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APPENDICES

Appendix A Programming Model for Retrofit without Relocation

\$TITLE HEN design- Automatic parameter calculation- KITISAK-1

* Equations that are different than in the paper +errata.

*(100) Just a nomenclature change

*(105) Just a nomenclature change

* Equations that are added to those that are in the paper

*(106) and (107)

* CONSISTENCY: Number of exchangers smaller than the number of shells

* Needed because the exchangers are related to the values of K.

*(108) LIMIT THE NUMBER OF EXCHANGERS

*(109) MINIMUM NUMBER OF EXCHANGERS

\$OFFUPPER

SETS

Z transfer zone /Z1*Z1/

*

*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS

I Hot streams /I1*I3/

J cold streams /J1*J3/

*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX

HU(I) Heating utilities /I3/

CU(J) Cooling utilities /J3/

*

M temperature intervals /M1*M85/

S SCENARIO /S1/

K temperature intervals /K1*K1/

R exchangers /R1*R7/

ALIAS (M,N,L,O)

ALIAS (I,I)

ALIAS (J,J)

ALIAS (K,KK)

ALIAS (Z,ZZ)

SET

ORDER(I)

/

J1

J2

/

PARAMETER NIZ(S,Z,I) # OF INTERVALS DESIRED FOR HOT STREAMS

/

S1.Z1.I1 30

S1.Z1.I2 8

S1.Z1.I3 2

/

PARAMETER NJZ(S,Z,J) # OF INTERVALS DESIRED FOR COLD STREAMS

/

S1.Z1.J1 35

S1.Z1.J2 8

S1.Z1.J3 2

/

PARAMETER HI(S,I) HEAT TR COEFF FOR HOT STREAMS

/

S1.I1 0.1

S1.I2 0.1

S1.I3 0.1

/

PARAMETER HJ(S,J) HEAT TR COEFF FOR COLD STREAMS

/

S1.J1 0.1

S1.J2 0.1

S1.J3 0.1

/

PARAMETERS

TIH(S,I) T IN FOR HOT STREAMS

/
 S1.I1 400
 S1.I2 140
 S1.I3 500

TOH(S,I) T OUT FOR HOT STREAMS

/
 S1.I1 100
 S1.I2 60
 S1.I3 499

TIC(S,J) T IN FOR COLD STREAMS

/
 S1.J1 50
 S1.J2 90
 S1.J3 30

TOC(S,J) T OUT FOR COLD STREAMS

/
 S1.J1 400
 S1.J2 165
 S1.J3 40

PARAMETERS

TIHZ(S,Z,I) T IN FOR HOT STREAMS

/
 S1.Z1.I1 400
 S1.Z1.I2 140
 S1.Z1.I3 500

TOHZ(S,Z,I) T OUT FOR HOT STREAMS

/
 S1.Z1.I1 100
 S1.Z1.I2 60
 S1.Z1.I3 499

TICZ(S,Z,J) T IN FOR COLD STREAMS

/
 S1.Z1.J1 50
 S1.Z1.J2 90
 S1.Z1.J3 30

TOCZ(S,Z,J) T OUT FOR COLD STREAMS

/
 S1.Z1.J1 400
 S1.Z1.J2 165
 S1.Z1.J3 40

/
 *-----
 *INTRODUCE THE FCp:

FH(S,I) FOR HOT STREAMS

/
 S1.I1 10
 S1.I2 30

FC(S,J) FOR COLD STREAMS

/
 S1.J1 10
 S1.J2 40

/
 *USE THE MAX FCp FOR THE UTILITIES

*-----
 SETS FREEH(I)

/
 I1
 I2
 I3

/
 FREEC(J)

/

```

J1
J2
J3
/
PARAMETER BIF(Z,I,J)
/
Z1.I1.J2 0
Z1.I2.J1 0
Z1.I3.J1 0
Z1.I2.J3 0
/
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
*
PARAMETER SPH(I)  SH in paper
/
I1  1
I2  1
I3  1
/
PARAMETER SPC(J)  SC in paper
/
J1  1
J2  1
J3  1
/
PARAMETER NIH(I)  Non isothermal splitting for hot streams in paper
/
I1  0
I2  0
I3  0
/
PARAMETER NIC(J)  Non isothermal splitting for cold streams in paper
/
J1  0
J2  0
J3  0
/
PARAMETER DTVIO(I,J)
/
I1.J1  1
I1.J2  1
I1.J3  1
I2.J1  1
I2.J2  1
I2.J3  1
I3.J1  1
I3.J2  1
I3.J3  1
/
PARAMETER KMAX(Z,I,J)
/
Z1.I1.J2  1
Z1.I2.J1  1
Z1.I3.J1  1
Z1.I2.J3  1

/
*****
***** ADD FOR RETROFIT *****
*****
*Context
PARAMETER AEX(Z,I,J)
/
Z1.I1.J2 841.86
Z1.I2.J1 554

```

```

Z1.I2.J3 660.18
Z1.I3.J1 262
/
PARAMETER AEX_B(K.Z.I.J)
/
K1.Z1.I1.J2 841.86
/
PARAMETER NHE0(S.Z.I.J)
/
S1.Z1.I1.J2 1
S1.Z1.I2.J1 1
S1.Z1.I3.J1 1
S1.Z1.I2.J3 1
/
PARAMETER AEX_U(Z.I.J)
/
Z1.I1.J2 2000
Z1.I2.J1 2000
Z1.I3.J1 2000
Z1.I2.J3 2000
/
PARAMETER AEX_U_B(K.Z.I.J)
/
K1.Z1.I1.J2 2000
/
PARAMETER A_NEW_MAX(Z,I,J)
/
Z1.(I1*I3).(J1*J3) 2000
/

```

```

*-----
*For Relocation
$ontext
PARAMETER AEX_I(R)
/
R1 1001.34
R2 1048.28
R3 121.53
R4 133.56
R5 584.15
R6 603.71
R7 246.81
/
PARAMETER AEX_B_I(R)
/
R1 1001.34
/
PARAMETER AEX_U_I(R)
/
R1 1502.01
R2 1572.42
R3 182.295
R4 200.34
R5 876.225
R6 905.565
R7 370.215
/
PARAMETER AEX_U_B_I(R)
/
R1 1502.01
/

PARAMETER R_ALL
*      Minimum DELTA T
/;/

```

```

$offtext
*****

```

```

*****
PARAMETER DTHU(I)
/
I3 1
/
PARAMETER DTCU(J)
/
J3 10
/
PARAMETER FMAX_HU(I)
/
I3 5000
/
PARAMETER FMAX_CU(J)
/
J3 5000
/
PARAMETER CHU(I)
/
I3 95.04
/
PARAMETER CCU(J)
/
J3 20
/
PARAMETER CF;
CF = 1000;
PARAMETER CA;
CA = 20;
*****
*****FOR RETEOFIT*****
*****
PARAMETER MAX_NEW_HEX
*      Maximum Number of new exchangers
/200/;

PARAMETER CAN;
CAN = 20;
PARAMETER CAE;
CAE = 20;
*****
PARAMETER QLHMIN
*      Minimum heat that can be transferred within an interval.Hot streams
/0.01/;
PARAMETER QLCMIN
*      Minimum heat that can be transferred within an interval.Cold streams
/0.01/;
PARAMETER AMAX
*      Maximum area per exchanger
/20000/;
PARAMETER ASHELLMAX
*      Maximum shell area
/5000/;
PARAMETER USHELLMAX
*      Maximum shell area
/5000/;

* Add for retrofit
PARAMETER A_NEW_SHELLMAX
*      Maximum shell area
/5000/;
PARAMETER NEW_USHELLMAX
*      Maximum shell area
/5000/;

*
PARAMETER TOTNEXCHMAX
*      Maximum NUMBER OF EXCHANGERS
/900/;
PARAMETER TOTNEXCHMIN
*      Minimum NUMBER OF EXCHANGERS

```

```

/0/;
PARAMETER DTmin
*      Minimum DELTA T
/0/;

parameter NINT
/263/;
parameter OPT
/1/;
*-----
*                END OF INPUT PARAMETERS
*-----
SCALARS Si, Zi, Mi, Ic, Ji

PARAMETERS IHminZ(S,Z,I),IHmaxZ(S,Z,I),IHmax(S,I),IHmin(S,I),HOT(S,I,M),
HOT2(S,M),HOTZ(S,Z,I,M),ICminZ(S,Z,J),ICmaxZ(S,Z,J),ICmin(S,J),
ICmax(S,J),COLD(S,J,M),COLD2(S,M),COLDZ(S,Z,J,M),H_I(S,I,M),H_J(S,J,M)

FOR(Si=1 TO CARD(S),
FOR(Zi=1 TO CARD(Z),
FOR(Ic=1 TO CARD(I),
  IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)=1
                AND ORD(Z)=1}= 0+ 1${NIZ(S,Z,I)>=1};
  IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)>1
                AND ORD(Z)=1}= 0+
    {SUM((ZZ,II){ORD(II)<ORD(I)},NIZ(S,ZZ,II))+1 }${NIZ(S,Z,I)>=1};
  IHminZ(S,Z,I){ORD(S)=Si AND ORD(Z)>1}= 0+
    {SUM((ZZ,II){ORD(II)<ORD(I)},NIZ(S,ZZ,II)
    +SUM(ZZ${ORD(ZZ)< Zi},NIZ(S,ZZ,I))+1 }${NIZ(S,Z,I)>=1};
  IHmaxZ(S,Z,I){ORD(S)=Si AND ORD(I)=Ic AND ORD(Z)=Zi}= 0+
    {IHminZ(S,Z,I)+NIZ(S,Z,I)-1 }${NIZ(S,Z,I)>=1};
  IHmin(S,I){ORD(S)=Si AND ORD(I)=Ic}=
    SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NIZ(S,ZZ,I))=0},IHminZ(S,Z,I)];
  IHmax(S,I){ORD(S)=Si AND ORD(I)=Ic}=
    SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NIZ(S,ZZ,I))=0},IHmaxZ(S,Z,I)];

FOR(Mi=1 TO CARD(M),
  HOT(S,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi}= 0+
    1${ORD(M)>= IHmin(S,I) AND ORD(M)<=IHmax(S,I)};
  HOT2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+ 1${ORD(M)<=
    SUM(I${ORD(I)=CARD(I)},IHmax(S,I))};
  HOTZ(S,Z,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
AND ORD(Z)=Zi}= 0+ 1${ORD(M)>= IHminZ(S,Z,I) AND ORD(M)<=IHmaxZ(S,Z,I)};
  H_I(S,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
                AND HOT(S,I,M)=1 }= HI(S,I) :
));
FOR(Ji=1 TO CARD(J),
  ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)=1 AND ORD(Z)=1}= 0+
    {SUM(I${ORD(I)=CARD(I)},IHmax(S,I))+1 }${NJZ(S,Z,J)>=1};
  ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)>1 AND ORD(Z)=1}= 0+
    {SUM(I${ORD(I)=CARD(I)},IHmax(S,I))
    +SUM((ZZ,JJ){ORD(JJ)<ORD(J)},NJZ(S,ZZ,JJ))+1 }${NJZ(S,Z,J)>=1};
  ICminZ(S,Z,J){ORD(S)=Si AND ORD(Z)>1}= 0+
    {SUM(I${ORD(I)=CARD(I)},IHmax(S,I))
    +SUM((ZZ,JJ){ORD(JJ)<ORD(J)},NJZ(S,ZZ,JJ))
    +SUM(ZZ${ORD(ZZ)< Zi},NJZ(S,ZZ,J))+1 }${NJZ(S,Z,J)>=1};
  ICmaxZ(S,Z,J){ORD(S)=Si AND ORD(J)=Ji AND ORD(Z)=Zi}= 0+
    {ICminZ(S,Z,J)+NJZ(S,Z,J)-1 }${NJZ(S,Z,J)>=1};
  ICmin(S,J) {ORD(S)=Si AND ORD(J)=Ji}=
    SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NJZ(S,ZZ,J))=0},ICminZ(S,Z,J)];
  ICmax(S,J) {ORD(S)=Si AND ORD(J)=Ji}=
    SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NJZ(S,ZZ,J))=0},ICmaxZ(S,Z,J)];

FOR(Mi=1 TO CARD(M),
  COLD(S,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi}= 0+
    1${ORD(M)>= ICmin(S,J) AND ORD(M)<=ICmax(S,J)};
  COLD2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+
    1${ORD(M)>SUM(I${ORD(I)=CARD(I)},IHmax(S,I))
    AND ORD(M)<= SUM(J${ORD(J)=CARD(J)},ICmax(S,J))};
  COLDZ(S,Z,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
AND ORD(Z)=Zi}= 0+ 1${ORD(M)>= ICminZ(S,Z,J)

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        AND ORD(M)<=ICmaxZ(S,Z,J));
    H_J(S,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
        AND COLD(S,J,M)=1] = HJ(S,J) ;
    )));

PARAMETERS DT(S,M),TU(S,M), TL(S,M),CPH(S,I,M),CPC(S,J,M),DHH(S,I,M),DHC(S,J,M);

*ALWAYS DEFINE Cp AS 1
CPH(S,I,M)$[HOT(S,I,M)=1] = 1;
CPC(S,J,M)$[COLD(S,J,M)=1] = 1;

DT(S,M) = SUM((Z,I)$[HOTZ(S,Z,I,M)=1], {{TIHZ(S,Z,I)-TOIIZ(S,Z,I)}/
    [IHmaxZ(S,Z,I)-IHminZ(S,Z,I)+1]})$[HOT2(S,M)=1]+
    SUM((Z,J)$[COLDZ(S,Z,J,M)=1], {{TOCZ(S,Z,J)-TICZ(S,Z,J)}/
    [ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]})$[COLD2(S,M)=1];

FOR(Si= 1 TO CARD(S),
    FOR (Mi=1 TO CARD(M),
        TU(S,M)$[ORD(S)=Si AND ORD(M)=Mi]= {SUM((Z,I)$[HOTZ(S,Z,I,M)=1
            AND ORD(M)=IHminZ(S,Z,I),TIHZ(S,Z,I)$[ORD(M)=IHminZ(S,Z,I)]]
            + SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)>IHminZ(S,Z,I)AND
                ORD(M)<=IHmaxZ(S,Z,I),
                {TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)}$[ORD(M)>
                IHminZ(S,Z,I)AND ORD(M)<=IHmaxZ(S,Z,I)]})$[HOT2(S,M)=1]
            + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICminZ(S,Z,J)],
                TOCZ(S,Z,J)$[ORD(M)=ICminZ(S,Z,J)])
            + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z,J)
                AND ORD(M)<=ICmaxZ(S,Z,J)],
                [TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]$[ORD(M)>
                ICminZ(S,Z,J)AND ORD(M)<=ICmaxZ(S,Z,J)])}$[COLD2(S,M)=1];
        TL(S,M)$[ORD(S)=Si AND ORD(M)=Mi]=
            {SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)=IHmaxZ(S,Z,I),
                TOHZ(S,Z,I)$[ORD(M)=IHmaxZ(S,Z,I)]]
            + SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z,I)
                AND ORD(M)>=IHminZ(S,Z,I),
                [TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$[ORD(M)<
                IHmaxZ(S,Z,I)AND ORD(M)>=IHminZ(S,Z,I)]})$[HOT2(S,M)=1]
            + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICmaxZ(S,Z,J)],
                TICZ(S,Z,J)$[ORD(M)=ICmaxZ(S,Z,J)])
            + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)<ICmaxZ(S,Z,J)
                AND ORD(M)>=ICminZ(S,Z,J)],
                [TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$[ORD(M)<
                ICmaxZ(S,Z,J)AND ORD(M)>=ICminZ(S,Z,J)])}$[COLD2(S,M)=1];
        FOR(Ic=1 TO CARD(I),
            DHH(S,I,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(I)=Ic
                AND HOT(S,I,M)=1]= FH(S,I)*CPH(S,I,M)*[TU(S,M)-TL(S,M)] ;
        );
        FOR(Ji=1 TO CARD(J),
            DHC(S,J,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(J)=Ji
                AND COLD(S,J,M)=1]= FC(S,J)*CPC(S,J,M)*[TU(S,M)-TL(S,M)] ;
        )));

PARAMETER HHEAD(S,M,N), CHEAD(S,M,N), LMTD(S,M,N), D(S,Z,M,N)
*MATCH ALLOWED BASED ON LMTD
    ALLOW(S,Z,I,J), ALLOW_H(S,Z,I,M,J), ALLOW_C(S,Z,J,M,I), ALLOW_2(Z,I,J) ;

HHEAD(S,M,N) = {TU(S,M)-TU(S,N)+ DTmin}$[HOT2(S,M) AND COLD2(S,N)];
CHEAD(S,M,N) = {TL(S,M)-TL(S,N)+ DTmin}$[HOT2(S,M) AND COLD2(S,N)];

LMTD(S,M,N)= {[HHEAD(S,M,N)-CHEAD(S,M,N)]
    /LOG[HHEAD(S,M,N)/CHEAD(S,M,N)]}$[HHEAD(S,M,N)> 0
    AND CHEAD(S,M,N)>0 AND HHEAD(S,M,N)> CHEAD(S,M,N)]
    + {[HHEAD(S,M,N)+CHEAD(S,M,N)]/2}$[HHEAD(S,M,N)>0 AND CHEAD(S,M,N)>0
    AND (HHEAD(S,M,N)< CHEAD(S,M,N)OR HHEAD(S,M,N)= CHEAD(S,M,N))];

D(S,Z,M,N)= 1$[HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[I$[HOT(S,I,M)=1
    AND HOT(S,I,N)=1],HOTZ(S,Z,I,M)=1 AND SUM[I$[HOT(S,I,N)=1
    AND HOT(S,I,M)=1],HOTZ(S,Z,I,N)=1]
    OR {COLD2(S,M)=1 AND COLD2(S,N)=1 AND SUM[J$(COLD(S,J,M)=1
    AND COLD(S,J,N)=1),COLDZ(S,Z,J,M)=1 AND SUM[J$(COLD(S,J,N)=1

```

```

AND COLD(S,J,M)=1,COLDZ(S,Z,J,N)=1 }
OR {(HHEAD(S,M,N)>=0.00001 AND CHEAD(S,M,N)>=0.00001)
AND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,I,M)]=1
AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)=1}];
* OR {LMTD(S,M,N)>0 AND SUM[I$(HOT(S,I,M)=1).HOTZ(S,Z,I,M)]=1
* AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)=1}];

FOR(Si= 1 TO CARD(S),
FOR(Zi=1 TO CARD(Z),
FOR(Ic=1 TO CARD(I),
FOR(Ji=1 TO CARD(J),
ALLOW(S,Z,I,J){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
AND ORD(J)=Ji}= 0+ 1$ {SUM{(M,N)$[HOT(S,I,M)=1
AND COLD(S,J,N)=1],D(S,Z,M,N)} >0
AND NOT[HU(I)AND CU(J)]};
FOR (Mi=1 TO CARD(M),
ALLOW_H(S,Z,I,M,J){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
AND ORD(J)=Ji AND ORD(M)=Mi
AND HOT(S,I,M)=1}= 0+
1$ {SUM[N$[COLD(S,J,N)=1],D(S,Z,M,N)} >0AND NOT[HU(I)AND CU(J)]};
ALLOW_C(S,Z,J,M,I){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1}= 0+
1$ {SUM[N$[HOT(S,I,N)=1],D(S,Z,N,M)} >0AND NOT[HU(I)AND CU(J)]};
)););
FOR(Zi=1 TO CARD(Z),
FOR(Ic=1 TO CARD(I),
FOR(Ji=1 TO CARD(J),
ALLOW_2(Z,I,J){ORD(Z)=Zi AND ORD(I)=Ic AND ORD(J)=Ji}= 0+
1$ {SUM[S,ALLOW(S,Z,I,J)} >0AND NOT[HU(I)AND CU(J)]};
)););
$ONTEXT
*NM-4S1-FINAL-6-FLEXIBILITY-S1.gms: August 9, 2004
* one scenario, the original values of 4s1.
*****
$OFFTEXT
$ontext
*DEFINES THE NUMBER OR TRANSFER ZONES
SET
Z transfer zone /Z1*Z2/

*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
SET I /I1*I15/
SET J /J1*J15/

SETS
M temperature intervals /M1*M250/
S SCENARIO /S1/
K number of heat exchangers /K1*K20/
X used to input numbers /X1*X15/

ALIAS (M,N,L,O)
ALIAS (I,I)
ALIAS (J,J)
ALIAS (K,KK)
ALIAS (Z,ZZ)

*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
*Heating utilities
$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=HU mg=GAMS\C49:149 Cdim=1
SET HU(I)
$GDXXIN isabel.gdx
$LOAD HU

*Cooling utilities
$CALL GDXXRW EXE c:\HENS\isabel.xls Set=CU mg=GAMS\C52:152 Cdim=1
SET CU(J)
$GDXXIN isabel.gdx
$LOAD CU

*****Input parameters *****

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```

* INPUTS 15 NUMBERS IN ONE VECTOR TO REDUCE LOADING TIME
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=DATA rng=Hoja!E48:F62 Rdim=1
PARAMETER DATA(X);
$GDXIN isabel.gdx
$LOAD DATA

*DEFINES WHICH EQUATIONS RUN OPT=0 GRASSROOTS OPT=1 RETROFIT OPT=2 RELOCATION
PARAMETER OPT;
OPT = DATA('X1');

*THE NUMBER OF INTERVALS TO BE USED
PARAMETER NINT;
NINT = DATA('X2');

*Maximum shell area
PARAMETER ASHELLMAX;
ASHELLMAX = DATA('X3');

*Maximum area per exchanger
PARAMETER AMAX;
AMAX = DATA('X4');

*Minimum DELTA T
PARAMETER DTmin;
DTmin = DATA('X5');

*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
PARAMETER BIF;
BIF = DATA('X6');

*LIMITS THE NUMBER OF HEAT EXCHANGERS IN ONE INTERVAL
PARAMETER KMAX;
KMAX = DATA('X7');

*Minimum heat that can be transferred within an interval.Hot streams
PARAMETER QLHMIN;
QLHMIN = DATA('X8');

*Minimum heat that can be transferred within an interval.Cold streams
PARAMETER QLCMIN;
QLCMIN = DATA('X8');

*Maximum NUMBER OF EXCHANGERS
PARAMETER TOTNEXCHMAX;
TOTNEXCHMAX = DATA('X9');

*Minimum NUMBER OF EXCHANGERS
PARAMETER TOTNEXCHMIN;
TOTNEXCHMIN = DATA('X10');

*FIXED COST FOR A HEAT EXCHANGER MATCHING STREAMS
PARAMETER CF;
CF = DATA('X11');

*VARIABLE COST FOR A HEAT EXCHANGER MATCHING STREAMS
PARAMETER CA;
CA = DATA('X12');

*COST OF RELOCATION
PARAMETER CAN;
CAN = DATA('X13');
PARAMETER CAE;
CAE = DATA('X13');

*NUMBER OF HEAT EXCHANGERS ORIGINALY PRESENT
PARAMETER KET;
KET= DATA('X14');

*MAXIMUM ADDITIONAL AREA

```

PARAMETER A_NEW_MAX;
A_NEW_MAX = DATA('X15');

*NUMBER OF INTERVALS ON HOT STREAM
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NIZ rng=GAMS!a1:q3 Rdim=2 Cdim=1
PARAMETER NIZ(S,Z,I);
\$GDXIN isabel.gdx
\$LOAD NIZ

*NUMBER OF INTERVALS ON COLD STREAM
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NJZ rng=GAMS!a5:q7 Rdim=2 Cdim=1
PARAMETER NJZ(S,Z,J);
\$GDXIN isabel.gdx
\$LOAD NJZ

*HEAT TRANSFER COEFF FOR HOT STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=HI rng=GAMS!B9:q10 Rdim=1 Cdim=1
PARAMETER HI(S,I);
\$GDXIN isabel.gdx
\$LOAD HI

*HEAT TRANSFER COEFF FOR COLD STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=HJ rng=GAMS!B12:q13 Rdim=1 Cdim=1
PARAMETER HJ(S,J);
\$GDXIN isabel.gdx
\$LOAD HJ

*TEMPERATURE FOR HOT INLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIH rng=GAMS!B15:q16 Rdim=1 Cdim=1
PARAMETER TIH(S,I);
\$GDXIN isabel.gdx
\$LOAD TIH

*TEMPERATURE FOR HOT OUTLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOH rng=GAMS!B18:q19 Rdim=1 Cdim=1
PARAMETER TOH(S,I);
\$GDXIN isabel.gdx
\$LOAD TOH

*TEMPERATURE FOR COLD INLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIC rng=GAMS!B21:q22 Rdim=1 Cdim=1
PARAMETER TIC(S,J);
\$GDXIN isabel.gdx
\$LOAD TIC

*TEMPERATURE FOR COLD OUTLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOC rng=GAMS!B24:q25 Rdim=1 Cdim=1
PARAMETER TOC(S,J);
\$GDXIN isabel.gdx
\$LOAD TOC

*PARAMETERS FOR Z ZONE, TEMPERATURA @ EACH ZONE AND FLOW
*TEMPERATURE FOR HOT INLET STREAMS @ Z
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIHZ rng=GAMS!A27:q29 Rdim=2 Cdim=1
PARAMETER TIHZ(S,Z,I);
\$GDXIN isabel.gdx
\$LOAD TIHZ

*TEMPERATURE FOR HOT OUTLET STREAMS @ Z
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOHZ rng=GAMS!A31:q33 Rdim=2 Cdim=1
PARAMETER TOHZ(S,Z,I);
\$GDXIN isabel.gdx
\$LOAD TOHZ

*TEMPERATURE FOR COLD INLET STREAMS @ Z
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TICZ rng=GAMS!A35:q37 Rdim=2 Cdim=1
PARAMETER TICZ(S,Z,J);
\$GDXIN isabel.gdx
\$LOAD TICZ

*TEMPERATURE FOR COLD OUTLET STREAMS @ Z

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOCZ rng=GAMS!A39:q41 Rdim=2 Cdim=1
 PARAMETER TOCZ(S,Z,J);
 \$GDXIN isabel.gdx
 \$LOAD TOCZ

*MASS FLOW FOR THE HOT STREAMS
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=FH rng=GAMS!B43:q44 Rdim=1 Cdim=1
 PARAMETER FH(S,I);
 \$GDXIN isabel.gdx
 \$LOAD FH

*MASS FLOW FOR THE COLD STREAMS
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=FC rng=GAMS!B46:q47 Rdim=1 Cdim=1
 PARAMETER FC(S,J);
 \$GDXIN isabel.gdx
 \$LOAD FC

*HOT PROCESS STREAMS
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=FREEH rng=GAMS!C1:q1 Cdim=1
 SET FREEH(I)
 \$GDXIN isabel.gdx
 \$LOAD FREEH

*COLD PROCESS STREAMS
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=FREEC rng=GAMS!C5:q5 Cdim=1
 SET FREEC(J)
 \$GDXIN isabel.gdx
 \$LOAD FREEC

*SPLITS ARE ALLOWED FOR HOT STREAMS BINARY SH in paper
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=SPH rng=GAMS!C55:q56 Cdim=1
 PARAMETER SPH(I);
 \$GDXIN isabel.gdx
 \$LOAD SPH

*SPLITS ARE ALLOWED FOR COLD STREAMS BINARY SC in paper
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=SPC rng=GAMS!C58:q59 Cdim=1
 PARAMETER SPC(J);
 \$GDXIN isabel.gdx
 \$LOAD SPC

*NON ISOTHERMAL MIXING IS PERMITTED FOR HOT STREAMS BINARY
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NIH rng=GAMS!C55:q56 Cdim=1
 PARAMETER NIH(I);
 \$GDXIN isabel.gdx
 \$LOAD NIH

*NON ISOTHERMAL MIXING IS PERMITTED FOR COLD STREAMS BINARY
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NIC rng=GAMS!C58:q59 Cdim=1
 PARAMETER NIC(J);
 \$GDXIN isabel.gdx
 \$LOAD NIC

*POSSIBLE TEMPERATURE DIFFERENCES BETWEEN EXCHANGING STREAMS
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=DTVIO rng=DTVIO!A1:C225 Rdim=2
 PARAMETER DTVIO(I,J);
 \$GDXIN isabel.gdx
 \$LOAD DTVIO

*TEMPERATURE DIFFERENCE IN THE HOT UTILITY
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=DTHU rng=GAMS!C49:q50 Cdim=1
 PARAMETER DTHU(I);
 \$GDXIN isabel.gdx
 \$LOAD DTHU

*TEMPERATURE DIFFERENCE IN THE COLD UTILITY
 \$CALL GDXXRW.EXE c:\HENS\isabel.xls par=DTCU rng=GAMS!C52:q53 Cdim=1
 PARAMETER DTCU(J);
 \$GDXIN isabel.gdx
 \$LOAD DTCU

```

*MAXIMUM MASS FLOW FOR THE HOT UTILITY
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=FMAX_HU rng=GAMS!C61:q62 Cdim=1
PARAMETER FMAX_HU(I);
$GDXIN isabel.gdx
$LOAD FMAX_HU

*MAXIMUM MASS FLOW FOR THE COLD UTILITY
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=FMAX_CU mg=GAMS!C64:q65 Cdim=1
PARAMETER FMAX_CU(J);
$GDXIN isabel.gdx
$LOAD FMAX_CU

*COST OF HOT UTILITY
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CHU mg=GAMS!C67:q68 Cdim=1
PARAMETER CHU(I);
$GDXIN isabel.gdx
$LOAD CHU

*COST OF COLD UTILITY
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CCU rng=GAMS!C70:q71 Cdim=1
PARAMETER CCU(J);
$GDXIN isabel.gdx
$LOAD CCU

*CP OF HOT PROCESS STREAM I
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CPH mg=CP!BE2:BH251 rdim=3
PARAMETER CPH(S,I,M);
$GDXIN isabel.gdx
$LOAD CPH

*CP OF COLD PROCESS STREAM J
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CPC mg=CP!BJ2:BM251 rdim=3
PARAMETER CPC(S,J,M);
$GDXIN isabel.gdx
$LOAD CPC

***** ADD FOR RETROFIT *****
*AREA OF EXISTING HEAT EXCHANGERS
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX rng=EXCHANGERS!L2:O8 Rdim=3
PARAMETER AEX(Z,I,J);
$GDXIN isabel.gdx
$LOAD AEX

*AREA OF EXISTING HEAT EXCHANGERS THAT CANNOT BE MOVED
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_B mg=EXCHANGERS!Q2:U21 Rdim=4
PARAMETER AEX_B(K,Z,I,J);
$GDXIN isabel.gdx
$LOAD AEX_B

*NUMBER OF HEAT EXCHANGERS
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NHE0 mg=EXCHANGERS!K45:O244 Rdim=4
PARAMETER NHE0(S,Z,I,J);
$GDXIN isabel.gdx
$LOAD NHE0

*MAXIMUM AREA OF EXCHANGERS
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U mg=EXCHANGERS!L23:O42 Rdim=3
PARAMETER AEX_U(Z,I,J);
$GDXIN isabel.gdx
$LOAD AEX_U

$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U_B mg=EXCHANGERS!Q23:U42 Rdim=4
PARAMETER AEX_U_B(K,Z,I,J);
$GDXIN isabel.gdx
$LOAD AEX_U_B

***** ADD FOR RELOCATION*****
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_R mg=EXCHANGERS!Z2:AA21 Rdim=1
PARAMETER AEX_R(K);
$GDXIN isabel.gdx
$LOAD AEX_R

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$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U_R rng=EXCHANGERS!Z23:AA42 Rdim=1
PARAMETER AEX_U_R(K);
$GDXIN isabel.gdx
$LOAD AEX_U_R

$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_B_R rng=EXCHANGERS!AC2:AD21 Rdim=1
PARAMETER AEX_B_R(K);
$GDXIN isabel.gdx
$LOAD AEX_B_R

$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U_B_R rng=EXCHANGERS!AC23:AD42 Rdim=1
PARAMETER AEX_U_B_R(K);
$GDXIN isabel.gdx
$LOAD AEX_U_B_R

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*-----
*                               END OF INPUT PARAMETERS
*-----

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SCALARS Si, Zi, Mi, Ic, Ji
*H_I HEAT TRANSFER COEFICIENT FOR HOT STREAM I
*H_I HEAT TRANSFER COEFICIENT FOR COLD STREAM J
*HOT HOT FLOW I PRESENT IN INTERVAL M
*COLD COLD FLOW J PRESENT IN INTERVAL N
PARAMETERS IHminZ(S,Z,I),IHmaxZ(S,Z,I),IHmax(S,I),IHmin(S,I),HOT(S,I,M),
HOT2(S,M),HOTZ(S,Z,I,M),ICminZ(S,Z,J),ICmaxZ(S,Z,J),ICmin(S,J),
ICmax(S,J),COLD(S,J,M),COLD2(S,M),COLDZ(S,Z,J,M),H_I(S,I,M),H_J(S,J,M)

FOR(Si=1 TO CARD(S),
  FOR(Zi=1 TO CARD(Z),
    FOR(Ic=1 TO CARD(FREEH),
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)=I
        AND ORD(Z)=1}= 0+ 1${NIZ(S,Z,I)}>=1};
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)>1
        AND ORD(Z)=1}= 0+
        {SUM((ZZ,II){ORD(II)<ORD(I),NIZ(S,ZZ,II)+1} ${NIZ(S,Z,I)}>=1};
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(Z)>1}= 0+
        {SUM((ZZ,II){ORD(II)<ORD(I),NIZ(S,ZZ,II)
        +SUM(ZZ${ORD(ZZ)<Zi},NIZ(S,ZZ,I)+1} ${NIZ(S,Z,I)}>=1};
      IHmaxZ(S,Z,I){ORD(S)=Si AND ORD(I)=Ic AND ORD(Z)=Zi}= 0+
        {IHminZ(S,Z,I)+NIZ(S,Z,I)-1} ${NIZ(S,Z,I)}>=1};
      IHmin(S,I){ORD(S)=Si AND ORD(I)=Ic}=
        SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NIZ(S,ZZ,I))=0},IHminZ(S,Z,I)];
      IHmax(S,I){ORD(S)=Si AND ORD(I)=Ic}=
        SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NIZ(S,ZZ,I))=0},IHmaxZ(S,Z,I)];

      FOR(Mi=1 TO NINT,
        HOT(S,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi}= 0+
          1${ORD(M)}>= IHmin(S,I) AND ORD(M)<=IHmax(S,I)};
        HOT2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+ 1${ORD(M)<=
          SUM(I${ORD(I)=CARD(FREEH)},IHmax(S,I))};
        HOTZ(S,Z,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
        AND ORD(Z)=Zi}= 0+ 1${ORD(M)}>= IHminZ(S,Z,I) AND ORD(M)<=IHmaxZ(S,Z,I)};
        H_I(S,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
        AND HOT(S,I,M)=1}= HI(S,I) ;
      ));
    FOR(Ji=1 TO CARD(FREEC),
      ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)=1 AND ORD(Z)=1}= 0+
        {SUM(I${ORD(I)=CARD(FREEH)},IHmax(S,I)+1} ${NJZ(S,Z,J)}>=1};
      ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)>1 AND ORD(Z)=1}= 0+
        {SUM(I${ORD(I)=CARD(FREEH)},IHmax(S,I)
        +SUM((ZZ,JJ){ORD(JJ)<ORD(J),NJZ(S,ZZ,JJ)+1} ${NJZ(S,Z,J)}>=1};
      ICminZ(S,Z,J){ORD(S)=Si AND ORD(Z)>1}= 0+
        {SUM(I${ORD(I)=CARD(FREEH)},IHmax(S,I)
        +SUM((ZZ,JJ){ORD(JJ)<ORD(J),NJZ(S,ZZ,JJ)
        +SUM(ZZ${ORD(ZZ)<Zi},NJZ(S,ZZ,J)+1} ${NJZ(S,Z,J)}>=1};
      ICmaxZ(S,Z,J){ORD(S)=Si AND ORD(J)=Ji AND ORD(Z)=Zi}= 0+
        {ICminZ(S,Z,J)+NJZ(S,Z,J)-1} ${NJZ(S,Z,J)}>=1};
      ICmin(S,J) ${ORD(S)=Si AND ORD(J)=Ji}=
        SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NJZ(S,ZZ,J))=0},ICminZ(S,Z,J)];

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ICmax(S,J)$(ORD(S)=Si AND ORD(J)=Ji)=
SUM[Z$(SUM(ZZ$(ORD(ZZ)>=ORD(Z)+1),NJZ(S,Z,Z,J))=0).ICmaxZ(S,Z,J)];

FOR(Mi=1 TO NJNT,
COLD(S,J,M)$(ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi)= 0+
I$(ORD(M)>=ICmin(S,J) AND ORD(M)<=ICmax(S,J));
COLD2(S,M)$(ORD(S)=Si AND ORD(M)=Mi)= 0+
I$(ORD(M)>SUM(I$(ORD(I)=CARD(FREEH)),IHmax(S,I))
AND ORD(I)<=SUM(J$(ORD(J)=CARD(FREC)),ICmax(S,J)));
COLDZ(S,Z,J,M)$(ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
AND ORD(Z)=Zi)= 0+ I$(ORD(M)>=ICminZ(S,Z,J)
AND ORD(M)<=ICmaxZ(S,Z,J));
H_J(S,J,M)$(ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
AND COLD(S,J,M)=1) = HJ(S,J) ;
));
*DHH ENTHALPY CHANGE FOR HOT PROCESS STREAM I
*DHC ENTHALPY CHANGE FOR COLD PROCESS STREAM J
*DT TEMPERATURE DIFERENCE BETWEEN STREAMS AT INTERVAL
*TU UPPER TEMPERATURE OF INTERVAL
*TL LOWER TEMPERATURE OF INTERCAL
PARAMETERS DT(S,M),TU(S,M), TL(S,M), DHH(S,I,M),DHC(S,J,M);

DT(S,M) = SUM((Z,I)$(HOTZ(S,Z,I,M)=1),{(TIHZ(S,Z,I)-TOHZ(S,Z,I))/
[IHmaxZ(S,Z,I)-IHminZ(S,Z,I)+1]})$(HOT2(S,M)=1)+
SUM((Z,J)$(COLDZ(S,Z,J,M)=1),{(TOCZ(S,Z,J)-TICZ(S,Z,J))/
[ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]})$(COLD2(S,M)=1);

FOR(Si= 1 TO CARD(S),
FOR (Mi=1 TO NJNT,
TU(S,M)$(ORD(S)=Si AND ORD(M)=Mi)= {SUM((Z,I)$(HOTZ(S,Z,I,M)=1
AND ORD(M)=IHminZ(S,Z,I)),TIHZ(S,Z,I)$(ORD(M)=IHminZ(S,Z,I))}
+ SUM((Z,I)$(HOTZ(S,Z,I,M)=1 AND ORD(M)>IHminZ(S,Z,I)AND
ORD(M)<=IHmaxZ(S,Z,I)),
[TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)]$(ORD(M)>
IHminZ(S,Z,I)AND ORD(M)<=IHmaxZ(S,Z,I))}$(HOT2(S,M)=1)}
+ {SUM((Z,J)$(COLDZ(S,Z,J,M)=1 AND ORD(M)=ICminZ(S,Z,J)),
TOCZ(S,Z,J)$(ORD(M)=ICminZ(S,Z,J))}
+ SUM((Z,J)$(COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z,J)
AND ORD(M)<=ICmaxZ(S,Z,J)),
[TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]$(ORD(M)>
ICminZ(S,Z,J)AND ORD(M)<=ICmaxZ(S,Z,J))}$(COLD2(S,M)=1)};
TL(S,M)$(ORD(S)=Si AND ORD(M)=Mi)=
{SUM((Z,I)$(HOTZ(S,Z,I,M)=1 AND ORD(M)=IHmaxZ(S,Z,I)),
TOHZ(S,Z,I)$(ORD(M)=IHmaxZ(S,Z,I))}
+ SUM((Z,I)$(HOTZ(S,Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z,I)
AND ORD(M)>=IHminZ(S,Z,I)),
[TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$(ORD(M)<
IHmaxZ(S,Z,I)AND ORD(M)>=IHminZ(S,Z,I))}$(HOT2(S,M)=1)}
+ {SUM((Z,J)$(COLDZ(S,Z,J,M)=1 AND ORD(M)=ICmaxZ(S,Z,J)),
TICZ(S,Z,J)$(ORD(M)=ICmaxZ(S,Z,J))}
+ SUM((Z,J)$(COLDZ(S,Z,J,M)=1 AND ORD(M)<ICmaxZ(S,Z,J)
AND ORD(M)>=ICminZ(S,Z,J)),
[TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$(ORD(M)<
ICmaxZ(S,Z,J)AND ORD(M)>=ICminZ(S,Z,J))}$(COLD2(S,M)=1)};
FOR(Ic=1 TO CARD(FREEH),
DHH(S,I,M)$(ORD(S)=Si AND ORD(M)=Mi AND ORD(I)=Ic
AND HOT(S,I,M)=1)= FH(S,I)*CPH(S,I,M)*[TU(S,M)-TL(S,M)] ;
);
FOR(Ji=1 TO CARD(FREC),
DHC(S,J,M)$(ORD(S)=Si AND ORD(M)=Mi AND ORD(J)=Ji
AND COLD(S,J,M)=1)= FC(S,J)*CPC(S,J,M)*[TU(S,M)-TL(S,M)] ;
));

*ALLOW_2 MATCH ALLOWED BASED ON LMTD
*ALLOW HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I AND COLD STREAM J
*ALLOW_H HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I@M AND COLD STREAM J
*ALLOW_C HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I AND COLD STREAM J@N
PARAMETER HHEAD(S,M,N), CHEAD(S,M,N), LMTD(S,M,N), D(S,Z,M,N)
ALLOW(S,Z,I,J), ALLOW_H(S,Z,I,M,J), ALLOW_C(S,Z,J,M,I), ALLOW_2(Z,I,J) ;

FOR(Ic=1 TO CARD(FREEH),

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FOR(Ji=1 TO CARD(FREEC),
HHEAD(S,M,N) = {TU(S,M)-TU(S,N) + DTmin}$[HOT2(S,M) AND COLD2(S,N)];
CHEAD(S,M,N) = {TL(S,M)-TL(S,N) + DTmin}$[HOT2(S,M) AND COLD2(S,N)];

LMTD(S,M,N)= {[HHEAD(S,M,N)-CHEAD(S,M,N)]
/LOG[HHEAD(S,M,N)/CHEAD(S,M,N)]}$[HHEAD(S,M,N)> 0
AND CHEAD(S,M,N)>0 AND HHEAD(S,M,N)> CHEAD(S,M,N)]
+ {[HHEAD(S,M,N)+CHEAD(S,M,N)]/2}$[HHEAD(S,M,N)>0 AND CHEAD(S,M,N)>0
AND (HHEAD(S,M,N)< CHEAD(S,M,N)OR HHEAD(S,M,N)= CHEAD(S,M,N))];

D(S,Z,M,N)= 1$[{HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[IS(HOT(S,I,M)=1
AND HOT(S,I,N)=1),HOTZ(S,Z,I,M)]=1 AND SUM[IS(HOT(S,I,N)=1
AND HOT(S,I,M)=1),HOTZ(S,Z,I,N)]=1}
OR {COLD2(S,M)=1 AND COLD2(S,N)=1 AND SUM[IS(COLD(S,J,M)=1
AND COLD(S,J,N)=1),COLDZ(S,Z,J,M)]=1 AND SUM[IS(COLD(S,J,N)=1
AND COLD(S,J,M)=1),COLDZ(S,Z,J,N)]=1}
OR {(HHEAD(S,M,N)>=0.00001 AND CHEAD(S,M,N)>=0.00001)
AND SUM[IS(HOT(S,I,M)=1),HOTZ(S,Z,I,M)]=1
AND SUM[IS(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}];

));
* OR {LMTD(S,M,N)>0 AND SUM[IS(HOT(S,I,M)=1),HOTZ(S,Z,I,M)]=1
* AND SUM[IS(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}];

FOR(Si= 1 TO CARD(S),
FOR(Zi=1 TO CARD(Z),
FOR(Ic=1 TO CARD(FREEH),
FOR(Ji=1 TO CARD(FREEC),
ALLOW(S,Z,I,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
AND ORD(J)=Ji]= 0+ 1$[SUM[(M,N)$[HOT(S,I,M)=1
AND COLD(S,J,N)=1],D(S,Z,M,N)] >0
AND NOT[HU(I)AND CU(J)]];
FOR (Mi=1 TO NINT,
ALLOW_H(S,Z,I,M,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
AND ORD(J)=Ji AND ORD(M)=Mi
AND HOT(S,I,M)=1]= 0+
1$[SUM[N$[COLD(S,J,N)=1],D(S,Z,M,N)] >0AND NOT[HU(I)AND CU(J)]];
ALLOW_C(S,Z,J,M,I)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1]= 0+
1$[SUM[N$[HOT(S,I,N)=1],D(S,Z,N,M)] >0AND NOT[HU(I)AND CU(J)]];
))));
FOR(Zi=1 TO CARD(Z),
FOR(Ic=1 TO CARD(FREEH),
FOR(Ji=1 TO CARD(FREEC),
ALLOW_2(Z,I,J)$[ORD(Z)=Zi AND ORD(I)=Ic AND ORD(J)=Ji]= 0+
1$[SUM[S,ALLOW(S,Z,I,J)] >0 AND NOT[HU(I)AND CU(J)]];
));
$offtext
*-----
VARIABLES
TCOST
PAR(Z,I,J)
Q(S,Z,I,M,J,N) heat load for process-process match
QNEW_M(S,Z,I,J,M)
QNEW_N(S,Z,I,J,N)
QNEW2_M(S,Z,I,J,M)
QNEW2_N(S,Z,I,J,N)
Y_M(S,Z,I,J,M)
Y_N(S,Z,I,J,N)
Y_M_B(S,Z,I,J,M)
Y_N_B(S,Z,I,J,N)
NHE_M0(S,Z,I,J,M)
NHE_M1(S,Z,I,J,M)
NHE_N0(S,Z,I,J,N)
NHE_N1(S,Z,I,J,N)
NHE_M0_B(S,Z,I,J,M)
NHE_M1_B(S,Z,I,J,M)
NHE_N0_B(S,Z,I,J,N)
NHE_N1_B(S,Z,I,J,N)
NHE(S,Z,I,J)
ALFA_M(S,Z,I,J,M)

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ALFA_N(S,Z,I,J,N)
FHU(I)      is FCP HU (MJ_h_C)
FCU(J)      is FCP CU(MJ_h_C)
B1(S,Z,I,M,J,N)  X(imjn) in the paper
QH(S,Z,I,M,N)
QC(S,Z,I,M,N)
Q2(S,Z,I,M,J,N)
X1_B(S,Z,I,J,M)
X_B(S,K,Z,I,J,M)
PAR_B(K,Z,I,J)
USHELL(Z,I,J)
USHELL_B(K,Z,I,J)
*$ontext
*****ADD FOR RETROFIT*****

PAR_N(S,Z,I,J)
PAR_N_B(K,Z,I,J)
DPAR_E(Z,I,J)
DPAR_E_B(K,Z,I,J)
NHE_S(S,Z,I,J)
DELTA(K,K)
PHI(Z,I,J,K)

HOT_UTILITY_COST
Cold_UTILITY_COST
Area_Cost
FIX_COST

*$offtext
,
, POSITIVE VARIABLE Q,QNEW2_M,QNEW2_N,QC,QH,Q2,PAR1,PAR2,DPAR_E,DPAR_E_B
,PAR_N,PAR_N_B
,PAR,QNEW_M,QNEW_N
, BINARY VARIABLE NHE_M0_B,NHE_M1_B,NHE_N0_B,NHE_N1_B,Y_M,Y_N,X1_B,X_B,NHE_S
, DELTA,Y_M_B,Y_N_B,NHE_M0,NHE_M1,NHE_N0,NHE_N1,ALFA_M,ALFA_N
, PHI
, INTEGER VARIABLE USHELL,USHELL_B

EQUATIONS
HBHU(S,I,M)
HBCU(S,J,N)
HBHS(S,I,M)
HBCS(S,J,N)
TRANSFOR_M(S,Z,I,J,M)
TRANSFOR_N(S,Z,I,J,N)
HBHS_NI(S,I,M)
HBCS_NI(S,J,N)
NOISOH(S,I,M)
NOISOC(S,J,N)
BINARY_M1(S,Z,I,J,M)
BINARY_M2(S,Z,I,J,M)
BINARY_M1_B(S,Z,I,J,M)
BINARY_M2_B(S,Z,I,J,M)
BINARY_N1(S,Z,I,J,N)
BINARY_N2(S,Z,I,J,N)
BINARY_N1_B(S,Z,I,J,N)
BINARY_N2_B(S,Z,I,J,N)
BINARY_M5(S,Z,I,J,M)
BINARY_M5b(S,Z,I,J,M)
BINARY_M3(S,Z,I,J,M)
BINARY_M4(S,Z,I,J,M)
BINARY_M8(S,Z,I,J,M)
BINARY_M9(S,Z,I,J,M)
BINARY_M6(S,Z,I,J,M)
BINARY_M7(S,Z,I,J,M)
BINARY_M3_B(S,Z,I,J,M)
BINARY_N5(S,Z,I,J,N)
BINARY_N5b(S,Z,I,J,N)

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BINARY_N3(S,Z,I,J,N)
 BINARY_N4(S,Z,I,J,N)
 BINARY_N8(S,Z,I,J,N)
 BINARY_N9(S,Z,I,J,N)
 BINARY_N6(S,Z,I,J,N)
 BINARY_N7(S,Z,I,J,N)
 BINARY_N3_B(S,Z,I,J,N)
 HE_COUNT_M0(S,Z,I,J)
 HE_COUNT_N0(S,Z,I,J)
 HE_COUNT_M1(S,Z,I,J)
 HE_COUNT_N1(S,Z,I,J)
 NEXCH(S,Z,I,J)
 NEXCH_B(S,Z,I,J)
 BIF_1(S,Z,I,J,M,N)
 BIF_2(S,Z,I,J,M,N)
 BIF_3(S,Z,I,J,M,N)
 BIF_4(S,Z,I,J,M,N)
 BIF_11(S,Z,I,J,M)
 BIF_6(S,Z,I,J,M)
 BIF_9(S,Z,I,J,M)
 BIF_5(S,Z,I,J,M)
 BIF_7(S,Z,I,J,N)
 BIF_8(S,Z,I,J,N)
 BIF_10(S,Z,I,J,N)
 BIF_12(S,Z,I,J,N)
 BIF_13_2(S,K,Z,I,J,M)
 BIF_13_1(S,K,Z,I,J,M)
 BIF_14(S,K,Z,I,J)
 BIF_15(S,Z,I,J,M)
 *BIF_15(S,Z,I,J,M)
 BIF_17(S,Z,I,J,M)
 BIF_18(S,Z,I,J,M,N)
 FEAS_M_01(S,Z,I,J,M)
 FEAS_M_01_B(S,Z,I,J,M)
 FEAS_M_02(S,Z,I,J,M)
 FEAS_M_02_B(S,Z,I,J,M)
 FEAS_M_03(S,Z,I,J,M)
 FEAS_M_03_B(S,Z,I,J,M)
 FEAS_M_04(S,Z,I,J,M)
 FEAS_M_2(S,Z,I,J,M)
 FEAS_M_1(S,Z,I,J,M)
 FEAS_M_3(S,Z,I,J,M)
 FEAS_M_4(S,Z,I,J,M)
 FEAS_M_3_B_2(S,Z,I,J,M)
 FEAS_M_3_B_1(S,Z,I,J,M)
 FEAS_M_4_B(S,Z,I,J,M)
 FEAS_M_1_SP(S,Z,I,J,M)
 FEAS_M_1_SP_B(S,Z,I,J,M)
 FEAS_N_01(S,Z,I,J,N)
 FEAS_N_01_B(S,Z,I,J,N)
 FEAS_N_02(S,Z,I,J,N)
 FEAS_N_02_B(S,Z,I,J,N)
 FEAS_N_03(S,Z,I,J,N)
 FEAS_N_03_B(S,Z,I,J,N)
 FEAS_N_04(S,Z,I,J,N)
 FEAS_N_2(S,Z,I,J,N)
 FEAS_N_1(S,Z,I,J,N)
 FEAS_N_3(S,Z,I,J,N)
 FEAS_N_4(S,Z,I,J,N)
 FEAS_N_3_B_2(S,Z,I,J,N)
 FEAS_N_3_B_1(S,Z,I,J,N)
 FEAS_N_4_B(S,Z,I,J,N)
 FEAS_N_1_SP(S,Z,I,J,N)
 FEAS_N_1_SP_B(S,Z,I,J,N)
 FEAS_BEG_SP(S,Z,I,J,M,N)
 FEAS_BEG_B_SP(S,Z,I,J,M,N)
 FEAS_END_SP(S,Z,I,J,M,N)
 FEAS_END_B_SP(S,Z,I,J,M,N)
 FEAS_BEG3(S,Z,I,J,M,N)
 FEAS_BEG(S,Z,I,J,M,N)
 FEAS_BEG2(S,Z,I,J,M,N)

```

FEAS_END3(S,Z,I,J,M,N)
FEAS_END(S,Z,I,J,M,N)
FEAS_END2(S,Z,I,J,M,N)
FEAS_BEG4_B(S,Z,I,J,M,N)
FEAS_BEG2_B(S,Z,I,J,M,N)
FEAS_BEG1_B(S,Z,I,J,M,N)
FEAS_BEG3_B(S,Z,I,J,M,N)
FEAS_END3_B(S,Z,I,J,M,N)
FEAS_END_B(S,Z,I,J,M,N)
FEAS_END2_B(S,Z,I,J,M,N)
PAREQ(S,Z,I,J)
SHELL(Z,I,J)
SHELL_B(K,Z,I,J)
KMAX1(S,Z,I,J)
KMAX2(S,Z,I,J)
TOTALCOST
TOTNEXCH_MAX
TOTNEXCH_MIN
* $ontext
*****ADD FOR RETROFIT*****
AREA_REST1(S,Z,I,J)
AREA_REST2(S,Z,I,J)
AREA_REST3(S,Z,I,J)

AREA_REST4(S,Z,I,J)
AREA_REST5(S,Z,I,J)
AREA_REST7(S,Z,I,J)
LIM_HEX(S,M)

AREA_REST1_B(S,K,Z,I,J)
AREA_REST2_B(S,K,Z,I,J)
AREA_REST3_B(S,K,Z,I,J)
AREA_REST4_B(S,K,Z,I,J)
AREA_REST5_B(S,K,Z,I,J)
AREA_REST6_B(S,Z,I,J)

* ADD_REST
* ADD_REST2(S,I,J)

HOT_U_C
Cold_U_C
Area_C
FIX_C

$ontext
*****ADD FOR RELOCATION*****
RELOCATE_1(S,Z,I,J)
RELOCATE_2(S,Z,I,J)
RELOCATE_3(S,Z,I,J)
RELOCATE_4(S,Z,I,J)
RELOCATE_5_1(S,Z,I,J)
RELOCATE_5_2(S,Z,I,J)
RELOCATE_5_3(Z,K)
RELOCATE_6(K,S,Z,I,J)
RELOCATE_7(K,S,Z,I,J)
RELOCATE_8(K,S,Z,I,J)
RELOCATE_9(K,S,Z,I,J)
RELOCATE_10(K,S,Z,I,J)
$oftext
:
*-----
*EQ (1)
*HEAT BALANCE ON HEATING UTILITIES
HBHU(S,I,M)$ (HOT(S,I,M)=1 AND HU(I) AND FREEH(I) AND ORD(M) LE NINT)..
FHU(I)*(TU(S,M)-TL(S,M))=E= SUM((Z,N,J)$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND COLD(S,I,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND FREEC(J)).Q(S,Z,I,M,J,N));
*-----

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*EQ (2)
HBCU(S,J,N)$COLD(S,J,N)=1 AND CU(J) AND FREEC(J) AND ORD(N) LE NINT)..
FCU(J)*(TU(S,N)-TL(S,N)) =E= SUM((Z,M,I)$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEH(I)),Q(S,Z,I,M,J,N));
*-----
*EQ (3)
HBHS(S,I,M)$H(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=0 AND ORD(M) LE NINT)..
DHH(S,I,M)=E=SUM((Z,N,J)$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
AND ALLOW_HI(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
*-----
*EQ (4)
HBCS(S,J,N)$COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=0 AND ORD(N) LE NINT)..
DHC(S,J,N)=E=SUM((Z,M,I)$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
*-----
*EQ (5)
TRANSFOR_M(S,Z,I,J,M)$H(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M) =E= SUM(N$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
*-----
*EQ (6)
TRANSFOR_N(S,Z,I,J,N)$COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
QNEW_N(S,Z,I,J,N)=E=SUM(M$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1),Q(S,Z,I,M,J,N));
*-----
*EQ (7)
HBHS_NI(S,I,M)$H(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1
AND ORD(M) LE NINT)..
DHH(S,I,M)=E= SUM((Z,N,J)$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
Q(S,Z,I,M,J,N))
+SUM((Z,N)$D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) GT ORD(M)),QH(S,Z,I,N,M))
-SUM((Z,N)$D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N));
*-----
*EQ (8)
HBCS_NI(S,J,N)$COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1)..
DHC(S,J,N)=E= SUM((Z,M,I)$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N))
+SUM((Z,M)$D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) LT ORD(N)),QC(S,Z,J,M,N))
-SUM((Z,M)$D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,N,M));
*-----
*EQ (9)
NOISOH(S,I,M)$H(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1 AND ORD(M) LE NINT)..
SUM((Z,N)$D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N))
=L=SUM((Z,N,J)$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
*-----
*EQ (10)
NOISOC(S,J,N)$COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1
AND ORD(N) LE NINT)..
SUM((Z,M)$D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,N,M))
=L= SUM((Z,M,I)$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
*-----
*EQ (11a and 13a) Case of BIF(I,J)=0 (i,j) not belonging to set B.

