```
1450 INPUT "OPTIONAL CHANGE OF M(MAX 1400),Interval,Time1 FOR F-SER APPROX (or0,0,0)",Mi,Ii,Ti
1460 IF Mi=0 THEN Nch
1470 M=Mi
1480 Interval=Ii
1490 Time1=Ti
1500 REDIM X(M),Y(M),F(M)
1510 Nch:INPUT "OPTIONAL CHANGE OF NUMBER OF F-COEFFS(N) FOR F-SERIES APPROX (or0)",Ni
1520 IF Ni=0 THEN Sum1
1530 N=Ni
1540 REDIM A(N),B(N)
1550 Sum1:Sum1=Sum2=Sum3=0
1560 DISP "-----PROGRAM RUNNING-----"
1570 FOR I=1 TO M
1580   X(I)=Time1+(I-1)*Interval
1590   IF X(I)<0 THEN F(I)=0
1600   IF X(I)<0 THEN Minus
1610   S=SIN(PI*X(I)/T)
1620   C=COS(PI*X(I)/T)
1630   F(I)=B0+A(1)*S+B(1)*C
1640   Vk2=0
1650   Vk1=1
1660   FOR K=2 TO N
1670     Vk=2*C*Vk1-Vk2
1680     Sk=Vk*S
1690     Ck=Vk*C-Vk1
1700     F(I)=F(I)+A(K)*Sk+B(K)*Ck
1710     Vk2=Vk1
1720     Vk1=Vk
1730   NEXT K
1740   Sum1=Sum1+F(I)
1750   Sum2=Sum2+F(I)*X(I)
1760   Sum3=Sum3+F(I)*X(I)^2
1770 Minus:NEXT I
1780 Mean=Sum2/Sum1
1790 Var=Sum3/Sum1-Mean^2
1800 Area=Sum1*Interval
1810 BEEP
1820 PRINT LIN(1),"FOURIER CURVE HAS BEEN COMPUTED"
1830 PRINT "NO OF READINGS=";M,"  NO OF F-COEFFS=";N
1840 PRINT "MEAN=";Mean,"  VAR=";Var;"AREA UNDER CURVE=";Area
1850 INPUT "IS A CRT PRINTOUT OF THE F-SERIES APPROXIMATION REQUD? Y/N",Q$
1860 IF Q$="N" THEN Fstore
1870 PRINT LIN(1),"I","X(I)","F(I)"
1880 FOR I=1 TO M
1890   PRINT I,X(I),F(I)
1900 NEXT I
1910 Fstore:INPUT "MUST THE FOURIER CURVE BE STORED ON TAPE? Y/N",Q$
1920 IF Q$="N" THEN St
1930 MAT Y=F
1940 Number=M
1950 Tail$="N"
1960 CALL Rtd_store
1970 St:STOP      !
```

```
1980 !      SUBROUTINE: Rtd_store
1990 !      ---------------------
2000 !
2010 !      THIS SUBROUTINE STORES THE RTD CURVE ON TAPE
2020 SUB Rtd_store
2030 OPTION BASE 1
2040 COM SHORT Y(*),INTEGER Number,REAL Interval,Time1,Mode$[1],Nor,Mean,Var,Tail$,C,B
2050 DIM File$[6]
2060 REDIM Y(Number)
2070 DISP "INSERT THE RTD DATA STORAGE CASSETTE"
2080 PAUSE
2090 INPUT "MUST EXISTING FILES BE DISPLAYED? Y/N",Q$
2100 IF Q$="Y" THEN CAT
2110 INPUT "ENTER THE FILENAME FOR THE CURRENT DATA",File$
2120 Bytes=4*(Number+14)
2130 Rec=INT(Bytes/256)+1
2140 CREATE File$,Rec
2150 ASSIGN #1 TO File$
2160 PRINT #1;Mode$,Number,Interval,Time1,Y(*),Nor
2170 IF (Nor=1) OR (Nor=2) THEN PRINT #1;Mean,Var
2180 IF Tail$="Y" THEN PRINT #1;C,B
2190 SUBEND     !
```

```
2200 !     SUBROUTINE: Rtd_retrieve
2210 !     ------------------------
2220 !
2230 !     THIS SUBROUTINE RETRIEVES A PREVIOUS RTD CURVE FROM TAPE
2240 SUB Rtd_retrieve
2250 OPTION BASE 1
2260 COM SHORT Y(*),INTEGER Number,REAL Interval,Time1,Mode$[1],Nor,Mean,Var,Tail$,C,B
2270 DIM File$[6]
2280 DISP "INSERT THE RTD DATA CASSETTE"
2290 PAUSE
2300 INPUT "MUST EXISTING FILES BE DISPLAYED? Y/N",Q1$
2310 IF Q1$="Y" THEN CAT
2320 INPUT "ENTER THE FILENAME TO BE RETRIEVED",File$
2330 ASSIGN #1 TO File$
2340 READ #1,1
2350 READ #1;Mode$,Number,Interval,Time1
2360 REDIM Y(Number)
2370 READ #1;Y(*),Nor
2380 IF (Nor=1) OR (Nor=2) THEN READ #1;Mean,Var
2390 INPUT "DOES THIS CURVE HAVE AN EXPON TAIL.? Y/N",Tail$
2400 IF Tail$="Y" THEN READ #1;C,B
2410 PRINT LIN(1),File$;" HAS BEEN RETRIEVED";SPA(5);"MODE IS ";Mode$
2420 PRINT USING Im1;Time1
2430 PRINT "NUMBER=";Number;SPA(5);
2440 PRINT USING Im2;Interval
2450 IF Tail$="Y" THEN PRINT "EXP TAIL: Y=C.EXP(-Bt)  C=";C;"  B=";B
2460 IF Nor=1 THEN PRINT USING Im3;Mean,Var
2470 IF Nor=2 THEN PRINT USING Im4;Mean,Var
2480 Im1:IMAGE "FIRST READING AT",M.DDDDDD
2490 Im2:IMAGE "INTERVAL=",.DDDDDD
2500 Im3:IMAGE "CURVE IS NORMALISED"/"MEAN=",D.DDD,"[sec] AND VARIANCE=",DD.DDD," [sec^2]"
2510 Im4:IMAGE "CURVE IS NORMALISED"/"MEAN=",D.DDD,"[sec] AND VARIANCE=",D.DDD," [DIMLESS]"
2520 SUBEND     !
```

```
2530 !     SUBROUTINE: PLOT
2540 !     ----------------
2550 !
2560 !     THE NEXT FOUR SUBROUTINES PLOT A GRAPH GIVEN VECTORS OF X AND Y VALUES
2570 SUB Plot(SHORT X(*),SHORT Y(*),REAL N,Xtit$,Ytit$,Head$,X0,Xfct,Y0,Yfct)
2580 OPTION BASE 1
2590 SHORT X1(N),X2(N),Y1(N),Y2(N)
2600 Pltr=705
2610 Nice=3                !(0,1,2,3)
2620 INPUT "MUST ONLY POINTS BE PLOTTED (SAME AXES)? Y/N",P$
2630 INPUT "INPUT LINE TYPE (0-7; 7=CONTINUOUS,0=NO LINE)",Lintyp
2640 Lt$=VAL$(INT(Lintyp))&";"
2650 IF Lintyp=7 THEN Lt$=";"
2660 INPUT "INPUT SYMBOL FOR POINTS (N=NO SYMBOL)",Symb$
2670 IF Symb$="N" THEN Symb$=" ;"
2680 Nn=N
2690 IF P$="Y" THEN Points1
2700 Xlen=250
2710 Ylen=170
2720 Xp=1000+Xlen/.025
2730 Yp=1000+Ylen/.025
2740 OUTPUT Pltr USING "K";"IN;IP1000,1000,",Xp,",",Yp
2750 OUTPUT Pltr USING "K";"SC0,",Xp-1000,",",0,",",Yp-1000
2760 CALL Scale(Y(*),Nn,Ylen,Nice,Y0,Ydiv)
2770 Yfct=800/Ydiv
2780 !
