TABLE 5 FRICTION FACTORS[1]

Airway Type	Degree of Surface Irregularity	Straight			Sinuous or Curved: Slightly			Moderately			Highly		
		Amount of Obstruction - C=Clean, S=Slight, M=Moderate											
		C	S	M	C	S	M	C	S	M	C	S	M
Smooth/Lined	Minimum	10	15	25	20	25	35	25	30	40	35	40	50
	Average	15	20	30	25	30	40	30	35	45	40	45	55
	Maximum	20	25	35	30	35	45	35	40	50	45	50	60
Sedimentary Rock or Coal	Minimum	30	35	45	40	45	55	45	50	60	55	60	70
	Average	55	60	70	65	70	80	70	75	85	80	85	95
	Maximum	70	75	85	80	85	95	85	95	100	95	100	110
Timbered (5-ft centers)	Minimum	80	85	95	90	95	105	95	100	110	105	110	120
	Average	95	100	110	105	110	120	110	115	125	120	125	135
	Maximum	105	110	120	115	120	130	120	125	135	130	135	145
Igneous Rock	Minimum	90	95	105	100	105	115	105	110	120	115	120	130
	Average	145	150	160	155	160	165	160	165	175	170	175	195
	Maximum	195	200	210	205	210	220	210	215	225	220	225	235

Friction Factor Units are $1.0*E^{-10}$ $lbm*min^2/ft^4$

[1] McElroy, G.E., Engineering Factors in the Ventilation of Metal Mines, U.S. Bureau of Mines, Bulletin 385, 1932

TABLE 6 THERMAL PROPERTIES OF ROCK

The thermal properties of rock required for MFIRE input are thermal conductivity, k, and thermal diffusivity, α. A third thermal property, constant pressure specific heat, C_p, may be used along with density, ρ, to relate k and α as,

$$k = \alpha * \rho * C_p$$

MFIRE uses thermal conductivity in units of BTU/hr*ft*°F and thermal diffusivity in units of ft^2/hr. Multiply SI thermal conductivity in units of W/m*°K by 0.5782 to obtain thermal conductivity in units of BTU/hr*ft*°F. Likewise, multiply SI thermal diffusivity units of m^2/s by 38,750 to obtain thermal diffusivity units of ft^2/hr.

The data in this appendix were assembled or calculated or extrapolated from various sources and is intended to provide a starting point for MFIRE users. Published data from other sources may range ± 100 pct or more from these values due to measurement methods and rock variations. In situ conditions, especially porosity and pore fluid greatly influence data values. In most cases the exact value is not critical as most of the thermal energy from a mine fire is carried away from the fire by the airflow and transferred to the rock at low rates over comparatively long distances and consequently a large surface area. If parametric simulations with MFIRE show that these values are critical to the outcome of a particular simulation, the user should thoroughly investigate the thermal properties of the rock in question.

ROCK/MATERIAL	Thermal conductivity, k	Thermal Diffusivity, α
	BTU/hr*ft*°F	ft^2/hr
brick	0.4	0.02
basalt	0.6 - 1.4	0.02 - 0.04
calcite	0.2	0.006
clay	0.8	0.004
anthracite coal	0.2	0.006
concrete	0.5 - 0.8	0.02 - 0.03
diabase	1.1 - 1.3	0.03 - 0.04
dolo-stone	0.8 - 3.6	0.02
granite	1.0 - 3.4	0.03 - 0.09
limestone	0.7 - 3.6	0.02 - 0.1
marble	1.2 - 3.2	0.03 - 0.08
sandstone	0.9 - 2.2	0.03 - 0.06

