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THE COLLEGE OF EARTH AND MINERAL SCIENCES

DEPARTMENT OF MINERAL ENGINEERING

FINAL REPORT

"A MASTER ENVIRONMENTAL CONTROL AND MINE SYSTEM DESIGN SIMULATOR FOR UNDERGROUND COAL MINING"

USBM Grant No. G0111808

VOLUME IV

ROOF SUPPORT

June 30, 1974

Department of the Interior
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THE PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PENNSYLVANIA

THE PENNSYLVANIA STATE UNIVERSITY

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16. Abstract

This report is volume 4 of an eleven-volume final report for a Grant completed by The Pennsylvania State University for the Bureau of Mines to develop a dynamic general purpose computer simulation model for underground coal mining. The simulator developed under the Grant has a wide range of possible applications in the design and evaluation of underground coal mining systems from the standpoints of health and safety, productivity, and mine environment. The Master Design Simulator consists of nine free-standing function-oriented subsystem models linked together into an integrated, comprehensive model of an entire mining system. The subsystems comprising the Master Design Simulator include geology and reserves, methane generation, roof support, subsidence, production, rail haulage, cost, water generation, and ventilation.

This volume of the final report describes the Roof Support subsystem of the Master Design Simulator. This model is based on popular roof support practices for different geological environments with related restrictions imposed by the Coal Mine Health and Safety Act of 1969. From geological sections, the model determines the anchor horizon for roof bolts and the density of roof support necessary. The roof support subsystem is tied to both the geology and reserves subsystem and the production subsystem of the Master Design Simulator, but can also operate as a free standing model. Several case studies are presented showing the application of the model. A detailed user's manual, including a program listing, is presented in the appendices.

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FOREWARD

This report was prepared by The Pennsylvania State University under USBM Contract No. G0111808. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of DMSE, with Mr. G. G. Schottler acting as the technical project officer. Mr. J. A. Herickes was the contract administrator for the Bureau of Mines.

The Roof Support Sub-system (GRSUP) represents one part of the total system entitled "A Master Environmental Control and Mine System Design Simulator for Underground Coal Mining". The development of GRSUP as outlined in the report is based on popular roof support practices for different geological environments with related restrictions as these are imposed by the 1969 Coal Mine Health and Safety Act. The sub-system determines the anchor horizon for bolts and the density of roof supports at the point of mining.

GRSUP is tied to both the Geology and Reserve, and the Production Sub-system as a part of MDS but can operate as a free standing routine. As a part of MDS, GRSUP requests data utilization through Geology and Reserves. The values for the first 10-15 feet of roof along with the joint trace density for that location serve as input to the sub-system. Output from the sub-system is placed in the roof support data banks for application by the Production Sub-system. Data selection for the proper location in the above ordering is determined by the last coordinate in the machine trampath as this is provided by the Production model.

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INTRODUCTION

Roof support in underground coal mine operations is without a doubt the most important single concern for mine management. The roof, ribs, and bottom provide the immediate geological environment for all work activities. Underground mining is always under the influence of a complex force-field which is rarely gravitational alone. Tectonic and genetic processes store a considerable amount of residual stresses in the strata. The country rock is seldom homogeneous and isotropic and rarely obeys any uniform laws of mechanics. In addition, the mine openings hardly have regular shapes and are generally associated with irregularly oriented planes of weakness.

In practice, however, some mine roofs are self-supporting while many others are maintained in good condition with the help of artificial supports. Standard support practices have been, more or less, applied for individual or neighboring mines working identical horizons. In spite of the many uncertain and indefinite elements involved, standard timbering and bolting plans have been established for the various roof conditions. Although several theories derived from the principles of rock mechanics are listed to explain the physical phenomena related to roof behavior, no mathematical method has been developed that will predict timbering and bolting requirements for underground operations.

MATHEMATICAL METHODS

Maintenance of the roof at considerable depth with or without artificial support suggests a redistribution of load near a cavity and this has generally led to the adoption of traditional arch or dome theories. Description of these theories may be found in any elementary book on mining. The detached or relaxed zone of strata constituting the roof above a mining void is potentially the most disturbed place. The behavior of strata in this area can be explained either as a beam or as a Vussoir Arch (Adler and Sun, 1968).

The movement of roof strata, which begins with the immediate roof, justifies the application of beam theory idealization of various types of beams depending on the confinement of the end support (fixed, simple, etc.) and the geometry of the beam (beam, plate, etc.). However, opponents to this approach point out that the roof level strata according to this theory is subjected to tensile stresses which according to visual observations, can hardly be sustained due to the presence of cracks. They suggest an alternative theory, i.e., a Vussoir Arch which assumes compressive stress at the roof level. This is primarily achieved by rotation and sliding of the blocks. There is another mechanism of roof failure, namely, shearing and failure of roof due to either a strong pillar or soft roof. The failure in the latter case generally takes place along one of the rib sides.

A review of available literature indicates some advances made in various numerical approaches to the problem of underground structures. These can be considered in four categories: (a) "no tension" analysis; (b) joint perturbation analysis; (c) elasto-plastic analysis; and (d) time dependent analysis. When numerous cracks and fissures are present in a rock mass, it has been assumed that the rock is incapable of withstanding tensile stresses. Zienkiewicz, et al. (1968) presented a method known as "no tension" or "stress transfer" analysis for modelling non-linear behavior of rock. Joint perturbation analysis was used for modelling the behavior of joints, bedding planes, and other geologic discontinuities (Goodman, et al., 1968). An "elasto-plastic" analysis has been suggested to explain the behavior of rock at high stress concentrations (Dahl, 1969). Time-dependent analysis has not been favored since most rocks do not exhibit significant time-dependent behavior (Chang, et al., 1972). Though some advances have been made in recent years in the application of numerical methods, very little is known about their performance capability in real life situations.

Field and model studies have been carried out to determine the support requirements vis-a-vis the roof behavior. In oil shale, it was found that a factor of safety of 8 should be adopted for design purposes (Merrill, 1954), but no quantitative relationship was established between the factor of safety and the strata characteristics. In model studies, by comparison, roof support reinforcement (i.e., increase in the factor of safety) could be determined for different roof bolt patterns, but the absolute factor of safety has to be chosen. The basis for making this choice, however, is largely unknown. The problem is more acute in the case of intersections (Stahl, 1962).

A COMPUTER MODEL

The approach described below was adopted as no reliable mathematical relationship is yet available between the geological environment and the roof support. While quite a large amount of data has been collected about the physical properties of rock material, relatively little is known about the strength of the rock mass. Moreover, it is not only the strength of the rock mass that determines the stability of a rock structure, but a host of other factors including geological irregularities and the shape of opening. The development of a roof support sub-system (GRSUP) as outlined here, therefore, is based on popular roof support practices for different geological environments with related restrictions as these are imposed by the legal requirements found in the Coal Mine Health and Safety Act, 1969.

The central requirement in connection with this model is the geological section related to the immediate roof strata (about 10 ft.). For the purposes of this model, the variation in rock types has been limited to the following strata commonly associated with coal bearing deposits - coal, draw-slate, soft shale, hard shale, sandstone, hard sandstone, and limestone. This list is, however, not exclusive and can easily be extended to cover other rock formations.

From the geological section, the model determines the anchor horizon for the rock bolt and the density of roof supports. The closest competent bed determines the anchor horizon, and consequently, the length of bolt required. Decision criteria for determining a competent bed includes the type (sandstone, shale, etc.), thickness, and the location of the stratum. In case the immediate bed is the competent bed, the roof is considered as 'approved'. The search for the competent bed depends on the height of the roadway and the length of bolt that can be installed. Where a competent bed is absent, provisions are made for additional conventional support.

The characteristics of the immediate roof determine the breaking pattern and hence the support density. Geological irregularities in the roof have serious effects on the roof supports. Joints have probably more deleterious influence than any other type of disturbances. The effect of joints have been taken care of in this model on the basis of a quantitative criterion recently suggested (Komar, et al. 1973). Accordingly, a 'suspect' area may be predicted when the joint trace density is greater than or equal to 6. Since further information on the degree of roof deterioration versus the joint trace density is not available, it would appear rational though conservative that instead of any arbitrary sliding scale of support requirements, the maximum should be prescribed when the density is greater than or equal to 6. In this connection, it may be emphasized that the above relationship was based on the joint trace density which can be picked up inexpensively from aerial photographs. It is also claimed that the surface joint traces correspond to the subsurface joint systems (Komar, et al. 1973). This rationale has been incorporated in GRSUP.

Other considerations which have been taken into account in building the model are as follows:

(1) Life and Utility of the Roadway - the roadways are divided into three categories depending on their life span - Permanent Roadway, Butt and Room. For the same geological environment, a Permanent Roadway is provided with better support than a Butt or a Room. Similarly, a haulroad has stronger support than a non-haulroad.

(2) Roof bolting has been adopted as the main support system considering its ubiquitous application in modern day mining. Bolt diameters are established at 5/8" since these are most commonly used in practice. Maximum spacing is established at five feet with the minimum at four feet as has been observed in the field. Spacing of the bolts and provision of straps are influenced by the presence of disintegrable immediate strata.

(3) Conventional supports are provided in case of additional support requirements. Dimensions of posts and bars are determined by the geometry of the mine roadway.

(4) A mathematical model of a rotary drill has been selected and programmed as a part of GRSUP to supply the required drilling rates (Tandanand, 1973). The model which is described by the following equation calculates the drilling rate in FPM as a function of the rock specific energy, diameter of the bit and the power applied. Here,

$$R = \text{Power}/SA_s = \text{Power}/S\pi D^2$$

where,

R = rate in FPM

Power = energy required for drilling in in.lb./cu.in.

A_s = area of the borehole in sq. inches

S = specific energy of the rock unit in in.lb./cu.in.

D = diameter of the drill bit in inches

For the above application the bit diameter and power values are established at 1 1/2 inches and 1.2 to 1.5 KW, respectively (Jeng, 1974). The specific energies are obtained from the published literature on data averages or by the user from drilling tests at the mine site (Teale, 1965).

Drilling rates for the different types of rock strata are obtained from the model and are listed in Table 1. Along with these extensions, the power calculations and drilling rates for blastholes in conventional faces have been included as a part of modelling.

Table 1

Rock Type		Drilling Rate Ft./Min.
Draw Slate	(DRSL)	5.74
Soft Shale	(SSHL)	4.74
Hard Shale	(HSHL)	3.32
Soft Sandstone	(SST)	2.30
Hard Sandstone	(HSST)	1.36
Limestone	(LMST)	1.10
Coal	(COAL)	10.30

The foregoing description outlines the approach on which the flow model in Appendix A and the computer program in Appendix B are based. Appendix C lists the input variables together with the necessary documentation required in applying the program.

CASE STUDIES

The model was checked against fifteen case studies. Six Pennsylvania mines were selected from different working horizons and nine other case studies in other states were included to obtain model comparisons on a national scale. The location of the mines, the actual roof support practice and model output is given in Part I, Appendix D. The respective geological sections with data listings are provided for in Parts II and III, respectively.

It may be seen that out of the fifteen cases tested, the output from GRSUP is nearly identical to that of actual roof support practices in seven of these; in four of the cases, model output is slightly conservative, i.e., more safe, while in two of these, the model provides lesser support, though the difference is marginal. In the remaining two cases, no valid comparison could be made because of incomplete information.

For case numbers 5 and 15, where model output provides less support than actually applied, it may be seen that for 15, the difference is slight, whereas for case 5, the bolt spacing is the same but the length is different. It may be noted, however, that no information is available which would indicate that a three foot bolt is inadequate. Hence, there is sufficient reason to believe that the roof support model is capable of predicting support requirements with a high degree of reliability.

MASTER DESIGN SIMULATOR

Although GRSUP is an independently standing model and may be applied as such, it is currently being linked to the Master Design Simulator to provide operating data for the roof support activity. This connection will be made through the mining section coordinates and cut cycle from the External Programming Language Interpreter to the Geology and Reserves Sub-System. Two sets of information will flow back from GRSUP to the Master Design Simulator: (1) the time required to set the support which influences productivity in the Production Sub-System and the exposure time for roof support personnel; and (2) the support material requirements that are applied to the Cost Control Sub-System. Figure 1 shows the information flow between the Roof Support and other sub-systems and the Master Design Simulator.