2790 !     CURVE IS PLOTTED IN SECTIONS
2800 Points1:INPUT "INPUT NUMBER OF SECTIONS FOR PLOT",Sec
2810 Num=INT(N/Sec-.001)+1
2820 REDIM X1(Num),Y1(Num),X2(Num),Y2(Num)
2830 Extra=Num*Sec-N
2840 FOR I=1 TO Sec
2850   IF I=1 THEN INPUT "IS PLOT OF FIRST SECTION REQUD? Y/N",Q$
2860   IF I<>1 THEN INPUT "IS PLOT OF NEXT SECTION REQUD? Y/N",Q$
2870   IF Q$="N" THEN Nex
2880   IF I=Sec THEN Num1=Num-Extra
2890   IF I<Sec THEN Num1=Num
2900   FOR J=1 TO Num1
2910     X1(J)=X(J+(I-1)*Num)
2920     Y1(J)=Y(J+(I-1)*Num)
2930   NEXT J
2940   IF I<Sec THEN L11
```

```
2950   IF Extra=0 THEN L11
2960   FOR J=Numi+i TO Num
2970     Xi(J)=X(N)
2980     Yi(J)=0
2990   NEXT J
3000   Num1=Num
3010 L11:  IF P$="Y" THEN Points2
3020   CALL Scale(Xi(*),Numi,Xlen,Nice,X0,Xdiv)
3030   Xfct=800/Xdiv
3040   CALL Axis(0,Xlen,X0,Xdiv,Xtit$)
3050   CALL Axis(i,Ylen,Y0,Ydiv,Ytit$)
3060 Points2:  CALL Trans(Xi(*),X2(*),X0,Xfct)
3070   CALL Trans(Yi(*),Y2(*),Y0,Yfct)
3080   !
3090   !     POINTS ARE NOW PLOTTED
3100   OUTPUT Pltr USING "K";"SM",Symb$
3110   OUTPUT Pltr USING "K";"PU;LT",Lt$,"PA",X2(i),",",Y2(i),";PD"
3120   FOR K=2 TO Numi
3130     OUTPUT Pltr USING "K";"PA",X2(K),",",Y2(K)
3140   NEXT K
3150   OUTPUT Pltr USING "K";"SM;"
3160   IF P$="Y" THEN Nex
3170   !
3180   !     TITLE IS PLOTTED
3190   Xpi=Xlen*20
3200   Ypi=Ylen*36
3210   OUTPUT Pltr USING "K";"PU;PA",Xpi,",",Ypi
3220   Nb=-.5*LEN(Head$)
3230   OUTPUT Pltr USING "K";"CP",Nb,",",0
3240   OUTPUT Pltr USING "K";"LB",Head$&CHR$(3),";PU"
3250 Nex:NEXT I
3260 SUBEND    !


3270 SUB Scale(SHORT X(*),REAL Nn,Axlen,Nice,X0,Xdiv)
3280 !     THIS SUBROUTINE SCALES THE PLOTTER,RETURNING X0 AND Xdiv
3290 OPTION BASE 1
3300 DIM Acc(8)
3310 Acc(1)=15
3320 Acc(2)=20
3330 Acc(3)=25
3340 Acc(4)=40
3350 Acc(5)=50
3360 Acc(6)=80
3370 Acc(7)=100
3380 Acc(8)=150
3390 Xmax=Xmin=X(1)
3400 FOR I=2 TO Nn
3410   Xmax=MAX(Xmax,X(I))
3420   Xmin=MIN(Xmin,X(I))
3430 NEXT I
3440 Ndiv=Axlen/20
3450 Xdiv=ABS((Xmax-Xmin)/Ndiv)
3460 M=0
3470 Iff1:IF Xdiv)10 THEN GOTO Iff2
3480       M=M+1
3490       Xdiv=Xdiv*10
3500       GOTO Iff1
3510 Iff2:IF Xdiv(=100 THEN Ok
3520       M=M-1
3530       Xdiv=Xdiv/10
3540       GOTO Iff2
3550 Ok:FOR I=1 TO 7
3560   IF Xdiv(Acc(I) THEN Found
3570 NEXT I
3580 STOP
3590 Found:Xdiv=Acc(I)/10^M
3600 X0=INT(Xmin/Xdiv)*Xdiv
3610 IF X0+Ndiv*Xdiv)=Xmax THEN 3800
3620 IF Nice=3 THEN 3780
3630 FOR Jj=2 TO 0 STEP -2
3640   OUTPUT Xmin$ USING "MDD.DE";Xmin
3650   Xmin$[5-Jj,5-Jj]="0"
3660   Xmin$[5,5]="0"
3670   Nd=3-Jj/2
3680   IF Xmin(0 THEN Xmin$[Nd,Nd]=VAL$(VAL(Xmin$[Nd,Nd])+1)
3690   X0=VAL(Xmin$)
3700   IF X0+Ndiv*Xdiv)=Xmax THEN 3800
3710   IF Nice=2 THEN 3780
3720 NEXT Jj
```

```
3730 IF Nice=1 THEN 3780
3740 IF Nice<>0 THEN STOP
3750 Xdiv=(Xmax-X  /Ndiv
3760 Xdiv=DROUND(Xdiv,3)
3770 SUBEXIT
3780 I=I+1
3790 GOTO Found
3800 SUBEND    !


3810 SUB Axis(Xory,Llen,Mini,Divi,Titi$)
3820 !     THIS SUBROUTINE DRAWS THE AXES
3830 DIM Tit$[35]
3840 Min=Mini
3850 Div=Divi
3860 Tit$=Titi$
3870 Pltr=705
3880 Len=Llen *.025
3890 M=INT(Llen/20)
3900 Len=Llen/.025
3910 IF NOT ((Xory=1) OR (Xory=0)) THEN STOP
3920 OUTPUT Pltr USING "K";"PU;PA0,0;PD"
3930 Xinc=800*(1-Xory)
3940 Yinc=800*Xory
3950 IF Xory=0 THEN T$=";XT"
3960 IF Xory=1 THEN T$=";YT"
3970 FOR I=1 TO M
3980   OUTPUT Pltr USING "K";"PR",Xinc,",",Yinc,T$
3990 NEXT I
4000 Xinc=Len*(1-Xory)
4010 Yinc=Len*Xory
4020 OUTPUT Pltr USING "K";"PA",Xinc,",",Yinc,";PU;PA0,0"
4030 IF Xory=1 THEN GOTO Laby
4040 Labx:Xinc=-2.5
4050       Yinc=-1
4060       Di$="1,0;"
4070       GOTO Lab
4080 Laby:Xinc=-5.7
4090       Yinc=-.25
4100       Di$="0,1;"
4110 Lab:OUTPUT Pltr USING "K";"CP",Xinc,",",Yinc,";PR0,0"
4120 M=M+1
4130 Xinc=800*(1-Xory)
4140 Yinc=800*Xory
4150 L=Min
4160 R=Min+(M-1)*Div
4170 Hi=MAX(ABS(L),ABS(R))
4180 Lo=MIN(ABS(L),ABS(R))
4190 IF L*R<0 THEN Lo=Div
4200 IF Lo=0 THEN Lo=Div
4210 IF LGT(Hi/Lo))=5 THEN E_notat
4220 E=INT(LGT(Lo))
4230 IF (Lo)=.1) AND (Hi<99999) THEN E=0
4240 FOR I=1 TO M
4250   Label=(Min+(I-1)*Div)/10^E
4260   IF Label<>0 THEN 4290
4270   Fmt$="XD.D"
4280   GOTO 4350
4290   N=INT(LGT(ABS(Label))+1
4300   IF N)=0 THEN 4330
4310   Fmt$="M.DDD"
4320   GOTO 4350
4330   Fmt$="M"&RPT$("D",N)
4340   IF N<=3 THEN Fmt$=Fmt$&" "&RPT$("D",3-N)
4350   OUTPUT Lab$ USING Fmt$;Label
4360   L1=LEN(Lab$)
4370   Lab$[L1-1,L1]=""
4380   Lab$=Lab$&CHR$(13)&CHR$(3)
4390   OUTPUT Pltr USING "K";"LB",Lab$
4400   OUTPUT Pltr USING "K";"PU;PR",Xinc,",",Yinc
4410 NEXT I
4420 IF E=0 THEN 4440
4430 Tit$=Tit$&"  x 10"
4440 Tit$=TRIM$(Tit$)
4450 !
