SSCL-582

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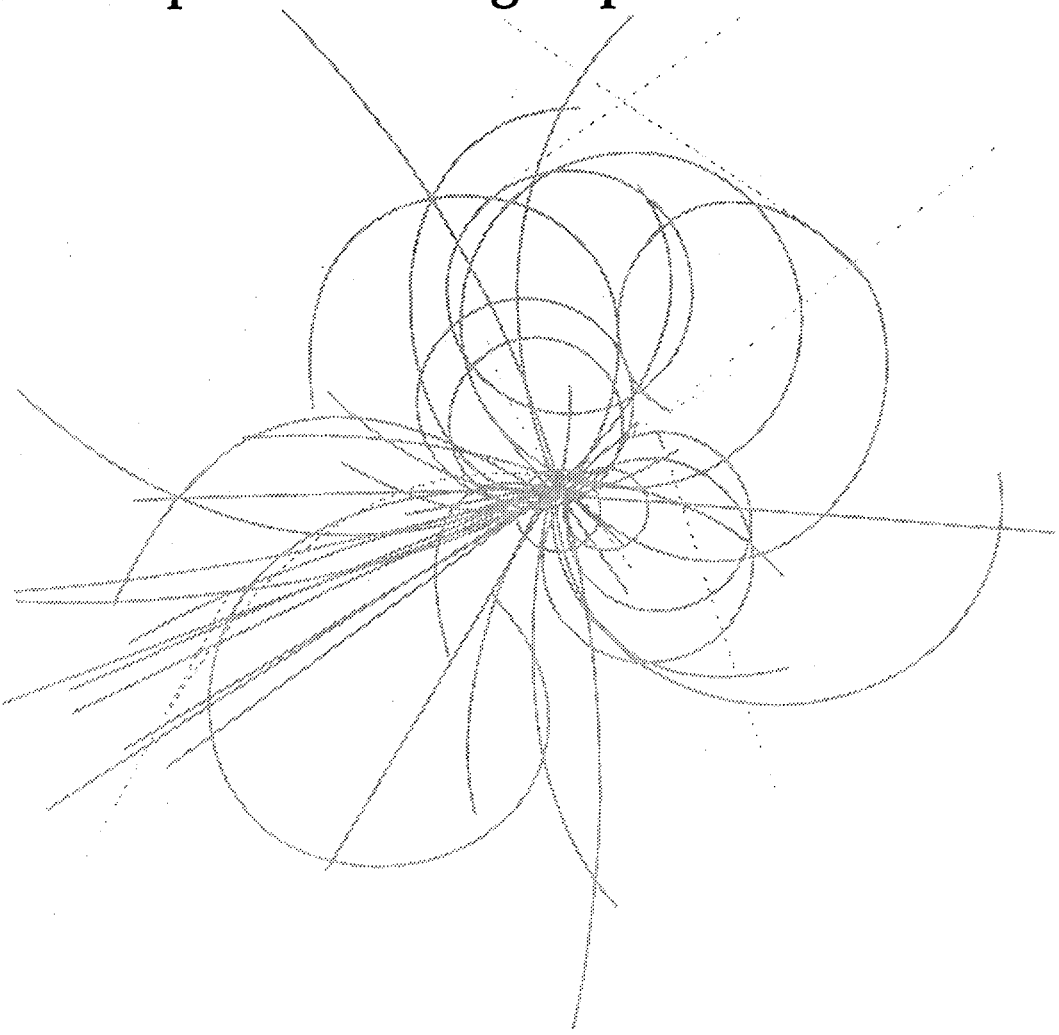
Superconducting Super Collider Laboratory



Kinematic Analysis of Six Strut Support System for Super Collider Components

C. D. Weaver

August 1992

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†Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

1.0 INTRODUCTION

The Superconducting Super Collider Laboratory (SSCL) has been established to design, build, maintain, and operate the Superconducting Super Collider, a high-energy subatomic particle accelerator that will be used in basic research to learn more about the fundamental nature of matter and energy. Now under construction in Ellis County, Texas, it will be housed in a 87-km, racetrack-shaped, underground tunnel, ranging in depth from 12 to 76 m. When operation begins at the turn of the century, the SSC will be capable of colliding protons with enough energy to simulate conditions that are thought to have occurred a fraction of a second after the birth of the universe.[1]

The collider contains two beams made up of billions of protons that will be accelerated to successively higher levels of energy through a series of four smaller accelerators known as boosters. Carefully synchronized bursts of radio frequency waves energize the protons, while thousands of powerful magnets guide and focus their path. For proper operation each of these magnets must be capable of being aligned to tolerances that are on the order of tenths of a millimeter. Consequently, the support structure upon which these magnets will be located must be capable of providing small movements in all six degrees of freedom.

