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## APPENDICES

### Appendix A Programming Model for Grass-Roots Design

```
$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*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*M56/
S SCENARIO /S1/
K temperature intervals /K1*K1/

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

PARAMETER NIZ(S,Z,I) # OF INTERVALS DESIRED FOR HOT STREAMS
/
S1.Z1.I1 13
S1.Z1.I2 11
S1.Z1.I3 4
/
PARAMETER NJZ(S,Z,J) # OF INTERVALS DESIRED FOR COLD STREAMS
/
S1.Z1.J1 12
S1.Z1.J2 12
S1.Z1.J3 4
/
PARAMETER HI(S,I) HEAT TR COEFF FOR HOT STREAMS
/
S1.I1 0.2
S1.I2 0.2
S1.I3 0.2
/
PARAMETER HJ(S,J) HEAT TR COEFF FOR COLD STREAMS
/
```

S1.J1 0.2  
 S1.J2 0.2  
 S1.J3 0.2

/

PARAMETERS

TIH(S,I) T IN FOR HOT STREAMS

/

S1.I1 175.0000  
 S1.I2 125.0000  
 S1.I3 180.0000

/

TOH(S,I) T OUT FOR HOT STREAMS

/

S1.I1 5.0000  
 S1.I2 65.0000  
 S1.I3 179.0000

/

TIC(S,J) T IN FOR COLD STREAMS

/

S1.J1 40.0000  
 S1.J2 60.0000  
 S1.J3 35.0000

/

TOC(S,J) T OUT FOR COLD STREAMS

/

S1.J1 175.0000  
 S1.J2 132.0000  
 S1.J3 45.0000

/

PARAMETERS

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

/

S1.Z1.I1 175.0000  
 S1.Z1.I2 125.0000  
 S1.Z1.I3 180.0000

/

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

/

S1.Z1.I1 45.0000  
 S1.Z1.I2 65.0000  
 S1.Z1.I3 179.0000

/

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

/

S1.Z1.J1 40.0000  
 S1.Z1.J2 60.0000  
 S1.Z1.J3 35.0000

/

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

/

S1.Z1.J1 175.0000  
 S1.Z1.J2 132.0000  
 S1.Z1.J3 45.0000

/

\*-----  
 \*INTRODUCE THE FCp:

FH(S,I) FOR HOT STREAMS

/

S1.I1 10  
 S1.I2 40  
 S1.I3 605

/

FC(S,J) FOR COLD STREAMS

/

S1.J1 20  
 S1.J2 15  
 S1.J3 52.5

/

\*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.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
/
PARAMETER NIC(J) Non isothermal splitting for cold streams in paper
/
J1 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.J1 1
/
PARAMETER DTHU(I)
/
I3 1
/
PARAMETER DTCU(J)
/
J3 10
/
PARAMETER FMAX_HU(I)
/
I3 605
/
PARAMETER FMAX_CU(J)
/
J3 52.5
/

```

PARAMETER CHU(I)

/

I3 19.750

/

PARAMETER CCU(J)

/

J3 1.861

/

PARAMETER CF;

CF = 5291.9;

PARAMETER CA;

CA = 77.788;

\*\*\*\*\*  
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

/20/;

\*

-----  
\* 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){OP.D(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)];

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$[ORD(I)=CARD(I)],IHmax(S,I)}
    +SUM((ZZ,J){ORD(J)<ORD(J),NJZ(S,ZZ,J)+1}$[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+
    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$[ORD(I)=CARD(I)],IHmax(S,I)
    AND ORD(M)<= SUM(J$[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+ 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) ;
));

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]}];

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$[SUM[NS[COLD(S,J,N)=1],D(S,Z,M,N)] >0AND NOT[HU(I)AND CU(J)]];
ALLOW_C(S,Z,J,M,I)$[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$[SUM[NS[HOT(S,I,N)=1],D(S,Z,N,M)] >0AND NOT[HU(I)AND CU(J)]];
)););
FOR(Zi=1 TO CARD(Z),
FOR(Ic=1 TO CARD(I),
FOR(Ji=1 TO CARD(J),
ALLOW_2(Z,I,J)$[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)

POSITIVE VARIABLE Q,QNEW2\_M,QNEW2\_N,QC,QH,Q2,PAR1,PAR2,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,Y\_M\_B  
 Y\_N\_B,NHE\_M0,NHE\_M1,NHE\_N0,NHE\_N1,ALFA\_M,ALFA\_N  
 INTEGER VARIABLE USHELL,USHELL\_B

EQUATIONS  
 HBHU(S,I,M)  
 HBCU(S,I,N)  
 HBHS(S,I,M)  
 HBCS(S,I,N)  
 TRANSFOR\_M(S,Z,I,J,M)  
 TRANSFOR\_N(S,Z,I,J,N)  
 HBHS\_NI(S,I,M)  
 HBCS\_NI(S,I,N)  
 NOISOH(S,I,M)  
 NOISOC(S,I,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
*FCU_MAX
TOTNEXCH_MAX
TOTNEXCH_MIN
;
*-----
*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)
HBHS(S,I,M)$ (HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=0)..
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$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1),Q(S,Z,I,M,J,N));
*-----
*EQ (7)
HBHS_NI(S,I,M)$ (HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1)..
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,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) $\$(HOT(S,I,M)=1 AND ALLOW\_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..$

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

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) $\$(HOT(S,I,M)=1 AND ALLOW\_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..$  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) $\$(COLD(S,J,N)=1 AND ALLOW\_C(S,Z,I,J,N)=1 AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..$

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

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) $\$(COLD(S,J,N)=1 AND ALLOW\_C(S,Z,I,J,N)=1 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..$  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 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) $\$(HOT(S,I,M)=1 AND ALLOW\_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..$

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  
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-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))..  
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(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)

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\*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)

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\*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)..  
 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)..  
 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=i;

\*-----  
 \*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)..  
 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)..

$$QNEW2\_M(S,Z,I,J,M) = L = NHE\_M1\_B(S,Z,I,J,M) * DHH(S,I,M);$$

\*-----  
 \*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)  
 $FEAS\_M\_2(S,Z,I,J,M) * (HOT(S,I,M-1) \text{ AND } HOT(S,I,M) = 1 \text{ AND } ALLOW\_H(S,Z,I,M,J) = 1$   
 $\text{AND } ALLOW\_H(S,Z,I,M-1,J) \text{ AND } SPH(I) = 1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 $QNEW\_M(S,Z,I,J,M) / (CPH(S,I,M) * (TU(S,M) - TL(S,M))) = L =$   
 $QNEW\_M(S,Z,I,J,M-1) / (CPH(S,I,M-1) * (TU(S,M-1) - TL(S,M-1)))$   
 $+ (1 - ALFA\_M(S,Z,I,J,M)) * DHH(S,I,M) / (CPH(S,I,M) * (TU(S,M) - TL(S,M)));$

\*EQ (62)  
 $FEAS\_M\_1(S,Z,I,J,M) * (HOT(S,I,M-1) \text{ AND } HOT(S,I,M) = 1 \text{ AND } ALLOW\_H(S,Z,I,M,J) = 1$   
 $\text{AND } ALLOW\_H(S,Z,I,M-1,J) \text{ AND } SPH(I) = 1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 $QNEW\_M(S,Z,I,J,M) / (CPH(S,I,M) * (TU(S,M) - TL(S,M)))$   
 $+ (1 - ALFA\_M(S,Z,I,J,M)) * DHH(S,I,M) / (CPH(S,I,M) * (TU(S,M) - TL(S,M)))$   
 $= G = QNEW\_M(S,Z,I,J,M-1) / (CPH(S,I,M-1) * (TU(S,M-1) - TL(S,M-1)));$



\*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))..  
- 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))..  
- 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))..  
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))..  
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))..  
(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)).. 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))..  
 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))..  
 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)).. 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))..  
 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)..  
 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)..  
 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) $\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M+1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N+1) \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_H(S,Z,I,M+1,J) \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } ALLOW\_C(S,Z,J,N+1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 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) $\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M+1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N+1) \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_H(S,Z,I,M+1,J) \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } ALLOW\_C(S,Z,J,N+1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 QNEW\_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) $\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N-1) \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_H(S,Z,I,M-1,J) \text{ AND } ALLOW\_C(S,Z,J,N,I) \text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 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) $\$(DTVIO(I,J)=1 \text{ AND } D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } TU(S,N) \text{ GT } TL(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } COLD(S,J,N-1) \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_H(S,Z,I,M-1,J) \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 (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)-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=SUM((M,N) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1, \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1, \text{ AND } BIF(Z,I,J)=1, \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 (QNEW\_N(S,Z,I,J,N)-QNEW2\_N(S,Z,I,J,N))/(TU(S,N)-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 (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=SUM((L,N) $\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND } TL(S,N) \text{ LT } TU(S,L) \text{ AND } HOT(S,I,L)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,L,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1, \text{ AND } ALLOW\_C(S,Z,J,N,I)=1, \text{ AND } BIF(Z,I,J)=1, \text{ AND } (SPH(I)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 (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)),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) 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))\*(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)=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))+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.. TCOS1 =E= SUM(IS(HU(I) AND FREEH(I)),CHU(I)\*FHU(I)\*DTHU(I))  
 + SUM(JS(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));
- \* 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;

MODEL MPERIOD /ALL/;

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

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,J,I,M) Flowrate of hot stream per HEx;

FC\_C(S,Z,J,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);

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;  
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;  
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 B Programming Model for Retrofit Heat Exchanger Network

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$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
*****

*****
* Delete BIF_16(S,Z,I,J,M) in Equation
* Change CPM(I,J,M) to CPH(I,J,M)
*****
$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*I4/
J cold streams /J1*J3/
*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
HU(I) Heating utilities /I4/
CU(J) Cooling utilities /J3/
*
M temperature intervals /M1*M57/
S SCENARIO /S1/
K temperature intervals /K1*K1/

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

PARAMETER NIZ(S,Z,I) # OF INTERVALS DESIRED FOR HOT STREAMS
/
S1.Z1.I1 12
S1.Z1.I2 10
S1.Z1.I3 7
S1.Z1.I4 4
/
PARAMETER NJZ(S,Z,J) # OF INTERVALS DESIRED FOR COLD STREAMS
/
S1.Z1.J1 12
S1.Z1.J2 8
S1.Z1.J3 4
/
PARAMETER HI(S,I) HEAT TR COEFF FOR HOT STREAMS
/
S1.I1 0.4
S1.I2 0.3
S1.I3 0.25
S1.I4 0.53
/
PARAMETER HJ(S,J) HEAT TR COEFF FOR COLD STREAMS

