APPENDIX B

Computer Program for Design and Analysis of Detector and Sprinkler Response
C MAIN PROGRAM DET.FOR VERSION 6.1
C
50 WRITE (*,900)
900 FORMAT (/'0PLEASE SELECT ONE OF THE FOLLOWING MENU
+ITEMS. '/
 2 ' 1 - NEW DESIGN '/
 3 ' 2 - ANALYZE AN EXISTING SYSTEM '/
 4 ' 3 - QUIT '/0')
C
100 READ (*,800) MENU1
800 FORMAT (I1)
C
GO TO (10, 20, 9999) MENU1
C
C IF A KEY IS Pressed WHICH DOESN'T CORRESPOND TO A MENU
C SELECTION
WRITE (*,990)
990 FORMAT (/'0INVALID ENTRY, PLEASE ENTER A MENU ITEM
+--NUMBER ONLY.')
GO TO 100
C
10 CALL DESIGN (MENU1)
C
GOTO 50
C
20 CALL EXIST (MENU1)
GOTO 50
C
9999 CONTINUE
C
END
C
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C SUBROUTINE FOR DESIGNING DETECTOR RESPONSE. CALCULATES
C REQUIRED DETECTOR SPACING
C
SUBROUTINE DESIGN (MENU1)
C
C NEWTON SUBROUTINE TO CONVERGE ON A DETECTOR SPACING
C
INTEGER DTYPE
C
TEST IS THE VALUE USED TO TEST THE SLOPE OF THE
FUNCTION USED TO CONVERGE ON R
C
TEST = 1E-10
C
MAX IS THE MAXIMUM NUMBER OF ITERATIONS TO SOLVE FOR R
C
MAX = 30
C
CALL INPUT SUBROUTINE
C
CALL NDIN( H, P, R, ALPHA, DETIME, DTHRESH, DTYPE, 
+ DSENS, QTHRESH, T0, TOL, MENU1 )
THE FOLLOWING LOOP STARTS WITH THE TRIAL R AND CALCULATES THE DETECTOR TEMPERATURE. A NEWTON-RAPHSON ALGORITHM IS USED TO CONVERGE ON R SUCH THAT THE DETECTOR TEMPERATURE IS EQUAL TO THE OPERATING TEMPERATURE WHEN THE FIRE REACHES THE THRESHOLD SIZE

DO 100 I = 1, MAX

CALL THE SUBROUTINE TO CALCULATE DETECTOR TEMPERATURE

CALL FUNCTR(ALPHA, DET, DETIME, DSENS, DTYPE, H, P, R, +T0, MENU1)

R1 = R

INCREMENT R BY A SMALL AMOUNT AND FIND NEW TEMPERATURE

RINC = R + 0.25

CALL FUNCTR(ALPHA, DETINC, DETIME, DSENS, DTYPE, H, P, RINC, +T0, MENU1)

START OF NEWTON-RAPHSON ALGORITHM

FR = DET - DTHRESH

DFR = (DET - DETINC)/(R - RINC)

IF (ABS(DFR) .LE. TEST) THEN
WRITE (*,900)
900 FORMAT (/"WARNING: THE SLOPE OF THE FUNCTION OF R IS CLOSE TO ZERO. "/'0")
ENDIF

DELTAR = FR / DFR

CALCULATE THE NEXT TRIAL VALUE OF R

R = R1 - DELTAR

IF ((ABS(DELTAR)) .LT. (ABS(TOL * R))) THEN
    LEAVE THE DO LOOP WITH THE CORRECT R
    GOTO 200
ENDIF

TEST TO MAKE SURE R DOES NOT GO NEGATIVE. LATER FORMULAS INCLUDE RAISING R TO FRACTIONAL EXPONENTS.

IF (DELTAR .GE. R1) THEN
    DELTAR = 0.95 * R1
R = R1 - DELTAR

ENDIF

CONTINUE

WRITE (*,910) MAX

FORMAT ('FAILED TO CONVERGE ON R AFTER ',I3,'+ITERATIONS.'/'0')

GOTO 999

WRITE (*,920) R

FORMAT ('THE DETECTOR WILL PROTECT A RADIUS OF ',F6.1,'+METERS')

S = R / .707

WRITE (*,940) S

FORMAT ('THIS CORRESPONDS TO A SPACING BETWEEN +DETECTORS OF ',F6.1,' METERS')

