OF DIFFERENCES IS .15 ON 5 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS 1.9206 * 10**6 psi OR 13.2428 GPa
STANDARD ERROR .00003 * 10**6 psi OR .00023 GPa

POISSON'S RATIO .2382 in/in (m/m)
STANDARD ERROR .0001 in/in (m/m)

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	30859493.09	2	15429746.55	************
DEVIATION	-.11	5	.02	
TOTAL VARIATION	30859492.98	7		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

***** ITERATION # 1 COMPLETED

CORRECTION FACTORS FOR HOLLOW INCLUSION INSTRUMENT:
K1 = 1.05825694
K2 = .99135481
K3 = 1.03534185
K4 = .95626473
C1 = .89816111

1

***** BEGIN ITERATION # 2

BIAXIAL HYDROSTATIC TEST DATA			X FACTORS FOR TEST DATA				
STRAIN	STRESS (psi)	STRESS (MPa)	BETA	XX(1)	XX(2)	YY(1)	INSTRUMENT
-532.72	2000.00	13.790	90.00	141.8953	-1134.8019	.0000	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5091.8381	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	919.1827	972.7315	Hollow Inclusion Cell

863.00	2000.00	13.790	45.00	372.3845	919.1827	972.7315	Hollow Inclusion Cell
863.00	2000.00	13.790	135.00	372.3845	919.1828	972.7315	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5091.8381	Hollow Inclusion Cell
-532.72	2000.00	13.790	90.00	141.8953	-1134.8019	.0000	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5091.8381	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	919.1827	972.7315	Hollow Inclusion Cell

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .11869918E+15

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
5091.84	5091.84	.00
972.73	972.73	.00
972.73	972.73	.00
972.73	972.73	.00
5091.84	5091.84	.00
.00	.00	.00
5091.84	5091.84	.00
972.73	972.73	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 7 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS	1.9961 * 10**6 psi	OR	13.7630 GPa
STANDARD ERROR	.00000 * 10**6 psi	OR	.00000 GPa
POISSON'S RATIO	.2496 in/in (m/m)		
STANDARD ERROR	.0000 in/in (m/m)		

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	40748334.28	2	20374167.14	************
DEVIATION	.00	7	.00	
TOTAL VARIATION	40748334.28	9		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .10159397E+15

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
5091.84	5091.84	.00
972.73	972.73	.00
972.73	972.73	.00
5 DISCARD NO. 1		
5091.84	5091.84	.00
.00	.00	.00
5091.84	5091.84	.00
972.73	972.73	.00

STANDARD DEVIATION OF DIFFERENCES IS .16 ON 6 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS 1.9961 * 10**6 psi OR 13.7630 GPa
STANDARD ERROR .00004 * 10**6 psi OR .00025 GPa

POISSON'S RATIO .2496 in/in (m/m)
STANDARD ERROR .0001 in/in (m/m)

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	39242684.92	2	19621342.46	*************
DEVIATION	-.16	6	.03	
TOTAL VARIATION	39242684.76	8		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .75537332E+14

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DEVIATIONS:

     FACTOR       COMPUTED FACTOR    DIFFERENCE
        1  DISCARD NO.  2
    5091.84          5091.84             .00
     972.73           972.73             .00
     972.73           972.73             .00
        5  DISCARD NO.  1
    5091.84          5091.84             .00
        .00              .00             .00
    5091.84          5091.84             .00
     972.73           972.73             .00

     STANDARD DEVIATION OF DIFFERENCES IS     .16 ON  5 DEGREES OF FREEDOM.
     GOODNESS OF FIT =1.00
     CORRELATION COEFFICIENT =1.00


          THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR
          REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND
          BEST FITTING VALUES OF THE ELASTIC COMPONENTS.


       ROCK ELASTIC COMPONENTS
      ------------------------

     YOUNG'S MODULUS    1.9961  * 10**6 psi  OR   13.7630  GPa
     STANDARD ERROR      .00004 * 10**6 psi  OR     .00024 GPa

     POISSON'S RATIO     .2496 in/in  (m/m)
     STANDARD ERROR      .0001 in/in  (m/m)


     NOTE:  THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC
     (YM & PR) COMPONENTS.  CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE
     OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY.
     THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC
     COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

 ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION
---------------------------------------------------

      SOURCE OF              SUM OF  DEGREES OF   MEAN
      VARIATION              SQUARES   FREEDOM   SQUARES    F-TEST

      REGRESSION        33331773.46       2 16665886.73
                                                     ************
      DEVIATION                -.12       5         .02

      TOTAL VARIATION   33331773.33       7

  THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

     ***** ITERATION #     2 COMPLETED

     CORRECTION FACTORS FOR HOLLOW INCLUSION INSTRUMENT:
          K1 =    1.05990112
          K2 =     .99699287
          K3 =    1.03648980
          K4 =     .95989843
          C1 =     .90230661


1
     ***** BEGIN ITERATION #   3
```

BIAXIAL HYDROSTATIC TEST DATA STRAIN	STRESS (psi)	STRESS (MPa)	X FACTORS FOR TEST DATA BETA	XX(1)	XX(2)	YY(1)	INSTRUMENT
-532.72	2000.00	13.790	90.00	141.8953	-1135.1430	.0000	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5101.2819	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	919.4590	974.5357	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	919.4590	974.5357	Hollow Inclusion Cell
863.00	2000.00	13.790	135.00	372.3845	919.4591	974.5356	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5101.2819	Hollow Inclusion Cell
-532.72	2000.00	13.790	90.00	141.8953	-1135.1430	.0000	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5101.2819	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	919.4590	974.5357	Hollow Inclusion Cell

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .11877054E+15

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
5101.28	5101.28	.00
974.54	974.54	.00
974.54	974.54	.00
974.54	974.54	.00
5101.28	5101.28	.00
.00	.00	.00
5101.28	5101.28	.00
974.54	974.54	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 7 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS 1.9998 * 10**6 psi OR 13.7886 GPa
STANDARD ERROR .00000 * 10**6 psi OR .00000 GPa

POISSON'S RATIO .2500 in/in (m/m)
STANDARD ERROR .0000 in/in (m/m)

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST

REGRESSION	40899626.80	2	20449813.40	************
DEVIATION	.00	7	.00	
TOTAL VARIATION	40899626.80	9		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .10165505E+15

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
5101.28	5101.28	.00
974.54	974.54	.00
974.54	974.54	.00
5 DISCARD NO. 1		
5101.28	5101.28	.00
.00	.00	.00
5101.28	5101.28	.00
974.54	974.54	.00

STANDARD DEVIATION OF DIFFERENCES IS .16 ON 6 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS 1.9998 * 10**6 psi OR 13.7886 GPa
STANDARD ERROR .00004 * 10**6 psi OR .00025 GPa

POISSON'S RATIO .2500 in/in (m/m)
STANDARD ERROR .0001 in/in (m/m)

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	39388387.19	2	19694193.59	************
DEVIATION	-.16	6	.03	
TOTAL VARIATION	39388387.03	8		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

1

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OUTPUT RESULTS:  RUN NUMBER  3
------------------------------


THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS    .75582748E+14


DEVIATIONS:

     FACTOR        COMPUTED FACTOR    DIFFERENCE
        1  DISCARD NO.  2
    5101.28          5101.28            .00
     974.54           974.54            .00
     974.54           974.54            .00
        5  DISCARD NO.  1
    5101.28          5101.28            .00
        .00              .00            .00
    5101.28          5101.28            .00
     974.54           974.54            .00

     STANDARD DEVIATION OF DIFFERENCES IS     .16 ON  5 DEGREES OF FREEDOM.
     GOODNESS OF FIT =1.00
     CORRELATION COEFFICIENT =1.00


          THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR
          REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND
          BEST FITTING VALUES OF THE ELASTIC COMPONENTS.


       ROCK ELASTIC COMPONENTS
      ------------------------

     YOUNG'S MODULUS     1.9998  * 10**6 psi  OR   13.7886  GPa
     STANDARD ERROR      .00004 * 10**6 psi  OR     .00024 GPa

     POISSON'S RATIO     .2500 in/in  (m/m)
     STANDARD ERROR      .0001 in/in  (m/m)


     NOTE:  THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC
     (YM & PR) COMPONENTS.  CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE
     OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY.
     THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC
     COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.


ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION
----------------------------------------------------

     SOURCE OF                SUM OF  DEGREES OF   MEAN
     VARIATION                SQUARES   FREEDOM   SQUARES    F-TEST

     REGRESSION         33455529.39        2 16727764.69
                                                       ************
     DEVIATION                  -.12        5         .02

     TOTAL VARIATION    33455529.26        7

 THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

     ***** ITERATION #     3 COMPLETED

     CORRECTION FACTORS FOR HOLLOW INCLUSION INSTRUMENT:
          K1 =     1.05999114
          K2 =      .99725369
          K3 =     1.03654921
```

K4 = .95999695
C1 = .90249408

1

***** BEGIN ITERATION # 4

BIAXIAL HYDROSTATIC TEST DATA			X FACTORS FOR TEST DATA				
STRAIN	STRESS (psi)	STRESS (MPa)	BETA	XX(1)	XX(2)	YY(1)	INSTRUMENT
-532.72	2000.00	13.790	90.00	141.8953	-1135.1584	.0000	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5101.7846	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	919.4715	974.6317	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	919.4715	974.6317	Hollow Inclusion Cell
863.00	2000.00	13.790	135.00	372.3845	919.4716	974.6316	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5101.7846	Hollow Inclusion Cell
-532.72	2000.00	13.790	90.00	141.8953	-1135.1584	.0000	Hollow Inclusion Cell
2258.72	2000.00	13.790	.00	2550.9080	.0000	5101.7846	Hollow Inclusion Cell
863.00	2000.00	13.790	45.00	372.3845	919.4715	974.6317	Hollow Inclusion Cell

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .11877377E+15

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
5101.78	5101.78	.00
974.63	974.63	.00
974.63	974.63	.00
974.63	974.63	.00
5101.78	5101.78	.00
.00	.00	.00
5101.78	5101.78	.00
974.63	974.63	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 7 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS 2.0000 * 10**6 psi OR 13.7899 GPa
STANDARD ERROR .00000 * 10**6 psi OR .00000 GPa

POISSON'S RATIO .2500 in/in (m/m)
STANDARD ERROR .0000 in/in (m/m)

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY.

THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC
COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	40907686.91	2	20453843.45	************
DEVIATION	.00	7	.00	
TOTAL VARIATION	40907686.91	9		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .10165781E+15

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
5101.78	5101.78	.00
974.63	974.63	.00
974.63	974.63	.00
5 DISCARD NO. 1		
5101.78	5101.78	.00
.00	.00	.00
5101.78	5101.78	.00
974.63	974.63	.00

STANDARD DEVIATION OF DIFFERENCES IS .16 ON 6 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR
REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND
BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS	2.0000 * 10**6 psi	OR	13.7899	GPa
STANDARD ERROR	.00004 * 10**6 psi	OR	.00025	GPa
POISSON'S RATIO	.2500 in/in (m/m)			
STANDARD ERROR	.0001 in/in (m/m)			

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC
(YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE
OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY.
THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC
COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	39396149.48	2	19698074.74	************
DEVIATION	-.16	6	.03	
TOTAL VARIATION	39396149.32	8		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

1

OUTPUT RESULTS: RUN NUMBER 3

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .75584802E+14

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
1 DISCARD NO. 2		
5101.78	5101.78	.00
974.63	974.63	.00
974.63	974.63	.00
5 DISCARD NO. 1		
5101.78	5101.78	.00
.00	.00	.00
5101.78	5101.78	.00
974.63	974.63	.00

STANDARD DEVIATION OF DIFFERENCES IS .16 ON 5 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS 2.0000 * 10**6 psi OR 13.7899 GPa
STANDARD ERROR .00004 * 10**6 psi OR .00024 GPa

POISSON'S RATIO .2500 in/in (m/m)
STANDARD ERROR .0001 in/in (m/m)

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	33462122.48	2	16731061.24	************
DEVIATION	-.12	5	.02	

```
          TOTAL VARIATION    33462122.36       7

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

         ***** ITERATION #     4 COMPLETED

         CORRECTION FACTORS FOR HOLLOW INCLUSION INSTRUMENT:
              K1 =     1.05999588
              K2 =      .99726757
              K3 =     1.03655235
              K4 =      .96000248
              C1 =      .90250407

         YOUNG'S MODULUS & POISSON'S RATIO DETERMINED AFTER     4 ITERATIONS.
```

Biaxial Data -- Triaxial Cell:

Filename: BIAX1

```
**************************************************
*                                                *
*                   STRESsOUT                    *
*                                                *
*                (Version 1.00)                  *
*                                                *
*  A STRESS MEASUREMENT DATA REDUCTION PROGRAM   *
*                                                *
**************************************************
```

GENERAL INFORMATION

INSTRUMENT TYPE: Triaxial cell
INSTRUMENT LOCATION: SRC
DATE OF BIAXIAL TEST: August 1990

OVERCORE INFORMATION:
The strains here are nearly exact for a biaxial test with pressure placed at a radius of infinity (7.5e6 in. radius).
The strain gauges are on the wall of the hole.
The results should converge to
Poisson's ratio = 0.25 Young's = 2.00 * 1.e6 psi

INNER RADIUS OF OVERCORE = 1.50
OUTER RADIUS OF OVERCORE = **********

BIAXIAL HYDROSTATIC TEST DATA			X FACTORS FOR TEST DATA				
STRAIN	STRESS (psi)	STRESS (MPa)	BETA	XX(1)	XX(2)	YY(1)	INSTRUMENT
-500.00	2000.00	13.790	90.00	125.0000	-1000.0000	.0000	Triaxial Cell
2000.00	2000.00	13.790	.00	2000.0000	.0000	4000.0000	Triaxial Cell
750.00	2000.00	13.790	45.00	281.2500	750.0000	750.0000	Triaxial Cell
750.00	2000.00	13.790	45.00	281.2500	750.0000	750.0000	Triaxial Cell
750.00	2000.00	13.790	135.00	281.2500	750.0000	750.0000	Triaxial Cell
2000.00	2000.00	13.790	.00	2000.0000	.0000	4000.0000	Triaxial Cell
-500.00	2000.00	13.790	90.00	125.0000	-1000.0000	.0000	Triaxial Cell
2000.00	2000.00	13.790	.00	2000.0000	.0000	4000.0000	Triaxial Cell
750.00	2000.00	13.790	45.00	281.2500	750.0000	750.0000	Triaxial Cell

1

OUTPUT RESULTS: RUN NUMBER 1

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .52125000E+14

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
4000.00	4000.00	.00
750.00	750.00	.00
750.00	750.00	.00
750.00	750.00	.00
4000.00	4000.00	.00
.00	.00	.00
4000.00	4000.00	.00
750.00	750.00	.00

STANDARD DEVIATION OF DIFFERENCES IS .00 ON 7 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

ROCK ELASTIC COMPONENTS

YOUNG'S MODULUS	2.0000 * 10**6 psi	OR	13.7900 GPa
STANDARD ERROR	.00000 * 10**6 psi	OR	.00000 GPa
POISSON'S RATIO	.2500 in/in (m/m)		
STANDARD ERROR	.0000 in/in (m/m)		

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	25250000.00	2	12625000.00	************
DEVIATION	.00	7	.00	
TOTAL VARIATION	25250000.00	9		

1

OUTPUT RESULTS: RUN NUMBER 2

THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS .45093750E+14

DEVIATIONS:

FACTOR	COMPUTED FACTOR	DIFFERENCE
.00	.00	.00
4000.00	4000.00	.00
750.00	750.00	.00
750.00	750.00	.00
5 DISCARD NO. 1		
4000.00	4000.00	.00
.00	.00	.00
4000.00	4000.00	.00
750.00	750.00	.00

STANDARD DEVIATION OF DIFFERENCES IS .13 ON 6 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00

THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND BEST FITTING VALUES OF THE ELASTIC COMPONENTS.

```
  ROCK ELASTIC COMPONENTS
 ------------------------

YOUNG'S MODULUS    2.0000  * 10**6 psi  OR   13.7900  GPa
STANDARD ERROR      .00004 * 10**6 psi  OR     .00026 GPa

POISSON'S RATIO     .2500 in/in  (m/m)
STANDARD ERROR      .0001 in/in  (m/m)


NOTE:  THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC
(YM & PR) COMPONENTS.  CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE
OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY.
THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC
COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.
```

```
ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION
---------------------------------------------------

 SOURCE OF                SUM OF   DEGREES OF   MEAN
 VARIATION                SQUARES   FREEDOM    SQUARES     F-TEST

 REGRESSION        24304687.54       2 12152343.77
                                                 *************
 DEVIATION                -.10       6          .02

 TOTAL VARIATION   24304687.44       8

 THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.
```

1

```
OUTPUT RESULTS:  RUN NUMBER  3
-----------------------------


THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS    .32671875E+14


DEVIATIONS:

     FACTOR       COMPUTED FACTOR    DIFFERENCE
        1  DISCARD NO.  2
    4000.00          4000.00            .00
     750.00           750.00            .00
     750.00           750.00            .00
        5  DISCARD NO.  1
    4000.00          4000.00            .00
        .00              .00            .00
    4000.00          4000.00            .00
     750.00           750.00            .00

STANDARD DEVIATION OF DIFFERENCES IS     .13 ON  5 DEGREES OF FREEDOM.
GOODNESS OF FIT =1.00
CORRELATION COEFFICIENT =1.00


     THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY THE MULTIPLE LINEAR
     REGRESSION METHOD WHICH OUTPUTS VARIOUS STATISTICAL DATA AND
     BEST FITTING VALUES OF THE ELASTIC COMPONENTS.


  ROCK ELASTIC COMPONENTS
 ------------------------

YOUNG'S MODULUS    2.0000  * 10**6 psi  OR   13.7900  GPa
STANDARD ERROR      .00004 * 10**6 psi  OR     .00025 GPa

POISSON'S RATIO     .2500 in/in  (m/m)
```

STANDARD ERROR .0001 in/in (m/m)

NOTE: THE STANDARD ERROR IS THE STANDARD DEVIATION OF THE ELASTIC (YM & PR) COMPONENTS. CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE OBTAINED BY USING THE STUDENT'S T DISTRIBUTION FOR THE DESIRED PROBABILITY. THE STANDARD ERROR TAKES NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN GAUGES.

ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F-TEST
REGRESSION	20678571.44	2	10339285.72	************
DEVIATION	-.08	5	.02	
TOTAL VARIATION	20678571.36	7		

THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.

