## REFERENCES

Bagajewicz, M.J. (1998) Energy savings horizons for the retrofit of chemical processes. Application to Crude Fractionation Units. Computer and Chemical Engineering, 23(1), 1-9.

Bagajewicz, M.J. and Soto, J. (2001) Rigorous procedure for the design of conventional atmospheric crude fractionation units. Part I: Targeting. Industrial and Engineering Chemistry Research, 40(2), 617-626.

Bagajewicz, M.J. and Soto, J. (2001) Rigorous procedure for the design of conventional atmospheric crude fractionation units. Part II: Heat Exchanger Networks. Industrial and Engineering Chemistry Research, 40(2), 627-634.

Bagajewicz, M.J. and Soto, J. (2003) Rigorous procedure for the design of conventional atmospheric crude fractionation units. Part III: Trade-Off between complexity and energy savings. Industrial and Engineering Chemistry Research, 42(6), 1196-1203.

Bagajewicz, M.J. and Soto, J. (2002) Rigorous targeting procedure for the design of crude fractionation units with pre-flashing or pre-fractionation. Industrial and Engineering Chemistry Research, 41(12), 3003-3011.
Barbaro, A. and Bagajewicz, M.J., New rigorous one-step MILP formulation for heat exchanger network synthesis. Computers and Chemical Engineering, 29, 1945-1976

Bjork, K. and Nordman, R. (2005) Solving large-scale retrofit heat exchanger network synthesis problems with mathematical optimization methods. Chemical Engineering and Processing, 44, 869-876.

Briones, V. and Kokossis, A.C. (1999) Hypertargets: a conceptual programming approach for the optimisation of industrial heat exchanger networks-II. Retrofit design. Chemical Engineering Science, 54(4), 541-561.

Cerda, J. and Westerburg, A.W. (1983) Synthesizing heat exchanger networks having restricted stream/stream matches using transportation problem formulations. Chemical Engineering Science, 38(10), 1723-1740.

Cerda, J., Westerburg, A.W., Mason, D., and Linnhoff, B. (1983) Minimum utility usage in heat exchanger network synthesis A transportation problem. Chemical Engineering Science, 38(3), 373-387.

Ciric, A.R. and Floudas, C.A. (1991) Heat exchanger network synthesis without decomposition. Computer \& Chemical Engineering, 15(6), 385-396.

Floudas, C.A., Ciric, A.R., and Grossmann, I.E. (1986) Automatic synthesis of optimum heat exchanger network configurations. AIChE Journal, 32(2), 276-290.

Furman, K. and Sahinidis, N. (2001) Computational complexity of heat exchanger network synthesis. Computers and Chemical Engineering, 25, 1371-1390.

Gundersen, T. and Grossmann, I.E. (1990) Improved optimization strategies for automated heat exchanger network synthesis through physical insights. Computers and Chemical Engineering, 14(9), 925-944.

Ma, K., Hui, C., and Yee, T. (2000) Constant approach temperature model for HEN retrofit. Applied Thermal Engineering, 20, 1505-1533.

Mamdouh G., Megan J., and Robin S. (April 2003) Increase capacity and decrease energy for existing refinery distillation columns (available at http://www.cepmegazine.org )
Tsiakis P., Shah N.,. and Pantelides C. (2001) Design of multi-echelon supply chain networks under demand uncertainty. Industrial and Engineering Chemistry Research, 40, 3585-3604.

Yee, T.F. and Grossmann, I.E. (1990) Simultaneous optimization models for heat integration-I. Heat exchanger network synthesis. Computer and Chemical Engineering, 14(10), 1165-1184.

## APPENDICES <br> Appendix A Programming Model for Retrofit without Relocation

```
$TITLE HEN design- Automatic parameter calculation- KITISAK-1
* Equations that are different than in the paper +errata.
*(100) Just a nomenclature change
*(105) Just a nomenclature change
*--
* Equations that are added to those that are in the paper
*(106) and (107)
* CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K
*(108) LIMIT THE NUMBER OF EXCHANGERS
*(109) MINIMUM NUMBER OF EXCHANGERS
$OFFUPPER
SETS
Z transfer zcne /ZI*ZI/
*
*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
    | Hot streams /l1*13/
    J cold streams /J]*J3/
*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
    HU(I) Heating utilities /I3/
    CU(J) Cooling utilities /J3/
*
    M temperature intervals /MI*M85/
    S SCENARIO /SI/
    K temperature intervals/Kl*Kl/
    R exchangers /RI*R7/
    ALIAS (M.N.L.O)
    ALIAS (I,II)
    ALIAS (J,JJ)
    ALIAS (K.KK)
    ALIAS (Z.ZZ)
SET
ORDER(J)
l
J1
J2
I
PARAMETER NIZ(S,Z.l) # OF INTERVALS DESIRED FOR HOT STREAMS
l
S1.Z1.11 }3
S1.21.128
S1.Z1.132
I
PARAMETER NJZ(S,Z,J) # OF INTERVALS DESIRED FOR COLD STREAMS
l
S1.Z1.J1 35
S1.Z1.J28
S1.Z1.J32
/
PARAMETER HI(S,I) HEAT TR CEOFF FOR HOT STREAMS
l
S1.11 0.1
Sl.12 0.1
S1.13 0.1
l
PARAMETER HJ(S.J) HEAT TR CEOFF FOR COLD STREAMS
/
S1.JI 0.1
SI.J2 0.1
SI.J3 0.1
l
PARAMETERS
```

```
TIH(S,I) T IN FOR HOT STREAMS
I
S1.11 400
S1.12 140
S1.13 500
/
TOH(S,I) T OUT FOR HOT STREAMS
/
S1.11 100
S 1.1260
SI.13499
l
TIC(S.J) T IN FOR COLD STREAMS
I
SI.J] }5
S1.J2 }9
SI.J3 }3
I
TOC(S.J) T OUT FOR COLD STREAMS
/
SIJl 400
S1.J2 165
S1.J340
/
PARAMETERS
TIHZ(S.Z,I) T IN FOR HOT STREAMS
/
S1.Z1.11 400
S1.Z1.I2 }14
S1.Z1.I3 500
/
TOHZ(S.Z.l) T OUT FOR HOT STREAMS
I
S1.Z1.11 100
S1.Z1.1260
S1.Z1.13499
I
TICZ(S.Z.J) T IN FOR COLD STREAMS
/
SlZ1JJ 50
S1.Z1J2 90
S1.21.J3 30
/
TOCZ(S,Z.J) T OUT FOR COLD STREAMS
/
S1.21.J1400
S1.Z1.J2 165
S1.Z1.J3 40
/
```



```
*INTRODUCE THE FCp:
FH(S,I) FOR HOT STREAMS
I
SI.II }1
S1.I2 }3
/
FC(S,J) FOR COLD STREAMS
l
S1.J1 }1
S1.J2 }4
/
*USE THE MAX FCp FOR THE UTILITIES
*
SETS FREEH(I)
/
II
12
13
/
    FREEC(J)
/
```

```
J]
J2
J3
l
PARAMETER BIF(Z,I.J)
/
Z1.11.J20
21.12.J10
Z1.13.J10
Z1.12.J30
l
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
*;
PARAMETER SPH(l) SH in paper
I
11 1
12 1
13 1
PARAMETER SPC(J) SC in paper
J1 I
J2 1
J3 1
l
PARAMETER NIH(I) Non isothermal splitting for hot streams in paper
/
11 0
12 0
13 0
/
PARAMETER NIC(J) Non isothermal splitting for cold streams in paper
|
J10
J2 0
J3 0
I
PARAMETER DTVIO(I.J)
I
11.31 1
11.J2 1
11.J3 1
12.J1 1
12.J2 1
12.J3 1
13.J] 1
13.J2 1
13.J3 1
l
PARAMETER KMAX(Z.I.J)
/
Z1.11.J2 1
Z1.12.J1 1
Z1.13.J1 1
Z1.I2.J3 1
I
```



```
******************************* ADD FOR RETROFIT *********************************
********
PARAMETER AEX(Z,l.J)
l
Z1.11.J2 841.86
Z1.12.J1554
```

```
Z1.12.J3 660.18
Z1.13.JI262
/
PARAMETER AEX_B(K.Z.I.J)
/
Kl.21.11.J2 841.86
/
PARAMETER NHEO(S.Z.I.J)
/
S1.ZIJ1 J21
SI.Z1.12.J11
Sl.Z1.13.J11
S1.Z1.12.J31
/
PARAMETER AEX U(Z.I.J)
/
Z1.11.J22000
Z1.12.J12000
Z1.13.J1 }200
Z1.12.J32000
/
PARAMETER AEX_U_B(K.Z.I.J)
/
KI.Z1.J1.J2 2000
/
PARAMETER A_NEW MAX(Z,1,J)
/
Z1.(II*I3).(J1*J3) 2000
/
*---.---.--...-....-
$ontext
PARAMETER AEX I(R)
/
R1 1001.34
R2 1048.28
R3 121.53
R4 133.56
R5 584.15
R6 603.71
R7 246.81
/
PARAMETER AEX_B_l(R)
/
R1 1001.34
/
PARAMETER AEX_U_l(R)
/
R1 1502.01
R2 1572.42
R3182.295
R4 200.34
R5 876.225
R6 905.565
R7 370.215
/
PARAMETER AEX_U_B_l(R)
/
RI 1502.01
/
PARAMETER R ALL
* Minimum DELTA T
17%:
```

\$offlext
$\qquad$

```
PARAMETER DTHU(I)
l
13 1
/
PARAMETER DTCU(J)
I
J3 10
l
PARAMETER FMAX_HU(I)
/
13 5000
l
PARAMETER FMAX_CU(J)
l
J3 5000
l
PARAMETER CHU(I)
I
13 95.04
/
PARAMETER CCU(J)
/
J3 20
I
PARAMETER CF
CF=1000;
PARAMETER CA;
CA=20;
******************************FOR RETEOFIT***************************************
*********************************************************************************
PARAMETER MAX NEW_HEX
* Maximum Number of new exchangers
/200/;
PARAMETER CAN:
CAN = 20;
PARAMETER CAE,
CAE = 20;
PARAMETER QLHMIN
* Minimum heat that can be transferred within an interval.Hot streams
/0.01/;
PARAMETER QLCMIN
* Minimum heat that can be transferred within an interval Cold streams
/0.01/;
PARAMETER AMAX
* Maximum area per exchanger
/20000/;
PARAMETER ASHELLMAX
* Maximum shell area
/5000/:
PARAMETER USHELLMAX
* Maximum shell area
/5000/;
*Add for retrofit
PARAMETER A_NEW_SHELLMAX
* Maximum shell area
/5000/;
PARAMETER NEW USHELLMAX
* Maximum shell area
/5000/;
*
PARAMETER TOTNEXCHMAX
* Maximum NUMBER OF EXCHANGERS
/900/;
PARAMETER TOTNEXCHMIN
* Minimum NUMBER OF EXCHANGERS
```


## /0/

PARAMETER DTmin
Minimum DELTA T
10/;
parameter NINT
/263/;
parameter OPT
/1/;


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_l(S,I,M), H_J(S.J,M)

```
FOR(Si=1 TO CARD(S),
    FOR(Zi=1 TO CARD(Z)
        FOR(lc=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)$[ORD(S)=Si AND ORD(1)>1
                                    AND ORD(Z)=1]= 0+
                    {SUM((ZZ,II)$[ORD(II)<ORD(I)],NIZ(S.ZZ,II))+I}$[NIZ(S,Z,I)>=1];
            1HminZ(S,Z,I)$[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}$NIZ(S,Z,I)>=1];
            1HmaxZ(S,Z,l)$[ORD(S)=Si AND ORD(I)=lc AND ORD (Z)=Zi]=0+
                    {IHminZ(S,Z,I)+NIZ(S,Z,I)-1}${NIZ(S,Z,1)>=1};
            lHmin(S,I)$[ORD(S)=Si AND ORD(1)=Ic]=
            SUM[Z${SUM(ZZ$[ORD(ZZ)<=ORD(Z)-1],NIZ(S,ZZ,I))=0},1HminZ(S.Z.I)];
            IHmax(S,I)$[ORD(S)=Si AND ORD(l)=Ic]=
                SUM[Z${SUM(ZZ$[ORD(ZZ)>=ORD(Z)+1],NIZ(S.ZZ.1))=0},1HmaxZ(S.Z.I)]:
            FOR(Mi=1 TO CARD(M),
                    HOT(S.I,M)$[ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi]= 0+
                    1$[ORD(M)>= IHmin(S,I) AND ORD(M)<=1Hmax(S.I)];
            HOT2(S,M)$[ORD(S)=Si AND ORD(M)=Mi]=0+{$[ORD(M)<=
                    SUM(I$(ORD(I)=CARD(I)),IHmax(S.I))];
            HOTZ(S,Z,I,M)$[ORD(S)=Si AND ORD(I)=lc AND ORD(M)=Mi
        AND ORD (Z)=Zi] = 0+ 1$[ORD(M)>= IHminZ(S,Z,I) AND ORD(M)<=lHmaxZ(S.Z.I)];
            H_I(S,I,M)$[ORD(S)=Si AND ORD(I)=Ic AND ORD(M)=Mi
                                    AND HOT(S.I.M)=1] = Hl(S,l) :
            ));
        FOR(Ji=1 TO CARD(J),
            ICminZ(S,Z,J)$[ORD(S)=Si AND ORD(J)=1 AND ORD(Z)=11=0+
                    {SUM(IS[ORD(I)=CARD(1)],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)];
            1Cmax(S.J) $[ORD(S)=Si AND ORD(J)=Ji]=
                SUM[Z${SUM(ZZ$[ORD(ZZ)>=ORD(Z)+I],NJZ(S,ZZ,J))=0},ICmaxZ(S,Z,J)];
            FOR(Mi=1 TO CARD(M),
                    COLD(S,J.M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi]= 0+
                            1$[ORD(M)>= ICmin(S.J) AND ORD(M)<=lCmax(S,J)];
                    COLD2(S,M)$[ORD(S)=Si AND ORD(M)=Mi]= 0+
                    1$[ORD(M)>SUM(I$(ORD(I)=CARD(I)),IHmax(S,I))
                            AND ORD(M)<= SUM(J$(ORD(J)=CARD(J)),ICmax(S.J))];
            COLDZ(S,Z,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
                    AND ORD (Z)=Zi] = 0+ 1$[ORD(M)>= ICminZ(S,Z.J)
```

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

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

*AIWAYS DEFINE Cp AS I
$\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) \$[\operatorname{HOT}(\mathrm{~S}, \mathrm{I} . \mathrm{M})=1]=1$;
$\operatorname{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{M}) \$[\operatorname{COLD}(\mathrm{~S}, \mathrm{~J} . \mathrm{M})=1]=1$;
DT(S,M) $=\operatorname{SUM}((Z, 1) \$[H O T Z(S, Z . I, M)=1],\{[T I H Z(S, Z . I)-T O I I Z(S, Z . I)] /$
[IHmaxZ(S.Z,I)-IHminZ(S.Z.I)+1]\})\$[HOT2(S.M)=1]+
SUM $((Z, J) \$[C O L D Z(S, Z, J, M)=1],\{[T O C Z(S, Z, J)-T I C Z(S . Z . J)] /$
$[1 \mathrm{CmaxZ}(\mathrm{S}, \mathrm{Z} . \mathrm{J})-\mathrm{ICminZ}(\mathrm{S}, \mathrm{Z} . \mathrm{J})+1]\}) \$[\mathrm{COLD} 2(\mathrm{~S} . \mathrm{M})=1]:$

```
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)$[ORD(M)=1HminZ(S.Z.I)])
            + SUM((Z.I)$[HOTZ(S.Z,I,M)=1 AND ORD(M)>IIIminZ(S.Z.I)AND
                    ORD(M)<=[HmaxZ(S,Z.I)],
                    [TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)]${ORD(M)>
                    IIlminZ(S.Z.I)AND ORD(M)<=lHmaxZ(S.Z.I)])}$[HOT2(S.M)=1]
            + {SUM((Z,J)$[COLDZ(S,Z.J,M)=1 AND ORD(M)=1CminZ(S.Z.J)],
                    TOCZ(S,Z,J)$[ORD(M)=ICminZ(S,Z.J)])
            + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z.J)
                    AND ORD(M)<=1CmaxZ(S,Z,J)],
                    [TOCZ(S.Z,J)-(ORD(M)-ICminZ(S,Z.J))*DT(S,M)]$[ORD(M)>
                    ICminZ(S,Z,J)AND ORD(M)<=1CmaxZ(S,Z,J)])}$[COLD2(S,M)=1]:
        TL}(\textrm{S},\textrm{M})$[ORD(S)=Si AND ORD(M)=Mi]
            {SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)=1HmaxZ(S,Z,I)]
                                    TOHZ(S,Z,I)$[ORD(M)=IHmaxZ(S.Z.I)])
                            + SUM((Z.I)$[HOTZ(S.Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z,l)
                    AND ORD(M)>=1HminZ(S,Z,1)],
                    [TOHZ(S.Z,I)+(IHmaxZ(S.Z,I)-ORD(M))*DT(S.M)]$[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)=JCmaxZ(S.Z.J)].
                        TlCZ(S,Z,J)$[ORD(M)=[CmaxZ(S,Z.J)])
                    + SUM((Z.J)$[COLDZ(S,Z,J,M)=\AND ORD(M)<ICmaxZ(S.Z.J)
                    AND ORD(M)>=1CminZ(S,Z,J)],
                    [TICZ(S,Z.J)+(ICmaxZ(S,Z.J)-ORD(M))*DT(S,M)]$[ORD(M)<
                    ICmaxZ(S,Z.J)AND ORD(M)>={CminZ(S.Z.J)])}S[COLD2(S.M)=1];
        FOR(Ic=1 TO CARD(I),
            DHH(S,I,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(1)=Ic
                        AND HOT(S,I,M)=1]= FH(S,I)**PH(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) ;
$\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TU}(\mathrm{S}, \mathrm{N})+\mathrm{DTmin}\} \$[\operatorname{HOT} 2(\mathrm{~S}, \mathrm{M})$ AND COLD2(S,N)];
CHEAD $(\mathrm{S} . \mathrm{M} . \mathrm{N})=\{\mathrm{TL}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{N})+\mathrm{DTmin}\} \$[\mathrm{HOT} 2(\mathrm{~S}, \mathrm{M})$ AND COLD2(S.N)]:
$\operatorname{LMTD}(S, M . N)=\{[\operatorname{HHEAD}(S, M, N)-\operatorname{CHEAD}(S, M, N)]$
$/ \operatorname{LOG}[\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N}) / \mathrm{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})]\} \$[\mathrm{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})>0$
AND CHEAD (S,M,N)>0 AND HHEAD(S.M.N)>CHEAD(S,M,N)]
$+\{[$ HHEAD $(\mathrm{S}, \mathrm{M}, \mathrm{N})+\mathrm{CHEAD}(\mathrm{S}, \mathrm{M} . \mathrm{N})\} / 2\} \$[$ HHEAD $(\mathrm{S} . \mathrm{M}, \mathrm{N})>0$ AND CHEAD $(\mathrm{S} . \mathrm{M}, \mathrm{N})>0$
AND (HHEAD(S.M.N)< CHEAD (S,M.N)OR HHEAD(S,M,N)= CHEAD(S,M,N))];
$D(S, Z, M, N)=1 \$[\{H O T 2(S, M)=1$ AND HOT2(S,N)=1 AND SUM[1\$(HOT(S.I.M)=1
AND HOT(S,l.N)=1), HOTZ(S.Z.I.M)]=1 AND SUM[I\$(HOT(S,I.N)=1
AND HOT(S,I.M)=1), $\operatorname{HOTZ}(S . Z, I, N)]=1\}$
OR $\{\operatorname{COLD} 2(\mathrm{~S}, \mathrm{M})=1$ AND COLD2(S,N)=1 AND SUM[J\$(COLD(S.J,M)=1
$\operatorname{AND} \operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1), \operatorname{COLDZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{M})]=1 \operatorname{AND} \operatorname{SUM}[\mathrm{~J} \$(\operatorname{COLD}(\mathrm{~S} . \mathrm{J}, \mathrm{N})=1$

```
    AND COLD(S,J,M)=1),COLDZ(S,Z,J,N)]=1}
    OR {(HHEAD(S,M,N)>=0.0000I AND CHEAD(S,M,N )>=0.00001)
    AND SUM[1$(HOT(S,l,M)=1),HOTZ(S,Z,l,M)]=1
        AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}]
* OR {LMTD(S,M,N)>0 AND SUM[I$(HOT(S,l,M)=1).HOTZ(S.Z,I.M)]=1
                                    AND SUM[J$(COLD(S,J,N)=1),COLDZ(S.Z J.N)]=1}];
FOR(Si=1 TO CARD(S),
    FOR(Zi=1 TO CARD(Z),
        FOR(lc=1 TO CARD(l),
            FOR(Ji=1 TO CARD(J),
                ALLOW(S,Z,I,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
                    AND ORD(J)=Ji]=0+1${SUM[(M,N)$[HOT(S.I.M)=]
                    AND COLD}(\textrm{S},\textrm{J},\textrm{N})=1],D(S,Z,M,N)]>
                        AND NOT[HU(I)AND CU(J)]}
            FOR (Mi=1 TO CARD(M),
                    ALLOW_H(S,Z,I,M,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
                    AND ORD(J)=Ji AND ORD(M)=Mi
                    AND HOT(S,I,M)={]= 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,l)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(l)=lc
                    AN}D ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1]=0
                    1${SUM[N$[HOT(S,1,N)=1],D(S,Z,N,M)]>0AND NOT[HU(1)AND CU(J)]};
                    )))));
FOR(Zi=1 TO CARD(Z),
    FOR(Ic=1 TO CARD(I),
        FOR(Ji=1 TO CARD(J),
            ALLOW 2(Z,I,J)$[ORD(Z)=Zi AND ORD(1)=lc AND ORD(J)=Ji]= 0+
                    1${SUM[S,ALLOW(S,Z,I,J)] >0AND NOT[HU(I)AND CU(J)]};
    )));
$ONTEXT
*NM-4SJ-FINAL-6-FLEXIBILITY-SJ.gms:August 9, 2004
* one scenario, the original values of 4sl.
$OFFTEXT Y)
$ontext
*DEFINES THE NUMBER OR TRANSFER ZONES
SET
    Z transfer zone IZ\*Z2/
    *ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
SETI /ll*Il5/
SET J/Jl*Jl5/
SETS
M temperature intervals/M1*M250/
S SCENARIO /S1/
K number of heat exchangers /K1*K20/
X used to input numbers /XI*X15/
ALIAS (M,N,L,O)
ALIAS (I,II)
ALIAS (J,JJ)
ALIAS (K,KK)
ALIAS (Z,ZZ)
*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
*Heating utilities
$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=HU mg=GAMS!C49:149 Cdim=1
SET HU(I)
$GDXIN isabel.gdx
$LOAD HU
*Cooling utilities
$CALL GDXXRW.EXE c:\HENS\isabel.xls Set=CU mg=GAMS!C52:152 Cdim=1
SET CU(J)
$GDXIN isabel gdx
$LOAD CU
```

* INPUTS 15 NUMBERS IN ONE VECTOR TO REDUCE LOADING TIME
\$CALL GDXXRW.EXE c:\HENS\isabel.xIs par=DATA rng=Hojal!E48:F62 Rdim=1
PARAMETER DATA(X)
\$GDXIN isabel.gdx
\$LOAD DATA
*DEFINES WHICH EQUATIONS RUN OPT=0 GRASSROOTS OPT=1 RETROFIT OPT=2 RELOCATION
PARAMETER OPT;
OPT = DATA('XI');
*THE NUMBER OF INTERVALS TO BE USED
PARAMETER NINT;
NINT = DATA('X2');
*Maximum shell area
PARAMETER ASHELLMAX
ASHELLMAX = DATA('X3')
*Maximum area per exchanger
PARAMETER AMAX;
AMAX = DATA('X4');
*Minimum DELTA T
PARAMETER DTmin;
DTmin = DATA('X5');
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
PARAMETER BIF;
BIF = DATA('X6');
*LIMITS THE NUMBER OF HEAT EXCHANGERS IN ONE INTERVAL
PARAMETER KMAX;
KMAX = DATA('X7');
*Minimum heat that can be transferred within an interval.Hot streams
PARAMETER QLHMIN;
QLHMIN = DATA('X8');
*Minimum heat that can be transferred within an interval.Cold streams
PARAMETER QLCMIN;
QLCMIN = DATA('X8');
*Maximum NUMBER OF EXCHANGERS
PARAMETER TOTNEXCHMAX
TOTNEXCHMAX = DATA('X9'); WULALONGIKORNV UN|VFERSTTV
Minimum NUMBER OF EXCHANGERS
PARAMETER TOTNEXCHMIN;
TOTNEXCHMIN = DATA('X10')
*FIXED COST FOR A HEAT EXCHANGER MATCHING STREAMS
PARAMETER CF;
CF = DATA('XII');
*VARIABLE COST FOR A HEAT EXCHANGER MATCHING STREAMS
PARAMETER CA;
CA = DATA('X12');
*COST OF REL0CATION
PARAMETER CAN;
CAN = DATA('X13');
PARAMETER CAE;
CAE = DATA('XI3');
*NUMBER OF HEAT EXCHANGERS ORIGINALY PRESENT
PARAMETER KET;
KET= DATA('XI4')
*MAXIMUM ADITIONAL AREA

```
```

PARAMETER A NEW MAX;
A_NEW_MAX = DATA('X15');
*NUMBER OF INTERVALS ON HOT STREAM
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NIZ mg=GAMS!al:q3 Rdim=2 Cdim=1
PARAMETER NIZ(S,Z,I);
\$GDXIN isabel.gdx
\$LOAD NIZ
*NUMBER OF INTERVALS ON COLD STREAM
\$CALL GDXXRW EXE c:\HENS\isabel xls par=NJZ rng=GAMS!a5:q7 Rdim=2 Cdim=1
PARAMETER NJZ(S,Z,J);
\$GDXIN isabel.gdx
\$LOAD NJZ
*HEAT TRANSFER CEOFF FOR HOT STREAMS
\$CALL GDXXRW EXE c:\HENS\isabel.xls par=HI mg=GAMS!B9:q10 Rdim=1 Cdim=1
PARAMETER HI(S,J);
\$GDXIN isabel.gdx
\$LOAD HI
*HEAT TRANSFER CEOFF FOR COLD STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel xIs par=HJ rng=GAMS!B12:q13 Rdim=1 Cdim=1
PARAMETER HJ(S,J);
\$GDXIN isatel.gdx
\$LOAD HJ
*TEMPERATURE FOR HOT INLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIH rng=GAMS!B15:q16 Rdim=1 Cdim=1
PARAMETER TIH(S.I):
\$GDXIN isabel gdx
\$LOAD TIH
*TEMPERATURE FOR HOT OUTLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOH mg=GAMS!B18:q!9 Rdim=1 Cdim=1
PARAMETER TOH(S,I);
\$GDXIN isabel gdx
\$LOAD TOH
*TEMPERATURE FOR COLD INLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TlC mg=GAMS!B21:q22 Rdim=1 Cdim=1
PARAMETER TIC(S.J):
\$GDXIN isabel.gdx
\$LOAD TIC
*TEMPERATURE FOR COLD OUTLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOC mg=GAMS!B24:q25 Rdim=1 Cdim=1
PARAMETER TOC(S,J);
\$GDXIN isabel.gdx
\$LOAD TOC
*PARAMETERS FOR Z ZONE, TEMPERATURA @ EACH ZONE AND FLOW
*TEMPERATURE FOR HOT INLET STREAMS @ Z
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIHZ mg=GAMS!A27:q29 Rdim=2 Cdim=1
PARAMETER TIHZ(S,Z.I);
\$GDXIN isabel.gdx
\$LOAD TIHZ
*TEMPERATURE FOR HOT OUTLET STREAMS @ Z
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TOHZ rng=GAMS!A31:q33 Rdim=2 Cdim=1
PARAMETER TOHZ(S.Z,I);
\$GDXIN isabel.gdx
\$LOAD TOHZ
*TEMPERATURE FOR COLD INLET STREAMS @ Z
\$CALL GDXXRW EXE c:\HENSlisabel xls par=TICZ rng=GAMS!A35:q37 Rdim=2 Cdim=1
PARAMETER TICZ(S,Z,J);
\$GDXIN isabel.gdx
\$LOAD TICZ
*TEMPERATURE FOR COLD OUTLET STREAMS @ Z

```

PARAMETER TOCZ(S.Z.J);
\$GDXIN isabel.gdx
\$LOAD TOCZ
*MASS FLOW FOR THE HOT STREAMS
\$CALL GDXXRW.EXE c:\HENS lisabel.xls par=FH rng=GAMS!B43:q44 Rdim=1 Cdim=1
PARAMETER FH(S,I);
\$GDXIN isabel.gdx
\$LOAD FH
*MASS FLOW FOR THE COLD STREAMS
\$CALL GDXXRW.EXE c :\HENS lisabel xls par=FC \(\mathrm{rng}=\) GAMS!B46: q 47 Rdim=1 Cdim=1 PARAMETER FC(S.J);
\$GDXIN isabel.gdx
\$LOAD FC
*HOT PROCESS STREAMS
\$CALL GDXXRW.EXE \(\mathrm{c}:\) \HENS \(\operatorname{lisabel}\).xls Set=FREEH rng=GAMS!C1:q1 Cdim=1
SET FREEH(1)
\$GDXIN isabel.gdx
\$LOAD FREEH
*COLD PROCESS STREAMS
\$CALL GDXXRW .EXE c:\HENS \isabel.xIs Set=FREEC \(\mathrm{mng}=\mathrm{GAMS}\) !C5: \(95 \mathrm{Cdim=1}\)
SET FREEC(J)
\$GDXIN isabel.gdx
\$LOAD FREEC
*SPLITS ARE ALLOWED FOR HOT STREAMS BINARY SH in paper
\$CALL GDXXRW.EXE c:\HENS lisabel. xls par=SPH mg=GAMS!C55:q56 Cdim=1
PARAMETER SPH(I);
\$GDXIN isabel.gdx
\$LOAD SPH
*SPLITS ARE ALLOWED FOR COLD STREAMS BINARY SC in paper \$CALL GDXXRW EXE c:\HENS \(\operatorname{lisabel} . x\) ls par-SPC mg=GAMS!C58:q59 Cdim=1 PARAMETER SPC(J):
\$GDXIN isabel.gdx
\$LOAD SPC
*NON ISOTHERMAL MIXING IS PERMITED FOR HOT STREAMS BINARY \$CALL GDXXRW.EXE c:/HENS PARAMETER NIH(I);
\$GDXIN isabel.gdx
\$LOAD NIH
*NON ISOTHERMAL MIXING IS PERMITED FOR COLD STREAMS BINARY
\$CALL GDXXRW.EXE c:\HENSlisabel.xls par=NIC mg=GAMS!C58:q59 Cdim=1 PARAMETER NIC(J);
\$GDXIN isabel.gdx
\$LOAD NIC
*POSIBLE TEMPERATURE DIFERENCES BETWEEN EXCHANGING STREAMS
\$CALL GDXXRW.EXE c:\HENS \isabel.xls par=DTVIO mg=DTVIO!A1:C225 Rdim=2 PARAMETER DTVIO(I.J);
\$GDXIN isabel.gdx
\$LOAD DTVIO
*TEMPERATURE DIFERENCE IN THE HOT UTILITY
\$CALL GDXXRW.EXE c : VHENS \isabel xls par=DTHU \(\mathrm{mg}=\) =GAMS!C49:q50 Cdim=1 PARAMETER DTHU(I);
\$GDXIN isabel.gdx
\$LOAD DTHU
*TEMPERATURE DIFERENCE IN THE COLD UTILITY
\$CALL GDXXRW.EXE c : H (HENS lisabel xls par=DTCU \(\mathrm{rng}=\) GAMS!C52:q53 Cdim=1 PARAMETER DTCU(J);
\$GDXIN isabel gdx
\$LOAD DTCU
```

*MAXIMUM MASS FLOW FOR THE HOT UTILITY
\$CALL GDXXRW EXE c:\HENS\isabel.xls par=FMAX_HU rng=GAMS!C61:q62 Cdim=1
PARAMETER FMAX HU(I);
\$GDXIN isabel.gdx
\$LOAD FMAX_HU
*MAXIMUM MASS FLOW FOR THE COLD UTILITY
\$CALL GDXXRW.EXE c:\HENSlisabel.xls par=FMAX_CU mg=GAMS!C64:q65 Cdim=1
PARAMETER FMAX_CU(J);
\$GDXIN isabel.gdx
\$LOAD FMAX_CU
*COST OF HOT UTILITY
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CHU mg=GAMS!C67:q68 Cdim=1
PARAMETER CHU(l);
\$GDXIN isabel.gdx
\$LOAD CHU

* COST OF COLD UTILITY
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CCU rng=GAMS!C70:q71 Cdim=1
PARAMETER CCU(J);
\$GDXIN isabel.gdx
\$LOAD CCU
*CP OF HOT PROCESS STREAM I
\$CALL GDXXRW.EXE c:\HENS\isabel xls par=CPH mg=CP!BE2:BH2S1 rdim=3
PARAMETER CPH(S,1,M);
\$GDXIN isabel.gdx
\$LOAD CPH
*CP OF COLD PROCESS STREAM J
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CPC rng-CP!BJ2:BM251 rdim=3
PARAMETER CPC(S,J,M);
\$GDXIN isabel.gdx
\$LOAD CPC
ADD FOR RETROFIT
*AREA OF EXISTING HEAT EXCHANGERS
\$CALL GDXXRW.EXE c:\HENS\isabel xls par=AEX rng=EXCHANGERS!L2:O8 Rdim=3
PARAMETER AEX(Z,l,J);
\$GDXIN isabel gdx
\$LOAD AEX
*AREA OF EXISTING HEAT EXCHANGERS THAT CANNOT BE MOVED
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX B mg=EXCHANGERS!Q2:U21 Rdim=4
PARAMETER AEX B(K,Z,I,J);
\$GDXIN isabel.gdx
\$LOAD AEX_B
*NUMBER OF HEAT EXCHANGERS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NHE0 mg=EXCHANGERS!K45:O244 Rdim=4
PARAMETER NHE0(S,Z,I,J);
\$GDXIN isabel.gdx
\$LOAD NHE0
*MAXIMUM AREA OF EXCHANGERS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U rng=EXCHANGERS!L23:O42 Rdim=3
PARAMETER AEX_U(Z,1,J);
\$GDXIN isabel gdx
\$LOAD AEX_U
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U_B mg=EXCHANGERS!Q23:U42 Rdim=4
PARAMETER AEX U_B(K.Z,I.J);
\$GDXIN isabel gdx
\$LOAD AEX U B
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_R mg-EXCHANGERS!Z2:AA21 Rdim=1
PARAMETER AEX_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX_R

```
\$CALL GDXXRW.EXE \(\mathrm{c}:\) :HENS \(\operatorname{lisabel.xls~par=AEX~U~R~rng=EXCHANGERS!Z23:AA42~Rdim=1~}\) PARAMETER AEX_U_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX U R
\$CALL GDXXRW.EXE c:\HENS\isabel xls par=AEX_B R mg=EXCHANGERS!AC2:AD2I Rdim=1 PARAMETER AEX_B_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX B R
\$CALL GDXXRW.EXE c:IHENS \isabel.xIs par=AEX U B R rng=EXCHANGERS!AC23:AD42 Rdim=1 PARAMETER AEX_U_B_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX_U_B_R
\(\qquad\)

SCALARS Si, Zi, Mi, lc, Ji
*H I HEAT TRANSFER COEFICIENT FOR HOT STREAM 1
*H_】 HEAT TRANSFER COEFICIENT FOR COLD STREAM J
*HOT HOT FLOW I PRESENT IN INTERVAL M
*COLD COLD FLOW J PRESENT IN INTERVAL N
PARAMETERS \(1 H \min Z(S, Z, 1), I H \max Z(S, Z, I), 1 H \max (S, 1), I H \min (S, I), H O T(S, l, M)\), 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_l(S,I,M), H_J(S,J,M)
FOR(Si=1 TO CARD(S),
\(\operatorname{FOR}(\mathrm{Zi}=1\) TO \(\operatorname{CARD}(\mathrm{Z})\),
FOR(Ic=1 TO CARD(FREEH),
\(\mathrm{IHminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{I})=1\)
\(\operatorname{AND} \operatorname{ORD}(Z)=1]=0+1 \$[N 1 Z(S, Z, 1)>=1]\);
\(\operatorname{IHminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}) \$[\mathrm{ORD}(\mathrm{S})=\) Si AND ORD \((1)>1\)
AND ORD \((Z)=1]=0+\)
\{SUM((ZZ.II)\$[ORD(II)<ORD(I)],NIZ(S,ZZ,II))+1\}\$[NIZ(S,Z,I)>=1\};
\(1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{Z})>1]=0+\)
\{SUM((ZZ,II)\$[ORD(II)<ORD(I)],NIZ(S.ZZ,II))
+SUM(ZZ\$[ORD(ZZ)<Zi],NIZ(S,ZZ,1))+1\}\$NIZ(S,Z,I)>=1;
\(1 \operatorname{HmaxZ}(\mathrm{~S}, \mathrm{Z}, \mathrm{I}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(1)=Ic AND ORD(Z)=Zi] \(=0+\)
\(\{1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})+\mathrm{NIZ}(\mathrm{S}, \mathrm{Z}, \mathrm{l})-1\} \$[\mathrm{NIZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})>=1\} ;\)
\(1 \mathrm{Hmir}(\mathrm{S}, \mathrm{I}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND \(\operatorname{ORD}(\mathrm{I})=\mathrm{lc}]=\)
SUM[Z\$\{SUM(ZZ\$[ORD(ZZ)<=ORD(Z)-1],NIZ(S.ZZ,I))=0\},1HminZ(S,Z,I)]; \(1 \operatorname{Hmax}(\mathrm{~S}, \mathrm{I}) \$[\) ORD(S)=Si AND ORD(1)=Ic]=
SUM \([Z \$\{\operatorname{SUM}(Z Z \$[\operatorname{ORD}(Z Z)>=O R D(Z)+1], N I Z(S, Z Z, I))=0\}, I \operatorname{HmaxZ}(S, Z, 1)] ;\)
FOR(Mi=1 TO NINT,
\(\operatorname{HOT}(\mathrm{S}, \mathrm{l}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{I})=\mathrm{lc}\) AND ORD \((\mathrm{M})=\mathrm{Mi}]=0+\) \(1 \$[\mathrm{ORD}(\mathrm{M})>=\mathrm{IHmin}(\mathrm{S}, \mathrm{I})\) AND \(\operatorname{ORD}(\mathrm{M})<=\mathrm{IHmax}(\mathrm{S}, \mathrm{I})]\);
HOT2 \((\mathrm{S}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{M})=\mathrm{Mi}]=0+1 \$[\mathrm{ORD}(\mathrm{M})<=\)
SUM ( \(1 \$(\mathrm{ORD}(\mathrm{I})=\mathrm{CARD}(\mathrm{FREEH}))\), IHmax \((\mathrm{S}, \mathrm{I}))\) ];
HOTZ \((\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(I)=lc AND ORD \((\mathrm{M})=\mathrm{Mi}\)
AND ORD \((\mathrm{Z})=\mathrm{Zi}]=0+1 \$[O R D(M)>=1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{l})\) AND \(\operatorname{ORD}(\mathrm{M})<=1 \mathrm{HmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{l})]\);
H_I(S,l,M)\$[ORD(S)=Si AND ORD(I)=lc AND ORD(M)=Mi
AND \(\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1]=\mathrm{HI}(\mathrm{S}, \mathrm{I})\);
));
FOR( \(\mathrm{Ji}=1\) TO CARD(FREEC),
\(\operatorname{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD(J)=1AND ORD(Z)=1]=0+ \{SUM(I\$[ORD(I)=CARD(FREEH)],IHmax(S,I))+1\}\$[NJZ(S,Z,J)>=1];
\(\operatorname{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD(J)>1AND ORD(Z) \(=1]=0+\) \{SUM \(\{\) IS[ORD(I) \(=\) CARD(FREEH)],IHmax(S,I) \(\}\) \(+\operatorname{SUM}((\mathrm{ZZ}, \mathrm{JJ}) \$[\mathrm{ORD}(\mathrm{JJ})<\) ORD \((\mathrm{J})], \mathrm{NJZ}(\mathrm{S}, \mathrm{ZZ}, \mathrm{JJ}))+1\} \$[\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})>=1] ;\)
\(\operatorname{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(Z)>1]=0+
\{SUM \(\{\operatorname{IS}[\operatorname{ORD}(\mathrm{I})=\mathrm{CARD}(\) FREEH \()]\) IHmax \((\mathrm{S}, \mathrm{I})\}\)
+SUM((ZZ.JJ)\$[ORD(JJ)<ORD(J)],NJZ(S,ZZ,JJ))
+ SUM \((Z Z \$[O R D(Z Z)<Z i], N J Z(S, Z Z, J))+1\} \$[N J Z(S, Z, J)>=1] ;\)
\(1 \mathrm{Cmax} Z(S, Z, J) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}\) AND \(\operatorname{ORD}(\mathrm{Z})=\mathrm{Zi}]=0+\)
\(\{\operatorname{lCminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})+\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})-1\} \$[\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})>=1\} ;\)
\(\operatorname{ICmin}(\mathrm{S}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}]=\)
SUM[Z\$\{SUM(ZZ\$[ORD(ZZ)<=ORD(Z)-1],NJZ(S.ZZ.J))=0\}.ICminZ(S.Z,J)];
```

    1Cmax(S,J) $[ORD(S)=Si AND ORD(J)=Ji]=
    SUM[Z${SUM(ZZ$[ORD(ZZ)>=ORD(Z)+1],NJZ(S.ZZ,J))=0}.ICmaxZ(S.Z.J)]:
    FOR(Mi=1 TO NINT,
    COLD(S,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi]= 0+
            1$[ORD(M)>=ICmin(S,J) AND ORD(M)<=lCmax(S.J)];
    COI_D2(S,M)$[ORD(S)=Si AND ORD(M)=Mi]=0+
        I$[ORD(M)>SUM(IS(ORD(I)=CARD(FREEH)):IHmax(S,I))
            AND ORI)(M)<=SUM(J$(ORD(J)=CARD(FREEC)),ICmax(S,J))]:
    COLDZ(S,Z,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
        AND ORD (Z)=Zi]=0+i$[ORD(M)>= ICminZ(S.Z,J)
                        AND ORD(M)<=ICmaxZ(S,Z,J)];
    H_J(S,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi
                AND COLD(S,J,M)=1] = HJ(S.J);
    ))));
    *DHH ENTHALPY CHANGE FOR HOT PROCESS STREAM 1
*DHC ENTHALPY CHANGE FOR COLD PROCESS STREAM J
*DT TEMPERATURE DIFERENCE BETWEEN STREAMS AT INTERVAL
*TU UPPER TEMPERATURE OF INTERVAL
*TL LOWER TEMPERATURE OF INTERCAL
PARAMETERS DT(S,M),TU(S,M),TL(S,M), DHH(S,I.M),DHC(S,J.M);
DT(S,M)= SUM((Z,I)$[HOTZ(S,Z,I,M)=1],{[TIHZ(S,Z,I)-TOHZ(S,Z,I)]/
            [1HmaxZ(S,Z,I)-1HminZ(S,Z,I)+1]})$[HOT2(S,M)=1]+
SUM((Z,J)$[COLDZ(S,Z,J,M)=1],{[TOCZ(S,Z,J)-TICZ(S,Z,J)]/
            [ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]})$[COLD2(S,M)=1];
FOR(Si=1 TO CARD(S),
FOR (Mi=1 TO NINT,
TU(S,M)$[ORD(S)=Si AND ORD(M)=Mi]={SUM((Z,I)$[HOTZ(S,Z,I,M)=1
AND ORD(M)=IHminZ(S,Z,I)],TIHZ(S,Z,I)S[ORD(M)=IHminZ(S.Z.I)])
+ SUM((Z,I)$[HOTZ(S,Z,I,M)=1AND 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)]$[ORD(M)>
lHminZ(S,Z,I)AND ORD(M)<=lHmaxZ(S,Z.I)]){$[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)$[COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z,J)
AND ORD(M)<=[CmaxZ(S,Z,J)],
[TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]$[ORD(M)>
                ICminZ(S,Z,J)AND ORD(M)<=ICmaxZ(S.Z.J)]);$[COLD2(S,M)=1]:
TL(S.M)S[ORD(S)=Si AND ORD(M)=Mi]=
{SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)=]HmaxZ(S,Z,I)],
                                    TOHZ(S,Z,I)$[ORD(M)=IHmaxZ(S,Z,I)])
+ SUM((Z,l)$[HOTZ(S,Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z.l)
                    AND ORD(M)>=1HminZ(S,Z,I)],
                    [TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$[ORD(M)<
lHmaxZ(S,Z,I)AND ORD(M)>=IHminZ(S,Z,I)])}\$[HOT2(S,M)=1]
+ {SUM((Z,) $[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICmaxZ(S,Z,J)],
                TICZ(S,Z,J)$[ORD(M)=ICmaxZ(S.Z,J)])
+ SUM((Z,J)$[COLDZ(S,Z,J,M)=1AND ORD(M)<ICmaxZ(S,Z,J)
                        AND ORD(M)>=ICminZ(S,Z,J)],
            [TlCZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$[ORD(M)<
ICmaxZ(S,Z,J)AND ORD(M)>=ICminZ(S,Z,J)])}$[COLD2(S,M)=1];
        FOR(Ic=1 TO CARD(FREEH),
            DHH(S,I,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(l)=Ic
AND HOT(S,l,M)=1]= FH(S,I)*CPH(S,I,M)*[TU(S,M)-TL(S,M)] :
);
FOR(Ji=1 TO CARD(FREEC),
DHC(S,J.M)\$[ORD(S)=Si AND ORD(M)=Mi AND ORD(J)=Ji
AND COLD(S.J,M)=1]= FC(S,J)*CPC(S.J,M)*[TU(S.M)-TL(S,M)] ;
));
*ALLOW_2 MATCH ALLOWED BASED ON LMTD
*ALLOW }\mp@subsup{}{}{-}\mathrm{ HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I AND COLD STREAM J
*ALLOW H HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I@M AND COLD STREAM J
*ALLOW_C HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I AND COLD STREAM J@N
PARAMETER HHEAD(S.M.N), CHEAD(S.M.N), LMTD(S.M.N). D(S.Z,M,N)
ALLOW(S.Z,I.J). ALLOW_H(S,Z.I.M.J), ALLOW_C(S.Z.J.M.I), ALLOW_2(Z.I.J);
FOR(lc=1 TO CARD(FREEH),

```
```

    FOR(Ji=1 TO CARD(FREEC),
    HHEAD(S,M,N) = {TU(S,M)-TU(S,N) + DTmin }S[HOT2(S:M) AND COLD2(S,N)]:
CHEAD}(\textrm{S},\textrm{M},\textrm{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}$[HHEAD}(S,M,N)>0 AND CHEAD(S,M,N)>0
    AND (HHEAD}(\textrm{S},\textrm{M},\textrm{N})<\operatorname{CHEAD}(\textrm{S},\textrm{M},\textrm{N})OR HHEAD(S,M,N)=CHEAD(S,M,N))]
D(S,Z,M,N)=1$[{HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[I$(HOT(S,I,M)=1
    AND HOT(S,I,N)=1),HOTZ(S,Z,I,M)]=1 AND SUM[IS(HOT(S,I,N)=1
    AND HOT(S,l,M)=1),HOTZ(S,Z,I,N)]=1}
    OR {COLD2(S,M)=1AND COLD2(S,N)=1 AND SUM[J$(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$(HOT(S,l,M)=1):HOTZ(S,Z,1,M)]=1
                                  AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,I,N)]=1}];
FOR(Si=1 TO CARD(S),
FOR(Zi=1 TO CARD(Z),
FOR(lc=1 TO CARD(FREEH),
FOR(Ji=1 TO CARD(FREEC),
ALLOW(S,Z,I,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
                  AND ORD(J)=Ji]=0+1${SUM[(M,N)$[HOT(S,I,M)=1
                      AND COLD}(\textrm{S},\textrm{J},\textrm{N})=1],\textrm{D}(\textrm{S},\textrm{Z},\textrm{M},\textrm{N})]>
                              AND NOT[HU(I)AND CU(J)]};
                  FOR (Mi=1 TO NINT,
                  ALLOW_H(S,Z,I,M,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
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)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
                                  AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1]=0+
              1${SUM[N$[HOT(S,I,N)=1],D(S,Z,N,M)]>0AND NOT[HU(I)AND CU(J)]};
                  )))));
FOR(Zi=1 TO CARD(Z),
  FOR(lc=1 TO CARD(FREEH),
      FOR(Ji=1 TO CARD(FREEC),
          ALLOW_2(Z,1,J)$[ORD(Z)=Zi AND ORD(l)=Ic AND ORD(J)=Ji]=0+
I\${SUM[S,ALLOW(S,Z,I,J)] >0 AND NOT[HU(I)AND CU(J)]};
)));
\$offtext
*-------.---------
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)
N\tilde{HE_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,1,J,M)
NHE_MI_B(S,Z,1,J,M)
NHE_N0_B(S,Z,I,J,N)
NHE_NI_B(S.Z,I,J,N)
NHE(S,Z,I,J)
ALFA_M(S,Z,I,J,M)

```
```

    ALFA_N(S,Z,1,J,N)
    FHU(I) is FCP HU (MJ_h_C)
    FCU(J) is FCP CU(MJ_h_C)
    Bl(S,Z,I,M,J,N) X(imjn) in the paper
    QH(S,Z,l,M,N)
    QC(S,Z,J,M,N)
    Q2(S,Z,1,M,J,N)
    XI B(S,Z,l,J,M)
    X_B(S,K,Z,1,J,M)
    PĀR_B(K,Z,I,J)
    USHELL(Z,l,J)
    USHELL_B(K,Z,l,J)
    ```
* Sontext
*******************************ADD FOR RETROFIT

PAR N(S,Z,I,J)
IAR_N_B(K,Z,I,J)
DPAR_E(Z,1,J)
DPAR_E_B(K,Z,I.J)
NHE \(\bar{S}(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{J})\)
DELTA(K,K)
PHI(Z,1,J,K)
HOT UTILITY COST
Cold_UTILITY_COST
Area Cost
FIX COST
* \$offlext

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, \(\overline{\mathrm{Q}} \mathrm{Q} E W \_\mathrm{N}\)
BINARY VARIABLE N̄HE_M0_B,NHE_M1_B,NHE_N0_B,NHE_NI_B,Y_M,Y_N,X1_B,X_B.NHE_S DELTA, Y_M_B,Y_N_B,NHE_M0,NHE_MI,NHE_N0.NHE_N1,ALFA_M,ALFA_N
. PHI
INTEGER VARIABLE USHELL, USHELL B

EQUATIONS
HBHU(S,I,M)
HBCU(S,J.N)
HBHS(S,I,M)
HBCS(S,J,N)
TRANSFOR_M(S,Z,I,J,M)
TRANSFOR_N(S,Z,I,J,N)
HBHS_NI(S,i,M)
HBCS_NI(S,J,N)
NOISOH(S,I,M)
NOISOC(S,J,N)
BINARY_Ml(S,Z,I,J,M)
BINARY M2(S,Z,I,J,M)
BINARY_M1_B(S,Z,1,J,M)
BINARY M2 B(S,Z,l,J,M)
BINARY_N1(S,Z,l,J,N)
BINARY_N2(S,Z,I,J,N)
BINARY N1 B(S,Z,l,J,N)
BINARY_N2_B(S,Z,I,J,N)
BINARY_M5(S,Z,I,J,M)
BINARY M5b(S.Z,l,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,l,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)
BINAR'Y N4(S,Z,I,J,N)
BINAR' \(\mathrm{N} 8(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})\)
BINARY_N9(S,Z,I,J,N)
BINARY N6(S,Z,I,J,N)
BINARY_N7(S,Z,1,J,N)
BINARY N3_B(S,Z,1,J,N)
HE_COUNT_MO(S,Z,I,J)
HE_COUNT_N0(S,Z,1,J)
HE COUNT M1 (S, \(\mathrm{Z}, 1, \mathrm{~J})\)
\(\mathrm{HE}_{-}^{-} \mathrm{COUNT}{ }^{-} \mathrm{N} 1(\mathrm{~S}, \mathrm{Z}, 1, \mathrm{~J})\)
NEXCH(S,Z,1,J)
NEXCH_B(S,Z,I,J)
BiF I(S,Z,1,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_1 \(1(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})\)
BIF_6(S,Z,I,J,M)
BIF_9(S,Z,l,J,M)
BIF 5(S,Z,l,J,M)
BIF 7(S,Z,I,J,N)
BIF 8 (S,Z,I,J,N)
BIF \(10(\mathrm{~S}, \mathrm{Z}, 1, \mathrm{~J}, \mathrm{~N})\)
BIF_12(S,Z,I,J,N)
BIF 13 2(S,K,Z,I,J,M)
BIF 13 1(S,K,Z,I,J,M)
BIF-14(S,K, Z, I,J)
BIF 15(S,Z.l,J,M)
*BIF_15(S,Z,1,J,M)
BIF 17(S,Z,l,J,M)
BIF_18(S,Z,I,J,M,N)
FEAS_M_01(S,Z,I,J,M)
FEAS M 01 B(S,Z,l,J,M)
FEAS \({ }^{-}{ }^{-} 02(\mathrm{~S}, \mathrm{Z}, 1, \mathrm{~J}, \mathrm{M})\)
FEAS M 02 B(S,Z,1,J,M)
FEAS_M_03(S,Z,I,J,M)
FEAS M 03 B(S,Z,I,J,M)
FEAS M 04(S, Z,1,J M)
FEAS \(\mathrm{M}^{-} 2(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})\)
FEAS M l(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,1,J,M)
FEAS M 4 B(S, Z,I,J,M)
FEAS_M_1_SP(S,Z,1,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 ( \(14(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})\)
FEAS N 2(S,Z, \(, \mathrm{J}, \mathrm{N})\)
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 \(1(S, Z, 1,1, N)\)
FEAS_N_4_B(S,Z,I,J,N)
FEAS N_1 SP(S,L,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,IJ.M.N)
FEAS_END_SP \((S, Z, 1, J, M, N)\)
FEAS END B SP(S, Z, \(1, \mathrm{~J}, \mathrm{M}, \mathrm{N})\)
FEAS_BEG3(S,Z,I,J,M,N)
FEAS BEG(S,Z,1,J,M,N)
FEAS BEG2(S,Z,I,J,M,N)

FEAS_END3(S,Z,I,J,M.N)
FEAS_END(S,Z,1,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_BEG]_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, \(1, \mathrm{~J})\)
SHELL(Z,I,J)
SHELL_B(K,Z,I,J)
KMAXI(S,Z,1,J)
KMAX2(S,Z.J,J)
TOTALCOST
TOTNEXCH MAX
TOTNEXCH_MIN
*\$ontext

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, \(1, J\) )
AREA_REST7(S,Z,I,J)
LIM_HEX(S,M)

AREA_REST1_B(S,K,Z,I,J)
AREA REST2 B(S,K,Z,1,J)
AREA_REST3_B(S,K,Z,I.J)
AREA_REST4_B(S,K,Z,I,J)
AREA_REST5_B(S,K,Z,I,J)
AREA_REST6_B(S.Z.I.J)
*ADD_REST
*ADD_REST2(S.I,J)
HOT_U_C
Cold_U_C
Area_C
FIX_C

\$ontext
*****************************ADD FOR RELOCATION
RELOCATE_1(S,Z,I,J)
RELOCATE 2(S,Z,I,J)
RELOCATE_3(S,Z,I,J)
RELOCATE_4(S,Z,I,J)
RELOCATE_5_1(S,Z,1,J)
RELOCATE_5_2(S,Z,l,J)
RELOCATE_5_3(Z,K)
REI.OCATE_6(K,S,Z,I.J)
RELOCATE_7(K,S,Z,l.J)
RELOCATE 8(K,S,Z,I,J)
RELOCATE_9(K,S,Z,I,J)
RELOCATE_10(K,S,Z.I.J)
\$offext
*
*EQ (1)
*HEAT BALANCE ON HEATING UTILITIES
\(\mathrm{HBHU}(\mathrm{S}, \mathrm{I}, \mathrm{M}) \$(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1\) AND HU(I) AND FREEH(I) AND ORD(M) LE NINT).
FHU(I)*(TU(S,M)-TL(S,M)) \(=\mathrm{E}=\mathrm{SUM}((\mathrm{Z}, \mathrm{N} . \mathrm{J}) \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{N})=1\) AND TL(S.N) LT TU(S,M)
AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\)
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEC(J)).Q(S.Z,I.M,J,N));
```

*EQ (2)
HBCU(S,J,N)$(COLD(S,J,N)=1 AND CU(J) AND FREEC(J) AND ORD(N) LE NINT).
FCU(J)*(TU(S,N)-TL(S,N))=E=SUM((Z,M,I)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEH(I)),Q(S,Z,I,M,J,N));
*EQ (3)
HBHS(S,I,M)$(HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=0 AND ORD(M) LE NINT)..
DHH(S,I,M)=E=SUM((Z,N,J)$(D(S,Z,M,N)=l 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,l,M,J,N));

* *-------
HBCS(S,J,N)$(COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=0 AND ORD(N) LE NINT).
DHC(S,J.N)=E=SUM((Z,M,I)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1):Q(S,Z,I,M,J,N));
*.
*EQ (5)
TRANSFOR_M(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
  AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
QNEW_M(S,Z,I,J,M) =E= SUM(N$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,l,M,J,N));
*---
*EQ (6)
TRANSFOR N(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW C(S,Z.J,N,I)=1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
QNEW_N(S,Z,I,J,N)=E=SUM(M$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,l,M.J)=1),Q(S,Z,I,M,J,N)),
*-------------------------------------------------------------------
*EQ (7)
HBHS_Nl(S,I,M)$(HOT(S,l,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1
AND ORD(M) LI: NINT)
DHH}(\textrm{S},\textrm{I},\textrm{M})=E=SUM((Z,N,J)$(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,L,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));
*--------
HBCS NI(S,J,N)$(COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1).
DHC(S
  AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N))
+SUM((Z,M)$(D(S,Z,M,N N)=1 AND COLD(S,J,M)=1 AND ORD(M) LT ORD(N)),QC(S,Z,J,M,N))
-SUM((Z.M)$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,N,M));
*EQ (9)
NOISOH(S,l,M)$(HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1 AND ORD(M) LE NINT).
SUM((Z,N)$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N))
  =L=SUM((Z,N,J)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLDD(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));
*-------.-
NOISOC(S,J,N)$(COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1
      AND ORD(N) LE NINT)..
SUM((Z,M)$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,N,M))
=L= SUM((Z,M,I)S(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,LM,J)=1 AND ALLOW C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
* *Q------------------------------------------------------------------
BINARY_M1(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
  AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S.Z,I,J,M)-Y_M(S,Z,IJ,J,M)*DHH(S,I,M)$(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(1,J)=0 (i,j) not belonging to set B
BINARY M2(S,Z,l,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0 AND
FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*QLHMIN=G=0;

```
```