4460 L1=LEN(Tit$)
4470 Xp=Len/2*(1-Xory)
4480 Yp=Len/2*Xory
4490 OUTPUT Pltr USING "K";"PA",Xp,",",Yp
4500 Xinc=-.*Xory-L1/2*(1-Xory)
```

```
4510 Yinc=-3*(1-Xory)-L1/4*Xory
4520 OUTPUT Pltr USING "K";"CP",Xinc,",",Yinc
4530 Tit$=Tit$&CHR$(3)
4540 OUTPUT Pltr USING "K";"DI",Di$,"LB",Tit$
4550 IF E=0 THEN 4610
4560 OUTPUT Pltr USING "K";"CP0.0,0.35"
4570 FIXED 0
4580 E$=VAL$(E)&CHR$(3)
4590 STANDARD
4600 OUTPUT Pltr USING "K";"LB",E$
4610 OUTPUT Pltr USING "K";"DI 1,0"
4620 OUTPUT Pltr USING "K";"PU;PA0,0"
4630 SUBEXIT
4640 E_notat:FLOAT 2
4650 FOR I=1 TO M
4660   Lab$=VAL$(Min+(I-1)*Div)&CHR$(13)&CHR$(3)
4670   OUTPUT Pltr USING "K";"LB",Lab$
4680   OUTPUT Pltr USING "K";"PU;PR",Xinc,",",Yinc
4690 NEXT I
4700 STANDARD
4710 E=0
4720 GOTO 4440
4730 OUTPUT Pltr USING "K";"PU;PA0,0"
4740 SUBEND    !


4750 SUB Trans(SHORT X(*),SHORT X2(*),REAL X0,Xfct)
4760 !      THIS SUBROUTINE TRANSFORMS VECTOR X INTO VECTOR X2 IN PLOTTER UNITS
4770 OPTION BASE 1
4780 MAT X2=X
4790 MAT X2=X2-(X0)
4800 MAT X2=X2*(Xfct)
4810 MAT X2=X2+(.5)
4820 MAT X2=INT(X2)
4830 SUBEND    !
```

```
4840 !      SUBROUTINE: F_store
4850 !      ------------------
4860 !
4870 !      THIS SUBROUTINE STORES THE F-COEFFICIENTS ON TAPE
4880 SUB F_store(M,Interval,Time1,N,T,B0,SHORT A(*),SHORT B(*))
4890 OPTION BASE 1
4900 DISP "INSERT THE F-COEEF DATA CASSETTE"
4910 PAUSE
4920 INPUT "ENTER THE FILENAME FOR THE F-COEFFS",File$
4930 Bytes=4*(2*N+12)
4940 Rec=INT(Bytes/256)+1
4950 CREATE File$,Rec
4960 ASSIGN #1 TO File$
4970 PRINT #1;M,Interval,Time1,N,T,B0,A(*),B(*)
4980 SUBEND      !


4990 !      SUBROUTINE : F_retrieve
5000 !      ----------------------
5010 !
5020 !      THIS SUBROUTINE RETRIEVES FOURIER COEFFS FROM TAPE
5030 SUB F_retrieve(M,Interval,Time1,N,T,B0,SHORT A(*),SHORT B(*))
5040 OPTION BASE 1
5050 DISP "INSERT THE F-COEFF DATA CASSETTE"
5060 PAUSE
5070 INPUT "ENTER THE FILENAME TO BE RETRIEVED",File$
5080 ASSIGN #1 TO File$
5090 READ #1,1
5100 READ #1;M,Interval,Time1,N,T,B0
5110 REDIM A(N),B(N)
5120 READ #1;A(*),B(*)
5130 PRINT LIN(1),File$;"HAS BEEN RETRIEVED";SPA(5);"NO OF READINGS=";M
5140 PRINT "TIME1=";Time1;SPA(5);"INTERVAL=";Interval
5150 PRINT "NO OF F-COEFFS=";N;SPA(5);"2T=";2*T
5160 SUBEND    !
```

APPENDIX XI.5

```
10   !      PROGRAM: P_MIX
20   !
30   !      THIS PROGRAM SOLVES FOR THE PARAMETERS OF A SIMPLE RECYCLE MODEL
40   !      WITH GAMMA DISTRIBUTIONS IN BOTH LOOPS,
50   !      BY MINIMISING F=SUM(A(K)-A_exp(K))^2 +SUM(B(K)-B_exp(K))^2.
60   !      TWO OR MORE PAIRS OF F-COEFFS CAN BE USED
70   !      MINIMIZATION SUBROUTINE "ZXMIN" MUST BE LINKED     !



80   !      MAIN PROGRAM
90   !      ------------
100  !
110  OPTION BASE 1
120  COM INTEGER K(125),REAL Nf,T,A_e(125),B_e(125),A(125),B(125),Mean !VARIABLES NEEDED BY SUB Fun
130  DIM X(4),H(10),G(4),W(12),A_exp(125),B_exp(125)
140  PRINTER IS 16
150  PRINT LIN(1),TAB(30);CHR$(27);"&dD";"PROGRAM: P_MIX";CHR$(27);"&d@"
160  CALL F_retrieve(M,Interval,Time1,Nf,T,B0_exp,A_exp(*),B_exp(*))
170  INPUT "INPUT MEAN OF F-CURVE",Mean
180  INPUT "MUST THE FIRST Nf PAIRS OF F-COEFFS BE USED? INPUT Nf (or 0)",Nf1
190  IF Nf1=0 THEN Ind
200  Nf=Nf1
210  REDIM K(Nf),A(Nf),B(Nf),A_exp(Nf),B_exp(Nf),A_e(Nf),B_e(Nf)
220  MAT A_e=A_exp
230  MAT B_e=B_exp
240  FOR J=1 TO Nf
250    K(J)=J
260  NEXT J
270  GOTO Cal
280 Ind: INPUT "INPUT NO OF INDIVIDUAL PAIRS OF F-COEFFS",Nf
290  REDIM K(Nf),A(Nf),B(Nf),A_e(Nf),B_e(Nf)
300  INPUT "INPUT THE No.s OF THE F-COEFFS [K(*)]",K(*)
310  FOR J=1 TO Nf
320    A_e(J)=A_exp(K(J))
330    B_e(J)=B_exp(K(J))
340  NEXT J
350  !