APPENDIX D.—CODE LISTING

```
*  PROGRAM STRESsOUT (Version 1.00)

****************************************************************************
* The U.S. Bureau of Mines expressly declares that there are no warranties *
* expressed or implied that apply to the software contained herein.  By    *
* acceptance and use of said software, which is conveyed to the user       *
* without consideration by the Bureau of Mines, the user hereof expressly  *
* waives any and all claims for damage and/or suits for or by reason of    *
* personal injury, or property damage, including special, consequential,   *
* or other similar damages arising out of or in any way connected with the *
* use of the software contained herein.                                    *
****************************************************************************


*     PROGRAM PROCESSES STRAIN/DISPLACEMENT MEASUREMENTS FROM
*     -HOLLOW INCLUSION CELLS
*     -TRIAXIAL CELLS
*     -BORED RAISE OVERCORING
*     -DOORSTOPPERS
*     -USBM BOREHOLE DEFORMATION GAUGE
*     -COMBINATIONS OF THE ABOVE

*     YOUNG'S MODULUS AND POISSON'S RATIO CAN BE CALCULATED
*     FROM BIAXIAL DATA FOR
*     -HOLLOW INCLUSION CELLS
*     -TRIAXIAL CELLS

*     ALL INPUT DATA IS ECHOED

*     OUTPUT IS IN THE FORM OF GLOBAL STRESSES THAT MINIMIZE THE SUM
*     OF THE SQUARE OF THE ERROR.  PRINCIPAL STRESSES AND THEIR
*     DIRECTIONS ARE CALCULATED FROM THE GLOBAL STRESSES.
*     SPECIFIC INTERMEDIATE STEPS ARE OUTPUT WITH STATISTICS RELATING
*     TO THE ACCURACY OF THE STRESS COMPONENT DETERMINATIONS.

*     AN ITERATIVE PROCESS IS SET UP TO ELIMINATE THOSE MEASURED
*     STRAINS/DISPLACEMENTS HAVING GREATEST DEVIATIONS FROM THE BEST
*     FIT SOLUTION BY MULTIPLE LINEAR REGRESSION.  IN THIS WAY THE
*     ERROR IN THE STRESS COMPONENT DETERMINATION IS REDUCED.

*     THIS CODE BASED ON PROGRAM MIMSICELL BY
*     D. J. FITZGERALD & ASSOC   JULY '78,
*     WHO FURTHER MODIFIED IT FOR THE PRIME COMPUTER  JUNE'79

*     UNIVERSITY OF UTAH VERSION--1985 BY MARK K. LARSON
*     PARTS OF MTU (JALKANEN) VERSION ADDED  JANUARY 1986

*     MODIFICATIONS FOR DOORSTOPPER AND USBM BOREHOLE DEFORMATION GAUGE
*     ADDED BETWEEN JUNE 1986 AND JULY 1989 BY MARK K. LARSON.
*     RESTRUCTURING OF CODE AND "COMBINATIONS" OPTION COMPLETED
*     BY MARK K. LARSON  JULY - AUGUST 1989.
*     FURTHER MODIFICATION TO BRING BIAXIAL ROUTINE TO MENU AND ADD
```

```
*    BIAXIAL ROUTINE FOR TRIAXIAL GAUGE -- SEPTEMBER 1990.

*  PROGRAM STRUCTURE:

*    MAIN PROGRAM (SO-MAIN) -
*         Selects type of input (keyboard or file) and the output file.
*         Selects type of data (overcore or biaxial).
*         Calls READ1.
*         Calls appropriate routine for type of data:
*              SFTINC -- for hollow inclusion, triaxial, or bored raise
*                data,
*              DOORST -- for doorstopper data,
*              BDG    -- for USBM borehole deformation gauge data.
*              These subroutines assemble the matrices, except
*                where measurements from a different instrument types
*                are combined.  In this case, SO-MAIN assembles
*                the coefficient matrix and the measurement matrix.
*              MODCAL -- for biaxial test data.
*         Calls MULTR for overcoring data.

*      READ1 -
*         Reads and writes information about the instruments, their location
*           elastic properties, and borehole orientations, etc. to output
*           file.
*      SFTINC -

*         Reads or calculates K-factors for hollow inclusion cell; calls
*           KFACT to calculate K-factors if indicated; sets K-factors to
*           1.0 for triaxial cells or bored raise data.
*         Reads measurements, angles, borehole numbers, and material types.
*         Calculates coefficient matrix elements.
*         Calls DCS to calculate direction cosines.
*         If indicated, writes local and global coefficients to
*           output file.

*      DOORST -

*         Reads stress concentration factor option.
*         Computes or reads stress concentration factors.
*         Reads doorstopper measurements, orientation angles,
*           borehole numbers, and material types.
*         Calculates coefficient matrix elements.
*         Calls DCS to calculate direction cosines.
*         If indicated, writes local and global coefficients to
*           output file.

*      BDG -

*         Reads diameter of boreholes.
*         Reads measurements obtained from borehole deformation
*           gauges, orientation angles, borehole numbers,
*           material types, and borehole diameter designations.
```

```
*           Calculates coefficient matrix elements.
*           Calls DCS to calculate direction cosines.
*           If indicated, writes local and global coeffiecients to
*             output file.

*       MODCAL -

*           For hollow inclusion cells:  Reads properties and geometries
*             of cells and reads estimates for correction factors.
*           Reads inner and outer diameters of overcore.
*           Reads biaxial test data, that is, strain, stress, and tilt
*             angle of gauges.
*           Assembles coefficients of equations in matrices.
*           For hollow inclusion cells:  Executes iterative cycle to
*             determine rock properties and K-factors:
*             Calls MULTR to fit rock properties.
*             Calls KFACT to calculate K-factors with current rock
*               properties.
*             Checks improvement; if below tolerance, stops iteration
*               cycle.
*             Recalculates coefficient.
*           For triaxial cells:  Calls MULTR to fit rock properties.

*       KFACT -

*           Calculates K-factors for given geometries and material
*             properties of overcores and hollow inclusion cells.

*       DCS -

*           Calculates direction cosines relating local and global
*             coordinate systems.

*       MULTR -

*           Reads number of additional analytical runs in which the
*             measurements farthest from the fitted solution are
*             eliminated.
*           Assembles least-squares coefficient matrix and vector.
*           Runs output cycle:
*                If indicated, writes coefficients of equations to
*                  be solved to output file.
*                Calls DETERM to calculate determinant of coefficient matrix.
*                  If matrix is singular, makes no attempt to solve for the
*                  global stresses or rock properties; instead, returns to
*                  calling program or subroutine.
*                Calls MATINV to invert coefficient matrix and
*                  calculate global stresses (or rock properties,
*                  if these are biaxial test data); writes results to
*                  output file.
*                Performs analysis of variance of results; writes
*                  results to output file.
```

```
*                Calculates principal stresses and directions in
*                  the case of overcoring data; writes results to
*                  output file.

*        DETERM -

*                Calculates the determinant of a matrix passed as an argument.
*                  Enters a loop to sum the product of the elements.  In doing
*                  so, it calls DETSUM to calculate products of the elements
*                  it designates.

*        DETSUM -

*                Calculates the product of designated elements of the matrix.

*        MATINV -

*             Inverts coefficient matrix and solves matrix equation,
*               storing the result in the one-dimensional array B(6,1).

*        ASIN -

*             External function which determines the arcsine of the
*               variable X.

*        ACOS -

*             External function which determines the arccosine of the
*               variable X.


*   MAJOR VARIABLE DESCRIPTION

*      PR,YM,YMM      Poisson's ratio, Young's modulus of rock
*                   (imperial, metric)
*      YY(NDIM,3)     An array that contains the strain, alpha, and
*                   beta for each overcore strain measurement
*      D(NDIM,3)      An array that returns from subroutine MULTR
*                   which contains the measurement, the predicted
*                   value, and the residual
*      XX(NDIM,6)     An array which contains the J factors, the
*                   transformed stress coefficients for each strain/displ.
*                   measurement in the global coordinate system
*      STR(NDIM)      An array which contains the inputted overcoring
*                   strains/displacements
*      ALP(NDIM)      An array which contains the inputted alpha angle for
*                   each measurement
*      BET(NDIM)      An array which contains the inputted beta angle for
*                   each measurement (where applicable)
*      IDTYPE         Type of measurement to be analyzed
*      IOUTPT         Output file name
*      IDBUG          Flag for output of miscellaneous data
```

```
*     NBH(NDIM)     An array of flags indicating the borehole in which a
*                   particular measurement was taken
*     NINSTR(NDIM)  An array indicating the type of instrument analysis
*                   for each measurement (used in output)
*     LFTYPE(NDIM)  An array indicating, in the case of a doorstopper
*                   analysis, which analysis is used--Rahn, Hocking, or
*                   other (used in output)

*  VARIABLE DECLARATIONS

      PARAMETER (NDIM = 99, NBHL = 10, NMTYP = 10)
      IMPLICIT REAL*8 (A-H,O-Z)
      LOGICAL THERE
      COMMON/MEAS/YY(NDIM,3),D(NDIM,3),XX(NDIM,6),STR(NDIM),ALP(NDIM),
     .    BET(NDIM),NBH(NDIM),MT(NDIM),NDD(NDIM),NINSTR(NDIM),
     .    LFTYPE(NDIM),N
      COMMON/BH/ AZ(NBHL),DP(NBHL)
      COMMON/MP/ NMAT,PR(NMTYP),YM(NMTYP),YMM(NMTYP)
      COMMON/BIAX/NDEL,NDFLAG
      COMMON/FILE/IFL
      CHARACTER*1 ANS
      CHARACTER*36 IOUTPT, IOUTPI
      CHARACTER*29 ITYPE

*  PRINT LIABILITY CLAUSE

      WRITE(*,10)
 10   FORMAT(/1X,76(1H*),/1X,'* The U.S. Bureau of Mines expressly ',
     .  'declares that there are no warranties *',/1X,'* expressed ',
     .  'or implied that apply to the software contained herein.  ',
     .  'By    *',/1X,'* acceptance and use of said software, which ',
     .  'is conveyed to the user       *',/1X,'* without ',
     .  'consideration by the Bureau of Mines, the user hereof ',
     .  'expressly  *',/1X,'* waives any and all claims for damage ',
     .  'and/or suits for or by reason of    *',/1X,'* personal ',
     .  'injury, or property damage, including special, ',
     .  'consequential,    *',/1X,'* or other similar damages arising ',
     .  'out of or in any way connected with the *',/1X,'* use of the ',
     .  'software contained herein.',36X,'*',/1X,76(1H*),//)
      PAUSE 'Hit RETURN to continue...'

*  CHOOSE WHETHER TO ACCEPT DATA FROM KEYBOARD OR FROM FILE

 100  WRITE(*,11)
  11  FORMAT(//1X,'ENTER  0  TO INPUT DATA FROM THE KEYBOARD',/,
     .       1X,'       1  TO ACCEPT INPUT FROM A DATA FILE',/)
      READ(*,*) IFL
      IF(IFL .NE. 0 .AND. IFL .NE. 1) GO TO 100

*  IF INPUT IS FROM FILE, NAME THE FILE

      IF(IFL.EQ.1) THEN
```

```
        WRITE(*,12)
 12     FORMAT(1X,'ENTER INPUT DATA FILE NAME',/)
        READ(*,13) IOUTPI
        OPEN (UNIT=1, FILE=IOUTPI)
      END IF
 13   FORMAT(A36)

*  CHOOSE THE KIND OF INSTRUMENT

 110  WRITE(*,14)
  14  FORMAT(//' HELLO, YOU ARE RUNNING PROGRAM',//
     .  10X,21(1H*),/10X,'*     STRESsOUT      *',/
     .  10X,'*   (Version 1.00)  *',/10X,21(1H*),//
     .  ' A MULTIPLE LINEAR REGRESSION PROGRAM FOR DETERMINING ',
     .  'STRESS',/' COMPONENTS FROM STRAIN GAUGE',
     .  ' OR DISPLACEMENT READINGS.',//
     .  ' TYPE IN THE CODE APPROPRIATE TO YOUR DATA:',//
     .  10X,'0-STOP...NO MORE DATA',/
     .  5X,'OVERCORING DATA',/
     .  10X,'1-HOLLOW INCLUSION CELL',/
     .  10X,'2-TRIAXIAL CELL',/
     .  10X,'3-STRAIN GAUGES ON WALL OF BORED RAISE',/
     .  10X,'4-DOORSTOPPER GAUGE',/
     .  10X,'5-USBM BOREHOLE DEFORMATION GAUGE',/
     .  10X,'6-COMBINATION OF ABOVE',/
     .  5X,'BIAXIAL COMPRESSION DATA ON OVERCORE',/
     .  10X,'7-HOLLOW INCLUSION CELL',/
     .  10X,'8-TRIAXIAL CELL',/)
      READ(IFL,*) IDTYPE

      IF(IDTYPE .LT. 0 .OR. IDTYPE .GT. 8) GO TO 110

      ICOMB = 0
      ICOMBN = 0
      N = 0
      MM = 6
      NDFLAG = 0

*  END PROGRAM PROVISION

      IF(IDTYPE.EQ.0) GO TO 170

*  READ IN OUTPUT FILE NAME

      WRITE(*,15)
 15   FORMAT(' TYPE IN OUTPUT FILE NAME',/)
      READ(IFL,13)IOUTPT

*  TEST FOR FILE'S EXISTENCE, OPEN IF ITS A NEW FILE

      INQUIRE(FILE=IOUTPT,EXIST=THERE)
```

```
      IF(.NOT.THERE) GO TO 120
      WRITE(*,*) ' FILE ALREADY EXISTS'
      GO TO 170
 120  OPEN(UNIT = 4, FILE = IOUTPT, STATUS='NEW')

*  CHOOSE WHETHER MATRIX COEFFICIENTS ARE TO BE PRINTED

      IDBUG=0
 130  WRITE(*,16)
  16  FORMAT(' DO YOU WANT MATRIX COEFFICIENTS PRINTED? (Y/N)',/)
      READ(IFL,17) ANS
      IF(ANS.NE.'Y' .AND. ANS.NE.'N' .AND. ANS.NE.'y' .AND. ANS.NE.'n')
     .   GO TO 130
  17  FORMAT(A1)
      IF(ANS.EQ.'Y' .OR. ANS.EQ.'y')IDBUG=1

*  PRINT TITLE

      WRITE(4,18)
  18  FORMAT(1X,/25X,49(1H*),/25X,'*',47X,'*',/25X,'*',19X,'STRESsOUT',
     .  19X,'*',/25X,'*',47X,'*',/25X,'*',17X,'(Version 1.00)',16X,'*',
     .  /25X,'*',47X,'*',/25X,'*  A STRESS MEASUREMENT DATA REDUCTION ',
     .  'PROGRAM  *',/25X,'*',47X,'*',/25X,49(1H*))

*  READ IN AND PRINT INFORMATION ABOUT SITE AND TEST,
*  BOREHOLE ORIENTATION, AND ISOTROPIC ELASTIC PROPERTIES

      CALL READ1(IDTYPE)

*  BRANCH TO THE ANALYSIS OF THE APPROPRIATE INSTRUMENT

      IF (IDTYPE .EQ. 1 .OR. IDTYPE .EQ. 2 .OR. IDTYPE .EQ. 3)
     .    CALL SFTINC(IDTYPE,IDBUG,ICOMB,ICOMBN)

      IF (IDTYPE .EQ. 4)
     .    CALL DOORST(IDTYPE,IDBUG,ICOMB,ICOMBN)

      IF (IDTYPE .EQ. 5)
     .    CALL BDG(IDTYPE,IDBUG,ICOMB,ICOMBN)

      IF (IDTYPE .EQ. 7 .OR. IDTYPE .EQ. 8)
     .    CALL MODCAL(MM,IDTYPE,IDBUG)

      IF(MM .EQ. 2) GO TO 110

      IF (IDTYPE .EQ. 6) THEN

*  SELECT THE KIND OF INSTRUMENTATION AND THE NUMBER OF READINGS

 140     WRITE(*,19)
  19     FORMAT(1X,'SELECT THE CODE APPROPRIATE TO YOUR DATA',//
     .     10X,'0-STOP...NO MORE DATA',/
```

```
     .      10X,'1-HOLLOW INCLUSION CELL',/
     .      10X,'2-TRIAXIAL CELL',/
     .      10X,'3-STRAIN GAUGES ON WALL OF BORED RAISE',/
     .      10X,'4-DOORSTOPPERS',/
     .      10X,'5-USBM BOREHOLE DEFORMATION GAUGE',/)
            READ(IFL,*) ICOMB
            IF(ICOMB .LT. 0 .OR. ICOMB .GT. 5) GO TO 140

            IF(ICOMB .EQ. 0) GO TO 150

            WRITE(*,20)
   20       FORMAT(1X,'HOW MANY READINGS OF THIS KIND?',/)
            READ(IFL,*) ICOMBN

*  BRANCH TO APPROPRIATE ANALYSIS

            IF (ICOMB .GE. 1 .AND. ICOMB .LE. 3)
     .          CALL SFTINC(IDTYPE,IDBUG,ICOMB,ICOMBN)

            IF (ICOMB .EQ. 4)
     .          CALL DOORST(IDTYPE,IDBUG,ICOMB,ICOMBN)

            IF (ICOMB .EQ. 5)
     .          CALL BDG(IDTYPE,IDBUG,ICOMB,ICOMBN)

            GO TO 140

  150   END IF

*  PRINT INPUT DATA (READING, ANGLES, BOREHOLE, INSTRUMENT)