*EQ (11a and l3a) Case of BIF(l,J)=1 (i,j) belonging to set B
BINARY_M1_B(S,Z,I.J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z.I.J) =1
    AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)-Y M_B(S,Z,I,J,M)*DHH(S,l,M)$(NOT HU(I))
-Y_M_B(S,Z,\,J,-M)*FMAX_HU(I)*DTHU(I)$(HU(I))=L=0
*EQ (11b and 13b) Case of BIF(l,J)=1 (i,j) belonging to set B
BINARY_M2_B(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,l,M,J)=1 AND BIF(Z,I.J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW M(S,Z,I,J,M)-Y M B(S.Z.I.J.M)*QLHMIN =G= 0:
*
*EQ (12a and 14a) Case of BIF(I,J)=0 (i,j) not belonging to set B
BINARY_Nl(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
    AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
QNEW_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N)*DHC(S,J,N)$(NOT CU(J))
-Y_N(S,Z,I,J,N)*FMAX_CU(J)*DTCU(J)$(CU(J))=L=0
*EQ (12b and 14b) Case of BIF(I,J)=0 (i,j) not belonging to set B
BINARY N2(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND FREEEH(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(1,J)=1 (i,j) belonging to set B
BINARY_N1_B(S,Z,1,J,N)$(COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)
    QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*DHC(S,J,N)$(NOT CU(J))
-Y_N_B(S,Z,I,J,N)*FMAX_CU(I)*DTCU(J)$(CU(J))=L=0;
*
*EQ (12b and 14b) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY N2 B(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).. QNEW_N(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N)*QLCMIN=G=0;
*
*EQ (15) NOT NEEDED

* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*EQ (16)
BINARY M5(S,Z,l,J,M)\$(HOT(S,l,M)=1 AND HOT(S,l,M-1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLON_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
NHE_MO(S,Z,1,J,M)=L=2-Y M(S,Z,1,J.M)-Y_M(S,Z,1,J,M-1);
*EQ (17) IS IN REALITY NOT NEEDED: BUT WAS ADDED TO ENFORCE K=0 WHEN Y=0
* AND HOT(S,l,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)=1AND ALLOW_H(S,Z,I,M,J)=1AND BIF(Z,\.J) =0
AND FREEEH(I) AND FREEC(J) AND ORD(M) LE NINT).. NHE_M0(S,Z,I,J,M) = L= Y_M(S,Z,l.J,M);
* IT TURNS OUT THAT THIS EQUATION ONLY FORCES THE VALUES OF K TO BE ZERO
* WHEN Y=0, WHICH HAPPENS NATURALLY IF ONE IS MINIMIZING THE NUMBER OF
* EXCHANGERS OR BECAUSE THE FIXED COSTS ARE BEING MINIMIZED.
* EVEN IF NOT DRIVEN TO ZERO BY THE OBJECTIVE FUNCTION IT IS HARMELESS.
* HOWEVER, IT TURNS OUT THAT IT COULD MAKE EXTENSIONS OF THE MODEL HAVE
* PROBLEMS. SO, ALTHOUGH THE EQUATION IS NOT NEEDED, IT GIVES SOME EXTRA VALUES
* OF K WHEN THEY DO NOT REALLY MATTER.
**--------
BINARY_M3(S,Z,I,J,M)$(HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
  NHE_M0(S,Z,I.J,M) =G= Y_M(S,Z,I,J,M)-Y_M(S,Z,I.J.M-1)$(HOT(S,I,M-1)
AND ALLOW_H(S,Z,I,M-I,J));
**----..---
BINARY M4(S.Z.l,J,M)\$(HOT(S,l,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,1,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
NHE_M0(S,Z,l,J,M)=G=0;
*EQ (20) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
* *--------
BINARY M8(S,Z,l,J,M)\$(HOT(S,l,M)=1 AND HOT(S,I.M+1) AND ALLOW H(S,Z,I,M.J)=1
AND ALLOW_H(S,Z,l,M+1,J) AND BIF(Z.I.J) =0 AND FREEH(I) AND FRE\overline{ECC(J) AND ORD(M) LE NINT)..}

```
```

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

```
```

* SEE COMMENTS ON EQUATION (17)

```
* SEE COMMENTS ON EQUATION (17)
*
*
*EQ (23)
*EQ (23)
BINARY M6(S,Z,I,J,M)$(HOT(S,l,M)=I AND ALLOW H(S,Z,l.M.J)=\ AND BIF(Z.I,J) =0
BINARY M6(S,Z,I,J,M)$(HOT(S,l,M)=I AND ALLOW H(S,Z,l.M.J)=\ AND BIF(Z.I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT}).. NHE_MI(S,Z,I,J,M)=G=Y_M(S,Z,1,J,M)-Y_M(S,Z,1,J,M+1)
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT}).. NHE_MI(S,Z,I,J,M)=G=Y_M(S,Z,1,J,M)-Y_M(S,Z,1,J,M+1)
                            $(HOT(S,l,M+1) AND ALLOW_H(S,Z,I,M+1.J))
                            $(HOT(S,l,M+1) AND ALLOW_H(S,Z,I,M+1.J))
*_
*_
*EQ (24)
*EQ (24)
BINARY M7(S,Z,l,J,M)$(HOT(S,I,M)=1 AND HOT(S,l,M+1) AND ALLOW H(S,Z,I,M,J)=1
BINARY M7(S,Z,l,J,M)$(HOT(S,I,M)=1 AND HOT(S,l,M+1) AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I.J) =0 AND FREEH(I) AND FREEEC(J) AND ORD(M) LE NINT).
AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I.J) =0 AND FREEH(I) AND FREEEC(J) AND ORD(M) LE NINT).
                                    NHE_MI(S,Z,1,J,M)=G=0;
                                    NHE_MI(S,Z,1,J,M)=G=0;
*
*
*EQ (25)
*EQ (25)
BINARY M3 B(S,Z,I,J,M)$(HOT(S,l,M)=1 AND ALLOW H(S,Z,l,M,J)=1 AND BIF(Z,l,J) =1
BINARY M3 B(S,Z,I,J,M)$(HOT(S,l,M)=1 AND ALLOW H(S,Z,l,M,J)=1 AND BIF(Z,l,J) =1
AND FREEEH(I) AND FREEC(J) AND ORD(M) LE NINT).
AND FREEEH(I) AND FREEC(J) AND ORD(M) LE NINT).
    Y_M B(S,Z,l,J,M) =E= SUM(O$(HOT(S,1,O)=1 AND ORD(O) LE ORD(M)
    Y_M B(S,Z,l,J,M) =E= SUM(O$(HOT(S,1,O)=1 AND ORD(O) LE ORD(M)
    AND ALLOW_H(S,Z,I,O,J)=1),NHE_M0 B(S,Z,1,,O))
    AND ALLOW_H(S,Z,I,O,J)=1),NHE_M0 B(S,Z,1,,O))
    -SUM(O$(HOT
    -SUM(O$(HOT
                                    AND ALLOW_H(S,Z,1,O,J)=1),NHE_M1_B(S,Z,1,J,O));
                                    AND ALLOW_H(S,Z,1,O,J)=1),NHE_M1_B(S,Z,1,J,O));
*
*
*EQ (26) NOT NEEDED
*EQ (26) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*
*
*EQ (27)
*EQ (27)
BNNARY_N5(S,Z,I,J,N)$(COLD(S,J,N)=1 AND COLD(S,J:N-1) AND ALLOW_C(S,Z,J,N,I)=1
BNNARY_N5(S,Z,I,J,N)$(COLD(S,J,N)=1 AND COLD(S,J:N-1) AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
                                    NHE_N0(S,Z,I,J,N)=L=2-Y_N(S,Z,1,J,N)-Y_N(S,Z,I,J,N-1);
                                    NHE_N0(S,Z,I,J,N)=L=2-Y_N(S,Z,1,J,N)-Y_N(S,Z,I,J,N-1);
*
*
*EQ (28) NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0
*EQ (28) NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0
* AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
* AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
BINARY N5b(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
BINARY N5b(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
        AND FREEH(I) AND FREEC(J))
        AND FREEH(I) AND FREEC(J))
                            NHE_N0(S,Z,I,J,N)=L= Y_N(S,Z,I,J,N)
                            NHE_N0(S,Z,I,J,N)=L= Y_N(S,Z,I,J,N)
* SEE COMMENTS ON EQUATION (17)
* SEE COMMENTS ON EQUATION (17)
*EQ (29)
*EQ (29)
BINARY_N3(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
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 FREEIH(I) AND FREEC(J) AND (ORD(N) LE NINI).
AND FREEIH(I) AND FREEC(J) AND (ORD(N) LE NINI).
NHE_N0(S,Z,I,J,N) =G= Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1)
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));
                            $(COLD(S,J,N-1) AND ALLOW_C(S,Z.J,N-1,I));
*-
*-
*EQ (30)
*EQ (30)
BINARY N4(S,Z,I,J,N)$(COLD(S,J,N)=I AND COLD(S,J,N-1) AND ALLOW C(S,Z,J,N,I)=1
BINARY N4(S,Z,I,J,N)$(COLD(S,J,N)=I AND COLD(S,J,N-1) AND ALLOW C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-I,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
AND ALLOW_C(S,Z,J,N-I,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
                            NHE_N0(S,Z,I,J,N)=G=0;
                            NHE_N0(S,Z,I,J,N)=G=0;
*-
*-
*EQ (31) NOT NEEDED
*EQ (31) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*
*
*EQ (32)
*EQ (32)
BINARY N8(S,Z,I,J,N)$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1
BINARY N8(S,Z,I,J,N)$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I.J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I.J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
                            NHE_Nl(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,l,J,N+1);
                            NHE_Nl(S,Z,I,J,N)=L=2-Y_N(S,Z,I,J,N)-Y_N(S,Z,l,J,N+1);
*.
*.
*EQ (33) NOT NEEDED BUT ADDED TO ENFORCE K=0 WHEN Y=0
*EQ (33) NOT NEEDED BUT ADDED TO ENFORCE K=0 WHEN Y=0
    AND COLD(S,J,N-1) AND ALLOW C(S,Z,J,N-1,I)
    AND COLD(S,J,N-1) AND ALLOW C(S,Z,J,N-1,I)
BINARY_N9(S,Z,I,J,N)$(COLD(S,J,N)=I A}
BINARY_N9(S,Z,I,J,N)$(COLD(S,J,N)=I A}
        AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
        AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
                            NHE Nl(S,Z,l,J,N)=L= Y N(S,Z.I,J,N)
```

                            NHE Nl(S,Z,l,J,N)=L= Y N(S,Z.I,J,N)
    ```
```

* SEE COMMENTS ON EQUATION (17)
**EQ (34)
BINARY_N6(S,Z,l,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
NHE_N](S,Z,I,J,N)=G=Y_N(S,Z,l,J,N)-Y_N(S,Z,I,J,N+1)
$(COLD(S,J,N+1) A
*EQ (35)
BINARY_N7(S,Z,l,J,N)$(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,l,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
NHE_Nl(S,Z,l,J,N)=G=0;
* 

*EQ (36)
BINARY_N3_B(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,1,J) =1
AND FREEH(1)AND FREEC(J) AND ORD(N) LE NINT).
Y_N_B(S,Z,l,J,N)=E=SUM(O$(COLD(S,J,O) AND ORD(O) LE ORD(N)
AN̄D
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)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)).
NHE(S,Z,1,J)=E=SUM(M$(HOT(S,I,M)=1 AND ALLOW H(S,Z,1.M.J)=1 AND BIF(Z,1,J) =1),
NHE_M0_B(S,Z,1,J,M)) + SUM(M$(HOT(S,1,M)=1 AND ALLOW H(S,Z,I,M,J)=1
AND BIF(Z,I,J) =0),NHE_M0(S,Z,I,J,M));
*.
*
*EQ (38)
    HE_COUNT_N0(S,Z,I,J)$(ALLOW(S,Z,1,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,1,J,N))

+ SUM(N\$(COLD(S,J,N)=1 AND ALI.OW C(S.Z.J,N,1)=1 AND BIF(Z,I,J) =0),
NHE_NO(S.Z,1,J,N));
* 

*------
HE_COUNT_MI(S,Z,l,J)\&(ALLOW(S,Z,1,J)=1 AND FREEH(1) AND FREEC(J)).
NHE(S,Z,I,J)=E=SUM(M$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,1,J)=1),
    NHE_M1_B(S,Z,I,J,M)) + SUM(M$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND BIF(Z,I,J) =0), NHE_Ml(S,Z,I,J,M));
*EQ (40)
HE COUNT Nl(S,Z,l,J)$(ALLOW(S,Z,l,J)=1 AND FREEH(I) AND FREEC(J)).
NHE(S,Z,I,J)=E=SUM(N$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) = 1),
NHE_NI_B(S,Z,I,J,N)) + SUM(N$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
    AND BIF(Z,I,J) =0), NHE_NI(S,Z,I,J,N));
*
*EQ (41)
    NEXCH(S,Z,I,J)$(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;
*----------
NEXCH_B(S,Z,I,J)$(ALLOW(S,Z,l,J)=1 AND BIF(Z,I,J) =1 AND FREEH(I)
    AND FREEC(J))..NHE(S,Z,I,J)=l=KMAX(Z,I,J) ;
*
*EQ (43)
BIF_1(S,Z,I,J,M,N)$(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)=1AND BIF(Z,I,J) = 1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT AND ORD(N) LE NINT)..
SUM(L$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
    AND ALLOW H(S,Z,I,L,J)=1),
        QNEW_M(S.Z,I,J,L)) - QNEW2_M(S,Z,I,J,M) =L=
SUM(O$(D(S,Z,M,O)=1 AND ORD(O)LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
+ Bl(S,Z,I,M,J,N)*4* max(SUM(L$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
    AND HOT(S,I,L)=I AND ALLOW H(S,Z,lL,J)=1),DHH(S,I,L)),
                    SUM(O$(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(SZ,l,J,M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,l,M)=1 AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND
ALLOW_H(S,Z,I,M,J)=1 AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,l, J) =1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT AND ORD(N) LE NINT).
SUM(L\$(D(S,Z,L.N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
AND ALLOW_H(S,Z,I,L,J)=1),
QNEW_M(S,Z.I.J.L.)) - QNEW2_M(S,Z.I,J,M) \(=\) G=
SUM(O\$(D(S,Z,M,O)=1 AND ORD(O)LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
QNEW N(S,Z,I,J,O)) - QNEW2 N(S,Z,1,J,N)
\(-\mathrm{Bl}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J}, \mathrm{N})\) * \(^{*} \max (\mathrm{SUM}(\mathrm{L} \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{L}, \mathrm{N})=1\) 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)),
\(\operatorname{SUM}(O \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{O})=1\) AND \(\operatorname{ORD}(\mathrm{O})\) LE ORD(N) AND COLD(S,J,O)
AND ALLOW_C(S.Z,J,O,l)),DHC(S,J,O)));
*.
*EQ (45)
BIF_3(S,Z,1,J,M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)= AND COLD \((\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 \(\operatorname{AND} \operatorname{BIF}(\mathrm{Z}, \mathrm{l}, \mathrm{J})=1\) AND FREEH(I) ĀND FREEC(J) AND ORD(M) L̄E NINT). \(\mathrm{B} 1(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J}, \mathrm{N})=\mathrm{E}=2-0.25^{*} \operatorname{SUM}(\mathrm{~L} \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{L}, \mathrm{N})=1\) AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1 AND ALLOW H(S,Z.I,L,J)=1),NHE MI/B(S,Z.I,J,L)) +0.25 *SUM \((\mathrm{OS}(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{O})=1\) AND ORD(O)LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),NHE_NI_B(S,Z,I,J,O)) -NHE_M1_B(S,Z,I,J,M)-NHE NI_B(S,Z, 1, 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 \(\operatorname{HOT}(S, I, M)=1\) AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW C(S,Z,J,N,I)=1 AND BIF \((Z, I, J)=1\) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT AND ORD(N)).
SUM(L\$(HOT(S,l,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(OW(COLD(S,J,O) AND ORD(O)LE ORD(N) AND ALLOW_C(S, Z, J, O, I)), NHE_NI_B(S,Z,I,J,O))=G=0;
*-
*EQ (47)
BIF_ll(S,Z,1,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z.I,M,J)=1 AND BIF(Z,I.J)=1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
\(\operatorname{SUM}(\mathrm{O}(\mathrm{HOT}(\mathrm{S}, \mathrm{I} . \mathrm{O})=1\) AND ORD \((\Theta)\) LE ORD(M) AND ALLOW_H(S Z, \(1, \mathrm{O}, \mathrm{J})=1)\), 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( \(J\) ) AND ORD(N) LE NINT). SUM \((O \$(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{O})\) 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;
*---------
BIF_6(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..

QNEW2_M(S,Z,I,J,M) =L= QNEW_M(S,Z,I,J,M);
* EQ (50)

BIF 9(S,Z,I,J,M)\$(HOT(S,l,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1 AND FREEH(I)AND FREEC(J) AND ORD(M) LE NINT). QNEW2_M(S,Z,I,J,M) \(=\mathrm{L}=\) NHE_M0_B(S,Z,I,J,M)* \(\mathrm{DHH}(\mathrm{S}, \mathrm{I}, \mathrm{M})\);
*---------
BIF_5(S,Z,I,J,M)\$(HOT(S,I,M)=1AND ALLOW_H(S,Z,I,M,J)=1AND BIF(Z,1,J)=1
AND FREEH(I)AND FREEC(J) AND ORD(M) LE NINT).
QNEW2_M(S,Z,I,J,M) =L=NHE_MI_B(S,Z,I,J,M)*IHH(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) AND ORD(N) LE NINT).
QNEW2_N(S,Z,I,J,N) \(=\mathrm{L}=\) QNEW_N(S,Z,I,J,N \() ;\)
*EQ (54)

BIF_10(S,Z,lJ,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=I AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).

QNEW2_N(S,Z,I,J,N) =L= NHE_N0_B(S,Z,I,J,N)*DHC(S,J,N);

\section*{*----------}

BIF_7(S,Z,I,J,N)\$(COLD(S.J,N)=1 AND ALLOW C(S,Z,J,N,l)=1 AND BIF(Z,l,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
QNEW2_N(S,Z,I,J,N) = \(=\) 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,l,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,l,J) \(=0\) AND SPH(1)=1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).

ALFA_M(S,Z,I,J,M) \(=\mathrm{L}=1-\mathrm{NHE}\) _M0(S,Z,I,J,M-1)-NHE_M0(S,Z,I,J,M);
FEAS_M_01_B(S,Z,1,J,M)\$(HOT(S,1,M-1) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,1,M,J)=1 AND ALLOW_H(S,Z,I,M-I,J) AND BIF(Z, \(1, \mathrm{~J})=1\) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT). ALFA_M(S,Z,I,J,M)=L=1-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M);
*EQ (58)
FEAS M 02(S,Z,1,J,M)\$(HOT(S,l,M-1) AND HOT(S,l,M)=1 AND ALLOW H(S,Z,l,M,J)=1 AND ĀLLOW_H \((\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}-1, \mathrm{~J})\) AND BIF \((\mathrm{Z}, 1, \mathrm{~J})=0\) AND SPH \((\mathrm{I})=1\) AND FREEH \((\mathrm{I})\) AND FREEC(J) AND ORD(M) LE NINT).

ALFA_M(S,Z,I,J,M)=L=1-NHE_M1(S,Z,l,J,M-1)-NHE_M1(S,Z,l,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,1,M,J)=1 AND ALL'OW_H(S,Z,I.M-1,J) AND BIF \((Z, I, J)=1\) AND FREEH(1) AND FREEC(J)). ALFA_M(S,Z.I.J,M)=L=1-NHE_M1_B(S,Z.1.J,M-1)-NHE_M1_B(S.Z.I.J,M);
*-
*EQ (59)
FEAS_M_03(S,Z,1,J,M) \(\$(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}-1)\) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,IM-1,J) AND BIF \((\mathrm{Z}, \mathrm{I}, \mathrm{J})=0\) AND SPH \((\mathrm{l})=1\) AND FREEEH(I) AND FREEC(J) AND ORD(M) LE NINT).

ALFA_M(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-NHE M0(S,Z,I,J,M-1)-NHE_M0(S,Z,I,J,M) NHE_MI(S, Z, 1,J,M-1)-NHE MI (S,Z,I,J,M);
FEAS_M_03_B(S,Z,1,J,M)\$(HOT(S,1,M-1) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,1,M,J)=1 AND ALLO - \(\mathrm{H}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}-1, \mathrm{~J})\) AND BIF( \(\mathrm{Z}, \mathrm{I}, \mathrm{J})=1\) AND FREEH(I) AND FREEC(J)).
ALFA_M(S,Z,I, J, M) \(=\mathrm{G}=\mathrm{Y}\) M \(\mathrm{B}(\mathrm{S}, \mathrm{Z,IJ}, \mathrm{M})\)-NHE M0 B(S,Z.IJ.M-I)-NHE M0 B(S,Z,I.J.M)
- NHE_M1_B(S,Z,1,J,M-1)-NHE_M1_B(S,Z,1,J,M);
*EQ (60)
FEAS_M_04(S,Z,1,J,M)\$(HOT(S,1,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND
ALLŌW_H(S,Z,I,M-1,J) AND (BIF(Z,l,J) \(=1\) OR SPH(I)=1)AND FREEH \((\mathrm{I})\)
AND FREEC(J) AND ORD(M) LE NINT). ALFA_M(S,Z,I,J,M) \(=\mathrm{G}=0\);
*
*EQ (61)
FEAS_M_2(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC( \((\mathrm{J})\) AND ORD-(M) LE NINT)..
QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) \(=\mathrm{L}=\)
QNEW_M(S,Z,1,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
\(+\left(1-\mathrm{ALFA} \mathrm{M}_{-}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})\right)^{*} \mathrm{DHH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) /\left(\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M})^{*}(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M}))\right)\);
*EQ (62)
FEAS_M_l (S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J))..
QNEW_M(S, \(\bar{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}) /(\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) *(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M})))\)
\(+\left(1-A L F A \_M(S, Z, I, J, M)\right)^{*}\) DHH(S,l,M) /(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
\(=\bar{G}=\) 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, \(1, \mathrm{~J}, \mathrm{M}) \$(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}-1)\) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW H(S,Z, \(1, M-1, \mathrm{~J})\) AND BIF \((\mathrm{Z}, \mathrm{l}, \mathrm{J})=0\) AND SPH \((\mathrm{I})=1\) AND FREEH( I\()\)
AND FREEC(J) AND ORD(M) LE NINT).
- QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
+ QNEW_M \(^{-}(S, Z, 1 . J, M) /(C P H(S, I, M) *(T U(S . M)-T L(S . M)))\)
\(+(1+\) NHE \(\quad\) Ml(S,Z,I.J,M-I) + NHE_MI(S,Z,I,J,M) - NHE_M0(S,Z.I,J,M-I)) \({ }^{*} \operatorname{DHH}(\mathrm{~S}, \mathrm{l}, \mathrm{M}) /(\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) *(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M})))^{*} 1.00001=\mathrm{G}=0\) :
```

*EQ (64)
FEAS_M_4(S,Z,l,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_Il(S,Z,l,M-1,J) AND BIF(Z,l,J) =0 AND SPH(1)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..

- QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
+ QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
+(1+ NHE_M0(S,Z,I,J,M-I)+NHE_M0(S,Z,I,J,M)-NHE_Ml(S,Z,I,J.M))
* DHH(S,1,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)=I AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,1,J) =1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT).
QNEW M(S,Z,1,J,M-1)/(CPH(S,l,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,l,J,M-1)+NHE_M1_B(S,Z,I,J,M)-NHE_M0 B(S,Z,1,J,M-1))
    * DHH(S,I,M)/(CPH(S,l,M)*(TU(S,M)-TL(S,M)));
*-
*EQ (66)
FEAS_M_3_B_l(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW H(S,Z,I,M-1,J) AND BIF(Z,I,J) =1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
QNEW2_M(S,Z,1,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_MI_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)$(HOT(S,l,M-1) AND HOT(S,l,M)=1 AND ALLOW H(S,Z,l.M,J)=1
AND ALLLO-W_H(S,Z,I,M-1,J) AND BIF(Z,1,J)=1 AND SPH(1)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT).
(QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) =L=
QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
    +(2 + NHE_M0_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M))
                                    *DHH(S,I,M)/(CPM}(S,\overline{I},\textrm{M})*(TU(S,M)-TL(S,M));
*
*EQ (68)
FEAS M_1_SP(S,Z,I,J,M)$(HOT(S,1,M-1) AND HOT(S,1,M)=1 AND HOT(S,I,M+1)
AND ALLOW H(S,Z,l,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,1,J)=0 AND SPH(I)=0
AND FREEH(\overline{I})}\mathrm{ AND FREEC(J) AND ORD(M}) LE NINT).. QNEW_M(S,Z,I,J,M)=G=(Y_M(S,Z,I,J,M)-
NHE MO(S,Z,I,J,M) + NHE MI(S,Z,I,J,M))*
FEAS_M_1_SP_B(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,1,M+1,J) AND BIF(Z,1,J) = 1 AND SPH(I)=0
AND FREEH(\overline{l})}\mathrm{ AND FREEC(J)) .. QNEW_M(S,Z,l,J,M)=G=(Y_M_B(S,Z,l,J,M)-
                                    NHE_M0_B(S,Z,I,J,M)+NHE_M0_B(S,Z,1,J,M))*DHH(S,l,M);
*
*EQ (69)
FEAS_N_01(S,Z,I,J,N)$(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-1,1) AND BIF(Z,1,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,l,J,N)-NHE_N0(S,Z,I,J,N-1);
FEAS N 01 B(S,Z,l,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,l)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,l,J) =1 AND FREEH(I) AND FREEC(J)).
    ALFA_N(S,Z,I,J,N)=L=1-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z.l,J,N-I);
*EQ (70)
FEAS N 02(S,Z,l,J,N)$(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-1,1) AND BIF(Z,I,J) =0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(\overline{J})}\mathrm{ ).
ALFA N(S,Z,l,J.N)=L=1-NHE_N1(S,Z,l,J,N)-NHE Nl(S,Z,I,J,N-1);
FEAS_N_02_B(S,Z,Z,I,J,N)$(COLD(S,J,N-I) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLLOW C(S,Z,J,N-1,I) AND BIF(Z,l,J) =I AND FREEH(I) AND FREEC(J)).
ALFA_N(S,Z,I,J.N)=L=1-NHE_N1_B(S,Z,1,J,N)-NHE_NI_B(S,Z,1,J,N-1);
*
*EQ (71)
FEAS_N_03(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLLOW_C(S,Z,J,N-1,l) AND BIF(Z,l,J) =0 AND SPC(J)=1 AND FREE-H(l)
AND FREEC(J))..
ALFA_N(S,Z,I,J,N)=G=Y_N(S,Z,l,J,N)-NHE_N0(S,Z.I,J,N)-NHE_N0(S,Z.I,J.N-1)

```
```

- NHE N1(§,Z,1,J,N)-NHE N1(S,Z,1,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,1,J) =1 AND FREEH(I) AND FREEC(J)).
ALFA_N(S,Z,l,J,N)=G=Y_N_B(S,Z,l,J,N)-NHE_N0_B(S,Z,l,J,N)-NHE_N0_B(S,Z,l,J,N-I)
-NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,1,J,N-1);
* 

*EQ (72)
FEAS_N_04(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW C(S,Z,J,N-I,I) AND (BIF(Z,I,J) =1 OR SPC(J)=1) AND FREEH(I)
AND FREEC(J))..
                                    ALFA_N(S,Z,l,J,N)=G=0;
*EQ (73)
FEAS_N_2(S,Z.I,J,N)$(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-1,1) AND SPC(J)=1 AND FREEH(1) 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)));
*---------
FEAS N 1(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(1) AND FREEC(J))..
QNEW_N(S.Z.I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
    +(1-A}L\mp@code{LFA_N(S,Z,I,J,N))*
    /(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=QNEW_N(S,Z,1,J,N-1)/
                                    (CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)));
*---------
FEAS_N_3(S,Z,I,J,N)$(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,1,J) =0 AND SPC(J)=1 AND FREEH(1)
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)))+(I+NHE N1(S,Z,I,J,N-I)
+NHE_Nl(S,Z,I,J,N)
-NHE_NO(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N))}\mp@subsup{)}{}{*}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,1,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,1,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+(1+NHE} N0(S,Z,1,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,1,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND ALLOWW_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-I)/(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,1,J,N-1)+ NHE_N!_B(S,Z,1,J,N)-NHE_N0_B(S,Z,l,J,N-1))
* DHC(S,J,\overline{N})/(\overline{CPC}(S,J,N)*(TU(S,N)-TL(S,N )})=\mathbf{C}=0
*--
*EQ (78)
FEAS_N_3_B_l(S,Z,1,J,N)\$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND AL-LDOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,1) 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,1,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,\overline{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-AL_DOW_C(S,Z,J,N-1,I) AND BIF(Z,l.J) =1 AND SPC(J)=1 AND FREEH(1)
AND FREEC(J))..

```
```

-(QNEW_N(S,Z,l,J,N)-QNEW2_N(S,Z,l,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,l,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)AND
ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z.J,N-I,I) AND ALLOW_C(S,Z,J,N+1,I)
AND BIF
AND SPC(J)=0 AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N) =G=
  (Y_N(S,Z,I,J,N)-NHE_NO(S,Z,I.J,N)-NHE_N1(S,Z,I,J,N))*DHC(S,J,N);
FEAS_N_1_SP_B(S,Z,I,J,N)$(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,!,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);
*---------
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,},\textrm{I},\textrm{M})=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
TL(S,M) - TL(S,N) - QNEW N(S,Z,l,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,1,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 ANI) COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
TL(S,M) - TL(S,N) -QNEW N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
+ QNEW M(S,Z,1,J,M)/(FH(S,1)*CPH(S,1,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,l,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW H(S,Z,1,M,J)=1
AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND SPH(I)=0
AND ORD(M) LE NINT).. TU(S,M)-TU(S,N)
-QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) +QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
    +(2-NHE_M1(S,Z,I,J,M)-NHE_Nl(S,Z,I,J,N))*TU(S,N)=G=0;
FEAS_END_B_SP(S,Z,I,J,M,N)S(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
ANDHOT(SIM)=1 AND COLD(S JN)=1 AND ALLOW H(S Z[M J)=
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J)) .. TU(S,M)-TU(S,N)
-QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPII(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
                            +(2-NHE_Ml_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*TU(S,N)=G=0;
*
*EQ (83)
FEAS BEG3(S,Z,I,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TUU(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,l,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(\overline{J})=1) AND FREEH(I) AND FREEC(J
AND ORD(M) LE NINT).
NHE_N1(S,Z,l,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 IU(S,N) GT TL(S,M) AND HOT(S,1,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,l,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,l,J) =0
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)
/(TU(S,N+1)-TL(S,N+1))* CPC(S,J,N)/CPC(S,J,N+1)
+(2-NHE_M0(S,Z,1,J,M)-NHE_NO(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)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
    AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
    AND COLD(S,J,N+1)
    AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J) AND ALLOW_C(S,Z,J,N,I)=1
    AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,1,J) =0 AND (SPH(1)=1 OR SPC(J)=1)
    AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)
    QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=
    QNEW_M(S,Z,l,J,M+1)/(TU(S,M+1)-TL(S,M+1))
    * CPH(S,l,M)/CPII(S,l,M+1)-(2-NHE_M0(S,Z,I,J,M)-NHE_N0(S,Z,I,J,N))
    *DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));
*
*EQ (86)
FEAS END3(S,Z,I,J,M,N)$(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,l,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)=I AND ALLOW_C(S,Z,J,N-I,I)
AND BIF(Z,I,J)}=0\mathrm{ AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)
AND ORD(M) LE NINT).
NHE_M0(S,Z,I,J,M)=L=(2-NHE_Ml(S,Z,I,J,M)-NHE_Nl(S,Z,1,J,N));
*EQ (87)
FEAS_END(S,Z,1,J,M,N)$(DTVIO(1,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
    AND TU(S,N) GT TL(S,M) AND HOT(S,l,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
    AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
    AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,l) AND BIF(Z,I,J) =0
    AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW M(S,Z,1,J,M-1)/(TU(S,M-1)-TL(S,M-1))
    *CPH(S,I,M)/CPH(S,I,M-1)+(2-NHE_Ml(S,Z,l,J,M)-NHE_Nl(S,Z,I,J,N))
    *DHH(S,I,M)/(TU(S,M)-TL(S,N));
*
*EQ (88)
FEAS END2(S,Z,I,J,M,N)$(DTVIO(l,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,l,M)=1 AND HOT(S,1,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-I,J)
AND ALLOW C(S,Z,J.N,I)=I AND ALLOW C(S,Z,J,N-I,I) AND BIF(Z,I,J) =0
AND (SPH(l)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND ORD(M) LE NINT).
QNEW N(S,Z,1,J,N)/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=QNEW N(S.Z.1,J.N-1)/
(TU(S,N-1)-TL(S,N-1))
*CPC(S,J,N)/CPC(S,J,N-1)-(2-NHE_MI(S,Z,l,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,1,J,M,N)$(DTVIO(1,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N N GT TL(S,M)
AND HOT(S,l,M)=1 AND HOT(S,l,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
AND ALLOW_II(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J)AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I)
AND BIF(Z,I,J) =1 AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
    NHE_N1_B(S,Z,I,J,N) = I_=
(1+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,l,J,N));
*
*EQ (90)
FEAS_BEG2_B(S,Z,1,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I.M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M+1,J)
AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,I) AND BIF(Z,I,J) =1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=
QNEW_N(S,Z,I,J,N+1)/(TU(S,N+1)-TL(S,N+1))
* CPC(S,J,N)/CPC(S,J,N+1)+
(1+Y_N_B(S,Z,1,J,N)-NHE_M0_B(S,Z,1,J,M)-NHE_N0_B(S,Z,1,J,N))
*DHC(S.J,N)/(TU(S,M)-TL(S,N)
*
*EQ (91)
FEAS BEGl 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,l,M)=1 AND HOT(S,l,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,l) AND BIF(Z.l,J) =1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..

```
```

    QNEW2_N(S,Z,l,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,l.J,N+I)/
    (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,l,J,M,N)\$(DTVIO(l,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,1,M+1) AND COLD(S,J,N)=1
AND COLD(S,J,N+1) AND ALLOW H(S,Z,l,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(l)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND ORD(M) LE NINT).
QNEW_M(S,Z,l,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=QNEW_M(S,Z,l,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,1,M+1)/(TU(S,M+1)-TL(S,M+1));
*-
*EQ (93)
FEAS_END3_B(S,Z,I,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N) GT TL(S,M)
AND HOT(S,l,M)=1 AND HOT(S,l,M-1) AND COLD(S,J,N)=1 AND COLD(S,J,N-1)
AND ALLOW_H(S,Z,I.M,J)=1
AND ALLOW_H(S,Z,LM-I,J)AND ALLOW_C(S,Z,J,N,I) AND ALLOW C(S,Z,J,N-1,l)
AND BIF(Z,1,J)}=1\mathrm{ AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)
AND ORD(M) LE NINT)..
NHE_M0_B(S,Z,I,J,M)=L=
(1+Y_M_B(S,Z,I,J,M)-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N));
*EQ (94)
FEAS_END_B(S,Z,1,J,M,N)$(DTVIO(1,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,l,M,J)=1 AND ALLOW H(S,Z,l,M-1,J)
AND ALLOW C(S,Z,J,N,I)=1 AND ALLOW C(S,Z,J,N-1,1) AND BIF(Z,I,J) =1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND ORD(M) LE NINT)..
(QNEW M(S,Z,I,J,M)-QNEW2 M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L=
QNEW_M(S,Z.l,J,M-1)/
(TU(S,M-1)-TL(S,M-1))*CPH(S,I,M)/CPH(S,I,M-1)+
(2-NHE_Ml_B(S,Z,I,J,M)-NHE_Nl_B(S,Z,I,J,N))*DHH(S,l,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,l) AND BIF(Z,I,J) =1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
(QNEW_N(S,Z,l,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_NI_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)*(I/H_I(S,l,M)+ l/H_J(S,J,N))/LMTD(S,M,N));
*
*EQ (97)
BIF_13_2(S,K,Z,I,J.M)$(ORD(K) LT KMAX(Z,I,J) AND HOT(S,I,M)=1
    AND
    AND BIF(Z,I,J) = I AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
    PAR_B(K,Z,1,J)=L=SUM((L,N)S(D(S.Z,L,N)=1 AND ORD(L) LE ORD(M)
    AND TL(S,N) LT TU(S,L)
    AND HOT(S,l,L)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S.Z,I,L,J)=1
    AND ALLOW_C(S,Z,J N,I)=1),
    (Q(S,Z,l,L,J.N)-Q2(S,Z.l,L,J,N))*(l/H I(S,l,L)+1/H J(S,J,N))/LMTD(S,L,N))
            +AMAX*(2-NHE_MI_B(S,Z,Z,I,J,M)-X1_B
            SUM(KK$(ORD(KK) GT 1 AND ORD(KKK) 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 I to kmax-1. Here we use XI_B and then a
* summation from 2 to kmax-I. See equation (100) as well.

```
```

*EQ (98)
BIF 13_l(S,K,Z,l,J,M)$(ORD(K) LT KMAX(Z,I,J) AND HOT(S,l,M)=1
    AND ALLOW_H(S,Z,I.M.J)=1
    AND BIF(Z,l,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
    PAR B(K,Z,l,J)=G= SUM((L,N)$(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))*(l/H_I(S,I,L)+1/H_J(S,J,N))/LMTD(S,L,N))
-AMAX*(2-NHE_M1_B(S,Z,Z,I,J,M)-X1_B(S,Z,I,J,M)-
SUM(KK$(ORD(KK) GT I AND ORD(KK) LT ORD(K)),X_B(S,KK,Z,I,J,M)))
*
*EQ (99)
    BIF 14(S,K,Z,I,J)$(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,l,J)=G=PAR(Z,1,J)-SUM(KK$(ORD(KK) LT ORD(K)),PAR_B(KK,Z,1,J));
*-
*EQ (100)
    BIF 15(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND̄ FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)
XI_B(S,Z,I,J,M)+SUM(K$(ORD(K) GT I AND ORD(K) LE KMAX(Z,I,J) ),
        ORD(K)*X_B(S,K,Z.I,J.M))=E= SUM(L$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND
ALLOW_H(S,Z,IL,J)=1),NHE_M0_B(S,Z,I,J,L))+1-Y_M_B(S,Z,I,J,M);
*Comment: In the paper XI B does not show. Only one variable, X_B is used
* to make summations from I 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)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,1,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(I) AND ORD(M) LE NINT).
SUM(N&(D(S,Z,M,N)=I AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1 AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q2(S,Z,I,M,J,N))=E=
                                    QNEW2_M(S,Z,I,J,M);
*EQ (102)
BIF_18(S.Z.,J,M.N)$(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,1,J) = 1 AND FREEH(I) A}\mathrm{ AND FREEC(J) AND ORD(M) LE NINT).
Q2(S,Z,I,M,JN)=L=Q(S,Z,I,M,J,N);
*----------
SHELL(Z,I,J)S(SUM[S.ALLOW(S,Z,I,J)]>=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,J) =0).
PAR(Z,I,J)=L=ASHELLMAX*USHELL(Z,I,J);
**------
SHELL_B(K,Z,I,J)$(SUM[S,ALLOW(S,Z,I,I)]>= 1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,J)=1).
PAR_B(K,Z,I,J)=L=ASHELLMAX*USHELL_B(K,Z,I,J);
*EQ (105)
TOTALCOST.. TCOST =E= SUM(IS(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
                                    + SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
$ontext
        + SUM((Z,1,J)$(OPT=0 AND SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I)
AND FREEC(J)AND BIF(Z,l.J)=0), CF*USHELL(Z,l.J))
+ SUM((K,Z,I,J)$(OPT=0 AND SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
    AND BIF(Z,I,J)=1), CF*USHELL_B(K,Z,I,J))
    + SUM((Z,1,J)$(OPT=0 AND SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)),
CAE*PAR(Z,I,J))
$offtext
*$ontext
+SUM((S,Z,1.J)$(OPT=1 AND ALLOW(S,Z,l,J)=1 AND FREEH(I) AND FREEC(J))
        ,CF*(NHE(S.Z,I,J)+NHE_S(S,Z,I,J)$(NHEO(S,Z,I,J)=1)-NHE0(S,Z,1,J)))
+SUM((S,Z,1,J)$(OPT=1 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
        AND BIF(Z,I,J)=0).CAE*DPAR_E(Z,I,J)+CAN*PAR_N(S,Z,I,J))
        +SUM((S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I.J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)
,CAE*DPAR_E_B(K,Z,I,J)+CAN*PAR_N_B(K,Z,l,J))

```
```

*\$offlext
$ontext
    +SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,l,J)=0)
(CF*(NHE(S,Z,I,J)-(NHE0(S,Z,I.J)*(SUM(K$(ORD(K) LE KET),
    Phi(Z,1,J,K))))))+(CAE*DPAR_E(Z,1,J))+CAN*PAR_N(S,Z,1,J))
    +SUM((S,Z,l,J)$(OPT=2 AND ALLOW(S,Z,l,J)=1 AND FREEH(l) AND FREEC(J)
AND BIF=1)
(CF*(NHE(S,Z,l,J)-SUM((KK,K)$(OPT=2 AND ORD(K) LE KET AND
    ORD(K)LE KMAX(Z,I,J)),DELTA(KK.K))))
*may be wronge equation (by warapon)
    +SUM(K$(OPT=I AND ORD(K) LE NHEO(S,Z,l,J)),(CAE*DPAR_E_B(K,Z,1,J))
+(CAN*PAR_N_B(K,Z,I,J))));
*TOTALCOST.. TCOST =E= SUM(1\$(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)]>= I AND FREEH(I) AND FREEC(J)
* AND BIF=0), CF*USHELL(Z,I,J))
*     + SUM((K,Z,I,J)\$(SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
* AND BIF=1), CF*USHELL_B(K,Z,I,J))
*     + SUM((Z,1,J)\$(SUM[S,ALLOW(S,Z,1,J)]>= 1 AND FREEH(1) AND FREEC(J) ),
* CA*PAR(Z,I,J))
\$OFFTEXT
*Depending on the option selected by the user diferent sums come into action.
* Here we have an equation that is made simpler than in the paper. We account
* for the total area of the exchangers (use PAR and not PAR B)
* The result is the same
*--
*-
*EQ (106) CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K
KMAXI(S,Z.I,J)$(ALLOW(S,Z,I.J)=1 AND FREEH(1) AND FREEC(J) AND BIF(Z.I,J) =0)
NHE(S,Z.I.J) =L= USHELL(Z,I,J);
*EQ (107)
KMAX2(S,Z,l,J)$(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)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)),
  NHE(S,Z,I,J))=L=TOTNEXCHMAX;
*EQ (109) MINIMUM NUMBER OF EXCHANGERS
TOTNEXCH_MIN(S).. SUM((Z,1,J)$(ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=G=TOTNEXCHMIN;
*$ontext
****************************Equation for Retrofit*********************************
*-
*EQ(110)
AREA_REST1(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,1,J)=1 AND FREEH(1) AND FREEC(J)
AND BIF(Z,1,J)=0)..
PAR(Z,1,J)=L=AEX(Z,1,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,l,J);
*EQ(111)
AREA REST2(S,Z,I.J)$(OPT= I AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
  AND BIF(Z,I,J)=0)..
  DPAR_E(Z,I,J)=L=AEX_U(Z,1,J)-AEX(Z,1,J);
*EQ(112)
AREA REST3(S,Z,1,J)$(OPT=1 AND ALLOW(S,Z,1,J)=1 AND FREEH(1) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR_N(S,Z,l,J)=L=A_NEW_MAX(Z,l,J)*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)\$(NHE0(S,Z,I,J)=1)-NHE0(S,Z,I.J))

```
```

*ADD EQ.(KITISAK'EQ)
*EQ(Retrofit 4)
AREA_REST4(S,Z,1,J)$(OPT=1 AND ALLOW(S,Z,1.J)=1 AND FREEH(I) AND FREEC(J)
        AND BIF(Z,I,J)=0 )..
(NHE(S,Z,1,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,1.J)=1)) = L= TOTNEXCHMAX ;
*EQ(Retrofit 5)
AREA_REST5(S,Z,1,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
        AND BIF(Z,I,J)=0 AND NHEO(S,Z,I,J)= 0)..
PAR_N(S,Z,I.J) = L= A_NEW_MAX(Z,I,J)* (NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1));
*.
*EQ(Retrofit 7)
AREA REST7(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,1,J)=1 AND FREEH(1) AND FREEC(J)
        AND BIF(Z,I,J)=0 AND NHE0(S,Z,l,J)= 0).
(NHE(S.Z,I,J)+NHE_S(S,Z,1,J)$(NHE0(S,Z,1,J)=1)) =L= TOTNEXCHMAX ;
*
*=
*EQ(113)
AREA_REST1_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z1.J) AND ALLOW(S,Z,I,J)=1
            AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1).
    PAR_B(K,Z,I,J)=L=SUM(KK$(ORD(KK) LE NHE0(S,Z,l,J)),AEX B(KK,Z,I,J)
*DELTA(KK,K))+DPAR_E_B(K,Z,I,J)+PAR_N_B(K,Z,I,J);
*.
*EQ(114)
AREA REST2_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,l.J) AND ALLOW(S,Z,1,J)=1
            AND FREEH(1) AND FREEC(J) AND BIF(Z,1,J)=1).
    DPAR_E_B(K,Z,I,J)=L=SUM(KK$(ORD(KK) LE NHEO(S,Z,1,J)),(AEX_U_B(KK,Z,I,J)
-AEX_B(KK,Z,I,J))*DELTA(KK.K));
*.
*EQ(115)
AREA_REST3_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,l,J)=1
        AND FREEH(l) AND FREEC(J) AND BIF(Z,1,J)=1).
PAR_N_B(K,Z,I,J)=L=A_NEW_MAX(Z,I,J)*(I-SUM(KK$(ORD(KK) LE NHE0(S,Z,l,J)).DELTA(KK,K)));
*
*EQ(116)
AREA REST4 B(S,K,Z,1,J)$(OPT=1 AND ORD(K) LE KMAX(Z,1,J) AND ALLOW(S.Z,I,J)=1
        ANDD FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1).
    SUM(KK$(ORD(KK) LE NHE0(S,Z,l,J)),DELTA(KK,K))=L=l;
*---------
AREA_REST5_B(S,K.Z,I,J)$(OPT=1 AND ORD(K) LE NHE0(S,Z,l,J) AND ALLOW(S,Z,l,J)=1
                        AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1).
    SUM(KK$(ORD(KK) LE KMAX(Z,l,J)),DELTA(K,KK))=L=l;
*---------
AREA_REST6_B(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(1)
                    AND FREEC(J) AND BIF(Z,I,J)=1)..
    SUM((K,KK)$(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);
$ONTEXT
*EQ(119)
    ADD_REST..
    SUM((S,Z,1,J)$(OPT=1 AND ALLOW(S,Z,1,J)=1
AND FREEH(I) AND FREEC(J)),NHE(S,Z,I.J)
-NHEO(S,Z.I,J))=L=2:
*-
*EQ(120)
ADD_REST2(S,1,J)$(OPT=1 AND FREEH(I) AND FREEC(J))
        SUM}(\textrm{Z}$(ALLOW(S,Z,I,J)=1),NHE(S,Z,1,J)-NHE0(S,Z:1,J))=G=0
*
\$OFFTEXT
*EQ(Retrofit 14)
LIM_HEX(S,M).

```
```

SUM((Z,1,J)$(OPT=1
                    AND
ALLOW_H(S,Z,I,M,J)=I);(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1))-NHE0(S,Z,l.J))
=L= MAX_NEW_HEX
*\$offlext
$ontext
***************************Equation for Retrofit Relocation**
*
*EQ(Retrofit 16)
RELOCATE_l(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF=0).
PAR(Z,I.J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,I.J);
*EQ(Retrofit 17)
RELOCATE_2(S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
        AND BIF=0).
    AEX(Z.l.J) =E= SUM(K$(ORD(K) LE KET),(AEX_R(K)*Phi(Z,I,J,K)));
*EQ(Retrofit 18)
RELOCATE_3(S,Z.I.J)$(OPT=2 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
        AND BIF=0)..
    DPAR_E(Z,I,J)=L=SUM(K$(ORD(K) LE KET),(AEX_U_R(K)-AEX_R(K))
*Phi(Z,I,J,K));
*EQ(Retrofit 19)
RELOCATE 4(S,Z,1,J)$(OPT=2 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
        AND BIF=0 ).
    PAR_N(S,Z,I,J)=L= A_NEW_MAX * NHE(S,Z,I.J)-(NHE0(S,Z,1,J)*
                SUM(K$(ORD(K) LE KET),Phi(Z,1,J,K)) ));
*-
*EQ(Retrofit 20)
RELOCATE }5\mathrm{ l(S,Z.1,J)$(OPT=2 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
                AND BIF=0).. NHE(S,Z,I,J) =L= TOTNEXCHMAX ;
RELOCATE 5 2(S.Z,I,J)$(OPT=2 AND FREEH(I) AND FREEC(J)
AND \overline{BIF}=0).. SUM((K)\$(ORD(K) LE KET),Phi(Z,I,J.K))=L=1:

* Extra Eq. Limits number of phi matches
RELOCATE_5_3(Z.K)$(OPT=2).. SUM((i,j), Phi(Z,1,J,K))=L=1
**--------------
RELOCATE 6(K,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I.J)=1
AND FREEH(1) AND FREEC(J) AND BIF=1).
PAR_B(K,Z,I,J)=L=AEX_B(K,Z.I,J)+DPAR_E_B(K,Z,I,J)+PAR_N_B(K,Z.I.J);
* 

*EQ(Retrofit 22)
RELOCATE_7(K,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF =1)..
    AEX_B(K,Z,1,J)=E=SUM(KK$(ORD(KK) LE KET),(AEX_B_R(KK)*DELTA(KK,K)));
**
*EQ(Retrofit 23)
RELOCATE 8(K,S.Z,1.J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S.Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF=1).
    DPAR_E_B(K,Z,I,J)=L= SUM(KK$(ORD(KK) LE KET),(AEX_U_B_R(KK)-AEX_B_R(KK))
*DELTA(KK,K));
*.
*EQ(Retrofit 24)
RELOCATE_9(K,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF=1)..
    PAR_N_B(K,Z,l,J) =L= A NEW_MAX*(I-SUM(KK$(ORD(KK) LE KET)
,DELTA(KK,K)));
**
*EQ(Retrofit 25)
RELOCATE_10(K,S,Z,1,J)$(OPT=2 AND ORD(K) LE KMAX AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF=1).
    SUM(KK$(ORD(KK) LE KET),DELTA(KK.K)) =L= 1;
*-
\$OFFTEXT

* Show All cost for chacking

```

HOT U C.
HOT_UTILITY_COST \(=\mathrm{E}=\mathrm{SUM}(\mathbb{I}(\mathrm{HU}(\mathrm{I})\) AND FREEH(1)):CHU(I)*FHU(I)*DTHU(I)):
Cold U C
Culd UTILITY_COST \(=\mathrm{E}=\mathrm{SUM}(\mathrm{J}(\mathrm{CU}(\mathrm{J})\) AND FREEC(J)), CCU(J)*FCU(J)*DTCU(J));
*.
Area_C..
Area_Cost=E=SUM((S,Z,1,J)\$(OPT=1 AND ALLOW(S,Z.I, J)=1 AND FREEH(I) AND FREEC(J)


FIX_C..
FIX_COST \(=\mathrm{E}=\mathrm{SUM}((\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}) \$(\mathrm{OPT}=\mathrm{I}\) AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC( J\())\) CF* \(\operatorname{NHE}(\mathrm{S} . \mathrm{Z}, 1, \mathrm{~J})+\mathrm{NHE}\) - \(\mathrm{S}(\mathrm{S} . \mathrm{Z}, 1, \mathrm{~J}) \$(\mathrm{NHE} 0(\mathrm{~S}, \mathrm{Z}, 1, \mathrm{~J})=1)-\mathrm{NHE} 0(\mathrm{~S}, \mathrm{Z}, 1, \mathrm{~J})))\);

MODEL MPERIOD / ALL/;
OPTION LIMROW \(=5000\);
OPTION LIMCOL \(=5000\);
OPTION SOLPRINT = OFF;
OPTION OPTCR=0
OPTION OPTCA \(=0\);
OPTION reslim \(=135800\);
SOLVE MPERIOD USING MIP MINIMIZING TCOST;
PARAMETER QMATCH(S,Z:1,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 \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})\) 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))* \(\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M})]\)
PARAMETER FC C(S,Z,J,1,M) Flowrate of cold 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))* \(\mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{M})]\)
PARAMETER NHE2(S Z,J,I):
NHE2(S.Z,J,I) = NHE.L(S.Z.I,J);
OPTION Cold UTILITY COST:3:0:1; DISPLAY Cold UTILITY COST L;
OPTION HOT_UTILITY_COST:3:0:1, DISPLAY HOT_UTILITY _COST.L;
OPTION Area Cost:3:0:1: DISPLAY Area Cost L;
OPTION FIX_COST: \(3: 0: 1\); DISPLAY FIX COST.L;
option Q:3:0:1; display Q.L;
option FHU 3:0:1; display FHU.L;
option FCU:3:0:1; display FCU.L;
OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
OPTION PAR:4:0:I; DISPLAY PAR.L;
OPTION QMATCH:4:0:1; DISPLAY QMATCH;
OPTION FH_H:3:0:1; DISPLAY FII_H;
OPTION FC_C:3:0:1; DISPLAY FC_C;
OPTION LMTD:3:0:1; DISPLAY LMTD;
\$ONTEXT
DISPLAY DTVIO;
DISPLAY AEX;
DISPLAY CPH;
DISPLAY CPC
DISPLAY PHIL;
EXECUTE_UNLOAD "isabelout.gdx",PAR, QMATCH, FH_H, FC_C, AEX; EXECUTE 'GDXXRW.EXE isabeloutgdx par=QMATCH mg=al';
EXECUTE 'GDXXRW.EXE isabeloutgdx var \(=P A R\) rng \(=r 1\) ';
EXECUTE 'GDXXRW EXE isabeloutgdx PAR=AEX mg=afl';
EXECUTE 'GDXXRW.EXE isabelout.gdx par=FH_H rng=a20';
EXECUTE 'GDXXRW EXE isabeloutgdx par=FC_C mg=a40';
EXECUTE 'GDXXRW.EXE isabeloutgdx par \(=\mathrm{PHI} \mathrm{mg}=\mathrm{a} 60\) ':
EXECUTE 'GDXXRW EXE isabeloutgdx \(\vee A R=D P A R ~ m g=R 60\) ';
\$OFFTEXT

\section*{Appendix B Programming Model for Retrofit with Relocation}
\$TITLE HEN design- Automatic parameter calculation- KITISAK-1

* Equations that are different than in the paper +errata.
*(100) Just a nomenclature change
*(105) Just a nomenclature change
* Equations that are added to those that are in the paper
* (106) and (107)
* CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K
*(108) LIMIT THE NUMBER OF EXCHANGERS
*(109) MINIMUM NUMBER OF EXCHANGERS
\$OFFUPPER
SETS
Z transfer zone /Z1/
*
* ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS I Hot streams /I1*13/
J cold streams \(\quad / \mathrm{J} \mid * \mathrm{~J} 3 /\)
*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
HU(I) Heating utilities \(/ 13 /\)
\(\mathrm{CU}(\mathrm{J})\) Cooling utilities \(/ \mathrm{J} 3 /\)
*
M temperature intervals / \(\mathrm{MI}^{*} \mathrm{M} 85 /\)
S SCENARIO /SI/
K temperature intervals \(/ \mathrm{K} 1^{*} \mathrm{~K} 1 /\)
R exchangers /RI*R7/
ALlAS (M,N.L.O)
ALIAS ( \(\mathrm{I}, \mathrm{II}\) )
ALIAS (J.JJ)
ALIAS (K,KK)
ALIAS (Z.ZZ)
ALIAS (R,RR)
SET
ORDER(J)
/
J1
J2
J3
1
PARAMETER NIZ(S,Z,I) \# OF INTERVALS DESIRED FOR HOT STREAMS
/
SI.Z1.11 30
S1.Z1.I2 8
S1.Z1.132

1
PARAMETER NJZ(S,Z.J) \# OF INTERVALS DESIRED FOR COLD STREAMS
1
S1 Z1J1 35
S1.Z1.J2 8
S1.Z1.J3 2

1
PARAMETER HI(S.I) HEAT TR CEOFF FOR HOT STREAMS
/
S1II 0.1
S1.12 0.1
S1.130.1
1
PARAMETER HJ(S.J) HEAT TR CEOFF FOR COLD STREAMS
1
```

Si.Jl 0.1
SI J2 0.1
SI.J3 0.1
/
PARAMETERS
TIH(S,I) T IN FOR HOT STREAMS
/
SI.11 400
S1.12 }14
S1.13 500
l
TOH(S,I) T OUT FOR HOT STREAMS
/
SIII }10
SI.I260
SI.13499
/
TlC(S,J) T IN FOR COLD STREAMS
I
S1.J1 }5
S1.J2 }9
SI.J3 }3
I
TOC(S,j) T OUT FOR COLD STREAMS
l
SI.Jl }40
S1 J2 165
S1.J3 40
l
PARAMETERS
TIHZ(S.Z.I) T IN FOR HOT STREAMS
/
SIZ1.II 400
SIZ1.I2 140
S1.Z1.13 500
/
TOHZ(S,Z,I) T OUT FOR HOT STREAMS
/
SI.Z1.I1 }10
S1.Z1.1260
S1.Z1.13499
l
TICZ(S,Z,J) T IN FOR COLD STREAMS
|
S1.Z1.J1 }5
S1.Z1.J2 90
SI.Z1J3 30
l
TOCZ(S.Z.J) T OUT FOR COLD STREAMS
I
SI.Z1.J1 400
S1.Z1.J2 165
SI.ZIJ3 40
l
*INTRODUCE THE FCp:
FH(S.I) FOR HOT STREAMS
I
SI.II 10
SI.I2 30
l
.FC(S.J) FOR COLD STREAMS

```
```

/
S1.J1 10
S1.J2 40
|
*USE THE MAX FCp FOR THE UTILITIES
SETS FREEH(I)
l
II
12
13
/
FREEC(J)
/
J1
J2
J3
|
PARAMETER BIF(Z,I.J)
|
Z1.I1.J20
Z1.12.J10
Z1.12.J3 }
Z1.13.J10
/
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
*;
PARAMETER SPH(I) SH in paper
/
11 1
12 1
13 1
/
PARAMETER SPC(J) SC in paper
Jl 1
J2 1
J3 1
l
PARAMETER NIH(I) Non isothermal splitting for hot streams in paper
l
11 0
12 0
I3 0
/
PARAMETER NIC(J) Non isothermal splitting for cold streams in paper
/
Jl 0
J2 0
J3 0
l
PARAMETER DTVIO(I.J)
/
11.31 1
11.J2 l
11.J3 1
12.J1 1
12.J2 1
12.J3 1
13.J] 1
13.J2 !

```
```