BINARY_M1(S,Z,I,J,M)$H(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*DHH(S,I,M)$H(S,I,M)=1
-Y_M(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)$H(U(I))=L=0;
*-----
*EQ (11b and 13b) Case of BIF(I,J)=0 (i,j) not belonging to set B
***** ***** MINIMUM VALUE OF QNEW_M=0.01!!!!!!
BINARY_M2(S,Z,I,J,M)$H(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0 AND
FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*QLHMIN=G=0;
*-----

```

*EQ (11a and 13a) Case of BIF(I,J)=1 (i,j) belonging to set B
 BINARY_M1_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*DHH(S,I,M)\$(NOT HU(I))
 -Y_M_B(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)\$(HU(I))=L=0;

*EQ (11b and 13b) Case of BIF(I,J)=1 (i,j) belonging to set B
 BINARY_M2_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN =G= 0;

*EQ (12a and 14a) Case of BIF(I,J)=0 (i,j) not belonging to set B
 BINARY_N1(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*DHC(S,J,N)\$(NOT CU(J))
 -Y_N(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)\$(CU(J))=L=0;

*EQ (12b and 14b) Case of BIF(I,J)=0 (i,j) not belonging to set B
 BINARY_N2(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*QLCMIN=G=0;

*EQ (12a and 14a) Case of BIF(I,J)=1 (i,j) belonging to set B
 BINARY_N1_B(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*DHC(S,J,N)\$(NOT CU(J))
 -Y_N_B(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)\$(CU(J))=L=0;

*EQ (12b and 14b) Case of BIF(I,J)=1 (i,j) belonging to set B
 BINARY_N2_B(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).. QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*QLCMIN=G=0;

*EQ (15) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)

*EQ (16)
 BINARY_M5(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 NHE_M0(S,Z,I,J,M)=L=2-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1);

*EQ (17) IS IN REALITY NOT NEEDED. BUT WAS ADDED TO ENFORCE K=0 WHEN Y=0
 * AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M,J)=1
 * AND ALLOW_H(S,Z,I,M,J)=1

BINARY_M5b(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. NHE_M0(S,Z,I,J,M) =L= Y_M(S,Z,I,J,M);

* IT TURNS OUT THAT THIS EQUATION ONLY FORCES THE VALUES OF K TO BE ZERO
 * WHEN Y=0, WHICH HAPPENS NATURALLY IF ONE IS MINIMIZING THE NUMBER OF
 * EXCHANGERS OR BECAUSE THE FIXED COSTS ARE BEING MINIMIZED.
 * EVEN IF NOT DRIVEN TO ZERO BY THE OBJECTIVE FUNCTION IT IS HARMELESS.
 * HOWEVER, IT TURNS OUT THAT IT COULD MAKE EXTENSIONS OF THE MODEL HAVE
 * PROBLEMS. SO. ALTHOUGH THE EQUATION IS NOT NEEDED, IT GIVES SOME EXTRA VALUES
 * OF K WHEN THEY DO NOT REALLY MATTER.

*EQ (18)
 BINARY_M3(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 NHE_M0(S,Z,I,J,M) =G= Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1)\$(HOT(S,I,M-1)
 AND ALLOW_H(S,Z,I,M-1,J));

*EQ (19)
 BINARY_M4(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 NHE_M0(S,Z,I,J,M)=G=0;

*EQ (20) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)

*EQ (21)
 BINARY_M8(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..

$$\text{NHE_M1}(S,Z,I,J,M)=L-2-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M+1);$$

*-----
 *EQ (22) : ORIGINALLY NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0
 * AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M-1,J)
 BINARY_M9(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 NHE_M1(S,Z,I,J,M) =L= Y_M(S,Z,I,J,M) ;

* SEE COMMENTS ON EQUATION (17)

*-----
 *EQ (23)
 BINARY_M6(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. NHE_M1(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M+1)
 \$(HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M+1,J)) ;

*-----
 *EQ (24)
 BINARY_M7(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 NHE_M1(S,Z,I,J,M)=G=0;

*-----
 *EQ (25)
 BINARY_M3_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 Y_M_B(S,Z,I,J,M) =E= SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M)
 AND ALLOW_H(S,Z,I,O,J)=1),NHE_M0_B(S,Z,I,J,O))
 -SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE [ORD(M)-1]
 AND ALLOW_H(S,Z,I,O,J)=1),NHE_M1_B(S,Z,I,J,O));

*-----
 *EQ (26) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)

*-----
 *EQ (27)
 BINARY_N5(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N0(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1);

*-----
 *EQ (28) NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0
 * AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
 BINARY_N5b(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J))..
 NHE_N0(S,Z,I,J,N) =L= Y_N(S,Z,I,J,N);

* SEE COMMENTS ON EQUATION (17)

*-----
 *EQ (29)
 BINARY_N3(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N0(S,Z,I,J,N) =G= Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1)
 \$(COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I));

*-----
 *EQ (30)
 BINARY_N4(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N0(S,Z,I,J,N)=G=0;

*-----
 *EQ (31) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)

*-----
 *EQ (32)
 BINARY_N8(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N1(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1);

*-----
 *EQ (33) NOT NEEDED BUT ADDED TO ENFORCE K=0 WHEN Y=0
 * AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
 BINARY_N9(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N1(S,Z,I,J,N) =L= Y_N(S,Z,I,J,N);

* SEE COMMENTS ON EQUATION (17)

*EQ (34)

BINARY_N6(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1 \text{ AND } BIF(Z,I,J) =0$
 $\text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } ORD(N) \text{ LE } NINT)..$
 $NHE_N1(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1)$
 $\$(COLD(S,J,N+1) \text{ AND } ALLOW_C(S,Z,I,N+1,I));$

*EQ (35)

BINARY_N7(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } COLD(S,J,N+1) \text{ AND } ALLOW_C(S,Z,I,N,I)=1$
 $\text{ AND } ALLOW_C(S,Z,I,N+1,I) \text{ AND } BIF(Z,I,J) =0 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } ORD(N) \text{ LE } NINT)..$
 $NHE_N1(S,Z,I,J,N)=G=0;$

*EQ (36)

BINARY_N3_B(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1 \text{ AND } BIF(Z,I,J) =1$
 $\text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } ORD(N) \text{ LE } NINT)..$
 $Y_N_B(S,Z,I,J,N)=E=\text{SUM}(O\$(COLD(S,J,O) \text{ AND } ORD(O) \text{ LE } ORD(N)$
 $\text{ AND } ALLOW_C(S,Z,I,O,I)),NHE_N0_B(S,Z,I,I,O) - \text{SUM}(O\$(COLD(S,J,O) \text{ AND } ORD(O) \text{ LE } ORD(N)-1$
 $\text{ AND } ALLOW_C(S,Z,I,O,I)),NHE_N1_B(S,Z,I,I,O));$

*EQ (37)

HE_COUNT_M0(S,Z,I,J) $\$(ALLOW(S,Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE(S,Z,I,J)=E=\text{SUM}(M\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J) =1),$
 $NHE_M0_B(S,Z,I,J,M)) + \text{SUM}(M\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1$
 $\text{ AND } BIF(Z,I,J) =0), NHE_M0(S,Z,I,J,M));$

*EQ (38)

HE_COUNT_N0(S,Z,I,J) $\$(ALLOW(S,Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE(S,Z,I,J)=E=\text{SUM}(N\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1 \text{ AND } BIF(Z,I,J) =1),$
 $NHE_N0_B(S,Z,I,J,N))$
 $+ \text{SUM}(N\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1 \text{ AND } BIF(Z,I,J) =0),$
 $NHE_N0(S,Z,I,J,N));$

*EQ (39)

HE_COUNT_M1(S,Z,I,J) $\$(ALLOW(S,Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE(S,Z,I,J)=E=\text{SUM}(M\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J) =1),$
 $NHE_M1_B(S,Z,I,J,M)) + \text{SUM}(M\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1$
 $\text{ AND } BIF(Z,I,J) =0), NHE_M1(S,Z,I,J,M));$

*EQ (40)

HE_COUNT_N1(S,Z,I,J) $\$(ALLOW(S,Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE(S,Z,I,J)=E=\text{SUM}(N\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1 \text{ AND } BIF(Z,I,J) =1),$
 $NHE_N1_B(S,Z,I,J,N)) + \text{SUM}(N\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1$
 $\text{ AND } BIF(Z,I,J) =0), NHE_N1(S,Z,I,J,N));$

*EQ (41)

NEXCH(S,Z,I,J) $\$(ALLOW(S,Z,I,J)=1 \text{ AND } BIF(Z,I,J) =0 \text{ AND } FREEH(I)$
 $\text{ AND } FREEC(J)).NHE(S,Z,I,J)=L=1;$

*EQ (42)

NEXCH_B(S,Z,I,J) $\$(ALLOW(S,Z,I,J)=1 \text{ AND } BIF(Z,I,J) =1 \text{ AND } FREEH(I)$
 $\text{ AND } FREEC(J)).NHE(S,Z,I,J)=L=KMAX(Z,I,J) ;$

*EQ (43)

BIF_1(S,Z,I,J,M,N) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1 \text{ AND } BIF(Z,I,J) =1 \text{ AND } FREEH(I)$
 $\text{ AND } FREEC(J) \text{ AND } ORD(M) \text{ LE } NINT \text{ AND } ORD(N) \text{ LE } NINT)..$
 $\text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND } HOT(S,I,L)=1$
 $\text{ AND } ALLOW_H(S,Z,I,L,J)=1),$
 $QNEW_M(S,Z,I,J,L) - QNEW2_M(S,Z,I,J,M) =L=$
 $\text{SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N) \text{ AND } COLD(S,J,O) \text{ AND } ALLOW_C(S,Z,I,O,I)),$
 $QNEW_N(S,Z,I,J,O) - QNEW2_N(S,Z,I,J,N)$
 $+ B1(S,Z,I,M,J,N) *4 * \text{max}(\text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M)$
 $\text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW_H(S,Z,I,L,J)=1),DHH(S,I,L)),$
 $\text{SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N)$
 $\text{ AND } COLD(S,J,O) \text{ AND } ALLOW_C(S,Z,I,O,I)),DHC(S,I,O));$

*EQ (44)

$BIF_2(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND}$
 $\text{ ALLOW_H}(S,Z,I,M,J)=1 \text{ AND } \text{ ALLOW_C}(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J) =1 \text{ AND } \text{ FREEH}(I)$
 $\text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(M) \text{ LE } \text{ NINT} \text{ AND } \text{ ORD}(N) \text{ LE } \text{ NINT})..$
 $\text{ SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } \text{ ORD}(L) \text{ LE } \text{ ORD}(M) \text{ AND } \text{ HOT}(S,I,L)=1$
 $\text{ AND } \text{ ALLOW_H}(S,Z,I,L,J)=1),$
 $\text{ QNEW_M}(S,Z,I,J,L)) - \text{ QNEW2_M}(S,Z,I,J,M) = G =$
 $\text{ SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } \text{ ORD}(O) \text{ LE } \text{ ORD}(N) \text{ AND } \text{ COLD}(S,J,O) \text{ AND } \text{ ALLOW_C}(S,Z,J,O,I)),$
 $\text{ QNEW_N}(S,Z,I,J,O)) - \text{ QNEW2_N}(S,Z,I,J,N)$
 $- B1(S,Z,I,M,J,N) * 4 * \text{ max}(\text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } \text{ ORD}(L) \text{ LE } \text{ ORD}(M)$
 $\text{ AND } \text{ HOT}(S,I,L)=1 \text{ AND } \text{ ALLOW_H}(S,Z,I,L,J)=1), \text{ DHH}(S,I,L)),$
 $\text{ SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } \text{ ORD}(O) \text{ LE } \text{ ORD}(N) \text{ AND } \text{ COLD}(S,J,O)$
 $\text{ AND } \text{ ALLOW_C}(S,Z,J,O,I)), \text{ DHC}(S,J,O)));$
 *-----
 *EQ (45)
 $BIF_3(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } \text{ ALLOW_H}(S,Z,I,M,J)=1 \text{ AND } \text{ ALLOW_C}(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J) =1 \text{ AND } \text{ FREEH}(I) \text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(M) \text{ LE } \text{ NINT})..$
 $B1(S,Z,I,M,J,N) = E = 2 - 0.25 * \text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } \text{ ORD}(L) \text{ LE } \text{ ORD}(M)$
 $\text{ AND } \text{ HOT}(S,I,L)=1 \text{ AND } \text{ ALLOW_H}(S,Z,I,L,J)=1), \text{ NHE_M1_B}(S,Z,I,J,L))$
 $+ 0.25 * \text{SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } \text{ ORD}(O) \text{ LE } \text{ ORD}(N) \text{ AND } \text{ COLD}(S,J,O)$
 $\text{ AND } \text{ ALLOW_C}(S,Z,J,O,I)), \text{ NHE_N1_B}(S,Z,I,J,O))$
 $- \text{NHE_M1_B}(S,Z,I,J,M) - \text{NHE_N1_B}(S,Z,I,J,N);$
 *-----
 *EQ (46)
 $BIF_4(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } TL(S,N) \text{ GE } TL(S,M)$
 $\text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } \text{ ALLOW_H}(S,Z,I,M,J)=1$
 $\text{ AND } \text{ ALLOW_C}(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J) =1 \text{ AND } \text{ FREEH}(I) \text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(M) \text{ LE } \text{ NINT}$
 $\text{ AND } \text{ ORD}(N))..$
 $\text{ SUM}(L\$(HOT(S,I,L)=1 \text{ AND } \text{ ORD}(L) \text{ LE } \text{ ORD}(M) \text{ AND}$
 $\text{ ALLOW_H}(S,Z,I,L,J)=1), \text{ NHE_M1_B}(S,Z,I,J,L))$
 $- \text{SUM}(O\$(COLD(S,J,O) \text{ AND } \text{ ORD}(O) \text{ LE } \text{ ORD}(N) \text{ AND } \text{ ALLOW_C}(S,Z,J,O,I)),$
 $\text{ NHE_N1_B}(S,Z,I,J,O)) = G = 0;$
 *-----
 *EQ (47)
 $BIF_11(S,Z,I,J,M)\$(HOT(S,I,M)=1 \text{ AND } \text{ ALLOW_H}(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J) =1$
 $\text{ AND } \text{ FREEH}(I) \text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(M) \text{ LE } \text{ NINT})..$
 $\text{ SUM}(O\$(HOT(S,I,O)=1 \text{ AND } \text{ ORD}(O) \text{ LE } \text{ ORD}(M) \text{ AND } \text{ ALLOW_H}(S,Z,I,O,J)=1),$
 $\text{ NHE_M0_B}(S,Z,I,J,O) - \text{NHE_M1_B}(S,Z,I,J,O)) = L = 1 ;$
 *-----
 *EQ (48)
 $BIF_12(S,Z,I,J,N)\$(COLD(S,J,N)=1 \text{ AND } \text{ ALLOW_C}(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J) =1$
 $\text{ AND } \text{ FREEH}(I) \text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(N) \text{ LE } \text{ NINT})..$
 $\text{ SUM}(O\$(COLD(S,J,O) \text{ AND } \text{ ORD}(O) \text{ LE } \text{ ORD}(N) \text{ AND } \text{ ALLOW_C}(S,Z,J,O,I)),$
 $\text{ NHE_N0_B}(S,Z,I,J,O) - \text{NHE_N1_B}(S,Z,I,J,O)) = L = 1 ;$
 *-----
 *EQ (49)
 $BIF_6(S,Z,I,J,M)\$(HOT(S,I,M)=1 \text{ AND } \text{ ALLOW_H}(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J) =1$
 $\text{ AND } \text{ FREEH}(I) \text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(M) \text{ LE } \text{ NINT})..$
 $\text{ QNEW2_M}(S,Z,I,J,M) = L = \text{ QNEW_M}(S,Z,I,J,M);$
 *-----
 *EQ (50)
 $BIF_9(S,Z,I,J,M)\$(HOT(S,I,M)=1 \text{ AND } \text{ ALLOW_H}(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J) =1$
 $\text{ AND } \text{ FREEH}(I) \text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(M) \text{ LE } \text{ NINT})..$
 $\text{ QNEW2_M}(S,Z,I,J,M) = L = \text{ NHE_M0_B}(S,Z,I,J,M) * \text{DHH}(S,I,M);$
 *-----
 *EQ (51)
 $BIF_5(S,Z,I,J,M)\$(HOT(S,I,M)=1 \text{ AND } \text{ ALLOW_H}(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J) =1$
 $\text{ AND } \text{ FREEH}(I) \text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(M) \text{ LE } \text{ NINT})..$
 $\text{ QNEW2_M}(S,Z,I,J,M) = L = \text{ NHE_M1_B}(S,Z,I,J,M) * \text{DHH}(S,I,M);$
 *-----
 *EQ (52) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE
 *-----
 *EQ (53)
 $BIF_8(S,Z,I,J,N)\$(COLD(S,J,N)=1 \text{ AND } \text{ ALLOW_C}(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J) =1$
 $\text{ AND } \text{ FREEH}(I) \text{ AND } \text{ FREEC}(J) \text{ AND } \text{ ORD}(N) \text{ LE } \text{ NINT})..$
 $\text{ QNEW2_N}(S,Z,I,J,N) = L = \text{ QNEW_N}(S,Z,I,J,N);$
 *-----
 *EQ (54)

BIF_10(S,Z,I,J,N) $\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..$
 QNEW2_N(S,Z,I,J,N) =L= NHE_N0_B(S,Z,I,J,N)*DHC(S,J,N);

*EQ (55)

BIF_7(S,Z,I,J,N) $\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..$
 QNEW2_N(S,Z,I,J,N) =L= NHE_N1_B(S,Z,I,J,N)*DHC(S,J,N);

*EQ (56) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE

*EQ (57)

FEAS_M_01(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 ALFA_M(S,Z,I,J,M)=L=1-NHE_M0(S,Z,I,J,M-1)-NHE_M0(S,Z,I,J,M);

FEAS_M_01_B(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 ALFA_M(S,Z,I,J,M)=L=1-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M);

*EQ (58)

FEAS_M_02(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 ALFA_M(S,Z,I,J,M)=L=1-NHE_M1(S,Z,I,J,M-1)-NHE_M1(S,Z,I,J,M);
 FEAS_M_02_B(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J)..$
 ALFA_M(S,Z,I,J,M)=L=1-NHE_M1_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M);

*EQ (59)

FEAS_M_03(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 ALFA_M(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-NHE_M0(S,Z,I,J,M-1)-NHE_M0(S,Z,I,J,M)-NHE_M1(S,Z,I,J,M-1)-NHE_M1(S,Z,I,J,M);
 FEAS_M_03_B(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J)..$
 ALFA_M(S,Z,I,J,M)=G=Y_M_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M)-NHE_M1_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M);

*EQ (60)

FEAS_M_04(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND (BIF(Z,I,J) =1 OR SPH(I)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 ALFA_M(S,Z,I,J,M)=G=0;

*EQ (61)

FEAS_M_2(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) =L=
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +(1-ALFA_M(S,Z,I,J,M))*DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)));

*EQ (62)

FEAS_M_1(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J)..$
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(1-ALFA_M(S,Z,I,J,M))*DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 =G= QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)));

*EQ (63)

FEAS_M_3(S,Z,I,J,M) $\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 - QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 + QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(1+ NHE_M1(S,Z,I,J,M-1) + NHE_M1(S,Z,I,J,M) - NHE_M0(S,Z,I,J,M-1))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M))) * 1.00001 =G= 0;

*EQ (64)

FEAS_M_4(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
- QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
+ QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
+(1+NHE_M0(S,Z,I,J,M-1)+NHE_M0(S,Z,I,J,M)-NHE_M1(S,Z,I,J,M))
DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)))*1.00001 =G= 0;

*EQ (65)

FEAS_M_3_B_2(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
+(1+NHE_M1_B(S,Z,I,J,M-1)+NHE_M1_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1))
DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));

*EQ (66)

FEAS_M_3_B_1(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
QNEW2_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))) =L=
QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))+(2 + NHE_M1_B(S,Z,I,J,M)
-NHE_M0_B(S,Z,I,J,M-1)-Y_M_B(S,Z,I,J,M-1))
DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));

*EQ (67)

FEAS_M_4_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
(QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) =L=
QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
+(2 + NHE_M0_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M))
DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));

*EQ (68)

FEAS_M_1_SP(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J) =0 AND SPH(I)=0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I,J,M)=G=(Y_M(S,Z,I,J,M)-
NHE_M0(S,Z,I,J,M) + NHE_M1(S,Z,I,J,M))*DHH(S,I,M);
FEAS_M_1_SP_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J) =1 AND SPH(I)=0
AND FREEH(I) AND FREEC(J)).. QNEW_M(S,Z,I,J,M)=G=(Y_M_B(S,Z,I,J,M)-
NHE_M0_B(S,Z,I,J,M)+NHE_M0_B(S,Z,I,J,M))*DHH(S,I,M);

*EQ (69)

FEAS_N_01(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
ALFA_N(S,Z,I,J,N) =L= 1-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1);
FEAS_N_01_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=L=1-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1);

*EQ (70)

FEAS_N_02(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=L=1-NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N-1);
FEAS_N_02_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=L=1-NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);

*EQ (71)

FEAS_N_03(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1)

- NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N-1);

FEAS_N_03_B(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=G=Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1)-NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);

*EQ (72)

FEAS_N_04(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND (BIF(Z,I,J) =1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=G=0;

*EQ (73)

FEAS_N_2(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
 QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=L=QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))+(1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)));

*EQ (74)

FEAS_N_1(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
 QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)));

*EQ (75)

FEAS_N_3(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
 -QNEW_N(S,Z,I,J,N)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
 +QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(1+NHE_N1(S,Z,I,J,N-1)+NHE_N1(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;

*EQ (76)

FEAS_N_4(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
 -QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
 +QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
 +(1+NHE_N0(S,Z,I,J,N-1)+NHE_N0(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;

*EQ (77)

FEAS_N_3_B_2(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
 -QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
 +QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
 +(1+NHE_N1_B(S,Z,I,J,N-1)+NHE_N1_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;

*EQ (78)

FEAS_N_3_B_1(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
 -QNEW2_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
 +QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(2+NHE_N1_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1)-Y_N_B(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;

*EQ (79)

FEAS_N_4_B(S,Z,I,J,N) $\$($ COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..

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-(QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+ QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+(2 + NHE_N0_B(S,Z,I,J,N-1) -NHE_N1_B(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N))
  *DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;
-----
*EQ (80)
FEAS_N_1_SP(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1) AND
ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J) =0
AND SPC(J)=0 AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N) =G=
(Y_N(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N))*DHC(S,J,N);

FEAS_N_1_SP_B(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J) =1
AND SPC(J)=0 AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N) =G=
(Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N))*DHC(S,J,N);
-----
*EQ (81)
FEAS_BEG_SP(S,Z,I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J))*CPC(S,J,N))
+ QNEW_M(S,Z,I,J,M)/(FH(S,I))*CPH(S,I,M))
+ (2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*TU(S,N)=G=0;

FEAS_BEG_B_SP(S,Z,I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  TL(S,M) - TL(S,N) -QNEW_N(S,Z,I,J,N)/(FC(S,J))*CPC(S,J,N))
+ QNEW_M(S,Z,I,J,M)/(FH(S,I))*CPH(S,I,M))
+ (2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))*TU(S,N)=G=0;
-----
*EQ (82)
FEAS_END_SP(S,Z,I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J)
AND ORD(M) LE NINT).. TU(S,M)-TU(S,N)
-QNEW_M(S,Z,I,J,M)/(FH(S,I))*CPH(S,I,M)) +QNEW_N(S,Z,I,J,N)/(FC(S,J))*CPC(S,J,N))
  +(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))*TU(S,N)=G=0;
FEAS_END_B_SP(S,Z,I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J)) .. TU(S,M)-TU(S,N)
-QNEW_M(S,Z,I,J,M)/(FH(S,I))*CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J))*CPC(S,J,N))
  +(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*TU(S,N)=G=0;
-----
*EQ (83)
FEAS_BEG3(S,Z,I,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M)
AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J) =0 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)
AND ORD(M) LE NINT)..
  NHE_N1(S,Z,I,J,N)=L=(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N));
-----
*EQ (84)
FEAS_BEG(S,Z,I,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND D(S,Z,M,N)=1
AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =0
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)
/(TU(S,N+1)-TL(S,N+1))* CPC(S,J,N)/CPC(S,J,N+1)
  +(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*DHC(S,J,N)/(TU(S,M)-TL(S,N));
-----

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*EQ (85)

FEAS_BEG2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1)
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) = 0 AND (SPH(I)=1 OR SPC(J)=1)
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=
QNEW_M(S,Z,I,J,M+1)/(TU(S,M+1)-TL(S,M+1))
*CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))
*DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));

*

*EQ (86)

FEAS_END3(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1 AND COLD(S,J,N-1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I)
AND BIF(Z,I,J) = 0 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)
AND ORD(M) LE NINT)..
NHE_M0(S,Z,I,J,M)=L=(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N));

*

*EQ (87)

FEAS_END(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) = 0
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW_M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))
*CPH(S,I,M)/CPH(S,I,M-1)+(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))
*DHH(S,I,M)/(TU(S,M)-TL(S,N));

*

*EQ (88)

FEAS_END2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) = 0
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_N(S,Z,I,J,N)/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/
(TU(S,N-1)-TL(S,N-1))
*CPC(S,J,N)/CPC(S,J,N-1)-(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))
*DHC(S,J,N-1)/(TU(S,N-1)-TL(S,N-1));

*

*EQ (89)

FEAS_BEG4_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M)
AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J) = 1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
NHE_N1_B(S,Z,I,J,N) = L=
(1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N));

*

*EQ (90)

FEAS_BEG2_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) = 1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=
QNEW_N(S,Z,I,J,N+1)/(TU(S,N+1)-TL(S,N+1))
*CPC(S,J,N)/CPC(S,J,N+1)+
(1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
*DHC(S,J,N)/(TU(S,M)-TL(S,N));

*

*EQ (91)

FEAS_BEG1_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) = 1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..

$$\begin{aligned} & QNEW2_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)/ \\ & (TU(S,N+1)-TL(S,N+1)) \\ & *CPC(S,J,N)/CPC(S,J,N+1)+(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N)) \\ & *DHC(S,J,N)/(TU(S,M)-TL(S,N)); \end{aligned}$$

*EQ (92)

$$\begin{aligned} & FEAS_BEG3_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \\ & \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M+1) \text{ AND } COLD(S,J,N)=1 \\ & \text{ AND } COLD(S,J,N+1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M+1,J) \\ & \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } ALLOW_C(S,Z,J,N+1,I) \text{ AND } BIF(Z,I,J) =1 \\ & \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } ORD(M) \text{ LE } NINT).. \\ & QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=QNEW_M(S,Z,I,J,M+1)/ \\ & (TU(S,M+1)-TL(S,M+1)) \\ & *CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N)) \\ & *DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1)); \end{aligned}$$

*EQ (93)

$$\begin{aligned} & FEAS_END3_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \\ & \text{ AND } TU(S,N) \text{ GT } TL(S,M) \\ & \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N-1) \\ & \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \\ & \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } ALLOW_C(S,Z,J,N,I) \text{ AND } ALLOW_C(S,Z,J,N-1,I) \\ & \text{ AND } BIF(Z,I,J) =1 \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J) \\ & \text{ AND } ORD(M) \text{ LE } NINT).. \\ & NHE_M0_B(S,Z,I,J,M)=L= \\ & (1+Y_M_B(S,Z,I,J,M)-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N)); \end{aligned}$$

*EQ (94)

$$\begin{aligned} & FEAS_END_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \\ & \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } COLD(S,J,N)=1 \\ & \text{ AND } COLD(S,J,N-1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \\ & \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } ALLOW_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J) =1 \\ & \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } ORD(M) \text{ LE } NINT).. \\ & (QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L= \\ & QNEW_M(S,Z,I,J,M-1)/ \\ & (TU(S,M-1)-TL(S,M-1))*CPH(S,I,M)/CPH(S,I,M-1)+ \\ & (2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHH(S,I,M)/(TU(S,M)-TL(S,N)); \end{aligned}$$

*EQ (95)

$$\begin{aligned} & FEAS_END2_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \\ & \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } COLD(S,J,N)=1 \\ & \text{ AND } COLD(S,J,N-1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \\ & \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } ALLOW_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J) =1 \\ & \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } ORD(M) \text{ LE } NINT).. \\ & (QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G= \\ & QNEW_N(S,Z,I,J,N-1)/(TU(S,N-1)-TL(S,N-1))*CPC(S,J,N)/CPC(S,J,N-1) \\ & -(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHC(S,J,N-1)/ \\ & (TU(S,N-1)-TL(S,N-1)); \end{aligned}$$

*EQ (96)

$$\begin{aligned} & PAREQ(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J)).. \\ & PAR(Z,I,J)=E=SUM((M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1 \\ & \text{ AND } COLD(S,J,N)=1 \\ & \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1), \\ & Q(S,Z,I,M,J,N)*(1/H_I(S,I,M)+1/H_J(S,J,N))/LMTD(S,M,N)); \end{aligned}$$

*EQ (97)

$$\begin{aligned} & BIF_13_2(S,K,Z,I,J,M)\$(ORD(K) \text{ LT } KMAX(Z,I,J) \text{ AND } HOT(S,I,M)=1 \\ & \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \\ & \text{ AND } BIF(Z,I,J) =1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } ORD(M) \text{ LE } NINT).. \\ & PAR_B(K,Z,I,J)=L=SUM((L,N)\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \\ & \text{ AND } TL(S,N) \text{ LT } TU(S,L) \\ & \text{ AND } HOT(S,I,L)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,L,J)=1 \\ & \text{ AND } ALLOW_C(S,Z,J,N,I)=1), \\ & (Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))*(1/H_I(S,I,L)+1/H_J(S,J,N))/LMTD(S,L,N)) \\ & +AMAX*(2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,I,J,M)- \\ & SUM(KK\$(ORD(KK) \text{ GT } 1 \text{ AND } ORD(KK) \text{ LT } ORD(K)),X_B(S,KK,Z,I,J,M))); \end{aligned}$$

*Comment: In the paper X1_B does not show. Only one variable, X_B is used
 * to make summations from 1 to kmax-1. Here we use X1_B and then a
 * summation from 2 to kmax-1. See equation (100) as well.

*EQ (98)

BIF_13_1(S,K,Z,I,J,M)\$ (ORD(K) LT KMAX(Z,I,J) AND HOT(S,I,M)=1
 AND ALLOW_H(S,Z,I,M,J)=1
 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 PAR_B(K,Z,I,J)=G=SUM((L,N)\$ (D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND TL(S,N) LT TU(S,L)
 AND HOT(S,I,L)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,L,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1),
 (Q(S,Z,I,L,N)-Q2(S,Z,I,L,J,N))*(1/H_I(S,I,L)+1/H_J(S,J,N))/LMTD(S,L,N))
 -AMAX*(2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,I,J,M)-
 SUM(KK\$(ORD(KK) GT 1 AND ORD(KK) LT ORD(K)),X_B(S,KK,Z,I,J,M)));

*EQ (99)

BIF_14(S,K,Z,I,J)\$ (ORD(K) EQ KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1 AND FREEH(I)
 AND FREEC(J) AND BIF(Z,I,J) =1)..
 PAR_B(K,Z,I,J)=G=PAR(Z,I,J)-SUM(KK\$(ORD(KK) LT ORD(K)),PAR_B(KK,Z,I,J));

*EQ (100)

BIF_15(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 X1_B(S,Z,I,J,M)+SUM(K\$(ORD(K) GT 1 AND ORD(K) LE KMAX(Z,I,J)),
 ORD(K)*X_B(S,K,Z,I,J,M))=E=SUM(L\$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND
 ALLOW_H(S,Z,I,L,J)=1),NHE_M0_B(S,Z,I,J,L))+1-Y_M_B(S,Z,I,J,M);

* Comment: In the paper X1_B does not show. Only one variable, X_B is used

* to make summations from 1 to kmax-1. Here we use X1_B and then a
 * summation from 2 to kmax-1.

*EQ (101)

BIF_17(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 SUM(N\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1 AND COLD(S,J,N)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q2(S,Z,I,M,J,N))=E=
 QNEW2_M(S,Z,I,J,M);

*EQ (102)

BIF_18(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 Q2(S,Z,I,M,J,N)=L=Q(S,Z,I,M,J,N);

*EQ (103)

SHELL(Z,I,J)\$ (SUM[S.ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J) =0)..
 PAR(Z,I,J)=L=ASHELLMAX*USHELL(Z,I,J);

*EQ (104)

SHELL_B(K,Z,I,J)\$ (SUM[S.ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J) =1)..
 PAR_B(K,Z,I,J)=L=ASHELLMAX*USHELL_B(K,Z,I,J);

*EQ (105)

TOTALCOST.. TCOST =E= SUM(I\$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
 + SUM(J\$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))

\$ontext

+ SUM((Z,I,J)\$ (OPT=0 AND SUM[S.ALLOW(S,Z,I,J)]>= 1 AND FREEH(I)
 AND FREEC(J) AND BIF(Z,I,J)=0), CF*USHELL(Z,I,J))

+ SUM((K,Z,I,J)\$ (OPT=0 AND SUM[S.ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J)=1), CF*USHELL_B(K,Z,I,J))

+ SUM((Z,I,J)\$ (OPT=0 AND SUM[S.ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)),
 CAE*PAR(Z,I,J))

\$offtext

*\$ontext

+SUM((S,Z,I,J)\$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
 ,CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)\$ (NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)))

+SUM((S,Z,I,J)\$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J)=0),CAE*DPAR_E(Z,I,J)+CAN*PAR_N(S,Z,I,J))

+SUM((S,K,Z,I,J)\$ (OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)
 ,CAE*DPAR_E_B(K,Z,I,J)+CAN*PAR_N_B(K,Z,I,J))


```

*$offtext
$ontext
+SUM((S,Z,I,J)$$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)
.(CF*(NHE(S,Z,I,J)-(NHE0(S,Z,I,J)*(SUM(K$(ORD(K) LE KET),
Phi(Z,I,J,K)))))+(CAE*DPAR_E(Z,I,J))+CAN*PAR_N(S,Z,I,J))
+SUM((S,Z,I,J)$$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF=1)
.(CF*(NHE(S,Z,I,J)-SUM((KK,K)$$(OPT=2 AND ORD(K) LE KET AND
ORD(K)LE KMAX(Z,I,J)),DELTA(KK.K))))
*may be wronge equation (by warapon)
+SUM(K$(OPT=1 AND ORD(K) LE NHE0(S,Z,I,J)),(CAE*DPAR_E_B(K,Z,I,J))
+(CAN*PAR_N_B(K,Z,I,J)));

*TOTALCOST.. TCOST =E= SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
* + SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
* + SUM((Z,I,J)$$(SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
AND BIF=0), CF*USHELL(Z,I,J))
* + SUM((K,Z,I,J)$$(SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
AND BIF=1), CF*USHELL_B(K,Z,I,J))
* + SUM((Z,I,J)$$(SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J) ),
CA*PAR(Z,I,J))
$OFFTEXT
;

*Depending on the option selected by the user diferent sums come into action.
* Here we have an equation that is made simpler than in the paper. We account
* for the total area of the exchangers (use PAR and not PAR_B).
* The result is the same.
*-----
*-----
*-----
*EQ (106) CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K.

KMAX1(S,Z,I,J)$$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J) =0)..
NHE(S,Z,I,J) =L= USHELL(Z,I,J) ;
*EQ (107)
KMAX2(S,Z,I,J)$$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J) =1)..
NHE(S,Z,I,J) =L= SUM(K,USHELL_B(K,Z,I,J)) ;
*-----
*-----
* EXTRA EQUATIONS NOT IN PAPER BUT NEEDED
*-----
*EQ (108) LIMIT THE NUMBER OF EXCHANGERS
TOTNEXCH_MAX(S).. SUM((Z,I,J)$$(ALLOW(S,Z,I,J)= 1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=L=TOTNEXCHMAX;
*-----
*EQ (109) MINIMUM NUMBER OF EXCHANGERS
TOTNEXCH_MIN(S).. SUM((Z,I,J)$$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=G=TOTNEXCHMIN;

*$ontext
*****Equation for Retrofit*****
*-----

*EQ(110)
AREA_REST1(S,Z,I,J)$$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,I,J);
*-----

*EQ(111)
AREA_REST2(S,Z,I,J)$$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
DPAR_E(Z,I,J)=L=AEX_U(Z,I,J)-AEX(Z,I,J);
*-----

*EQ(112)
AREA_REST3(S,Z,I,J)$$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR_N(S,Z,I,J)=L=A_NEW_MAX(Z,I,J)*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$$(NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J));
*-----

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=====
*ADD EQ (KITISAK'EQ)
*EQ(Retrofit 4)
AREA_REST4(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)) =L= TOTNEXCHMAX ;
*-----
*EQ(Retrofit 5)
AREA_REST5(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0 AND NHE0(S,Z,I,J)= 0)..
PAR_N(S,Z,I,J) =L= A_NEW_MAX(Z,I,J)* (NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1));
*-----
*EQ(Retrofit 7)
AREA_REST7(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0 AND NHE0(S,Z,I,J)= 0)..
(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)) =L= TOTNEXCHMAX ;
*-----
=====
*EQ(113)
AREA_REST1_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_B(K,Z,I,J)=L=SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),AEX_B(KK,Z,I,J)
*DELTA(KK,K))+DPAR_E_B(K,Z,I,J)+PAR_N_B(K,Z,I,J);
*-----
*EQ(114)
AREA_REST2_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
DPAR_E_B(K,Z,I,J)=L=SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),(AEX_U_B(KK,Z,I,J)
-AEX_B(KK,Z,I,J))*DELTA(KK,K));
*-----
*EQ(115)
AREA_REST3_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_N_B(K,Z,I,J)=L=A_NEW_MAX(Z,I,J)*(1-SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K)));
*-----
*EQ(116)
AREA_REST4_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K))=L=1;
*-----
*EQ(117)
AREA_REST5_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE NHE0(S,Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM(KK$(ORD(KK) LE KMAX(Z,I,J)),DELTA(K,KK))=L=1;
*-----
*EQ(118)
AREA_REST6_B(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I)
AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM((K,KK)$(ORD(K) LE KMAX(Z,I,J) AND ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K))
=E= NHE0(S,Z,I,J);
*-----
SONTEXT
*EQ(119)
ADD_REST..
SUM((S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J)),NHE(S,Z,I,J)
-NHE0(S,Z,I,J))=L=2;
*-----
*EQ(120)
ADD_REST2(S,I,J)$(OPT=1 AND FREEH(I) AND FREEC(J))..
SUM(Z$(ALLOW(S,Z,I,J)=1),NHE(S,Z,I,J)-NHE0(S,Z,I,J))=G=0;
*-----
SOFFTEXT
*EQ(Retrofit 14)
LIM_HEX(S,M)..