        WRITE(4,21)
   21   FORMAT(//25X,'READINGS:',/
     .    29X,'-THE READINGS REFLECT THE CHANGE IN STRAIN OR ',
     .    'DISPLACEMENT AT THE GAUGE',/30X,'DUE TO OVERCORING.  SIGN ',
     .    'CONVENTION:  TENSILE STRAIN OR EXTENSION IS POSITIVE.',/
     .    30X,'BECAUSE THE READINGS ARE DUE TO STRESS RELIEF, THE SIGN ',
     .    'CONVENTION',/30X,'FOR STRESS IS OPPOSITE -- COMPRESSIVE ',
     .    'STRESS IS POSITIVE.' )

        WRITE(4,22)
   22   FORMAT(29X,'-ALPHA IS THE ANGLE IN DEGREES DESCRIBING THE POSITI',
     .    'ON OF THE',/30X,'MIDPOINT OF THE GAUGE ON THE CIRCUMFERENCE ',
     .    ' OF THE BOREHOLE OR RAISE.',/30X,'(LOOKING INTO THE BOREHOLE,',
     .    ' IT IS MEASURED CLOCKWISE FROM NORTH OR UP.)')

        WRITE(4,23)
   23   FORMAT(29X,'-BETA IS THE ANGLE IN DEGREES DESCRIBING THE TILT ',
     .    ' OF THE GAUGE.',/30X,'LOOKING ALONG THE POSITIVE R-AXIS ',
     .    '(R-ALPHA-Z SYSTEM), BETA IS',/30X,'MEASURED POSITIVE FROM ',
     .    'THE ALPHA-AXIS CLOCKWISE TO THE AXIS OF THE ',/30X,
     .    'STRAIN GAUGE.')
```

```
      WRITE(4,24)
 24   FORMAT(//15X,'MICROSTRAIN',/20X,'OR',25X,'BOREHOLE  MATERIAL  ',
     .   'DIAMETER',/15X,'MICROINCHES   ALPHA      BETA    NUMBER',5X,
     .   'TYPE     NUMBER   INSTRUMENT',/15X,91(1H-))

      DO 160 I = 1, N

         IF(NINSTR(I) .EQ. 1) ITYPE = 'Hollow Inclusion Cell'
         IF(NINSTR(I) .EQ. 2) ITYPE = 'Triaxial Cell'
         IF(NINSTR(I) .EQ. 3) ITYPE = 'Gauges on Wall of Bored Raise'
         IF(NINSTR(I) .EQ. 4) THEN
           IF(LFTYPE(I).EQ.1) ITYPE = 'Doorstopper--Rahn'
           IF(LFTYPE(I).EQ.2) ITYPE = 'Doorstopper--Hocking'
           IF(LFTYPE(I).EQ.3) ITYPE = 'Doorstopper--Other'
         END IF
         IF(NINSTR(I) .EQ. 5) ITYPE = 'Borehole Deformation Gauge'

         IF(NINSTR(I).GE.1 .AND. NINSTR(I).LE.3) THEN

            WRITE(4,25) (YY(I,J), J=1,3), NBH(I), MT(I), ITYPE
 25         FORMAT(15X,3F10.2,5X,I2,8X,I2,15X,A29)

          ELSE IF(NINSTR(I).EQ.4) THEN

            WRITE(4,26) (YY(I,J), J=1,2), NBH(I), MT(I), ITYPE
 26         FORMAT(15X,2F10.2,15X,I2,8X,I2,15X,A29)

          ELSE

            WRITE(4,27) (YY(I,J), J=1,2), NBH(I), MT(I), NDD(I), ITYPE
 27         FORMAT(15X,2F10.2,15X,I2,2(8X,I2),5X,A29)

         END IF

 160  CONTINUE

*  DO A MULTIPLE LINEAR REGRESSION ON U AND J FACTORS TO SOLVE FOR
*  STRESS COMPONENTS AND ASSESS ERRORS IN MEASURED STRAINS

      CALL MULTR(XX,YY,N,MM,D,IDBUG,IDTYPE)

      GO TO 110

 170  IF(.NOT. THERE) CLOSE (4)

      STOP 777
      END
```

```
*  SUBROUTINE READ1

*  THIS SUBROUTINE READS IN GENERAL INFORMATION ABOUT THE INSTURMENT(S),
*  THE TEST SITE LOCATION, AND TIME OF INSTALLATION AND OVERCORING
*  OR TIME OF THE BIAXIAL COMPRESSION TEST.
*  FOR OVERCORING DATA, THE ORIENTATION ANGLES OF THE BOREHOLE(S) AND THE
*  ELASTIC PROPERTIES ARE ALSO READ IN.

*  MAJOR VARIABLES :

*       CTYPE       Type of instrument(s)
*       CLOC        Location of test site
*       DATI        Date of installation
*       DATO        Date of overcoring
*       NORT        North coord. Of test site
*       EAST        East coord. Of test site
*       ELEV        Elevation of test site
*       CLAB1..
*         CLAB5     Setting depth information
*       AZ(NBHL)    Array of borehole azimuths
*       DP(NBHL)    Array of borehole inclinations
*       PR(NMTYP)   Array of Poisson's ratio
*       YM(NMTYP)   Array of Young's modulus (psi)
*       YMM(NMTYP)  Array of Young's modulus (GPa)

      SUBROUTINE READ1(IDTYPE)

*  VARIABLE DECLARATIONS

      PARAMETER (NDIM = 99, NBHL = 10, NMTYP = 10)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/BH/ AZ(NBHL),DP(NBHL)
      COMMON/MP/ NMAT,PR(NMTYP),YM(NMTYP),YMM(NMTYP)
      COMMON/FILE/IFL
      DIMENSION NM(NMTYP),NMO(NMTYP)
      CHARACTER*80 CTYPE, CLOC, DATI, DATO
      CHARACTER*80 CLAB1, CLAB2, CLAB3, CLAB4, CLAB5
      CHARACTER*1 IMPMET
      REAL*8 NORT

*  PRINT HEADINGS

      WRITE(4,10)
   10 FORMAT(//20X,'GENERAL INFORMATION'/19X,21(1H-))

*  INPUT DESCRIPTION LABELS

      WRITE(*,11)
   11 FORMAT(' TYPE IN LABEL DESCRIBING INSTRUMENT TYPE(S)',/)
```

```
      READ(IFL,12)CTYPE
   12 FORMAT(A80)

      WRITE(*,13)
   13 FORMAT(' TYPE IN TEST SITE LOCATION INFORMATION',/)
      READ(IFL,12)CLOC

      IF(IDTYPE .GE. 1 .AND. IDTYPE .LE. 6) THEN

        WRITE(*,14)
   14   FORMAT( ' TYPE IN NORTHING, EASTING, AND ELEVATION OF TEST ',
     .    'SITE',/)
        READ(IFL,*)NORT,EAST,ELEV

        WRITE(*,15)
   15   FORMAT(' TYPE IN DATE OF INSTALLATION INFORMATION',/)
        READ(IFL,12)DATI

        WRITE(*,16)
   16   FORMAT(' TYPE IN DATE OF OVERCORING INFORMATION',/)
        READ(IFL,12)DATO

        WRITE(4,17)CTYPE,CLOC,NORT,EAST,ELEV,DATI,DATO
   17   FORMAT(25X,'INSTRUMENT TYPE:',6X,A72/25X,'INSTRUMENT LOCATION'
     .    ,':  ',A72/36X,'NORTHING:  ',F8.2,/36X,'EASTING:   ',F8.2,
     .    /36X,'ELEVATION: ',F8.2,/25X,'DATE OF ',
     .    'INSTALLATION: ',A72/25X,'DATE OF OVERCORING:   ',A72)

      ELSE

        WRITE(*,18)
   18   FORMAT (' TYPE IN DATE OF BIAXIAL TEST',/)
        READ(IFL,12)DATI

        WRITE(4,19)CTYPE,CLOC,DATI
   19   FORMAT(25X,'INSTRUMENT TYPE:',6X,A80/25X,'INSTRUMENT LOCATION'
     .    ,':  ',A80/25X,'DATE OF BIAXIAL TEST: ',A80)
      END IF

*  FOR BIAXIAL TEST, ENTER OVERCORE DESCRIPTION

      IF(IDTYPE .GE. 7) THEN
        WRITE(*,20)
   20   FORMAT(' TYPE IN 5 LINES OF 80 CHARACTERS OR LESS DESCRIBING',
     .    /,' THE OVERCORE (LENGTH, ROCK TYPE, CONDITION, ETC.)',/
     .    ' (Return after each line)'/)
        READ(IFL,12) CLAB1
        READ(IFL,12) CLAB2
        READ(IFL,12) CLAB3
        READ(IFL,12) CLAB4
        READ(IFL,12) CLAB5
```

```
        WRITE(4,21)
  21    FORMAT(/20X,'OVERCORE INFORMATION: ')

        WRITE(4,22) CLAB1,CLAB2,CLAB3,CLAB4,CLAB5
  22    FORMAT(15X,A80)

      END IF

*  BIAXIAL TEST RETURN CLAUSE

      IF(IDTYPE .GE. 7) RETURN

*  INPUT INSTRUMENT SETTING DEPTH INFORMATION

      WRITE(*,23)
  23  FORMAT(' TYPE IN 5 LINES OF 80 CHARACTERS OR LESS DESCRIBING THE',
     .   /' SETTING DEPTH INFORMATION OF EACH INSTRUMENT',/' (Return ',
     .   'after each line)'/)
      READ(IFL,12) CLAB1
      READ(IFL,12) CLAB2
      READ(IFL,12) CLAB3
      READ(IFL,12) CLAB4
      READ(IFL,12) CLAB5

      WRITE(4,24)
  24  FORMAT(/20X,'SETTING DEPTH INFORMATION: ')

      WRITE(4,22) CLAB1,CLAB2,CLAB3,CLAB4,CLAB5

*     INPUT ELASTIC PROPERTIES

      WRITE(*,25)
  25  FORMAT(1X,'ENTER NUMBER OF MATERIAL TYPES',/)
      READ(IFL,*) NMAT

 100  WRITE(*,26)
  26  FORMAT(1X,'ENTER  E  IF ROCK MODULI WILL BE INPUT IN ',
     .  'ENGLISH UNITS (psi)',/8X,'M  IF ROCK MODULI WILL ',
     .  'BE INPUT IN METRIC UNITS (GPa)',/)
      READ(IFL,27,ERR=100) IMPMET
  27  FORMAT(A1)
      IF(IMPMET .NE. 'E' .AND. IMPMET .NE. 'e' .AND. IMPMET .NE. 'M'
     .  .AND. IMPMET .NE. 'm') GO TO 100

      DO 110 I = 1, NMAT

      IF(IMPMET .EQ. 'E' .OR. IMPMET .EQ. 'e') THEN
 120     WRITE(*,28) I
  28      FORMAT(1X,'ENTER THE ELASTIC PROPERTIES FOR MATERIAL ',I2,
     .       ':',/1X,44HPOISSON'S RATIO (in/in) AND YOUNG'S MODULUS ,
     .       12H(*10**6 psi),/)
          READ(IFL,*) PR(I),YM(I)
```

```
          IF(YM(I) .EQ. 0.) GO TO 120
          YMM(I) = YM(I) * 6.895

        ELSE
 130      WRITE(*,29) I
  29      FORMAT(1X,'ENTER THE ELASTIC PROPERTIES FOR MATERIAL ',I2,
     .      ':',/1X,42HPOISSON'S RATIO (m/m) AND YOUNG'S MODULUS ,
     .      5H(GPa),/)
          READ(IFL,*) PR(I),YMM(I)
          IF(YMM(I) .EQ. 0.) GO TO 130
          YM(I) = YMM(I) / 6.895
        END IF

 110  CONTINUE

*  WRITE ELASTIC PROPERTIES TO OUTPUT

        WRITE(4,30)
  30    FORMAT(//,20X,'ROCK ELASTIC PROPERTIES:',//25X,'MATERIAL',
     .    2X,32HPOISSON'S    YOUNG'S      YOUNG'S,/27X,'TYPE',6X,
     .    'RATIO ',2(5X,'MODULUS'),/37X,'(m/m)',4X,
     .    '(*10**6 psi)   (GPa)',/25X,43(1H-))

      DO 140 I = 1, NMAT

        WRITE(4,31) I,PR(I),YM(I),YMM(I)
  31    FORMAT(28X,I2,2X,3(4X,F8.4))

 140  CONTINUE

*  DETERMINE CAUTIONS ABOUT ISOTROPIC RANGE OF POISSON'S RATIO

*    INITIALIZE VARIABLES

      DO 150 I = 1, NMAT
        NM(I) = 0
        NMO(I) = 0
 150  CONTINUE
      K = 0

*    TEST FOR BEING OUT OF USUAL ISOTROPIC RANGE, IF SO SET FLAG

      DO 160 I = 1, NMAT

        IF(PR(I) .LT. 0. .OR. PR(I) .GT. 0.5) THEN
          NM(I) = 1
          K = K + 1
          NMO(K) = I
        END IF

 160  CONTINUE
```

```
*    WRITE WARNING FOR FLAGGED MATERIALS

      IF(NMO(1) .NE. 0) THEN
        WRITE(4,32)
  32    FORMAT(/20X,'WARNING:  ',10HPOISSON'S ,'RATIO FOR THE ',
     .    'FOLLOWING MATERIALS IS',/30X,'OUTSIDE OF THE USUAL RANGE ',
     .    'OF ISOTROPIC VALUES (0. TO 0.5).',)

        WRITE(4,33) (NMO(I),I=1,K)
  33    FORMAT(29X,10(1X,I2))
      END IF

*  FOR HOLLOW INCLUSION CELLS, POISSON'S RATIO NEAR ZERO CAUSES
*  ILL-CONDITIONING IN THE CALCULATION OF K-FACTOR, K4.

      IF(IDTYPE .EQ. 1 .OR. IDTYPE .EQ. 6) THEN

*    INITIALIZE VARIABLES

        DO 170 I = 1, NMAT
          NM(I) = 0
          NMO(I) = 0
 170    CONTINUE
        K = 0

*    TEST FOR POISSON'S RATIO NEAR ZERO, IF SO, SET FLAG

        DO 180 I = 1, NMAT

1000      IF(ABS(PR(I)) .LT. 1.E-2) THEN
            NM(I) = 1
            K = K + 1
            NMO(K) = I
          END IF

 180    CONTINUE

*    WRITE WARNING FOR FLAGGED MATERIALS

        IF(NMO(1) .NE. 0) THEN
          WRITE(4,34)
  34      FORMAT(/20X,'WARNING:  THE VALUE OF ',10HPOISSON'S ,'RATIO ',
     .   'FOR THE FOLLOWING',/30X,'MATERIALS MAY CAUSE CALCULATION OF ',
     .   'UNREASONABLE VALUES',/30X,'FOR HOLLOW INCLUSION CELL ',
     .   'K-FACTORS.')

          WRITE(4,33) (NMO(I),I=1,K)

        END IF

      END IF
```

```
*  IDENTIFY AND WRITE WARNING FOR NEGATIVE VALUES OF YOUNG'S MODULUS

*    INITIALIZE VARIABLES

      DO 190 I = 1, NMAT
        NM(I) = 0
        NMO(I) = 0
 190  CONTINUE
      K = 0

*    TEST FOR NEGATIVE YOUNG'S MODULUS

      DO 200 I = 1, NMAT

        IF(YM(I) .LT. 0.) THEN
          NM(I) = 1
          K = K + 1
          NMO(K) = I
        END IF

 200  CONTINUE

*    WRITE WARNING FOR FLAGGED MATERIALS

      IF(NMO(1) .NE. 0) THEN
        WRITE(4,35)
  35    FORMAT(/20X,'WARNING:  ',8HYOUNG'S ,'MODULUS FOR THE ',
     .    'FOLLOWING MATERIALS IS NEGATIVE.',)

        WRITE(4,33) (NMO(I),I=1,K)

      END IF

*  INPUT BOREHOLE ORIENTATION INFORMATION

      WRITE(*,36)
  36  FORMAT(1X,'ENTER NUMBER OF BOREHOLES (OR BORED RAISES)',/)
      READ(IFL,*) NUMBH

      WRITE(4,37)
  37  FORMAT(//,20X,'BOREHOLE ORIENTATIONS:'//25X,'BOREHOLE',9X,
     .  'AZIMUTH',4X,'INCLINATION',/26X,'NUMBER',3X,2(8X,'(deg)'),
     .   /25X,39(1H-))

      DO 210 I = 1, NUMBH
         WRITE(*,38) I
  38     FORMAT(1X,'ENTER AZIMUTH (DEGREES CLOCKWISE FROM NORTH) ',
     .     /1X,'AND INCLINATION (DEGREES POS. DOWN, NEG. UP) ',
     .     /1X,'FOR BOREHOLE (OR BORED RAISE) ',I2,/)
         READ(IFL,*) AZ(I),DP(I)
         WRITE(4,39) I,AZ(I),DP(I)
         AZ(I)=AZ(I)*0.017453292519943
```

```
         DP(I)=DP(I)*0.017453292519943
  39     FORMAT(29X,I2,11X,F6.2,7X,F6.2)
 210  CONTINUE

      RETURN
      END
```

```
*  SUBROUTINE SoFT INClusion cell

*  MAJOR VARIABLE DESCRIPTION

*     FA,...,F6       Matrix stress coefficients in the local
*                   coordinate system
*     K1,...,K4       Correction factors for hollow inclusion cell
*     L1,...,N3       Direction cosines for orientation of overcore
*                   borehole relative to global coordinate system
*     YY(NID,3)       An array which contains the strain, alpha, and
*                   beta for each overcore strain measurement
*     D(NDIM,3)       An array that returns from subroutine MULTR
*                   which contains the measurement, the predicted value,
*                   and the residual
*     XX(NDIM,6)    An array which contains the transformed matrix
*                   stress coefficients for each strain measurement
*                   in the global coordinate system
*     STR(NDIM)     An array which contains the strains due to stress
*                   relief by overcoring
*     ALP(NDIM)     An array of angles describing the location of each
*                   strain gauge around the borehole (clockwise from up
*                   or north when looking into borehole)
*     BETA(NDIM)    An array which contains the inputted beta angle
*     IDTYPE        Type of measurement to be analyzed
*     IDBUG         Flag for output of matrix coefficients
*     YM(NMTYP)     Array of Young's moduli (psi)
*     YMM(NMTYP)    Array of Young's moduli (GPa)
*     PR(NMTYP)     Array of Poisson's ratios
*     NBH(NDIM)     Array of borehole numbers (indicating borehole of
*                     measurement i)
*     MT(NDIM)      Array of material property numbers (indicating
*                     material type of measurement i)

      SUBROUTINE SFTINC(IDTYPE,IDBUG,ICOMB,ICOMBN)

*  VARIABLE DECLARATIONS
```

```
      PARAMETER (NDIM = 99, NBHL = 10, NMTYP = 10)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 K1(NMTYP),K2(NMTYP),K3(NMTYP),K4(NMTYP),
     .  L1,L2,L3,M1,M2,M3,N1,N2,N3
      COMMON/FILE/IFL
      COMMON/MEAS/ YY(NDIM,3),D(NDIM,3),XX(NDIM,6),STR(NDIM),ALP(NDIM),
     .    BET(NDIM),NBH(NDIM),MT(NDIM),NDD(NDIM),NINSTR(NDIM),
     .    LFTYPE(NDIM),N
      COMMON/BH/ AZ(NBHL),DP(NBHL)
      COMMON/MP/ NMAT,PR(NMTYP),YM(NMTYP),YMM(NMTYP)
      CHARACTER*1 IMPMET

*  OBTAIN K-FACTORS--BRANCH TO APPROPRIATE PROMPTS

      IF(IDTYPE .EQ. 1 .OR. (IDTYPE.EQ.6 .AND. ICOMB.EQ.1)) THEN

*  MENU TO SELECT WHETHER K-FACTORS WILL BE READ-IN OR CALCULATED

 100    WRITE(*,10)
  10    FORMAT(1X,'ENTER:',/,3X,'1 - IF K FACTORS ARE TO BE INPUT',
     .    /,3X,'2 - IF K FACTORS ARE TO BE CALCULATED',/)
        READ(IFL,*) KFFLAG
        IF(KFFLAG.NE.1 .AND. KFFLAG.NE.2) GO TO 100

*  IF BLOCK FOR READING K-FACTORS

        IF(KFFLAG.EQ.1) THEN

          DO 110 I = 1, NMAT

            WRITE(*,11)
  11        FORMAT(1X,'ENTER K1, K2, K3, AND K4 FOR MATERIAL ',I2,/)
            READ(IFL,*) K1(I),K2(I),K3(I),K4(I)

 110      CONTINUE

*  IF BLOCK FOR CALCULATING K-FACTORS

        ELSE IF(KFFLAG.EQ.2) THEN

 120      WRITE(*,12)
  12      FORMAT(1X,'ENTER  E  IF EPOXY CELL MODULUS WILL BE INPUT ',
     .      'IN ENGLISH UNITS (psi)',/8X,'M  IF EPOXY CELL MODULUS ',
     .      'WILL BE INPUT IN METRIC UNITS (GPa)',/)
          READ(IFL,13) IMPMET
  13      FORMAT(A1)
          IF(IMPMET .NE. 'E' .AND. IMPMET .NE. 'e'
     .      .AND. IMPMET .NE. 'M' .AND. IMPMET .NE. 'm') GO TO 120

          IF(IMPMET .EQ. 'E' .OR. IMPMET .EQ. 'e') THEN

            WRITE(*,14)
```

```
 14        FORMAT(1X,'FOR HOLLOW INCLUSION CELL, ENTER :',/5X,
     .       9HPOISSON'S,' RATIO OF EPOXY,',/5X,8HYOUNG'S
     .       'MODULUS OF EPOXY (*10**6 psi),',/5X,'INNER RADIUS ',
     .       'OF CELL,',/5X,'OUTER RADIUS OF EPOXY OR HOLE,',
     .       /5X,'AND RADIUS OF STRAIN GAUGES.',/)
           READ(IFL,*) V1,E1,R1,R2,P
           E1M = E1 * 6.895

         ELSE

           WRITE(*,15)
 15        FORMAT(1X,'FOR HOLLOW INCLUSION CELL, ENTER :',/5X,
     .       9HPOISSON'S,' RATIO OF EPOXY,',/5X,8HYOUNG'S