```

```

/
S1.J1 0.15
S1.J2 0.5
S1.J3 0.53
/
PARAMETERS
TIH(S,I) T IN FOR HOT STREAMS
/
S1.I1 432.0000
S1.I2 540.0000
S1.I3 616.0000
S1.I4 773.0000
/
TOH(S,I) T OUT FOR HOT STREAMS
/
S1.I1 350.0000
S1.I2 361.0000
S1.I3 363.0000
S1.I4 772.0000
/
TIC(S,J) T IN FOR COLD STREAMS
/
S1.J1 299.0000
S1.J2 391.0000
S1.J3 293.0000
/
TOC(S,J) T OUT FOR COLD STREAMS
/
S1.J1 400.0000
S1.J2 538.0000
S1.J3 313.0000
/
PARAMETERS
TIHZ(S,Z,I) T IN FOR HOT STREAMS
/
S1.Z1.I1 432.0000
S1.Z1.I2 540.0000
S1.Z1.I3 616.0000
S1.Z1.I4 773.0000
/
TOHZ(S,Z,I) T OUT FOR HOT STREAMS
/
S1.Z1.I1 350.0000
S1.Z1.I2 361.0000
S1.Z1.I3 363.0000
S1.Z1.I4 772.0000
/
TICZ(S,Z,J) T IN FOR COLD STREAMS
/
S1.Z1.J1 299.0000
S1.Z1.J2 391.0000
S1.Z1.J3 293.0000
/
TOCZ(S,Z,J) T OUT FOR COLD STREAMS
/
S1.Z1.J1 400.0000
S1.Z1.J2 538.0000
S1.Z1.J3 313.0000
/
*-----
*INTRODUCE THE FCp:
FH(S,I) FOR HOT STREAMS
/
S1.I1 228.5
S1.I2 20.4
S1.I3 53.8
/
FC(S,J) FOR COLD STREAMS
/
S1.J1 93.2
S1.J2 196.1

```

```

/
*USE THE MAX FCp FOR THE UTILITIES
*-----
SETS FREEH(I)
/
I1
I2
I3
I4
/
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  1
I2  1
I3  1
I4  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
/
PARAMETER NIC(J)  Non isothermal splitting for cold streams in paper
/
J1  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.J1  1
/
*****
***** ADD FOR RETROFIT *****
*****
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
/
PARAMETER A_NEW_MAX(Z,I,J)
/
Z1.(I1*I4).(J1*J3) 3000
/
*****
*****

PARAMETER DTHU(I)
/
I4 1
/
PARAMETER DTCU(J)
/
J3 20
/
PARAMETER FMAX_HU(I)
/
I4 10000
/
PARAMETER FMAX_CU(J)
/
J3 10000
/
PARAMETER CHU(I)
/
I4 95.04
/
PARAMETER CCU(J)
/
J3 20
/
PARAMETER CF;
CF = 3460;
*****
*****FOR RETEOFIT*****
*****
PARAMETER CAN;
CAN = 171.4;
PARAMETER CAE;
CAE = 171.4;

```

```

*****
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 A_NEW_MAX
* Maximum area per exchanger
*/5000/;
PARAMETER ASHELLMAX
* Maximum shell area
/5000/;
PARAMETER TOTNEXCHMAX
* Maximum NUMBER OF EXCHANGERS
/900/;
PARAMETER MAX_NEW_HEX
* Maximum Number of new exchangers
/20/;
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\_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} ${NIZ(S,Z,J)}>=1];
  ICminZ(S,Z,J){ORD(S)=Si AND ORD(J)>1 AND ORD(Z)=1}= 0+
    {SUM(I${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)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi]= 0+
  I$[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$[ORD(I)=CARD(I)], IHmax(S, I))
  AND ORD(M)<= SUM(J$[ORD(J)=CARD(J)], ICmax(S, J))];
  COLDZ(S, Z, J, M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
  AND ORD(Z)=Zi]= 0+ I$[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) ;
));

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)$[ORD(M)=IHminZ(S, Z, I)]}
    + SUM((Z, J)$[HOTZ(S, Z, J, 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[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(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 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)
;

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
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
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)

*ADD_REST
*ADD_REST2(S,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)
HBHS(S,I,M)$ (HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=0)..
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)
HBKS(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)
HBHS_NI(S,I,M)$ (HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1)..

```

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,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))..  
 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)).. 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))..  
 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)).. 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 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)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
AND FREEH(I) AND FREEC(J))..
      NHE_M0(S,Z,I,J,M)=G-Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1)$(HOT(S,I,M-1)
AND ALLOW_H(S,Z,I,M-1,J));
*-----
*EQ (19)
BINARY_M4(S,Z,I,J,M)$(HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
      NHE_M0(S,Z,I,J,M)=G=0;
*-----
*EQ (20) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*-----
*EQ (21)
BINARY_M8(S,Z,I,J,M)$(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-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))..
      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)

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\*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))..  
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))..  
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(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)-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(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)-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))..  
 QNEW2\_M(S,Z,I,J,M) =L= NHE\_M0\_B(S,Z,I,J,M)\*DHH(c,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))..  
 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,J,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,J,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,J,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) -

$$\text{NHE\_M1}(S,Z,I,J,M-1) - \text{NHE\_M1}(S,Z,I,J,M);$$

$$\text{FEAS\_M\_03\_B}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

$$\text{ALFA\_M}(S,Z,I,J,M) = G = Y\_M\_B(S,Z,I,J,M) - \text{NHE\_M0\_B}(S,Z,I,J,M-1) - \text{NHE\_M0\_B}(S,Z,I,J,M) - \text{NHE\_M1\_B}(S,Z,I,J,M-1) - \text{NHE\_M1\_B}(S,Z,I,J,M);$$


---

\*EQ (60)
$$\text{FEAS\_M\_04}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=i \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } (\text{BIF}(Z,I,J)=1 \text{ OR } \text{SPH}(I)=1) \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

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


---

\*EQ (61)
$$\text{FEAS\_M\_2}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

$$\text{QNEW\_M}(S,Z,I,J,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M))) = L =$$

$$\text{QNEW\_M}(S,Z,I,J,M-1) / (\text{CPH}(S,I,M-1) * (\text{TU}(S,M-1) - \text{TL}(S,M-1)))$$

$$+ (1 - \text{ALFA\_M}(S,Z,I,J,M)) * \text{DHH}(S,I,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)));$$


---

\*EQ (62)
$$\text{FEAS\_M\_1}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

$$\text{QNEW\_M}(S,Z,I,J,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)))$$

$$+ (1 - \text{ALFA\_M}(S,Z,I,J,M)) * \text{DHH}(S,I,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)))$$

$$= G = \text{QNEW\_M}(S,Z,I,J,M-1) / (\text{CPH}(S,I,M-1) * (\text{TU}(S,M-1) - \text{TL}(S,M-1)));$$