2.0 THE SIX STRUT SYSTEM

The *Minimally Constrained Six Strut System* is being very strongly considered for the task. The Six Strut System was developed at Lawrence Berkeley Laboratory by Mr. Ted Lauritzen of the Mechanical Engineering Department.[2] A schematic drawing of a Six Strut System is shown in Figure 1. All of the struts are adjustable in length by differential threads that allow the strut to be turned a known amount to give a controlled length change. In the configuration shown in Figure 1, a rigid body is supported by three vertical (z) struts that carry the weight of the body. These struts (labeled 1, 2, and 3) control the height, roll, and pitch of the structure. The two horizontal struts (5 and 6) are mounted in the transverse (x) direction. These struts control motion in the "sideways" direction as well as the yaw of the body. Finally, strut 4 in the horizontal (y) direction controls longitudinal motion. All struts are mounted (at both ends) with ball joints that permit free rotational motion of the strut. A major advantage of this system is that for small rotations the degrees of freedom are minimally coupled; furthermore, this coupling is predictable. For example, a *small* change in height is obtained by changing the length of the vertical struts 1, 2, and 3. When these struts are lengthened the horizontal struts 4, 5, and 6 simply rotate about their ends and only require a minimal change in length.

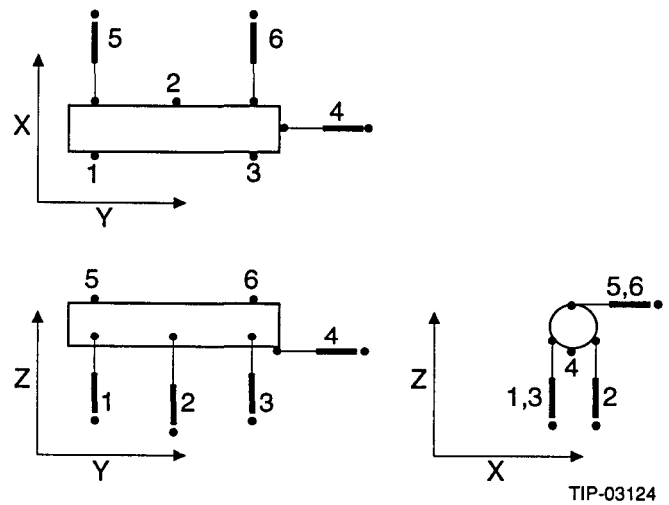

Figure 1. Schematic Representation of a Six Strut System Supporting a Rigid Body.

3.0 ALIGNMENT

In order for the SSC to function, the alignment of the magnets must be in accordance with the calculated specifications of the physicists. Each magnet must be located precisely at a particular point in space with a tolerance on the order of tenths of a millimeter. In addition to a specific location, the angular orientation of the magnet is also specified. The location and orientation of the magnet are determined by alignment fiducials mounted on the magnet structure, as illustrated in Figure 2.

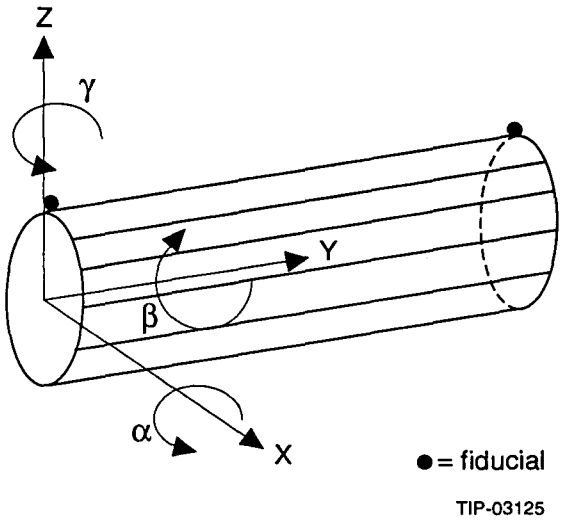

Figure 2. Magnet Coordinate System.

The locations of the fiducials are surveyed when the magnets are first placed in the collider tunnel. The position of the struts (top and bottom) is also surveyed. These survey points are compared with the physicists' requirements, and typically some adjustment motion is required. In this study the adjustment motion is given in terms of a single fiducial translation (x, y, z) and rotations about the magnet coordinate axes. These rotations are denoted as:

α – about the x axis–pitch

β – about the y axis–roll

γ – about the z axis–yaw.