CONTINUE

RETURN

END

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INPUT SUBROUTINE

SUBROUTINE NDIN ( H, P, R,ALPHA, DETIME, DTHRESH, +MENU3, DSENS, QTHRESH, T0, TOL, MENU1 )

WRITE (*,900)

FORMAT ('ENVIRONMENTAL INFORMATION '+PLEASE ENTER +THE CEILING HEIGHT ABOVE THE FIRE SOURCE OR THE CEILING +HEIGHT '/' ABOVE THE FLOOR IN METERS.'/'0')

READ (*,*) H

WRITE (*,905)

FORMAT ('ENTER THE AMBIENT TEMPERATURE IN DEGREES +C.'/'0')

READ (*,*) T0

SET THE EXPONENT FOR THE POWER-LAW EQUATIONS

P = 2.0

WRITE (*,910)

FORMAT ('YOU MUST ENTER THE FIRE GROWTH +COEFFICIENT ALPHA (KW/SEC^2) OR THE TIME (SEC) '/ +REQUIRED FOR THE FIRE TO REACH A HEAT OUTPUT OF 1055
WRITE (*,915)
915 FORMAT (/ 'PLEASE SELECT EITHER:  '///' 1 - ALPHA 
+''//'' 2 - TIME TO REACH 1055 KW. ''/'/0')
C
100 READ (*,800) MENU2
800 FORMAT (I1)
C
GO TO (10,20) MENU2
C
C IF A KEY IS PRESSED WHICH DOESN'T CORRESPOND TO A MENU 
C SELECTION
C
WRITE (*,990)
990 FORMAT (/''INVALID ENTRY, PLEASE ENTER A MENU ITEM 
+NUMBER ONLY.''/'0')
60 TO 100
C
10 WRITE (*,920)
920 FORMAT (///' PLEASE ENTER ALPHA, THE FIRE GROWTH 
+COEFFICIENT.'/'0')
C
READ (*,* ) ALPHA
C
GO TO 30
C
20 WRITE (*,922)
922 FORMAT (///' PLEASE ENTER THE TIME FOR THE FIRE TO 
+REACH A HEAT OUTPUT OF 1055 KW.'/'0')
C
READ (*,*) TCRIT
C
ALPHA = 1055 / (TCRIT ** P)
C
30 CONTINUE
C
WRITE (*,925)
925 FORMAT(/'0DETECTOR DATA'///' SELECT A DETECTOR TYPE 
+FOR ANALYSIS.'///' 1 - FIXED TEMPERATURE HEAT DETECTOR' 
+''//'' 2 - RATE OF RISE HEAT DETECTOR'///' 3 - SMOKE 
+DETECTOR''/'0')
C
200 READ (*,810) MENU3
810 FORMAT (I1)
C
GO TO (40, 50, 60) MENU3
C
WRITE (*,990)
GO TO 200
C
40 WRITE (*,930)
930 FORMAT ('/'0WHAT IS THE OPERATING TEMPERATURE IN DEGREES 
+C ?'/'0')
C
READ (*,*) DTHRESH
C
GO TO 70
C
50 WRITE (*,940)
940 FORMAT ('AT WHAT RATE OF TEMPERATURE INCREASE
+(DEGREES / MIN) WILL THE DETECTOR RESPOND (DEGREES C)
+?'/0')
C
READ (*,*) DTHRESH
C
DTHRESH = DTHRESH 60
C
70 WRITE (*,935)
935 FORMAT ('WHAT IS THE RESPONSE TIME INDEX OF THE
+DETECTOR ?'/0')
C
READ (*,*) DSENS
C
GO TO 80
C
60 WRITE (*,945)
945 FORMAT ('WHAT IS THE DETECTOR MATERIAL RESPONSE
+NUMBER (DMR) FOR THE PARTICULAR SMOKE/D ' DETECTOR -
+FUEL COMBINATION ?'/0')
C
READ (*,*) DTHRESH
C
THE FOLLOWING LINES COULD BE ACTIVATED TO INPUT L.
C
FORMULAS ARE NOT INCLUDED AT THIS TIME TO USE L
C
C
WRITE (*,950)
950 FORMAT ('WHAT IS THE CHARACTERISTIC LENGTH OF THE
+SMOKE DETECTOR HOUSING AND CHAMBER ?'/0')
C
READ (*,*) DSENS
C
80 CONTINUE
C
MENU SELECTION I IS TO DESIGN NEW SYSTEMS
C
IF (MENU1 .EQ. 1) THEN
C
WRITE (*,955)
955 FORMAT ('SYSTEM GOALS'/YOU MUST ENTER EITHER THE
+REQUIRED RESPONSE TIME OF THE DETECTOR (SECONDS) OR'/'
+THE THRESHOLD FIRE SIZE THAT THE DETECTOR MUST RESPOND
+TO.'/PLEASE SELECT EITHER:'/// 1 - REQUIRED
+RESPONSE TIME'/// 2 - THRESHOLD FIRE SIZE AT RESPONSE'
+/'0')
C
85 READ (*,*) MENU4
C
GO TO (90,95) MENU4
C
WRITE (*,990)
GO TO 85
C
90 WRITE (*,960)
960 FORMAT ('ENTER THE REQUIRED DETECTOR RESPONSE TIME
+IN SECONDS'/'O')
C
READ (*,*) DETIME
C
QTHRESH = ALPHA * DETIME ** P
GO TO 98
C
95 WRITE (*,965)
965 FORMAT ('ENTER THE THRESHOLD FIRE SIZE IN KILO'/'WATTS'/'O')
C
READ (*,*) QTHRESH
C
DETIME = (QTHRESH / ALPHA)**(1/P)
C
98 CONTINUE
C
ELSE
C
IF THE MENU SELECTION WAS 2 (ANALYZE EXISTING SYSTEM) THEN
C
MAKE A FIRST GUESS AT DETIME
C
DETIME = 300
C
QTHRESH = ALPHA * DETIME ** P
C
ENDIF
C
IF (MENU1 .EQ. 1) THEN
C
FIRST GUESS FOR A DETECTOR SPACING AND RADIUS
C
S = 5.0
C
R = .707 * S
C
ELSE
C
IF THE MENU SELECTION WAS 2 (ANALYZE EXISTING SYSTEM) THEN:
C
WRITE (*,970)
970 FORMAT ('YOU MUST ENTER EITHER THE SPACING OF THE'+'
+EXISTING DETECTORS OR'/' THE RADIUS THAT THE DETECTOR'+'
+IS PROTECTING IN METERS.'/' PLEASE SELECT EITHER:'+'
+'///' 1 - DETECTOR SPACING'///' 2 - DETECTOR'+'
+RADIUS'/'O')
C
99 READ (*,*) MENU5
60 TO (91, 92) MENU5