---

\*EQ (63)
$$\text{FEAS\_M\_3}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=0 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

$$- \text{QNEW\_M}(S,Z,I,J,M-1) / (\text{CPH}(S,I,M-1) * (\text{TU}(S,M-1) - \text{TL}(S,M-1)))$$

$$+ \text{QNEW\_M}(S,Z,I,J,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)))$$

$$+ (1 + \text{NHE\_M1}(S,Z,I,J,M-1) + \text{NHE\_M1}(S,Z,I,J,M) - \text{NHE\_M0}(S,Z,I,J,M-1))$$

$$* \text{DHH}(S,I,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M))) * 1.00001 = G = 0;$$


---

\*EQ (64)
$$\text{FEAS\_M\_4}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=0 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

$$- \text{QNEW\_M}(S,Z,I,J,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)))$$

$$+ \text{QNEW\_M}(S,Z,I,J,M-1) / (\text{CPH}(S,I,M-1) * (\text{TU}(S,M-1) - \text{TL}(S,M-1)))$$

$$+ (1 + \text{NHE\_M0}(S,Z,I,J,M-1) + \text{NHE\_M0}(S,Z,I,J,M) - \text{NHE\_M1}(S,Z,I,J,M))$$

$$* \text{DHH}(S,I,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M))) * 1.00001 = G = 0;$$


---

\*EQ (65)
$$\text{FEAS\_M\_3\_B\_2}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=1 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

$$\text{QNEW\_M}(S,Z,I,J,M-1) / (\text{CPH}(S,I,M-1) * (\text{TU}(S,M-1) - \text{TL}(S,M-1))) = L =$$

$$\text{QNEW\_M}(S,Z,I,J,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)))$$

$$+ (1 + \text{NHE\_M1\_B}(S,Z,I,J,M-1) + \text{NHE\_M1\_B}(S,Z,I,J,M) - \text{NHE\_M0\_B}(S,Z,I,J,M-1))$$

$$* \text{DHH}(S,I,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)));$$


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\*EQ (66)
$$\text{FEAS\_M\_3\_B\_1}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=1 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

$$\text{QNEW2\_M}(S,Z,I,J,M-1) / (\text{CPH}(S,I,M-1) * (\text{TU}(S,M-1) - \text{TL}(S,M-1))) = L =$$

$$\text{QNEW\_M}(S,Z,I,J,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M))) + (2 + \text{NHE\_M1\_B}(S,Z,I,J,M) - \text{NHE\_M0\_B}(S,Z,I,J,M-1) - \text{Y\_M\_B}(S,Z,I,J,M-1))$$

$$* \text{DHH}(S,I,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)));$$


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\*EQ (67)
$$\text{FEAS\_M\_4\_B}(S,Z,I,J,M) \$ (\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=1 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..$$

$$(\text{QNEW\_M}(S,Z,I,J,M) - \text{QNEW2\_M}(S,Z,I,J,M)) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M))) = L =$$

$$\text{QNEW\_M}(S,Z,I,J,M-1) / (\text{CPH}(S,I,M-1) * (\text{TU}(S,M-1) - \text{TL}(S,M-1)))$$

$$+ (2 + \text{NHE\_M0\_B}(S,Z,I,J,M-1) - \text{NHE\_M1\_B}(S,Z,I,J,M) - \text{Y\_M\_B}(S,Z,I,J,M))$$

$$* \text{DHH}(S,I,M) / (\text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M)));$$


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\*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)).. 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)))\*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)))=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) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M) AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW\_H(S,Z,I,M,J)=1 AND ALLOW\_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J))..$   
 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) $\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M) AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW\_H(S,Z,I,M,J)=1 AND ALLOW\_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J))..$   
 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).. 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))..  
 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))..  
 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))..  
 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))..  
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 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\_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)..  

$$\frac{(QNEW\_N(S,Z,I,J,N)-QNEW2\_N(S,Z,I,J,N))/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=}{QNEW\_N(S,Z,I,J,N-1)/(TU(S,N-1)-TL(S,N-1))*CPC(S,J,N)/CPC(S,J,N-1)}$$

$$-(2-NHE\_MI\_B(S,Z,I,J,M)-NHE\_N1\_B(S,Z,I,J,N))*DHC(S,J,N-1)/$$

$$(TU(S,N-1)-TL(S,N-1));$$

\*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)..  
 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),  

$$(Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))*(1/H\_I(S,I,L)+1/H\_J(S,J,N))/LMTD(S,L,N))$$

$$+AMAX*(2-NHE\_MI\_B(S,Z,I,J,M)-X1\_B(S,Z,I,J,M)-$$

$$SUM(KK $\$(ORD(KK) GT 1 AND ORD(KK) LT ORD(K)),X\_B(S,KK,Z,I,J,M))));$$$

\*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\_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)..  
 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),  

$$(Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))*(1/H\_I(S,I,L)+1/H\_J(S,J,N))/LMTD(S,L,N))$$

$$-AMAX*(2-NHE\_MI\_B(S,Z,I,J,M)-X1\_B(S,Z,I,J,M)-$$

$$SUM(KK $\$(ORD(KK) GT 1 AND ORD(KK) LT ORD(K)),X\_B(S,KK,Z,I,J,M))));$$$

\*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 $\$(ORD(K) GT 1 AND ORD(K) LE KMAX(Z,I,J)),$   

$$ORD(K)*X\_B(S,K,Z,I,J,M))=E=SUM(L $\$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND$   
 ALLOW_H(S,Z,I,L,J)=1),NHE_M0_B(S,Z,I,J,L))+1-Y_M_B(S,Z,I,J,M);$$$$

\*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)

\* 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.

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) $\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=0),$   
 CF\*(NHE(S,Z,I,J)+NHE\_S(S,Z,I,J) $\$(NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J))$ )  
 +SUM((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));

\*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);
*-----
*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 ;
*-----
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,I,N,J)=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,J,I,M) Flowrate of hot stream per HEX;  
 $FC\_C(S,Z,J,I,M) = QNEW\_N.L(S,Z,I,J,M) / [(TU(S,M) - TL(S,M)) * CPC(S,J,M)]$

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

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 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 NHE\_S:3:0:1; DISPLAY NHE\_S.L;  
 OPTION DELTA:3:0:1; DISPLAY DELTA.L;  
 OPTION TCOST:3:0:1; DISPLAY TCOST.L;  
 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;  
 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;  
 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;  
 OPTION AI:4:0:1; DISPLAY AI.L;  
 OPTION BI:4:0:1; DISPLAY BI.L;  
 OPTION AJ:4:0:1; DISPLAY AJ.L;  
 OPTION BJ:4:0:1; DISPLAY BJ.L;  
 OPTION PI:3:0:1; DISPLAY PI.L;  
 OPTION PJ:3:0:1; DISPLAY PJ.L;  
 OPTION NHE\_M0P:3:0:1; DISPLAY NHE\_M0P.L;  
 OPTION NHE\_M1P:3:0:1; DISPLAY NHE\_M1P.L;  
 OPTION NHE\_N0P:3:0:1; DISPLAY NHE\_N0P.L;  
 OPTION NHE\_N1P:3:0:1; DISPLAY NHE\_N1P.L;  
 OPTION IHmin:4:0:1; DISPLAY IHmin;



OPTION IHmax:4:0:1; DISPLAY IHmax;  
OPTION HOT:4:0:1; DISPLAY HOT;  
OPTION HOT2:4:0:1; DISPLAY HOT2;  
OPTION DT:3:0:1; DISPLAY DT;  
OPTION TU:3:0:1; DISPLAY TU;  
OPTION TL:3:0:1; DISPLAY TL;  
OPTION LMTD:3:0:1; DISPLAY LMTD;  
OPTION D:3:0:1; DISPLAY D;

## Appendix C Programming Model for Design Heat Exchanger Network of Crude Fractionation Unit

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

\*\*\*\*\*

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

\*(109)

\*(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\*K1/

\*

\*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)

\*PARAMETER FOR PUMP-AROUND CASE

\*

PARAMETER BLOCK(S,Z,I,J)

/

S1.Z1.(I1,I2,I3,I5).J2 0

S1.Z1.(I4,I6,I7,I8).J1 0

S1.Z1.I9.J1 1

S1.Z1.(I7).J1 1

S1.Z1.(I1,I2,I3,I5).(J1,J3) 1

S1.Z1.(I4,I6,I7,I8).(J2,J3) 1

S1.Z1.I9.J2 1

/

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

/

I2.R1 267.0042

I2.R2 213.6033

I2.R3 160.2025  
I2.R4 106.8017

I4.R1 136.6040  
I4.R2 156.1189  
I4.R3 175.6337  
I4.R4 195.1486

I6.R1 68.60310  
I6.R2 91.47080  
I6.R3 114.3385  
I6.R4 137.2062

/  
PARAMETER TOTAL\_QPA Total PA load ;  
TOTAL\_QPA =100000;

