G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m
C o m p i l a t i o n

```
INCLUDE    /var/www/html/interfaces/cgi-bin/synheat/ex1.dat
```


SIMULTANEOUS OPTIMIZATION FOR HEN SYNTHESIS (Yee and Grossmann, 1989)
C o m p i l a t i o n

```
  3
  7 *
  8
  9 SET    I    HOT STREAMS   /1*2/
 10
 11              I1(i)     SUBSET I NON-ISOTHERMAL  /1*2/
 12              I2(i)     SUBSET I ISOTHERMAL  //
 13
 14         J    COLD STREAMS  /1*2/
 15
 16              J1(j)     SUBSET I NON-ISOTHERMAL  /1*2/
 17              J2(j)     SUBSET I ISOTHERMAL  //
 18
 19         S    HOT EXTREME AND INTERMMEDIATE UTILITIES /1*1/
 20         W    COLD EXTREME AND INTERMMEDIATE UTILITIES /1*1/;
 21
 22 SCALAR  NOK  NUMBER OF STAGES IN SUPERSTRUCTURE /2/;
 23
 24
 25 PARAMETERS
 26 FCI(I)        HEAT CAPACITY FLOWRATE OF HOT STREAM
 27 FCJ(J)        HEAT CAPACITY FLOWRATE OF COLD STREAM
 28 CFI(I)        STREAM-INDIVIDUAL FILM COEFFICIENT HOT I
 29 CFJ(J)        STREAM-INDIVIDUAL FILM COEFFICIENT COLD J
 30
 31 TMAPP         MINIMUM APPROACH OF TEMPERATURE
 32
 33 CFHU          STREAM-INDIVIDUAL FILM COEFFICIENT HOT UTILITY
 34 CFCU          STREAM-INDIVIDUAL FILM COEFFICIENT COLD UTILITY
 35 CFHUINT(S)    STREAM-INDIVIDUAL FILM COEFFICIENT HOT INT UTILITY
 36 CFCUINT(W)    STREAM-INDIVIDUAL FILM COEFFICIENT COLD INT UTILITY
 37
 38 THUIN         INTLET TEMPERATURE HOT UTILITY
 39 THUOUT        OUTLET TEMPERATURE HOT UTILITY
 40 TCUIN         INTLET TEMPERATURE COLD UTILITY
 41 TCUOUT        OUTLET TEMPERATURE COLD UTILITY
 42 TUHINT(S)     INTLET TEMPERATURE HOT INT UTILITY
 43 TUCINT(W)     INTLET TEMPERATURE COLD INT UTILITY
 44
 45 HUCOST        COST OF HEATING UTILITY
 46 CUCOST        COST OF COOLING UTILITY
 47 HUINTCOST(S)  COST OF HOT INT UTILITY
 48 CUINTCOST(W)  COST OF COLD INT UTILITY
 49 UNITC         FIXED CHARGE FOR EXCHANGER
 50 ACOEFF        AREA COST COEFFICIENT FOR EXCHANGERS
 51 HUCOEFF       AREA COST COEFFICIENT FOR HEATERS
 52 CUCOEFF       AREA COST COEFFICIENT FOR COOLERS
 53 HUINTCOEFF    AREA COST COEFFICIENT FOR HOT INT UTILITY
 54 CUINTCOEFF    AREA COST COEFFICIENT FOR COLD INT UTILITY
 55 AEXP          AREA COST EXPONENT FOR EXCHANGERS;
 56
 57 VARIABLES
```

```
  58  TIIN(I)      SUPPLY TEMP. OF HOT STREAM
  59  TIOUT(I)     TARGET TEMP. OF HOT STREAM
  60  TJIN(J)      SUPPLY TEMP. OF COLD STREAM
  61  TJOUT(J)     TARGET TEMP. OF COLD STREAM;
  62
  63  *
  64  *PROCESS STREAMS
  65  *
  66
  67  *HOT:
  68  TIIN.FX('1') = 650.00;
  69  TIOUT.FX('1') = 370.00;
  70  FCI('1') = 10.00;
  71  CFI('1') = 1.00;
  72
  73  TIIN.FX('2') = 590.00;
  74  TIOUT.FX('2') = 370.00;
  75  FCI('2') = 20.00;
  76  CFI('2') = 1.00;
  77
  78  *COLD:
  79  TJIN.FX('1') = 410.00;
  80  TJOUT.FX('1') = 650.00;
  81  FCJ('1') = 15.00;
  82  CFJ('1') = 1.00;
  83
  84  TJIN.FX('2') = 350.00;
  85  TJOUT.FX('2') = 500.00;
  86  FCJ('2') = 13.00;
  87  CFJ('2') = 1.00;
  88
  89  TMAPP = 10.00;
  90
  91  *
  92  *EXTREME UTILITIES
  93  *
  94
  95  CFHU = 5.00;
  96  THUIN = 680.00;
  97  THUOUT = 680.00;
  98  CFCU = 1.00;
  99  TCUIN = 300.00;
 100  TCUOUT = 320.00;
 101
 102  *
 103  *INTERMMEDIATE UTILITIES
 104  *
 105
 106  CFHUINT(S) = 0;
 107  TUHINT(S) = 0;
 108  CFCUINT(W) = 0;
 109  TUCINT(W) = 0;
 110
 111  *
 112  *COSTS
 113  *
 114
 115
 116  *EXTREME UTILITIES
 117
 118  HUCOST = 85.00;
 119  CUCOST = 15.00;
 120  UNITC = 1000.00;
```

```
ACOEFF = 380.00;
HUCOEFF = 380.00;
CUCOEFF = 380.00;

*INTERMMEDIATE UTILITIES

HUINTCOST(S) = 0;
HUINTCOEFF = 0;
CUINTCOST(W) = 0;
CUINTCOEFF = 0;

AEXP = 1.00;

*
*SPLIT CONSTRAINTS:
* 0 = NONE, 1 = HOT STREAMS, 2 = COLD STREAMS, 3 = BOTH
*

SCALAR SPLIT   /0/;

*
*FORBIDDEN MATCHES:
*

PARAMETERS FORBID(I,J),FORBIDCU(I), FORBIDHU(J),FORBIDHINT(S,J), FORBIDCINT(I,W);
FORBID(I,J) = 0;
FORBIDCU(I) = 0;
FORBIDHU(J) = 0;
FORBIDHINT(S,J) = 0;
FORBIDCINT(I,W) = 0;

*
*REQUIRED MATCHES:
*

PARAMETERS REQUIR(I,J),REQUIRCU(I), REQUIRHU(J), REQUIRCINT(I,W), REQUIRHINT(S,J);
REQUIR(I,J) = 0;
REQUIRCU(I) = 0;
REQUIRHU(J) = 0;
REQUIRCINT(I,W) = 0;
REQUIRHINT(S,J) = 0;

*
*MINIMUM UTILITY COSTS DATA
*
SET     KK   TEMPERATURE INTERVALS  /1*50/;

PARAMETERS
TINS(S)  inlet temperature of hot utilities
TINW(W)  inlet temperature of cold utilities
CS(S)    cost of hot utilities
CW(W)    cost of cold utilities
AS(S)    availability of hot utilities
AW(W)    availability of cold utilities;

*
*UTILITIES
*


*
*EXTREME UTILITIES
*
```

```
 184
 185  TINS('1') = THUIN;
 186  TINW('1') = TCUIN;
 187  CS('1') = HUCOST;
 188  CW('1') = CUCOST;
 189  AS('1') = inf;
 190  AW('1') = inf;
 191
 192  *
 193  *INTERMMEDIATE UTILITES
 194  *
 195
 196  LOOP(S$(ORD(S) GT 1),
 197       TINS(S) = TUHINT(S);
 198       CS(S) = HUINTCOST(S);
 199       AS(S) = INF;
 200  );
 201  LOOP(W$(ORD(W) GT 1),
 202       TINW(W) = TUCINT(W);
 203       CW(W) = CUINTCOST(W);
 204       AW(W) = INF;
 205  );
 206
 207  *
 208  *BOUNDS FOR HEAT EXCHANGE
 209  *
 210
 211  PARAMETERS
 212  QLHC(I,J)  lower bound between hot and cold streams
 213  QUHC(I,J)  upper bound between hot and cold streams
 214  QLHW(I,W)  lower bound between hot stream and cold utility
 215  QUHW(I,W)  upper bound between hot stream and cold utility
 216  QLCS(J,S)  lower bound between cold stream and hot utility
 217  QUCS(J,S)  upper bound between cold stream and hot utility;
 218
 219  QLHC(I,J) = 0;
 220  QUHC(I,J) = inf;
 221  QLHW(I,W) = 0;
 222  QUHW(I,W) = inf;
 223  QLCS(J,S) = 0;
 224  QUCS(J,S) = inf;
 225
 226  *
 227  *FORBIDDEN MATCHES
 228  *
 229  QUHC(I,J)$(FORBID(I,J) EQ 1)  = 0;
 230  QUHW(I,W)$(FORBIDCU(I) EQ 1 AND ORD(W) EQ 1)  = 0;
 231  QUCS(J,S)$(FORBIDHU(J) EQ 1 AND ORD(S) EQ 1)  = 0;
 232  QUHW(I,W)$(FORBIDCINT(I,W) EQ 1 AND ORD(W) EQ 1)  = 0;
 233  QUCS(J,S)$(FORBIDHINT(S,J) EQ 1 AND ORD(S) EQ 1)  = 0;
INCLUDE    /var/www/html/interfaces/cgi-bin/synheat/variables.inc
 235  SET    K   NOK+1          /1*4/;
 236
 237
 238
 239  PARAMETERS QWMIN1,QWMIN2,QSMIN1,QSMIN2;
 240  QWMIN1=0;
 241  QWMIN2=0;
 242  QSMIN1=0;
 243  QSMIN2=0;
 244  SCALAR TRANS  no utility heat loads constraints /0/;
 245  BINARY VARIABLES  Z(I,J,K), ZCU(I), ZHU(J);
INCLUDE    /var/www/html/interfaces/cgi-bin/synheat/minlp.inc
```

```
247  **
248  **                      MINLP SINGLE UTILITIES MODEL
249  **
250
254
255  OPTION OPTCR=0.10;
256  OPTION OPTCA = 1000000;
257  OPTION ITERLIM=1000000;
258  OPTION RESLIM=1000000;
259  *OPTION LIMCOL = 0;
260  *OPTION LIMROW = 0;
261  OPTION MIP = CPLEX;
262  *OPTION MIP=XA;