     .       'MODULUS OF EPOXY (GPa),',/5X,'INNER RADIUS OF CELL,',
     .       /5X,'OUTER RADIUS OF EPOXY OR HOLE,',/5X,
     .       'AND RADIUS OF STRAIN GAUGES.',/)
           READ(IFL,*) V1,E1M,R1,R2,P
           E1 = E1M / 6.895

         END IF

         WRITE(4,16) V1,E1,E1M,R1,R2,P
 16      FORMAT(//20X,'PROPERTIES OF HOLLOW INCLUSION CELL:',/
     .     /25X,39HPOISSON'S   YOUNG'S    YOUNG'S    INNER,
     .     6X,'HOLE',4X,'RADIUS OF',/27X,'RATIO',1X,2(4X,'MODULUS'),
     .     2(4X,'RADIUS'),4X,'GAUGES',/27X,'(m/m)',6X,'(psi)',6X,
     .     '(GPa)',/25X,62(1H-),/25X,F8.5,2F11.5,2(2X,F8.3),3X,F8.3)

*    CALCULATE K-FACTORS

         DO 130 I = 1, NMAT

           CALL KFACT(V1,E1,R1,R2,P,YM(I),PR(I),K1(I),K2(I),K3(I),
     .       K4(I),C1)

130      CONTINUE

       END IF

*  WRITE TABLE OF K-FACTORS

       WRITE(4,17)
 17    FORMAT(//20X,'CORRECTION FACTORS FOR HOLLOW INCLUSION ',
     .     'CELL:',//,25X,'MATERIAL',6X,'K1',9X,'K2',9X,'K3',9X,'K4',
     .     /25X,52(1H-))

       DO 140 I = 1, NMAT
         WRITE(4,18) I,K1(I),K2(I),K3(I),K4(I)
 18      FORMAT(28X,I2,3X,4(3X,F8.5))
140    CONTINUE

     END IF
```

```
      IF(IDTYPE.EQ.2 .OR. IDTYPE.EQ.3 .OR. (IDTYPE.EQ.6 .AND.
     .  (ICOMB.EQ.2 .OR. ICOMB.EQ.3))) THEN

         DO 150 I = 1, NMAT
           K1(I) = 1.
           K2(I) = 1.
           K3(I) = 1.
           K4(I) = 1.
 150       CONTINUE

      END IF

*  READ IN MEASUREMENTS, ANGLES, AND BOREHOLES

      IF(IDTYPE.EQ.1 .OR. IDTYPE.EQ.2) WRITE(*,19)
  19  FORMAT(' ENTER MICROSTRAIN,',/
     .  ' ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),',
     .  /' BETA (TILT OF GAUGE),',/' BOREHOLE NUMBER,',
     .  /' AND MATERIAL TYPE.',
     .  //,' ENTER  0  FOR BOREHOLE NUMBER OR MATERIAL TYPE ',
     .  /,' TO END MEASUREMENT INPUT LOOP.',/)

      IF(IDTYPE .EQ. 6) WRITE(*,20)
  20  FORMAT(' ENTER MICROSTRAIN,',/
     .  ' ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),',
     .  /' BETA (TILT OF GAUGE),',/' BOREHOLE NUMBER,',
     .  /' AND MATERIAL TYPE.',/)

*  BEGIN CYCLE OF READINGS

 160  N=N+1

      IF(IDTYPE.EQ.6 .AND. ICOMBN.EQ.0) GO TO 180

 170  WRITE(*,21) N
  21  FORMAT(' TYPE IN MICROSTRAIN, ALPHA, BETA, BOREHOLE NUMBER,',
     .  /,' AND MATERIAL TYPE FOR READING',I5,'.',/)
      READ(IFL,*,ERR=170) STR(N),ALP(N),BET(N),NBH(N),MT(N)

      IF(IDTYPE.GE.1 .AND. IDTYPE.LE.3) NINSTR(N) = IDTYPE
      IF(IDTYPE .EQ. 6) NINSTR(N) = ICOMB

*  ESCAPE CLAUSE

      IF(NBH(N) .EQ. 0 .OR. MT(N) .EQ. 0) GO TO 180

*  STORE DATA IN (N BY 3) MATRIX

      YY(N,1)=STR(N)
      YY(N,2)=ALP(N)
      YY(N,3)=BET(N)
```

```
*  CONVERT DEGREES TO RADIANS

      ALP(N)=ALP(N)*0.017453292519943
      BET(N)=BET(N)*0.017453292519943

*  CALCULATE F FACTOR FOR EACH STRAIN ORIENTATION

      FA=0.5*(K1(MT(N))-PR(MT(N)))+0.5*(K1(MT(N))+PR(MT(N)))
     .   *COS(2.0*BET(N))
      FB=(1.0-PR(MT(N))*PR(MT(N)))*COS(2.0*ALP(N))
     .   *(1.0+COS(2.0*BET(N)))*K2(MT(N))
      F1=(FA-FB)/YM(MT(N))
      F2=(FA+FB)/YM(MT(N))
      F3=(0.5*(1.0-PR(MT(N))*K4(MT(N)))-0.5*(1.0+PR(MT(N))*K4(MT(N)))
     .   *COS(2.0*BET(N)))/YM(MT(N))
      F4=(2.0*(PR(MT(N))*PR(MT(N))-1.0)*SIN(2.0*ALP(N))
     .   *(1.0+COS(2.0*BET(N)))*K2(MT(N)))/YM(MT(N))
      F5=(2.0*(1.0+PR(MT(N)))*COS(ALP(N))*SIN(2.0*BET(N))*K3(MT(N)))
     .   /YM(MT(N))
      F6=(-2.0*(1.0+PR(MT(N)))*SIN(ALP(N))*SIN(2.0*BET(N))*K3(MT(N)))
     .   /YM(MT(N))

*  CALCULATE DIRECTION COSINES

      CALL DCS(AZ(NBH(N)),DP(NBH(N)),L1,L2,L3,M1,M2,M3,N1,N2,N3)


*  CALCULATE THE (N BY 6) COEFFICIENT MATRIX

*  NORMAL STRESS-X
      XX(N,1)=(F1*L1*L1+F2*L2**2+F3*L3**2+F4*L1*L2+F5*L2*L3+F6*L3*L1)
*  NORMAL STRESS-Y
      XX(N,2)=(F1*M1**2+F2*M2**2+F3*M3**2+F4*M1*M2+F5*M2*M3+F6*M3*M1)
*  NORMAL STRESS-Z
      XX(N,3)=(F1*N1**2+F2*N2**2+F3*N3**2+F4*N1*N2+F5*N2*N3+F6*N3*N1)
*  SHEAR STRESS-XY
      XX(N,4)=(2.0*F1*L1*M1+2.0*F2*L2*M2+2.0*F3*L3*M3+F4*(L1*M2+L2*M1)
     .  +F5*(L2*M3+L3*M2)+F6*(L1*M3+L3*M1))
*  SHEAR STRESS-YZ
      XX(N,5)=(2.0*F1*M1*N1+2.0*F2*M2*N2+2.0*F3*M3*N3+F4*(M1*N2+M2*N1)
     .  +F5*(M2*N3+M3*N2)+F6*(M3*N1+M1*N3))
*  SHEAR STRESS-ZX
      XX(N,6)=(2.0*F1*N1*L1+2.0*F2*N2*L2+2.0*F3*N3*L3+F4*(N1*L2+N2*L1)
     .  +F5*(N2*L3+N3*L2)+F6*(N3*L1+N1*L3))

*  IF INDICATED, PRINT LOCAL AND GLOBAL COEFFICIENTS

      IF (IDBUG.EQ.1)
     .  WRITE(4,22)N,YY(N,2),YY(N,3),F1,F2,F3,F4,F5,F6,(XX(N,J),
     .  J=1,6)
   22 FORMAT(1X,I3,2F6.1,6F8.4,7X,6F8.4)
```

```
      ICOMBN = ICOMBN - 1
      GO TO 160
 180  N = N - 1

      RETURN
      END




*   SUBROUTINE K-FACTor

*   THE FOLLOWING ROUTINE CALCULATES THE K-FACTORS FOR A HOLLOW INCLUSION
*   CELL SUCH AS THE CSIRO HICELL

*          MAJOR VARIABLE DESCRIPTIONS

*           V1=Poisson's ration of epoxy
*           V2=Poisson's ratio of rock
*           E1=Modulus of elasticity of the epoxy
*           E2=Modulus of elasticity of the rock
*           R1=Inner radius of soft inclusion probe
*           R2=Radius of pilot hole(i.e. epoxy/rock interface)
*           P= Radial coordinate at position of strain gauges

*    NOTE:  VARIABLES SUCH AS E, M, LA1, LA2, D, D1,...D6, K1,..
*    AND C1 ARE VARIABLES AS PRESENTED BY DUNCAN FAMA AND PENDER (1980)
*    IN THEIR COMPLETE SOLUTION FOR A GENERAL HOLLOW INCLUSION CELL.
*    ALSO CALCULATED IN THIS SUBROUTINE IS NOT THE "C1" AS DESCRIBED BY
*    DUNCAN FAMA AND PENDER BUT RATHER IT IS THAT "C1" WITHOUT THE
*    RESPECTIVE RADII SQUARED.

      SUBROUTINE KFACT(V1,E1,R1,R2,P,E2,V2,K1,K2,K3,K4,C1)

*   VARIABLE DECLARATIONS

      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 M,LA1,LA2,K1,K2,K3,K4

*   CALCULATE PRELIMINARY VARIABLES

      E=(E1*(1.0+V2))/(E2*(1.0+V1))
      M=R1/R2
      LA1 = 3. - 4. * V1
      LA2 = 3. - 4. * V2
      D = ((1.+LA2*E)*(LA1+E+(1.-E)*(3.*M**2-6.*M**4+4.*M**6)) +
     .    ((LA1-LA2*E)*(M**2)*((1-E)*M**6+(LA1+E)))
```

```
      D1 = 1./(1.-2.*V1+M**2+E*(1.-M**2))
      D2 = (12.*(1.-E)*M**2*(1.-M**2))/(R2**2*D)
      D3 = (1./D)*(M**4*(4.*M**2-3.)*(1.-E)+LA1+E)
      D4 = (-4.*R1**2/D)*(M**6*(1.-E)+LA1+E)
      D5 = (3.*R1**4/D)*(M**4*(1.-E)+LA1+E)
      D6 = 1./(1.+M**2+E*(1-M**2))

*  CALCULATE K-FACTORS

      K1 = D1*(1.-V1*V2)*(1.-2.*V1+(R1**2/P**2))+V1*V2
      K2 = ((1.-V1)*D2*P**2+D3+V1*D4/P**2+D5/P**4)
      K3 = D6*(1.+R1**2/P**2)
      K4 = ((-D1*(V1-V2)/V2)*(1.-2.*V1+R1**2/P**2)+V1/V2)
      C1 = 1.-(2.*E*(1.-M**2)*(1.-V1*V2)*D1)/(1.+V2)

      RETURN
      END
```

```
*     SUBROUTINE Direction CoSines

*  SUBROUTINE TO CALCULATE THE DIRECTION COSINES OF THE
*    MEASUREMENT SITE.

*  MAJOR VARIABLE DESCRIPTION

*        L1,...,N3      DIRECTION COSINES OF THE ROCK OVERCORE HOLE
*                  RELATIVE TO THE GLOBAL COORDINATE SYSTEM.
*        BRG            AZIMUTH OF THE OVERCORE HOLE RELATIVE TO THE
*                  GLOBAL COORDINATE SYSTEM.
*        DIP            INCLINATION OF THE OVERCORE HOLE RELATIVE TO
*                  THE GLOBAL COORDINATE SYSTEM.

      SUBROUTINE DCS(BRG,DIP,L1,L2,L3,M1,M2,M3,N1,N2,N3)

*  VARIABLE DECLARATIONS

      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 L1,L2,L3,M1,M2,M3,N1,N2,N3

*  CALCULATE DIRECTION COSINES

      N3=DSIN(DIP)
      M2=DCOS(BRG)
      N1=-DCOS(DIP)
      L2=-DSIN(BRG)
```

```
      N2=0.0
      L1=N3*M2
      M1=N3*(-L2)
      L3=M2*(-N1)
      M3=-L2*(-N1)
      RETURN
      END
```

```
*  SUBROUTINE DOORSTopper

*  THIS SUBROUTINE READS IN DOORSTOPPER MEASUREMENT DATA AND
*  CALCULATES THE COEFFICIENT MATRIX ACCORDING TO SELECTED
*  STRESS CONCENTRATION FACTORS.

*  STRESS CONCENTRATION FACTOR OPTIONS AVAILABLE:
*       - RAHN (1984) (according to a 3-D Finite Element study)
*       - HOCKING (1976) (according to a 3-D Boundary Element study)
*       - SELECT OWN FACTORS

*  MAJOR VARIABLES:

*     A1,B1,C1,D1   Stress concentration factors
*     FA,...,F6     Matrix stress coefficients in the local
*                  coordinate system
*     K1,...,K4     Correction factors for hollow inclusion cell
*     L1,...,N3     Direction cosines for orientation of overcore
*                  borehole relative to global coordinate system
*     YY(NID,3)     An array which contains the strain, alpha, and
*                  beta for each overcore strain measurement
*     XX(NDIM,6)    An array which contains the transformed matrix
*                  stress coefficients for each strain measurement
*                  in the global coordinate system
*     STR(NDIM)     An array which contains the strains due to stress
*                  relief by overcoring
*     ALP(NDIM)     An array which contains angle describing the
*                  orientation of the strain gauges (clockwise from up
*                  or north when looking into borehole)
*     IDTYPE        Type of measurement to be analyzed
*     IDBUG         Flag for output of matrix coefficients
*     YM(NMTYP)     Array of Young's moduli (psi)
*     YMM(NMTYP)    Array of Young's moduli (GPa)
*     PR(NMTYP)     Array of Poisson's ratios
*     NBH(NDIM)     Array of borehole numbers (indicating borehole of
*                     measurement i)
*     MT(NDIM)      Array of material property numbers (indicating
```

```
*                          material type of measurement i)


      SUBROUTINE DOORST(IDTYPE,IDBUG,ICOMB,ICOMBN)

*  VARIABLE DECLARATIONS

      PARAMETER (NDIM = 99, NBHL = 10, NMTYP = 10)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 L1,L2,L3,M1,M2,M3,N1,N2,N3,A1(NMTYP),B1(NMTYP),C1(NMTYP),
     .    D1(NMTYP)
      COMMON/FILE/IFL
      COMMON/MEAS/ YY(NDIM,3),D(NDIM,3),XX(NDIM,6),STR(NDIM),ALP(NDIM),
     .    BET(NDIM),NBH(NDIM),MT(NDIM),NDD(NDIM),NINSTR(NDIM),
     .    LFTYPE(NDIM),N
      COMMON/BH/ AZ(NBHL),DP(NBHL)
      COMMON/MP/ NMAT,PR(NMTYP),YM(NMTYP),YMM(NMTYP)

*  SELECT STRESS CONCENTRATION FACTORS

 100  WRITE(*,10)
  10  FORMAT(1X,'SELECT OPTION FOR STRESS CONCENTRATION FACTORS',/
     .   10X,'1 - FACTORS ACCORDING TO RAHN (1984) ',
     .   '(FEM--AXISYMMETRIC ELEMENTS)',/
     .   10X,'2 - FACTORS BASED ON HOCKING (1976) (3-D BEM)',/
     .   10X,'3 - SELECT OWN FACTORS',/)
      READ(IFL,*) IFTYPE
      IF(IFTYPE.NE.1 .AND. IFTYPE.NE.2 .AND. IFTYPE.NE.3) GO TO 100

*  COMPUTE OR READ FACTORS

      GO TO (110,130,150) IFTYPE

*  FACTORS ACCORDING TO RAHN (1984)

 110  DO 120 I = 1, NMAT

        A1(I) = 1.32 + 0.08*PR(I)*(1+PR(I))
        B1(I) = -0.12 + 0.18*PR(I)*(1.+2.55*PR(I))
        C1(I) = -1.09*(0.33+PR(I))
        D1(I) = A1(I) - B1(I)

 120  CONTINUE

      GO TO 170

*  FACTORS BASED ON HOCKING (1976)

 130  DO 140 I = 1, NMAT

        A1(I) =  1.3302  + 0.08529*PR(I) + 0.087445*PR(I)*PR(I)
```

```
      B1(I) = -0.12745 + 0.17342*PR(I) + 0.54919*PR(I)*PR(I)
      C1(I) = -0.37140 - 1.0139 *PR(I) - 0.25717*PR(I)*PR(I)
      D1(I) = A1(I) - B1(I)

 140  CONTINUE

      GO TO 170

*  CHOOSE OWN FACTORS

 150  DO 160 I = 1, NMAT

        WRITE(*,11) I
  11    FORMAT(1X,'ENTER STRESS CONCENTRATION FACTORS a, b, c, AND d',
     .    /' FOR MATERIAL ',I2,/)
        READ(IFL,*) A1(I),B1(I),C1(I),D1(I)

 160  CONTINUE

      GO TO 170

*  WRITE TABLE OF STRESS CONCENTRATION FACTORS

 170  IF(IFTYPE .EQ. 1) WRITE(4,12)
  12  FORMAT(//20X,'STRESS CONCENTRATION FACTORS (RAHN):',/
     .  /25X,'MATERIAL',6X,'a',11X,'b',11X,'c',11X,'d',/25X,56(1H-))

      IF(IFTYPE .EQ. 2) WRITE(4,13)
  13  FORMAT(//20X,'STRESS CONCENTRATION FACTORS (HOCKING):',/
     .  /25X,'MATERIAL',6X,'a',11X,'b',11X,'c',11X,'d',/25X,56(1H-))

      IF(IFTYPE .EQ. 3) WRITE(4,14)
  14  FORMAT(//20X,'STRESS CONCENTRATION FACTORS (OTHER):',/
     .  /25X,'MATERIAL',6X,'a',11X,'b',11X,'c',11X,'d',/25X,56(1H-))

      DO 180 I = 1, NMAT

        WRITE(4,15) I,A1(I),B1(I),C1(I),D1(I)
  15    FORMAT(28X,I2,3X,4(3X,F9.6))

 180  CONTINUE


*  READ IN MEASUREMENTS, ANGLES, AND BOREHOLES

      IF(IDTYPE .EQ. 4) WRITE(*,16)
  16  FORMAT(1X,'ENTER MICROSTRAIN,'/
     .  ' ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),',
     .  /' BOREHOLE NUMBER,',/' AND MATERIAL TYPE.',
     .  //,' ENTER  0  FOR BOREHOLE NUMBER OR MATERIAL TYPE ',
     .  /,' TO END MEASUREMENT INPUT LOOP.',/)
```

```
      IF(IDTYPE .EQ. 6) WRITE(*,17)
   17 FORMAT(' ENTER MICROSTRAIN,'/
     . ' ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),',
     . /' BOREHOLE NUMBER,',/' AND MATERIAL TYPE.',/)

*  BEGIN CYCLE OF READINGS

  190 N=N+1

      IF(IDTYPE.EQ.6 .AND. ICOMBN.EQ.0) GO TO 210

  200 WRITE(*,18) N
   18 FORMAT(' TYPE IN MICROSTRAIN, ALPHA, BOREHOLE NUMBER, ',
     . 'AND MATERIAL TYPE',/,' FOR READING',I5,'.',/)
      READ(IFL,*,ERR=200) STR(N),ALP(N),NBH(N),MT(N)

      IF(IDTYPE .EQ. 4) NINSTR(N) = IDTYPE
      IF(IDTYPE .EQ. 6) NINSTR(N) = ICOMB
      LFTYPE(N) = IFTYPE

*  ESCAPE CLAUSE

      IF(NBH(N) .EQ. 0 .OR. MT(N) .EQ. 0) GO TO 210

*  STORE DATA IN (N BY 3) MATRIX

      YY(N,1)=STR(N)
      YY(N,2)=ALP(N)

*  CONVERT DEGREES TO RADIANS

      ALP(N)=ALP(N)*0.017453292519943

*  CALCULATE F FACTOR FOR EACH STRAIN ORIENTATION

      FA = A1(MT(N))-PR(MT(N))*B1(MT(N))
      FB = B1(MT(N))-PR(MT(N))*A1(MT(N))
      C2 = (COS(ALP(N)))**2
      S2 = (SIN(ALP(N)))**2

      F1 = (FA*C2+FB*S2)/YM(MT(N))
      F2 = (FB*C2+FA*S2)/YM(MT(N))
      F3 = (C1(MT(N))*(1.-PR(MT(N))))/YM(MT(N))
      F4 = (D1(MT(N))*2.*(1.+PR(MT(N)))*SIN(ALP(N))*COS(ALP(N)))
     .     /YM(MT(N))
      F5 = 0.
      F6 = 0.

*  CALCULATE DIRECTION COSINES

      CALL DCS(AZ(NBH(N)),DP(NBH(N)),L1,L2,L3,M1,M2,M3,N1,N2,N3)
```

```
*  CALCULATE THE (N BY 6) COEFFICIENT MATRIX

*  NORMAL STRESS-X
      XX(N,1)=(F1*L1*L1+F2*L2**2+F3*L3**2+F4*L1*L2+F5*L2*L3+F6*L3*L1)
*  NORMAL STRESS-Y
      XX(N,2)=(F1*M1**2+F2*M2**2+F3*M3**2+F4*M1*M2+F5*M2*M3+F6*M3*M1)
*  NORMAL STRESS-Z
      XX(N,3)=(F1*N1**2+F2*N2**2+F3*N3**2+F4*N1*N2+F5*N2*N3+F6*N3*N1)
*  SHEAR STRESS-XY
      XX(N,4)=(2.0*F1*L1*M1+2.0*F2*L2*M2+2.0*F3*L3*M3+F4*(L1*M2+L2*M1)
     .   +F5*(L2*M3+L3*M2)+F6*(L1*M3+L3*M1))
*  SHEAR STRESS-YZ
      XX(N,5)=(2.0*F1*M1*N1+2.0*F2*M2*N2+2.0*F3*M3*N3+F4*(M1*N2+M2*N1)
     .   +F5*(M2*N3+M3*N2)+F6*(M3*N1+M1*N3))
*  SHEAR STRESS-ZX
      XX(N,6)=(2.0*F1*N1*L1+2.0*F2*N2*L2+2.0*F3*N3*L3+F4*(N1*L2+N2*L1)
     .   +F5*(N2*L3+N3*L2)+F6*(N3*L1+N1*L3))

*  IF INDICATED, PRINT LOCAL AND GLOBAL COEFFICIENTS

      IF (IDBUG.EQ.1)
     .   WRITE(4,19) N,YY(N,2),NBH(N),F1,F2,F3,F4,F5,F6,(XX(N,J),
     .   J=1,6)
   19 FORMAT(1X,I3,F6.1,I5,6F8.4,7X,6F8.4)

      ICOMBN = ICOMBN - 1
      GO TO 190
  210 N = N - 1

      RETURN
      END
```

```
*  SUBROUTINE Borehole Deformation Gauge

*  THIS SUBROUTINE READS IN BOREHOLE DEFORMATION GAUGE MEASUREMENT
*  DATA AND CALCULATES THE COEFFICIENT MATRIX.


*  MAJOR VARIABLES:

*     FA,...,F6      Matrix stress coefficients in the local
*                  coordinate system
*     L1,...,N3      Direction cosines for orientation of overcore
*                  borehole relative to global coordinate system
*     YY(NID,3)      An array which contains the strain, alpha, and
```

```
*                   beta for each overcore strain measurement
*     XX(NDIM,6)      An array which contains the transformed matrix
*                   stress coefficients for each strain measurement
*                   in the global coordinate system
*     STR(NDIM)       An array which contains the strains due to stress