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SUM((Z,I,J)$(OPT=1                                AND                                HOT(S,I,M)=1
ALLOW_H(S,Z,I,M,J)=1),(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1))-NHE0(S,Z,I,J))
=L= MAX_NEW_HIEX :
*$offtext
$ontext
*-----
*****Equation for Retrofit Relocation*****
*-----
*EQ(Retrofit 16)
RELOCATE_1(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF=0)..
PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,I,J);
*-----
*EQ(Retrofit 17)
RELOCATE_2(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF=0)..
AEX(Z,I,J)=E= SUM(K$(ORD(K) LE KET),(AEX_R(K)*Phi(Z,I,J,K)));
*-----
*EQ(Retrofit 18)
RELOCATE_3(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF=0)..
DPAR_E(Z,I,J)=L= SUM(K$(ORD(K) LE KET),(AEX_U_R(K)-AEX_R(K))
*Phi(Z,I,J,K));
*-----
*EQ(Retrofit 19)
RELOCATE_4(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF=0)..
PAR_N(S,Z,I,J)=L= A_NEW_MAX *(NHE(S,Z,I,J)-(NHE0(S,Z,I,J)*
SUM(K$(ORD(K) LE KET),Phi(Z,I,J,K))));
*-----
*EQ(Retrofit 20)
RELOCATE_5_1(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF=0).. NHE(S,Z,I,J)=L= TOTNEXCHMAX ;

RELOCATE_5_2(S,Z,I,J)$(OPT=2 AND FREEH(I) AND FREEC(J)
AND BIF=0).. SUM((K)$(ORD(K) LE KET),Phi(Z,I,J,K))=L= 1 ;

*Extra Eq. Limits number of phi matches
RELOCATE_5_3(Z,K)$(OPT=2).. SUM((i,j), Phi(Z,I,J,K))=L= 1 ;
*-----
*EQ(Retrofit 21)
RELOCATE_6(K,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF=1)..
PAR_B(K,Z,I,J)=L=AEX_B(K,Z,I,J)+DPAR_E_B(K,Z,I,J)+PAR_N_B(K,Z,I,J);
*-----
*EQ(Retrofit 22)
RELOCATE_7(K,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF=1)..
AEX_B(K,Z,I,J)=E=SUM(KK$(ORD(KK) LE KET),(AEX_B_R(KK)*DELTA(KK,K)));
**
*EQ(Retrofit 23)
RELOCATE_8(K,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF=1)..
DPAR_E_B(K,Z,I,J)=L= SUM(KK$(ORD(KK) LE KET),(AEX_U_B_R(KK)-AEX_B_R(KK))
*DELTA(KK,K));
*-----
*EQ(Retrofit 24)
RELOCATE_9(K,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF=1)..
PAR_N_B(K,Z,I,J)=L= A_NEW_MAX*(1-SUM(KK$(ORD(KK) LE KET)
,DELTA(KK,K)));
**
*EQ(Retrofit 25)
RELOCATE_10(K,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF=1)..
SUM(KK$(ORD(KK) LE KET),DELTA(KK,K))=L= 1 ;
*-----
$OFFTEXT
*-----
* Show All cost for chacking
*-----

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HOT_U_C..
HOT_UTILITY_COST =E= SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I));
*-----
Cold_U_C..
Cold_UTILITY_COST =E= SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J));
*-----
Area_C..
Area_Cost=E= SUM((S,Z,I,J)$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0),CAE*DPAR_E(Z,I,J)+CAN*PAR_N(S,Z,I,J));
*-----
FIX_C..
FIX_COST =E= SUM((S,Z,I,J)$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
.CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$ (NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J))) ;

MODEL MPERIOD / ALL/;

OPTION LIMROW =5000;
OPTION LIMCOL =5000;
OPTION SOLPRINT = OFF;
OPTION OPTCR=0 ;
OPTION OPTCA=0 ;
OPTION reslim = 135800;

SOLVE MPERIOD USING MIP MINIMIZING TCOST;

PARAMETER QMATCH(S,Z,I,J);
QMATCH(S,Z,I,J)=SUM((M,N)$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND D(S,Z,M,N)=1
AND COLD(S,J,N) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,I,N,I)=1).
Q.L(S,Z,I,M,J,N));

PARAMETER FH_H(S,Z,I,J,M) Flowrate of hot stream per HEX;
FH_H(S,Z,I,J,M)$ (HOT(S,I,M))=QNEW_M.L(S,Z,I,J,M)/[(TU(S,M)-TL(S,M))*CPH(S,I,M)]

PARAMETER FC_C(S,Z,I,J,M) Flowrate of cold stream per HEX;
FC_C(S,Z,I,J,M)$ (COLD(S,J,M))=QNEW_N.L(S,Z,I,J,M)/[(TU(S,M)-TL(S,M))*CPC(S,J,M)]

PARAMETER NHE2(S,Z,I,J);
NHE2(S,Z,I,J)= NHE.L(S,Z,I,J);

OPTION Cold_UTILITY_COST:3:0:1; DISPLAY Cold_UTILITY_COST.L;
OPTION HOT_UTILITY_COST:3:0:1; DISPLAY HOT_UTILITY_COST.L;
OPTION Area_Cost:3:0:1; DISPLAY Area_Cost.L;
OPTION FIX_COST:3:0:1; DISPLAY FIX_COST.L;

option Q:3:0:1; display Q.L;
option FHU:3:0:1; display FHU.L;
option FCU:3:0:1; display FCU.L;
OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
OPTION PAR:4:0:1; DISPLAY PAR.L;
OPTION QMATCH:4:0:1; DISPLAY QMATCH;
OPTION FH_H:3:0:1; DISPLAY FH_H;
OPTION FC_C:3:0:1; DISPLAY FC_C;
OPTION LMTD:3:0:1; DISPLAY LMTD;
$ONTEXT
DISPLAY DTVIO;
DISPLAY AEX;
DISPLAY CPH;
DISPLAY CPC;
DISPLAY PHI.L;

EXECUTE_UNLOAD "isabelout.gdx",PAR, QMATCH, FH_H, FC_C, AEX;
EXECUTE 'GDXXRW.EXE isabelout.gdx par=QMATCH rng=a1';
EXECUTE 'GDXXRW.EXE isabelout.gdx var=PAR rng=r1';
EXECUTE 'GDXXRW.EXE isabelout.gdx PAR=AEX mg=af1';
EXECUTE 'GDXXRW.EXE isabelout.gdx par=FH_H rng=a20';
EXECUTE 'GDXXRW.EXE isabelout.gdx par=FC_C mg=a40';
EXECUTE 'GDXXRW.EXE isabelout.gdx par=PHI mg=a60';
EXECUTE 'GDXXRW.EXE isabelout.gdx vAR=DPAR rng=R60';
$OFFTEXT

```

Appendix B Programming Model for Retrofit with Relocation

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$TITLE HEN design- Automatic parameter calculation- KITISAK-I
*****
* Equations that are different than in the paper +errata.
*(100) Just a nomenclature change
*(105) Just a nomenclature change
*-----
* Equations that are added to those that are in the paper
*(106) and (107)
* CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K.
*(108) LIMIT THE NUMBER OF EXCHANGERS
*(109) MINIMUM NUMBER OF EXCHANGERS
*****
$OFFUPPER
SETS
Z transfer zone /Z1/
*
*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
I Hot streams /I1*I3/
J cold streams /J1*J3/
*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
HU(I) Heating utilities /I3/
CU(J) Cooling utilities /J3/
*
M temperature intervals /M1*M85/
S SCENARIO /S1/
K temperature intervals /K1*K1/

R exchangers /R1*R7/

ALIAS (M,N,L,O)
ALIAS (I,I)
ALIAS (J,J)
ALIAS (K,KK)
ALIAS (Z,ZZ)
ALIAS (R,RR)
SET
ORDER(J)
/
J1
J2
J3
/

PARAMETER NIZ(S,Z,I) # OF INTERVALS DESIRED FOR HOT STREAMS
/
S1.Z1.I1 30
S1.Z1.I2 8
S1.Z1.I3 2
/

PARAMETER NJZ(S,Z,J) # OF INTERVALS DESIRED FOR COLD STREAMS
/
S1.Z1.J1 35
S1.Z1.J2 8
S1.Z1.J3 2
/

PARAMETER HI(S,I) HEAT TR CEOFF FOR HOT STREAMS
/
S1.I1 0.1
S1.I2 0.1
S1.I3 0.1
/

PARAMETER HJ(S,J) HEAT TR CEOFF FOR COLD STREAMS
/

```

S1.J1 0.1
 S1.J2 0.1
 S1.J3 0.1

/
 PARAMETERS
 TIH(S,I) T IN FOR HOT STREAMS

/
 S1.I1 400
 S1.I2 140
 S1.I3 500

/
 TOH(S,I) T OUT FOR HOT STREAMS

/
 S1.I1 100
 S1.I2 60
 S1.I3 499

/
 TIC(S,J) T IN FOR COLD STREAMS

/
 S1.J1 50
 S1.J2 90
 S1.J3 30

/
 TOC(S,J) T OUT FOR COLD STREAMS

/
 S1.J1 400
 S1.J2 165
 S1.J3 40

/
 PARAMETERS
 TIHZ(S,Z,I) T IN FOR HOT STREAMS

/
 S1.Z1.I1 400
 S1.Z1.I2 140
 S1.Z1.I3 500

/
 TOHZ(S,Z,I) T OUT FOR HOT STREAMS

/
 S1.Z1.I1 100
 S1.Z1.I2 60
 S1.Z1.I3 499

/
 TICZ(S,Z,J) T IN FOR COLD STREAMS

/
 S1.Z1.J1 50
 S1.Z1.J2 90
 S1.Z1.J3 30

/
 TOCZ(S,Z,J) T OUT FOR COLD STREAMS

/
 S1.Z1.J1 400
 S1.Z1.J2 165
 S1.Z1.J3 40

/
 *-----
 *INTRODUCE THE FCp:
 FH(S,I) FOR HOT STREAMS

/
 S1.I1 10
 S1.I2 30

/
 FC(S,J) FOR COLD STREAMS

```

/
S1.J1  10
S1.J2  40
/
*USE THE MAX FCp FOR THE UTILITIES
*-----
SETS FREEH(I)
/
I1
I2
I3
/
FREEC(J)
/
J1
J2
J3
/
PARAMETER BIF(Z,I,J)
/

Z1.I1.J2 0
Z1.J2.J1 0
Z1.I2.J3 0
Z1.I3.J1 0
/
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
*;
PARAMETER SPH(I)  SH in paper
/
I1  1
I2  1
I3  1
/
PARAMETER SPC(J)  SC in paper
/
J1  1
J2  1
J3  1
/
PARAMETER NIH(I)  Non isothermal splitting for hot streams in paper
/
I1  0
I2  0
I3  0
/
PARAMETER NIC(J)  Non isothermal splitting for cold streams in paper
/
J1  0
J2  0
J3  0
/
PARAMETER DTVIO(I,J)
/
I1.J1  1
I1.J2  1
I1.J3  1

I2.J1  1
I2.J2  1
I2.J3  1

I3.J1  1
I3.J2  1
/

```

```

PARAMETER KMAX(Z,I,J)
/

Z1.I1.J2 1
Z1.I2.J1 1
Z1.I2.J3 1
Z1.I3.J1 1
/
*****
***** ADD FOR RETROFIT *****
*****
$ontext
PARAMETER AEX(Z,I,J)
/
Z1.I1.J1 1001.34
Z1.I1.J3 1048.28
Z1.I2.J2 121.53
Z1.I2.J3 133.56
Z1.I3.J1 584.15
Z1.I3.J2 603.71
Z1.I4.J2 246.81
/
PARAMETER AEX_B(K,Z,I,J)
/
K1.Z1.I1.J1 1001.34
/
PARAMETER NHE0(S,Z,I,J)
/
S1.Z1.I1.J1 1
S1.Z1.I1.J3 1
S1.Z1.I2.J2 1
S1.Z1.I2.J3 1
S1.Z1.I3.J1 1
S1.Z1.I3.J2 1
S1.Z1.I4.J2 1
/
PARAMETER AEX_U(Z,I,J)
/
Z1.I1.J1 1502.01
Z1.I1.J3 1572.42
Z1.I2.J2 182.295
Z1.I2.J3 200.34
Z1.I3.J1 876.225
Z1.I3.J2 905.565
Z1.I4.J2 370.215
/
PARAMETER AEX_U_B(K,Z,I,J)
/
K1.Z1.I1.J1 1502.01
/
*-----
$offtext
*For Relocation
PARAMETER NHE0(S,Z,I,J)
/
S1.Z1.I1.J2 1
S1.Z1.I2.J1 1
S1.Z1.I2.J3 1
S1.Z1.I3.J1 1
/

PARAMETER AEX_R(R)
/
R1 841.86
R2 554
R3 660.18
R4 262
/

```


PARAMETER AEX_B_1(R)

/
 R1 841.86
 R2 554
 R3 660.18
 R4 262

/

PARAMETER AEX_U_1(R)

/
 R1 2000
 R2 2000
 R3 2000
 R4 2000

/

PARAMETER AEX_B_R(r)

/
 R1 841.86
 R2 554
 R3 660.18
 R4 262

/

PARAMETER AEX_U_B_R(RR)

/
 R1 2000
 R2 2000
 R3 2000
 R4 2000

/

PARAMETER AEX_U_B_1(R)

/
 R1 2000
 R2 2000
 R3 2000
 R4 2000
 /

PARAMETER R_ALL

* Minimum DELTA T
 /4/;

PARAMETER KET

/4/;
 *\$offtext
 *\$ontext

PARAMETER DTHU(I)

/
 I3 1

/

PARAMETER DTCU(J)

/
 J3 10

/

PARAMETER FMAX_HU(I)

/
 I3 5000

/

PARAMETER FMAX_CU(J)

/
 J3 5000

/

PARAMETER CHU(I)

/

```

13  95.04
/
PARAMETER CCU(J)
/
J3  20
/
PARAMETER CF;
CF = 1000;
PARAMETER CA;
CA = 20;
*****
*****FOR RETEOFIT*****
*****
PARAMETER CAN;
CAN = 20;
PARAMETER CAE;
CAE = 20;
*****
*$offset

PARAMETER QLHMIN
*   Minimum heat that can be transferred within an interval Hot streams
/0.01/;
PARAMETER QLCMIN
*   Minimum heat that can be transferred within an interval.Cold streams
/0.01/;
PARAMETER AMAX
*   Maximum area per exchanger
/20000/;
PARAMETER ASHELLMAX
*   Maximum shell area
/5000/;
PARAMETER USHELLMAX
*   Maximum shell area
/5000/;

*Add for retrofit

PARAMETER A_NEW_MAX(Z,I,J)
/
Z1.(I1*I3).(J1*J3) 300
/

PARAMETER A_NEW_SHELLMAX
*   Maximum shell area
/5000/;
PARAMETER NEW_USHELLMAX
*   Maximum shell area
/5000/;

*
PARAMETER TOTNEXCHMAX
*   Maximum NUMBER OF EXCHANGERS
/900/;
PARAMETER TOTNEXCHMIN
*   Minimum NUMBER OF EXCHANGERS
/0/;
PARAMETER DTmin
*   Minimum DELTA T
/0/;

parameter NINT
/263/;
parameter OPT
/2/;
*-----
*           END OF INPUT PARAMETERS
*-----
SCALARS Si, Zi, Mi, Ic, Ji

PARAMETERS IHminZ(S,Z,I),IHmaxZ(S,Z,I),IHmax(S,I),IHmin(S,I),HOT(S,I,M),

```

```

HOT2(S,M), HOTZ(S,Z,I,M), ICminZ(S,Z,J), ICmaxZ(S,Z,J), ICmin(S,J),
ICmax(S,J), COLD(S,J,M), COLD2(S,M), COLDZ(S,Z,J,M), H_I(S,I,M), H_J(S,J,M)

FOR(Si=1 TO CARD(S),
  FOR(Zi=1 TO CARD(Z),
    FOR(Ic=1 TO CARD(I),
      IHminZ(S,Z,I)$[ORD(S)=Si AND ORD(I)=1
        AND ORD(Z)=1]= 0+ 1$[NIZ(S,Z,I)>=1];
      IHminZ(S,Z,I)$[ORD(S)=Si AND ORD(I)>1
        AND ORD(Z)=1]= 0+
        {SUM((ZZ,I)$[ORD(I)<ORD(I)],NIZ(S,ZZ,I))+1}$[NIZ(S,Z,I)>=1];
      IHminZ(S,Z,I)$[ORD(S)=Si AND ORD(Z)>1]= 0+
        {SUM((ZZ,I)$[ORD(I)<ORD(I)],NIZ(S,ZZ,I))
          +SUM(ZZ$[ORD(ZZ)< Zi],NIZ(S,ZZ,I))+1}$[NIZ(S,Z,I)>=1];
      IHmaxZ(S,Z,I)$[ORD(S)=Si AND ORD(I)=Ic AND ORD(Z)=Zi]= 0+
        {IHminZ(S,Z,I)+NIZ(S,Z,I)-1}$[NIZ(S,Z,I)>=1];
      IHmin(S,I)$[ORD(S)=Si AND ORD(I)=Ic]=
        SUM[Z$ {SUM(ZZ$[ORD(ZZ)<=ORD(Z)-1],NIZ(S,ZZ,I))=0}, IHminZ(S,Z,I)];
      IHmax(S,I)$[ORD(S)=Si AND ORD(I)=Ic]=
        SUM[Z$ {SUM(ZZ$[ORD(ZZ)>=ORD(Z)+1],NIZ(S,ZZ,I))=0}, IHmaxZ(S,Z,I)];

      FOR(Mi=1 TO CARD(M),
        HOT(S,I,M)$[ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi]= 0+
          1$[ORD(M)>= IHmin(S,I) AND ORD(M)<=IHmax(S,I)];
        HOT2(S,M)$[ORD(S)=Si AND ORD(M)=Mi]= 0+ 1$[ORD(M)<=
          SUM(I$[ORD(I)=CARD(I)],IHmax(S,I))];
        HOTZ(S,Z,I,M)$[ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
          AND ORD(Z)=Zi]= 0+ 1$[ORD(M)>= IHminZ(S,Z,I) AND ORD(M)<=IHmaxZ(S,Z,I)];
        H_I(S,I,M)$[ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
          AND HOT(S,I,M)=1] = HI(S,I) ;
      ));
    FOR(Ji=1 TO CARD(J),
      ICminZ(S,Z,J)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(Z)=1]= 0+
        {SUM(I$[ORD(I)=CARD(I)],IHmax(S,I))+1}$[NJZ(S,Z,J)>=1];
      ICminZ(S,Z,J)$[ORD(S)=Si AND ORD(J)>1 AND ORD(Z)=1]= 0+
        {SUM{I$[ORD(I)=CARD(I)],IHmax(S,I)}
          +SUM((ZZ,J)$[ORD(J)<ORD(J)],NJZ(S,ZZ,J))+1}$[NJZ(S,Z,J)>=1];
      ICminZ(S,Z,J)$[ORD(S)=Si AND ORD(Z)>1]= 0+
        {SUM{I$[ORD(I)=CARD(I)],IHmax(S,I)}
          +SUM((ZZ,J)$[ORD(J)<ORD(J)],NJZ(S,ZZ,J))
          +SUM(ZZ$[ORD(ZZ)< Zi],NJZ(S,ZZ,J))+1}$[NJZ(S,Z,J)>=1];
      ICmaxZ(S,Z,J)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(Z)=Zi]= 0+
        {ICminZ(S,Z,J)+NJZ(S,Z,J)-1}$[NJZ(S,Z,J)>=1];
      ICmin(S,J) $[ORD(S)=Si AND ORD(J)=Ji]=
        SUM[Z$ {SUM(ZZ$[ORD(ZZ)<=ORD(Z)-1],NJZ(S,ZZ,J))=0}, ICminZ(S,Z,J)];
      ICmax(S,J) $[ORD(S)=Si AND ORD(J)=Ji]=
        SUM[Z$ {SUM(ZZ$[ORD(ZZ)>=ORD(Z)+1],NJZ(S,ZZ,J))=0}, ICmaxZ(S,Z,J)];

      FOR(Mi=1 TO CARD(M),
        COLD(S,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi]= 0+
          1$[ORD(M)>= ICmin(S,J) AND ORD(M)<=ICmax(S,J)];
        COLD2(S,M)$[ORD(S)=Si AND ORD(M)=Mi]= 0+
          1$[ORD(M)>SUM(I$[ORD(I)=CARD(I)],IHmax(S,I))
            AND ORD(M)<= SUM(J$[ORD(J)=CARD(J)],ICmax(S,J))];
        COLDZ(S,Z,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
          AND ORD(Z)=Zi]= 0+ 1$[ORD(M)>= ICminZ(S,Z,J)
            AND ORD(M)<=ICmaxZ(S,Z,J)];
        H_J(S,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
          AND COLD(S,J,M)=1] = HJ(S,J) ;
      ));
    ));
PARAMETERS DT(S,M), TU(S,M), TL(S,M), CPH(S,I,M), CPC(S,J,M), DHH(S,I,M), DHC(S,J,M);

*ALWAYS DEFINE Cp AS 1
CPH(S,I,M)$[HOT(S,I,M)=1] = 1;
CPC(S,J,M)$[COLD(S,J,M)=1] = 1;

DT(S,M) = SUM((Z,I)$[HOTZ(S,Z,I,M)=1], {TIHZ(S,Z,I)-TOHZ(S,Z,I)/
  [IHmaxZ(S,Z,I)-IHminZ(S,Z,I)+1]}$[HOT2(S,M)=1]+
  SUM((Z,J)$[COLDZ(S,Z,J,M)=1], {TOCZ(S,Z,J)-TICZ(S,Z,J)/
  [ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]}$[COLD2(S,M)=1];

```

```

FOR(Si= 1 TO CARD(S),
  FOR (Mi=1 TO CARD(M),
    TU(S,M){ORD(S)=Si AND ORD(M)=Mi}= {SUM((Z,I){HOTZ(S,Z,I,M)=1
      AND ORD(M)=IHminZ(S,Z,I),TIHZ(S,Z,I){ORD(M)=IHminZ(S,Z,I)}
      + SUM((Z,I){HOTZ(S,Z,I,M)=1 AND ORD(M)>IHminZ(S,Z,I)AND
        ORD(M)<=IHmaxZ(S,Z,I),
          [TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)]{ORD(M)>
            IHminZ(S,Z,I)AND ORD(M)<=IHmaxZ(S,Z,I)}]{HOT2(S,M)=1}
      + {SUM((Z,J){COLDZ(S,Z,J,M)=1 AND ORD(M)=ICminZ(S,Z,J)},
        TOCZ(S,Z,J){ORD(M)=ICminZ(S,Z,J)}
      + SUM((Z,J){COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z,J)
        AND ORD(M)<=ICmaxZ(S,Z,J)},
          [TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]{ORD(M)>
            ICminZ(S,Z,J)AND ORD(M)<=ICmaxZ(S,Z,J)}]{COLD2(S,M)=1};
    TL(S,M){ORD(S)=Si AND ORD(M)=Mi}=
      {SUM((Z,I){HOTZ(S,Z,I,M)=1 AND ORD(M)=IHmaxZ(S,Z,I),
        TOHZ(S,Z,I){ORD(M)=IHmaxZ(S,Z,I)}
      + SUM((Z,I){HOTZ(S,Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z,I)
        AND ORD(M)>=IHminZ(S,Z,I),
          [TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]{ORD(M)<
            IHmaxZ(S,Z,I)AND ORD(M)>=IHminZ(S,Z,I)}]{HOT2(S,M)=1}
      + {SUM((Z,J){COLDZ(S,Z,J,M)=1 AND ORD(M)=ICmaxZ(S,Z,J)},
        TICZ(S,Z,J){ORD(M)=ICmaxZ(S,Z,J)}
      + SUM((Z,J){COLDZ(S,Z,J,M)=1 AND ORD(M)<ICmaxZ(S,Z,J)
        AND ORD(M)>=ICminZ(S,Z,J)},
          [TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]{ORD(M)<
            ICmaxZ(S,Z,J)AND ORD(M)>=ICminZ(S,Z,J)}]{COLD2(S,M)=1};
    FOR(Ic=1 TO CARD(I),
      DHH(S,I,M){ORD(S)=Si AND ORD(M)=Mi AND ORD(I)=Ic
        AND HOT(S,I,M)=1}= FH(S,I)*CPH(S,I,M)*[TU(S,M)-TL(S,M)] ;
    );
    FOR(Ji=1 TO CARD(J),
      DHC(S,J,M){ORD(S)=Si AND ORD(M)=Mi AND ORD(J)=Ji
        AND COLD(S,J,M)=1}= FC(S,J)*CPC(S,J,M)*[TU(S,M)-TL(S,M)] ;
    ));

```

```

PARAMETER HHEAD(S,M,N), CHEAD(S,M,N), LMTD(S,M,N), D(S,Z,M,N)
*MATCH ALLOWED BASED ON LMTD
  ALLOW(S,Z,I,J), ALLOW_H(S,Z,I,M,J), ALLOW_C(S,Z,J,M,I), ALLOW_2(Z,I,J) ;

```

```

HHEAD(S,M,N) = {TU(S,M)-TU(S,N)+ DTmin}{HOT2(S,M) AND COLD2(S,N)};
CHEAD(S,M,N) = {TL(S,M)-TL(S,N)+ DTmin}{HOT2(S,M) AND COLD2(S,N)};

```

```

LMTD(S,M,N)= {[HHEAD(S,M,N)-CHEAD(S,M,N)]
  /LOG[HHEAD(S,M,N)/CHEAD(S,M,N)]}{HHEAD(S,M,N)> 0
  AND CHEAD(S,M,N)>0 AND HHEAD(S,M,N)> CHEAD(S,M,N)}
+ {[HHEAD(S,M,N)+CHEAD(S,M,N)]/2}{HHEAD(S,M,N)>0 AND CHEAD(S,M,N)>0
  AND (HHEAD(S,M,N)< CHEAD(S,M,N)OR HHEAD(S,M,N)= CHEAD(S,M,N))};

```

```

D(S,Z,M,N)= 1 ${HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[IS(HOT(S,I,M)=1
  AND HOT(S,I,N)=1),HOTZ(S,Z,I,M)=1 AND SUM[IS(HOT(S,I,N)=1
  AND HOT(S,I,M)=1),HOTZ(S,Z,I,N)=1}
OR {COLD2(S,M)=1 AND COLD2(S,N)=1 AND SUM[JS(COLD(S,J,M)=1
  AND COLD(S,J,N)=1),COLDZ(S,Z,J,M)=1 AND SUM[JS(COLD(S,J,N)=1
  AND COLD(S,J,M)=1),COLDZ(S,Z,J,N)=1}
OR {(HHEAD(S,M,N)>=0.00001 AND CHEAD(S,M,N)>=0.00001)
  AND SUM[IS(HOT(S,I,M)=1),HOTZ(S,Z,I,M)=1
  AND SUM[JS(COLD(S,J,N)=1),COLDZ(S,Z,J,N)=1]}];

```

```

* OR {LMTD(S,M,N)>0 AND SUM[IS(HOT(S,I,M)=1),HOTZ(S,Z,I,M)=1
* AND SUM[JS(COLD(S,J,N)=1),COLDZ(S,Z,J,N)=1]}];

```

```

FOR(Si= 1 TO CARD(S),
  FOR(Zi=1 TO CARD(Z),
    FOR(Ic=1 TO CARD(I),
      FOR(Ji=1 TO CARD(J),
        ALLOW(S,Z,I,J){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
          AND ORD(J)=Ji}= 0+ 1${SUM[(M,N){HOT(S,I,M)=1
          AND COLD(S,J,N)=1},D(S,Z,M,N)]>0

```

```

        AND NOT[HU(I)AND CU(J)];
FOR (Mi=1 TO CARD(M).
    ALLOW_H(S,Z,I,M,J){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
        AND ORD(J)=Ji AND ORD(M)=Mi
        AND HOT(S,I,M)=1}= 0+
    I${SUM[N${COLD(S,J,N)=1},D(S,Z,M,N)] >0 AND NOT[HU(I)AND CU(J)]};
    ALLOW_C(S,Z,J,M,I){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
        AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1}= 0+
    I${SUM[N${HOT(S,I,N)=1},D(S,Z,N,M)] >0 AND NOT[HU(I)AND CU(J)]};
    )));
FOR(Zi=1 TO CARD(Z),
    FOR(Ic=1 TO CARD(I),
        FOR(Ji=1 TO CARD(J),
            ALLOW_2(Z,I,J){ORD(Z)=Zi AND ORD(I)=Ic AND ORD(J)=Ji}= 0+
            I${SUM[S,ALLOW(S,Z,I,J)] >0 AND NOT[HU(I)AND CU(J)]};
        ));
$ONTEXT
*NM-4S1-FINAL-6-FLEXIBILITY-S1.gms: August 9, 2004
* one scenario, the original values of 4s1.
*****
$OFFTEXT
$ontext
*DEFINES THE NUMBER OR TRANSFER ZONES
SET
    Z transfer zone      /Z1*Z2/

*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
SET I /I1*I15/
SET J /J1*J15/

SETS
M temperature intervals /M1*M250/
S SCENARIO      /S1/
K number of heat exchangers /K1*K20/
X used to input numbers /X1*X15/

ALIAS (M,N,L,O)
ALIAS (I,II)
ALIAS (J,JJ)
ALIAS (K,KK)
ALIAS (Z,ZZ)

*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
*Heating utilities
$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=HU rng=GAMS!C49:149 Cdim=1
SET HU(I)
$GDXIN isabel.gdx
$LOAD HU

*Cooling utilities
$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=CU rng=GAMS!C52:152 Cdim=1
SET CU(J)
$GDXIN isabel.gdx
$LOAD CU

*****Input parameters *****

* INPUTS 15 NUMBERS IN ONE VECTOR TO REDUCE LOADING TIME
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=DATA rng=Hoja1!E48:F62 Rdim=1
PARAMETER DATA(X);
$GDXIN isabel.gdx
$LOAD DATA

*DEFINES WHICH EQUATIONS RUN OPT=0 GRASSROOTS OPT=1 RETROFIT OPT=2 RELOCATION
PARAMETER OPT;
OPT = DATA('X1');

*THE NUMBER OF INTERVALS TO BE USED
PARAMETER NINT;
NINT = DATA('X2');
```

```

*Maximum shell area
PARAMETER ASHELLMAX;
ASHELLMAX = DATA('X3');

*Maximum area per exchanger
PARAMETER AMAX;
AMAX = DATA('X4');

*Minimum DELTA T
PARAMETER DTmin;
DTmin = DATA('X5');

*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
PARAMETER BIF;
BIF = DATA('X6');

*LIMITS THE NUMBER OF HEAT EXCHANGERS IN ONE INTERVAL
PARAMETER KMAX;
KMAX = DATA('X7');

*Minimum heat that can be transferred within an interval.Hot streams
PARAMETER QLHMIN;
QLHMIN = DATA('X8');

*Minimum heat that can be transferred within an interval.Cold streams
PARAMETER QLCMIN;
QLCMIN = DATA('X8');

*Maximum NUMBER OF EXCHANGERS
PARAMETER TOTNEXCHMAX;
TOTNEXCHMAX = DATA('X9');

*Minimum NUMBER OF EXCHANGERS
PARAMETER TOTNEXCHMIN;
TOTNEXCHMIN = DATA('X10');

*FIXED COST FOR A HEAT EXCHANGER MATCHING STREAMS
PARAMETER CF;
CF = DATA('X11');

*VARIABLE COST FOR A HEAT EXCHANGER MATCHING STREAMS
PARAMETER CA;
CA = DATA('X12');

*COST OF RELOCATION
PARAMETER CAN;
CAN = DATA('X13');
PARAMETER CAE;
CAE = DATA('X13');

*NUMBER OF HEAT EXCHANGERS ORIGINALY PRESENT
PARAMETER KET;
KET= DATA('X14');

*MAXIMUM ADDITIONAL AREA
PARAMETER A_NEW_MAX;
A_NEW_MAX = DATA('X15');

*NUMBER OF INTERVALS ON HOT STREAM
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NIZ rng=GAMS!a1:q3 Rdim=2 Cdim=1
PARAMETER NIZ(S.Z.I);
$GDXIN isabel.gdx
$LOAD NIZ

*NUMBER OF INTERVALS ON COLD STREAM
$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NJZ rng=GAMS!a5:q7 Rdim=2 Cdim=1
PARAMETER NJZ(S.Z.J);
$GDXIN isabel.gdx
$LOAD NJZ

```

*HEAT TRANSFER COEFF FOR HOT STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=HI rng=GAMS!B9:q10 Rdim=1 Cdim=1
 PARAMETER HI(S,I);
 \$GDXIN isabel.gdx
 \$LOAD HI

*HEAT TRANSFER COEFF FOR COLD STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=HJ rng=GAMS!B12:q13 Rdim=1 Cdim=1
 PARAMETER HJ(S,J);
 \$GDXIN isabel.gdx
 \$LOAD HJ

*TEMPERATURE FOR HOT INLET STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIH rng=GAMS!B15:q16 Rdim=1 Cdim=1
 PARAMETER TIH(S,I);
 \$GDXIN isabel.gdx
 \$LOAD TIH

*TEMPERATURE FOR HOT OUTLET STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOH rng=GAMS!B18:q19 Rdim=1 Cdim=1
 PARAMETER TOH(S,J);
 \$GDXIN isabel.gdx
 \$LOAD TOH

*TEMPERATURE FOR COLD INLET STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIC rng=GAMS!B21:q22 Rdim=1 Cdim=1
 PARAMETER TIC(S,I);
 \$GDXIN isabel.gdx
 \$LOAD TIC

*TEMPERATURE FOR COLD OUTLET STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOC rng=GAMS!B24:q25 Rdim=1 Cdim=1
 PARAMETER TOC(S,J);
 \$GDXIN isabel.gdx
 \$LOAD TOC

*PARAMETERS FOR Z ZONE, TEMPERATURA @ EACH ZONE AND FLOW

*TEMPERATURE FOR HOT INLET STREAMS @ Z

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIHZ rng=GAMS!A27:q29 Rdim=2 Cdim=1
 PARAMETER TIHZ(S,Z,I);
 \$GDXIN isabel.gdx
 \$LOAD TIHZ

*TEMPERATURE FOR HOT OUTLET STREAMS @ Z

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOHZ rng=GAMS!A31:q33 Rdim=2 Cdim=1
 PARAMETER TOHZ(S,Z,J);
 \$GDXIN isabel.gdx
 \$LOAD TOHZ

*TEMPERATURE FOR COLD INLET STREAMS @ Z

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TICZ rng=GAMS!A35:q37 Rdim=2 Cdim=1
 PARAMETER TICZ(S,Z,I);
 \$GDXIN isabel.gdx
 \$LOAD TICZ

*TEMPERATURE FOR COLD OUTLET STREAMS @ Z

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOCZ rng=GAMS!A39:q41 Rdim=2 Cdim=1
 PARAMETER TOCZ(S,Z,J);
 \$GDXIN isabel.gdx
 \$LOAD TOCZ

*MASS FLOW FOR THE HOT STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=FH rng=GAMS!B43:q44 Rdim=1 Cdim=1
 PARAMETER FH(S,I);
 \$GDXIN isabel.gdx
 \$LOAD FH

*MASS FLOW FOR THE COLD STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=FC rng=GAMS!B46:q47 Rdim=1 Cdim=1
 PARAMETER FC(S,J);
 \$GDXIN isabel.gdx

\$LOAD FC

*HOT PROCESS STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=FREEH rng=GAMS!C1:q1 Cdim=1
 SET FREEH(I)
 \$GDXIN isabel.gdx
 \$LOAD FREEH

*COLD PROCESS STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=FREEC rng=GAMS!C5:q5 Cdim=1
 SET FREEC(J)
 \$GDXIN isabel.gdx
 \$LOAD FREEC

*SPLITS ARE ALLOWED FOR HOT STREAMS BINARY SH in paper

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=SPH rng=GAMS!C55:q56 Cdim=1
 PARAMETER SPH(I);
 \$GDXIN isabel.gdx
 \$LOAD SPH

*SPLITS ARE ALLOWED FOR COLD STREAMS BINARY SC in paper

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=SPC rng=GAMS!C58:q59 Cdim=1
 PARAMETER SPC(J);
 \$GDXIN isabel.gdx
 \$LOAD SPC

*NON ISOTHERMAL MIXING IS PERMITTED FOR HOT STREAMS BINARY

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NIH rng=GAMS!C55:q56 Cdim=1
 PARAMETER NIH(I);
 \$GDXIN isabel.gdx
 \$LOAD NIH

*NON ISOTHERMAL MIXING IS PERMITTED FOR COLD STREAMS BINARY

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NIC rng=GAMS!C58:q59 Cdim=1
 PARAMETER NIC(J);
 \$GDXIN isabel.gdx
 \$LOAD NIC

*POSSIBLE TEMPERATURE DIFFERENCES BETWEEN EXCHANGING STREAMS

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=DTVIO rng=DTVIO!A1:C225 Rdim=2
 PARAMETER DTVIO(I,J);
 \$GDXIN isabel.gdx
 \$LOAD DTVIO

*TEMPERATURE DIFFERENCE IN THE HOT UTILITY

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=DTHU rng=GAMS!C49:q50 Cdim=1
 PARAMETER DTHU(I);
 \$GDXIN isabel.gdx
 \$LOAD DTHU

*TEMPERATURE DIFFERENCE IN THE COLD UTILITY

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=DTCU rng=GAMS!C52:q53 Cdim=1
 PARAMETER DTCU(J);
 \$GDXIN isabel.gdx
 \$LOAD DTCU

*MAXIMUM MASS FLOW FOR THE HOT UTILITY

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=FMAX_HU rng=GAMS!C61:q62 Cdim=1
 PARAMETER FMAX_HU(I);
 \$GDXIN isabel.gdx
 \$LOAD FMAX_HU

*MAXIMUM MASS FLOW FOR THE COLD UTILITY

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=FMAX_CU rng=GAMS!C64:q65 Cdim=1
 PARAMETER FMAX_CU(J);
 \$GDXIN isabel.gdx
 \$LOAD FMAX_CU

*COST OF HOT UTILITY

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CHU rng=GAMS!C67:q68 Cdim=1
 PARAMETER CHU(I);

\$GDXIN isabel.gdx
\$LOAD CHU

*COST OF COLD UTILITY
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CCU rng=GAMS!C70:q71 Cdim=1
PARAMETER CCU(J);
\$GDXIN isabel.gdx
\$LOAD CCU

*CP OF HOT PROCESS STREAM I
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CPH rng=CP!BE2:BH251 rdim=3
PARAMETER CPH(S,I,M);
\$GDXIN isabel.gdx
\$LOAD CPH

*CP OF COLD PROCESS STREAM J
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CPC rng=CP!BJ2:BM251 rdim=3
PARAMETER CPC(S,J,M);
\$GDXIN isabel.gdx
\$LOAD CPC

***** ADD FOR RETROFIT *****

*AREA OF EXISTING HEAT EXCHANGERS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX rng=EXCHANGERS!L2:O8 Rdim=3
PARAMETER AEX(Z,I,J);
\$GDXIN isabel.gdx
\$LOAD AEX

*AREA OF EXISTING HEAT EXCHANGERS THAT CANNOT BE MOVED
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_B rng=EXCHANGERS!Q2:U21 Rdim=4
PARAMETER AEX_B(K,Z,I,J);
\$GDXIN isabel.gdx
\$LOAD AEX_B

*NUMBER OF HEAT EXCHANGERS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NHE0 rng=EXCHANGERS!K45:O244 Rdim=4
PARAMETER NHE0(S,Z,I,J);
\$GDXIN isabel.gdx
\$LOAD NHE0

*MAXIMUM AREA OF EXCHANGERS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U rng=EXCHANGERS!L23:O42 Rdim=3
PARAMETER AEX_U(Z,I,J);
\$GDXIN isabel.gdx
\$LOAD AEX_U

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U_B rng=EXCHANGERS!Q23:U42 Rdim=4
PARAMETER AEX_U_B(K,Z,I,J);
\$GDXIN isabel.gdx
\$LOAD AEX_U_B

***** ADD FOR RELOCATION*****

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_R rng=EXCHANGERS!Z2:AA21 Rdim=1
PARAMETER AEX_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX_R

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U_R rng=EXCHANGERS!Z23:AA42 Rdim=1
PARAMETER AEX_U_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX_U_R

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_B_R rng=EXCHANGERS!AC2:AD21 Rdim=1
PARAMETER AEX_B_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX_B_R

\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U_B_R rng=EXCHANGERS!AC23:AD42 Rdim=1
PARAMETER AEX_U_B_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX_U_B_R

```

*-----
*                END OF INPUT PARAMETERS
*-----

SCALARS Si, Zi, Mi, Ic, Ji
*H_I  HEAT TRANSFER COEFFICIENT FOR HOT STREAM I
*H_J  HEAT TRANSFER COEFFICIENT FOR COLD STREAM J
*HOT  HOT FLOW I PRESENT IN INTERVAL M
*COLD  COLD FLOW J PRESENT IN INTERVAL N
PARAMETERS IHminZ(S,Z,I),IHmaxZ(S,Z,I),IHmax(S,I),IHmin(S,I),HOT(S,I,M),
            HOT2(S,M), HOTZ(S,Z,I,M), ICminZ(S,Z,J),ICmaxZ(S,Z,J),ICmin(S,J),
            ICmax(S,J),COLD(S,J,M),COLD2(S,M), COLDZ(S,Z,J,M), H_I(S,I,M), H_J(S,J,M)

FOR(Si=1 TO CARD(S),
  FOR(Zi=1 TO CARD(Z),
    FOR(Ic=1 TO CARD(FREEH),
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)=1
                    AND ORD(Z)=1}= 0+ 1${NIZ(S,Z,I)>=1};
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)>1
                    AND ORD(Z)=1}= 0+
        {SUM((ZZ,II){ORD(II)<ORD(I)},NIZ(S,ZZ,II))+1}{NIZ(S,Z,I)>=1};
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(Z)>1}= 0+
        {SUM((ZZ,II){ORD(II)<ORD(I)},NIZ(S,ZZ,II))
          +SUM(ZZ${ORD(ZZ)<Zi},NIZ(S,ZZ,I))+1}{NIZ(S,Z,I)>=1};
      IHmaxZ(S,Z,I){ORD(S)=Si AND ORD(I)=Ic AND ORD(Z)=Zi}= 0+
        {IHminZ(S,Z,I)+NIZ(S,Z,I)-1}{NIZ(S,Z,I)>=1};
      IHmin(S,I){ORD(S)=Si AND ORD(I)=Ic}=
        SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NIZ(S,ZZ,I))=0},IHminZ(S,Z,I)];
      IHmax(S,I){ORD(S)=Si AND ORD(I)=Ic}=
        SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NIZ(S,ZZ,I))=0},IHmaxZ(S,Z,I)];

      FOR(Mi=1 TO NINT,
        HOT(S,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi}= 0+
          1${ORD(M)>= IHmin(S,I) AND ORD(M)<=IHmax(S,I)};
        HOT2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+ 1${ORD(M)<=
          SUM(1${ORD(I)=CARD(FREEH)},IHmax(S,I))};
        HOTZ(S,Z,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
          AND ORD(Z)=Zi}= 0+ 1${ORD(M)>= IHminZ(S,Z,I) AND ORD(M)<=IHmaxZ(S,Z,I)};
        H_I(S,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
          AND HOT(S,I,M)=1} = HI(S,I) ;
      ));
    FOR(Ji=1 TO CARD(FREEC),
      ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)=1 AND ORD(Z)=1}= 0+
        {SUM(1${ORD(I)=CARD(FREEH)},IHmax(S,I))+1}{NJZ(S,Z,J)>=1};
      ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)>1 AND ORD(Z)=1}= 0+
        {SUM(1${ORD(I)=CARD(FREEH)},IHmax(S,I))
          +SUM((ZZ,JJ){ORD(JJ)<ORD(J)},NJZ(S,ZZ,JJ))+1}{NJZ(S,Z,J)>=1};
      ICminZ(S,Z,J){ORD(S)=Si AND ORD(Z)>1}= 0+
        {SUM(1${ORD(I)=CARD(FREEH)},IHmax(S,I))
          +SUM((ZZ,JJ){ORD(JJ)<ORD(J)},NJZ(S,ZZ,JJ))
          +SUM(ZZ${ORD(ZZ)<Zi},NJZ(S,ZZ,J))+1}{NJZ(S,Z,J)>=1};
      ICmaxZ(S,Z,J){ORD(S)=Si AND ORD(J)=Ji AND ORD(Z)=Zi}= 0+
        {ICminZ(S,Z,J)+NJZ(S,Z,J)-1}{NJZ(S,Z,J)>=1};
      ICmin(S,J) ${ORD(S)=Si AND ORD(J)=Ji}=
        SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NJZ(S,ZZ,J))=0},ICminZ(S,Z,J)];
      ICmax(S,J) ${ORD(S)=Si AND ORD(J)=Ji}=
        SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NJZ(S,ZZ,J))=0},ICmaxZ(S,Z,J)];

      FOR(Mi=1 TO NINT,
        COLD(S,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi}= 0+
          1${ORD(M)>= ICmin(S,J) AND ORD(M)<=ICmax(S,J)};
        COLD2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+
          1${ORD(M)>SUM(1${ORD(I)=CARD(FREEH)},IHmax(S,I))
            AND ORD(M)<= SUM(1${ORD(J)=CARD(FREEC)},ICmax(S,J))};
        COLDZ(S,Z,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
          AND ORD(Z)=Zi}= 0+ 1${ORD(M)>= ICminZ(S,Z,J)
            AND ORD(M)<=ICmaxZ(S,Z,J)};
        H_J(S,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
          AND COLD(S,J,M)=1} = HJ(S,J) ;
      ));
  ));
);

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*DHH  ENTHALPY CHANGE FOR HOT PROCESS STREAM I
*DHC  ENTHALPY CHANGE FOR COLD PROCESS STREAM J
*DT   TEMPERATURE DIFERENCE BETWEEN STREAMS AT INTERVAL
*TU   UPPER TEMPERATURE OF INTERVAL
*TL   LOWER TEMPERATURE OF INTERCAL
PARAMETERS DT(S,M),TU(S,M), TL(S,M), DHH(S,I,M),DHC(S,J,M);

DT(S,M) = SUM((Z,I)$[HOTZ(S,Z,I,M)=1],{[TIHZ(S,Z,I)-TOHZ(S,Z,I)]/
      [IHmaxZ(S,Z,I)-IHminZ(S,Z,I)+1]})$[HOT2(S,M)=1]+
      SUM((Z,J)$[COLDZ(S,Z,J,M)=1],{[TOCZ(S,Z,J)-TICZ(S,Z,J)]/
      [ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]})$[COLD2(S,M)=1];

FOR(Si= 1 TO CARD(S),
  FOR (Mi=1 TO NINT,
    TU(S,M)$[ORD(S)=Si AND ORD(M)=Mi]= {SUM((Z,I)$[HOTZ(S,Z,I,M)=1
      AND ORD(M)=IHminZ(S,Z,I)],TIHZ(S,Z,I)$[ORD(M)=IHminZ(S,Z,I)]
      + SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)>IHminZ(S,Z,I)AND
      ORD(M)<=IHmaxZ(S,Z,I)],
      [TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)]$[ORD(M)>
      IHminZ(S,Z,I)AND ORD(M)<=IHmaxZ(S,Z,I)]})$[HOT2(S,M)=1]
      + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICminZ(S,Z,J)],
      TOCZ(S,Z,J)$[ORD(M)=ICminZ(S,Z,J)]
      + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z,J)
      AND ORD(M)<=ICmaxZ(S,Z,J)],
      [TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]$[ORD(M)>
      ICminZ(S,Z,J)AND ORD(M)<=ICmaxZ(S,Z,J)]})$[COLD2(S,M)=1];
    TL(S,M)$[ORD(S)=Si AND ORD(M)=Mi]=
      {SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)=IHmaxZ(S,Z,I)],
      TOHZ(S,Z,I)$[ORD(M)=IHmaxZ(S,Z,I)]
      + SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z,I)
      AND ORD(M)>=IHminZ(S,Z,I)],
      [TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$[ORD(M)<
      IHmaxZ(S,Z,I)AND ORD(M)>=IHminZ(S,Z,I)]})$[HOT2(S,M)=1]
      + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICmaxZ(S,Z,J)],
      TICZ(S,Z,J)$[ORD(M)=ICmaxZ(S,Z,J)]
      + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)<ICmaxZ(S,Z,J)
      AND ORD(M)>=ICminZ(S,Z,J)],
      [TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$[ORD(M)<
      ICmaxZ(S,Z,J)AND ORD(M)>=ICminZ(S,Z,J)]})$[COLD2(S,M)=1];
    FOR(Ic=1 TO CARD(FREEH),
      DHH(S,I,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(I)=Ic
      AND HOT(S,I,M)=1]= FH(S,I)*CPH(S,I,M)*[TU(S,M)-TL(S,M)] ;
    );
    FOR(Ji=1 TO CARD(FREEC),
      DHC(S,J,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(J)=Ji
      AND COLD(S,J,M)=1]= FC(S,J)*CPC(S,J,M)*[TU(S,M)-TL(S,M)] ;
    ));

*ALLOW_2 MATCH ALLOWED BASED ON LMTD
*ALLOW  HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I AND COLD STREAM J
*ALLOW_H HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I@M AND COLD STREAM J
*ALLOW_C HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I AND COLD STREAM J@N
PARAMETER HHEAD(S,M,N), CHEAD(S,M,N), LMTD(S,M,N), D(S,Z,M,N)
  ALLOW(S,Z,I,J), ALLOW_H(S,Z,I,M,J), ALLOW_C(S,Z,J,M,I), ALLOW_2(Z,I,J) ;

FOR(Ic=1 TO CARD(FREEH),
  FOR(Ji=1 TO CARD(FREEC),
    HHEAD(S,M,N) = {TU(S,M)-TU(S,N) + DTmin}$[HOT2(S,M) AND COLD2(S,N)];
    CHEAD(S,M,N) = {TL(S,M)-TL(S,N) + DTmin}$[HOT2(S,M) AND COLD2(S,N)] ;

    LMTD(S,M,N)= {[HHEAD(S,M,N)-CHEAD(S,M,N)]
      /LOG[HHEAD(S,M,N)/CHEAD(S,M,N)]}$[HHEAD(S,M,N)> 0
      AND CHEAD(S,M,N)>0 AND HHEAD(S,M,N)> CHEAD(S,M,N)]
      + {[HHEAD(S,M,N)+CHEAD(S,M,N)]/2}$[HHEAD(S,M,N)>0 AND CHEAD(S,M,N)>0
      AND (HHEAD(S,M,N)< CHEAD(S,M,N)OR HHEAD(S,M,N)= CHEAD(S,M,N))];

    D(S,Z,M,N)= 1$[{HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[I$(HOT(S,I,M)=1
      AND HOT(S,I,N)=1),HOTZ(S,Z,I,M)=1 AND SUM[I$(HOT(S,I,N)=1
      AND HOT(S,I,M)=1),HOTZ(S,Z,I,N)=1]
      OR {COLD2(S,M)=1 AND COLD2(S,N)=1 AND SUM[J$(COLD(S,J,M)=1
      AND COLD(S,J,N)=1),COLDZ(S,Z,J,M)=1 AND SUM[J$(COLD(S,J,N)=1

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AND COLD(S,J,M)=1,COLDZ(S,Z,J,N)=1}
OR {(HHEAD(S,M,N)>=0.00001 AND CHEAD(S,M,N)>=0.00001)
AND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,I,M)]=1
AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)=1}];
));
* OR {LMTD(S,M,N)>0 AND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,I,M)]=1
* AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)=1}];

FOR(SI= 1 TO CARD(S),
FOR(ZI=1 TO CARD(Z),
FOR(IC=1 TO CARD(FREEH),
FOR(JI=1 TO CARD(FREEC),
ALLOW(S,Z,I,J)$[ORD(S)=SI AND ORD(Z)=ZI AND ORD(I)=IC
AND ORD(J)=JI]= 0+ 1$[SUM[(M,N)$[HOT(S,I,M)=1
AND COLD(S,J,N)=1],D(S,Z,M,N)] >0
AND NOT[HU(I)AND CU(J)]];
FOR(MI=1 TO NINT,
ALLOW_H(S,Z,I,M,J)$[ORD(S)=SI AND ORD(Z)=ZI AND ORD(I)=IC
AND ORD(J)=JI AND ORD(M)=MI
AND HOT(S,I,M)=1]= 0+
1$[SUM[N$(COLD(S,J,N)=1),D(S,Z,M,N)] >0AND NOT[HU(I)AND CU(J)]];
ALLOW_C(S,Z,J,M,I)$[ORD(S)=SI AND ORD(Z)=ZI AND ORD(I)=IC
AND ORD(J)=JI AND ORD(M)=MI AND COLD(S,J,M)=1]= 0+
1$[SUM[N$(HOT(S,I,N)=1),D(S,Z,N,M)] >0AND NOT[HU(I)AND CU(J)]];
))));
FOR(ZI=1 TO CARD(Z),
FOR(IC=1 TO CARD(FREEH),
FOR(JI=1 TO CARD(FREEC),
ALLOW_2(Z,I,J)$[ORD(Z)=ZI AND ORD(I)=IC AND ORD(J)=JI]= 0+
1$[SUM[S,ALLOW(S,Z,I,J)] >0 AND NOT[HU(I)AND CU(J)]];
));
$offtext
*-----
VARIABLES
TCOST
PAR(Z,I,J)
Q(S,Z,I,M,J,N) heat load for process-process match
QNEW_M(S,Z,I,J,M)
QNEW_N(S,Z,I,J,N)
QNEW2_M(S,Z,I,J,M)
QNEW2_N(S,Z,I,J,N)
Y_M(S,Z,I,J,M)
Y_N(S,Z,I,J,N)
Y_M_B(S,Z,I,J,M)
Y_N_B(S,Z,I,J,N)
NHE_M0(S,Z,I,J,M)
NHE_M1(S,Z,I,J,M)
NHE_N0(S,Z,I,J,N)
NHE_N1(S,Z,I,J,N)
NHE_M0_B(S,Z,I,J,M)
NHE_M1_B(S,Z,I,J,M)
NHE_N0_B(S,Z,I,J,N)
NHE_N1_B(S,Z,I,J,N)
NHE(S,Z,I,J)
ALFA_M(S,Z,I,J,M)
ALFA_N(S,Z,I,J,N)
FHU(I) is FCP HU (MJ_h_C)
FCU(J) is FCP CU(MJ_h_C)
B1(S,Z,I,M,J,N) X(imjn) in the paper
QH(S,Z,I,M,N)
QC(S,Z,J,M,N)
Q2(S,Z,I,M,J,N)
X1_B(S,Z,I,J,M)
X_B(S,K,Z,I,J,M)
PAR_B(K,Z,I,J)
USHELL(Z,I,J)
USHELL_B(K,Z,I,J)
*$ontext
*****ADD FOR RETROFIT*****

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PAR_N(S,Z,I,J)

DPAR_E(Z,I,J)
NHE_S(S,Z,I,J)
DELTA(Z,I,J,R,R,K)
PHI(Z,I,J,R)

PAR_B_R(K,R,Z,I,J)
DPAR_E_B(K,R,Z,I,J)
PAR_N_B(K,R,Z,I,J)

*$offset
HOT_UTILITY_COST
Cold_UTILITY_COST
Area_Cost
FIX_COST
;
POSITIVE VARIABLE Q,QNEW2_M,QNEW2_N,QC,QH,Q2,PAR1,PAR2,DPAR_E,DPAR_E_B
,PAR_N,PAR_N_B,AEX,AEX_B
,PAR,QNEW_M,QNEW_N,FIX_COST
BINARY VARIABLE NHE_M0_B,NHE_M1_B,NHE_N0_B,NHE_N1_B,Y_M,Y_N,X1_B,X_B,NHE_S
,DELTA,Y_M_B,Y_N_B,NHE_M0,NHE_M1,NHE_N0,NHE_N1,ALFA_M,ALFA_N
,PHI
INTEGER VARIABLE USHELL,USHELL_B

EQUATIONS
HBHU(S,I,M)
HBCU(S,J,N)
HBHS(S,I,M)
HBSC(S,J,N)
TRANSFOR_M(S,Z,I,I,M)
TRANSFOR_N(S,Z,I,I,N)
HBHS_NI(S,I,M)
HBSC_NI(S,I,N)
NOISOH(S,I,M)
NOISOC(S,J,N)
BINARY_M1(S,Z,I,I,M)
BINARY_M2(S,Z,I,I,M)
BINARY_M1_B(S,Z,I,I,M)
BINARY_M2_B(S,Z,I,I,M)
BINARY_N1(S,Z,I,I,N)
BINARY_N2(S,Z,I,I,N)
BINARY_N1_B(S,Z,I,I,N)
BINARY_N2_B(S,Z,I,I,N)
BINARY_M5(S,Z,I,I,M)
BINARY_M5b(S,Z,I,I,M)
BINARY_M3(S,Z,I,I,M)
BINARY_M4(S,Z,I,I,M)
BINARY_M8(S,Z,I,I,M)
BINARY_M9(S,Z,I,I,M)
BINARY_M6(S,Z,I,I,M)
BINARY_M7(S,Z,I,I,M)
BINARY_M3_B(S,Z,I,I,M)
BINARY_N5(S,Z,I,I,N)
BINARY_N5b(S,Z,I,I,N)
BINARY_N3(S,Z,I,I,N)
BINARY_N4(S,Z,I,I,N)
BINARY_N8(S,Z,I,I,N)
BINARY_N9(S,Z,I,I,N)
BINARY_N6(S,Z,I,I,N)
BINARY_N7(S,Z,I,I,N)
BINARY_N3_B(S,Z,I,I,N)
HE_COUNT_M0(S,Z,I,I)
HE_COUNT_N0(S,Z,I,I)
HE_COUNT_M1(S,Z,I,I)
HE_COUNT_N1(S,Z,I,I)
NEXCH(S,Z,I,I)
NEXCH_B(S,Z,I,I)

```

BIF_1(S,Z,I,J,M,N)
 BIF_2(S,Z,I,J,M,N)
 BIF_3(S,Z,I,J,M,N)
 BIF_4(S,Z,I,J,M,N)
 BIF_11(S,Z,I,J,M)
 BIF_6(S,Z,I,J,M)
 BIF_9(S,Z,I,J,M)
 BIF_5(S,Z,I,J,M)
 BIF_7(S,Z,I,J,N)
 BIF_8(S,Z,I,J,N)
 BIF_10(S,Z,I,J,N)
 BIF_12(S,Z,I,J,N)
 BIF_13_2(S,K,Z,I,J,M)
 BIF_13_1(S,K,Z,I,J,M)
 BIF_14(S,K,Z,I,J)
 BIF_15(S,Z,I,J,M)
 *BIF_16(S,Z,I,J,M)
 BIF_17(S,Z,I,J,M)
 BIF_18(S,Z,I,J,M,N)
 FEAS_M_01(S,Z,I,J,M)
 FEAS_M_01_B(S,Z,I,J,M)
 FEAS_M_02(S,Z,I,J,M)
 FEAS_M_02_B(S,Z,I,J,M)
 FEAS_M_03(S,Z,I,J,M)
 FEAS_M_03_B(S,Z,I,J,M)
 FEAS_M_04(S,Z,I,J,M)
 FEAS_M_2(S,Z,I,J,M)
 FEAS_M_1(S,Z,I,J,M)
 FEAS_M_3(S,Z,I,J,M)
 FEAS_M_4(S,Z,I,J,M)
 FEAS_M_3_B_2(S,Z,I,J,M)
 FEAS_M_3_B_1(S,Z,I,J,M)
 FEAS_M_4_B(S,Z,I,J,M)
 FEAS_M_1_SP(S,Z,I,J,M)
 FEAS_M_1_SP_B(S,Z,I,J,M)
 FEAS_N_01(S,Z,I,J,N)
 FEAS_N_01_B(S,Z,I,J,N)
 FEAS_N_02(S,Z,I,J,N)
 FEAS_N_02_B(S,Z,I,J,N)
 FEAS_N_03(S,Z,I,J,N)
 FEAS_N_03_B(S,Z,I,J,N)
 FEAS_N_04(S,Z,I,J,N)
 FEAS_N_2(S,Z,I,J,N)
 FEAS_N_1(S,Z,I,J,N)
 FEAS_N_3(S,Z,I,J,N)
 FEAS_N_4(S,Z,I,J,N)
 FEAS_N_3_B_2(S,Z,I,J,N)
 FEAS_N_3_B_1(S,Z,I,J,N)
 FEAS_N_4_B(S,Z,I,J,N)
 FEAS_N_1_SP(S,Z,I,J,N)
 FEAS_N_1_SP_B(S,Z,I,J,N)
 FEAS_BEG_SP(S,Z,I,J,M,N)
 FEAS_BEG_B_SP(S,Z,I,J,M,N)
 FEAS_END_SP(S,Z,I,J,M,N)
 FEAS_END_B_SP(S,Z,I,J,M,N)
 FEAS_BEG3(S,Z,I,J,M,N)
 FEAS_BEG(S,Z,I,J,M,N)
 FEAS_BEG2(S,Z,I,J,M,N)
 FEAS_END3(S,Z,I,J,M,N)
 FEAS_END(S,Z,I,J,M,N)
 FEAS_END2(S,Z,I,J,M,N)
 FEAS_BEG4_B(S,Z,I,J,M,N)
 FEAS_BEG2_B(S,Z,I,J,M,N)
 FEAS_BEG1_B(S,Z,I,J,M,N)
 FEAS_BEG3_B(S,Z,I,J,M,N)
 FEAS_END3_B(S,Z,I,J,M,N)
 FEAS_END_B(S,Z,I,J,M,N)
 FEAS_END2_B(S,Z,I,J,M,N)
 PAREQ(S,Z,I,J)
 SHELL(Z,I,J)
 SHELL_B(K,Z,I,J)

KMAX1(S,Z,I,J)
 KMAX2(S,Z,I,J)
 TOTALCOST
 TOTNEXCH_MAX
 TOTNEXCH_MIN

HOT_U_C
 Cold_U_C
 Area_C
 FIX_C

\$ontext

*****ADD FOR RETROFIT*****

AREA_REST1(S,Z,I,J)
 AREA_REST2(S,Z,I,J)
 AREA_REST3(S,Z,I,J)
 AREA_REST1_B(S,K,Z,I,J)
 AREA_REST2_B(S,K,Z,I,J)
 AREA_REST3_B(S,K,Z,I,J)
 AREA_REST4_B(S,K,Z,I,J)
 AREA_REST5_B(S,K,Z,I,J)
 AREA_REST6_B(S,Z,I,J)
 ADD_REST
 ADD_REST2(S,I,J)

\$offtext

*\$ontext

*****ADD FOR RELOCATION*****

RELOCATE_1(S,Z,I,J)
 RELOCATE_2(S,Z,I,J)
 RELOCATE_3(S,Z,I,J)
 RELOCATE_4(S,Z,I,J)
 RELOCATE_5_1(S,Z,I,J)
 RELOCATE_5_2(S,Z,I,J)
 RELOCATE_5_3(Z,R)
 RELOCATE_6(K,R,S,Z,I,J)
 RELOCATE_7(K,R,S,Z,I,J)
 RELOCATE_8(K,R,S,Z,I,J)
 RELOCATE_9(K,R,S,Z,I,J)
 RELOCATE_10(K,R,S,Z,I,J)

*\$offtext

:

*EQ (1)

*HEAT BALANCE ON HEATING UTILITIES

HBHU(S,I,M)\$ (HOT(S,I,M)=1 AND HU(I) AND FREEH(I) AND ORD(M) LE NINT)..
 FHU(I)*(TU(S,M)-TL(S,M))=E= SUM((Z,N,J)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND COLD(S,J,N)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEC(J)),Q(S,Z,I,M,J,N));

*EQ (2)

HBCU(S,J,N)\$ (COLD(S,J,N)=1 AND CU(J) AND FREEC(J) AND ORD(N) LE NINT)..
 FCU(J)*(TU(S,N)-TL(S,N))=E= SUM((Z,M,I)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND HOT(S,I,M)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEH(I)),Q(S,Z,I,M,J,N));

*EQ (3)

HBHS(S,I,M)\$ (HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=0 AND ORD(M) LE NINT)..
 DHH(S,I,M)=E=SUM((Z,N,J)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

*EQ (4)

HBCS(S,J,N)\$ (COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=0 AND ORD(N) LE NINT)..
 DHC(S,J,N)=E=SUM((Z,M,I)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

*EQ (5)

TRANSFOR_M(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 QNEW_M(S,Z,I,J,M)=E= SUM(N\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)

AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

*EQ (6)

TRANSFOR_N(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
QNEW_N(S,Z,I,J,N)=E=SUM(M\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1),Q(S,Z,I,M,J,N));

*EQ (7)

HBHS_NI(S,I,M)\$(HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1
AND ORD(M) LE NINT)..
DHH(S,I,M)=E= SUM((Z,N,J)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
Q(S,Z,I,M,J,N))
+SUM((Z,N)\$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) GT ORD(M)),QH(S,Z,I,N,M))
-SUM((Z,N)\$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N));

*EQ (8)

HBCS_NI(S,J,N)\$(COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1)..
DHC(S,J,N)=E= SUM((Z,M,I)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N))
+SUM((Z,M)\$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) LT ORD(N)),QC(S,Z,I,M,N))
-SUM((Z,M)\$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,I,N,M));

*EQ (9)

NOISOH(S,I,M)\$(HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1 AND ORD(M) LE NINT)..
SUM((Z,N)\$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N))
=L=SUM((Z,N,J)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

*EQ (10)

NOISOC(S,J,N)\$(COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1
AND ORD(N) LE NINT)..
SUM((Z,M)\$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,I,N,M))
=L= SUM((Z,M,I)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

*EQ (11a and 13a) Case of BIF(I,J)=0 (i,j) not belonging to set B.