360  !      CALLING VALUES FOR Zxmin
370 Cal: N=4            ! 4 PARAMETERS
380  Nsig=3             ! DIGITS OF ACCURACY OF PARAMETERS
390  Maxfn=700          ! MAXIMUM 700 EVALUATIONS OF F
400  Iopt=0
410  INPUT "INPUT INITIAL ESTIMATES OF THE 4 PARAMETERS",X(1),X(2),X(3),X(4)
420  X(3)=X(3)*100
430  X(4)=X(4)*10
440  DISP SPA(17);"********** PROGRAM RUNNING **********"
450  CALL Zxmin(N,Nsig,Maxfn,Iopt,X(*),H(*),G(*),F,W(*),Ier)
460  X(3)=X(3)/100
470  X(4)=X(4)/10
480  Mean2=((1-X(1))*Mean-X(2))/X(1)
490  Volfrac=X(2)/((1-X(1))*Mean)
500  R=X(1)/(1-X(1))
510  !
520  !      PRINTOUT OF RESULTS
530  PRINTER IS 7,1,WIDTH(130)
540  FLOAT 5
550  PRINT LIN(5),"SUM OF SQUARES HAS BEEN MINIMIZED"
560  PRINT "PARAMETERS=";X(1);SPA(2);X(2);SPA(2);X(3);SPA(2);X(4)
570  PRINT "MEAN IN REG 2=";Mean2
580  PRINT "VARIANCE/MEAN^2=  REG 1:";X(3)/X(2)^2;"   REG 2:";X(4)/Mean2^2
590  PRINT "VOL FRAC OF REG 1=";Volfrac
600  PRINT "RECYCLE RATIO=";R
610  PRINT "GRADIENTS=";G(1);SPA(2);G(2);SPA(2);G(3);SPA(2);G(4)
620  PRINT "FINAL FUNCTION VALUE=";F
630  PRINT "NO. OF FUNCTION EVALUATIONS=";W(2)
640  IF Ier()0 THEN PRINT "ERROR PARAMETER=";Ier
650  INPUT "MUST EXP AND THEOR F-COEFFS BE DISPLAYED FOR COMPARISON? Y/N",Q$
660  IF Q$="N" THEN Sto
```

```
670  FIXED 5
680  PRINT LIN(5)
690  PRINT SPA(7);"K";SPA(11);"A_exp(K)";SPA(9);"A(K)";SPA(9);"B_exp(K)";SPA(9);"B(K)"
700  FOR J=1 TO Nf
710    PRINT K(J);SPA(7);A_e(J);SPA(7);A(J);SPA(7);B_e(J);SPA(7);B(J)
720  NEXT J
730  !
740  !     STORAGE OF THEORETICAL F-COEFFS ON TAPE
750 Sto: IF Nf1=0 THEN STOP
760  INPUT "MUST THEORETICAL F-COEFFS BE STORED ON TAPE? Y/N",Q$
770  IF Q$="Y" THEN CALL F_store(M,Interval,Time1,Nf,T,E0_exp,A(*),B(*))
780  STOP      !



790  !     SUBROUTINE: FUN
800  !     ---------------
810  !
820  !     THIS SUBROUTINE CALCULATES FUNTION F FOR GIVEN PARAMETER VALUES X(*)
830  SUB Fun(N,X(*),F)
840  OPTION BASE 1
850  COM INTEGER K(*),REAL Nf,T,A_e(*),B_e(*),A(*),B(*),Mean
860  DIM Adif(Nf),Bdif(Nf)
870  P=X(1)                          ! RECYCLE FRACTION
880  Mean1=X(2)                      ! MEAN RES TIME OF REGION 1
890  Var1=X(3)/100                   ! VARIANCE OF REGION 1
900  Var2=X(4)/10                    ! VARIANCE OF REGION 2
910  Mean2=((1-P)*Mean-Mean1)/P      ! MEAN RES TIME OF REGION 2
920  N1=Mean1^2/Var1                 ! EQUIVALENT NUMBER OF CSTRs
930  N2=Mean2^2/Var2                 !       "       "    "   "
940  RAD
950  FOR J=1 TO Nf
960    Freq=K(J)*PI/T
970    R1=SQR(1+(Freq*Mean1/N1)^2)
980    R2=SQR(1+(Freq*Mean2/N2)^2)
990    Theta1=ATN(Freq*Mean1/N1)
1000   Theta2=ATN(Freq*Mean2/N2)
1010   Den=R1^(2*N1)*R2^(2*N2)-2*P*R1^N1*R2^N2*COS(N1*Theta1+N2*Theta2)+P^2
1020   Nume=(1-P)*R2^N2
1030   A(J)=1/T*Nume*(R1^N1*R2^N2*SIN(N1*Theta1)+P*SIN(N2*Theta2))/Den
1040   B(J)=1/T*Nume*(R1^N1*R2^N2*COS(N1*Theta1)-P*COS(N2*Theta2))/Den
1050 NEXT J
1060 MAT Adif=A-A_e
1070 MAT Bdif=B-B_e
1080 Dota=DOT(Adif,Adif)
1090 Dotb=DOT(Bdif,Bdif)
1100 F=Dota+Dotb
1110 PRINTER IS 7,1,WIDTH(130)
1120 FIXED 5
1130 PRINT X(1),X(2),X(3),X(4),,F
1140 STANDARD
1150 PRINTER IS 16
1160 SUBEND     !



1170 !     SUBROUTINE: F_store
1180 !     -------------------
1190 !
1200 !     THIS SUBROUTINE STORES THE F-COEFFICIENTS ON TAPE
1210 SUB F_store(M,Interval,Time1,N,T,E0,A(*),B(*))
1220 OPTION BASE 1
1230 DISP "INSERT THE F-COEEF DATA CASSETTE"
1240 PAUSE
1250 INPUT "ENTER THE FILENAME FOR THE F-COEFFS",File$
1260 Bytes=8*(2*N+6)
1270 Rec=INT(Bytes/256)+1
1280 CREATE File$,Rec
1290 ASSIGN #1 TO File$
1300 PRINT #1;M,Interval,Time1,N,T,E0,A(*),B(*)
1310 SUBEND     !
```

```
1320 !     SUBROUTINE: F_retrieve
1330 !     ----------------------
1340 !
1350 !     THIS SUBROUTINE RETRIEVES FOURIER COEFFS FROM TAPE
1360 SUB F_retrieve(M,Interval,Time1,N,T,B0,A(*),B(*))
1370 OPTION BASE 1
1380 DISP "INSERT THE F-COEFF DATA CASSETTE"
1390 PAUSE
1400 INPUT "ENTER THE FILENAME TO BE RETRIEVED",File$
1410 ASSIGN #1 TO File$
1420 READ #1,1
1430 READ #1;M,Interval,Time1,N,T,B0
1440 REDIM A(N),B(N)
1450 READ #1;A(*),B(*)
1460 PRINT LIN(1),File$;"HAS BEEN RETRIEVED";SPA(5);"NO OF READINGS=";M
1470 PRINT "TIME1=";Time1;SPA(5);"INTERVAL=";Interval
1480 PRINT "NO OF F-COEFFS=";N;SPA(5);"2T=";2*T
1490 SUBEND    !
```

APPENDIX XI.6

```
10   !     PROGRAM: P_DISP
20   !
30   !     THIS PROGRAM SOLVES FOR THE PARAMETERS OF A SIMPLE RECYCLE MODEL
40   !     WITH AXIAL DISPERSION IN BOTH LOOPS,
50   !     BY MINIMISING F=SUM(A(K)-A_exp(K))^2 +SUM(B(K)-B_exp(K))^2.
60   !     TWO OR MORE PAIRS OF F-COEFFS CAN BE USED
70   !     MINIMIZATION SUBROUTINE "ZXMIN" MUST BE LINKED    !