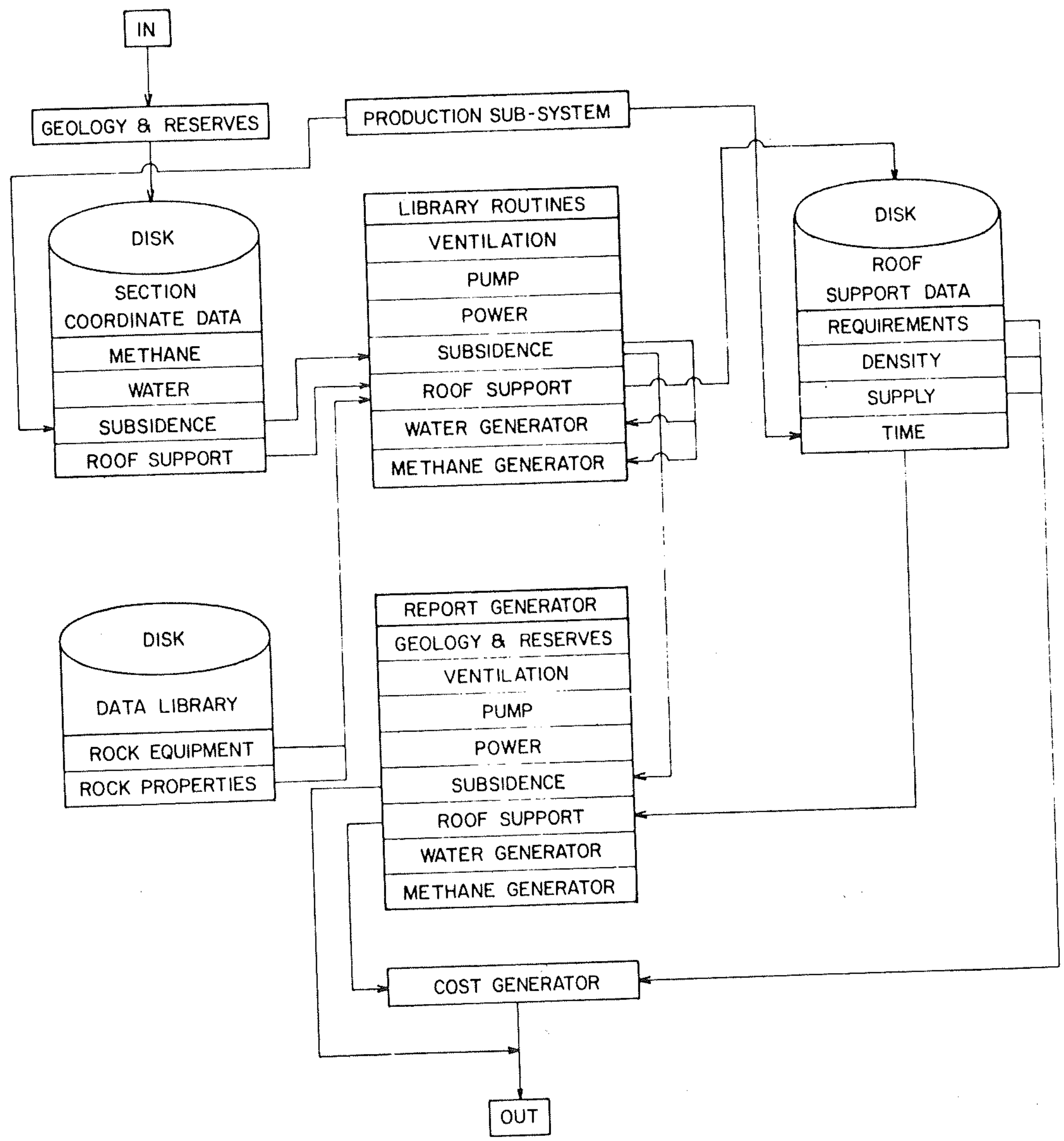

Figure 1. Information Flow Between Roof Support and Other Systems.

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APPENDIX A

FLOW MODEL OF ROOF SUPPORT PROGRAM

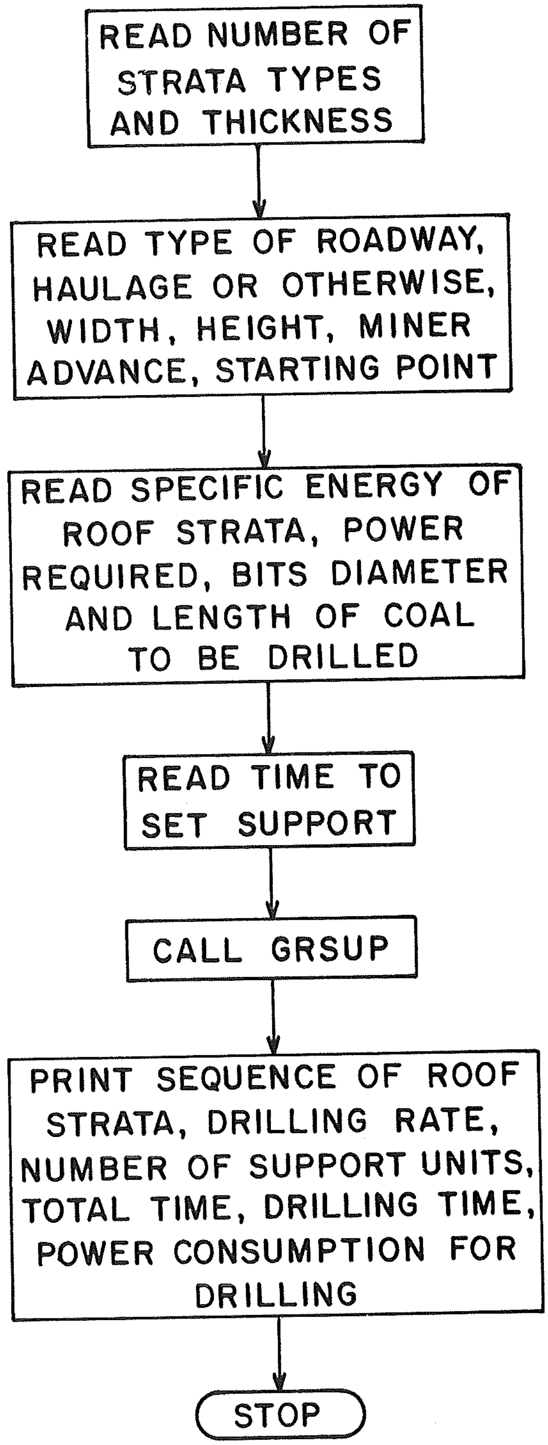


Figure 2. Flow Model for Roof Support Subroutine (page 1 of 5).

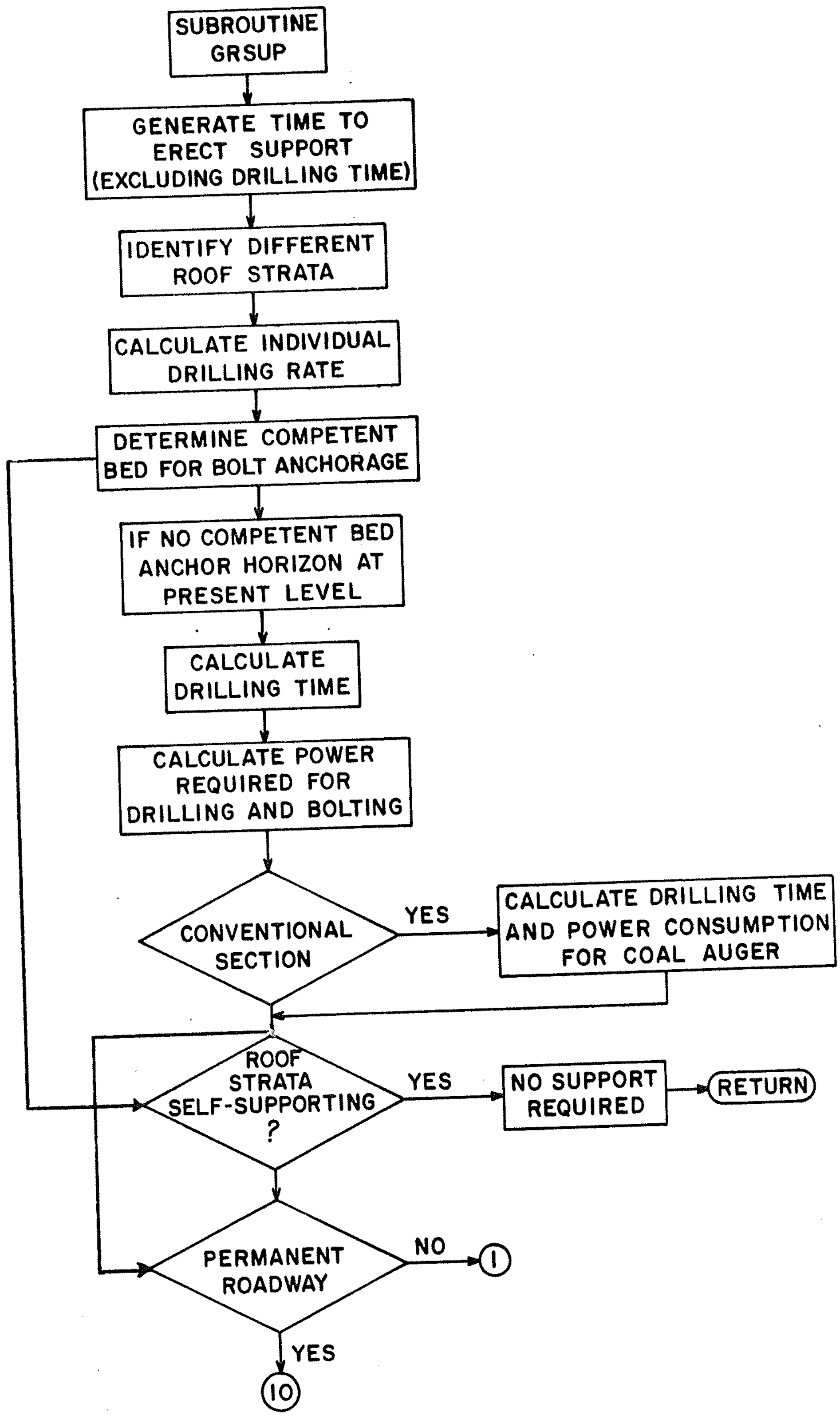


Figure 2. Flow Model for Roof Support Subroutine (page 2 of 5).

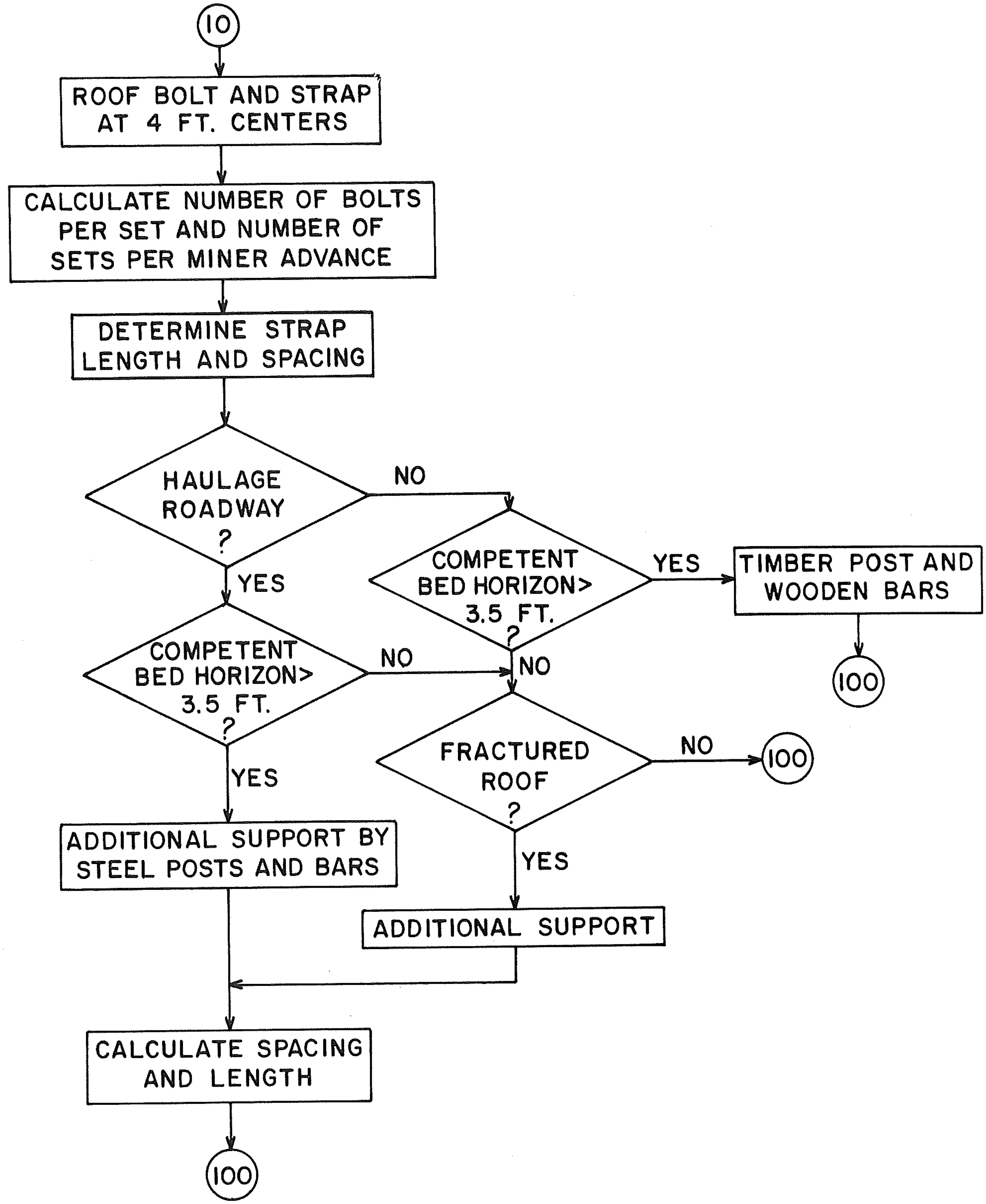


Figure 2. Flow Model for Roof Support Subroutine (page 3 of 5).