\*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 0.0039  
I4 0.0055  
I5 0.0038  
I6 0.0052  
I7 0.0037  
I8 0.0032  
I9 0

/  
PARAMETER B\_cp\_H(I) Intercept for Cp

/  
I1 1.9259  
I2 1.7943  
I3 1.7493  
I4 1.4681  
I5 1.7061  
I6 1.3896  
I7 1.6799  
I8 1.7235  
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 0.0037  
J3 0

/  
PARAMETER B\_cp\_C(J) Coefficients for Cp

/  
J1 1.8922  
J2 1.6935  
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 -0.001110  
I4 0.001765  
I6 0.003808

/

PARAMETER B\_1(I) Coefficients for PA(2)

/  
I2 -1.1E-05

```

I4 -4.4E-05
I6 -0.00017
/
PARAMETER C_I(I) Coefficients for PA(3)
/
I2 -0.00211
I4 0.003773
I6 0.007794
/
PARAMETER D_I_1(I) Intercept
/
I2 90.47993
I4 -138.838
I6 -299.496
/

```

```

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

/

S1.Z1.J1 6

S1.Z1.J2 3

S1.Z1.J3 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.I5.(J1\*J2) 0.306

S1.I8.(J1\*J2) 0.470

S1.(I1,I2).J3 1.400

S1.(I3,I7).J3 1.020

S1.(I4,I6).J3 0.511

S1.(I5).J3 0.765

S1.(I8).J3 0.765

S1.(I9).J3 5.110

/

PARAMETERS

TIH(S,I) T IN FOR HOT STREAMS

/

S1.I1 48.30000

S1.I2 183.4510

S1.I3 214.7460

S1.I4 269.0350

S1.I5 252.1680

S1.I6 310.3060

S1.I7 298.3720

S1.I8 354.3190

S1.I9 180.0000

/

TOH(S,I) T OUT FOR HOT STREAMS

/

S1.I1 26.11000

S1.I2 104.4400

S1.I3 26.11000

S1.I4 173.6250

S1.I5 26.11000

S1.I6 232.2220

S1.I7 26.11000

S1.I8 260.0000

S1.I9 179.0000

/

TIC(S,J) T IN FOR COLD STREAMS

/

S1.J1 16.11000

S1.J2 132.7800

S1.J3 35.00

/

TOC(S,J) T OUT FOR COLD STREAMS

/

S1.J1 132.7780

S1.J2 148.8890

S1.J3 45.00000

/

PARAMETERS

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

/

S1.Z1.I1 48.30000

S1.Z1.I2 183.4510

S1.Z1.I3 214.7460

S1.Z1.I4 269.0350

S1.Z1.I5 252.1680

S1.Z1.I6 310.3060

S1.Z1.I7 298.3720

S1.Z1.I8 354.3190

```

S1.Z1.I9 180.0000
/
TOHZ(S,Z,I) T OUT FOR HOT STREAMS
/
S1.Z1.I1 26.11000
S1.Z1.I2 104.4400
S1.Z1.I3 26.11000
S1.Z1.I4 173.6250
S1.Z1.I5 26.11000
S1.Z1.I6 232.2220
S1.Z1.I7 26.11000
S1.Z1.I8 260.0000
S1.Z1.I9 179.0000
/
TICZ(S,Z,J) T IN FOR COLD STREAMS
/
S1.Z1.J1 16.11000
S1.Z1.J2 132.7800
S1.Z1.J3 35.00
/
TOCZ(S,Z,J) T OUT FOR COLD STREAMS
/
S1.Z1.J1 132.7780
S1.Z1.J2 148.8890
S1.Z1.J3 45.00000
/
*-----
*INTRODUCE THE FCp:
FH(S,I) FOR HOT STREAMS
/
S1.I1 51.037
S1.I3 119.594
S1.I5 53.7120
S1.I7 23.5180
S1.I8 494.300
/
FC(S,J) FOR COLD STREAMS
/
S1.J1 823.446
S1.J2 743.342
/
*USE THE MAX FCp FOR THE UTILITIES
*-----
SETS FREEH(I)
/
I1*I9
/
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 CA;
CA = 77.788;

*****
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\_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$[ORD(I)=CARD(I)],IHmax(S,I)];
        HCTZ(S,Z,I,M)$[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);

$$DT(S,M) = \frac{\text{SUM}((Z,I)\$[HOTZ(S,Z,I,M)=1], \{[TIHZ(S,Z,I)-TOHZ(S,Z,I)] / [IHmaxZ(S,Z,I)-IHminZ(S,Z,I)+1]\})\$\{HOT2(S,M)=1\} + \text{SUM}((Z,J)\$[COLDZ(S,Z,J,M)=1], \{[TOCZ(S,Z,J)-TICZ(S,Z,J)] / [ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]\})\$\{COLD2(S,M)=1\}}{2}$$

```
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) ;

$$HHEAD(S,M,N) = \{TU(S,M)-TU(S,N) + DTmin\}\$\{HOT2(S,M) \text{ AND } COLD2(S,N)\};$$

$$CHEAD(S,M,N) = \{TL(S,M)-TL(S,N) + DTmin\}\$\{HOT2(S,M) \text{ AND } COLD2(S,N)\} ;$$

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

$$D(S,Z,M,N) = 1\$\{[HOT2(S,M)=1 \text{ AND } HOT2(S,N)=1 \text{ AND } \text{SUM}[\$(HOT(S,I,M)=1 \text{ AND } HOT(S,I,N)=1),HOTZ(S,Z,I,M)=1 \text{ AND } \text{SUM}[\$(HOT(S,I,N)=1$$

```

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)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
          AND ORD(J)=Ji
        AND NOT BLOCK(S,Z,I,J)=0
        ]= 0+ 1$[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
          AND NOT BLOCK(S,Z,I,J)=0
        ]= 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)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
            AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1
          AND NOT BLOCK(S,Z,I,J)=0
        ]= 0+
          1$[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)
          BI(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 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\_Dt(I)

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,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

EQUATIONS  
 HBHU(S,I,M)  
 HBCU(S,J,N)  
 HBHS(S,I,M)  
 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

\*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)
*
A_MATCH(S,Z,I,M,J,N)
;
*-----
*ADD(1)
A_MATCH(S,Z,I,M,J,N)*(BLOCK(S,Z,I,J)=0)..
Q(S,Z,I,M,J,N)=E=0;
*-----
*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
AND BLOCK(S,Z,I,J)=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,I)\$(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,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,I)\$(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,I,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 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,I,J,N)=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 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 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
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-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))..
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(NS(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(NS(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(NS(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(NS(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 AND ALLOW\_C(S,Z,J,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,J,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,J,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))..

$$\text{ALFA\_M}(S,Z,I,J,M)=L=1-\text{NHE\_M1\_B}(S,Z,I,J,M-1)-\text{NHE\_M1\_B}(S,Z,I,J,M);$$

\*EQ (59)

FEAS\_M\_03(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=0 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..

$$\text{ALFA\_M}(S,Z,I,J,M)=G=Y \text{ M}(S,Z,I,J,M)-\text{NHE\_M0}(S,Z,I,J,M-1)-\text{NHE\_M0}(S,Z,I,J,M) - \text{NHE\_M1}(S,Z,I,J,M-1)-\text{NHE\_M1}(S,Z,I,J,M);$$

FEAS\_M\_03\_B(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..

$$\text{ALFA\_M}(S,Z,I,J,M)=G=Y \text{ M\_B}(S,Z,I,J,M)-\text{NHE\_M0\_B}(S,Z,I,J,M-1)-\text{NHE\_M0\_B}(S,Z,I,J,M) - \text{NHE\_M1\_B}(S,Z,I,J,M-1)-\text{NHE\_M1\_B}(S,Z,I,J,M);$$

\*EQ (60)

FEAS\_M\_04(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } (\text{BIF}(Z,I,J)=1 \text{ OR } \text{SPH}(I)=1) \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J))..