*                   relief by overcoring
*     ALP(NDIM)       An array which contains angle describing the
*                   orientation of the strain gauges (clockwise from up
*                   or north when looking into borehole)
*     IDTYPE          Type of measurement to be analyzed
*     IDBUG           Flag for output of matrix coefficients
*     YM(NMTYP)       Array of Young's moduli (psi)
*     YMM(NMTYP)      Array of Young's moduli (GPa)
*     PR(NMTYP)       Array of Poisson's ratios
*     NBH(NDIM)       Array of borehole numbers (indicating borehole of
*                       measurement i)
*     MT(NDIM)        Array of material property numbers (indicating
*                       material type of measurement i)
*     DIAM(NDIA)      Array of borehole diameters (in)
*     DIAMM(NDIA)     Array of borehole diameters (mm)
*     NDD(NDIA)       Array of borehole diameter numbers (indicating
*                       borehole diameter designation of measurement i)


      SUBROUTINE BDG(IDTYPE,IDBUG,ICOMB,ICOMBN)

*  VARIABLE DECLARATIONS

      PARAMETER (NDIM = 99, NBHL = 10, NMTYP = 10, NDIA = 10)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 L1,L2,L3,M1,M2,M3,N1,N2,N3,DIAM(NDIA),DIAMM(NDIA)
      COMMON/FILE/IFL
      COMMON/MEAS/ YY(NDIM,3),D(NDIM,3),XX(NDIM,6),STR(NDIM),ALP(NDIM),
     .    BET(NDIM),NBH(NDIM),MT(NDIM),NDD(NDIM),NINSTR(NDIM),
     .    LFTYPE(NDIM),N
      COMMON/BH/ AZ(NBHL),DP(NBHL)
      COMMON/MP/ NMAT,PR(NMTYP),YM(NMTYP),YMM(NMTYP)
      CHARACTER*1 IMPMET

*  READ IN DIAMETER OF BOREHOLES

      WRITE(*,10)
   10 FORMAT(1X,'ENTER NUMBER OF DIFFERENT VALUES OF BOREHOLE ',
     .  'DIAMETER',/)
      READ(IFL,*) NDIAM

  100 WRITE(*,11)
   11 FORMAT(1X,'ENTER  E  IF BOREHOLE DIAMETERS WILL BE INPUT IN ',
     .  'ENGLISH UNITS (in)',/8X,'M  IF BOREHOLE DIAMETERS WILL BE ',
     .  'INPUT IN METRIC UNITS (mm)',/)
      READ(IFL,12,ERR=100) IMPMET
```

```
   12  FORMAT(A1)
       IF(IMPMET .NE. 'E' .AND. IMPMET .NE. 'e' .AND. IMPMET .NE. 'M'
     .   .AND. IMPMET .NE. 'm') GO TO 100

       DO 110 I = 1, NDIAM

         IF(IMPMET .EQ. 'E' .OR. IMPMET .EQ. 'e') THEN
           WRITE(*,13) I
   13      FORMAT(1X,'ENTER BOREHOLE DIAMETER (in) # ',I2,/)
           READ(IFL,*) DIAM(I)
           DIAMM(I) = DIAM(I) * 25.4

         ELSE
           WRITE(*,14) I
   14      FORMAT(1X,'ENTER BOREHOLE DIAMETER (mm) # ',I2,/)
           READ(IFL,*) DIAMM(I)
           DIAM(I) = DIAMM(I) / 25.4

         END IF

  110  CONTINUE

*  WRITE TABLE OF BOREHOLE DIAMETERS

       WRITE(4,15)
   15  FORMAT(//20X,'BOREHOLE DIAMETER:',//25X,'DIAMETER',8X,
     .   '* * DIAMETER * *',/25X,
     .   ' NUMBER',11X,'(in)',5X,'(mm)',/25X,33(1H-))

       DO 120 I = 1, NDIAM
         WRITE(4,16) I,DIAM(I),DIAMM(I)
   16    FORMAT(28X,I2,8X,2(2X,F8.4))
  120  CONTINUE


*  READ IN MEASUREMENTS, ANGLES, AND BOREHOLES

       IF(IDTYPE .EQ. 5) WRITE(*,17)
   17  FORMAT(1X,'ENTER MICROINCHES,',/
     .   ' ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),',/
     .   ' BOREHOLE NUMBER,',/,' MATERIAL TYPE,',/
     .   ' AND BOREHOLE DIAMETER DESIGNATION.',
     .   //,' ENTER  0  FOR BOREHOLE NUMBER, MATERIAL TYPE, OR ',
     .   /' BOREHOLE DIAMETER DESIGNATION TO END MEASUREMENT INPUT',
     .   ' LOOP.',/)

       IF(IDTYPE .EQ. 6) WRITE(*,18)
   18  FORMAT(' ENTER MICROINCHES,',/
     .   ' ALPHA (GAUGE ORIENTATION ANGLE CLOCKWISE FROM UP OR NORTH),',/
     .   ' BOREHOLE NUMBER,',/,' MATERIAL TYPE,',/
     .   ' AND BOREHOLE DIAMETER DESIGNATION.',/)
```

```
*  BEGIN CYCLE OF READINGS

 130  N=N+1

      IF(IDTYPE.EQ.6 .AND. ICOMBN.EQ.0) GO TO 150

 140  WRITE(*,19) N
  19  FORMAT(' TYPE IN MICROINCHES, ALPHA, BOREHOLE NUMBER,',
     .  ' MATERIAL TYPE,',/' AND BOREHOLE DIAMETER DESIGNATION',
     .  ' FOR READING',I5,'.',/)
      READ(IFL,*,ERR=140) STR(N),ALP(N),NBH(N),MT(N),NDD(N)

      IF(IDTYPE .EQ. 5) NINSTR(N) = IDTYPE
      IF(IDTYPE .EQ. 6) NINSTR(N) = ICOMB

*  ESCAPE CLAUSE

      IF(NBH(N).EQ.0 .OR. MT(N).EQ.0 .OR. NDD(N).EQ.0) GO TO 150

*  STORE DATA IN (N BY 3) MATRIX

      YY(N,1)=STR(N)
      YY(N,2)=ALP(N)

*  CONVERT DEGREES TO RADIANS

      ALP(N)=ALP(N)*0.017453292519943

*  CALCULATE F FACTOR FOR EACH STRAIN ORIENTATION

      FA = 2.*(1.-PR(MT(N))*PR(MT(N)))*COS(2.*ALP(N))
      F1 = (1.+FA)*DIAM(NDD(N))/YM(MT(N))
      F2 = (1.-FA)*DIAM(NDD(N))/YM(MT(N))
      F3 = -PR(MT(N))*DIAM(NDD(N))/YM(MT(N))
      F4 = 4.*(1.-PR(MT(N))*PR(MT(N)))*SIN(2.*ALP(N))*DIAM(NDD(N))
     .     /YM(MT(N))
      F5 = 0.
      F6 = 0.


*  CALCULATE DIRECTION COSINES

      CALL DCS(AZ(NBH(N)),DP(NBH(N)),L1,L2,L3,M1,M2,M3,N1,N2,N3)


*  CALCULATE THE (N BY 6) COEFFICIENT MATRIX

*  NORMAL STRESS-X
      XX(N,1)=(F1*L1*L1+F2*L2**2+F3*L3**2+F4*L1*L2+F5*L2*L3+F6*L3*L1)
*  NORMAL STRESS-Y
      XX(N,2)=(F1*M1**2+F2*M2**2+F3*M3**2+F4*M1*M2+F5*M2*M3+F6*M3*M1)
*  NORMAL STRESS-Z
```

```
      XX(N,3)=(F1*N1**2+F2*N2**2+F3*N3**2+F4*N1*N2+F5*N2*N3+F6*N3*N1)
*  SHEAR STRESS-XY
      XX(N,4)=(2.0*F1*L1*M1+2.0*F2*L2*M2+2.0*F3*L3*M3+F4*(L1*M2+L2*M1)
     .  +F5*(L2*M3+L3*M2)+F6*(L1*M3+L3*M1))
*  SHEAR STRESS-YZ
      XX(N,5)=(2.0*F1*M1*N1+2.0*F2*M2*N2+2.0*F3*M3*N3+F4*(M1*N2+M2*N1)
     .  +F5*(M2*N3+M3*N2)+F6*(M3*N1+M1*N3))
*  SHEAR STRESS-ZX
      XX(N,6)=(2.0*F1*N1*L1+2.0*F2*N2*L2+2.0*F3*N3*L3+F4*(N1*L2+N2*L1)
     .  +F5*(N2*L3+N3*L2)+F6*(N3*L1+N1*L3))

*  IF INDICATED, PRINT LOCAL AND GLOBAL COEFFICIENTS

      IF (IDBUG.EQ.1)
     .  WRITE(4,20) N,YY(N,2),NBH(N),F1,F2,F3,F4,F5,F6,(XX(N,J),
     .  J=1,6)
   20 FORMAT(1X,I3,F6.1,I5,6F8.4,7X,6F8.4)

      ICOMBN = ICOMBN - 1
      GO TO 130
  150 N = N - 1

      RETURN
      END




*  SUBROUTINE MODulus CALculation

*  SUBROUTINE TO CALCULATE THE MATERIAL PROPERTIES OF A HOLLOW
*  INCLUSION CELL USING BIAXIAL COMPRESSION

*  MAJOR VARIABLE DESCRIPTION
*
*     Z(9,3)          Array which contains inputted strain, stress and
*                beta angle for each biaxial strain measurement
*     XX(NDIM,6)      Array which contains the stress coefficients for
*                each biaxial strain equation
*     B(6)            Array which contains the solution to the series of
*                regression equations
*     STR(NDIM)       Array which contains the strain values for each
*                biaxial strain measurement
*     STRES(NBIAX)  Array which contains the applied radial stress for
*                each biaxial stress measurement (English units)
*     STRESM(NBIAX) Array which contains the applied radial stress for
*                each biaxial stress measurement (metric units)
*     BETA(NBIAX)   Array which contains the beta angle for each biaxial
```

```
*              strain measurement (degrees)
*     BET(NDIM)     Array which contains the beta angle for each biaxial
*              strain measurement (converted to radians)
*     YY(NDIM,3)    Array which contains the factor values for each
*              biaxial strain measurement
*     K11           Initial K1 estimate for the soft inclusion cell
*     C11           Initial C1 estimate for the soft inclusion cell
*     TF            Tolerance factor for K1 and C1
*     IIII          Maximum number or iterations allowed for biaxial
*              routine
*     V1            Poisson's ratio of epoxy pipe (assume grout same as
*              pipe)
*     E1,E1M        Young's modulus of epoxy pipe (imperial, metric)
*     R1            Inner radius of epoxy pipe
*     R2            Outer radius of grouted in place epoxy pipe (i.e.
*              radius of EX hole)
*     P             Radial distance of strain gauges in epoxy pipe
*     AA            Inner radius of rock overcore (i.e. R2)
*     BB            Outer radius of rock overcore (i.e. R3)

      SUBROUTINE MODCAL(MO,IDTYPE,IDBUG)

*   VARIABLE DECLARATIONS

      PARAMETER (NDIM = 99, NBHL = 12, NBIAX = 13)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 K11,K1,K2,K3,K4
      DIMENSION STRES(NBIAX),STRESM(NBIAX),BETA(NBIAX)
      COMMON/LS/ B(6),A(6,6)
      COMMON/MEAS/ YY(NDIM,3),D(NDIM,3),XX(NDIM,6),STR(NDIM),ALP(NDIM),
     .    BET(NDIM),NBH(NDIM),MT(NDIM),NDD(NDIM),NINSTR(NDIM),
     .    LFTYPE(NDIM),N
      COMMON/MP/ PR,YM,YMM
      COMMON/FILE/IFL
      COMMON/BIAX/NDEL,NDFLAG

*   FOR HOLLOW INCLUSION CELL, ENTER CELL PROPERTIES AND GEOMETRY

      IF(IDTYPE .EQ. 7) THEN

 100    WRITE(*,10)
  10    FORMAT(1X,'ENTER  E  IF EPOXY CELL MODULUS WILL BE INPUT ',
     .    'IN ENGLISH UNITS (psi)',/8X,'M  IF EPOXY CELL MODULUS ',
     .    'WILL BE INPUT IN METRIC UNITS (GPa)',/)
        READ(IFL,11,ERR=100) IMPMET
  11    FORMAT(A1)
        IF(IMPMET .NE. 'E' .AND. IMPMET .NE. 'e' .AND. IMPMET .NE. 'M'
     .    .AND. IMPMET .NE. 'm') GO TO 100

        IF(IMPMET .EQ. 'E' .OR. IMPMET .EQ. 'e') THEN
          WRITE(*,12)
```

```
 12      FORMAT(1X,'FOR HOLLOW INCLUSION CELL, ENTER :',/5X,
    .      9HPOISSON'S,' RATIO OF EPOXY,',/5X,8HYOUNG'S
    .      'MODULUS OF EPOXY (*10**6 psi),',/5X,'INNER RADIUS ',
    .      'OF CELL,',/5X,'OUTER RADIUS OF EPOXY OR HOLE,',
    .      /5X,'AND RADIUS OF STRAIN GAUGES.',/)
         READ(IFL,*) V1,E1,R1,R2,P
         E1M = E1 * 6.895

       ELSE
         WRITE(*,13)
 13      FORMAT(1X,'FOR HOLLOW INCLUSION CELL, ENTER :',/5X,
    .      9HPOISSON'S,' RATIO OF EPOXY,',/5X,8HYOUNG'S
    .      'MODULUS OF EPOXY (GPa),',/5X,'INNER RADIUS OF CELL,',
    .      /5X,'OUTER RADIUS OF EPOXY OR HOLE,',/5X,
    .      'AND RADIUS OF STRAIN GAUGES.',/)
         READ(IFL,*) V1,E1M,R1,R2,P
         E1 = E1M / 6.895

       END IF

       WRITE(4,14) V1,E1,E1M,R1,R2,P
 14    FORMAT(//20X,'PROPERTIES OF HOLLOW INCLUSION CELL:',/
    .    25X,34HPOISSON'S RATIO OF CELL OR EPOXY =,F10.5,/25X,
    .    34HYOUNG'S MODULUS OF CELL OR EPOXY =,F10.5,' * 10**6 psi',
    .    '  OR  ',F10.5,' GPa',/25X,'INNER RADIUS =',4X,F10.5,
    .    /25X,'OUTER RADIUS =',4X,F10.5,/25X,'RADIUS OF GAUGES =',
    .    F10.5)

      END IF

*  FOR HOLLOW INCLUSION CELL,
*  ENTER DATA CONCERNING ESTIMATES OF CORRECTION FACTORS

      IF(IDTYPE .EQ.7) THEN

       WRITE(*,15)
 15    FORMAT(1X,'ENTER INITIAL ESTIMATES FOR K1 AND C1 FACTORS,'
    .    ,/,' MAXIMUM NUMBER OF ITERATIONS FOR ROUTINE,',/,' AND ',
    .    'TOLERANCE FACTOR ON BOTH K1 AND C1.',/)
       READ(IFL,*) K11,C11,IIII,TF
       WRITE(4,16) K11,C11,IIII,TF
 16    FORMAT(/20X,'INITIAL ESTIMATE FOR K1 =',F10.5,
    .    /20X,'INITIAL ESTIMATE FOR C1 =',F10.5,/20X,'MAXIMUM NUMBER',
    .    ' OF ITERATIONS FOR ROUTINE =',I5,/20X,'TOLERANCE FACTOR ON',
    .    ' K1 AND C1 =',F10.5)

      ELSE

       K11 = 1.
       C11 = 1.

      END IF
```

```
*  INITIALIZE MEASUREMENT COUNTER

      K=0

*  INPUT INNER AND OUTER DIAMETER OF ROCK OVERCORE

      WRITE(*,17)
   17 FORMAT(1X,'ENTER INNER AND OUTER DIAMETER OF ROCK OVERCORE',
     . /' (ENGLISH OR METRIC UNITS)',/)
      READ(IFL,*)AA,BB
      WRITE(4,18)AA,BB
   18 FORMAT(/20X,'INNER RADIUS OF OVERCORE = ',F10.2,/20X,
     . 'OUTER RADIUS OF OVERCORE = ',F10.2,/)

*  INPUT BIAXIAL RESULTS: STRAIN, STRESS, AND TILT ANGLE

      WRITE(*,19)
   19 FORMAT(' ENTER BIAXIAL HYDROSTATIC TEST DATA AS REQUESTED.'
     . ,/'     TO FINISH...SET BETA=777.0',//)
  110 WRITE(*,20)
   20 FORMAT(1X,'ENTER  E  IF APPLIED STRESS WILL BE INPUT IN ENGLISH',
     . ' UNITS (psi)',/8X,'M  IF APPLIED STRESS WILL BE INPUT IN ',
     . 'METRIC UNITS (MPa)',/)
      READ(IFL,11,ERR=110) IMPMET
      IF(IMPMET .NE. 'E' .AND. IMPMET .NE. 'e' .AND.
     .   IMPMET .NE. 'M' .AND. IMPMET .NE. 'm') GO TO 110

*  BEGIN READ CYCLE

  120 K=K+1
      WRITE(*,21) K
   21 FORMAT(' ENTER VALUES OF STRAIN, STRESS, BETA FOR READING',I5,/)
      READ(IFL,*) STR(K),STRES(K),BET(K)
      IF(IMPMET .EQ. 'E' .OR. IMPMET .EQ. 'e') THEN
        STRESM(K) = STRES(K) * 0.006895
       ELSE
        STRESM(K) = STRES(K)
        STRES(K) = STRES(K) / 0.006895
       END IF
      IF(BET(K).EQ.777.0) GO TO 130

*  CONVERT ANGLE TO RADIANS

      BETA(K) = BET(K)
      BET(K) = BET(K)*0.017453292519943

*  ASSEMBLE INITIAL MATRIX EQUATIONS

      YY(K,1)=K11*STR(K)*(1.+COS(2.*BET(K)))*(1./(1.-(AA/BB)**2*C11))
      XX(K,1) = STR(K)**2/STRES(K)
      XX(K,2) = STR(K)*(1.-COS(2.*BET(K)))*(1./(1.-(AA/BB)**2*C11))
```

```
      GO TO 120

 130  K = K-1
      MO = 2

*  BRANCH TO ROUTINE FOR TYPE OF CELL

      IF(IDTYPE .EQ. 8) GO TO 180

*******************************************
*  HOLLOW INCLUSION CELL ITERATION ROUTINE:
*******************************************

*  INITIALIZE ITERATION COUNTER

      III = 1

*  BEGIN ITERATION LOOP TO DETERMINE ELASTIC PROPERTIES AND K-FACTORS

 140  WRITE(*,22) III
  22  FORMAT(/1X,'***** BEGIN ITERATION # ',I3,/)

      WRITE(4,23) III
  23  FORMAT(//,'1',/20X,'***** BEGIN ITERATION # ',I3,/)

      WRITE(4,24)
  24  FORMAT(1X,//10X,'BIAXIAL HYDROSTATIC TEST DATA',
     . 9X,'X FACTORS FOR TEST DATA',/,11X,
     . 'STRAIN      STRESS      STRESS      BETA',9X,'XX(1)',
     . 8X,'XX(2)',8X,'YY(1)', 5X,'INSTRUMENT',/,23X,'(psi)',
     . 7X,'(MPa)',/,10X,107(1H-),/)

      DO 150 ID = 1,K
         WRITE(4,25) STR(ID),STRES(ID),STRESM(ID),BETA(ID),
     .      XX(ID,1),XX(ID,2),YY(ID,1)
  25     FORMAT(8X,F9.2,3X,F9.2,3X,F9.3,3X,F7.2,2X,3(3X,F10.4),
     .      4X,'Hollow Inclusion Cell')

 150  CONTINUE

*  CALL MULTR TO CALCULATE ROCK'S ELASTIC PROPERTIES

      CALL MULTR(XX,YY,K,MO,D,IDBUG,IDTYPE)

      YM = B(1)
      PR = B(2)

*  CALCULATE K-FACTORS WITH CURRENT ELASTIC PROPERTIES

      CALL KFACT(V1,E1,R1,R2,P,YM,PR,K1,K2,K3,K4,C1)

*  WRITE OUT CORRECTION FACTORS
```

```
      WRITE(4,26) III,K1,K2,K3,K4,C1
   26 FORMAT(/20X,'***** ITERATION # ',I5,' COMPLETED',
     . //20X,'CORRECTION FACTORS FOR HOLLOW INCLUSION INSTRUMENT:',
     . /25X,'K1 = ',F13.8,/25X,'K2 = ',F13.8,/25X,'K3 = ',
     . F13.8,/25X,'K4 = ',F13.8,/25X,'C1 = ',F13.8,/)

*  CHECK TOLERANCE

      IF((ABS(K11-K1).LT.TF).AND.(ABS(C11-C1).LT.TF)) GO TO 170
      K11 = K1
      C11 = C1

*  QUIT CLAUSE FOR MAXIMUM ITERATIONS

      IF(III.EQ.IIII) GO TO 170
      III = III + 1

*  RELOOP TO FIND BETTER FIT FOR PR AND YM

*  RECALCULATE COEFFICIENTS

      DO 160 I = 1,K
         YY(I,1)=K11*STR(I)*(1.+COS(2.*BET(I)))*(1./(1.-(AA/BB)**2
     .     *C11))
         XX(I,2) = STR(I)*(1.-COS(2.*BET(I)))*(1./(1.-(AA/BB)**2
     .     *C11))
  160 CONTINUE

      GO TO 140

  170 NDFLAG = 0
      WRITE(4,27) III
   27 FORMAT(/20X,45HYOUNG'S MODULUS & POISSON'S RATIO DETERMINED ,
     .    'AFTER ',I5,' ITERATIONS.')

      RETURN

*************************
*  TRIAXIAL CELL ROUTINE:
*************************

  180 WRITE(4,24)

      DO 190 ID = 1,K
         WRITE(4,28) STR(ID),STRES(ID),STRESM(ID),BETA(ID),
     .     XX(ID,1),XX(ID,2),YY(ID,1)
   28    FORMAT(8X,F9.2,3X,F9.2,3X,F9.3,3X,F7.2,2X,3(3X,F10.4),
     .     4X,'Triaxial Cell')

  190 CONTINUE

*  CALL MULTR TO CALCULATE ROCK'S ELASTIC PROPERTIES
```

```
      CALL MULTR(XX,YY,K,MO,D,IDBUG,IDTYPE)

      YM = B(1)
      PR = B(2)

      RETURN
      END
```

```
*  SUBROUTINE MULTR

*  SUBROUTINE WHICH PERFORMS A MULTIPLE LINEAR REGRESSION ON A
*  DATA SET N BY M (N = NUMBER OF EQUATIONS, M = NUMBER OF
*  UNKNOWNS; MAXIMUM NUMBER: N = NDIM, M = 6).  THE SUBROUTINE