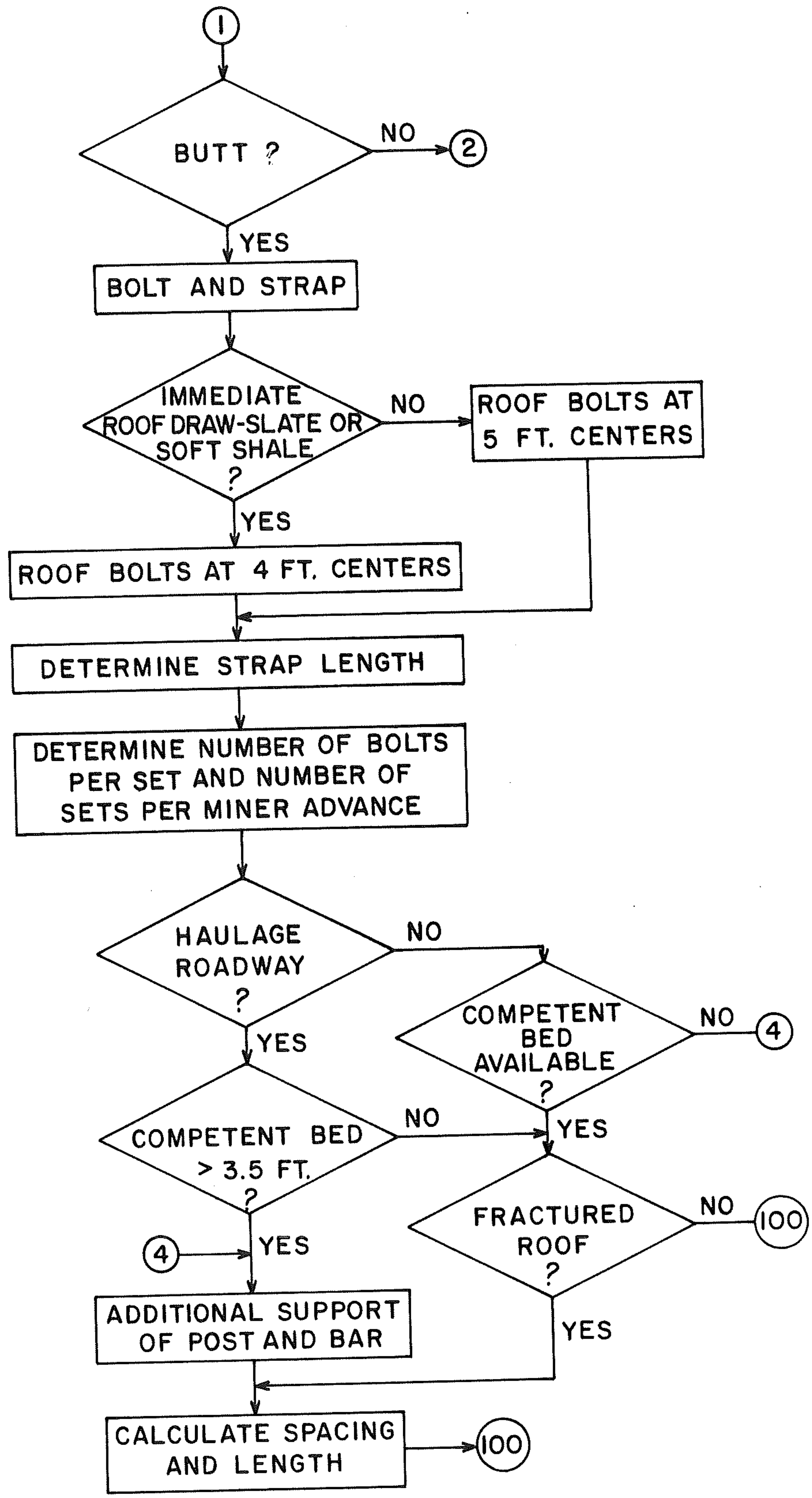


Figure 2. Flow Model for Roof Support Subroutine (page 4 of 5).

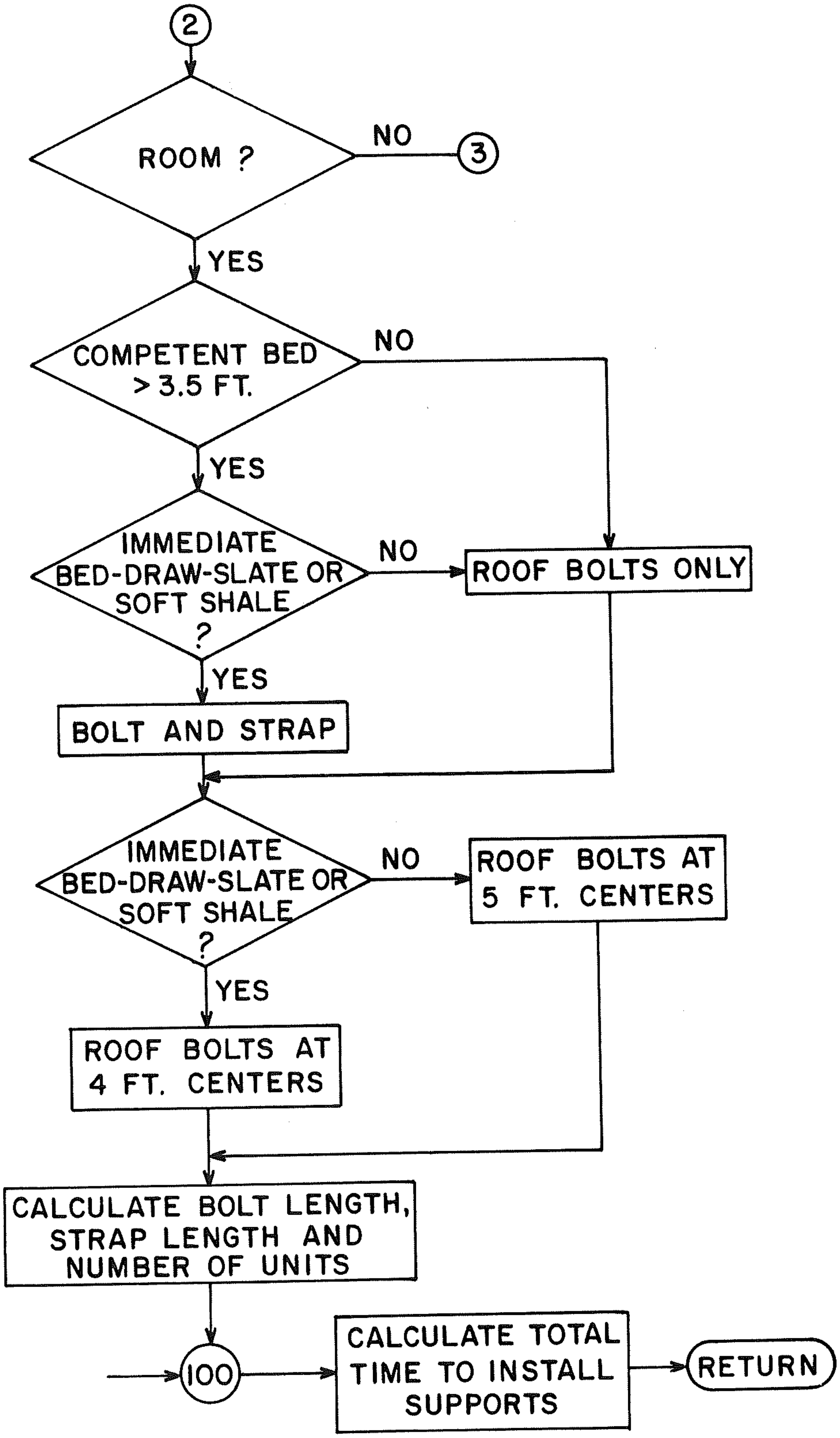


Figure 2. Flow Model for Roof Support Subroutine (page 5 of 5).