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

\*EQ (61)

FEAS\_M\_2(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J) \text{ AND } \text{NOT PA}(I))..

$$\text{QNEW\_M}(S,Z,I,J,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) = L = \text{QNEW\_M}(S,Z,I,J,M-1)/(\text{CPH}(S,I,M-1)*(\text{TU}(S,M-1)-\text{TL}(S,M-1))) + (1-\text{ALFA\_M}(S,Z,I,J,M))*\text{DHH}(S,I,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M)));$$

\*EQ (62)

FEAS\_M\_1(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J) \text{ AND } \text{NOT PA}(I))..

$$\text{QNEW\_M}(S,Z,I,J,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) + (1-\text{ALFA\_M}(S,Z,I,J,M))*\text{DHH}(S,I,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) = G = \text{QNEW\_M}(S,Z,I,J,M-1)/(\text{CPH}(S,I,M-1)*(\text{TU}(S,M-1)-\text{TL}(S,M-1)));$$

\*EQ (63)

FEAS\_M\_3(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=0 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J) \text{ AND } \text{NOT PA}(I))..

$$-\text{QNEW\_M}(S,Z,I,J,M-1)/(\text{CPH}(S,I,M-1)*(\text{TU}(S,M-1)-\text{TL}(S,M-1))) + \text{QNEW\_M}(S,Z,I,J,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) + (1+\text{NHE\_M1}(S,Z,I,J,M-1) + \text{NHE\_M1}(S,Z,I,J,M) - \text{NHE\_M0}(S,Z,I,J,M-1)) * \text{DHH}(S,I,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) * 1.00001 = G = 0;$$

\*EQ (64)

FEAS\_M\_4(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=0 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J) \text{ AND } \text{NOT PA}(I))..

$$-\text{QNEW\_M}(S,Z,I,J,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) + \text{QNEW\_M}(S,Z,I,J,M-1)/(\text{CPH}(S,I,M-1)*(\text{TU}(S,M-1)-\text{TL}(S,M-1))) + (1+\text{NHE\_M0}(S,Z,I,J,M-1)+\text{NHE\_M0}(S,Z,I,J,M)-\text{NHE\_M1}(S,Z,I,J,M)) * \text{DHH}(S,I,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) * 1.00001 = G = 0;$$

\*EQ (65)

FEAS\_M\_3\_B\_2(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=1 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J) \text{ AND } \text{NOT PA}(I))..

$$\text{QNEW\_M}(S,Z,I,J,M-1)/(\text{CPH}(S,I,M-1)*(\text{TU}(S,M-1)-\text{TL}(S,M-1))) = L = \text{QNEW\_M}(S,Z,I,J,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) + (1+\text{NHE\_M1\_B}(S,Z,I,J,M-1)+\text{NHE\_M1\_B}(S,Z,I,J,M)-\text{NHE\_M0\_B}(S,Z,I,J,M-1)) * \text{DHH}(S,I,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M)));$$

\*EQ (66)

FEAS\_M\_3\_B\_1(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=1 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I) \text{ AND } \text{FREEC}(J) \text{ AND } \text{NOT PA}(I))..

$$\text{QNEW2\_M}(S,Z,I,J,M-1)/(\text{CPH}(S,I,M-1)*(\text{TU}(S,M-1)-\text{TL}(S,M-1))) = L = \text{QNEW\_M}(S,Z,I,J,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M))) + (2 + \text{NHE\_M1\_B}(S,Z,I,J,M) - \text{NHE\_M0\_B}(S,Z,I,J,M-1) - Y \text{ M\_B}(S,Z,I,J,M-1)) * \text{DHH}(S,I,M)/(\text{CPH}(S,I,M)*(\text{TU}(S,M)-\text{TL}(S,M)));$$

\*EQ (67)

FEAS\_M\_4\_B(S,Z,I,J,M)\$\$(\text{HOT}(S,I,M-1) \text{ AND } \text{HOT}(S,I,M)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M,J)=1 \text{ AND } \text{ALLOW\\_H}(S,Z,I,M-1,J) \text{ AND } \text{BIF}(Z,I,J)=1 \text{ AND } \text{SPH}(I)=1 \text{ AND } \text{FREEH}(I)

AND FREEC(J) AND NOT PA(I))..

$$\begin{aligned} & (QNEW\_M(S,Z,I,J,M)-QNEW2\_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))=L= \\ & QNEW\_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1))) \\ & + (2 + NHE\_M0\_B(S,Z,I,J,M-1)-NHE\_M1\_B(S,Z,I,J,M)-Y\_M\_B(S,Z,I,J,M)) \\ & \quad *DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))); \end{aligned}$$

\*EQ (68)

$$\begin{aligned} & FEAS\_M\_1\_SP(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) \\ & AND ALLOW\_H(S,Z,I,M,J)=1 \\ & AND ALLOW\_H(S,Z,I,M-1,J) AND ALLOW\_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND SPH(I)=0 \\ & AND FREEH(I) AND FREEC(J) AND NOT PA(I)).. \\ & \quad QNEW\_M(S,Z,I,J,M)=G=(Y\_M(S,Z,I,J,M)- \\ & \quad NHE\_M0(S,Z,I,J,M) + NHE\_M1(S,Z,I,J,M))*DHH(S,I,M); \\ & FEAS\_M\_1\_SP\_B(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) \\ & AND ALLOW\_H(S,Z,I,M,J)=1 \\ & AND ALLOW\_H(S,Z,I,M-1,J) AND ALLOW\_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=1 AND SPH(I)=0 \\ & AND FREEH(I) AND FREEC(J) AND NOT PA(I)).. \\ & \quad QNEW\_M(S,Z,I,J,M)=G=(Y\_M\_B(S,Z,I,J,M)- \\ & \quad NHE\_M0\_B(S,Z,I,J,M)+NHE\_M1\_B(S,Z,I,J,M))*DHH(S,I,M); \end{aligned}$$

\*EQ (69)

$$\begin{aligned} & FEAS\_N\_01(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I) \\ & AND FREEC(J)).. \\ & \quad ALFA\_N(S,Z,I,J,N)=L=1-NHE\_N0(S,Z,I,J,N)-NHE\_N0(S,Z,I,J,N-1); \\ & FEAS\_N\_01\_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J)).. \\ & \quad ALFA\_N(S,Z,I,J,N)=L=1-NHE\_N0\_B(S,Z,I,J,N)-NHE\_N0\_B(S,Z,I,J,N-1); \end{aligned}$$

\*EQ (70)

$$\begin{aligned} & FEAS\_N\_02(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I) \\ & AND FREEC(J)).. \\ & \quad ALFA\_N(S,Z,I,J,N)=L=1-NHE\_N1(S,Z,I,J,N)-NHE\_N1(S,Z,I,J,N-1); \\ & FEAS\_N\_02\_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J)).. \\ & \quad ALFA\_N(S,Z,I,J,N)=L=1-NHE\_N1\_B(S,Z,I,J,N)-NHE\_N1\_B(S,Z,I,J,N-1); \end{aligned}$$

\*EQ (71)

$$\begin{aligned} & FEAS\_N\_03(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I) \\ & AND FREEC(J)).. \\ & \quad ALFA\_N(S,Z,I,J,N)=G=Y\_N(S,Z,I,J,N)-NHE\_N0(S,Z,I,J,N)-NHE\_N0(S,Z,I,J,N-1) \\ & \quad - NHE\_N1(S,Z,I,J,N)-NHE\_N1(S,Z,I,J,N-1); \\ & FEAS\_N\_03\_B(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J)).. \\ & \quad ALFA\_N(S,Z,I,J,N)=G=Y\_N\_B(S,Z,I,J,N)-NHE\_N0\_B(S,Z,I,J,N)-NHE\_N0\_B(S,Z,I,J,N-1) \\ & \quad - NHE\_N1\_B(S,Z,I,J,N)-NHE\_N1\_B(S,Z,I,J,N-1); \end{aligned}$$

\*EQ (72)

$$\begin{aligned} & FEAS\_N\_04(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND (BIF(Z,I,J)=1 OR SPC(J)=1) AND FREEH(I) \\ & AND FREEC(J)).. \end{aligned}$$

$$ALFA\_N(S,Z,I,J,N)=G=0;$$

\*EQ (73)

$$\begin{aligned} & FEAS\_N\_2(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J)).. \\ & \quad QNEW\_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=L=QNEW\_N(S,Z,I,J,N-1) \\ & \quad /(CPC(S,J,N-1) \\ & \quad *(TU(S,N-1)-TL(S,N-1)))+(1-ALFA\_N(S,Z,I,J,N))*DHC(S,J,N)/ \\ & \quad (CPC(S,J,N)*(TU(S,N)-TL(S,N))); \end{aligned}$$

\*EQ (74)

$$\begin{aligned} & FEAS\_N\_1(S,Z,I,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW\_C(S,Z,J,N,I)=1 \\ & AND ALLOW\_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J)).. \\ & \quad QNEW\_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N))) \\ & \quad +(1-ALFA\_N(S,Z,I,J,N))*DHC(S,J,N) \\ & \quad /(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=QNEW\_N(S,Z,I,J,N-1)/ \\ & \quad (CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1))); \end{aligned}$$

\*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)))=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))..  
-(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))  
+ (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,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)=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 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\_MI\_B(S,Z,I,J,M)-NHE\_NI\_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\_MI\_B(S,Z,I,J,M)-NHE\_NI\_B(S,Z,I,J,N))\*DHC(S,J,N-1)/  
 (TU(S,N-1)-TL(S,N-1));