*  IS BROKEN UP TO PERFORM THE LEAST SQUARES ANALYSIS FOR EITHER
*  BIAXIAL DATA OR OVERCORING DATA.  IT THEN OUTPUTS THE FINAL
*  BEST FIT SOLUTION AND THE DESIRED STATISTICS FOR EITHER
*  BIAXIAL OR OVERCORING CONDITIONS.  FOR OVERCORING DATA, THE
*  PRINCIPAL STRESSES AND DIRECTIONS ARE CALCULATED AND OUTPUTTED.

*  MAJOR VARIABLE DESCRIPTION

*     X(NDIM,6)     Inputted set of equation coefficients which is to
*                 be used to solve for the best fit of the desired
*                 stress or elastic components from data reduction
*     YY(NDIM,3)    Inputted set of measured strains or factors used to
*                 solve for the best fit of the desired stress or
*                 elastic components
*     A(6,6)        Regression matrix A of the inputted data
*     B(6)          Regression matrix B of the inputted data
*     M             Number of unknowns in inputted set of equations
*     N             Number of equations in inputted data set
*     D(NDIM,3)     Array which contains the measurements, the predicted
*                 values, and their differences
*     SST           Total sum of the squares of the differences between
*                 measured and mean strains/displacements
*     SSR           Sum of the squares of the differences between the
*                 predicted values and the mean values (explained
*                 deviations)
*     SSD           Sum of the squares of the differences between
*                 measured and predicted strains/displacements
*     NDFI          Degrees of freedom about the regression line
*     NDF2          Degrees of freedom of the deviation about the
*                 regression line
*     AMSR          Mean squares of the predicted values about the
*                 regression line
```

```
*     AMSD            Mean squares of the deviation about the regression
*                   line
*     SD              Standard deviation of the data set
*     SE(6)           Standard error of each calculated elastic property
*                   or of each calculated stress component
*     GF              Goodness of fit of the data to the regression
*                   equation (R squared)
*     R               Correlation coefficient of the data to the
*                   regression equation
*     F               F test of the data set
*     C(3,2)          Array of principal stresses (imperial and metric)
*     DP(3)           Array which contains the inclination of each principal
*                   stress
*     BR(3)           Array which contains the azimuth of each
*                   principal stress
*     CL(3),CM(3),CN(3)   Direction cosines of the principal directions
*     IFLAG(3,2)      An array indicating whether azimuth or inclination angles
*                   should be printed:  0 = yes,  1 = no


      SUBROUTINE MULTR(X,YY,N,M,D,IDBUG,IDTYPE)

*  VARIABLE DECLARATIONS

      PARAMETER (NDIM = 99, NBHL = 10)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 X(NDIM,6),YY(NDIM,3),D(NDIM,3),SE(6),BS(6),
     . BSP(6),ASP(6,6),C(3,3),NEQ(NDIM),NEQD(NDIM),DP(3),
     . BR(3),CL(3),CM(3),CN(3),IFLAG(3,2)
      INTEGER B1,B2
      COMMON/LS/ B(6),A(6,6)
      COMMON/FILE/IFL
      COMMON/BIAX/NDEL,NDFLAG

*  INPUT NUMBER OF MEASUREMENTS TO BE DELETED

      IF(NDFLAG.EQ.0) THEN
         MAXDEL = N - M - 1
 100     WRITE(*,10) MAXDEL
  10     FORMAT(1X,'ENTER NUMBER OF RUN PASSES TO BE EXECUTED',/
     .      ' IN WHICH SUCCESSIVELY WORST READINGS ARE ELIMINATED;',/
     .      ' NUMBER MUST BE EQUAL TO OR LESS THAN (',I2,').',/)
         READ(IFL,*) NDEL
         IF(NDEL .GT. MAXDEL) GO TO 100
         NDFLAG  = 1
      END IF

*  INITIALIZE COEFFICIENT MATRIX AND MEASUREMENT/STRESS VECTOR

      DO 110 I=1,6
         B(I)=0.0
      DO 110 J=1,6
```

```
        A(I,J)=0.0
 110  CONTINUE

*  INITIALIZE VECTOR INDICATING DISCARDED MEASUREMENTS

      DO 120 I=1,NDIM
         NEQD(I) = 0.
 120  CONTINUE

*  ASSEMBLE LEAST SQUARES COEFFIECIENT MATRIX AND VECTOR

      DO 130 I=1,N
         Y=YY(I,1)
         YY(I,1)=1.0
         DO 140 J=1,M
            B(J)=B(J)+X(I,J)*Y
            BSP(J)=B(J)
            BS(J)=B(J)
         DO 140 K=1,M
            A(J,K)=A(J,K)+X(I,J)*X(I,K)
            ASP(J,K)=A(J,K)
 140     CONTINUE
         YY(I,1)=Y
 130  CONTINUE

*  BEGIN OUTPUT RUN CYCLE

      IRUN=0
 150  IRUN=IRUN+1

*  PRINT HEADING TABLE

      WRITE(4,11)IRUN
  11  FORMAT('1',//20X,'OUTPUT RESULTS:  RUN NUMBER ',I2,/20X,30(1H-))

      IF(IDTYPE.EQ.7) WRITE(*,12) IRUN
  12  FORMAT(/1X,'RUN NUMBER',I3)

*  PRINT COEFFICIENTS OF EQUATIONS TO BE SOLVED, IF INDICATED

      IF(IDBUG.NE.1) GO TO 170
      WRITE(4,13)
  13  FORMAT(//,10X' ECHO OF MATRIX TO BE INVERTED',//)

      DO 160 J = 1,M
         WRITE(4,14)(A(J,K),K=1,M),BS(J)
  14     FORMAT(1X,7(2X,G12.6))
 160  CONTINUE

*  CHECK FOR SINGULAR COEFFICIENT MATRIX, A

 170  CALL DETERM(A,M,DETR)
```

```
      WRITE(4,15) DETR
  15  FORMAT(//20X,'THE DETERMINANT OF THE COEFFICIENT MATRIX, A, IS ',
     .   E16.8)

1000  IF(ABS(DETR) .LE. 1.E-6) THEN
         WRITE(4,16)
  16     FORMAT(/7X,74(1H!),/7X,'THE COEFFICIENT MATRIX, A, MAY BE ',
     .      'SINGULAR.',/7X,'THE MEASUREMENTS MAY NOT BE ',
     .      'SUFFICIENT TO DETERMINE A UNIQUE STRESS STATE.',/7X,
     .      74(1H!))
         WRITE(*,16)
      END IF

1001  IF(ABS(DETR) .LE. 1.E-6) RETURN

*  INVERT COEFFICIENT MATRIX, COMPUTE GLOBAL STRESSES OR ROCK PROPERTIES

      CALL MATINV(A,6,BS,-1,DET,IRR)

       DO 180 J=1,6
         B(J)=BS(J)
 180  CONTINUE

      IF(M.EQ.2) THEN

*  WRITE HEADING FOR MEASUREMENT/FITTED MEASUREMENT/DIFFERENCE TABLE

         WRITE(4,17)
  17     FORMAT(//15X,'DEVIATIONS:',//20X,'FACTOR',7X,'COMPUTED FACTOR'
     .     ,'    DIFFERENCE')

      ELSE IF(IDTYPE.EQ.1 .OR. IDTYPE.EQ.2 .OR. IDTYPE.EQ.3 .OR.
     .         IDTYPE.EQ.4) THEN

         WRITE(4,18)
  18     FORMAT(//15X,'DEVIATIONS:',//20X,'STRAIN',7X,'COMPUTED STRAIN',
     .     '     DIFFERENCE')

      ELSE IF(IDTYPE .EQ. 5) THEN

         WRITE(4,19)
  19     FORMAT(//15X,'DEVIATIONS:',//20X,'DISPL.',7X,'COMPUTED DISPL.',
     .     '     DIFFERENCE')

      ELSE IF(IDTYPE .EQ. 6) THEN

         WRITE(4,20)
  20     FORMAT(//15X,'DEVIATIONS:',//16X,'MEASUREMENT',3X,
     .     'COMPUTED MEASUREMENT',3X,'DIFFERENCE')

      END IF
```

```
*  INITIALIZE VARIABLES FOR ANALYSIS OF RESIDUALS

      DMAX=0.0
      SY=0.0
      SYY=0.0
      SYC=0.0
      SYYC=0.0

      K11=IRUN-1

*  LOOP TO PRINT MEASUREMENT FIT TABLE; ACCUMULATE STATISTICS

      DO 190 I=1,N
         NEQ(I)=I
         IF(IRUN.LT.2) GO TO 210

         DO 200 K=1,K11
            IF(NEQ(I).NE.NEQD(K)) GO TO 200
            WRITE(4,21)I,K
 21         FORMAT(20X,I4,'  DISCARD NO.',I3)
            GO TO 190
200      CONTINUE

210      D(I,1)=YY(I,1)
         D(I,2)=0.0

*  CALCULATE FITTED STRAIN/DISPLACEMENT, DIFFERENCE

         DO 220 J=1,M
            D(I,2)=D(I,2)+B(J)*X(I,J)
220      CONTINUE

         D(I,3)=D(I,1)-D(I,2)

*  PRINT MEASURED STRAIN/DISPLACEMENT, FITTED STRAIN/DISPLACEMENT,
*  AND THEIR DIFFERENCE

         WRITE(4,22)(D(I,J),J=1,3)
 22      FORMAT(F26.2,F17.2,F16.2)

*  UPDATE MAXIMUM DIFFERENCE

         IF(ABS(D(I,3)).LE.DMAX)GO TO 230
         DMAX=ABS(D(I,3))
         IDMAX=I

*  ACCUMULATE STATISTICS

230      SY=SY+D(I,1)
         SYY=SYY+D(I,1)**2
         SYC=SYC+D(I,2)
         SYYC=SYYC+D(I,2)**2
```

```
 190  CONTINUE

*  CALCULATE STATISTICS

      NEQD(IRUN)=NEQ(IDMAX)
      SST=SYY-SY**2/FLOAT((N-K11))
      SSR=SYYC-SYC**2/FLOAT((N-K11))
      SSD=SST-SSR
      NDF1=M
      AMSR=SSR/FLOAT(NDF1)
      NDF2=N-M-K11
      AMSD= SSD/FLOAT(NDF2)

*  TEST FOR NUMERICAL PROBLEM WITH STATISTICS -- IF SO, SET MFLAG = 1
*  GO AHEAD AND PRINT THE VARIANCE TABLE.  A COMMENT ABOUT NEGATIVE
*  MEAN OF DEVIATION WILL BE PRINTED LATER.

      IF(AMSD .LT. 0.0) THEN
        MFLAG = 1
        AMSD = -AMSD
       ELSE
        MFLAG = 0
       END IF

*  CALCULATE STANDARD DEVIATION OF DIFFERENCES

      SD=SQRT(AMSD)

      DO 240 J=1,6
         IF (A(J,J).LT.0.0) A(J,J)=-A(J,J)
         SE(J)=SD*SQRT(A(J,J))
 240  CONTINUE

*  SET NRFLAG = 1 IF ANALYSIS OF VARIANCE SHOULD NOT BE DONE BECAUSE
*  OF NEGLIGIBLE ERROR IN THE MEASUREMENTS.

      NRFLAG = 0
1010  IF(SST .LE. 1.E-8) NRFLAG = 1
1011  IF(SST .LE. 1.E-8) GO TO 250

*  CALCULATE GOODNESS OF FIT, CORRELATION COEFFICIENT, F-VALUE

      GF=SSR/SST
      R=SQRT(GF)
      IF(GF.NE.1.0)F=AMSR/AMSD
1020  IF(GF.EQ.1.0)F=1000.
      NDF3=NDF1+NDF2

*  PRINT STAND. DEV. OF DIFF., DEG. OF FREED., G. OF FIT, CORR. COEFF.

      WRITE(4,23)SD,NDF2,GF,R
  23  FORMAT(/20X,'STANDARD DEVIATION OF DIFFERENCES IS',F8.2,' ON',I3,
```

```
     .  ' DEGREES OF FREEDOM.',/20X,'GOODNESS OF FIT =',F4.2,/20X,
     .  'CORRELATION COEFFICIENT =',F4.2)


*********************
* BIAXIAL STATISTICS

 250  IF(M.EQ.2) THEN

*  PRINT LEAST SQUARES FIT OF PARAMETERS

        WRITE(4,24)
  24    FORMAT(//25X,'THE ROCK ELASTIC PROPERTIES ARE COMPUTED BY ',
     .    'THE MULTIPLE LINEAR'/25X,'REGRESSION METHOD WHICH OUTPUTS ',
     .    'VARIOUS STATISTICAL DATA AND'/25X,'BEST FITTING VALUES ',
     .    'OF THE ELASTIC COMPONENTS.')

        YMM = B(1) * 6.895
        SEM = SE(1) * 6.895

        WRITE(4,25)
  25    FORMAT(//22X,'ROCK ELASTIC COMPONENTS',/21X,25(1H-))

        WRITE(4,26) B(1),YMM,SE(1),SEM
  26    FORMAT(/20X,15HYOUNG'S MODULUS,F10.4,13H  * 10**6 psi,
     .    4H  OR,F10.4,5H  GPa,/20X,14HSTANDARD ERROR,F12.5,
     .    12H * 10**6 psi,4H  OR,F11.5,4H GPa)

        WRITE(4,27)B(2),SE(2)
  27    FORMAT(/20X,15HPOISSON'S RATIO,F10.4,13H in/in  (m/m),/20X,
     .    14HSTANDARD ERROR,F11.4,13H in/in  (m/m))

        WRITE(4,28)
  28    FORMAT(//20X,'NOTE:  THE STANDARD ERROR IS THE STANDARD ',
     .    'DEVIATION OF THE ELASTIC',/20X,'(YM & PR) COMPONENTS.',
     .    '  CONFIDENCE LIMITS FOR THE ELASTIC COMPONENTS ARE',/20X,
     .    'OBTAINED BY USING THE ',9HSTUDENT'S,' T DISTRIBUTION FOR ',
     .    'THE DESIRED PROBABILITY.',/20X,'THE STANDARD ERROR TAKES ',
     .    'NO ACCOUNT OF THE POSSIBLE ERROR IN THE ELASTIC',/20X,
     .    'COMPONENTS DUE TO INACCURATE READINGS FOR THE STRAIN ',
     .    'GAUGES.')

*  SKIP ANALYSIS OF RESIDUALS TABLE IF NEGLIGIBLE ERROR

      IF(NRFLAG .EQ. 1) WRITE(4,38)

      IF(NRFLAG .EQ. 1) GO TO 260


*  PRINT ANALYSIS OF RESIDUALS TABLE

        WRITE(4,39)
```

```
         WRITE(4,40)
         WRITE(4,41) SSR,NDF1,AMSR,F
         WRITE(4,42) SSD,NDF2,AMSD
         WRITE(4,43) SST,NDF3

         IF(MFLAG.EQ.1) WRITE(4,44)

 260     IF(NDF2.EQ.1) GO TO 999

*  INPUT OPTION FLAG FOR REJECTING LARGEST RESIDUAL

         IF(IRUN .GT. NDEL) GO TO 999

*  SUBTRACT EFFECT OF LARGEST RESIDUAL FROM MATRIX AND VECTOR

         DO 280 I = 1,M
            B(I) = BSP(I)-X(IDMAX,I)*YY(IDMAX,1)
            BSP(I) = B(I)
            BS(I) = B(I)
         DO 280 J = 1,M
            A(I,J) = ASP(I,J)-X(IDMAX,I)*X(IDMAX,J)
            ASP(I,J) = A(I,J)
 280     CONTINUE

      END IF


      IF(M.EQ.2) GO TO 150


*********************
*  TRIAXIAL STATISTICS

*  PRINT LEAST SQUARES FIT OF PARAMETERS

      WRITE(4,29)
  29  FORMAT(///20X,'THE STRESSES IN THE ROCK ARE COMPUTED BY THE',
     . ' MULTIPLE LINEAR REGRESSION METHOD',/20X,'WHICH GIVES ',
     . 'VARIOUS STATISTICAL DATA AND BEST FITTING VALUES (BY '
     . 'LEAST SQUARES',/20X,'METHOD) OF THE STRESS COMPONENTS IN ',
     . 'THE GLOBAL SYSTEM.  THE MAGNITUDE AND',/20X,'DIRECTION OF ',
     . 'PRINCIPAL STRESSES ARE DETERMINED FROM THESE STRESS ',
     . 'COMPONENTS.')

      WRITE(4,30)
  30  FORMAT(//10X,'**** STRESS COMPONENTS IN REFERENCE SYSTEM ****',
     . //20X,'COMPONENT',14X,'S T R E S S E S',/20X,'DESIGNATION',
     . 11X,'(psi)',7X,'(MPa)',/19X,43(1H-))

      BMET = B(1) * 0.006895
      SEM = SE(1) * 0.006895
      WRITE(4,31) B(1),BMET,SE(1),SEM
```

```
   31 FORMAT(/20X,'NORMAL NORTH-SOUTH',F10.2,F12.3,/20X,
     .  'STANDARD ERROR',F15.3,F12.4)

      BMET = B(2) * 0.006895
      SEM = SE(2) * 0.006895
      WRITE(4,32) B(2),BMET,SE(2),SEM
   32 FORMAT(/20X,'NORMAL EAST-WEST',F12.2,F12.3,/20X,
     .  'STANDARD ERROR',F15.3,F12.4)

      BMET = B(3) * 0.006895
      SEM = SE(3) * 0.006895
      WRITE(4,33) B(3),BMET,SE(3),SEM
   33 FORMAT(/20X,'NORMAL VERTICAL',F13.2,F12.3,/20X,
     .  'STANDARD ERROR',F15.3,F12.4)

      BMET = B(4) * 0.006895
      SEM = SE(4) * 0.006895
      WRITE(4,34) B(4),BMET,SE(4),SEM
   34 FORMAT(/20X,'SHEAR N-S/E-W',F15.2,F12.3,/20X,
     .  'STANDARD ERROR',F15.3,F12.4)

      BMET = B(5) * 0.006895
      SEM = SE(5) * 0.006895
      WRITE(4,35) B(5),BMET,SE(5),SEM
   35 FORMAT(/20X,'SHEAR E-W/VERT',F14.2,F12.3,/20X,
     .  'STANDARD ERROR',F15.3,F12.4)

      BMET = B(6) * 0.006895
      SEM = SE(6) * 0.006895
      WRITE(4,36) B(6),BMET,SE(6),SEM
   36 FORMAT(/20X,'SHEAR VERT/N-S',F14.2,F12.3,/20X,
     .  'STANDARD ERROR',F15.3,F12.4)

      WRITE(4,37)
   37 FORMAT(//20X,'NOTE:  THE STANDARD ERROR IS THE STANDARD DEVIATI',
     .  'ON OF THE STRESS COMPONENTS.',/20X,'CONFIDENCE LIMITS FOR ',
     .  'THE STRESS COMPONENTS ARE OBTAINED BY USING THE ',
     .  9HSTUDENT'S,/20X,'T DISTRIBUTION FOR THE DESIRED PROBABILITY.',
     .  '  THE STANDARD ERROR TAKES NO ACCOUNT',/20X,'OF THE POSSIBLE ',
     .  'ERROR IN THE STRESS COMPONENTS DUE TO INACCURATE READINGS OF',
     .  /20X,'THE STRAIN GAUGES.')

*  SKIP ANALYSIS OF RESIDUALS TABLE IF NEGLIGIBLE ERROR

      IF(NRFLAG .EQ. 1) WRITE(4,38)
   38 FORMAT(//10X,'ANALYSIS OF RESIDUALS WAS NOT DONE BECAUSE OF ',
     .  'NEGLIGIBLE ERROR IN MEASUREMENTS.')
      IF(NRFLAG .EQ. 1) GO TO 290

*  PRINT ANALYSIS OF RESIDUALS TABLE

      WRITE(4,39)
```

```
   39 FORMAT(//10X,'ANALYSIS OF VARIANCE TABLE FOR MULTIPLE REGRESSION',
     . /9X,52(1H-))

      WRITE(4,40)
   40 FORMAT(/21X,'SOURCE OF',13X,'SUM OF  DEGREES OF   MEAN',/
     . 21X,'VARIATION',13X,'SQUARES   FREEDOM   SQUARES    F-TEST')

      WRITE(4,41) SSR,NDF1,AMSR,F
   41 FORMAT(/21X,'REGRESSION',F20.2,I8,F12.2,/70X,F12.4)

      WRITE(4,42) SSD,NDF2,AMSD
   42 FORMAT(21X,'DEVIATION',F21.2,I8,F12.2)

      WRITE(4,43) SST,NDF3
   43 FORMAT(/21X,'TOTAL VARIATION',F15.2,I8)

      IF(MFLAG.EQ.1) WRITE(4,44)
   44 FORMAT(/,11X,'THE MEAN SQUARES OF THE DEVIATION IS NEGATIVE.')

*********************
*  CALCULATION OF THE PRINCIPAL STRESSES AND DIRECTIONS


  290 BB=-(B(1)+B(2)+B(3))/3.0
      CC=(B(1)*B(2)+B(2)*B(3)+B(3)*B(1)-B(4)**2-B(5)**2-B(6)**2)/3.0
      DD=-B(1)*B(2)*B(3)-2.0*B(4)*B(5)*B(6)+B(1)*B(5)**2+B(2)*B(6)**2
     . +B(3)*B(4)**2
      BC = (BB**2) - CC

*  AVOID NUMERICAL PROBLEM IF "BC" IS NEGATIVE.

      IF(BC.LE.0.) E = 0.
      IF(BC.LE.0.) GO TO 300
      E = SQRT(BC)

  300 F=-(BB**3)+(3.0*BB*CC-DD)/2.0
      IF(BC.LE.0.) AB = 0.
      IF(BC.LE.0.) GO TO 310

*  DO NOT CALCULATE PRINCIPAL STRESSES IF THERE ARE NUMERICAL PROBLEMS

 1030 IF(ABS(E).LE.1.E-8) THEN
         WRITE(4,45)
   45    FORMAT(//,10X,'PRINCIPAL STRESSES WERE NOT CALCULATED DUE TO ',
     .      'NUMERICAL PROBLEMS.')
         WRITE(4,46) E
   46    FORMAT(10X,'THE VARIABLE E (VALUE = ',E16.8,') IS TOO CLOSE ',
     .      'TO ZERO.',/10X,'BECAUSE E OCCURS IN THE DENOMINATOR OF ',