PARAMETER KMAX(Z,\,J)
l
2.1.11 J2 1
21.12.311
Z1.12.J31
21.13.J11
l
******************************* ADD FOR RETROFIT *********************************
\$ontext
PARAMETER AEX(Z.I.J)
/
Z1.II.J1 1001.34
Z1.II.J3 1048.28
Z1.12.J2 121.53
Z1.12.J3 133.56
Z1.13.J1584.15
Z1.13.J2 603.71
Z1.14.J2 246.81
l
PARAMETER AEX_B(K,Z,I,J)
I
K1.21.11.J11001.34
I
PARAMETER NHE0(S,Z,1,J)
I
SI Z1.11.J1]
S1.21.11.J31
S1.Z1.I2.J21
S1.21.12.J31
S1.Z1.13.J11
S1 2113.J21
S1.21.14.J21
l
PARAMETER AEX_U(Z.I,J)
I
Z1.11.J1 1502.01
Z1.11.J31572.42
Z1.12.J2182.295
Z1.12.J3200.34
Z1.13.J1 876.225
Z1.13.J2 905.565
Z1.I4.J2 370.215
l
PARAMETER AEX_U_B(K,Z.I.J)
/
K1.Z1.II J] 1502.01
I
\$offtext
*For Relocation
PARAMETER NIIE0(S,Z.I.J)
l
S1.Z1.I1.J21
S1Z1.I2.J11
S1.Z1.12.J31
SIZ1.I3.J11
l
PARAMETER AEX R(R)
/
R1 841 86
R2 }55
R3 660.18
R4 }26

```
1
```

PARAMETER AEX_B_l(R)
/
R1 841.86
R2 }55
R3 660.18
R4 }26
/
PARAMETER AEX_U_l(R)
l
R12000
R22000
R32000
R42000
l
PARAMETER AEX_B_R (r)
/
Rl 841.86
R2 }55
R3 660.18
R4 }26
|
PARAMETER AEX_U_B_R(RR)
R12000
R2 2000
R3 }200
R42000
l
PARAMETER AEX_U_B_l(R)
l
R12000
R22000
R32000
R42000
/
PARAMETER R_ALL
*
Minimum DELTA T
/4/;
PARAMETER KET
14/;
*\$offtext
*\$ontext

```


```

PARAMETER DTHU(I)
1
$13 \quad 1$
1
PARAMETER DTCU(J)
I
J3 10
1
PARAMETER FMAX_HU(I)
1
$13 \quad 5000$
1
PARAMETER FMAX_CU(J)
1
J3 5000
1
PARAMETER CHU(I)
1

```
```

13 95.04
/
PARAMETER CCU(J)
I
J3 20
PARAMETER CF;
CF = 1000;
PARAMETER CA;
CA = 20;
*******************************FOR RETEOFIT****************************************
PARAMETER CAN;
CAN =20;
PARAMETER CAE;
CAE = 20;
*\$offlex!
PARAMETER QLHMIN
*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
15000/;
PARAMETER USHELLMAX
* Maximum shell area
15000/;
*Add for retrofit
PARAMETER A_NEW_MAX(Z;I,J)
I
Z1.(I1*I3).(J1*J3) 300
I
PARAMETER A_NEW_SHELLMAX
Maximum shell area
/5000/;
PARAMETER NEW USHELLMAX
* Maximum shell area
/5000/;
* 

PARAMETER TOTNEXCHMAX

* Maximum NUMBER OF EXCHANGERS
/900/;
PARAMETER TOTNEXCHMIN
* Minimum NUMBER OF EXCHANGERS
/0/;
PARAMETER DTmin
* Minimum DELTA T
10/;
parameter NINT
/263/;
parameter OPT
12/;
*----------------------------------------------------------
* END OF INPUT PARAMETE-----------------------------------------------------------------
SCALARS Si, Zi, Mi, Ic, Ji
PARAMETERS IHminZ(S,Z,I),IHmaxZ(S.Z,l),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)
\(\operatorname{FOR}(\mathrm{Si}=1\) TO CARD \((\mathrm{S})\),
\(\mathrm{FOR}(\mathrm{Z} i=1 \mathrm{TO} \operatorname{CARD}(\mathrm{Z})\),
FOR(Zi=1 TO CARD(Z),
FOR(lc=1 TO CARD(I),
\(1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}) \$ \mid \mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(I)=1
AND \(\operatorname{ORD}(Z)=1]=0+1 \$[\mathrm{NIZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})>=1]\) :
\(\operatorname{IHminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{l}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD(I)>1
AND ORD \((Z)=1]=0+\)
\{SUM( \(\mathrm{ZZ}, \mathrm{II}\) )\$[ORD(II)<ORD(I)],NIZ(S,ZZ,II))+1\}\$[NIZ(S,Z.I)>=1]:
\(1 \mathrm{Hmin} Z(\mathrm{~S}, \mathrm{Z}, \mathrm{l}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{Z})>1]=0+\)
\{SUM((ZZ,II)\$[ORD(II)<ORD(I)],NIZ(S,ZZ,II))
+ SUM \((Z Z \$[O R D(Z Z)<Z i], N I Z(S, Z Z, I))+1\} \$[\) NIZ \((S, Z, I)>=1]\) :
\(\operatorname{IHmaxZ}(S, Z, I) \$[O R D(S)=\) Si AND ORD(I)=Ic AND ORD \((Z)=Z i]=0+\)
\{IHminZ(S,Z,I)+NIZ(S,Z,I)-1\}\$[NIZ(S.Z.I)>=1];
\(\operatorname{IHmin}(\mathrm{S}, \mathrm{l}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD( I\()=\mathrm{lc}]=\)
SUM[Z\$\{SUM(ZZ\$[ORD(ZZ)<=ORD(Z)-1],NIZ(S,ZZ,I))=0\},IHminZ(S,Z,I)];
\(\operatorname{lHmax}(\mathrm{S}, \mathrm{I}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{l})=\mathrm{Ic}]=\)
SUM[Z\$\{SUM(ZZ\$[ORD(ZZ)>=ORD(Z)+1],NIZ(S.ZZ,I))=0\},IHmaxZ(S.Z,I)];
\(\operatorname{FOR}(\mathrm{Mi}=1 \operatorname{TOCARD}(\mathrm{M})\),
\(\operatorname{HOT}(\mathrm{S}, \mathrm{l}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND \(\operatorname{ORD}(\mathrm{f})=\mathrm{lc}\) AND \(\operatorname{ORD}(\mathrm{M})=\mathrm{Mi}]=0+\)
\(1 \$[\) ORD \((\mathrm{M})>=1 \mathrm{Hmin}(\mathrm{S}, \mathrm{I})\) AND ORD \((\mathrm{M})<=1 \mathrm{Hmax}(\mathrm{S}, \mathrm{I})]\);
\(\operatorname{HOT} 2(\mathrm{~S}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{M})=\mathrm{Mi} \mid=0+1 \$[\mathrm{ORD}(\mathrm{M})<=\)
\(\operatorname{SUM}(\mathrm{I} \$(\mathrm{ORD}(\mathrm{I})=\mathrm{CARD}(\mathrm{l})), \mathrm{IHmax}(\mathrm{S}, \mathrm{I}))]\);
\(\operatorname{HOTZ}(\mathrm{S}, \mathrm{Z}, \mathrm{l}, \mathrm{M}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{l})=\mathrm{lc}\) AND ORD \((\mathrm{M})=\mathrm{Mi}\) \(\operatorname{AND} \operatorname{ORD}(\mathrm{Z})=\mathrm{Zi}]=0+1 \$[\mathrm{ORD}(\mathrm{M})>=1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})\) AND \(\operatorname{ORD}(\mathrm{M})<=1 \mathrm{HmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})]\);
\(\mathrm{H}_{-} \mathrm{I}(\mathrm{S}, \mathrm{I}, \mathrm{M}) \mathbb{S} \operatorname{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{I})=\mathrm{lc}\) AND ORD \((\mathrm{M})=\mathrm{Mi}\) AND \(\operatorname{HOT}(S, 1, M)=1]=\mathrm{HI}(\mathrm{S}, 1)\) )); FOR( \(\mathrm{J}=1\) TO CARD(J).
\(1 \mathrm{CminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD( J\()=1\) AND ORD \((\mathrm{Z})=1]=0+\)
\(\{\operatorname{SUM}(\$ \$ \operatorname{ORD}(\mathrm{I})=\operatorname{CARD}(\mathrm{I})], \operatorname{IH} \max (\mathrm{S}, \mathrm{I}))+1\} \$(\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})>=1\}\);
\(1 \mathrm{CminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})>1\) AND ORD \((\mathrm{Z})=1]=0+\)
\(\{\operatorname{SUM}\{\operatorname{IS}\{O R D(I)=\operatorname{CARD}(\mathrm{I})], \operatorname{IHmax}(\mathrm{S}, \mathrm{I})\}\)
\(+\operatorname{SUM}((Z Z \mathrm{JJ}) \$[O R D(\mathrm{JJ})<\) ORD(J)],NJZ(S,ZZ.JJ))+1 \(\} \$[\mathrm{NJZ}(\mathrm{S} . Z . \mathrm{J})>=1]\);
ICminZ(S,Z.J) \([\) ORD(S) \(=\) Si AND ORD(Z) \(>1]=0+\)
\{SUM\{IS[ORD(1)=CARD(1)],IHmax(S,I)\}
+SUM((ZZ,JJ)\$[ORD(JJ)<ORD(J)],NJZ(S,ZZ,JJ))
+ SUM \((Z Z \$[O R D(Z Z)<Z i], N J Z(S, Z Z, J))+1\} \$[N J Z(S, Z, J)>=1\}\);
\(\operatorname{ICmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}\) AND ORD \((\mathrm{Z})=\mathrm{Zi}]=0+\)
\(\{\mathrm{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})+\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})-\mathrm{I}\} \$(\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})>=1\} ;\)
\(1 \mathrm{Cmin}(\mathrm{S} . \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD(J) \(=\mathrm{Ji}]=\)
SUM[Z\$\{SUM(ZZ\$[ORD(ZZ)<=ORD(Z)-1].NJZ(S,ZZ,J))=0\},ICminZ(S,Z,J)];
\(\operatorname{ICmax}(\mathrm{S}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD(J) \(=\mathrm{Ji}]=\)
SUM[Z\$\{SUM(ZZ\$[ORD(ZZ)>=ORD(Z)+1],NJZ(S,ZZ,J))=0\},ICmaxZ(S,Z,J)];
\(\operatorname{FOR}(\mathrm{Mi}=1\) TO \(\operatorname{CARD}(\mathrm{M})\),
\(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{M}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}\) AND ORD \((\mathrm{M})=\mathrm{Mi}]=0+\)
\(1 \$[\mathrm{ORD}(\mathrm{M})>=1 \mathrm{Cmin}(\mathrm{S}, \mathrm{J}) \operatorname{AND} \operatorname{ORD}(\mathrm{M})<=1 \mathrm{Cmax}(\mathrm{S}, \mathrm{J})] ;\)
\(\operatorname{COLD} 2(\mathrm{~S}, \mathrm{M}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si} \operatorname{AND} \operatorname{ORD}(\mathrm{M})=\mathrm{Mi}]=0+\)
\(1 \$ \operatorname{ORD}(\mathrm{M})>\operatorname{SUM}(\mathrm{I} \$(\operatorname{ORD}(\mathrm{I})=\operatorname{CARD}(\mathrm{I}))\),IHmax\((\mathrm{S}, \mathrm{I}))\)
AND ORD(M)<=SUM(J\$(ORD(J)=CARD(J)), ICmax(S.J))];
\(\operatorname{COLDZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}\) AND ORD \((\mathrm{M})=\mathrm{Mi}\)
\(\operatorname{AND} \operatorname{ORD}(\mathrm{Z})=\mathrm{Zi}]=0+1 \$[\mathrm{ORD}(\mathrm{M})>=1 \mathrm{CminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})\)
AND ORD \((\mathrm{M})<=1 \mathrm{Cmax} Z(\mathrm{~S}, \mathrm{Z}, \mathrm{J})]\);
\(\mathrm{H}_{-} \mathrm{J}(\mathrm{S}, \mathrm{J}, \mathrm{M}) \mathbb{S}[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(J)=Ji AND ORD(M)=Mi \(\operatorname{AND} \operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{M})=1]=\mathrm{HJ}(\mathrm{S}, \mathrm{J}) ;\)
))));
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 CR AS I
\(\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) \mathbb{S}[\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1]=1\);
\(\mathrm{CPC}(\mathrm{S} . \mathrm{J}, \mathrm{M}) \$[\operatorname{COLD}(\mathrm{~S} . \mathrm{J} . \mathrm{M})=1]=1\);
DT(S,M) \(=\operatorname{SUM}((Z, I) \$[H O T Z(S, Z, 1, M)=1],\{[T I H Z(S, Z, 1)-T O H Z(S, Z, I)] /\)
[IHmaxZ(S,Z,I)-IHminZ(S,Z.I)+1]\})\$[HOT2(S,M)=1]+
\(\operatorname{SUM}((Z, J) \$[C O L D Z(S, Z, J, M)=1],\{[T O C Z(S, Z, J)-T I C Z(S, Z, J)] /\)
[ICmaxZ(S,Z,J)-ICminZ(S,Z,J) +1\(]\}) \$[C O L D 2(S, M)=1] ;\)
```

FOR(Si= 1 TO CARD(S),
FOR (Mi=1 TO CARD(M),
TU(S,M)$[ORD(S)=Si AND ORD(M)=Mi]={SUM((Z,1)$[HOTZ(S,Z,1,M)=1
AND ORD(M)=1HminZ(S,Z,I)],TIHZ(S,Z,I)$[ORD(M)=1HminZ(S,Z,I)])
            + SUM((Z,I)$[HOTZ(S,Z,I,M)=1AND ORD(M)>IHminZ(S,Z,I)AND
ORD(M)<=IHmaxZ(S,Z,1)],
[TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,l))*DT(S,M)]$[ORD(M)>
                1HminZ(S,Z,I)AND ORD(M)<=IHmaxZ(S,Z,I)])}$[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)=lCminZ(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)])}$[COLD2(S,M)=1];
    TL}(\textrm{S},\textrm{M})$[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)$[HOTZ(S,Z,I,M)=1 AND ORD(M)<IHmaxZ(S,Z,I)
                AND ORD(M)>=IHminZ(S,Z,I)],
                    [TOHZ(S,Z,l)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$[ORD(M)<
IHmaxZ(S,Z,I)AND ORD(M)>=1HminZ(S,Z,I)])}$[HOT2(S,M)=1]
            + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1AND ORD(M)=1CmaxZ(S,Z,J)},
TICZ(S,Z,J)$[ORD(M)=ICmaxZ(S,Z,J)])
            + SUM((Z,J)$[COLDZ(S,Z,J,M)=1AND ORD(M)<lCmaxZ(S,Z,J)
AND ORD(M)>=ICminZ(S,Z,J)],
[TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$[ORD(M)<
                    ICmaxZ(S,Z,J)AND ORD(M)>=1CminZ(S,Z,J])}$[COLD2(S,M)=1];
FOR(Ic=1 TO CARD(1),
DHH(S,I,M)$[ORD(S)=Si AND ORD(M)=Mi AND ORD(I)=Ic
                AND HOT(S,1,M)=1]= FH(S,I)*CPH(S,1,M)*[TU(S,M)-TL(S,M)] ;
        );
    FOR(Ji=1 TO CARD(J),
        DHC(S,J,M)$[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)] ;
i);;
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,l,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)]}$[HHEAD(S,M,N)>0
            AND CHEAD(S,M,N)>0 AND HHEAD(S,M,N)>CHEAD(S,M,N)]
    + {[HHEAD}(\textrm{S},\textrm{M},\textrm{N})+CHEAD(S,M,N)]/2}$[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)=1S[{HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[1$(HOT(S,I,M)=1
    AND HOT(S,I,N)=1),HOTZ(S,Z,I,M)]=1 AND SUM[IS(HOT(S,I,N)=1
    AND HOT(S,I,M)=1),HOTZ(S,Z,1,N)]=1}
    OR {COLD2(S,M)=1 AND COLD2(S,N)=1 AND SUM[J$(COLD(S,J,M)=1
AND COLD(S,y,N)=1),COLDZ(S,Z,J,M)]=1 AND SUM[J$(COLD(S,J,N)=1
        AND COLD (S,J,M)=1),COLDZ(S,Z,J,N)]=1}
        OR {(HHEAD}(\textrm{S},\textrm{M},\textrm{N})>=0.00001 AND CHEAD(S,M,N )>=0.00001
            AND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,I,M)]=1
AND SUM[JS(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}];

* OR {LMTD(S,M,N)>0 AND SUM[1$(HOT(S,1,M)=1),HOTZ(S,Z,1,M)]=1
                      AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}];
FOR(Si=1 TO CARD(S),
FOR(Zi=1 IO CARD(Z),
FOR(Ic=1 TO CARD(1),
FOR(Ji=1 TO CARD(J),
ALLOW(S,Z,l,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
                      AND ORD(J)=Ji]=0+1${SUM
AND COLD(S,J,N )=1\rceil,D(S,Z,M,N)]>0

```
```

            AND NOT[HU(I)AND CU(J)]};
        FOR (Mi=1 TO CARD(M),
        ALLOW_H(S,Z,l,M,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
                        AND ORD(J)=Ji AND ORD(M)=Mi
        AND HOT(S,I,M)=1]= 0+
        1${SUM[N$[COLD(S,J,N)=1],D(S,Z,M,N)] >0AND NOT[HU(I)AND CU(J)]}:
        Al.L.OW_C(S.Z,J,M.I)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
        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(lc=1 TO CARD(l),
FOR(Ji=1 TO CARD(J),
ALLOW_2(Z,I,J)$[ORD(Z)=Zi AND ORD(I)=Ic AND ORD(J)=Ji]= 0+
                                    1${SUM[S,ALLOW(S.Z,I.J)] >0AND NOT[HU(I)AND CU(J)]};
)));
\$ONTEXT
*NM-4SI-FINAL-6-FLEXIBILITY-SI gms: August 9, 2004

* one scenario, the original values of 4sl.
************************************************************************************
\$OFFTEXT
\$ontext
*DEFINES THE NUMBER OR TRANSFER ZONES
SET
Z transfer zone /ZI*Z2/
*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
SETI /II*IlS/
SET J/Jl*J15/
SETS
M temperature intervals /M1*M250/
S SCENARIO /S1/
K number of heat exchangers /KI*K20/
X used to input numbers /XI*X15/
ALIAS (M,N,L.O)
ALIAS (1,II)
ALIAS (J,JJ)
ALIAS (K,KK)
ALIAS (Z,ZZ)

```

```

*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
*Heating utilities
\$CALL GDXXRW EXE c:\HENS\isabel. xls Set=HU rng=GAMS!C49:I49 Cdim=1
SET HU(I)
\$GDXIN isabel.gdx
\$LOAD HU
*Cooling utilities
\$CALL GDXXRW.EXE c:\HENS $\backslash$ isabel. $x$ ls Set=CU mg=GAMS!C52:152 Cdim=1
SET CU(J)
\$GDXIN isabel.gdx
\$LOAD CU

* INPUTS 15 NUMBERS IN ONE VECTOR TO REDUCE LOADING TIME
\$CALL GDXXRW.EXE c:\HENS $\backslash$ isabel. xls par=DATA $\mathrm{mg}=$ Hojal! E 48 :F62 Rdim=1 PARAMETER DATA(X);
\$GDXIN isabel gdx
\$LOAD DATA
*DEFINES WHICH EQUATIONS RUN OPT=0 GRASSROOTS OPT=1 RETROFIT OPT=2 RELOCATION
PARAMETER OPT:
OPT = DATA('XI');
*THE NUMBER OF INTERVALS TO BE USED
PARAMETER NINT;
NINT = DATA('X2');

```
```

*Maximum shell area
PARAMETER ASHELLMAX;
ASHELLMAX = DATA('X3');
*Maximum area per exchanger
PARAMETER AMAX;
AMAX = DATA('X4');
*Minimum DELTA T
PARAMETER DTmin;
DTmin = DATA('X5');
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1:
*MAXNEXCHPERMATCH = 2
PARAMETER BIF;
BIF = DATA('X6');
*LIMITS THE NUMBER OF HEAT EXCHANGERS IN ONE INTERVAL
PARAMETER KMAX;
KMAX = DATA('X7');
*Minimum heat that can be transferred within an interval.Hot streams
PARAMETER QLHMIN;
QLHMIN = DATA('X8');
*Minimum heat that can be transferred within an interval.Cold streams
PARAMETER QLCMIN;
QLCMIN = DATA('X8');
*Maximum NUMBER OF EXCHANGERS
PARAMETER TOTNEXCHMAX;
TOTNEXCHMAX = DATA('X9')
*Minimum NUMBER OF EXCHANGERS
PARAMETER TOTNEXCHMIN;
TOTNEXCHMIN = DATA('XIO')
*FIXED COST FOR A HEAT EXCHANGER MATCHING STREAMS
PARAMETER CF;
CF = DATA('XI!');
*VARIABLE COST FOR A HEAT EXCHANGER MATCHING STREAMS
PARAMETER CA;
CA = DATA('X12');
*COST OF RELOCATION
PARAMETER CAN;
CAN = DATA('X13');
PARAMETER CAE;
CAE = DATA('X13');
*NUMBER OF HEAT EXCHANGERS ORIGINALY PRESENT
PARAMETER KET;
KET= DATA('XI4');
*MAXIMUM ADITIONAL AREA
PARAMETER A_NEW_MAX;
A_NEW_MAX = DATA('X15');
*NUMBER OF INTERVALS ON HOT STREAM
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NIZ rng=GAMS!al:q3 Rdim=2 Cdim=1
PARAMETER NIZ(S.Z.I);
\$GDXIN isabel.gdx
\$LOAD NIZ
*NUMBER OF INTERVALS ON COLD STREAM
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=NJZ rng=GAMS!a5:q7 Rdim=2 Cdim=1
PARAMETER NJZ(S.Z.J);
\$GDXIN isabel gdx
\$LOAD NJZ

```
*HEAT TRANSFER CEOFF FOR HOT STREAMS
\$CALL GDXXRW.EXE c:LHENS lisabel. xls par=HI mg=GAMS!B9:q10 Rdim=1 Cdim=1 PARAMETER HI(S,I)
\$GDXIN isabel.gdx
\$LOAD HI
*HEAT TRANSFER CEOFF FOR COLD STREAMS
\$CALL GDXXRW.EXE c :\HENS \isabel. xls par=HJ mg=GAMS!B12:q13 Rdim=1 Cdim=1
PARAMETER HJ(S,J);
\$GDXIN isabel.gdx
\$LOAD HJ
*TEMPERATURE FOR HOT INLET STREAMS
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=TIH rng=GAMS!B15:q16 Rdim=1 Cdim=1 PARAMETER TIH(S,I);
\$GDXIN isabel gdx
\$LOAD TIH
*TEMPERATURE FOR HOT OUTLET STREAMS
\$CALL GDXXRW.EXE c : LHENS lisabel \(\mathrm{xls} \mathrm{par}=\mathrm{TOH} \mathrm{mg}=\mathrm{GAMS}\) ! B 18:q19 Rdim=1 Cdim=1 PARAMETER TOH(S.I);
\$GDXIN isabel gdx
\$LOAD TOH
*TEMPERATURE FOR COLD INLET STREAMS
\$CALL GDXXRW.EXE \(\mathrm{c}:\) \HENS \(\backslash \mathrm{isabel} . \mathrm{xis}\) par=TIC \(\mathrm{rng}=\) GAMS!B21:q22 Rdim=1 Cdim=1 PARAMETER TIC(S.J),
\$GDXIN isabel.gdx
\$LOAD TIC
*TEMPERATURE FOR COLD OUTLET STREAMS
\$CALL GDXXRW EXE \(\mathrm{c}:\) :HENS isabel xls par-TOC mg=GAMS!B24:q25 Rdim=1 Cdim=1 PARAMETER TOC(S,J);
\$GDXIN isabel.gdx
\$LOAD TOC
*PARAMETERS FOR Z ZONE, TEMPERATURA @ EACH ZONE AND FLOW
*TEMPERATURE FOR HOT INLET STREAMS @ Z
\$CALL GDXXRW EXE \(\mathrm{c}:\) :HENS \(\operatorname{lisabel}\). x Is par=TIHZ \(\mathrm{mg}=\) GAMS!A27:q29 Rdim=2 \(\mathbf{C d i m = 1}\) PARAMETER TIHZ(S,Z,I);
\$GDXIN isabel.gdx
\$LOAD TIHZ
*TEMPERATURE FOR HOT OUTLET STREAMS @ Z
\$CALL GDXXRW EXE c :\HENS lisabel \(\cdot \mathrm{xls}\) par=TOHZ \(\mathrm{rng}=\mathrm{GAMS}\) !A31:q33 Rdim=2 \(\mathrm{Cdim}=1\) PARAMETER TOHZ(S,Z,1);
\$GDXIN isabel.gdx
\$LOAD TOHZ
*TEMPERATURE FOR COLD INLET STREAMS @ Z
\$CALL GDXXRW.EXE c :LHENS \(\operatorname{lisabel.xIs~par=TICZ~mg=GAMS!A35:q37~Rdim=2~Cdim=1~}\) PARAMETER TICZ(S,Z,J);
\$GDXIN isabel.gdx
\$LOAD TICZ
*TEMPERATURE FOR COLD OUTLET STREAMS @ Z
\$CALL GDXXRW.EXE c:\HENS\isabel xls par=TOCZ rng=GAMS!A39:q41 Rdim=2 Cdim=1 PARAMETER TOCZ(S,Z,J);
\$GDXIN isabel.gdx
\$LOAD TOCZ
*MASS FLOW FOR THE HOT STREAMS
\$CALL GDXXRW.EXE c:lHENS \(\operatorname{lisabel} . x 1 \mathrm{~s}\) par=FH rng=GAMS!B43:q44 Rdim=1 Cdim=1 PARAMETER FH(S.I);
\$GDXIN isabel gdx
\$LOAD FH
*MASS FLOW FOR THE COLD STREAMS
\$CALL GDXXRW EXE c:\HENS PARAMETER FC(S,J);
\$GDXIN isabel gdx
\$LOAD FC
*HOT PROCESS STREAMS
\$CALL GDXXRW.EXE c : HENS lisabel. xls Set=FREEH rng=GAMS!C1:qI Cdim=1 SET FREEH(I)
\$GDXIN isabel.gdx
\$LOAD FREEH
*COLD PROCESS STREAMS
\$CALL GDXXRW.EXE c :IHENSlisabel. xls Sel=FREEC mg=GAMS!C5:q5 Cdim=1
SET FREEC(J)
\$GDXIN isabel.gdx
SLOAD FREEC
*SPLITS ARE ALLOWED FOR HOT STREAMS BINARY SH in paper
\$CALL GDXXRW.EXE c :IHENS lisabel. xls par=SPH rng=GAMS!C55: \(\mathbf{q} 56\) Cdim=1
PARAMETER SPH(I);
\$GDXIN isabel.gdx
\$LOAD SPH
*SPLITS ARE ALLOWED FOR COLD STREAMS BINARY SC in paper \$CALL GDXXRW.EXE c:\HENS lisabel.xls par=SPC mg=GAMS!C58:q59 Cdim=1 PARAMETER SPC(J);
\$GDXIN isabel.gdx
\$LOAD SPC
*NON ISOTHERMAL MIXING IS PERMITED FOR HOT STREAMS BINARY \$CALL GDXXRW.EXE c:\HENSlisabel.xls par=NIH mg=GAMS!C55: 956 Cdim=1 PARAMETER NIH(1)
\$GDXIN isabel.gdx
\$LOAD NIH
*NON ISOTHERMAL MIXING IS PERMITED FOR COLD STREAMS BINARY \$CALL GDXXRW EXE c:\HENS\isabel xls par=NIC rng=GAMS!C58:q59 Cdim=1 PARAMETER NIC(J);
\$GDXIN isabel.gdx
\$LOAD NIC
* POSIBLE TEMPERATURE DIFERENCES BETWEEN EXCHANGING STREAMS \$CALL GDXXRW.EXE c:\HENS lisabel xls par=DTVIO rng=DTVIO!A!:C225 Rdim=2 PARAMETER DTVIO(l,J);
\$GDXIN isabel.gdx
\$LOAD DTVIO
*TEMPERATURE DIFERENCE IN THE HOT UTILITY
\$CALL GDXXRW.EXE c:\HENS isabel.xls par=DTHU rng=GAMS!C49:q50 Cdim=1 PARAMETER DTHU(I);
\$GDXIN isabel.gdx
\$LOAD DTHU
*TEMPERATURE DIFERENCE IN THE COLD UTILITY
\$CALL GDXXRW.EXE c :UHENS lisabel .xls par=DTCU rng=GAMS!C52: \(\mathrm{q} 53 \mathrm{Cdim}=1\) PARAMETER DTCU(J);
\$GDXIN isakel.gdx
\$LOAD DTCU
*MAXIMUM MASS FLOW FOR THE HOT UTILITY
\$CALL GDXXRW EXE \(\mathrm{c}:\) IHENS \(\backslash\) isabel xls par=FMAX_HU rng=GAMS!C61: \(\mathrm{q} 62 \mathrm{Cdim=1}\)
PARAMETER FMAX_HU(I);
\$GDXIN isabel.gdx
\$LOAD FMAX_HU
*MAXIMUM MASS FLOW FOR THE COLD UTILITY
\$CALL GDXXRW EXE c :\HENS lisabel. xls par=FMAX_CU mg=GAMS!C64:q65 Cdim=1
PARAMETER FMAX_CU(J);
\$GDXIN isabel.gdx
\$LOAD FMAX_CU
*COST OF HOT UTILITY
\$CALL GDXXRW EXE c:\HENS lisabel xls par=CHU mg=GAMS!C67:q68 Cdim=1 PARAMETER CHU(I);
```

\$GDXIN isabel.gdx
\$LOAD CHU
*COST OF COLD UTILITY
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CCU mg=GAMS!C70:q71 Cdim=1
PARAMETER CCU(J);
\$GDXIN isabel.gdx
\$LOAD CCU
*CP OF HOT PROCESS STREAM
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=CPH mg=CP!BE2:BH251 rdim=3
PARAMETER CPH(S,I,M);
\$GDXIN isabel.gdx
\$LOAD CPH
*CP OF COLD PROCESS STREAM J
\$CALL GDXXRW.EXE c:\HENS\isabel xls par=CPC rng=CP!BJ2:BM251 rdim=3
PARAMETER CPC(S,J,M);
\$GDXIN isabel gdx
\$LOAD CPC
*AREA OF EXISTING HEAT EXCHANGERS
\$CALL GDXXRW EXE c:\HENS\isabel xls par=AEX mn=EXCHANGERS!L2:O8 Rdim=3
PARAMETER AEX(Z,1,J);
\$GDXIN isabel.gdx
\$LOAD AEX
*AREA OF EXISTING HEAT EXCHANGERS THAT CANNOT BE MOVED
\$CALL GDXXRW.EXE c:\HENS\isabel xls par=AEX_B mg=EXCHANGERS!Q2:U21 Rdim=4
PARAMETER AEX_B(K,Z,I,J);
\$GDXIN isabel.gdx
\$LOAD AEX B
*NUMBER OF HEAT EXCHANGERS
\$CALL GDXXRW EXE c:\HENS\isabel xls par=NHE0 rng=EXCHANGERS!K45:O244 Rdim=4
PARAMETER NHE0(S,Z,I.J);
\$GDXIN isabel gdx
\$LOAD NHE0
*MAXIMUM AREA OF EXCHANGERS
\$CALL GDXXRW EXE c:\HENS\isabel.xls par=AEX_U mg=EXCHANGERS!L23:O42 Rdim=3
PARAMETER AEX U(Z.I.J);
\$GDXIN isabel.gdx
\$LOAD AEX_U
\$CALL GDXXRW.EXE c:LHENS\isabel.xls par=AEX_U_B mg=EXCHANGERS!Q23:U42 Rdim=4
PARAMETER AEX U B(K,Z,I,J);
\$GDXIN isabel.gdx
\$LOAD AEX_U_B
******************************* ADD FOR RELOCATION********************************
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_R mg=EXCHANGERS!Z2:AA21 Rdim=1
PARAMETER AEX R(K):
\$GDXIN isabel gdx
\$LOAD AEX R
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX_U_R mg=EXCHANGERS!Z23:AA42 Rdim=1
PARAMETER AEX_U_R(K);
\$GDXIN isabel.gdx
\$LOAD AEX_U_R
\$CALL GDXXRW.EXE c:\HENS\isabel.xls par=AEX B_R mg=EXCHANGERS!AC2:AD21 Rdim=1
PARAMETER AEX B R(K);
\$GDXIN isabel.gdx
\$LOAD AEX B R
\$CALL GDXXRW EXE c:\HENSlisabel xls par=AEX_U_B_R rng=EXCHANGERS!AC23:AD42 Rdim=1
PARAMETER AEX_U_B_R(K);
\$GDXIN isabel gdx
\$LOAD AEX_U_B_R

```

SCALARS Si, \(\mathrm{Zi}, \mathrm{Mi}, \mathrm{Ic}\), Ji
*H_I HEAT TRANSFER COEFICIENT FOR HOT STREAM I
*H_I HEAT TRANSFER COEFICIENT FOR COLD STREAM J
*HOT HOT FLOW I PRESENT IN INTERVAL M
*COLD COLD FLOW J PRESENT IN INTERVAL N
PARAMETERS IHminZ(S,Z,I),IHmaxZ(S,Z,I),IHmax(S,I),IHmin(S,l),HOT(S,I,M),
HOT2(S,M), HOTZ(S,Z,I,M), ICminZ(S,Z,J),ICmaxZ(S,Z,J),ICmin(S.J),
lCmax(S,J),COLD(S,J,M),COLD2(S,M), COLDZ(S,Z,J,M), H_l(S,l,M), H_J(S,J,M)
FOR( \(\mathrm{Si}=1\) TO CARD(S),
\(\operatorname{FOR}(\mathrm{Zi}=1\) TO CARD \((\mathrm{Z})\),
FOR(Ic=1 TO CARD(FREEH),
\(1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(1)=1
\(\operatorname{AND} \operatorname{ORD}(\mathrm{Z})=1]=0+1 \$[\operatorname{NIZ}(\mathrm{~S}, \mathrm{Z}, \mathrm{I})>=1]\);
IHmir.Z(S,Z,I)\$[ORD(S)=Si AND ORD(I)>1
\(\operatorname{AND} \operatorname{ORD}(\mathrm{Z})=1]=0+\)
\(\{\) SUM \(((Z Z, I I) \$[O R D(I I)<O R D(I)], N I Z(S, Z Z, I I))+1\}\) SNIZ \((S, Z, I)>=1]\);
\(1 \mathrm{Hmin} Z(S, Z, I) \$[O R D(S)=S i\) AND ORD \((Z)>1]=0+\)
\{SUM((ZZ,II)\$[ORD(II)<ORD(I)],NIZ(S.ZZ,II))
+SUM(ZZ\$[ORD(ZZ)<Zi],NIZ(S,ZZ,1))+1\}\$NIZ(S,Z,I)>=1];
\(\operatorname{IHmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{I})=1 \mathrm{c}\) AND ORD \((\mathrm{Z})=\mathrm{Zi}]=0+\)
\(\{\mathrm{IHminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})+\mathrm{NIZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})-1\} \$(\mathrm{NIZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})>=1]\);
\(\operatorname{IHmin}(\mathrm{S}, \mathrm{I}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{I})=\mathrm{Ic}]=\)
SUM[Z\$\{SUM(ZZ\$[ORD(ZZ)<=ORD(Z)-1],NIZ(S,ZZ,I))=0\},IHminZ(S,Z,I)];
\(\operatorname{IHmax}(\mathrm{S}, \mathrm{I}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{I})=\mathrm{Ic}]=\)
SUM \([Z \$\{\operatorname{SUM}(Z Z \$[O R D(Z Z)>=O R D(Z)+1], N I Z(S, Z Z, 1))=0\}, I \operatorname{lnax} Z(S, Z, I)] ;\)
FOR(Mi=1 TO NINT,
\(\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{I})=\mathrm{Ic}\) AND \(\operatorname{ORD}(\mathrm{M})=\mathrm{Mi}]=0+\) \(1 \$[\mathrm{ORD}(\mathrm{M})>=\mathrm{IHmin}(\mathrm{S}, \mathrm{I})\) AND \(\mathrm{ORD}(\mathrm{M})<=1 \mathrm{Hmax}(\mathrm{S}, \mathrm{I})]\);
\(\operatorname{HOT} 2(\mathrm{~S}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{M})=\mathrm{Mi}]=0+1 \$[\mathrm{ORD}(\mathrm{M})<=\) SUM( \(1 \$(\operatorname{ORD}(\mathrm{I})=\mathrm{CARD}(\) FREEH \()\) ), IHmax \((\mathrm{S}, \mathrm{I}))\) ];
\(\operatorname{HOTZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{I})=\) lc AND ORD \((\mathrm{M})=\mathrm{Mi}\)
AND ORD \((\mathrm{Z})=\mathrm{Zi}]=0+1 \$[\mathrm{ORD}(\mathrm{M})>=1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})\) AND ORD \((\mathrm{M})<=1 \mathrm{HmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})]\); \(\mathrm{H}_{-}(\mathrm{S}, \mathrm{l}, \mathrm{M}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{l})=\mathrm{lc}\) AND ORD \((\mathrm{M})=\mathrm{Mi}\)
AND \(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1]=\mathrm{HI}(\mathrm{S}, \mathrm{I})\);
));
FOR( \(\mathrm{Ji}=1\) TO CARD(FREEC):
\(1 \mathrm{CminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \mathbb{\$}[\operatorname{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(J) \(=1\) AND ORD \((\mathrm{Z})=1]=0+\) \(\{\operatorname{SUM}(\operatorname{IS}[\operatorname{ORD}(\mathrm{I})=\mathrm{CARD}(\) FREEH \()], \mathrm{IHmax}(\mathrm{S}, \mathrm{I}))+\mathrm{I}\} \$[\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})>=1] ;\)
\(\operatorname{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})>1\) AND ORD \((Z)=1]=0+\) \{SUM \(\{1 \$[\) ORD (I)=CARD(FREEH)],IHmax(S,I) \} \(+\operatorname{SUM}((\mathrm{ZZ}, \mathrm{JJ}) \$[\mathrm{ORD}(\mathrm{JJ})<\mathrm{ORD}(\mathrm{J})], \mathrm{NJZ}(\mathrm{S}, \mathrm{ZZ}, \mathrm{JJ}))+1\} \$[\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})>=1]\);
\(1 \mathrm{CminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[O R D(S)=\) Si AND ORD \((Z)>1]=0+\)
\{SUM\{I\$[ORD(I)=CARD(FREEH)],IHmax(S,I)\}
+SUM((ZZ,JJ)\$[ORD(JJ)<ORD(J)|,NJZ(S,ZZ,JJ))
+ SUM \((Z Z \$[O R D(Z Z)<Z i], N J Z(S, Z Z, J))+1\} \$(N J Z(S, Z, J)>=1] ;\)
\(\operatorname{ICmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}\) AND ORD \((\mathrm{Z})=\mathrm{Zi}]=0+\) \(\{\mathrm{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})+\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})-1\} \$[\mathrm{NJZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})>=1] ;\)
\(\operatorname{JCmin}(\mathrm{S}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}]=\)
SUM[Z\$\{SUM(ZZ\$[ORD(ZZ)<=ORD(Z)-1],NJZ(S,ZZ,J))=0\},ICminZ(S,Z,J)];
\(\operatorname{ICmax}(\mathrm{S}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{J} i]=\)
\[
\text { SUM }[Z \$\{\operatorname{SUM}(Z Z \$[O R D(Z Z)>=O R D(Z)+1], N J Z(S, Z Z, J))=0\} . \operatorname{ICmaxZ}(S . Z . J)] ;
\]
FOR(Mi=1 TO NINT,
\(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}\) AND \(\operatorname{ORD}(\mathrm{M})=\mathrm{Mi}]=0+\) \(1 \$[\mathrm{ORD}(\mathrm{M})>=\mathrm{ICmin}(\mathrm{S}, \mathrm{J})\) AND ORD(M)<=ICmax\((\mathrm{S}, \mathrm{J})]\);
\(\operatorname{COLD} 2(\mathrm{~S}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(M)=Mi] \(=0+\)
\(1 \$[\) ORD \((\mathrm{M})>\operatorname{SUM}(1 \$(\mathrm{ORD}(\mathrm{I})=\mathrm{CARD}(\) FREEH \())\), \(\mathrm{IHmax}(\mathrm{S}, \mathrm{I}))\)
AND ORD \((\mathrm{M})<=\operatorname{SUM}(\mathrm{J} \$(\operatorname{ORD}(\mathrm{~J})=\mathrm{CARD}(\) FREEC \()\) ), \(\operatorname{ICmax}(\mathrm{S} . \mathrm{J})\) )];
\(\operatorname{COLDZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD \((\mathrm{J})=\mathrm{Ji}\) AND ORD \((\mathrm{M})=\mathrm{Mi}\)
\(\operatorname{AND} \operatorname{ORD}(\mathrm{Z})=\mathrm{Zi}]=0+1 \$[\mathrm{ORD}(\mathrm{M})>=1 \mathrm{CminZ}(\mathrm{S} . \mathrm{Z}, \mathrm{J})\)
AND ORD(M)<=ICmaxZ(S.Z,J)];
H_J(S,J.M \() \$[O R D(S)=S i A N D O R D(J)=J i A N D ~ O R D(M)=M i\) \(\operatorname{AND~COLD}(\mathrm{S}, \mathrm{J}, \mathrm{M})=1 \mathrm{~J}=\mathrm{HJ}(\mathrm{S} . \mathrm{J})\);
))));

\footnotetext{
*DHH ENTHALPY CHANGE FOR HOT PROCESS STREAM I
*DHC ENTHALPY CHANGE FOR COLD PROCESS STREAM J
*DT TEMPERATURE DIFERENCE BETWEEN STREAMS AT INTERVAL
*TU UPPER TEMPERATURE OF INTERVAL
*TL LOWER TEMPERATURE OF INTERCAL
PARAMETERS DT(S,M),TU(S,M), TL(S,M), DHH(S,I,M),DHC(S,J,M);
DT(S,M) \(=\) SUM \(((Z, I) \$[H O T Z(S, Z, I, M)=1],\{[T I H Z(S, Z, 1)-T O H Z(S, Z, I)] /\)
\([1 H \max Z(S, Z, 1)-I H m i n Z(S, Z, I)+1]\}) \$[H O T 2(S, M)=1]+\)
\(\operatorname{SUM}((Z, J) \$[\operatorname{COLDZ}(\mathrm{~S}, \mathrm{Z}, \mathrm{J}, \mathrm{M})=1],\{[\operatorname{TOCZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})-\mathrm{TICZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})] /\)
[ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]\})\$[COLD2(S,M)=1];
\(\operatorname{FOR}(\mathrm{Si}=1\) TO CARD(S),
FOR ( \(\mathrm{Mi}=1\) TO NINT,
 AND ORD(M)=IHminZ(S,Z,I)],TIHZ(S,Z,I)\$[ORD(M)=IHminZ(S,Z,I)])
\(+\operatorname{SUM}((\mathrm{Z}, \mathrm{I}) \$[\mathrm{HOTZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M})=1\) AND ORD \((\mathrm{M})>1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})\) AND ORD(M)<=lHmaxZ(S,Z,I)],
[TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)]\$[ORD(M)> \(1 \mathrm{HminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})\) AND \(\operatorname{ORD}(\mathrm{M})<=1 \mathrm{HmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})])\} \$[\mathrm{HOT} 2(\mathrm{~S}, \mathrm{M})=1]\)
\(+\{\operatorname{SUM}((\mathrm{Z}, \mathrm{J}) \$[\operatorname{COLDZ}(\mathrm{~S}, \mathrm{Z}, \mathrm{J}, \mathrm{M})=1\) AND ORD \((\mathrm{M})=\mathrm{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})]\), \(\operatorname{TOCZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[\operatorname{ORD}(\mathrm{M})=\mathrm{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})])\)
\(+\operatorname{SUM}((\mathrm{Z}, \mathrm{J}) \$[\operatorname{COLDZ}(\mathrm{~S}, \mathrm{Z}, \mathrm{J}, \mathrm{M})=1\) AND ORD(M)>ICminZ(S,Z,J) AND \(\operatorname{ORD}(\mathrm{M})<=1 \mathrm{Cmax} Z(\mathrm{~S}, \mathrm{Z}, \mathrm{J})]\), [TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]\$[ORD(M)> \(\operatorname{ICminZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})\) AND ORD(M)<=ICmaxZ(S,Z,J)]) \}\$[COLD2(S,M)=1]; \(\operatorname{TL}(\mathrm{S}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}\) AND ORD(M)=Mi]=
\{SUM \(((\mathrm{Z}, \mathrm{I}) \$[\mathrm{HOTZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M})=1\) AND ORD(M)=IHmaxZ(S,Z,I)], TOHZ(S,Z,1)\$[ORD(M)=lHmaxZ(S,Z,I)])
\(+\operatorname{SUM}((\mathrm{Z}, \mathrm{I}) \$[\operatorname{HOTZ}(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{M})=1\) AND ORD(M)<IHmaxZ(S,Z,I) AND ORD(M)>=1HminZ(S,Z,I)],
\(\left[\mathrm{TOHZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})+(\mathrm{IHmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})-\mathrm{ORD}(\mathrm{M}))^{*} \mathrm{DT}(\mathrm{S}, \mathrm{M})\right] \$[\mathrm{ORD}(\mathrm{M})<\) lHmaxZ(S,Z,I)AND ORD(M)>=1HminZ(S,Z,I)]) \}\$[HOT2(S,M)=1] \(+\{\operatorname{SUM}((\mathrm{Z}, \mathrm{J}) \$[\operatorname{COLDZ}(\mathrm{~S}, \mathrm{Z}, \mathrm{J}, \mathrm{M})=1\) AND ORD \((\mathrm{M})=\mathrm{IC} \operatorname{maxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})]\), \(\operatorname{TICZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}) \$[O R D(\mathrm{M})=1 \mathrm{CmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})])\)
+ SUM((Z.J)\$[COLDZ(S,Z,J,M)=1AND ORD(M)<1CmaxZ(S,Z,J) AND ORD \((\mathrm{M})>=1 \mathrm{Cmin} Z(\mathrm{~S}, \mathrm{Z}, \mathrm{J})]\),
\(\left[\operatorname{TICZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})+(\mathrm{ICmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})-\mathrm{ORD}(\mathrm{M}))^{*} \mathrm{DT}(\mathrm{S}, \mathrm{M})\right] \$[\mathrm{ORD}(\mathrm{M})<\) \(\operatorname{ICmaxZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})\) AND ORD(M) \(=1 \mathrm{C} \cdot \min Z(\mathrm{~S}, \mathrm{Z} . \mathrm{J})])\} \$[\operatorname{COLD} 2(\mathrm{~S}, \mathrm{M})=1]\); FOR( \(\mathrm{lc}=1\) TO \(\mathrm{CARD}(\mathrm{FREEH})\),

DHH \((\mathrm{S}, \mathrm{I}, \mathrm{M}) \$[O R D(\mathrm{~S})=\) Si AND ORD(M)=Mi AND ORD \((\mathrm{l})=\mathrm{lc}\) AND \(\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1]=\mathrm{FH}(\mathrm{S}, \mathrm{I})^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M})^{*}[\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M})]\); ); FOR( \(\mathrm{Ji}=1\) TO CARD(FREEC), DHC \((\mathrm{S}, \mathrm{J}, \mathrm{M}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}\) AND ORD(M)=Mi AND ORD \((\mathrm{J})=\mathrm{Ji}\) AND COLD(S,J,M)=1]= FC(S,J)*CPC(S,J,M)*[TU(S,M)-TL(S,M)] ; )));
*ALLOW 2 MATCH ALLOWED BASED ON LMTD
*ALLOW \({ }^{-}\)HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I AND COLD STREAM J
*ALLOW_H HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM @@M AND COLD STREAM J
*ALLOW_C HEAT EXCHANGE IS PERMITTED BETWEEN HOT STREAM I AND COLD STREAM J@N
PARAMETER HHEAD (S,M,N), CHEAD(S,M,N), LMTD(S,M,N), D(S,Z,M,N)
ALLOW(S,Z,I,J). ALLOW_H(S,Z,I,M,J), ALLOW_C(S,Z,J,M,I), ALLOW_2(Z,l,J) ;
FOR( \(\mathrm{lc}=1\) TO CARD(FREEH), FOR( \(\mathrm{Ji}=1\) TO CARD(FREEC),
\(\operatorname{HHEAD}(S, M, N)=\{T U(S, M)-T U(S, N)+D T m i n\} \$[H O T 2(S, M)\) AND COLD2(S,N)]; \(\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{\mathrm{TL}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{N})+\mathrm{DTmin}\} \$[\mathrm{HOT} 2(\mathrm{~S}, \mathrm{M})\) AND COLD2(S,N)];
\(\operatorname{LMTD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{[\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})-\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})]\)
\(/\) LOG[HHEAD \((S, M, N) / C H E A D(S, M, N)]\} \$[\operatorname{HHEAD}(S, M, N)>0\)
AND CHEAD \((\mathrm{S}, \mathrm{M}, \mathrm{N})>0\) AND \(\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})>\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})]\)
\(+\{[\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})+\operatorname{CHEAD}(\mathrm{S} . \mathrm{M}, \mathrm{N})] / 2\} \$[\operatorname{HHEAD}(\mathrm{~S}, \mathrm{M}, \mathrm{N})>0\) AND CHEAD \((\mathrm{S}, \mathrm{M}, \mathrm{N})>0\) AND \((\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})<\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})\) OR \(\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N}))]\) :
}
```

        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)
            A.ND SUM[I$(HOT(S,I,M)=1),HOTZ(S,Z,l,M)]=1
        AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}];
    );;

* OR {LMTD(S,M,N)>0 AND SUM[I$(HOT(S,1,M)=1),HOTZ(S,Z,I,M)]=1
              AND SUM[J$(COLD(S,J,N)=1),COLDZ(S,Z,J,N)]=1}];
FOR(Si= 1 TO CARD(S),
FOR(Zi=1 TO CARD(Z),
FOR(Ic=1 TO CARD(FREEH),
FOR(Ji=1 TO CARD(FREEC),
ALLOW(S,Z,l,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(l)=lc
                  AND ORD(J)=Ji]= 0+1${SUM[(M,N)$[HOT(S,l,M)=1
                  AND COLD(S.J,N)=1],D(S,Z,M,N)]>0
                  AND NOT[HU(I)AND CU(J)]};
              FOR (Mi=1 TO NINT,
                  ALLOW_H(S,Z,I,M,J)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
AND ORD(J)=Ji AND ORD(M)=Mi
AND HOT(S,I,M)=1]= 0+
1${SUM[N$[COLD(S,J,N)=1],D(S,Z,M,N)]>0AND NOT[HU(I)AND CU(J)]};
ALLOW_C(S,Z,J,M,I)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=Ic
                  AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=1}=0+
              1${SUM[N$[HOT(S,I,N)=1],D(S,Z,N,M)]>0AND NOT[HU(I)AND CU(J)]};
                  )))));
FOR(Zi=1 TO CARD(Z),
  FOR(Ic=1 TO CARD(FREEH),
      FOR(Ji=1 TO CARD(FREEC),
          ALLOW_2(Z,1, ))S[ORD(Z)=Zi AND ORD(1)=Ic AND ORD(J)=Ji] = 0+
              1${SUM[S,ALLOW(S,Z,1,J)] >0 AND NOT[HU(I)AND CU(J)]};
)));
$offext
*-----------------
      TCOST
      PAR(Z,I,J)
      Q(S,Z,I,M,J,N) heat load for process-process match
      QNEW_M(S,Z,l,J,M)
      QNEW N(S,Z,I,J,N)
      QNEW2 M(S,Z,I,J,M)
      QNEW2_N(S,Z,I,J.N)
      Y M(S,Z,I,J,M)
      Y_N(S,Z,I,J,N)
      Y_M_B(S,Z,I,J.M)
      Y_N_B(S,Z,I,J,N)
      NHE_M0(S,Z,1,J,M)
      NHE M1(S,Z,I,J,M)
      NHE_N0(S,Z,I,J,N)
      NHE_Nl(S,Z,I,J,N)
      NHE M0 B(S,Z,l,J,M)
      NHE_M1_B(S,Z,IJ.M)
      NHE NO_B(S,Z,I,J,N)
      NHE_N1_B(S,Z,I,J,N)
      NHE(S,Z,I,J)
      ALFA_M(S.Z,I,J,M)
      ALFA_N(S,Z,I,J,N)
      FHU(I) is FCP HU (MJ_h_C)
      FCU(J) is FCP CU(MJ_h_C)
      B1(S,Z,I,M,J,N) X(imjn) in the paper
      QH(S,Z,l,M,N)
      QC(S,Z,J,M,N)
      Q2(S,Z,I,M,J,N)
      XI_B(S,Z,l,J,M)
      X_\overline{B}
      PAR_B(K,Z,I,J)
      USHELL(Z,I,J)
      USHELL_B(K,Z,I.J)
*$ontext

```


PAR_N(S,Z,I,J)
DPAR E(Z,l,J)
NHE S(S,Z,I,J)
DELT̄TA \((Z, I, J, R, R, K)\)
PHI(Z.I.J,R)
PAR_B_R(K,R,Z,I,J)
DPAR_E_B(K,R,Z,I,J)
PAR_N_B \((K, R, Z, I, J)\)
```

*\$offext
HOT_UTILITY_COST
Cold_UTILITY_COST
Area_Cost
FIX_COST
POSITIVE VARIABLE Q,QNEW2_M,QNEW2_N,QC,QH,Q2,PAR1,PAR2,DPAR_E,DPAR_E_B
,PAR N ,PAR N B,AEX,AEX B
,PAR,QNEW_M,\overline{QNEW_N},\,FIX_COST
BINARY VĀRIABLE N̄HE_M0_B,NHE_MI_B,NIIE_NO B.NHE_NI_B,Y_M,Y_N,XI_B,X_B,NHE_S
,I)ELTA,Y_M_B,Y_N_B,NHE_M0,NHE_MI,NHE_N0,NHE_N1,ALFA_M,ALFA_N
,PHI
INTEGER VARIABLE USHELL,USHELL_B

```

EQUATIONS
HBHU(S,I,M)
\(\operatorname{HBCU}(\mathrm{S}, \mathrm{J}, \mathrm{N})\)
HBHS(S,I,M)
HBCS(S,J,N)
TRANSFOR_M(S,Z,1,J,M)
TRANSFOR_N(S,Z,I,J,N)
HBHS_NI(S,I,M)
HBCS NI(S,J,N)
\(\mathrm{NOISOH}(S, I, M)\)
NOISOC(S.J,N)
BINARY_MI(S,Z,I,J,M)
BINARY M2(S,Z,I,J,M)
BINARY_MI_B(S,Z,I,J,M)
BINARY_M2_B(S,Z.I,J.M)
BINARY NI(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,l,J,N)
BINARY_N3(S,Z,l,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_MO(S,Z,I,J)
HE_COUNT NO(S,Z,l,J)
HE_COUNT_M1(S,Z,I.J)
HE_COUNT_NI(S,Z,1.J)
NEXCH (S, Z, \(1, \mathrm{~J})\)
NEXCH_B(S,Z,I,J)
```

BIF_1(S,Z,l,J,M,N)
BIF_2(S,Z,I_J,M,N)
BIF 3(S,Z,I,J,M,N)
BIF_4(S,Z,1,J,M,N)
BIF-11(S,Z,1,J,M)
BIF_6(S,Z,I,J,M)
BIF_9(S,Z,I,J,M)
BIF 5 (S,Z,I,J,M)
BIF_7(S,Z,I,J,N)
BIF 8(S,Z,I,J,N)
BIF_10(S,Z,I,J,N)
BIF_12(S,Z,I,J,N)
BIF_13_2(S,K,Z,1,J,M)
BIF_13_1(S,K,Z,1,J,M)
BIF 14(S,K,Z,I,J)
BIF-15(S,Z,I,J,M)
*BIF 16(S,Z,I,J,M)
BIF_17(S,Z,I,J,M)
BIF_18(S,Z,I,J,M,N)
FEAS_M_01(S,Z,I,J,M)
FEAS_M_01_B(S,Z,I,J,M)
FEAS M 02(S,Z,I,J,M)
FEAS_M_02_B(S,Z,I,J,M)
FEAS_M_03(S,Z,IJ,M)
FEAS_M_03_B(S,Z,I,J,M)
FEAS_M-04(S,Z,1,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,\overline{Z},1,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,1,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,1,J,M,N)
FEAS_BEG4_B(S,Z,I,J,M,N)
FEAS_BEG2_B(S,Z,I,J,M,N)
FEAS BEG1 B(S,Z,I,J,M,N)
FEAS_BEG3_B(S,Z,I,J,M,N)
FEAS END3 B(S,Z,I,J,M,N)
FEAS_END_B(S,Z,I,J,M,N)
FEAS_END2_B(S,Z,I,J,M,N)
PAREQ(S,Z,I,J)
SHELL(Z,I,J)
SHELL_B(K,Z.I_J)