\*EQ (96)  
 ?AREQ(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\_MI\_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\_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))..  
 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\_MI\_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))+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(NS(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(IS(HU(I) AND FREEH(I)), CHU(I)\*FHU(I)\*DTHU(I))  
+ SUM(JS(CU(I) 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 ;

\* 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;

\*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,I,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)\$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 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)\$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 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)\$H(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)\$H(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)\$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 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)\$H(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)\$H(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)\$H(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)\$H(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,I,N,I)=1  
 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)..  
 SUM(L\$(D(S,Z,I,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(OS\$(D(S,Z,M,O)=1 AND ORD(O)LE ORD(N) AND COLD(S,J,O) AND ALLOW\_C(S,Z,I,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,I,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)..

$$XM(S,Z,I,M,J,N) - (TE(S,Z,I,M,J,N) * OMEGA(S,Z,I,M,J,N)) = G = \text{SUM}(R, (XW(S,Z,I,M,J,N,R) * \\ \text{FPR}(I,R) * \text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } \text{ORD}(L) \text{ LE } \text{ORD}(M) \\ \text{AND } \text{HOT}(S,I,L)=1 \text{ AND } \text{ALLOW\_H}(S,Z,I,L,J)=1), (\text{CPH}(S,I,L)) * (\text{TU}(S,L) - \text{TL}(S,L))))));$$

\*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)..

$$XM(S,Z,I,M,J,N) - ((1 - TE(S,Z,I,M,J,N)) * OMEGA(S,Z,I,M,J,N)) = L = B1(S,Z,I,M,J,N) * \\ \text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } \text{ORD}(L) \text{ LE } \text{ORD}(N) \\ \text{AND } \text{COLD}(S,J,L)=1 \text{ AND } \text{ALLOW\_C}(S,Z,J,L,I)=1), \text{DHC}(S,J,L));$$

\*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)..

$$XM(S,Z,I,M,J,N) = G = B1(S,Z,I,M,J,N) * \text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } \text{ORD}(L) \text{ LE } \text{ORD}(N) \\ \text{AND } \text{COLD}(S,J,L)=1 \text{ AND } \text{ALLOW\_C}(S,Z,J,L,I)=1), \text{DHC}(S,J,L));$$

\*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)..  
$$\text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } \text{ORD}(L) \text{ LE } \text{ORD}(M) \text{ AND } \text{HOT}(S,I,L)=1 \\ \text{AND } \text{ALLOW\_H}(S,Z,I,L,J)=1), \\ \text{QNEW\_M}(S,Z,I,J,L) - \text{QNEW2\_M}(S,Z,I,J,M) = G = \\ \text{SUM}(O\$ (D(S,Z,M,O)=1 \text{ AND } \text{ORD}(O) \text{ LE } \text{ORD}(N) \text{ AND } \text{COLD}(S,J,O) \text{ AND } \text{ALLOW\_C}(S,Z,J,O,I)), \\ \text{QNEW\_N}(S,Z,I,J,O)) - \text{ONEW2\_N}(S,Z,I,J,N) \\ - 4 * XM(S,Z,I,M,J,N);$$

\*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)..  
$$\text{QNEW2\_M}(S,Z,I,J,M) = L = \text{FPK\_H\_0}(S,Z,I,J,M) * \text{CPH}(S,I,M) * (\text{TU}(S,M) - \text{TL}(S,M));$$

\*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)..

$$\text{FPK\_H\_0}(S,Z,I,J,M) = E = \text{SUM}(R, (\text{FPR}(I,R) * \text{KW\_0}(S,Z,I,J,M,R)));$$

\*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)-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,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,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=

$$\frac{QNEW\_M(S,Z,I,J,M+1)}{(TU(S,M+1)-TL(S,M+1))}$$

$$*CPH(S,I,M)/CPH(S,I,M+1)-((2*FP(I))-FPK\_H\_0(S,Z,I,J,M)-FPK\_C\_0(S,Z,I,J,N))$$

$$*CPH(S,I,M+1)*(TU(S,M+1)-TL(S,M+1))/(TU(S,M+1)-TL(S,M+1));$$


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\*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)..  

$$FP(I)=E=SUM(R,FP(R)*W(I,R));$$


---

\*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 63 and 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)$(HOT(S,I,M)=1 AND NOT SPH(I) AND FREEH(I)).
SST(I) =E= (A_1(I)*PA1)+(B_1(I)*PA2)+(C_1(I)*PA3)+D_1(I);
*-----
PA_62..
Cost_side_stripping_steam =E= SUM(I,(CSS(I)*SST(I)));
*-----
PA_63 ..
TOTAL_Q =G= TOTAL_QPA_MIN;
*-----
PA_64 ..
TOTAL_Q =L= TOTAL_QPA_MAX;
*-----
PA_65 ..
TOTAL_QPA_MIN =E= TOTAL_QPA-(TOTAL_QPA*0.0001);
*-----
PA_66 ..
TOTAL_QPA_MAX =E= TOTAL_QPA+(TOTAL_QPA*0.0001);
*-----
PA_67 ..
SUM(I,QPA(I)$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)$(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,J,I,M) Flowrate of hot stream per HEX;
FC_C(S,Z,J,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,J,I);
NHE2(S,Z,J,I)=NHE.L(S,Z,I,J);

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;  
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;  
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 Heat Exchanger Network of Crude Fractionation Unit

```

$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*K1/
*
*NEW SET FOR PUMP-AROUND.
PA(I) Pump-around streams /I2,I4,I6/
*
ALIAS (M,N,L,O)
ALIAS (I,II)
ALIAS (J,JI)
ALIAS (K,KK)
ALIAS (Z,ZZ)

*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

I6.R1 37.59575

```

I6.R2 39.94549  
 I6.R3 84.59044  
 I6.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 NJZ(S,Z,I) # OF INTERVALS DESIRED FOR COLD STREAMS

/

S1.Z1.J1 6  
 S1.Z1.J2 3  
 S1.Z1.J3 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.I1 48.30000
S1.I2 182.5720
S1.I3 224.6850
S1.I4 268.7880
S1.I5 275.6570
S1.I6 308.5100
S1.I7 323.5120
S1.I8 347.1810
S1.I9 180.0000
/

```

TOH(S,I) T OUT FOR HOT STREAMS

```

/
S1.I1 26.11000
S1.I2 104.4400
S1.I3 26.11000
S1.I4 173.6270
S1.I5 26.11000
S1.I6 232.2220
S1.I7 26.11000
S1.I8 260.0000
S1.I9 179.0000
/

```

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 143.8890
S1.J3 30.00000
/

```

## PARAMETERS

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

```

/
S1.Z1.I1 48.30000
S1.Z1.I2 182.5720
S1.Z1.I3 224.6850
S1.Z1.I4 268.7880
S1.Z1.I5 275.6570
S1.Z1.I6 308.5100
S1.Z1.I7 323.5120
S1.Z1.I8 347.1810
S1.Z1.I9 180.0000
/

```

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

```

/
S1.Z1.I1 26.11000
S1.Z1.I2 104.4400
S1.Z1.I3 26.11000
S1.Z1.I4 173.6270
S1.Z1.I5 26.11000
S1.Z1.I6 232.2220
S1.Z1.I7 26.11000
/

```

```

S1.Z1.I8 260.0000
S1.Z1.I9 179.0000
/
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 143.8890
S1.Z1.J3 30.00000
/
*-----
*INTRODUCE THE FCp:
FH(S,I) FOR HOT STREAMS
/
S1.I1 177.826
S1.I3 126.158
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.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.I7.J3 1
S1.Z1.I8.J3 1

```



```

S1.Z1.I1.J3 1
S1.Z1.I3.J3 1
S1.Z1.I5.J3 1
S1.Z1.I6.J3 1
/
PARAMETER AEX_U(Z,I,J)
/
Z1.I2.J1 2000.000
Z1.I4.J1 700.0000
Z1.I9.J1 1700.000
Z1.I8.J2 250.0000
Z1.I7.J3 1600.000
Z1.I8.J3 400.0000
Z1.I1.J3 650.0000
Z1.I3.J3 1200.000
Z1.I5.J3 750.0000
Z1.I6.J3 350.0000
/
PARAMETER AEX_U_B(K,Z,I,J)
/
K1.Z1.I1.J1 2000.000
/
PARAMETER A_NEW_MAX(Z,I,J)
/
Z1.(I1*I4).(J1*J3) 3000.000
/
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,I,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))

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+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$(ORD(I)=CARD(I)),IHmax(S,I))
    +SUM((ZZ,J)$[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)
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)],

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      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)$[COLDZ(S,Z,J,M)=1AND ORD(M)=ICmaxZ(S,Z,J)],
      TICZ(S,Z,J)$[ORD(M)=ICmaxZ(S,Z,J)])
+ SUM((Z,J)$[COLDZ(S,Z,J,M)=1AND ORD(M)<ICmaxZ(S,Z,J)
      AND ORD(M)>=ICminZ(S,Z,J)],
      [TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$[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[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(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

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        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)] >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+
      1${SUM[S,ALLOW(S,Z,I,J)] >0 AND 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 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