BINARY_M1(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*DHH(S,I,M)\$(NOT HU(I))
-Y_M(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)\$(HU(I))=L=0;

*EQ (11b and 13b) Case of BIF(I,J)=0 (i,j) not belonging to set B

***** MINIMUM VALUE OF QNEW_M=0.01!!!!!!!!!!
BINARY_M2(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0 AND
FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*QLHMIN=G=0;

*EQ (11a and 13a) Case of BIF(I,J)=1 (i,j) belonging to set B

BINARY_M1_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*DHH(S,I,M)\$(NOT HU(I))
-Y_M_B(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)\$(HU(I))=L=0;

*EQ (11b and 13b) Case of BIF(I,J)=1 (i,j) belonging to set B

BINARY_M2_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN =G= 0;

*EQ (12a and 14a) Case of BIF(I,J)=0 (i,j) not belonging to set B

BINARY_N1(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*DHC(S,J,N)\$(NOT CU(J))
-Y_N(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)\$(CU(J))=L=0;

*EQ (12b and 14b) Case of BIF(I,J)=0 (i,j) not belonging to set B

BINARY_N2(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*QLCMIN=G=0;


```

*-----
*EQ (12a and 14a) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_N1_B(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
  QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*DHC(S,J,N)$(NOT CU(J))
  -Y_N_B(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)$(CU(J))=L=0;
*-----
*EQ (12b and 14b) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_N2_B(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).. QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*QLCMIN=G=0;
*-----
*EQ (15) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*-----
*EQ (16)
BINARY_M5(S,Z,I,J,M)$(HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  NHE_M0(S,Z,I,J,M)=L=2-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1);
*-----
*EQ (17) IS IN REALITY NOT NEEDED, BUT WAS ADDED TO ENFORCE K=0 WHEN Y=0
* AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M,J)=1
* AND ALLOW_H(S,Z,I,M,J)=1

BINARY_M5b(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. NHE_M0(S,Z,I,J,M) =L= Y_M(S,Z,I,J,M);

* IT TURNS OUT THAT THIS EQUATION ONLY FORCES THE VALUES OF K TO BE ZERO
* WHEN Y=0. WHICH HAPPENS NATURALLY IF ONE IS MINIMIZING THE NUMBER OF
* EXCHANGERS OR BECAUSE THE FIXED COSTS ARE BEING MINIMIZED.
* EVEN IF NOT DRIVEN TO ZERO BY THE OBJECTIVE FUNCTION IT IS HARMELESS.
* HOWEVER, IT TURNS OUT THAT IT COULD MAKE EXTENSIONS OF THE MODEL HAVE
* PROBLEMS. SO, ALTHOUGH THE EQUATION IS NOT NEEDED. IT GIVES SOME EXTRA VALUES
* OF K WHEN THEY DO NOT REALLY MATTER.
*-----
*EQ (18)
BINARY_M3(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  NHE_M0(S,Z,I,J,M) =G= Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1)$(HOT(S,I,M-1)
  AND ALLOW_H(S,Z,I,M-1,J)) ;
*-----
*EQ (19)
BINARY_M4(S,Z,I,J,M)$(HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  NHE_M0(S,Z,I,J,M)=G=0;
*-----
*EQ (20) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*-----
*EQ (21)
BINARY_M8(S,Z,I,J,M)$(HOT(S,I,M)=1 AND HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  NHE_M1(S,Z,I,J,M)=L=2-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M+1);
*-----
*EQ (22) : ORIGINALLY NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0
* AND HOT(S,I,M-i) AND ALLOW_H(S,Z,I,M-1,J)
BINARY_M9(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  NHE_M1(S,Z,I,J,M) =L= Y_M(S,Z,I,J,M) ;

* SEE COMMENTS ON EQUATION (17)
*-----
*EQ (23)
BINARY_M6(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. NHE_M1(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M+1)
$(HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M+1,J)) ;
*-----
*EQ (24)
BINARY_M7(S,Z,I,J,M)$(HOT(S,I,M)=1 AND HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..

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$$\text{NHE_M1}(S,Z,I,J,M)=G=0;$$

*EQ (25)

BINARY_M3_B(S,Z,I,J,M)\$\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 Y_M_B(S,Z,I,J,M) =E= SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M)
 AND ALLOW_H(S,Z,I,O,J)=1),NHE_M0_B(S,Z,I,J,O))
 -SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE [ORD(M)-1]
 AND ALLOW_H(S,Z,I,O,J)=1),NHE_M1_B(S,Z,I,J,O));

*EQ (26) NOT NEEDED

* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)

*EQ (27)

BINARY_N5(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N0(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1);

*EQ (28) NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0

* AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
 BINARY_N5b(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J)).
 NHE_N0(S,Z,I,J,N) =L= Y_N(S,Z,I,J,N);

* SEE COMMENTS ON EQUATION (17)

*EQ (29)

BINARY_N3(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N0(S,Z,I,J,N) =G= Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1)
 \$(COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I));

*EQ (30)

BINARY_N4(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N0(S,Z,I,J,N)=G=0;

*EQ (31) NOT NEEDED

* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)

*EQ (32)

BINARY_N8(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N1(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1);

*EQ (33) NOT NEEDED BUT ADDED TO ENFORCE K=0 WHEN Y=0

* AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
 BINARY_N9(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N1(S,Z,I,J,N) =L= Y_N(S,Z,I,J,N);

* SEE COMMENTS ON EQUATION (17)

*EQ (34)

BINARY_N6(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N1(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1)
 \$(COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N+1,I));

*EQ (35)

BINARY_N7(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 NHE_N1(S,Z,I,J,N)=G=0;

*EQ (36)

BINARY_N3_B(S,Z,I,J,N)\$\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
 Y_N_B(S,Z,I,J,N)=E=SUM(O\$(COLD(S,J,O) AND ORD(O) LE ORD(N)
 AND ALLOW_C(S,Z,J,O,I),NHE_N0_B(S,Z,I,J,O)) - SUM(O\$(COLD(S,J,O) AND ORD(O) LE
 ORD(N)-1 AND ALLOW_C(S,Z,J,O,I),NHE_N1_B(S,Z,I,J,O));

*EQ (37)

HE_COUNT_M0(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 NHE(S,Z,I,J)=E=SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1),
 NHE_M0_B(S,Z,I,J,M)) + SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND BIF(Z,I,J) =0), NHE_M0(S,Z,I,J,M));

*EQ (38)

HE_COUNT_N0(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 NHE(S,Z,I,J)=E=SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1),
 NHE_N0_B(S,Z,I,J,N))
 + SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0),
 NHE_N0(S,Z,I,J,N));

*EQ (39)

HE_COUNT_M1(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 NHE(S,Z,I,J)=E=SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1),
 NHE_M1_B(S,Z,I,J,M)) + SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND BIF(Z,I,J) =0), NHE_M1(S,Z,I,J,M));

*EQ (40)

HE_COUNT_N1(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 NHE(S,Z,I,J)=E=SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1),
 NHE_N1_B(S,Z,I,J,N)) + SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J) =0), NHE_N1(S,Z,I,J,N));

*EQ (41)

NEXCH(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND BIF(Z,I,J) =0 AND FREEH(I)
 AND FREEC(J))..NHE(S,Z,I,J)=L=1;

*EQ (42)

NEXCH_B(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND BIF(Z,I,J) =1 AND FREEH(I)
 AND FREEC(J))..NHE(S,Z,I,J)=L=KMAX(Z,I,J) ;

*EQ (43)

BIF_1(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND
 ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT AND ORD(N) LE NINT)..
 SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
 AND ALLOW_H(S,Z,I,L,J)=1),
 QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =L=
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
 QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
 + B1(S,Z,I,M,J,N) *4* max(SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),DHH(S,I,L)),
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N)
 AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I),DHC(S,J,O)));

*EQ (44)

BIF_2(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND
 ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT AND ORD(N) LE NINT)..
 SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
 AND ALLOW_H(S,Z,I,L,J)=1),
 QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =G=
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
 QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
 -B1(S,Z,I,M,J,N) *4* max(SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),DHH(S,I,L)),
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O)
 AND ALLOW_C(S,Z,J,O,I),DHC(S,J,O)));

*EQ (45)

BIF_3(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 B1(S,Z,I,M,J,N) =E= 2 - 0.25* SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),NHE_M1_B(S,Z,I,J,L))

+ 0.25 *SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,I,O)
AND ALLOW_C(S,Z,I,O.I)),NHE_N1_B(S,Z,I,J,O))
-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N);

*EQ (46)

BIF_4(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND TL(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,I,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT
AND ORD(N))..
SUM(L\$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND
ALLOW_H(S,Z,I,L,J)=1),NHE_M1_B(S,Z,I,J,L))
-SUM(O\$(COLD(S,I,O) AND ORD(O) LE ORD(N) AND ALLOW_C(S,Z,I,O.I)),
NHE_N1_B(S,Z,I,J,O))=G=0;

*EQ (47)

BIF_11(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M) AND ALLOW_H(S,Z,I,O,J)=1),
NHE_M0_B(S,Z,I,J,O)-NHE_M1_B(S,Z,I,J,O))=L=1 ;

*EQ (48)

BIF_12(S,Z,I,J,N)\$ (COLD(S,I,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
SUM(O\$(COLD(S,I,O) AND ORD(O) LE ORD(N) AND ALLOW_C(S,Z,I,O.I)),
NHE_N0_B(S,Z,I,J,O)-NHE_N1_B(S,Z,I,J,O))=L=1 ;

*EQ (49)

BIF_6(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW2_M(S,Z,I,J,M) =L= QNEW_M(S,Z,I,J,M);

*EQ (50)

BIF_9(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW2_M(S,Z,I,J,M) =L= NHE_M0_B(S,Z,I,J,M)*DHH(S,I,M);

*EQ (51)

BIF_5(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW2_M(S,Z,I,J,M) =L= NHE_M1_B(S,Z,I,J,M)*DHH(S,I,M);

*EQ (52) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE

*EQ (53)

BIF_8(S,Z,I,J,N)\$ (COLD(S,I,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
QNEW2_N(S,Z,I,J,N) =L= QNEW_N(S,Z,I,J,N);

*EQ (54)

BIF_10(S,Z,I,J,N)\$ (COLD(S,I,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
QNEW2_N(S,Z,I,J,N) =L= NHE_N0_B(S,Z,I,J,N)*DHC(S,I,N);

*EQ (55)

BIF_7(S,Z,I,J,N)\$ (COLD(S,I,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
QNEW2_N(S,Z,I,J,N) =L= NHE_N1_B(S,Z,I,J,N)*DHC(S,I,N);

*EQ (56) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE

*EQ (57)

FEAS_M_01(S,Z,I,J,M)\$ (HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
ALFA_M(S,Z,I,J,M)=L=1-NHE_M0(S,Z,I,J,M-1)-NHE_M0(S,Z,I,J,M);

FEAS_M_01_B(S,Z,I,J,M)\$ (HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
ALFA_M(S,Z,I,J,M)=L=1-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M);

*-----
 *EQ (58)
 FEAS_M_02(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT)..
 ALFA_M(S,Z,I,J,M)=L=1-NHE_MI(S,Z,I,J,M-1)-NHE_MI(S,Z,I,J,M);
 FEAS_M_02_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J))..
 ALFA_M(S,Z,I,J,M)=L=1-NHE_MI_B(S,Z,I,J,M-1)-NHE_MI_B(S,Z,I,J,M);
 *-----
 *EQ (59)
 FEAS_M_03(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT)..
 ALFA_M(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-NHE_M0(S,Z,I,J,M-1)-NHE_M0(S,Z,I,J,M) -
 NHE_MI(S,Z,I,J,M-1)-NHE_MI(S,Z,I,J,M);
 FEAS_M_03_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J))..
 ALFA_M(S,Z,I,J,M)=G=Y_M_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M)
 - NHE_MI_B(S,Z,I,J,M-1)-NHE_MI_B(S,Z,I,J,M);
 *-----
 *EQ (60)
 FEAS_M_04(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND
 ALLOW_HI(S,Z,I,M-1,J) AND (BIF(Z,I,J) =1 OR SPH(I)=1)AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT)..
 ALFA_M(S,Z,I,J,M)=G=0;
 *-----
 *EQ (61)
 FEAS_M_2(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J)
 AND ORD(M) LE NINT)..
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) =L=
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +(1-ALFA_M(S,Z,I,J,M))*DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)));
 *-----
 *EQ (62)
 FEAS_M_1(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J))..
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(1-ALFA_M(S,Z,I,J,M))*DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 =G= QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)));
 *-----
 *EQ (63)
 FEAS_M_3(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT)..
 - QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 + QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(1+ NHE_MI(S,Z,I,J,M-1) + NHE_MI(S,Z,I,J,M) - NHE_M0(S,Z,I,J,M-1))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)))*1.00001 =G= 0;
 *-----
 *EQ (64)
 FEAS_M_4(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT)..
 - QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 + QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +(1+ NHE_M0(S,Z,I,J,M-1)+NHE_M0(S,Z,I,J,M)-NHE_MI(S,Z,I,J,M))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)))*1.00001 =G= 0;
 *-----
 *EQ (65)
 FEAS_M_3_B_2(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT)..
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(1+NHE_MI_B(S,Z,I,J,M-1)+NHE_MI_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));
 *-----
 *EQ (66)
 FEAS_M_3_B_1(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_HI(S,Z,I,M,J)=1

AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT)..
 QNEW2_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))) =L=
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))+(2 + NHE_M1_B(S,Z,I,J,M)
 -NHE_M0_B(S,Z,I,J,M-1)-Y_M_B(S,Z,I,J,M-1))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));

*EQ (67)

FEAS_M_4_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND ORD(M) LE NINT)..
 (QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) =L=
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +(2 + NHE_M0_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));

*EQ (68)

FEAS_M_1_SP(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J) =0 AND SPH(I)=0
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I,J,M)=G=(Y_M(S,Z,I,J,M)-
 NHE_M0(S,Z,I,J,M) + NHE_M1(S,Z,I,J,M))*DHH(S,I,M);
 FEAS_M_1_SP_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J) =1 AND SPH(I)=0
 AND FREEH(I) AND FREEC(J).. QNEW_M(S,Z,I,J,M)=G=(Y_M_B(S,Z,I,J,M)-
 NHE_M0_B(S,Z,I,J,M)+NHE_M0_B(S,Z,I,J,M))*DHH(S,I,M);

*EQ (69)

FEAS_N_01(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=L=1-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1);
 FEAS_N_01_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=L=1-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1);

*EQ (70)

FEAS_N_02(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=L=1-NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N-1);
 FEAS_N_02_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=L=1-NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);

*EQ (71)

FEAS_N_03(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1)
 -NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N-1);
 FEAS_N_03_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=G=Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1)
 -NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);

*EQ (72)

FEAS_N_04(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND (BIF(Z,I,J) =1 OR SPC(J)=1) AND FREEH(I)
 AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=G=0;

*EQ (73)

FEAS_N_2(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
 QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=L=QNEW_N(S,Z,I,J,N-1)
 /(CPC(S,J,N-1))
 *(TU(S,N-1)-TL(S,N-1)))+(1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)/
 (CPC(S,J,N)*(TU(S,N)-TL(S,N)));

*EQ (74)

FEAS_N_1(S,Z,I,J,N) $\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..$
 $QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))$
 $+ (1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)$
 $/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/$
 $(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))$;

*EQ (75)

FEAS_N_3(S,Z,I,J,N) $\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..$
 $-QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))$
 $+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(1+NHE_N1(S,Z,I,J,N-1)$
 $+NHE_N1(S,Z,I,J,N)$
 $-NHE_N0(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))*1.00001 =G= 0$;

*EQ (76)

FEAS_N_4(S,Z,I,J,N) $\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..$
 $-QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))$
 $+QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))$
 $+ (1+NHE_N0(S,Z,I,J,N-1)$
 $+ NHE_N0(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N))*DHC(S,J,N)/$
 $(CPC(S,J,N)*(TU(S,N)-TL(S,N)))*1.00001=G=0$;

*EQ (77)

FEAS_N_3_B_2(S,Z,I,J,N) $\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..$
 $-QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))$
 $+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))$
 $+ (1 + NHE_N1_B(S,Z,I,J,N-1)+ NHE_N1_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1))$
 $*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0$;

*EQ (78)

FEAS_N_3_B_1(S,Z,I,J,N) $\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..$
 $-QNEW2_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))$
 $+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(2 + NHE_N1_B(S,Z,I,J,N)$
 $-NHE_N0_B(S,Z,I,J,N-1)-Y_N_B(S,Z,I,J,N-1))$
 $*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0$;

*EQ (79)

FEAS_N_4_B(S,Z,I,J,N) $\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..$
 $-(QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))$
 $+ QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))$
 $+ (2 + NHE_N0_B(S,Z,I,J,N-1) -NHE_N1_B(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N))$
 $*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0$;

*EQ (80)

FEAS_N_1_SP(S,Z,I,J,N) $\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J))..$ $QNEW_N(S,Z,I,J,N) =G=$
 $(Y_N(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N))*DHC(S,J,N)$;

FEAS_N_1_SP_B(S,Z,I,J,N) $\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =1 AND SPC(J)=0 AND FREEH(I) AND FREEC(J))..$ $QNEW_N(S,Z,I,J,N) =G=$
 $(Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N))*DHC(S,J,N)$;

*EQ (81)

FEAS_BEG_SP(S,Z,I,J,M,N) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$

AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
 + QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M))
 + (2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*TU(S,N)=G=0;

FEAS_BEG_B_SP(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
 + QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M))
 + (2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))*TU(S,N)=G=0;

*EQ (82)

FEAS_END_SP(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J)
 AND ORD(M) LE NINT).. TU(S,M)-TU(S,N)
 -QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
 + (2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))*TU(S,N)=G=0;
 FEAS_END_B_SP(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J)). TU(S,M)-TU(S,N)
 -QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
 + (2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*TU(S,N)=G=0;

*EQ (83)

FEAS_BEG3(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M)
 AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I)
 AND BIF(Z,I,J) =0 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)
 AND ORD(M) LE NINT)..
 NHE_N1(S,Z,I,J,N)=L=(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N));

*EQ (84)

FEAS_BEG(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND D(S,Z,M,N)=1
 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =0
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)
 /(TU(S,N+1)-TL(S,N+1))*CPC(S,J,N)/CPC(S,J,N+1)
 + (2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*DHC(S,J,N)/(TU(S,M)-TL(S,N));

*EQ (85)

FEAS_BEG2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1)
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =0 AND (SPH(I)=1 OR SPC(J)=1)
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=
 QNEW_M(S,Z,I,J,M+1)/(TU(S,M+1)-TL(S,M+1))
 *CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))
 *DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));

*EQ (86)

FEAS_END3(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M)
 AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1 AND COLD(S,J,N-1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I)
 AND BIF(Z,I,J) =0 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)
 AND ORD(M) LE NINT)..

NHE_M0(S,Z,I,J,M)=L=(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N));

*EQ (87)

FEAS_END(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW_M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))
*CPH(S,I,M)/CPH(S,I,M-1)+(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))
*DHH(S,I,M)/(TU(S,M)-TL(S,N));

*EQ (88)

FEAS_END2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_N(S,Z,I,J,N)/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/
(TU(S,N-1)-TL(S,N-1))
*CPC(S,J,N)/CPC(S,J,N-1)-(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))
*DHC(S,J,N-1)/(TU(S,N-1)-TL(S,N-1));

*EQ (89)

FEAS_BEG4_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M)
AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J) =1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
NHE_N1_B(S,Z,I,J,N) =L=
(1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N));

*EQ (90)

FEAS_BEG2_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=
QNEW_N(S,Z,I,J,N+1)/(TU(S,N+1)-TL(S,N+1))
*CPC(S,J,N)/CPC(S,J,N+1)+
(1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
*DHC(S,J,N)/(TU(S,M)-TL(S,N));

*EQ (91)

FEAS_BEG1_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW2_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)/
(TU(S,N+1)-TL(S,N+1))
*CPC(S,J,N)/CPC(S,J,N+1)+(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
*DHC(S,J,N)/(TU(S,M)-TL(S,N));

*EQ (92)

FEAS_BEG3_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=QNEW_M(S,Z,I,J,M+1)/
(TU(S,M+1)-TL(S,M+1))
*CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
*DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));

*EQ (93)

FEAS_END3_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M)
AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1 AND COLD(S,J,N-1)

AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_C(S,Z,J,N,I) AND ALLOW_C(S,Z,J,N-1,I)
 AND BIF(Z,I,J) =1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)
 AND ORD(M) LE NINT)..
 NHE_M0_B(S,Z,I,J,M)=L=
 (1+Y_M_B(S,Z,I,J,M)-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N));

*EQ (94)

FEAS_END_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 (QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L=
 QNEW_M(S,Z,I,J,M-1)/
 (TU(S,M-1)-TL(S,M-1))*CPH(S,I,M)/CPH(S,I,M-1)+
 (2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHH(S,I,M)/(TU(S,M)-TL(S,N));

*EQ (95)

FEAS_END2_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 (QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=
 QNEW_N(S,Z,I,J,N-1)/(TU(S,N-1)-TL(S,N-1))*CPC(S,J,N)/CPC(S,J,N-1)
 -(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHC(S,J,N-1)/
 (TU(S,N-1)-TL(S,N-1));

*EQ (96)

PAREQ(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 PAR(Z,I,J)=E=SUM((M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
 Q(S,Z,I,M,J,N)*(1/H_I(S,I,M)+1/H_J(S,J,N))/LMTD(S,M,N));

*EQ (97)

BIF_13_2(S,K,Z,I,J,M)\$(ORD(K) LT KMAX(Z,I,J) AND HOT(S,I,M)=1
 AND ALLOW_H(S,Z,I,M,J)=1
 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 PAR_B(K,Z,I,J)=L= SUM((L,N)\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND TL(S,N) LT TU(S,L)
 AND HOT(S,I,L)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,L,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1),
 (Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))*(1/H_I(S,I,L)+1/H_J(S,J,N))/LMTD(S,L,N)
 +AMAX*(2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,I,J,M)-
 SUM(KK\$(ORD(KK) GT 1 AND ORD(KK) LT ORD(K)),PAR_B(KK,Z,I,J)));

*Comment: In the paper X1_B does not show. Only one variable, X_B is used

* to make summations from 1 to kmax-1. Here we use X1_B and then a
 * summation from 2 to kmax-1. See equation (100) as well.

*EQ (98)

BIF_13_1(S,K,Z,I,J,M)\$(ORD(K) LT KMAX(Z,I,J) AND HOT(S,I,M)=1
 AND ALLOW_H(S,Z,I,M,J)=1
 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
 PAR_B(K,Z,I,J)=G= SUM((L,N)\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND TL(S,N) LT TU(S,L)
 AND HOT(S,I,L)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,L,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1),
 (Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))*(1/H_I(S,I,L)+1/H_J(S,J,N))/LMTD(S,L,N)
 -AMAX*(2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,I,J,M)-
 SUM(KK\$(ORD(KK) GT 1 AND ORD(KK) LT ORD(K)),PAR_B(KK,Z,I,J)));

*EQ (99)

BIF_14(S,K,Z,I,J)\$(ORD(K) EQ KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1 AND FREEH(I)
 AND FREEC(J) AND BIF(Z,I,J) =1)..
 PAR_B(K,Z,I,J)=G=PAR(Z,I,J)-SUM(KK\$(ORD(KK) LT ORD(K)),PAR_B(KK,Z,I,J));

*EQ (100)

BIF_15(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..

$X1_B(S,Z,I,J,M)+SUM(K$(ORD(K) GT 1 AND ORD(K) LE KMAX(Z,I,J)),$
 $ORD(K)*X_B(S,K,Z,I,J,M))=E= SUM(L$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND$
 $ALLOW_H(S,Z,I,L,J)=1),NHE_M0_B(S,Z,I,J,L))+1-Y_M_B(S,Z,I,J,M) ;$
 *Comment: In the paper X1_B does not show. Only one variable, X_B is used
 * to make summations from 1 to kmax-1. Here we use X1_B and then a
 * summation from 2 to kmax-1.

*EQ (101)
 $BIF_17(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1$
 $AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 $SUM(N$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1 AND COLD(S,J,N)=1$
 $AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q2(S,Z,I,M,J,N))=E=$
 $QNEW2_M(S,Z,I,J,M);$

*EQ (102)
 $BIF_18(S,Z,I,J,M,N)$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1$
 $AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1$
 $AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..$
 $Q2(S,Z,I,M,J,N)=L=Q(S,Z,I,M,J,N);$

*EQ (103)
 $SHELL(Z,I,J)$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)$
 $AND BIF(Z,I,J) =0)..$
 $PAR(Z,I,J)=L=ASHELLMAX*USHELL(Z,I,J);$

*EQ (104)
 $SHELL_B(K,Z,I,J)$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)$
 $AND BIF(Z,I,J) =1)..$
 $PAR_B(K,Z,I,J)=L=ASHELLMAX*USHELL_B(K,Z,I,J);$

*EQ (105)
 $TOTALCOST.. TCOST =E= SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))$
 $+ SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))$
 $Sontext$
 $+ SUM((Z,I,J)$ (OPT=0 AND SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I)$
 $AND FREEC(J) AND BIF(Z,I,J)=0), CF*USHELL(Z,I,J))$
 $+ SUM((K,Z,I,J)$ (OPT=0 AND SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)$
 $AND BIF(Z,I,J)=1), CF*USHELL_B(K,Z,I,J))$
 $+ SUM((Z,I,J)$ (OPT=0 AND SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)),$
 $CAE*PAR(Z,I,J))$
 $Sofftext$
 $Sontext$
 $+SUM((S,Z,I,J)$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))$
 $,CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$ (NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)))$
 $+SUM((S,Z,I,J)$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)$
 $AND BIF(Z,I,J)=0),CAE*DPAR_E(Z,I,J)+CAN*PAR_N(S,Z,I,J))$
 $+SUM((S,K,Z,I,J)$ (OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1$
 $AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)$
 $,CAE*DPAR_E_B(K,Z,I,J)+CAN*PAR_N_B(K,Z,I,J))$
 $Sofftext$
 $*Sontext$
 $+SUM((S,Z,I,J)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)$
 $AND BIF(Z,I,J)=0)$
 $, (CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$ (NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)*(SUM(R$(ORD(R) LE KET),$
 $Phi(Z,I,J,R)))))+(CAE*DPAR_E(Z,I,J))+CAN*PAR_N(S,Z,I,J))$
 $+SUM((S,Z,I,J)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)$
 $AND BIF(Z,I,J)=1)$
 $, (CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$ (NHE0(S,Z,I,J)=1)-SUM((RR,R,K)$ (OPT=2 AND ORD(R) LE KET AND$
 $ORD(K) LE KMAX(Z,I,J)),DELTA(Z,I,J,RR,R,K))))$
 $+SUM((S,I,J,K,R)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)$
 $AND BIF(Z,I,J)=1 AND ORD(K) LE KMAX(Z,I,J))$
 $+SUM(K$(ORD(K) LE KMAX(Z,I,J))$
 $, (CAE*DPAR_E_B(K,R,Z,I,J)+CAN*PAR_N_B(K,R,Z,I,J)))$
 $*may be wronge equation (by warapon)$
 $* +SUM(K$(OPT=1 AND ORD(K) LE NHE0(S,Z,I,J)), (CAE*DPAR_E_B(K,Z,I,J))$
 $* +(CAN*PAR_N_B(K,Z,I,J))));$
 $*TOTALCOST.. TCOST =E= SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))$
 $+ SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))$

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* + SUM((Z,I,J)$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
*   AND BIF=0), CF*USHELL(Z,I,J))
* + SUM((K,Z,I,J)$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
*   AND BIF=1), CF*USHELL_B(K,Z,I,J))
* + SUM((Z,I,J)$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J) ),
*   CA*PAR(Z,I,J))
*$OFFTEXT
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* Depending on the option selected by the user diferent sums come into action.
* Here we have an equation that is made simpler than in the paper. We account
* for the total area of the exchangers (use PAR and not PAR_B).
* The result is the same.
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*EQ (106) CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K.

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```

KMAX1(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J) =0)..
NHE(S,Z,I,J) =L= USHELL(Z,I,J) ;

```

```

*EQ (107)
KMAX2(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J) =1)..
NHE(S,Z,I,J) =L= SUM(K,USHELL_B(K,Z,I,J)) ;
* -----
* -----

```

```

* EXTRA EQUATIONS NOT IN PAPER BUT NEEDED
*_*

```

```

*EQ (108) LIMIT THE NUMBER OF EXCHANGERS
TOTNEXCH_MAX(S).. SUM((Z,I,J)$ (ALLOW(S,Z,I,J)= 1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=L=TOTNEXCHMAX;
* -----

```

```

*EQ (109) MINIMUM NUMBER OF EXCHANGERS
TOTNEXCH_MIN(S).. SUM((Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=G=TOTNEXCHMIN;

```

```

$ontext

```

```

*****Equation for Retrofit*****
* -----

```

```

*EQ(110)
AREA_REST1(S,Z,I,J)$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,I,J);
* -----

```

```

*EQ(111)
AREA_REST2(S,Z,I,J)$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
DPAR_E(Z,I,J)=L=AEX_U(Z,I,J)-AEX(Z,I,J);
* -----

```

```

*EQ(112)
AREA_REST3(S,Z,I,J)$ (OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR_N(S,Z,I,J)=L=ASHELLMAX*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)
$(NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J));
* -----

```

```

*EQ(113)
AREA_REST1_B(S,K,Z,I,J)$ (OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_B(K,Z,I,J)=L=SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),AEX_B(KK,Z,I,J)
*DELTA(KK,K))+DPAR_E_B(K,Z,I,J)+PAR_N_B(K,Z,I,J);
* -----

```

```

*EQ(114)
AREA_REST2_B(S,K,Z,I,J)$ (OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
DPAR_E_B(K,Z,I,J)=L=SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),(AEX_U_B(KK,Z,I,J)
-AEX_B(KK,Z,I,J))*DELTA(KK,K));
* -----

```

```

*EQ(115)
AREA_REST3_B(S,K,Z,I,J)$ (OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1

```

```

AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_N_B(K,Z,I,J)=L=ASHELLMAX*(1-SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K)));
*-----
*EQ(116)
AREA_REST4_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K))=L=1;
*-----
*EQ(117)
AREA_REST5_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE NHE0(S,Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM(KK$(ORD(KK) LE KMAX(Z,I,J)),DELTA(K,K))=L=1;
*-----
*EQ(118)
AREA_REST6_B(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I)
AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM((K,KK)$(ORD(K) LE KMAX(Z,I,J) AND ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K))
=E= NHE0(S,Z,I,J);
*-----
*EQ(119)
ADD_REST..
SUM((S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J)),NHE(S,Z,I,J)
-NHE0(S,Z,I,J))=L=2;
*-----
*EQ(120)
ADD_REST2(S,I,J)$(OPT=1 AND FREEH(I) AND FREEC(J))..
SUM(Z$(ALLOW(S,Z,I,J)=1),NHE(S,Z,I,J)-NHE0(S,Z,I,J))=G=0;
$offtext
*$ontext
*-----
*****Equation for Retrofit Relocation*****
*-----
*EQ(Retrofit 16)
RELOCATE_1(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,I,J);
*-----
*EQ(Retrofit 17)
RELOCATE_2(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
AEX(Z,I,J)=E= SUM(R$(ORD(R) LE KET),(AEX_R(R)*Phi(Z,I,J,R)));
*-----
*EQ(Retrofit 18)
RELOCATE_3(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
DPAR_E(Z,I,J)=L= SUM(R$(ORD(R) LE KET),(AEX_U_1(R)-AEX_R(R))
*Phi(Z,I,J,R));
*-----
*EQ(Retrofit 19)
RELOCATE_4(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR_N(S,Z,I,J)=L= A_NEW_MAX(Z,I,J) *(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-(NHE0(S,Z,I,J)*
SUM(R$(ORD(R) LE KET),Phi(Z,I,J,R))));
*-----
*EQ(Retrofit 20)
RELOCATE_5_1(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0).. NHE(S,Z,I,J)=L= TOTNEXCHMAX ;

RELOCATE_5_2(S,Z,I,J)$(OPT=2 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0).. SUM((R)$(ORD(R) LE KET),Phi(Z,I,J,R))=L= 1 ;

*Extra Eq. Limits number of phi matches
RELOCATE_5_3(Z,R)$(OPT=2).. SUM((i,j), Phi(Z,I,J,R))=L= 1 ;
*-----
*$ONTEXT
**EQ(Retrofit 21)
RELOCATE_6(K,R,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_B_R(K,R,Z,I,J)=L=AEX_B(K,R,Z,I,J)+DPAR_E_B(K,R,Z,I,J)+PAR_N_B(K,R,Z,I,J);
*-----

```

```

*EQ(Retrofit 22)
RELOCATE_7(K,R,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
  AEX_B(K,R,Z,I,J)=E=SUM(RR$(ORD(RR) LE KET),(AEX_B_R(RR)*DELTA(Z,I,J,RR,R,K)));
**-----
*EQ(Retrofit 23)
RELOCATE_8(K,R,S,Z,I,J)$(OPT=2 AND ORD(R) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
  DPAR_E_B(K,R,Z,I,J)=L= SUM(RR$(ORD(RR) LE KET),(AEX_U_B_R(RR)-AEX_B_R(RR))
  *DELTA(Z,I,J,RR,R,K));
*-----
*EQ(Retrofit 24)
RELOCATE_9(K,R,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
  PAR_N_B(K,R,Z,I,J)=L= A_NEW_MAX(Z,I,J) *(1-SUM(RR$(ORD(RR) LE KET)
  ,DELTA(Z,I,J,RR,R,K)));
**-----
*EQ(Retrofit 25)
RELOCATE_10(K,R,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
  SUM(RR$(ORD(RR) LE KET),DELTA(Z,I,J,RR,R,K)) =L= 1 ;
*-----
*$OFFTEXT

HOT_U_C..
HOT_UTILITY_COST =E= SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I));
*-----
Cold_U_C..
Cold_UTILITY_COST =E= SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J));
*-----
Area_C..
Area_Cost=E=
+SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)
,(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-(NHE0(S,Z,I,J)*(SUM(R$(ORD(R) LE KET)
Phi(Z,I,J,R)))))))+(CAE*DPAR_E(Z,I,J))+CAN*PAR_N(S,Z,I,J));

$ONTEXT
SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)
,(CAE*DPAR_E(Z,I,J))+CAN*PAR_N(S,Z,I,J))

+SUM((S,Z,I,J,K,R)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1 AND ORD(K)LE KMAX(Z,I,J))
* +SUM (K$(ORD(K)LE KMAX(Z,I,J) )
,(CAE*DPAR_E_B(K,R,Z,I,J))+CAN*PAR_N_B(K,R,Z,I,J));
$OFFTEXT
*-----
FIX_C..
FIX_COST =E= SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1)
,(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-SUM((RR,R,K)$(OPT=2 AND ORD(R) LE KET AND
ORD(K)LE KMAX(Z,I,J),DELTA(Z,I,J,RR,R,K))))))
+SUM((S,Z,I,J,K,R)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1 AND ORD(K)LE KMAX(Z,I,J))
* +SUM (K$(ORD(K)LE KMAX(Z,I,J) )
,(CAE*DPAR_E_B(K,R,Z,I,J))+CAN*PAR_N_B(K,R,Z,I,J))
;

$ONTEXT
SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)
,(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-(NHE0(S,Z,I,J)*(SUM(R$(ORD(R) LE KET)
Phi(Z,I,J,R))))))
* +SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1)
*
+(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-SUM((RR,R,K)$(OPT=2 AND ORD(R) LE KET AND

```

```

ORD(K)LE KMAX(Z,I,J),DELTA(Z,I,J,RR,R,K))))
:
$OFFTEXT
*-----

MODEL MPERIOD / ALL/;

OPTION LIMROW =5000;
OPTION LIMCOL =5000;
OPTION SOLPRINT = OFF;
OPTION OPTCR=0 ;
OPTION OPTCA=0 ;
OPTION reslim = 135800;

SOLVE MPERIOD USING MIP MINIMIZING TCOST;

PARAMETER QMATCH(S,Z,I,J);
QMATCH(S,Z,I,J)=SUM((M,N)$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND D(S,Z,M,N)=1
AND COLD(S,J,N) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
Q.L(S,Z,I,M,J,N));

PARAMETER FH_H(S,Z,I,J,M) Flowrate of hot stream per HEX;
FH_H(S,Z,I,J,M)$[HOT(S,I,M)]=QNEW_M.L(S,Z,I,J,M)/((TU(S,M)-TL(S,M))*CPH(S,I,M))

PARAMETER FC_C(S,Z,I,J,M) Flowrate of cold stream per HEX;
FC_C(S,Z,I,J,M)$[COLD(S,J,M)]=QNEW_N.L(S,Z,I,J,M)/((TU(S,M)-TL(S,M))*CPC(S,J,M))

PARAMETER NHE2(S,Z,I,J);
NHE2(S,Z,I,J)= NHE.L(S,Z,I,J);

option NHE:3:0:1; display NHE.L;
option NHE_S:3:0:1; display NHE_S.L;
OPTION Cold_UTILITY_COST:3:0:1; DISPLAY Cold_UTILITY_COST.L;
OPTION HOT_UTILITY_COST:3:0:1; DISPLAY HOT_UTILITY_COST.L;
OPTION Area_Cost:3:0:1; DISPLAY Area_Cost.L;
OPTION FIX_COST:3:0:1; DISPLAY FIX_COST.L;

option Q:3:0:1; display Q.L;
option FHU:3:0:1; display FHU.L;
option FCU:3:0:1; display FCU.L;
* OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
* OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
OPTION PAR:4:0:1; DISPLAY PAR.L;
OPTION QMATCH:4:0:1; DISPLAY QMATCH;
OPTION FH_H:3:0:1; DISPLAY FH_H;
OPTION FC_C:3:0:1; DISPLAY FC_C;
OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
OPTION PHI:3:0:1; DISPLAY PHI.L;
OPTION AEX:3:0:1; DISPLAY AEX.L;
$ONTEXT
DISPLAY DTVIO;
DISPLAY AEX;
DISPLAY CPH;
DISPLAY CPC;
DISPLAY PHI.L;

EXECUTE_UNLOAD "isabelout.gdx",PAR, QMATCH, FH_H, FC_C, AEX;
EXECUTE 'GDXXRW.EXE isabelout.gdx par=QMATCH rng=a1';
EXECUTE 'GDXXRW.EXE isabelout.gdx var=PAR rng=r1';
EXECUTE 'GDXXRW.EXE isabelout.gdx PAR=AEX rng=a1';
EXECUTE 'GDXXRW.EXE isabelout.gdx par=FH_H rng=a20';
EXECUTE 'GDXXRW.EXE isabelout.gdx par=FC_C rng=a40';
EXECUTE 'GDXXRW.EXE isabelout.gdx par=PHI rng=a60';
EXECUTE 'GDXXRW.EXE isabelout.gdx vAR=DPAR rng=R60';
$OFFTEXT

```

Appendix C Programming Model for Retrofit without Relocation Apply for Crude Fractionation Unite

```

$TITLE HEN design- Automatic parameter calculation- KITISAK-1
*****
* Equations that are different than in the paper +errata.
*(100)
*(105)
*-----
* Equations that are added to those that are in the paper
*(106) and (107)
* CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K.
*(108) LIMIT THE NUMBER OF EXCHANGERS
*(109) MINIMUM NUMBER OF EXCHANGERS
*****
    
```

\$OFFUPPER

```

$ONTEXT
*NM-4S1-FINAL-6-FLEXIBILITY-S1.gms: August 9, 2004
- one scenario, the original values of 4s1.
*****
    
```

\$OFFTEXT

SETS

```

Z transfer zone /Z1/
*
*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
I Hot streams /I1*I19/
J cold streams /J1*J3/
R /R1*R4/
*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
HU(I) Heating utilities /I9/
CU(J) Cooling utilities /J3/
*
M temperature intervals /M1*M111/
S SCENARIO /S1/
K temperature intervals /K1*K1/
*
*NEW SET FOR PUMP-AROUND.
PA(I) Pump-around streams /I2,I4,I6/
*
    
```

```

ALIAS (M,N,L,O)
ALIAS (I,I1)
ALIAS (J,J1)
ALIAS (K,KK)
ALIAS (Z,ZZ)
    
```

*PARAMETER FOR PUMP-AROUND CASE

PARAMETER FPR(I,R) Candidate values for pump-around flowrate i

```

/
12.R1 701.4780
12.R2 647.5181
12.R3 539.5984
12.R4 485.6386
    
```

```

14.R1 78.28034
14.R2 115.4635
14.R3 156.5607
14.R4 176.1308
    
```

```

16.R1 37.59575
16.R2 39.94549
16.R3 84.59044
16.R4 108.0878
    
```



```

/
PARAMETER TOTAL_QPA Total PA load ;
TOTAL_QPA =158000;

*linear function for Cp for hot streams
*Cp = A_cp_H*T + B_cp_H
PARAMETER A_cp_H(I) Coefficients for Cp
/
I1  0.0035
I2  0.0040
I3  0.0040
I4  0.0055
I5  0.0039
I6  0.0052
I7  0.0038
I8  0.0031
I9  0
/
PARAMETER B_cp_H(I) Intercept for Cp
/
I1  1.9098
I2  1.7979
I3  1.7483
I4  1.4682
I5  1.7044
I6  1.3834
I7  1.6756
I8  1.8201
I9  4.18
/
*linear function for Cp for cold streams
*Cp = A_cp_C*T + B_cp_C
PARAMETER A_cp_C(J) Coefficients for Cp
/
J1  0.0037
J2  0.0035
J3  0
/
PARAMETER B_cp_C(J) Coefficients for Cp
/
J1  1.9966
J2  1.8143
J3  4.18
/

* y = a*PA(1)+b*PA(2)+c*PA(2)+d from usig regression.

PARAMETER A_1(I) Coefficients for PA(1)
/
I2  2.82E-05
I4  -6.3E-05
I6  -2.7E-05
/
PARAMETER B_1(I) Coefficients for PA(2)
/
I2  4.56E-05
I4  -5.4E-05
I6  -2.8E-05
/
PARAMETER C_1(I) Coefficients for PA(3)
/
I2  5.91E-05
I4  -2.4E-05
I6  -2.3E-05
/
PARAMETER D_1(I) Intercept
/
I2  -3.81232
I4  11.14212
I6  6.491449

```

```

/
*-----
PARAMETER T(S,Z,I,M,J,N) Upper bound
/
S1.Z1.I2.(M3*M10).J1.(M84*M94) 10000
S1.Z1.I2.(M3*M10).J2.(M95*M109) 10000
S1.Z1.I2.(M3*M10).J3.(M110*M111) 10000

S1.Z1.I4.(M26*M35).J1.(M84*M94) 10000
S1.Z1.I4.(M26*M35).J2.(M95*M109) 10000
S1.Z1.I4.(M26*M35).J3.(M110*M111) 10000

S1.Z1.I6.(M51*M57).J1.(M84*M94) 10000
S1.Z1.I6.(M51*M57).J2.(M95*M109) 10000
S1.Z1.I6.(M51*M57).J3.(M110*M111) 10000
/

PARAMETER TE(S,Z,I,M,J,N) Upper bound
/
S1.Z1.I2.(M3*M10).J1.(M84*M94) 10000
S1.Z1.I2.(M3*M10).J2.(M95*M109) 10000
S1.Z1.I2.(M3*M10).J3.(M110*M111) 10000

S1.Z1.I4.(M26*M35).J1.(M84*M94) 10000
S1.Z1.I4.(M26*M35).J2.(M95*M109) 10000
S1.Z1.I4.(M26*M35).J3.(M110*M111) 10000

S1.Z1.I6.(M51*M57).J1.(M84*M94) 10000
S1.Z1.I6.(M51*M57).J2.(M95*M109) 10000
S1.Z1.I6.(M51*M57).J3.(M110*M111) 10000
/

PARAMETER OMEGA(S,Z,I,M,J,N) Upper bound
/
S1.Z1.I2.(M3*M10).J1.(M84*M94) 10000
S1.Z1.I2.(M3*M10).J2.(M95*M109) 10000
S1.Z1.I2.(M3*M10).J3.(M110*M111) 10000

S1.Z1.I4.(M26*M35).J1.(M84*M94) 10000
S1.Z1.I4.(M26*M35).J2.(M95*M109) 10000
S1.Z1.I4.(M26*M35).J3.(M110*M111) 10000

S1.Z1.I6.(M51*M57).J1.(M84*M94) 10000
S1.Z1.I6.(M51*M57).J2.(M95*M109) 10000
S1.Z1.I6.(M51*M57).J3.(M110*M111) 10000
/

PARAMETER NIZ(S,Z,I) # OF INTERVALS DESIRED FOR HOT STREAMS
/
S1.Z1.I1 2
S1.Z1.I2 8
S1.Z1.I3 15
S1.Z1.I4 10
S1.Z1.I5 15
S1.Z1.I6 7
S1.Z1.I7 15
S1.Z1.I8 8
S1.Z1.I9 3
/

PARAMETER NIJ(S,Z,I) # OF INTERVALS DESIRED FOR COLD STREAMS
/
S1.Z1.I1 11
S1.Z1.I2 15
S1.Z1.I3 2
/

* Used Over all heat transfer Coeff instead of hot and cold heat transfer Coeff.
* This values come from text book
PARAMETER U(S,I,J) OVER ALL HEAT TRANSFER COEFFICIENT
/
S1.(I1*I3,I7,I9).(J1*J2) 0.715
S1.(I4,I6).(J1*J2) 0.715