```
```

KMAX1(S,Z,1,J)
KMAX2(S,Z,1,J)
TOTALCOST
TOTNEXCH MAX
TOTNEXCH_MIN
HOT_U_C
Cold U C
Area_C
FIX C

```
\$ontext
解
AREA_RESTI (S,Z,I,J)
AREA REST2(S,Z,IJ)
AREA_REST3(S,Z,I,J)
AREA REST1 B(S,K,Z,I,J)
AREA_REST2_B(S,K,Z,I,J)
AREA_REST3_B(S,K,Z,I,J)
AREA REST4_B(S,K,Z,I,J)
AREA_REST5_B(S,K,Z,I,J)
AREA REST6 B(S,Z,I,J)
ADD REST
ADD_REST2(S,I,J)
\$offlext
* \$ontext
****************************ADD FOR RELOCATION*******************************
RELOCATE_1(S,Z,1,J)
RELOCATE \(2(S, 2,1, \mathrm{~J})\)
RELOCATE 3(S,Z,I.J)
RELOCATE_4(S,Z,1,J)
RELOCATE 5 1(S,Z,I,J)
RELOCATE_5_2(S,Z, J,J)
RELOCATE_5_3(Z,R)
RELOCATE 6(K,R,S,Z,I,J)
RELOCATE_7(K,R,S,Z,I,J)
RELOCATE 8(K,R,S,Z,I.J)
RELOCATE_9(K,R,S,Z,I,J)
RELOCATE_10(K,R,S,Z,I,J)
*\$offlext
;
*EQ (1)
*HEAT BALANCE ON HEATING UTILITIES
\(\operatorname{HBHU}(\mathrm{S}, \mathrm{I}, \mathrm{M}) \$(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1\) AND HU(I) AND FREEH(1) AND ORD(M) LE NINT).
FHU(I)*(TU(S,M)-TL(S,M)) \(=\mathrm{E}=\mathrm{SUM}((\mathrm{Z}, \mathrm{N}, \mathrm{J}) \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{N})=1\) AND TL(S,N) LT TU(S,M)
AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\)
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)
\(\operatorname{HBCU}(\mathrm{S}, \mathrm{J}, \mathrm{N}) \$(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{~N})=1\) AND CU(J) AND FREEC(J) AND ORD(N) LE NINT).
\(\operatorname{FCU}(\mathrm{J}) *(\mathrm{TU}(\mathrm{S}, \mathrm{N})-\mathrm{TL}(\mathrm{S}, \mathrm{N}))=\mathrm{E}=\mathrm{SUM}((\mathrm{Z}, \mathrm{M}, \mathrm{I}) \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{N})=1\) AND TL(S,N) LT TU(S,M)
AND \(\operatorname{HOT}(S, 1, M)=1\)
AND ALLOW \(\mathrm{H}(\mathrm{S}, \mathrm{Z}, \mathrm{l}, \mathrm{M}, \mathrm{J})=1\) AND ALLOW \(\mathrm{C}(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N}, \mathrm{l})=1\) AND FREEH(I)),Q(S.Z.l,M.J,N));
*-- EQ (3)
HBHS(S,I,M)\$(HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=0 AND ORD(M) LE NINT).
\(\operatorname{DHH}(\mathrm{S} . \mathrm{I} . \mathrm{M})=\mathrm{E}=\mathrm{SUM}((\mathrm{Z}, \mathrm{N}, \mathrm{J}) \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{N})=1\) 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)
\(\operatorname{HBCS}(\mathrm{S}, \mathrm{J}, \mathrm{N}) \$(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{~N})=1\) AND NOT CU(J) AND FREEC(J) AND NIC(J)=0 AND ORD(N) LE NINT)
DHC(S.J.N \()=E=S U M((Z . M, I) \$(D(S, Z, M, N)=1\) AND TL(S.N) LT TU(S,M) AND HOT(S,I.M) \(=1\)
    AND ALLOW_H(S,Z,LM,J)=1 AND ALLOW_C(S,Z,J,N,I)=I), Q(S,Z,I,M,J,N));
* *-....--
TRANSFOR M(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND ALLOW H(S,Z,l,M,J)=1
    AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
    QNEW_M(S,Z,I,J,M) =E=SUM(N\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
```

AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N))
*EQ (6)
TRANSFOR_N(S,Z,1,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
QNEW_N(S.Z,l.J,N)=E=SUM(M$(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,1,M,J,N));
*EQ (7)
HBHS Nl(S,!,M)$(HOT(S,l,M)=I AND NOT HU(I) AND FREEH(I) AND NIH(I)=1
AND ORD(M) LE NINT).
DHH(S,l,M)=E=SUM((Z,N,J)$(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)=I 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)=I 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) LTTU(S,M) AND HOT(S,I,M)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,1)=1),Q(S,Z,I,M,J,N))
+SUM((Z,M)$(D(S,Z,M,N)=\ AND COLD(S.J,M)=1 AND ORD(M)LT ORD(N)),QC(S,Z,J,M,N))
SUM((Z.M)$(D(S,Z,M,N)=1 AND COLD(S.J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,N,M));
**-.--
NOISOH(S,l,M)$(HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(I)=1 AND ORD(M) LE NINT).
SUM((Z,N)$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M.N))
=L=SUM((Z,N,J)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,I,M,J,N));
*EQ (10)
NOISOC(S,J,N)$(COLD(S,J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=1
AND ORD(N) LE NINT).
SUM((Z,M)$(D(S,Z,M,N)=1 AND COLD(S,J.M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,N.M))
=L= SUM((Z,M,I)$(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,l)=1),Q(S,Z,l,M,J,N));
*EQ (11a and 13a) Case of BIF(1,J)=0 (i,j) not belonging to set B
BINARY_M1(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I.M.J)=1 AND BIF(Z,I,J) =0
    AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*DHH(S,I,M)$(NOT HU(I))
-Y_M(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)$(HU(I))=L=0;
*.
*EQ (11b and 13b) Case of BIF(l,J)=0 (i,j) not belonging to set B
****** ********** MINIMUM VALUE OF QNEW M=0.01!!!!!!!!!
BINARY_M2(S,Z,1,J,M)$(HOT(S,I,M)=1 AND ALLOW_Il(S,Z,I,M,J)=1 AND BIF(Z,IJ) =0 AND
FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I.J,M)-Y_M(S,Z,I.J,M)*QLHMIN=G=0;
*EQ (11a and 13a) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY_M1_B(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,l,M,J)=1 AND BIF(Z,1,J) =1
                                    AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)* DHH(S,I,M)$(NOT HU(I))
-Y_M_B(S.Z,l,J,M)*FMAX_HU(I)*DTHU(I)S(HU(I))=L=0;
*EQ (I1b and 13b) Case of BIF(I,J)=1 (i,j) belonging to set B
BINARY M2 B(S.Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN =G=0;
*EQ (12a and 14a) Case of BIF(I,J)=0 (i,j) not belonging to set B
BINARY NI(S,Z.I,J,N)$(COLD(S,J,N)=1 AND AI.LOW_C(S;Z,J.N.I)=1 AND BIF(Z.I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
QNEW_N(S.Z.I,J,N)-Y_N(S,Z,I,J,N)*DHC(S,J,N)$(NOT CU(J))
    -Y N(S,Z,l,J,N)*FMAX_CU(J)*DTCU(J)$(CU(J))=L=0;
*EQ ( 12 b and 14 b ) Case of BIF( $1, \mathrm{~J}$ )=0 ( $\mathrm{i}, \mathrm{j}$ ) 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.l,J) =0
AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,l,J,N)-Y_N(S,Z,I,J,N)*QLCMIN=G=0;

```
```

*EQ (12a and 14a) Case of BIF(1,J)=1 (i,j) belonging to set B
BINARY_N1_B(S,Z,l,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N.I)=1 AND BIF(Z,I.J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
    QNEW_N(S,Z,l,J.N)-Y_N_B(S,Z.I.J.N)*DHC(S,J;N)$(NOT CU(J))
-Y_N_B(S,Z.I.J,N)*FMAX_CU(J)*DTCU(J)$(CU(J))=L=0;
*--.-----------------------------------------------------------
BINARY_N2_B(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).* QNEW_N(S,Z.I,J,N)-Y_N_B(S,Z,I,J,N)*QLCMIN=G=0;
*
*EQ (15) NOT NEEDED

* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*.
*EQ (16)
BINARY_M5(S,Z.I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,I,M-I) AND ALLOW_H(S,Z,I.M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
N
*..
*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.J,M.J)=1
* AND ALLOW_H(S,Z,I,M,J)=1
BINARY_MSb(S,Z,I,J,M)\$(HOT(S,I.M)=lAND ALLOW_H(S,Z,I,M,J)=IAND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).. NHE_M0(S,Z.I.J.M) =L= Y_M(S,Z,I,J,M);
* IT TURNS OUT THAT THIS EQUATION ONLY FORCES THE VALUES OF K TO BE ZERO
* WHEN Y=0. WHICH HAPPENS NATURALLY IF ONE IS MNNIMIZING THE NUMBER OF
* EXCHANGERS OR BECAUSE THE FIXED COSTS ARE BEING MINIMIZED.
* EVEN IF NOT DRIVEN TO ZERO BY THE OBJECTIVE FUNCTION IT IS HARMELESS
* HOWEVER, IT TURNS OUT THAT IT COULD MAKE EXTENSIONS OF THE MODEL HAVE
* PROBLEMS. SO, ALTHOUGH THE EQUATION IS NOT NEEDED. IT GIVES SOME EXTRA VALUES
* OF K WHEN THEY DO NOT REALLY MATTER.
*EQ (18)
BINARY M3(S,Z.I,J.M)$(HOT(S,I,M)=1 AND ALLOW H(S.Z,I.M,J)=1 AND BIF(Z.l.J) =0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
  NHE_M0(S,Z,I,J,M)=G= Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M-1)$(HOT(S,I,M-1)
AND AlLOW_H(S,Z,I,M-1,J))
*EQ (19)
BINARY_M4(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,1_M,J)=1
AND ALLDOW H(S,Z:I,M-1.J) AND BIF(Z,1.J) =0 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
NHE_M0(S,Z,I,J,M)=G=0;
*----------------------------
* *Q (20) NOT NEEDED (GAMS WRITES IT AUTOMATICALLY WHENIT WRITES EQUATION (18)
* 

*EQ (21)
BINARY M8(S,Z,I,J,M)\$(HOT(S,I,M)=1 AND HOT(S,l,M+1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLLOW_H(S,Z,l,M+1,J) AND BIF(Z,l,J) =0 AND FREEH(l) AND FREEC(J) AND ORD(M) LE NINT).
N
*
*EQ (22) : ORIGINALLY NOT NEEDED, BUT ADDED TO ENFORCE K=0 WHEN Y=0

* AND HOT(S,I,M-i) AND ALLOW_H(S,Z,I,M-1,J)
BINARY_M9(S,Z,IIJ,M)\$(HOT(S,I,M)=IAND ALLOW_H(S.Z.I,M.J)=1AND BIF (Z,I,J) =0
AND FREEH(I)AND FREEC(J) AND ORD(M) LE NINT).
NHE_MI(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,1,J)=0
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..NHE_MI(S,Z,I,J,M)=G=Y_M(S,Z,I,J,M)-Y_M(S,Z,I.J,M+1)
$(HOT(S,1,M+1) AND ALLOW_H(S.Z.I.M+1.J)) :
*--------
BINARY_M7(S,Z,1,J,M)$(HOT(S,l,M)=1 AND HOT(S,l,M+1) AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z,1,M+1,J) AND BIF(Z,1,J) =0 AND FREEH(1) AND FREEC(J) AND ORD(M) LE NINT)..

```
```

NHE_MI(S.Z.I, J,M)=G=0;
*EQ (25)
B3INARY_M3_B(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,1,J) =1
AND FREEH(l) AND FREEC(J) AND ORD(M) LE NINT).
    Y_M_B(S,Z,I,J,M) =E=SUM(O$(HOT(S.1:O)=1 AND ORD(O) LE ORD(M)
AND ALLOW_H(S,Z:I,O,J)=1),NHE_M0_B(S,Z,1,J,O))

```

```

                AND ALLOW_H(S,Z,I,O.J)=1),NHE_M1_B(S.Z,l,J,O));
    *EQ (26) NOT NEEDED

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

*EQ (27)
BINARY_N5(S,Z,I,J,N)S(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-I,I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
NHE_N0(S,Z,1,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)=I AND ALLOW C(S.Z,J.N,I)=\ AND BIF(Z.l,J) =0
AND FREEH(l) 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,1,J)=0
AND FRE\overline{EH(I) AND FREEC(J) AND ORD(N) LE NINT).}
NHE_N0(S,Z,1,J,N) =G= Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N-1)
$(COLD(S,J,N-I) AND ALLOW_C(S,Z,J,N-1,1));
*--.------
BINARY N4(S,Z,I,J,N)$(COLD(S,J,N)=1 AND COLD(S.J,N-I) AND ALLOW_C(S,Z,J,N,I)=1
AND ALLLOW_C(S,Z.J.N-I.I) AND BIF(Z,I,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
NHE_N0(S,Z.l,J:N)=G=0;
*--------------------------
* GAMS WRITES IT AUTOMATICALLY WHENIT WRITES EQUATION (18)
*-...------
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 ALLLOW_C(S,Z,J,N+1,I) AND BIF(Z,l,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
NHE_NI(S,Z,l,J,N)=L=2-Y_N(S,Z,1,J,N)-Y_N(S,Z,l,J,N+1);
*EQ (33) NOT NEEDED BUT ADDED TO ENFORCE K=0 WHEN Y=0
* AND COLD(S,J,N-I) AND ALLOW_C(S,Z,J,N-1,I)
BINARY N9(S,Z,I,J,N)\$(COLD(S,J,N)=1 ÄND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
NHE_Nl(S,Z,I,J,N) =L = Y_N(S,Z,I,J,N);
* SEE COMMENTS ON EQUATION (17)
*---------
BINARY_N6(S,Z,I,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,1,J) =0
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).
NHE_Nl(S,Z,l,J,N)=G=Y_N(S,Z,I,J,N)-Y_N(S,Z,I,J,N+1)
$(COLD(S,J,N+1) ĀND AI.LOW_C(S.Z.J.N+1.I));
*EQ (35)
BINARY N7(S,Z,I,J,N)$(COLD(S.J,N)=1 AND COLD(S.J,N+1) AND ALL.OW_C(S.Z.J,N,I)=1
AND AL\overline{LOW_C(S,Z,J,N+1,l) AND BIF(Z,1,J) =0 AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT).}
NHE_NI(S,Z,I,J,N)=G=0;
* 

*EQ (36)
BINARY_N3_B(S,Z,I.J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z.J,N,l)=1 AND BIF(Z,I,J) =1
AND FREEH(I)AND FREEC(J) AND ORD(N) LE NINT).
Y_N_B(S,Z,I,J,N)=E=SUM(O$(COLD(S,J,O) AND ORD(O) LE ORD(N)
AND ALLOW_C(S,Z,J,O,l)),NHE_N0_B(S,Z,l,J,O)) - SUM(O\$(COLD(S,J,O) AND ORD(O) LE
ORD(N)-1 AND AlLOW_C(S,Z,J,O,I)),NHE_NI_B(S,Z,l,J,O));

```
```

*EQ (37)
HE_COUNT_M0(S,Z,I.J)$(ALLOW(S,Z,I,J)=I AND FREEH(I) AND FREEC(J)).
NHE(S,Z,l,J)=E=SUM(M$(HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,l,J) =1),
NHE_M0_B(S,Z,l.J,M)) + SUM(M$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND BIF(Z l,J) =0), NHE_M0(S,Z,l,J,M));
*..-
*
*EQ (38)
HE_COUNT_N0(S,Z,l,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(1) AND FREEC(J))..
NHE(S,Z,l,J)=E=SUM(N\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,l)=1 AND BIF(Z,1,J) =1),
NHE N0 B(S,Z,1,J,N))

+ SUM(N$(COLD(S,J;N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I.J) =0).
              NHE_NO(S,Z,1,J,N);
*EQ (39)
HE_COUNT_MI(S,Z,I,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
NHE(S,Z,I,J)=E=SUM(M$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,1,J)=1),
NHE_M1_B(S,Z,I,J,M)) + SUM(M$(HOT(S,I.M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND BIF(Z.l.J) =0), NHE MI(S,Z,l,J,M));
*EQ (40)
HE_COUNT_NI(S.Z,I,J)$(ALLOW(S,Z,l.J)=1 AND FREEH(I) AND FREEC(J)).
NHE(S,Z,I,J)=E=SUM(N$(COLD(S,J,N)=1 AND ALLOW_C(S,Z.J,N,I)=1 AND BIF(Z,1,J) =1),
NHE Nl 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,l.J) =0), NHE_NI(S,Z.I.J,N));
* 

*EQ (41)
NEXCH(S,Z,1,J)$(ALLOW(S,Z,l.J)=1 AND BIF(Z,l,J) =0 AND FREEH(l)
    AND FREEC(J)).NHE(S,Z,1,J)=L=1;
*----.---
    NEXCH B(S,Z,I,J)$(ALLOW(S,Z,1,J)=1 AND BIF(Z,1,J) =1 AND FREEH(I)
AND FREEC(J))..NHE(S,Z,1,J)=l=KMAX(Z,l,J);
*EQ (43)
BIF 1(S.Z,l,J,M,N)$(D(S.Z,M,N)=1 AND TL(S,N) LT TU(S.M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND
ALLOW H(S,Z,I,M,J)=1 AND ALLOW C(S,Z,J,N,I)=IAND BIF(Z,1,J) =1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT AND ORD(N) LE NINT).
SUM(LS(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S.I,L)=1
    AND ALLOW_H(S,Z,I.L,J)=1),
    QNEW M(S,Z.I.J.L)) - QNEW2 M(S.Z.I.J.M) =L=
SUM(O$(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)
+ Bl(S,Z,\overline{l},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$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N)
AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,1)),DHC(S,J,O)));
*EQ (44)
BIF_2(S,Z,I,J,M,N)$(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,1,M,J)=1 AND ALLOW_C(S.Z,J,N,I)=1 AND BIF(Z,I,J) = 1 AND FREEH(I)
    AND FREEC(J) AND ORD(M) LE NINT AND ORD(N) LE NINT).
    SUM(L$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S.I,L)=1
AND ALLOW_H(S,Z,I,L,J)=1),
QNEW M(S,Z,l,J,L)) - QNEW2_M(S,Z.l,J,M) =G=
SUM(O$(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)
    -BI(S,Z.I,M,J,N) *4* max(SUM(LS(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
    AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,1,L,J)=1),DHH(S,I,L)),
    SUM(O$(D(S,Z,M,O)=1 AND ORD(O) LE ORD(N) AND COLD(S,J,O)
AND ALLOW_C(S,Z,J,O,I)),DHC(S,J,O)));
*.
*EQ (45)
BIF_3(S,Z,I,J,M,N)$(D(S,Z,M,N)=1 AND TL(S.N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z.I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
Bl(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_MI_B(S,Z,I,J,L))

```
```

    +0.25 *SUM(O$(D(S,Z,M,O)=1 AND ORD(O)LE ORD(N) AND COLD(S,J,O)
    AND ALLOW_C(S,Z,J,O,l)),NHE_N1_B(S,Z,I,J_O))
                -NHE_MI_B(S,Z,I.J.M)-NHE_NI_B(S,Z.I.J.N);
    *.
*EQ (46)
B1F_4(S,Z,l,J,M,N)$(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) AND ORD(M) LE NINT
AND ORD(N)).
SUM(L$(HOT(S,l,L)=1 AND ORD(L) LE ORD(M) AND
ALLOW_H(S,Z,I,L,J)=1),NHE_M1_B(S,Z,I,J,L))
-SUM(O\overline{$}(COLD(S,J,O) AND ORD(O)LE ORD(N) AND ALLOW_C(S,Z,J,O.l)),
                                    NHE_NI_B(S.Z,I,J,O))=G=0;
*
*EQ (47)
BIF_11(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S.Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
SUM(O$(HOT(S,1,O)=1 AND ORD(O) LE ORD(M) AND ALLOW_H(S,Z,1,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)$(COLD(S,J,N)=1 AND ALLOW C(S,Z.J,N,I)=1 AND BIF(Z.I.J) =1
AND FREEH(I)AND FREEC(J) AND ORD(N) LENINT).
SUM(O$(COLD(S.J,O) AND ORD(O) LE ORD(N) AND ALLOW C(S,Z,J,O,l)),
                                    NHE_N0_B(S,Z,1,J,O)-NHE_N1_B(S,Z,I,J,O))= - = =1;
*
*EQ (49)
BIF_6(S,Z,1,J,M)$(HOT(S,I,M)=1 AND ALLOW/H(S,Z,1,M,J)=1 AND BIF(Z,1,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
QNEW2_M(S.Z,I.J,M) =L= QNEW M(S.Z.I.J.M);
*
*EQ (50)
BIF 9(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S.Z.I,M,J)=1 AND BIF(Z,I.J) =1
AND FREEH(I)AND FREEC(J) AND ORD(M) LE NINT)..
                                    QNEW2_M(S,Z,I,J,M) =L= NHE_M0_B(S,Z,I,J,M)*DHH(S.I,M);
*
*EQ (51)
BIF_5(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M.J)=1AND BIF(Z.IJ)=1
AND FREEH(I)AND FREEC(J) AND ORD(M) LE NINT).
QNEW2_M(S,Z,I,J,M) =L=NHE_MI_B(S,Z,I,J,M)*DHH(S,1,M);
*
*EQ (52) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE
*----------
*EQ (53)
BIF_8(S,Z,1,J,N)$(COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,1,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
                            QNEW2_N(S,Z,I,J,N) =L= QNEW_N(S,Z,I,J,N);
*EQ (54)
BIF_10(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NNT)..
QNEW2_N(S,Z,I,J,N) = L= NHE_N0_B(S,Z,I,J,N)*DHC(S,J,N);
*EQ (55)
BIF_7(S,Z,I,J,N)$(COLD(S,J,N)=1 AND AI.LOW_C(S.Z.J,N,I)=I AND BIF(Z,1,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(N) LE NINT)..
    QNEW2_N(S,Z,I,J,N)=l=NHE_NI_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.1,J) =0 AND SPH(1)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
ALFA_M(S,Z,I,J,M)=L=1-NHE_M0(S,Z,1.J,M-1)-NHE_M0(S,Z.I,J,M);

```
FEAS M \(01 \mathrm{~B}(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{J}, \mathrm{M}) \$(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}-1)\) AND \(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1\) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_ \(1(S, Z, 1, M-1, \mathrm{~J})\) AND \(\operatorname{BIF}(\mathrm{Z}, \mathrm{I}, \mathrm{J})=1\) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
    ALF.A_M(S,Z,1,J.M)=L=1-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M);
```

* *----.-.-
FEAS_M_02(S,Z,1,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z.I,M.J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,l,J) =0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
          ALFA_M(S,Z,I,J,M)=L=1-NHE_MI(S,Z,I,J,M-1)-NHE_MI(S,Z,I.J,M);
FEAS_M_02_B(S,Z,1,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 ANDD ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) = 1 AND FREEH(1) AND FREEC((J))
ALFA_M(S,Z:I,J,M)=L=1-NHE_M1_B(S,Z,l,J,M-1)-NHE_MI_B(S,Z,I,J,M);
*EQ (59)
FEAS_M_03(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z.I,M.J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J) =0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
  ALFA_M(S,Z,I,J,M)=G=Y_M(S,Z,l,J,M)-NHE_M0(S,Z,I,J,M-I)-NHE_M0(S.Z,I,J,M) -
      N-NHE_M1(S,Z,1,J,M-1)-NHE_M1(S,Z,I,J,M);
FEAS_M_03_B(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z,1,M-1,J) AND BIF(Z,1,J) = I AND FREEH(1) AND FREEC(J))..
ALFA_M(S,Z,I,J,M)=G=Y_M_B(S,Z,1,J,M)-NHE_M0_B(S,Z,1,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,IM);
*-
*EQ (60)
FEAS_M_04(S,Z,I,J,M)$(HOT(S,1,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S.Z,I,M,J)=1 AND
ALLOW_-H(S,Z,I,M-1,J) AND (BIF(Z,1,J)=1 OR SPH(I)=1)AND FREEH(1)
      AND FREEC(J) AND ORD(M) LE NINT).
                                  ALFA_M(S,Z,1,J,M)=G=0;
*.-
*EQ (61)
FEAS_M_2(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1/AND FREEH(I) AND FREEC(J)
AND ORD-(M) LE NINT)..
QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) = L=
QNEW_M(S,Z,\J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
+(1-ALFFA_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,1,J,M)$(HOT(S,1,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z.I,M.J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J)).
    QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
    +(1-ALFA M(S,Z,I,J,M))*DHH(S,I,M)/(CPH(S,l,M)*(TU(S,M)-TL(S,M)))
            =G= QNEW_M(S,Z,1,J,M-1)/(CPH(S,1,M-1)*(TU(S,M-1)-TL(S,M-1)));
*
*EQ (63)
FEAS_M_3(S,Z,l,J,M)$(HOT(S,l,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z,l,M,J)=1
AND ALLOW H(S,Z,l,M-1,J) AND BIF(Z,l,J) =0 AND SPH(l)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT).
- QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
+ QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
+(1+ NHE_M1(S,Z,I,J,M-1) + NHE_M1(S,Z,I,J,M) - NHE_M0(S,Z,I,J,M-1))
*DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))* 1.00001 =G=0;
*

* EQ (64)
FEAS M 4(S,Z,I,J,M)\$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALL`OW H(S,Z.I.M-1,J) AND BIF(Z,l,J) =0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT)..
    - QNEW_M(S,Z,I,J.M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
    + QNEW M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-I)-TL(S,M-1)))
+(1+ NHE_M0(S.Z.I,J.M-I)+NHE_M0(S,Z,I,J,M)-NHE_Ml(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)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALL'OW_H(S,Z,1,M-1,J) AND BIF(Z,1,J) =1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND ORD(M) LE NINT).
QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
    +(I+NHE_M1_B(S.Z.I,J.M-1)+NHE_M1_B(S.Z,I,J,M)-NHE_M0_B(S,Z,I.J,M-1))
    * DHH(S,1,M)/(CPH(S,I,M)*(TU(S,\overline{M})-T-T(S,M)));
*
*EQ (66)
FEAS_M_3_B_l(S,Z.I,J.M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ^LLOW_H(S,Z,I.M,J)=1

```

```

*EQ (74)
FEAS_N_1(S,Z,1,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z.J.N.I)=1
AND ALLOW_C(S,Z,J,N-1,l) AND SPC(J)=I AND FREEH(I) AND FREEC(J))..
    QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
        +(I-A}LFA_N(S,Z,I.J,N))*DHC(S.J,N
    /(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=QNEW N(S,Z,I,J,N-1)/
                                    (CPC(S,J,N-1)*(TU(S,N}-1)-TL(S,N-1)))
*EQ (75)
FEAS_N_3(S,Z,l,J,N)$(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(l)
AND FREEC(J)
-QNEW N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-I)))
+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(1+NHE_N1(S,Z,1,J,N-1)
+NHE Nl(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)))*!.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 ALLLOW_C(S,Z,J,N-1,I) AND BIF(Z,l,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,1,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+(1+NHE_NO(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)$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND Al.l.OWW C(S,Z,J,N,I)=1
AND ALLOW C(S,Z,J,N-1,I) AND BIF(Z,I,J) = I AND SPC(J)=1 AND FREEH(I)
AND FREEC(J)).
-QNEW N(S,Z,1,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+QNEW N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+(1 + NHE_N1_B(S,Z,1,J,N-1)+ NHE_N1_B(S,Z,1,J,N)-NHE_N0_B(S,Z,1,J.N-1))
    *DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0
*
*EQ (78)
FEAS_N 3 B_1(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND ALLOWW 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_NI_B(S,Z,I,J,N)
-NHE_N0_B(S,Z,1,J,N-1)-Y_N_B(S,Z,1,J,N-1))
*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0
*-----.--
FEAS N 4 B(S,Z,l,J,N)$(COLD(S,J,N-I) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLDOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J) =1 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J)).
    -(QNEW_N(S,Z,I,J,N)-QNEW2_N(S,Z,I,J,N))/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
    + QNEW N(S,Z,1,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
    +(2 + NHE N0 B(S,Z,I,J,N-1) -NHE N1_B(S,Z,I,J,N)-Y_N_B(S,Z,I,J,N))
                                    * DHC(S,J,N)/(CPC}(\textrm{S},\textrm{J},\textrm{N})*(TU(S,N)-TL(S,N,N)))=G=0
*
*EQ (80)
    FEAS N 1_SP(S,Z,I,J,N)$(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)=I AND ALLOW_C(S,Z,J,N-1,l) AND ALLOW_C(S,Z,J,N+1,l)
AND BIF
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,l,J,N)-NHE_NI(S,Z,I,J,N))*DHC(S,J,N);
FEAS N I SP_B(S,Z,I,J,N)$(COLD(S,J,N-I) AND COLD(S.J,N)=1 AND COLD(S:J,N+1)
    AND ALLLOW - C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-I,I) AND ALLOW_C(S,Z,J,N+1.I)
    AND BIF(Z,1,J)=1
    AND SPC(J)=0 AND FREEH(I) AND FREEC(J)).. QNEW N(S.Z,I,J,N) =G=
        (Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,l,J,N)-NHE_N1_B(S,Z,1,J,N))*DHC(S.J,N);
*---------
FEAS_BEG_SP(S,Z.I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)

```

AND \(\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1\) AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S.Z,I.M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z.l,J) \(=0\)
AND SPH \((\mathrm{I})=0\) AND \(\operatorname{SPC}(\mathrm{J})=0\) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
+ QNEW_M(S,Z,I,J,M)/(FH(S,, \(\left.\mathbf{I})^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M})\right)\)
\(+\left(2-N H E \_M 0(S, Z, 1, J, M)-N H E \_N 0(S, Z, 1, J, N)\right) * T U(S, N)=G=0\);
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 \(\operatorname{HOT}(\mathrm{S}, \mathrm{l}, \mathrm{M})=1\) AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H \((\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=1\)
AND ALLOW_C(S,Z, \(; \mathrm{N}, \mathrm{l})=1\) AND BIF \((\mathrm{Z}, \mathrm{l}, \mathrm{J})=1\)
AND \(\operatorname{SPH}(\mathrm{I})=0\) AND SPC( J\()=0\) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
TL(S,M) - TL(S,N) -QNEW N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
+ QNEW_M(S,Z,l,J,M)/(FH(S.I)*CPH(S,I,M))
\(+\left(2-N H E \_M 0 \_B(S, Z, 1, J, M)-N H E \_N 0 \_B(S, Z, 1, J, N)\right) * T U(S, N)=G=0\);
*----------
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 \(\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1\) AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S,Z, \(1, M, \mathrm{~J})=1\)
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF \((Z, I, J)=0\)
AND SPH \((\mathrm{I})=0\) AND SPC \((\mathrm{J})=0\) AND FREEH \((\mathrm{I})\) AND FREEC \((\mathrm{J})\)
AND ORD(M) LE NINT).. TU(S,M)-TU(S,N)
- QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) +QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N)) \(+\left(2-N H E \_M 1(S, Z, 1, J, M)-N H E \_N 1(S, Z, 1, J, N)\right)^{*} T U(S, N)=G=0\);
FEAS_END_B_SP(S,Z,I,J,M,N)\$(TL(S,N) LETU(S,M) AND TU(S,N) GE TL(S,M)
AND \(\operatorname{HOT}(\bar{S}, 1, M)=1\) AND COLD \((S, J, N)=1\) AND ALLOW_H \((S, Z, I, M, J)=1\)
AND ALLOW_C(S,Z,J,N,l)=1 AND BIF \((Z, I, J)=1\)
AND \(\operatorname{SPH}(\mathrm{I})=0\) AND SPC \((\mathrm{J})=0\) AND FREEH(1) AND FREEC(J))..TU(S,M)-TU(S,N)
-QNEW _M \((\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}) /\left(\mathrm{FH}(\mathrm{S}, \mathrm{I})^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M})\right)+\mathrm{QNEW}\) N(S,Z,I,J,N)/(FC(S.J)*CPC(S,J.N)) \(+\left(2-N H E \_M 1 \_B(S, Z, I, J, M)-N H E \_N 1 \_B(S, Z, I, J, N)\right)^{*} T U(S, N)=G=0\);
*
*---------
FEAS_BEG3(S,Z,I,J,M,N)\$(DTVIO(1,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,l,M)=1 AND \(\operatorname{HOT}(\mathrm{S}, \mathrm{l}, \mathrm{M}+1)\) AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N}+1)\) 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+1,1) \(\operatorname{AND} \operatorname{BIF}(\mathrm{Z}, \mathrm{I}, \overline{\mathrm{J}})=0\) AND \((\mathrm{SPH}(\mathrm{I})=1 \mathrm{OR} \mathrm{SPC}(\overline{\mathrm{J}})=1)\) AND FREEH \((\mathrm{I})\) AND FREEC( J\()\) AND ORD(M) LE NINT).

NHE_N1(S,Z.I.J,N \()=\mathrm{L}=(2-\mathrm{NHE} M 0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})-\mathrm{NHE}\) NO(S, Z,I.J,N \()\) );
*
*EQ (84)
FEAS_BEG(S,Z,I,J,M,N)\$(DTVIO(1,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,l,M)=1 AND HOT(S,l,M+1) AND COLD(S, J,N)=1 AND COLD \((S, \mathrm{~J}, \mathrm{~N}+1)\) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,L,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 \((\mathrm{J})=1)\) AND FREEH( I\()\) AND FREEC( J\()\) AND ORD(M) LE NINT).. QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1) \(/(\mathrm{TU}(\mathrm{S}, \mathrm{N}+1)-\mathrm{TL}(\mathrm{S}, \mathrm{N}+1))^{*} \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}) / \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}+1)\)
+(2-NHE_M0(S,Z,I,J,M)-NHE_NO(S,Z,I,J,N))*DHC(S,J,N)/(TU(S,M)-TL(S,N));
*EQ (85)
FEAS_BEG2(S,Z,1,J,M,N)\$(DTVIO(1,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,l,M)=1 AND HOT(S,I.M+1) AND COLD(S,J,N)=1 AND COLD(S, J,N+I)
AND ALLOW \(\mathrm{H}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=\mathrm{I}\) 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( \((\mathbf{J})=1)\)
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
QNEW_M(S,Z,l,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=
QNEW_M(S,Z,1,J,M+1)/(TU(S,M+1)-TL(S,M+1))
\({ }^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{l}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}+1)-(2-\mathrm{NHE} \mathrm{M} 0(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{J}, \mathrm{M})-\mathrm{NHE} \mathrm{N} 0(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{J}, \mathrm{N}))\) * \(\mathrm{DHH}(\mathrm{S}, \mathrm{I}, \mathrm{M}+1) /(\mathrm{TU}(\mathrm{S}, \mathrm{M}+1)-\mathrm{TL}(\mathrm{S}, \mathrm{M}+1))\);
*
*EQ (86)
FEAS_END3(S,Z,I,J,M,N)\$(DTVIO(1,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, \(1, \mathrm{M})=1\) AND HOT(S,l,M-1) AND COLD(S, J,N \()=1\) AND COLD(S, J,N-1) AND ALLOW \(\mathrm{H}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=1\) AND ALLOW_H(S,Z,I,M-I,J)AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S.Z,J.N-I,I) \(\operatorname{AND} \operatorname{BIF}(\mathrm{Z}, \mathrm{I}, \overline{\mathrm{J}})=0\) AND \((\mathrm{SPH}(\mathrm{I})=1\) OR SPC \((\mathrm{J})=1)\) AND FREEH(I) AND FREEC( J\()\) AND ORD(M) LE NINT).

NHE_M0(S,Z,I,J,M)=L=(2-NHE_MI(S,Z,I.J,M)-NHE_N1(S.Z,I,J,N));
*.
*EQ (87)
FEAS_END(S,Z,IJ, 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) ANI) HOT(S,I,M)=1 AND HOT(S,I,M-I) 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-I,I) AND BIF (Z,I,J) =0 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT). QNEW_M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW_M(S,Z,I.J,M-1)/(TU(S,M-1)-TL(S,M-1)) \({ }^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}-1)+(2-\mathrm{NHE} M 1(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{J}, \mathrm{M})-\mathrm{NHE}, \mathrm{Nl}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N}))\) *DHH(S,1,M)/(TU(S,M)-TL(S,N));
*
*EQ (88)
FEAS_END2(S,Z,I,J,M,N)\$(DTVIO(1,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( \(\overline{\mathrm{I}})\) AND FREEC(J) AND ORD(M) LE NINT). QNEW_N(S,Z,I,J,N)/(TU(S,N)-MAX(TL(S.M),TL(S,N)))=G=QNEW_N(S,Z,I,J,N-I)/ (TU(S, \(\overline{\mathrm{N}}-1)-\mathrm{TL}(\mathrm{S}, \mathrm{N}-1))\)
*CPC(S,J,N)/CPC(S,J,N-1)-(2-NHE_M1(S,Z,I,J,M)-NHE_N1(S,Z,1,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,l,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 ALI.OW_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) \(\operatorname{AND} \operatorname{BIF}(\mathrm{Z}, \mathrm{I}, \overline{\mathrm{J}})=1 \mathrm{AND}(\mathrm{SPH}(\mathrm{I})=1 \mathrm{OR} \mathrm{SPC}(\mathrm{J})=1)\) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
NHE_N1_B(S,Z, \(1, \mathrm{~J}, \mathrm{~N})=\mathrm{I}=\)
(1+Y_N_B(S,Z,1,J,N)-NHE_M0_B(S,Z,l,J,M)-NHE_N0_B(S,Z,l,J,N));
*
*EQ (90)
FEAS_BEG2_B(S,Z,I,J,M,N)\$(DTVIO(1,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,1,M+1) AND COLD(S,J,N)=1 AND COLD \((\mathrm{S}, \mathrm{J}, \mathrm{N}+1)\) AND ALLOW \(\mathrm{H}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=1\) AND ALLOW \(\mathrm{H}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}+1, \mathrm{~J})\) AND ALLOW C(S,Z. J, N, I)=1 AND ĀLLOW C(S,Z, \(, \mathrm{N}+1,1)\) AND BIF \((\mathrm{Z}, \mathrm{l}, \mathrm{J})=1\) AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND ORD(M) LE NINT). QNEW_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=
QNEW_N(S,Z,1,J,N+1)/(TU(S,N+1)-TL(S,N+1))
*CPC(S,J,N)/CPC(S,J,N+1)+
( \(1+\mathrm{Y}\) N B \(\left.(S, Z, I, J, N)-N H E_{-} M 0 \_B(S, Z, I, J, M)-N H E_{-} N 0 \_B(S, Z, 1, J, N)\right)\)
* \(\mathrm{DHC}(\mathrm{S}, \mathrm{J}, \mathrm{N}) /(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{N})\) );
*-
*EQ (91)
FEAS_BEG1_B(S,Z,I,J,M,N)\$(DTVIO(1,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND TU(S, \(\bar{N})\) GT TL(S,M) AND HOT(S, \(1, M)=1\) AND HOT(S,1,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 ĀLLOW_C(S,Z,J,N+1,I) AND BIF \((Z, I, J)=1\) AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(l) AND FREEC(J) AND ORD(M) LE NINT).. QNEW2_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+l)/ (TU(S,N+1)-TL(S,N+1))
* \(\mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}) / \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}+1)+\left(2-\mathrm{NHE} M 0 \_B(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})-\mathrm{NHE} \mathrm{N} 0 \_B(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})\right)\)
*DHC(S,J,N)/(TU(S,M)-TL(S,N));
*-
*EQ (92)
FEAS_BEG3_B(S,Z,1,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,l,M+1) AND COLD(S,J,N)=1 AND COLD \((\mathrm{S}, \mathrm{J}, \mathrm{N}+1)\) 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 A-ALOW_C(S,Z,J,N+1,I) AND BIF(Z,, J\()=1\) AND (SPH(1)=1 OR SPC(J)=1) AND FREEH (1) AND FREEC(J) AND ORD(M) LE NINT) QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S.M))=G=QNEW_M(S,Z,I,J,M+1)/ (TU(S,M+1)-TL(S,M+1))
* \(\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, 1, \mathrm{M}+1)-\left(2-\mathrm{NHE} \mathrm{M}_{-}\right.\)- \(\left.\mathrm{B}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})-\mathrm{NHE} \mathrm{N} 0 \_B(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})\right)\) \({ }^{*} \operatorname{DIIH}(\mathrm{~S}, \mathrm{I}, \mathrm{M}+1) /(\mathrm{TU}(\mathrm{S}, \mathrm{M}+1)-\mathrm{TL}(\mathrm{S}, \overline{\mathrm{M}}+1))\);
*EQ (93)
FEAS_END3_B(S,Z,l,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 \(\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}-1)\) AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N}-1)\)
```

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-I,I)
AND BIF(Z.1.J) =1 AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)
AND ORD(M) LE NINT).
NHE_M0_B(S,Z,1,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,1.J,N));
*EO------
FEAS_END_B(S,Z,I,J,M,N)$(DTVIO(1,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
    AND TU(S,N) GT TL(S,M) AND HOT(S,l,M)=1 AND HOT(S,I,M-1) AND COLD(S,J.N)=1
    AND COLD(S,J,N-1) AND ALLOW_H(S,Z,1,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
    AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,1,J) =1
    AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
    (QNEW_M(S,Z,I,J,M)-QNEW2_M(S,Z.1,J,M))/(TU(S,M)-TL(S,N))=L=
    QNEW M(S,Z,I,J,M-1)/
    (TU(S,M-1)-TL(S,M-1))* CPH(S,I,M)/CPH(S,l,M-1)+
    (2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,1,J,N))*DHH(S,I,M)/(TU(S,M)-TL(S,N));
*EQ (95)
FEAS END2 B(S,Z,I,J,M,N)$(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,l,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,l)=1 AND AILLOW C(S.Z,J.N-1,I) AND BIF(Z,I.J) =1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND ORD(M) LE NINT).
(QNEW_N(S,Z,l,J,N)-QNEW2_N(S,Z,I,J,N))/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=
QNEW_N(S,Z,1,J,N-1)/(TU(S,N-I)-TL(S,N-1))*CPC(S,J,N)/CPC(S,J,N-1)
-(2-NHE__Ml_B(S,Z,I,J,M)-NHE_N1_B(S,Z,1,J,N))*DHC(S,J,N-1)/
(TU(S,N-1)-TL(S,N-1));
*EQ (96)
PAREQ(S,Z,l,J)$(ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J))..
PAR(Z,1,J)=E=SUM((M,N)$(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)*(I/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)$(ORD(K) LT KMAX(Z.I,J) AND HOT(S,I,M)=1
    AND ALLOW_H(S,Z,I,M,J)=1
    AND BIF(Z,I,J)}=1\mathrm{ AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
    PAR B(K,Z,I,J)=L= SUM((L,N)$(D(S,Z.L.N)=1 AND ORD(L) LE ORD(M)
AND'TL(S,N) LT TU(S,L)
AND HOT(S,l,L)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,l,L,J)=1
AND ALLOW_C(S,Z,J,N,l)=1),
(Q(S,Z,I,L,J,N)-Q2(S,Z,l,L,J,N))*(1/H_l(S,I,L)+1/H J(S,J,N))/LMTD(S,L,N))
+AMAX*(2-NHE_M1 B(S,Z,I,J,M)-XI_B(S,Z_I,J,M)-
SUM(KK\$(ORD(K\overline{K}) GT}1\mathrm{ AND ORD(KK}) LT ORD(K)),PAR_B(KK,Z,1,J)));
*Comment: In the paper X1_B does not show. Only one variable, X_B is used

* to make summations from 1 to kmax-1. Here we use X1_B and then a
* summation from 2 to kmax-1. See equation (100) as well.
*EQ (98)
BIF 13 l(S,K,Z,I,J,M)$(ORD(K) LT KMAX(Z,l.J) AND HOT(S,I,M)=1
  AND ALLLOW_H(S,Z,I,M,J)=1
  AND BIF(Z,I,J) =1 AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT)..
  PAR_B(K,Z,I,J)=G=SUM((L,N)$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
AND TL(S,N) LT TU(S,L)
AND HOT(S,I,L)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,l,L,J)=1
AND ALLOW_C(S,Z,J,N,I)=1),
(Q(S,Z,I,L,J,N)-Q2(S,Z,1,L,J,N))*(1/H_l(S,1,L)+1/H_J J(S,J,N))/LMTD(S,L.N))
-AMAX*(2-NHE Ml B(S,Z,I,J,M)-X1 B(S,Z,I,J,M)-
SUM(KK$(ORD(K\overline{K}) GT I AND ORD(K\overline{K}) LT ORD(K)),PAR_B(KK,Z,I.J)));
*...
*EQ (99)
  BIF_14(S,K,Z,I,J)$(ORD(K) EQ KMAX(Z.I.J) AND ALLOW(S,Z,I.J)=l AND FREEH(I)
AND FREEC(J) AND BIF(Z,I,J) = 1).
PAR_B(K,Z,I,J)=G=PAR(Z,1.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,l.M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,1,J) =1
AND

```
```

    X1_B(S,Z,1, l,M)+SUM(K$(ORD(K) GT I AND ORD(K) LE KMAX(Z,1,J) ),
    ORD(K)*X_B(S,K,Z,I,J,M))=E=SUM(LS(HOT(S,l,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 I to kmax-1. Here we use XI_B and then a
* summation from 2 to kmax-1.
*EQ (101)
BIF_17(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J) =1
AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
SUM(N$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1 AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=l),Q2(S,Z,l,M,J,N))=E=
QNEW2_M(S,Z,I,J,M);
* 

*EQ (102)
BIF_18(S,Z,l,J,M,N)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,l,J) = \ AND FREEH(I) AND FREEC(J) AND ORD(M) LE NINT).
                            Q2(S,Z,l,M,J,N)=L=Q(S,Z,I,M,J,N);
*.
*EQ (103)
SHELL(Z,1,J)$(SUM[S,ALLOW(S,Z,I.J)]>= I AND FREEH(I) AND FREEC(J)
AND BIF(Z,l,J)=0)..
PAR(Z,I,J)=L=ASHELLMAX*USHELL(Z,I.J);
*EQ (104)
SHELL B(K,Z,1,J)$(SUM[S,ALLOW(S,Z,I,J)]>= | AND FREEH(1) AND FREEC(J)
AND BIF(Z,1,J)=1).
PAR_B(K,Z,I,J)=L=ASHELLMAX*USHELL_B(K,Z,1,J);
*EQ (105)
TOTALCOST.. TCOST =E= SUM(IS(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
    + SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
$ontext
    + SUM((Z,I,J)$(OPT=0 AND SUM[S,AILLOW(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,1,J)$(OPT=0 AND SUM[S,ALLOW (S,Z,1,J)]}>={ | AND FREEH(I) AND FREEC(J
    AND BIF(Z,IJJ)=1), CF*USHELL_B(K,Z,l,J))
    + SUM((Z,I,J)$(OPT=0 AND SUM[S,ALLOW(S,Z,l.J)]>= 1 AND FREEH(I) AND FREEC(J)),
CAE*PAR(Z,I,J))
\$offlext
$ontext
    +SUM((S,Z,l,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
,CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)))
    +SUM((S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0),CAE*DPAR_E(Z,I,J)+CAN*PAR_N(S,Z,I,J))
+SUM((S,K,Z,I,J)\$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND AI,LOWW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1)
,CAE*DPAR_E_B(K,Z,I,J)+CAN*PAR_N_B(K,Z,I,J))
$offtext
*$ontext
+SUM((S.Z,I,J)$(OPT=2 AND ALLOW(S.Z.I,J)=1 AND FREEH(I) AND FREEC(J)
        AND BIF(Z,I,J)=0)
    ,(CF*(NHE(S,Z,1,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,1,J)=1)-(NHE0(S,Z,1,J)*(SUM(R$(ORD(R) LE KET),
    Phi(Z.l,J,R))))))+(CAE*DPAR_E(Z,I,J))'CAN*PAR_N(S,Z.I,J))
    +SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z:I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1)
(CF*}(NHE(S,Z,1,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,1,J)=1)-SUM((RR.R,K)$(OPT=2 AND ORD(R) LE KET AND
ORD(K)LE KMAX(Z.I.J)).DELTA(Z,I,J,RR,R,K)))))
+SUM((S,Z,1,J,K,R)\$(OPT=2 AND ALLOW(S,Z,l,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,l,J)=1 AND ORD(K)LE KMAX(Z,I,J))

* +SUM (K\$(ORD(K)LE KMAX(Z,1,J))
,(CAE*DPAR_E B(K,R,Z,1,J)+CAN*PAR_N_B(K,R,Z,l,J)))
*may be wronge equation (by warapon)
* +SUM(K\$(OPT=1 AND ORD(K) LE NHE0(S,Z,I,J)),(C^E*DPAR_E_B(K,Z.l.J))
* +(CAN*PAR_N_B(K.Z,l.J))));
*TOTALCOST.. TCOST =E= SUM(I\$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
*     + SUM(J\$(CU(J) AND FREEC(J)).CCU(J)*FCU(J)*DTCU(J))

```
```

*     + SUM((Z,I,J)\$(SUM[S,ALLOW(S,Z,I,J)]>= I AND FREEH(1) AND FREEC(J)
* AND BIF=0), CF*USHELL(Z,1,J))
*     + SUM((K,Z,I,J)\$(SUM[S,ALLOW(S,Z,1,J)]>= 1 AND FREEH(I) AND FREEC(J)
* AND BIF=1), CF*USHELL_B(K,Z,I,J))
*     + SUM((Z,I,J)\$(SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J) ),
CA*PAR(Z,I,J))
*OFFFTEXT
,
*Depending on the option selected by the user diferent sums come into action.
* Here we have an equation that is made simpler than in the paper. We account
* for the total area of the exchangers (use PAR and not PAR_B).
* The result is the same.
*--
*--
*EQ (106) CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K
KMAXI(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,1,J)=1 AND FREEH(1) AND FREEC(J) AND BIF(Z,1,J) =1).
NHE(S,Z,l,J) =L= SUM(K,USHELL_B(K,Z,l,J));
* 
* EXTRA EQUATIONS NOT IN PAPE-------------------------------
EXTRA EQUATIONS NOT IN PAPER BUT NEEDED
*EQ (108) LIMIT THE NUMBER OF EXCHANGERS
TOTNEXCH_MAX(S).. SUM((Z,1,J)$(ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=L=TOTNEXCHMAX;
*EQ (109) MINIMUM NUMBER OF EXCHANGERS
TOTNEXCH_MIN(S).. SUM((Z,l,J)$(ALLOW(S,Z,1,J)=1 AND FREEH(1) AND FREEC(J)),
NHE(S,Z.I,J))=G=TOTNEXCHMIN;
$ontext
***************************Equation for Retrofit**********************************
*EQ(110)
AREA_RESTI(S,Z,l,J)$(OPT=1 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0).
PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,l,J);
*-
*EQ(111)
AREA_REST2(S,Z,1,J)$(OPT=1 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
  AND BIF(Z,I,J)=0)..
  DPAR_E(Z,I,J)=L=AEX_U(Z,I,J)-AEX(Z,I,J);
*-
*EQ(112)
AREA_REST3(S,Z,I,J)$(OPT=1 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR_N(S,Z,I,J)=L=ASHELLMAX*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)
$(NHE0(S,Z,I,J)=1)-NHE0(S,Z,1,J));
*-
*EQ(113)
  AREA_REST1_B(S.K,Z,1,J)$(OPT=1 AND ORD(K) LE KMAX(Z,1,J) AND ALLOW(S,Z,1,J)=1
ĀND FREEH(I) AND FREEC(J) AND BIF(Z.I.J)=1)
PAR B(K,Z,I,J)=L=SUM(KK$(ORD(KK) LE NHE0(S,Z,l,J)),AEX_B(KK,Z,I,J)
              *DELTA(KK,K))+DPAR_E_B(K,Z,1,J)+PAR_N_B(K,Z,\,J);
*EQ(114)
  AREA_REST2_B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,1,J) AND ALLOW(S,Z,1,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1)
DPAR_E_B(K,Z,IJ)=L=SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),(AEX_U_B(KK_Z,I,J)
              -AEX_B(KK,Z,1,J))*DELTA(KK,K));
*EQ(115)
AREA REST3 B(S,K,Z,I,J)$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1

```

AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1).