APPENDIX B

LIST OF EXTERNAL VARIABLES

AND PROGRAM LISTING

```
// EXEC FWCLG
//SYSIN DD *
C  IT IS BASED ON EMPIRICAL RELATIONSHIP AS OBSERVED IN THE
C  FIELD.  THE DIFFERENT INPUT VARIABLES ARE AS FOLLOWS.
C  ADVMIN- LENGTH OF THE ROADWAY TO BE SUPPORTED
C  BTDM= BIT DIAMETER OF ROOF DRILL
C  BTDMA= BIT DIAMETER OF COAL DRILL
C  COMSG(N)= SPECIFIC ENERGY OF INDIVIDUAL DED ----- (1)= DRSL,
C             (2)= SSHL,   (3)= COAL,   (4)= HSHL,   (5)= SST
C             (6)= HSST,   (7)= LMST,   (9)= COAL DRILL,
C  HOSPD,HOSPWD- POWER VALUE FOR ROOF AND COAL DRILLING
C  HOSP= HORSEPOWER FOR ROOF DRILL
C  HOSPW= HORSEPOWER FOR COAL DRILL
C  IBASE- BASE OF THE RANDOM NUMBER GENERATOR
C  DRLN= DRILLING LENGTH FOR COAL DRILL
C  JTDEN- JOINT DENSITY; IF >6 ROOF IS JOINTED
C  ROOFI- IDENTIFICATION NAME FOR ROADWAY.  FOLLOWING TYPES
C         OF ROADWAY ARE CONSIDERED IN THIS PROGRAM:
C         'PRWY'- PERMANENT ROADWAY, 'BUTT'- BUTT, 'ROOM'-
C         ROOM.
C  ROOFJ- WIDTH(FT.) OF ROADWAY
C  ROOFK- HEIGHT(FT.)OF    "
C  STRT(I)- IDENTIFICATION FOR INDIVIDUAL BED 'I'.  THIS
C         PROGRAM AT PRESENT DEALS WITH FOLLOWING BEDS
C         COMMONLY ASSOCIATED WITH COAL BEARING ROCKS.
C         'COAL'- COAL, 'DRSL'- DRAWSLATE, 'SSHL'- SOFT
C         SHALE, 'SST '- S.SST., 'HSST'- HARD S.SST.
C          'LMST'-LIME STONE
C  STRTH(I)- THICKNESS(FT.) OF BED 'I'
C  ROOFN- IDENTIFICATION FOR HAUL ROAD('HLRD'),ELSE BLANK
C  STRTN- NUMBER OF DIFFERENT BEDS IN THE FIRST 10FT OF ROOF
C  STRTPT- OUTBYE CO-ORDINATE POINT
C  TAVBLT,DEVBLT- MEAN TIME FOR INSTALLING BOLT AND DEV.
C  TAVPBR,DEVPBR-  "    "            "       POST&BAR AND DEV
C  TAVPST,DEVPST-  "    "            "       POST AND DEV.
C  *****************************************************************
      INTEGER STRTN ,IBASE,STRT(10),ROOFI,ROOFN,NUMBLT,NUMSPT,NUMSBR,NUM
     1TPT,NUMSSP,NUMTBR,STCH
      REAL ROOFJ,ROOFK,STRTH(10),LNGBLT,SECBLT,LNGSPT,SECSPT,LNGSBR,SECS
     2BR,LNGTPT,SECTPT,SECSSP,LNGSSP,SUPTIM,ADVMIN,TAVBLT,DEVBLT,TAVPBR,
     3DEVPBR,STRTPT,JTDEN,LNGTBR,SECTBR,TAVPST,DEVPST,COMSG(10),HOSP,BTD
     4M,HOSPW,BTDMA,DRTIMA,POWCAU,TDRLTM,POWBLT,DRLN
      READ 412,IBASE
  412 FORMAT(80A1)
  222 PRINT 111
```

```
111 FORMAT('1','SIMULATED ROOF SUPPORT SYSTEM')
    NUMBLT=0
    NUMSPT=0
    NUMSBR=0
    NUMTPT=0
    NUMSSP=0
    NUMTBR=0
    LNGBLT=0.0
    SECBLT=0.0
    LNGSPT=0.0
    SECSPT=0.0
    LNGSBR=0.0
    SECSBR=0.0
    LNGTPT=0.0
    SECTPT=0.0
    SECSSP=0.0
    LNGSSP=0.0
    SECTBR=0.0
    LNGTBR=0.0
    SUPTIM=0.0
    ADVMIN=0.0
    READ 401,STRTN
401 FORMAT(I5)
    READ 402,(STRT(I),STRTH(I),I=1,STRTN)
    PRINT 421
421 FORMAT('0','SEQUENCE OF ROOF STRATA')
    K=STRTN+1
    DO 31 I=1,STRTN
    II=K-I
    PRINT 420,STRT(II),STRTH(II)
 31 CONTINUE
420 FORMAT('0',5X,A4,1X,'-',F4.1)
402 FORMAT(8(A4,1X,F4.1,1X))
    READ 403,ROOFI,ROOFN,ROOFJ,ROOFK
403 FORMAT(2(A4,1X),2(F4.1,1X))
    READ 404,(COMSG(N),N=1,10)
    READ 404,HOSP,HOSPD,BTDM,BTDMA,HOSPW,HOSPWD,DRLN
    READ 404,TAVBLT,DEVBLT,TAVPBR,DEVPBR,TAVPST,DEVPST
404 FORMAT(10F8.2)
    READ 404,JTDEN
    PRINT 423,JTDEN
423 FORMAT('0','JOINT TRACE DENSITY-',F4.1)
    CALL GRSUP(STRTN,STRT,STRTH,ROOFI,ROOFN,ROOFJ,ROOFK,
   1NUMBLT,LNGBLT,SECBLT,NUMSPT,LNGSPT,SECSPT,NUMSBR,LNGSBR,SECSBR,NUM
   2TPT,LNGTPT,SECTPT,NUMSSP,SECSSP,LNGSSP,SUPTIM,TAVBLT,DEVBLT,TAVPBR
   3,DEVPBR,IBASE,JTDEN,NUMTBR,LNGTBR,SECTBR,TAVPST,DEVPST,COMSG,HOSP,
   4BTDM,STCH,HOSPW,BTDMA,DRTIMA,POWCAU,TDRLTM,POWBLT,DRLN,HOSPD,
   5HOSPWD)
    PRINT 406,NUMBLT,LNGBLT,SECBLT
```

```
406 FORMAT('0','BOLTS:NUMBER=',I2,',LENGTH=',F8.2,'FT.,SECTION=',F8.2,
   1'SQ.INCHES')
    PRINT 407,NUMSSP,LNGSSP,SECSSP
407 FORMAT('0','STEEL STRAPS: NUMBER=',I2,',LENGTH=',F8.2,'FT.,SECTION
   2=',F8.2,'SQ.INCHES')
    PRINT 408,NUMSPT,LNGSPT,SECSPT
408 FORMAT('0','STEEL POSTS:  NUMBER=',I2  ,',LENGTH=',F8.2,'FT.,SECTI
   1ON=',F8.2,'SQ.INCHES')
    PRINT 409,NUMSBR,LNGSBR,SECSBR
409 FORMAT('0','STEEL BARS: NUMBER=',I2,',LENGTH=',F 8.2,'FT.,SECTION=
   1',F 8.2,'SQ.INCHES')
    PRINT 410,NUMTPT,LNGTPT,SECTPT
410 FORMAT('0','TIMBER POSTS: NUMBER=',I2,',LENGTH=',F8.2,'FT.,SECTION
   1=',F8.2,'SQ.INCHES')
    PRINT 413,NUMTBR,LNGTBR,SECTBR
413 FORMAT('0','WOODEN X-BARS:NUMBER=',I2,',LENGTH=',F8.2,'FT.,
   +SECTION=',F8.2,'SQ.INCH')
    PRINT 411,SUPTIM
411 FORMAT('0','TIME REQUIRED TO SET SUPPORT=',F 8.2,'MINUTES')
    PRINT 514,BTDM,BTDMA
514 FORMAT('0','BIT DIA.=',F8.2,'INCH',10X,'AUGER DIA.=',F8.2,'INCH')
    PRINT 510, TDRLTM
510 FORMAT ('0','TOTAL DRILLING TIME PER BOLT   =',F8.2,'MINUTES')
    PRINT 512,POWBLT
512 FORMAT ('0','POWER CONSUMPTION PER BOLT =',F8.2,'KW-HR')
    PRINT 511,DRTIMA
511 FORMAT ('0','DRILLING TIME PER HOLE FOR COAL AUGER =',F8.2,'MINUTE
   1S')
    PRINT 513, POWCAU
513 FORMAT ('0','POWER CONSUMPTION PER HOLE FOR AUGER =',F8.2,'KW-HR')
    STOP
    END
    SUBROUTINE GRSUP(STRTN,STRT,STRTH,ROOFI,ROOFN,ROOFJ,ROOFK,
   1       NUMBLT,LNGBLT, SECBLT, NUMSPT, LNGSPT, SECSPT,NUMSBR,
   2LNGSBR, SECSBR, NUMTPT, LNGTPT,SECTPT, NUMSSP,SECSSP,LNGSSP,
   3SUPTIM, TAVBLT,DEVBLT, TAVPBR,DEVPBR, IBASE,JTDEN,
   4NUMTBR,LNGTBR,SECTBR,TAVPST,DEVPST,COMSG,HOSP,BTDM,
   5STCH,HOSPW,BTDMA,DRTIMA,POWCAU,TDRLTM,POWBLT,DRLN,HOSPD,HOSPWD)
    LOGICAL   JOINT,NCOMP,COMB
    INTEGER PRMRD/'PRWY'/,BUTT/'BUTT'/,ROOM/'ROOM'/,PRMJCT/ 'PJCT'/,
   1SMPRJT/'SJCT'/,ROOFI,DRSL/'DRSL'/,SSHL/'SSHL'/,HSHL/'HSHL'/,
   2SST/'SST'/,COAL/'COAL'/,HSST/'HSST'/,STRT(10),STCH,STCHR(10),
   3HLRD/'HLRD'/,ROOFN,STRTN,SUPSET,NEWSET,OLDSET,NUMBLT,
   4NUMSPT,NUMSBR,NUMTPT,NUMSSP,NUMTBR
   5,LMST/'LMST'/
    REAL ROOFJ,ROOFK,MINCB,JTDEN,HORZ,STRTH(10),SUPM,
   1SUPTIM, LNGBLT, SECBLT,LNGSPT,SECSPT,STRHR(10), HORCB, HRANCH,
   2ADVMIN, DEV, STRTPT,  LNGSBR,SECSBR, LNGTPT,SECTPT, LNGSSP,
```

```
   3SECSSP,TAVBLT,DEVBLT,TAVPBR,DEVPBR,DRLTIM(10),TDRLTM,
   4LNGTBR,SECTBR,TIMPST,TAVPST,DEVPST,DRLN,
   5 DTIM(10),    COMSG(10),HOSP,BTDM,HOSPW,BTDMA,DRTIMA,POWCAU,POWBLT
    IF(ROOFJ.GT.30.0) GO TO 58
    IF(ROOFJ.LT.20.0) GO TO 57
    PRINT 402
402 FORMAT('0','ROOF SUPPORT ACCORDING TO ''COMBINATION ROOF CONTROL
   +PLAN''')
 57 NUMSET=0
    DRTIMA=0
    POWCAU=0
    POWBLT=0
    TDRLTM=0.0
    COMB=.FALSE.
    MINCB=ROOFK
    CALL RANDN(IBASE,DEV)
    TIMBLT=TAVBLT+DEVBLT*DEV
    CALLRANDN(IBASE,DEV)
    TIMPBR=TAVPBR+DEVPBR*DEV
    CALL RANDN(IBASE,DEV)
    TIMPST=TAVPST+DEVPST*DEV
    HORZ=0.0
    PRINT 99
 99 FORMAT ('0','DRILLING RATE    SPECIFIC ENERGY')
    IF(JTDEN.GT.6.0) GO TO 18
    JOINT=.FALSE.
    GO TO 19
 18 JOINT=.TRUE.
C   ***********************************************************
C   DIFFERENT BEDS ARE IDENTIFIED AND DRILLING RATES CALCULATED
C   ***********************************************************
 19 DO 2 J=1,STRTN
    IF(J-1)3,4,3
  4 IF(STRT(J).EQ.HSST)GO TO 6
    IF(STRT(J).EQ.LMST) GO TO 6
    GO TO 3
  6 IF(STRTH(J)-3.0)3,8,8
  3 IF(STRT(J).EQ.DRSL)GO TO 9
    IF(STRT(J).EQ.SSHL)GO TO 11
    IF(STRT(J).EQ.HSHL) GO TO 12
    IF(STRT(J).EQ.SST ) GO TO 13
    IF(STRT(J).EQ.HSST) GO TO 14
    IF(STRT(J).EQ.LMST) GO TO 45
    IF(STRT(J).EQ.COAL) GO TO 16
    GO TO 899
  9 STCH=1
    GO TO 17
 11 STCH=2
```

```
      GO TO 17
   12 STCH=4
      GO TO 17
   13 STCH=5
      GO TO 17
   14 STCH=6
      GO TO 17
   45 STCH=7
      GO TO 17
   16 STCH=3
   17 DRRT=HOSPD*42000./(COMSG(STCH)*BTDM**2)
      PRINT 95,DRRT,COMSG(STCH)
   95 FORMAT ('0',F10.2,6X,F10.2)
      DTIM(STCH)=1.0/DRRT
      CALL RANDN(IBASE,DEV)
      DRLTIM(J)=DTIM(STCH)+0.1*DTIM(STCH)*DEV
      STCHR(J)=STCH
      STRHR(J)=HORZ
      HORZ=HORZ+STRTH(J)
    2 CONTINUE
      IF (BTDMA .NE. 0) GO TO 90
      GO TO 46
   90 DRRTA=HOSPWD*42000./(COMSG(9)*BTDMA**2)
      DTDA=DRLN/DRRTA
      CALL RANDN(IBASE,DEV)
      DRTIMA=DTDA+0.1*DTDA*DEV
      POWCAU=(DRTIMA*HOSPW*0.75)/60.
C     ***********************************************************
C     COMPETENT BED SEARCHED FOR BOLT ANCHOR HORIZON AND
C     DRILLING TIME CALCULATED
C     ***********************************************************
   46 DO 23 J=1,STRTN
      IF(STCHR(J).GT.3)GO TO 22
      GO TO 23
   22 IF(J.EQ.1) GO TO 61
      IF(STRTH(J)-2.0)23,27,27
   61 IF(STRTH(J)-3.0)23,63,63
   23 CONTINUE
      HORCB=10.0
      GO TO 21
   27 HORCB=STRHR(J)
   21 IF(MINCB.GE.5.0) GO TO 47
      MINCB=5.0
   47 IF(MINCB.LE.9.0) GO TO 1
      MINCB=9.0
    1 IF(HORCB-MINCB)28,28,29
   29 PRINT 411,MINCB
      NCOMP=.TRUE.
```

```
 411 FORMAT('0','NO COMPETENT BED WITHIN',F4.1,'FT.')
     HRANCH=MINCB+1.0
     GO TO 31
  28 NCOMP=.FALSE.
     HRANCH=HORCB+1.0
     IF (HRANCH-4.0) 76,31,31
  76 HRANCH=4.0
  31 DO 32 J=1,STRTN
     IF(HRANCH-STRHR(J))34,34,32
  32 L=J
     CONTINUE
     THICKR=HRANCH-STRHR(L)
     K=L-1
     GO TO 49
  34 K=J-1
     THICKR=HRANCH-STRHR(K)
     IF (K.EQ.1.0) GO TO 71
     K=K-1
  49 DO 33 I=1,K
     KOUNT=I+1
  33 TDRLTM=TDRLTM+DRLTIM(I)*STRTH(I)
     GO TO 64
  63 HRANCH=3.0
     THICKR=3.0
  71 KOUNT=1
  64 TDRLTM=TDRLTM+DRLTIM(KOUNT)*THICKR
     POWBLT=((TDRLTM+TIMBLT)*HOSP*0.75)/60.
     PRINT 412,HRANCH
 412 FORMAT('0','ROOF ANCHOR HORIZON AT=',F10.2,'FT. FROM ROOF LEVEL')
     GO TO 36
   8 HRANCH=-1.0
  36 PRINT 405,ROOFI,ROOFJ,ROOFK
 405 FORMAT('0','SUPP.SYS.FOR',2X,A4,':','WIDTH=',F10.2,'FT.',2X,'HT.='
    +,F10.2,'FT.')
     IF (ROOFN.NE.HLRD) GO TO 570
     PRINT 565
 565 FORMAT('0','HAULAGE ROADWAY')
C    ***************************************************************
C    BRANCHES OFF DEPENDING ON ROADWAY TYPE
C    ***************************************************************
 570 IF(ROOFI.EQ.PRMRD)       GO TO 5
     IF (ROOFI.EQ.BUTT) GO TO 10
     IF (ROOFI.EQ.ROOM) GO TO 15
     IF (ROOFI.EQ.PRMJCT)  GO TO 899
     IF (ROOFI.EQ.SMPRJT)GO TO 899
     GO TO 899
C    ***************************************************************
C    ROOF SUPPORT REQUIREMENTS FOR PERMANENT ROADWAY
```

```
C    ***********************************************************
      5 IF(HRANCH)24,30,30
     24 IF(JOINT) GO TO 26
        PRINT 410
    410 FORMAT('0','NO SUPPORT REQUIRED')
        GO TO 900
C    ***********************************************************
C    ADDITIONAL SUPPORTS FOR JOINTED ROOF
C    ***********************************************************
     26 SUPM=4.0
        SUPSET=ROOFJ/SUPM
CC      NEWSET=(STRTPT+ADVMIN)/SUPM
CC      OLDSET=STRTPT/SUPM
CC      NUMSET=NEWSET-OLDSET
        NUMSET=1
        IF(ROOFI.EQ.PRMRD) GO TO 510
        IF(ROOFI.EQ.BUTT ) GO TO 530
        IF(ROOFI.EQ.ROOM ) GO TO 530
        GO TO 899
    549 IF(ROOFN.NE.HLRD) GO TO 890
        PRINT 545
        GO TO 530
    550 PRINT 545
    545 FORMAT('0','ADDITIONAL SUPPORT')
        IF(ROOFI.EQ.ROOM) GO TO 530
        IF(ROOFN.NE.HLRD) GO TO 530
    510 IF(ROOFN.EQ.HLRD) GO TO 525
        GO TO 530
    555 PRINT 545
    530 PRINT 600
    600 FORMAT('0','SUPPORT WITH TIMBER POST AND WOODEN CROSS BAR')
        PRINT 440
        LNGTPT=ROOFK
        IF(ROOFK.LE.4.0) GO TO 556
        DIA=ROOFK
        SECTPT=22.0*DIA*DIA/28.0
        GO TO 557
    556 SECTPT=12.5
    557 NUMTPT=NUMSET*2
        COMB=.TRUE.
        PRINT 425,LNGTPT,SECTPT,NUMTPT
        PRINT 445
        LNGTBR=ROOFJ-1.0
        IF(LNGTBR.LE.10.0) GO TO 558
        SECTBR=2*LNGTBR
        GO TO 559
    558 SECTBR=20.0
    559 NUMTBR=NUMSET
```

```
      PRINT 425,LNGTBR,SECTBR,NUMSET
      SUPTIM=SUPTIM+TIMPBR*NUMTBR
      GO TO 900
  525 PRINT 605
  605 FORMAT('0','SUPPORT WITH STEEL POST AND STEEL BARS')
      PRINT 440
      LNGSPT=ROOFK
      SECSPT=7.43
      NUMSPT=NUMSET*2
      COMB=.TRUE.
      PRINT 425,LNGSPT,SECSPT,NUMSPT
      PRINT 445
      LNGSBR=ROOFJ-1.0
      SECSBR=7.43
      NUMSBR=NUMSET
      PRINT 425,LNGSBR,SECSBR,NUMSET
      SUPTIM=SUPTIM+TIMPBR*NUMSBR
      GO TO 900
   30 PRINT 415
  415 FORMAT('0','ROOF BOLT & STRAP')
      PRINT 420
  420 FORMAT('0','ROOF BOLT SPECIFICATIONS')
      LNGBLT=HRANCH
      SECBLT=0.31
      SUPM=4.0
      SUPSET=ROOFJ/SUPM
CC    NEWSET=(STRTPT+ADVMIN)/SUPM
CC    OLDSET=STRTPT/SUPM
CC    NUMSET=NEWSET-OLDSET
      NUMSET=1
      NUMBLT=SUPSET*NUMSET
      PRINT 563,SUPM
  563 FORMAT('0','BOLT SPACING=',F5.2,'FT.')
      PRINT 425,LNGBLT,SECBLT,NUMBLT
  425 FORMAT('0','LENGTH=',F5.2,'FT.',2X,'X-SEC=',F5.2,'SQ.IN.',2X,
     +'NUMBER OF UNITS=',I2,2X,'FOR ONE SET')
      PRINT 430
  430 FORMAT('0','STRAP SPECIFICATIONS')
      LNGSSP=ROOFJ-1.0
      SECSSP=0.5
      NUMSSP=NUMSET
      PRINT 425,LNGSSP,SECSSP,NUMSET
      SUPTIM=(TDRLTM+TIMBLT)*NUMBLT
      IF(JOINT) GO TO 550
      IF(HRANCH-4.5)900,900,40
   40 IF(ROOFN.EQ.HLRD)GO TO 41
      GO TO 86
   41 PRINT 435
```

```
435 FORMAT ('0','ADDITIONAL SUPPORT WITH STEEL POSTS & STEEL BAR')
    PRINT 440
440 FORMAT('0','POST SPECIFICATIONS')
    LNGSPT=ROOFK
    SECSPT=7.43
    NUMSPT=NUMSET*2
    COMB=.TRUE.
    PRINT 425,LNGSPT,SECSPT,NUMSPT
    PRINT 445
445 FORMAT ('0','BAR SPECIFICATIONS')
    LNGSBR=ROOFJ-1.0
    SECSBR=7.43
    NUMSBR=NUMSET
    PRINT 425,LNGSBR,SECSBR,NUMSET
    SUPTIM=SUPTIM+TIMPBR*NUMSBR
    GO TO 900
C   ************************************************************
C   ROOF SUPPORT FOR BUTT
C   ************************************************************
 10 IF(HRANCH)24,50,50
 50 PRINT 415
    LNGBLT=HRANCH
    SECBLT=0.31
    IF(STCHR(1)-2.0)60,60,55
 55 SUPM=5.0
    GO TO 65
 60 SUPM = 4.0
 65 SUPSET=ROOFJ/SUPM
CC  NEWSET=(STRTPT+ADVMIN)/SUPM
CC  OLDSET=STRTPT/SUPM
CC  NUMSET=NEWSET-OLDSET
    NUMSET=1
    NUMBLT=SUPSET*NUMSET
    PRINT 420
    PRINT 563,SUPM
    PRINT 425,LNGBLT,SECBLT,NUMBLT
    PRINT 430
    LNGSSP=ROOFJ-1.0
    SECSSP=0.5
    NUMSSP=NUMSET
 80 PRINT 425,LNGSSP,SECSSP,NUMSET
    SUPTIM=(TDRLTM+TIMBLT)*NUMBLT
    IF(JOINT) GO TO 555
    IF(HRANCH-4.5)900,900,85
 85 IF(ROOFN.EQ.HLRD)GO TO 86
    IF(NCOMP) GO TO 86
    GO TO 900
 86 PRINT 450
```

```
 450 FORMAT('0','ADDITIONAL SUPPORT WITH TIMBER POSTS & WOODEN BARS')
     PRINT 440
     LNGTPT=ROOFK
     IF(ROOFK.LE.4.0) GO TO 333
     DIA=ROOFK
     SECTPT=22.0*DIA*DIA/28.0
     GO TO 334
 333 SECTPT=12.5
 334 NUMTPT=NUMSET*2
     COMB=.TRUE.
     PRINT 425,LNGTPT,SECTPT,NUMTPT
     PRINT 445
     LNGTBR=ROOFJ-1.0
     IF(LNGTBR.LT.10.0) GO TO 561
     SECTBR=2.0*LNGTBR
     GO TO 562
 561 SECTBR=20.0
 562 NUMTBR=NUMSET
     PRINT 425,LNGTBR,SECTBR,NUMSET
     SUPTIM=SUPTIM+TIMPBR*NUMTBR
     GO TO 900
C    ***********************************************************
C    ROOF SUPPORT FOR ROOM
C    ************************************************************
  15 IF(HRANCH)24,125,125
 125 IF(HRANCH-4.5)130,130,135
 130 PRINT 455
 455 FORMAT('0','ROOF BOLTS ONLY')
     LNGBLT=HRANCH
     SECBLT=.31
     IF(STCHR(1)-2.0)145,145,140
 140 SUPM = 5.0
     GO TO 175
 145 SUPM = 4.0
 175 SUPSET=ROOFJ/SUPM
     NUMSET=1
     NUMBLT=SUPSET*NUMSET
     PRINT 420
     PRINT 563,SUPM
     PRINT 425,LNGBLT,SECBLT,NUMBLT
     SUPTIM=(TDRLTM+TIMBLT)*NUMBLT
     GO TO 887
 135 LNGBLT=HRANCH
     SECBLT=.31
     SUPM=4.0
     SUPSET=ROOFJ/SUPM
CC   NEWSET=(STRTPT+ADVMIN)/SUPM
CC   OLDSET=STRTPT/SUPM
```

```
CC    NUMSET=NEWSET-OLDSET
      NUMBLT=SUPSET*NUMSET
      NUMSET=1
      IF(STCHR(1)-2)136,136,137
  137 PRINT 455
      PRINT 420
      PRINT 563,SUPM
      PRINT 425,LNGBLT,SECBLT,NUMBLT
      SUPTIM=(TDRLTM+TIMBLT)*NUMBLT
      GO TO 887
  136 PRINT 415
      PRINT 420
      PRINT 563,SUPM
      PRINT 425,LNGBLT,SECBLT,NUMBLT
      PRINT 430
      LNGSSP=ROOFJ-1.0
      SECSSP=0.5
      NUMSSP=NUMSET
      PRINT 425,LNGSSP,SECSSP,NUMSET
      SUPTIM=(TDRLTM+TIMBLT)*NUMBLT
      GO TO 887
  899 PRINT 499
  499 FORMAT('0','DATA NOT PROPER FOR THIS SUBROUTINE')
      GO TO 900
  887 IF(NCOMP) GO TO 549
  890 IF (JOINT) GO TO 550
  900 IF(ROOFJ-20.0)52,52,51
   51 IF(ROOFJ-21.0)53,53,54
   54 IF(ROOFJ.LE.26.0) GO TO 56
      NADTPT=NUMSET*3
      GO TO 59
   56 NADTPT=NUMSET*2
      GO TO 59
   53 NADTPT=NUMSET
   59 IF(COMB) NADTPT=NADTPT-NUMSET
      NUMTPT=NUMTPT+NADTPT
      LNGTPT=ROOFK
      IF(ROOFK.LE.4.0) GO TO 72
      DIA=ROOFK
      SECTPT=22.0*DIA*DIA/28.0
      GO TO 73
   72 SECTPT=12.5
   73 SUPTIM=SUPTIM+TIMPST*NADTPT
      GO TO 52
   58 PRINT 401
  401 FORMAT ('0','WIDTH OF GALLERY IN EXCESS OF 30 FT. NOT PERMITTED UN
     +ER STATUTORY REQUIREMENTS')
   52 RETURN
```

```
         END
/*             THIS IS A SLASH ASTERISK CARD
//DATA.INPUT DD *
```