```

S1.15.(J1*J2)	0.306
S1.18.(J1*J2)	0.470
S1.(11,12).J3	1.400
S1.(13,17).J3	1.020
S1.(14,16).J3	0.511
S1.(15).J3	0.765
S1.(18).J3	0.765
S1.(19).J3	5.110

/

PARAMETERS

TIH(S,I) T IN FOR HOT STREAMS

/

S1.11	48.30000
S1.12	182.5720
S1.13	224.6850
S1.14	268.7880
S1.15	275.6570
S1.16	308.5100
S1.17	323.5120
S1.18	347.1810
S1.19	400.0000

/

TOH(S,I) T OUT FOR HOT STREAMS

/

S1.11	26.11000
S1.12	104.4400
S1.13	26.11000
S1.14	173.6270
S1.15	26.11000
S1.16	232.2220
S1.17	26.11000
S1.18	260.0000
S1.19	399.0000

/

TIC(S,J) T IN FOR COLD STREAMS

/

S1.J1	16.11000
S1.J2	132.7800
S1.J3	20.00

/

TOC(S,J) T OUT FOR COLD STREAMS

/

S1.J1	132.780
S1.J2	360
S1.J3	30.00000

/

PARAMETERS

TIHZ(S,Z,I) T IN FOR HOT STREAMS

/

S1.Z1.11	48.30000
S1.Z1.12	182.5720
S1.Z1.13	224.6850
S1.Z1.14	268.7880
S1.Z1.15	275.6570
S1.Z1.16	308.5100
S1.Z1.17	323.5120
S1.Z1.18	347.1810
S1.Z1.19	400.0000

/

TOHZ(S,Z,I) T OUT FOR HOT STREAMS

/

S1.Z1.11	26.11000
S1.Z1.12	104.4400
S1.Z1.13	26.11000
S1.Z1.14	173.6270
S1.Z1.15	26.11000
S1.Z1.16	232.2220
S1.Z1.17	26.11000
S1.Z1.18	260.0000
S1.Z1.19	399.0000

/

TICZ(S,Z,J) T IN FOR COLD STREAMS

/
 S1.Z1.J1 16.11000
 S1.Z1.J2 132.7800
 S1.Z1.J3 20.00
 /

TOCZ(S,Z,J) T OUT FOR COLD STREAMS

/
 S1.Z1.J1 132.7780
 S1.Z1.J2 360
 S1.Z1.J3 30.00000
 /

*-----
 *INTRODUCE THE FCp:
 FH(S,I) FOR HOT STREAMS

/
 S1.I1 177.826
 S1.I3 120.158
 S1.I5 59.1990
 S1.I7 102.417
 S1.I8 211.705
 /

FC(S,J) FOR COLD STREAMS

/
 S1.J1 752.594
 S1.J2 673.422
 /

*USE THE MAX FCp FOR THE UTILITIES

*-----
 SETS FREEH(I)

/
 I1*19
 /

FREEC(J)

/
 J1
 J2
 J3
 /

PARAMETER BIF(Z,I,J)

/
 Z1.I1.J1 0
 /

*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;

*MAXNEXCHPERMATCH = 2

*,

PARAMETER SPH(I) SH in paper

/
 (I1,I3,I5,I7,I8,I9) 1
 (I2,I4,I6) 0
 /

PARAMETER SPC(J) SC in paper

/
 J1 1
 J2 1
 J3 1
 /

PARAMETER NIH(I) Non isothermal splitting for hot streams in paper

/
 I1 0
 /

PARAMETER NIC(J) Non isothermal splitting for cold streams in paper

/
 J1 0
 /

PARAMETER DTVIO(I,J)

/
 (I1*I9).(J1*J3) 1
 /

```

PARAMETER KMAX(Z,I,J)
/
Z1.I1.J1 1
/

PARAMETER DTHU(I)
/
I9 1
/
PARAMETER DTCU(J)
/
J3 10
/
PARAMETER FMAX_HU(I)
/
I9 100000
/
PARAMETER FMAX_CU(J)
/
J3 100000
/
PARAMETER CHU(I)
/
I9 19.750
/
PARAMETER CCU(J)
/
J3 1.861
/
PARAMETER CSS(I) Cost of side stripping
/
I2 20.33
I4 20.33
I6 20.33
/
PARAMETER CF:
CF = 5291.9;
PARAMETER CAN;
CAN = 171.4;
PARAMETER CAE;
CAE = 171.4;

** Retrofit
PARAMETER AEX(Z,I,J)
/
Z1.I1.J3 515.685
Z1.I2.J1 2239.929
Z1.I3.J1 1000.000
Z1.I3.J2 204.200
Z1.I3.J3 617.797
Z1.I4.J1 572.096
Z1.I4.J2 179.428
Z1.I5.J1 133.625
Z1.I5.J2 529.892
Z1.I5.J3 546.822
Z1.I6.J3 184.5
Z1.I7.J1 608.858
Z1.I7.J2 798.965
Z1.I7.J3 425.397
Z1.I8.J3 240.7
Z1.I9.J2 4489.5
/
PARAMETER AEX_B(K,Z,I,J)
/
K1.Z1.I1.J3 515.685
/
PARAMETER NHE0(S,Z,I,J)
/
S1.Z1.I1.J3 1
S1.Z1.I2.J1 1
S1.Z1.I3.J1 1

```

```

S1.Z1.I3.J2.I
S1.Z1.I3.J3.I
S1.Z1.I4.J1.I
S1.Z1.I4.J2.I
S1.Z1.I5.J1.I
S1.Z1.I5.J2.I
S1.Z1.I5.J3.I
S1.Z1.I6.J3.I
S1.Z1.I7.J1.I
S1.Z1.I7.J2.I
S1.Z1.I7.J3.I
S1.Z1.I8.J3.I
S1.Z1.I9.J2.I
/
PARAMETER AEX_U(Z,I,J)
/
Z1.I1.J3.3000
Z1.I2.J1.3000
Z1.I3.J1.3000
Z1.I3.J2.3000
Z1.I3.J3.3000
Z1.I4.J1.3000
Z1.I4.J2.3000
Z1.I5.J1.3000
Z1.I5.J2.3000
Z1.I5.J3.3000
Z1.I6.J3.3000
Z1.I7.J1.3000
Z1.I7.J2.3000
Z1.I7.J3.3000
Z1.I8.J3.3000
Z1.I9.J2.5000
/
PARAMETER AEX_U_B(K,Z,I,J)
/
K1.Z1.I1.J1.3000.000
/
PARAMETER A_NEW_MAX(Z,I,J)
/
Z1.(I1*I4).(J1*J3).5000.000
/
PARAMETER MAX_NEW_HEX
*      Maximum Number of new exchangers
/50/;
*****
PARAMETER QLHMIN
*      Minimum heat that can be transferred within an interval.Hot streams
/0.01/;
PARAMETER QLCMIN
*      Minimum heat that can be transferred within an interval.Cold streams
/0.01/;
PARAMETER AMAX
*      Maximum area per exchanger
/20000/;
PARAMETER ASHELLMAX
*      Maximum shell area
/5000/;
PARAMETER TOTNEXCHMAX
*      Maximum NUMBER OF EXCHANGERS
/900/;
PARAMETER TOTNEXCHMIN
*      Minimum NUMBER OF EXCHANGERS
/0/;
PARAMETER DTmin
*      Minimum DELTA T
/0/;
*-----
*      END OF INPUT PARAMETERS
*-----
SCALARS Si, Zi, Mi, Ic, Ji

```

```

PARAMETERS IHminZ(S,Z,I),IHmaxZ(S,Z,I),IHmax(S,I),IHmin(S,I),HOT(S,I,M),
HOT2(S,M),HOTZ(S,Z,I,M),ICminZ(S,Z,J),ICmaxZ(S,Z,J),ICmin(S,J),
ICmax(S,J),COLD(S,J,M),COLD2(S,M),COLDZ(S,Z,J,M),H_(S,I,M),H_(S,J,M)

FOR(Si=1 TO CARD(S),
FOR(Zi=1 TO CARD(Z),
FOR(Ic=1 TO CARD(I),
  IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)=1
    AND ORD(Z)=1}= 0+ 1${NIZ(S,Z,I)}>=1];
  IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)>1
    AND ORD(Z)=1}= 0+
    {SUM((ZZ,II){ORD(II)<ORD(I),NIZ(S,ZZ,II)}+1)}${NIZ(S,Z,I)}>=1];
  IHminZ(S,Z,I){ORD(S)=Si AND ORD(Z)>1}= 0+
    {SUM((ZZ,II){ORD(II)<ORD(I),NIZ(S,ZZ,II)}
    +SUM(ZZ${ORD(ZZ)< Zi},NIZ(S,ZZ,I)}+1)}${NIZ(S,Z,I)}>=1];
  IHmaxZ(S,Z,I){ORD(S)=Si AND ORD(I)=Ic AND ORD(Z)=Zi}= 0+
    {IHminZ(S,Z,I)+NIZ(S,Z,I)-1}$[NIZ(S,Z,I)}>=1];
  IHmin(S,I){ORD(S)=Si AND ORD(I)=Ic}=
    SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NIZ(S,ZZ,I))=0},IHminZ(S,Z,I)];
  IHmax(S,I){ORD(S)=Si AND ORD(I)=Ic}=
    SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NIZ(S,ZZ,I))=0},IHmaxZ(S,Z,I)];

  FOR(Mi=1 TO CARD(M),
    HOT(S,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi}= 0+
      1${ORD(M)}>= IHmin(S,I) AND ORD(M)<=IHmax(S,I)];
    HOT2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+ 1${ORD(M)}<=
      SUM(1${ORD(I)=CARD(I)},IHmax(S,I)];
    HOTZ(S,Z,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
    AND ORD(Z)=Zi}= 0+ 1${ORD(M)}>= IHminZ(S,Z,I) AND ORD(M)<=IHmaxZ(S,Z,I)];

  ));
FOR(Ji=1 TO CARD(J),
  ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)=1 AND ORD(Z)=1}= 0+
    {SUM(1${ORD(I)=CARD(I)},IHmax(S,I)}+1)}${NJZ(S,Z,J)}>=1];
  ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)>1 AND ORD(Z)=1}= 0+
    {SUM{1${ORD(I)=CARD(I)},IHmax(S,I)}
    +SUM((ZZ,JJ){ORD(JJ)<ORD(J),NJZ(S,ZZ,JJ)}+1)}${NJZ(S,Z,J)}>=1];
  ICminZ(S,Z,J){ORD(S)=Si AND ORD(Z)>1}= 0+
    {SUM{1${ORD(I)=CARD(I)},IHmax(S,I)}
    +SUM((ZZ,JJ){ORD(JJ)<ORD(J),NJZ(S,ZZ,JJ)}
    +SUM(ZZ${ORD(ZZ)< Zi},NJZ(S,ZZ,J)}+1)}${NJZ(S,Z,J)}>=1];
  ICmaxZ(S,Z,J){ORD(S)=Si AND ORD(J)=Ji AND ORD(Z)=Zi}= 0+
    {ICminZ(S,Z,J)+NJZ(S,Z,J)-1}$[NJZ(S,Z,J)}>=1];
  ICmin(S,J){ORD(S)=Si AND ORD(J)=Ji}=
    SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NJZ(S,ZZ,J))=0},ICminZ(S,Z,J)];
  ICmax(S,J){ORD(S)=Si AND ORD(J)=Ji}=
    SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NJZ(S,ZZ,J))=0},ICmaxZ(S,Z,J)];

  FOR(Mi=1 TO CARD(M),
    COLD(S,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi}= 0+
      1${ORD(M)}>= ICmin(S,J) AND ORD(M)<=ICmax(S,J)];
    COLD2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+
      1${ORD(M)}>SUM(1${ORD(I)=CARD(I)},IHmax(S,I))
      AND ORD(M)<= SUM(1${ORD(I)=CARD(I)},ICmax(S,J)];
    COLDZ(S,Z,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
    AND ORD(Z)=Zi}= 0+ 1${ORD(M)}>= ICminZ(S,Z,J)
    AND ORD(M)<=ICmaxZ(S,Z,J)];

  )););
PARAMETERS DT(S,M),TU(S,M),TL(S,M),CPH(S,I,M),CPC(S,J,M),DHH(S,I,M),DHC(S,J,M)
CPH_U(S,I,M),CPC_U(S,J,M),CPH_L(S,I,M),CPC_L(S,J,M);

DT(S,M) = SUM((Z,I){HOTZ(S,Z,I,M)=1}, {[TIHZ(S,Z,I)-TOHZ(S,Z,I)]/
  [IHmaxZ(S,Z,I)-IHminZ(S,Z,I)+1]})$[HOT2(S,M)=1]+
SUM((Z,J){COLDZ(S,Z,J,M)=1}, {[TOCZ(S,Z,J)-TICZ(S,Z,J)]/
  [ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]})$[COLD2(S,M)=1];

FOR(Si= 1 TO CARD(S),

```

```

FOR (Mi=1 TO CARD(M),
  TU(S,M)$[ORD(S)=Si AND ORD(M)=Mi]= {SUM((Z,I)$[HOTZ(S,Z,I,M)=1
    AND ORD(M)=IHminZ(S,Z,I)],TIHZ(S,Z,I)$[ORD(M)=IHminZ(S,Z,I)]}
  + SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)>IHminZ(S,Z,I)AND
    ORD(M)<=IHmaxZ(S,Z,I)],
    [TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)]$[ORD(M)>
    IHminZ(S,Z,I)AND ORD(M)<=IHmaxZ(S,Z,I)]}$[HOT2(S,M)=1]
  + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICminZ(S,Z,J)],
    TOCZ(S,Z,J)$[ORD(M)=ICminZ(S,Z,J)]}
  + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z,J)
    AND ORD(M)<=ICmaxZ(S,Z,J)],
    [TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]$[ORD(M)>
    ICminZ(S,Z,J)AND ORD(M)<=ICmaxZ(S,Z,J)]}$[COLD2(S,M)=1];
  TL(S,M)$[ORD(S)=Si AND ORD(M)=Mi]=
  {SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)=IHmaxZ(S,Z,I)],
    TOHZ(S,Z,I)$[ORD(M)=IHmaxZ(S,Z,I)]}
  + SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z,I)
    AND ORD(M)>=IHminZ(S,Z,I)],
    [TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$[ORD(M)<
    IHmaxZ(S,Z,I)AND ORD(M)>=IHminZ(S,Z,I)]}$[HOT2(S,M)=1]
  + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICmaxZ(S,Z,J)],
    TICZ(S,Z,J)$[ORD(M)=ICmaxZ(S,Z,J)]}
  + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)<ICmaxZ(S,Z,J)
    AND ORD(M)>=ICminZ(S,Z,J)],
    [TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$[ORD(M)<
    ICmaxZ(S,Z,J)AND ORD(M)>=ICminZ(S,Z,J)]}$[COLD2(S,M)=1];

```

```

CPH_U(S,I,M)$[HOT(S,I,M)=1] = A_cp_H(I)*TU(S,M)+ B_cp_H(I) ;
CPC_U(S,J,M)$[COLD(S,J,M)=1] = A_cp_C(J)*TU(S,M)+ B_cp_C(J) ;
CPH_L(S,I,M)$[HOT(S,I,M)=1] = A_cp_H(I)*TL(S,M)+ B_cp_H(I) ;
CPC_L(S,J,M)$[COLD(S,J,M)=1] = A_cp_C(J)*TL(S,M)+ B_cp_C(J) ;
CPH(S,I,M)$[HOT(S,I,M)=1] = (CPH_U(S,I,M)+CPH_L(S,I,M))/2 ;
CPC(S,J,M)$[COLD(S,J,M)=1] = (CPC_U(S,J,M)+CPC_L(S,J,M))/2 ;

```

```

FOR(Ic=1 TO CARD(I),
  DHH(S,I,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(I)=Ic
    AND HOT(S,I,M)=1]= FH(S,I)*CPH(S,I,M)*[TU(S,M)-TL(S,M)] ;
);
FOR(Ji=1 TO CARD(J),
  DHC(S,J,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(J)=Ji
    AND COLD(S,J,M)=1]= FC(S,J)*CPC(S,J,M)*[TU(S,M)-TL(S,M)] ;
));

```

```

PARAMETER HHEAD(S,M,N), CHEAD(S,M,N), LMTD(S,M,N), D(S,Z,M,N)
*MATCH ALLOWED BASED ON LMTD
ALLOW(S,Z,I,J), ALLOW_H(S,Z,I,M,J), ALLOW_C(S,Z,J,M,I), ALLOW_2(Z,I,J) ;

```

```

HHEAD(S,M,N) = {TU(S,M)-TU(S,N) + DTmin}$[HOT2(S,M) AND COLD2(S,N)];
CHEAD(S,M,N) = {TL(S,M)-TL(S,N) + DTmin}$[HOT2(S,M) AND COLD2(S,N)] ;

```

```

LMTD(S,M,N)= {[HHEAD(S,M,N)-CHEAD(S,M,N)]
  /LOG[HHEAD(S,M,N)/CHEAD(S,M,N)]}$[HHEAD(S,M,N)> 0
  AND CHEAD(S,M,N)>0 AND HHEAD(S,M,N)> CHEAD(S,M,N)]
+ {[HHEAD(S,M,N)+CHEAD(S,M,N)]/2}$[HHEAD(S,M,N)>0 AND CHEAD(S,M,N)>0
  AND (HHEAD(S,M,N)< CHEAD(S,M,N)OR HHEAD(S,M,N)= CHEAD(S,M,N))];

```

```

D(S,Z,M,N)= 1$[{HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[I$(HOT(S,I,M)=1
  AND HOT(S,I,N)=1),HOTZ(S,Z,I,M)]=1 AND SUM[I$(HOT(S,I,N)=1
  AND HOT(S,I,M)=1),HOTZ(S,Z,I,N)]=1]
OR {COLD2(S,M)=1 AND COLD2(S,N)=1 AND SUM[J$(COLD(S,J,M)=1
  AND COLD(S,J,N)=1),COLDZ(S,Z,J,M)]=1 AND SUM[J$(COLD(S,J,N)=1
  AND COLD(S,J,M)=1),COLDZ(S,Z,J,N)]=1]
OR {(HHEAD(S,M,N)>=0.00001 AND CHEAD(S,M,N)>=0.00001)
  AND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,I,M)]=1
  AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}};

```

```

* OR {LMTD(S,M,N)>0 AND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,I,M)]=1
* AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}};

```



```

FOR(Si= 1 TO CARD(S),
  FOR(Zi=1 TO CARD(Z),
    FOR(Ic=1 TO CARD(I),
      FOR(Ji=1 TO CARD(J),
        ALLOW(S,Z,I,J){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
          AND ORD(J)=Ji}= 0+ 1${SUM[(M,N){HOT(S,I,M)=1
            AND COLD(S,J,N)=1}],D(S,Z,M,N)} >0
          AND NOT[HU(I)AND CU(J)]};
        FOR (Mi=1 TO CARD(M),
          ALLOW_H(S,Z,I,M,J){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
            AND ORD(J)=Ji AND ORD(M)=Mi
            AND HOT(S,I,M)=1}= 0+
            1${SUM[N${COLD(S,J,N)=1}],D(S,Z,M,N)} >0AND NOT[HU(I)AND CU(J)]};
          ALLOW_C(S,Z,J,M,I){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
            AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1}= 0+
            1${SUM[N${HOT(S,I,N)=1}],D(S,Z,N,M)} >0AND NOT[HU(I)AND CU(J)]};
          )));
      FOR(Zi=1 TO CARD(Z),
        FOR(Ic=1 TO CARD(I),
          FOR(Ji=1 TO CARD(J),
            ALLOW_2(Z,I,J){ORD(Z)=Zi AND ORD(I)=Ic AND ORD(J)=Ji}= 0+
              1${SUM[S,ALLOW(S,Z,I,J)} >0AND NOT[HU(I)AND CU(J)]};
            )));
  )));

```

*-----

VARIABLES

```

TCOST
PAR(Z,I,J)
Q(S,Z,I,M,J,N)  heat load for process-process match
QNEW_M(S,Z,I,J,M)
QNEW_N(S,Z,I,J,N)
QNEW2_M(S,Z,I,J,M)
QNEW2_N(S,Z,I,J,N)
Y_M(S,Z,I,J,M)
Y_N(S,Z,I,J,N)
Y_M_B(S,Z,I,J,M)
Y_N_B(S,Z,I,J,N)
NHE_M0(S,Z,I,J,M)
NHE_M1(S,Z,I,J,M)
NHE_N0(S,Z,I,J,N)
NHE_N1(S,Z,I,J,N)
NHE_M0_B(S,Z,I,J,M)
NHE_M1_B(S,Z,I,J,M)
NHE_N0_B(S,Z,I,J,N)
NHE_N1_B(S,Z,I,J,N)
NHE(S,Z,I,J)
ALFA_M(S,Z,I,J,M)
ALFA_N(S,Z,I,J,N)
FHU(I)          is FCP HU (MJ_h_C)
FCU(J)          is FCP CU(MJ_h_C)
B1(S,Z,I,M,J,N) X(imjn) in the paper
QH(S,Z,I,M,N)
QC(S,Z,J,M,N)
Q2(S,Z,I,M,J,N)
X1_B(S,Z,I,J,M)
X_B(S,K,Z,I,J,M)
PAR_B(K,Z,I,J)
USHELL(Z,I,J)
USHELL_B(K,Z,I,J)

```

*ADD FOR RETROFIT

```

PAR_N(S,Z,I,J)
PAR_N_B(K,Z,I,J)
DPAR_E(Z,I,J)
DPAR_E_B(K,Z,I,J)
NHE_S(S,Z,I,J)
DELTA(K,K)

```

*ADD FOR PUMP-AROUND CASE

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FP(I)
FPY(S,Z,I,J,M)  Case of BIF=0

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FPY_B(S,Z,I,J,M) Case of BIF=1
FPA(S,Z,I,J,M)
FPK_H_0(S,Z,I,J,M)
FPK_H_0_B(S,Z,I,J,M)
FPK_C_0(S,Z,I,J,N)
FPK_H_1(S,Z,I,J,M)
FPK_H_1_B(S,Z,I,J,M)
FPK_C_1(S,Z,I,J,N)
XM(S,Z,I,M,J,N)
FPQ(S,Z,I,J,M)
W(I,R)
YW(S,Z,I,J,M)
KW_0(S,Z,I,J,M,R)
KW_1(S,Z,I,J,M,R)
WA(S,Z,I,J,M,R)
XW(S,Z,I,M,J,N,R)
WQ(S,Z,I,J,M,R)
QPA(I)
TOTAL_QPA_MIN
TOTAL_QPA_MAX
Cost_side_stripping_steam
SST(I)
SST_1(I)
SST_2(I)
SST_3(I)
SST_4(I)
PA1
PA2
PA3
TOTAL_Q
Cp_Dt(I)

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;
POSITIVE VARIABLE Q,QNEW2_M,QNEW2_N,QC,QH,Q2,DPAR_E,DPAR_E_B,PAR_N
,PAR_N_B,PAR,QNEW_M,QNEW_N,YW,KW_0,KW_1,WA,XW,QPA,FP
BINARY VARIABLE NHE_M0_B,NHE_M1_B,NHE_N0_B,NHE_N1_B,Y_M,Y_N,X1_B,X_B,NHE_S
,DELTA,Y_M_B,Y_N_B,NHE_M0,NHE_M1,NHE_N0,NHE_N1,ALFA_M,ALFA_N
,W
INTEGER VARIABLE USHELL,USHELL_B

```

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EQUATIONS
HBHU(S,I,M)
HBCU(S,J,N)
HBHS(S,I,M)
HBCS(S,J,N)
TRANSFOR_M(S,Z,I,J,M)
TRANSFOR_N(S,Z,I,J,N)
HBHS_NI(S,I,M)
HBCS_NI(S,J,N)
NOISOH(S,I,M)
NOISOC(S,J,N)
BINARY_M1(S,Z,I,J,M)
BINARY_M2(S,Z,I,J,M)
BINARY_M1_B(S,Z,I,J,M)
BINARY_M2_B(S,Z,I,J,M)
BINARY_N1(S,Z,I,J,N)
BINARY_N2(S,Z,I,J,N)
BINARY_N1_B(S,Z,I,J,N)
BINARY_N2_B(S,Z,I,J,N)
BINARY_M5(S,Z,I,J,M)
BINARY_M5b(S,Z,I,J,M)
BINARY_M3(S,Z,I,J,M)
BINARY_M4(S,Z,I,J,M)
BINARY_M8(S,Z,I,J,M)
BINARY_M9(S,Z,I,J,M)
BINARY_M6(S,Z,I,J,M)
BINARY_M7(S,Z,I,J,M)
BINARY_M3_B(S,Z,I,J,M)
BINARY_N5(S,Z,I,J,N)
BINARY_N5b(S,Z,I,J,N)

```

BINARY_N3(S,Z,I,J,N)
 BINARY_N4(S,Z,I,J,N)
 BINARY_N8(S,Z,I,J,N)
 BINARY_N9(S,Z,I,J,N)
 BINARY_N6(S,Z,I,J,N)
 BINARY_N7(S,Z,I,J,N)
 BINARY_N3_B(S,Z,I,J,N)
 HE_COUNT_M0(S,Z,I,J)
 HE_COUNT_N0(S,Z,I,J)
 HE_COUNT_M1(S,Z,I,J)
 HE_COUNT_N1(S,Z,I,J)
 NEXCH(S,Z,I,J)
 NEXCH_B(S,Z,I,J)
 BIF_1(S,Z,I,J,M,N)
 BIF_2(S,Z,I,J,M,N)
 BIF_3(S,Z,I,J,M,N)
 BIF_4(S,Z,I,J,M,N)
 BIF_11(S,Z,I,J,M)
 BIF_12(S,Z,I,J,N)
 BIF_6(S,Z,I,J,M)
 BIF_9(S,Z,I,J,M)
 BIF_5(S,Z,I,J,M)
 BIF_8(S,Z,I,J,N)
 BIF_10(S,Z,I,J,N)
 BIF_7(S,Z,I,J,N)
 FEAS_M_01(S,Z,I,J,M)
 FEAS_M_01_B(S,Z,I,J,M)
 FEAS_M_02(S,Z,I,J,M)
 FEAS_M_02_B(S,Z,I,J,M)
 FEAS_M_03(S,Z,I,J,M)
 FEAS_M_03_B(S,Z,I,J,M)
 FEAS_M_04(S,Z,I,J,M)
 FEAS_M_2(S,Z,I,J,M)
 FEAS_M_1(S,Z,I,J,M)
 FEAS_M_3(S,Z,I,J,M)
 FEAS_M_4(S,Z,I,J,M)
 FEAS_M_3_B_2(S,Z,I,J,M)
 FEAS_M_3_B_1(S,Z,I,J,M)
 FEAS_M_4_B(S,Z,I,J,M)
 FEAS_M_1_SP(S,Z,I,J,M)
 FEAS_M_1_SP_B(S,Z,I,J,M)
 FEAS_N_01(S,Z,I,J,N)
 FEAS_N_01_B(S,Z,I,J,N)
 FEAS_N_02(S,Z,I,J,N)
 FEAS_N_02_B(S,Z,I,J,N)
 FEAS_N_03(S,Z,I,J,N)
 FEAS_N_03_B(S,Z,I,J,N)
 FEAS_N_04(S,Z,I,J,N)
 FEAS_N_2(S,Z,I,J,N)
 FEAS_N_1(S,Z,I,J,N)
 FEAS_N_3(S,Z,I,J,N)
 FEAS_N_4(S,Z,I,J,N)
 FEAS_N_3_B_2(S,Z,I,J,N)
 FEAS_N_3_B_1(S,Z,I,J,N)
 FEAS_N_4_B(S,Z,I,J,N)
 FEAS_N_1_SP(S,Z,I,J,N)
 FEAS_N_1_SP_B(S,Z,I,J,N)
 FEAS_BEG_SP(S,Z,I,J,M,N)
 FEAS_BEG_B_SP(S,Z,I,J,M,N)
 FEAS_END_SP(S,Z,I,J,M,N)
 FEAS_END_B_SP(S,Z,I,J,M,N)
 FEAS_BEG3(S,Z,I,J,M,N)
 FEAS_BEG(S,Z,I,J,M,N)
 FEAS_BEG2(S,Z,I,J,M,N)
 FEAS_END3(S,Z,I,J,M,N)
 FEAS_END(S,Z,I,J,M,N)
 FEAS_END2(S,Z,I,J,M,N)
 FEAS_BEG4_B(S,Z,I,J,M,N)
 FEAS_BEG2_B(S,Z,I,J,M,N)
 FEAS_BEG1_B(S,Z,I,J,M,N)
 FEAS_BEG3_B(S,Z,I,J,M,N)

FEAS_END3_B(S,Z,I,J,M,N)
 FEAS_END_B(S,Z,I,J,M,N)
 FEAS_END2_B(S,Z,I,J,M,N)
 PAREQ(S,Z,I,J)
 BIF_13_2(S,K,Z,I,J,M)
 BIF_13_1(S,K,Z,I,J,M)
 BIF_14(S,K,Z,I,J)
 BIF_15(S,Z,I,J,M)
 *BIF_16(S,Z,I,J,M)
 BIF_17(S,Z,I,J,M)
 BIF_18(S,Z,I,J,M,N)
 SHELL(Z,I,J)
 SHELL_B(K,Z,I,J)
 KMAX1(S,Z,I,J)
 KMAX2(S,Z,I,J)
 TOTALCOST
 * EXTRA EQUATIONS NOT IN PAPER
 TOTNEXCH_MAX
 TOTNEXCH_MIN

*-----
 *ADD FOR RETROFIT
 AREA_REST1(S,Z,I,J)
 AREA_REST2(S,Z,I,J)
 AREA_REST3(S,Z,I,J)
 AREA_REST4(S,Z,I,J)

AREA_REST5(S,Z,I,J)
 *AREA_REST6(S,Z,I,J)
 AREA_REST7(S,Z,I,J)

AREA_REST1_B(S,K,Z,I,J)
 AREA_REST2_B(S,K,Z,I,J)
 AREA_REST3_B(S,K,Z,I,J)
 AREA_REST4_B(S,K,Z,I,J)
 AREA_REST5_B(S,K,Z,I,J)
 AREA_REST6_B(S,Z,I,J)

LIM_HEX(S,M)

*-----
 *Equation for Pump-around
 PA_1(S,I,M)
 PA_2(S,I,M)
 PA_3(S,Z,I,J,M)
 PA_4(S,Z,I,J,M)
 PA_3_B(S,Z,I,J,M)
 PA_4_B(S,Z,I,J,M)
 PA_5(S,Z,I,J,M)
 PA_6(S,Z,I,J,M)
 PA_7(S,Z,I,J,M)
 PA_8(S,Z,I,J,M,R)
 PA_9(S,Z,I,J,M,R)
 PA_10(S,Z,I,J,M,N)
 PA_11(S,Z,I,J,M,N)
 PA_12(S,Z,I,J,M,N)
 PA_13(S,Z,I,J,M,N)
 PA_14(S,Z,I,J,M,N)
 PA_15(S,Z,I,J,M,N,R)
 PA_16(S,Z,I,J,M,N,R)
 PA_17(S,Z,I,J,M,N,R)
 PA_18(S,Z,I,J,M,N)
 PA_19(S,Z,I,J,M)
 PA_20(S,Z,I,J,M)
 PA_21(S,Z,I,J,M,R)
 PA_22(S,Z,I,J,M,R)
 PA_23(S,Z,I,J,M,R)
 PA_24(S,Z,I,J,M)
 PA_25(S,Z,I,J,M)
 PA_26(S,Z,I,J,M,R)
 PA_27(S,Z,I,J,M,R)
 PA_28(S,Z,I,J,M,R)
 PA_29(S,Z,I,J,M)

PA_30(S,Z,I,J,M)
 PA_31(S,Z,I,J,M,R)
 PA_32(S,Z,I,J,M,R)
 PA_33(S,Z,I,J,M,R)
 PA_34(S,Z,I,J,M)
 PA_35(S,Z,I,J,M)
 PA_36(S,Z,I,J,M)
 PA_37(S,Z,I,J,M)
 PA_38(S,Z,I,J,M)
 PA_39(S,Z,I,J,M)
 PA_40(S,Z,I,J,M)
 PA_41(S,Z,I,J,M)
 PA_42(S,Z,I,J,M,N)
 PA_43(S,Z,I,J,M,N)
 PA_44(S,Z,I,J,M,N)
 PA_45(S,Z,I,J,M,N,R)
 PA_46(S,Z,I,J,M,N,R)
 PA_47(S,Z,I,J,M,N,R)
 PA_48(S,Z,I,J,M,N)
 PA_49(S,Z,I,J,M,N)
 PA_50(S,Z,I,J,M,N)
 PA_51(S,Z,I,J,M,N)
 PA_52(S,Z,I,J,M,N)
 PA_53(S,Z,I,J,M,N)
 PA_54(S,Z,I,J,M)
 PA_55(S,Z,I,J,M)
 PA_56(S,Z,I,J)
 *PA_57
 PA_58
 PA_59
 PA_60
 PA_61(S,Z,I,J,M)
 PA_62
 PA_63
 PA_64
 PA_65
 PA_66
 PA_67
 PA_68(S,Z,I,J)

;

*

 *EQ (1)

HBHU(S,I,M)\$ (HOT(S,I,M)=1 AND HU(I) AND FREEH(I)).
 FHU(I)*(TU(S,M)-TL(S,M)) =E= SUM((Z,N,J)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND COLD(S,J,N)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEC(J)),Q(S,Z,I,M,J,N));

*

 *EQ (2)

HBCU(S,J,N)\$ (COLD(S,J,N)=1 AND CU(J) AND FREEC(J)).
 FCU(J)*(TU(S,N)-TL(S,N)) =E= SUM((Z,M,I)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND HOT(S,I,M)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEH(I)),Q(S,Z,I,M,J,N));

*

 *EQ (3 a)

HBHS(S,I,M)\$ (HOT(S,I,M)=1 AND NOT HU(I) AND
 FREEH(I) AND NIH(I)=0 AND NOT PA(I)).
 DHH(S,I,M)=E=SUM((Z,N,J)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

*

 *EQ (4)

HBCS(S,J,N)\$ (COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=0).
 DHC(S,J,N)=E=SUM((Z,M,I)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

*

 *EQ (5)

TRANSFOR_M(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND FREEH(I) AND FREEC(J)).
 QNEW_M(S,Z,I,J,M) =E= SUM(N\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

*

*EQ (6)
TRANSFOR_N(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,I,J,N)=E=SUM(M\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1),Q(S,Z,I,M,J,N));
*-----

*EQ (7_a)
HBHS_NI(S,I,M)\$(HOT(S,I,M)=1 AND NOT HU(I)
AND FREEH(I) AND NIH(I)=1 AND NOT PA(I))..
DHH(S,I,M)=E= SUM((Z,N,J)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
Q(S,Z,I,M,J,N))
+SUM((Z,N)\$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) GT ORD(M)),QH(S,Z,I,N,M))
-SUM((Z,N)\$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N));
*-----

*EQ (8)
HBCS_NI(S,J,N)\$(COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1)..
DHC(S,J,N)=E= SUM((Z,M,I)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N))
+SUM((Z,M)\$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) LT ORD(N)),QC(S,Z,J,M,N))
-SUM((Z,M)\$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,N,M));
*-----

*EQ (9)
NOISOH(S,I,M)\$(HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1)..
SUM((Z,N)\$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N))
=L=SUM((Z,N,J)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
*-----

*EQ (10)
NOISOC(S,J,N)\$(COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1)..
SUM((Z,M)\$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,M,N))
=L= SUM((Z,M,I)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
*-----

*EQ (11a and 13a) Case of BIF(I,J)=0 (i,j) not belonging to set B.
BINARY_M1(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*DHH(S,I,M)\$(NOT HU(I))
-Y_M(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)\$(HU(I))=L=0;
*-----

*EQ (11b and 13b) Case of BIF(I,J)=0 (i,j) not belonging to set B
***** ***** MINIMUM VALUE OF QNEW_M=0.01!!!!!!!!!!!!
BINARY_M2(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0 AND
FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*QLHMIN=G=0;
*-----

*EQ (11a and 13a) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_M1_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*DHH(S,I,M)\$(NOT HU(I))
-Y_M_B(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)\$(HU(I))=L=0;
*-----

*EQ (11b and 13b) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_M2_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN=G=0;
*-----

*EQ (12a and 14a) Case of BIF(I,J)=0 (i,j) not belonging to set B
BINARY_N1(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*DHC(S,J,N)\$(NOT CU(J))
-Y_N(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)\$(CU(J))=L=0;
*-----

*EQ (12b and 14b) Case of BIF(I,J)=0 (i,j) not belonging to set B
BINARY_N2(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*QLCMIN=G=0;
*-----

*EQ (12a and 14a) Case of BIF(I,J)=1 (i,j) belonging to set B

BINARY_N1_B(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$

QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*DHC(S,J,N) $\$(NOT \ CU(J))$
 $-Y_N_B(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)\$(CU(J))=L=0;$

*-----
 *EQ (12b and 14b) Case of BIF(I,J)=1 (i,j) belonging to set B
 BINARY_N2_B(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,I,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$ QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*QLCMIN=G=0;

*-----
 *EQ (15) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)

*-----
 *EQ (16)
 BINARY_M5(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE_M0(S,Z,I,J,M)=L=2-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1);$

*-----
 *EQ (17) IS IN REALITY NOT NEEDED, BUT WAS ADDED TO ENFORCE K=0 WHEN Y=0
 * AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M,J)=1
 * AND ALLOW_H(S,Z,I,M,J)=1

BINARY_M5b(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$ NHE_M0(S,Z,I,J,M) =L= Y_M(S,Z,I,J,M);

* IT TURNS OUT THAT THIS EQUATION ONLY FORCES THE VALUES OF K TO BE ZERO
 * WHEN Y=0, WHICH HAPPENS NATURALLY IF ONE IS MINIMIZING THE NUMBER OF
 * EXCHANGERS OR BECAUSE THE FIXED COSTS ARE BEING MINIMIZED.
 * EVEN IF NOT DRIVEN TO ZERO BY THE OBJECTIVE FUNCTION IT IS HARMLESS.
 * HOWEVER, IT TURNS OUT THAT IT COULD MAKE EXTENSIONS OF THE MODEL HAVE
 * PROBLEMS SO, ALTHOUGH THE EQUATION IS NOT NEEDED, IT GIVES SOME EXTRA VALUES
 * OF K WHEN THEY DO NOT REALLY MATTER.

*-----
 *EQ (18)
 BINARY_M3(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE_M0(S,Z,I,J,M)=G= Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1)\$(HOT(S,I,M-1) \text{ AND } ALLOW_H(S,Z,I,M-1,J));$

*-----
 *EQ (19)
 BINARY_M4(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE_M0(S,Z,I,J,M)=G=0;$

*-----
 *EQ (20) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)

*-----
 *EQ (21)
 BINARY_M8(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } HOT(S,I,M+1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M+1,J) \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE_M1(S,Z,I,J,M)=L=2-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M+1);$

*-----
 *EQ (22) : ORIGINALLY NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0
 * AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M-1,J)
 BINARY_M9(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE_M1(S,Z,I,J,M)=L= Y_M(S,Z,I,J,M);$

* SEE COMMENTS ON EQUATION (17)

*-----
 *EQ (23)
 BINARY_M6(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$ NHE_M1(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M+1)
 $\$(HOT(S,I,M+1) \text{ AND } ALLOW_H(S,Z,I,M+1,J));$

*-----
 *EQ (24)
 BINARY_M7(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } HOT(S,I,M+1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M+1,J) \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $NHE_M1(S,Z,I,J,M)=G=0;$

*EQ (25)

BINARY_M3_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..

Y_M_B(S,Z,I,J,M)=E=SUM(OS\$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M)
AND ALLOW_H(S,Z,I,O,J)=1),NHE_M0_B(S,Z,I,J,O))
-SUM(OS\$(HOT(S,I,O)=1 AND ORD(O) LE [ORD(M)-1]
AND ALLOW_H(S,Z,I,O,J)=1),NHE_M1_B(S,Z,I,J,O));

*-----
*EQ (26) NOT NEEDED

* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*-----

*EQ (27)

BINARY_N5(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..

NHE_N0(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1);

*-----
*EQ (28) NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0

* AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
BINARY_N5b(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
NHE_N0(S,Z,I,J,N)=L= Y_N(S,Z,I,J,N);

* SEE COMMENTS ON EQUATION (17)
*-----

*EQ (29)

BINARY_N3(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..

NHE_N0(S,Z,I,J,N)=G= Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1)
\$(COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I));

*-----
*EQ (30)

BINARY_N4(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..

NHE_N0(S,Z,I,J,N)=G=0;

*-----
*EQ (31) NOT NEEDED

* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*-----

*EQ (32)

BINARY_N8(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..

NHE_N1(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1);

*-----
*EQ (33) NOT NEEDED BUT ADDED TO ENFORCE K=0 WHEN Y=0

* AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
BINARY_N9(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
NHE_N1(S,Z,I,J,N)=L= Y_N(S,Z,I,J,N);

* SEE COMMENTS ON EQUATION (17)
*-----

*EQ (34)

BINARY_N6(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J)).. NHE_N1(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1)
\$(COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N+1,I));

*-----
*EQ (35)

BINARY_N7(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..

NHE_N1(S,Z,I,J,N)=G=0;

*-----
*EQ (36)

BINARY_N3_B(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..

Y_N_B(S,Z,I,J,N)=E=SUM(OS\$(COLD(S,J,O) AND ORD(O) LE ORD(N)
AND ALLOW_C(S,Z,J,O,I)),NHE_N0_B(S,Z,I,J,O)) - SUM(OS\$(COLD(S,J,O) AND ORD(O) LE
ORD(N)-1 AND ALLOW_C(S,Z,J,O,I)),NHE_N1_B(S,Z,I,J,O));

*-----
*EQ (37)

HE_COUNT_M0(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..

NHE(S,Z,I,J)=E=SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1),

NHE_M0_B(S,Z,I,J,M)) + SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0), NHE_M0(S,Z,I,J,M));

*-----
*

*EQ (38)

HE_COUNT_N0(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
NHE(S,Z,I,J)=E=SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1),
NHE_N0_B(S,Z,I,J,N))
+ SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0),
NHE_N0(S,Z,I,J,N));

*-----
*

*EQ (39)

HE_COUNT_M1(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
NHE(S,Z,I,J)=E=SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1),
NHE_M1_B(S,Z,I,J,M)) + SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND BIF(Z,I,J)=0), NHE_M1(S,Z,I,J,M));

*-----
*

*EQ (40)

HE_COUNT_N1(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
NHE(S,Z,I,J)=E=SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1),
NHE_N1_B(S,Z,I,J,N)) + SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=0), NHE_N1(S,Z,I,J,N));

*-----
*

*EQ (41)

NEXCH(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND BIF(Z,I,J)=0 AND FREEH(I)
AND FREEC(J)). NHE(S,Z,I,J)=L=1;

*-----
*

*EQ (42)

NEXCH_B(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND BIF(Z,I,J)=1 AND FREEH(I)
AND FREEC(J)). NHE(S,Z,I,J)=L=KMAX(Z,I,J);

*-----
*

*EQ (43)

BIF_1(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
AND ALLOW_H(S,Z,I,L,J)=1),
QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =L=
SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
+ B1(S,Z,I,M,J,N) *4* max(SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),DHH(S,I,L)),
SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N)
AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),DHC(S,J,O)));

*-----
*

*EQ (44)

BIF_2(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND
ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(I)
AND FREEC(J) AND NOT PA(I))..
SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
AND ALLOW_H(S,Z,I,L,J)=1),
QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =G=
SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
-B1(S,Z,I,M,J,N) *4* max(SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),DHH(S,I,L)),
SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O)
AND ALLOW_C(S,Z,J,O,I)),DHC(S,J,O)));

*-----
*

*EQ (45)

BIF_3(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
B1(S,Z,I,M,J,N) =E= 2 - 0.25 * SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),NHE_M1_B(S,Z,I,J,L))
+ 0.25 * SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O)
AND ALLOW_C(S,Z,J,O,I)),NHE_N1_B(S,Z,I,J,O))
-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N);

*-----
*

*EQ (46)

BIF_4(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND TL(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
SUM(L\$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND
ALLOW_H(S,Z,I,L,J)=1),NHE_M1_B(S,Z,I,J,L))
-SUM(O\$(COLD(S,I,O) AND ORD(O) LE ORD(N) AND ALLOW_C(S,Z,I,O,I)),
NHE_N1_B(S,Z,I,J,O))=G=0;

*

*EQ (47)

BIF_11(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J))..
SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M) AND ALLOW_H(S,Z,I,O,J)=1),
NHE_M0_B(S,Z,I,J,O)-NHE_M1_B(S,Z,I,J,O))=L=1 ;

*

*EQ (48)

BIF_12(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J))..
SUM(O\$(COLD(S,I,O) AND ORD(O) LE ORD(N) AND ALLOW_C(S,Z,I,O,I)),
NHE_N0_B(S,Z,I,J,O)-NHE_N1_B(S,Z,I,J,O))=L=1;

*

*EQ (49)

BIF_6(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J))..
QNEW2_M(S,Z,I,J,M) =L= QNEW_M(S,Z,I,J,M);

*

*EQ (50)

BIF_9(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW2_M(S,Z,I,J,M) =L= NHE_M0_B(S,Z,I,J,M)*DHH(S,I,M);

*

*EQ (51)

BIF_5(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW2_M(S,Z,I,J,M) =L= NHE_M1_B(S,Z,I,J,M)*DHH(S,I,M);

*

*EQ (52) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE

*

*EQ (53)

BIF_8(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J))..
QNEW2_N(S,Z,I,J,N) =L= QNEW_N(S,Z,I,J,N);

*

*EQ (54)

BIF_10(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J))..
QNEW2_N(S,Z,I,J,N) =L= NHE_N0_B(S,Z,I,J,N)*DHC(S,J,N);

*

*EQ (55)

BIF_7(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J))..
QNEW2_N(S,Z,I,J,N) =L= NHE_N1_B(S,Z,I,J,N)*DHC(S,J,N);

*

*EQ (56) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE

*

*EQ (57)

FEAS_M_01(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J))..
ALFA_M(S,Z,I,J,M)=L=1-NHE_M0(S,Z,I,J,M-1)-NHE_M0(S,Z,I,J,M);

FEAS_M_01_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
ALFA_M(S,Z,I,J,M)=L=1-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M);

*

*EQ (58)

FEAS_M_02(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J))..