263  OPTION NLP = CONOPT;
264
265  ALIAS(K, K1);
266
267  SET IT /1*4/;
268  ALIAS(IT, ITE);
269
270  SET ONE /1/
271      DOS /1/;
272
273  SCALAR D /20/;
274  SCALAR SUB /0/;
275
276
277  PARAMETERS
278
279   QCI(I)      HEAT CONTENT OF HOT I
280   QCJ(J)      HEAT CONTENT OF COLD J
281   DTMAX(I,J) UPPER BOUND OF DRIVING FORCE
282   AL(I,J,K)  AREA FOR EXCHANGER FOR MATCH IJ IN INTERVAL K (Chen approx.)
283   A(I,J,K)   AREA CALCULATED WITH LOG MEAN
284   ACU(I)     AREA COOLERS
285   AHU(J)     AREA HEATERS
286   COSTHEAT   COST OF HEATING
287   COSTCOOL   COST OF COOLING
288   INVCOST    INVESTMENT COST
289
290  *INTEGER CUT
291
292   ITER
293   ZIT(I,J,K,IT)
294   ZCUIT(I,IT)
295   ZHUIT(J,IT);
296
297
298  *
299  *FORBIDEN MATCHES
300  *
301
302  LOOP(I,
303       LOOP(J$(FORBID(I,J) EQ 1),
304                 Z.FX(I,J,K) = 0;
305       );
306  );
307  LOOP(I$(FORBIDCU(I) EQ 1), ZCU.FX(I) = 0);
308  LOOP(J$(FORBIDHU(J) EQ 1), ZHU.FX(J) = 0);
309
310
311  *
312  * REQUIRED MATCHES BETWEEN STREAMS AND UTILITIES
```

```
313  *
314
315  LOOP(I$(REQUIRCU(I) EQ 1), ZCU.FX(I) = 1);
316  LOOP(J$(REQUIRHU(J) EQ 1), ZHU.FX(J) = 1);
317
318
319  POSITIVE VARIABLES
320
321   QCOLD(I)    CONSUMPTION OF COLD UTILITY FOR HOT STREAM I,
322   QHOT(J)     CONSUMPTION OF HOT UTILITY FOR COLD STREAM J,
323   TKI(I,K)    STAGE BOUNDARY TEMP. OF HOT STREAM I,
324   TKJ(J,K)    STAGE BOUNDARY TEMP. OF COLD STREAM J,
325   Q(I,J,K)    HEAT LOAD OF MATCH BETWEEN I AND J IN STAGE K,
326   DT(I,J,K)   DRIVING FORCE OF BOUNDARY OF INTERVAL K,
327   DTHU(J)     DRIVING FORCE FOR HEATERS,
328   DTCU(I)     DRIVING FORCE FOR COOLERS,
329   FC(I,J,K)   FLOW OF COLD STREAM J WITH HOT STREAM I IN STAGE K
330   FH(I,J,K)   FLOW OF HOT STREAM I WITH COLD STREAM J IN STAGE K
331   TC(I,J,K)   TEMPERATURE OF COLD STREAMS PER EXCHANGER
332   TH(I,J,K)   TEMPERATURE OF HOT STREAMS PER EXCHANGER
333   DT1(I,J,K)   DRIVING FORCE OF BOUNDARY OF INTERVAL K,
334   DT2(I,J,K)   DRIVING FORCE OF BOUNDARY OF INTERVAL K;
335
336   VARIABLE COST    HEN AND UTILITY COST
337            COSTNLP;
338
339
340
341   EQUATIONS
342
343   STRENBH(I)   STREAM ENERGY BALANCE OF HOT STREAM,
344   STRENBHI(I)  STREAM ENERGY BALANCE OF HOT STREAM ISOTERMIC,
345   STRENBC(J)   STREAM ENERGY BALANCE OF COLD STREAM,
346   STRENBCI(J)  STREAM ENERGY BALANCE OF COLD STREAM ISOTERMIC,
347   LOADHM(I,K)  LOAD OF HOT SIDE MATCH IN INTERVAL K,
348   LOADCM(J,K)  LOAD OF COLD SIDE MATCH IN INTERVAL K,
349   TIINTK(I)    TIIN=TKI1,
350   TJINTK(J)    TJIN=TKJLAST,
351   TKICON(I,K)  CONSTRAINT ON TKI,
352   TKICONA(I,K) CONSTRAINT ON TKI FOR ISOTERMIC STREAM,
353   TKJCON(J,K)  CONSTRAINT ON TKJ,
354   TKJCONA(J,K) CONSTRAINT ON TKJ FOR ISOTERMIC STREAM,
355   TCON1(I)     CONSTRAINT ON TIOUT,
356   TCON2(J)     CONSTRAINT ON TJOUT,
357   LOADQC(I)    HEAT LOAD COLD UTILITY WITH HOT I,
358   LOADQH(J)    HEAT LOAD HOT UTILITY WITH COLD J,
359   LOGCOND(I,J,K)   LOGICAL CONSTRAINTS FOR UNIT ASSIGNMENT,
360   LOGCU(I)         LOGICAL CONSTRAINTS FOR COOLERS,
361   LOGHU(J)         LOGICAL CONSTRAINTS FOR HEATERS,
362   DTCON(I,J,K)     DRIVING FORCE FOR INLET STAGE K,
363   DTCONA(I,J,K)    DRIVING FORCE FOR OUTLET STAGE NOK,
364   DTHUCON(J)       DETERMINING DRIVING FORCE FOR HEATERS,
365   DTCUCON(I)       DETERMINING DRIVING FORCE FOR COOLERS,
366
367  *SPLIT CONSTRAINTS.
368
369   SPLITH(I,K)      SPLIT OF HOT STREAMS
370   SPLITC(J,K)      SPLIT OF COLD STREAMS
371   INTCUT(IT)       INTEGER CUT
372
373  *REQUIRED MATCHES CONSTRAINT.
374
375   REQUIRED(I,J)    REQUIRED MATCHES BETWEEN HOT AND COLD STREAMS
```

```
 376
 377  *MINIMUM UTILITY.
 378
 379   HUTILFX          HOT UTILITY HEAT LOAD FIXED
 380   CUTILFX          COLD UTILITY HEAT LOAD FIXED
 381   HUTILUP          HOT UTILITY HEAT LOAD UPPER BOUND
 382   CUTILUP          COLD UTILITY HEAT LOAD UPPER BOUND
 383
 384  * ADDITIONAL NLP CONSTRAINTS.