APPENDIX C

DESCRIPTION OF INPUT DATA

WITH RELATED CARD TYPES

CARD TYPES

1st Card Type - (I5) (one card)
Col. 1-5 STRTH - Number of different Beds in the first 10 ft. of roof.

2nd Card Type - (8(A4, 1X, F4.1, 1X)) (As many cards as needed)

Col.	1-4	STRT(II)	- Identification for individual Bed "II".
Col.	6-9	STRTN(II)	- Thickness of Bed "II" in Ft.
Col.	11-14	STRT(II)	- Thickness of Bed "II" in Ft.
Col.	16-19	STRTN(II)	- Thickness of Bed "II" in Ft.

3rd Card Type - (2(A4.1X), 2(F4.1, 1S)) (one card)

Col.	1-4	ROOFI	- Identification Name for Roadway
Col.	6-9	ROOFN	- Identification for Hand Road ("HLRD"), Else Blank.
Col.	11-14	ROOFJ	- Width of Roadway in Ft.
Col.	16-19	ROOFK	- Height of Roadway in Ft.

4th Card Type - (10F 8.2) (one card)

Col.	1-8	COMSG(1)	- Specific Energy for Draw Shale in lb. per cu. in.
Col.	9-16	COMSG(2)	- Specific Energy for Soft Shale in lb. per cu. in.
Col.	17-24	COMSG(3)	- Specific Energy for Coal in lb. per cu. in.
Col.	25-32	COMSG(4)	- Specific Energy for Hard Shale in lb. per cu. in.
Col.	33-40	COMSG(5)	- Specific Energy for Soft Sandstone in lb. per cu. in.
Col.	41-48	COMSG(6)	- Specific Energy for Hard Sandstone in lb. per cu. in.
Col.	49-56	COMSG(7)	- Specific Energy for Limestone in lb. per cu. in.
Col.	57-64	COMSG(8)	- Blank
Col.	65-72	COMSG(9)	- Specific Energy for Coal drilling in lb. per cu. in.
Col.	73-80	COMSG(10)	- Blank

5th Card Type - (F8.2) (one card)

Col.	1-8	HOSP	- Horsepower required for drilling.
Col.	9-16	HOSPD	- Power value for roof drilling.
Col.	17-24	BTDM	- Bit diameter of roof drill.
Col.	25-32	BTDMA	- Bit diameter of coal auger, if = 0, no coal drilling in this section.
Col.	33-40	HOSPW	- Horsepower required for coal auger, if = 0, no calculation needed.
Col.	41-48	HOSPWD	- Power value for coal drilling.
Col.	49-56	DRLN	- Drilling length for coal auger, if = 0, no calculation needed.

6th Card Type - (F8.2) (one card)

Col.	1-8	TAVBLT	- Mean Time for installing bolt.
Col.	9-16	DEVBLT	- Dev. for installing bolt.
Col.	17-24	TAVPBT	- Mean time for installing steel post and bar.
Col.	25-32	DEVPBR	- Dev. for installing steel post and bar.
Col.	33-40	TAVPST	- Mean time for installing wooden post and bar.
Col.	40-48	DEVPST	- Dev. for installing wooden post and bar.

7th Card Type - (F8.2) (one card)

Col.	1-8	JTDEN	- Joint density, IF > 5. roof is jointed.