$ALFA_M(S,Z,I,J,M)=L=1-NHE_M1(S,Z,I,J,M-1)-NHE_M1(S,Z,I,J,M);$
 $FEAS_M_02_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..$
 $ALFA_M(S,Z,I,J,M)=L=1-NHE_M1_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M);$
 *-----
 *EQ (59)
 $FEAS_M_03(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I)$
 $AND FREEC(J))..$
 $ALFA_M(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-NHE_M0(S,Z,I,J,M-1)-NHE_M0(S,Z,I,J,M) -$
 $NHE_M1(S,Z,I,J,M-1)-NHE_M1(S,Z,I,J,M);$
 $FEAS_M_03_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..$
 $ALFA_M(S,Z,I,J,M)=G=Y_M_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M)$
 $- NHE_M1_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M);$
 *-----
 *EQ (60)
 $FEAS_M_04(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND$
 $ALLOW_H(S,Z,I,M-1,J) AND (BIF(Z,I,J)=1 OR SPH(I)=1) AND FREEH(I) AND FREEC(J))..$
 $ALFA_M(S,Z,I,J,M)=G=0;$
 *-----
 *EQ (61)
 $FEAS_M_2(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..$
 $QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M))) =L=$
 $QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)* (TU(S,M-1)-TL(S,M-1)))$
 $+ (1-ALFA_M(S,Z,I,J,M))*DHH(S,I,M)/ (CPH(S,I,M)* (TU(S,M)-TL(S,M)));$
 *-----
 *EQ (62)
 $FEAS_M_1(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..$
 $QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M)))$
 $+ (1-ALFA_M(S,Z,I,J,M))*DHH(S,I,M) / (CPH(S,I,M)* (TU(S,M)-TL(S,M)))$
 $=G= QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)* (TU(S,M-1)-TL(S,M-1)));$
 *-----
 *EQ (63)
 $FEAS_M_3(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I)$
 $AND FREEC(J) AND NOT PA(I))..$
 $- QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)* (TU(S,M-1)-TL(S,M-1)))$
 $+ QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M)))$
 $+ (1+ NHE_M1(S,Z,I,J,M-1) + NHE_M1(S,Z,I,J,M) - NHE_M0(S,Z,I,J,M-1))$
 $*DHH(S,I,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M))) * 1.00001 =G= 0;$
 *-----
 *EQ (64)
 $FEAS_M_4(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I)$
 $AND FREEC(J) AND NOT PA(I))..$
 $- QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M)))$
 $+ QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)* (TU(S,M-1)-TL(S,M-1)))$
 $+ (1+ NHE_M0(S,Z,I,J,M-1)+NHE_M0(S,Z,I,J,M)-NHE_M1(S,Z,I,J,M))$
 $*DHH(S,I,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M))) * 1.00001 =G= 0;$
 *-----
 *EQ (65)
 $FEAS_M_3_B_2(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)$
 $AND FREEC(J) AND NOT PA(I))..$
 $QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)* (TU(S,M-1)-TL(S,M-1)))=L=$
 $QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M)))$
 $+ (1+NHE_M1_B(S,Z,I,J,M-1)+NHE_M1_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1))$
 $*DHH(S,I,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M)));$
 *-----
 *EQ (66)
 $FEAS_M_3_B_1(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)$
 $AND FREEC(J) AND NOT PA(I))..$
 $QNEW2_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)* (TU(S,M-1)-TL(S,M-1))) =L=$
 $QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M))) + (2 + NHE_M1_B(S,Z,I,J,M)$
 $-NHE_M0_B(S,Z,I,J,M-1)-Y_M_B(S,Z,I,J,M-1))$
 $*DHH(S,I,M)/(CPH(S,I,M)* (TU(S,M)-TL(S,M)));$
 *-----

*EQ (67)

FEAS_M_4_B(S,Z,I,J,M)\$ (HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND NOT PA(I))..
(QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))=L=
QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
+(2 + NHE_M0_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M))
DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));

*EQ (68)

FEAS_M_1_SP(S,Z,I,J,M)\$ (HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND SPH(I)=0
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)=G=(Y_M(S,Z,I,J,M)-
NHE_M0(S,Z,I,J,M) + NHE_M1(S,Z,I,J,M))*DHH(S,I,M);
FEAS_M_1_SP_B(S,Z,I,J,M)\$ (HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=1 AND SPH(I)=0
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)=G=(Y_M_B(S,Z,I,J,M)-
NHE_M0_B(S,Z,I,J,M)+NHE_M1_B(S,Z,I,J,M))*DHH(S,I,M);

*EQ (69)

FEAS_N_01(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=L=1-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1);
FEAS_N_01_B(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=L=1-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1);

*EQ (70)

FEAS_N_02(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=L=1-NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N-1);
FEAS_N_02_B(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=L=1-NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);

*EQ (71)

FEAS_N_03(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1)
-NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N-1);
FEAS_N_03_B(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=G=Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1)
-NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);

*EQ (72)

FEAS_N_04(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND (BIF(Z,I,J)=1 OR SPC(J)=1) AND FREEH(I)
AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=G=0;

*EQ (73)

FEAS_N_2(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=L=QNEW_N(S,Z,I,J,N-1)
/(CPC(S,J,N-1)
*(TU(S,N-1)-TL(S,N-1)))+(1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)/
(CPC(S,J,N)*(TU(S,N)-TL(S,N)));

*EQ (74)

FEAS_N_1(S,Z,I,J,N)\$ (COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,J,N,I)=1
AND ALLOW_C(S,Z,I,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+(1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)

```

/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/
(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
*-----
*EQ (75)
FEAS_N_3(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
-QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(1+NHE_N1(S,Z,I,J,N-1)
+NHE_N1(S,Z,I,J,N)
-NHE_N0(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))*1.00001=G=0;
*-----
*EQ (76)
FEAS_N_4(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
-QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+(1+NHE_N0(S,Z,I,J,N-1)
+NHE_N0(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N))*DHC(S,J,N)/
(CPC(S,J,N)*(TU(S,N)-TL(S,N)))*1.00001=G=0;
*-----
*EQ (77)
FEAS_N_3_B_2(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
-QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+(1+NHE_N1_B(S,Z,I,J,N-1)+NHE_N1_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1))
*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;
*-----
*EQ (78)
FEAS_N_3_B_1(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
-QNEW2_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(2+NHE_N1_B(S,Z,I,J,N)
-NHE_N0_B(S,Z,I,J,N-1)-Y_N_B(S,Z,I,J,N-1))
*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;
*-----
*EQ (79)
FEAS_N_4_B(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
-(QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+(2+NHE_N0_B(S,Z,I,J,N-1)-NHE_N1_B(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N))
*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;
*-----
*EQ (80)
FEAS_N_1_SP(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)AND
ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J)=0
AND SPC(J)=0 AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N)=G=
(Y_N(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N))*DHC(S,J,N);

FEAS_N_1_SP_B(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J)=1
AND SPC(J)=0 AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N)=G=
(Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N))*DHC(S,J,N);
*-----
*EQ (81)
FEAS_BEG_SP(S,Z,I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
+QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M))

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+ (2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*TU(S,N)=G=0;

FEAS_BEG_B_SP(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
TL(S,M) - TL(S,N) -QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
+ QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M))
+ (2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))*TU(S,N)=G=0;

*-----
*EQ (82)

FEAS_END_SP(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
TU(S,M)-TU(S,N)
-QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) +QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
+ (2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))*TU(S,N)=G=0;
FEAS_END_B_SP(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
TU(S,M)-TU(S,N)
-QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
+ (2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*TU(S,N)=G=0;

*-----
*EQ (83)

FEAS_BEG3(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M)
AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
NHE_N1(S,Z,I,J,N)=L=(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N));

*-----
*EQ (84)

FEAS_BEG(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND D(S,Z,M,N)=1
AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)
/(TU(S,N+1)-TL(S,N+1))*CPC(S,J,N)/CPC(S,J,N+1)
+ (2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*DHC(S,J,N)/(TU(S,M)-TL(S,N));

*-----
*EQ (85)

FEAS_BEG2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1)
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1)
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=
QNEW_M(S,Z,I,J,M+1)/(TU(S,M+1)-TL(S,M+1))
*CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))
*DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));

*-----
*EQ (86)

FEAS_END3(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M)
AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1 AND COLD(S,J,N-1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I)
AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
NHE_M0(S,Z,I,J,M)=L=(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N));

*-----
*EQ (87)

FEAS_END(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)

AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,I,N-1,I) AND BIF(Z,I,J)=0
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 QNEW_M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW_M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))
 *CPH(S,I,M)/CPH(S,I,M-1)+(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))
 *DHH(S,I,M)/(TU(S,M)-TL(S,N));

*EQ (88)

FEAS_END2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,I,N,I)=1 AND ALLOW_C(S,Z,I,N-1,I) AND BIF(Z,I,J)=0
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 QNEW_N(S,Z,I,J,N)/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/
 (TU(S,N-1)-TL(S,N-1))
 *CPC(S,J,N)/CPC(S,J,N-1)-(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))
 *DHC(S,J,N-1)/(TU(S,N-1)-TL(S,N-1));

*EQ (89)

FEAS_BEG4_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M)
 AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I)
 AND BIF(Z,I,J)=1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 NHE_NI_B(S,Z,I,J,N)=L=
 (1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N));

*EQ (90)

FEAS_BEG2_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=
 QNEW_N(S,Z,I,J,N+1)/(TU(S,N+1)-TL(S,N+1))
 *CPC(S,J,N)/CPC(S,J,N+1)+
 (1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
 *DHC(S,J,N)/(TU(S,M)-TL(S,N));

*EQ (91)

FEAS_BEG1_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
 AND ALLOW_C(S,Z,I,N,I)=1 AND ALLOW_C(S,Z,I,N+1,I) AND BIF(Z,I,J)=1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 QNEW2_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)/
 (TU(S,N+1)-TL(S,N+1))
 *CPC(S,J,N)/CPC(S,J,N+1)+(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
 *DHC(S,J,N)/(TU(S,M)-TL(S,N));

*EQ (92)

FEAS_BEG3_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
 AND ALLOW_C(S,Z,I,N,I)=1 AND ALLOW_C(S,Z,I,N+1,I) AND BIF(Z,I,J)=1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=QNEW_M(S,Z,I,J,M+1)/
 (TU(S,M+1)-TL(S,M+1))
 *CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
 *DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));

*EQ (93)

FEAS_END3_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M)
 AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1 AND COLD(S,J,N-1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_C(S,Z,J,N,I) AND ALLOW_C(S,Z,J,N-1,I)
 AND BIF(Z,I,J)=1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 NHE_M0_B(S,Z,I,J,M)=L=
 (1+Y_M_B(S,Z,I,J,M)-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N));

*EQ (94)

FEAS_END_B(S,Z,I,J,M,N) $\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N-1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } ALLOW_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I))..$
 $(QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L=$
 $QNEW_M(S,Z,I,J,M-1)/$
 $(TU(S,M-1)-TL(S,M-1))*CPH(S,I,M)/CPH(S,I,M-1)+$
 $(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHH(S,I,M)/(TU(S,M)-TL(S,N));$

*EQ (95)

FEAS_END2_B(S,Z,I,J,M,N) $\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N-1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } ALLOW_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $(QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(TU(S,N)-\text{MAX}(TL(S,M),TL(S,N)))=G=$
 $QNEW_N(S,Z,I,J,N-1)/(TU(S,N-1)-TL(S,N-1))*CPC(S,J,N)/CPC(S,J,N-1)$
 $-(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHC(S,J,N-1)/$
 $(TU(S,N-1)-TL(S,N-1));$

*EQ (96)

PAREQ(S,Z,I,J) $\$(ALLOW(S,Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $PAR(Z,I,J)=E=\text{SUM}((M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1$
 $\text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1),$
 $Q(S,Z,I,M,J,N)/(U(S,I,J)*LMTD(S,M,N)));$

*EQ (97)

BIF_13_2(S,K,Z,I,J,M) $\$(ORD(K) \text{ LT } KMAX(Z,I,J) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } ALLOW_H(S,Z,I,M,J)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $PAR_B(K,Z,I,J)=L=\text{SUM}((L,N)\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M)$
 $\text{ AND } TL(S,N) \text{ LT } TU(S,L)$
 $\text{ AND } HOT(S,I,L)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,L,J)=1$
 $\text{ AND } ALLOW_C(S,Z,J,N,I)=1),$
 $(Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))/(U(S,I,J)*LMTD(S,L,N))$
 $+AMAX*(2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,I,J,M)-$
 $\text{SUM}(KK\$(ORD(KK) \text{ GT } 1 \text{ AND } ORD(KK) \text{ LT } ORD(K)),X_B(S,KK,Z,I,J,M))));$

*Comment: In the paper X1_B does not show. Only one variable, X_B is used

* to make summations from 1 to kmax-1. Here we use X1_B and then a

* summation from 2 to kmax-1. See equation (100) as well.

*EQ (98)

BIF_13_1(S,K,Z,I,J,M) $\$(ORD(K) \text{ LT } KMAX(Z,I,J) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } ALLOW_H(S,Z,I,M,J)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $PAR_B(K,Z,I,J)=G=\text{SUM}((L,N)\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M)$
 $\text{ AND } TL(S,N) \text{ LT } TU(S,L)$
 $\text{ AND } HOT(S,I,L)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,L,J)=1$
 $\text{ AND } ALLOW_C(S,Z,J,N,I)=1),$
 $(Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))/(U(S,I,J)*LMTD(S,L,N))$
 $-AMAX*(2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,I,J,M)-$
 $\text{SUM}(KK\$(ORD(KK) \text{ GT } 1 \text{ AND } ORD(KK) \text{ LT } ORD(K)),X_B(S,KK,Z,I,J,M))));$

*EQ (99)

BIF_14(S,K,Z,I,J) $\$(ORD(K) \text{ EQ } KMAX(Z,I,J) \text{ AND } ALLOW(S,Z,I,J)=1 \text{ AND } FREEH(I)$
 $\text{ AND } FREEC(J) \text{ AND } BIF(Z,I,J)=1)..$
 $PAR_B(K,Z,I,J)=E=PAR(Z,I,J)-\text{SUM}(KK\$(ORD(KK) \text{ LT } ORD(K)),PAR_B(KK,Z,I,J));$

*EQ (100)

BIF_15(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=1$
 $\text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $X1_B(S,Z,I,J,M)+\text{SUM}(K\$(ORD(K) \text{ GT } 1 \text{ AND } ORD(K) \text{ LE } KMAX(Z,I,J)),$
 $ORD(K)*X_B(S,K,Z,I,J,M))=E=\text{SUM}(L\$(HOT(S,I,L)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND}$
 $\text{ ALLOW_H(S,Z,I,L,J)=1),NHE_M0_B(S,Z,I,J,L))+1-Y_M_B(S,Z,I,J,M);$

*Comment: In the paper X1_B does not show. Only one variable, X_B is used

* to make summations from 1 to kmax-1. Here we use X1_B and then a

* summation from 2 to kmax-1.

*EQ (101)

BIF_17(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J))..
SUM(N\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1 AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1), Q2(S,Z,I,M,J,N))=E=
QNEW2_M(S,Z,I,J,M);

*EQ (102)

BIF_18(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
Q2(S,Z,I,M,J,N)=L=Q(S,Z,I,M,J,N);

*EQ (103)

SHELL(Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR(Z,I,J)=L=ASHELLMAX*USHELL(Z,I,J);

*EQ (104)

SHELL_B(K,Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1)..
PAR_B(K,Z,I,J)=L=ASHELLMAX*USHELL_B(K,Z,I,J);

*EQ (105)

*TOTALCOST.. TCOST=E= SUM(I\$(HU(I) AND FREEH(I)), CHU(I)*FHU(I)*DTHU(I))
* + SUM(J\$(CU(J) AND FREEC(J)), CCU(J)*FCU(J)*DTCU(J))
* + SUM((Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
* AND BIF(Z,I,J)=0), CF*USHELL(Z,I,J))
* + SUM((K,Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
* AND BIF(Z,I,J)=1), CF*USHELL_B(K,Z,I,J))
* + SUM((Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)),
* CA*PAR(Z,I,J))
* + Cost_side_stripping_steam ;

TOTALCOST.. TCOST=E=SUM(I\$(HU(I) AND FREEH(I)), CHU(I)*FHU(I)*DTHU(I))
+SUM(J\$(CU(J) AND FREEC(J)), CCU(J)*FCU(J)*DTCU(J))
+SUM((S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)\$ (NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)))
+SUM((S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0), CAE*DPAR_E(Z,I,J)+CAN*PAR_N(S,Z,I,J))
+SUM((S,K,Z,I,J)\$ (ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)
CAE*DPAR_E_B(K,Z,I,J)+CAN*PAR_N_B(K,Z,I,J))+Cost_side_stripping_steam;

* Here we have an equation that is made simpler than in the paper. We account
* for the total area of the exchangers (use PAR and not PAR_B).
* The result is the same.

*EQ (106) CONSISTENCY: Number of exchangers smaller than the number of shells

* Needed because the exchangers are related to the values of K.

KMAX1(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=0)..
NHE(S,Z,I,J)=L= USHELL(Z,I,J) ;

*EQ (107)

KMAX2(S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
NHE(S,Z,I,J)=L= SUM(K, USHELL_B(K,Z,I,J)) ;

* EXTRA EQUATIONS NOT IN PAPER BUT NEEDED

*EQ (108) LIMIT THE NUMBER OF EXCHANGERS

TOTNEXCH_MAX(S).. SUM((Z,I,J)\$ (ALLOW(S,Z,I,J)= 1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=L=TOTNEXCHMAX;

*EQ (109) MINIMUM NUMBER OF EXCHANGERS

TOTNEXCH_MIN(S).. SUM((Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=G=TOTNEXCHMIN;

*Equation for Retrofit

*EQ(Retrofit 1)

AREA_REST1(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..

PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,I,J);

*EQ(Retrofit 2)

AREA_REST2(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..

DPAR_E(Z,I,J)=L=AEX_U(Z,I,J)-AEX(Z,I,J);

*EQ(Retrofit 3)

AREA_REST3(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..

PAR_N(S,Z,I,J)=L=A_NEW_MAX(Z,I,J) *(NHE(S,Z,I,J)- NHE0(S,Z,I,J));

*EQ(Retrofit 4)

AREA_REST4(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..

(NHE(S,Z,I,J))=L= TOTNEXCHMAX ;

*EQ(Retrofit 5)

AREA_REST5(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0 AND NHE0(S,Z,I,J)= 0)..

PAR_N(S,Z,I,J)=L= A_NEW_MAX(Z,I,J)* (NHE(S,Z,I,J));

*EQ(Retrofit 6)

*Eq retrofit 6 is same as Eq retrofit 5

*EQ(Retrofit 7)

AREA_REST7(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0 AND NHE0(S,Z,I,J)= 0)..

(NHE(S,Z,I,J))=L= TOTNEXCHMAX ;

*EQ(Retrofit 8)

AREA_REST1_B(S,K,Z,I,J)\$(ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..

PAR_B(K,Z,I,J)=L=SUM(KK\$(ORD(KK) LE NHE0(S,Z,I,J)),AEX_B(KK,Z,I,J)
*DELTA(KK,K))+DPAR_E_B(K,Z,I,J)+PAR_N_B(K,Z,I,J);

*EQ(Retrofit 9)

AREA_REST2_B(S,K,Z,I,J)\$(ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..

DPAR_E_B(K,Z,I,J)=L=SUM(KK\$(ORD(KK) LE NHE0(S,Z,I,J)),(AEX_U_B(KK,Z,I,J)
-AEX_B(KK,Z,I,J))*DELTA(KK,K));

*EQ(Retrofit 10)

AREA_REST3_B(S,K,Z,I,J)\$(ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..

PAR_N_B(K,Z,I,J)=L=A_NEW_MAX(Z,I,J)
*(1-SUM(KK\$(ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K)));

*EQ(Retrofit 11)

AREA_REST4_B(S,K,Z,I,J)\$(ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..

SUM(KK\$(ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K))=L=1;

*EQ(Retrofit 12)

AREA_REST5_B(S,K,Z,I,J)\$(ORD(K) LE NHE0(S,Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..

SUM(KK\$(ORD(KK) LE KMAX(Z,I,J)),DELTA(K,K))=L=1;

*EQ(Retrofit 13)

AREA_REST6_B(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I)
AND FREEC(J) AND BIF(Z,I,J)=1)..

SUM((K,KK)\$(ORD(K) LE KMAX(Z,I,J) AND ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K))
=E= NHE0(S,Z,I,J);

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*-----
*EQ(Retrofit 14)
LIM_HEX(S,M)..

SUM((Z,I,J)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1), (NHE(S,Z,I,J))-NHE0(S,Z,I,J))
=L= MAX_NEW_HEX ;
*-----

*Add Eq for PA
*-----
*EQ (3_b)
PA_1(S,I,M)$ (HOT(S,I,M)=1 AND NOT HU(I) AND
FREEH(I) AND NIH(I)=0 AND PA(I))..
FP(I)*CPH(S,I,M)*(TU(S,M)-TL(S,M)) =E=SUM((Z,N,J)$ (D(S,Z,M,N)=1
AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1).Q(S,Z,I,M,J,N));
*-----
*EQ (7_b)
PA_2(S,I,M)$ (HOT(S,I,M)=1 AND NOT HU(I)
AND FREEH(I) AND NIH(I)=1 AND PA(I))..
FP(I)*CPH(S,I,M)*(TU(S,M)-TL(S,M)) =E= SUM((Z,N,J)$ (D(S,Z,M,N)=1
AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1).Q(S,Z,I,M,J,N))
+SUM((Z,N)$ (D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) GT ORD(M)),QH(S,Z,I,N,M))
-SUM((Z,N)$ (D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N));
*-----
*EQ 11_b Case of BIF(I,J)=0 (i,j) not belonging to set B
PA_3(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J) AND PA(I)) ..
QNEW_M(S,Z,I,J,M)-FPY(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M))$ (NOT HU(I))=L=0;
*-----
*EQ 11_b Case of BIF(I,J)=0 (i,j) not belonging to set B
***** MINIMUM VALUE OF QNEW_M=0.01!!!!!!!!!!!!
PA_4(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0 AND
FREEH(I) AND FREEC(J) AND PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*QLHMIN=G=0;
*-----
*EQ 11_b Case of BIF(I,J)=1 (i,j) belonging to set B
PA_3_B(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))..
QNEW_M(S,Z,I,J,M)-FPY_B(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M))$ (NOT HU(I))=L=0;
*-----
*EQ 11_b Case of BIF(I,J)=1 (i,j) belonging to set B
PA_4_B(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN =G= 0;
*-----
*EQ 11_C_1
PA_5(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J) AND PA(I))..
FPY(S,Z,I,J,M) =E= SUM(R, (FPR(I,R)*YW(S,Z,I,J,M)));
*-----
*EQ 11_C_2
PA_6(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))..
FPY_B(S,Z,I,J,M) =E= SUM(R, (FPR(I,R)*YW(S,Z,I,J,M)));
*-----
*EQ 11_D
PA_7(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))..
YW(S,Z,I,J,M)-Y_M(S,Z,I,J,M) =L= 0;
*-----
*EQ 11_E
PA_8(S,Z,I,J,M,R)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))..
YW(S,Z,I,J,M) =L= W(I,R);
*-----
*EQ 11_F
PA_9(S,Z,I,J,M,R)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))..
YW(S,Z,I,J,M) =G= Y_M(S,Z,I,J,M)+ W(I,R)-1;

```

 *EQ (43_b)
 PA_10(S,Z,I,J,M,N) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I))..$
 $SUM(I\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND } HOT(S,I,L)=1$
 $\text{ AND } ALLOW_H(S,Z,I,L,J)=1),$
 $QNEW_M(S,Z,I,J,L) - QNEW2_M(S,Z,I,J,M) =L=$
 $SUM(O\$(D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N) \text{ AND } COLD(S,J,O) \text{ AND } ALLOW_C(S,Z,J,O,I),$
 $QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)+ 4 *XM(S,Z,I,M,J,N);$

 *EQ 43_C
 PA_11(S,Z,I,J,M,N) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I))..$
 $XM(S,Z,I,M,J,N)-(TE(S,Z,I,M,J,N)*OMEGA(S,Z,I,M,J,N))=L=SUM(R,(XW(S,Z,I,M,J,N,R)*$
 $FPR(I,R)*SUM(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M)$
 $\text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW_H(S,Z,I,L,J)=1),(CPH(S,I,L)*(TU(S,L)-TL(S,L)))));$

 *EQ 43_D
 PA_12(S,Z,I,J,M,N) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I))..$
 $XM(S,Z,I,M,J,N)-(TE(S,Z,I,M,J,N)*OMEGA(S,Z,I,M,J,N))=G=SUM(R,(XW(S,Z,I,M,J,N,R)*$
 $FPR(I,R)*SUM(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M)$
 $\text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW_H(S,Z,I,L,J)=1),(CPH(S,I,L)*(TU(S,L)-TL(S,L)))));$

 *EQ 43_E
 PA_13(S,Z,I,J,M,N) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I))..$
 $XM(S,Z,I,M,J,N)-((1-TE(S,Z,I,M,J,N))*OMEGA(S,Z,I,M,J,N))=L=B1(S,Z,I,M,J,N)*$
 $SUM(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(N)$
 $\text{ AND } COLD(S,J,L)=1 \text{ AND } ALLOW_C(S,Z,J,L,I)=1),DHC(S,J,L));$

 *EQ 43_F
 PA_14(S,Z,I,J,M,N) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I))..$
 $XM(S,Z,I,M,J,N)=G= B1(S,Z,I,M,J,N)*SUM(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(N)$
 $\text{ AND } COLD(S,J,L)=1 \text{ AND } ALLOW_C(S,Z,J,L,I)=1),DHC(S,J,L));$

 *EQ 43_G
 PA_15(S,Z,I,J,M,N,R) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I))..$
 $XW(S,Z,I,M,J,N,R)-(T(S,Z,I,M,J,N)*W(I,R)) =L= 0 ;$

 *EQ 43_H
 PA_16(S,Z,I,J,M,N,R) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I))..$
 $(B1(S,Z,I,M,J,N)- XW(S,Z,I,M,J,N,R))-(1-W(I,R))*T(S,Z,I,M,J,N) =L= 0 ;$

 *EQ 43_I
 PA_17(S,Z,I,J,M,N,R) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1$
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I))..$
 $(B1(S,Z,I,M,J,N)- XW(S,Z,I,M,J,N,R)) =G= 0 ;$

 *EQ (44_b)
 PA_18(S,Z,I,J,M,N) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ..$

ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(I)
 AND FREEC(J) AND PA(I)..
 SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
 AND ALLOW_H(S,Z,I,L,J)=1),
 QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =G=
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)).
 QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
 -4*XM(S,Z,I,M,J,N);

 *EQ (50_b)
 PA_19(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW2_M(S,Z,I,J,M) =L= FPK_H_0(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M));

 *EQ 50_C
 PA_20(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..

FPK_H_0(S,Z,I,J,M) =E= SUM(R,(FPR(I,R)*KW_0(S,Z,I,J,M,R)));

 *EQ 50_D
 PA_21(S,Z,I,J,M,R)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..

KW_0(S,Z,I,J,M,R)- NHE_M0_B(S,Z,I,J,M) =L= 0;

 *EQ 50_E
 PA_22(S,Z,I,J,M,R)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..

KW_0(S,Z,I,J,M,R) =L= W(I,R);

 *EQ 50_F
 PA_23(S,Z,I,J,M,R)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..

KW_0(S,Z,I,J,M,R) =G= NHE_M0_B(S,Z,I,J,M) + W(I,R) - 1;

 *EQ (51_b)
 PA_24(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW2_M(S,Z,I,J,M) =L= FPK_H_1(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M));

 *EQ 51_C
 PA_25(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..

FPK_H_1(S,Z,I,J,M) =E= SUM(R,(FPR(I,R)*KW_1(S,Z,I,J,M,R)));

 *EQ 51_D
 PA_26(S,Z,I,J,M,R)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..

KW_1(S,Z,I,J,M,R)- NHE_M1_B(S,Z,I,J,M) =L= 0;

 *EQ 51_E
 PA_27(S,Z,I,J,M,R)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..

KW_1(S,Z,I,J,M,R) =L= W(I,R);

 *EQ 51_F
 PA_28(S,Z,I,J,M,R)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..

KW_1(S,Z,I,J,M,R) =G= NHE_M1_B(S,Z,I,J,M) + W(I,R) - 1;

 *EQ (61_b)
 PA_29(S,Z,I,J,M)\$ (HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

$$\begin{aligned} & QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) = L = \\ & QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))) \\ & + (FP(I)-FPA(S,Z,I,J,M)); \end{aligned}$$

*EQ 61_C

$$\begin{aligned} & PA_30(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I)). \end{aligned}$$

$$FPA(S,Z,I,J,M) = E = \text{SUM}(R, (FPR(I,R)*WA(S,Z,I,J,M,R)));$$

*EQ 61_D

$$\begin{aligned} & PA_31(S,Z,I,J,M,R)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I)). \end{aligned}$$

$$WA(S,Z,I,J,M,R) - ALFA_M(S,Z,I,J,M) = L = 0;$$

*EQ 61_E

$$\begin{aligned} & PA_32(S,Z,I,J,M,R)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I)). \end{aligned}$$

$$WA(S,Z,I,J,M,R) = L = W(I,R);$$

*EQ 61_F

$$\begin{aligned} & PA_33(S,Z,I,J,M,R)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I)). \end{aligned}$$

$$WA(S,Z,I,J,M,R) = G = ALFA_M(S,Z,I,J,M) + W(I,R) - 1;$$

*EQ (62_b)

$$\begin{aligned} & PA_34(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I)). \end{aligned}$$

$$\begin{aligned} & QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) \\ & + (FP(I)-FPA(S,Z,I,J,M)) \\ & = G = QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))); \end{aligned}$$

*EQ (63_b)

$$\begin{aligned} & PA_35(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I) \\ & AND FREEC(J) AND PA(I)). \\ & - QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))) \\ & + QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) \\ & + (FP(I)+FPK_H_1(S,Z,I,J,M-1)+FPK_H_1(S,Z,I,J,M)-FPK_H_0(S,Z,I,J,M-1)) = G = 0; \end{aligned}$$

*EQ (64_b)

$$\begin{aligned} & PA_36(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I) \\ & AND FREEC(J) AND PA(I)). \\ & - QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) \\ & + QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))) \\ & + (FP(I)+FPK_H_0(S,Z,I,J,M-1)+FPK_H_0(S,Z,I,J,M)-FPK_H_1(S,Z,I,J,M)) = G = 0; \end{aligned}$$

*EQ (65_b)

$$\begin{aligned} & PA_37(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I) \\ & AND FREEC(J) AND PA(I)). \\ & QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))) = L = \\ & QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) \\ & + (FP(I)+FPK_H_1(S,Z,I,J,M-1)+FPK_H_1(S,Z,I,J,M)-FPK_H_0(S,Z,I,J,M-1)); \end{aligned}$$

*EQ (66_b)

$$\begin{aligned} & PA_38(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I) \\ & AND FREEC(J) AND PA(I)). \\ & QNEW2_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))) = L = \\ & QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) \\ & + ((2*FP(I)+FPK_H_1(S,Z,I,J,M)-FPK_H_0(S,Z,I,J,M-1)-FPY(S,Z,I,J,M-1))); \end{aligned}$$

*EQ (67_b)

$$\begin{aligned} & PA_39(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 \\ & AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I) \end{aligned}$$

AND FREEC(J) AND PA(I)..
 (QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) =L=
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +((2*FP(I))+FPK_H_0(S,Z,I,J,M-1)-FPK_H_1(S,Z,I,J,M)-FPY(S,Z,I,J,M-1));
 *-----
 *EQ (68_b)
 PA_40(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND SPH(I)=0
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)=G=(FPY(S,Z,I,J,M)-FPK_H_0(S,Z,I,J,M)-FPK_H_1(S,Z,I,J,M))
 (CPH(S,I,M)(TU(S,M)-TL(S,M)));

 PA_41(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=1 AND SPH(I)=0
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)=G=(FPY_B(S,Z,I,J,M)-FPK_H_0_B(S,Z,I,J,M)
 -FPK_H_1_B(S,Z,I,J,M))*(CPH(S,I,M)*(TU(S,M)-TL(S,M)));
 *-----
 *EQ (81_b)
 PA_42(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..
 TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
 + (FPQ(S,Z,I,J,M)/CPH(S,I,M))
 + (2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*TU(S,N)=G=0;

 PA_43(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..
 TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
 + (FPQ(S,Z,I,J,M)/CPH(S,I,M))
 + (2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))*TU(S,N)=G=0;
 *-----
 *EQ 81_C
 PA_44(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..

 FPQ(S,Z,I,J,M) =E= SUM(R,WQ(S,Z,I,J,M,R)/FPR(I,R)) ;
 *-----
 *EQ 81_D
 PA_45(S,Z,I,J,M,N,R)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..

 WQ(S,Z,I,J,M,R)-(T(S,Z,I,M,J,N)*W(I,R)) =L= 0 ;
 *-----
 *EQ 81_E
 PA_46(S,Z,I,J,M,N,R)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..

 (QNEW_M(S,Z,I,J,M) - WQ(S,Z,I,J,M,R))-(1-W(I,R))*T(S,Z,I,M,J,N) =L= 0 ;
 *-----
 *EQ 81_F
 PA_47(S,Z,I,J,M,N,R)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..

 QNEW_M(S,Z,I,J,M) - WQ(S,Z,I,J,M,R) =G= 0;
 *-----
 *EQ (82_b)
 PA_48(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)

AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J)=0
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I)..
 TU(S,M)-TU(S,N)

-(FPQ(S,Z,I,J,M)/CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
 +(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))*TU(S,N)=G=0;
 PA_49(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J)=1
 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I)..
 TU(S,M)-TU(S,N)
 -(FPQ(S,Z,I,J,M)/CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
 +(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*TU(S,N)=G=0;

*-----
 *EQ (85_b)

PA_50(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1)
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,I,N,I)=1
 AND ALLOW_C(S,Z,I,N+1,I) AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1)
 AND FREEH(I) AND FREEC(J) AND PA(I)..
 QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M), TU(S,N))-TL(S,M))=G=
 QNEW_M(S,Z,I,J,M+1)/(TU(S,M+1)-TL(S,M+1))
 *CPH(S,I,M)/CPH(S,I,M+1)-((2*FP(I))-FPK_H_0(S,Z,I,J,M)-FPK_C_0(S,Z,I,J,N))
 CPH(S,I,M+1)(TU(S,M+1)-TL(S,M+1))/(TU(S,M+1)-TL(S,M+1));

*-----
 *EQ (87_b)

PA_51(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,I,N,I)=1 AND ALLOW_C(S,Z,I,N-1,I) AND BIF(Z,I,J)=0
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(I)..
 QNEW_M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW_M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))
 *CPH(S,I,M)/CPH(S,I,M-1)+((2*FP(I))-FPK_H_1(S,Z,I,J,M)-FPK_C_1(S,Z,I,J,N))
 CPH(S,I,M)(TU(S,M)-TL(S,M))/(TU(S,M)-TL(S,M));

*-----
 *EQ (92_b)

PA_52(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
 AND ALLOW_C(S,Z,I,N,I)=1 AND ALLOW_C(S,Z,I,N+1,I) AND BIF(Z,I,J)=1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(I)..
 QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M), TU(S,N))-TL(S,M))=G=QNEW_M(S,Z,I,J,M+1)/
 (TU(S,M+1)-TL(S,M+1))
 *CPH(S,I,M)/CPH(S,I,M+1)-((2*FP(I))-FPK_H_0(S,Z,I,J,M)-FPK_C_0(S,Z,I,J,N))
 CPH(S,I,M+1)(TU(S,M+1)-TL(S,M+1))/(TU(S,M+1)-TL(S,M+1));

*-----
 *EQ (94_b)

PA_53(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,I,N,I)=1 AND ALLOW_C(S,Z,I,N-1,I) AND BIF(Z,I,J)=1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(I)..
 (QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L=
 QNEW_M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))*CPH(S,I,M)/CPH(S,I,M-1)
 +((2*FP(I))-FPK_H_1(S,Z,I,J,M)-FPK_C_1(S,Z,I,J,N))*CPH(S,I,M)
 *(TU(S,M)-TL(S,M))/(TU(S,M)-TL(S,M));

*-----
 *EQ (XX_1)

PA_54(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND NOT SPH(I) AND
 FREEH(I) AND PA(I)..

FP(I) =E= SUM(R, FPR(I,R)*W(I,R));

*-----
 *EQ (XX_2)

PA_55(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND NOT SPH(I) AND
 FREEH(I) AND PA(I)..

SUM(R, W(I,R)) =E= 1 ;

*-----


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*EQ (XX_3)
PA_56(S,Z,I,J)$(NOT SPH(I) AND
FREEH(I) AND PA(I)).

QPA(I) =E= SUM(M,FP(I)*CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*-----
*The summation of each pump around duty is not exactly equal Total_QPA but It is
*nearly equal, so The eq 63and 66 are added
*
*EQ (XX_4)
*PA_57 ..

SUM(I,QPA(I)$PA(I)) =E= TOTAL_QPA;
*-----
PA_58..
PA1 =E= SUM(I,QPA(I)$(ORD(I)=2));
*-----
PA_59..
PA2 =E= SUM(I,QPA(I)$(ORD(I)=4));
*-----
PA_60..
PA3 =E= SUM(I,QPA(I)$(ORD(I)=6));
*-----
* Find the relation between side stripping steam and Pump around duty by using
* the model from regression.
PA_61(S,Z,I,J,M)$(HOT(S,I,M)=1 AND NOT SPH(I) AND FREEH(I))..
SST(I) =E= (A_1(I)*PA1)+(B_1(I)*PA2)+(C_1(I)*PA3)+D_1(I);
*-----
PA_62..
Cost_side_stripping_steam =E= SUM(I,(CSS(I)*SST(I)));
*-----
PA_63 ..
TOTAL_Q =G= TOTAL_QPA_MIN;
*-----
PA_64 ..
TOTAL_Q =L= TOTAL_QPA_MAX;
*-----
PA_65 ..
TOTAL_QPA_MIN =E= TOTAL_QPA-(TOTAL_QPA*0.001);
*-----
PA_66 ..
TOTAL_QPA_MAX =E= TOTAL_QPA+(TOTAL_QPA*0.001);
*-----
PA_67 ..
SUM(I,QPA(I)$PA(I)) =E= TOTAL_Q;
*-----
PA_68(S,Z,I,J)$(NOT SPH(I) AND
FREEH(I) AND PA(I)).

Cp_Dt(I) =E= SUM(M,CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*-----
MODEL MPERIOD /ALL/ ;

OPTION LIMROW =0;
OPTION LIMCOL =0;
OPTION SOLPRINT = OFF;
OPTION OPTCR=0 ;
OPTION OPTCA=0 ;
OPTION ITERLIM = 1000000000;
OPTION RESLIM = 1000000;
MPERIOD.OPTFILE = 1;

SOLVE MPERIOD USING MIP MINIMIZING TCOST ;

PARAMETER QMATCH(S,Z,I,J);
QMATCH(S,Z,I,J)=SUM((M,N)$(I(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND D(S,Z,M,N)=1
AND COLD(S,J,N) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
Q.L(S,Z,I,M,J,N));

PARAMETER FH_H(S,Z,I,J,M) Flowrate of hot stream per HEX;
FH_H(S,Z,I,J,M)$(HOT(S,I,M))=QNEW_M.L(S,Z,I,J,M)/[(TU(S,M)-TL(S,M))*CPH(S,I,M)];

```

PARAMETER FC_C(S,Z,I,M) Flowrate of hot stream per HEx;
 FC_C(S,Z,I,M)\$[COLD(S,J,M)]=QNEW_N.L(S,Z,I,J,M)/[(TU(S,M)-TL(S,M))*CPC(S,J,M)];

PARAMETER NHE2(S,Z,I,J);
 NHE2(S,Z,I,J)= NHE.L(S,Z,I,J);

PARAMETER AREA_COST;
 AREA_COST = SUM((S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
 ,CF*(NHE.L(S,Z,I,J)+NHE_S.L(S,Z,I,J)\$ (NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)))
 +SUM((S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J)=0),CAE*DPAR_E.L(Z,I,J)+CAN*PAR_N.L(S,Z,I,J))
 +SUM((S,K,Z,I,J)\$ (ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)
 ,CAE*DPAR_E_B.L(K,Z,I,J)+CAN*PAR_N_B.L(K,Z,I,J));

PARAMETER UTILITY_COST;
 UTILITY_COST = SUM(I\$(HU(I) AND FREEH(I)),CHU(I)*FHU.L(I)*DTHU(I))
 +SUM(J\$(CU(J) AND FREEC(J)),CCU(J)*FCU.L(J)*DTCU(J));

OPTION UTILITY_COST:3:0:1; DISPLAY UTILITY_COST;
 OPTION AREA_COST:3:0:1; DISPLAY AREA_COST;
 OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
 OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
 OPTION PAR_B:3:0:1; DISPLAY PAR_B.L;
 OPTION DPAR_E_B:3:0:1; DISPLAY DPAR_E_B.L;
 OPTION PAR_N_B:3:0:1; DISPLAY PAR_N_B.L;
 OPTION Q:3:0:1; DISPLAY Q.L;
 OPTION PAR:3:0:1; DISPLAY PAR.L;
 OPTION QMATCH:3:0:1; DISPLAY QMATCH;
 OPTION FHU:3:0:1; DISPLAY FHU.L;
 OPTION FCU:3:0:1; DISPLAY FCU.L;

OPTION TU:3:0:1; DISPLAY TU;
 OPTION TL:3:0:1; DISPLAY TL;
 OPTION Cp_Dt:3:0:1; DISPLAY Cp_Dt.L;
 OPTION TOTAL_Q:3:0:1; DISPLAY TOTAL_Q.L;
 OPTION PA1:3:0:1; DISPLAY PA1.L;
 OPTION PA2:3:0:1; DISPLAY PA2.L;
 OPTION PA3:3:0:1; DISPLAY PA3.L;
 OPTION Cst_side_stripping_steam:3:0:1; DISPLAY Cost_side_stripping_steam.L;
 OPTION SST:3:0:1; DISPLAY SST.L;
 OPTION QPA:3:0:1; DISPLAY QPA.L;
 OPTION W:3:0:1; DISPLAY W.L;
 OPTION FPR:3:0:1; DISPLAY FPR;
 OPTION FP:3:0:1; DISPLAY FP.L;
 OPTION DHH:3:0:1; DISPLAY DHH;
 OPTION DHC:3:0:1; DISPLAY DHC;
 OPTION HHEAD:3:2:1; DISPLAY HHEAD;
 OPTION CHEAD:3:2:1; DISPLAY CHEAD;
 OPTION ALLOW:3:0:1; DISPLAY ALLOW;
 OPTION ALLOW_H:3:0:1; DISPLAY ALLOW_H;
 OPTION ALLOW_C:3:0:1; DISPLAY ALLOW_C;
 OPTION ALLOW_2:2:0:1; DISPLAY ALLOW_2;
 OPTION QNEW_M:3:0:1; DISPLAY QNEW_M.L;
 OPTION QNEW_N:3:0:1; DISPLAY QNEW_N.L;
 OPTION QNEW2_M:3:0:1; DISPLAY QNEW2_M.L;
 OPTION QNEW2_N:3:0:1; DISPLAY QNEW2_N.L;
 OPTION Y_M:3:0:1; DISPLAY Y_M.L;
 OPTION Y_N:3:0:1; DISPLAY Y_N.L;
 OPTION NHE_M0:3:0:1; DISPLAY NHE_M0.L;
 OPTION NHE_M1:3:0:1; DISPLAY NHE_M1.L;
 OPTION NHE_N0:3:0:1; DISPLAY NHE_N0.L;
 OPTION NHE_N1:3:0:1; DISPLAY NHE_N1.L;
 OPTION Y_M_B:3:0:1; DISPLAY Y_M_B.L;
 OPTION Y_N_B:3:0:1; DISPLAY Y_N_B.L;
 OPTION NHE_M0_B:3:0:1; DISPLAY NHE_M0_B.L;
 OPTION NHE_M1_B:3:0:1; DISPLAY NHE_M1_B.L;
 OPTION NHE_N0_B:3:0:1; DISPLAY NHE_N0_B.L;
 OPTION NHE_N1_B:3:0:1; DISPLAY NHE_N1_B.L;
 OPTION ALFA_M:3:0:1; DISPLAY ALFA_M.L;

OPTION ALFA_N:3:0:1; DISPLAY ALFA_N.L;
OPTION NHE:3:0:1; DISPLAY NHE.L;
OPTION QH:3:0:1; DISPLAY QH.L;
OPTION QC:3:0:1; DISPLAY QC.L;
OPTION X1_B:3:0:1; DISPLAY X1_B.L;
OPTION X_B:3:0:1; DISPLAY X_B.L;
OPTION Q2:3:0:1; DISPLAY Q2.L;
OPTION NHE2:3:0:1; DISPLAY NHE2;
OPTION PAR_B:3:0:1; DISPLAY PAR_B.L;
OPTION FH_H:3:0:1; DISPLAY FH_H;
OPTION FC_C:3:0:1; DISPLAY FC_C;
OPTION LMTD:3:0:1; DISPLAY LMTD;

Appendix D Programming Model for Retrofit with Relocation Apply for Crude Fractionation Unite

\$TITLE HEN design- Automatic parameter calculation- KITISAK-1

* Equations that are different than in the paper +errata.

*(100)

*(105)

*

* Equations that are added to those that are in the paper

*(106) and (107)

* CONSISTENCY: Number of exchangers smaller than the number of shells

* Needed because the exchangers are related to the values of K.

*(108) LIMIT THE NUMBER OF EXCHANGERS

*(109) MINIMUM NUMBER OF EXCHANGERS

\$OFFUPPER

\$ONTEXT

*NM-4S1-FINAL-6-FLEXIBILITY-S1.gms: August 9, 2004

- one scenario, the original values of 4s1.

\$OFFTEXT

SETS

Z transfer zone /Z1/

*

* ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS

I Hot streams /I1*I19/

J cold streams /J1*J3/

R /R1*R4/

* ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX

HU(I) Heating utilities /I9/

CU(J) Cooling utilities /J3/

*

M temperature intervals /M1*M68/

S SCENARIO /S1/

K temperature intervals /K1*K11/

*FOR RELOCATION CHANGING R IN RELOCATON'S EQ TO E

E exchangers /E1*E16/

*

*NEW SET FOR PUMP-AROUND.

PA(I) Pump-around streams /I2,I4,I6/

*

ALIAS (M,N,L,O)

ALIAS (I,II)

ALIAS (J,JJ)

ALIAS (K,KK)

ALIAS (Z,ZZ)

ALIAS (E,EE)

*PARAMETER FOR PUMP-AROUND CASE

PARAMETER FPR(I,R) Candidate values for pump-around flowrate i

/

I2.R1 701.4780

I2.R2 647.5181

I2.R3 539.5984

I2.R4 485.6386

I4.R1 78.28034

I4.R2 115.4635

I4.R3 156.5607

I4.R4 176.1308

```

16.R1 37.59575
16.R2 39.94549
16.R3 84.59044
16.R4 108.0878

/
PARAMETER TOTAL_QPA Total PA load ;
TOTAL_QPA =158000;

*linear function for Cp for hot streams
*Cp = A_cp_H*T + B_cp_H
PARAMETER A_cp_H(I) Coefficients for Cp
/
I1 0.0035
I2 0.0040
I3 0.0040
I4 0.0055
I5 0.0039
I6 0.0052
I7 0.0038
I8 0.0031
I9 0
/
PARAMETER B_cp_H(I) Intercept for Cp
/
I1 1.9098
I2 1.7979
I3 1.7483
I4 1.4682
I5 1.7044
I6 1.3834
I7 1.6756
I8 1.8201
I9 4.18
/
*linear function for Cp for cold streams
*Cp = A_cp_C*T + B_cp_C
PARAMETER A_cp_C(J) Coefficients for Cp
/
J1 0.0037
J2 0.0035
J3 0
/
PARAMETER B_cp_C(J) Coefficients for Cp
/
J1 1.9966
J2 1.8143
J3 4.18
/

* y = a*PA(1)+b*PA(2)+c*PA(2)+d from usig regression.