WRITE (*, 990)
GO TO 99

91 WRITE (*, 980)
980 FORMAT (/'ENTER THE EXISTING DETECTOR SPACING IN
+METERS'/'0')

READ (*, *) S

R = .707 * S

GO TO 81

92 WRITE (*, 985)
985 FORMAT (/'ENTER THE EXISTING DETECTOR RADIUS IN
+METERS'/'0')

READ (*, *) R

81 CONTINUE
ENDIF

TOLERANCE FOR CONVERGING ON A DETECTOR SPACING

TOL = 0.05

RETURN
END

SUBROUTINE TO CALCULATE DETECTOR TEMPERATURE

SUBROUTINE FUNCTR(ALPHA, DET, DETIME, DSENS, DTYPE, H, P, R, +T0, MENU1)

TYPE DECLARATIONS
INTEGER DTYPE

SPECIFIC HEAT OF AIR AT CONSTANT PRESSURE KJ/KG/K
CP = 1.040

DENSITY OF AMBIENT AIR KG/M**3
RHO = 1.1

GRAVITATIONAL CONSTANT M/S**2
G = 9.81

T0K = T0 + 273
A = G / (CP * T0K * RHO)

T2F = 0.954 * (1 + R / H)

T2STAR = DETIME / (((A**(-1/(3+P))) * (ALPHA**(-1/(3+P))) + (H**(4/(3+P))))

CHECK TO SEE IF THE HEAT FRONT HAS REACHED THE DETECTOR. IF IT HASN'T, FOR DESIGNS TRY NEW R, FOR ANALYSIS TRY NEW DETIME

IF ((T2F/T2STAR).GE.1.0) THEN
   IF (MENU1 .EQ. 1) THEN
      WRITE (*,900)
      900 FORMAT ('THE HEAT FRONT HAS NOT REACHED THE DETECTOR.'/
               'TRYING R = ',F3.1 /
      WRITE (*,910) R
      910  FORMAT ('TRYING R = ',F3.1 /
      GOTO 10
   ELSE
      WRITE (*,900)
      DETIME = DETIME +30
      WRITE (*,920) DETIME
      920  FORMAT ('TRYING DETIME ',F6.1/
      GOTO 10
   ENDIF