4.0 MATHEMATICAL DESCRIPTION OF THE PROBLEM

The strut system was modeled using vectors. Figure 3 shows this vector description for a particular strut. In this figure an origin is selected and the vectors shown are:

$\mathbf{F}_{1\text{-}6}$ – Origin to fiducial—(called fiducial vector)

$\mathbf{A}_{1\text{-}6}$ – Origin to bottom of strut—(called location vector)

$\mathbf{S}_{1\text{-}6}$ – Bottom to top of strut—(called strut vector)

$\mathbf{B}_{1\text{-}6}$ – Top of strut to fiducial—(called body vector).

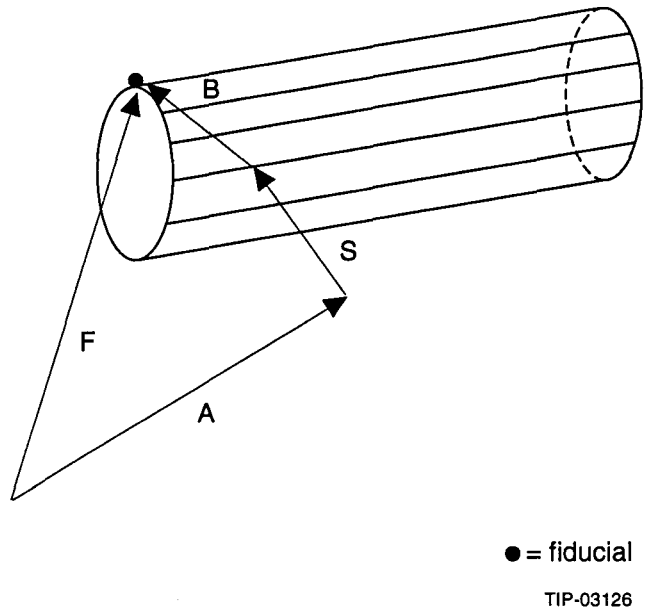

Figure 3. Schematic Representation of the Location, Strut, Body, and Fiducial Vectors.

For any (and all struts 1–6) we have:

$$\mathbf{F}_{1\text{-}6} = \mathbf{B}_{1\text{-}6} + \mathbf{S}_{1\text{-}6} + \mathbf{A}_{1\text{-}6} \tag{1}$$

or in component form:

$$(F_x)_{1\text{-}6} = (B_x)_{1\text{-}6} + (S_x)_{1\text{-}6} + (A_x)_{1\text{-}6}$$
$$(F_y)_{1\text{-}6} = (B_y)_{1\text{-}6} + (S_y)_{1\text{-}6} + (A_y)_{1\text{-}6}$$
$$(F_z)_{1\text{-}6} = (B_z)_{1\text{-}6} + (S_z)_{1\text{-}6} + (A_z)_{1\text{-}6}.$$

$\mathbf{S}_{1\text{-}6}$ is the strut vector and describes the length and angle of the strut. Initially the survey defines the fiducial vector $\mathbf{F}_{1\text{-}6}$, the strut vector $\mathbf{S}_{1\text{-}6}$, and the location vector $\mathbf{A}_{1\text{-}6}$. From this we are able to obtain the body vector:

$$\mathbf{B}_{1\text{-}6} = \mathbf{F}_{1\text{-}6} - \mathbf{S}_{1\text{-}6} - \mathbf{A}_{1\text{-}6}. \tag{2}$$

The length of the body vector $|\mathbf{B}_{1\text{-}6}|$ remains constant. However, as the body (magnet) rotates its angle changes. This is discussed in the next section. After the adjustment is made the vectors $\mathbf{F}_{1\text{-}6}$ and $\mathbf{B}_{1\text{-}6}$ will have new values. $\widehat{\mathbf{F}}_{1\text{-}6}$ is given as the new location of the fiducial. $\widehat{\mathbf{B}}_{1\text{-}6}$ will change due to the rotations of the body. Equation (1) can then be rewritten to determine the new (final) strut vector:

$$\widehat{\mathbf{S}}_{1\text{-}6} = \widehat{\mathbf{F}}_{1\text{-}6} - \widehat{\mathbf{B}}_{1\text{-}6} - \mathbf{A}_{1\text{-}6} \tag{3}$$

or in component form:

$$(\hat{S}_x)_{1\text{-}6} = (\hat{F}_x)_{1\text{-}6} - (\hat{B}_x)_{1\text{-}6} - (\hat{A}_x)_{1\text{-}6}$$
$$(\hat{S}_y)_{1\text{-}6} = (\hat{F}_y)_{1\text{-}6} - (\hat{B}_y)_{1\text{-}6} - (\hat{A}_y)_{1\text{-}6}$$
$$(\hat{S}_z)_{1\text{-}6} = (\hat{F}_z)_{1\text{-}6} - (\hat{B}_z)_{1\text{-}6} - (\hat{A}_z)_{1\text{-}6}.$$

The change in length for each strut is:

$$|\Delta S_{1\text{-}6}| = |\hat{S}_{1\text{-}6}| - |S_{1\text{-}6}|. \tag{4}$$

5.0 ROTATION OF THE BODY VECTOR

The orientation of the magnet is described in terms of three separate rotations about the three axes shown in Figure 2. The rotation of the body vector is done in three steps. Each step gives a new body vector angle. In Figure 4 we show the body vector and its components on the *x, y,* and *z* axes.