```

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\_Dt(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  
 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

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,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,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(NS(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) $\$(COLD(S,J,N)=1 \text{ AND NOT } CU(J) \text{ AND } FREEC(J) \text{ AND } NIC(J)=1)..$   
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) $\$(HOT(S,I,M)=1 \text{ AND NOT } HU(I) \text{ AND } FREEH(I) \text{ AND } NIH(I)=1)..$   
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,I) $\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } COLD(S,I,N)=1$   
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) $\$(COLD(S,J,N)=1 \text{ AND NOT } CU(J) \text{ AND } FREEC(J) \text{ AND } NIC(J)=1)..$   
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,J,M) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=0$   
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) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=0 \text{ AND}$   
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) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=1$   
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) $\$(HOT(S,I,M)=1 \text{ AND } ALLOW_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=1$   
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) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=0$   
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) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=0$   
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) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1$   
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) $\$(COLD(S,J,N)=1 \text{ AND } ALLOW_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1$   
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) $\$(HOT(S,I,M)=1 \text{ AND } HOT(S,I,M-1) \text{ AND } ALLOW_H(S,Z,I,M,J)=1$   
AND ALLOW\_H(S,Z,I,M-1,J) AND BIF(Z,I,I)=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 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 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  
 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-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))..  
 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,I,N)=1 AND COLD(S,I,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 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),

$NHE\_M1\_B(S,Z,I,J,M)) + \text{SUM}(M\$(HOT(S,I,M)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=0), NHE\_M1(S,Z,I,J,M));$   
 -----  
 \*EQ (40)  
 $HE\_COUNT\_N1(S,Z,I,J)\$(ALLOW(S,Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 $NHE(S,Z,I,J)=E=\text{SUM}(N\$(COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1),$   
 $NHE\_N1\_B(S,Z,I,J,N)) + \text{SUM}(N\$(COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } BIF(Z,I,J)=0), NHE\_N1(S,Z,I,J,N));$   
 -----  
 \*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)  
 $BIF\_1(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$   
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I))..$   
 $\text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND } HOT(S,I,L)=1$   
 $\text{ AND } ALLOW\_H(S,Z,I,L,J)=1),$   
 $QNEW\_M(S,Z,I,J,L) - QNEW2\_M(S,Z,I,J,M)=L=$   
 $\text{SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N) \text{ AND } COLD(S,J,O) \text{ AND } ALLOW\_C(S,Z,J,O,I)),$   
 $QNEW\_N(S,Z,I,J,O) - QNEW2\_N(S,Z,I,J,N)$   
 $+ B1(S,Z,I,M,J,N) *4* \text{max}(\text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M)$   
 $\text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW\_H(S,Z,I,L,J)=1),DHH(S,I,L)),$   
 $\text{SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N)$   
 $\text{ AND } COLD(S,J,O) \text{ AND } ALLOW\_C(S,Z,J,O,I)),DHC(S,J,O));$   
 -----  
 \*EQ (44)  
 $BIF\_2(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$   
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I)$   
 $\text{ AND } FREEC(J) \text{ AND } NOT \text{ PA}(I))..$   
 $\text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND } HOT(S,I,L)=1$   
 $\text{ AND } ALLOW\_H(S,Z,I,L,J)=1),$   
 $QNEW\_M(S,Z,I,J,L) - QNEW2\_M(S,Z,I,J,M)=G=$   
 $\text{SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N) \text{ AND } COLD(S,J,O) \text{ AND } ALLOW\_C(S,Z,J,O,I)),$   
 $QNEW\_N(S,Z,I,J,O) - QNEW2\_N(S,Z,I,J,N)$   
 $-B1(S,Z,I,M,J,N) *4* \text{max}(\text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M)$   
 $\text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW\_H(S,Z,I,L,J)=1),DHH(S,I,L)),$   
 $\text{SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N) \text{ AND } COLD(S,J,O)$   
 $\text{ AND } ALLOW\_C(S,Z,J,O,I)),DHC(S,J,O));$   
 -----  
 \*EQ (45)  
 $BIF\_3(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1$   
 $\text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 $B1(S,Z,I,M,J,N) = E = 2 - 0.25 * \text{SUM}(L\$(D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M)$   
 $\text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW\_H(S,Z,I,L,J)=1),NHE\_M1\_B(S,Z,I,J,L))$   
 $+ 0.25 * \text{SUM}(O\$(D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N) \text{ AND } COLD(S,J,O)$   
 $\text{ AND } ALLOW\_C(S,Z,J,O,I)),NHE\_N1\_B(S,Z,I,J,O))$   
 $-NHE\_M1\_B(S,Z,I,J,M)-NHE\_N1\_B(S,Z,I,J,N);$   
 -----  
 \*EQ (46)  
 $BIF\_4(S,Z,I,J,M,N)\$(D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } TL(S,N) \text{ GE } TL(S,M)$   
 $\text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 $\text{SUM}(I\$(HOT(S,I,L)=1 \text{ AND } ORD(I) \text{ I E } ORD(M) \text{ AND } ALLOW\_H(S,Z,I,L,J)=1),NHE\_M1\_B(S,Z,I,J,L))$   
 $- \text{SUM}(O\$(COLD(S,J,O) \text{ AND } ORD(O) \text{ LE } ORD(N) \text{ AND } ALLOW\_C(S,Z,J,O,I)),$   
 $NHE\_N1\_B(S,Z,I,J,O))=G=0;$   
 -----  
 \*EQ (47)  
 $BIF\_11(S,Z,I,J,M)\$(HOT(S,I,M)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=1$   
 $\text{ AND } FREEH(I) \text{ AND } FREEC(J))..$   
 $\text{SUM}(O\$(HOT(S,I,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(M) \text{ AND } ALLOW\_H(S,Z,I,O,J)=1),$   
 $NHE\_M0\_B(S,Z,I,J,O)-NHE\_M1\_B(S,Z,I,J,O))=L=1;$

-----  
\*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))..  
SUM(OS(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,I,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,I,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,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))..  
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))..  
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)-

$NHE\_M0(S,Z,I,J,M) + NHE\_M1(S,Z,I,J,M) * DHH(S,I,M);$   
 $FEAS\_M\_1\_SP\_B(S,Z,I,J,M) \$ (HOT(S,I,M-1) \text{ AND } HOT(S,I,M)=1 \text{ AND } HOT(S,I,M+1)$   
 $\text{ AND } ALLOW\_H(S,Z,I,M,J)=1$   
 $\text{ AND } ALLOW\_H(S,Z,I,M-1,J) \text{ AND } ALLOW\_H(S,Z,I,M+1,J) \text{ AND } BIF(Z,I,J)=1 \text{ AND } SPH(I)=0$   
 $\text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } NOT\ PA(I)..$   
 $QNEW\_M(S,Z,I,J,M)=G=(Y\_M\_B(S,Z,I,J,M)-$   
 $NHE\_M0\_B(S,Z,I,J,M)+NHE\_M1\_B(S,Z,I,J,M))*DHH(S,I,M);$

\*EQ (69)

$FEAS\_N\_01(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPC(J)=1 \text{ AND } FREEH(I)$   
 $\text{ AND } FREEC(J)..$

$ALFA\_N(S,Z,I,J,N)=L-1-NHE\_N0(S,Z,I,J,N)-NHE\_N0(S,Z,I,J,N-1);$   
 $FEAS\_N\_01\_B(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J)..$   
 $ALFA\_N(S,Z,I,J,N)=L-1-NHE\_N0\_B(S,Z,I,J,N)-NHE\_N0\_B(S,Z,I,J,N-1);$

\*EQ (70)

$FEAS\_N\_02(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPC(J)=1 \text{ AND } FREEH(I)$   
 $\text{ AND } FREEC(J)..$

$ALFA\_N(S,Z,I,J,N)=L-1-NHE\_N1(S,Z,I,J,N)-NHE\_N1(S,Z,I,J,N-1);$   
 $FEAS\_N\_02\_B(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J)..$   
 $ALFA\_N(S,Z,I,J,N)=L-1-NHE\_N1\_B(S,Z,I,J,N)-NHE\_N1\_B(S,Z,I,J,N-1);$

\*EQ (71)

$FEAS\_N\_03(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPC(J)=1 \text{ AND } FREEH(I)$   
 $\text{ AND } FREEC(J)..$