APPENDIX D

CASE STUDIES

PART I

OUTPUT RESULTS AND SUMMARIES

SIMULATED ROOF SUPPORT SYSTEM (Case A)

SEQUENCE OF ROOF STRATA

HSHL - 5.0

SST - 1.0

HSHL - 1.5

HSST - 2.0

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
1.36	22000.00
3.32	9000.00
2.30	13000.00
3.32	9000.00

ROOF ANCHOR HORIZON AT= 5.50FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 18.00FT. HT.= 4.30FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 5.50FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

ADDITIONAL SUPPORT WITH STEEL POSTS & STEEL BAR

POST SPECIFICATIONS

LENGTH= 4.30FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 2 FOR ONE SET

BAR SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 5.50FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 2,LENGTH= 4.30FT.,SECTION= 7.43SQ.INCHES

STEEL BARS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 7.43SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 16.17MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 2.64MINUTES

POWER CONSUMPTION PER BOLT = 0.84KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.49MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.52KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case B)

SEQUENCE OF ROOF STRATA

SST - 5.5

SSHL - 4.5

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
4.74	6300.00
2.30	13000.00

ROOF ANCHOR HORIZON AT= 5.50FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 16.00FT. HT.= 7.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 5.50FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=15.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

ADDITIONAL SUPPORT WITH STEEL POSTS & STEEL BAR

POST SPECIFICATIONS

LENGTH= 7.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 2 FOR ONE SET

BAR SPECIFICATIONS

LENGTH=15.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 5.50FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 15.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 2,LENGTH= 7.00FT.,SECTION= 7.43SQ.INCHES

STEEL BARS: NUMBER= 1,LENGTH= 15.00FT.,SECTION= 7.43SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 11.07MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 1.37MINUTES

POWER CONSUMPTION PER BOLT = 0.46KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.65MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.58KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case C)

SEQUENCE OF ROOF STRATA

HSHL - 9.5

DRSL - 0.5

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
5.74	5200.00
3.32	9000.00

ROOF ANCHOR HORIZON AT= 4.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 16.00FT. HT.= 6.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 4.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=15.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 4.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 15.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 4.97MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 1.09MINUTES

POWER CONSUMPTION PER BOLT = 0.37KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.65MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.58KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case D)

SEQUENCE OF ROOF STRATA

SST - 5.0

COAL - 1.0

SSHL - 1.0

COAL - 1.5

DRSL - 1.5

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
5.74	5200.00
10.30	2900.00
4.74	6300.00
10.30	2900.00
2.30	13000.00

ROOF ANCHOR HORIZON AT= 6.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 18.00FT. HT.= 6.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 6.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

ADDITIONAL SUPPORT WITH STEEL POSTS & STEEL BAR

POST SPECIFICATIONS

LENGTH= 6.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 2 FOR ONE SET

BAR SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 6.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 2,LENGTH= 6.00FT.,SECTION= 7.43SQ.INCHES

STEEL BARS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 7.43SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 10.20MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 1.15MINUTES

POWER CONSUMPTION PER BOLT = 0.39KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.48MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.52KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case E)

SEQUENCE OF ROOF STRATA

SST -10.0

JOINT TRACE DENSITY- 5.0

DRILLING RATE SPECIFIC ENERGY

2.30 13000.00

ROOF ANCHOR HORIZON AT= 3.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 18.00FT. HT.= 5.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 3.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 3.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 5.85MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 1.31MINUTES

POWER CONSUMPTION PER BOLT = 0.44KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.42MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.50KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case F)

SEQUENCE OF ROOF STRATA

HSHL -10.0

JOINT TRACE DENSITY- 5.0

DRILLING RATE SPECIFIC ENERGY

3.32 9000.00

ROOF ANCHOR HORIZON AT= 3.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 18.00FT. HT.= 4.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 3.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 3.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 4.23MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 0.91MINUTES

POWER CONSUMPTION PER BOLT = 0.32KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.42MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.50KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case G)

SEQUENCE OF ROOF STRATA

HSHL - 7.0

COAL - 1.0

DRSL - 1.0

COAL - 1.0

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
10.30	2900.00
5.74	5200.00
10.30	2900.00
3.32	9000.00

ROOF ANCHOR HORIZON AT= 4.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 18.00FT. HT.= 7.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 4.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 4.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 3.08MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 0.62MINUTES

POWER CONSUMPTION PER BOLT = 0.23KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.49MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.52KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case H)

SEQUENCE OF ROOF STRATA

SST - 0.5

HSHL - 6.0

SSHL - 1.0

COAL - 1.0

SSHL - 0.5

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
4.74	6300.00
10.30	2900.00
4.74	6300.00
3.32	9000.00
2.30	13000.00

ROOF ANCHOR HORIZON AT= 4.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 18.00FT. HT.= 6.50FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 4.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 4.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 3.82MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 0.81MINUTES

POWER CONSUMPTION PER BOLT = 0.29KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.48MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.52KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case I)

SEQUENCE OF ROOF STRATA

HSHL - 7.5

SSHL - 2.5

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
4.74	6300.00
3.32	9000.00

ROOF ANCHOR HORIZON AT= 4.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 18.00FT. HT.= 5.50FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 4.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 4.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 4.44MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 0.96MINUTES

POWER CONSUMPTION PER BOLT = 0.33KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.65MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.58KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case J)

SEQUENCE OF ROOF STRATA

SST - 4.5

HSHL - 3.5

SSHL - 1.0

SST - 1.0

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
2.30	13000.00
4.74	6300.00
3.32	9000.00
2.30	13000.00

ROOF ANCHOR HORIZON AT= 4.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 18.00FT. HT.= 6.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 4.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 4 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=17.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 4,LENGTH= 4.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 17.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 5.82MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 1.30MINUTES

POWER CONSUMPTION PER BOLT = 0.44KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.49MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.52KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case K)

SEQUENCE OF ROOF STRATA

HSHL - 9.3

COAL - 0.5

SSHL - 0.3

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
4.74	6300.00
10.30	2900.00
3.32	9000.00

ROOF ANCHOR HORIZON AT= 4.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 15.00FT. HT.= 3.75FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 4.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 3 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=14.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 3,LENGTH= 4.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 14.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 4.00MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 1.18MINUTES

POWER CONSUMPTION PER BOLT = 0.40KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.23MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.43KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case L)

SEQUENCE OF ROOF STRATA

SST - 4.0

HSHL - 2.0

SSHL - 2.0

COAL - 1.0

SSHL - 1.0

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
4.74	6300.00
10.30	2900.00
4.74	6300.00
3.32	9000.00
2.30	13000.00

ROOF ANCHOR HORIZON AT= 5.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 15.00FT. HT.= 8.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 5.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 3 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=14.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

ADDITIONAL SUPPORT WITH STEEL POSTS & STEEL BAR

POST SPECIFICATIONS

LENGTH= 8.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 2 FOR ONE SET

BAR SPECIFICATIONS

LENGTH=14.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 3,LENGTH= 5.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 14.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 2,LENGTH= 8.00FT.,SECTION= 7.43SQ.INCHES

STEEL BARS: NUMBER= 1,LENGTH= 14.00FT.,SECTION= 7.43SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 8.51MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 1.02MINUTES

POWER CONSUMPTION PER BOLT = 0.35KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.48MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.52KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case M)

SEQUENCE OF ROOF STRATA

SST - 6.0

COAL - 4.0

JOINT TRACE DENSITY- 5.0

DRILLING RATE SPECIFIC ENERGY

10.30 2900.00

2.30 13000.00

ROOF ANCHOR HORIZON AT= 5.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 15.00FT. HT.= 10.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 5.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 3 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=14.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

ADDITIONAL SUPPORT WITH STEEL POSTS & STEEL BAR

POST SPECIFICATIONS

LENGTH=10.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 2 FOR ONE SET

BAR SPECIFICATIONS

LENGTH=14.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 3,LENGTH= 5.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 14.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 2,LENGTH= 10.00FT.,SECTION= 7.43SQ.INCHES

STEEL BARS: NUMBER= 1,LENGTH= 14.00FT.,SECTION= 7.43SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 7.86MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 0.80MINUTES

POWER CONSUMPTION PER BOLT = 0.29KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.65MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.58KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case N)

SEQUENCE OF ROOF STRATA

SST - 4.0

SSHL - 5.5

COAL - 0.5

JOINT TRACE DENSITY- 5.0

DRILLING RATE	SPECIFIC ENERGY
10.30	2900.00
4.74	6300.00
2.30	13000.00

ROOF ANCHOR HORIZON AT= 7.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 15.00FT. HT.= 8.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 7.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 3 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=14.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

ADDITIONAL SUPPORT WITH STEEL POSTS & STEEL BAR

POST SPECIFICATIONS

LENGTH= 8.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 2 FOR ONE SET

BAR SPECIFICATIONS

LENGTH=14.00FT. X-SEC= 7.43SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 3,LENGTH= 7.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 14.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 2,LENGTH= 8.00FT.,SECTION= 7.43SQ.INCHES

STEEL BARS: NUMBER= 1,LENGTH= 14.00FT.,SECTION= 7.43SQ.INCHES

TIMBER POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 10.35MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 1.63MINUTES

POWER CONSUMPTION PER BOLT = 0.54KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.23MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.43KW-HR

SIMULATED ROOF SUPPORT SYSTEM (Case 0)

SEQUENCE OF ROOF STRATA

HSHL -10.0

JOINT TRACE DENSITY- 5.0

DRILLING RATE SPECIFIC ENERGY

3.32 9000.00

ROOF ANCHOR HORIZON AT= 3.00FT. FROM ROOF LEVEL

SUPP.SYS.FOR PRWY:WIDTH= 15.00FT. HT.= 7.00FT.

HAULAGE ROADWAY

ROOF BOLT & STRAP

ROOF BOLT SPECIFICATIONS

BOLT SPACING= 4.00FT.

LENGTH= 3.00FT. X-SEC= 0.31SQ.IN. NUMBER OF UNITS= 3 FOR ONE SET

STRAP SPECIFICATIONS

LENGTH=14.00FT. X-SEC= 0.50SQ.IN. NUMBER OF UNITS= 1 FOR ONE SET

BOLTS:NUMBER= 3,LENGTH= 3.00FT.,SECTION= 0.31SQ.INCHES

STEEL STRAPS: NUMBER= 1,LENGTH= 14.00FT.,SECTION= 0.50SQ.INCHES

STEEL POSTS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

STEEL BARS: NUMBER= 0,LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

TIMBER POSTS: NUMBER= 0.LENGTH= 0.00FT.,SECTION= 0.00SQ.INCHES

WOODEN X-BARS:NUMBER= 0,LENGTH= 0.00FT., SECTION= 0.00SQ.INCH

TIME REQUIRED TO SET SUPPORT= 3.17MINUTES

BIT DIA.= 1.50INCH AUGER DIA.= 2.50INCH

TOTAL DRILLING TIME PER BOLT = 0.91MINUTES

POWER CONSUMPTION PER BOLT = 0.32KW-HR

DRILLING TIME PER HOLE FOR COAL AUGER = 1.42MINUTES

POWER CONSUMPTION PER HOLE FOR AUGER = 0.50KW-HR

Table 2. Summary of Case Studies

CASE NUMBER	LOCATION	COLUMNAR SECTION OF IMMEDIATE ROOF STRATA	ACTUAL ROOF SUPPORT PRACTICE	MODEL OUTPUT	REMARK
(1)	(2)	(3)	(4)	(5)	(6)
A	Pa.	Fig. 3	4' bolts at 4' centers with header board	5.5' bolts at 4' centers, additional support by steel post and bar	conservative
B	Pa.	Fig. 3	4' - 6' bolts at 4' centers; header blocks are used	5.5' bolts at 4' centers, additional support by steel post and bar	--do--
C	Pa.	Fig. 4	4' - 8' bolts at 4' centers	4' bolts at 4' centers with straps	conservative
D	Pa.	Fig. 4	6' bolts at 4' centers	6' bolts at 4' centers additional support by steel post and bar	conservative
E	Pa.	Fig. 5	4' bolts at 4' centers	3' bolts at 4' centers with straps	less
F	Pa.	Fig. 5	4' - 8' bolts at 4' centers	3' bolts at 4' centers	definition of the strata condition is variable and hence not valid for comparison

Table 2. Summary of Case Studies Continued.

CASE NUMBER	LOCATION	COLUMNAR SECTION OF IMMEDIATE ROOF STRATA	ACTUAL ROOF SUPPORT PRACTICE	MODEL OUTPUT	REMARK
(1)	(2)	(3)	(4)	(5)	(6)
G	--	Fig. 6	4' bolts at 4' centers	4' bolts at 4' centers with straps	Same
H	--	Fig. 6	5' bolts at 4.5' centers	4' bolts at 4' centers with straps	Same
F	--	Fig. 7	3 rows of 4' bolts across and 4 1/2' along the roadway. One row of post on each side of the rib at 4' center.	4' bolts at 4' centers with straps	Nearly same
F	--	Fig. 7	4' bolt on 4' across and 4 1/2' along roadway	4' bolts at 4' centers with straps	Same
K	--	Fig. 8	3' bolt at 4' center	4' bolt at 4' centers with strap	Nearly same
L	New Mexico	Fig. 8	5' bolt at 4' center with 1' mat; x-bars as additional support	5' bolt at 4' centers additional support with steel posts and bars	Same

Table 2. Summary of Case Studies Continued.