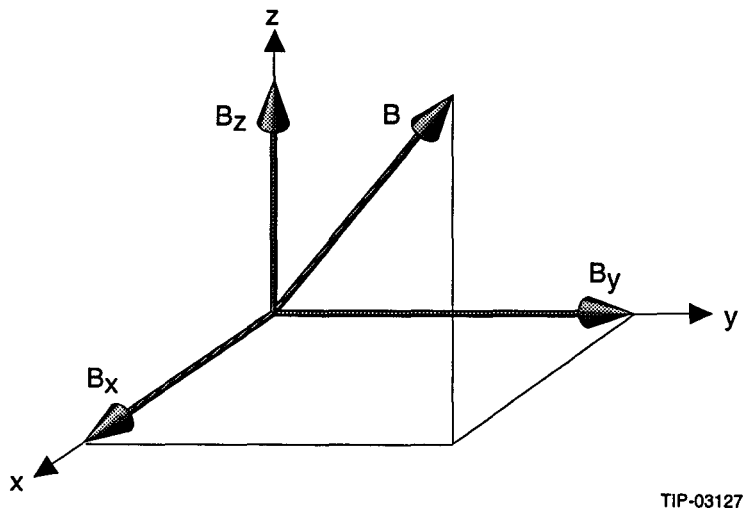

Figure 4. Representation of the Body Vector and Its *x, y* and *z* Components of the Body Vector.

For a rotation about the x axis we consider the projection of B in the y, z plane (see Figure 5). This projection is called B_{yz}.

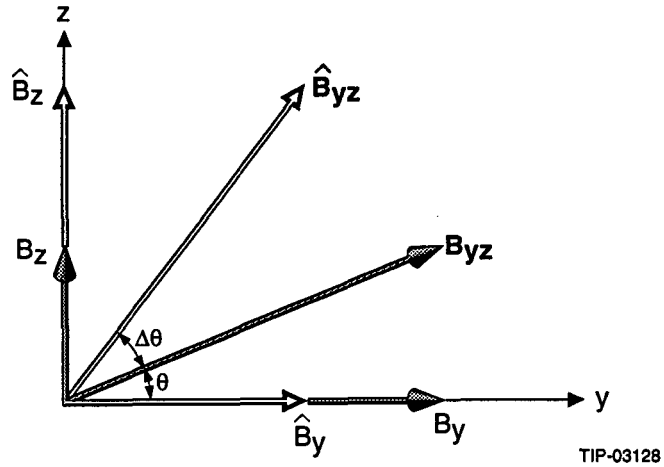

Figure 5. Projection of the Changing Body Vector in the *y, z* Plane.

The original angle of B_{yz}, θ, is given as:

$$\theta = \tan^{-1}\left(B_z/B_y\right).$$

The magnitude is given as:

$$\left|\mathbf{B}_{yz}\right| = \left(B_y^2 + B_z^2\right)^{1/2}.$$

After a rotation about the x axis of $\Delta\theta$ the new body vector in the y, z plane is denoted as $\hat{B}_{yz}$. Its magnitude remains a constant. The new angle θ is $\theta + \Delta\theta$. The new y and z components are:

$$\hat{B}_y = \left|B_{yz}\right|\cos\hat{\theta}$$

$$\hat{B}_z = \left|B_{yz}\right|\sin\hat{\theta}.$$

Therefore the new body vector (due to a change in pitch) is:

$$\hat{\mathbf{B}} = \left(B_x, \hat{B}_y, \hat{B}_z\right).$$

The same type of analysis is used to describe the change in the body vector components due to the rotation about the y and z axes.

6.0 DESCRIPTION OF THE PROGRAM

The computer language FORTRAN was implemented to develop software needed to describe how the lengths of each strut must be changed to obtain a desired adjustment motion.

The program reads a data file that contains information on the initial and final position of a fiducial, the initial position of the top and bottom of the strut, and the pitch, yaw, and tilt adjustments. Then the program calculates the unique combination of strut lengths that constitute the answer.