     .      'THE EQUATION FOR CALCULATING THE PRINCIPAL STRESSES,',/10X,
     .      'CONTINUING WILL RESULT IN DIVISION BY ZERO OR SPURIOUS ',
     .      'VALUES OF PRINCIPAL STRESS.')
      END IF
```

```
1031  IF(ABS(E).LE.1.E-8) GO TO 440
      FFEE = ABS(F)/(E*E*E)

*  THE FOLLOWING IS AN ATTEMPT TO AVOID TAKING THE ARCCOSINE OF A
*  NUMBER GREATER THAN ONE.

1040  IF((ABS(1.-FFEE)).LE.1.E-5.AND.FFEE.GT.1.) FFEE = 1.
1041  IF((ABS(-1.-FFEE)).LE.1.E-5.AND.FFEE.LT.-1.) FFEE = -1.
      IF(FFEE .GT. 1. .OR. FFEE .LT. -1.) THEN
         WRITE(4,45)
         WRITE(4,47) FFEE
  47     FORMAT(10X,'THE VARIABLE FFEE (VALUE = ',E16.8,') IS ',
     .      'OUTSIDE OF',/10X,'THE RANGE FOR WHICH THE ARC COSINE ',
     .      'FUNCTION IS DEFINED.')
      END IF
      IF(FFEE .GT. 1. .OR. FFEE .LT. -1.) GO TO 440
      AB=ACOS(FFEE)/3.0

 310  H1 = 1.
      H=2.0*E*SIGN(H1,F)

*  INITIALIZE FLAGS INDICATING WHETHER TO PRINT PRINCIPAL
*  DIRECTION ANGLES.

      DO 320 KK = 1,3
         IFLAG(KK,1) = 0
         IFLAG(KK,2) = 0
 320  CONTINUE

*  CALCULATE PRINCIPAL STRESSES

      DO 330 K=1,3
         C(K,1)=-BB+H*COS(AB+2.094395103*FLOAT(K-1))

*  CHECK FOR DENOMINATOR (IN PRINCIPAL DIRECTION CALCULATION)
*  IS TOO CLOSE TO ZERO.

         DEN1 = (C(K,1)-B(1))*B(5)+B(4)*B(6)
         DEN2 = (C(K,1)-B(2))*B(6)+B(5)*B(4)
         DEN3 = (C(K,1)-B(3))*B(4)+B(6)*B(5)


*  IF ANY (DEN1,DEN2,DEN3) IS TOO SMALL, FLAG OUT ALL SIX ANGLES

1050     IF(.NOT.((ABS(DEN1).LE.1.E-21)
     .     .OR.(ABS(DEN2).LE.1.E-21)
     .     .OR.(ABS(DEN3).LE.1.E-21))) GO TO 340

         IFLAG(1,1) = 1
         IFLAG(1,2) = 1
         IFLAG(2,1) = 1
         IFLAG(2,2) = 1
```

```
          IFLAG(3,1) = 1
          IFLAG(3,2) = 1
          GO TO 330

*  CALCULATE DIRECTION COSINES OF PRINCIPAL DIRECTIONS

 340      AD=1.0/(DEN1)
          BD=1.0/(DEN2)
          CD=1.0/(DEN3)
          DDD=1.0/SQRT(AD**2+BD**2+CD**2)
          CL(K)=AD*DDD
          CM(K)=BD*DDD
          CN(K)=CD*DDD

 330   CONTINUE

*  ORDER PRINCIPAL STRESSES, MAXIMUM TO MINIMUM.

       DO 360 K = 1,2
          IF((C(K+1,1)-C(K,1)) .GT. 0.) THEN
             CAUX = C(K,1)
             C(K,1) = C(K+1,1)
             C(K+1,1) = CAUX

             IF(IFLAG(1,1).EQ.1 .AND. IFLAG(1,2).EQ.1
      .        .AND. IFLAG(2,1).EQ.1 .AND. IFLAG(2,2).EQ.1
      .        .AND. IFLAG(3,1).EQ.1 .AND. IFLAG(3,2).EQ.1) GO TO 350

             CLAUX = CL(K)
             CMAUX = CM(K)
             CNAUX = CN(K)
             CL(K) = CL(K+1)
             CM(K) = CM(K+1)
             CN(K) = CN(K+1)
             CL(K+1) = CLAUX
             CM(K+1) = CMAUX
             CN(K+1) = CNAUX

 350      END IF
 360   CONTINUE

*  IF ALL NO-PRINT FLAGS HAVE BEEN SET, BRANCH TO SECTION OF CODE
*  WHERE PRINCIPAL STRESSES ARE PRINTED.

       IF(IFLAG(1,1).EQ.1 .AND. IFLAG(1,2).EQ.1
      .   .AND. IFLAG(2,1).EQ.1 .AND. IFLAG(2,2).EQ.1
      .   .AND. IFLAG(3,1).EQ.1 .AND. IFLAG(3,2).EQ.1)  GO TO 420

*  CHECK FOR EQUALITY OF PRINCIPAL STRESSES.
*  (NONUNIQUE PRINCIPAL DIRECTIONS)

       S1 = ABS(C(1,1))
```

```
      DO 370 K = 1,2
         IF(ABS(C(K+1,1)).GT.ABS(S1)) THEN
            S1 = ABS(C(K+1,1))
         END IF
 370  CONTINUE

      DO 380 K = 1,2
      DO 380 J = K+1,3

         CX = C(J,1) - C(K,1)
1060     IF(ABS(CX/S1) .LE. 1.E-5) THEN
            IFLAG(K,1) = 1
            IFLAG(K,2) = 1
            IFLAG(J,1) = 1
            IFLAG(J,2) = 1
         END IF
 380  CONTINUE

*  CHECK FOR RIGHT-HANDED PRINCIPAL SYSTEM.

      DET1 = CM(2)*CN(3) - CM(3)*CN(2)
      DET2 = CL(2)*CN(3) - CL(3)*CN(2)
      DET3 = CL(2)*CM(3) - CL(3)*CM(2)
      DET4 = CL(1)*DET1 - CM(1)*DET2 + CN(1)*DET3

*  IF NEEDED, CHANGE DIRECTION OF THE MAXIMUM PRINCIPAL STRESS
*  TO INSURE A RIGHT-HANDED SYSTEM.

      IF(DET4.LT.0.0) THEN
         CL(1) = -CL(1)
         CM(1) = -CM(1)
         CN(1) = -CN(1)
      END IF

*  CHECK FOR ERROR IN ONE PRINCIPAL DIRECTION:
*  CHECK FOR TWO ZERO GLOBAL SHEAR STRESSES AND A ZERO PRINCIPAL
*  STRESS.  FLAG OUT DIRECTIONS FROM OUTPUT UNLESS THEY CAN BE
*  CALCULATED FROM THE OTHER PRINCIPAL STRESSES.

      S4 = ABS(B(4)/S1)
      S5 = ABS(B(5)/S1)
      S6 = ABS(B(6)/S1)

*  BEGIN LOOP.  DETERMINE THE TWO GOOD DIRECTIONS

      DO 390 K = 1,3

1070     IF((S4.LT.1.E-5).AND.(ABS(C(K,1)).LT.5.E-1)
     .      .OR.(S5.LT.1.E-5).AND.(ABS(C(K,1)).LT.5.E-1)
     .      .OR.(S6.LT.1.E-5).AND.(ABS(C(K,1)).LT.5.E-1))
     .      THEN
```

```
*  IF NO "NO PRINT" FLAGS ARE SET, THEN DETERMINE THE INDICES OF THE
*  "GOOD" PRINCIPAL DIRECTIONS.

           IF(IFLAG(1,1).EQ.0.AND.IFLAG(1,2).EQ.0.AND.IFLAG(2,1).EQ.0
     .      .AND.IFLAG(2,2).EQ.0.AND.IFLAG(3,1).EQ.0.AND.IFLAG(3,2).EQ.0)
     .       THEN
             IF(K.EQ.1) THEN
               B1 = 2
               B2 = 3
             ELSE IF(K.EQ.2) THEN
               B1 = 3
               B2 = 1
             ELSE IF(K.EQ.3) THEN
               B1 = 1
               B2 = 2
             END IF

*  CALCULATE PRINCIPAL DIRECTION COSINES FOR ONE DIRECTION
*  BASED ON OTHER DIRECTIONS.

            CL(K) = CM(B1)*CN(B2) - CM(B2)*CN(B1)
            CM(K) = CL(B2)*CN(B1) - CL(B1)*CN(B2)
            CN(K) = CL(B1)*CM(B2) - CL(B2)*CM(B1)

          END IF

        END IF

 390    CONTINUE

*  FLAG OUT AZIMUTH FROM OUTPUT IF INCLINATION IS 90 OR -90.

        DO 400 K = 1,3
1080       IF(ABS(ABS(CN(K))-1.).LE.3.8E-5) IFLAG(K,1) = 1
 400    CONTINUE

*  CALCULATE PRINCIPAL DIRECTION ANGLES

        DO 410 K = 1,3
           DP(K)=57.29577951*ASIN(CN(K))
1090       IF(ABS(CL(K)) .LT. 1.E-15) BR(K) = 90.
1091       IF(ABS(CL(K)) .LT. 1.E-15) GO TO 410
           RR=CM(K)/CL(K)
           BR(K) = 57.29577951*ATAN(RR)
           IF(CL(K).LT.0.0) BR(K)=BR(K)+180.0
 410    CONTINUE

*  PRINT TABLE OF PRINCIPAL STRESSES AND DIRECTIONS

 420    WRITE(4,48)
  48    FORMAT(///26X,'PRINCIPAL STRESSES     AZIMUTH  INCLINATION',
     .   /28X,'(psi)',
```

```
     .  5X,'(MPa)',7X,'(deg)',5X,'(deg)',/26X,18(1H-),5X,
     .  7(1H-),2X,11(1H-))

      DO 430 K=1,3
1100     IF(BR(K).LE.-5.E-2)BR(K)=BR(K)+360.0

         C(K,2) = C(K,1) * 0.006895

         IF(IFLAG(K,1).EQ.1) THEN
            IF(IFLAG(K,2).EQ.1) THEN
               WRITE(4,49) C(K,1),C(K,2)
  49           FORMAT(/20X,F14.2,F9.3,8X,'--',8X,'--')

             ELSE
               WRITE(4,50) C(K,1),C(K,2),DP(K)
  50           FORMAT(/20X,F14.2,F9.3,8X,'--',4X,F8.1)

            END IF
          ELSE
            WRITE(4,51) C(K,1),C(K,2),BR(K),DP(K)
  51        FORMAT(/20X,F14.2,F9.3,F12.1,F10.1)

         END IF
 430  CONTINUE

*  IF NO NO-PRINT FLAGS WERE SET, CHECK FOR ORTHOGONAL DIRECTIONS

      IF(IFLAG(1,1).EQ.0 .AND. IFLAG(1,2).EQ.0 .AND. IFLAG(2,1).EQ.0
     .  .AND. IFLAG(2,2).EQ.0 .AND. IFLAG(3,1).EQ.0 .AND. IFLAG(3,2)
     .  .EQ.0) THEN

*        RECALCULATE DETERMINANT OF DIRECTION COSINES

         DET1 = CM(2)*CN(3) - CM(3)*CN(2)
         DET2 = CL(2)*CN(3) - CL(3)*CN(2)
         DET3 = CL(2)*CM(3) - CL(3)*CM(2)
         DET4 = CL(1)*DET1 - CM(1)*DET2 + CN(1)*DET3

*        IF PRINCIPAL STRESS DIRECTIONS ARE NOT ALL ORTHOGONAL,
*        STATE SO IN THE OUTPUT

1110     IF(ABS(ABS(DET4)-1.) .GE. 1.E-2) WRITE(4,52)
  52     FORMAT(/20X,'THE PRINCIPAL DIRECTIONS ARE NOT ORTHOGONAL.')
      END IF

*  PRINT NOTES ON PRINCIPAL STRESSES AND DIRECTIONS

      WRITE(4,53)
  53  FORMAT(/20X,'NOTE:  (1) AZIMUTH IS THE ANGLE IN DEGREES ',
     .  'POSITIVE CLOCKWISE FROM NORTH.',/27X,'(2) INCLINATION IS ',
     .  'THE ANGLE IN DEGREES POSITIVE DOWN FROM HORIZONTAL.',/27X,
     .  '(3) "--" INDICATES VALUE IS NOT UNIQUE.')
```

```
*  STOP CLAUSE

 440  IF(NDF2.EQ.1)GO TO 999
      IF(IRUN.GT.NDEL)GO TO 999

*  SUBTRACT EFFECT OF LARGEST RESIDUAL FROM MATRIX AND VECTOR

      DO 450 I=1,6
         B(I)=BSP(I)-X(IDMAX,I)*YY(IDMAX,1)
         BSP(I)=B(I)
         BS(I)=B(I)
      DO 450 J=1,6
         A(I,J)=ASP(I,J)-X(IDMAX,I)*X(IDMAX,J)
         ASP(I,J)=A(I,J)
 450  CONTINUE
      GO TO 150

 999  RETURN
      END
```

```
*      Subroutine DETERMinate

*   THIS SUBROUTINE CALCULATES THE DETERMINANT OF AN NSIZE-BY-NSIZE
*   MATRIX, A, AND RETURNS THE VALUE IN VARIABLE DETR.

*   VARIABLES:
*       A(6,6)      MATRIX FOR WHICH DETERMINANT IS CALCULATED
*       N           DIMENSION OF MATRIX (N BY N)
*       DETR        VALUE OF DETERMINANT
*       I(6)        VECTOR OF INDICES


      SUBROUTINE DETERM(A,N,DETR)

      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 A(6,6)
      DIMENSION I(6)


*  GO THROUGH N LOOPS TO DETERMINE PERMUTATIONS.
*  AFTER THE DEPTH OF LOOPS IS N, CALL SUBROUTINE
*  DETSUM TO CALCULATE ANOTHER PRODUCT TO BE ADDED
*  TO THE VARIABLE DETR.  AFTER GOING THROUGH ALL OF
*  THE LOOPS, DETR IS THE DETERMINANT.
```

```
      DETR = 0.

*   BEGIN FIRST LOOP

      DO 100 I1 = 1, N

        I(1) = I1

*   BEGIN SECOND LOOP

        DO 110 I2 = 1, N

          IF(I2 .EQ. I1) GO TO 110

          I(2) = I2

          IF(N .EQ. 2) THEN
            CALL DETSUM(I,N,A,D)
            DETR = DETR + D
          END IF

          IF(N .EQ. 2) GO TO 110

*   BEGIN THIRD LOOP

          DO 120 I3 = 1, N

            IF(I3 .EQ. I1 .OR. I3 .EQ. I2) GO TO 120

            I(3) = I3

            IF(N .EQ. 3) THEN
              CALL DETSUM(I,N,A,D)
              DETR = DETR + D
            END IF

            IF(N .EQ. 3) GO TO 120

*   BEGIN FOURTH LOOP

            DO 130 I4 = 1, N

              IF(I4.EQ.I1 .OR. I4.EQ.I2 .OR.
     .           I4.EQ.I3) GO TO 130

              I(4) = I4

              IF(N .EQ. 4) THEN
                CALL DETSUM(I,N,A,D)
                DETR = DETR + D
              END IF
```

```
               IF(N .EQ. 4) GO TO 130

*  BEGIN FIFTH LOOP

               DO 140 I5 = 1, N

                 IF(I5.EQ.I1 .OR. I5.EQ.I2 .OR. I5.EQ.I3
     .              .OR. I5.EQ.I4) GO TO 140

                 I(5) = I5

                 IF(N .EQ. 5) THEN
                   CALL DETSUM(I,N,A,D)
                   DETR = DETR + D
                 END IF

                 IF(N .EQ. 5) GO TO 140

* BEGIN SIXTH LOOP

                 DO 150 I6 = 1, N

                   IF(I6.EQ.I1 .OR. I6.EQ.I2 .OR. I6.EQ.I3
     .                .OR. I6.EQ.I4 .OR. I6.EQ.I5) GO TO 150

                   I(6) = I6

                   CALL DETSUM(I,N,A,D)
                   DETR = DETR + D

 150             CONTINUE

 140           CONTINUE

 130         CONTINUE

 120       CONTINUE

 110     CONTINUE

 100   CONTINUE

       RETURN
       END
```

```
*  SUBROUTINE DETSUM

*  THIS SUBROUTINE AIDS IN THE CALCULATION OF THE DETERMINANT
*  OF MATRIX A, IT CALCULATES PRODUCTS OF A SERIES OF MATRIX ELEMENTS.
*  IN OTHER WORDS, IT CALCULATES

*        e                 * A     * A     * A     * ... * A
*         j1 j1 j3 ... jn     1 j1    2 j2    3 j3           n jn

*  WHERE
*            A
*             k m

*                    ARE THE ELEMENTS OF MATRIX A, AND

*        e                   =  1  IF j1 j2 j3 ... jn ARE AN ODD PERMUTATION
*         j1 j2 j3 ... jn
*                            = -1  IF j1 j2 j3 ... jn ARE AN ODD PERMUTATION

      SUBROUTINE DETSUM(I,N,A,D)

      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 A(6,6)
      DIMENSION I(6)

*  CALCULATE PRODUCT

      D = 1.

      DO 100 J = 1, N
         D = D*A(J,I(J))
 100  CONTINUE

*  DETERMINE WHETHER PERMUTATION IS ODD OR EVEN

      E = 1.
      KK = 0

      DO 110 J = 1, N-1

        DO 120 K = J+1, N
          IF(I(J) .GT. I(K)) THEN
            E = -E
            KK = KK+1
          END IF
 120    CONTINUE

 110  CONTINUE

*  MULTIPLY PRODUCT BY PERMUTATION VALUE

      D = E * D
```

```
      RETURN
      END




*   SUBROUTINE MATrix INVert

*   THIS SUBROUTINE SOLVES THE MATRIX EQUATION "AX=B".
*   THE (N BY N) COEFFICIENT MATRIX "A" AND THE (N BY 1) VECTOR "B"
*   ARE PASSED TO THIS SUBROUTINE, AND THE (N BY 1) VECTOR "X" IS
*   SOLVED.  THIS IS ACCOMPLISHED BY INVERTING "A" AND OPERATING
*   ON "B" SUCH THAT UPON RETURNING TO THE CALLING PROGRAM UNIT,
*   THE MATRIX "A" IS A UNIT MATRIX, AND THE VECTOR "B" CONTAINS
*   THE SOLUTION TO "X".

*   MAJOR VARIABLE DESCRIPTIONS

*      A(6,6)    Array which enters matinv as the regression matrix
*              "A" and returns as its inverted matrix
*      B(6,1)    Array which enters matinv as the regression matrix
*              "B" and returns as the solution of the set of equations


      SUBROUTINE MATINV(A,N,B,L,D,IRROR)

*   VARIABLE DECLARATIONS

      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION A(6,6),B(6,1),IPIV(6),IND(6,2)

*   INITIALIZE VARIABLES

      M=IABS(L)
      D=1.0

      DO 100 I=1,N
         IPIV(I)=0
 100  CONTINUE

      DO 310 I=1,N
         AMAX=0.0

*   LOCATE LARGEST COEFFICIENT

         DO 150 J=1,N
            IF(IPIV(J))160,110,150
```

```
 110        DO 140 K=1,N
               IF(IPIV(K)-1)120,140,160
 120           IF(ABS(A(J,K))-AMAX)140,140,130
 130           IROW=J
               ICOL=K
               AMAX=ABS(A(J,K))
 140        CONTINUE
 150     CONTINUE
         IPIV(ICOL)=IPIV(ICOL)+1

*  IDENTIFY ILL-CONDITIONING

         IF(AMAX-1.0E-28)160,160,170

 160     IRROR=1

         RETURN

 170     IF(IROW-ICOL)180,220,180
 180     D=-D

*  INTERCHANGE "A" MATRIX ROWS

         DO 190 K=1,N
            AMAX=A(IROW,K)
            A(IROW,K)=A(ICOL,K)
            A(ICOL,K)=AMAX
 190     CONTINUE

         IF(M)220,220,200

*  INTERCHANGE "B" VECTOR ROWS

 200     DO 210 K=1,M
            AMAX=B(IROW,K)
            B(IROW,K)=B(ICOL,K)
            B(ICOL,K)=AMAX
 210     CONTINUE

*  IDENTIFY INTERCHANGE

 220     IND(I,1)=IROW
         IND(I,2)=ICOL
         AMAX=A(ICOL,ICOL)
         D=D*AMAX
         A(ICOL,ICOL)=1.0

*  DIVIDE COEFFICIENTS IN ROW "ICOL" BY DIAGONAL

         DO 230 K=1,N
            A(ICOL,K)=A(ICOL,K)/AMAX
 230     CONTINUE
```

```
      IF(M)260,260,240

*  DIVIDE VECTOR COMPONENT BY "A" MATRIX DIAGONAL IN ROW "ICOL"

 240    DO 250 K=1,M
           B(ICOL,K)=B(ICOL,K)/AMAX
 250    CONTINUE

 260    DO 310 J=1,N
           IF(J-ICOL)270,310,270

 270       AMAX=A(J,ICOL)
           A(J,ICOL)=0.0

*  MANIPULATE "A" MATRIX TO ZERO THE OFF-DIAGONAL COMPONENTS

           DO 280 K=1,N
              A(J,K)=A(J,K)-A(ICOL,K)*AMAX
 280       CONTINUE

           IF(M)310,310,290

*  DO SAME OPERATION TO "B" VECTOR

 290       DO 300 K=1,M
              B(J,K)=B(J,K)-B(ICOL,K)*AMAX
 300       CONTINUE
 310  CONTINUE

      IF(L)320,320,360

*  CONDITION FOR COLUMN INTERCHANGE

 320  DO 350 I=1,N
        J=N+1-I
        IF(IND(J,1)-IND(J,2))330,350,330
 330    IROW=IND(J,1)
        ICOL=IND(J,2)

*  INTERCHANGE COLUMNS

        DO 340 K=1,N
           AMAX=A(K,IROW)
           A(K,IROW)=A(K,ICOL)
           A(K,ICOL)=AMAX
 340    CONTINUE

 350  CONTINUE

 360  IRROR=0

      RETURN
```

```
      END

      REAL*8 FUNCTION ASIN(X)

      IF(ABS(X).LT.1.0)GO TO 200
      IF(X.LT.0.0)GO TO 100
      ASIN=1.570796327
      RETURN

100   ASIN=4.712388980
      RETURN

200   ASIN=ATAN2(X,SQRT(1-X**2))
      RETURN
      END

      REAL*8 FUNCTION ACOS(X)

      IF(ABS(X).LT.1.0)GO TO 200
      IF(X.LT.0.0)GO TO 100
      ACOS=0.0
      RETURN

100   ACOS=3.141592654
      RETURN

200   ACOS=ATAN2(SQRT(1-X**2),X)
      RETURN
      END
```