* \(\mathrm{EQ}(116)\)

AREA_REST4_B(S,K,Z,I,J)\$(OPT=1 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,1,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I.J)=1).
\(\operatorname{SUM}(\mathrm{KK} \$(\operatorname{ORD}(\mathrm{KK}) \operatorname{LE} \operatorname{NHE} 0(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{J})), \operatorname{DELTA}(\mathrm{KK}, \mathrm{K}))=\mathrm{L}=1\);
*EQ(117)
AREA_REST5_B(S,K,Z,1,J)\$(OPT=1 AND ORD(K) LE NHE0(S,Z,1,J) AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC( J\()\) AND BIF(Z, \(1, \mathrm{~J})=1\) ).
\(\operatorname{SUM}(\mathrm{KK} \$(\operatorname{ORD}(\mathrm{KK}) \operatorname{LE} \operatorname{KMAX}(\mathrm{Z}, \mathrm{I}, \mathrm{J}))\), \(\operatorname{DELTA}(\mathrm{K}, \mathrm{KK}))=\mathrm{L}=1\);
*EQ(118)
AREA_REST6_B(S,Z, \(1, \mathrm{~J}) \$(\mathrm{OPT}=1\) AND ALLOW \((\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})=1\) AND FREEH( I\()\) AND FREEC(J) AND BIF(Z,I,J)=1)..
\(\operatorname{SUM}((\mathrm{K}, \mathrm{KK}) \$(\mathrm{ORD}(\mathrm{K})\) LE KMAX \((\mathrm{Z}, \mathrm{I}, \mathrm{J})\) AND ORD(KK) LE NHE0(S,Z,1,J)),DELTA(KK,K)) \(=\mathrm{E}=\mathrm{NHE} 0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})\);
*--
*----------
ADD_REST..
\(\operatorname{SUM}((\mathrm{S}, \mathrm{Z}, 1, \mathrm{~J}) \$(\mathrm{OPT}=1\) AND ALLOW(S,Z,1.J)=1
AND FREEH(I) AND FREEC(J)),NHE(S,Z,1,J)
\(-\operatorname{NHE} 0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}))=\mathrm{L}=2\);
*
*EQ(120)
ADD_REST2(S,1,J)\$(OPT=1 AND FREEH(1) AND FREEC(J)).
\(\operatorname{SUM}(\mathrm{Z} \$(\operatorname{ALLOW}(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})=1), \mathrm{NHE}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})-\mathrm{NHE}(\mathrm{S}, \mathrm{Z}, 1 . \mathrm{J}))=\mathrm{G}=0\);
\$offtext
*\$ontext
*

***************************Equation for Retrofit Relocation***
*EQ(Retrofit 16)
RELOCATE_ \(1(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}) \$(\mathrm{OPT}=2\) AND ALLOW(S, \(\mathrm{Z}, \mathrm{l}, \mathrm{J})=1\) AND FREEH(I) AND FREEC( J\()\) AND BIF \((Z, 1, J)=0)\)..
\(\operatorname{PAR}(Z, I, J)=\mathrm{L}=\operatorname{AEX}(\mathrm{Z}, \mathrm{I}, \mathrm{J})+\) DPAR_E(Z,I,J)+PAR_N(S,Z,I,J);
*----------1.------
RELOCATE_2(S,Z,1,J)\$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF \((\mathrm{Z}, \mathrm{I}, \mathrm{J})=0)\)..
\(\operatorname{AEX}(\mathrm{Z}, \mathrm{I}, \mathrm{J})=\mathrm{E}=\operatorname{SUM}\left(\mathrm{R} \$(\operatorname{ORD}(\mathrm{R})\right.\) LE KET \(\left.),\left(\operatorname{AEX} R(\mathrm{R})^{*} \operatorname{Phi}(\mathrm{Z}, \mathrm{l}, \mathrm{J}, \mathrm{R})\right)\right) ;\)
*EQ(Retrofit 18)
RELOCATE \(3(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{J}) \$(\mathrm{OPT}=2\) AND ALLOW \((\mathrm{S}, \mathrm{Z}, \mathrm{l}, \mathrm{J})=1\) AND FREEH(I) AND FREEC( J\()\) AND BIF \((Z, 1, J)=0)\). DPAR_E(Z,I,J) \(=\mathrm{L}=\mathrm{SUM}(\mathrm{R} \$(\mathrm{ORD}(\mathrm{R})\) LE KET),(AEX_U_1(R)-AEX_R(R))
*Phi(Z,I,J,R));
*
*EQ(Retrofit 19)
RELOCATE_4(S,Z,I,J)\$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF \((Z, I, J)=0)\).. PAR_N(S,Z,I,J) \(=\mathrm{L}=\mathrm{A}_{-}\)NEW_MAX \((\mathrm{Z}, \mathrm{I}, \mathrm{J}){ }^{*}\left(\mathrm{NHE}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})+\mathrm{NHE} \mathrm{S}_{-}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}) \$(\mathrm{NHE} 0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})=1)-(\mathrm{NHE} 0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}) *\right.\)
* \(\operatorname{SUM}(\operatorname{RS}(\mathrm{ORD}(\mathrm{R})\) LE KET \(), \operatorname{Phi}(\mathrm{Z}, \mathrm{I} . \mathrm{J}, \mathrm{R}))\) ) );
*EQ(Retrofit 20)
RELOCATE_5_1(S,Z,IJ)\$(OPT=2 AND ALLOW(S,Z,IJJ)=1 AND FREEH(I) AND FREEC(J) ĀND \(\operatorname{BIF}(\mathrm{Z}, \mathrm{l}, \mathrm{J})=0)\).. NHE \((\mathrm{S}, \mathrm{Z}, \mathrm{l}, \mathrm{J})=\mathrm{L}=\) TOTNEXCHMAX ;

RELOCATE \(5 \_2(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}) \$(\mathrm{OPT}=2\) AND FREEH(I) AND FREEC(J) AND \(\overline{\operatorname{BI}} \operatorname{IF}(\mathrm{Z}, \mathrm{I}, \mathrm{J})=0)\). SUM \(((\mathrm{R}) \$(\operatorname{ORD}(\mathrm{R})\) LE KET \(), \operatorname{Phi}(\mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{R}))=\mathrm{L}=1\);
*Extra Eq. Limits number of phi matches
RELOCATE_5_3(Z,R)\$(OPT=2).. \(\quad \operatorname{SUM}(i, j), \operatorname{Phi}(Z, I, J . R))=\mathrm{L}=1\);
*-------------
**EQ(Retrofit 21)
RELOCATE 6(K,R,S,Z,I,J)\$(OPT=2 AND ORD(K) LE KMAX(Z,I.J) AND ALLOW(S:Z,I.J) \(=1\)
AND FREEH(I) AND FREEC(J) AND BIF(Z,I.J)=1)..
PAR_B_R(K,R,Z,I,J)=L=AEX_B(K,R,Z,I,J)+DPAR_E_B(K,R,Z,l,J)+PAR_N_B(K,R,Z,I,J);
```

*EQ(Retrofit 22)
RELOCATE 7(K,R,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z.I.J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I.J)=1)
    AEX_B(K,R,Z,1,J)=E=SUM(RR$(ORD(RR) LE KET),(AEX_B_R(RR)*DELTA(Z,I,J,RR.R,K)));
**
*EQ(Retrofit 23)
RELOCATE_8(K,R,S,Z,I,J)$(OPT=2 AND ORD(R) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1)..
    DPAR_E_B(K,R,Z,I,J)=L=SUM(RR$(ORD(RR) LE KET),(AEX_U_B_R(RR)-AEX_B_R(RR))
* DELTA(Z,1,J,RR,R,K));
*EQ(Retrofit 24)
RELOCATE_9(K,R,S,Z,l,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1).
    PAR_N_B(K,R,Z,I,J)=L=A_NEW_MAX(Z,I,J) *(l-SUM(RR$(ORD(RR) LE KET)
,DELTA(Z,I,J,RR,R,K)));
**
*EQ(Retrofit 25)
RELOCATE_10(K,R,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1).
    SUM(RR$(ORD(RR) LE KET),DELTA(Z,l,J,RR.R.K))=L=l
*$OFFTEXT
HOT U C..
HOT_UTILITY_COST =E= SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I));
Cold_U_C.
Cold_UTILITY_COST =E= SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J));
Area_C.-
Area_Cost=E=
+SUM((S,Z,1,J)$(OPT=2 AND ALI.OW(S.Z;I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,IJ)=0)
(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,1,J)=1)-(NHE0(S,Z,I,J)*(SUM(R$(ORD(R) LE KET),
Phi(Z,1,J,R))))))+(CAE*DPAR_E(Z,1,J))+CAN*PAR_N(S,Z,I,J));
$ONTEXT
SUM((S,Z,1,J)$(OPT=2 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)
,(CAE*DPAR_E(Z.I,J))+CAN*PAR_N(S,Z,I,J))
+SUM((S,Z,I,J,K,R)\$(OPT=2 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,J)=1 AND ORD(K)LE KMAX(Z,I,J))

* +SUM (K\$(ORD(K)LE KMAX(Z,1,J))
,(CAE*DPAR_E_B(K,R,Z,I,J)+CAN*PAR_N_B(K,R,Z,I,J)));
\$OFFTEXT
* 

FIX C..
FIX_COST =E= SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
    AND BIF(Z,I,J)=1)
    ,(CF*(NHE(S,Z,1,J)+NHE_S(S,Z,l,J)$(NHE0(S,Z,I,J)=1)-SUM((RR.R,K)$(OPT=2 AND ORD(R) LE KET AND
    ORD(K)LE KMAX(Z,I,J)).DELTA(Z,I,J,RR,R,K)))))
    +SUM((S,Z,I,J,K,R)$(OPT=2 AND ALLOW(S,Z,l,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1 AND ORD(K)LE KMAX(Z,I.J))

* +SUM(K\$(ORD(K)LE KMAX(Z,I,J))
,(CAE*DPAR_E_B(K,R,Z,I,J)+CAN*PAR_N_B(K,R,Z,I,J)))
;
$ONTEXT
SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S.Z,I.J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)
,(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-(NHE0(S,Z,I,J)*(SUM(R$(ORD(R) LE KET),
Phi(Z,I,J,R))))))
* +SUM((S,Z,I,J)\$(OPT=2 AND AL.LOW(S.Z.I.J)=1 AND FREEH(I) AND FREEC(J)
* AND BIF(Z,I,J)=1)
+(CF*}(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S.Z,I,J)=1)-SUM((RR,R,K)$(OPT=2 AND ORD(R) LE KET AND

```
```

\$OFFTEXT

```

MODEL MPERIOD / ALL/;
OPTION LIMROW =5000;
OPTION LIMCOL \(=5000\);
OPTION SOLPRINT = OFF;
OPTION OPTCR=0
OPTION OPTCA=0
OPTION reslim \(=135800\);
SOLVE MPERIOD USING MIP MINIMIZING TCOST;
PARAMETER QMATCH(S,Z,I,J);
QMATCH \((S, Z, I, J)=S U M((M, N) \$(D(S, Z, M, N)=1\) 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,1,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,l,J,M)\$[HOT(S,l,M)]=QNEW_M.L(S,Z,I,J,M)/[(TU(S,M)-TL(S,M))* \(\mathrm{CPH}(\mathrm{S}, \mathrm{l}, \mathrm{M})]\)

PARAMETER FC C(S,Z,J,I,M) Flowsate of cold 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 NHE:3:0:1; display NHE.L;
option NHE S:3:0:1; display NHE_S.L;
OPTION Cold_UTILITY_COST:3:0:1; DISPLAY Cold UTILITY COST.L;
OPTION HOT_UTILITY_COST:3:0:1; DISPLAY HOT UTILITY_COST.L;
OPTION Area_Cost \(3: 0: 1\); DISPLAY Area_Cost.L;
OPTION FIX_COST:3:0:1; DISPLAY FIX_COSTL;
option Q:3:0:1; display Q.L;
option FHU:3:0:1; display FHU.L;
option FCU:3:0:1; display FCU.L;
* OPTION DPAR_E:3:0:1; DISPLAY DPAR E.L;
* OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;

OPTION PAR:4:0:1; DISPLAY PAR L;
OPTION QMATCH:4:0:1; DISPLAY QMATCH;
OPTION FH_H:3:0:1; DISPLAY FH_H;
OPTION FC_C:3:0:1; DISPLAY FC_C;
OPTION PAR_N:3:0:1; DISPLAY PAR_N.L;
OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L:
OPTION PHI:3:0:1; DISPLAY PHIL;
OPTION AEX:3:0:1; DISPLAY AEXL,
\$ONTEXT
DISPLAY DTVIO;
DISPLAY AEX;
DISPLAY CPH;
DISPLAY CPC;
DISPLAY PHI.L;
EXECUTE_UNLOAD "isabelout.gdx",PAR, QMATCH, FH_H, FC_C, AEX; EXECUTE 'GDXXRW.EXE isabelout.gdx par=QMATCH rng=al'; EXECUTE 'GDXXRW.EXE isabelout gdx var=PAR rng=rl'; EXECUTE 'GDXXRW EXE isabeloutgdx \(\mathrm{PAR}=\mathrm{AEX} \mathrm{mg}=\mathrm{afl}\) ': EXECUTE 'GDXXRW EXE isabelout.gdx par=FH_H rng=a20'; EXECUTE 'GDXXRW.EXE isabelout.gdx par=FC_C \(\mathrm{mg}=\mathrm{a} 4 \mathbf{0}^{\prime}\) ': EXECUTE 'GDXXRW.EXE isabelout gdx par \(=\mathrm{PHI} \mathrm{rng}=a 60\) '; EXECUTE 'GDXXRW. EXE isabelout \(\mathrm{gdx} \vee \mathrm{vR}=\mathrm{DPAR} \mathrm{m}_{\mathrm{n}} \mathrm{g}=\mathrm{R} 60\) '; \$OFFTEXT

\section*{Appendix C Programming Model for Retrofit without Relocation Apply for Crude Fractionation Unite}
\$TITLE HEN design- Automatic parameter calculation- KITISAK-I
* 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-4SI-FINAL-6-FLEXIBILITY-S1.gms: August 9, 2004
- one scenario, the original values of 4 s .
\$OFFTEXT
SETS
Z transfer zone
121/
*
*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
1 Hot streams /II*19/
J cold streams \(\quad / \mathrm{J} 1^{*} \mathrm{~J} 3 /\)
R /RI*R4
*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
HU(I) Heating utilities /I9/
CU(J) Cooling utilities /J3/
*
M temperature intervals /Ml*MIII/
S SCENARIO
/S1/
K temperature intervals / K I*Kl/
*
*NEW SET FOR PUMP-AROUND. PA(I) Pump-around streams /I2,14,16/
*
ALIAS (M,N,L,O)
ALIAS ( \(1,1 \mathrm{II}\) )
ALIAS (J,JJ)
ALIAS (K,KK)
ALIAS (Z,ZZ)
*PARAMETER FOR PUMP-AROUND CASE
```

PARAMETER FPR(l,R) Candidate values for pump-around flowrate i
/
12.R1 701.4780
12.R2 647.5181
I2.R3 539.5984
12.R4 485.6386
I4.RI 78.28034
14.R2 115.4635
14.R3 156.5607
14.R4 176.1308

```
l
PARAMETER TOTAL_QPA Total PA load ;
TOTAL_QPA = 158000;
*linear function for }\textrm{Cp}\mathrm{ for hot streams
* Cp = A cp H*T + B cp H
PARAMETER A_cp_H(I) Coefficients for Cp
/
11 0.0035
12 0.0040
13 0.0040
0.0055
0.0039
0.0052
0.0038
0.0031
0
PARAMETER B_cp_H(1) Intercept for Cp
/
11 1.9098
12 1.7979
13 1.7483
I4 1.4682
15 1.7044
16 1.3834
17 1.6756
I8 1.8201
19 4.18
l
*linear function for }\textrm{Cp}\mathrm{ for cold streams
*Cp = A_cp_C*T + B_cp_C
PARAMETER A_cp_C(J) Coefficients for Cp
I
J1 0.0037
J2 0.0035
J3 0
I
PARAMETER B_cp_C(J) Coefficients for Cp
/
J] 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)
I
12 2.82E-05
14 -6.3E-05
I6 -2.7E-05
I
PARAMETER B_l(I) Coefficients for PA(2)
/
I2 4.56E-05
I4 -5.4E-05
16 -2.8E-05
/
PARAMETER C_1(1) Coefficients for PA(3)
/
12 5.9IE-05
14 -2.4E-05
I6 -2.3E-05
l
PARAMETER D_I_l(I) Intercept
/
12 -3.81232
14\quad11.14212
16 6.491449
```

```
I
    PARAMETER T(S,Z,I,M,J,N) Upper bound
/
Sl.Z1.I2.(M3*M10).J1.(M84*M94) 10000
SI Z1.12.(M3*M10).J2.(M95*M109) }1000
SI.Z1.I2.(M3*M10).J3.(Ml10*MIl1) 10000
S1.Z1.I4.(M26*M35).J1.(M84*M94) 10000
SI Z1.14.(M26*M35).J2.(M95*M109) }1000
S1.Z1.14.(M26*M35).J3.(M110*M111) 10000
SI.ZI.I6.(M51*M57).JI.(M84*M94) 10000
SI_ZI.16.(M51*M57).J2.(M95*M109) 10000
SI.Z1.16.(M51*M57).J3.(M110*M111) 10000
l
PARAMETER TE(S,Z,l,M,J,N) Upper bound
I
SI Z1.I2.(M3*M10).J1.(M84*M94) 10000
S1 Z1.12.(M3*M10).J2.(M95*M109) 10000
SI.Z1.I2.(M3*M10).J3.(M110*M111) 10000
S1.Z1 14 (M26*M35).J1.(M84*M94) 10000
S1.Z1.14.(M26*M35).J2.(M95*M109) 10000
SI.Z1.14.(M26*M35).J3.(M110*M111) }1000
SI.Z116.(M51*M57).J1.(M84*M94) 10000
S1Z1.16.(M51*M57).J2.(M95*M109) }1000
SI.Z1.16.(M51*M57).J3.(M110*M111) 10000
/
PARAMETER OMEGA(S,Z,1.M.J,N) Upper bound
/
SI.Z1.12.(M3*M10).J1.(M84*M94) 10000
SI.Z1.I2.(M3*M10).J2.(M95*M109) 10000
SI.Z1.12.(M3*M10).J3.(M110*MI11) }1000
SI Z1.I4.(M26*M35).JI.(M84*M94) 10000
SI.Z1.I4.(M26*M35).J2.(M95*M109) }1000
Sl.Z1.14.(M26*M35).J3.(M110*M111) 10000
S1.Z1.16.(M51*M57).J1.(M84*M94) 10000
S1.Z1.16.(M51*M57).J2.(M95*M109) }1000
S1.Z1.16.(M51*M57).J3.(M110*M111) }1000
l
PARAMETER NIZ(S,Z,I) # OF INTERVALS DESIRED FOR HOT STREAMS
/
S1.21.112
S1.21.128
S1.21.1315
S1.21.1410
S1.21.1515
S1.21.167
S1.Z11715
SI.Z1.188
SI Z1.19 3
|
PARAMETER NJZ(S,Z,J) # OF INTERVALS DESIRED FOR COLD STREAMS
/
S1 Z1.J111
S1 Z1.J215
S1.Z1J32
l
* Used Over all heat transfer Coeff insteat of hot and cold heat transfer Coeff.
* This values come from text book
PARAMETER U(S,I,J) OVER ALL HEAT TRANSFER COEFFICIENT
/
SI.(II*13,17,19).(J1*J2) 0.715
S1.(14.16).(J1*J2) 0.715
```

```
0.306
S1.18.(J]*J2) 0.470
S1.(11,I2).J3 1.400
Sl.(13,17).J3 1.020
S1.(14,16)J3 0.511
S1.(15).J3 0.765
S1.(18).J3 0.765
Sl.(19).J3 5.110
/
PARAMETERS
TIH(S,l) T IN FOR HOT STREAMS
l
S1.II 48.30000
S1.12 182.5720
S1.13224.6850
S1.14 268.7880
S1.15 275.6570
S1.16 308.5100
S1.17 323.5120
SI.18 347.1810
SI.19400.0000
/
TOH(S,l) T OUT FOR HOT STREAMS
/
S1.I1 26.11000
S1.I2 104.4400
S1.I3 26.11000
SI.14 173.6270
SI.I5 26.11000
S1.16 232.2220
S1.I7 26.11000
S1.18 260.0000
S1.19 399.0000
|
TIC(S,J) T IN FOR COLD STREAMS
l
S1.J1 16.11000
S1.J2 132.7800
SIJ3 20.00
l
TOC(S,J) T OUT FOR COLD STREAMS
I
SI Jl 132.780
S1.J2 }36
S1.J3 30.00000
/
PARAMETERS
TIHZ(S,Z,I) T IN FOR HOT STREAMS
/
S1.Z1.I1 48.30000
S1.21.12 182.5720
SI.Z1.13 224.6850
S1.Z1.14 268.7880
SI.Z1.I5 275.6570
S1.Z1.16 308.5100
SIZI.17 323.5120
SI.Z1.18 347.1810
SJ.Z1.19400.0000
l
TOHZ(S,Z,I) T OUT FOR HOT STREAMS
/
S1.Z1.11 26.11000
S1.Z1.I2 104.4400
S1.Z1.13 26.11000
S1.Z1.14 173.6270
S1.Z1.15 26.11000
S1.Z1.16 232.2220
SI.Z117 26.11000
S1.ZI.I8 260.0000
S1.Z1 19 399.0000
l
```

```
TICZ(S,Z,J) T IN FOR COLD STREAMS
/
SIZ1.Jl 16.11000
SI.Z1.J2 132.7800
SI.Z1.J3 20.00
I
TOCZ(S,Z,J) T OUT FOR COLD STREAMS
/
SI.Z1.JI 132.7780
S1.Z1.J2360
S1.Z1.J3 30.00000
/
*INTRODUCE THE FCp:
FH(S,I) FOR HOT STREAMS
l
S1.11 177.826
SI.I3 120.158
SI.15 59.1990
S1.17 102.417
S1.18 211.705
/
FC(S,J) FOR COLD STREAMS
/
Sl.Jl 752.594
S1.J2 673.422
/
*USE THE MAX FCp FOR THE UTILITIES
*-----------------
/
11*19
|
    FREEC(J)
l
J1
J2
J3
l
PARAMETER BIF(Z,I,J)
/
Z1.IJ.J1 0
/
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
*;
PARAMETER SPH(I) SH in paper
/
(I1,13,15,17,18,19) ।
(12,14,16)
l
PARAMETER SPC(J) SC in paper
l
|l 1
J2 1
J3 1
PARAMETER NIH(1) Non isothermal splitting for hot streams in paper
I
|] 0
l
PARAMETER NIC(J) Non isothermal splitting for cold streams in paper
I
Jl 0
PARAMETER DTVIO(I.J)
l
(11*19).(J1*J3) I
/
```

```
PARAMETER KMAX(Z.I.J)
l
Z1.II.J1 1
l
PARAMETER DTHU(I)
I
19 1
/
PARAMETER DTCU(J)
/
J3 10
I
PARAMETER FMAX HU(I)
/
19 100000
/
PARAMETER FMAX_CU(J)
I
J3 100000
PARAMETER CHU(I)
l
19 19.750
l
PARAMETER CCU(J)
/
J3 1.861
PARAMETER CSS(I) Cost of side stripping
I
12 20.33
14 20.33
16 20.33
I
PARAMETER CF:
CF = 5291.9;
PARAMETER CAN;
CAN = 171.4;
PARAMETER CAE;
CAE = 171.4;
** Retrofit
PARAMETER AEX (Z,1,J)
l
Z1.11.J3 515.685
Z1.I2.J1 2239.929
Z1.13.J] 1000.000
Z1.I3.J2 204.200
Z1.13.J3 617.797
Z1.14.J1 572.096
Z1.14.J2 179.428
Z1.15.J1 133.625
Z1.15.J2 529.892
Z1.15 J3 546.822
Z1.16.J3 184.5
Z117.J1 608.858
Z1.17.J2 798.965
Z1.17.J3 425.397
Z1.18.J3 240.7
Z1.19.J2 4489.5
/
PARAMETER AEX_B(K,Z,l,J)
|
K1.Z1.11.J3 515.685
l
PARAMETER NHE0(S.Z.1,J)
l
S1.21.11.J31
S1.Z1.12.J11
S1.21.I3.J11
```

```
S1.21.13131
SI.Z1.13.J31
SI.Z1.14.J1I
SI.Z1.14.J21
SI.Z1.15.J11
S1.21.15.J21
SI21.15.J31
SI.21.16.J31
S121.17.J11
S1.21.17.J21
S1.21.17.J31
SI.Z1 18.J31
S1.21.19.J2 I
l
PARAMETER AEX U(Z,I,J)
/
Z1.11J3 3000
Z1.12.J1 }300
Z1.13.J1 }300
ZI.13.J2 3000
Z1.13.J3 3000
ZI.I4.J1 }300
Z1.I4.J2 }300
Z1.15.J1 }300
Z1.15.J2 3000
Z1.15.J3 3000
Z1.16.J3 3000
Z1.17.J1 }300
Z1.17.J2 3000
Z1.17.J3 3000
ZI.I8.J3 }300
Z1.19.J2 5000
l
PARAMETER AEX_U_B(K;Z,l,J)
l
K1.Z1.11.J1 3000.000
l
PARAMETER A_NEW_MAX(Z,I.J)
I
Z1.(11*14).(J1*J3) 5000.000
/
PARAMETER MAX NEW HEX
* Maximum Number of new exchangers
150/;
PARAMETER QLHMIN
* Minimum heat that can be transferred within an interval.Hot streams ERSST]
/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
10/;
*-----------------------------------------------------------
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_l(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(l),
            IHminZ(S.Z,l)$[ORD(S)=Si AND ORD(I)=1
                                    AND ORD(Z)=1]= 0+1$[NIZ(S,Z,I)>=1];
            IHminZ(S,Z,l)$[ORD(S)=Si AND ORD(I)>1
                    AND ORD(Z)=1]=0+
            {SUM((ZZ,II)$[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)<ZZ],NIZ(S,ZZ,I))+1}$[NIZ(S,Z,I)>=1];
            IHmaxZ(S,Z,I)$[ORD(S)=Si AND ORD(I)=lc 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)-I],NIZ(S,ZZ,I))=0},IHminZ(S,Z,I)];
            IHmax(S,I)$[ORD(S)=Si AND ORD(I)=Ic]=
                SUM[Z${SUM(ZZ$[ORD(ZZ)>=ORD(Z)+1],NIZ(S,ZZ,l))=0},1HmaxZ(S,Z,I)];
            FOR(Mi=1 TO CARD(M),
            HOT(S,I,M)$[ORD(S)=Si AND ORD(I)=lc 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,l)];
            ));
        FOR(Ji=1 TO CARD(J),
            JCminZ(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)>1AND ORD(Z)=1]=0+
                    {SUM{IS[ORD(1)=CARD(I)],IHmax(S,I)}
                    +SUM((ZZ,JJ)S[ORD(JJ)<ORD(J)],NJZ(S,ZZ.JJ))+1}$NNJZ(S,Z,J)>=1];
            ICminZ(S,Z,J)S[ORD(S)=Si AND ORD(Z)>1]=0+
                    {SUM{1$[ORD(I)=CARD(I)].IHmax(S,I)}
                    + SUM((ZZ,JJ)$[ORD(JJ)<ORD(J)],NJZ(S,ZZ,JJ))
                    +SUM(ZZ$[ORD(ZZ)< Zi],NJZ(S,ZZ,J))+1}$[NJZ(S,Z,J)>=1};
            lCmaxZ(S,Z,J)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(Z)=Zi]
                    {lCminZ(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)-I],NJZ(S,ZZ,J))=0},ICminZ(S,Z,J)];
            1Cmax(S.J) $[ORD(S)=Si AND ORD(J)=Ji]=
            SUM\Z${SUM(ZZ$[ORD(ZZ)>=ORD(Z)+I],NJZ(S,ZZ,J))=0},ICmaxZ(S,Z,J)];
            FOR(Mi=1 TO CARD(M),
            COLD(S,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi]= 0+
                            1$[ORD(M)>= ICmin(S,J) AND ORD(M)<=ICmax(S,J)];
                    COLD2(S,M)$ 
                    1$[ORD(M)>SUM(I$(ORD(I)=CARD(I)),IHmax(S,l))
                        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,l,M),CPC_U(S,J,M),CPH_L(S,I,M),CPC_L(S,J,M);
DT(S.M) $=\operatorname{SUM}((\mathrm{Z}, \mathrm{I}) \$[$ HOTZ $(\mathrm{S}, \mathrm{Z}, \mathrm{I} . \mathrm{M})=1],\{[\mathrm{TIHZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})-\mathrm{TOHZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I})] /$
$[I H \operatorname{maxZ}(S . Z, 1)-I H \min Z(S . Z, 1)+1]\}) \$[H O T 2(S, M)=1]+$
$\operatorname{SUM}((\mathrm{Z} . \mathrm{J}) \$[\operatorname{COLDZ}(\mathrm{~S}, \mathrm{Z}, \mathrm{J}, \mathrm{M})=\mathrm{I}] .\{[\mathrm{TOCZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})-\mathrm{TICZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J})] /$
[ICmaxZ(S,Z,J)-ICminZ(S,Z,J)+1]\})\$[COLD2(S,M)=1];
$\operatorname{FOR}(\mathrm{Si}=1 \operatorname{TOCARD}(\mathrm{~S})$,

```
FOR (Mi=1 TO CARD(M),
    TU(S.M)$[ORD(S)=Si AND ORD(M)=Mi]={SUM((Z,I)$[HOTZ(S,Z.l,M)=1
            AND ORD(M)=[HminZ(S,Z,I)],TIHZ(S,Z,I)$[ORD(M)=[IHminZ(S,Z,I)])
            + SUM((Z,I)$[HOTZ(S,Z,I,M)=IAND ORD(M)>IHminZ(S,Z,I)AND
                    ORD(M)<=IHmaxZ(S,Z,I)],
                    [T]HZ(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)$[COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z.J)
                    AND ORD(M)<=[CmaxZ(S,Z,J)],
                    [TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S.M)]$[ORD(M)>
            ICminZ(S,Z,J)AND ORD(M)<=lCmaxZ(S:Z,J)])}${COLD2(S,M)=1];
    TL(S.M)$[ORD(S)=Si AND ORD(M)=Mi]=
            {SUM((Z,I)S[HOTZ(S,Z,I,M)=1 AND ORD(M)=lHmaxZ(S,Z,l)],
                    TOHZ(S,Z,l)$[ORD(M)=]HmaxZ(S,Z,I)])
            + SUM((Z,l)$[HOTZ(S,Z,I,M)=1 AND ORD(M)<lHmaxZ(S,Z,l)
                AND ORD(M)>=IHminZ(S,Z,I)],
                    [TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$[ORD(M)<
            11 imaxZ(S.Z,I)AND ORD(M)>=IHminZ(S,Z,I)])}$[HOT2(S,M)=1]
            + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1AND ORD(M)=1CmaxZ(S,Z.J)],
                TICZ(S,Z.J)$[ORD(M)=[CmaxZ(S,Z,J)])
            + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)<lCmaxZ(S,Z,J)
                    AND ORD(M)>=[CminZ(S.Z.J)].
                    [TICZ(S,Z,J)+(lCmaxZ(S,Z,J)-ORD(M))*DT(S,M)]S[ORD(M)<
                    ICmaxZ(S,Z,J)AND ORD(M)}>=|=|minZ(S,Z.J)|)}$[COLD2(S,M)=1]
```

$\mathrm{CPH} \mathrm{C}_{-}(\mathrm{S}, \mathrm{l}, \mathrm{M}) \$[\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=\mathrm{I}]=\mathrm{A}_{-} \mathrm{cp}-\mathrm{H}(\mathrm{l}) * \mathrm{TU}(\mathrm{S}, \mathrm{M})+\mathrm{B}_{-} \mathrm{cp} \mathrm{p}_{-} \mathrm{H}(\mathrm{l})$;
$\mathrm{CPC}_{-}^{-} \mathrm{U}(\mathrm{S}, \mathrm{J}, \mathrm{M}) \mathbb{S}[\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{M})=\mathrm{I}]=\mathrm{A}_{-} \mathrm{cp} \_\mathrm{C}(\mathrm{J})^{*} \mathrm{TU}(\mathrm{S}, \mathrm{M})+\bar{B}_{-} \mathrm{Cp} \_\mathrm{C}(\mathrm{J}) ;$
CPH_L $(S, J, M) \$[H O T(S, I, M)=1]=A_{-} c p \_H(I) * T L(S, M)+B<p \_H(1)$;
CPC_L(S,J,M)\$[COLD(S,J,M)=1] =A_cp_C(J)*TL(S,M)+BCpC(J);
$\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) \$[\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1]=\left(\mathrm{CPH} \mathbf{U}(\mathrm{S}, \mathrm{I}, \mathrm{M})+\mathrm{CPH} \_\mathrm{L}(\mathrm{S} . \mathrm{I}, \mathrm{M})\right) / 2$;
$\mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{M}) \$[\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{M})=1]=(\mathrm{CPC} \mathbf{U}(\mathrm{S}, \mathrm{J}, \mathrm{M})+\mathrm{CPC} L(\mathrm{~S}, \mathrm{~J}, \mathrm{M})) / 2$;
FOR( $\mathrm{Ic}=1$ TO CARD(I),
$\operatorname{DHH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) \$[\operatorname{ORD}(\mathrm{~S})=\mathrm{Si}$ AND ORD(M)=Mi AND ORD(I)=Ic
AND HOT $(\mathrm{S}, \mathrm{I}, \mathrm{M})=1]=\mathrm{FH}(\mathrm{S}, \mathrm{I})^{*} \mathrm{CPH}(\mathrm{S}, 1, \mathrm{M})^{*}[\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M})]$
);
$\operatorname{FOR}(\mathrm{Ji}=1$ TO CARD(J),
DHC $\left.{ }_{( }^{\prime} \mathrm{S}, \mathrm{J}, \mathrm{M}\right) \mathbb{S}[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}$ AND ORD(M)=Mi AND ORD(J)=Ji
AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{M})=1]=\mathrm{FC}(\mathrm{S} . \mathrm{J})^{*} \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{M})^{*}[\mathrm{TU}(\mathrm{S} . \mathrm{M})-\mathrm{TL}(\mathrm{S} . \mathrm{M})]$
));
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,1,J), ALLOW_H(S,Z,I,M,J), ALLOW_C(S,Z,J,M,I), ALLOW_2(Z,I,J) ;
$\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TU}(\mathrm{S}, \mathrm{N})+\mathrm{DTmin}\} \$[\mathrm{HOT} 2(\mathrm{~S}, \mathrm{M})$ AND COLD2(S,N)];
$\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{\mathrm{TL}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{N})+\mathrm{DTmin}\} \$[\mathrm{HOT} 2(\mathrm{~S}, \mathrm{M})$ AND COLD2(S,N)]
$\operatorname{LMTD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{[\mathrm{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})-\mathrm{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})]$
$/ \operatorname{LOG}[\operatorname{HHEAD}(S, M, N) / \mathrm{CHEAD}(S, M, N)]\} \$[\operatorname{HHEAD}(\mathrm{~S}, \mathrm{M}, \mathrm{N})>0$
AND CHEAD $(\mathrm{S}, \mathrm{M}, \mathrm{N})>0$ AND HHEAD $(\mathrm{S}, \mathrm{M}, \mathrm{N})>\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})]$
$+\{[\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})+\mathrm{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})] / 2\} \$[\operatorname{HHEAD}(\mathrm{~S}, \mathrm{M}, \mathrm{N})>0$ AND CHEAD $(\mathrm{S}, \mathrm{M}, \mathrm{N})>0$
AND ( $\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})<\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})$ OR $\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N}))$ ];
$\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{N})=1 \$[\{\mathrm{HOT} 2(\mathrm{~S}, \mathrm{M})=1$ AND $11 \mathrm{OT} 2(\mathrm{~S}, \mathrm{~N})=1$ AND SUM $[I \$(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1$
AND $\operatorname{HOT}(\mathrm{S}, 1, \mathrm{~N})=1), \operatorname{HOTZ}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M})]=\mathrm{I}$ AND SUM[IS(HOT(S,I,N)=1
AND HOT(S, $1, M)=1), \operatorname{HOTZ}(S, Z, I, N)]=1\}$
OR $\{\operatorname{COLD} 2(\mathrm{~S}, \mathrm{M})=1$ AND COLD2(S,N) $=1$ AND SUM $[J \$(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{M})=1$
$\operatorname{AND} \operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1), \operatorname{COLDZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{M})]=1 \operatorname{AND} \operatorname{SUM}[\mathrm{~J}(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{~N})=1$
$\operatorname{AND} \operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{M})=1), \operatorname{COLDZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N}) \mathrm{J}=1\}$
OR $\{(\operatorname{HHEAD}(S . M, N)>=0.00001$ AND CHEAD $(\mathrm{S}, \mathrm{M} . \mathrm{N})>=0.00001)$
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\}];
$* \mathrm{OR}\{\operatorname{LMTD}(\mathrm{S}, \mathrm{M}, \mathrm{N})>0$ AND SUM $[\mathrm{IS}(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1), \operatorname{HOTZ}(\mathrm{S}, \mathrm{Z}, \mathrm{LM})]=1$
$* \quad$ AND SUM $[\mathrm{J} \$(\operatorname{COILD}(\mathrm{~S}, \mathrm{~J}, \mathrm{~N})=1), \operatorname{COLDZ}(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N})]=1\}] ;$

```
FOR(Si=1 TO CARD(S),
    FOR(Zi=1 TO CARD(Z),
        FOR(Ic=1 TO CARD(1),
            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)$[HOT(S.l,M)=1
                            AND COLD(S,J,N)=1],D(S,Z,M,N)]>0
                                    AND NOT[HU(I)AND CU(J)]};
            FOR (Mi=1 TO CARD(M),
                        ALLOW_H(S,Z,I,M,J)$[ORD(S)=Si AND ORD (Z)=Zi AND ORD(l)=lc
                        AND ORD(J)=Ji AND ORD(M)}=\textrm{Mi
                            AND HOT(S,I,M)=1]=0+
                I${SUM[N$[COLD(S,J,N)=1],D(S.Z,M,N)] >0AND NOT[HU(I)AND CU(J)]};
                ALLOW_C(S,Z,J,M,l)$[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
                        ANDD ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)={]= 0+
                1${SUM[N$[HOT(S,I.N)=1],D(S.Z,N,M)] >0AND NOT[HU(I)AND CU(J)]};
                    )))));
FOR(Zi=1 TO CARD(Z),
    FOR(lc=1 TO CARD(l),
        FOR(Ji=1 TO CARD(J),
            ALLOW_2(Z,1,J)$[ORD(Z)=Zi AND ORD(1)=lc 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,l,J,M)
        QNEW_N(S,Z,I,J,N)
        QNEW2 M(S,Z,I,J,M)
        QNEW2_N(S,Z,1,J:N)
        Y_M(S,Z,I.J,M)
        Y_N(S,Z,I,J,N)
        Y_M_B(S,Z,l,J,M)
    Y_N_B(S,Z,l,J,N)
    NHE_M0(S,Z,I,J,M)
    NHE_Ml(S,Z,l,J,M)
    NHE_N0(S,Z,I,J,N)
    NHE_N1(S,Z,I,J,N)
    NHE_MO_B(S,Z,I,J,M)
    NHE_M1_B(S,Z,IJ,M)
    NHE_N0-B(S,Z,I,J,N)
    NHE N1_B(S,Z,I,J.N)
    NHE(S,Z,1,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)
    Bl(S,Z,I,M,J,N) X(imjn) in the paper
    QH(S,Z,l,M,N)
    QC(S,Z,J,M,N)
    Q2(S,Z,I,M,J,N)
    X1_B(S,Z,l,J,M)
    X_-B}(S,K,Z,1,J,M
    PAR B(K,Z,l,J)
    USHELL(Z,I,J)
    USHELL.B(K.Z,I.J)
*ADD FOR RETROFIT
    PAR_N(S,Z,1,J)
    PAR_N_B(K,Z,I,J)
    DPAR_\overline{R}(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,1,J,M)
    FPK C 0(S,Z,l,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_l(S.Z.IJ.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(l)
    SST_2(I)
    SST_3(I)
    SST_4(I)
    PAI
    PA2
    PA3
    TOTAL_Q
    Cp_Dt(1)
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_MI_B,NHE_NO_B,NHE_N1_B,Y_M,Y_N,XI_B,X_B,NHE_S
    DELTA,Y_M_B,Y_N_B.NHE_M0,\overline{NHE MI_NHE_NO.NHE_NI,ALFA_M,AL\overline{FA_N}}\mathbf{N}=\overline{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,1,J,M)
TRANSFOR_N(S,Z,I,J,N)
HBHS_NI(S,I,M)
HBCS NI(S,J,N)
NOISOH(S,l,M)
NOISOC(S,J,N)
BINARY M1(S,Z,l.J,M)
BINARY_M2(S,Z,I,J,M)
BINARY_M1_B(S,Z,l,J,M)
BINARY_M2_B(S,Z,I.J,M)
BINARY_Nl(S,Z, \(1, \mathrm{~J}, \mathrm{~N})\)
BNARY_N2(S,Z,I:J,N)
BINARY_NI_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 \({ }^{-}\)M \(7(S, Z, 1, J, M)\)
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,1 J,N)
BINARY_N4(S,Z,I,J,N) BINARY_N8(S,Z,I,J,N) BINARY ${ }^{-}$N9(S,Z,Z,I,J,N) BINARY_N6(S,Z,I,J,N) BINARY_N7(S,Z,I,1,N) BINARY_N3_B(S,2,1,J,N) HE_COUNT_M0(S,Z,I,J)
HE_COUNT_NO(S,Z,I,J)
HE_COUNT_M1(S,Z.I,J)
HE_COUNT_N1(S,Z,IJ)
NEXCH(S,Z,1,J)
NEXCH_B(S,Z,1,J)
BIF_1(S,Z,I,J,M,N)
BIF_2 $2(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}, \mathrm{N})$
BIF_3(S,Z,I,J,M,N)
BIF_4(S,Z,I,J,M,N)
BIF_11(S,Z,1,J,M)
BIF_12(S,Z,I,J,N)
BIF_6(S,Z,1,J,M)
BIF_9(S,Z,I,J,M)
BIF_5(S,Z,1,J,M)
BIF $8(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})$
BIF_10(S,Z,1,J,N)
BIF $^{-} 7(\mathrm{~S}, \mathrm{Z}, \mathrm{J}, \mathrm{J}, \mathrm{N})$ FEAS_M_01(S,Z,1,J,M) FEAS_M_01_B(S,Z,1,J,M) FEAS_M_02(S,Z,1,J,M) FEAS_M_02_E(S,Z, I,J,M) FEAS M_03(S,Z,I,J,M) FEAS_M_03_B(S.Z,I,J,M) FEAS_M_(14(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_3_2(S,Z,1,J,M) FEAS_M_3_B_i(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,1,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,1,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,1,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,1,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,1,J,M,iv) FEAS_BEG_B_SP(S,Z,I,J,M,N) FEAS_END_SP(S,Z,1,J,M,N) FEAS_END_B_SP(S,Z, $1, J, M, N)$ FEAS_BEG3(S,Z,1,J,M,N) FEAS_BEG(S,Z,I,J,M,N) FEAS_BEG2(S,Z,I,J,M,N) FEAS_END3(S,Z,LJ,M,N) FEAS_END ( $(, Z, Z, 1, J, M, N)$ FEAS_END2(S,Z,1,J,M,N) FEAS_BEG4 B(S,Z,1,J,M,N) FEAS_BEG2 B(S,Z,1,J,M,N) FEAS_BEG1 B(S,Z,I,J,M,N) FEAS_BEG3_B(S,Z,1,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,1,J,M)
BIF_13_1(S,K,Z,1,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,1,J,M)
BIF_18(S,Z,I,J,M,N)
$\operatorname{SHELL}(Z, I, J)$
SHELL_B(K,Z,1,J)
$\operatorname{KMAXI}_{1}^{-}(\mathrm{S}, \mathrm{Z}, 1, \mathrm{~J})$
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,1,J)
*AREA_REST6(S,Z,I,J)
AREA_-REST7(S.Z,I,J)
AREA_RESTI_B(S,K,Z,1,J)
AREA_REST2_B(S,K.Z,1,J)
AREA_REST3_B(S,K,Z,I,J)
AREA_REST4 ${ }^{-} \mathrm{B}(\mathrm{S}, \mathrm{K}, \mathrm{Z}, \mathrm{I}, \mathrm{J})$
AREA_REST5 B(S,K,Z,I.J)
AREA_REST6_B(S,Z,I.J)
LIM_HEX(S,M)
*-------------------------------
PA_1(S,I,M)
$\mathrm{PA}_{-}^{-} 2(\mathrm{~S}, \mathrm{I}, \mathrm{M})$
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 $10(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}, \mathrm{N})$
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,IJ,M,N,R)
PA ${ }^{-} 18(\mathrm{~S}, \mathrm{Z}, \mathrm{J}, \mathrm{M}, \mathrm{N})$
PA_19(S,Z,I J,M)
PA_20(S,Z, $1, \mathrm{~J}, \mathrm{M})$
PA $21(S, Z, 1, J, M, R)$
PA_22(S,Z,I,J,M,R)
PA_23(S,Z,I,J,M,R)
PA_24(S,Z,l,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,l,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,1,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,l,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_5!(S,Z,I,J,M,N)
PA 52(S,Z,1,J,M,N)
PA_53(S,Z.I,J.M,N)
PA_54(S,Z,I,J,M)
PA_55(S,Z,l,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 }6
PA_66
PA }6
PA_68(S,Z.1,J)
;
*EQ (1)
HBHU(S,I,M)$(HOT(S,l,M)=1 AND HU(I) AND FREEH(I)).
FHU(I)*(TU(S,M)-TL(S,M))=E=SUM((Z,N,J)$(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)=| 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))
*---.----
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,l,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,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND FREEH(1) ^ND FREEC(J))
QNEW M(S,Z.l,J,M) =E=SUM(N$(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.J)=1),Q(S,Z,l,M.J,N));
```

```
*EQ (6)
TRANSFOR_N(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z.J.N,I)=1
AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,l,J,N)=E=SUM(M$(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)=I ),Q(S,Z,I,M,J.N));
*.
*EQ (7_a)
HBHS_Nl(S,l,M)$(HOT(S,l,M)=1 AND NOT HU(l)
AND FREEH(I) AND NIH(I)=1 AND NOT PA(I)).
DHH(S,l,M)=E=SUM((Z,N,J)$(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)$(D(S,Z,M,N)=1 AND HOT(S,l,N)=1 AND ORD(N) GT ORD(M)).QH(S,Z.I,N,M))
-SUM((Z,N)$(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_NJ(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,l,M)=1
    AND ALLOW_H(S,Z,l,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)$(HOT(S,I,M)=1 AND NOT HU(1) AND FREEH(1) AND NIH(1)=1)..
SUM((Z,N)$(D(S,Z,M,N)=1 AND HOT(S,l,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N))
=L=SUM((Z,N,J)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND COLD(S,J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,l,M,J,N));
*EQ (10)
NOISOC(S,J,N)$(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,IMM)=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 (Ila and 13a) Case of BIF(I,J)=0 (i,j) not belonging to set B
BINARY_Ml(S,Z,I,J,M)$(HOT(S,l,M)=1 AND ALLOW H(S,Z.I.M.J)=1 AND BIF(Z.l.J)=0
    AND FREEH(I) AND FREEC(J)AND NOT PA(I)).
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*DHH(S,I,M)$(NOT HU(I))
    -Y_M(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)$(HU(I))=L=0;
*-------------------------------------------------------------
****** ********** MINIMUM VALUE OF QNEW_M=0.01!!!!!!!!!
BINARY_M2(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M},\textrm{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(1,J)=1 (i,j) belonging to set B
BINARY M1 B(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,l,M,J)=1 AND BIF(Z,I,J)=1
                AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*DHH(S,I,M)$(NOT HU(1))
    -Y_M_B(S,Z,I,J,M)*FMAX_HU(I)*DTHU(I)$(HU(I))=L=0;
*EQ (11b and 13b) Case of BIF(1,J)=1 (i,j) belonging to set B
BINARY_M2_B(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S.Z,I,M,J)=1 AND BIF(Z,l,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)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J.N,I)=1 AND BIF(Z,l,J)=0
                        AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,l,J,N)-Y_N(S,Z,I,J,N)*DHC(S,J,N)$(NOT CU(J))
    -Y N(S,Z,I,J,N )
*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 FREEEH(l) AND FREEC(J)).. QNEW_N(S,Z,IIJ,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)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J.N.I)=1 AND BIF(Z.l,J)=1
AND FREEII(I) AND FREEC(J) )..
    QNEW_N(S,Z,I,J,N)-Y N B(S,Z,l,J,N)*DHC(S,J,N)$(NOT CU(J))
        Y_N_B(S,Z,l,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,IJ,N)*QLCMIN=G=0;
*.--
*EQ (15) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*EQ (16)
BINARY_M5(S,Z,l,J,M)$(HOT(S,I,M)=1 AND HOT(S,I.M-1) AND ALLOW_H(S,Z,I,M.J)=1
AND ALLLOW_H(S,Z,1,M-1,J) AND BIF(Z,1,J)=0 AND FREFH(1) AND FREEC(J)).
    NHE_M0(S,Z,I,J,M)=L=2-Y_M(S,Z,I,J,M)-Y_M(S,Z.I,J.M-1):
*EQ (17) IS IN REALITY NOT NEEDED, BUT WAS ADDED TO ENFORCE K=0 WHEN Y=0
* AND HOT(S,I,M-1) AND ALLOW_H(S,Z,I,M-1,J)AND ALLOW_H(S,Z.I,M.J)=1
* AND ALLOW_H(S,Z,I,M,J)=1
BINARY_M5b(S,Z,I,J,M)$(HOT(S,1,M)=I AND ALLOW_H(S,Z,I,M,J)=1AND BIF(Z,I,J)=0
    AND FREEH(I) AND FREEC(J)).. NHE_M0(S,Z,l,J,M)=L=Y_M(S,Z,IJJ,M);
* IT TURNS OUT THAT THIS EQUATION ONLY FORCES THE VALUES OF K TO BE ZERO
* WHEN Y=0, WHICH HAPPENS NATURALLY IF ONE IS MINIMIZING THE NUMBER OF
* EXCHANGERS OR BECAUSE THE FIXED COSTS ARE BEING MINIMIZED.
* EVEN IF NOT DRIVEN TO ZERO BY THE OBJECTIVE FUNCTION IT IS HARMELESS.
* HOWEVER, IT TURNS OUT THAT IT COULD MAKE EXTENSIONS OF THE MODEL HAVE
* PROBLEMS. SO, ALTHOUGH THE EQUATION IS NOT NEEDED, IT GIVES SOME EXTRA VALUES
* OF K WHEN THEY DO NOT REALLY MATTER.
*EQ (18)
BINARY_M3(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z.I,J)=0
AND FREEH(I) AND FREEC(J)).
    NHE_M0(S,Z,I,J,M)=G= Y_M(S,Z,I,J,M)-Y_M(S,Z,I,J.M-1)$(HOT(S,I,M-1)
                                    AND ALLOW_H(S,2,1,M-1,J));
*EQ (19)
BINARY M4(S,Z,1,J,M)$(HOT(S,I,M)=1 AND HOT(S,I,M-1) AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J)).
                                    NHE_MO(S,Z,I,J,M)=G=0;
*-
*EQ (20) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*
*EQ (21)
BINARY_M8(S,Z,I,J,M)$(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,l,M+1,J) AND BIF(Z,l,J)=0 AND FREEH(I) AND FREEC(J))..
    N
* (a)
*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,1,M-1,J)
BINARY_M9(S,Z,I,J,M)$(HOT(S,I,M)=1AND ALLOW_H(S,Z,1,M,J)=1 AND BIF(Z,I,J)=0
        AND FREEH(I)AND FREEC(J)).
                            NHE_Ml(S,Z,I,J,M) =L= Y_M(S,Z,I,J.M);
* SEE COMMENTS ON EQUATION (17)
*.
*EQ (23)
BINARY_M6(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,l,M,J)=1 AND BIF(Z,1,J)=0
AND FREEH(I) AND FREEC(J)).. NHE_Ml(S,Z,I,J,M)=G=Y_M(S,Z,l,J,M)-Y_M(S,Z,l,J_M+1)
                                    $(HOT(S,I,M+1) \}\mathrm{ ND ALLOW_H(S,Z,\,M+1,J));
*EQ (24)
BINARY_M7(S,Z,1,J,M)$(HOT(S,I,M)=1 AND HOT(S,I,M+1) AND ALLOW_H(S.Z.I.M.J)=1
AND ALL}OW H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND FREEH(l) AND FREEC(J)).
                                    NHE_Ml(S.Z,I.J,M)=G=0;
```

```
*EQ (25)
BINARY_M3_B(S,Z,I,J,M)$(HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z.l,J)=1
AND FREEH(I) AND FREEC(J)).
    Y_M_B(S,Z,l,J,M)=E=SUM(O$(HOT(S,l,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)=I 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,1,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,l,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,1,J)=0
        AND FREEH(I) AND FREEC(J)).
                                    NHE_N0(S,Z,1,J,N) =L= Y N(S,Z,1,J.N);
* SEE COMMENTS ON EQUATION (17)
**--.--.--
BINARY_N3(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,l,J)=0
AND FREEH(l) AND FREEC(J))..
NHE_N0(S,Z,I,J,N) =G= Y_N(S,Z,l,J,N)-Y_N(S,Z,I,J,N-1)
                                    $(COLDD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I));
*EQ (30)
BINARY_N4(S,Z,I,J,N)$(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,l) AND BIF(Z,I,J)=0 AND FREEH(1) AND FREEC(J)).
                                    NHE_NO(S,Z,1,J,N)=G=0;
*EQ (3I) NOT NEEDED
* GAMS WRITES IT AUTOMATICALLY WHEN IT WRITES EQUATION (18)
*
*EQ (32)
BINARY N8(S,Z,l,J,N)$(COLD(S,J,N)=1 AND COLD(S,J,N+1) AND ALLOW C(S.Z,J,N,I)=1
AND ALL-OW_C(S,Z,J,N+1,l) AND BIF(Z,I,J)=0 AND FREEH(I) AND FREEC(J))..
            NHE_Nl(S,Z,I,J,N)=L=2-Y_N(S,Z,1,J,N)-Y_N(S,Z,I,J,N+1);
*----------------------------------------------------------------
* AND COLD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I)
BINARY_N9(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,l,J)=0
                AND FREEH(I) AND FREEC(J)).
                    NHE_Nl(S,Z,I,J,N) =L= Y_N(S,Z,l,J,N);
* SEE COMMENTS ON EQUATION (17)
*-
*EQ (34)
BINARY N6(S,Z,l,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_Nl(S,Z,I,J,N)=-\overline{G}=\textrm{Y}_N(S,Z,l,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,l) AND BIF(Z,1,J)=0 AND FREEH(1) AND FREEC(J))..
                NHE_Nl(S.Z.I,J,N)=G=0;
*-
*EQ (36)
BINARY N3 B(S,Z,1,J,N)$(COLD(S,J,N)=1 AND AI.I.OW_C(S.Z.J.N.I)=1 AND BIF(Z.l,J)=1
AND FREEEH(I)AND FREEC(J))..
Y_N_B(S,Z,I,J,N)=E=SUM(O$(COLD(S,J,O) AND ORD(O) LE ORD(N)
AN̄D-' ALLOW_C(S,Z,J,O,I)),NHE_N0_B(S,Z,I,J,O)) - SUM(O$(COLD(S,J,O) AND ORD(O) LE
            ORD(N)-1 AND ALLOW_C(S,Z,J,O,l)),NHE_N1_B(S,Z,I,J,O));
*
*EQ (37)
HE_COUNT_M0(S,Z,I,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
NHE}(\textrm{S},\textrm{Z},1,\textrm{J})=\textrm{E}=\textrm{SUM}(\textrm{M}(\textrm{HOT}(\textrm{S},\textrm{I},\textrm{M})=1 AND ALLOW_H(S,Z.l,M,J)=1 AND BIF(Z,I.J)=1)
```

```
NHE_M0 B(S,Z.I.J,M)) \(+\operatorname{SUM}(M \$(H O T(S, 1, M)=1\) AND ALLOW_H(S,Z,I,M,J)=1
AND \(\operatorname{BIF}(Z, I, J)=0)\), NHE_M0(S,Z,I,J,M));
*
*EQ (38)
    HE_COUNT_N0(S,Z,1,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)).
NHE(S,Z,I.J)=I:=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, \(, \mathbf{,}, \mathrm{J}, \mathrm{N})\) )
\(+\operatorname{SUM}(\mathrm{N} \$(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{~N})=1\) AND ALLOW C \((\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N}, \mathrm{l})=1\) AND BIF(Z,l,J)=0),
                NHE_NO(S,Z,I,J,N));
*---------
HE_COUNT_M1(S,Z,I,J)\$(ALLOW(S,Z, \(1, \mathrm{~J})=1\) AND FREEH(I) AND FREEC(J))..
\(\operatorname{NHE}(S, Z, 1, J)=E=S U M(M \$(H O T(S, I, M)=1\) AND ALLOW \(H(S, Z, 1, M, J)=1\) AND BIF \((Z, 1, J)=1)\).
NHE_M1_B(S,Z,l,J,M)) + SUM(M\$(HOT(S,l,M)=1 AND ALLOW_H(S,Z.I,M.J)=1
AND \(\overline{B I F}(Z, I, J)=0), \quad\) NHE_M1(S, \(\mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})\) );
*EQ (40)
HE COUNT_N \((\mathrm{S}, \mathrm{Z}, \mathrm{l}, \mathrm{J}) \$(\) ALLOW \((\mathrm{S}, \mathrm{Z}, 1, \mathrm{~J})=1\) AND FREEH( l\()\) AND FREEC(J))..
\(\operatorname{NHE}(\mathrm{S}, \mathrm{Z}, 1, \mathrm{~J})=\mathrm{E}=\mathrm{SUM}(\mathrm{N} \$(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{~N})=1\) AND ALLOW C \((\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N}, \mathrm{l})=1\) AND BIF \((\mathrm{Z}, \mathrm{I}, \mathrm{J})=1)\),
    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, \(\mathrm{Z}, \mathrm{l}, \mathrm{J})=\mathbf{L}=1\);
\({ }^{*}\)..
*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,1,J)=L=KMAX (Z,1,J);
*
*EQ (43)
BIF_I(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 \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW C(S,Z,J,N,I)=1
    AND \(\operatorname{BIF}(\mathrm{Z}, \mathrm{l}, \mathrm{J})=1\) AND FREEH( l\()\) AND FREEC( J\()\) AND NOT PA( l\()\) )..
    SUM(LS(D(S,Z:L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S, \(1, \mathrm{~L})=1\)
    AND ALLOW H(S,Z,l,L,J)=1),
    QNEW_M(S,Z,I,J,L)) - QNEW2_M (S, Z, \(1, \mathrm{~J}, \mathrm{M})=\mathrm{L}=\)
```



```
    QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,1,J,N)
    \(+\mathrm{BI}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J}, \mathrm{N}) * 4^{*} \max (\mathrm{SUM}(\mathrm{L} \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{L}, \mathrm{N})=1\) AND ORD(L) LE ORD(M)
    AND HOT(S,l,L)=1 AND ALLOW_H(S,Z,l,L,J)=1),DHH(S,I,L)),
                    SUM \((\mathrm{O} \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{O})=1\) AND ORD(O) LE ORD(N)
                    AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,J)),DHC(S,J,O)));
*
*EQ (44)
BIF_2(S,Z,l,J,M,N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,l,M)=1
    AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND
    ALLOW H(S,Z,1,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1AND 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,l,L,J)=1),
        QNEW_M(S,Z,I, \(\mathrm{J}, \mathrm{L}))\) - QNEW2_M(S,Z,I,J,M) \(=\mathrm{G}=\)
SUM \((O \$(\bar{D}(\mathrm{~S}, \mathrm{Z}, \mathrm{M}, \mathrm{O})=1\) AND \(\operatorname{ORD}(\mathrm{O}) \mathrm{LE}\) ORD(N) AND COLD(S,J,O) AND ALLOW_C(S, \(\mathrm{Z}, \mathrm{J}, \mathrm{O}, \mathrm{I}))\),
    QNEW_N(S,Z,1,J,O)) - QNEW2_N(S,Z,I,J,N)
    \(-\mathrm{BI}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J}, \mathrm{N}) * 4^{*} \max (\mathrm{SUM}(\mathrm{L} \overline{\$}(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{L}, \mathrm{N})=1\) 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)),
    \(\operatorname{SUM}(\mathrm{O}(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{O})=1\) AND ORD(O) LE ORD(N) AND COLD(S,J,O)
    AND ALLOW_C(S,Z,3,O,I)),DHC(S,J,O)));
*
*EQ (45)
BIF \(3(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}, \mathrm{N}) \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{N})=1\) AND TL(S,N) LT TU(S,M) AND HOT(S, I,M)=1
AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S,Z, \(1, \mathrm{M}, \mathrm{J})=1\) AND ALLOW_C(S,Z,J,N.I)=1
AND \(\operatorname{BIF}(\mathrm{Z}, 1, \mathrm{~J})=1\) AND FREEH(I) AND FREEC( J\()\) ).
    \(\mathrm{B} 1(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{M}, \mathrm{J}, \mathrm{N})=\mathrm{E}=2-0.25^{*} \mathrm{SUM}(\mathrm{L} \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{L}, \mathrm{N})=1 \mathrm{AND} \operatorname{ORD}(\mathrm{L}) \operatorname{LE} \operatorname{ORD}(\mathrm{M})\)
    AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,I,L,J)=1), NHE M1_B(S.Z.l,J,L))
    +0.25 * \(\operatorname{SUM}(O \$(D(S, Z . M, O)=1\) AND ORD(O)LE ORD(N) AND COLD(S,J,O)
        AND ALLOW_C(S,Z,J.O,l)),NHE_N1_B(S,Z,l,J,O))
                                    -NHE_M1_B(S,Z,I,J,M)-NHE_NI_B(S,Z.I,J,N);
```

```
*EQ (46)
BIF_4(S.Z,I,J,M,N)$(D(S,Z.M,N)=1 AND TL(S,N) LT TU(S,M) AND TL(S,N) GE TL(S,M)
    AND HOT(S,l,M)=1 AND COLD(S,J,N)=1 AND ALLOW H(S,Z,l,M,J)=1
    AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J)).
    SUM(L$(HOT(S,I,L)=1 AND ORD(L) LE ORD(M) AND
    ALLOW_H(S,Z,I,L,J)=1),NHE_MI_B(S,Z,I,J,L))
    -SUM(O\overline{$}(COLD(S,J,O) AND ORD(O)LE ORD(N) AND ALLOW_C(S,Z,J,O,I)),
        NHE_N1_B(S,Z,1,J,O))=G=0;
*-
*EQ (47)
BIF_11(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,l,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J)).
        SUM(O$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M) AND ALLOW_H(S,Z,I.O,J)=1),
                        NHE_M0_B(S,Z,1,J,O)-NHE_M1_B(S,Z,I,J,O))=L=1 ;
**-------
BIF_12(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,1,J)=1
AND FREEH(I)AND FREEC(J)).
    SUM(O$(COLD(S,J,O) AND ORD(O) LE ORD(N) AND ALLOW C(S,Z,J,O,1)),
                NHE_N0_B(S,Z,I,J,O)-NHE NI B(S,Z,1,J,0))=L=1,
**--------
BIF_6(S,Z,1,J,M)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,l,J)=1
    AND FREEH(I) AND FREEC(J))..
        QNEW2_M(S,Z.I.J,M) = = = 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
*---------
BIF_8(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J)).
                                    QNEW2_N(S,Z,I,J,N) =L= QNEW_N(S,Z,I.J,N);
*.
*EQ (54)
BIF_10(S,Z,1,J,N)$(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,l,J,N)*DHC(S,J,N);
*
*EQ (55)
BIF_7(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J)).
    QNEW2_N(S,Z,l,J,N) =L= NHE_N1_B(S,Z,l,J,N)*DHC(S,J,N);
*
*EQ (56) NOT NEEDED. THE VARIABLE IS DECLARED POSITIVE
*----.-----
*EQ (57)
FEAS M_0l(S,Z,I,J,M)$(HOT(S,l,M-I) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z,l,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,1,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)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_ _H(S,ZIIM-1,J) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J)).
            ALFA_M(S,Z,1,J,M)=L=1-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M);
*.
*EQ (58)
    FEAS M_02(S,Z,l,J,M)$(HOT(S,l,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLCOW_H(S.Z.I,M-1,J) AND BIF(Z.I,J)=0 AND SPH(I)=1 AND FREE-H(I)
AND FREEC(J))..
```

```
    ALFA_M(S,Z,l,J,M)=L=1-NHE_MI(S,Z,l,J,M-1)-NHE_Ml(S,Z,I,J,M);
FEAS_M_02_B(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREE\overline{C}(J))..
            ALFA_M(S,Z,1,J,M)=L=1-NHE_M1_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,1,J,M);
*EQ (59)
FEAS_M 03(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,l,M)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M-I,J) AND BIF(Z,I,J)=0 AND SPH(I)=! 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,l,J,M-1)-NHE_M0(S,Z,I,J,M) -
        NHE_M1(S,Z,1,J,M-1)-NHE_M1(S,Z,1,J,M);
FEAS_M_03_B(S,Z,1,J,M)$(HOT(S,1,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J)).
ALFA_M(S,Z,I,J,M)=G=Y_M_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z,I,J,M)
                            - NHE_M1_B(S,Z,I,J.M-1)-NHE_M1_B(S,Z,1,J,M);
*-
*EQ (60)
FEAS_M_04(S,Z,1,J,M)$(HOT(S,l,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND
ALLO--H(S,Z,1,M-1,J) AND (BIF(Z,I,J)=1 OR SPH(1)=1)AND FREEH(1) A- ND FREEC(J)).
                                    ALFA_M(S,Z,I,J,M)=G=0;
*-
*EQ (61)
FEAS_M 2(S,Z,I,J,M)$(HOT(S,l,M-1) AND HOT(S,1,M)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALLOOW_H(S,Z,l,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J)AND NOT PA(I))..
QNEW_M(S,Z,l,J,M)/(CPH(S,l,M)*(TU(S,M)-TL(S,M)))}=\textrm{L}
    QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
    +(1-ALFA_M(S,Z,1,J,M))*DHH(S,I,M)/ (CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*
*EQ (62)
FEAS M 1(S,Z,I,J,M)$(HOT(S,l,M-1) AND HOT(S,l,M)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALİOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J)AND NOT PA(I)).
    QNEW_M(S,\overline{Z},1,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
    +(1-ALF
            =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)$(HOT(S,I,M-1) AND HOT(S,I.M)=1 AND ALLOW H(S,Z.I,M,J)=1
ANI) ALLLOW H(S.Z,I.M-1.J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND NOT PA(I))..
    - QNEW M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
    + QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
    +(1+ NHE_M1(S,Z,I,J,M-1) + NHE_M1(S,Z,I,J,M) - NHE_M0(S,Z,I,J,M-1))
    *DHH(S.I.M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))* 1.0000J =G= 0;
*
*EQ (64)
FEAS_M_4(S,Z,I,J,M)$(HOT(S,l,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,1,M-1,J) AND BIF(Z,1,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)))* * .00001 =G=0;
*--
*EQ (65)
FEAS M 3_B_2(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALL
AND FREEC(J) AND NOT PA(I)).
QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
QNEW_M(S,Z,l,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
+(1+NHE_M1_B(S,Z,I,J,M-1)+NHE_M1_B(S,Z,I,J,M)-NHE_M0_B(S,Z,I,J,M-1))
    * DHH(S.I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*
*EQ (66)
FEAS_M_3_B_l(S,Z,I.J.M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,l,M.J)=1
AND ALLOW_H(S,Z.I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(1)
AND FREEC(J) AND NOT PA(I)).
QNEW2_M(S,Z.1,J.M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
QNEW_M
    -NHE_M0_B(S,Z,1,J,M-1)-Y_M_B(S,Z,1,J,M-1))
                                    * *HH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)));
```

```
*EQ (67)
FEAS_M_4_B(S,Z,I,J,M)$(HOT(S,I,M-I) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M.J)=1
AND ALLOW_H(S,Z,l,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND NOT PA(I))..
    (QNEW M(S,Z,I,J,M)-QNEW2 M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) = L=
QNEW_M(S,Z,I.J,M-1)/(CPH(S,l,M-1)*(TU(S,M-1)-TL(S,M-I)))
    +(2 + N}HHE_M0_B(S,Z,1,J,M-1)-NHE_M1_B(S,Z,1,J,M)-Y_M_B(S,Z,I.J,M))
                            *DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*
*EQ (68)
FEAS_M_1_SP(S,Z,I,J,M)$(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,l,J,M)=G=(Y_M(S,Z,l,J,M)-
    NHE_M0(S,Z,1,J,M) + NHE_M1(S,Z,I,J,M))*DHH(S.I,M):
FEAS_M_1_SP_B(S,Z,I,J,M)$(HOT(S,l,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,l,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=1 AND SPH(I)=0
AND FREEH(I) AND FREEC(J) AND NOT PA(I))
    QNEW_M(S,Z,I,J,M)=G=(Y_M_B(S,Z,I,J.M)-
    NHE_M}0_B(S,Z,I.J.M)+NHE_M0_B(S,Z,I,J,M))*DHH(S,I.M)
*EQ (69)
FEAS N 01(S,Z,I,J,N)$(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-I,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,1,J,N)-NHE N0(S,Z,I,J,N-1);
FEAS_N_01_B(S,Z,1,J,N)$(COLD(S,J,N-1) AND COLD(S.J,N)=1 AND ALLOW_C(S,Z,J.N,I)=1
AND ALLOW C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(\overline{3}))..
    ALFA_N(S,Z,I,J,N)=L=1-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S.Z,1,J,N-1);
*
*EQ (70)
FEAS_N_02(S,Z,1,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z.J,N,1)=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_NI(S,Z,I,J,N)-NHE_NI(S,Z,I,J,N-1);
FEAS N 02 B(S,Z.I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,l)=1
AND ALLO--_C(S,Z,J,N-1,I) AND BIF(Z,1,J)=1 AND FREEH(I) AND FREEC(J)).
            ALFA__N(S,Z,I,J,N)=L=1-NHE_N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,1,J,N-1);
*---------
FEAS N 03(S,Z,I,J,N)$(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,l,J,N)-NHE_N0(S,Z,I,J,N)-NHE_N0(S,Z,1,J,N-1)
                            - NHE_N1(S,Z,1,J,N)-NHE_N1(S,Z,1,J,N-1);
FEAS N 03 B(S,Z,I,J,N)$(CO-LD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,1,J)=1 AND FREEH(I) AND FREEC(\overline{J}))..
    AlFA_N(S,Z,I,J,N)=G=Y N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N-1)
        -NHE_-N1_B(S,Z,I,J,N)-NHE_N1_B(S,Z,I,J,N-1);
*_
*EQ (72)
FEAS_N_04(S,Z,I,J,N)$(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)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW C(S,Z,J,N-1,1) AND SPC(J)=1 AND FREEH(1) AND FREEC(J))..
    QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N))}==\textrm{L}=\textrm{QNEW}N(S,Z,I,J,N-1
    /(CPC(S,J,N-1)
    *(TU(S.N-1)-TL(S.N-1)))+(1-ALFA_N(S,Z,I,J,N))*DHC(S,J,N)/
                                    (CPC(S,J,N)*(TU(S,N)-TL(S,N)));
*EQ (74)
FEAS N 1(S,Z,l,J,N)$(COLD(S,J,N-I) AND COLD(S,J,N)=1 AND ALLOW_C(S.Z.J,N,l)=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)))
        +(I-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)));
*RQQ (75)
P!:AS_N_3(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-I,I) AND BIF(Z,I.J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
-QNEW_N(S,Z,1,J,N-1)/(CPC(S,J,N-I)*(TU(S,N-1)-TL(S,N-1)))
+QNEW N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))+(1+NHE_N1(S,Z,1,J,N-1)
    +NHE_N1(S,Z,I,J,N)
    -NHE_N0(S,Z,1,J,N-1))*DHC(S.J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))*1.00001 =G= 0;
*EQ (76)
FEAS_N_4(S,Z,I,J,N)$(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)=I AND FREE-H(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,1,J,N-1)
+ NHE_N0(S,Z,I,J,N)-NHE_Nl(S,Z,1,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,1,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND ALLOWW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1 AND SPC(J)=1 AND FREEH(1)
AND FREEC(\overline{J})).
-QNEW_N(S,Z,1,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+(1 + NHE_N1_B(S,Z,1,J,N-1)+ NHE_N1_B(S,Z,1,J,N)-NHE_N0_B(S,Z,I,J,N-1))
* DHC(S,J,N})/(\overline{\textrm{CPC}}(\textrm{S},\textrm{J},\textrm{N})*(TU(S,N)-TL(S,N)))=G=0;
*-
*EQ (78)
FEAS_N_3_B_1(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND ALLOWW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,l) AND BIF(Z,I.J)=1 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
-QNEW2_N(S,Z,1,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_NI_B(S,Z,1,J,N)
-NHE N0_B(S,Z,1,J,N-1)-Y_N_B(S,Z,1,J,N-1))
                                    * DHC(S,\overline{J},N/\/(CPC(S,J,N)*(TU(S,N)-TL(S.N)))=G=0;
**-...-.---
FEAS_N_4_B(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOWW_C(S,Z,J,N-1,I) AND BIF(Z,1,J)=1 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
    -(QNEW_N(S,Z,1,J,N)-QNEW2_N(S,Z,I,J,N))/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+ QNEW_N(S,Z,I,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
    +(2 + NHE_N0_B(S,Z,I,J,N-1) -NHE_N1_B(S,Z,1.J,N)-Y_N_B(S,Z.I,J,N))
                            *DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=0;
*
*EQ (80)
    FEAS_N_1_SP(S,Z,1,J,N)$(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
    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_NI(S,Z,I,J,N))*DHC(S,J,N);
    FEAS N 1 SP B(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
    AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND ALLOW_C(S,Z,J,N+1,I)
    AND BIF(Z,I,J)=1
    AND SPC(J)=0 AND FREEH(I) AND FREEC(J)).. QNEW_N(S,Z,I,J,N) =G=
    (Y_N_B(S,Z,I,J,N)-NHE_N0_B(S,Z,I,J,N)-NHE_NI_B(S,Z,I,J.N))*DHC(S,J,N);
*E--------
FEAS_BEG_SP(S,Z,I,J,M,N)$(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,l)=1 AND BIF(Z.1.J)=0
AND SPH(I)=0
    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))
```