80   !     MAIN PROGRAM
90   !     ------------
100  !
110  OPTION BASE 1
120  COM INTEGER K(125),REAL Nf,T,A_e(125),B_e(125),A(125),B(125),Mean !VARIABLES NEEDED BY SUB Fun
130  DIM X(4),H(10),G(4),W(12),A_exp(125),B_exp(125)
140  PRINTER IS 16
150  PRINT LIN(1),TAB(30);CHR$(27);"&dD";"PROGRAM. P_DISP";CHR$(27);"&d@"
160  CALL F_retrieve(M,Interval,Time1,Nf,T,B0_exp,A_exp(*),B_exp(*))
170  INPUT "INPUT MEAN OF F-CURVE",Mean
180  INPUT "MUST THE FIRST Nf PAIRS OF F-COEFFS BE USED? INPUT Nf (or 0)",Nf1
190  IF Nf1=0 THEN Ind
200  Nf=Nf1
210  REDIM K(Nf),A(Nf),B(Nf),A_exp(Nf),B_exp(Nf),A_e(Nf),B_e(Nf)
220  MAT A_e=A_exp
230  MAT B_e=B_exp
240  FOR J=1 TO Nf
250    K(J)=J
260  NEXT J
270  GOTO Cal
280 Ind: INPUT "INPUT NO OF INDIVIDUAL PAIRS OF F-COEFFS",Nf
290  REDIM K(Nf),A(Nf),B(Nf),A_e(Nf),B_e(Nf)
300  INPUT "INPUT THE No.s OF THE F-COEFFS [K(*)]",K(*)
310  FOR J=1 TO Nf
320    A_e(J)=A_exp(K(J))
330    B_e(J)=B_exp(K(J))
340  NEXT J
350  !
360  !     CALLING VALUES FOR Zxmin
370 Cal: N=4           ! 4 PARAMETERS
380  Nsig=3           ! DIGITS OF ACCURACY OF PARAMETERS
390  Maxfn=700        ! MAXIMUM 700 EVALUATIONS OF F
400  Iopt=0
410  INPUT "INPUT INITIAL ESTIMATES OF THE 4 PARAMETERS",X(1),X(2);X(3),X(4)
420  X(3)=X(3)*100
430  X(4)=X(4)*10
440  DISP SPA(17);"********** PROGRAM RUNNING **********"
450  CALL Zxmin(N,Nsig,Maxfn,Iopt,X(*),H(*),G(*),F,W(*),Ier)
460  X(3)=X(3)/100
470  X(4)=X(4)/10
480  Mean2=((1-X(1))*Mean-X(2))/X(1)
490  Disp1=X(3)/(2*X(2)^2)
500  Disp2=X(4)/(2*Mean2^2)
510  Volfrac=X(2)/((1-X(1))*Mean)
520  R=X(1)/(1-X(1))
530  !
540  !     PRINTOUT OF RESULTS
550  PRINTER IS 7,1,WIDTH(130)
560  FLOAT 5
570  PRINT LIN(5),"SUM OF SQUARES HAS BEEN MINIMIZED"
580  PRINT "PARAMETERS=";X(1);SPA(2);X(2);SPA(2);X(3);SPA(2);X(4)
590  PRINT "MEAN IN REGION 2=";Mean2
600  PRINT "VARIANCE/(MEAN^2)=  REG 1:";X(3)/X(2)^2;"   REG 2:";X(4)/Mean2^2
610  PRINT "DISP NUMBERS=       REG 1:";Disp1;"   REG 2:";Disp2
620  PRINT "VOL FRAC OF REG 1=";Volfrac
630  PRINT "RECYCLE RATIO=";R
640  PRINT "GRADIENTS=";G(1);SPA(2);G(2);SPA(2);G(3);SPA(2);G(4)
650  PRINT "FINAL FUNCTION VALUE=";F
660  PRINT "NO. OF FUNCTION EVALUATIONS=";W(2)
670  IF Ier<>0 THEN PRINT "ERROR PARAMETER=";Ier
680  INPUT "MUST EXP AND THEOR F-COEFFS BE DISPLAYED FOR COMPARISON? Y/N",Q$
690  IF Q$="N" THEN Sto
700  FIXED 5
```

APPENDIX XI.6

```
10   !      PROGRAM: P_DISP
20   !
30   !      THIS PROGRAM SOLVES FOR THE PARAMETERS OF A SIMPLE RECYCLE MODEL
40   !      WITH AXIAL DISPERSION IN BOTH LOOPS,
50   !      BY MINIMISING F=SUM(A(K)-A_exp(K))^2 +SUM(B(K)-B_exp(K))^2.
60   !      TWO OR MORE PAIRS OF F-COEFFS CAN BE USED
70   !      MINIMIZATION SUBROUTINE "ZXMIN" MUST BE LINKED     !



80   !      MAIN PROGRAM
90   !      ------------
100  !
110  OPTION BASE 1
120  COM INTEGER K(125),REAL Nf,T,A_e(125),B_e(125),A(125),B(125),Mean !VARIABLES NEEDED BY SUB Fun
130  DIM X(4),H(10),G(4),W(12),A_exp(125),B_exp(125)
140  PRINTER IS 16
150  PRINT LIN(1),TAB(30);CHR$(27);"&dD";"PROGRAM: P_DISP";CHR$(27);"&d@"
160  CALL F_retrieve(M,Interval,Time1,Nf,T,B0_exp,A_exp(*),B_exp(*))
170  INPUT "INPUT MEAN OF F-CURVE",Mean
180  INPUT "MUST THE FIRST Nf PAIRS OF F-COEFFS BE USED? INPUT Nf (or 0)",Nf1
190  IF Nf1=0 THEN Ind
200  Nf=Nf1
210  REDIM K(Nf),A(Nf),B(Nf),A_exp(Nf),B_exp(Nf),A_e(Nf),B_e(Nf)
220  MAT A_e=A_exp
230  MAT B_e=B_exp
240  FOR J=1 TO Nf
250    K(J)=J
260  NEXT J
270  GOTO Cal
280 Ind: INPUT "INPUT NO OF INDIVIDUAL PAIRS OF F-COEFFS",Nf
290  REDIM K(Nf),A(Nf),B(Nf),A_e(Nf),B_e(Nf)
300  INPUT "INPUT THE No.s OF THE F-COEFFS [K(*)]",K(*)
310  FOR J=1 TO Nf
320    A_e(J)=A_exp(K(J))
330    B_e(J)=B_exp(K(J))
340  NEXT J
350  !
360  !      CALLING VALUES FOR Zxmin
370 Cal: N=4           ! 4 PARAMETERS
380  Nsig=3            ! DIGITS OF ACCURACY OF PARAMETERS
390  Maxfn=700         ! MAXIMUM 700 EVALUATIONS OF F
400  Iopt=0
410  INPUT "INPUT INITIAL ESTIMATES OF THE 4 PARAMETERS",X(1),X(2),X(3),X(4)
420  X(3)=X(3)*100
430  X(4)=X(4)*10
440  DISP SPA(17);"********** PROGRAM RUNNING **********"
450  CALL Zxmin(N,Nsig,Maxfn,Iopt,X(*),H(*),G(*),F,W(*),Ier)
460  X(3)=X(3)/100
470  X(4)=X(4)/10
480  Mean2=((1-X(1))*Mean-X(2))/X(1)
490  Disp1=X(3)/(2*X(2)^2)
500  Disp2=X(4)/(2*Mean2^2)
510  Volfrac=X(2)/((1-X(1))*Mean)
520  R=X(1)/(1-X(1))
530  !