APPENDIX 2   INPUT DATA FILE TEMPLATE

```
$----------------------------------------------------------------------$
$                                                                      $
$      ***  INPUT FORMAT INSTRUCTION FILE FOR PROGRAM MFIRE   ***      $
$                                                                      $
$    GENERAL RULES FOR DATA INPUT:                                     $
$                                                                      $
$   * NO NEED TO DISTINGUISH INTERGER AND REAL NUMBERS. SYMBOLS USED   $
$   IN NUMERICAL INPUT COMPRISE THE FOLLOWING LIST:                    $
$            1 2 3 4 5 6 7 8 9 0 . , - + BLANK                         $
$   * FREE FORMAT ALLOWED. COMMA AND BLANK SPACE CAN BOTH BE DELIMINA- $
$   TORS. SEQUENTIALLY DISTRIBUTED BLANK SPACES ACT AS ONE DELIMINATOR.$
$   BLANKS ADJACENT TO A COMMA HAS NO EFFECT IN SEPARATING INPUT TERMS.$
$   * ZERO INPUT CAN BE OMITTED BUT ITS DELIMINATOR CAN'T EXCEPT BEING $
$   THE LAST ONE IN A LINE.                                            $
$   * A LINE WHOSE FIRST NON-BLANK SYMBOL IS "$" IS AN INSTRUCTION     $
$   LINE WHICH WILL BE IGNORED IN A PROGRAM RUN.                       $
$   * A LINE WHOSE FIRST NON-BLANK SYMBOL IS NEITHER ONE USED IN THE   $
$   ABOVE LIST FOR NUMERICAL INPUT NOR "$", OR WHICH CONTAINS MORE     $
$   THAN 3 SYMBOLS OUTSIDE OF THE LIST, IS A COMMENT LINE WHICH WILL   $
$   BE SHOWN IN THE OUTPUT FILE.                                       $
$----------------------------------------------------------------------$

$----------------------------------------------------------------------$
$   (1) COMMENTS  (OPTIONAL)                                           $
$                                                                      $
$     YOU MAY PUT NOTES HERE TO REMIND YOU IN THE FUTURE. THEY WILL BE $
$   SHOWN IN THE OUTPUT FILE. THE NUMBER OF TOTAL ACTIVE COMMENT LINES $
$   IS 50. THE ACTIVE WIDTH OF A LINE IS 72 COLUMNS.                   $
$-----------------   INPUT YOUR COMMENTS HERE    ----------------------$

$----------------------------------------------------------------------$
$  (2) CONTROL CARD I:                                                 $
$     NB,NFNUM,INFLOW,NVPN,NETW,TR,MADJ,ITN,NTEMP,TINC,SPAN,IOUT,TOUT  $
$     CONCT,DR                                                         $
$                                                                      $
$     NB: NUMBER OF AIRWAYS IN NETWORK, MAX. 500                       $
$     NFNUM: NUMBER OF FAN CHARACTERISTICS, MAX. 10.                   $
$     INFLOW: NUMBER OF CONTAMINATION SOURCES, MAX. 10.                $
$     NVPN: MARKER FOR PRESENCE OF JUNCTION CARDS, 0: PRESENT.         $
$     NETW: MARKER, 1: ONLY THE NETWORK PART WILL BE PERFORMED.        $
$     TR: REFERENCE TEMPERATURE OF AIR, DEG. F. DEFAULT VALUE 75.      $
$     MADJ: MAX. NO. OF ITERATION IN TEMP. PART. DEFAULT 20.           $
$     ITN: MAX. NO. OF ITERATION IN DYNAMIC PART, DEFAULT 20.          $
$     NTEMP: MARKER. 1: SIMULATION GOES ONLY UP TO TEMPERATURE PART.   $
$     TINC: TIME INCREMENT IN DYNAMIC SIMULATION PART, SEC.            $
$     SPAN: TIME SPAN OF DYNAMIC SIMULATION, MIN.                      $
$     IOUT: OUTPUT, 0: BRIEF; 1: NORMAL; -1: DETAIL; -2; MORE DETAILED.$
$     TOUT: TIME INTERVAL FOR OUTPUT, IN MIN.                          $
```

```
$     CONCT: MARKER. 1: SIMULATION GO TO TRANSIENT CONCENTRATION ONLY  $
$                    0: SIMULATION GO TO ALL TRANSIENT STATE           $
$     DR: REFERENCE DENSITY IN LBM/FT3, DEFAULT BASED ON TR AND 1 ATM. $
$                                                                      $
$           ***  INPUT DATA FOR CONTROL CARD I HERE   ***              $
$NB,NFNUM,INFLOW,NVPN,NETW,TR,MADJ,ITN,NTEMP,TINC,SPAN,IOUT,TOUT,CONCT,DR

$  AIRWAY LINES HERE
$     NO,JS,JF,NWTYP,R,Q,KF,LA,A,O,HA,HK,CH4V,CH4PA,TROCK              $
$                                                                      $
$   * IF NB IS 2 OR LARGER, THE NUMBER OF AIRWAY CARDS (LINES) MUST BE $
$   NB. IF NB IS 1 OR LESS, THE AIRWAY CARDS MUST END WITH 9999.       $
$   * KF,LA,A,O,HA,HK HAVE THEIR AVERAGE OR DEFAULT VALUES WHICH ARE   $
$   ACTIVATED BY INPUTING ZERO FOR THE RESPECTIVE TERMS.               $
$   * TROCK DOES NOT NEED TO INPUT EXCEPT WHEN YOU WANT TO OVERRIDE THE$