## $+\left(2-N H E \_M 0(S, Z, I, J, M)-N H E \_N 0(S, Z, 1, J, N)\right)^{*} T U(S, N)=G=0$;

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)=I 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))
$+\left(2-N H E \_M 0 \_B(S, Z, 1, J, M)-N H E \_N 0 \_B(S, Z, I, J, N)\right) * T U(S . N)=G=0$;
* 

*EQ (82)
FEAS_END_SP(S,Z,IJ,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND $\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1$ AND COLD(S,J,N $)=1$ AND ALLOW_H $(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=1$
AND ALLOW C(S, Z, J,N,I)=1 AND BIF(Z,I,J)=0
AND SPH $(\mathrm{I})=0$ AND SPC $(\mathrm{J})=0$ AND FREEH $(\mathrm{l})$ AND FREEC( J$)$ AND NOT PA(I)). TU(S,M)-TU(S,N)
-QNEW_M(S,Z,I,J,M)/(FH(S,l)* $\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}))+\mathrm{QNEW}$ _N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N)) $+\left(2-N H E \_M 1(S, Z, 1, J, M)-N H E \_N I(S, Z, \overline{1}, J, N)\right)^{*} T U(S, N)=G=0$,
FEAS_END_B_SP(S,Z,I, $\bar{J}, M, N) \$(T L(S, N)$ LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND $\operatorname{HOT}(\overline{\mathrm{S}}, \mathrm{I}, \mathrm{M})=1$ AND COLD(S,J,N $)=1$ AND ALLOW_H(S.Z, $, \mathrm{M}, \mathrm{J})=1$
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND SPH $(\mathrm{I})=0$ AND SPC $(\mathrm{J})=0$ AND FREEH $(\mathrm{l})$ AND FREEC( J$)$ AND NOT PA( l$)$ ).
TU(S,M)-TU(S,N)
-QNEW_M(S,Z,I,J,M)/(FH(S,I)*CPH(S,I,M)) + QNEW N(S,Z,1,J,N)/(FC(S,J)*CPC(S,J,N))
$+\left(2-N H E \_M 1 \_B(S, Z, I, J, M)-N H E \_N 1 \_B(S, Z, 1, J, N)\right) * T U(S, N)=G=0$;
*EQ (83)
FEAS_BEG3(S,Z,I,J,M,N)\$(DTVIO(l,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND $\bar{T} U(S, N)$ GT TL(S,M)
AND $\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1$ AND $\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}+1)$ AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1$ AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N}+1)$
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 $\operatorname{BIF}(\mathrm{Z}, \mathrm{I}, \overline{\mathrm{J}})=0$ AND $(\mathrm{SPH}(\mathrm{I})=1 \mathrm{OR} \operatorname{SPC}(\mathrm{J})=1)$ AND FREEH(1) AND FREEC( J$)$ ).
NHE_N1 (S,Z,1,J,N)=L=(2-NHE_MO(S,Z,I,J,M)-NHE_NO(S,Z,1,J,N));
*
*EQ (84)
FEAS_BEG(S,Z,l,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,1,M)=1 AND HOT(S,1.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 ALLLOW_C(S,Z,J,N+1,l) AND BIF(Z,I,J)=0
AND (SPH $(\mathrm{I})=1$ OR SPC $(\mathrm{J})=1)$ AND FREEH $(\mathrm{I})$ 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)
$/(\mathrm{TU}(\mathrm{S}, \overline{\mathrm{N}}+1)-\mathrm{TL}(\mathrm{S}, \mathrm{N}+1))^{*} \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}) / \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}+1)$
$+\left(2-N H E \_M 0(S, Z, 1, J, M)-N H E \_N 0(S, Z, I, J, N)\right)^{*} D H C(S, J, N) /(T U(S, M)-T L(S, N))$;
*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,l)=1 AND ALLOW_C(S,Z,J,N+1,l) AND BIF(Z, $1, \mathrm{~J})=0$ AND (SPH(1)=1 OR SPC(J)=1) AND FREEH( $(\overline{\mathrm{I}})$ AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,I,J,M)/(MN(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))
${ }^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}+\mathrm{I})-(2-\mathrm{NHE}$ M $0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})-\mathrm{NHE}$-N0(S,Z,I,J,N)

* $\mathrm{DHH}(\mathrm{S}, \mathrm{I}, \mathrm{M}+1) /(\mathrm{TU}(\mathrm{S}, \mathrm{M}+1)-\mathrm{TL}(\mathrm{S}, \mathrm{M}+\mathrm{I}))$;
* 

*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, $1, \mathrm{M})=1$ AND $\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}-1)$ AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1$ AND COLD(S,J,N-1)
AND ALLOW H(S, $Z, I, M, J)=1$
AND ALLOW_H(S,Z.IM-I,J)ANI) ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND $\operatorname{BIF}(\mathrm{Z}, \mathrm{I}, \mathrm{J})=0$ AND ( $\mathrm{SPH}(\mathrm{I})=1$ OR SPC( $\overline{\mathrm{J}})=1)$ AND FREEH(I) AND FREEC(J))..
NHE_M0(S,Z,I,J,M)=L=(2-NHE_M1(S,Z,I,J,M)-NHE_N I (S,Z,I,J,N));
*EQ (87)
FEAS_END $(S, Z, I . J, M, N) \$(D T V I O(I, J)=1$ 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(1)=1 OR SPC( J$)=1)$ AND FREEH(l) AND FREEC(J) AND NOT PA(1)).. 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)) ${ }^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}-1)+(2-\mathrm{NHE}$ MI(S,Z,I,J,M)-NHE_NI(S,Z,I,J,N)) *DHH(S,I,M)/(TU(S,M)-TL(S.N));
*.
*EQ (88)
FEAS_END2(S,Z,1,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(1)=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-I)/ (TU(S,N-1)-TL(S,N-I))

* CPC(S,J,N)/CPC(S,J,N-1)-(2-NHE_Ml(S,Z,I,J,M)-NHE_NI (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)=I AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND TU(S, N$)$ GT TL(S,M)
AND $\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1$ AND $\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}+1)$ AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1 / \operatorname{AND} \operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N}+1)$ 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 $(\mathrm{Z}, \mathrm{I}, \mathrm{J})=1$ AND $(\mathrm{SPH}(\mathrm{I})=1$ OR SPC( J$)=1)$ AND FREEH $(\mathrm{I})$ AND FREEC $(\mathrm{J})$ ).
NHE_N1_B(S,Z,I, ,,N) $=\mathrm{L}=$
( $\left.1+Y \_N \_B(S, Z, I, J, N)-N H E \_M 0 \_B(S, Z, 1, J, M)-N H E \_N 0 \_B(S, Z, 1, J, N)\right)$;
*-
*EQ (90)
FEAS_BEG2_B(S,Z,IJ,M,N)\$(DTVIO(1,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,l,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 ALI.OW H(S,Z,I.M+1.J) AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N+1,l) AND BIF(Z,I,J)=1 AND ( $\mathrm{SPH}(\mathrm{l})=1$ OR SPC $(\mathrm{J})=1)$ AND FREEH $(\mathrm{I})$ AND FREEC( J$)$ ).
QNEW N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=
QNEW N(S, Z, $1, \mathrm{~J}, \mathrm{~N}+1) /(\mathrm{TU}(\mathrm{S}, \mathrm{N}+1)-\mathrm{TL}(\mathrm{S}, \mathrm{N}+1))$
*CPC(S.J,N)/CPC(S,J,N+1)+
( $1+\mathrm{Y} \_\mathrm{N}, \mathrm{B}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})-\mathrm{NHE}$-M0_B(S,Z,I,J.M)-NHE_N0_B(S,Z,I.J,N) $)$
${ }^{*} \mathrm{DHC}(\mathrm{S}, \mathrm{J}, \mathrm{N}) /(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{N})$ );

## *EQ (91)

FEAS_BEGI_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, $\overline{\mathrm{N}}) \mathrm{GT}$ TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,1,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))
${ }^{*} \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}) / \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}+\mathrm{I})+\left(2-\mathrm{NHE} M 0 \_\mathrm{B}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})-\mathrm{NHE} \mathrm{N} 0 \_\mathrm{B}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})\right)$ *DHC(S,J,N)/(TU(S,M)-TL(S,N));
*
*EQ (92)
FEAS_BEG3_B(S,Z,I,J,M,N)\$(DTVIO(1,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND TU(S, $\overline{\mathrm{N}}) \mathrm{GT}$ TL(S,M) AND HOT(S, $1, \mathrm{M})=1$ AND $\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}+1)$ AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1$ 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 ( $\mathrm{SPH}(\mathrm{l})=1$ OR SPC( J$)=1)$ AND FREEH $(\mathrm{l})$ AND FREEC(J) AND NOT PA( l$)$ ). QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=QNEW_M(S,Z,l,J,M+1)/ (TU(S, $\bar{M}+1)-\mathrm{TL}(\mathrm{S}, \mathrm{M}+1)$ )
${ }^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}+1)-(2-\mathrm{NHE}$ M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N)) ${ }^{*} \mathrm{DHH}(\mathrm{S}, \mathrm{I}, \mathrm{M}+1) /(\mathrm{TU}(\mathrm{S}, \mathrm{M}+\mathrm{I})-\mathrm{TL}(\mathrm{S}, \mathrm{M}+1))$;
*----------
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 $\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M}-1)$ AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1$ AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N}-\mathrm{I})$
AND ALLOW $\mathrm{H}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=1$
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, 1$)$ AND BIF $(\mathrm{Z}, \mathrm{I}, \mathrm{J})=1$ AND $(\mathrm{SPH}(\mathrm{I})=1$ OR SPC( J$)=1)$ AND FREEH(I) AND FREEC( J$)$ ). NHE_M0_B(S,Z,1,J,M)=L= $\left(1+Y_{-} M_{-} B(S, Z, I, J, M)-N H E \_M 1 \_B(S, Z, I . J, M)-N H E \_N 1 \_B(S, Z, I, J, N)\right)$;
*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-I) AND ALLOW_H(S,Z,l,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-I,I) AND BIF(Z,I,J)=1 AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND NOT PA(1)).
(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))* $\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}-\mathrm{I})+$
(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,1,J,M,N)S(DTVIO(1,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,l,M)=1 AND HOT(S,l,M-1) AND COLD(S, J,N)=1 AND COLD(S, J,N-I) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
AND ALLOW_C( $\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N}, \mathrm{I})=1$ AND ALLOW_C( $\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N}-1, \mathrm{I})$ AND BIF $(\mathrm{Z}, \mathrm{I}, \mathrm{J})=1$
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( $\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N}-\mathrm{I}) /(\mathrm{TU}(\mathrm{S}, \mathrm{N}-1)-\mathrm{TL}(\mathrm{S}, \mathrm{N}-1))^{*} \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}) / \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{N}-\mathrm{I})$
$-\left(2-\mathrm{NHE}_{-} \mathrm{MI} \_\mathrm{B}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})-\mathrm{NHE} \mathrm{NI}_{-} \mathrm{B}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})\right) * \mathrm{DHC}(\mathrm{S}, \mathrm{J}, \mathrm{N}-1) /$
(TU(S, $\mathrm{N}-\mathrm{I})$-TL $(\mathrm{S}, \mathrm{N}-1)$ );
*-
*EQ (96)
$\operatorname{PAREQ}(S, Z, 1, J) \$(\operatorname{ALLOW}(S, Z, 1,1)=1$ AND FREEH(I) AND FREEC( $(\mathrm{J})$ ).
$\operatorname{PAR}(Z, \mathrm{I}, \mathrm{J})=\mathrm{E}=\mathrm{SUM}((\mathrm{M}, \mathrm{N}) \$(\mathrm{D}(\mathrm{S}, \mathrm{Z}, \mathrm{M}, \mathrm{N})=1$ 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),
$\overline{\mathrm{Q}}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J}, \mathrm{N}) /(\mathrm{U}(\mathrm{S}, \mathrm{I}, \mathrm{J}) * \mathrm{LMTD}(\overline{\mathrm{S}}, \mathrm{M}, \mathrm{N}))$;
*EQ (97)
BIF_13 2(S,K,Z,I,J,M)S(ORD(K) LT KMAX $(Z, 1, J)$ AND HOT(S,1,M)=1
AND ALLOW_H(S,Z,I,M,J)=1
AND $\operatorname{BIF}(\mathrm{Z}, \mathrm{I}, \mathrm{J})=1$ AND FREEH(I) AND FREEC(J)).
PAR_B(K,Z,I,J)=L=SUM(L,N)S(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),
$(\mathrm{Q}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{L}, \mathrm{J}, \mathrm{N})-\mathrm{Q} 2(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{L}, \mathrm{J}, \mathrm{N})) /\left(\mathrm{U}(\mathrm{S}, \mathrm{I}, \mathrm{J}) * \mathrm{LM}^{-} \mathrm{LD}(\mathrm{S}, \mathrm{L}, \mathrm{N})\right)$
+AMAX* (2-NHE_MI_B(S,Z,IJ.M)-XI B(S,Z,I.J.M)
$\operatorname{SUM}(\mathrm{KK} \$(\operatorname{ORD}(\mathrm{KK}) \mathrm{GT} 1$ AND ORD(KK) LT ORD(K)), X B B(S,KK Z, $, 1 \mathrm{~J}, \mathrm{M}))$ )),
*Comment: In the paper XI_B does not show. Only one variable, X_B is used

* to make summations from 1 to kmax-1. Here we use XI_B and then a
* summation from 2 to $\mathrm{kmax}-1$. See equation (100) as well.
*EQ (98)
BIF_13_1(S,K,Z,1,J,M)S(ORD(K) LT KMAX(Z,I.J) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND BIF( $Z, \mathbf{I}, \bar{J})=1$ AND FREEH( $\mathbf{I})$ AND FREEC( $\mathbf{J})$ ).
PAR_B(K,Z,I,J)=G=SUM((L,N)\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
AND ${ }^{-1 L}(S, N)$ LT TU(S,L)
AND HOT(S, $\mathrm{I}, \mathrm{L})=1$ AND $\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1$ AND ALLOW_H( $(\mathrm{Z}, \mathrm{Z}, \mathrm{I}, \mathrm{L}, \mathrm{J})=1$
AND ALLOW_C(S,Z,J,N,I)=1),
(Q(S,Z,I,L,J,N)-Q2(S,Z,I,L,J,N))(U(S,I,J)*LMTD(S,L,N))
-AMAX* (2-NHE_M1_B(S,Z,I,J,M)-X1_B(S,Z,L,J,M)-
$\operatorname{SUM}\left(\mathrm{KK}(\mathrm{ORD}(\mathrm{K} \overline{\mathrm{K}}) \mathrm{G} \overline{\mathrm{T}}\right.$ I $\left.\operatorname{AND} \operatorname{ORD}(\mathrm{K} \overline{\mathrm{K}}) \operatorname{LT} \operatorname{ORD}(\mathrm{K})), \mathrm{X} \_\mathrm{B}(\mathrm{S}, \mathrm{KK}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})\right)$ ));
* 

*EQ (99)
BIF_14(S,K,Z,IJ)S(ORD(K) EQ KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF $(2,1, J)=1)$.. 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_IS(S,Z,1,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))..

XI_B(S,Z,I,J,M)+SUM(K\$(ORD(K) GT 1 AND ORD(K) LE KMAX(Z,I,J)).
ORD (K)* $\left.\mathrm{X}_{\mathrm{Z}} \mathrm{B}(\mathrm{S}, \mathrm{K}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})\right)=\mathrm{E}=\operatorname{SUM}(\mathrm{L} \$(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{L})=1$ AND ORD(L) LE ORD(M) AND
ALLOW H(S, Z, l, L, J) $=1$ ), NHE_M0 B(S,Z,I,J,L))+1-Y_M_B(S,Z,I,J,M);
*Comment: In the paper XI_B does not show. Only one variable, X_B is used

* to make summations from I to kmax-1. Here we use XI_B and then a
* summation from 2 to $\mathrm{kmax}-\mathrm{I}$.

```
EQ (101)
BIF_17(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z.I.M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(1) AND FREEC(J))
SUM(N$(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,1,J,M,N)S(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,l,M.J)=1 AND ALLOW_C(S,Z,J.N,1)=1
AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J)).
                                    Q2(S,Z,l,M,J,N)=L=Q(S.Z,I.M.J.N);
* EQ (103)
SHELL(Z,1,J)$(SUM[S,ALLOW(S,Z,l,J)]>= I AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0).
PAR(Z,I,J)=L=ASHELLMAX*USHELL(Z,I,J);
*-
*EQ (104)
SHELL_B(K,Z,I,J)$(SUM[S,ALLOW(S,Z,I,J)]>= I AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,J)=1)..
PAR_B(K,Z,1,J)=L=ASHELLMAX*USHELL_B(K,Z,1,J);
*-
*EQ (105)
*TOTALCOST.. TCOST =E= SUM($(HU(I) AND FREEH(1)) CHU(I)*FHU(I)*DTHU(I))
* + SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
* + SUM((Z,I,J)$(SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
* AND BIF(Z,1,J)=0), CF*USHELL(Z,1,J)
* + SUM((K,Z,1,J)$(SUM[S,ALLOW(S,Z,1,J)]>= 1/AND FREEH(I) AND FREEC(J)
* AND BIF(Z,1,J)=1), CF*USHEIL B(K,Z,1,J))
* + SUM((Z,I,J)$(SUM[S,ALLOW(S,Z,l,J)]>= 1/AND FREEH(I) AND FREEC(J) ),
* CA*PAR(Z,1,J))
* + Cost_side_stripping_sleam
TOTALCOST.. TCOST=E=SUM(1S(HU(l) AND FREEH(1)),CHU(l)**HU(1)*DTHU(1))
    +SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
    +SUM((S,Z.I,J)$(ALLOW(S.Z,I,J)=1 AND FREEH(1) AND FREEC(J))
    CF*(NHE(S,Z,1,J)+NHE S(S,Z.IJ)$(NHE0(S,Z,1,J)=1)-NHE0(S,Z.1J)))
    +SUM((S.Z,I,J)$(ALLOW(S,Z,1,J)=1 AND FREEH(1) AND FREEC(J)
    AND BIF(Z,I,J)=0),CAE*DPAR_E(Z.1,J)+CAN*PAR_N(S,Z,1,J))
    +SUM((S,K Z,l.J)$(ORD(K) LE KMAX(Z.l,J) AND ALLOW(S,Z.l,J)=1
    AND FREEH(1) AND FREEC(J) AND BIF(Z,1,J)=1)
    ,CAE*DPAR_E_B(K,Z,I,J)+CAN*PAR_N_B(K.Z,I,J))+Cost_side_stripping_steam;
* Here we have an equation that is made simpler than in the paper. We account
* for the total area of the exchangers (use PAR and notPAR_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,l,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=0).
NHE(S,Z,I,J)=l= USHELL(Z,l,J);
*EQ (107)
KMAX2(S,Z,1,J)$(ALLOW(S.Z,1,J)=1 AND FREEH(1) AND FREEC(J) AND BIF(Z.1,J)=1).
NHE(S,Z,l,J)=L= SUM(K,USHELL_B(K,Z,l,J));
----------------------------------------------------------
*---------------------------------------------------
*_*
*EQ (108) LIMIT THE NUMBER OF EXCHANGERS
TOTNEXCH MAX(S).. SUM((Z,I.J)$(ALLOW(S,Z,l,J)= \ AND FREEH(I) AND FREEC(J)),
    NHE(S,Z,I,J))=L=TOTNEXCHMAX;
*
* EQ (109) MINIMUM NUMBER OF EXCHANGERS
TOTNEXCH_MIN(S).. SUM((Z,I,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(1) AND FREEC(J)),
NHE(S,Z,l,J))=G=TOTNEXCHMIN;
```

```
*Equation for Retrofit
*EQ(Retrofit 1)
AREA REST1(S,Z,I,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
                AND BIF(Z,1,J)=0 ).
    PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I.J)+PAR_N(S,Z.I,J).
*EQ(Retrofit 2)
AREA_REST2(S,Z,I,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(1) AND FREEC(J)
        AND BIF(Z,I,J)=0 ).
    DPAR_E(Z,I,J)=L=AEX_U(Z,1,J)-AEX(Z,l,J);
*
*EQ(Retrofit 3)
AREA_REST3(S,Z,I,J)$(ALLOW(S,Z,I,J)=\ AND FREEH(I) AND FREEC(J)
                AND BIF(Z,1,J)=0 ).
    PAR_N(S,Z,I,J)=L=A_NEW_MAX(Z,I,J) *(NHE(S,Z,I,J)-NHE0(S,Z,1,J));
*EQ(Retrofit 4)
AREA_REST4(S,Z,l,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
        AND BIF(Z,l,J)=0 ).
(NHE(S,Z,1,J)) = L= TOTNEXCHMAX ;
*EQ(Retrofit 5)
AREA_REST5(S,Z,I,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
                                    AND BIF}(Z,1,J)=0 AND NHEO(S,Z,I,J)=0).
PAR_N(S,Z,1,J) =l= A_NEW_MAX(Z,1,J)* NHE(S,Z,I,J));
*EQ(Retrofit 6)
*Eq retrofit 6 is same as Eq retrofit 5
*
*EQ(Retrofit 7)
AREA_REST7(S,Z,1,J)$(ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
    AND BIF(Z,1,J)=0 AND NHEO(S,Z,1,J)=0).
(NHE(S,Z,l,J)) = L= TOTNEXCHMAX ;
*EQ(Retrofit 8)
AREA REST1_B(S,K,Z,1.J)$(ORD(K) LE KMAX(Z,1.J) AND ALLOW(S,Z,I,J)=1
                                    A
    PAR_B(K,Z,l,J)=L=SUM(KK$(ORD(KK) LE NHEO(S,Z,I,J)),AEX_B(KK,Z,I,J)
                *DELTA(KK,K))+DPAR_E_B(K,Z,1,J)+PAR_N_B(K,Z,1,J);
*
*EQ(Retrofit 9)
AREA REST2 B(S,K,Z,I,J)$(ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
    AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1).
    DPAR_E_B(K,Z,l,J)=L=SUM(KK$(ORD(KK) LE NHE0(S,Z,l,J)),(AEX_U_B(KK,Z,I,J)
        -AEX_B(KK,Z,I,J))}\mp@subsup{}{}{*}DELTA(KK,K))
*
*EQ(Retrofit 10)
    AREA_REST3_B(S,K,Z,I,J)$(ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
                        AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1).
    PAR_N_B(K_Z,l,J)=L=A_NEW_MAX(Z,1,J)
                                    *(1-SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K)));
*
*EQ(Retrofit 11)
AREA_REST4_B(S,K,Z,I,J)$(ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
                                    AND FREEH(I) AND FREEC(J) AND BIF(Z,IJJ=1).
    SUM(KK$(ORD(KK) LE NHE0(S,Z,I,J)),DELTA(KK,K))=L=1;
*
*EQ(Retrofit 12)
AREA_REST5_B(S,K,Z,I,J)$(ORD(K) LE NHE0(S,Z,I,J) AND ALLOW(S,Z,1,J)=1
                                    AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1).
    SUM(KK$(ORD(KK) LE KMAX(Z,l,J)),DELTA(K,KK))=L=1;
*-----------------
*EQ(Retront 13) 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)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1),(NHE(S,Z,I,J))-NHE0(S,Z,I,J))
=L= MAX_NEW_HEX;
*------.-----------------.--------------------------------------------------
* Add Eq for PA
*-.
*EQ (3_b)
PA l(S,l,M)$(HOT(S,l,M)=1 AND NOT HU(I) AND
FREEH(1) AND NIH(1)=0 AND PA(1))
FP(I)*}\textrm{CPH}(\textrm{S},\textrm{l},\textrm{M})*(TU(S,M)-TL(S,M))=E=SUM((Z,N,J)$(D(S,Z,M,N)=
AND TL(S,N) LT TU(S,M) AND COLD(S.J,N)=1
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1):Q(S,Z,I,M,J.N));
*EQ (7_b)
PA_2(S,l,M)$(HOT(S,I,M)=1 AND NOT HU(l)
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)$(D(S,Z,M,N)=1
AND TL(S,N) LT TU(S,M)AND COLD(S,J,N)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,1,M.J,N))
+SUM((Z,N)$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) GT ORD(M)),QH(S,Z,1,N,M))
-SUM((Z,N)$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)),QH(S,Z,I,M,N));
*EQ 11_b Case of BIF(I,J)=0 (i,j) not belonging to set B
PA_3(S,Z,1,J,M)$(HOT(S,1,M)=1 AND ALLOW_H(S,Z,1,M,J)=1 AND BIF(Z,1,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))$(NOT HU(I))=L=0;
*EQ II_b Case of BIF(I,J)=0 (i,j) not belonging to set B
******* ********* MINIMUM VALUE OF QNEW M=0.01!!!!!!!!!
PA 4(S,Z,I,J,M)$(HOT(S,l,M)=1 AND ALLOW II(S,Z,l,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)$(HOT(S,1,M)=1 AND ALLOW_H(S.Z,I,M,J)=1 AND BIF(Z,I,J)=1
                                    AND FREEH(I) AND FREEC(J) AND PA(1)
QNEW_M(S,Z,I,J,M)-FPY_B(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M))$(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,IJ,M)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN =G= 0;
*EQ 11 C 1
PA_5(S,Z,1,J,M)$(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,1,J,M)$(HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,l,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
FPY_B(S,Z,I,J,M) =E=SUM(R,(FPR(I,R)*YW(S,Z,I,J,M)));
*EQ 11_D
PA_7(S.Z,I,J,M)$(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,IJ,M)=L=0;
*EQ |I E
PA_8(S,Z,I.J,M,R)$(HOT(S,l,M)=1 AND ALLOW_H(S,Z,I,M.J)=1 AND BIF(Z,I,J)=1
AND FREEH(1) AND FREEC(J) AND PA(1)).
YW(S,Z,I,J,M)=L=W(I,R);
*EQ 11 F
PA 9(S,Z,I,J,M,R)$(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)-I;
```

```
*.
*EQ (43 b)
PA_10(S,Z,I,J,M,N)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
    AND COLD(S,J,N)=1 AND ALLOW H(S,Z,I,M,J)=\ AND ALLOW C(S,Z,J,N,I)=1
    AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)).
    SUM(I$(D(S,Z,L,N)=I AND ORD(L) LE ORD(M) AND HOT(S,l,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$(D(S,Z,M,O)=I AND ORD(O)LE ORD(N) AND COLD(S,J,O) AND ALLOW C(S,Z,J,O,I))
    QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I.J,N)+ 4*XM(S,Z,I,M,J,N);
*
*EQ 43 C
PA_11(S,Z.IJ,M,N)$(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,1,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)).
XM(S,Z,I,M,J,N)-(TE(S,Z,l,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$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
    AND HOT(S,l.L)=1 AND ALLOW_H(S,Z,I,L,J)=1),(CPH(S,l,L)*(TU(S,L)-TL(S,L))))));
*EQ 43_D
PA 12(S,Z,l,J,M,N)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
    ANDD COLD(S,J,N)=1 AND ALLOW_H(S,Z,l,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
    AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I))
XM(S,Z,I,M,J,N)-(TE(S,Z,I,M,J.N)*OMEGA(S,Z,I,M,J,N))=G=SUM(R,(XW(S,Z,I,M,J,N,R)*
FPR(l,R)*SUM(LS(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
    AND HOT(S,I,L)=1 AND ALLOW_H(S,Z,1,L,J)=1),(CPH(S,I,L)*(TU(S,L)-TL(S,L))))));
*-
*EQ 43_E
PA_13(-S,Z.I,J,M,N)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,1,M)=1
    AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,l)=1
    AND BIF(Z,J,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)).
XM(S,Z,I,M,J,N)-((1-TE(S,Z,I,M,J,N))*OMEGA(S,Z,I,M,J,N))=L=Bl(S,Z,I,M,J,N)*
    SUM(LS(D(S,Z,L,N)=1 AND ORD(L) LE ORD(N)
    AND COLD(S,J,L)=1 AND ALLOW_C(S,Z,J,L,I)=1),DHC(S,J,L));
*EQ 43_F
PA_14(S,Z,I,J,M,N)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,I.J)=1 AND FREEH(I) AND FREEC(J) AND PA(I))
XM(S,Z,I.M,J,N ) =G= B1(S,Z,I,M,J,N)*SUM(L$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(N)
    AND COLD(S,J,L)=1 AND ALLOW_C(S,Z,J,L,I)=1),DHC(S,J,L));
*EQ 43_G
PA 15(S,Z,IJ,M,N,R)$(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 ALLOOW_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;
*----------
PA 16(S,Z,Z,I,J,M,N,R)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
    ANDD COLD(S,J,N)=1 AND ALLOW H(S,Z,I,M,J)=1 AND ALLOW C(S,Z,J,N,I)=1
    AND BIF(Z,I,J)=I AND FREEH(I) AND FREEC(J) AND PA(l)).
(Bl(S,Z,I,M,J,N)- XW(S,Z,I,M,J,N,R))-(1-W(I,R))*T(S,Z,I,M,J,N) =L=0;
**--------
PA_17(S,Z,IIJ.M,N,R)$(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(1)).
(Bl(S,Z,l,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
ANND 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$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
    AND ALLOW_H(S,Z,I,L,J)=1),
    QNEW_M(S,Z,1,J,L)) - QNEW2_M(S,Z,l,J,M) =G=
SUM(O$(D(S,Z,M,O)=1 AND ORD(O)LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S:Z,J,O.l))
    QNEW_N(S,Z,l,J,O)) - QNEW2_N(S,Z,I,J,N)
-4*XM(S,Z,I,M,J,N);
*-
*EQ (50 b)
PA_19(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=I AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
QNEW2_M(S,Z,I,J,M) =L= FPK_H_0(S,Z,I,J,M)*CPH(S.I,M)*(TU(S,M)-TL(S,M));
*EQ 50 C
PA_20(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I.J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))
FPK_H_0(S,Z,I,J,M)=E=SUM(R,(FPR(I,R)*KW_0(S,Z,I,J,M,R)));
*EQ 50_D
PA_21(S,Z,I,J,M,R)$(HOT(S,I,M)=I AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))
KW_0(S,Z,I,J,M,R)- NHE_M0_B(S,Z,I,J,M) =L= 0;
*EQ 50 E
PA_22(S,Z,l,J,M,R)$(HOT(S,l,M)=1 AND ALLOW_H(S,Z,l,M,J)=I AND BIF(Z,l.J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))
KW_O(S,Z,I,J.M,R)=L=W(I,R);
*EQ 50 F
PA_23(\overline{S},Z,I,J,M,R)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,1,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))
KW_0(S,Z,1,J,M,R) =G= NHE_M0_B(S,Z,I,J,M) + W(1,R)-1;
*EQ (51_b)
PA 24(S,Z,I,J.M)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1AND BIF(Z,1,J)=1
AND FREEH(I)AND FREEC(J) AND PA(I)).
    QNEW2_M(S,Z,I,J,M) = = = FPK_H_l(S,Z,I,J,M)* CPH(S,LM)*(TU(S,M)-TL(S,M));
*EQ 51_C
PA 25(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I))..
FPK H_l(S,Z,l,J,M) =E= SUM(R,(FPR(I,R)*KW_l(S,Z,I,J,M,R)));
*
*EQ 51_D
PA_26(S,Z,I,J,M,R)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
ANDD FREEH(I) AND FREEC(J) AND PA(I)).
KW_l(S,Z,I,J,M,R)- NHE_M1_B(S,Z,I,J,M)=L=0;
*EQ 51_E
PA 27(\overline{S},\textrm{Z},1,J,M,R)$(HOT(S,1,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,1,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
KW_l(S,Z,I,J.M,R)=L=W(l,R);
*EQ 51_F
PA 28(S,Z,l,J,M,R)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,1,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
KW l(S,Z,I.),M,R)=G=NHE_MI_B(S,Z,I,J,M) + W(I,R)- I;
*EQ(61 b)
PA_29(S.Z,1,J,M)$(HOT(S,l,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,l.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,1,J,M)/(CPH(S,1,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)$(HOT(S,I,M-I) AND HOT(S,l,M)=I AND ALLOW_H(S,Z,IM,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=I AND FREEH(I) AND FREEC(J) AND PA(I)).
FPA(S,Z,I,J,M)=E=SUM(R,(FPR(I,R)*WA(S,Z,I,J,M,R)));
*..
* EQ 61_D
PA 31(S,Z,I,J,M,R)$(HOT(S,l,M-1) AND HOT(S,I,M)=I AND ALLOW H(S,Z,l,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND SPH(l)=1 AND FREEH(l) AND FREEC(J) AND PA(I)).
WA(S,Z.I,J,M.R)-ALFA_M(S,Z,I,J,M)=L= 0;
*---------
PA_32(S,Z,1,J,M,R)$(HOT(S,l,M-1) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,l,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I)).
WA(S,Z,I,J,M,R)=L=W(I,R);
*EQ61_F
PA_33(S,Z,I,J,M,R)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S;Z,l,M,J)=1
ANDD ALLOW_H(S,Z,l,M-1,J) AND SPH(l)=1 AND FREEH(l) AND FREEC(J) AND PA(l)).
WA(S,Z,I,J,M,R)=G= ALFA_M(S,Z,I,J,M)+W(1,R)-1;
* EQ (62 b)
PA 34(S,Z,I,J,M)S(HOT(S,I,M-1) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1/AND FREEH(I) AND FREEC(J) AND PA(1)).
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,1,J,M-1)/(CPH(S,1,M-1)*(TU(S,M-1)-TL(S,M-1)));
*
*EQ (63 b)
PA_35(S,Z,1,J,M)$(HOT(S,1,M-1) AND HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW H(S,Z,l,M-1,J) AND BIF(Z,l,J)=0 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND PA(I))..
    - QNEW_M(S,Z,1,J,M-1)/(CPH(S,l,M-1)*(TU(S,M-1)-TL(S,M-1)))
    + QNEW M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
    +(FP(I)+\overline{FPK_H_1(S,Z,1,J,M-1)+FPK_H_1(S,Z,1,J,M)-FPK_H_O(S,Z:1,J,M-1)) =G=0;}
*
*EQ (64_b)
PA_36(S,Z,1,J,M)$(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)+\overline{FPK_H_0(S,Z,I,J,M-1)+FPK_H_0(S,Z,I,J,M)-FPK_H_l(S,Z,I,J,M)) =G=0;}
*
*EQ (65 b)
PA 37(S,Z,l,J,M)$(HOT(S,l,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z;I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(l)=I AND FREEH(1)
AND FREEC(J) AND PA(I))..
QNEW_M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-I)))=L=
QNEW_M(S,Z,1,J,M)/(CPH(S,l,M)*(TU(S,M)-TL(S,M)))
+(FP(I)+FPK_H_l(S,Z,I,J,M-I)+FPK_H_l(S,Z,I,J,M)-FPK_H_0(S,Z,I.J.M-1));
*EQ (66_b)
PA 38(S.Z,I.J,M)$(HOT(S,1,M-1) AND HOT(S,l,M)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW H(S,Z,1,M-1,J) AND BIF(Z,1,J)=I AND SPH(1)=I 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_l(S,Z,I,J,M)-FPK H O(S,Z,I,J,M-1)-FPY(S,Z,I,J,M-1));
*EQ (67 b)
PA 39(S,Z.l.J,M)$(HOT(S,l,M-1) AND HOT(S,l,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,l,J,M))/(CPH(S,l,M)*(TU(S,M)-TL(S,M))) = L=
QNEW_M(S,Z,1,J,M-1)/(CPH(S,l,M-1)*(TU(S,M-1)-TL(S,M-1)))
    -((2.*FP(I))+FPK_H_0(S,Z,I,J,M-I)-FPK_H_l(S,Z,I,J,M)-FPY(S,Z,1,J,M-1));
*
*EQ (68 b)
PA 40(S,Z,I,J,M)$(HOT(S,l,M-I) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
AND ALLOW_H(S,Z,1,M,J)=l
AND ALLOW_H(S,Z,I,M-1,J) AND ALLOW_H(S,Z,I,M+1,J) AND BIF(Z,I,J)=0 AND SPH(l)=0
AND FREEH(1) AND FREEC(J) AND PA(I)).
    QNEW_M(S,Z,I,J,M)=G=(FPY(S,Z,I,J,M)-FPK_H_0(S,Z,I,J,M)-FPK_H_1(S,Z,I,J,M))
    * (CPH(S,I,M)*(TU(S,M)-TL(S,M)));
PA_41(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,l,M+1)
AND ALLOW_H(S,Z,I,M.J)=1
AND ALLOW H(S,Z,l,M-1,J) AND ALLOW H(S,Z,l,M+1,J) AND BIF(Z,I,J)=1 AND SPH(I)=0
AND FREEH(1) AND FREEC(J) AND PA(1)).
    QNEW_M(S,Z,I,J,M)=G=(FPY B(S,Z,I,J,M)-FPK H_0 B(S,Z,l,J,M)
    -FPK_H_1_B(S,Z,l,J,M))*(CPH(S,l,M)*(TU(S,M)-TL(S,M)));
*
*EQ (81_b)
PA_42(S,Z,I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW H(S,Z, , M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..
TL(S,M) - TL(S,N) - QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
+ (FPQ(S,Z,I,J,M)/CPH(S,I,M))
+ (2-NHE M0(S,Z,1,J,M)-NHE N0(S,Z,1,J,N))*TU(S,N)=G=0;
PA_43(S,Z,I,J,M,N)$(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,1,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,1,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,l,J,M)/CPH(S,l,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)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(l) AND FREEC(J) AND PA(I))
FPQ(S,Z,I,J,M) =E= SUM(R,WQ(S,Z,I,J,M,R)/FPR(I,R));
*---------
PA_45(-S,Z,I,J,M,N,R)$(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,l,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND SPH(I)=0 AND SPC}(\textrm{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(\overline{S},Z,I,J,M,N,R)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,l,M,J)=1
AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=1
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I)).
(QNEW_M(S,Z,I,J,M)-WQ(S,Z,I,J,M,R))-(I-W(I,R))*T(S,Z,I,M,J,N) =L= 0;
*EQ }81\textrm{F
PA_47(\overline{S},Z,I,J,M,N,R)$(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,1,J,M)-WQ(S,Z,1,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,l,M)=1 AND COLD(S,J,N)=l AND ALLOW H(S.Z,l,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,l,M)) +QNEW_N(S,Z,I.J,N)/(FC(S,J)*CPC(S,J,N))
    +(2-NHE_Ml(S,Z,l,J,M)-NHE_N1(S,Z,I,J,N))*TU(S,N)=G=0;
PA_49(S,Z,I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,I,M)=1 AND COLD(S,J,N)=I AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z.I,J)=1
AND SPH(I)=0 AND SPC(I)=0 AND FREEH(I) AND FREEC(J) AND PA(I))..
TU(S,M)-TU(S,N)
-(FPQ(S,Z,l,J,M)/CPH(S,l,M)) + QNEW_N(S,Z,l,J,N)/(FC(S,J)*CPC(S,J,N))
                            +(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*TU(S,N)=G=0;
*EQ (85 b)
PA_50(S,Z,l,J,M,N)$(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,l,M+1,J) AND ALLOW C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N+1,l) AND BIF(Z,1,J)=0 AND (SPH(I)=1 OR SPC(J)=1)
AND FREEH(1) 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,1,J,M)-FPK_C 0(S,Z,I,J,N))
    * CPH(S,1,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)$(DTVIO(1,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
    AND TU(S,N) GT TL(S,M) AND HOT(S,1,M)=1 AND HOT(S,l,M-1) AND COLD(S,J,N)=1
    AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
    AND ALLOW C(S,Z,J,N,I)=1 AND ALLOW C(S.Z,J,N-1,I) AND BIF(Z,I,J)=0
    AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(I)).
    QNEW M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))
    * CPH(S,I,M)/CPH(S,l,M-1)+((2*FP(I))-FPK H 1(S,Z,1,J,M)-FPK C 1(S,Z,I,J,N))
    * CPH(S,I,M)*(TU(S,M)-TL(S,M))/(TU(S,M)-TL(S,M));
*--
*EQ (92_b)
PA_52(S.Z,I,J,M,N)$(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,l,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,1,M,J)=1 AND ALLOW_H(S,Z,1,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(1) 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,1,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)*(TJ(S,M+1)-TL(S,M+1))/(TU(S,M+1)-TL(S,M+1));
*
*EQ (94 b)
PA 53(S,Z,l,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
    ANND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
    AND COLD(S,J,N-1) AND ALLOW H(S,Z,l,M,J)=1 AND ALLOW_H(S,Z,I,M-1,J)
    AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,l,J)=1
    AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(I)).
    (QNEW M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L=
    QNEW_M(S,Z,l,J,M-1)/(TU(S,M-1)-TL(S,M-1))*CPH(S,l,M)/CPH(S,I,M-1)
    +((2*FP(I))-FPK H l(S,Z,I,J,M)-FPK_C_l(S,Z,I,J,N))*CPH(S,I,M)
    *(TU(S,M)-TL(S,M))/(TU(S,M)-TL(S,M));
*.
* EQ (XX 1)
PA_54(S,Z,I,J,M)$(HOT(S,l,M)=1 AND NOT SPH(I) AND
FREEH(I) AND PA(I)).
```

$\mathrm{FP}(\mathrm{I})=\mathrm{E}=\operatorname{SUM}\left(\mathrm{R}, \mathrm{FPR}(\mathrm{I}, \mathrm{R})^{*} \mathrm{~W}(\mathrm{I}, \mathrm{R})\right)$;
*EQ (XX_2)
PA 55(S.Z,I, J.M)\$(HOT(S,l,M)=1 AND NOT SPH(1) AND
FREEH(I) AND PA(I))
$\operatorname{SUM}(\mathrm{R}, \mathrm{W}(\mathrm{I}, \mathrm{R}))=\mathrm{E}=1$;
*EQ (XX 3)
PA_56(S,Z,I,J)\$(NOT SPH(I) AND
FREEH(I) AND PA(I))..
$\operatorname{QPA}(\mathrm{I})=\mathrm{E}=\mathrm{SUM}\left(\mathrm{M}, \mathrm{FP}(\mathrm{I})^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M})^{*}(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M}))\right)$;
*The sumation 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)) $=\mathrm{E}=$ TOTAL_QPA;
*-------
$\mathrm{PAl}=\mathrm{E}=\operatorname{SUM}(\mathrm{I}, \mathrm{QPA}(\mathrm{I}) \$(\mathrm{ORD}(\mathrm{l})=2))$;
PA...-.....
$\operatorname{PA} \overline{2}=\mathrm{E}=\operatorname{SUM}(\mathrm{I} . \mathrm{QPA}(\mathrm{I}) \$(\operatorname{ORD}(\mathrm{l})=4))$;
*
PA_60..
$\operatorname{PA} \overline{3}=\mathrm{E}=\operatorname{SUM}(\mathrm{I}, \mathrm{QPA}(\mathrm{I}) \$(\operatorname{ORD}(\mathrm{I})=6))$;

* 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)).
$\operatorname{SST}(\mathrm{I})=\mathrm{E}=\left(\mathrm{A}_{-} 1(\mathrm{I})^{*} \mathrm{PA} \mathrm{I}\right)+\left(\mathrm{B} \_1(\mathrm{I}) * \mathrm{PA} 2\right)+\left(\mathrm{C} \_1(\mathrm{I}) * \mathrm{PA} 3\right)+\mathrm{D}$ I_1 I$)$;
*--
PA_62..
Cost_side_stripping_steam $=\mathrm{E}=\operatorname{SUM}(\mathrm{l},(\operatorname{CSS}(\mathrm{I}) * \operatorname{SST}(\mathrm{I}))$ );
*--
PA_63..
TOTAL_Q $=\mathrm{G}=$ TOTAL_QPA_MIN;
*-------
TOTAL_Q $=\mathrm{L}=$ TOTAL_QPA_MAX;
*--------
TOTAL_QPA_MIN $=\mathrm{E}=$ TOTAL_QPA-(TOTAL_QPA*0.001)
*---------
PA_66..
TOTAL_QPA_MAX $=\mathrm{E}=$ TOTAL_QPA+(TOTAL_QPA*0.001);
PA 67
$\operatorname{SUM}(1, \mathrm{QPA}(\mathrm{l}) \$ P A(\mathrm{I}))=\mathrm{E}=$ TOTAL_Q;
*-------------------------------------1)
FREEH(l) AND PA(l)).
$\mathrm{Cp} \_\mathrm{Dt}(\mathrm{I})=\mathrm{E}=\mathrm{SUM}(\mathrm{M}, \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) *(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M})))$;
*-------------------------------
OPTION LIMROW $=0$;
OPTION LIMCOL $=0$; OPTION SOLPRINT $=$ OFF; OPTION OPTCR=0 ; OPTION OPTCA=0 OPTION ITERLIM $=1000000000$; OPTION RESLIM $=1000000$; MPERIOD. OPTFILE $=1$;

SOLVE MPERIOD USING MIP MINIMIZING TCOST ;
PARAMETER QMATCH(S,Z,I,J);
QMATCH(S,Z,I.J)=SUM((M,N)\$(I)(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND D(S,Z,M,N)=1
AND COLD(S,J,N) AND ALLOW_H(S,Z.1,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))* $\left.{ }^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M})\right]$;

PARAMETER FC_C(S,Z,J,1,M) Flowrate of hot stream per HEx;
FC_C $(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{I}, \mathrm{M}) \mathbb{S}[\mathrm{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{M})]=\mathrm{QNEW}, \mathrm{N} . \mathrm{L}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}) /\left[(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M}))^{*} \mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{M})\right] ;$
PARAMETER NHE2(S,Z,J,I);
NHE2 (S, $\mathrm{Z}, \mathrm{J}, \mathrm{I})=\mathrm{NHE} . \mathrm{L}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})$;
PARAMETER AREA_COST;
AREA_COST $=\operatorname{SUM}((\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}) \$(\operatorname{ALLOW}(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})=1$ AND FREEH(I) AND FREEC(J))
, ${ }_{\mathrm{C}} \mathrm{F}^{*}($ NHE.L(S,Z,I,J)+NHE_S.L(S,Z,I,J)\$(NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)))
$+\mathrm{SUM}(\mathrm{S}, \mathrm{Z}, 1, \mathrm{~J}) \$($ ALLOW $(\overline{\mathrm{S}}, \mathrm{Z}, 1, \mathrm{~J})=1$ AND FREEH(I) AND FREEC( J$)$ AND BIF(Z,I,J)=0),CAE*DPAR_E.L(Z,1,J)+CAN*PAR_N.L(S,Z,I,J)) +SUM((S,K,Z,I,J)\$(ORD(K) LE KMAX(Z,I,J) AND ALLOW AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1) ,CAE*DPAR_E_B.L(K,Z,I,J)+CAN*PAR_N_B.L(K,Z,I,J));

PARAMETER UTILITY_COST;
UTILITY_COST = SUM(1\$(HU(I) AND FREEH(I)),CHU(I)*FHU.L(I)*DTHU(I))

- $\mathrm{SUM}(\mathrm{J} \$(\mathrm{CU}(\mathrm{J})$ AND FREEC(J)),CCU(J)*FCU.L(J)*DTCU(J)) ;

OPTION UTILITY_COST:3:0:1; DISPLAY UTILITY_COST; OPTION AREA_CŌST:3:0:1; DISPLAY AREA_COST; OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L; OPTION PAR_N $\mathbf{N} \cdot 3: 0: 1$; DISPLAY PAR_N. $\bar{L}$; 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_BL; OPTION Q:3:0 1; DISPLAY Q.L; OPTION PAR:3:0:1; DISPLAY PAR.L; OPTION QMATCH 3:0:1; DISPLAY QMATCH; OPTION FHU:3:0:1; DISPLAY FHU.L;
OPTION FCU:3:0:1; DISPLAY FCUL;
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 Cest_side_stripping_steam :3:0:1; DISPLAY Cost_side_stripping_steam.L;
OPTION SST:3:0:1; DISPLAY SST.L;
OPTION QPA:3:0:1; DISPLAY QPA.L;
OPTION W:3:0:1; DISPLAY W.L;
OPTION FPR:3:0:1; DISPLAY FPR;
OPTION FP:3:0:1; DISPLAY FP.L;
OPTION DHH:3:0:1; DISPLAY DHH;
OPTION DHC:3:0:1; DISPLAY DHC;
OPTION HHEAD:3:2:1; DISPLAY HHEAD;
OPTION CHEAD:3:2:1; DISPLAY CHEAD;
OPTION ALLOW:3:0:1; DISPLAY ALLOW;
OPTION ALLOW_H:3:0:1; DISPLAY ALLOW_H;
OPTION ALLOW_C:3:0:1; DISPLAY ALLOW_C;
OPTION ALLOW_2:2:0:1; DISPLAY ALLOW_2;
OPTION QNEW_M:3:0:1; DISPLAY QNEW_M.L;
OPTION QNEW_N:3:0:1; DISPLAY QNEW_N.L;
OPTION QNEW 2 _M:3:0:1; DISPLAY QNEW 2 _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_BL; 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. $\bar{M} \cdot \overline{\text {; }}$

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 XI_B:3:0:1: DISPLAY XI_B.L;
OPTION X_B:3:0:1; DISPLAY X_B.L;
OPTION Q2:3:0:1; DISPLAY Q2.L;
OPTION NHE2:3:0:1; DISPLAY NHE2
OPTION PAR_B:3:0:1; DISPLAY PAR_B.L;
OPTION FH $\bar{H}: 3: 0: 1$; DISPLAY FH_1I;
OPTION FC_C:3:0:1; DISPLAY FC_C;
OPTION LMTD:3:0:1; DISPLAY LMTD;


## Appendix D Programming Model for Retrofit with Relocation Apply for Crude Fractionation Unite

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


* Equations that are different than in the paper +errata.
*(100)
*(105)
* Equations that are added to those that are in the paper
*(106) and (107)
* CONSISTENCY: Number of exchangers smaller than the number of shells
* Needed because the exchangers are related to the values of K
*(108) LIMIT THE NUMBER OF EXCHANGERS
*(109) MINIMUM NUMBER OF EXCHANGERS
\$OFFUPPER
\$ONTEXT
*NM-4S1-FINAL-6-FLEXIBILITY-S1.gms: August 9, 2004
- one scenario, the original values of 4 sl

```
******************************
```

\$OFFTEXT
SETS
Z transfer zone $\quad \mathrm{Z} 1 /$
*
*ALWAYS DEFINE THE HOT STREAMS FIRST, AND THEN THE COLD STREAMS
I Hot streams /l1*19/
J cold streams $\quad / \mathrm{J}^{*} \mathbf{3} 3 /$
R /R1*R4/
*ALWAYS DEFINE THE UTILITIES WITH THE HIGHEST INDEX
HU(I) Heating utilities /19/
CU(J) Cooling utilities /J3/

* temperature intervals /M1*M68/
S SCENARIO /SI/
K temperature intervals / $\mathrm{K} 1^{*} \mathrm{~K} 1 /$
*FOR RELOCATION CHANGING R IN RELOCATON'S EQ TO E
E exchangers /E1*E16/
* 