$ALFA\_N(S,Z,I,J,N)=G=Y\_N(S,Z,I,J,N)-NHE\_N0(S,Z,I,J,N)-NHE\_N0(S,Z,I,J,N-1)$   
 $-NHE\_N1(S,Z,I,J,N)-NHE\_N1(S,Z,I,J,N-1);$   
 $FEAS\_N\_03\_B(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J)..$   
 $ALFA\_N(S,Z,I,J,N)=G=Y\_N\_B(S,Z,I,J,N)-NHE\_N0\_B(S,Z,I,J,N)-NHE\_N0\_B(S,Z,I,J,N-1)$   
 $-NHE\_N1\_B(S,Z,I,J,N)-NHE\_N1\_B(S,Z,I,J,N-1);$

\*EQ (72)

$FEAS\_N\_04(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } (BIF(Z,I,J)=1 \text{ OR } SPC(J)=1) \text{ AND } FREEH(I)$   
 $\text{ AND } FREEC(J)..$

$ALFA\_N(S,Z,I,J,N)=G=0;$

\*EQ (73)

$FEAS\_N\_2(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } SPC(J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J)..$

$QNEW\_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=L-QNEW\_N(S,Z,I,J,N-1)$   
 $/(CPC(S,J,N-1))$   
 $*(TU(S,N-1)-TL(S,N-1))+(1-ALFA\_N(S,Z,I,J,N))*DHC(S,J,N)/$   
 $(CPC(S,J,N)*(TU(S,N)-TL(S,N)));$

\*EQ (74)

$FEAS\_N\_1(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } SPC(J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J)..$

$QNEW\_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))$   
 $+(1-ALFA\_N(S,Z,I,J,N))*DHC(S,J,N)$   
 $/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G-QNEW\_N(S,Z,I,J,N-1)/$   
 $(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)));$

\*EQ (75)

$FEAS\_N\_3(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPC(J)=1 \text{ AND } FREEH(I)$   
 $\text{ AND } FREEC(J)..$

$-QNEW\_N(S,Z,I,J,N)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))$   
 $+QNEW\_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(1+NHE\_N1(S,Z,I,J,N-1)$   
 $+NHE\_N1(S,Z,I,J,N)$   
 $-NHE\_N0(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))*1.00001 =G=0;$

\*EQ (76)

$FEAS\_N\_4(S,Z,I,J,N) \$ (COLD(S,J,N-1) \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1$   
 $\text{ AND } ALLOW\_C(S,Z,J,N-1,I) \text{ AND } BIF(Z,I,J)=0 \text{ AND } SPC(J)=1 \text{ AND } FREEH(I)$

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,I,N,I)=1  
 AND ALLOW\_C(S,Z,I,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;

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\*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,I,N,I)=1  
 AND ALLOW\_C(S,Z,I,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;

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\*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,I,N,I)=1  
 AND ALLOW\_C(S,Z,I,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;

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\*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,I,N,I)=1 AND ALLOW\_C(S,Z,I,N-1,I) AND ALLOW\_C(S,Z,I,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,I,N,I)=1 AND ALLOW\_C(S,Z,I,N-1,I) AND ALLOW\_C(S,Z,I,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);

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\*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,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 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(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,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 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;

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\*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,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 NOT PA(I))..



$TU(S,M)-TU(S,N)$   
 $-QNEW\_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) + QNEW\_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))$   
 $+ (2-NHE\_M1(S,Z,I,J,M)-NHE\_N1(S,Z,I,J,N))*TU(S,N)=G=0;$   
 $FEAS\_END\_B\_SP(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)$   
 $AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW\_H(S,Z,I,M,J)=1$   
 $AND ALLOW\_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1$   
 $AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND NOT PA(I)).$   
 $TU(S,M)-TU(S,N)$   
 $-QNEW\_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) + QNEW\_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))$   
 $+ (2-NHE\_M1\_B(S,Z,I,J,M)-NHE\_N1\_B(S,Z,I,J,N))*TU(S,N)=G=0;$

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**\*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)**  
 $FEAS\_BEG2(S,Z,I,J,M,N)\$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)$   
 $AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1$   
 $AND COLD(S,J,N+1)$   
 $AND ALLOW\_H(S,Z,I,M,J)=1 AND ALLOW\_H(S,Z,I,M+1,J) AND ALLOW\_C(S,Z,J,N,I)=1$   
 $AND ALLOW\_C(S,Z,J,N+1,I) AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1)$   
 $AND FREEH(I) AND FREEC(J) AND NOT PA(I)).$   
 $QNEW\_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=$   
 $QNEW\_M(S,Z,I,J,M+1)/(TU(S,M+1)-TL(S,M+1))$   
 $*CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE\_M0(S,Z,I,J,M)-NHE\_N0(S,Z,I,J,N))$   
 $*DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));$

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**\*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)=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 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,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)..  
 (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,I,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,I,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,I,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,I,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\_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))..  
 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,I,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))+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,I,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,I,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));

\* 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) ..

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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)$(ORD(K) LE KMAX(Z,I,J) AND ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K))
=E= NHE0(S,Z,I,J);
*-----
*EQ(Retrofit 14)
LIM_HEX(S,M)..
SUM((Z,I,J)$(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 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(OS\$(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))..

$$XM(S,Z,I,M,J,N) - (TE(S,Z,I,M,J,N) * OMEGA(S,Z,I,M,J,N)) = L = \text{SUM}(R, (XW(S,Z,I,M,J,N,R) * FPR(I,R) * \text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW\_H(S,Z,I,L,J)=1), (CPH(S,I,L) * (TU(S,L) - TL(S,L))))));$$

\*EQ 43\_D

$$PA\_12(S,Z,I,J,M,N) \$ (D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I));$$

$$XM(S,Z,I,M,J,N) - (TE(S,Z,I,M,J,N) * OMEGA(S,Z,I,M,J,N)) = G = \text{SUM}(R, (XW(S,Z,I,M,J,N,R) * FPR(I,R) * \text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW\_H(S,Z,I,L,J)=1), (CPH(S,I,L) * (TU(S,L) - TL(S,L))))));$$

\*EQ 43\_E

$$PA\_13(S,Z,I,J,M,N) \$ (D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I));$$

$$XM(S,Z,I,M,J,N) - ((1 - TE(S,Z,I,M,J,N)) * OMEGA(S,Z,I,M,J,N)) = L = B1(S,Z,I,M,J,N) * \text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(N) \text{ AND } COLD(S,J,L)=1 \text{ AND } ALLOW\_C(S,Z,J,L,I)=1), DHC(S,J,L));$$

\*EQ 43\_F

$$PA\_14(S,Z,I,J,M,N) \$ (D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I));$$

$$XM(S,Z,I,M,J,N) = G = B1(S,Z,I,M,J,N) * \text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(N) \text{ AND } COLD(S,J,L)=1 \text{ AND } ALLOW\_C(S,Z,J,L,I)=1), DHC(S,J,L));$$

\*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)

$$PA\_18(S,Z,I,J,M,N) \$ (D(S,Z,M,N)=1 \text{ AND } TL(S,N) \text{ LT } TU(S,M) \text{ AND } HOT(S,I,M)=1 \text{ AND } COLD(S,J,N)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } ALLOW\_C(S,Z,J,N,I)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I));$$

$$\text{SUM}(L\$ (D(S,Z,L,N)=1 \text{ AND } ORD(L) \text{ LE } ORD(M) \text{ AND } HOT(S,I,L)=1 \text{ AND } ALLOW\_H(S,Z,I,L,J)=1),$$

$$QNEW\_M(S,Z,I,J,L)) - QNEW2\_M(S,Z,I,J,M) = G =$$

$$\text{SUM}(O\$ (D(S,Z,M,O)=1 \text{ AND } ORD(O) \text{ LE } ORD(N) \text{ AND } COLD(S,J,O) \text{ AND } ALLOW\_C(S,Z,J,O,I)),$$

$$QNEW\_N(S,Z,I,J,O)) - QNEW2\_N(S,Z,I,J,N)$$

$$- 4 * XM(S,Z,I,M,J,N);$$

\*EQ (50\_b)

$$PA\_19(S,Z,I,J,M) \$ (HOT(S,I,M)=1 \text{ AND } ALLOW\_H(S,Z,I,M,J)=1 \text{ AND } BIF(Z,I,J)=1 \text{ AND } FREEH(I) \text{ AND } FREEC(J) \text{ AND } PA(I));$$

$$QNEW2\_M(S,Z,I,J,M) = L = FPK\_H\_0(S,Z,I,J,M) * CPH(S,I,M) * (TU(S,M) - TL(S,M));$$

\*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))..

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)\$(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)-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,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,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..

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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)$ (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,J,I,M) Flowrate of hot stream per HEX;
FC_C(S,Z,J,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));

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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 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;  
 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;  
 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;

**CURRICULUM VITAE**

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