$   PROGRAM CALCULATED VALUE.                                          $
$   * COMMENT LINES ARE ACTIVE IN THIS DATA PARAGRAPH.                 $
$                                                                      $
$     NO:    AIRWAY ID NUMBER (1 TO 9980).                             $
$     JS:    JUNCTION ID NUMBER OF AIRWAY BEGINNING (1 TO 999).        $
$     JF:    JUNCTION ID NUMBER OF AIRWAY END (1 TO 999).              $
$     NWTYP: AIRWAY TYPE, 1: FAN; 0: ORDINARY; -1: FIXED-Q.            $
$     R:     RESISTANCE OF AIRWAY 1.E-10 IN. W.G./(CFM)2.              $
$     Q:     AIRFLOW RATE IN CFM.                                      $
$     KF:    FRICTION FACTOR IN 1.E-10 LBM*MIN2/FT4.                   $
$     LA:    AIRWAY LENGTH IN FT.                                      $
$     A:     AIRWAY CROSS SECTIONAL AREA IN FT**2.                     $
$     O:     AIRWAY PERIMETER IN FT.                                   $
$     HA:    THERMAL DIFFUSIVITY OF ROCK, FT2/HR.                      $
$     HK:    THERMAL CONDUCTIVITY OF ROCK, BTU/HR*FT*F.                $
$     CH4V:  METHANE EMISION RATE IN AIRWAYS FT3/MIN.                  $
$     CH4PA: METHANE EMISION RATE PER UNIT SURFACE AREA, FT/MIN.       $
$     TROCK: AVERAGE ROCK TEMPERATURE IN AIRWAY, DEGREE F.             $
$                                                                      $
$            ***   INPUT DATA FOR AIRWAY CARDS HERE   ***              $
$-------- NO,JS,JF,NWTYP,R,Q,KF,LA,A,O,HA,HK,CH4V,CH4PA,TROCK ---------$

$----------------------------------------------------------------------$
$   (4) JUNCTION CARDS:                                                $
$     JNO,T,Z,CH4C                                                     $
$                                                                      $
$   * IF NVPN IS 0 OR LESS, EACH JUNCTION SPECIFIED IN JS AND JF  MUST $
$   HAVE  A ONE-LINE INPUT HERE. OTHERWISE JUNCTION CARDS MUST BE      $
$   OMITTED.                                                           $
$                                                                      $
$     JNO:   JUNCTION ID NUMBER (1 TO 999)                             $
$     T:     TEMPERATURE OF AIR IN JUNCTIONS, DEGREE F.                $
$     Z:     ELEVATION OF JUNCTIONS, FT.                               $
$     CH4C:  METHANE CONCENTRATION IN JUNCTIONS, PERCENTAGE.           $
$                                                                      $
$              ***    INPUT JUNCTION CARDS HERE    ***                 $
$------------------------- JNO,T,Z,CH4C -------------------------------$
```

```
$-----------------------------------------------------------------------$
$      (5) JUNCTION CARDS II (JUNCTIONS IN THE ATMOSPHERE)              $
$     A STARTING JUNCTION IS THE JUNCTION WHERE ATMOSPHERE CONDITIONS   $
$   ARE DEFINED. ALL OTHER JUNCTIONS ON THE SURFACE ARE JUNCTIONS IN    $
$   THE ATMOSPHERE.                                                     $
$     IF THERE ARE MORE THAN ONE JUNCTION IN THE ATMOSPHERE, JUNCTION   $
$   CARD II IS EMPLOYED. OTHERWISE, ONLY NUMBER "1" IS READ IN.         $
$                                                                       $
$      JAN: THE NUMBER OF THE JUNCTIONS IN THE ATMOSPHERE               $
$      JA:  JUNCTION ID NUMBER                                          $
$      JATP: JUNCTION TYPE:                                             $
$            0: STARTING JUNCTION                                       $
$            1: OTHER ATMOSPHERE JUNCTIONS EXCEPT STARTING JUNCTION     $
$                                                                       $
$          ****    INPUT DATA FOR JUNCTION CARD II HERE    ****         $
                                                              $
$--------------------------- JAN ---------------------------------------$
$------------------------- JA,JATP -------------------------------------$

$-----------------------------------------------------------------------$
$      FAN CARDS I AND II COMPRISE A DATA GROUP WHICH MUST REPEAT NFNUM $
$    TIMES FOR NFNUM FAN CURVES. IF NFNUM IS 0 OR LESS, FAN CARDS I AND $
$    II MUST BE OMITTED.                                                $
$                                                                       $
$    (5) FAN CARD I:                                                    $