APPENDIX E.—EQUATION SYMBOLS USED IN THIS REPORT

Note that subscript i ($_i$) designates number. Designations of some symbols differ between text and code because the code cannot accept Greek letters.

[A]	Coefficient matrix of dimension 6 × 6 condensed from [XX] in the least squares fit; [A] is formed by $[A] = [T]^T [XX]^T [XX] [T]$
A1, B1, C1, D1	Stress concentration factors on end of borehole (same as a, b, c, and d in text, but used this way in code to avoid confusion with other variables). In the code, these factors are arrays in which each element corresponds to a different material type
Az_i	Azimuth
a,b,c	Representation of right-handed coordinate system 1,2,3, where order a,b,c represents an even permutation (that is, 1,2,3,-2,3,1,-3,1,2)
a, b, c, d	Stress concentration factors on end of borehole
{B}	Vector of dimension $N \times 1$ condensed from {YY} in least-squares fit; {B} is formed by $\{B\} = [XX]^T \{YY\}$
C1	Variable used in subroutine MODCAL to set up systems of equations to solve for material properties of overcore
$\{C_i\}$	Vector of dimension 6 × 1 of coefficients for measurement *i*
$\{C\}_i^T$	Transposed vector of dimension 1 × 6 of coefficients for measurement *i*
DIAM	Diameter of borehole
E1	Young's modulus of hollow inclusion cell
e_i	Error for *i*th measurement
K1, K2, K3, K4 or K_1, K_2, K_3, K_4	K-factors that relate strain on walls of borehole to strain at locations of strain gauges. In the code, these factors are arrays in which each element corresponds to a different material type
l_i, m_i, n_i	Direction cosines (or components of eigenvector) of *i*th principal direction
M_i	Measurement *i*
P	Radius of strain gauges in hollow inclusion cell
PR	Isotropic Poisson's ratio (used in code)
R1	Inner radius of hollow inclusion cell
R2	Borehole radius or outer diameter of hollow inclusion cell (including glue thickness)
$r\alpha z$	Local polar coordinate system
[T]	Transformation matrix
V1	Poisson's ratio of hollow inclusion cell
[XX]	Coefficient matrix of dimension $N \times 6$, where there are N total measurements, whose *i*th row consists of the $\{C\}_i^T$ for measurement *i*
YM	Isotropic Young's modulus
{YY}	Vector of dimension $N \times 1$ containing N measurements
α	Orientation angle (for hollow inclusion cells, triaxial cells, and strain gauges on wall of bored raise, α = angle between x-axis and line extending from origin to midpoint of strain gauge; for doorstopper gauges and borehole deformation gauges, α = angle between x-axis and centerline of gauge or piston)
β	Tilt of gauge
δ_i	Inclination
ν	Isotropic Poisson's ratio (used in text)
$\left.\begin{matrix}\sigma_1\\ \sigma_2\\ \sigma_3\end{matrix}\right\}$	Principal stress components
$\{\sigma^G\}$	Vector of fitted global stress components

σ_i	Any one of principal stress components
$\{\sigma^L\}$	Vector of stress components in local coordinate system
σ_{NN}, σ_{EE}, σ_{VV}, σ_{NE}, σ_{EV}, σ_{VN}	Stress-state components in global coordinate system
σ_{xx}, σ_{yy}, σ_{zz}, σ_{xy}, σ_{yz}, σ_{zx}	Stress-state components in local coordinate system

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