The program works by defining and using a body vector, a strut vector, a location vector, and a fiducial vector for each of the six struts from information given in the data file. The magnitude of each of the body vectors is defined and remains constant. Only the direction and/or position of each of the body vectors will change. Therefore the program updates the body vectors for each rotation of pitch, yaw, and tilt. The vectors $A_{1\text{-}6}$ remain constant, and the vectors $F_{1\text{-}6}$ are updated once from the information in the data file. Then the program uses these vectors in the equations of the *x, y* and *z* components of the vectors to solve for the *x, y* and *z* components of the strut length of each strut.

Since this program works with vector equations the six struts do not have to be placed in the scheme of the Six Strut System. The struts may be placed in any position on the magnet. This may not give proper support, but the program will still be able to solve for the required strut lengths. The support as stated earlier depends on the arrangement of the six struts. See the Appendix for the program listing.

7.0 SENSITIVITY ANALYSES

Due to the different strut configuration geometry some strut adjustments will have a greater effect on the movement of the fiducial than will others.

The length of the fiducial vector is:

$$F^2 = F_x^2 + F_y^2 + F_z^2. \tag{5}$$

From Eq. (1):

$$F^2 = (S_x + A_x + B_x)^2 + (S_y + A_y + B_y)^2 + (S_z + A_z + B_z)^2. \tag{6}$$

Using differentials on the previous equation:

$$2F\Delta F = 2(S_x + A_x + B_x)\Delta s_x + 2(S_y + A_y + B_y)\Delta s_y + 2(S_z + A_z + B_z)\Delta s_z \tag{7}$$

or

$$\Delta F = \frac{F_x}{F}\,\Delta S_x + \frac{F_y}{F}\,\Delta S_y + \frac{F_z}{F}\,\Delta S_z.$$

This equation is true for all struts. It is an approximation that tells how sensitively the change in fiducial location (ΔF) depends on small changes in the length of any strut (ΔS_x, ΔS_y, and ΔS_z).

REFERENCES

1. *To the Heart of Matter—The Superconducting Super Collider*, (SSC Pamphlet), Universities Research Association, Washington, D.C., June 1992.
2. Lauritzen T., "Six Strut Support and Alignment System," *Proc. Workshop on Vibration Control and Dynamic Alignment Issues at the SSC*, SSCL-SR-1185, Feb. 1992.