$      NOF,MPTS,NSWT                                                    $
$      NOF:   ID NUMBER OF FAN BRANCH.                                  $
$      MPTS:  NUMBER OF POINTS DEFINING FAN CHAR, MAXIMUM 10.           $
$      NSWT:  SELECTION OF FAN CURVE FITTING, 1: LEAST SQUARES          $
$             2: SPLINE  3. AUTO  4.AUTO+MANUAL                         $
$    (6) FAN CARD II:  (IF MPTS IS LARGER THAN 5, CONTINUE IN 2ND LINE.)$
$      QF,PF,QF,PF,QF,PF,QF,PF,QF,PF                                    $
$      QF:    AIRFLOW AT GIVEN POINT OF FAN CHAR, CFM.                  $
$      PF:    PRESSURE AT GIVEN POINT OF FAN CHAR, IN.W.G.              $
$    (7) FAN CARD III: NPLOT                                            $
$      NPLOT: TREATMENT OF THE BOUNDARY RANGE OF FAN CURVE              $
$             1: EXTEND FAN CURVE BY FOLLOWING GRADIENTS OF TWO ENDS.   $
$             2: EXTEND FAN CURVE AS ABOVE AT LEFT BOUNDARY REGION AND  $
$                SEND GRADIENT OF RIGHT BOUNDARY REGION TO ZERO.        $
$             3. SEND GRADIENT OF BOTH SIDES OF BOUNDARY REGION TO ZERO.$
$             ***    INPUT FAN CARDS I,II, AND III HERE    ***          $
$--------------------------- NOF,MPTS,NSWT -----------------------------$
$------------------ QF,PF,QF,PF,QF,PF,QF,PF,QF,PF ----------------------$
$-----------------------------NPLOT-------------------------------------$


$-----------------------------------------------------------------------$
$    (7) CONTAMINATION (HEAT SOURCE) CARDS:                             $
$      NCENT,CONT,CONC,HEAT,O2MIN,SMPO2,HTPO2,QCENT,TPR                 $
$                                                                       $
```

```
$   * EACH HEAT SOURCE MUST HAVE  A ONE-LINE INPUT HERE. THE NUMBER OF $
$   TOTAL FIRE SOURCES WAS SPECIFIED BY "INFLOW" IN CONTROL CARD I.    $
$                                                                      $
$     NCENT: ID NUMBER OF AIRWAYS WHERE HEAT SOURCES LOCATE.           $
$     CONT:  VOLUME FLOW RATE OF CONTAMINATED GAS INFLOW IN CFM.       $
$     CONC:  CONCENTRATION OF CONTAMINANT IN GAS INFLOW, %.            $
$     HEAT:  HEAT ENTERING OR LEAVING AIRWAY IN BTU/MIN.               $
$     O2MIN: OXYGEN CONCENTRATION OF AIR CURRECT LEAVING FIRE ZONE, %. $
$     SMPO2: CONTAMINANT PRODUCTION PER FT**3 OF OXYGEN DELIVERY.      $
$     HTPO2: HEAT PRODUCTION (BTU) PER FT**3 OF OXYGEN DELIVERY.       $
$     QCENT: REF. Q DEFINING FIRE CHARACTERISTICS, CFM.                $
$     TPR: LEADING TIME PERIOD IN MIN. FOR FIRE TO REACH FULL STRENGTH.$
$                                                                      $
$           ***    INPUT DATA FOR FIRE SOURCES HERE      ***           $
$---------- NCENT,CONT,CONC,HEAT,O2MIN,SMPO2,HTPO2,QCENT,TPR ----------$


$----------------------------------------------------------------------$
$   (8) CONTROL CARD II                                                $
$   NAV,JSTART,TSTART,TIME,CRITSM,CRITGS,CRITHT,WRNPR,WRNSM,WRNGS,WRNHT$
$                                                                      $
$   * A SET OF DEFAULT VALUES ARE AVAILABLE. THEY CAN BE ACTIVATED BY  $
$   INPUTING ZERO FOR THE RESPECTIVE TERMS.                            $
$                                                                      $
$     NAV: MARKER. 1 OR LARGER: AVERAGE-VALUE CARD IS PRESENT.         $
$     JSTART: STARTING JUNCTION (ATMOSPHERE).                          $
$     TSTART: TEMPERATURE AT THE START JUNCTION, DEGREE F.             $
$     TIME: TIME SPAN TO ASSUME QUASI-EQUILIBRIUM, HOUR. DEFAULT 10.   $
$     CRITSM: ACCURACY IN FUME CALCULATION, %. DEFAULT 0.005.          $
$     CRITGS: ACCURACY IN METHAME CALCULATION, %, DEFAULT .01.         $
$     CRITHT: ACCURACY IN TEMPERATURE CALCULATION, F. DEFAULT 0.1.     $
$     WRNPR: PRESSURE DROP WARNING CRITERIA, IN.W.G. DEFAULT 0.01.     $
$     WRNSM: FUME CONCENTRATION WARNING CRITERIA, %. DEFAULT 0.05.     $
$     WRNGS: METHANE CONCENTRATION WARNING CRITERIA, %. DEFAULT 1.0.   $
$     WRNHT: HIGH TEMPERATURE WARNING CRITERIA, F. DEFAULT 100.0.      $
$                                                                      $
$          ***    INPUT DATA FOR CONTROL CARD II HERE    ***           $
$- NAV,JSTART,TSTART,TIME,CRITSM,CRITGS,CRITHT,WRNPR,WRNSM,WRNGS,WRNHT-$