*NEW SET FOR PUMP-AROUND.
PA(1) Pump-around streams / $12,14,16 /$
*
ALIAS (M,N,L,O)
ALIAS (I,II)
ALIAS (J,JJ)
ALIAS (K,KK)
ALIAS (Z,ZZ)
ALIAS (E,EE)
*PARAMETER FOR PUMP-AROUND CASE
PARAMETER $\operatorname{FPR}(I, R)$ Candidate values for pump-around flowrate $i$
/
12.R1 701.4780
I2.R2 647.5181
12.R3 539.5984
$\begin{array}{ll}\text { I2 R4 } & 485.6386\end{array}$
I4.R1 78.28034
I4.R2 115.4635
14.R3 156.5607
14.R4 176.1308

```
16.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
/
II 0.0035
l2 0.0040
0.0040
0.0055
0.0039
0.0052
0.0038
0.0031
0
/
PARAMETER B_cp_H(I) Intercept for Cp
11 1.9098
12 1.7979
1.7483
1.4682
1.7044
1.3834
1.6756
1.8201
4 . 1 8
*linear function for Cp for cold streams
*Cp = \dot{A}_cp_C*T + B_cp_C
PARAMETER A_cp_C(J) Coefficients for Cp
I
Jl 0.0037
J2 0.0035
J3 0
PARAMETER B_cp_C(J) Coefficients for Cp
/
J1 1.9966
J2 1.8143
J3 4.18
l
* y = a*PA(1)+b*PA(2)+c*PA(2)+d from usig regression.
PARAMETER A_l(I) Coefficients for PA(1)
/
I2 2.82E-05
14 -6.3E-05
I6 -2.7E-05
I
PARAMETER B_1(I) Coefficients for PA(2)
I
12 4.56E-05
14 -5.4E-05
I6 -2.8E-05
/
PARAMETER C_I(I) Coefficients for PA(3)
l
12 5.91E-05
14 -2.4E-05
l6 -2.3E-05
I
PARAMETER D_I_1(I) Intercept
```

```
I
I2 -3.81232
14 11.14212
16 6.491449
/
PARAMETER T(S,Z,l,M,J,N) Upper bound
I
S1.Z1.I2.(M3*M8).J1.(M58*M63) 10000
S1.Z1.12.(M3*M8).32.(M64*M66) 10000
SI.Z1.12.(M3*M8).J3.(M67*M68) }1000
S1.Z1.14.(M16*M21)J1.(M58*M63) 10000
S1.Z1.14.(M16*M21)J2.(M64*M66) 10000
S1.Z1.I4.(M16*M21).J3.(M67*M68) 10000
S1 Z1.16.(M33*M38).J1.(M58*M63) 10000
S1.Z1.16.(M33*M38).J2.(M64*M66) 10000
SI.Z1.16.(M33*M38).J3.(M67*M68) }1000
/
PARAMETER TE(S,Z,l,M,J,N) Upper bound
/
Sl.Z1.I2.(M3*M8).J1.(M58*M63) 10000
S1.Z1.12.(M3*M8).J2.(M64*M66) 10000
S1.Z1.12.(M3*M8).J3.(M67*M68) 10000
S1.Z1.14.(M16*M21)J1.(M58*M63) 10000
S1.Z1.I4.(M16*M21).J2.(M64*M66) }1000
S1.Z1.I4.(M16*M2I).J3.(M67*M68) 10000
S1.Z1.16.(M33*M38).J1.(M58*M63) 10000
S1.Z1.16.(M33*M38).J2.(M64*M66) }1000
SI Z1.16.(M33*M38).J3.(M67*M68) 10000
l
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
SI.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
SI.Z1.16.(M33*M38).J1.(M58*M63) 10000
S1.Z1.I6.(M33*M38).J2.(M64*M66) 10000
S1.Z1.I6.(M33*M38).J3.(M67*M68) 10000
l
PARAMETER NIZ(S,Z,I) # OF INTERVALS DESIRED FOR HOT STREAMS
/
S1.Z1.I12
S1.Z1.I26
S1.Z1.137
S1.Z1.146
S1Z1.15 11
S1.Z1.166
S1.21.I711
S1.Z1.185
S1.Z1.19 3
l
PARAMETER NJZ(S,Z,J) # OF INTERVALS DESIRED FOR COLD STREAMS
l
SI.Z1.J16
S1.Z1.J23
S1.Z1.J32
I
* Used Over all heat transfer Coeff insteat of hot and cold heat transfer Coeff.
* This values come from text book.
```



```
S1.Z1.17 26.11000
SI Z1.I8 260.0000
S1.Z1.19 399.0000
l
TICZ(S.Z,J) T IN FOR COLD STREAMS
I
S1.Z1.J1 16.11000
S1.Z1.J2 132.7800
SI Z1.J3 20.00
/
TOCZ(S,Z,J) T OUT FOR COLD STREAMS
/
S1.21.J1 132.7780
SI.Z1.J2 }36
SI.Z1.J3 30.00000
l
*INTRODUCE THE FCp:
FH(S,l) FOR HOT STREAMS
l
S1.II 177.826
SI.I3 120.158
S1.15 59.1990
S1.17 102.417
S1.18 211.705
l
FC(S,J) FOR COLD STREAMS
l
Sl.J] }752.59
SI.J2 673.422
l
*USE THE MAX FCp FOR THE UTILITIES
*
SETS FREEH(I)
l
11*19
FREEC(J)
I
II
J2
J3
l
PARAMETER BIF(Z,1,J)
/
Z1.11.J1 0
/
*PARAMETER MAXNEXCHPERMATCH MAXIMUM NUMBER OF MATCHES WHEN BIF=1;
*MAXNEXCHPERMATCH = 2
*;
PARAMETER SPH(I) SH in paper
/
(11.13,15.17.18.19) 1
(I2,14,16) 0
/
PARAMETER SPC(J) SC in paper
/
J1}
J2 1
J3 1
PARAMETER NIH(I) Non isothermal splitting for hot streams in paper
l
11 0
l
PARAMETER NIC(J) Non isothermal splitting for cold streams in paper
/
J) 0
I
PARAMETER DTVIO(I,J)
```

```
l
(11*19)(J1*J3) 1
l
PARAMETER KMAX(Z.I,J)
l
21.11.J1 1
l
PARAMETER DTHU(I)
/
19 I
/
PARAMETER DTCU(J)
J3 10
l
PARAMETER FMAX_HU(I)
l
19 100000
l
PARAMETER FMAX_CU(J)
/
J3 100000
/
PARAMETER CHU(I)
I
19 19.750
l
PARAMETER CCU(J)
l
J3 1.861
PARAMETER CSS(I) Cost of side stripping
|
12 20.33
14 20.33
16 20.33
l
PARAMETER CF;
CF = 5291.9;
PARAMETER CAIN;
CAN = 171.4;
PARAMETER CAE;
CAE = 171.4;
$ontext
** Retrofit
PARAMETER AEX(Z,I,J)
l
Z1.I2.J1 1267.954
Z1.14.J1470.4239
Z1.19.J1 1300.546
21.18.J2188.1183
Z1.17.J3 941.5554
Z1.18.J3167.4541
Z1.II.J3 518.2402
Z1.I3.J3966.0800
Z1 I5.J3682.7927
Z116.J3184.5678
l
PARAMETER AEX_B(K,Z,I.J)
|
K1.Z1.11.J11267.954
I
PARAMETER NHE0(S,Z,I.J)
I
SIZ112.J11
S1Z1.14.J11
SI.Z1.19.J11
SI.Z1 I8.J2 ]
```

```
SI.21.17.J3
SI.2118.J31
SIZI.II.J31
SI.Z1.13.J31
SI.2.1.15.J3
SI.Z1.16.J31
l
PARAMETER AEX_U(Z.l.J)
/
Z1.12.J1 2000.000
Z.1.14.J1700.0000
Z.1 19.J1 1700.000
ZI.18.J2 250.0000
Z1.17.J31600.000
Z1.I8.J3400.0000
Z1.11.J3650.0000
ZI.13.J31200.000
ZI.15.J3 750.0000
21.16.33 350.0000
l
PARAMETER AEX_U_B(K,Z,1,J)
/
KI Z1 11 J1 2000.000
l
$offlext
211
*FOR RELOCATION
PARAMETER NHE0(S,Z,1,J)
/
SI.Z1.11.J31
S1.Z1.12.J11
S1.21.13.111
S1.21.13.J21
SI.ZI.I3.J31
SI.Z1.14J11
SI.Z1.14.J21
SI.21.15.J1]
SI.Z1.15.J21
S1.21.15.J31
S!.21.16.J31
S1.21.17.J1
SI.21.17.J21
S1.21.17.J31
S1.Z1.18.J31
S1.ZI 19.J2
l
PARAMETER AEX_R(E)
/
E1 515.685
E2 2239.929
E3 1000.000
E4 204.200
E5 617.797
E6 572.096
E7 179.428
E8 133.625
E9 529.892
E10 546.822
EII 184.5
E12 608.858
E13 798.965
E14 425.397
E15 240.7
E16 4489.5
l
PARAMETER AEX B l(E)
/
E1 515.685
E2 2239.929
```

| E3 | 1000.000 |
| :---: | :---: |
| E4 | 204.200 |
| E5 | 617.797 |
| E6 | 572.096 |
| E7 | 179.428 |
| E8 | 133.625 |
| E9 | 529.892 |
| E10 | 546.822 |
| E11 | 184.5 |
| E12 | 608.858 |
| E13 | 798.965 |
| E14 | 425.397 |
| E15 | 240.7 |
| E16 | 4489.5 |
| / |  |
| PARAMETER AEX_U_l (E) |  |
| 1 |  |
| E1 | 3000 |
| E2 | 3000 |
| E3 | 3000 |
| E4 | 3000 |
| E5 | 3000 |
| E6 | 3000 |
| E7 | 3000 |
| E8 | 3000 |
| E9 | 3000 |
| E10 | 3000 |
| EII | 3000 |
| E12 | 3000 |
| E13 | 3000 |
| E14 | 3000 |
| E15 | 3000 |
| E16 | 5000 |
| 1 |  |
| PARAMETER AEX $\quad$ B R (E) |  |
| 1 P15.685 |  |
| E1 | 515.685 |
| E2 | 2239.929 |
| E3 | 1000.000 |
| E4 | 204.200 |
| E5 | 617.797 |
| E6 | 572.096 |
| E7 | 179.428 |
| E. 8 | 133.625 |
| E9 | 529.892 |
| E10 | 546.822 |
| Ell | 184.5 U |
| E12 | 608.858 |
| E13 | 798.965 |
| E14 | 425.397 |
| E15 | 240.7 |
| E16 | 4489.5 |
| 1 |  |
| PARAMETER AEX_U_B_R(EE) |  |
| 1 P 3000 |  |
| E1 | 3000 |
| E2 | 3000 |
| E3 | 3000 |
| E4 | 3000 |
| E5 | 3000 |
| E6 | 3000 |
| E7 | 3000 |
| E8 | 3000 |
| E9 | 3000 |
| E10 | 3000 |
| E1] | 3000 |
| E12 | 3000 |
| E13 | 3000 |
| E14 | 3000 |
| EIS | 3000 |

```
E16
5 0 0 0
/
PARAMETER AEX_U_B_l(E)
/
El 3000
E2 3000
E3 3000
E4 3000
E5 3000
E6 3000
E7 3000
E8 3000
E9 3000
El0 3000
EIl 3000
E12 3000
E13 3000
E14 3000
EI5 3000
E16 5000
l
PARAMETER R_ALL
* Minimum DELTA T
/16/;
PARAMETER KET
/16/;
PARAMETER A NEW MAX(Z,1,J)
l
Z1(II*I4).(J1*33) 5000.000
/
PARAMETER MAX_NEW_HEX
*
/50/;
**********************
*
/0.01/;
PARAMETER QLCMIN
* Minimum heat that can be transferred within an interval.Cold streams
/0.01/;
PARAMETER AMAX
* Maximum area per exchanger
/20000/;
PARAMETER ASHELLMAX
* Maximum shell area
/5000/;
PARAMETER TOTNEXCHMAX
* Maximum NUMBER OF EXCHANGERS
/900/;
PARAMETER TOTNEXCHMIN
* Minimum NUMBER OF EXCHANGERS
/0/;
PARAMETER DTmin
* Minimum DELTA T
/0/;
parameter NINT
/263/;
parameter OPT
12/;
*-----------------------------------------------------------
*---------.--------------------------------------------------------------
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). JCminZ(S,Z.J),ICmaxZ(S,Z,J),ICmin(S.J),
```

```
FOR(Si=1 TO CARD(S),
    FOR(Zi=1 TO CARD(Z),
        FOR(Ic=1 TO CARD(1),
            IHminZ(S,Z,I)$[ORD(S)=Si AND ORD(I)=1
                AND ORD(Z)=1]= 0+ 1$[NIZ(S,Z,I)>=1];
            1HminZ(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}$[NIZ(S,Z,I)>=1];
            lHminZ(S,Z,I)S[ORD(S)=Si AND ORD(Z)>1]= 0+
                    {SUM((ZZ,II)$[ORD(II)<ORD(I)],NIZ(S,ZZ,II))
                    +SUM(ZZ$[ORD(ZZ)< Zi],NIZ(S,ZZ,I))+1}$[NIZ(S,Z,I)>=1];
            lHmaxZ(S,Z,I)$[ORD(S)=Si AND ORD(I)=lc AND ORD(Z)=Zi]=0+
                    {IHminZ(S.Z,I)+NIZ(S,Z.I)-1}$[NIZ(S,Z.I)>=1];
            IHmin(S,I)$[ORD(S)=Si AND ORD(I)=Ic]=
            SUM[Z${SUM(ZZ$[ORD(ZZ)<=ORD(Z)-1],NIZ(S,ZZ.I))=0}.IHminZ(S,Z,1)];
            lHmax(S.l)$[ORD(S)=Si AND ORD(I)=lc]=
                SUM[Z${SUM(ZZ$[ORD(ZZ)>=ORD(Z)+1],NIZ(S,ZZ,I))=0},IHmaxZ(S,Z,l)];
            FOR(Mi=1 TO CARD(M).
            HOT(S,I,M)$[ORD(S)=Si AND ORD(l)=lc AND ORD(M)=Mi]=0+
                    I$[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$(ORD(I)=CARD(I)),1Hmax(S,I))];
                    HOTZ(S,Z,I,M)$[ORD(S)=Si AND ORD(I)=lc AND ORD(M)=Mi
    AND ORD (Z)=Zi] = 0+1$[ORD(M)>= IHminZ(S,Z,I) AND ORD(M)<=IHmaxZ(S,Z,I)];
    ));
    FOR(Ji=1 TO CARD(J),
    ICminZ(S,Z,J)$[ORD(S)=Si AND ORD(J)=1 AND ORD(Z)=1]=0+
                            {SUM(1$[ORD(I)=CARD(I)],IHmax(S,I))+1}${NJZ(S,Z,J)>=1};
        ICminZ(S,Z,J)$[ORD(S)=Si AND ORD(J)>1AND ORD(Z)=1]=0+
            {SUM{IS[ORD(I)=CARD(I)].IIImax(S,I)}
            +SUM((ZZ,JJ)$[ORD(JJ)<ORD(J)],NJZ(S,ZZ,JJ))+1}$NNZ(S,Z,J)>=1];
        ICminZ(S,ZJ)$[ORD(S)=Si AND ORD(Z)>1]=0+
                    {SUM{IS[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)$[ORD(S)=Si AND ORD(J)=Ji AND ORD (Z)=Zi]=0+
                    {JCminZ(S,Z,J)+NJZ(S,Z,J)-I}${NJZ(S,Z.J)>=1];
            1Cmin}(\textrm{S},\textrm{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$[ORD(ZZ)>=ORD(Z)+1].NJZ(S,ZZ,J))=0}.ICmaxZ(S,Z,J)];
            FOR(Mi=1 TO CARD(M),
                COI.D(S,J,M)$[ORD(S)=Si AND ORD(J)=Ji AND ORD(M)=Mi]=0+
                        IS[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,l,M),CPC_L(S,J,M);
DT(S,M) $=\operatorname{SUM}((Z, I) \$[\operatorname{HOTZ}(S, Z, 1, M)=1],\{[T I H Z(S, Z, 1)-$ TOHZ $(S, Z, 1)] /$
$[1 H \max Z(S, Z, I)-1 H \min Z(S, Z, I)+1]\}) \$[H O T 2(S, M)=I]+$
SUM ((Z,J)\$[COLDZ(S,Z,J,M)=1],\{[TOCZ(S,Z,J)-TICZ(S,Z,J)]/
[1CmaxZ(S.Z.J)-ICminZ(S.Z.J)+1]\})\$[COL.D2(S.M)=1];
FOR(Si= 1 TO CARD(S),
FOR ( $\mathrm{Mi}=1$ TO CARD(M),
$\operatorname{TU}(\mathrm{S}, \mathrm{M}) \$[\mathrm{ORD}(\mathrm{S})=\mathrm{Si}$ AND ORD(M)=Mi]=\{SUM((Z,1)\$[HOTZ(S,Z,L,M)=1.
AND ORD(M)=IHminZ(S,Z,l)],TIHZ(S,Z,I)\$[ORD(M)=1HminZ(S,Z,I)])

```
    + SUM((Z,I)S[HOTZ(S,Z,I,M)=IAND ORD(M)>IHminZ(S,Z,I)AND
                    ORD(M)<=lHmaxZ(S,Z,I)],
        [TIHZ(S,Z,I)-(ORD(M)-IHminZ(S,Z,I))*DT(S,M)]$[ORD(M)>
        IHminZ(S,Z,I)AND ORD(M)<=1HmaxZ(S,Z,I)])}$[HOT2(S,M)=1]
    + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=1CminZ(S,Z,J)],
            TOCZ(S,Z,J)$[ORD(M)=ICminZ(S,Z,J)])
    + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)>ICminZ(S,Z,J)
                AND ORD(M)<=\CmaxZ(S,Z,J)],
            [TOCZ(S,Z,J)-(ORD(M)-ICminZ(S,Z,J))*DT(S,M)]$[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,l)])
+ SUM((Z,I)$[HOTZ(S,Z,I,M)=1 AND ORD(M)<lHmaxZ(S,Z,l)
                        AND ORD(M)>=IHminZ(S,Z,I)],
    [TOHZ(S,Z,I)+(IHmaxZ(S,Z,I)-ORD(M))*DT(S,M)]$[ORD(M)<
    lHmaxZ(S,Z,l)AND ORD(M)>=lHminZ(S,Z,l)])}$[HOT2(S,M)=1]
    + {SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)=ICmaxZ(S,Z,J)],
        TICZ(S,Z,J)$[ORD(M)=lCmaxZ(S,Z,J)])
    + SUM((Z,J)$[COLDZ(S,Z,J,M)=1 AND ORD(M)<1CmaxZ(S,Z,J)
                AND ORD(M)>=ICminZ(S,Z,J)],
    [TICZ(S,Z,J)+(ICmaxZ(S,Z,J)-ORD(M))*DT(S,M)]$[ORD(M)<
    ICmaxZ(S,Z,J)AND ORD(M)>=1CminZ(S.Z,J)])}$[COLD2(S,M)=1];
CPH U(S,l,M)$[HOT(S,l,M)=l] = A_cp_H(I)*TU(S,M)+ B_cp_H(l)
CPC_U(S,J,M)$[COLD(S,J,M)=1] = A__cp_C(J)*TU(S,M)+ B_cp_C(J);
CPH_L(S,I,M)$[HOT(S,I,M)=1] = A_cp_H(l)*TL(S,M)+ B_cp_H(l)
CPC_L(S,J,M)$[COLD(S,J,M)=1] = A_cp_C(J)*TL(S,M)+ B_cp_C(J) ;
CPH(S,1,M)$[HOT(S,1,M)=1] =(CPH_U U(S,I,M)+CPH L(S,1,M))/2
CPC(S,J,M)$[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)=lc
        AND HOT(S,1,M)=1]= FH(S,I)* CPH(S,1,M)*[TU(S.M)-TL(S.M)] ;
    );
FOR(Ji=1 TO CARD(J),
    OR(Ji=1 TO CARD(J),
        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) ;
\(\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TU}(\mathrm{S}, \mathrm{N})+\mathrm{DTmin}\} \$[\operatorname{HOT} 2(\mathrm{~S}, \mathrm{M})\) AND COLD2(S,N)]; \(\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{\mathrm{TL}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{N})+\mathrm{DTmin}\} \$[\operatorname{HOT}(\mathrm{~S}, \mathrm{M})\) AND COLD2(S,N)] ;
\(\operatorname{LMTD}(\mathrm{S}, \mathrm{M}, \mathrm{N})=\{[\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})-\mathrm{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})]\)
\(/ \operatorname{LOG}[\operatorname{HHEAD}(S, M, N) /\) CHEAD \((S, M, N)]\} \$[H H E A D(S, M, N)>0\)
AND \(\operatorname{CHEAD}(S, M, N)>0\) AND \(\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})>\operatorname{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})]\)
\(+\{[\operatorname{HHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})+\mathrm{CHEAD}(\mathrm{S}, \mathrm{M}, \mathrm{N})] / 2\} \$[\operatorname{HHEAD}(\mathrm{~S}, \mathrm{M}, \mathrm{N})>0\) AND CHEAD \((\mathrm{S}, \mathrm{M}, \mathrm{N})>0\) AND ( \(\operatorname{HHEAD}(S, M, N)<\operatorname{CHEAD}(S . M, N) O R \operatorname{HHEAD}(S, M, N)=\operatorname{CHEAD}(S, M, N))] ;\)
```

D(S,Z,M,N)=1$[{HOT2(S,M)=1 AND HOT2(S,N)=1 AND SUM[1$(HOT(S,I,M)=1
AND HOT(S,I,N)=1),HOTZ(S,Z,I,M)]=1 AND SUM[I$(HOT(S,I,N)=1
    AND HOT(S,I,M)=1),HOTZ(S,Z,I,N)]=1}
    OR {COLD2(S,M)=1 AND COLD2(S,N)=1 AND SUM[J$(COLD(S.J,M)=1
AND COLD(S,J,N)=1),COLDZ(S,Z,J,M)]=1 AND SUM[J$(COLD(S,J,N)=1
        AND COLD(S,J,M)=1),COLDZ(S,Z,J,N)]=1}
    OR {(HHEAD}(S,M,N)>=0.00001 AND CHEAD(S,M,N )>=0.00001
        AND SUM[1$(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(lc=1 TO CARD(1),
    FOR(Ji=1 TO CARD(J),
        ALLOW(S,Z,I,J)S[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
            AND ORD(J)=Ji]=0+1${SUM[(M,N)$[HOT(S,I,M)=1
                    AND COLD(S,J,N)={},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)S[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
                    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)S[ORD(S)=Si AND ORD(Z)=Zi AND ORD(I)=lc
            AND ORD(J)=Ji AND ORD(M)=Mi AND COLD(S,J,M)=l]=0+
        I${SUM[N${HOT(S,I,N)=1],D(S,Z,N,M)]>0AND NOT[HU(I)AND CU(J)]};
            ))))):
    FOR(Zi=1 TO CARD(Z).
FOR(lc=1 TO CARD(l).
FOR(Ji=1 TO CARD(J),
ALLOW_2(Z,1,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)]};
)));
*-..--------
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,1,J,N)
QNEW2
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.IJ,N)
NHE_M0(S,Z,I,J,M)
NHE_MI(S.Z.I.,M)
NHE-NO(S,Z.I,J,N)
NHE_Nl(S,ZIJ,N)
NHE-M0_B(S,Z,I,J,M)
NHE_MI-B(S.Z,I,J,M)
NHE_NO_B(S,Z,I,J.N)
NHE_NI_B(S,Z,IJ,N)
NHE(S,Z.IJ)
ALFA_M(S.Z.I,J,M)
ALFA_N(S,Z,I,J,N)
FHU(I) is FCPHU (MJ_h_C)
FCU(J) is FCPCU(MJ_C)
Bl(S,Z,1,M,J,N) X(imjn) in the paper
QH(S,Z,I,M,N)
QC(S,Z,J,M,N)
Q2(S,Z,I,M,J,N)
XI_B(S:Z,I_J,M)
X B(S,K.Z,I,J,M)
PAR_B(K.Z,I,J)
USHELL(Z,I,J)
USHELL_B(K,Z:I,J)
*ADD FOR RELOCATON
PAR_N(S,Z,I,J)
PAR_N_B(K,E,Z.I,J)
DPAR E(Z,I,J)
DPAR_E_B(K,E,Z,I,J)
NHE S(S,Z,I,J)
DELTA(Z,I,J,E,E.K)
PHI(Z,I,J,E)
PAR_B_R(K,E,Z,I.J)
HOT UTILITY COST
Cold_UTILITY_COST
Area_Cost

```
```

    FIX_COST
    *ADD FOR PUMP-AROUND CASE
FP(I)
FPY(S,Z,I,J,M) Case of BIF=0
FPY_B(S,Z,I,J,M) Case of BIF=1
FPA(S,Z.l,J.M)
FPK_H_0(S,Z,1,J,M)
FPK_H_0_B(S,Z,I,J,M)
FPK_C_O(S,Z,I,J,N)
FPK_H_1(S,Z,I,J,M)
FPK H I 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(l,R)
YW(S,Z.I,J,M)
KW_0(S,Z,I.J,M,R)
KW_l(S,Z,l,J,M,R)
WA(S,Z.I,J,M,R)
XW(S,Z,l,M,J,N,R)
WQ(S,L,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(1)
PAI
PA2
PA3
TOTAL Q
Cp_Dt(I)
POSITIVE VARIABLE Q,QNEW2_M.QNEW2 N:QC,QH.Q2.DPAR_E,DPAR_E_BPAR_N
,PAR N B,PAR,QNEW M,QNEW N,YW,KW_0,KW_I,WA,XW:QPA,FP
,AEX,AEX_B
BINARY VARIABLE NHE_M0_B,NHE_MI B,NHE_N0_B;NHE_NI_B,Y_M,Y_N,XI_B,X_B.NHE_S
DELTA,Y_M_B,Y_N_B,NHE_M0,NHE_MI,NHE_N0,NHE_N1,ALFA M,ALFA_N
,W
PHI
INTEGER VARIABLE USHELL.USHELL_B
EQUATIONS
HBHU(S,I,M)
HBCU(S,J,N)
HBHS(S,l,M)
HBCS(S,J,N)
TRANSFOR_M(S,Z.I,J,M)
TRANSFOR_N(S,Z,IJ,N)
HBHS_NI(S,I,M)
HBCS NI(S.J,N
NOISOH(S,I,M)
NOISOC(S,J,N)
BINARY MI(S,Z.l,J,M)
BINARY_M2(S,Z_1,J,M)
BINARY_MI_B(S,Z,I,J,M)
BINARY M2 B(S,Z,I.J,M)
BINARY_NI(S,Z,I,J,N)
BINARY N2(S,Z,I,J,N)
BINARY_NI_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_M?(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,l,,\(N\) )
BINARY_N4(SZZ,I,J,N)
BINARY_N8(S,Z,IJ,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 MO(S,Z,I.J)
HE_COUNT_NO(S,Z.I,J)
HE_COUNT_MI(S,Z,l,J)
HE COUNT NI (S,Z, I, J)
\(\mathrm{NE} \overline{\mathrm{X}} \mathrm{CH}(\mathrm{S}, \mathrm{Z}, \overline{\mathrm{I}}, \mathrm{J})\)
NEXCH_B(S,Z.I,J)
BIF_1(S,Z,I,J,M,N)
BIF \(2(S, Z, 1, J, M, N)\)
BIF 3(S,Z,I.J,M,N)
BIF_4(S,Z,I,J,M,N)
BIF_11(S,Z,l,J,M)
BIF_12(S,Z,I,J,N)
BIF-6(S,Z,1,J,M)
BIF 9(S,Z,l,J,M)
BIF_5(S,Z,1,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,1,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,1,J.M)
FEAS \({ }^{-}\)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,IJ,M)
FEAS_M_1(S,Z1J,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.IJ,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,1,J,N)
FEAS N_03(S,Z,I,J,N)
FEAS_N_03_B(S,Z,I,J,N)
FEAS_N_04(S,Z,1,J,N)
FEAS_N_2(S,Z,I,J,N)
FEAS_N_1(S,Z,I,J,N)
FEAS N 3(S,Z,1,J,N)
FEAS_N_4(S,Z, \(1, \mathrm{~J} N)\)
FEAS_N_3_B_2(S,Z,I,J,N)
FEAS_N_3_B_(S,Z,1,J,N)
FEAS_N_4_B(S,Z,I.J.N)
FEAS N_1 SP(S,ZI,J,N)
FEAS_N_1_SP_B(S,Z.I,J,N)
FEAS_BEG_SP(S,Z,I,J,M,N)
FEAS_BEG_B_SI(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,1,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_BEGI_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,l,J,M,N)
FEAS_END2 B(S,Z,I,J,^1,N)
PAREQ(S,Z,1,J)
BIF_13_2(S,K.Z,I,J,M)
BIF_13_l(S,K,Z,l,J,M)
BIF_I4(S,K,Z.I.J)
BIF_1S(S,Z,l,J,M)
*BIF 16(S,Z,1,J,M)
BIF_17(S,Z,1,J,M)
BIF_18(S,Z,I,J,M,N)
SHELL(Z,I,J)
SHELL_B(K,Z,I.J)
KIMAXI(S,Z,1,J)
KMAX2(S,Z,1,J)
TOTALCOST

* EXTRA EQUATIONS NOT IN PAPER
TOTNEXCH MAX
TOTNEXCH MIN
HOT_U_C
Cold_U_C
Area C
FIX_C
\$ONTEXT
*ADD FOR RETROFIT
AREA RESTI(S,Z.I,J)
AREA_REST2(S.Z.1.J)
AREA REST3(S.Z,I,J)
AREA_REST4(S:Z,I,J)
AREA_REST5(S,Z,1.J)
*AREA__REST6(S,Z,I,J)
AREA_REST7(S,Z,l,J)
AREA_REST1_B(S,K,Z,l,J)
AREA_REST2_B(S,K,Z,I,J)
AREA_REST3_B(S,K,Z,I,J)
AREA REST4 B(S,K,Z,I,J)
AREA_REST5_B(S,K,Z,I,J)
AREA_REST6_B(S,Z,I,J)
LIM_HEX(S,M)
\$OFFTEXT
*****************************ADD FOR RELOCATION**********************************
RELOCATE_l(S,Z,1,J)
RELOCATE 2(S,Z,I,J)
RELOCATE_3(S,Z,I,J)
RELOCATE 4(S,Z,1,J)
RELOCATE_5_l(S,Z,I,J)
RELOCATE_5_2(S.Z,I,J)
RELOCATE 5 3(Z,E)
RELOCATE_6(K,E,S,Z,I,J)
RELOCATE-7(K.E,S,Z,1,J)
RELOCATE_8(K,E,S,Z,I,J)
RELOCATE_9(K,E,S,Z,I,J)
RELOCATE_10(K.E,S,Z,I,J)
*Equation for Pump-around

```
\begin{tabular}{|c|}
\hline PA_I(S,I.M) \\
\hline PA_2(S,I.M) \\
\hline PA_3(S,Z, l, J,M) \\
\hline PA_4(S,Z, \(1, \mathrm{~J}, \mathrm{M}\) ) \\
\hline PA_3_B(S,Z, \(1, \mathrm{~J}, \mathrm{M}\) ) \\
\hline PA_4_B(S,Z.I,J.M) \\
\hline PA_5(S,Z, \(1, \mathrm{~J}, \mathrm{M}\) ) \\
\hline PA 6(S,Z, \(1, \mathrm{~J}, \mathrm{M}\) ) \\
\hline PA_7(S, \(2,1, \mathrm{~J}, \mathrm{M})\) \\
\hline PA_8(S,Z,1,J,M,R) \\
\hline PA_9(S,Z,1,J,M,R) \\
\hline PA_10(S.Z,I,J,M,N) \\
\hline PA_11(S,Z,I,J,M,N) \\
\hline PA_12(S.Z,1,J,M,N) \\
\hline PA_13(S,Z,I,J,M,N) \\
\hline PA_14(S.Z,1,J,M,N) \\
\hline PA \({ }^{\text {_ }}\) 15(S, Z, \(\left.1, \mathrm{~J}, \mathrm{M}, \mathrm{N} . \mathrm{R}\right)\) \\
\hline PA_16(S,Z,I,J,M,N,R) \\
\hline PA_17(S,Z,1, J,M,N,R) \\
\hline PA_18(S,Z,I,J,M,N) \\
\hline PA_19(S,Z, \(1, \mathrm{~J}, \mathrm{M}\) ) \\
\hline PA_20(S,Z,1,J,M) \\
\hline PA_21(S,Z,I,J,M,R) \\
\hline PA_22(S, \(2,1, J, M, R)\) \\
\hline PA_23(S, Z, 1, J,M,R) \\
\hline PA_24(S,Z,1,J,M) \\
\hline PA_25(S,Z, I, J, M) \\
\hline PA 26(S,Z, 1, J,M,R) \\
\hline PA_27(S,Z, 1, J,M,R) \\
\hline PA_23(S, \(\mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}, \mathrm{R}\) ) \\
\hline PA_29(S,Z,I, , , M ) \\
\hline PA_30(S,Z,I,J,M) \\
\hline PA_31(S,Z,I,J,M,R) \\
\hline PA_32(S,Z,I,J,M,R) \\
\hline PA_33(S, Z, I, J,M,R) \\
\hline PA_34(S.Z,1,J,M) \\
\hline PA_35(S.Z,I,J,M) \\
\hline PA_36(S,Z,1, , M \()\) \\
\hline PA_37(S,Z,1,J,M) \\
\hline PA_38(S, Z, I, J, M) \\
\hline PA_39(S, \(2,1, \mathrm{~J}, \mathrm{M})\) \\
\hline PA \(40(\mathrm{~S}, \mathrm{Z}, 1, \mathrm{~J}, \mathrm{M})\) \\
\hline PA_41(S:Z, I, J,M) \\
\hline PA_42(S, Z, I, J,M,N) \\
\hline PA_43(S, Z, I, J,M,N) \\
\hline PA_44(S, Z, I, J,M,N) \\
\hline PA 45(S,Z,1,J,M,N,R) \\
\hline PA_46(S,Z,I,J,M,N,R) \\
\hline PA 47(S,Z,I,J,M,N,R) \\
\hline PA_48(S, Z, I, J,M,N) \\
\hline PA_49(S,Z,I,J,M,N) \\
\hline PA_50(S, Z, l, J,M,N) \\
\hline PA_51(S,Z,1,J,M,N) \\
\hline PA_S2(S,Z,1,J,M,N) \\
\hline PA_53(S,Z, \(1, \mathrm{~J}, \mathrm{M}, \mathrm{N}\) ) \\
\hline PA_54(S,Z, I,J,M) \\
\hline PA_55(S, Z, I, J, M) \\
\hline PA_ \(56(\mathrm{~S}, \mathrm{Z}, 1, \mathrm{~J})\) \\
\hline *PA- 57 \\
\hline PA 58 \\
\hline PA_59 \\
\hline PA_60 \\
\hline PA_61(S,Z,1,J,M) \\
\hline PA 62 \\
\hline PA_63 \\
\hline PA_64 \\
\hline PA_65 \\
\hline PA_66 \\
\hline PA_67 \\
\hline PA \({ }^{-} 68(\mathrm{~S}, \mathrm{Z}, 1 \mathrm{l})\) \\
\hline
\end{tabular}
```

;
*EQ (1)
HBHU(S,l,M)$(HOT(S,l,M)=1 AND HU(I) AND FREEH(I))
FHU(l)*(TU(S,M)-TL(S,M)) =E= SUM((Z,N,J)$(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)$(COLD(S.J.N)=1 AND CU(J) AND FREEC(J))..
FCU(J)*}(\textrm{TU}(\textrm{S},\textrm{N})-\textrm{TL}(\textrm{S},\textrm{N}))=E=SUM((Z,M,I)$(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.l,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND FREEH(I)),Q(S.Z,I.M,J.N)):
*----------
HBHS(S,I.M)$(HOT(S.I,M)=1 AND NOT HU(1) AND
FREEH(I) AND NIH(I)=0 AND NOT PA(I)).
DHH(S,I.M)=E=SUM((Z,N,J)$(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)$(COLD(S.J,N)=1 AND NOT CU(J) AND FREEC(J) AND NIC(J)=0).
DHC(S,J,N)=E=SUM((Z,M,1)$(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,\,M,J,N));
*
*EQ (5)
TRANSFOR M(S,Z,I,J,M)$(HOT(S,l,M)=1 AND ALLOW H(S,Z,l,M,J)=1
AND FREEH(I) AND FREEC(J))..
QNEW_M(S,Z,1,J,M)=E=SUM(N$(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,l,M,J,N));
*--------
TRANSFOR_N(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J.N,I)=1
AND FREEH}(\textrm{I}) AND FREEC(J)).
QNEW_N(S,Z,1,J,N)=E=SUM(M$(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,1,M,J)=1),Q(S,Z,I,M,J,N));
*EQ (7_a)
HBHS -Nl(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)$(D(S,Z,M,N)=1 AND HOT(S,l,N)=1 AND ORD(N) GT ORD(M)),QH(S,Z,I,N,M))
-SUM((Z,N)$(D(S,Z,M,N)=I AND HOT(S,I,N)=1 AND ORD(N) LT ORD(M)):QH(S,Z.I.M.N));
*EQ (8)
HBCS Nl(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 II(S,Z,I.M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,l,M,J,N))
+SUM((Z,M)$(D(S,Z,M,N)=1 AND COLD(S,J,M)=1 A
-SUM((Z,M)$(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)$(HOT(S,I,M)=1 AND NOT HU(I) AND FREEH(I) AND NIH(1)=1)
SUM((Z,N)$(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(IZ.M)$(D(S.Z,M.N)=1 AND COLD(S,J,M)=1 AND ORD(M) GT ORD(N)),QC(S,Z,J,N.M))
    =L= SUM((Z,M,l)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,l,M)=1
AND ALLOW_H(S,Z,I,M.J)=1 AND ALLOW_C(S,Z,J,N,I)=1),Q(S,Z,l,M,J,N));
*EQ (1la and 13a) Case of BIF(1,J)=0 (i,j) not belonging to set B.
BINARY_MI(S,Z,I,J.M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M.J)=1 AND BIF(Z.I.J)=0
    AND FREEH(I) AND FREEC(J)AND NOT P
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*DHH(S,I,M)$(NOT HU(I))
-Y_M(S.Z,I.J,M)*FMAX_HU(I)*DTHU(I)\$(HU(I))=L=0;

```

```

****** ********** MNNMUM VALUE OF QNEW_M=0.01!!!!!!!!!!
BINARY_M2(S,Z,I,J,M)\$(HOT(S,1,M)=1 AND ALLOW_H(S,Z,I.M,J,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 (1la and 13a) Case of BIF(1,J)=1 (i,j) belonging to set B
BINARY_M1_B(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,l,M,J)=1 AND BIF(Z,I,J)=1
          AND FREEH(I) AND FREEC(J) AND NÖT PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z,l,J,M)*DHH(S,l,M)$(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.l,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
QNEW_M(S,Z,1,J,M)-Y_M_B(S,Z,I,J,M)*QLHMIN =G=0;
*EQ (I2a and I4a) Case of BIF(I,J)=0 (i,j) not belonging to set B
BINARY NI(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I,J)=0
          AND FREEH(I) AND FREEC(J))..
QNEW_N(S,Z,I,J,N)-Y N(S,Z,l,J,N)*DHC(S,J,N)$(NOT CU(J))
-Y_N(S,Z,I,J,N )}\mp@subsup{)}{}{*}FMAX_CU(J)*DTCU(J)S(CU(J))=L=0
*EQ (12b and 14b) Case of BIF(1,J)=0 (i,j) not belonging to set B
BINARY_N2(S,Z,I,J,N)S(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,1)=1 AND BIF(Z,I,J)=0
AND FREEEH(l) AND FREEC(J)).. QNEW N(S,Z,l,J,N)-Y_N(S,Z,l,J,N)*QLCMIN=G=0;
*EQ (12a and I4a) 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,l,J,N)*FMAX_CU(J)*DTCU(J)$(CU(J))=L=0;
*-------------------------------------------------------------
BINARY_N2_B(S,Z,I,J,N)$(COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1 AND BIF(Z,1,J)=1
AND FREEEH(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,l,J,M)\$(HOT(S,l,M)=1 AND HOT(S,l,M-1) AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z,1,M-1,J) AND BIF(Z,1,J)=0 AND FREEH(I) AND FREEC(J)).
N
*-
*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,1,M-1,J)AND ALLOW_H(S,Z,I,M,J)=1
* AND ALLOW_H(S,Z,1,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,l,J)=0
AND FREEH(I) AND FREEC(J)).. NHE_M0(S,Z,I,J,M)=L= Y_M(S,Z,I.J,M);
* IT TURNS OUT THAT THIS EQUATION ONLY FORCES THE VALUES OF K TO BE ZERO
* WHEN Y=0, WHICH HAPPENS NATURALLY IF ONE IS MINIMIZING THE NUMBER OF
* EXCHANGERS OR BECAUSE THE FIXED COSTS ARE BEING MINIMIZED.
* EVEN IF NOT DRIVEN TO ZERO BY THE OBJECTIVE FUNCTION IT IS HARMELESS
* HOWEVER, IT TURNS OUT THAT IT COULD MAKE EXTENSIONS OF THE MODEL HAVE
* PROBLEMS. SO, ALTHOUGH THE EQUATION IS NOT NEEDED, IT GIVES SOME EXTRA VALUES
* OF K WHEN THEY DO NOT REALLY MATTER
*--
*EQ (18)
BINARY_M3(S,Z,I.J,M)$(HOT(S,I.M)=1 AND ALLOW_H(S,Z.I,M.J)=1 AND BIF(Z.I_J)=0
AND FREEH(l) AND FREEC(J)).
  NHE_M0(S,Z,I,J;M) =G= Y_M(S,Z,I,J,M)-Y_M(S,Z,1,J,M-1)$(HOT(S,1,M-1)
AND ALLOW_H(S,Z,I,M-1.J));
*EQ (19)
BINARY_M4(S,Z,l,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)
BNNARY_M8(S,Z,l,J,M)\$(HOT(S,l,M)=1 AND HOT(S,l,M+1) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,l,M+1,J) AND BIF(Z,1,J)=0 AND FREEH(I) AND FREEEC(J))..
N
*_
*EQ (22) : ORIGINALLY NOT NEEDED. BUT ADDED TO ENFORCE K=0 WHEN Y=0
* AND HOT(S,l,M-i) AND ALLOW_H(S,Z,I,M-1,J)
BINARY_M9(S,Z,I,J,M)S(HOT(S,I,M)=1AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
AND FREEH(I)AND FREEC(J)).
NHE_MI(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,l,J)=0
AND FREEH(I) AND FREEC(J)).. NHE_MI(S,Z,1,J,M)=G=Y_M(S,Z,I,J,M)-Y_M(S,Z,1,J,M+1)
$(HOT(S,1,M+1) AND ALLOW/H(S,Z.l,M+1,J));
*EQ (24)
BINARY M7(S,Z,I,J,M)$(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,1,J,M)$(HOT(S,1,M)=1 AND ALLOW_H(S,Z.I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J)).
    Y_M_B(S,Z,I,J,M) =E=SUM(O$(HOT(S,I,O)=1 AND ORD(O) LE ORD(M)
A}N\overline{D}\mathrm{ ALLOW_H(S,Z,1,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));
*.
*-----------------

* 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))..
N
*---------------------------------------------------------------

* 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,l,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)
*----------
BINARY_N3(S.Z,I.J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S.Z.J,N,I)=1 AND BIF(Z.1,J)=0
AND FREEH(I) AND FREEC(J)).
NHE_N0(S,Z,1,J,N) =G= Y_N(S,Z,l,J.N)-Y_N(S,Z,I,J,N-1)
$(COLDD(S,J,N-1) AND ALLOW_C(S,Z,J,N-1,I));
*-
  *EQ (30)
BINARY_N4(S,Z,I,J,N)$(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-I.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_NJ(S,Z.I.J,N)=L=2-Y_N(S.Z.l,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 A}NND ALLOW C(S,Z.J.N,I)=1 AND BIF(Z,l,J)=0
AND FREEH(I) AND FREEC(J))
NHE_N1(S,Z,l,J,N)=L=Y N(S,Z,l,J,N);

```
* SEE COMMENTS ON EQUATION (17)
*EQ (34)
BINARY_N6(S,Z,1,J,N)\$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J.N,I)=1 AND BIF(Z, \(1, \mathrm{~J})=0\)
AND FREEH(I) AND FREEC(J)).. NHE NI (S, Z, I, J,N \()=\mathbf{G}=Y \_N(S, Z, I, J, N)-Y \_N(S, Z, I, J, N+1)\)
                                    \$(COLD(S,J,N+1) AND ALLOW_C(S, \(\bar{Z}, \mathrm{~J}, \mathrm{~N}+1,1)\) );
*EQ (35)
BINARY_N7(S,Z,1,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_N \(1(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})=\mathrm{G}=0\);
*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(1)AND FREEC(J)).
Y_N_B(S,Z,I,J,N)=E=SUM(O\$(COLD(S,J,O) AND ORD(O) LE ORD(N)
AN̄D 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 ALİ.OW_C(S,Z,J,O.I)), NI II: NI_B(S,Z,1,J.O));
*--
*EQ (37)
HE_COUNT_M0(S,Z,1,J)\$(ALLOW(S, Z, \(1, \mathrm{~J})=1\) AND FREEH(1) AND FREEC(J)).
\(\mathrm{NHE}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})=\mathrm{E}=\mathrm{SUM}(\mathrm{M} \$(\mathrm{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1\) AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,1,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 \(\overline{(Z, I . J)=0), ~ N H E-M 0(S, Z, I, J, M)) ; ~}\)

*
*EQ (38)
    HE_COUNT_N0(S,Z,1.J)\$(ALLOW(S,Z,1,J)=1 AND FREEH(1) AND FREEC(J)).
\(\operatorname{NHE}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})=\overline{\mathrm{E}}=\mathrm{SUM}(\mathrm{N} \$(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{~N})=1\) AND ALLOW C(S.Z,J,N.I)=1 AND BIF(Z.I,J)=1),
    NHE_N0_B(S,Z,I,J,N))
\(+\operatorname{SUM}(\mathbb{N} \mathbb{( C O L D}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW \(\mathrm{C}(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N}, \mathrm{I})=1\) AND BIF(Z,I, J\()=0)\),
                                    NHE_NO(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\()\) ).
\(\operatorname{NHE}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})=\mathrm{E}=\mathrm{SUM}(\mathrm{M} \$(\mathrm{HOT}(\mathrm{S}, 1, \mathrm{M})=\mathrm{I}\) AND ALLOW_H(S,Z,1,M,J)=1 AND BIF \((\mathrm{Z}, \mathrm{I}, \mathrm{J})=1)\),
NHE_M1_B(S,Z,I,J,M)) + SUM(MS(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 \(\mathrm{Nl}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}) \$(\) ALLOW \((\mathrm{S}, \mathrm{Z}, \mathrm{l}, \mathrm{J})=1\) AND FREEH(I) AND FREEC(J))..
\(\operatorname{NHE}\left(S, Z, 1, J_{\bar{j}}=\mathrm{E}=\mathrm{SUM}(\mathrm{N} \$(\operatorname{COLD}(\mathrm{~S}, \mathrm{~J}, \mathrm{~N})=1\right.\) AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,1,J)=1),
    NHE_NI_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,1,J)=0), NHE_N1(S,Z,1,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, \(, 1, \mathrm{I}, \mathrm{J})=\mathrm{L}=1\);
*EQ (42)
NEXCH_B(S.Z.I, \() \mathbb{S}(\operatorname{ALLOW}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J})=1\) AND BIF(Z,I.J)=1 AND FREEH(I)
AND FREEC(J)). NHE(S,Z.I,J)=L=KMAX(Z,I.J);
*----------
BIF \(1(S, Z, 1 . J, M, N) \$(D(S . Z . M, N)=1\) AND TL(S,N) LT TU(S.M) AND HOT(S,I,M)=1
AND COLD \((\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S,Z,I,M,J)=I AND ALLOW_C(S,Z,J,N,I)=1
AND \(\operatorname{BIF}(Z, 1, \mathrm{~J})=1\) AND FREEH(1) AND FREEC(J) AND NOT PA(1)) .
SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND \(\because O T(S, I, L)=1\)
    AND ALLOW_H(S,Z,I,L,J)=1),
    QNEW M(S,Z,I,JL)) - 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,1)),
```

    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)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
  AND COLD(S,J,N)=1 AND
ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,l)=1 AND BIF(Z,1,J)=1 AND FREEH(1)
AND FREEC(J) AND NOT PA(I))..
SUM(L$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,l,L)=1
AND ALLOW_H(S.Z,I,L,J)=1),
QNEW M(S.Z.,1,J,L)) - QNEW2 M(S,Z,I.J,M) =G=
SUM(O$(D(S,Z,M,O)=1 AND ORD(O))LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
  QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z,I,J,N)
  -Bl(S,Z,I,M,J,N) *4* max(SUM(L$(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,1,J)=1 AND FREEH(1) AND FREEC(J))
Bl(S,Z,I,M.J,N)=E=2-0.25* SUM(L$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
  AND HOT(S,l,L)=1 AND ALLOW H(S,Z,I,L,J)=1),NHE MI B(S,Z,I,J,L))
  +0.25 *SUM(O$(D(S,Z,M,O)=1 AND ORD(O)LE ORD(N) ANDD 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,l,J,M,N)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND TL(S,N) GE TL(S,M)
    AND HOT(S,l,M)=1 AND COLD(S,J,N)=1 AND ALLOW H(S,Z,I,M,J)=1
    AND ALLOW_C(S.Z,J,N,I)=1 AND BIF(Z,I,J)=1 AND FREEH(1) AND FREEC(J))..
    SUM(L$(HOT(S,I.L)=1 AND ORD(L) LE ORD(M) AND
ALLOW H(S,Z,I,L,J)=1),NHE MI B(S,Z,I,J,L))
-SUM(O\overline{$}(\textrm{COLD}(\textrm{S},\textrm{J},O) AND ORD(O)LE ORD(N) AND ALLOW_C(S.Z,J_O,1)),
                NHE NI_B(S,Z,IJ,O))=G=0;
*.
*EQ (47)
BIF_11(S,Z,I,J,M)$(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$(COLD(S,J,O) AND ORD(O) LE ORD(N) AND ALLOW_C(S,Z,J,O,I)),
                NIIE_N0_B(S,Z,I,J,O)-NHE_NI_B(S,Z,I,J,O))=L=1;
*
*EQ (49)
BIF_6(S,Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,l,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)$(HOT(S,I,M)=1 AND ALLOW H(S,Z,l,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I)AND FREEC(J) AND NOT PA(\overline{l})
                                    QNEW2_M(S,Z,I,J,M) =L= NHE_M0_B(S,Z,I,J,M)*DHH(S,l,M);
*EQ (51)
BIF 5(S,Z,l.J,M)$(HOT(S,l,M)=1 AND ALLOW H(S,Z,l,M.J)=1 AND BIF(Z,1,J)=1
AND FREEH(I)AND FREEC(J) AND NOT PA(1)).
QNEW2 M(S,Z,I,J,M) =L= NHE_MI_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,l,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)$(COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND BIF(Z,I.J)=1
AND FREEH(l) AND FREEC(J)).
    QNEW2_N(S,Z,1,J,N) =L= NHE_N1_B(S,Z,1,J,N)*DHC(S.J,N);
**--------------------------------------------------------------------
*------------------------------------------------------------------------------
*EQ (57)
FEAS_M_01(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOOW_H(S,Z,I,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1/AND FREEEH(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)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW H(S.Z,I,M,J)=1
AND ALL-OW_-H(S,Z,1,M-1,J) AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J))..
            ALFA_M(S,Z,1,J,M)=L=1-NHE_M0_B(S,Z,1,J,M-1)-NHE_M0_B(S,Z.I,J,M);
*
*EQ (58)
    FEAS M 02(S,Z,1,J,M)$(HOT(S,I,M-1) AND HOT(S,1,M)=1 AND ALLOW H(S,Z.I,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,1,J)=0 AND SPH(l)=1 AND FREEH(l)
AND FREEC(J)).
ALFA_M(S,Z,I,J,M)=L=1-NHE_Ml(S,Z,I,J,M-1)-NHE_MI(S,Z,l,J,M);
FEAS_M_02_B(S,Z,1,J,M)$(HOT(S,I,M-1) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,l,M,J)=1
AND ALLOW_H(S,Z,l,M-1,J) AND BIF(Z,l,J)=1 AND FREEH(1) AND FREEC(J)).
ALFA_M(S,Z,I,J,M)=L=1-NHE_M1_B(S,Z,I,J.M-1)-NHE_M1_B(S,Z,I,J.M);
*EQ (59)
FEAS_M_03(S,Z,I,J.M)$(HOT(S,I,M-1) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,I.M.J)=1
AND ALLOW H(S.Z.I,M-1,J) AND BIF(Z,l,J)=0 AND SPH(1)=1 AND FREEH(1)
AND FREEC(J))..
ALFA_M(S,Z,I,J,M)=G=Y_M(S,Z,I.J,M)-NHE_M0(S,Z,1,J,M-I)-NHE_M0(S,Z,I.J,M) -
NHE_M1(S,Z,I,J,M-1)-NHE_M1(S,Z,l,J,M);
FEAS_M_03_B(S,Z,I_J,M)$(IIOT(S,I,M-I) AND HOT(S,1,M)=1 AND ALLOW_H(S,Z,I.M,J)=1
AND ALL
ALFA_M(S,Z,I.J,M)=G=Y_M_B(S,Z,1,J,M)-NHE_M0_B(S,Z,I,J,M-1)-NHE_M0_B(S,Z.I.J,M)
                                    - NHE_M1_B(S,Z,I,J,M-1)-NHE_M1_B(S,Z,I,J,M);
*
*EQ (60)
FEAS M 04(S,Z,1,J,M)$(HOT(S,l,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND
ALLO-W_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,l,J,M)=G=0;
*
*EQ (61)
FEAS_M_2(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW H(S,Z,I,M-1,J) AND SPH(1)=1 AND FREEH(I) AND FREEC(J)AND NOT PA(1)).
QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))=L=
    QNEW_M(S,Z.I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
        +(1-ALFA_M(S,Z.l,J,M))*DHH(S,I,M)/ (CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*--
*EQ (62)
FEAS_M_l(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,IM,J)=1
AND ALLOW H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(1) AND FREEC(J)AND NOT PA(I)).
QNEW_M(S,\overline{Z},\textrm{I},\textrm{J},\textrm{M})/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
+(I-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,LM-1)*(TU(S,M-1)-TL(S,M-1)));
*
*EQ (63)
FEAS_M_3(S.Z,1.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,1,M-1,J) AND BIF(Z.I,J)=0 AND SPH(I)=1 AND FREEEH(1)
AND FREEC(J) AND NOT PA(1)).

- 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)))
+(l+ NHE_Ml(S,Z,l,J,M-1) + NHE_Ml(S,Z,I,J,M) - NHE_M0(S,Z,l,J,M-1))
    * DHH(S,I,M)/(CPH(S,1,M)*(TU(S,M)-TL(S,M)))*1.0000 - =G=0;
* 

*EQ (64)
FEAS_M_4(S,Z,I,J,M)\$(HOT(S,l,M-I) AND HOT(S,I,M)=1 AND ALI.OW H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,1,M-1,J) AND BIF(Z,I,J)=0 AND SPH(I)=1 AND FREEEH(l)
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)))
+(I+ NHE_M0(S,Z,l,J,M-I)+NHE_M0(S,Z,I,J,M)-NHE_Ml(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,l,M)*(TU(S,M)-TL(S,M)))
+(1+NHE_MI_B(S,Z,I,J,M-1)+NHE_Ml_B(S,Z,l,J,M)-NHE_M0_B(S,Z,I,J.M-1))
    * DHH(S,1,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*.
*EQ (66)
FEAS M 3 B l(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1
AND ALLOWW-H(S,Z,l,M-1,J) AND BIF(Z,I,J)=1 AND SPH(1)=1 AND FREEH(1)
AND FREEC(J) AND NOT PA(I)).
QNEW2_M(S,Z,1,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))+(2 + NHE_MI_B(S,Z,I,J.M)
-NHE_M0_B(S,Z,I,J,M-1)-Y_M_B(S,Z,1,J,M-1))
                              * DHH(S,I,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*-
*EQ (67)
FEAS_M_4_B(S,Z,I,J,M)$(HOT(S,1,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,l,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,1,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)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I.M+1)
AND ALLO-W_H(S,Z,I,M,J)=1
AND ALLOW H(S,Z,l,M-1,J) AND ALLOW H(S,Z,l,M+1,J) AND BIF(Z.l.J)=0 AND SPH(I)=0
AND FREEH(I) AND FREEC(J) AND NOT PA(I))..
    QNEW_M(S,Z,l,J,M)=G=(Y_M(S,Z,l,J,M)-
    NHE M0(S,Z,I,J,M) + NHE MI(S,Z,I,J,M))*DHH(S,I,M);
FEAS M_1_SP B(S,Z,IJ,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND HOT(S,I,M+1)
AND ALLOW H(S,Z,l,M,J)=1
AND ALLOW_H(S,Z,1,M-1,J) AND ALLOW_H(S,Z,l,M+1,J) AND BIF(Z,I,J)=1 AND SPH(I)=0
AND FREEH(I) AND FREEC(J) AND NOT PA(I)).
QNEW_M(S,Z,I,J,M)=G=(Y_M_B(S,Z,l,J,M)-
NHE_M0_B(S,Z,I,J,M)+NHE_M
*--
*EQ (69)
FEAS_N_01(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S.Z,J.N.I)=1
AND ALLOW C(S,Z,J,N-1,I) AND BIF(Z,1,J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J)).
    ALFA_N(S,Z,l,J,N) =l=1-NHE_N0(S,Z,l,J,N)-NHE_N0(S,Z;I,J,N-1);
FEAS_N_01_B(S,Z,I,J,N)$(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,l) AND BIF(Z,l.J)=1 AND FREEH(I) AND FREEC(J))
ALFA_N(S,Z,1,J,N)=L=1-NHE_N0_B(S,Z.l,J,N)-NHE_N0_B(S:Z,1.J,N-1);
*----------
FEAS N 02(S.Z.I,J,N)$(COLD(S.J.N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J.N.I)=1
AND ALLOW_C(S,Z,J,N-1,1) AND BIF(Z,I;J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))
ALFA_N(S,Z,I,J,N)=L=1-NHE_N1(S,Z,I,J,N)-NHE_N1(S,Z,l.J,N-I);
FEAS_N_02_B(S,Z,I,J,N)$(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)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1
AND ALLOW C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J)).
    ALFA_N(S,Z,I,J,N)=G=Y_N(S,Z,I,J,N)-NHE N0(S,Z,I,J,N)-NHE N0(S,Z.I,J,N-I)
                            - NHE_Nl(S,Z,I,J,N)-NHEENI(S,Z,I,J,N-1);
FEAS N 03 B(S,Z,l,J,N)$(COLD(S,J,N-1) AND C-OLD(S,J,N)=1 AND ALLOW C(S.Z,J,N,l)=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,1,J,N)-NHE_N1_B(S,Z,1,J,N-1);
*
*EQ (72)
FEAS N_04(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND (BIF(Z,I,J)=1 OR SPC(J)=1) AND FREEH(I)
AND FREEC(J)).
Al_---------------------------------------------------
*EQ (73)
FEAS_N_2(S,Z,l,J,N)$(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,1,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=L=QNEW_N(S,Z,1,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_l(S,Z,I,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND SPC(J)=1 AND FREEH(I) AND FREEC(J)).
    QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
        +(1-ALFA N(S,Z,I,J,N))*
    /(CPC(S,J,N)*(TU(S,N)-TL(S,N)))=G=QNEW_N(S,Z,I,J,N-1)/
                                    (CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)));
*
*EQ (75)
FEAS N 3(S,Z,l,J,N)$(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-I,l) AND BIF(Z,1,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_NI(S,Z.I,J,N-1)
+NHE_Nl(S,Z,I,J,N)
-NHE - N 0(S,Z,I,J,N-1))*DHC(S,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))*].00001 =G=0;
*
*EQ (76)
FEAS_N_4(S,Z,l,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,1,J)=0 AND SPC(J)=1 AND FREEH(I)
AND FREEC(J))..
-QNEW_N(S,Z,1,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
(CPC(S,J,N)*(TU(S,N)-TL(S,N)))*1.00001=G=0;
* 

*EQ (77)
FEAS_N_3_B_2(S,Z,1,J,N)$(COLD(S,J,N-1) AND COLD(S,J,N)=1
AND ALLOWW_C(S,Z,J,N,I)=1
AND ALLOW_C(S,Z,J,N-1,I) AND BIF(Z,1,J)=1 AND SPC(J)=1 AND FREEH(1)
AND FREEC(J)).
-QNEW N(S,Z,1,J,N-1)/(CPC(S,J,N-1)*(TU(S,N-1)-TL(S,N-1)))
+QNEW_N(S,Z,I,J,N)/(CPC(S,J,N)*(TU(S,N)-TL(S,N)))
+(1 + NHE NI B(S,Z,I,J,N-1)+NHE NI_B(S,Z,I,J,N)-NHE N0 B(S,Z,l,J,N-1))
    * DHC(S.J,N)/(CPC(S,J.N)*(TU(S,N)-Tl(S,N)))=G=0;
*
*EQ (78)
FEAS_N_3_B_1(S,Z.I,J,N)$(COLD(S,J;N-1) AND COLD(S.J.N)=1
AND ALLOWW_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,1,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,1,J,N-1))