APPENDIX

Program Listing

```
C-----------------------------------------------------------------------
C     COLIN WEAVER
C     SUPERCONDUCTING SUPER COLLIDER
C     DEPARTMENT OF APPLIED GEODESY
C     SIX STRUT ADJUSTMENT SYSTEM
C     LAST UPDATE AUGUST 1992
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
C      THIS PROGRAM IS DESIGNED TO MINIMIZE THE ADJUSTMENTS TO THE
C     STRUTS OF THE SIX STRUT ADJUSTMENT SYSTEM TO OBTAIN DESIRED
C     POSITION OF A FIDUCIAL.
C      SURVEY DATA OF THE INITIAL POSITION OF THE STRUT , THE ROTATIONS
C     OF THE MAGNET AND THE INITIAL AND FINAL POSITION OF THE STRUT ARE
C     REQUIRED TO RUN THIS PROGRAM.
C      AT THE BOTTOM OF THE PROGRAM THERE IS AN EXAMPLE OF HOW THE
C     DATA FILE MUST BE ORGANIZED.
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
C                       VARIABLES OF THE MAIN
C-----------------------------------------------------------------------
C     SBIX = X COMPONENT OF THE POSITION OF THE STRUT BOTTOM INITIALLY
C     SBIY = Y COMPONENT OF THE POSITION OF THE STRUT BOTTOM INITIALLY
C     SBIZ = Z COMPONENT OF THE POSITION OF THE STRUT BOTTOM INITIALLY
C
C     AIX =  X COMPONENT OF THE VECTOR FROM THE MONUMENT TO THE BOTTOM
C            OF THE STRUT.
C     AIY =  Y COMPONENT OF THE VECTOR FROM THE MONUMENT TO THE BOTTOM
C            OF THE STRUT.
C     AIZ =  Z COMPONENT OF THE VECTOR FROM THE MONUMENT TO THE BOTTOM
C            OF THE STRUT.
C
C     SIX =  X COMPONENT OF THE STRUT VECTOR INITIALLY
C     SIY =  Y COMPONENT OF THE STRUT VECTOR INITIALLY
C     SIZ =  Z COMPONENT OF THE STRUT VECTOR INITIALLY
C
C     BIX =  X COMPONENT OF THE BODY VECTOR INITIALLY
C     BIY =  Y COMPONENT OF THE BODY VECTOR INITIALLY
C     BIZ =  Z COMPONENT OF THE BODY VECTOR INITIALLY
C
C     STIX = X COMPONENT OF THE POSITION OF THE STRUT TOP INITIALLY
C     STIY = Y COMPONENT OF THE POSITION OF THE STRUT TOP INITIALLY
C     STIZ = Z COMPONENT OF THE POSITION OF THE STRUT TOP INITIALLY
C
C     SFX =  X COMPONENT OF THE STRUT VECTOR FINALLY
C     SFY =  Y COMPONENT OF THE STRUT VECTOR FINALLY
C     SFZ =  Z COMPONENT OF THE STRUT VECTOR FINALLY
C
C     DMAG = THE MAGNITUDE OF THE BODY VECTOR
C
C     FNAME = NAME OF THE FILE THAT CONTAINS THE SURVEY INFORMATION
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
C                    DECLARATION OF THE MAIN
C-----------------------------------------------------------------------
```

```
      DIMENSION SBIX(10),SBIY(10),SBIZ(10)
     +          ,AIX(10),AIY(10),AIZ(10),SIX(10),SIY(10),SIZ(10),BIX(10)
     +          ,BIY(10),BIZ(10),STIX(10),STIY(10),STIZ(10),DMAG(10)
     +          ,SFX(10),SFY(10),SFZ(10)
      CHARACTER*12 FNAME

C-----------------------------------------------------------------------
C                     OPEN AND READ THE DATA FILE
C-----------------------------------------------------------------------
      write(*,100)
  100 format(' ENTER INPUT FILE NAME')


      READ(*,101) FNAME
  101 FORMAT(A12)

C*****OPENS THE DATA FILE
      OPEN(2,FILE=FNAME,STATUS='OLD')

C*****OPENS THE OUTFILE
      OPEN(3,FILE='outfile',STATUS='unknown')


C*****READS THE INITIAL POSITION OF THE FIDUCIAL
      READ(2,102) FIX,FIY,FIZ,FFX,FFY,FFZ
  102 FORMAT(6F10.5)

C-----------------------------------------------------------------------
C          DO LOOP TO CALL SUBROUTINE CDATA, FVECTOR, MAGNITUDE
C-----------------------------------------------------------------------

      DO 1 I=1,6


      CALL CDATA(SBIX(I),SBIY(I),SBIZ(I),STIX(I),STIY(I),STIZ(I))
      CALL FVECTOR(AIX(I),AIY(I),AIZ(I),SIX(I),SIY(I),SIZ(I)
     +             ,SBIX(I),SBIY(I),SBIZ(I),STIX(I),STIY(I),STIZ(I)
     +             ,BIX(I),BIY(I),BIZ(I),FIX,FIY,FIZ)