 385
 386   LOADHM2(I,J,K)  LOAD OF HOT SIDE MATCH IN INTERVAL K,
 387   LOADCM2(I,J,K)  LOAD OF COLD SIDE MATCH IN INTERVAL K,
 388   LOGCOND2(I,J,K)   LOGICAL CONSTRAINTS FOR UNIT ASSIGNMENT,
 389   LOGCU2(I)         LOGICAL CONSTRAINTS FOR COOLERS,
 390   LOGHU2(J)         LOGICAL CONSTRAINTS FOR HEATERS,
 391   DTCON2(I,J,K)     DRIVING FORCE FOR INLET STAGE K,
 392   DTCON22(I,J,K) DRIVING FORCE FOR OUTLET STAGE NOK,
 393   CHECKH(I,J,K)
 394   CHECKC(I,J,K)
 395   ENERBALH(I,K)     ENERGY BALANCE FOR HOT STREAMS PER EXCHANGER
 396  ENERBALHI(I,J,K)
 397   ENERBALC(J,K)     ENERGY BALANCE FOR COLD STREAMS PER EXCHANGER
 398  ENERBALCI(I,J,K)
 399   FLOWH(I,K)        TOTAL FLOW OF HOT STREAMS
 400   FLOWC(J,K)        TOTAL FLOW OF COLD STREAMS
 401
 402   OBJNLP            OBJECTIVE FUNCTION FOR NLP
 403   OBJLP             OBJECTIVE FUNCTION FOR LP
 404   OBJMINLP          OBJECTIVE FUNCTION FOR MINLP;
 405
 406  *
 407  * MINLP CONSTRAINTS
 408  *
 409   STRENBH(I1).. (TIIN(I1)-TIOUT(I1))*FCI(I1)=E=SUM((K,J)$(ORD(K) LE NOK),Q(I1,J,K))+QCOLD
(I1);
 410
 411   STRENBHI(I2).. FCI(I2)=E=SUM((K,J)$(ORD(K) LE NOK),Q(I2,J,K))+QCOLD(I2);
 412
 413   STRENBC(J1).. (TJOUT(J1)-TJIN(J1))*FCJ(J1)=E=SUM((K,I)$(ORD(K) LE NOK),Q(I,J1,K))+QHOT(
J1);
 414
 415   STRENBCI(J2).. FCJ(J2)=E=SUM((K,I)$(ORD(K) LE NOK), Q(I,J2,K))+QHOT(J2);
 416
 417   LOADHM(I1,K)$(ORD(K) LE NOK).. (TKI(I1,K)-TKI(I1,K+1))*FCI(I1)=E= SUM(J,Q(I1,J,K));
 418
 419   LOADCM(J1,K)$(ORD(K) LE NOK).. (TKJ(J1,K)-TKJ(J1,K+1))*FCJ(J1) =E=SUM(I,Q(I,J1,K));
 420
 421   TIINTK(I).. TIIN(I)=E=TKI(I,'1');
 422
 423   TJINTK(J).. TJIN(J)=E=SUM(K$(ORD(K) EQ (NOK+1)), TKJ(J,K));
 424
 425   TKICON(I1,K)$(ORD(K) LE NOK)..TKI(I1,K)=G= TKI(I1,K+1);
 426
 427   TKICONA(I2,K)$(ORD(K) LE NOK).. TKI(I2,K)=E=TIIN(I2);
 428
 429   TKJCON(J1,K)$(ORD(K) LE NOK).. TKJ(J1,K)=G= TKJ(J1,K+1);
 430
 431   TKJCONA(J2,K)$(ORD(K) LE NOK).. TKJ(J2,K)=G=TJIN(J2);
 432
 433   TCON1(I1).. TIOUT(I1)=L=SUM(K$(ORD(K) EQ (NOK+1)), TKI(I1,K));
 434
 435   TCON2(J1).. TJOUT(J1)=G=TKJ(J1,'1');
 436
```

```
 437   LOADQC(I1).. (SUM(K$(ORD(K) EQ (NOK+1)), TKI(I1,K))-TIOUT(I1))*FCI(I1) =E=QCOLD(I1);
 438
 439   LOADQH(J1).. (TJOUT(J1)-TKJ(J1,'1'))*FCJ(J1) =E=QHOT(J1);
 440
 441   LOGCOND(I,J,K)$(ORD(K) LE NOK)..
 442       Q(I,J,K) - MIN( QCI(I), QCJ(J)) * Z(I,J,K)=L=0;
 443   LOGCU(I)..
 444       QCOLD(I) - QCI(I) * ZCU(I)=L=0;
 445   LOGHU(J)..
 446       QHOT(J) - QCJ(J) * ZHU(J)=L=0;
 447   DTCON(I,J,K)$(ORD(K) LE NOK)..
 448       DT(I,J,K)=L=TKI(I,K)-TKJ(J,K)+DTMAX(I,J)*(1-Z(I,J,K));
 449   DTCONA(I,J,K)$((ORD(K) LE NOK))..
 450       DT(I,J,K+1)=L=TKI(I,K+1)-TKJ(J,K+1)+DTMAX(I,J)*(1-Z(I,J,K));
 451   DTHUCON(J)..
 452       DTHU(J)=L=(THUOUT-TKJ(J,'1'));
 453   DTCUCON(I)..
 454      DTCU(I)=L=(SUM(K$(ORD(K) EQ (NOK+1)),TKI(I,K))-TCUOUT)  ;
 455
 456   OBJMINLP..   COST =E= UNITC* (  SUM((I,J,K)$(ORD(K) LE NOK), Z(I,J,K))
 457    + SUM(I, ZCU(I)) + SUM(J, ZHU(J))  )
 458    + ACOEFF* SUM((I,J,K)$(ORD(K) LE NOK),
 459         ( Q(I,J,K)*((1/CFI(I))+(1/CFJ(J)))
 460   /(((DT(I,J,K)*DT(I,J,K+1)*(DT(I,J,K)+DT(I,J,K+1))/2)**0.33333)
 461     )+1E-6)**AEXP)
 462    +HUCOEFF * SUM(J, (QHOT(J)*((1/CFJ(J))+(1/CFHU))
 463   /(((THUIN-TJOUT(J))*DTHU(J)*((THUIN-TJOUT(J)+DTHU(J))/2))**0.33333
 464     )+1E-6)**AEXP)
 465    +CUCOEFF * SUM(I, (QCOLD(I)*((1/CFI(I))+(1/CFCU))
 466   /(((TIOUT(I)-TCUIN)*DTCU(I)*(TIOUT(I)-TCUIN+DTCU(I))/2)**0.33333
 467     )+1E-6)**AEXP)
 468     + SUM(J, QHOT(J)*HUCOST) + SUM(I, QCOLD(I)*CUCOST);
 469
 470     COST.LO=-1000;
 471
 472  *
 473  * NLP CONSTRAINTS.
 474  *
 475
 476   LOADHM2(I1,J,K)$((ORD(K) LE NOK) )..
 477    (TKI(I1,K)-TH(I1,J,K))*FH(I1,J,K) =E= Q(I1,J,K);
 478   LOADCM2(I,J1,K)$((ORD(K) LE NOK))..
 479    (TC(I,J1,K)-TKJ(J1,K+1))*FC(I,J1,K) =E= Q(I,J1,K);
 480   ENERBALH(I1,K)$((ORD(K) LE NOK))..
 481    SUM(J, FH(I1,J,K)*TH(I1,J,K))=E= FCI(I1)*TKI(I1,K+1);
 482   ENERBALHI(I2,J,K)$((ORD(K) LE NOK))..
 483    TH(I2,J,K) =E= TIIN(I2);
 484   ENERBALC(J1,K)$((ORD(K) LE NOK) )..
 485    SUM(I, FC(I,J1,K)*TC(I,J1,K))=E= FCJ(J1)*TKJ(J1,K);
 486   ENERBALCI(I,J2,K)$((ORD(K) LE NOK)).. TC(I,J2,K) =E= TJIN(J2);
 487   CHECKH(I1,J,K)$(ORD(K) LE NOK)..
 488    TH(I1,J,K) =L= TKI(I1,K);
 489   CHECKC(I,J1,K)$(ORD(K) LE NOK)..
 490    TKJ(J1,K+1) =L= TC(I,J1,K);
 491   FLOWH(I1,K)$((ORD(K) LE NOK))..
 492    SUM(J, FH(I1,J,K)) =E= FCI(I1);
 493   FLOWC(J1,K)$((ORD(K) LE NOK))..
 494    SUM(I, FC(I,J1,K)) =E= FCJ(J1);
 495   LOGCOND2(I,J,K)$(ORD(K) LE NOK)..
 496    Q(I,J,K) - MIN( QCI(I), QCJ(J)) * Z.L(I,J,K)=L=0;
 497   LOGCU2(I)..
 498    QCOLD(I) - QCI(I) * ZCU.L(I)=L=0;
 499   LOGHU2(J)..
```