CASE NUMBER	LOCATION	COLUMNAR SECTION OF IMMEDIATE ROOF STRATA	ACTUAL ROOF SUPPORT PRACTICE	MODEL OUTPUT	REMARK
(1)	(2)	(3)	(4)	(5)	(6)
M	Colorado	Fig. 9	5' - 12' bolt at 5' centers; some matting; timbering in weak areas	5' bolts at 4' centers additional support with steel posts and bars	Data not adequate
N	Colorado	Fig. 9	7' bolts on 4' centers; timbering on wide areas of drift	7' bolts at 4' centers; additional support by steel posts and bars	Same
O	Illinois	Fig. 10	4' bolts on 4.5' centers	3' bolts on 4' centers with straps	Less

PART II

GEOLOGICAL SECTIONS

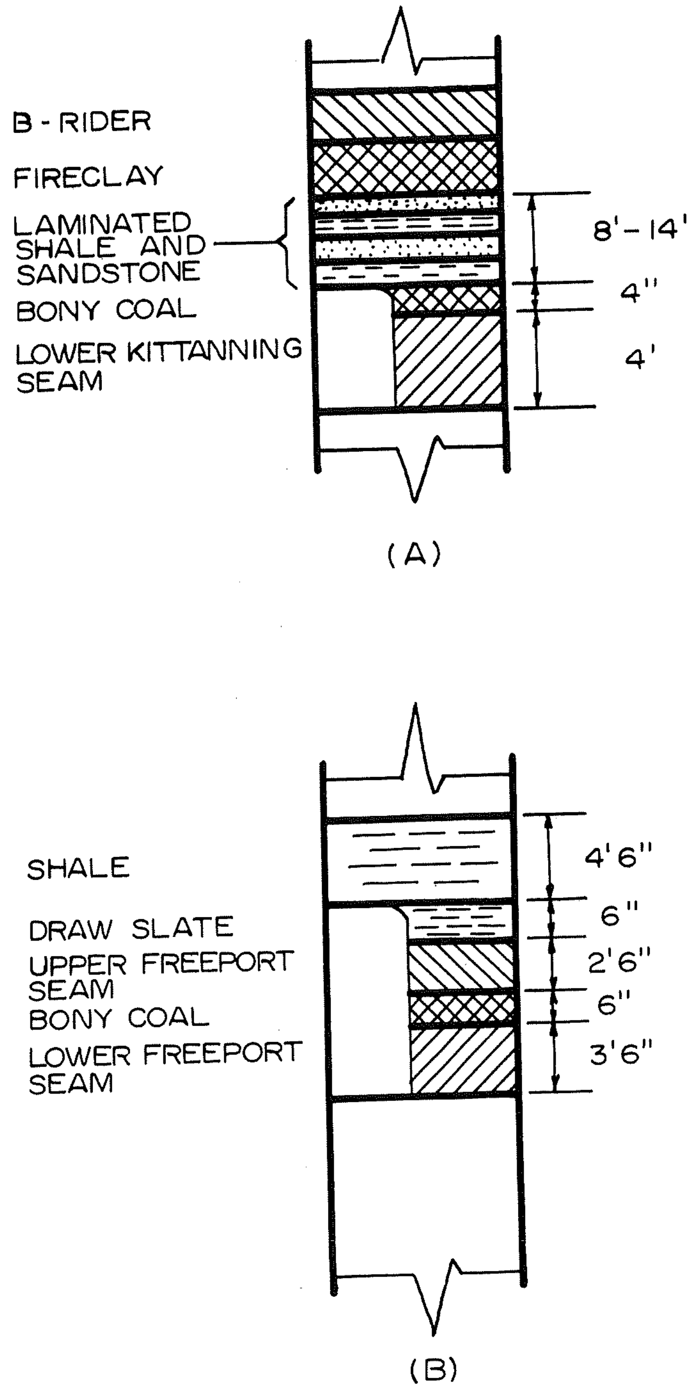
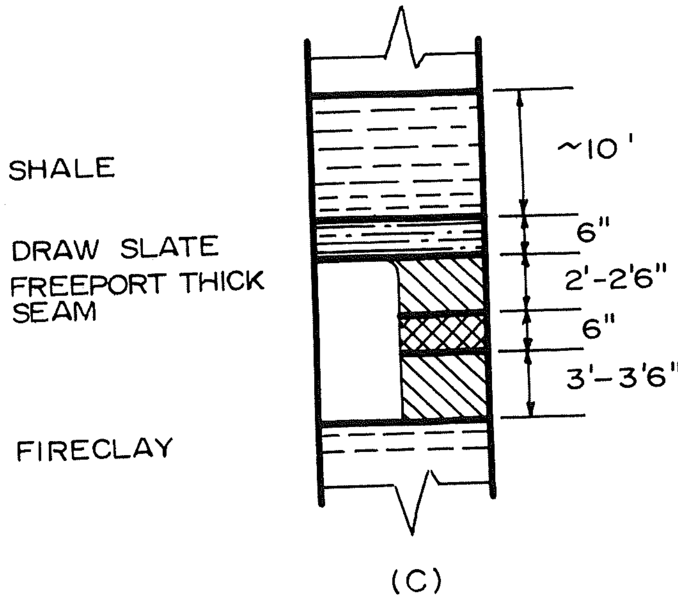


Figure 3. Geological Section for Cases A & B.



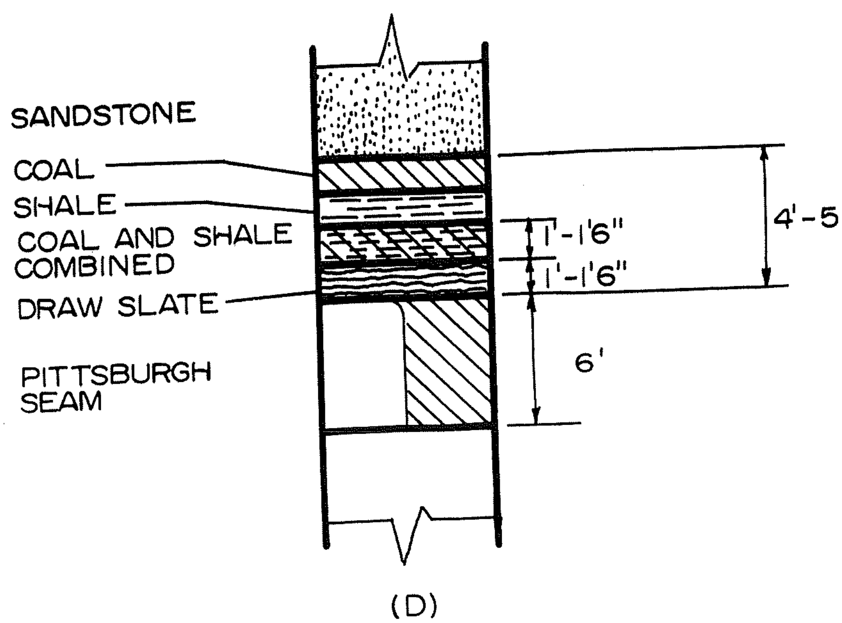


Figure 4. Geological Section for Cases C & D.

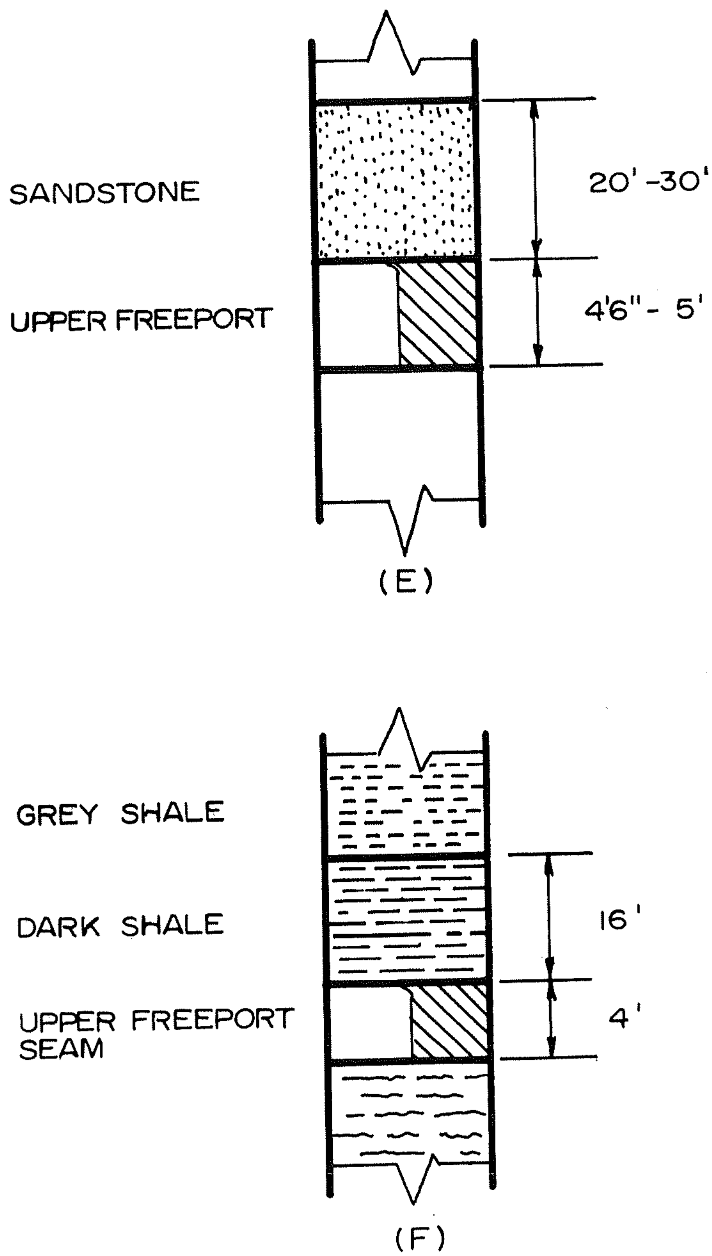
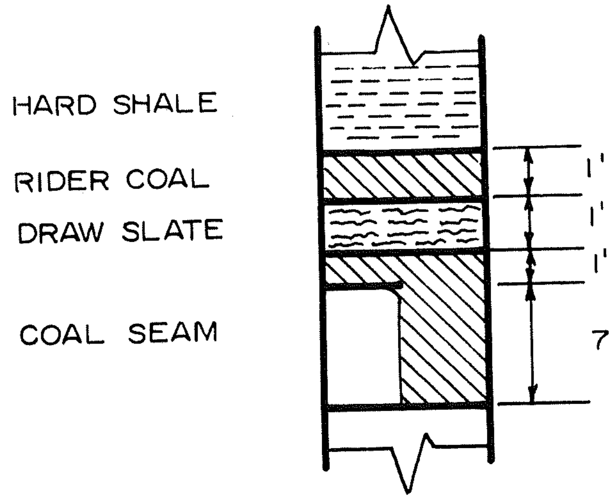
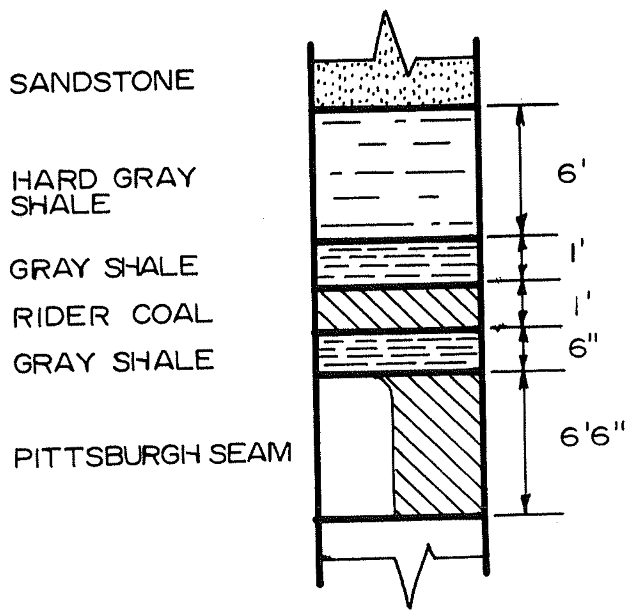


Figure 5. Geological Section for Cases E & F.

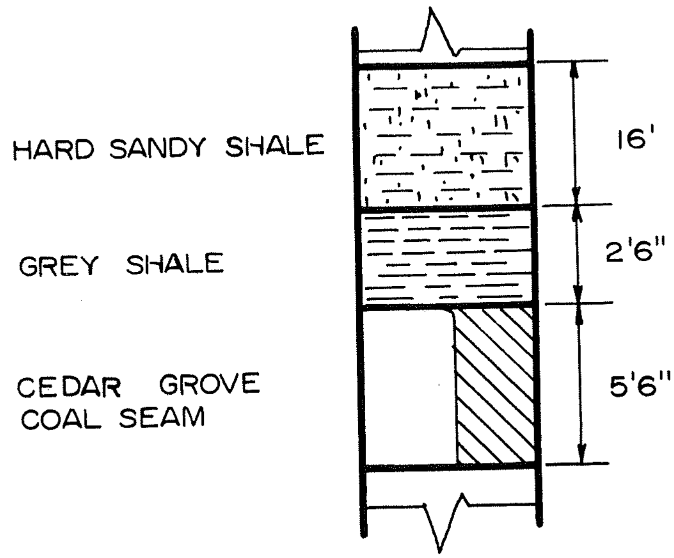


(G)

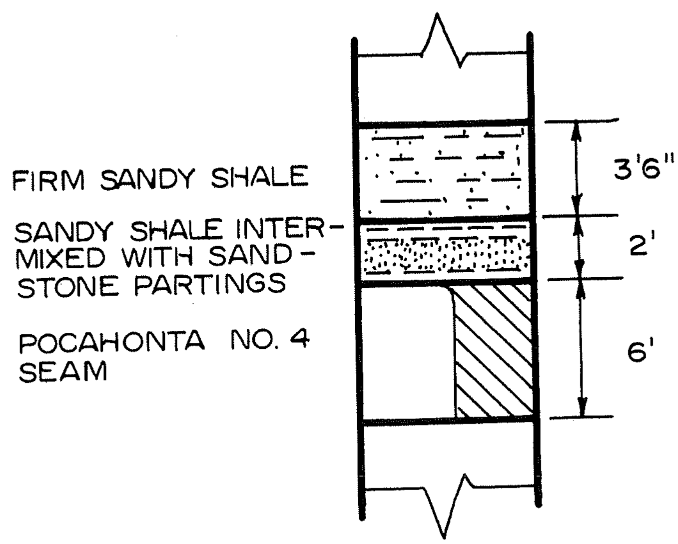


(H)

Figure 6. Geological Section for Cases G & H.



(I)



(J)

Figure 7. Geological Section for Cases I & J.