C      CALL MAGNITUDE(BIX(I),BIY(I),BIZ(I),DMAG(I))

    1 continue

C*****CLOSES DATA FILE
      CLOSE(2)

C-----------------------------------------------------------------------
C           LOOP 10 TO CALL ON ROCK, ROLL, AND TWIST SUBROUTINES
C-----------------------------------------------------------------------

   10 continue
      write(*,103)
  103 format('  1 - ROLL'/
     +       '  2 - ROCK'/
     +       '  3 - TWIST'/
     +       '  4 - CONTINUE')

      READ(*,104) KWHAT
  104 FORMAT(I3)
```

```
C*****IF STATEMENT TO CALL ROLL SUBROUTINE
      IF (KWHAT.EQ.1) THEN
         CALL ROL(BIX,BIZ)
      ENDIF

C*****IF STATEMENT TO CALL ROCK SUBROUTINE
      IF (KWHAT.EQ.2) THEN
         CALL ROC(BIY,BIZ)
      ENDIF


C*****IF STATEMENT TO CALL TWIST SUBROUTINE
      IF (KWHAT.EQ.3) THEN
         CALL TWIS(BIX,BIY)
      ENDIF

C*****IF STATEMENT TO CONTINUE PROGRAM
      IF (KWHAT.EQ.4) GO TO 99

      GO TO 10

   99 CONTINUE
C*****END OF LOOP 10


C-----------------------------------------------------------------------
C            DO LOOP TO SOLVE EQUATIONS AND PRINT THE ANSWERS
C-----------------------------------------------------------------------
         DO 3 I=1,6

C*****SOLUTION FOR STRUT LENGTH (X,Y,Z) FINAL
      SFX(I)=FFX-BIX(I)-AIX(I)
      SFY(I)=FFY-BIY(I)-AIY(I)
      SFZ(I)=FFZ-BIZ(I)-AIZ(I)

C*****SOLUTION FOR MAGNITUDE OF STRUT INITIALLY
      SMAGI=(SIX(I)*SIX(I)+SIY(I)*SIY(I)+SIZ(I)*SIZ(I))**.5

C*****SOLUTION FOR MAGNITUDE OF STRUT FINAL
      SMAGF=(SFX(I)*SFX(I)+SFY(I)*SFY(I)+SFZ(I)*SFZ(I))**.5

C*****SOLUTION FOR CHANGE IN STRUT LENGTH
      DELTA=SMAGF-SMAGI
      WRITE(*,200) I,DELTA
      WRITE(3,200) I,DELTA

  200 FORMAT('  STRUT  ',I1,'  MUST CHANGE BY  ' ,F10.5)
    3     CONTINUE

      WRITE(*,202)
      WRITE(3,202)
  202 FORMAT(//)

C-----------------------------------------------------------------------
C             DO LOOP FOR PRINTING ANSWER TO SCREEN
C-----------------------------------------------------------------------
```

```
      DO 4 I=1,6
      WRITE(*,201) I, SFX(I), SFY(I), SFZ(I)
      WRITE(3,201) I, SFX(I), SFY(I), SFZ(I)

  201 FORMAT('  STRUT ',I1,'  X = ',F10.5,'  Y = ',F10.5,
     +       '  Z = ',F10.5)

    4 CONTINUE
C*****CLOSE DO LOOP

C*****CLOSE OUTFILE
      CLOSE(3)

      END

C*********************************************************************
      SUBROUTINE CDATA(SBIX,SBIY,SBIZ,STIX,STIY,STIZ)

C*****READS POSITION OF THE STRUT
      READ(2,102) SBIX,SBIY,SBIZ,STIX,STIY,STIZ

  102 FORMAT( 6F10.5)

      RETURN
      END

C*********************************************************************
      SUBROUTINE FVECTOR(AIX,AIY,AIZ,SIX,SIY,SIZ,SBIX,SBIY,SBIZ,STIX,
     +                   STIY,STIZ,BIX,BIY,BIZ,FIX,FIY,FIZ)

C*****CHANGES SURVEY POSITIONS OF THE BOTTOM OF THE STRUT TO THE MONUMENT
C*****VECTOR
      AIX=SBIX
      AIY=SBIY
      AIZ=SBIZ

C*****CHANGES SURVEY POSITIONS OF THE TOP AND BOTTOM OF THE STRUT TO A
C*****VECTOR
      SIX=STIX-SBIX
      SIY=STIY-SBIY
      SIZ=STIZ-SBIZ

C*****FINDS THE BODY VECTOR FROM THE FIDUCIAL, STRUT, AND MONUMENT
C*****VECTORS
      BIX=FIX-SIX-AIX
      BIY=FIY-SIY-AIY
      BIZ=FIZ-SIZ-AIZ

      END

C*********************************************************************
      SUBROUTINE ROL(BIX,BIZ)

C*****PULLS THE ARRAYS BIX(1-10), BIZ(1-10) DOWN FROM THE MAIN
      DIMENSION BIX(1),BIZ(1)
      REAL GAMMA

      WRITE(*,*)'ENTER ROLL IN DEGREES.'
      READ(*,*) DEGREES
```

```
C*****CHANGES FROM DEGREES TO RADIANS
      ROLL=DEGREES*3.141592654/180.

C-----------------------------------------------------------------------
C     DO LOOP FOR FINDING THE MAGNITUDE, ANGLE, AND COMPONENTS OF THE