540  !      PRINTOUT OF RESULTS
550  PRINTER IS 7,1,WIDTH(130)
560  FLOAT 5
570  PRINT LIN(5),"SUM OF SQUARES HAS BEEN MINIMIZED"
580  PRINT "PARAMETERS=";X(1);SPA(2);X(2);SPA(2);X(3);SPA(2);X(4)
590  PRINT "MEAN IN REGION 2=";Mean2
600  PRINT "VARIANCE/(MEAN^2)=  REG 1:";X(3)/X(2)^2;"   REG 2:";X(4)/Mean2^2
610  PRINT "DISP NUMBERS=       REG 1:";Disp1;"   REG 2:";Disp2
620  PRINT "VOL FRAC OF REG 1=";Volfrac
630  PRINT "RECYCLE RATIO=";R
640  PRINT "GRADIENTS=";G(1);SPA(2);G(2);SPA(2);G(3);SPA(2);G(4)
650  PRINT "FINAL FUNCTION VALUE=";F
660  PRINT "NO. OF FUNCTION EVALUATIONS=";W(2)
670  IF Ier<>0 THEN PRINT "ERROR PARAMETER=";Ier
680  INPUT "MUST EXP AND THEOR F-COEFFS BE DISPLAYED FOR COMPARISON? Y/N",Q$
690  IF Q$="N" THEN Sto
700  FIXED 5
```

```
710  PRINT LIN(5)
720  PRINT SPA(7);"K";SPA(11);"A_exp(K)";SPA(9);"A(K)";SPA(9);"B_exp(K)";SPA(9);"B(K)"
730  FOR J=1 TO Nf
740    PRINT K(J);SPA(7);A_e(J);SPA(7);A(J);SPA(7);B_e(J);SPA(7);B(J)
750  NEXT J
760  !
770  !      STORAGE OF THEORETICAL F-COEFFS ON TAPE
780 Sto: IF Nf=0 THEN STOP
790  INPUT "MUST THEORETICAL F-COEFFS BE STORED ON TAPE? Y/N",Q$
800  IF Q$="Y" THEN CALL F_store(M,Interval,Time1,Nf,T,B0_exp,A(*),B(*))
810  STOP      !



820  !      SUBROUTINE: FUN
830  !      ---------------
840  !
850  !      THIS SUBROUTINE CALCULATES FUNTION F FOR GIVEN PARAMETER VALUES X(*)
860  SUB Fun(N,X(*),F)
870  OPTION BASE 1
880  COM INTEGER K(*),REAL Nf,T,A_e(*),B_e(*),A(*),B(*),Mean
890  DIM Adif(Nf),Bdif(Nf)
900  P=X(1)                          ! RECYCLE FRACTION
910  Mean1=X(2)                      ! MEAN RES TIME OF REGION 1
920  Var1=X(3)/100                   ! VARIANCE OF REGION 1
930  Var2=X(4)/10                    ! VARIANCE OF REGION 2
940  Mean2=((1-P)*Mean-Mean1)/P      ! MEAN RES TIME OF REGION 2
950  A1=Mean1^2/Var1
960  A2=Mean2^2/Var2
970  RAD
980  FOR J=1 TO Nf
990    Freq=K(J)*PI/T
1000   B1=2*Mean1^3*Freq/Var1
1010   B2=2*Mean2^3*Freq/Var2
1020   R1=(A1^4+B1^2)^.25
1030   R2=(A2^4+B2^2)^.25
1040   Theta1=.5*ATN(B1/A1^2)
1050   Theta2=.5*ATN(B2/A2^2)
1060   Alpha1=R1*COS(Theta1)
1070   Alpha2=R2*COS(Theta2)
1080   Beta1=R1*SIN(Theta1)
1090   Beta2=R2*SIN(Theta2)
1100   Aa1=A1-Alpha1
1110   Aa2=A2-Alpha2
1120   Den=1-2*P*EXP(Aa1+Aa2)*COS(Beta1+Beta2)+P^2*EXP(2*Aa1+2*Aa2)
1130   Nume=(1-P)*EXP(Aa1)
1140   A(J)=1/T*Nume*(SIN(Beta1)+P*EXP(Aa1+Aa2)*SIN(Beta2))/Den
1150   B(J)=1/T*Nume*(COS(Beta1)-P*EXP(Aa1+Aa2)*COS(Beta2))/Den
1160 NEXT J
1170 MAT Adif=A-A_e
1180 MAT Bdif=B-B_e
1190 Dota=DOT(Adif,Adif)
1200 Dotb=DOT(Bdif,Bdif)
1210 F=Dota+Dotb
1220 PRINTER IS 7,1,WIDTH(130)
1230 FIXED 5
1240 PRINT X(1),X(2),X(3),X(4),,F
1250 STANDARD
1260 PRINTER IS 16
1270 SUBEND     !



1280 !      SUBROUTINE: F_store
1290 !      -------------------
1300 !
1310 !      THIS SUBROUTINE STORES THE F-COEFFICIENTS ON TAPE
1320 SUB F_store(M,Interval,Time1,N,T,B0,A(*),B(*))
1330 OPTION BASE 1
1340 DISP "INSERT THE F-COEEF DATA CASSETTE"
1350 PAUSE
1360 INPUT "ENTER THE FILENAME FOR THE F-COEFFS",File$
1370 Bytes=8*(2*N+6)
1380 Rec=INT(Bytes/256)+1
1390 CREATE File$,Rec
1400 ASSIGN #1 TO File$
1410 PRINT #1;M,Interval,Time1,N,T,B0,A(*),B(*)
1420 SUBEND     !
```

```
1430 !      SUBROUTINE: F_retrieve
1440 !      ----------------------
1450 !
1460 !      THIS SUBROUTINE RETRIEVES FOURIER COEFFS FROM TAPE
1470 SUB F_retrieve(M,Interval,Time1,N,T,B0,A(*),B(*))
1480 OPTION BASE 1
1490 DISP "INSERT THE F-COEFF DATA CASSETTE"
1500 PAUSE
1510 INPUT "ENTER THE FILENAME TO BE RETRIEVED",File$
1520 ASSIGN #1 TO File$
1530 READ #1,1
1540 READ #1;M,Interval,Time1,N,T,B0
1550 REDIM A(N),B(N)
1560 READ #1;A(*),B(*)
1570 PRINT LIN(1),File$;"HAS BEEN RETRIEVED";SPA(5);"NO OF READINGS=";M
1580 PRINT "TIME1=";Time1;SPA(5);"INTERVAL=";Interval
1590 PRINT "NO OF F-COEFFS=";N;SPA(5);"2T=";2*T
1600 SUBEND    !
```

APPENDIX XI.7

```
10   !     PROGRAM: P_PASS
20   !
30   !     THIS PROGRAM SOLVES FOR THE PARAMETERS OF THE "BYPASS MODEL"
40   !     BY MINIMISING F=SUM(A(K)-A_exp(K))^2 +SUM(B(K)-B_exp(K))^2
50   !     TWO OR MORE PAIRS OF F-COEFFS CAN BE USED
60   !     MINIMIZATION SUBROUTINE "ZXMIN" MUST BE LINKED    !



70   !     MAIN PROGRAM
80   !     ------------
90   !