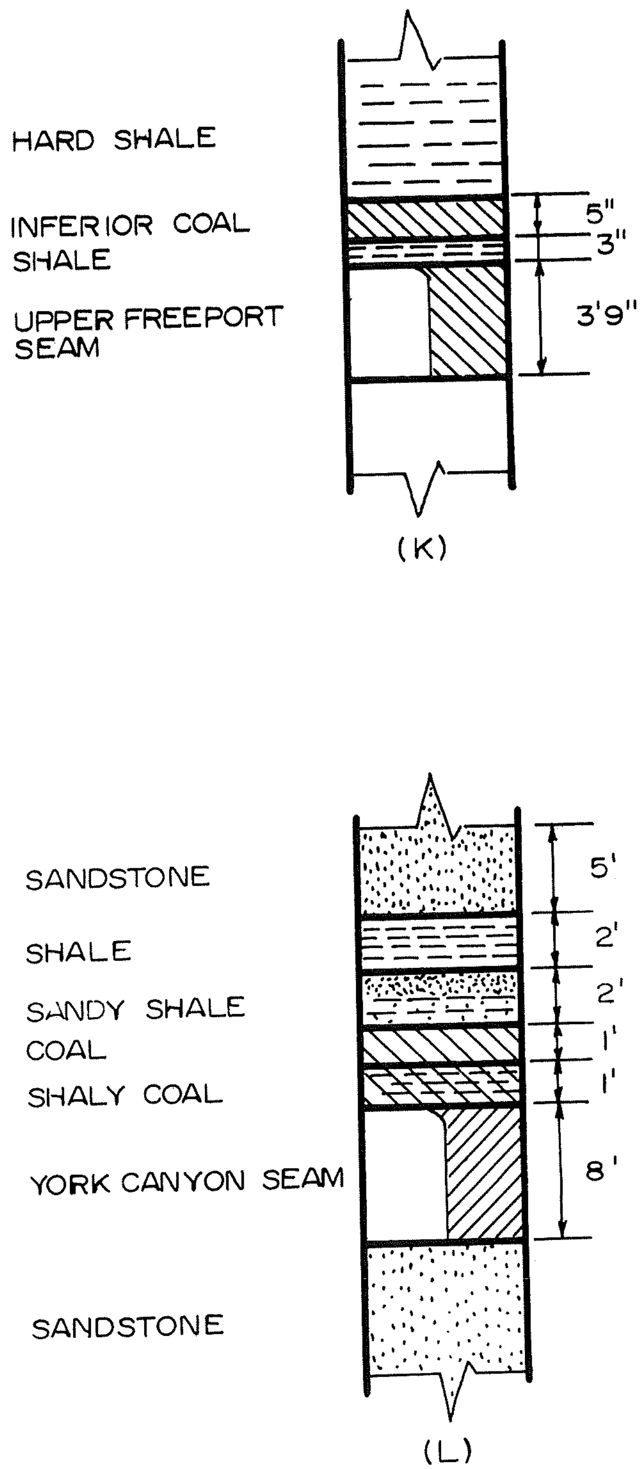
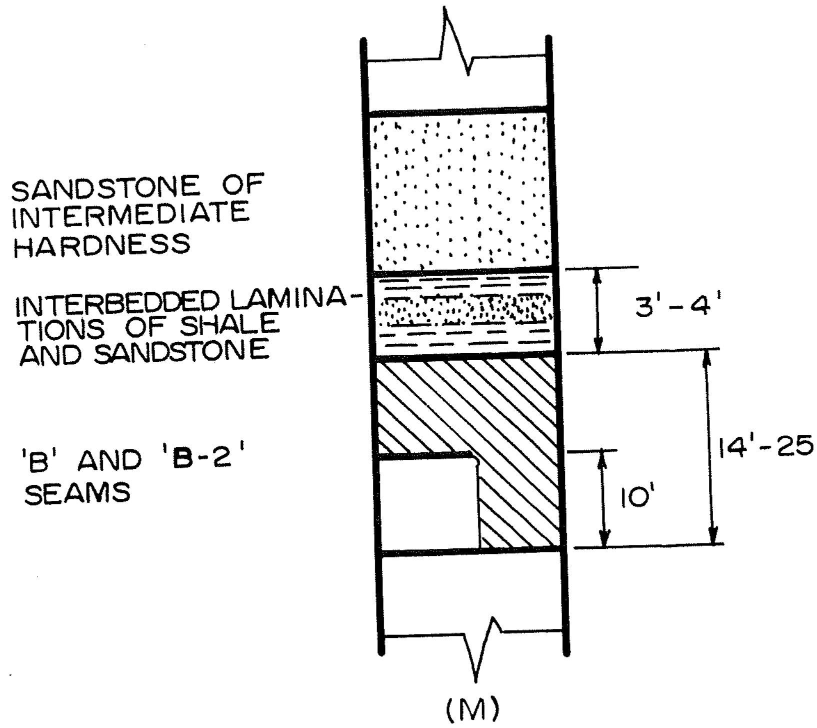


Figure 8. Geological Section for Cases K & L.



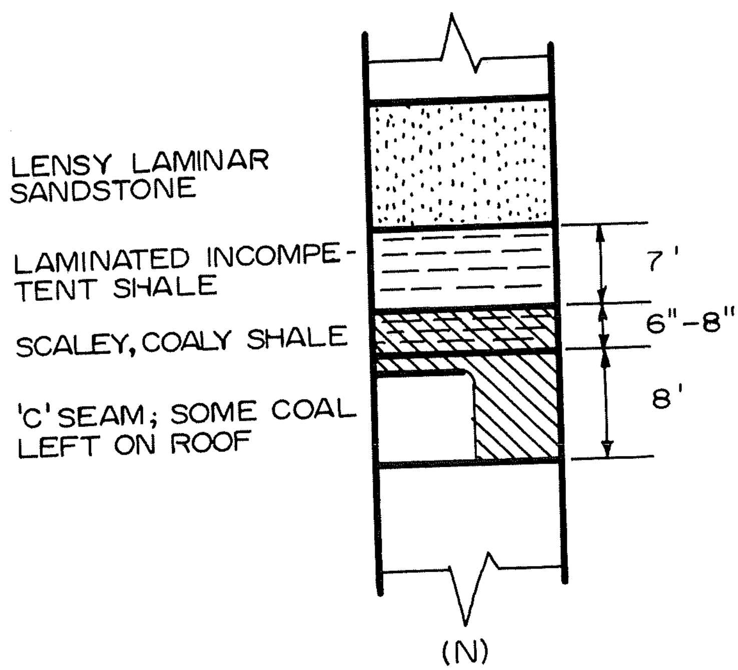


Figure 9. Geological Section for Cases M & N.

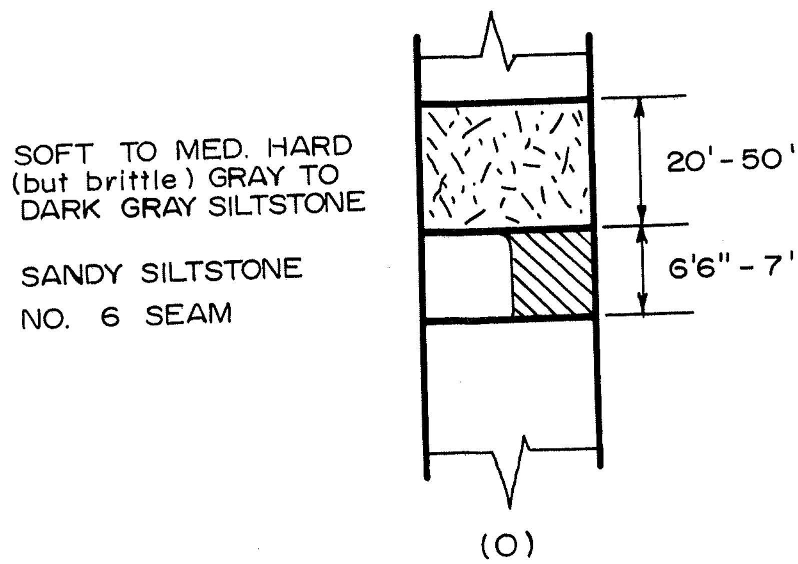


Figure 10. Geological Section for Case 0.

PART III

DATA INPUT

```
1173777333          (Case A)
    4
HSST 2.00 HSHL 1.50 SST  1.00 HSHL 5.00
PRWY HLRD 18.0 4.3
5200.   6300.   2900.   9000.   13000.  22000.  27000.  0.0     2000.   0.
24.0    1.60    1.50    2.50    28.0    1.60    8.0
0.15    0.0     5.0     0.0
5.0
1173777333          (Case B)
    2
SSHL 4.50 SST  5.50
PRWY HLRD 16.0 7.0
5200.   6300.   2900.   9000.   13000.  22000.  27000.  0.      2000.   0.
24.0    1.60    1.50    2.50    28.0    1.60    8.0
0.15    0.0     5.0     0.0
5.0
1173777333          (Case C)
    2
DRSL 0.50 HSHL 9.50
PRWY HLRD 16.0 6.0
5200.   6300.   2900.   9000.   13000.  22000.  27000.  0.      2000.   0.
24.0    1.60    1.50    2.50    28.0    1.60    8.0
0.15    0.0     5.0     0.0
5.0
1173777333          (Case D)
    5
DRSL 1.50 COAL 1.50 SSHL 1.00 COAL 1.00 SST  5.00
PRWY HLRD 18.0 6.0
5200.   6300.   2900.   9000.   13000.  22000.  27000.  0.      2000.   0.
24.0    1.60    1.50    2.50    28.0    1.60    8.0
0.15    0.0     5.0     0.0
5.0
1173777333          (Case E)
    1
SST  10.0
PRWY HLRD 18.0 5.0
5200.   6300.   2900.   9000.   13000.  22000.  27000.  0.      2000.   0.
24.0    1.60    1.50    2.50    28.0    1.60    8.0
0.15    0.0     5.0     0.0
5.0
1173777333          (Case F)
    1
HSHL 10.0
PRWY HLRD 18.0 4.0
5200.   6300.   2900.   9000.   13000.  22000.  27000.  0.      2000.   0.
24.0    1.60    1.50    2.50    28.0    1.60    8.0
0.15    0.0     5.0     0.0
5.0
1173777333          (Case G)
    4
COAL 1.00 DRSL 1.00 COAL 1.00 HSHL 7.00
PRWY HLRD 18.0 7.0
5200.   6300.   2900.   9000.   13000.  22000.  27000.  0.      2000.   0.
24.0    1.60    1.50    2.50    28.0    1.60    8.0
0.15    0.0     5.0     0.0
5.0
1173777333          (Case H)
    5
SSHL 0.50 COAL 1.00 SSHL 1.00 HSHL 6.00 SST 1.50
PRWY HLRD 18.0 6.5
5200.   6300.   2900.   9000.   13000.  22000.  27000.  0.      2000.   0.
24.0    1.60    1.50    2.50    28.0    1.60    8.0
0.15    0.0     5.0     0.0
5.0
```

```
1173777333          (Case I)
    2
SSHL 2.50 HSHL 7.50
PRWY HLRD 18.0 5.5
5200.    6300.    2900.    9000.    13000.   22000.   27000.   0.        2000.     0.
24.0     1.60     1.50     2.50     28.0     1.60     8.0
0.15     0.0      5.0      0.0
5.0
1173777333          (Case J)
    4
SST  1.00 SSHL 1.00 HSHL 3.50 SST  4.50
PRWY HLRD 18.0 6.0
5200.    6300.    2900.    9000.    13000.   22000.   27000.   0.        2000.     0.
24.0     1.60     1.50     2.50     28.0     1.60     8.0
0.15     0.0      5.0      0.0
5.0
1173777333          (Case K)
    3
SSHL 0.25 COAL 0.50 HSHL 9.25
PRWY HLRD 15.0 3.75
5200.    6300.    2900.    9000.    13000.   22000.   27000.   0.        2000.     0.
24.0     1.60     1.50     2.50     28.0     1.60     6.00
0.15     0.0      5.0      0.0
5.0
1173777333          (Case L)
    5
SSHL 1.00 COAL 1.00 SSHL 2.00 HSHL 2.00 SST  4.00
PRWY HLRD 15.0 8.0
5200.    6300.    2900.    9000.    13000.   22000.   27000.   0.        2000.     0.
24.0     1.60     1.50     2.50     28.0     1.60     8.0
0.15     0.0      5.0      0.0
5.0
1173777333          (Case M)
    2
COAL 4.00 SST  6.00
PRWY HLRD 15.0 10.0
5200.    6300.    2900.    9000.    13000.   22000.   27000.   0.        2000.     0.
24.0     1.60     1.50     2.50     28.0     1.60     8.0
0.15     0.0      5.0      0.0
5.0
1173777333          (Case N)
    3
COAL 0.50 SSHL 5.50 SST  4.00
PRWY HLRD 15.0 8.0
5200.    6300.    2900.    9000.    13000.   22000.   27000.   0.        2000.     0.
24.0     1.60     1.50     2.50     28.0     1.60     8.0
0.15     0.0      5.0      0.0
5.0
1173777333          (Case O)
    1
HSHL 10.0
PRWY HLRD 15.0 7.0
5200.    6300.    2900.    9000.    13000.   22000.   27000.   0.        2000.     0.
24.0     1.60     1.50     2.50     28.0     1.60     8.0
0.15     0.0      5.0      0.0
5.0
```