C     BODY VECTOR
C-----------------------------------------------------------------------
      DO 1 I=1,6
      DMAG=(BIX(I)*BIX(I)+BIZ(I)*BIZ(I))**.5
      THETA=ATAN2(BIZ(I),BIX(I))

C*****FINDS THE ANGLE OF THE BODY VECTOR IN RELATION WITH THE GLOBAL
C*****COORDINATE SYSTEM
      GAMMA=THETA+ROLL

C*****FINDS THE COMPONENTS OF THE BODY VECTOR IN RELATION WITH THE
C*****GLOBAL COORDINATE SYSTEM
      BIX(I)=DMAG*COS(GAMMA)
      BIZ(I)=DMAG*SIN(GAMMA)

C     WRITE(*,100) I
C100  FORMAT(' ',I2,1X,60('-'))
C      WRITE(*,*)'ROLL THETA GAMMA ',ROLL,THETA,GAMMA
C      WRITE(*,*)'BFX BFZ',BIX(I),BIZ(I)

    1 CONTINUE
      END

C***********************************************************************
      SUBROUTINE ROC(BIY,BIZ)

C*****PULLS THE ARRAYS BIY(1-10), BIZ(1-10) DOWN FROM THE MAIN
      DIMENSION BIY(1),BIZ(1)
      REAL GAMMA

      WRITE(*,*)'ENTER ROCK IN DEGREES.'
      READ(*,*) DEGREES

C*****CHANGES FROM DEGREES TO RADIANS
      ROCK=DEGREES*3.141592654/180.

C-----------------------------------------------------------------------
C     DO LOOP FOR FINDING THE MAGNITUDE, ANGLE, AND COMPONENTS OF THE
C     BODY VECTOR
C-----------------------------------------------------------------------
      DO 1 I=1,6
      DMAG=(BIZ(I)*BIZ(I)+BIY(I)*BIY(I))**.5
      PHI=ATAN2(BIZ(I),BIY(I))

C*****FINDS THE ANGLE OF THE BODY VECTOR IN RELATION WITH THE GLOBAL
C*****COORDINATE SYSTEM
      GAMMA=PHI+ROCK


C*****FINDS THE COMPONENTS OF THE BODY VECTOR IN RELATION WITH THE
C*****GLOBAL COORDINATE SYSTEM
      BIY(I)=DMAG*COS(GAMMA)
      BIZ(I)=DMAG*SIN(GAMMA)

C     WRITE(*,100) I
```

```
C100  FORMAT(' ',I2,1X,60('-'))
C     WRITE(*,*)'ROCK THETA GAMMA ',ROCK,THETA,GAMMA
C     WRITE(*,*)'BFY BFZ',BIY(I),BIZ(I)
C     WRITE(*,*)
    1 CONTINUE
      END

C*********************************************************************
      SUBROUTINE TWIS(BIX,BIY)
      DIMENSION BIX(1),BIY(1)
      REAL GAMMA

      WRITE(*,*)'ENTER TWIST IN DEGREES.
      READ(*,*) DEGREES

C*****CHANGES FROM DEGREES TO RADIANS
      TWIST=DEGREES*3.141592654/180.

C---------------------------------------------------------------------
C     DO LOOP FOR FINDING THE MAGNITUDE, ANGLE, AND COMPONENTS OF THE
C     BODY VECTOR
C---------------------------------------------------------------------
      DO 1 I=1,6
      DMAG=(BIX(I)*BIX(I)+BIY(I)*BIY(I))**.5
      BETA=ATAN2(BIY(I),BIX(I))

C*****FINDS THE ANGLE OF THE BODY VECTOR IN RELATION WITH THE GLOBAL
C*****COORDINATE SYSTEM
      GAMMA=BETA+TWIST

C*****FINDS THE COMPONENTS OF THE BODY VECTOR IN RELATION WITH THE
C*****GLOBAL COORDINATE SYSTEM
      BIX(I)=DMAG*COS(GAMMA)
      BIY(I)=DMAG*SIN(GAMMA)

C     WRITE(*,100) I
C100  FORMAT(' ',I2,1X,60('-'))
C     WRITE(*,*)'TWIST BETA GAMMA ',TWIST,BETA,GAMMA
C     WRITE(*,*)'BFX BFY',BIX(I),BIY(I)
C     WRITE(*,*)
    1 CONTINUE
      END

C---------------------------------------------------------------------
C                    DATA FILE EXAMPLE WITH VARIABLES
C---------------------------------------------------------------------
C*****DATA MUST START IN COLUMNS 2, 11, 21, 31, ECT..
C*****ALL NUMBERS MUST HAVE THE CORRECT DECIMAL PLACES
C*****DATA FILE MUST BE FILED WITH NOTABS.
C*****EXAMPLE "FILE FNAME NOTABS"
CTOP OF FILE
CFIX      FIY       FIZ       FFX       FFY       FFZ
CSBIX(1)  SBIY(1)   SBIZ(1)   STIX(1)   STIY(1)   STIZ(1)
CSBIX(2)  SBIY(2)   SBIZ(2)   STIX(2)   STIY(2)   STIZ(2)
CSBIX(3)  SBIY(3)   SBIZ(3)   STIX(3)   STIY(3)   STIZ(3)
CSBIX(4)  SBIY(4)   SBIZ(4)   STIX(4)   STIY(4)   STIZ(4)
CSBIX(5)  SBIY(5)   SBIZ(5)   STIX(5)   STIY(5)   STIZ(5)
CSBIX(5)  SBIY(6)   SBIZ(6)   STIX(6)   STIY(6)   STIZ(6)
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