```
 500    QHOT(J) - QCJ(J) * ZHU.L(J)=L=0;
 501   DTCON2(I,J,K)$(ORD(K) LE NOK)..
 502    DT1(I,J,K)=L=TKI(I,K)-TC(I,J,K)+DTMAX(I,J)*(1-Z.L(I,J,K));
 503   DTCON22(I,J,K)$(ORD(K) LE NOK)..
 504    DT2(I,J,K)=L=TH(I,J,K)-TKJ(J,K+1)+DTMAX(I,J)*(1-Z.L(I,J,K));
 505
 506
 507  OBJNLP..   COSTNLP =E=
 508  UNITC*(SUM((I,J,K)$(ORD(K) LE NOK),Z.L(I,J,K))+SUM(I,ZCU.L(I))+SUM(J,ZHU.L(J)))
 509    + ACOEFF* SUM((I,J,K)$(ORD(K) LE NOK),
 510           ( Q(I,J,K)*((1/CFI(I))+(1/CFJ(J)))
 511      /(((DT1(I,J,K)*DT2(I,J,K)*(DT1(I,J,K)+DT2(I,J,K))/2)**0.33333)
 512      )+1E-6)**AEXP)
 513    +HUCOEFF * SUM(J, (QHOT(J)*((1/CFJ(J))+(1/CFHU))
 514      /(((THUIN-TJOUT(J))*DTHU(J)*(THUIN-TJOUT(J)+DTHU(J))/2)**0.33333
 515      )+1E-6)**AEXP)
 516    +CUCOEFF * SUM(I,(QCOLD(I)*((1/CFI(I))+(1/CFCU))
 517      /(((TIOUT(I)-TCUIN)*DTCU(I)*(TIOUT(I)-TCUIN+DTCU(I))/2)**0.33333
 518      )+1E-6)**AEXP)
 519    + SUM(J, QHOT(J)*HUCOST) + SUM(I, QCOLD(I)*CUCOST);
 520
       OBJNLP..   COSTNLP =E= UNITC*(
          SUM( (I,J,K)$(ORD(K) LE NOK),Z.L(I,J,K) )
        + SUM( I,ZCU.L(I) )
        + SUM( J,ZHU.L(J) ) )
        + ACOEFF*
          SUM( (I,J,K)$( (ORD(K) LE NOK) AND (DT1(I,J,K) NE DT2(I,J,K)) ),
          ( Q(I,J,K)*( 1/CFI(I) + 1/CFJ(J) )/
          ( (DT1(I,J,K)-DT2(I,J,K)) / (LOG (DT1(I,J,K)/DT2(I,J,K)) ) )) )
        + ACOEFF*
          SUM( (I,J,K)$( (ORD(K) LE NOK) AND (DT1(I,J,K) EQ DT2(I,J,K)) ),
          ( Q(I,J,K)*( 1/CFI(I) + 1/CFJ(J) )/DT1(I,J,K) ) )
        +HUCOEFF*
          SUM( J$( (THUIN-TJOUT(J)) NE (THUOUT-TKJ(J,'1')) ),
          ( QHOT(J)*(1/CFJ(J) + 1/CFHU) /
          ( ( (THUIN-TJOUT(J)) - (THUOUT-TKJ(J,'1')) ) /
          ( LOG( (THUIN-TJOUT(J)) / (THUOUT-TKJ(J,'1')) ) ) ) )
        +HUCOEFF*
          SUM( J$( (THUIN-TJOUT(J)) EQ (THUOUT-TKJ(J,'1')) ),
          ( QHOT(J)*(1/CFJ(J) + 1/CFHU)/
          ( THUIN - TJOUT(J) ) ) )
        +CUCOEFF*
          SUM( I$( (SUM(K$(ORD(K) EQ (NOK+1)),TKI(I,K))-TCUOUT) NE (TIOUT(I)-TCUIN)),
          ( QCOLD(I)*(1/CFI(I) + 1/CFCU)/
          ( ((SUM(K$(ORD(K) EQ (NOK+1)),TKI(I,K)) - TCUOUT) - (TIOUT(I)-TCUIN) )/
          ( LOG( (SUM(K$(ORD(K) EQ (NOK+1)),TKI(I,K))-TCUOUT)
            / (TIOUT(I)-TCUIN) ) ) ) ) )
        +CUCOEFF*
         SUM( I$( (SUM(K$(ORD(K) EQ (NOK+1)),TKI(I,K))-TCUOUT) EQ (TIOUT(I)-TCUIN) ),
          ( QCOLD(I)*(1/CFI(I) + 1/CFCU)/
          ( TIOUT(I) - TCUIN) ) )
        +SUM(J, QHOT(J)*HUCOST)
        +SUM(I, QCOLD(I)*CUCOST);
 555
 556  *
 557  * LP OBJECTIVE FUNCTION
 558  *
 559
 560   OBJLP..   COST =E=
 561      UNITC* (  SUM((I,J,K)$(ORD(K) LE NOK), Z(I,J,K))
 562    + SUM(I, ZCU(I)) + SUM(J, ZHU(J))  )
 563    + ACOEFF* SUM((I,J,K,K1)$((ORD(K) LE NOK) AND (ORD(K1) EQ (ORD(K)+1))),
 564        ( Q(I,J,K)*((1/CFI(I))+(1/CFJ(J)))
```

```
 565   /D))
 566    +HUCOEFF * SUM(J,
 567         (QHOT(J)*((1/CFJ(J))+(1/CFHU))
 568   /D))
 569    +CUCOEFF * SUM(I,
 570         (QCOLD(I)*((1/CFI(I))+(1/CFCU))
 571   /D))
 572     + SUM(J, QHOT(J)*HUCOST) + SUM(I, QCOLD(I)*CUCOST);
 573
 574     COST.LO=-1000;
 575
 576
 577  *
 578  *SPLIT CONSTRAINTS
 579  *
 580
 581   SPLITH(I,K)$((SPLIT EQ 1 OR SPLIT EQ 3) AND (ORD(K) LE NOK))..
 582      SUM(J, Z(I,J,K)) =L= 1;
 583   SPLITC(J,K)$((SPLIT EQ 2 OR SPLIT EQ 3) AND (ORD(K) LE NOK))..
 584      SUM(I, Z(I,J,K)) =L= 1;
 585
 586  *
 587  *INTEGER CUT
 588  *
 589
 590   INTCUT(IT)$(ORD(IT) LE ITER)..
 591      SUM(I, SUM(J, SUM(K, Z(I,J,K)$(ZIT(I,J,K,IT) EQ 1))))+
 592      SUM(I, ZCU(I)$(ZCUIT(I,IT) EQ 1))+
 593      SUM(J, ZHU(J)$(ZHUIT(J,IT) EQ 1))-
 594      SUM(I, SUM(J, SUM(K, Z(I,J,K)$(ZIT(I,J,K,IT) EQ 0))))-
 595      SUM(I, ZCU(I)$(ZCUIT(I,IT) EQ 0))-
 596      SUM(J, ZHU(J)$(ZHUIT(J,IT) EQ 0))-
 597      SUM(I, SUM(J, SUM(K, ZIT(I,J,K,IT))))-
 598      SUM(I, ZCUIT(I,IT))-
 599      SUM(J, ZHUIT(J,IT)) + 1 =L= 0;
 600
 601
 602  *
 603  * REQUIRED MATCHES CONSTRAINT
 604  *
 605
 606   REQUIRED(I,J)$(REQUIR(I,J) EQ 1).. SUM(K$(ORD(K) LE NOK), Z(I,J,K)) =E= 1;
 607
 608
 609  *
 610  * MINIMUM UTILITY
 611  *
 612
 613   CUTILFX$(TRANS EQ 1).. SUM(I, QCOLD(I)) =E= QWMIN1;
 614   HUTILFX$(TRANS EQ 1).. SUM(J, QHOT(J))  =E= QSMIN1;
 615   CUTILUP$(TRANS EQ 2).. SUM(I, QCOLD(I)) =L= QWMIN1;
 616   HUTILUP$(TRANS EQ 2).. SUM(J, QHOT(J))  =L= QSMIN1;
 617
 618
 619  MODEL LINEAR FOR LP/
 620   STRENBH,
 621   STRENBC,
 622   LOADHM,
 623   LOADCM,
 624   TIINTK,
 625   TJINTK,
 626   TKICON,
 627   TKJCON,
```

```
 628   TCON1,
 629   TCON2,
 630   LOADQC,
 631   LOADQH,
 632   LOGCOND,
 633   LOGCU,
 634   LOGHU,
 635   DTCON,
 636   DTCONA,
 637   DTHUCON,
 638   DTCUCON,
 639   OBJLP/;
 640
 641  MODEL MIXED FOR MINLP /
 642   STRENBH,
 643   STRENBHI,
 644   STRENBC,
 645   STRENBCI,
 646   LOADHM,
 647   LOADCM,
 648   TIINTK,
 649   TJINTK,
 650   TKICON,
 651   TKICONA,
 652   TKJCON,
 653   TKJCONA,
 654   TCON1,
 655   TCON2,
 656   LOADQC,
 657   LOADQH,
 658   LOGCOND,
 659   LOGCU,
 660   LOGHU,
 661   DTCON,
 662   DTCONA,
 663   DTHUCON,
 664   DTCUCON,
 665   SPLITH,
 666   SPLITC,
 667   REQUIRED,
 668   HUTILFX,
 669   CUTILFX,
 670   HUTILUP,
 671   CUTILUP,
 672   OBJMINLP/;
 673
 674
 675  MODEL NONLINEAR FOR NLP/
 676   STRENBH,
 677   STRENBHI,
 678   STRENBC,
 679   STRENBCI,
 680   LOADHM2,
 681   LOADCM2,
 682   TIINTK,
 683   TJINTK,
 684   TKICON,
 685   TKICONA,
 686   TKJCON,
 687   TKJCONA,
 688   TCON1,
 689   TCON2,
 690   LOADQC,
```

```
 691   LOADQH,
 692   LOGCOND2,
 693   LOGCU2,
 694   LOGHU2,
 695   DTCON2,
 696   DTCON22,
 697   DTHUCON,
 698   DTCUCON,
 699   ENERBALH,
 700   ENERBALHI,
 701   ENERBALC,