PARAMETER A_1(I) Coefficients for PA(1)
/
I2 2.82E-05
I4 -6.3E-05
I6 -2.7E-05
/
PARAMETER B_1(I) Coefficients for PA(2)
-/
I2 4.56E-05
I4 -5.4E-05
I6 -2.8E-05
/
PARAMETER C_1(I) Coefficients for PA(3)
/
I2 5.91E-05
I4 -2.4E-05
I6 -2.3E-05
/
PARAMETER D_I_1(I) Intercept

```

```

/
I2 -3.81232
I4 11.14212
I6 6.491449
/

```

```

*
```

```

PARAMETER T(S,Z,I,M,J,N) Upper bound
/

```

```

S1.Z1.I2.(M3*M8).J1.(M58*M63) 10000
S1.Z1.I2.(M3*M8).J2.(M64*M66) 10000
S1.Z1.I2.(M3*M8).J3.(M67*M68) 10000

```

```

S1.Z1.I4.(M16*M21).J1.(M58*M63) 10000
S1.Z1.I4.(M16*M21).J2.(M64*M66) 10000
S1.Z1.I4.(M16*M21).J3.(M67*M68) 10000

```

```

S1.Z1.I6.(M33*M38).J1.(M58*M63) 10000
S1.Z1.I6.(M33*M38).J2.(M64*M66) 10000
S1.Z1.I6.(M33*M38).J3.(M67*M68) 10000
/

```

```

PARAMETER TE(S,Z,I,M,J,N) Upper bound
/

```

```

S1.Z1.I2.(M3*M8).J1.(M58*M63) 10000
S1.Z1.I2.(M3*M8).J2.(M64*M66) 10000
S1.Z1.I2.(M3*M8).J3.(M67*M68) 10000

```

```

S1.Z1.I4.(M16*M21).J1.(M58*M63) 10000
S1.Z1.I4.(M16*M21).J2.(M64*M66) 10000
S1.Z1.I4.(M16*M21).J3.(M67*M68) 10000

```

```

S1.Z1.I6.(M33*M38).J1.(M58*M63) 10000
S1.Z1.I6.(M33*M38).J2.(M64*M66) 10000
S1.Z1.I6.(M33*M38).J3.(M67*M68) 10000
/

```

```

PARAMETER OMEGA(S,Z,I,M,J,N) Upper bound
/

```

```

S1.Z1.I2.(M3*M8).J1.(M58*M63) 10000
S1.Z1.I2.(M3*M8).J2.(M64*M66) 10000
S1.Z1.I2.(M3*M8).J3.(M67*M68) 10000

```

```

S1.Z1.I4.(M16*M21).J1.(M58*M63) 10000
S1.Z1.I4.(M16*M21).J2.(M64*M66) 10000
S1.Z1.I4.(M16*M21).J3.(M67*M68) 10000

```

```

S1.Z1.I6.(M33*M38).J1.(M58*M63) 10000
S1.Z1.I6.(M33*M38).J2.(M64*M66) 10000
S1.Z1.I6.(M33*M38).J3.(M67*M68) 10000
/

```

```

PARAMETER NIZ(S,Z,I) # OF INTERVALS DESIRED FOR HOT STREAMS
/

```

```

S1.Z1.I1 2
S1.Z1.I2 6
S1.Z1.I3 7
S1.Z1.I4 6
S1.Z1.I5 11
S1.Z1.I6 6
S1.Z1.I7 11
S1.Z1.I8 5
S1.Z1.I9 3
/

```

```

PARAMETER NIJ(S,Z,I) # OF INTERVALS DESIRED FOR COLD STREAMS
/

```

```

S1.Z1.I1 6
S1.Z1.I2 3
S1.Z1.I3 2
/

```

* Used Over all heat transfer Coeff instead of hot and cold heat transfer Coeff.

* This values come from text book.

PARAMETER U(S,I,J) OVER ALL HEAT TRANSFER COEFFICIENT

/

S1.(11*13,17,19).(J1*J2)	0.715
S1.(14,16).(J1*J2)	0.715
S1.15.(J1*J2)	0.306
S1.18.(J1*J2)	0.470
S1.(11,12).J3	1.400
S1.(13,17).J3	1.020
S1.(14,16).J3	0.511
S1.(15).J3	0.765
S1.(18).J3	0.765
S1.(19).J3	5.110

PARAMETERS

TIH(S,I) T IN FOR HOT STREAMS

/

S1.11	48.30000
S1.12	182.5720
S1.13	224.6850
S1.14	268.7880
S1.15	275.6570
S1.16	308.5100
S1.17	323.5120
S1.18	347.1810
S1.19	400.0000

TOH(S,I) T OUT FOR HOT STREAMS

/

S1.11	26.11000
S1.12	104.4400
S1.13	26.11000
S1.14	173.6270
S1.15	26.11000
S1.16	232.2220
S1.17	26.11000
S1.18	260.0000
S1.19	399.0000

TIC(S,J) T IN FOR COLD STREAMS

/

S1.J1	16.11000
S1.J2	132.7800
S1.J3	20.00

TOC(S,J) T OUT FOR COLD STREAMS

/

S1.J1	132.780
S1.J2	360
S1.J3	30.00000

PARAMETERS

TIHZ(S,Z,I) T IN FOR HOT STREAMS

/

S1.Z1.11	48.30000
S1.Z1.12	182.5720
S1.Z1.13	224.6850
S1.Z1.14	268.7880
S1.Z1.15	275.6570
S1.Z1.16	308.5100
S1.Z1.17	323.5120
S1.Z1.18	347.1810
S1.Z1.19	400.0000

TOHZ(S,Z,I) T OUT FOR HOT STREAMS

/

S1.Z1.11	26.11000
S1.Z1.12	104.4400
S1.Z1.13	26.11000
S1.Z1.14	173.6270
S1.Z1.15	26.11000
S1.Z1.16	232.2220

```

S1.Z1.I7 26.11000
S1.Z1.I8 260.0000
S1.Z1.I9 399.0000
/
TICZ(S,Z,J) T IN FOR COLD STREAMS
/
S1.Z1.J1 16.11000
S1.Z1.J2 132.7800
S1.Z1.J3 20.00
/
TOCZ(S,Z,J) T OUT FOR COLD STREAMS
/
S1.Z1.J1 132.7780
S1.Z1.J2 360
S1.Z1.J3 30.00000
/
*-----
*INTRODUCE THE FCp:
FH(S,I) FOR HOT STREAMS
/
S1.I1 177.826
S1.I3 120.158
S1.I5 59.1990
S1.I7 102.417
S1.I8 211.705
/
FC(S,J) FOR COLD STREAMS
/
S1.J1 752.594
S1.J2 673.422
/
*USE THE MAX FCp FOR THE UTILITIES
*-----
SETS FREEH(I)
/
I1*19
/
FREEC(J)
/
J1
J2
J3
/
PARAMETER BIF(Z,I,J)
/
Z1.I1.J1 0
/
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
*
PARAMETER SPH(I) SH in paper
/
(I1,I3,I5,I7,I8,I9) 1
(I2,I4,I6) 0
/
PARAMETER SPC(J) SC in paper
/
J1 1
J2 1
J3 1
/
PARAMETER NIH(I) Non isothermal splitting for hot streams in paper
/
I1 0
/
PARAMETER NIC(J) Non isothermal splitting for cold streams in paper
/
J1 0
/
PARAMETER DTVIO(I,J)

```



```

/
(11*19).(J1*J3) 1
/

PARAMETER KMAX(Z,I,J)
/
Z1.I1.J1 1
/

PARAMETER DTHU(I)
/
I9 1
/
PARAMETER DTCU(J)
/
J3 10
/
PARAMETER FMAX_HU(I)
/
I9 100000
/
PARAMETER FMAX_CU(J)
/
J3 100000
/
PARAMETER CHU(I)
/
I9 19.750
/
PARAMETER CCU(J)
/
J3 1.861
/
PARAMETER CSS(I) Cost of side stripping
/
I2 20.33
I4 20.33
I6 20.33
/
PARAMETER CF;
CF = 5291.9;
PARAMETER CAN;
CAN = 171.4;
PARAMETER CAE;
CAE = 171.4;

$ontext
** Retrofit
PARAMETER AEX(Z,I,J)
/
Z1.I2.J1 1267.954
Z1.I4.J1 470.4239
Z1.I9.J1 1300.546
Z1.I8.J2 188.1183
Z1.I7.J3 941.5554
Z1.I8.J3 167.4541
Z1.I1.J3 518.2402
Z1.I3.J3 966.0800
Z1.I5.J3 682.7927
Z1.I6.J3 184.5678
/
PARAMETER AEX_B(K,Z,I,J)
/
K1.Z1.I1.J1 1267.954
/
PARAMETER NHE0(S,Z,I,J)
/
S1.Z1.I2.J1 1
S1.Z1.I4.J1 1
S1.Z1.I9.J1 1
S1.Z1.I8.J2 1

```

```

S1.Z1.17.J3 1
S1.Z1.18.J3 1
S1.Z1.11.J3 1
S1.Z1.13.J3 1
S1.Z1.15.J3 1
S1.Z1.16.J3 1
/
PARAMETER AEX_U(Z,I,J)
/
Z1.12.J1 2000.000
Z1.14.J1 700.0000
Z1.19.J1 1700.000
Z1.18.J2 250.0000
Z1.17.J3 1600.000
Z1.18.J3 400.0000
Z1.11.J3 650.0000
Z1.13.J3 1200.000
Z1.15.J3 750.0000
Z1.16.J3 350.0000
/
PARAMETER AEX_U_B(K,Z,I,J)
/
K1.Z1.11.J1 2000.000
/
$offtext
*-----
*FOR RELOCATION
*-----
PARAMETER NHE0(S,Z,I,J)
/
S1.Z1.11.J3 1
S1.Z1.12.J1 1
S1.Z1.13.J1 1
S1.Z1.13.J2 1
S1.Z1.13.J3 1
S1.Z1.14.J1 1
S1.Z1.14.J2 1
S1.Z1.15.J1 1
S1.Z1.15.J2 1
S1.Z1.15.J3 1
S1.Z1.16.J3 1
S1.Z1.17.J1 1
S1.Z1.17.J2 1
S1.Z1.17.J3 1
S1.Z1.18.J3 1
S1.Z1.19.J2 1
/
PARAMETER AEX_R(E)
/
E1 515.685
E2 2239.929
E3 1000.000
E4 204.200
E5 617.797
E6 572.096
E7 179.428
E8 133.625
E9 529.892
E10 546.822
E11 184.5
E12 608.858
E13 798.965
E14 425.397
E15 240.7
E16 4489.5
/
PARAMETER AEX_B_1(E)
/
E1 515.685
E2 2239.929

```

E3 1000.000
E4 204.200
E5 617.797
E6 572.096
E7 179.428
E8 133.625
E9 529.892
E10 546.822
E11 184.5
E12 608.858
E13 798.965
E14 425.397
E15 240.7
E16 4489.5

/
PARAMETER AEX_U_I(E)

/
E1 3000
E2 3000
E3 3000
E4 3000
E5 3000
E6 3000
E7 3000
E8 3000
E9 3000
E10 3000
E11 3000
E12 3000
E13 3000
E14 3000
E15 3000
E16 5000

/
PARAMETER AEX_B_R(E)

/
E1 515.685
E2 2239.929
E3 1000.000
E4 204.200
E5 617.797
E6 572.096
E7 179.428
E8 133.625
E9 529.892
E10 546.822
E11 184.5
E12 608.858
E13 798.965
E14 425.397
E15 240.7
E16 4489.5

/
PARAMETER AEX_U_B_R(EE)

/
E1 3000
E2 3000
E3 3000
E4 3000
E5 3000
E6 3000
E7 3000
E8 3000
E9 3000
E10 3000
E11 3000
E12 3000
E13 3000
E14 3000
E15 3000

E16 5000

/

PARAMETER AEX_U_B_1(E)

/

E1 3000

E2 3000

E3 3000

E4 3000

E5 3000

E6 3000

E7 3000

E8 3000

E9 3000

E10 3000

E11 3000

E12 3000

E13 3000

E14 3000

E15 3000

E16 5000

/

PARAMETER R_ALL

* Minimum DELTA T

/16/;

PARAMETER KET

/16/;

PARAMETER A_NEW_MAX(Z,I,J)

/

Z1 (I1*I4).(J1*J3) 5000.000

/

PARAMETER MAX_NEW_HEX

* Maximum Number of new exchangers

/50/;

PARAMETER QLHMIN

* Minimum heat that can be transferred within an interval.Hot streams

/0.01/;

PARAMETER QLCMIN

* Minimum heat that can be transferred within an interval.Cold streams

/0.01/;

PARAMETER AMAX

* Maximum area per exchanger

/20000/;

PARAMETER ASHELLMAX

* Maximum shell area

/5000/;

PARAMETER TOTNEXCHMAX

* Maximum NUMBER OF EXCHANGERS

/900/;

PARAMETER TOTNEXCHMIN

* Minimum NUMBER OF EXCHANGERS

/0/;

PARAMETER DTmin

* Minimum DELTA T

/0/;

parameter NINT

/263/;

parameter OPT

/2/;

*-----

* END OF INPUT PARAMETERS

*-----

SCALARS Si, Zi, Mi, Ic, Ji

PARAMETERS IHminZ(S,Z,I),IHmaxZ(S,Z,I),IHmax(S,I),IHmin(S,I),HOT(S,I,M),
HOT2(S,M), HOTZ(S,Z,I,M), ICminZ(S,Z,J),ICmaxZ(S,Z,J),ICmin(S,J),

```

ICmax(S,J),COLD(S,J,M),COLD2(S,M),COLDZ(S,Z,J,M),H_I(S,I,M),H_J(S,J,M)
FOR(Si=1 TO CARD(S),
  FOR(Zi=1 TO CARD(Z),
    FOR(Ic=1 TO CARD(I),
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)=1
        AND ORD(Z)=1}= 0+ 1${NIZ(S,Z,I)>=1};
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(I)>1
        AND ORD(Z)=1}= 0+
        {SUM((ZZ,II){ORD(II)<ORD(I),NIZ(S,ZZ,II)+1} ${NIZ(S,Z,I)>=1};
      IHminZ(S,Z,I){ORD(S)=Si AND ORD(Z)>1}= 0+
        {SUM((ZZ,II){ORD(II)<ORD(I),NIZ(S,ZZ,II)
          +SUM(ZZ${ORD(ZZ)<Zi},NIZ(S,ZZ,I))+1} ${NIZ(S,Z,I)>=1};
      IHmaxZ(S,Z,I){ORD(S)=Si AND ORD(I)=Ic AND ORD(Z)=Zi}= 0+
        {IHminZ(S,Z,I)+NIZ(S,Z,I)-1} ${NIZ(S,Z,I)>=1};
      IHmin(S,I){ORD(S)=Si AND ORD(I)=Ic}=
        SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NIZ(S,ZZ,I))=0}.IHminZ(S,Z,I)];
      IHmax(S,I){ORD(S)=Si AND ORD(I)=Ic}=
        SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NIZ(S,ZZ,I))=0}.IHmaxZ(S,Z,I)];

    FOR(Mi=1 TO CARD(M),
      HOT(S,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi}= 0+
        1${ORD(M)>= IHmin(S,I) AND ORD(M)<=IHmax(S,I)};
      HOT2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+ 1${ORD(M)<=
        SUM(I${ORD(I)=CARD(I)},IHmax(S,I))};
      HOTZ(S,Z,I,M){ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
        AND ORD(Z)=Zi}= 0+ 1${ORD(M)>= IHminZ(S,Z,I) AND ORD(M)<=IHmaxZ(S,Z,I)};

    ));
  FOR(Ji=1 TO CARD(J),
    ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)=1 AND ORD(Z)=1}= 0+
      {SUM(I${ORD(I)=CARD(I)},IHmax(S,I))+1} ${NJZ(S,Z,J)>=1};
    ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)>1 AND ORD(Z)=1}= 0+
      {SUM(I${ORD(I)=CARD(I)},IHmax(S,I))
      +SUM((ZZ,JJ){ORD(JJ)<ORD(J),NJZ(S,ZZ,JJ)+1} ${NJZ(S,Z,J)>=1};
    ICminZ(S,Z,J){ORD(S)=Si AND ORD(Z)>1}= 0+
      {SUM(I${ORD(I)=CARD(I)},IHmax(S,I))
      +SUM((ZZ,JJ){ORD(JJ)<ORD(J),NJZ(S,ZZ,JJ)
      +SUM(ZZ${ORD(ZZ)<Zi},NJZ(S,ZZ,J))+1} ${NJZ(S,Z,J)>=1};
    ICmaxZ(S,Z,J){ORD(S)=Si AND ORD(J)=Ji AND ORD(Z)=Zi}= 0+
      {ICminZ(S,Z,J)+NJZ(S,Z,J)-1} ${NJZ(S,Z,J)>=1};
    ICmin(S,J) ${ORD(S)=Si AND ORD(J)=Ji}=
      SUM[Z${SUM(ZZ${ORD(ZZ)<=ORD(Z)-1},NJZ(S,ZZ,J))=0}.ICminZ(S,Z,J)];
    ICmax(S,J) ${ORD(S)=Si AND ORD(J)=Ji}=
      SUM[Z${SUM(ZZ${ORD(ZZ)>=ORD(Z)+1},NJZ(S,ZZ,J))=0}.ICmaxZ(S,Z,J)];

    FOR(Mi=1 TO CARD(M),
      COLD(S,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi}= 0+
        1${ORD(M)>= ICmin(S,J) AND ORD(M)<=ICmax(S,J)};
      COLD2(S,M){ORD(S)=Si AND ORD(M)=Mi}= 0+
        1${ORD(M)>SUM(I${ORD(I)=CARD(I)},IHmax(S,I))
        AND ORD(M)<= SUM(I${ORD(I)=CARD(I)},ICmax(S,J))};
      COLDZ(S,Z,J,M){ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
        AND ORD(Z)=Zi}= 0+ 1${ORD(M)>= ICminZ(S,Z,J)
        AND ORD(M)<=ICmaxZ(S,Z,J)};

    ));
  ));
PARAMETERS DT(S,M),TU(S,M),TL(S,M),CPH(S,I,M),CPC(S,J,M),DHH(S,I,M),DHC(S,J,M)
CPH_U(S,I,M),CPC_U(S,J,M),CPH_L(S,I,M),CPC_L(S,J,M);

DT(S,M) = SUM((Z,I){HOTZ(S,Z,I,M)=1},{TIHZ(S,Z,I)-TOHZ(S,Z,I)/
  [IHmaxZ(S,Z,I)-IHminZ(S,Z,I)+1]})$[HOT2(S,M)=1]+
SUM((Z,J){COLDZ(S,Z,J,M)=1},{TOCZ(S,Z,J)-TICZ(S,Z,J)/
  [ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]})$[COLD2(S,M)=1];

FOR(Si= 1 TO CARD(S),
  FOR (Mi=1 TO CARD(M),
    TU(S,M){ORD(S)=Si AND ORD(M)=Mi}= {SUM((Z,I){HOTZ(S,Z,I,M)=1
      AND ORD(M)=IHminZ(S,Z,I),TIHZ(S,Z,I){ORD(M)=IHminZ(S,Z,I)}

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+ SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)>IHminZ(S,Z,I) AND
ORD(M)<=IHmaxZ(S,Z,I)],
[THZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)]$[ORD(M)>
IHminZ(S,Z,I) AND ORD(M)<=IHmaxZ(S,Z,I)])$[HOT2(S,M)=1]
+ {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICminZ(S,Z,J)],
TOCZ(S,Z,J)$[ORD(M)=ICminZ(S,Z,J)])}
+ SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z,J)
AND ORD(M)<=ICmaxZ(S,Z,J)],
[TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]$[ORD(M)>
ICminZ(S,Z,J) AND ORD(M)<=ICmaxZ(S,Z,J)])$[COLD2(S,M)=1];
TL(S,M)$[ORD(S)=Si AND ORD(M)=Mi]=
{SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)=IHmaxZ(S,Z,I)],
TOHZ(S,Z,I)$[ORD(M)=IHmaxZ(S,Z,I)])}
+ SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z,I)
AND ORD(M)>=IHminZ(S,Z,I)],
[TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$[ORD(M)<
IHmaxZ(S,Z,I) AND ORD(M)>=IHminZ(S,Z,I)])$[HOT2(S,M)=1]
+ {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICmaxZ(S,Z,J)],
TICZ(S,Z,J)$[ORD(M)=ICmaxZ(S,Z,J)])}
+ SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)<ICmaxZ(S,Z,J)
AND ORD(M)>=ICminZ(S,Z,J)],
[TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$[ORD(M)<
ICmaxZ(S,Z,J) AND ORD(M)>=ICminZ(S,Z,J)])$[COLD2(S,M)=1];

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```

CPH_U(S,I,M)$[HOT(S,I,M)=1] = A_cp_H(I)*TU(S,M)+ B_cp_H(I) ;
CPC_U(S,J,M)$[COLD(S,J,M)=1] = A_cp_C(J)*TU(S,M)+ B_cp_C(J) ;
CPH_L(S,I,M)$[HOT(S,I,M)=1] = A_cp_H(I)*TL(S,M)+ B_cp_H(I) ;
CPC_L(S,J,M)$[COLD(S,J,M)=1] = A_cp_C(J)*TL(S,M)+ B_cp_C(J) ;
CPH(S,I,M)$[HOT(S,I,M)=1] = (CPH_U(S,I,M)+CPH_L(S,I,M))/2 ;
CPC(S,J,M)$[COLD(S,J,M)=1] = (CPC_U(S,J,M)+CPC_L(S,J,M))/2 ;

```

```

FOR(Ic=1 TO CARD(I),
DHH(S,I,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(I)=Ic
AND HOT(S,I,M)=1]= FH(S,I)*CPH(S,I,M)*[TU(S,M)-TL(S,M)] ;
);

```

```

FOR(Ji=1 TO CARD(J),
DHC(S,J,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(J)=Ji
AND COLD(S,J,M)=1]= FC(S,J)*CPC(S,J,M)*[TU(S,M)-TL(S,M)] ;
);

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));

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```

PARAMETER HHEAD(S,M,N), CHEAD(S,M,N), LMTD(S,M,N), D(S,Z,M,N)
*MATCH ALLOWED BASED ON LMTD
ALLOW(S,Z,I,J), ALLOW_H(S,Z,I,M,J), ALLOW_C(S,Z,J,M,I), ALLOW_2(Z,I,J) ;

```

```

HHEAD(S,M,N) = {TU(S,M)-TU(S,N) + DTmin}$[HOT2(S,M) AND COLD2(S,N)];
CHEAD(S,M,N) = {TL(S,M)-TL(S,N) + DTmin}$[HOT2(S,M) AND COLD2(S,N)] ;

```

```

LMTD(S,M,N)= {[HHEAD(S,M,N)-CHEAD(S,M,N)]
/LOG[HHEAD(S,M,N)/CHEAD(S,M,N)]}$[HHEAD(S,M,N)> 0
AND CHEAD(S,M,N)>0 AND HHEAD(S,M,N)> CHEAD(S,M,N)]
+ {[HHEAD(S,M,N)+CHEAD(S,M,N)]/2}$[HHEAD(S,M,N)>0 AND CHEAD(S,M,N)>0
AND (HHEAD(S,M,N)< CHEAD(S,M,N)OR HHEAD(S,M,N)= CHEAD(S,M,N))];

```

```

D(S,Z,M,N)= 1$[{HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[I$(HOT(S,I,M)=1
AND HOT(S,I,N)=1),HOTZ(S,Z,I,M)=1 AND SUM[I$(HOT(S,I,N)=1
AND HOT(S,I,M)=1),HOTZ(S,Z,I,N)=1]}
OR {COLD2(S,M)=1 AND COLD2(S,N)=1 AND SUM[J$(COLD(S,J,M)=1
AND COLD(S,J,N)=1),COLDZ(S,Z,J,M)=1 AND SUM[J$(COLD(S,J,N)=1
AND COLD(S,J,M)=1),COLDZ(S,Z,J,N)=1]}
OR {(HHEAD(S,M,N)>=0.00001 AND CHEAD(S,M,N)>=0.00001)
AND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,I,M)=1]
AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)=1]}];

```

```

* OR {LMTD(S,M,N)>0 AND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,I,M)=1]
* AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)=1]}];

```

```

FOR(Si= 1 TO CARD(S),
FOR(Zi=1 TO CARD(Z),

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```

FOR(Ic=1 TO CARD(I),
  FOR(Ji=1 TO CARD(J),
    ALLOW(S,Z,I,J){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
      AND ORD(J)=Ji}= 0+ 1${SUM[(M,N){HOT(S,I,M)=1
      AND COLD(S,J,N)=1},D(S,Z,M,N)] >0
      AND NOT[HU(I)AND CU(J)]};
    FOR (Mi=1 TO CARD(M),
      ALLOW_H(S,Z,I,M,J){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
        AND ORD(J)=Ji AND ORD(M)=Mi
        AND HOT(S,I,M)=1}= 0+
      1${SUM[N${COLD(S,J,N)=1},D(S,Z,M,N)] >0AND NOT[HU(I)AND CU(J)]};
      ALLOW_C(S,Z,J,M,I){ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
        AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1}= 0+
      1${SUM[N${HOT(S,I,N)=1},D(S,Z,N,M)] >0AND NOT[HU(I)AND CU(J)]};
    )));
FOR(Zi=1 TO CARD(Z).
  FOR(Ic=1 TO CARD(I).
    FOR(Ji=1 TO CARD(J).
      ALLOW_2(Z,I,J){ORD(Z)=Zi AND ORD(I)=Ic AND ORD(J)=Ji}= 0+
      1${SUM[S,ALLOW(S,Z,I,J)] >0AND NOT[HU(I)AND CU(J)]};
    )));

```

VARIABLES

```

TCOST
PAR(Z,I,J)
Q(S,Z,I,M,J,N)  heat load for process-process match
QNEW_M(S,Z,I,J,M)
QNEW_N(S,Z,I,J,N)
QNEW2_M(S,Z,I,J,M)
QNEW2_N(S,Z,I,J,N)
Y_M(S,Z,I,J,M)
Y_N(S,Z,I,J,N)
Y_M_B(S,Z,I,J,M)
Y_N_B(S,Z,I,J,N)
NHE_M0(S,Z,I,J,M)
NHE_M1(S,Z,I,J,M)
NHE_N0(S,Z,I,J,N)
NHE_N1(S,Z,I,J,N)
NHE_M0_B(S,Z,I,J,M)
NHE_M1_B(S,Z,I,J,M)
NHE_N0_B(S,Z,I,J,N)
NHE_N1_B(S,Z,I,J,N)
NHE(S,Z,I,J)
ALFA_M(S,Z,I,J,M)
ALFA_N(S,Z,I,J,N)
FHU(I)          is FCP HU (MJ_h_C)
FCU(J)          is FCP CU(MJ_h_C)
B1(S,Z,I,M,J,N) X(imjn) in the paper
QH(S,Z,I,M,N)
QC(S,Z,I,M,N)
Q2(S,Z,I,M,J,N)
X1_B(S,Z,I,J,M)
X_B(S,K,Z,I,J,M)
PAR_B(K,Z,I,J)
USHELL(Z,I,J)
USHELL_B(K,Z,I,J)

```

*ADD FOR RELOCATON

```

PAR_N(S,Z,I,J)
PAR_N_B(K,E,Z,I,J)
DPAR_E(Z,I,J)
DPAR_E_B(K,E,Z,I,J)
NHE_S(S,Z,I,J)
DELTA(Z,I,J,E,E.K)
PHI(Z,I,J,E)
PAR_B_R(K,E,Z,I,J)

```

```

HOT_UTILITY_COST
Cold_UTILITY_COST
Area_Cost

```

FIX_COST

*ADD FOR PUMP-AROUND CASE

FP(I)
 FPY(S,Z,I,J,M) Case of BIF=0
 FPY_B(S,Z,I,J,M) Case of BIF=1
 FPA(S,Z,I,J,M)
 FPK_H_0(S,Z,I,J,M)
 FPK_H_0_B(S,Z,I,J,M)
 FPK_C_0(S,Z,I,J,N)
 FPK_H_1(S,Z,I,J,M)
 FPK_H_1_B(S,Z,I,J,M)
 FPK_C_1(S,Z,I,J,N)
 XM(S,Z,I,M,J,N)
 FPQ(S,Z,I,J,M)
 W(I,R)
 YW(S,Z,I,J,M)
 KW_0(S,Z,I,J,M,R)
 KW_1(S,Z,I,J,M,R)
 WA(S,Z,I,J,M,R)
 XW(S,Z,I,M,J,N,R)
 WQ(S,Z,I,J,M,R)
 QPA(I)
 TOTAL_QPA_MIN
 TOTAL_QPA_MAX
 Cost_side_stripping_steam
 SST(I)
 SST_1(I)
 SST_2(I)
 SST_3(I)
 SST_4(I)
 PA1
 PA2
 PA3
 TOTAL_Q
 Cp_D(I)

POSITIVE VARIABLE Q,QNEW2_M,QNEW2_N,QC,QH,Q2.DPAR_E,DPAR_E_B,PAR_N
 ,PAR_N_B,PAR,QNEW_M,QNEW_N,YW,KW_0,KW_1,WA,XW,QPA,FP

.AEX,AEX_B

BINARY VARIABLE NHE_M0_B,NHE_M1_B,NHE_N0_B,NHE_N1_B,Y_M,Y_N,X1_B,X_B,NHE_S
 ,DELTA,Y_M_B,Y_N_B,NHE_M0,NHE_M1,NHE_N0,NHE_N1,ALFA_M,ALFA_N
 ,W

.PHI

INTEGER VARIABLE USHELL.USHELL_B

EQUATIONS

HBHU(S,I,M)
 HBCU(S,J,N)
 HBHS(S,I,M)
 HBCS(S,J,N)
 TRANSFOR_M(S,Z,I,J,M)
 TRANSFOR_N(S,Z,I,J,N)
 HBHS_NI(S,I,M)
 HBCS_NI(S,J,N)
 NOISOH(S,I,M)
 NOISOC(S,J,N)
 BINARY_M1(S,Z,I,J,M)
 BINARY_M2(S,Z,I,J,M)
 BINARY_M1_B(S,Z,I,J,M)
 BINARY_M2_B(S,Z,I,J,M)
 BINARY_N1(S,Z,I,J,N)
 BINARY_N2(S,Z,I,J,N)
 BINARY_N1_B(S,Z,I,J,N)
 BINARY_N2_B(S,Z,I,J,N)
 BINARY_M5(S,Z,I,J,M)
 BINARY_M5b(S,Z,I,J,M)
 BINARY_M3(S,Z,I,J,M)

BINARY_M4(S,Z,I,J,M)
 BINARY_M8(S,Z,I,J,M)
 BINARY_M9(S,Z,I,J,M)
 BINARY_M6(S,Z,I,J,M)
 BINARY_M7(S,Z,I,J,M)
 BINARY_M3_B(S,Z,I,J,M)
 BINARY_N5(S,Z,I,J,N)
 BINARY_N5b(S,Z,I,J,N)
 BINARY_N3(S,Z,I,J,N)
 BINARY_N4(S,Z,I,J,N)
 BINARY_N8(S,Z,I,J,N)
 BINARY_N9(S,Z,I,J,N)
 BINARY_N6(S,Z,I,J,N)
 BINARY_N7(S,Z,I,J,N)
 BINARY_N3_B(S,Z,I,J,N)
 HE_COUNT_M0(S,Z,I,J)
 HE_COUNT_N0(S,Z,I,J)
 HE_COUNT_M1(S,Z,I,J)
 HE_COUNT_N1(S,Z,I,J)
 NEXCH(S,Z,I,J)
 NEXCH_B(S,Z,I,J)
 BIF_1(S,Z,I,J,M,N)
 BIF_2(S,Z,I,J,M,N)
 BIF_3(S,Z,I,J,M,N)
 BIF_4(S,Z,I,J,M,N)
 BIF_11(S,Z,I,J,M)
 BIF_12(S,Z,I,J,N)
 BIF_6(S,Z,I,J,M)
 BIF_9(S,Z,I,J,M)
 BIF_5(S,Z,I,J,M)
 BIF_8(S,Z,I,J,N)
 BIF_10(S,Z,I,J,N)
 BIF_7(S,Z,I,J,N)
 FEAS_M_01(S,Z,I,J,M)
 FEAS_M_01_B(S,Z,I,J,M)
 FEAS_M_02(S,Z,I,J,M)
 FEAS_M_02_B(S,Z,I,J,M)
 FEAS_M_03(S,Z,I,J,M)
 FEAS_M_03_B(S,Z,I,J,M)
 FEAS_M_04(S,Z,I,J,M)
 FEAS_M_2(S,Z,I,J,M)
 FEAS_M_1(S,Z,I,J,M)
 FEAS_M_3(S,Z,I,J,M)
 FEAS_M_4(S,Z,I,J,M)
 FEAS_M_3_B_2(S,Z,I,J,M)
 FEAS_M_3_B_1(S,Z,I,J,M)
 FEAS_M_4_B(S,Z,I,J,M)
 FEAS_M_1_SP(S,Z,I,J,M)
 FEAS_M_1_SP_B(S,Z,I,J,M)
 FEAS_N_01(S,Z,I,J,N)
 FEAS_N_01_B(S,Z,I,J,N)
 FEAS_N_02(S,Z,I,J,N)
 FEAS_N_02_B(S,Z,I,J,N)
 FEAS_N_03(S,Z,I,J,N)
 FEAS_N_03_B(S,Z,I,J,N)
 FEAS_N_04(S,Z,I,J,N)
 FEAS_N_2(S,Z,I,J,N)
 FEAS_N_1(S,Z,I,J,N)
 FEAS_N_3(S,Z,I,J,N)
 FEAS_N_4(S,Z,I,J,N)
 FEAS_N_3_B_2(S,Z,I,J,N)
 FEAS_N_3_B_1(S,Z,I,J,N)
 FEAS_N_4_B(S,Z,I,J,N)
 FEAS_N_1_SP(S,Z,I,J,N)
 FEAS_N_1_SP_B(S,Z,I,J,N)
 FEAS_BEG_SP(S,Z,I,J,M,N)
 FEAS_BEG_B_SP(S,Z,I,J,M,N)
 FEAS_END_SP(S,Z,I,J,M,N)
 FEAS_END_B_SP(S,Z,I,J,M,N)
 FEAS_BEG3(S,Z,I,J,M,N)
 FEAS_BEG(S,Z,I,J,M,N)

FEAS_BEG2(S,Z,I,J,M,N)
 FEAS_END3(S,Z,I,J,M,N)
 FEAS_END(S,Z,I,J,M,N)
 FEAS_END2(S,Z,I,J,M,N)
 FEAS_BEG4_B(S,Z,I,J,M,N)
 FEAS_BEG2_B(S,Z,I,J,M,N)
 FEAS_BEG1_B(S,Z,I,J,M,N)
 FEAS_BEG3_B(S,Z,I,J,M,N)
 FEAS_END3_B(S,Z,I,J,M,N)
 FEAS_END_B(S,Z,I,J,M,N)
 FEAS_END2_B(S,Z,I,J,M,N)
 PAREQ(S,Z,I,J)
 BIF_13_2(S,K,Z,I,J,M)
 BIF_13_1(S,K,Z,I,J,M)
 BIF_14(S,K,Z,I,J)
 BIF_15(S,Z,I,J,M)
 *BIF_16(S,Z,I,J,M)
 BIF_17(S,Z,I,J,M)
 BIF_18(S,Z,I,J,M,N)
 SHELL(Z,I,J)
 SHELL_B(K,Z,I,J)
 KMAX1(S,Z,I,J)
 KMAX2(S,Z,I,J)
 TOTALCOST
 * EXTRA EQUATIONS NOT IN PAPER
 TOTNEXCH_MAX
 TOTNEXCH_MIN
 HOT_U_C
 Cold_U_C
 Area_C
 FIX_C

*-----

\$ONTEXT
 *ADD FOR RETR.OFIT
 AREA_REST1(S,Z,I,J)
 AREA_REST2(S,Z,I,J)
 AREA_REST3(S,Z,I,J)
 AREA_REST4(S,Z,I,J)

 AREA_REST5(S,Z,I,J)
 *AREA_REST6(S,Z,I,J)
 AREA_REST7(S,Z,I,J)

AREA_REST1_B(S,K,Z,I,J)
 AREA_REST2_B(S,K,Z,I,J)
 AREA_REST3_B(S,K,Z,I,J)
 AREA_REST4_B(S,K,Z,I,J)
 AREA_REST5_B(S,K,Z,I,J)
 AREA_REST6_B(S,Z,I,J)

LIM_HEX(S,M)
 \$OFFTEXT

*-----

*****ADD FOR RELOCATION*****

RELOCATE_1(S,Z,I,J)
 RELOCATE_2(S,Z,I,J)
 RELOCATE_3(S,Z,I,J)
 RELOCATE_4(S,Z,I,J)
 RELOCATE_5_1(S,Z,I,J)
 RELOCATE_5_2(S,Z,I,J)
 RELOCATE_5_3(Z,E)
 RELOCATE_6(K,E,S,Z,I,J)
 RELOCATE_7(K,E,S,Z,I,J)
 RELOCATE_8(K,E,S,Z,I,J)
 RELOCATE_9(K,E,S,Z,I,J)
 RELOCATE_10(K,E,S,Z,I,J)

*-----

*Equation for Pump-around

PA_1(S,I,M)
 PA_2(S,I,M)
 PA_3(S,Z,I,I,M)
 PA_4(S,Z,I,I,M)
 PA_3_B(S,Z,I,I,M)
 PA_4_B(S,Z,I,I,M)
 PA_5(S,Z,I,I,M)
 PA_6(S,Z,I,I,M)
 PA_7(S,Z,I,I,M)
 PA_8(S,Z,I,I,M,R)
 PA_9(S,Z,I,I,M,R)
 PA_10(S,Z,I,I,M,N)
 PA_11(S,Z,I,I,M,N)
 PA_12(S,Z,I,I,M,N)
 PA_13(S,Z,I,I,M,N)
 PA_14(S,Z,I,I,M,N)
 PA_15(S,Z,I,I,M,N,R)
 PA_16(S,Z,I,I,M,N,R)
 PA_17(S,Z,I,I,M,N,R)
 PA_18(S,Z,I,I,M,N)
 PA_19(S,Z,I,I,M)
 PA_20(S,Z,I,I,M)
 PA_21(S,Z,I,I,M,R)
 PA_22(S,Z,I,I,M,R)
 PA_23(S,Z,I,I,M,R)
 PA_24(S,Z,I,I,M)
 PA_25(S,Z,I,I,M)
 PA_26(S,Z,I,I,M,R)
 PA_27(S,Z,I,I,M,R)
 PA_28(S,Z,I,I,M,R)
 PA_29(S,Z,I,I,M)
 PA_30(S,Z,I,I,M)
 PA_31(S,Z,I,I,M,R)
 PA_32(S,Z,I,I,M,R)
 PA_33(S,Z,I,I,M,R)
 PA_34(S,Z,I,I,M)
 PA_35(S,Z,I,I,M)
 PA_36(S,Z,I,I,M)
 PA_37(S,Z,I,I,M)
 PA_38(S,Z,I,I,M)
 PA_39(S,Z,I,I,M)
 PA_40(S,Z,I,I,M)
 PA_41(S,Z,I,I,M)
 PA_42(S,Z,I,I,M,N)
 PA_43(S,Z,I,I,M,N)
 PA_44(S,Z,I,I,M,N)
 PA_45(S,Z,I,I,M,N,R)
 PA_46(S,Z,I,I,M,N,R)
 PA_47(S,Z,I,I,M,N,R)
 PA_48(S,Z,I,I,M,N)
 PA_49(S,Z,I,I,M,N)
 PA_50(S,Z,I,I,M,N)
 PA_51(S,Z,I,I,M,N)
 PA_52(S,Z,I,I,M,N)
 PA_53(S,Z,I,I,M,N)
 PA_54(S,Z,I,I,M)
 PA_55(S,Z,I,I,M)
 PA_56(S,Z,I,I)
 *PA_57
 PA_58
 PA_59
 PA_60
 PA_61(S,Z,I,I,M)
 PA_62
 PA_63
 PA_64
 PA_65
 PA_66
 PA_67
 PA_68(S,Z,I,I)

 *EQ (1)
 HBHU(S,I,M) $\$(HOT(S,I,M)=1 \text{ AND } HU(I) \text{ AND } FREEH(I))$..
 FHU(I) $*(TU(S,M)-TL(S,M)) = E = \text{SUM}((Z,N,J)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } COLD(S,J,N)=1$
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEC(J)),Q(S,Z,I,M,J,N));

 *EQ (2)
 HBCU(S,J,N) $\$(COLD(S,J,N)=1 \text{ AND } CU(J) \text{ AND } FREEC(J))$..
 FCU(J) $*(TU(S,N)-TL(S,N)) = E = \text{SUM}((Z,M,I)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEH(I)),Q(S,Z,I,M,J,N));

 *EQ (3 a)
 HBHS(S,I,M) $\$(HOT(S,I,M)=1 \text{ AND } \text{NOT } HU(I) \text{ AND } FREEH(I) \text{ AND } NIH(I)=0 \text{ AND } \text{NOT } PA(I))$..
 DHH(S,I,M)=E=SUM((Z,N,J) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } COLD(S,J,N)=1$
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

 *EQ (4)
 HBCS(S,J,N) $\$(COLD(S,J,N)=1 \text{ AND } \text{NOT } CU(J) \text{ AND } FREEC(J) \text{ AND } NIC(J)=0)$..
 DHC(S,J,N)=E=SUM((Z,M,I) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

 *EQ (5)
 TRANSFOR_M(S,Z,I,J,M) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))$..
 QNEW_M(S,Z,I,J,M)=E=SUM(N $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1)$,Q(S,Z,I,M,J,N));

 *EQ (6)
 TRANSFOR_N(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))$..
 QNEW_N(S,Z,I,J,N)=E=SUM(M $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 AND ALLOW_H(S,Z,I,M,J)=1),Q(S,Z,I,M,J,N));

 *EQ (7 a)
 HBHS_NI(S,I,M) $\$(HOT(S,I,M)=1 \text{ AND } \text{NOT } HU(I) \text{ AND } FREEH(I) \text{ AND } NIH(I)=1 \text{ AND } \text{NOT } PA(I))$..
 DHH(S,I,M)=E=SUM((Z,N,J) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1)$,
 Q(S,Z,I,M,J,N))
 +SUM((Z,N) $\$(D(S,Z,M,N)=1 \text{ AND } HOT(S,I,N)=1 \text{ AND } ORD(N) \text{ GT } ORD(M))$,QH(S,Z,I,N,M))
 -SUM((Z,N) $\$(D(S,Z,M,N)=1 \text{ AND } HOT(S,I,N)=1 \text{ AND } ORD(N) \text{ LT } ORD(M))$,QH(S,Z,I,M,N));

 *EQ (8)
 HBCS_NI(S,J,N) $\$(COLD(S,J,N)=1 \text{ AND } \text{NOT } CU(J) \text{ AND } FREEC(J) \text{ AND } NIC(J)=1)$..
 DHC(S,J,N)=E=SUM((Z,M,I) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N))
 +SUM((Z,M) $\$(D(S,Z,M,N)=1 \text{ AND } COLD(S,J,M)=1 \text{ AND } ORD(M) \text{ LT } ORD(N))$,QC(S,Z,J,M,N))
 -SUM((Z,M) $\$(D(S,Z,M,N)=1 \text{ AND } COLD(S,J,M)=1 \text{ AND } ORD(M) \text{ GT } ORD(N))$,QC(S,Z,J,N,M));

 *EQ (9)
 NOISOH(S,I,M) $\$(HOT(S,I,M)=1 \text{ AND } \text{NOT } HU(I) \text{ AND } FREEH(I) \text{ AND } NIH(I)=1)$..
 SUM((Z,N) $\$(D(S,Z,M,N)=1 \text{ AND } HOT(S,I,N)=1 \text{ AND } ORD(N) \text{ LT } ORD(M))$,QH(S,Z,I,M,N))
 =L=SUM((Z,N,J) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } COLD(S,J,N)=1$
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

 *EQ (10)
 NOISOC(S,J,N) $\$(COLD(S,J,N)=1 \text{ AND } \text{NOT } CU(J) \text{ AND } FREEC(J) \text{ AND } NIC(J)=1)$..
 SUM((Z,M) $\$(D(S,Z,M,N)=1 \text{ AND } COLD(S,J,M)=1 \text{ AND } ORD(M) \text{ GT } ORD(N))$,QC(S,Z,J,N,M))
 =L=SUM((Z,M,I) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));

 *EQ (11a and 13a) Case of BIF(I,J)=0 (i,j) not belonging to set B.
 BINARY_M1(S,Z,I,I,M) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } \text{NOT } PA(I))$..
 QNEW_M(S,Z,I,I,M)-Y_M(S,Z,I,I,M)*DHH(S,I,M) $\$(\text{NOT } HU(I))$
 -Y_M(S,Z,I,I,M)*FMAX_HU(I)*DTHU(I) $\$(HU(I))$ =L=0;

```

*-----
*EQ (11b and 13b) Case of BIF(I,J)=0 (i,j) not belonging to set B
***** MINIMUM VALUE OF QNEW_M=0.01!!!!!!!
BINARY_M2(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0 AND
FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*QLHMIN=G=0;

*-----
*EQ (11a and 13a) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_M1_B(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*DHH(S,I,M)$ (NOT HU(I))
-Y_M_B(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)$ (HU(I))=L=0;

*-----
*EQ (11b and 13b) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_M2_B(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN =G= 0;

*-----
*EQ (12a and 14a) Case of BIF(I,J)=0 (i,j) not belonging to set B

BINARY_N1(S,Z,I,J,N)$ (COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*DHC(S,J,N)$ (NOT CU(J))
-Y_N(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)$ (CU(J))=L=0;

*-----
*EQ (12b and 14b) Case of BIF(I,J)=0 (i,j) not belonging to set B
BINARY_N2(S,Z,I,J,N)$ (COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*QLCMIN=G=0;

*-----
*EQ (12a and 14a) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_N1_B(S,Z,I,J,N)$ (COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*DHC(S,J,N)$ (NOT CU(J))
-Y_N_B(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)$ (CU(J))=L=0;

*-----
*EQ (12b and 14b) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_N2_B(S,Z,I,J,N)$ (COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*QLCMIN=G=0;

*-----
*EQ (15) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*-----
*EQ (16)
BINARY_M5(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
NHE_M0(S,Z,I,J,M)=L=2-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1);

*-----
*EQ (17) IS IN REALITY NOT NEEDED, BUT WAS ADDED TO ENFORCE K=0 WHEN Y=0
* AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M,J)=1
* AND ALLOW_H(S,Z,I,M,J)=1

BINARY_M5b(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J)).. NHE_M0(S,Z,I,J,M)=L= Y_M(S,Z,I,J,M);

* IT TURNS OUT THAT THIS EQUATION ONLY FORCES THE VALUES OF K TO BE ZERO
* WHEN Y=0, WHICH HAPPENS NATURALLY IF ONE IS MINIMIZING THE NUMBER OF
* EXCHANGERS OR BECAUSE THE FIXED COSTS ARE BEING MINIMIZED.
* EVEN IF NOT DRIVEN TO ZERO BY THE OBJECTIVE FUNCTION IT IS HARMELESS.
* HOWEVER, IT TURNS OUT THAT IT COULD MAKE EXTENSIONS OF THE MODEL HAVE
* PROBLEMS. SO, ALTHOUGH THE EQUATION IS NOT NEEDED, IT GIVES SOME EXTRA VALUES
* OF K WHEN THEY DO NOT REALLY MATTER.

*-----
*EQ (18)
BINARY_M3(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J))..
NHE_M0(S,Z,I,J,M)=G= Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1)$ (HOT(S,I,M-1)
AND ALLOW_H(S,Z,I,M-1,J)) ;

*-----
*EQ (19)
BINARY_M4(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M,J)=1

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AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J)..
 NHE_M0(S,Z,I,J,M)=G=0;

*-----
 *EQ (20) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
 *-----

*EQ (21)
 BINARY_M8(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
 NHE_M1(S,Z,I,J,M)=L=2-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M+1);

*-----
 *EQ (22) : ORIGINALLY NOT NEEDED. BUT ADDED TO ENFORCE K=0 WHEN Y=0
 * AND HOT(S,I,M-i) AND ALLOW_H(S,Z,I,M-1,J)
 BINARY_M9(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
 AND FREEH(I) AND FREEC(J))..
 NHE_M1(S,Z,I,J,M) =L= Y_M(S,Z,I,J,M) ;

* SEE COMMENTS ON EQUATION (17)

*-----
 *EQ (23)
 BINARY_M6(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
 AND FREEH(I) AND FREEC(J)).. NHE_M1(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M+1)
 \$(HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M+1,J)) ;

*-----
 *EQ (24)
 BINARY_M7(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
 NHE_M1(S,Z,I,J,M)=G=0;

*-----
 *EQ (25)
 BINARY_M3_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J))..
 Y_M_B(S,Z,I,J,M) =E= SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M)
 AND ALLOW_H(S,Z,I,O,J)=1),NHE_M0_B(S,Z,I,J,O))
 -SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE [ORD(M)-1]
 AND ALLOW_H(S,Z,I,O,J)=1),NHE_M1_B(S,Z,I,J,O));

*-----
 *EQ (26) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
 *-----

*EQ (27)
 BINARY_N5(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
 NHE_N0(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1);

*-----
 *EQ (28) NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0
 * AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
 BINARY_N5b(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
 AND FREEH(I) AND FREEC(J))..
 NHE_N0(S,Z,I,J,N) =L= Y_N(S,Z,I,J,N);

* SEE COMMENTS ON EQUATION (17)

*-----
 *EQ (29)
 BINARY_N3(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
 AND FREEH(I) AND FREEC(J))..
 NHE_N0(S,Z,I,J,N) =G= Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1)
 \$(COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I));

*-----
 *EQ (30)
 BINARY_N4(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
 NHE_N0(S,Z,I,J,N)=G=0;

*-----
 *EQ (31) NOT NEEDED
 * GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
 *-----

*EQ (32)
 BINARY_N8(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1

AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J)..
 NHE_N1(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1);

*-----
 *EQ (33) NOT NEEDED BUT ADDED TO ENFORCE K=0 WHEN Y=0
 * AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
 BINARY_N9(S,Z,I,J,N)(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
 AND FREEH(I) AND FREEC(J))..
 NHE_N1(S,Z,I,J,N)=L= Y_N(S,Z,I,J,N);

* SEE COMMENTS ON EQUATION (17)

*-----
 *EQ (34)
 BINARY_N6(S,Z,I,J,N)(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
 AND FREEH(I) AND FREEC(J)).. NHE_N1(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1)
 \$(COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N+1,I));

*-----
 *EQ (35)
 BINARY_N7(S,Z,I,J,N)(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
 NHE_N1(S,Z,I,J,N)=G=0;

*-----
 *EQ (36)
 BINARY_N3_B(S,Z,I,J,N)(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J))..
 Y_N_B(S,Z,I,J,N)=E=SUM(O\$(COLD(S,J,O) AND ORD(O) LE ORD(N)
 AND ALLOW_C(S,Z,J,O,I)),NHE_N0_B(S,Z,I,J,O)) - SUM(O\$(COLD(S,J,O) AND ORD(O) LE
 ORD(N)-1 AND ALLOW_C(S,Z,J,O,I)),NHE_N1_B(S,Z,I,J,O));

*-----
 *EQ (37)
 HE_COUNT_M0(S,Z,I,J)(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 NHE(S,Z,I,J)=E=SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1),
 NHE_M0_B(S,Z,I,J,M)) + SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND BIF(Z,I,J)=0), NHE_M0(S,Z,I,J,M));

*-----
 *EQ (38)
 HE_COUNT_N0(S,Z,I,J)(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 NHE(S,Z,I,J)=E=SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1),
 NHE_N0_B(S,Z,I,J,N))
 + SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0),
 NHE_N0(S,Z,I,J,N));

*-----
 *EQ (39)
 HE_COUNT_M1(S,Z,I,J)(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 NHE(S,Z,I,J)=E=SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1),
 NHE_M1_B(S,Z,I,J,M)) + SUM(M\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND BIF(Z,I,J)=0), NHE_M1(S,Z,I,J,M));

*-----
 *EQ (40)
 HE_COUNT_N1(S,Z,I,J)(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 NHE(S,Z,I,J)=E=SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1),
 NHE_N1_B(S,Z,I,J,N)) + SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J)=0), NHE_N1(S,Z,I,J,N));

*-----
 *EQ (41)
 NEXCH(S,Z,I,J)(ALLOW(S,Z,I,J)=1 AND BIF(Z,I,J)=0 AND FREEH(I)
 AND FREEC(J)). NHE(S,Z,I,J)=L=1;

*-----
 *EQ (42)
 NEXCH_B(S,Z,I,J)(ALLOW(S,Z,I,J)=1 AND BIF(Z,I,J)=1 AND FREEH(I)
 AND FREEC(J)). NHE(S,Z,I,J)=L=KMAX(Z,I,J);

*-----
 *EQ (43)
 BIF_1(S,Z,I,J,M,N)(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
 AND ALLOW_H(S,Z,I,L,J)=1),
 QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M)=L=
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),

QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
 + B1(S,Z,I,M,J,N) *4* max(SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),DHH(S,I,L)),
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N)
 AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),DHC(S,J,O)));
 *-----
 *EQ (44)
 BIF_2(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND
 ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(I)
 AND FREEC(J) AND NOT PA(I))..
 SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
 AND ALLOW_H(S,Z,I,L,J)=1),
 QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =G=
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
 QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
 -B1(S,Z,I,M,J,N) *4* max(SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),DHH(S,I,L)),
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O)
 AND ALLOW_C(S,Z,J,O,I)),DHC(S,J,O)));
 *-----
 *EQ (45)
 BIF_3(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 B1(S,Z,I,M,J,N) =E= 2 - 0.25* SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),NHE_M1_B(S,Z,I,J,L))
 + 0.25 *SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O)
 AND ALLOW_C(S,Z,J,O,I)),NHE_N1_B(S,Z,I,J,O))
 -NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N);
 *-----
 *EQ (46)
 BIF_4(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND TL(S,N) GE TL(S,M)
 AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 SUM(L\$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND
 ALLOW_H(S,Z,I,L,J)=1),NHE_M1_B(S,Z,I,J,L))
 -SUM(O\$(COLD(S,J,O) AND ORD(O) LE ORD(N) AND ALLOW_C(S,Z,J,O,I)),
 NHE_N1_B(S,Z,I,J,O))=G=0;
 *-----
 *EQ (47)
 BIF_11(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J))..
 SUM(O\$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M) AND ALLOW_H(S,Z,I,O,J)=1),
 NHE_M0_B(S,Z,I,J,O)-NHE_M1_B(S,Z,I,J,O))=L=1 ;
 *-----
 *EQ (48)
 BIF_12(S,Z,I,J,N)\$ (COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J))..
 SUM(O\$(COLD(S,J,O) AND ORD(O) LE ORD(N) AND ALLOW_C(S,Z,J,O,I)),
 NHE_N0_B(S,Z,I,J,O)-NHE_N1_B(S,Z,I,J,O))=L=1;
 *-----
 *EQ (49)
 BIF_6(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J))..
 QNEW2_M(S,Z,I,J,M) =L= QNEW_M(S,Z,I,J,M);
 *-----
 *EQ (50)
 BIF_9(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 QNEW2_M(S,Z,I,J,M) =L= NHE_M0_B(S,Z,I,J,M)*DHH(S,I,M);
 *-----
 *EQ (51)
 BIF_5(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 QNEW2_M(S,Z,I,J,M) =L= NHE_M1_B(S,Z,I,J,M)*DHH(S,I,M);
 *-----
 *EQ (52) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE
 *-----

*EQ (53)

BIF_8(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $QNEW2_N(S,Z,I,J,N) = L = QNEW_N(S,Z,I,J,N);$

*EQ (54)

BIF_10(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $QNEW2_N(S,Z,I,J,N) = L = NHE_N0_B(S,Z,I,J,N)*DHC(S,J,N);$

*EQ (55)

BIF_7(S,Z,I,J,N) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $QNEW2_N(S,Z,I,J,N) = L = NHE_N1_B(S,Z,I,J,N)*DHC(S,J,N);$

*EQ (56) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE

*EQ (57)

FEAS_M_01(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPH(I)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $ALFA_M(S,Z,I,J,M) = L = 1 - NHE_M0(S,Z,I,J,M-1) - NHE_M0(S,Z,I,J,M);$

FEAS_M_01_B(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $ALFA_M(S,Z,I,J,M) = L = 1 - NHE_M0_B(S,Z,I,J,M-1) - NHE_M0_B(S,Z,I,J,M);$

*EQ (58)

FEAS_M_02(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPH(I)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $ALFA_M(S,Z,I,J,M) = L = 1 - NHE_M1(S,Z,I,J,M-1) - NHE_M1(S,Z,I,J,M);$
 FEAS_M_02_B(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $ALFA_M(S,Z,I,J,M) = L = 1 - NHE_M1_B(S,Z,I,J,M-1) - NHE_M1_B(S,Z,I,J,M);$

*EQ (59)

FEAS_M_03(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPH(I)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $ALFA_M(S,Z,I,J,M) = G = Y_M(S,Z,I,J,M) - NHE_M0(S,Z,I,J,M-1) - NHE_M0(S,Z,I,J,M) -$
 $NHE_M1(S,Z,I,J,M-1) - NHE_M1(S,Z,I,J,M);$
 FEAS_M_03_B(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $ALFA_M(S,Z,I,J,M) = G = Y_M_B(S,Z,I,J,M) - NHE_M0_B(S,Z,I,J,M-1) - NHE_M0_B(S,Z,I,J,M) -$
 $NHE_M1_B(S,Z,I,J,M-1) - NHE_M1_B(S,Z,I,J,M);$

*EQ (60)

FEAS_M_04(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } (BIF(Z,I,J)=1 \text{ OR } SPH(I)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$
 $ALFA_M(S,Z,I,J,M) = G = 0;$

*EQ (61)

FEAS_M_2(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } SPH(I)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I))..$
 $QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) = L =$
 $QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))$
 $+ (1 - ALFA_M(S,Z,I,J,M))*DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)));$

*EQ (62)

FEAS_M_1(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } SPH(I)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I))..$
 $QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))$
 $+ (1 - ALFA_M(S,Z,I,J,M))*DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))$
 $= G = QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)));$

*EQ (63)

FEAS_M_3(S,Z,I,J,M) $\$(HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M-1,J) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPH(I)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I))..$
 $- QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))$

+ QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(1+ NHE_M1(S,Z,I,J,M-1) + NHE_M1(S,Z,I,J,M) - NHE_M0(S,Z,I,J,M-1))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M))) * 1.00001 =G= 0;
 *-----
 *EQ (64)
 FEAS_M_4(S,Z,I,J,M)(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND NOT PA(I))..
 - QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 + QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +(1+ NHE_M0(S,Z,I,J,M-1)+NHE_M0(S,Z,I,J,M)-NHE_M1(S,Z,I,J,M))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M))) * 1.00001 =G= 0;
 *-----
 *EQ (65)
 FEAS_M_3_B_2(S,Z,I,J,M)(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND NOT PA(I))..
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(1+NHE_M1_B(S,Z,I,J,M-1)+NHE_M1_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));
 *-----
 *EQ (66)
 FEAS_M_3_B_1(S,Z,I,J,M)(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND NOT PA(I))..
 QNEW2_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))+(2 + NHE_M1_B(S,Z,I,J,M)
 -NHE_M0_B(S,Z,I,J,M-1)-Y_M_B(S,Z,I,J,M-1))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));
 *-----
 *EQ (67)
 FEAS_M_4_B(S,Z,I,J,M)(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)
 AND FREEC(J) AND NOT PA(I))..
 (QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))=L=
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +(2 + NHE_M0_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M))
 DHH(S,I,M)/(CPH(S,I,M)(TU(S,M)-TL(S,M)));
 *-----
 *EQ (68)
 FEAS_M_1_SP(S,Z,I,J,M)(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND SPH(I)=0
 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 QNEW_M(S,Z,I,J,M)=G=(Y_M(S,Z,I,J,M)-
 NHE_M0(S,Z,I,J,M) + NHE_M1(S,Z,I,J,M))*DHH(S,I,M);
 FEAS_M_1_SP_B(S,Z,I,J,M)(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=1 AND SPH(I)=0
 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 QNEW_M(S,Z,I,J,M)=G=(Y_M_B(S,Z,I,J,M)-
 NHE_M0_B(S,Z,I,J,M)+NHE_M0_B(S,Z,I,J,M))*DHH(S,I,M);
 *-----
 *EQ (69)
 FEAS_N_01(S,Z,I,J,N)(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1
 AND ALLOW_C(S,Z,I,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=L=1-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1);
 FEAS_N_01_B(S,Z,I,J,N)(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1
 AND ALLOW_C(S,Z,I,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=L=1-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1);
 *-----
 *EQ (70)
 FEAS_N_02(S,Z,I,J,N)(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1
 AND ALLOW_C(S,Z,I,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=L=1-NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N-1);
 FEAS_N_02_B(S,Z,I,J,N)(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,I,N,I)=1
 AND ALLOW_C(S,Z,I,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 ALFA_N(S,Z,I,J,N)=L=1-NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);

*-----
 *EQ (71)

FEAS_N_03(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..