$----------------------------------------------------------------------$
$   (9) AVERAGE-VALUE CARD:                                            $
$     HAAVR,HKAVR,KFAVR,LAAVR,AAVR,OAVR                                $
$                                                                      $
$     IT MUST EXIST IF NAV IN CONTROL CARD II IS 1 OR LARGER. A DEFAULT$
$   VALUE CAN BE ACTIVATED BY INPUTING ZERO FOR THE RESPECTIVE TERM.   $
$   WHEN NAV IS ZERO OR LESS, THE WHOLE SET OF DEFAULT VALUES WILL BE  $
$   TAKEN.                                                             $
$                                                                      $
$     HAAVR: AVERAGE THERMAL DIFFUSIVITY OF ROCK, FT2/HR. DEFAULT 0.1. $
$     HKAVR: AVERAGE THERMAL CONDUCTIVITY OF ROCK, BTU/HR*FT*F.        $
$            DEFAULT 3.0.                                              $
```

```
$     KFAVR: FRICTION FACTOR, 1.E-10 LBM*MIN2/FT4. DEFAULT 100.        $
$     LAAVR: AVERAGE LENGTH OF AIRWAY, FT. DEFAULT 500.                $
$     AAVR: AVERAGE SECTIONAL AREA OF AIRWAY, FT2. DEFAULT 100.        $
$     OAVR: AVERAGE PERIMETER, FT. DEFAULT 40.                         $
$                                                                      $
$         ***   INPUT AVERAGE-VALUE CARD HERE IF NEEDED   ***          $
$---------------- HAAVR,HKAVR,KFAVR,LAAVR,AAVR,OAVR -----------------$

$--------------------------------------------------------------------$
$    (10) TIME TABLE FOR CONDITION CHANGES:                            $
$                                                                      $
$      THIS TIME TABLE CAN CONTAIN THE FOLLOWING CONDITION CHANGES. IT $
$    MUST END WITH A ONE-LINE INPUT OF A VALUE LARGER THAN "SPAN" IN   $
$    CONTROL CARD I. THIS TIME TABLE MUST EXIST, BUT MAY CONTAIN ONLY  $
$    THE ENDING LINE. THE ORDER OF CHANGING CONDITIONS MUST BE ARRANGED$
$    ACCORDING TO THE RESPECTIVE OCCURING TIME.                        $
$                                                                      $
$    1) TS,1,NBR,R                                                     $
$       THIS INPUT CHANGES BRANCH "NBR" TO AN ORDINARY AIRWAY WITH     $
$     AIRFLOW RESISTANCE EQUAL TO "R" AT "TS" MIN. AFTER TIME ZERO.    $
$       TS: OCCURING TIME OF THE CHANGE CONDITION, MIN.                $
$       NBR: AIRWAY ID NUMBER.                                         $
$       R: RESISTANCE OF AIRWAY 1.E-10 IN. W.G./(CFM)2.                $
$    2) TS,2,NBR,INDEX,QF1,PF1,QF2,PF2,QF3,PF3,QF4,PF4,QF5,PF5         $
$       THIS INPUT CHANGES BRANCH "NBR" TO A FAN BRANCH WITH ITS       $
$     CHARACTERISTICS SPECIFIED BY "QF1" TO "PF5".                     $
$       INDEX: NUMBER OF DATA POINTS TO DEFINE FAN CHAR. MAX. 5.       $
$       QF: AIRFLOW RATE IN FT**3/MIN.                                 $
$       PF: CORRESPONDING FAN PRESSURE IN IN. W.G.                     $
$    3) TS,3,NBR,CONT,CONC,HEAT,02MIN,SMPO2,HTPO2,QCENT,TPR            $
$       THIS INPUT CHANGES BRANCH "NBR" TO A FIRE SOURCE BRANCH WITH   $
$     FIRE CHAR. SPECIFIED BY "CONT" TO "TPR", WHICH RETAIN THE SAME   $
$     MEANING AS IN FIRE SOURCE CARD (7). REFER BACK TO (7) FOR DETAIL $
$    4) TS,4,NBR                                                       $
$       THIS INPUT CHANGES FIRE BRANCH "NBR" TO AN ORDINARY AIRWAY AT  $
$     TIME "TS".                                                       $
$    5) TS,5,TINC                                                      $
$       THIS INPUT CHANGES TIME INCREMENT IN SYNAMIC SIMULATION TO A   $
$     NEW VALUE "TINC" IN SEC.                                         $
$    6) TS,6,TOUT                                                      $
$       THIS INPUT CHANGES OUTPUT INTERVAL TO A NEW VALUE OF "TOUT"    $
$     MIN.                                                             $
$    7) TS,7,JDPP                                                      $
$       THIS INPUT FORCES DETAILED RECORDS TO BE SET UP FOR AIRWAYS    $
$     WHICH ARE ON THE IMMEDIATE DOWN-STREAM SIDE OF JUNCTION "JDPP"   $
$     AT "TS" MIN. AFTER TIME ZERO.                                    $
$                                                                      $
$         ***    INPUT CONDITION CHANGE TIME TABLE HERE    ***         $
$-- (IT MUST END WITH A ONE-LINE VALUE LARGER THAN "SPAN" IN CARD I) --$
```