 702   ENERBALCI,
 703   CHECKH,
 704   CHECKC,
 705   FLOWH,
 706   FLOWC,
 707   HUTILFX,
 708   CUTILFX,
 709   HUTILUP,
 710   CUTILUP,
 711   OBJNLP/;
 712

       LOOP(ITE,
       ITER = ORD(ITE);
       LOOP(IT$(ORD(IT) EQ ITER),
       ZIT(I,J,K,IT) = Z.L(I,J,K);
       ZCUIT(I,IT) = ZCU.L(I);
       ZHUIT(J,IT) = ZHU.L(J);

       );
 724
 725
 726  *
 727  *BOUNDS
 728  *
 729
 730  DT.LO(I,J,K)=TMAPP;
 731  DTHU.LO(J)=TMAPP;
 732  DTCU.LO(I)=TMAPP;
 733  TKI.UP(I,K)=TIIN.L(I);
 734  TKI.LO(I,K)=TIOUT.L(I);
 735  TKJ.UP(J,K)=TJOUT.L(J);
 736  TKJ.LO(J,K)=TJIN.L(J);
 737
 738  *
 739  * INITIALIZATION
 740  *
 741
 742  TKI.L(I,K)=TIIN.L(I);
 743  TKJ.L(J,K)=TJIN.L(J);
 744  DTHU.L(J)=THUOUT-TJIN.L(J);
 745  DTCU.L(I)=TIIN.L(I)-TCUOUT;
 746  QCI(I)=FCI(I)*(TIIN.L(I)-TIOUT.L(I));
 747  QCI(I2)=FCI(I2);
 748  QCJ(J)=FCJ(J)*(TJOUT.L(J) - TJIN.L(J));
 749  QCJ(J2)=FCJ(J2);
 750  DTMAX(I,J)=MAX(0,TIIN.L(I)-TJIN.L(J),TJOUT.L(J)-TIOUT.L(I));
 751  DTMAX(I,J)$((TIIN.L(I)-TJIN.L(J)) LT TMAPP)=ABS(TIIN.L(I)-TJIN.L(J))+TMAPP;
 752  DT.L(I,J,K)=TIIN.L(I)-TJIN.L(J);
 753
 754  Q.L(I,J,K)$(ORD(K) LE NOK)=MIN(QCI(I), QCJ(J));
 755
```

```
 756
 757  *
 758  * LP
 759  *
 760
 761  * SOLVE LINEAR USING MIP MINIMIZING COST;
 762
 763
 764  *
 765  * MINLP
 766  *
 767   MIXED.WORKSPACE = 10;
 768   SOLVE MIXED USING MINLP MINIMIZING COST;
 769
 770   SUB = 0;
 771
 772  *
 773  * AREA AND COST CALCULATIONS
 774  *
 775
 776  LOOP(K$(ORD(K) LE NOK),
 777
 778
 779  *AREAS BY PATERSON APPROXIMATION
 780
 781   A(I,J,K)$(Q.L(I,J,K) NE 0) = Q.L(I,J,K)*((1/CFI(I))+(1/CFJ(J)))/
 782              (2/3*SQRT(DT.L(I,J,K)*DT.L(I,J,K+1)+1E-6)
 783              +1/6*(DT.L(I,J,K)+DT.L(I,J,K+1)));
 784
 785  *AREAS BY LOG MEAN TEMPERATURE
 786
 787   A(I,J,K)$((Q.L(I,J,K) NE 0) AND
 788              ((TKI.L(I,K)-TKJ.L(J,K)) NE (TKI.L(I,K+1)-TKJ.L(J,K+1)))) =
 789       Q.L(I,J,K)*((1/CFI(I))+(1/CFJ(J)))/
 790       (((TKI.L(I,K)-TKJ.L(J,K))-(TKI.L(I,K+1)-TKJ.L(J,K+1)))/
 791       (LOG((TKI.L(I,K)-TKJ.L(J,K))/(TKI.L(I,K+1)-TKJ.L(J,K+1)))));
 792
 793   A(I,J,K)$((Q.L(I,J,K) NE 0) AND
 794     ((TKI.L(I,K)-TKJ.L(J,K)) EQ (TKI.L(I,K+1)-TKJ.L(J,K+1)))) =Q.L(I,J,K)*((1/CFI(I))+(1/C
FJ(J)))/
 795                                                 (TKI.L(I,K)-TKJ.L(J,K));
 796
 797  *AREAS BY CHEN APPROXIMATION
 798
 799   AL(I,J,K)$(Q.L(I,J,K) NE 0) = (Q.L(I,J,K)*((1/CFI(I))+(1/CFJ(J))))/
 800               (((DT.L(I,J,K)*DT.L(I,J,K+1)*(DT.L(I,J,K)+DT.L(I,J,K+1))/2)
 801               **0.33333));
 802
 803  );
 804
 805  *AREAS OF HEATERS AND COOLERS
 806
 807       AHU(J) = (QHOT.L(J)*((1/CFJ(J))+(1/CFHU))/
 808            (((THUIN-TJOUT.L(J))*DTHU.L(J)*((THUIN-TJOUT.L(J)+DTHU.L(J)))/2)+1E-6)
 809            **0.33333 );
 810
 811       ACU(I) = (QCOLD.L(I)*((1/CFI(I))+(1/CFCU))/
 812            (((TIOUT.L(I)-TCUIN)*DTCU.L(I)*(TIOUT.L(I)-TCUIN+DTCU.L(I))/2+1E-6)
 813            **0.33333 ));
 814
 815  *UTILITY COSTS
 816
 817   COSTHEAT = SUM(J,QHOT.L(J)*HUCOST);
```

```
 818   COSTCOOL = SUM(I,QCOLD.L(I)*CUCOST);
 819
 820  *INVESTMENT COST
 821
 822   INVCOST = COST.L-COSTHEAT-COSTCOOL;
 823
 824   DISPLAY A, AL, ACU, AHU;
 825   DISPLAY COSTHEAT, COSTCOOL;
 826   DISPLAY INVCOST;
 827
 828  *
 829  * STREAM SPLITS CHECKING
 830  *
 831
 832   PARAMETERS SPH(I,K), SPC(J,K), SPLH, SPLC, NI,NJ;
 833
 834   SPH(I,K) = SUM(J, Z.L(I,J,K));
 835   SPC(J,K) = SUM(I, Z.L(I,J,K));
 836   SPLH = 0;
 837   SPLC = 0;
 838
 839   LOOP(K$(ORD(K) LE NOK),
 840       LOOP(I$(SPLH EQ 0),
 841            SPLH$(SPH(I,K) GT 1.001) = 1;
 842       );
 843       LOOP(J$(SPLC EQ 0),
 844            SPLC$(SPC(J,K) GT 1.001) = 1;
 845       );
 846   );
 847
 848  DISPLAY SPH, SPC;
 849
 850
 851   LOOP(ONE$( SPLH EQ 1 OR SPLC EQ 1) ,
 852
 853
 854  *
 855  * NLP BOUNDS
 856  *
 857
 858   SUB = 1;
 859
 860   NI = CARD(I);
 861   NJ = CARD(J);
 862
 863   TH.LO(I,J,K) = TIOUT.L(I);
 864   TH.UP(I,J,K) = TIIN.L(I);
 865   TC.LO(I,J,K) = TJIN.L(J);
 866   TC.UP(I,J,K) = TJOUT.L(J);
 867   FH.UP(I,J,K) = FCI(I);
 868   FC.UP(I,J,K) = FCJ(J);
 869   DT1.LO(I,J,K) = TMAPP;
 870   DT2.LO(I,J,K) = TMAPP;
 871
 872  *
 873  * NLP INITIALIZATION
 874  *
 875
 876
 877   Z.L(I,J,K) = 0;
 878   Z.L(I,J,K)$(Q.L(I,J,K) GT 0) = 1;
 879   DT1.L(I,J,K) = DT.L(I,J,K);
 880   DT2.L(I,J,K) = DT.L(I,J,K);
```

```
 881   FH.L(I1,J,K)$(((TKI.L(I1,K) - TKI.L(I1,K+1)) GT 0.1))
 882               = Q.L(I1,J,K)/(TKI.L(I1,K) - TKI.L(I1,K+1));
 883   FC.L(I,J1,K)$(((TKJ.L(J1,K) - TKJ.L(J1,K+1)) GT 0.1))
 884               = Q.L(I,J1,K)/(TKJ.L(J1,K) - TKJ.L(J1,K+1));
 885
 886   FH.LO(I,J,K)$(Z.L(I,J,K) EQ 1) = 0.00001;
 887   FC.LO(I,J,K)$(Z.L(I,J,K) EQ 1) = 0.00001;
 888
 889   TH.L(I,J,K) = TKI.L(I,K+1);
 890   TC.L(I,J,K) = TKJ.L(J,K);
 891
 892
 893   DISPLAY FH.L, FC.L, TH.L, TC.L, DT1.L, DT2.L, Z.L, Q.L, THUIN, THUOUT,
 894           TCUIN, TCUOUT;
 895
 896  *
 897  * NLP OPTIMIZATION
 898  *
 899
 900
 901   SOLVE NONLINEAR USING NLP MINIMIZING COSTNLP;
 902
 903
 904  *
 905  * AREA AND COST CALCULATIONS
 906  *
 907
 908  LOOP(K$(ORD(K) LE NOK),
 909
 910  *AREAS BY PATERSON APPROXIMATION
 911
 912   A(I,J,K)$(Q.L(I,J,K) NE 0) = Q.L(I,J,K)*((1/CFI(I))+(1/CFJ(J)))/
 913              (2/3*SQRT(DT1.L(I,J,K)*DT2.L(I,J,K)+1E-6)
 914              +1/6*(DT1.L(I,J,K)+DT2.L(I,J,K)));
 915
 916  *AREAS BY LOG MEAN TEMPERATURE
 917
 918   A(I,J,K)$((Q.L(I,J,K) NE 0) AND ( DT1.L(I,J,K) NE DT2.L(I,J,K)))
 919      = Q.L(I,J,K)*((1/CFI(I))+(1/CFJ(J)))
 920       /((DT1.L(I,J,K) - DT2.L(I,J,K))/(LOG(DT1.L(I,J,K)/DT2.L(I,J,K))));
 921