```

```

AND ALLOW_C(S,Z,J,N,I)=I 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(1) 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)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
    AND TU(S,N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M+1) AND COLD(S,J,N)=1
    AND COLD(S,J,N+1)
    AND ALLOW H(S,Z,I,M,J)=1 AND ALLOW H(S,Z,I,M+1,J) AND ALLOW C(S,Z,J,N,l)=1
    AND ALLOW C(S,Z,J,N+I,I) AND BIF(Z,I,J)=0 AND (SPH(I)=1 OR SPC(J)=1)
    AND FREEH(l) AND FREEC(J) AND NOT PA(1))
    QNEW_M(S,Z,I,J,M)/(MIN(TU(S,M),TU(S,N))-TL(S,M))=G=
    QNEW_M(S,Z,I,J,M+1)/(TU(S,M+1)-TL(S,M+1))
    * CPH(S,I,M)/CPH(S,I,M+1)-(2-NHE M0(S,Z,I,J,M)-NHE N0(S,Z,I,J,N))
    *DHH(S,I,M+1)/(TU(S,M+1)-TL(S,M+1));
*
*EQ (86)
FEAS_END3(S,Z,1,J,M,N)$(DTVIO(1,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,l,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-I,J)AND ALLOW C(S,Z,J,N,I)=1 AND ALLOW C(S,Z,J,N-I,I)
AND BIF(Z,I,J)=0 AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)).
NHE_M0(S,Z,I,J,M)=L=(2-NHE_Ml(S,Z,I,J,M)-NHE_NI(S,Z,I,J,N));
*
*EQ (87)
FEAS_END(S,Z,I,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
    AND TU(S.N) GT TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
    AND COLD(S,J,N-1) AND ALLOW_H(S,Z,1,M,J)=1 AND ALLOW_H(S,Z,1,M-1,J)
    AND ALLOW C(S,Z,J,N,l)= I AND ALLOW C(S,Z,J,N-1,I) AND BIF(Z,I,J)=0
    AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND NOT PA(I))..
QNEW M(S,Z,1,J,M)/(TU(S,M)-TL(S,N))=L=QNEW M(S,Z,I,J,M-1)/(TU(S,M-1)-TL(S,M-1))
    * CPH(S,I,M)/CPH(S,I,M-1)+(2-NHE_MI(S,Z,I,J,M)-NHE_NI(S,Z,I,J,N))
    *DHH(S,I,M)/(TU(S,M)-TL(S,N));
*EQ (88)
FEAS_END2(S,Z,I,J,M,N)$(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)=| AND HOT(S,I,M-I) 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-I,I) AND BIF(Z.I,J)=0
AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J))
QNEW N(S,Z,1,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_Ml(S,Z,I.J,M)-NHE_NI(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)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N N GT TL(S,M)
AND HOT(S,l,M)=1 AND HOT(S,l,M+1) AND COLD(S,J,N)=1 AND COLD(S,J,N+1)
AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S,Z,I,M+1,J)AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z.J,N+1.1)
AND BIF(Z,I,J)=1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)).
    NHE_N1_B(S,Z,1,J,N) =L=
                            (l+Y_N_B(S,Z,I,J,N)-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N));
*
*EQ (90)
FEAS BEG2 B(S,Z,l,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N
AND COLD(S,J,N+I) 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(1) AND FREEC(J))
QNEW N(S.Z,1,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)+
(I+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 BEGI B(S,Z.I,J,M,N)$(DTVIO(I.J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
    AND TU(S,N) GT TL(S,M) AND 11OT(S,I.M)=1 AND HOT(S,l,M+1) AND COLD(S,J,N)=1
    AND COLD(S,J,N+1) AND ALLOW_H(S,Z,l,M,J)=1 AND ALLOW_II(S,Z,l,M+1,J)
    AND ALLOW C(S,Z,J,N,I)=1 AND ALLOW C(S,Z,J,N+1,I) AND BIF(Z,I,J)=1
    AND (SPH(I)=\overline{l}}\mathrm{ OR SPC(J)=1) AND FREEH(I) AND FREEC(J)).
    QNEW2_N(S,Z,I,J,N)/(TU(S,M)-TL(S,N))=L=QNEW_N(S,Z,I,J,N+1)/
    (TU(S,N+1)-TL(S,N+1))
    *CPC(S,J,N)/CPC(S,J,N+1)+(2-NHE_M0_B(S,Z,I,J,M)-NHE_N0_B(S,Z,I,J,N))
    *DHC(S.J;N)/(TU(S,M)-TL(S.N));
*
*EQ (92)
FEAS_BEG3_B(S,Z,lJ,M,N)$(DTVIO(l,J)=1 AND D(S,Z,M,N)=I AND TL(S,N) LT TU(S,M)
AND TU(S.N) GT TL(S,M) AND HOT(S,1,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 ĀLLOW_C(S,Z,J,N+1,l) AND BIF(Z.IJ)=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,1,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-I) AND COLD(S,J,N)=1 AND COLD(S.J,N-I)
AND ALLOW H(S.Z.I.M.J)=I
AND ALLOW_H(S,Z,l,M-1,J)AND ALLOW_C(S,Z,J,N,l) AND ALLOW_C(S,Z,J,N-1,I)
AND BIF}(\textrm{Z},\textrm{I},\overline{J})=1 AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)).
NHE M0 B(S,Z,1,J,M)=1=

* (I+Y_M_B(S,Z.I.J,M)-NHE_Ml_B(S,Z.I,J,M)-NHE_NI_B(S,Z,I,J,N))
*EQ (94)
FEAS_END_B(S,Z,I,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
  AND TU(S.N) GT TL(S,M) AND HOT(S,l,M)=1 AND HOT(S,l,M-1) AND COLD(S,J,N)=1
  AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,L,M-1,J)
  AND ALLOW_C(S.Z.J,N,I)=1 AND ALLOW_C(S,Z.J,N-1,I) AND BJF(Z,1,J)=1
  AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND NOT PA(1)).
      (QNEW_M(S,Z.I.J.M)-QNEW2_M(S,Z,I.J,M))/(TU(S,M)-TL(S.N))=L=
      QNEW M(S,Z.I.J,M-1)/
      (TU(S,M-1)-TL(S,M-1))* CPH(S,I,M)/CPH(S.I.M-1)+
      (2-NHE_M1_B(S,Z,I,J,M)-NHE_NI_B(S.Z,I,J,N))*DHH(S,1,M)/(TU(S,M)-TL(S,N));
*..
*EQ (95)
FEAS END2 B(S,Z,I,J,M,N)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M)
AND TU(S,N})\textrm{GT}TL(S,M) AND HOT(S,I,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=
AND COLD(S,J,N-1) AND ALLOW_H(S,Z,l,M,J)=1 AND ALLOW_H(S,Z,I,M-1.J)
AND ALLOW C(S,Z,J,N,I)=1 AND ALLOW C(S,Z,J,N-1,I) AND BIF(Z,I,J)=1
AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J)).
(QNEW N(S,Z,I,J,N)-QNEW2 N(S,Z,I,J,N))/(TU(S,N)-MAX(TL(S,M),TL(S,N)))=G=
QNEW_N(S,Z,I,J,N-1)/(TU(S,N-1)-TL(S,N-1))*CPC(S,J,N)/CPC(S,J,N-1)
-(2-NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N))*DHC(S,J,N-1)/
(TU(S,N-1)-TL(S,N-1));

```

```

*EQ (96)
PAREQ(S,Z,1,J)$(ALLOW(S,Z,1,J)=1 AND FREEH(1) AND FREEC(J))..
PAR(Z,I,J)=E=SUM((M,N)$(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)=I
AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1),
Q(S,Z,l.M,J,N)/(U(S,l,J)*LMTD(S,M,N)));
*EQ (97)
BIF 13 2(S.K,Z,I,J,M)$(ORD(K) LT KMAX(Z,I,J) AND HOT(S,I,M)=1
    AND ALLLOW_H(S,Z,l,M,J)=1
    AND BIF(Z.I,J)=1 AND FREEH(I) AND FREEC(J)).
    PAR B(K,Zl,J)=L=SUM((L,N)$(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 Ml B(S,Z,l,J,M)-Xl B(S,Z,I,J,M)-
SUM(KK\$(ORD(KK) GT I 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 XI_B and then a
* summation from 2 to kmax-1. See equation (100) as well
*EQ (98)
BIF 13 1(S,K,Z,l.J,M)$(ORD(K) LT KMAX(Z,I,J) AND HOT(S,I,M)=1
  AND}\mathrm{ AL̄LOW_H(S,Z,I,M,J)=1
  AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J)).
  PAR_B(K,Z,I,J)=G=SUM((L,N)$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M)
AND-
AND HOT(S,I,L)=I AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,l,L,J)=I
AND ALLOW_C(S,Z,J,N,I)=1),
(Q(S.Z,J.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$(ORD(K\overline{K}) GT I AND ORD(KK}) LT ORD(K)),X_B(S,KK,Z,I,J,M))))
*EQ (99)
  BIF 14(S,K,Z,I,J)$(ORD(K) EQ KMAX(Z,I,J) AND ALLOW(S,Z,l,J)=1 AND FREEH(l)
AND FREEC(J) AND BIF(Z,I,J)=1).
PAR_B(K.Z,I,J)=E=PAR(Z,1,J)-SUM(KK\$(ORD(KK) LT ORD(K)),PAR_B(KK,Z,1,J));
* 

*EQ (100)
BIF_15(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
    AND FREEH(I) AND FREEC(J)).
    XI B(S,Z,l,J,M)+SUM(K$(ORD(K) GT I AND ORD(K) LE KMAX(Z,1,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,1,L,J)=1),NHE_M0_B(S,Z,1,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 I to kmax-1. Here we use XI_B and then a
* summation from 2 to kmax-1.
*-
*EQ (101)
BIF_17(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,l,J)=1
AND FREEH(I) AND FREEC(J)).
SUM(N$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,1,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,l,J,M,N)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1
AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,l,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,1,J)=1 AND FREEH(1) AND FREEC(J)).
                                    Q2(S,Z,l,M,J,N)=L=Q(S,Z,I,M,J,N);
*-
*EQ (103)
SHELL(Z,I,J)$(SUM[S,ALLOW(S,Z,I,J)]>= I AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=0)..
PAR(Z,I,J)=L=ASHELLMAX*USHELL(Z,I,J);
*----------
SHELL B(K,Z,I,J)$(SUM[S,ALLOW(S,Z,I,J)]>= 1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,J)=1)..
PAR_B(K,Z,l,J)=L=ASHELLMAX*USHELL_B(K,Z,I,J);
*----------
*TOTALCOST.. TCOST =E= SUM(I$(HU(l) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))

*     + SUM(J\$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
*     + SUM((Z,1,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,1,J)=1), CF*USHELL_B(K,Z,I.J))
*     + SUM((Z,l,J)\$(SUM[S,ALLOW(S,Z,Z,1,J)]>= 1 AND FREEH(I) AND FREEC(J) ),
* CA*PAR(Z,I,J))
$ONTEXT
TOTALCOST.. TCOST=E=SUM(IS(HU(I) AND FREEH(1)),CHU(I)*FHU(I)*DTHU(I))
  +SUM(J$(Cl(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
SUM((S,Z.I.J)$(ALI.OW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J))
  CF*(NHE(S,Z,I.J)+NHE S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-NHE0(S,Z,I,J)))
+SUM((S,Z,1,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,1,J)$(ORD(K) LE KMAX(Z.I,J) AND ALLOW(S.Z.I.J)=1
    AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1)
    CAE*DPAR_E_B(K,Z,l,J)+CAN*PAR N B(K,Z,l,J))
    $OFFTEXT
I()\AI.COST.. TCOST =E= SUM(IS(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I))
            + SUM(J$(CU(J) AND FREEC(J)),CCU(J)*FCU(J)*DTCU(J))
+SUM((S,Z,l,J)$(OPT=2 AND ALLOW(S,Z,l,J)=1 AND FREEH(I) AND FREEC(J)
    AND BIF(Z,1,J)=0)
    (CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-(NHE0(S,Z.I,J)*(SUM(E$(ORD(E) LE KET),
    Phi(Z,I,J,E))))))+(CAE*DPAR_E(Z,I,J))+CAN*PAR_N(S,Z,1,J))
    +SUM((S,Z,I,J)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I.J)=1)
(CF*
ORD(K)LE KMAX(Z,I,J)),DELTA(Z,I,J,EE,E,K)))))
+SUM((S,Z,l,J,K,E)\$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1 AND ORD(K)LE KMAX(Z,l,J))

* +SUM(K\$(ORD(K)LE KMAX(Z,I,J))
,(CAE*DPAR_E_B(K,E.Z.l,J)+CAN*PAR_N_B(K,E,Z.I,J)))
+Cost_side_stripping_steam;
* Here we have an equation that is made simpler than in the paper. We account
* for the total area of the exchangers (use PAR and not PAR_B)
* The result is the same.
* 

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

* Needed because the exchangers are related to the values of K
KMAX1(S,Z,l,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(1) AND FREEC(J) AND BIF(Z,1,J)=0).
NHE(S.Z,I,J) = = = USHELL(Z,I,J);
*EQ (107)
KMAX2(S,Z,I.J)$(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 (J08) LIMIT THE NUMBER OF EXCHANGERS
TOTNEXCH_MAX(S).. SUM((Z,I,J)$(ALLOW(S,Z,I,J)= I AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=L=TOTNEXCHMAX;•
*EQ (109) MINIMUM NUMBER OF EXCHANGERS
TOTNEXCH_MIN(S).. SUM((Z,I,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)),
NHE(S,Z,I,J))=G=TOTNEXCHMIN;
\$ONTEXT
* Equation for Retrofit
*EQ(Retrofit 1)
AREA_REST1(S.Z,I,J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,I)=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)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
  AND BIF(Z,1,J)=0 ).
  DPAR_E(Z,1,J)=L=AEX_U(Z,I,J)-AEX(Z,I,J);
*-----------------
AREA REST3(S.Z.I,J)$(ALLOW(S,Z,I,J)=I AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,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,1.J)\$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,J)=0 )..
(NHE(S,Z,1,J)) = L= TOTNEXCHMAX ;

```
```

*EQ(Retrofit 5)
AREA_REST5(S,Z,I.J)$(ALLOW(S,Z,l,J)=1 AND FREEH(1) AND FREEC(J)
AND BIF(Z,I,J)=0 AND NHEO(S,Z,1,J)= 0)..
PAR_N(S,Z,l,J)=L= A_NEW_MAX(Z,1,J)* (NHE(S,Z,I,J));
*EQ(Retrofit 6)
*Eq retrofit 6 is same as Eq retrofit 5
*-
*EQ(Retrofit 7)
AREA_REST7(S,Z,I.J)$(ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z.l,J)=0 AND NHE0(S,Z,I,J)= 0).
(NHE(S,Z,1,J)) =L= TOTNEXCHMAX ;
*EQ(Retrofit 8)
AREA_RESTI_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,1,J)$(ORD(K) LE KMAX(Z.I.J) AND ALLOW(S,Z,l,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1)
    DPAR_E_B(K,Z,I,J)=L=SUM(KK$(ORD(KK) LENHE0(S,Z,I,J)),(AEX_U_B(KK:Z,l,J)
-AEX_B(KK,Z,I,J))*DELTA(KK,K));

* EQ(Retrofit 10)
AREA_REST3_B(S,K,Z,I,J)$(ORD(K) LE KMAX(Z,1,J) AND ALLOW(S,Z,1.J)=1
              AND FREEH(I) AND FREEC(J) AND BIF(Z,I,J)=1).
  PAR_N_B(K,Z,I,J)=L=A_NEW_MAX(Z,l,J)
                                  *(1-SUM(KK\overline{$}(ORD-\overline{(KK}) LE NHE0(S,Z,I,J)),DELTA(KK,K)));
*EQ(Retrofit 11)
AREA REST4 B(S,K.Z,1,J)$(ORD(K) LE KMAX(Z,I,J) AND ALLOW(S.Z,I,J)=1
              AND FREEH(I) AND FREEC(J) AND BIF(Z,l,J)=1)
  SUM(KK$(ORD(KK) LE NHE0(S,Z,I.J)),DELTA(KK,K))=L=1
*EQ(Retrofit 12)
AREA REST5_B(S.K,Z,I,J)$(ORD(K) LE NHEO(S,Z,I,J) AND ALLOW(S.Z,I.J)=1
                                  AND FREEH(1) AND FREEC(J) AND BIF(Z,l,J)=1)
  SUM(KK$(ORD(KK) LE KMAX(Z,I,J)),DELTA(K,KK))=L=1;
*EQ(Retrofit 13)
AREA_REST6 B(S,Z,I,J)$(ALLOW(S,Z,I,J)=1 AND FREEH(l)
              AND FREEC(J) AND BIF(Z,I.J)=1)
SUM((K,KK)$(ORD(K) LE KMAX(Z,l,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,l,J)\$(HOT(S,I,M)=1 AND ALLOW H(S,Z,I,M,J)=1),(NHE(S,Z,I,J))-NHE0(S,Z,I,J))
=L= MAX_NEW_HEX ,
*---------------------------------------------------------------------------
$OFFTEXT
*.------------------------------------------------------------------------------
**************************** Equation for Retrofit Relocation**
*EQ(Retrofit 16)
RELOCATE 1(S.Z,1,J)$(OPT=2 AND ALLOW(S,Z.1,J)=1.AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,J)=0 ).
PAR(Z,I,J)=L=AEX(Z,I,J)+DPAR_E(Z,I,J)+PAR_N(S,Z,I.J);
* 

*EQ(Retrofit 17)
RELOCATE_2(S,Z,1,J)$(OPT=2 AND ALLOW(S,Z,l,J)=1 AND FREEH(I) AND FREEC(J)
                AND BIF(Z,I,J)=0).
AEX(Z.I.J) =E= SUM(E$(ORD(E) LE KET);(AEX_R(E)*Phi(Z.I,J,E)));

```
```

*EQ(Retrofit 18)
RELOCATE_3(S,Z,IJ)$(OPT=2 AND ALLOW(S,Z,I,J)=1 AND FREEH(I) AND FREEC(J)
                AND BIF(Z,1,J)=0 )..
    DPAR_E(Z,I,J)=L=SUM(ES(ORD(E) LE KET),(AEX_U_l(E)-AEX_R(E))
            *Phi(Z,I,J,E));
*
*EQ(Retrofit 19)
RELOCATE_4(S,Z,\J)$(OPT=2 AND ALLOW(S,Z,l,J)=\ AND FREEH(I) AND FREEC(J)
AND BIF(Z,1,J)=0).
PAR N(S,Z,I,J) = L= A_NEW_MAX(Z,I,J) *(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,1,J)=1)-(NHE0(S,Z,I,J)*
                        SUM(ES(ORD(E) LE KET),Phi(Z,I,J,E)) ));
*
*EQ(Retrofit 20)
RELOCATE_5_1(S,Z,I,J)$(OPT=2 AND ALLOW(S.Z,1.J)=1 AND FREEH(1) AND FREEC(J)
A
RELOCATE_5_2(S,Z,1,J)$(OPT=2 AND FREEH(I) AND FREEC(J)
        AND BIF(Z,I!J)=0).. SUM((E)$(ORD(E) LE KET);Phi(Z:I,J,E))=L=1;

* Extra Eq. Limits number of phi matches
RELOCATE_5_3(Z,E)$(OPT=2).. SUM((i,j), Phi(Z,l,J,E)) =L=1
*------------
**EQ(Retrofit 21)
RELOCATE_6(K,E,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1)
PAR_B_R(K,E,Z,I,J)=L=AEX_B(K,E,Z,I,J)+DPAR_E_B(K.E.Z,I,J)+PAR_N_B(K,E,Z,I,J);
*-
*EQ(Retrofit 22)
RELOCATE_7(K,E,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,I,J) AND ALLOW(S,Z,1,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z.I.J)=1).
  AEX_B(K,E,Z,I,J)=E=SUM(EE$(ORD(EE) LE KET),(AEX_B_R(EE)*DELTA(Z,I,J,EE,E,K)));
**
*EQ(Retrofit 23)
RELOCATE 8(K,E,S,Z,I,J)$(OPT=2 AND ORD(E) LE KMAX(Z,1,J) AND ALLOW(S,Z,1,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1).
  DPAR_E_B(K,E,Z,I,J)=L= SUM(EES(ORD(EE) LE KET),(AEX_U_B_R(EE)-AEX_B_R(EE))
              *DELTA(Z.l,J,EE,E,K));
*------------------
RELOCATE 9(K,E,S,Z,1,J)$(OPT=2 AND ORD(K) LE KMAX(Z,1,J) AND ALLOW(S,Z,l,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1).
PAR_N_B(K,E,Z,l,J)=L= A_NEW_MAX(Z,l,J) *(l-SUM(EE$(ORD(EE) LE KET)
                                  DELTA(Z,I,J,E咗,E,K))
**
*EQ(Retrofit 25)
RELOCATE_10(K,E,S,Z,I,J)$(OPT=2 AND ORD(K) LE KMAX(Z,1,J) AND ALLOW(S,Z,1,J)=1
AND FREEH(I) AND FREEC(J) AND BIF(Z,1,J)=1).
SUM(EE\$(ORD(EE) LE KET),DELTA(Z,I,J,EE,E,K)) =L= 1;

```
```

*Add Eq for PA
*EQ (3_b)
PA l(S,l,M)$(HOT(S,l,M)=1 AND NOT HU(I) AND
FREEH(1) AND NIH(I)=0 AND PA(I)).
FP(1)*CPH(S,l,M)*(TU(S,M)-TL(S,M)) =E=SUM((Z,N,J)$(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));
**---------
PA_2(S.I,M)$(HOT(S,I,M)=1 AND NOT HU(I)
AND FREEH(l) AND NIH(I)=1 AND PA(I)).
FP(I)*CPH(S,l,M)*
AND TL(S,N) LT TU(S,M)AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C(S,Z.J,N,I)=1),Q(S,Z,I.M,J.N))
+SUM((Z,N)$(D(S,Z,M,N)=1 AND HOT(S,I,N)=1 AND ORD(N) GT ORD(M)),QH(S,Z,l,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 II_b Case of BIF(I,J)=0 (i,j) not belonging to set B.
PA_3(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=0
    AND FREEH(I) AND FREEC(J)AND PA(I))
QNEW_M(S,Z,I,J,M)-FPY(S,Z,I,J,M)*}CPM(S,I,M)*(TU(S,M)-TL(S,M))$(NOT HU(I))=L=0
*EQ 1!_b Case of BIF(1,J)=0 (i,j) not belonging to set B
******- ********** MNIMUM VALUE OF QNEW_M=0.01!!!!!!!!!
PA 4(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALL.OW_H(S.Z.I.M.J)=I AND IBIF(Z.I.J)=0 AND
    FREEH(I) AND FREEC(J) AND PA(I)).
QNEW_M(S,Z,I,J,M)-Y_M(S,Z,I,J,M)*QLHMIN=G=0;
*EQ 11_b Case of BIF(1,J)=1 (i,j) belonging to set B
PA_3_B(S,Z,I,J,M)$(HOT(S,1,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,1,J)=1
AND FREEH(I) AND FREEC(J) AND PA(l)).
QNEW_M(S,Z,I,J.M)-FPY_B(S,Z,I,J,M)*CPH(S,I,M)*(TU(S.M)-TL(S,M))$(NOT HU(I))=L=0;
*EQ 11_b Case of BIF(I,J)=1 (i,j) belonging to set B
PA_4_B(S,Z,l,J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,l,J)=1
ANDD FREEH(I) AND FREEC(J) AND PA(I))..
QNEW_M(S,Z,I,J,M)-Y_M_B(S,Z.l,J,M)*QLHMIN =G=0:
*EQ 11 C 1
PA 5(S.Z,I,J,M)$(HOT(S,I,M)=1 AND ALLOW H(S.Z,I,M,J)=1 AND BIF(Z.I,J)=0
AND FREEH(I) AND FREEC(J) AND PA(I))
FPY(S,Z,l,J,M)=E=SUM(R,(FPR(I,R)*YW(S,Z,1,J,M)));
*EQ 11_C_2
PA 6(S,Z,I.J,M)$(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,l,J,M)=E=SUM(R,(FPR(I,R)*YW(S,Z,1,J,M)));
*EQ 11_D
PA 7(S,Z,I,J,M)$(HOT(S.I,M)=1 AND ALLOW H(S,Z,I.M.J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
YW(S,Z,I,J.M)-Y_M(S,Z.I,J,M) =L= 0;
*----------
PA 8(S,Z,I,J,M,R)$(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)$(HOT(S,I,M)=1 AND ALLOW H(S:Z.I.M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
YW(S,Z,I,J,M) =G= Y_M(S_Z,I,J,M)+W(I,R)-1;
*EQ (43_b)
PA 10(S,Z,IJ,M,N)$(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,l,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1
AND BIF(Z,1,J)=1 AND FREEH(I) AND FREEC(J) AND PA(I)).
SUM(L$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(M) AND HOT(S,I,L)=1
    AND ALLOW_H(S,Z,1,L,J)=1),
    QNEW M(S,Z,I,J,L)) - QNEW2_M(S.Z,l,J,M) =L=
SUM(O$(D(S,Z,M,O)=1 AND ORD(O)LE ORD(N) AND COLD(S,J,O) AND ALLOW_C(S,Z,J,O,I)),
QNEW_N(S,Z,I,J,O)) - QNEW2_N(S,Z.I,J,N)+ 4*XM(S,Z,I,M,J,N),
*---
*EQ 43_C
PA_11(\overline{S},Z,I,J,M,N)$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I.M)=1
    AND COLD(S,J,N)=1 AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J.N.I)=1
    AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC(J) AND PA(1))..
XM(S,Z,I,M,J,N)-(TE(S,Z,I,M,J,N)*OMEGA(S.Z,I,M,J,N))=L=SUM(R,(XW(S.Z.I,M,J,N,R)*
FPR(1,R)*SUM(L$(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))))));
*--.......-
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
ANDD 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,1,J)=1 AND FREEH(1) A\overline{ND FREEC(J) AND PA(1))..}

```

XM(S.Z,I,M,J.N)-TE(S,Z.I.M,J.N)*OMEGA(S,Z,I,M,J,N))=G=SUM(R,(XW(S,Z,l,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)=I),(CPH(S,I,L)*(TU(S,L)-TL(S,L))))));
*EQ 43_E
PA 13(S.Z.I.J.M.N)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S.M) AND HOT(S,I,M)=1 AND COLD \((\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S,Z.I.M.J) \(=1\) AND ALLOW_C(S,Z,J,N,I)=1 AND \(\operatorname{BIF}(\mathrm{Z}, \mathrm{I}, \mathrm{J})=1\) AND FREEH(I) AND FREEC(J) AND PA(1)).

XM(S,Z,l,M,J,N)-(( \(\left.1-T E(S, Z, I, M, J, N))^{*} O M E G A(S, Z, 1, M, J, N)\right)=L=B 1(S, Z, I, M, J, N)^{*}\) SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(N) AND COLD(S,J,L)=1 AND ALLOW_C(S,Z,J,L,I)=1),DHC(S,J.L));
*-
\({ }^{*}\) EQ 43 F
PA_14(S.Z,IJ,M.N)\$(D(S.Z.M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,I,M)=1 AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW \(\mathrm{H}(\mathrm{S} . \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=1\) 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,l,M,J,N) =G= Bl(S,Z,I,M,J,N)*SUM(L\$(D(S,Z,L,N)=1 AND ORD(L) LE ORD(N) AND COLD(S,J.L)=1 AND ALLOW_C(S,Z,J,L.I)=1).DHC(S,J,L));
*
*EQ 43 G
PA 15(S,Z,IJ.M,N,R)\$(D(S.Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,l,M)=1 AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H( \(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=1\) AND ALLOW_C(S,Z,J,N,I)=1 AND BIF( \(\mathrm{Z}, \mathrm{l}, \mathrm{J})=1\) AND FREEH(I) AND FREEC(J) AND PA(1)).

XW(S.Z:I,M,J,N,R)-(T(S,Z,l,M,J,N)*W(I,R)) =L=0
*EQ 43_H
PA 16(S,Z,l,J,M,N.R)\$(D(S,Z,M,N)=1 AND TL(S,N) LT TU(S,M) AND HOT(S,l,M)=1 AND COLD \((\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S,Z,I,M.J)=1 AND ALLOW_C(S,Z,J,N,I)=1 AND \(\operatorname{BIF}(\mathrm{Z}, \mathrm{l}, \mathrm{J})=1\) AND FREEH(I) AND FREEC( J\()\) AND PA(I)).
(BI(S,Z,I,M,J,N)-XW(S,Z,I,M,J,N,R))-(I-W(I,R))*T(S,Z,I.M.J,N) \(=\mathrm{L}=0\);
*EQ 43 I
PA \(17(\bar{S}, Z, I, J, M, N, R) \$(D(S, Z, M, N)=1\) AND TL(S.N) LT TU(S.M) AND HOT(S,I.M)=1 AND COLD \((\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW \(\mathrm{H}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J})=1\) AND ALLOW C(S,Z,J,N.I)=1 AND BIF(Z,I,J)=1 AND FREEH(I) AND FREEC( \((\mathrm{J})\) AND PA( I\()\) )
\((\mathrm{Bl}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J}, \mathrm{N})-\mathrm{XW}(\mathrm{S} . Z .1, M . J . N . R))=\mathrm{G}=0\);
*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 \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND
ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_C(S,Z,J,N,I)=1AND 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,1,J,M) \(=\mathrm{G}=\)
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.1,J,N)
-4* XM(S,Z,I,M,J,N);
*EQ (50_b)
PA 19(S,Z,I,J,M)\$(HOT(S,l,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1 AND FREEH(1) AND FREEC(J) AND PA(1))..
QNEW2_M(S,Z,I,J,M) \(=\mathrm{L}=\) FPK_H_O(S.Z,I.J,M)* \(\mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M})^{*}(\mathrm{TU}(\mathrm{S}, \mathrm{M})-\mathrm{TL}(\mathrm{S}, \mathrm{M}))\) :
*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 \(0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M})=\mathrm{E}=\mathrm{SUM}\left(\mathrm{R},\left(\mathrm{FPR}(\mathrm{I} . \mathrm{R})^{*} \mathrm{KW} \quad 0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}, \mathrm{R})\right)\right.\) );
*EQ 50_D
PA_21(S,Z,I,J,M,R)\$(HOT(S,l,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))..
\(K W \_0(S, Z, I, J, M, R)-N H E \_M 0 \_B(S, Z, I, J, M)=L_{-}=0 ;\)
```

*EQ 50_E
PA 22(S,Z,l,J,M,R)$(HOT(S,l,M)=1 AND ALLOW H(S,Z,l,M,J)=1 AND BIF(Z,I;J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
KW_O(S,Z,I,J,M,R)=L=W(I,R);
KW
*EQ 50_F
PA_23(S,Z,1,J,M,R)$(flOT(S,1,M)=1 AND ALLOW_H(S.Z,l,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
K_W_0(S,Z,l,J_M.R )=G= NHE_M0_B(S,Z,1,J,M) + W(l,R)- 1;
*-
*EQ (51_b)
PA_24(S.Z.I.J.M)$(HOT(S.I,M)= I AND ALLOW_H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I)AND FREEC(J) AND PA(I))
    QNEW2_M(S,Z,I.J,M) =L= FPK_H_I(S,Z,I,J,M)*CPH(S,I,M)*(TU(S,M)-TL(S,M));
*
*EQ 51_C
PA_25(\overline{S},Z,I.J,M)$(HOT(S,I,M)=1 AND ALLOW_H(S,Z,1,M,J)=1 AND BIF(Z,1.J)=1
AND FREEH(l) AND FREEC(J) AND PA(I)).
FPK_H_l(S,Z,1,J,M)=E=SUM(R,(FPR(I.R)*KW_l(S,Z,1.J,M,R)));
*EQ 51_D
PA_26(S
AND FREEH(I) AND FREEC(J) AND PA(J)).
KW_1(S,Z,IIJ,M,R)- NHE_MI_B(S,Z,I,J,M) =L=0;
*EQ 51 E
PA 27(S,Z,1,J,M,R)$(HOT(S,1,M)=1 AND ALLOW H(S,Z,I,M,J)=1 AND BIF(Z,I,J)=1
AND FREEH(I) AND FREEC(J) AND PA(I)).
KW_l(S,Z.I_J,M.R)=L=W(1,R);
*---------
PA_28(S,Z,I,J,M,R)$(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(1)).
KW_J(S,Z,IJ,M.R)=G=NHE_MI_B(S,Z,IJMM) + W(I,R)- I;
*EQ (61_b)
PA_29(S,Z,l,J,M)$(HOT(S,I,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z:IM,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND SPH(1)=1 AND FREEH(I) AND FREEC(J) AND PA(I)).
QNEW_M(S,Z.I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))=L=
    QNEW_M(S,Z,I.J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
    +(FP(I)-FPA(S,Z,I,J,M));
*-
*EQ 61_C
PA_30(S,Z,IIJ,M)$(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(1))..
FPA(S,Z,I,J,M) =E= SUM(R,(FPR(I,R)*WA(S,Z,I,J,M,R)));
*EQ ́rl_D
PA_31(\overline{S},Z,I,J,M,R)$(HOT(S,I,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S,Z,l,M,J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I)).
WA(S,Z,I, J,M,R)-ALFA_M(S,Z,I, J,M)=L=0;
*---------
*EQ 61_E
PA_32(S,Z,I,J,M,R)$(HOT(S,I.M-I) 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)=I AND FREEH(I) AND FREEC(J) AND PA(l)).
WA(S,Z,I.J,M,R)=L=W(I.R):
*--.-------
PA 33(S,Z,1,J,M,R)\$(HOT(S,I,M-I) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,1,M,J)=1
AND ALLOW_H(S,Z,I.M-I.J) AND SPH(I)=1 AND FREEH(I) AND FRIEEC(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)$(HOT(S,I,M-I) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_H(S.Z.I.M-I.J) AND SPH(I)=1 AND FREEH(I) AND FREEC(J) AND PA(I)).
    QNEW_M(S,Z,I,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
    +(FP(I)-FPA(S,Z,I,J.M))
                            =G= QNEW_M(S,Z,I,J,M-I )/(CPH(S,l,M-1)*(TU(S,M-1)-TL(S,M-1)));
*EQ (63_b)
PA_35(S,Z,IJJ,M)$(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,l.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-I)*(TU(S,M-I)-TL(S,M-1)))
+ QNEW_M(S,Z,I,J,M)/(CPH(S,1,M)*(TU(S,M)-TL(S,M)))
+(FP(I)+FPK_H_l(S,Z,IJ,M-1)+FPK_H_l(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_l(S,Z,I,I,M))=G=0;
* 

*EQ (65 b)
PA_37(S,Z,I,J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=1 AND ALLOW_H(S,Z,I,M.J)=1
AND ALLOW_H(S,Z,I,M-1,J) AND BIF(Z,1,J)=1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND PA(1))
QNEW_M(S,Z,1,J,M-1)/(CPH(S,1,M-1)*(TU(S,M-1)-TL(S,M-1)))=L=
QNEW M(S,Z.1,J,M)/(CPH(S,I,M)*(TU(S,M)-TL(S,M)))
+(FP(I)+FPK H_l(S,Z,I,J.M-I)+FPK_H_l(S,Z,I,J,M)-FPK_H_O(S,Z,I,J,M-I));
*EQ (66 b)
PA_38(S,Z.I.J.M)$(HOT(S.IM-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,1,M-1)*(TU(S,M-1)-TL(S.M-1)))=L=

```

```

    +((2*FP(I))+FPK H_l(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.l,J.M)$(HOT(S,I,M-1) AND HOT(S,l,M)=1 AND ALLOW_H(S.Z.l,M,J)=1
AND ALLOW_H(S.Z,I,M-1,J) AND BIF(Z,I,J)=1 AND SPH(I)=1 AND FREEH(I)
AND FREEC(J) AND PA(I))
(QNEW M(S,Z,I,J,M)-QNEW2_M(S,Z,I,J,M))/(CPH(S,I,M)*(TU(S,M)-TL(S,M))) =L=
QNEW M(S,Z,I,J,M-1)/(CPH(S,I,M-1)*(TU(S,M-1)-TL(S,M-1)))
    +((2*-FP(I))+FPK_H_0(S,Z,I,J,M-1)-FPK_H_1(S,Z,I,J,M)-FPY(S,Z,I,J,M-1));
*
*EQ (68_b)
PA_40(S,Z,I,J,M)$(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,l,M+1,J) AND BIF(Z,1,J)=0 AND SPH(I)=0
AND FREEH(I) AND FREEC(J) AND PA(1))..
QNEW_M(S,Z,l.J.M)=G=(FPY(S.Z,I.J,M)-FPK_H_0(S,Z,I.J,M)-FPK_H_l(S.Z,l.J,M))
*(CPH(S,I,M)*(TU(S,M)-TL(S,M)));
PA_4l(SZ,I, J,M)$(HOT(S,I,M-1) AND HOT(S,I,M)=I AND HOT(S,I,M+1)
ANDD ALLOW_H(S,Z,1,M,J)=1
AND ALLOW H(S.Z,l,M-1,J) AND ALLOW H(S,Z.l,M+1,J) AND BIF(Z,I,J)=1 AND SPH(1)=0
AND FREEH(l) AND FREEC(J) AND PA(I))
    QNEW_M(S,Z,I.J,M)=G=(FPY_B(S.Z,I,J,M)-FPK_H_0_B(S,Z,I,J,M)
    -FPK_H_l_B(S,Z,I.J.M))*(CPH(S,I,M)*(TU(S,M)-TL(S.M)));
*
*EQ (81_b)
PA_42(S.Z,I,J,M,N)$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S.M)
ANDD 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(l) 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,\.J.M)-NHE_N0(S,Z,\,J,N))*TU(S,N)=G=0;
    ```
PA_43(S,Z,l,J,M,N)\$(TL(S,N) LE TU(S,M) AND TU(S,N) GE TL(S,M)
AND HOT(S,, M\()=1\) AND COLD \((\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S,Z,I,M,J)=1
AND ALLOW_C( \(\mathrm{C}, \mathrm{Z}, \mathrm{J}, \mathrm{N}, \mathrm{I})=1\) AND BIF \((\mathrm{Z}, \mathrm{I}, \mathrm{J})=1\)
ヘND 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)* \(\mathrm{CPC}(\mathrm{S}, \mathrm{J} . \mathrm{N}))\)
\(+(\) FPQ \((\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}))\)
\(+\left(2-N H E \_M 0 \_B(S, Z, I, J, M)-N H E \_N 0 \_B(S, Z, I, J, N)\right) * T U(S, N)=G=0\);
*.
*EQ 81_C
PA 44(S,ZI.J,M,N)§(TL(S.N) LE TU(S.M) AND TU(S.N) GE TL(S.M)
AND HOT (S,L,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) \(=\overline{0}\) AND \(\operatorname{SPC}(\mathrm{J})=0\) AND FREEH(I) AND FREEC(J) AND PA(I))..
\(\operatorname{FPQ}(S, Z, I, J, M)=E=S U M(R, W Q(S, Z, I, J, M, R) / F P R(I, R)) ;\)
*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 ALLOW C( \(\mathrm{S}, \mathrm{Z}, \mathrm{J}, \mathrm{N}, \mathrm{I})=1\) AND BIF \((\mathrm{Z} \mathrm{I}, \mathrm{J})=1\)
AND SPH(I)=0 AND SPC(J)=0 AND FREEH(I) AND FREEC(J) AND PA(I)).
\({ }_{*}^{\mathrm{W}} \mathrm{Q}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{M}, \mathrm{R})-\left(\mathrm{T}(\mathrm{S}, \mathrm{Z}, \mathrm{I}, \mathrm{M}, \mathrm{J}, \mathrm{N})^{*} \mathrm{~W}(\mathrm{I}, \mathrm{R})\right)=\mathrm{L}=0\);
*EQ 81 E

AND \(\operatorname{HOT}(S, \mathrm{I}, \mathrm{M})=1\) AND COLD(S, J,N \()=1\) AND ALLOW \(H(S, Z, \mathrm{I}, \mathrm{M}, \mathrm{J})=1\)
^ND ALLOW_C(S, \(\mathrm{Z}, \mathrm{J}, \mathrm{N}, \mathrm{I})=1\) AND BIF \((\mathrm{Z}, \mathrm{I}, \mathrm{J})=1\)
AND SPH (l) \(=0\) AND SPC( J\()=0\) AND FREEH(l) AND FREEC( J\()\) AND PA(I)).
\((\) QNEW_M(S,Z,I,J,M)-WQ(S,Z,I,J.M,R))-(I-W(I.R))*T(S,Z.I.M.J.N \()=\mathrm{L}=0\);
*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 \(\operatorname{HOT}(\mathrm{S}, \mathrm{I}, \mathrm{M})=1\) AND \(\operatorname{COLD}(\mathrm{S}, \mathrm{J}, \mathrm{N})=1\) AND ALLOW_H(S.Z,1.M.J) \(=1\)
AND ALLOW C(S,Z,J,N.I)=1 AND BIF(Z,I.J)=1
AND SPH \((\mathrm{I})=0\) 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) \(=\mathbf{G}=0\);
*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)
\(\Lambda \bar{N} D \operatorname{HOT}(S, I, M)=1\) AND COLD \((S, J, N)=1\) AND ALLOW_H(S.Z, \(1, M . J)=1\)
AND ALLOW_C(S,Z, \(, \mathrm{N}, \mathrm{I})=1\) AND BIF \((\mathrm{Z}, \mathrm{I}, \mathrm{J})=0\)
AND SPH \((\mathrm{I})=0\) 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))
                                    \(+(2-\mathrm{NHE} M 1(\mathrm{~S}, \mathrm{Z}, \mathrm{l}, \mathrm{J}, \mathrm{M})-\mathrm{NHE} N \mathrm{~N}(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N}))^{*} \mathrm{TU}(\mathrm{S}, \mathrm{N})=\mathrm{G}=0\);
PA_49(S,Z,I,J,M,N)\$(TL(S,N) LE TU(S,M) AN̄D 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 \((\mathrm{I})=0\) AND SPC(J) \(=0\) AND FREEH(I) AND FREEC(J) AND PA(I))..
TU(S,M)-TU(S,N)
-(FPQ(S,Z,l,J,M)/CPH(S,I,M)) + QNEW_N(S,Z,I,J,N)/(FC(S,J)*CPC(S,J,N))
                            \(+(2-\text { NHE_M1_B(S,Z,I,J,M)-NHE_N1_B(S,Z,I,J,N) })^{*} T U(S, N)=G=0 ;\)
*EQ (85_b)
PA \(50(S . Z, 1, J, M, N) \$(D T V I O(1, J)=1\) 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)=I 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.7.J,N.I)=1
    AND ALLOW_C(S,Z.J,N+1,1) AND BIF(Z.1,J)=0 AND (SPH(1)=1 OR SPC(J)=1)
    AND FREEH ( \(\overline{\mathrm{I}})\) AND FREEC(J) AND PA(1)).
    QNEW_M(S,Z,I.J.M)/(MIN(TU(S,M),TU(S.N))-TL(S.M))=G=
        QNEW M(S,Z,1,J,M+1)/(TU(S,M+1)-TL(S,M+1))
    \({ }^{*} \mathrm{CPH}(\mathrm{S}, \mathrm{I}, \mathrm{M}) / \mathrm{CPH}(\mathrm{S}, \mathrm{I} . \mathrm{M}+\mathrm{I})-\left(\left(2^{*} \mathrm{FP}(\mathrm{I})\right)-\mathrm{FPK} \mathrm{H} \quad 0(\mathrm{~S}, \mathrm{Z}, \mathrm{I} . \mathrm{J}, \mathrm{M})-\mathrm{FPK} \mathrm{C} \quad 0(\mathrm{~S}, \mathrm{Z}, \mathrm{I}, \mathrm{J}, \mathrm{N})\right)\)
    \({ }^{*} \mathrm{CPH}(\mathrm{S} . \mathrm{I}, \mathrm{M}+1)^{*}(\mathrm{TU}(\mathrm{S}, \mathrm{M}+1)-\mathrm{TL}(\mathrm{S}, \mathrm{M}+1)) /(\overline{\mathrm{T}}(\mathrm{S}, \mathrm{M}+1)-\mathrm{TL}(\mathrm{S} . \mathrm{M}+\overline{1}))\);
```

*-
*EQ (87 b)
PA 5l(S,Z,I,J,M,N)$(DTVIO(l,J)=I AND D(S.Z,M,N)=| AND TL(S,N) LT TU(S,M)
    AÑD TU(S,N) GT TL(S,M) AND HOT(S,1,M)=1 AND HOT(S,I,M-1) AND COLD(S,J,N)=1
    AND COLD(S,J,N-I) AND ALLOW H(S,Z,I.M,J)=1 AND ALLOW H(S.Z.I.M-1.J)
    AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW_C(S,Z,J,N-1,l) AND BIF(Z.I,J)=0
    AND (SPH(1)=1 OR SPC(J)=1) AND FREEH(I) AND FREEC(J) AND PA(1))
QNEW M(S,Z,I,J,M)/(TU(S,M)-TL(S,N))=L=QNEW M(S.Z,I,J.M-I)/(TU(S,M-1)-TL(S.M-1))
    * CPH(S
    * CPH(S,I,M)*(TU(S,M)-TL(S,M))/(TU(S,M)-TL(S,M));
*
*EQ (92 b)
PA 52(S,Z,I.J,M,N)$(DTVIO(I,J)=1 AND D(S.Z,M.N)=1 AND TL(S.N) LTT TU(S.M)
AN̄D TU(S,N) GT TL(S,M) AND HOT(S.1,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,IIJ)=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
* 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,l.J.N))
* CPH(S,1,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)$(DTVIO(I,J)=1 AND D(S,Z,M,N)=1 AND TL(S,N) LTTU(S.M)
    ANDD TU(S,N) GT TL(S,M) AND HOT(S,1,M)=1 AND HOT(S,I.M-1) AND COLD(S,J.N)=1
    AND COLD(S,J,N-1) AND ALLOW_H(S,Z,I,M,J)=1 AND ALLOW_H(S,Z,I,M-1.J)
    AND ALLOW_C(S,Z,J,N,I)=1 AND ALLOW C(S,Z,,N-1.1) AND BIF(Z.1,J)=1
    AND (SPH(I)=1 OR SPC(J)=1) AND FREEH(1) AND FREEC(J) AND PA(I)).
    (QNEW_M(S,Z,IJ,M)-QNEW2_M(S,Z,I,J,M))/(TU(S,M)-TL(S,N))=L=
    QNEW -M(S,Z,1,J,M-1)/(TU(S,M-1)-TL(S,M-1))* CPH(S,1,M)/CPH(S,1.M-1)
    +((2*FP(I))-FPK_II_1(S,Z,I,J,M)-FPK_C_l(S,Z.I,J,N))**CPH(S.I.M)
    *(TU(S,M)-TL(S,M))/(TU(S,M)-TL(S,M)
*
*EQ (XX_1)
PA 54(S,\overline{Z},I,J,M)$(HOT(S,l,M)=1 AND NOT SPH(I) AND
FREEH(I) AND PA(I)).
FP(I)=E=SUM(R,FPR(I,R)*W(I,R));
*------------
PA_55(S,\overline{Z},1,J,M)$(HOT(S,l,M)=1 AND NOT SPH(I) AND
FREEH(I) AND PA(I)).
SUM(R,W(1,R)) =E= 1;
*EQ (XX_3)
PA_56(S,Z,1,J)$(NOT SPH(1) AND
FREEH(I) AND PA(l)).
QPA(I) =E= SUM(M,FP(I)* CPH(S,I,M)*(TU(S,M)-TL(S,M)));
*The sumation 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)$PA(I)) =E= TOTAL_QPA;
PA 58..
PAI =E= SUM(I,QPA(I)$(ORD(I)=2));
*-.
PA 59.
PA2 =E= SUM(I,QPA(I)$(ORD(I)=4)):
PA 60..
PA3}=\textrm{E}=\operatorname{SUM(I,QPA(I)$(ORD(I)=6));
*-.

* Find the relation between side stripping steam and Pump around duty by using
* the modej from regression.

```
```

PA_61(S,Z,l,J,M)$(HOT(S,I,M)=1 AND NOT SPH(I) AND FREEH(1)).
SST}(\textrm{I})=\textrm{E}=(\mp@subsup{\textrm{A}}{-}{\prime}1(\textrm{I})*PAI)+(\mp@subsup{B}{-}{\prime}1(I)*PA2)+(C_I(I)*PA3)+D_1_1(I)
PA_62..
Cost_side_stripping_steam =E= SUM(I,(CSS(I)*SST(I)));
PA_63
TOTAL_Q =G= TOTAL_QPA_MIN;
PA }6
TOTAL_Q=L= TOTAL_QPA_MAX;
PA }6
TOTAL_QPA_MIN =E= TOTAL_QPA-(TOTAL_QPA*0.001);
*...----
TOTAL_QPA_MAX =E=TOTAL_QPA+(TOTAL_QPA*0.001);
*....
PA_67..
SUM(I,QPA(I)$PA(I)) = E= TOTAL_Q;
PA_68(S,Z,I,J)$(NOT SPH(I) AND
FREEH(I) AND PA(I))..
Cp_Dt(I) =E=SUM(M,CPH(S,l,M)*(TU(S,M)-TL(S,M)));
*CHECKING COST
HOT U C..
HOT_UTILITY_COST =E=SUM(I$(HU(I) AND FREEH(I)),CHU(I)*FHU(I)*DTHU(I));
*--
Cold U C..
Cold_UTILITY_COST =E=SUM(J$(CU(J) AND FREEC(J)).CCU(J)*FCU(J)*DTCU(J));
*--
Area_C..
Area_Cost=E=
+SUM((S,Z,1.J)$(OPT=2 AND ALLOW(S,Z.I.J)=1 AND FREEH(J) AND FREEC(J)
AND BIF(Z,I,J)=0)
(CF*(NHE(S,Z,I,J)+NHE_S(S,Z,I,J)$(NHE0(S,Z,I,J)=1)-(NHE0(S,Z,I.J)*(SUM(E$(ORD(E) LE KET),
Phi(Z,1,J,E))))))+(CAE*DPAR_E(Z,I,J))+CAN*PAR N(S,Z,I.J))
*-
FIX C..
FIX_COST =E= SUM((S,Z,I.J)$(OPT=2 AND ALLOW(S.Z.I.J) = | AND FREEH(I) AND FREEC(J)
    AND BIF(Z,1,J)=1)
    (CF*
    ORD(K)LE KMAX(Z,I,J)),DELTA(Z,I,J,EE,E,K)))))
    +SUM((S,Z,1,J,K,E)$(OPT=2 AND ALLOW(S,Z,1,J)=1 AND FREEH(I) AND FREEC(J)
AND BIF(Z,I,J)=1 AND ORD(K)LE KMAX(Z,I,J))

* +SUM (K$(ORD(K)LE KMAX(Z,1,J))
,(CAE*DPAR_E_B(K,E,Z,I,J)+CAN*PAR_N_B(K.E,Z,I,J)))
;
MODEL MPERIOD /ALL;
  OPTION LIMROW =0;
  OPTION LIMCOL =0;
  OPTION SOLPRINT = OFF;
  OPTION OPTCR=0
  OPTION OPTCA=0
  OPTION ITERLIM = 1000000000;
  OPTION RESLIM = 1000000;
  MPERIOD.OPTFILE = 1;
SOLVE MPERIOD USING MIP MINIMIZING TCOST :
PARAMETER QMATCH(S,Z,l,J);
QMATCH(S,Z,I,J)=SUM((M,N)$(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,l,M)]=QNEW_ML(S,Z,I,J,M)/[(TU(S,M)-TL(S,M))*CPH(S,1,M)];

\section*{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))* \(\mathrm{CPC}(\mathrm{S}, \mathrm{J}, \mathrm{M})] ;\)

\section*{PARAMETER NHE2(S,Z,J,I);}

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

\section*{SONTEXT}

PARAMETER AREA COST:
AREA_COST \(=\operatorname{SUM}((\mathrm{S} . \mathrm{Z} . \mathrm{LJ}) \$(\) ALLOW \((\mathrm{S}, \mathrm{Z}, \mathrm{I} . \mathrm{J})=1\) AND FREEH(1) 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)

+SUM((S,K,Z,1,J)\$(ORD(K) LE KMAX(Z.I.J) AND ALLOW(S,Z,I,J)=]
AND FREEH(1) AND FREEC(J) AND BIF(Z,1.J)=1)
:CAE*DPAR_E_B.L(K,Z,I.J)+CAN*PAR_N_B.L(K,Z,I,J));
PARAMETER UTILITY_COST;
UTILITY_COST = SUM(IS(HU(I) AND FREEH(I)),CHU(I)*FHU.L(I)*DTHU(I))
\({ }^{+} \mathrm{SUM}(\mathrm{J} \$(\mathrm{CU}(\mathrm{J})\) AND FREEC(J)),CCU(J)*FCU.L(J)*DTCU(J));
\$OFFTEXT
OPTION Cold_UTILITY_COST:3:0:1; DISPLAY Cold UTILITY COST.L; OPTION HOT_UTILITY_COST:3:0:1; DISPLAY HOT_UTILITY_COST.L; OPTION Area_Cost \(3: 0: 1^{-}\): DISPLAY Area_Cost.L, OPTION FIX_COST:3:0:1; DISPLAY FIX_COST.L;
option Q:3:0:1; display Q.L;
option FHU:3:0:1; display FHU.L;
option FCU:3:0:1; display FCU.L;
* OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L;
* OPTION PAR_N:3:0:1; DISPLAY PAR_N.L; OPTION PAR: \(\overline{4}: 0: 1\); DISPLAY PAR.L; OPTION QMATCH:4:0:1; DISPLAY QMATCH, OPTION PAR_N:3:0:1; DISPLAY PAR_N.L; OPTION DPAR_E:3:0:1; DISPLAY DPAR_E.L; OPTION PHI:3:0:1: DISPLAY PHIL; OPTION AEX:3:0:1; DISPLAY AEXL; OPTION FH_H:3:0:1; DISPLAY FH H; OPTION FC_C:3:0:1; DISPLAY FC_C; *OPTION UTILITY_COST 3:0:1: DISPLAY UTILITY_COST; OPTION AREA CŌST:3:0:1; DISPLAY AREA COST L; OPTION DPAR_I: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_BI;
OPTION PAR N B:3:0:1; DISPLAY PAR N B.L:
OPTION TU: \(3: 0: \overline{1}\); 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 PAI.L; OPTION PA2:3:0:1; DISPLAY PA2.L; OPTION PA3:3:0:1; DISPLAY PA3.L; OPTION Cost_side_stripping steam :3:0:I; 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:I: 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 QNEW \(\overline{2}\) _M 3:0:1; DISPLAY QNEW̄ 2 M.L; OPTION QNEW2_N:3:0:1; DISPLAY QNEW2_N.L; OPTION Y_M:3:0:1; DISPLAY Y_ML; OPTION Y N:3:0:1; DISPLAY Y_N.L; OPTION NH̄E_M0:3:0:1; DISPLĀY 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_N \(1: 3: 0: 1\); DISPLAY NHE_NI.L, OPTION Y_M_B:3:0:1; DISPLAY Y_M_B.L; OPTION Y_N_B:3:0:I: DISPLAY Y_N_B.L; OPTION NHE_M0_B:3:0:1; DISPLAY NHE_M0_B.L; OPTION NHE_MI_13:3:0:1; DISPLAY NHE_M1_BL; OPTION NHI:NO_B:3:0:1; DISPLAY NHE_NO_B.L, OPTION NHI NI B:3:0:1; DISPLAY NHE NI B.L; OPTION ALFA_M 3:1:1: DISPLAY ALFA_M.L; OPTION AI.FA_N:3:0:I: DISPLAY ALFA_N.L; OPTION NHE:3:0:1; DISPLAY NHE.L; OPTION QH:3:0:1; DISPLAY QHL ; OPTION QC:3:0:1; DISPLAY QC.L; OPTION XI_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 QMĀTCH: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;
```\(\underbrace{\text { LTCH }}_{\text {L; }}\)
```



## CURRICULUM VITAE

| Name: | Mr. Warapon Sripayap |
| :--- | :--- |
| Date of Birth: | July 5, 1979 |
| Nationality: | Thai |
| University Education: |  |

1998-2001 Bachelor Degree of Chemical Engineering, Faculty of Engineering, King Mongkut's Institute of Technology North Bangkok, Bangkok, Thailand

Working Experience:
Position:

Company name: $\quad$| Chemical Engineer |
| :--- |
| MT Picture Display (Thailand) Co., Ltd. |

2002-2004 Position: $\quad$ Chemical Engineer Company name: Mitr Phol Sugar Corp., Ltd.


จุฬาลงกรณ์มหาวิทยาลัย