APPENDIX 3 PROGRAM LISTING OF MFIRE VARIABLES

```
C     NB: NUMBER OF AIRWAYS IN NETWORK.
C     NJ: NUMBER OF JUNCTIONS IN NETWORK.
C     NFNUM: NUMBER OF FAN CHARACTERISTICS.
C     NVPN: MARKER FOR PRESENCE OF JUNCTION CARDS, 0: PRESENT.
C     NETW: MARKER, 1: ONLY THE NETWORK PART WILL BE PERFORMED.
C     NTEMP: MARKER, 1: ONLY UP TO THE TEMP. PART WILL BE PERFORMED.
C     MADJ: MAX. NO. OF ITERATION IN TEMP. PART.
C     ITN: MAX. NO. OF ITERATION IN NON-STEADY STATE SIMULATION.
C     DR: REFERENCE DENSITY OF AIR, LBM/FT3.
C     TR: REFERENCE TEMPERATURE OF AIR, DEG. F.
C     TINC: TIME INCREMENT IN SIMULATION, SEC..
C     SPAN: TIME SPAN OF SIMULATION, MIN..
C     IOUT: OUTPUT. 0: BRIEF; 1: NORMAL; -1: DETAIL; -2: MORE DETAILED.
C     TOUT: TIME INTERVAL FOR OUTPUT, MIN.
C     CONCT: MARKER. 1: SIMULATION FOR TRANSITE CONCENTRATION SIMULA-
C                       TION ONLY
C     NAV: MARKER FOR PRESENCE OF AVE. VALUE CARDS.
C     MAXJ: HIGHEST JUNCTION NUMBER.
C     INFLOW: NUMBER OF CONTAMINATION CARDS.
C     CRITSM: ACCURACY OF FUME CALCULATION.
C     CRITGS: ACCURACY OF METHAME CALCULATION.
C     CRITHT: ACCURACY OF TEMPERATURE CALCULATION.
C     NO(NMX): AIRWAY NUMBER.
C     JS(NMX): JUNCTION NUMBER OF AIRWAY BEGINNING.
C     JF(NMX): JUNCTION NUMBER OF AIRWAY END.
C     NWTYP(NMX): AIRWAY TYPE.
C     R(NMX): RESISTANCE OF AIRWAY 1.E-10 IN. W.G./(CFM)**2.
C     Q(NMX): BALANCED AIRFLOW RATE, ASSUMING EQUILIBRIA, CFM
C     P(NMX): CALCULATED PRESSURE LOSS IN IN. W.G..
C     KF(NMX): FRICTION FACTOR.
C     LA(NMX): AIRWAY LENGTH IN FT.
C     A(NMX): AIRWAY CROSS SECTIONAL AREA IN FT**2.
C     O(NMX): AIRWAY PERIMETER IN FT.
C     RSTD(NMX): RESISTANCE FACTOR BASED ON TR.
C     DZRD(NMX): ELEVATION CHANGE IN AIRWAY IN FT.
C     FRNVP(NMX): PRODUCT TMRD*DZRD.
C     NREV(NMX): NUMBER OF AIRFLOW REVERSALS IN AN INTERVAL.
C     RDCH4(NMX): METHANE CONCENTRATION AT ROADWAY ENDS.
C     RDPROP(NMX): CONTAMINANT CONCENTRATION AT ROADWAY ENDS.
C     TRD(NMX): TEMPERATURE AT ROADWAY ENDS.
C     TJS(NMX): TEMPERATURE AT ROADWAY BEGINNING.
C     RDOP(NMX): BACKUP ARRAY FOR RDPROP.
C     RCH4(NMX): BACKUP ARRAY FOR RDCH4.
C     FFRNVP(NMX): DZRD/TMRD.
C     RA(NMX): BACKUP ARRAY FOR R.
C     NNREV(NMX): NUMBER OF AIRFLOW REVERSALS SINCE TIME ZERO..
C     NOF(IMX): AIRWAY NUMBER OF FAN.
C     NFREG(IMX): LIST OF FANS WITH CHARACTERISTICS.
C     RGRAD(IMX): SLOPE OF FAN CHARACTERISTIC.
C     NFCW(IMX): LIST OF FANS WHOSE CHAR. EXCEEDED.
C     MPTS(IMX): NUMBER OF POINTS DEFINING FAN CHAR.
C     QF(IMX,IMY): AIRFLOW AT GIVEN POINT OF FAN CHAR.
C     PF(IMX,IMY): PRESSURE AT GIVEN POINT OF FAN CHAR.
C     NSKP(IMX): MARKER INDICATING PERFORMANCE OF SPLINE.
C     NEGQ(IMX): MARKER INDICATING AIRFLOW REVERSAL IN FAN BRANCH.
C     JSB(NMX): BACKUP ARRAY FOR JS.
C     NSWT(NMX): SWTCH TO SELECTED FAN CURVE FITTING METHOD
C                1 LEAST SQUARE 2.SPLINE 3.AUTOMATIC 4.AUTO+MANUAL

C     MNO: NUMBER OF MESHES IN NETWORK.
```

```
C      MEND(NMY): LIST OF MESH ENDS IN MSL-LIST.
C      MSL(LMX): LIST OF ALL INDEPENDENT MESHES.
C      FNVP(NMY): LIST OF NVP IN MESHES.
C      RQ(NMX): AUXILIARY LIST OF R*Q.
C      INU(NMX): AUXILIARY LIST FOR FORMING BASE SYST.
C      KNO(NXX): LIST OF AIRWAYS IN BASE SYSTEM.
C      KJS(NXX): LIST OF JUNCTIONS IN BASE SYSTEM.