 922   A(I,J,K)$((Q.L(I,J,K) NE 0) AND ( DT1.L(I,J,K) EQ DT2.L(I,J,K)))
 923      = Q.L(I,J,K)*((1/CFI(I))+(1/CFJ(J)))/DT1.L(I,J,K);
 924
 925  *AREA BY CHEN APPROXIMATION
 926
 927   AL(I,J,K)$(Q.L(I,J,K) NE 0) = (Q.L(I,J,K)*((1/CFI(I))+(1/CFJ(J))))/
 928              (((DT1.L(I,J,K)*DT2.L(I,J,K)*(DT1.L(I,J,K)+DT2.L(I,J,K))/2)
 929              **0.33333));
 930
 931  );
 932
 933  *AREAS OF HEATERS AND COOLERS
 934
 935   AHU(J) = (QHOT.L(J)*((1/CFJ(J))+(1/CFHU))/
 936           (((THUIN-TJOUT.L(J))*DTHU.L(J)*((THUIN-TJOUT.L(J)+DTHU.L(J)))/2)+1E-6)
 937           **0.33333 );
 938
 939   ACU(I) = (QCOLD.L(I)*((1/CFI(I))+(1/CFCU))/
 940           (((TIOUT.L(I)-TCUIN)*DTCU.L(I)*(TIOUT.L(I)-TCUIN+DTCU.L(I))/2+1E-6)
 941           **0.33333 ));
 942
 943  *UTILITY COSTS
```

```
 944
 945   COSTHEAT = SUM(J,QHOT.L(J)*HUCOST);
 946   COSTCOOL = SUM(I,QCOLD.L(I)*CUCOST);
 947
 948  *INVESTMENT COST
 949
 950   INVCOST = COSTNLP.L-COSTHEAT-COSTCOOL-
 951             SUM((I,J,K)$(Q.L(I,J,K) EQ 0), UNITC*Z.L(I,J,K))-
 952             SUM(I$(QCOLD.L(I) EQ 0), UNITC*ZCU.L(I))-
 953             SUM(J$(QHOT.L(J) EQ 0), UNITC*ZHU.L(J));
 954
 955   DISPLAY A, AL, ACU, AHU;
 956   DISPLAY COSTHEAT, COSTCOOL;
 957   DISPLAY INVCOST;
 958
 959  );
 960
INCLUDE    /var/www/html/interfaces/cgi-bin/synheat/repminlp.inc
 962  ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** **
 963
 964
 965
 966  *  seminlp.inc  file for the creation of the Summary of Results
 967
 968  *          for MINLP SINGLE UTILITIES MODEL
 969
 970  *  and data for the graphic display of solution.
 971
 972
 973
 974  ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** **
 975
 976
 977
 978
 979
 980  PARAMETER  FCP, TOT, AREA, AREAL, AREAT, EX, INTER, M, MCU, MHU, MR,
 981
 982             MCUR, MHUR;
 983
 984  AREAT = 0;
 985
 986  AREA = 0;
 987
 988  AREAL = 0;
 989
 990  INTER = 0;
 991
 992  EX = 0;
 993
 994  M = SUM(I,SUM(J, FORBID(I,J)));
 995
 996  MCU = SUM(I, FORBIDCU(I));
 997
 998  MHU = SUM(J, FORBIDHU(J));
 999
1000  MR = SUM((I,J), REQUIR(I,J));
1001
1002  MCUR = SUM(I, REQUIRCU(I));
1003
1004  MHUR = SUM(J, REQUIRHU(J));
1005
1006
```

```
1007
1008  *FIlE RES1 /output.html/
1009
1010  FIlE RES1 /"../../synheat/output.html"/
1011
1012  PUT RES1 "<html><head><title>OUTPUT</title>"/;
1013
1014  PUT RES1 '<style type="text/css">'/;
1015
1016  PUT RES1 "      HR {"/;
1017
1018  PUT RES1 "              border : thick outset #800000;"/;
1019
1020  PUT RES1 "              font-color: #800000;"/;
1021
1022  PUT RES1 "      }"/;
1023
1024
1025
1026  PUT RES1 "      TD.ref {"/;
1027
1028  PUT RES1 "              border : thick outset #FFFF130;"/;
1029
1030  PUT RES1 "              background-color : #C0C0C0;"/;
1031
1032  PUT RES1 "              padding-left : 1ex;"/;
1033
1034  PUT RES1 "              width : 50%;"/;
1035
1036  PUT RES1 "              font-size : small;"/;
1037
1038  PUT RES1 "              font-color: #800000;"/;
1039
1040  PUT RES1 "              padding-top : 6px;"/;
1041
1042  PUT RES1 "              padding-right : 6px;"/;
1043
1044  PUT RES1 "              padding-bottom : 6px;"/;
1045
1046  PUT RES1 "              padding-left : 6px;"/;
1047
1048  PUT RES1 "              text-align : 1em;"/;
1049
1050  PUT RES1 "              vertical-align : top;"/;
1051
1052  PUT RES1 "              font-weight : bold;"/;
1053
1054  PUT RES1 "      }"/;
1055
1056  PUT RES1 "</style>"/;
1057
1058  PUT RES1 "</head><body alink=#800000 link=#800000>"/;
1059
1060  PUT RES1 "<hr> <b>SYNHEAT</b></hr><hr></hr>"//;
1061
1062  PUT RES1 "<h4>  Optimal Design for Heat Exchanger Networks</h4><br>";
1063
1064
1065
1066  ** ** ** ** ** ** ** ** verify is optimal solution was found ** ** ** ** ** * ** * * **
1067
1068  ** ** ** ** ** ** * if it is found write summary of reults ** ** ** ** ** * ** * * **
1069
```

```
1070
1071
1072  if(mixed.modelstat eq 1 or mixed.modelstat eq 2 or mixed.modelstat eq 8  ,
1073
1074
1075
1076  ** ** ** ** ** ** ** ** * * * ** * ** ** ** ** ** * * ** * ** ** ** ** ** * ** * * **
1077
1078  ** ** ** ** ** * ** ** ** * * * * ** * * * * ** ** * * * ** ** ** ** ** ** * ** * * **
1079
1080
1081
1082  PUT RES1 "<table align=center  border =0>"/;
1083
1084  put RES1 "<td><b><h2>   - - - - -  PROBLEM DATA  - - - - -  </h2></b></table><p>"/;
1085
1086
1087
1088  PUT RES1 "<p><table border =2 bordercolor=#800000 width=90% align=center><b>HOT STREAMS<
/b>"/;
1089
1090  PUT RES1 "<tr><td> Stream <td>Tin(K) <td>Tout(k)<td>FCP(kW/K) <td>CFI(kW/m2 K)"/;
1091
1092  LOOP(I,
1093
1094       PUT RES1 "<tr><td> Stream"ORD(I):3:0;
1095
1096       PUT RES1 "<td>"TIIN.L(I):8:2;
1097
1098       PUT RES1 "<td>"TIOUT.L(I):8:2;
1099
1100       PUT RES1 "<td>"FCI(I):8:2;
1101
1102       PUT RES1 "<td>"CFI(I):8:2/;
1103
1104  );
1105
1106  PUT RES1 "</table>"/;
1107
1108  PUT RES1 "<p><table border =2 bordercolor=#800000 width=90% align=center><b>COLD STREAMS
</b>"/;
1109
1110  PUT RES1 "<td> Stream <td>Tin(K) <td>Tout(k)<td>FCP(kW/K) <td>CFJ(kW/m2 K)"/;
1111
1112  LOOP(J,
1113
1114       PUT RES1 "<tr><td>Stream"ORD(J):3:0;
1115
1116       PUT RES1 "<td>"TJIN.L(J):8:2;
1117
1118       PUT RES1 "<td>"TJOUT.L(J):8:2;
1119
1120       PUT RES1 "<td>"FCJ(J):8:2;
1121
1122       PUT RES1 "<td>"CFJ(J):8:2/;
1123
1124  );
1125
1126  PUT RES1 "</table>"/;
1127
1128
1129
1130  PUT RES1 "<p><table border =2 bordercolor=#800000 width=80% align=center><b>UTILITIES</b
```

```
>"/;
1131
1132  PUT RES1 "<td> Utillity <td>Tin(K) <td>Tout(k)<td>CFU(kW/m2 K)"/;
1133
1134  PUT RES1 "<tr><td>HOT"/;
1135