100  OPTION BASE 1
110  COM INTEGER K(125),REAL Nf,T,A_e(125),B_e(125),A(125),B(125),Mean !VARIABLES NEEDED BY SUB Fun
120  DIM X(3),H(6),G(3),W(9),A_exp(125),B_exp(125)
130  PRINTER IS 16
140  PRINT LIN(1),TAB(30);CHR$(27);"&dD";"PROGRAM: P_PASS";CHR$(27);"&d@"
150  CALL F_retrieve(M,Interval,Time1,Nf,T,B0_exp,A_exp(*),B_exp(*))
160  INPUT "INPUT MEAN OF F-CURVE",Mean
170  INPUT "MUST THE FIRST Nf PAIRS OF F-COEFFS BE USED? INPUT Nf (or 0)",Nf1
180  IF Nf1=0 THEN Ind
190  Nf=Nf1
200  REDIM K(Nf),A(Nf),B(Nf),A_exp(Nf),B_exp(Nf),A_e(Nf),B_e(Nf)
210  MAT A_e=A_exp
220  MAT B_e=B_exp
230  FOR J=1 TO Nf
240    K(J)=J
250  NEXT J
260  GOTO Cal
270 Ind: INPUT "INPUT NO OF INDIVIDUAL PAIRS OF F-COEFFS",Nf
280  REDIM K(Nf),A(Nf),B(Nf),A_e(Nf),B_e(Nf)
290  INPUT "INPUT THE No.s OF THE F-COEFFS [K(*)]",K(*)
300  FOR J=1 TO Nf
310    A_e(J)=A_exp(K(J))
320    B_e(J)=B_exp(K(J))
330  NEXT J
340  !
350  !     CALLING VALUES FOR Zxmin
360 Cal: N=3          ! 3 PARAMETERS
370  Nsig=3           ! DIGITS OF ACCURACY OF PARAMETERS
380  Maxfn=700        ! MAXIMUM 700 EVALUATIONS OF F
390  Iopt=0
400  INPUT "INPUT INITIAL ESTIMATES OF THE 3 PARAMETERS",X(1),X(2),X(3)
410  ! X(1)=P, X(2)=Mean1, X(3)=Var1/Mean1^2
420  ! X(3)=X(3)*10
430  DISP SPA(17);"********** PROGRAM RUNNING **********"
440  CALL Zxmin(N,Nsig,Maxfn,Iopt,X(*),H(*),G(*),F,W(*),Ier)
450  ! X(3)=X(3)/10
460  Mean2=(Mean-X(2))/X(1)
470  !
480  !     DISPLAY OF RESULTS
490  PRINTER IS 7,1,WIDTH(130)
500  FLOAT 5
510  PRINT LIN(5),"SUM OF SQUARES HAS BEEN MINIMIZED"
520  PRINT "PARAMETERS=";X(1);SPA(2);X(2);SPA(2);X(3)
530  PRINT "MEAN IN REG 2=";Mean2
540  PRINT "GRADIENTS=";G(1);SPA(2);G(2);SPA(2);G(3)
550  PRINT "FINAL FUNCTION-VALUE=";F
560  PRINT "NO. OF FUNCTION EVALUATIONS=";W(2)
570  IF Ier<>0 THEN PRINT "ERROR PARAMETER=";Ier
580  INPUT "MUST EXP AND THEOR F-COEFFS BE DISPLAYED FOR COMPARISON? Y/N",Q$
590  IF Q$="N" THEN Sto
600  FIXED 5
610  PRINT LIN(5)
620  PRINT SPA(7);"K";SPA(11);"A_exp(K)";SPA(9);"A(K)";SPA(9);"B_exp(K)";SPA(9);"B(K)"
630  FOR J=1 TO Nf
640    PRINT K(J);SPA(7);A_e(J);SPA(7);A(J);SPA(7);B_e(J);SPA(7);B(J)
650  NEXT J
660  !
670  !     STORAGE OF THEORETICAL F-COEFFS ON TAPE
680 Sto: IF Nf1=0 THEN STOP
690  INPUT "MUST THEORETICAL F-COEFFS BE STORED ON TAPE? Y/N",Q$
700  IF Q$="Y" THEN CALL F_store(M,Interval,Time1,Nf,T,B0_exp,A(*),B(*))
710  STOP      !
```

```
720  !     SUBROUTINE: FUN
730  !     ---------------
740  !
750  !     THIS SUBROUTINE CALCULATES FUNTION F FOR GIVEN PARAMETER VALUES X(*)
760  SUB Fun(N,X(*),F)
770  OPTION BASE 1
780  COM INTEGER K(*),REAL Nf,T,A_e(*),B_e(*),A(*),B(*),Mean
790  DIM Adif(Nf),Bdif(Nf)
800  P=X(1)                          ! FRACTION TO DEAD ZONE
810  Mean1=X(2)                      ! MEAN RES TIME OF REGION 1
820  ! X3=X(3)/10
830  Mean2=(Mean-X(2))/X(1)          ! MEAN RES TIME OF REGION 2
840  N1=1/X3                         ! EQUIVALENT NUMBER OF CSTRs
850  RAD
860  FOR J=1 TO Nf
870    Freq=K(J)*PI/T
880    R=1+(Freq*Mean1/N1)^2
890    Q=1+(1-P)*Mean2^2*Freq^2
900    Theta=ATN(Freq*Mean1/N1)
910    C=COS(N1*Theta)
920    S=SIN(N1*Theta)
930    Den=R^N1*(1+Mean2^2*Freq^2)
940    A(J)=1/T*R^(N1/2)*(Q*S+P*Mean2*Freq*C)/Den
950    B(J)=1/T*R^(N1/2)*(Q*C-P*Mean2*Freq*S)/Den
960  NEXT J
970  MAT Adif=A-A_e
980  MAT Bdif=B-B_e
990  Dota=DOT(Adif,Adif)
1000 Dotb=DOT(Bdif,Bdif)
1010 F=Dota+Dotb
1020 PRINTER IS 7,1,WIDTH(130)
1030 FIXED 5
1040 PRINT X(1),X(2),X(3),,F
1050 STANDARD
1060 PRINTER IS 16
1070 SUBEND     !



1080 !     SUBROUTINE: F_store
1090 !     -------------------
1100 !
1110 !     THIS SUBROUTINE STORES THE F-COEFFICIENTS ON TAPE
1120 SUB F_store(M,Interval,Time1,N,T,B0,A(*),B(*))
1130 OPTION BASE 1
1140 DISP "INSERT THE F-COEEF DATA CASSETTE"
1150 PAUSE
1160 INPUT "ENTER THE FILENAME FOR THE F-COEFFS",File$
1170 Bytes=8*(2*N+6)
1180 Rec=INT(Bytes/256)+1
1190 CREATE File$,Rec
1200 ASSIGN #1 TO File$
1210 PRINT #1;M,Interval,Time1,N,T,B0,A(*),B(*)
1220 SUBEND     !



1230 !     SUBROUTINE: F_retrieve
1240 !     ----------------------
1250 !
1260 !     THIS SUBROUTINE RETRIEVES FOURIER COEFFS FROM TAPE
1270 SUB F_retrieve(M,Interval,Time1,N,T,B0,A(*),B(*))
1280 OPTION BASE 1
1290 DISP "INSERT THE F-COEFF DATA CASSETTE"
1300 PAUSE
1310 INPUT "ENTER THE FILENAME TO BE RETRIEVED",File$
1320 ASSIGN #1 TO File$
1330 READ #1,1
1340 READ #1;M,Interval,Time1,N,T,B0
1350 REDIM A(N),B(N)
1360 READ #1;A(*),B(*)
1370 PRINT LIN(1),File$;"HAS BEEN RETRIEVED";SPA(5);"NO OF READINGS=";M
1380 PRINT "TIME1=";Time1;SPA(5);"INTERVAL=";Interval
1390 PRINT "NO OF F-COEFFS=";N;SPA(5);"2T=";2*T
1400 SUBEND     !
```

APPENDIX XI.8

```
10   !     PROGRAM: Q_MIX
20   !