C      KJF(NXX): LIST OF JUNCTIONS IN BASE SYSTEM.
C      JNO(NMY): JUNCTION NUMBER.
C      T(NMY): TEMPERATURE OF AIR IN JUNCTIONS.
C      Z(NMY): ELEVATION OF JUNCTIONS.
C      CH4C(NMY): METHANE CONCENTRATION IN JUNCTION.
C      JNOL(NMY): LIST OF JUNCTION NUMBERS IN INCREASING ORDER.
C      PROP(NMY): CONTAMINANT CONCENTRATION IN JUNCTION.
C      PRCH4(NMY): METHANE CONCENTRATION IN JUNCTION.
C      JLR(NMY): LIST RELATING JNO- AND JNOL-LISTS.
C      TROCK(NMX): AVERAGE ROCK TEMPERATURE IN AIRWAY.
C      TMRD(NMX): MEAN TEMPERATURE OF AIR IN AIRWAY.
C      HA(NMX): THERMAL DIFFUSIVITY OF ROCK.
C      HK(NMX): THERMAL CONDUCTIVITY OF ROCK.
C      NCENT(NMX): NUMBER OF AIRWAYS INTO WHICH FUME ENTERS.
C      CH4V(NMX): METHANE EMISION RATE IN AIRWAYS.
C      CH4PA(NMX): METHANE EMISION RATE PER UNIT SURFACE AREA.
C      CONT(IMX): VOLUME FLOW RATE OF CONTAMINATED GAS INFLOW.
C      CONC(IMX): CONCENTRATION OF CONTAMINANT IN GAS INFLOW.
C      HEAT(IMX): HEAT ENTERING AIRWAY.
C      O2MIN(IMX): OXYGEN CONCENTRATION OF FUMES LEAVING FIRE ZONE
C      SMPO2(IMX): CONTAMINANT PRODUCTION PER CUBIC FT OF OXYGEN.
C      HTPO2(IMX): HEAT PRODUCTION PER CUBIC FT OF OXYGEN DELIVERY
C      TFSI(IMX): AIR TEMPERATURE BEHIND HEAT SOURCE.
C      O2BEH(IMX): OXYGEN CONTENT BEHIND FIRE SOURCES.
C      TPR(IMX): TRANSITION TIME OF FIRE IN MIN.
C      HTAD(IMX): REDUCED HEAT INPUT DUE TO HIGH AIR TEMPERATURE.
C      QCENT(IMX): "STD. Q' AT WHCIH FIRE TAKES THE INPUT PARAMETERS.
C      NGIN(NMX): LIST OF AIRWAYS ENTERING JUNCTION.
C      MMIN(NMX): LIST OF LAST AIRWAY PER JUNCTION IN NGIN-LIST.
C      NGOUT(NMX): LIST OF AIRWAYS LEAVING JUNCTION.
C      LOUT(NMX): LIST OF LAST AIRWAY PER JUNCTION IN NGOUT-LIST.
C      MEMREC(NMX): TEMPORARY LIST OF AIRWAYS CARRYING RECIRC. AIR.
C      NOREC(NMX): PERMANENT LIST OF AIRWAYS.
C      ESTPR(NMX): ESTIMATED CONCENTRATION FOR RECIRCULATED AIR.
C      ESTCH4(NMX): ESTIMATED METHANE CONCENTRATION.
C      ESTTR(NMX): ESTIMATED TEMPERATURE.
C
C      XNEW(NMX): EXPONENT FOR TEMPERATURE CALCULATION.
C      DCOAGE(NMX): COEFFICIENT OF AGE.
C      TIME: TIME ASSUMING QUASI-EQUILIBRIA.
C      TSTART: TEMPERATURE AT THE START JUNCTION.
C      JSTART: START JUNCTION (ATMOSPHERE).
C      TLEFT(NMX): TIME INCREMENT FOR MAKING UP A NORMAL INTERVAL.
C      SUMQ(NMY): TOTAL AIRFLOW RATES ENTERING JUNCTION.
C      SUMC(NMY): TOTAL CONTAMINANT FLOW RATES ENTERING JUNCTION.
C      SUMM(NMY): TOTAL METHANE FLOW RATES ENTERING JUNCTION.
C      SMHEAT(NMY): TOTAL ENTHALPY/REFRENCE DENSITY ENTERING JUNCTI
C      PROPS(NMX): BACKUP ARRAY FOR PROP.
C      PRCH4S(NMX): BACKUP ARRAY FOR PRCH4.
C      QQ(NMX): DAMPED AND TIME-AVERAGED AIRFLOW RATE.
C      QTP(NMX): BACKUP ARRAY FOR Q, FIXED IN EACH INTERVAL.
C      TTJS(NMX): BACKUP ARRAY FOR TJS.
C      TTRD(NMX): BACKUP ARRAY FOR TRD.
C      TAS(NMX): BACKUP ARRAY OF T.
C      BI(NMX): BIOT NUMBER.
```

```
C      WRNPR: PRESSURE DROP WARNING CRITERIA.
C      WRNGS: METHANE CONCENTRATION WARNING CRITERIA.
C      WRNSM: FUME CONCENTRATION WARNING CRITERIA.
C      WRNHT: HIGH TEMPERATURE WARNING CRITERIA.
C      IOMIT(IMX): AIRWAYS FOR WHICH DETAILED DATA RECORDS WERE OMITTED.
C      ROMIT(IMX,3): DATA AT STARTING J OF DATA-OMITTED AIRWAY.
C      IAC: COUNTER OF IOMIT AND ROMIT.
C      DELTAT: SPAN OF TIME INCREMENT.