1136  PUT RES1 "<td>"THUIN:8:2;
1137
1138  PUT RES1 "<td>"THUOUT:8:2;
1139
1140  PUT RES1 "<td>"CFHU:8:2/;
1141
1142  PUT RES1 "<tr><td>COLD"/;
1143
1144  PUT RES1 "<td>"TCUIN:8:2;
1145
1146  PUT RES1 "<td>"TCUOUT:8:2;
1147
1148  PUT RES1 "<td>"CFCU:8:2/;
1149
1150  PUT RES1 "</table>"/;
1151
1152
1153
1154  PUT RES1 "<p><table border =2 bordercolor=#800000 width=88% align=center><b>COSTS</b>"/;
1155
1156  PUT RES1 "<tr><td>COST OF HEATING UTILITY <td>($/kW-yr) <td>"HUCOST:12:2/;
1157
1158  PUT RES1 "<tr><td>COST OF COOLING UTILITY   <td>($/kW-yr) <td>"CUCOST:12:2/;
1159
1160  PUT RES1 "<tr><td>FIXED CHARGE FOR EXCHANGER<td>  ($/yr)  <td>"UNITC:12:2/;
1161
1162  PUT RES1 "<tr><td>AREA COST COEFFICIENT FOR EXCHANGERS <td>($/m2) <td>"ACOEFF:12:2/;
1163
1164  PUT RES1 "<tr><td>AREA COST COEFFICIENT FOR HEATERS    <td>($/m2) <td>"HUCOEFF:12:2/;
1165
1166  PUT RES1 "<tr><td>AREA COST COEFFICIENT FOR COOLERS    <td>($/m2) <td>"CUCOEFF:12:2/;
1167
1168  PUT RES1 "<tr><td>AREA COST EXPONENT FOR EXCHANGERS     <td><td>"AEXP:12:2///;
1169
1170  PUT RES1 "</table><p>"/;
1171
1172
1173
1174  PUT RES1 "<p><table border =0 bordercolor=#800000  align=center>"/;
1175
1176  PUT RES1 "<tr><td><b>STAGES <b><td> "NOK:3:0//;
1177
1178  PUT RES1 "</table><table align=center>"/;
1179
1180  PUT RES1 "<tr><td colspan=3><b>MINIMUM APPROACH OF TEMPERATURE (EMAT)</b><td> (K) <td>"T
MAPP:6.2///;
1181
1182  PUT RES1 "</table><p>"/;
1183
1184
1185
1186  PUT RES1 "<p><table border =0 bordercolor=#800000 align=center><td colspan =4><b>FORBIDE
N MATCHES</b>"/;
1187
1188  LOOP(ONE $(M EQ 0 AND MCU EQ 0 AND MHU EQ 0),
1189
1190       PUT RES1 "<td>: NONE"//;
```

```
1191
1192  );
1193
1194  LOOP(ONE $(M GT 0),
1195
1196       PUT RES1 "<tr><td>HOT    <td>COLD"/;
1197
1198       LOOP(I,
1199
1200            LOOP(J $(FORBID(I,J) EQ 1),
1201
1202                 PUT RES1 "<tr><td>"ORD(I):3:0/;
1203
1204                 PUT RES1 "<td>"ORD(J):3:0/;
1205
1206            );
1207
1208       );
1209
1210          PUT RES1 "<tr>"/;
1211
1212  );
1213
1214  LOOP(ONE $(MCU GT 0),
1215
1216       PUT RES1 "<p><tr><td> HOT   <td>COLD UTILITY"/;
1217
1218       LOOP(I$(FORBIDCU(I) EQ 1),
1219
1220                 PUT RES1 "<tr><td>"ORD(I):3:0;
1221
1222                 PUT RES1 "<td>1"/;
1223
1224       );
1225
1226       PUT RES1 "<tr>"//;
1227
1228  );
1229
1230  LOOP(ONE $(MHU GT 0),
1231
1232       PUT RES1 "<p>";
1233
1234       PUT RES1 "<tr><td>COLD <td>   HOT UTILITY"/;
1235
1236       LOOP(J$(FORBIDHU(J) EQ 1),
1237
1238                 PUT RES1 "<tr><td>"ORD(J):3:0;
1239
1240                 PUT RES1 "   <td>      1"/;
1241
1242       );
1243
1244       PUT RES1 "<p>"//;
1245
1246  );
1247
1248  PUT RES1 "</table>"/;
1249
1250
1251
1252  PUT RES1 "<p><table border =0 bordercolor=#800000 align=center><td colspan =4><b>REQUIER
ED MATCHES</b>"/;
```

```
1253
1254  LOOP(ONE $(MR EQ 0 AND MCUR EQ 0 AND MHUR EQ 0),
1255
1256       PUT RES1 "<td>: NONE"//;
1257
1258  );
1259
1260  LOOP(ONE $(MR GT 0),
1261
1262       PUT RES1"<tr>"//;
1263
1264       PUT RES1 "  <td> HOT <td>COLD"/;
1265
1266       LOOP(I,
1267
1268            LOOP(J$(REQUIR(I,J) EQ 1),
1269
1270                 PUT RES1 "<tr><td>"ORD(I):3:0;
1271
1272                 PUT RES1 "<td>"ORD(J):3:0/;
1273
1274            );
1275
1276       );
1277
1278       PUT RES1 "<tr>";
1279
1280  );
1281
1282  LOOP(ONE $(MCUR GT 0),
1283
1284       PUT RES1"<p>"//;
1285
1286       PUT RES1 " <tr><td>HOT  <td>  COLD UTILITY"/;
1287
1288       LOOP(I$(REQUIRCU(I) EQ 1),
1289
1290                 PUT RES1 "<tr><td>"ORD(I):3:0;
1291
1292                 PUT RES1 " <td>1"/;
1293
1294       );
1295
1296       PUT RES1 "<p>"//;
1297
1298  );
1299
1300  LOOP(ONE $(MHUR GT 0),
1301
1302       PUT RES1 "<p><tr>"/;
1303
1304       PUT RES1 " <td>COLD   <td> HOT UTILITY"/;
1305
1306       LOOP(J$(REQUIRHU(J) EQ 1),
1307
1308                 PUT RES1 "<tr><td>"ORD(J):3:0;
1309
1310                 PUT RES1 "  <td>1"/;
1311
1312       );
1313
1314       PUT RES1 //;
1315
```

```
1316  );
1317
1318  PUT RES1 "</table><p>"/;
1319
1320
1321
1322  PUT RES1 "<p><table border =0 bordercolor=#800000 align=center><td colspan =4><b>SPLIT C
ONSTRAINTS</b>"/;
1323
1324  LOOP(ONE $(SPLIT EQ 0),
1325
1326       PUT RES1 "<td>: NONE"//;
1327
1328  );
1329
1330  LOOP(ONE $(SPLIT EQ 2),
1331
1332       PUT RES1 "<tr><td>COLD STREAMS"/;
1333
1334  );
1335
1336  LOOP(ONE $(SPLIT EQ 1),
1337
1338       PUT RES1 "<tr><td>HOT STREAMS"/;
1339
1340  );
1341
1342  LOOP(ONE $(SPLIT EQ 3),
1343
1344       PUT RES1 "<tr><td>COLD AND HOT STREAMS"/;
1345
1346  );
1347
1348  PUT RES1 "</table>"/;
1349
1350
1351
1352
1353
1354  ******PUT RES1 "</table>"/;
1355
1356
1357  PUT RES1 "<table align=center  border =0>"/;
1358
1359  put RES1 "<td><b><h2>   - - - - -  RESULTS  - - - - -   </h2></b></table><p>"/;
1360
1361
1362
1363  PUT RES1 "<p><table border =2 bordercolor=#800000 width=80% align=center><b>MATCHES</b>"
/;
1364
1365  LOOP(K,
1366
1367  LOOP(I,
1368
1369  LOOP(J $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
1370
1371  PUT RES1 "<tr><td colspan =4 align=center><b>STAGE : "ORD(K):3:0/;
1372
1373  EX = EX + 1;
1374
1375  PUT RES1 "HEAT EXCHANGER "EX:3:0//;
1376
```

```
1377  PUT RES1 "</b><tr><td>STREAM<td>Tin (K)<td>Tout (K)<td>FCP(kW/K)"/;
1378
1379  PUT RES1 "<tr><td>HOT  "ORD(I):3:0;
1380
1381  PUT RES1 "<td>"TKI.L(I, K):8:2;
1382
1383  PUT$(SPLH EQ 0) RES1 "<td>"TKI.L(I, K+1):8:2;
1384
1385  PUT$(SPLH EQ 1) RES1 "<td>"TH.L(I,J,K):8:2;
1386
1387  *FCP = Q.L(I,J,K)/(TKI.L(I,K)-TKI.L(I,K+1));