RATIOU=(A**(1/(3+P))) * (ALPHA**(1/(3+P))) *
       +(H**((P-1)/(3+P)))

RATIOT=(A**(2/(3+P)))*(T0K/G)*(ALPHA**(2/(3+P)))*
       +(H**((P-5)/(3+P)))

D = 0.188+0.313*R/H

DT2STR=(((T2STAR-T2F)/D)**(1.333)

IF ((DTYPE .EQ. 1) .OR. (DTYPE .EQ. 2)) THEN
   U2T2=0.59*((R/H)**(-0.63))
   Y=0.75*RATIOU**.5 *U2T2**.5 *DT2STR/DESENS*DETIME/
     +T2STAR*D

FOR FIXED TEMPERATURE HEAT DETECTORS
   IF (DTYPE .EQ. 1) THEN
      DET=(RATIOT*DT2STR*(1-(1-EXP(-Y))/Y))+T0
   ELSE

FOR RATE OF RISE HEAT DETECTORS
DET=((4/3*RATIOT*DT2STR**.25)/(DETIME/T2STAR*D)) + (1-EXP(-Y))
ENDIF
ELSE
FOR SMOKE DETECTORS
DET = RATIOT * DT2STR
ENDIF
RETURN
END

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SUBROUTINE FOR ANALYSIS OF EXISTING SYSTEMS

SUBROUTINE EXIST (MENU1)

NEWTON SUBROUTINE TO CONVERGE ON A DETECTOR RESPONSE TIME

INTEGER DTYPE

TEST IS FOR TESTING SLOPE OF FUNCTION TO CONVERGE ON RESPONSE TIME

TEST = 1E-10

MAX = 30

CALL INPUT SUBROUTINE

CALL NDIN( H, P, R, ALPHA, DETIME, DTHRESH, DTYPE, + DSENS, QTHRESH, T0, TOL, MENU1 )

THE FOLLOWING LOOP STARTS WITH THE TRIAL DETIME AND CALCULATES THE DETECTOR TEMPERATURE. A NEWTON-RAPHSON ALGORITHM IS USED TO CONVERGE ON DETIME SUCH THAT THE DET. TEMPERATURE IS EQUAL TO THE OPERATING TEMPERATURE

DO 100 1 = 1, MAX

CALL SUBROUTINE TO CALCULATE DETECTOR TEMPERATURE

CALL FUNCTR(ALPHA, DET, DETIME, DSENS, DTYPE, H, P, R, + T0, MENU1)

DETIM1 = DETIME

INCREMENT DETIME AND CALCULATE NEW DETECTOR TEMPERATURE

TIMEINC = DETIME + 30
CALL FUNCTR(ALPHA, DETINC, TIMEINC, DSENS, DTYPE, H, P, R, +T0, MENU1)

START OF NEWTON-RAPHSON ALGORITHM

FT = DET - DTHRESH

DFT = (DET - DETINC)/(DETIME - TIMEINC)

IF (ABS(DFT) .LE. TEST) THEN
WRITE (*,900)
900 FORMAT ('/WARNING: THE SLOPE OF THE FUNCTION OF T' +IS CLOSE TO ZERO. '/0')
ENDIF

DELTAT = FT / DFT

DETIME = DETIM1 - DELTAT

IF ((ABS(DELTAT)) LT. (ABS(TOL * DETIME)) THEN
    LEAVE THE DO LOOP WITH THE CORRECT DETIME
    GOTO 200
ENDIF

TEST TO MAKE SURE DETIME DOES NOT GO NEG. LATER
FORMULAS INCLUDE RAISING DETIME TO FRACTIONAL EXPONENTS.

IF (DELTAT GE. DETIM1) THEN
    DELTAT = 0.95 * DETIM1
    DETIME = DETIM1 - DELTAT
ENDIF

CONTINUE

WRITE (*,910) MAX
910 FORMAT ('/FAILED TO CONVERGE ON DETIME AFTER ',13' +TRIES.'/0')

GOTO 999

TIME = DETIME / 60
WRITE (*,920) DETIME, TIME
920 FORMAT ('/THE DETECTOR WILL RESPOND IN ',F7.0' +SECONDS ('F4.1' MIN.)')

QTHRESH = ALPHA * DETIME * DETIME

WRITE (*,940) QTHRESH
940 FORMAT(/' THIS CORRESPONDS TO A THRESHOLD FIRE SIZE OF ',F6.1 ' KW')

C
999 CONTINUE
C
RETURN
END

C