C      TACC: CUMULATED TIME AFTER EVENT IN SEC.
C      SUMFNV: SUM OF NVP CORRECTION IN SYSTEM.
C      IBTN(NMX): ARRAY HOLDING ADDRESS OF RECORD FOR AIRWAY (N
C      DPPA(NMZ,10,5): MASTER DATA STORAGE ARRAY IN DYNAMIC SIMULATI
C      NSAC(NMX,2): DATA RECORD STATUS OF AIRWAY (NMX).
C      TMRDA(NMX): BACKUP ARRAY FOR TMRD.
C      DELTAQ(NMX): VARIATION OF AIRFLOW IN AIRWAYS.
C      DPPB(NMZ,10,5): BACKUP ARRAY FOR DPPA.
C      NSACB(NMX,2): BACKUP ARRAY FOR NSAC.
C      GBTN(10,5): AUXILIARY ARRAY FOR DATA TRANSFER.
C      JCH(NMY): MARKER INDICATING JUNCTION COND. CHANGE.
C      TAUXA(NMZ,10): AIR TEMP. AT REAR ENDING OF SEGMENTS.
C      TAUXB(NMZ,10): BACKUP ARRAY FOR TAUXA.
C      TAUXC(NMZ): AIR TEMP. BEYOND THE FIRST SEGMENT.
C      TAUXD(NMZ): BACKUP ARRAY OF TAUXC.
C      FMASS(NMZ): MASS OF AIR BEYOND THE FIRST SEGMENT.
C      JDP: NUMBER OF JUNCTIONS INITIATING DATA RECORDS.
C      JDPP(IMX): JUNCTIONS WHICH INITIATE DATA RECORDS.
C      QRCD(NMX,10): AIRFLOW RATES DURING ITERATIONS.
C      TMRCD(NMX,10): MEAN AIR TEMP. IN AIRWAYS DURING ITERATION.
C      HRM(IMX): VARIATION OF NVP PER MESH DURING ITERATION.
C      JAN:  TOTAL NUMBER OF ATMOSPHERE JUNCTIONS
C      JAJ:  NUMBER OF ATMOSPHERE JUNCTIONS EXCEPT STARTING JUNCTION
C      JA1(10):  JUNCTION ID NUMBER (IN ATMOSPHERE)
C      JATP(10): JUNCTION TYPE (IN ATMOSPHERE)
C      JSTAR(10): JUNCTIONC CONNECTED WITH ENTRY AIRWAYS EXCEPT STARING
C                 JUNCTION
C      TSTAR(10): TEMPERATURE IN THE JUNCTION AT ARRAY (JSTAR)
C      MSTAR(10): JUNCTION NUMBER CORRESPONDING TO ARRAY (JNOL)
C      ISTAR(10): JUNCTION NUMBER CORRESPONDING TO ARRAY (JNO)
C      TTT: INTERMEDIATE ARRAY FOR TEMPERATURE WHEN SIMULATE FOR TRANSIENT
C           CONCENTRATION SIMULATION ONLY (CONCT=1).
C      TJSS:INTERMEDIATE ARRAY OFR TTJS WHEN CONCT=1.
C      TRDD: INTERMEDIATE ARRAY FOR TTRD WHEN CONCT=1.
C      QQQ:  INTERMEDIATE ARRAY FOR QQQ WHEN CONCT=1.
C      COF: THE COEFFIENT OF FAN EQUATION FITTED BY LEAST SQUARES.
C      ND: THE DEGREE OF FAN EQUATION FITTED BY LEAST SQUARES.
C      N1A: THE NUMBER OF COEFFICIENTS OF FAN EQUATION.
C      NSWT: TO SELECT FAN CURVE FITTING METHOD
C                 1 LEAST SQUARE 2.SPLINE 3.AUTOMATIC 4.AUTO+MANUAL
C      NCOF: ARRAY FOR THE NUMBER OF COEFFICIENTS OF FAN EQUATION
C      INIFAN: THE FLAG SHOWS THE LARGE STATE CHANGE IN SYSTEM AND THE
C              MESHES REFORM DESIRED.
C      NPLOT: TREATMENT OF THE BOUNDARY RANGE OF FAN CURVE
C             1: EXTEND FAN CURVE BY FOLLOWING GRADIENTS OF TWO ENDS.
C             2: EXTEND FAN CURVE AS ABOVE AT LEFT BOUNDARY REGION AND
C                SEND GRADIENT OF RIGHT BOUNDARY REGION TO ZERO.
C             3. SEND GRADIENT OF BOTH SIDES OF BOUNDARY RANGE TO ZERO.
```

APPENDIX 4 ADDITIONAL INFORMATION SOURCES

DiNenno, P.J., ed., SFPE Handbook of Fire Protection Engineering, First Edition, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA, 1988.

Mitchell, D.W., Mine Fires, Maclean Hunter Publishing Co., 29 North Wacker Dr., Chicago, IL, 1990.

Hartman, H.L., ed., Mine Ventilation and Air Conditioning, Second Edition, John Wiley and Sons, New York, NY, 1982.

Ho, C. Y., series editor, Y. S. Touloukian, W. R. Judd and R. F. Roy, editors, CINDAS DATA SERIES on MATERIAL PROPERTIES, Volume II-2 Physical Properties of Rocks and Minerals