ALFA_N(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,I,J,N-1)
 -NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N-1);

FEAS_N_03_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..

ALFA_N(S,Z,I,J,N)=G=Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1)
 -NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);

*-----
 *EQ (72)

FEAS_N_04(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND (BIF(Z,I,J)=1 OR SPC(J)=1) AND FREEH(I)
 AND FREEC(J))..

ALFA_N(S,Z,I,J,N)=G=0;

*-----
 *EQ (73)

FEAS_N_2(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..

QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=L=QNEW_N(S,Z,I,J,N-1)
 /(CPC(S,J,N-1)

*(TU(S,N-1)-TL(S,N-1)))+(1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)/
 (CPC(S,J,N)*(TU(S,N)-TL(S,N)));

*-----
 *EQ (74)

FEAS_N_1(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J))..

QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
 +(1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)
 /(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/
 (CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)));

*-----
 *EQ (75)

FEAS_N_3(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..

-QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
 +QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(1+NHE_N1(S,Z,I,J,N-1)
 +NHE_N1(S,Z,I,J,N)
 -NHE_N0(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
 *1.00001 =G= 0;

*-----
 *EQ (76)

FEAS_N_4(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..

-QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
 +QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
 +(1+NHE_N0(S,Z,I,J,N-1)
 +NHE_N0(S,Z,I,J,N)-NHE_N1(S,Z,I,J,N))*DHC(S,J,N)/
 (CPC(S,J,N)*(TU(S,N)-TL(S,N)))
 *1.00001=G=0;

*-----
 *EQ (77)

FEAS_N_3_B_2(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1
 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..

-QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
 +QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
 +(1 + NHE_N1_B(S,Z,I,J,N-1)+ NHE_N1_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1))
 DHC(S,J,N)/(CPC(S,J,N)(TU(S,N)-TL(S,N)))=G=0;

*-----
 *EQ (78)

FEAS_N_3_B_1(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1
 AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND SPC(J)=1 AND FREEH(I)
 AND FREEC(J))..

-QNEW2_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
 +QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(2 + NHE_N1_B(S,Z,I,J,N)
 -NHE_N0_B(S,Z,I,J,N-1)-Y_N_B(S,Z,I,J,N-1))

$$*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;$$

*EQ (79)

$$\begin{aligned} &FEAS_N_4_B(S,Z,I,J,N)\$(COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \\ &\text{ AND } ALLOW_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } SPC(J)=1 \text{ AND } FREEH(I) \\ &\text{ AND } FREEC(J)).. \\ &-(QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(CPC(S,J,N)*(TU(S,N)-TL(S,N))) \\ &+ QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1))) \\ &+(2 + NHE_N0_B(S,Z,I,J,N-1) - NHE_N1_B(S,Z,I,J,N) - Y_N_B(S,Z,I,J,N)) \\ &\quad *DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0; \end{aligned}$$

*EQ (80)

$$\begin{aligned} &FEAS_N_1_SP(S,Z,I,J,N)\$(COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N+1) \text{ AND } \\ &ALLOW_C(S,Z,J,N,I)=1 \text{ AND } ALLOW_C(S,Z,J,N-1,I) \text{ AND } ALLOW_C(S,Z,J,N+1,I) \\ &\text{ AND } BIF(Z,I,J)=0 \\ &\text{ AND } SPC(J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J)).. QNEW_N(S,Z,I,J,N) = G= \\ &\quad (Y_N(S,Z,I,J,N) - NHE_N0(S,Z,I,J,N) - NHE_N1(S,Z,I,J,N)) * DHC(S,J,N); \end{aligned}$$

$$\begin{aligned} &FEAS_N_1_SP_B(S,Z,I,J,N)\$(COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N+1) \\ &\text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } ALLOW_C(S,Z,J,N-1,I) \text{ AND } ALLOW_C(S,Z,J,N+1,I) \\ &\text{ AND } BIF(Z,I,J)=1 \\ &\text{ AND } SPC(J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J)).. QNEW_N(S,Z,I,J,N) = G= \\ &\quad (Y_N_B(S,Z,I,J,N) - NHE_N0_B(S,Z,I,J,N) - NHE_N1_B(S,Z,I,J,N)) * DHC(S,J,N); \end{aligned}$$

*EQ (81)

$$\begin{aligned} &FEAS_BEG_SP(S,Z,I,J,M,N)\$(TL(S,N) \text{ LE } TU(S,M) \text{ AND } TU(S,N) \text{ GE } TL(S,M) \\ &\text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \\ &\text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=0 \\ &\text{ AND } SPH(I)=0 \text{ AND } SPC(J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I)).. \\ &TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N)) \\ &+ QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) \\ &+ (2 - NHE_M0(S,Z,I,J,M) - NHE_N0(S,Z,I,J,N)) * TU(S,N) = G=0; \end{aligned}$$

$$\begin{aligned} &FEAS_BEG_B_SP(S,Z,I,J,M,N)\$(TL(S,N) \text{ LE } TU(S,M) \text{ AND } TU(S,N) \text{ GE } TL(S,M) \\ &\text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \\ &\text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \\ &\text{ AND } SPH(I)=0 \text{ AND } SPC(J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I)).. \\ &TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N)) \\ &+ QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) \\ &+ (2 - NHE_M0_B(S,Z,I,J,M) - NHE_N0_B(S,Z,I,J,N)) * TU(S,N) = G=0; \end{aligned}$$

*EQ (82)

$$\begin{aligned} &FEAS_END_SP(S,Z,I,J,M,N)\$(TL(S,N) \text{ LE } TU(S,M) \text{ AND } TU(S,N) \text{ GE } TL(S,M) \\ &\text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \\ &\text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=0 \\ &\text{ AND } SPH(I)=0 \text{ AND } SPC(J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I)).. \\ &TU(S,M) - TU(S,N) \\ &- QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N)) \\ &\quad + (2 - NHE_M1(S,Z,I,J,M) - NHE_N1(S,Z,I,J,N)) * TU(S,N) = G=0; \\ &FEAS_END_B_SP(S,Z,I,J,M,N)\$(TL(S,N) \text{ LE } TU(S,M) \text{ AND } TU(S,N) \text{ GE } TL(S,M) \\ &\text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \\ &\text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \\ &\text{ AND } SPH(I)=0 \text{ AND } SPC(J)=0 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I)).. \\ &TU(S,M) - TU(S,N) \\ &- QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N)) \\ &\quad + (2 - NHE_M1_B(S,Z,I,J,M) - NHE_N1_B(S,Z,I,J,N)) * TU(S,N) = G=0; \end{aligned}$$

*EQ (83)

$$\begin{aligned} &FEAS_BEG3(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \\ &\text{ AND } TU(S,N) \text{ GT } TL(S,M) \\ &\text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M+1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N+1) \\ &\text{ AND } ALLOW_H(S,Z,I,M,J)=1 \\ &\text{ AND } ALLOW_H(S,Z,I,M+1,J) \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } ALLOW_C(S,Z,J,N+1,I) \\ &\text{ AND } BIF(Z,I,J)=0 \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J)).. \\ &\quad NHE_N1(S,Z,I,J,N) = L = (2 - NHE_M0(S,Z,I,J,M) - NHE_N0(S,Z,I,J,N)); \end{aligned}$$

*EQ (84)

$$\begin{aligned} &FEAS_BEG(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } D(S,Z,M,N)=1 \\ &\text{ AND } TL(S,N) \text{ LT } TU(S,M) \\ &\text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M+1) \text{ AND } COLD(S,J,N)=1 \\ &\text{ AND } COLD(S,J,N+1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } ALLOW_H(S,Z,I,M+1,J) \end{aligned}$$

AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)..
 QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)
 /(TU(S,N+1)-TL(S,N+1))*CPC(S,J,N)/CPC(S,J,N+1)
 +(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*DHC(S,J,N)/(TU(S,M)-TL(S,N));

*EQ (85)

FEAS_BEG2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1)
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1
 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1)
 AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=
 QNEW_M(S,Z,I,J,M+1)/(TU(S,M+1)-TL(S,M+1))
 *CPH(S,I,M)/CPH(S,I,M+1)+(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))
 *DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));

*EQ (86)

FEAS_END3(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M)
 AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1 AND COLD(S,J,N-1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I)
 AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 NHE_M0(S,Z,I,J,M)=L=(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N));

*EQ (87)

FEAS_END(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
 QNEW_M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW_M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))
 *CPH(S,I,M)/CPH(S,I,M-1)+(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))
 *DHH(S,I,M)/(TU(S,M)-TL(S,N));

*EQ (88)

FEAS_END2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 QNEW_N(S,Z,I,J,N)/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/
 (TU(S,N-1)-TL(S,N-1))
 *CPC(S,J,N)/CPC(S,J,N-1)+(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))
 *DHC(S,J,N-1)/(TU(S,N-1)-TL(S,N-1));

*EQ (89)

FEAS_BEG4_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M)
 AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I)
 AND BIF(Z,I,J)=1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 NHE_N1_B(S,Z,I,J,N)=L=
 (1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N));

*EQ (90)

FEAS_BEG2_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
 QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=
 QNEW_N(S,Z,I,J,N+1)/(TU(S,N+1)-TL(S,N+1))
 *CPC(S,J,N)/CPC(S,J,N+1)+
 (1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
 *DHC(S,J,N)/(TU(S,M)-TL(S,N));

*EQ (91)

FEAS_BEG1_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
QNEW2_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)/
(TU(S,N+1)-TL(S,N+1))
*CPC(S,J,N)/CPC(S,J,N+1)+(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
*DHC(S,J,N)/(TU(S,M)-TL(S,N));

*-----
*EQ (92)

FEAS_BEG3_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=QNEW_M(S,Z,I,J,M+1)/
(TU(S,M+1)-TL(S,M+1))
*CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
*DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));

*-----
*EQ (93)

FEAS_END3_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M)
AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1 AND COLD(S,J,N-1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_C(S,Z,J,N,I) AND ALLOW_C(S,Z,J,N-1,I)
AND BIF(Z,I,J)=1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
NHE_M0_B(S,Z,I,J,M)=I=
(1+Y_M_B(S,Z,I,J,M)-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N));

*-----
*EQ (94)

FEAS_END_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
(QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L=
QNEW_M(S,Z,I,J,M-1)/
(TU(S,M-1)-TL(S,M-1))*CPH(S,I,M)/CPH(S,I,M-1)+
(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHH(S,I,M)/(TU(S,M)-TL(S,N));

*-----
*EQ (95)

FEAS_END2_B(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J))..
(QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=
QNEW_N(S,Z,I,J,N-1)/(TU(S,N-1)-TL(S,N-1))*CPC(S,J,N)/CPC(S,J,N-1)
-(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHC(S,J,N-1)/
(TU(S,N-1)-TL(S,N-1));

*-----
*EQ (96)

PAREQ(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
PAR(Z,I,J)=E=SUM((M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
Q(S,Z,I,M,J,N)/(U(S,I,J)*LMTD(S,M,N)));

*-----
*EQ (97)

BIF_13_2(S,K,Z,I,J,M)\$(ORD(K) LT KMAX(Z,I,J) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
PAR_B(K,Z,I,J)=L= SUM((L,N)\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
AND TL(S,N) LT TU(S,L)
AND HOT(S,I,L)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,L,J)=1
AND ALLOW_C(S,Z,J,N,I)=1),
(Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))/(U(S,I,J)*LMTD(S,L,N))
+AMAX*(2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,I,J,M)-
SUM(KK\$(ORD(KK) GT 1 AND ORD(KK) LT ORD(K)),X_B(S,KK,Z,I,J,M))));

*Comment: In the paper X1_B does not show. Only one variable, X_B is used
 * to make summations from 1 to kmax-1. Here we use X1_B and then a
 * summation from 2 to kmax-1. See equation (100) as well.

*EQ (98)

BIF_13(S,K,Z,I,J,M)\$ (ORD(K) LT KMAX(Z,I,J) AND HOT(S,I,M)=1
 AND ALLOW_H(S,Z,I,M,J)=1
 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 PAR_B(K,Z,I,J)=G= SUM((L,N)\$ (D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND TL(S,N) LT TU(S,L)
 AND HOT(S,I,L)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,L,J)=1
 AND ALLOW_C(S,Z,J,N,I)=1),
 (Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))/(U(S,I,J)*LMTD(S,L,N))
 -AMAX*(2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,I,J,M)-
 SUM(KK\$(ORD(KK) GT 1 AND ORD(KK) LT ORD(K)),X_B(S,KK,Z,I,J,M))));

*EQ (99)

BIF_14(S,K,Z,I,J)\$ (ORD(K) EQ KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1 AND FREEH(I)
 AND FREEC(J) AND BIF(Z,I,J)=1)..
 PAR_B(K,Z,I,J)=E=PAR(Z,I,J)-SUM(KK\$(ORD(KK) LT ORD(K)),PAR_B(KK,Z,I,J));

*EQ (100)

BIF_15(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J))..
 X1_B(S,Z,I,J,M)+SUM(K\$(ORD(K) GT 1 AND ORD(K) LE KMAX(Z,I,J)),
 ORD(K)*X_B(S,K,Z,I,J,M))=E= SUM(L\$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND
 ALLOW_H(S,Z,I,L,J)=1),NHE_M0_B(S,Z,I,J,L))+I-Y_M_B(S,Z,I,J,M);

*Comment: In the paper X1_B does not show. Only one variable, X_B is used
 * to make summations from 1 to kmax-1. Here we use X1_B and then a
 * summation from 2 to kmax-1.

*EQ (101)

BIF_17(S,Z,I,J,M)\$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J))..
 SUM(N\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1 AND COLD(S,J,N)=1
 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q2(S,Z,I,M,J,N))=E=
 QNEW2_M(S,Z,I,J,M);

*EQ (102)

BIF_18(S,Z,I,J,M,N)\$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
 Q2(S,Z,I,M,J,N)=L=Q(S,Z,I,M,J,N);

*EQ (103)

SHELL(Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J)=0)..
 PAR(Z,I,J)=L=ASHELLMAX*USHELL(Z,I,J);

*EQ (104)

SHELL_B(K,Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J)=1)..
 PAR_B(K,Z,I,J)=L=ASHELLMAX*USHELL_B(K,Z,I,J);

*EQ (105)

*TOTALCOST.. TCOST=E= SUM(I\$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
 * + SUM(J\$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
 * + SUM((Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
 * AND BIF(Z,I,J)=0), CF*USHELL(Z,I,J))
 * + SUM((K,Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
 * AND BIF(Z,I,J)=1), CF*USHELL_B(K,Z,I,J))
 * + SUM((Z,I,J)\$ (SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)),
 * CA*PAR(Z,I,J))
 * + Cost_side_stripping_steam ;

\$ONTEXT

TOTALCOST.. TCOST=E=SUM(I\$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
 +SUM(J\$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
 +SUM((S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
 ,CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)\$ (NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)))
 +SUM((S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J)=0),CAE*DPAR_E(Z,I,J)+CAN*PAR_N(S,Z,I,J))

```

+SUM((S,K,Z,I,J)$ (ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)
.CAE*DPAR_E_B(K,Z,I,J)+CAN*PAR_N_B(K,Z,I,J))
$OFFTEXT
TOTALCOST.. TCOST =E= SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
+ SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))

+SUM((S,Z,I,J)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)
.(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$ (NHE0(S,Z,I,J)=1)-(NHE0(S,Z,I,J)*(SUM(E$(ORD(E) LE KET),
Phi(Z,I,J,E)))))+(CAE*DPAR_E(Z,I,J))+CAN*PAR_N(S,Z,I,J))
+SUM((S,Z,I,J)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1)
.(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$ (NHE0(S,Z,I,J)=1)-SUM((EE,E,K)$ (OPT=2 AND ORD(E) LE KET AND
ORD(K) LE KMAX(Z,I,J)),DELTA(Z,I,J,EE,E,K))))))
+SUM((S,Z,I,J,K,E)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1 AND ORD(K) LE KMAX(Z,I,J))
* +SUM (K$(ORD(K) LE KMAX(Z,I,J)
,(CAE*DPAR_E_B(K,E,Z,I,J)+CAN*PAR_N_B(K,E,Z,I,J)))

+Cost_side_stripping_steam;

* Here we have an equation that is made simpler than in the paper. We account
* for the total area of the exchangers (use PAR and not PAR_B).
* The result is the same.

*-----
*EQ (106) CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K.

KMAX1(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=0)..
NHE(S,Z,I,J) =L= USHELL(Z,I,J) ;

*EQ (107)
KMAX2(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
NHE(S,Z,I,J) =L= SUM(K,USHELL_B(K,Z,I,J)) ;
*-----
*-----
* EXTRA EQUATIONS NOT IN PAPER BUT NEEDED
*-----
*EQ (108) LIMIT THE NUMBER OF EXCHANGERS
TOTNEXCH_MAX(S).. SUM((Z,I,J)$ (ALLOW(S,Z,I,J)= 1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=L=TOTNEXCHMAX; *
*-----
*EQ (109) MINIMUM NUMBER OF EXCHANGERS
TOTNEXCH_MIN(S).. SUM((Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=G=TOTNEXCHMIN;
*-----
$ONTEXT
*Equation for Retrofit
*-----
*EQ(Retrofit 1)
AREA_REST1(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,I,J);
*-----
*EQ(Retrofit 2)
AREA_REST2(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
DPAR_E(Z,I,J)=L=AEX_U(Z,I,J)-AEX(Z,I,J);
*-----
*EQ(Retrofit 3)
AREA_REST3(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR_N(S,Z,I,J)=L=A_NEW_MAX(Z,I,J) *(NHE(S,Z,I,J)-NHE0(S,Z,I,J));
*-----
*EQ(Retrofit 4)
AREA_REST4(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
(NHE(S,Z,I,J)) =L= TOTNEXCHMAX ;

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*-----
*EQ(Retrofit 5)
AREA_REST5(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0 AND NHE0(S,Z,I,J)=0)..

PAR_N(S,Z,I,J) =L= A_NEW_MAX(Z,I,J)* (NHE(S,Z,I,J));
*-----
*EQ(Retrofit 6)
*Eq retrofit 6 is same as Eq retrofit 5
*-----
*EQ(Retrofit 7)
AREA_REST7(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0 AND NHE0(S,Z,I,J)=0)..
(NHE(S,Z,I,J)) =L= TOTNEXCHMAX ;
*-----
*EQ(Retrofit 8)
AREA_REST1_B(S,K,Z,I,J)$ (ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_B(K,Z,I,J) =L= SUM(KK$ (ORD(KK) LE NHE0(S,Z,I,J)), AEX_B(KK,Z,I,J)
*DELTA(KK,K)) + DPAR_E_B(K,Z,I,J) + PAR_N_B(K,Z,I,J);
*-----
*EQ(Retrofit 9)
AREA_REST2_B(S,K,Z,I,J)$ (ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
DPAR_E_B(K,Z,I,J) =L= SUM(KK$ (ORD(KK) LE NHE0(S,Z,I,J)), (AEX_U_B(KK,Z,I,J)
-AEX_B(KK,Z,I,J))*DELTA(KK,K));
*-----
*EQ(Retrofit 10)
AREA_REST3_B(S,K,Z,I,J)$ (ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_N_B(K,Z,I,J) =L= A_NEW_MAX(Z,I,J)
*(1-SUM(KK$ (ORD(KK) LE NHE0(S,Z,I,J)), DELTA(KK,K)));
*-----
*EQ(Retrofit 11)
AREA_REST4_B(S,K,Z,I,J)$ (ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM(KK$ (ORD(KK) LE NHE0(S,Z,I,J)), DELTA(KK,K)) =L= 1;
*-----
*EQ(Retrofit 12)
AREA_REST5_B(S,K,Z,I,J)$ (ORD(K) LE NHE0(S,Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM(KK$ (ORD(KK) LE KMAX(Z,I,J)), DELTA(K,KK)) =L= 1;
*-----
*EQ(Retrofit 13)
AREA_REST6_B(S,Z,I,J)$ (ALLOW(S,Z,I,J)=1 AND FREEH(I)
AND FREEC(J) AND BIF(Z,I,J)=1)..

SUM((K,KK)$ (ORD(K) LE KMAX(Z,I,J) AND ORD(KK) LE NHE0(S,Z,I,J)), DELTA(KK,K))
=E= NHE0(S,Z,I,J);
*-----
*EQ(Retrofit 14)
LIM_HEX(S,M)..

SUM((Z,I,J)$ (HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1), (NHE(S,Z,I,J)) - NHE0(S,Z,I,J))
=L= MAX_NEW_HEX ;
*-----
$OFFTEXT
*-----
*****Equation for Retrofit Relocation*****
*-----
*EQ(Retrofit 16)
RELOCATE_1(S,Z,I,J)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR(Z,I,J) =L= AEX(Z,I,J) + DPAR_E(Z,I,J) + PAR_N(S,Z,I,J);
*-----
*EQ(Retrofit 17)
RELOCATE_2(S,Z,I,J)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
AEX(Z,I,J) =E= SUM(E$ (ORD(E) LE KET), (AEX_R(E)*Phi(Z,I,J,E)));
*-----

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*EQ(Retrofit 18)
RELOCATE_3(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
DPAR_E(Z,I,J)=L=SUM(E$(ORD(E) LE KET),(AEX_U_1(E)-AEX_R(E))
*Phi(Z,I,J,E));
*-----
*EQ(Retrofit 19)
RELOCATE_4(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR_N(S,Z,I,J)=L= A_NEW_MAX(Z,I,J) *(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-(NHE0(S,Z,I,J)*
SUM(E$(ORD(E) LE KET),Phi(Z,I,J,E))));
*-----
*EQ(Retrofit 20)
RELOCATE_5_1(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0).. NHE(S,Z,I,J)=L= TOTNEXCHMAX ;

RELOCATE_5_2(S,Z,I,J)$(OPT=2 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0).. SUM((E)$(ORD(E) LE KET),Phi(Z,I,J,E))=L= 1 ;

*Extra Eq. Limits number of phi matches
RELOCATE_5_3(Z,E)$(OPT=2).. SUM((i,j), Phi(Z,I,J,E))=L= 1 ;
*-----
*$ONTEXT
**EQ(Retrofit 21)
RELOCATE_6(K,E,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_B_R(K,E,Z,I,J)=L=AEX_B(K,E,Z,I,J)+DPAR_E_B(K,E,Z,I,J)+PAR_N_B(K,E,Z,I,J);
*-----
*EQ(Retrofit 22)
RELOCATE_7(K,E,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
AEX_B(K,E,Z,I,J)=E=SUM(EE$(ORD(E) LE KET),(AEX_B_R(E)*DELTA(Z,I,J,EE,E,K)));
*-----
*EQ(Retrofit 23)
RELOCATE_8(K,E,S,Z,I,J)$(OPT=2 AND ORD(E) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
DPAR_E_B(K,E,Z,I,J)=L=SUM(EE$(ORD(E) LE KET),(AEX_U_B_R(E)-AEX_B_R(E))
*DELTA(Z,I,J,EE,E,K));
*-----
*EQ(Retrofit 24)
RELOCATE_9(K,E,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
PAR_N_B(K,E,Z,I,J)=L= A_NEW_MAX(Z,I,J) *(1-SUM(EE$(ORD(E) LE KET)
,DELTA(Z,I,J,EE,E,K)));
*-----
*EQ(Retrofit 25)
RELOCATE_10(K,E,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)..
SUM(EE$(ORD(E) LE KET),DELTA(Z,I,J,EE,E,K))=L= 1 ;
*-----

*Add Eq for PA
*-----
*EQ (3_b)
PA_1(S,I,M)$(HOT(S,I,M)=1 AND NOT HU(I) AND
FREEH(I) AND NIH(I)=0 AND PA(I))..
FP(I)*CPH(S,I,M)*(TU(S,M)-TL(S,M))=E=SUM((Z,N,J)$(D(S,Z,M,N)=1
AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1).Q(S,Z,I,M,J,N));
*-----
*EQ (7_b)
PA_2(S,I,M)$(HOT(S,I,M)=1 AND NOT HU(I)
AND FREEH(I) AND NIH(I)=1 AND PA(I))..
FP(I)*CPH(S,I,M)*(TU(S,M)-TL(S,M))=E=SUM((Z,N,J)$(D(S,Z,M,N)=1
AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1).Q(S,Z,I,M,J,N))
+SUM((Z,N)$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) GT ORD(M)),QH(S,Z,I,N,M))
-SUM((Z,N)$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N));

```

 *EQ 11_b Case of BIF(I,J)=0 (i,j) not belonging to set B.
 PA_3(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)-FPY(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M))\$(NOT HU(I))=L=0;

 *EQ 11_b Case of BIF(I,J)=0 (i,j) not belonging to set B
 ***** MINIMUM VALUE OF QNEW_M=0.01!!!!!!
 PA_4(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0 AND
 FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*QLHMIN=G=0;

 *EQ 11_b Case of BIF(I,J)=1 (i,j) belonging to set B
 PA_3_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)-FPY_B(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M))\$(NOT HU(I))=L=0;

 *EQ 11_b Case of BIF(I,J)=1 (i,j) belonging to set B
 PA_4_B(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN =G= 0;

 *EQ 11_C_1
 PA_5(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 FPY(S,Z,I,J,M) =E= SUM(R,(FPR(I,R)*YW(S,Z,I,J,M)));

 *EQ 11_C_2
 PA_6(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 FPY_B(S,Z,I,J,M) =E= SUM(R,(FPR(I,R)*YW(S,Z,I,J,M)));

 *EQ 11_D
 PA_7(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 YW(S,Z,I,J,M)-Y_M(S,Z,I,J,M) =L= 0;

 *EQ 11_E
 PA_8(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 YW(S,Z,I,J,M) =L= W(I,R);

 *EQ 11_F
 PA_9(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 YW(S,Z,I,J,M) =G= Y_M(S,Z,I,J,M)+W(I,R)-1;

 *EQ (43_b)
 PA_10(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..
 SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
 AND ALLOW_H(S,Z,I,L,J)=1),
 QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =L=
 SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
 QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)+ 4*XM(S,Z,I,M,J,N);

 *EQ 43_C
 PA_11(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..
 XM(S,Z,I,M,J,N)-(TE(S,Z,I,M,J,N)*OMEGA(S,Z,I,M,J,N))=L=SUM(R,(XW(S,Z,I,M,J,N,R)*
 FPR(I,R)*SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
 AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),(CPH(S,I,L)*(TU(S,L)-TL(S,L))))));

 *EQ 43_D
 PA_12(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

XM(S,Z,I,M,J,N)-(TE(S,Z,I,M,J,N)*OMEGA(S,Z,I,M,J,N))=G=SUM(R,(XW(S,Z,I,M,J,N,R)*
FPR(I,R)*SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1),(CPH(S,I,L)*(TU(S,L)-TL(S,L))))));

*-----
*EQ 43_E

PA_13(S,Z,I,J,M,N)\$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)..

XM(S,Z,I,M,J,N)-((1-TE(S,Z,I,M,J,N))*OMEGA(S,Z,I,M,J,N))=L=B1(S,Z,I,M,J,N)*
SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(N)
AND COLD(S,J,L)=1 AND ALLOW_C(S,Z,I,L,I)=1),DHC(S,J,L));

*-----
*EQ 43_F

PA_14(S,Z,I,J,M,N)\$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)..

XM(S,Z,I,M,J,N)=G= B1(S,Z,I,M,J,N)*SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(N)
AND COLD(S,J,L)=1 AND ALLOW_C(S,Z,I,L,I)=1),DHC(S,J,L));

*-----
*EQ 43_G

PA_15(S,Z,I,J,M,N,R)\$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)..

XW(S,Z,I,M,J,N,R)-(T(S,Z,I,M,J,N)*W(I,R)) =L= 0 ;

*-----
*EQ 43_H

PA_16(S,Z,I,J,M,N,R)\$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)..

(B1(S,Z,I,M,J,N)- XW(S,Z,I,M,J,N,R))-(1-W(I,R))*T(S,Z,I,M,J,N) =L= 0 ;

*-----
*EQ 43_I

PA_17(S,Z,I,J,M,N,R)\$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)..

(B1(S,Z,I,M,J,N)- XW(S,Z,I,M,J,N,R)) =G= 0 ;

*-----
*EQ (44_b)

PA_18(S,Z,I,J,M,N)\$D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND
ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(I)
AND FREEC(J) AND PA(I)..
SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
AND ALLOW_H(S,Z,I,L,J)=1),
QNEW_M(S,Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =G=
SUM(O\$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
-4*XM(S,Z,I,M,J,N);

*-----
*EQ (50_b)

PA_19(S,Z,I,J,M)\$HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)..
QNEW2_M(S,Z,I,J,M) =L= FPK_H_0(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M));

*-----
*EQ 50_C

PA_20(S,Z,I,J,M)\$HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)..

FPK_H_0(S,Z,I,J,M) =E= SUM(R,(FPR(I,R)*KW_0(S,Z,I,J,M,R)));

*-----
*EQ 50_D

PA_21(S,Z,I,J,M,R)\$HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)..

KW_0(S,Z,I,J,M,R)- NHE_M0_B(S,Z,I,J,M) =L= 0;

 *EQ 50_E
 PA_22(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 KW_0(S,Z,I,J,M,R) =L= W(I,R);

 *EQ 50_F
 PA_23(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 KW_0(S,Z,I,J,M,R) =G= NHE_M0_B(S,Z,I,J,M) + W(I,R)- 1;

 *EQ (51_b)
 PA_24(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW2_M(S,Z,I,J,M) =L= FPK_H_1(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M));

 *EQ 51_C
 PA_25(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 FPK_H_1(S,Z,I,J,M) =E= SUM(R,(FPR(I,R)*KW_1(S,Z,I,J,M,R)));

 *EQ 51_D
 PA_26(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 KW_1(S,Z,I,J,M,R)- NHE_M1_B(S,Z,I,J,M) =L= 0;

 *EQ 51_E
 PA_27(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 KW_1(S,Z,I,J,M,R) =L= W(I,R);

 *EQ 51_F
 PA_28(S,Z,I,J,M,R)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND PA(I))..
 KW_1(S,Z,I,J,M,R) =G= NHE_M1_B(S,Z,I,J,M) + W(I,R)- 1;

 *EQ (61_b)
 PA_29(S,Z,I,J,M,R)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) =L=
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +(FP(I)-FPA(S,Z,I,J,M));

 *EQ 61_C
 PA_30(S,Z,I,J,M,R)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..
 FPA(S,Z,I,J,M) =E= SUM(R,(FPR(I,R)*WA(S,Z,I,J,M,R)));

 *EQ 61_D
 PA_31(S,Z,I,J,M,R)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..
 WA(S,Z,I,J,M,R)-ALFA_M(S,Z,I,J,M) =L= 0;

 *EQ 61_E
 PA_32(S,Z,I,J,M,R)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..
 WA(S,Z,I,J,M,R) =L= W(I,R);

 *EQ 61_F
 PA_33(S,Z,I,J,M,R)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

WA(S,Z,I,J,M,R)=G=ALFA_M(S,Z,I,J,M)+W(I,R)-1;

*EQ (62_b)

PA_34(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(FP(I)-FPA(S,Z,I,J,M))
 =G=QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)));

*EQ (63_b)

PA_35(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

- QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 + QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(FP(I)+FPK_H_1(S,Z,I,J,M-1)+FPK_H_1(S,Z,I,J,M)-FPK_H_0(S,Z,I,J,M-1))=G=0;

*EQ (64_b)

PA_36(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

- QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 + QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +(FP(I)+FPK_H_0(S,Z,I,J,M-1)+FPK_H_0(S,Z,I,J,M)-FPK_H_1(S,Z,I,J,M))=G=0;

*EQ (65_b)

PA_37(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +(FP(I)+FPK_H_1(S,Z,I,J,M-1)+FPK_H_1(S,Z,I,J,M)-FPK_H_0(S,Z,I,J,M-1));

*EQ (66_b)

PA_38(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

QNEW2_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
 QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
 +((2*FP(I))+FPK_H_1(S,Z,I,J,M-1)-FPK_H_0(S,Z,I,J,M-1)-FPY(S,Z,I,J,M-1));

*EQ (67_b)

PA_39(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I))..

(QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))=L=
 QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
 +((2*FP(I))+FPK_H_0(S,Z,I,J,M-1)-FPK_H_1(S,Z,I,J,M)-FPY(S,Z,I,J,M-1));

*EQ (68_b)

PA_40(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND SPH(I)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..

QNEW_M(S,Z,I,J,M)=G=(FPY(S,Z,I,J,M)-FPK_H_0(S,Z,I,J,M)-FPK_H_1(S,Z,I,J,M))
 (CPH(S,I,M)(TU(S,M)-TL(S,M)));

PA_41(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)

AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=1 AND SPH(I)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..

QNEW_M(S,Z,I,J,M)=G=(FPY_B(S,Z,I,J,M)-FPK_H_0_B(S,Z,I,J,M)-
 -FPK_H_1_B(S,Z,I,J,M))*(CPH(S,I,M)*(TU(S,M)-TL(S,M)));

*EQ (81_b)

PA_42(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M) AND HOT(S,I,M)=1 AND COLD(S,I,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,I,N,I)=1 AND BIF(Z,I,J)=0

AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..

$TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))$
 $+ (FPQ(S,Z,I,J,M)/CPH(S,I,M))$
 $+ (2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))*TU(S,N)=G=0;$

PA_43(S,Z,I,J,M,N) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$
 $AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1$
 $AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..$
 $TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))$
 $+ (FPQ(S,Z,I,J,M)/CPH(S,I,M))$
 $+ (2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))*TU(S,N)=G=0;$

$-----$
***EQ 81_C**
PA_44(S,Z,I,J,M,N) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$
 $AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1$
 $AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..$

$FPQ(S,Z,I,J,M) = E = SUM(R, WQ(S,Z,I,J,M,R)/FPR(I,R)) ;$
 $-----$

***EQ 81_D**
PA_45(S,Z,I,J,M,N,R) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$
 $AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1$
 $AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..$

$WQ(S,Z,I,J,M,R) - (T(S,Z,I,M,J,N) * W(I,R)) = L = 0 ;$
 $-----$

***EQ 81_E**
PA_46(S,Z,I,J,M,N,R) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$
 $AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1$
 $AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..$

$(QNEW_M(S,Z,I,J,M) - WQ(S,Z,I,J,M,R)) - (1 - W(I,R)) * T(S,Z,I,M,J,N) = L = 0 ;$
 $-----$

***EQ 81_F**
PA_47(S,Z,I,J,M,N,R) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$
 $AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1$
 $AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..$

$QNEW_M(S,Z,I,J,M) - WQ(S,Z,I,J,M,R) = G = 0;$
 $-----$

***EQ (82_b)**
PA_48(S,Z,I,J,M,N) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$
 $AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0$
 $AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..$
 $TU(S,M) - TU(S,N)$
 $- (FPQ(S,Z,I,J,M)/CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))$
 $+ (2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,I,J,N))*TU(S,N)=G=0;$

PA_49(S,Z,I,J,M,N) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$
 $AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1$
 $AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1$
 $AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..$
 $TU(S,M) - TU(S,N)$
 $- (FPQ(S,Z,I,J,M)/CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))$
 $+ (2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*TU(S,N)=G=0;$

$-----$

***EQ (85_b)**
PA_50(S,Z,I,J,M,N) $\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)$
 $AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1$
 $AND COLD(S,J,N+1)$
 $AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1$
 $AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1)$
 $AND FREEH(I) AND FREEC(J) AND PA(I))..$
 $QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M), TU(S,N)) - TL(S,M)) = G =$
 $QNEW_M(S,Z,I,J,M+1)/(TU(S,M+1) - TL(S,M+1))$
 $*CPH(S,I,M)/CPH(S,I,M+1) - ((2*FP(I)) - FPK_H_0(S,Z,I,J,M) - FPK_C_0(S,Z,I,J,N))$
 $*CPH(S,I,M+1) * (TU(S,M+1) - TL(S,M+1)) / (TU(S,M+1) - TL(S,M+1));$

 *EQ (87_b)
 PA_51(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW_M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))
 *CPH(S,I,M)/CPH(S,I,M-1)+((2*FP(I))-FPK_H_1(S,Z,I,J,M)-FPK_C_1(S,Z,I,J,N))
 CPH(S,I,M)(TU(S,M)-TL(S,M))/(TU(S,M)-TL(S,M));

 *EQ (92_b)
 PA_52(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
 AND COLD(S,J,N+1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(I))..
 QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=QNEW_M(S,Z,I,J,M+1)/
 (TU(S,M+1)-TL(S,M+1))
 *CPH(S,I,M)/CPH(S,I,M+1)-((2*FP(I))-FPK_H_0(S,Z,I,J,M)-FPK_C_0(S,Z,I,J,N))
 CPH(S,I,M+1)(TU(S,M+1)-TL(S,M+1))/(TU(S,M+1)-TL(S,M+1));

 *EQ (94_b)
 PA_53(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
 AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
 AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
 AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1
 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(I))..
 (QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L=
 QNEW_M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))*CPH(S,I,M)/CPH(S,I,M-1)
 +((2*FP(I))-FPK_H_1(S,Z,I,J,M)-FPK_C_1(S,Z,I,J,N))*CPH(S,I,M)
 *(TU(S,M)-TL(S,M))/(TU(S,M)-TL(S,M));

 *EQ (XX_1)
 PA_54(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND NOT SPH(I) AND
 FREEH(I) AND PA(I))..

FP(I) =E= SUM(R,FPR(I,R)*W(I,R));

 *EQ (XX_2)
 PA_55(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND NOT SPH(I) AND
 FREEH(I) AND PA(I))..

SUM(R.W(I,R)) =E= 1 ;

 *EQ (XX_3)
 PA_56(S,Z,I,J)\$(NOT SPH(I) AND
 FREEH(I) AND PA(I))..

QPA(I) =E= SUM(M,FP(I)*CPH(S,I,M)*(TU(S,M)-TL(S,M)));

 *The summation of each pump around duty is not exactly equal Total_QPA but It is
 *nearly equal, so The eq 63and 66 are added

*
 *EQ (XX_4)
 *PA_57 ..

*SUM(I,QPA(I)\$PA(I)) =E= TOTAL_QPA;

 PA_58..
 PA1 =E= SUM(I,QPA(I)\$(ORD(I)=2));

 PA_59..
 PA2 =E= SUM(I,QPA(I)\$(ORD(I)=4));

 PA_60..
 PA3 =E= SUM(I,QPA(I)\$(ORD(I)=6));

 * Find the relation between side stripping steam and Pump around duty by using
 * the model from regression.


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PA_61(S,Z,I,J,M)$ (HOT(S,I,M)=1 AND NOT SPH(I) AND FREEH(I))..
SST(I) =E= (A_1(I)*PA1)+(B_1(I)*PA2)+(C_1(I)*PA3)+D_1_1(I);
*-----
PA_62..
Cost_side_stripping_steam =E= SUM(I,(CSS(I)*SST(I)));
*-----
PA_63 ..
TOTAL_Q =G= TOTAL_QPA_MIN;
*-----
PA_64 ..
TOTAL_Q =L= TOTAL_QPA_MAX;
*-----
PA_65 ..
TOTAL_QPA_MIN =E= TOTAL_QPA-(TOTAL_QPA*0.001);
*-----
PA_66 ..
TOTAL_QPA_MAX =E= TOTAL_QPA+(TOTAL_QPA*0.001);
*-----
PA_67 ..
SUM(I,QPA(I)$PA(I)) =E= TOTAL_Q;
*-----
PA_68(S,Z,I,J)$ (NOT SPH(I) AND
FREEH(I) AND PA(I))..

Cp_Di(I) =E= SUM(M,CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*-----
*CHECKING COST
HOT_U_C..
HOT_UTILITY_COST =E= SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I));
*-----
Cold_U_C..
Cold_UTILITY_COST =E= SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J));
*-----
Area_C..
Area_Cost=E=
+SUM((S,Z,I,J)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)
,(CF*(NHE(S,Z,I,J)+NHE S(S,Z,I,J)$ (NHE0(S,Z,I,J)=1)-(NHE0(S,Z,I,J))* (SUM(E$(ORD(E) LE KET),
Phi(Z,I,J,E)))))+(CAE*DPAR_E(Z,I,J))+CAN*PAR_N(S,Z,I,J));
*-----
FIX_C..
FIX_COST =E= SUM((S,Z,I,J)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1)
,(CF*(NHE(S,Z,I,J)+NHE S(S,Z,I,J)$ (NHE0(S,Z,I,J)=1)-SUM((EE,E,K)$ (OPT=2 AND ORD(E) LE KET AND
ORD(K) LE KMAX(Z,I,J)),DELTA(Z,I,J,EE,E,K))))
+SUM((S,Z,I,J,K,E)$ (OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1 AND ORD(K) LE KMAX(Z,I,J))
* +SUM (K$(ORD(K) LE KMAX(Z,I,J) )
,(CAE*DPAR_E_B(K,E,Z,I,J))+CAN*PAR_N_B(K,E,Z,I,J))
;

MODEL MPERIOD /ALL/ ;

OPTION LIMROW =0;
OPTION LIMCOL =0;
OPTION SOLPRINT = OFF;
OPTION OPTCR=0 ;
OPTION OPTCA=0 ;
OPTION ITERLIM = 1000000000;
OPTION RESLIM = 1000000;
MPERIOD.OPTFILE = 1;

SOLVE MPERIOD USING MIP MINIMIZING TCOST :

PARAMETER QMATCH(S,Z,I,J);
QMATCH(S,Z,I,J)=SUM((M,N)$ (D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND D(S,Z,M,N)=1
AND COLD(S,J,N) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
Q.L(S,Z,I,M,J,N));

```

PARAMETER FH_H(S,Z,I,J,M) Flowrate of hot stream per HEx;

$$FH_H(S,Z,I,J,M) = QNEW_M.L(S,Z,I,J,M) / ((TU(S,M) - TL(S,M)) * CPH(S,I,M));$$

PARAMETER FC_C(S,Z,I,J,M) Flowrate of hot stream per HEx;

$$FC_C(S,Z,I,J,M) = QNEW_N.L(S,Z,I,J,M) / ((TU(S,M) - TL(S,M)) * CPC(S,I,M));$$

PARAMETER NHE2(S,Z,I,J);

$$NHE2(S,Z,I,J) = NHE.L(S,Z,I,J);$$

\$ONTEXT

PARAMETER AREA_COST;

AREA_COST = SUM((S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
 .CF*(NHE.L(S,Z,I,J)+NHE.S.L(S,Z,I,J)*(NHE0(S,Z,I,J)=1-NHE0(S,Z,I,J)))
 +SUM((S,Z,I,J)\$ (ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
 AND BIF(Z,I,J)=0), CAE*DPAR_E.L(Z,I,J)+CAN*PAR_N.L(S,Z,I,J))
 +SUM((S,K,Z,I,J)\$ (ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)
 .CAE*DPAR_E.B.L(K,Z,I,J)+CAN*PAR_N.B.L(K,Z,I,J));

PARAMETER UTILITY_COST;

UTILITY_COST = SUM(I\$(HU(I) AND FREEH(I)), CHU(I)*FHU.L(I)*DTHU(I))
 +SUM(J\$(CU(J) AND FREEC(J)), CCU(J)*FCU.L(J)*DTCU(J));

\$OFFTEXT

OPTION Cold_UTILITY_COST:3:0:1; DISPLAY Cold_UTILITY_COST.L;
 OPTION HOT_UTILITY_COST:3:0:1; DISPLAY HOT_UTILITY_COST.L;
 OPTION Area_Cost:3:0:1; DISPLAY Area_Cost.L;
 OPTION FIX_COST:3:0:1; DISPLAY FIX_COST.L;

option Q:3:0:1; display Q.L;
 option FHU:3:0:1; display FHU.L;
 option FCU:3:0:1; display FCU.L;
 * OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
 * OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
 OPTION PAR:4:0:1; DISPLAY PAR.L;
 OPTION QMATCH:4:0:1; DISPLAY QMATCH;
 OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
 OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
 OPTION PHI:3:0:1; DISPLAY PHIL;
 OPTION AEX:3:0:1; DISPLAY AEX.L;
 OPTION FH_H:3:0:1; DISPLAY FH_H;
 OPTION FC_C:3:0:1; DISPLAY FC_C;
 *OPTION UTILITY_COST:3:0:1; DISPLAY UTILITY_COST;
 OPTION AREA_COST:3:0:1; DISPLAY AREA_COST.L;
 OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
 OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
 OPTION PAR_B:3:0:1; DISPLAY PAR_B.L;
 OPTION DPAR_E_B:3:0:1; DISPLAY DPAR_E_B.L;
 OPTION PAR_N_B:3:0:1; DISPLAY PAR_N_B.L;
 OPTION TU:3:0:1; DISPLAY TU;
 OPTION TL:3:0:1; DISPLAY TL;
 OPTION Cp_Dt:3:0:1; DISPLAY Cp_Dt.L;
 OPTION TOTAL_Q:3:0:1; DISPLAY TOTAL_Q.L;
 OPTION PA1:3:0:1; DISPLAY PA1.L;
 OPTION PA2:3:0:1; DISPLAY PA2.L;
 OPTION PA3:3:0:1; DISPLAY PA3.L;
 OPTION Cost_side_stripping_steam:3:0:1; DISPLAY Cost_side_stripping_steam.L;
 OPTION SST:3:0:1; DISPLAY SST.L;
 OPTION QPA:3:0:1; DISPLAY QPA.L;
 OPTION W:3:0:1; DISPLAY W.L;
 OPTION FPR:3:0:1; DISPLAY FPR;
 OPTION FP:3:0:1; DISPLAY FP.L;
 OPTION DHH:3:0:1; DISPLAY DHH;
 OPTION DHC:3:0:1; DISPLAY DHC;
 OPTION HHEAD:3:2:1; DISPLAY HHEAD;
 OPTION CHEAD:3:2:1; DISPLAY CHEAD;
 OPTION ALLOW:3:0:1; DISPLAY ALLOW;
 OPTION ALLOW_H:3:0:1; DISPLAY ALLOW_H;
 OPTION ALLOW_C:3:0:1; DISPLAY ALLOW_C;
 OPTION ALLOW_2:2:0:1; DISPLAY ALLOW_2;
 OPTION Q:3:0:1; DISPLAY Q.L;

OPTION QNEW_M:3:0:1; DISPLAY QNEW_M.L;
OPTION QNEW_N:3:0:1; DISPLAY QNEW_N.L;
OPTION QNEW2_M:3:0:1; DISPLAY QNEW2_M.L;
OPTION QNEW2_N:3:0:1; DISPLAY QNEW2_N.L;
OPTION Y_M:3:0:1; DISPLAY Y_M.L;
OPTION Y_N:3:0:1; DISPLAY Y_N.L;
OPTION NHE_M0:3:0:1; DISPLAY NHE_M0.L;
OPTION NHE_M1:3:0:1; DISPLAY NHE_M1.L;
OPTION NHE_N0:3:0:1; DISPLAY NHE_N0.L;
OPTION NHE_N1:3:0:1; DISPLAY NHE_N1.L;
OPTION Y_M_B:3:0:1; DISPLAY Y_M_B.L;
OPTION Y_N_B:3:0:1; DISPLAY Y_N_B.L;
OPTION NHE_M0_B:3:0:1; DISPLAY NHE_M0_B.L;
OPTION NHE_M1_B:3:0:1; DISPLAY NHE_M1_B.L;
OPTION NHE_N0_B:3:0:1; DISPLAY NHE_N0_B.L;
OPTION NHE_N1_B:3:0:1; DISPLAY NHE_N1_B.L;
OPTION ALFA_M:3:0:1; DISPLAY ALFA_M.L;
OPTION ALFA_N:3:0:1; DISPLAY ALFA_N.L;
OPTION NHE:3:0:1; DISPLAY NHE.L;
OPTION QH:3:0:1; DISPLAY QH.L;
OPTION QC:3:0:1; DISPLAY QC.L;
OPTION X1_B:3:0:1; DISPLAY X1_B.L;
OPTION X_B:3:0:1; DISPLAY X_B.L;
OPTION Q2:3:0:1; DISPLAY Q2.L;
OPTION FHU:3:0:1; DISPLAY FHU.L;
OPTION FCU:3:0:1; DISPLAY FCU.L;
OPTION NHE2:3:0:1; DISPLAY NHE2.L;
OPTION PAR:3:0:1; DISPLAY PAR.L;
OPTION PAR_B:3:0:1; DISPLAY PAR_B.L;
OPTION QMATCH:3:0:1; DISPLAY QMATCH.L;
OPTION FH_H:3:0:1; DISPLAY FH_H.L;
OPTION FC_C:3:0:1; DISPLAY FC_C.L;
OPTION LMTD:3:0:1; DISPLAY LMTD.L;

CURRICULUM VITAE

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1998-2001 Bachelor Degree of Chemical Engineering, Faculty of Engineering, King Mongkut's Institute of Technology North Bangkok, Bangkok, Thailand

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	Company name:	Mitr Phol Sugar Corp., Ltd.