30   !     THIS PROGRAM SOLVES FOR THE PARAMETERS OF A SIMPLE RECYCLE MODEL
40   !     WITH GAMMA DISTRIBUTIONS IN BOTH LOOPS,
50   !     BY MINIMISING F=SU  A(K)-A_exp(K))^2 +SUM(B(K)-B_exp(K))^2.
60   !     SETS OF F-COEFFS AK  USED AT INCREASING FREQUENCY
70   !     MINIMIZATION SUBROUTINE "ZXMIN" MUST BE LINKED    !



80   !     MAIN PROGRAM
90   !     ----------
100  !
110  OPTION BASE 1
120  COM INTEGER K(125),REAL Nf,T,A_e(125),B_e(125),A(125),B(125),Mean !VARIABLES NEEDED BY SUB Fun
130  DIM X(4),H(10),G(4),W(12),A_exp(125),B_exp(125)
140  PRINTER IS 16
150  PRINT LIN(1),TAB(30);CHR$(27);"&dD";"PROGRAM: Q_MIX";CHR$(27);"&d@"
160  CALL F_retrieve(M,Interval,Time1,Nf,T,Bu_exp,A_exp(*),B_exp(*))
170  INPUT "INPUT MEAN OF F-CURVE",Mean
180  Nf=5
190  REDIM K(Nf),A(Nf),B(Nf),A_e(Nf),B_e(Nf)
200  FOR I=1 TO 12
210  FOR J=1 TO Nf
220    K(J)=5*(I-1)+J
230    A_e(J)=A_exp(K(J))
240    B_e(J)=B_exp(K(J))
250  NEXT J
260  !
270  !     CALLING VALUES FOR Zxmin
280 Cal: N=4          ! 4 PARAMETERS
290  Nsig=3          ! DIGITS OF ACCURACY OF PARAMETERS
300  Maxfn=500       ! MAXIMUM 500 EVALUATIONS OF F
310  Iopt=0
320  X(1)=.6541
330  X(2)=.2278
340  X(3)=.005365
350  X(4)=.03339
360  X(3)=X(3)*100
370  X(4)=X(4)*10
380  MAT H=(0)
390  MAT G=(0)
400  F=0
410  MAT W=(0)
420  Ier=0
430  DISP SPA(17);"********** PROGRAM RUNNING **********"
440  CALL Zxmin(N,Nsig,Maxfn,Iopt,X(*),H(*),G(*),F,W(*),Ier)
450  X(3)=X(3)/100
460  X(4)=X(4)/10
470  Mean2=((1-X(1))*Mean-X(2))/X(1
480  Volfrac=X(2)/((1-X(1))*Mean)
490  R=X(1)/(1-X(1))
500  !
510  !     DISPLAY OF RESULTS
520  PRINTER IS 7,1
530  FLOAT 5
540  PRINT LIN(7)
550  PRINT "PARAMETERS=";X(1);SPA(2);X(2);SPA(2);X(3);SPA(2);X(4)
560  PRINT "MEAN IN REGION 2=";Mean2
570  PRINT "VARIANCE/(MEAN^2)=  REG 1:";X(3)/X(2)^2;"   REG 2:";X(4)/Mean2^2
580  PRINT "VOL FRAC OF REG 1=";Volfrac
590  PRINT "RECYCLE RATIO=";R
600  PRINT "GRADIENTS=";G(1);SPA(2);G(2);SPA(2);G(3);SPA(2);G(4)
610  PRINT "FINAL FUNCTION VALUE=";F
620  PRINT "NO. OF FUNCTION EVALUATIONS=";W(2)
630  IF Ier<>0 THEN PRINT "ERROR PARAMETER=";Ier
640  FIXED 5
650  PRINT LIN(1)
660  PRINT SPA(7);"K";SPA(11);"A_exp(K)";SPA(9);"A(K)";SPA(9);"B_exp(K)";SPA(9);"B(K)"
670  FOR J=1 TO Nf
680    PRINT K(J);SPA(7);A_e(J);SPA(7);A(J);SPA(7);B_e(J);SPA(7);B(J)
```

```
690  NEXT J
700  NEXT I
710  DISP ""
720  STOP
```

```
730  !     SUBROUTINE: FUN
740  !     ---------------
750  !
760  !     THIS SUBROUTINE CALCULATES FUNTION F FOR GIVEN PARAMETER VALUES X(*)
770  SUB Fun(N,X(*),F)
780  OPTION BASE 1
790  COM INTEGER K(*),REAL Nf,T,A_e(*),B_e(*),A(*),B(*),Mean
800  DIM Adif(Nf),Bdif(Nf)
810  P=X(1)                          ! RECYCLE FRACTION
820  Mean1=X(2)                      ! MEAN RES TIME OF REGION 1
830  Var1=X(3)/100                   ! VARIANCE OF REGION 1
840  Var2=X(4)/10                    ! VARIANCE OF REGION 2
850  Mean2=((1-P)*Mean-Mean1)/P      ! MEAN RES TIME OF REGION 2
860  N1=Mean1^2/Var1                 ! EQUIVALENT NUMBER OF CSTRs
870  N2=Mean2^2/Var2                 !       "      "   "   "
880  RAD
890  FOR J=1 TO Nf
900    Freq=K(J)*PI/T
910    R1=SQR(1+(Freq*Mean1/N1)^2)
920    R2=SQR(1+(Freq*Mean2/N2)^2)
930    Theta1=ATN(Freq*Mean1/N1)
940    Theta2=ATN(Freq*Mean2/N2)
950    Den=R1^(2*N1)*R2^(2*N2)-2*P*R1^N1*R2^N2*COS(N1*Theta1+N2*Theta2)+P^2
960    Nume=(1-P)*R2^N2
970    A(J)=1/T*Nume*(R1^N1*R2^N2*SIN(N1*Theta1)+P*SIN(N2*Theta2))/Den
980    B(J)=1/T*Nume*(R1^N1*R2^N2*COS(N1*Theta1)-P*COS(N2*Theta2))/Den
990  NEXT J
1000 MAT Adif=A-A_e
1010 MAT Bdif=B-B_e
1020 Dota=DOT(Adif,Adif)
1030 Dotb=DOT(Bdif,Bdif)
1040 F=Dota+Dotb
1050 ! PRINTER IS 7,1,WIDTH(130)
1060 ! FIXED 5
1070 ! PRINT X(1),X(2),X(3),X(4),,F
1080 ! STANDARD
1090 ! PRINTER IS 16
1100 SUBEND
```

```
1110 !     SUBROUTINE: F_retrieve
1120 !     ----------------------
1130 !
1140 !     THIS SUBROUTINE RETRIEVES FOURIER COEFFS FROM TAPE
1150 SUB F_retrieve(M,Interval,Time1,N,T,B0,A(*),B(*))
1160 OPTION BASE 1
1170 DISP "INSERT THE F-COEFF DATA CASSETTE"
1180 PAUSE
1190 INPUT "ENTER THE FILENAME TO BE RETRIEVED",File$
1200 ASSIGN #1 TO File$
1210 READ #1,1
1220 READ #1;M,Interval,Time1,N,T,B0
1230 REDIM A(N),B(N)
1240 READ #1;A(*),B(*)
1250 PRINT LIN(1),File$;"HAS BEEN RETRIEVED";SPA(5);"NO OF READINGS=";M
1260 PRINT "TIME1=";Time1;SPA(5);"INTERVAL=";Interval
1270 PRINT "NO OF F-COEFFS=";N;SPA(5);"2T=";2*T
1280 SUBEND
```