1388  FCP$(TKI.L(I,K) GT TKI.L(I,K+1)) = Q.L(I,J,K)/(TKI.L(I,K)-TKI.L(I,K+1));
1389
1390  FCP$(TKI.L(I,K) EQ TKI.L(I,K+1)) = 0;
1391  PUT$(SUB EQ 0) "<td>"FCP:8:2;
1392
1393  PUT$(SUB EQ 1) "<td>"FH.L(I,J,K):8:2;
1394
1395  PUT RES1 "<tr><td>COLD "ORD(J):3:0;
1396
1397  PUT RES1 "<td>"TKJ.L(J, K+1):8:2;
1398
1399  PUT$(SPLC EQ 1) RES1 "<td>"TC.L(I,J,K):8:2;
1400
1401  PUT$(SPLC EQ 0) RES1 "<td>"TKJ.L(J, K):8:2;
1402
1403  *FCP = Q.L(I,J,K)/(TKJ.L(J,K)-TKJ.L(J,K+1));
1404  FCP$(TKJ.L(J,K) GT TKJ.L(J,K+1)) = Q.L(I,J,K)/(TKJ.L(J,K)-TKJ.L(J,K+1));
1405
1406  FCP$(TKJ.L(J,K) EQ TKJ.L(J,K+1)) = 0;
1407  PUT$(SUB EQ 0) "<td>"FCP:8:2;
1408
1409  PUT$(SUB EQ 1) "<td>"FC.L(I,J,K):8:2;
1410
1411  PUT RES1 "<tr><td><td colspan=2>HEAT LOAD (kW)                    = <td>"Q.L(I,J,K):10:2/
;
1412
1413  PUT RES1 "<tr><td><td colspan=2>AREA BY CHEN APPROXIMATION (m2)  = <td>"AL(I,J,K):10:2/;
1414
1415  PUT RES1 "<tr><td><td colspan=2>AREA BY LOG MEAN (m2)            = <td>"A(I,J,K):10:2///
/;
1416
1417  AREAT = AREAT + AL(I,J,K);
1418
1419  AREAL = AREAL + A(I,J,K);
1420
1421  );
1422
1423  );
1424
1425  );
1426
1427  PUT RES1 "</table>"/;
1428
1429
1430
1431  PUT RES1 "<p><table border =2 bordercolor=#800000 width=80% align=center><b>AREA AND HEA
T LOAD OF HEATERS</b>"/;
1432
1433  PUT RES1 "<td>HEAT EXCHANGER<td>COLD STREAM  <td>AREA(m2) <td>HEAT LOAD(kW)"/;
1434
1435  LOOP(J$(QHOT.L(J) NE 0),
1436
```

```
1437  EX = EX + 1;
1438
1439  PUT RES1 "<tr><td>"EX:3:0;
1440
1441  PUT RES1 "<td>"ORD(J):3:0;
1442
1443  PUT RES1 "<td>"AHU(J):10:2;
1444
1445  PUT RES1 "<td>"QHOT.L(J):10:2/;
1446
1447  );
1448
1449  AREA = SUM(J, AHU(J));
1450
1451  INTER = SUM(J, QHOT.L(J));
1452
1453  PUT RES1 "<tr><td>TOTAL <td><td>"AREA:10:2;
1454
1455  PUT RES1 "<td>"INTER:10:2///;
1456
1457  PUT RES1 "</table>"/;
1458
1459
1460
1461  PUT RES1 "<p><table border =2 bordercolor=#800000 width=80% align=center><b>AREA AND COO
LING LOAD OF COOLERS</b>"/;
1462
1463  PUT RES1 "<td>HEAT EXCHANGER<td>HOT STREAM  <td>AREA(m2) <td>COOLING LOAD(kW)"/;
1464
1465  LOOP(I$(QCOLD.L(I) NE 0),
1466
1467  EX = EX + 1;
1468
1469  PUT RES1 "<tr><td>"EX:3:0;
1470
1471  PUT RES1 "<td>"ORD(I):3:0;
1472
1473  PUT RES1 "<td>"ACU(I):10:2;
1474
1475  PUT RES1 "<td>"QCOLD.L(I):10:2/;
1476
1477  );
1478
1479  AREA = SUM(I, ACU(I));
1480
1481  INTER = SUM(I, QCOLD.L(I));
1482
1483  PUT RES1 "<tr><td>TOTAL       <td><td>"AREA:10:2;
1484
1485  PUT RES1 "<td>"INTER:10:2/;
1486
1487  PUT RES1 "</table>"/;
1488
1489
1490
1491  PUT RES1 "<p><table border=2 bordercolor=#800000 align=center>"/;
1492
1493  PUT RES1 "<tr><td colspan=3><b>TOTAL HEAT LOAD OF UTILITIES (kW) :</b><td>"(SUM(I,QCOLD.
L(I))+SUM(J,QHOT.L(J))):10:2////;
1494
1495  PUT RES1 "<tr><td colspan=3><b>TOTAL NUMBER OF HEAT EXCHANGERS    :</b><td>"EX:3:0//;
1496
1497  PUT RES1 "<tr><td colspan=3><b>TOTAL AREA OF HEAT EXCHANGERS (m2) : </b><td>"(AREAL+SUM(
```

```
I,ACU(I))+SUM(J,AHU(J))):10:2/;
1498
1499  PUT RES1 "<tr><td><td><td colspan=2>HOT AND COLD STREAMS"/;
1500
1501  PUT RES1 "<tr><td><td><td>BY CHEN APPROXIMATION : <td>"AREAT:10:2/;
1502
1503  PUT RES1 "<tr><td><td><td>BY LOG MEAN : <td>"AREAL:10:2/;
1504
1505  PUT RES1 "<tr><td><td><td>UTILITIES : <td>"(SUM(I,ACU(I))+SUM(J,AHU(J))):10:2///;
1506
1507  TOT = COSTHEAT+COSTCOOL;
1508
1509  PUT RES1 "<tr><td colspan=2><b>TOTAL UTILITY COSTS ($/yr)   : </b><td>"TOT:12:2/;
1510
1511  PUT RES1 "<tr><td><td>HEATING                : <td>"COSTHEAT:12:2/;
1512
1513  PUT RES1 "<tr><td><td>COOLING                : <td>"COSTCOOL:12:2///;
1514
1515  PUT RES1 "<tr><td colspan=2><b>INVESTMENT COST ($/yr)      </b> : <td>"INVCOST:12:2///;
1516
1517  TOT = TOT + INVCOST;
1518
1519  PUT RES1 "<tr><td colspan=2><b>TOTAL NETWORK COST ($/yr)   : </b><td>"TOT:12:2;
1520
1521  PUT RES1 "</table><p>"/;
1522
1523
1524
1525
1526
1527
1528
1529  PUT RES1 '<br><table align=center><td class="ref"><A HREF="./../cgi-bin/synheat/graph1.h
tml" target=new_window>Optimal Network Configuration</A>'/;
1530
1531  PUT RES1 '<tr><td class="ref"><A HREF="./../cgi-bin/synheat/graph2.html" target=new_wind
ow>T - Q Curve </A>'/;
1532
1533  PUT RES1 '<tr><td class="ref"><a href="model.pdf" target=new_window>GAMS LIST FILE</a>'/
;
1534
1535  PUT RES1 "</table>"//;
1536
1537
1538
1539
1540
1541  else
1542
1543
1544
1545  PUT RES1 '<br><p><b> THE MODEL DID NOT FIND A FEASIBLE SOLUTION!!</b>';
1546
1547
1548
1549  );
1550
1551
1552
1553  PUT RES1 "</body></html>"//;
1554
1555  PUT RES1 "</table></body></html>"/;
1556
```

```
INCLUDE    /var/www/html/interfaces/cgi-bin/synheat/splot.inc
1558  * HEN Configuration
1559
1560  TIOUT.L(I2)=TIIN.L(I2)-1;
1561  TJOUT.L(J2)=TJIN.L(J2)+1;
1562
1563
1564  PARAMETERS EXN, EXC, EXH, EXM, NH, NC, NE;
1565
1566  EXC = 0;
1567  LOOP(I$(ZCU.L(I) EQ 1 AND QCOLD.L(I) GT 0),
1568    EXC = EXC + 1 ;
1569  );
1570
1571  EXH = 0;
1572  LOOP(J$(ZHU.L(J) EQ 1 AND QHOT.L(J) GT 0),
1573    EXH = EXH + 1 ;
1574  );
1575
1576  EXN = EX - EXC - EXH;
1577  EXM = EXN + 1;
1578
1579  NH =  CARD(I);
1580  NC =  CARD(J);
1581
1582  NE =  NH + NC;
1583
1584  PARAMETERS SSPH(I,K), SSPC(J,K), SPH1(I), SPC1(J), SHK(I,K), SCK(J,K),
1585             SH1(I), SC1(J), SCK3(J,K), SC13(J);
1586
1587  SSPH(I,K)$(ORD(K) NE CARD(K)) = SUM(J$(Q.L(I,J,K) NE 0), Z.L(I,J,K));
1588  SSPC(J,K)$(ORD(K) NE CARD(K)) = SUM(I$(Q.L(I,J,K) NE 0), Z.L(I,J,K));
1589
1590  SPH1(I) = SUM((J,K)$(Q.L(I,J,K) NE 0 AND ORD(K) NE CARD(K)), Z.L(I,J,K));
1591  SPC1(J) = SUM((I,K)$(Q.L(I,J,K) NE 0 AND ORD(K) NE CARD(K)), Z.L(I,J,K));
1592
1593  SHK(I,K)$(ORD(K) NE CARD(K)) = SSPH(I,K)$SSPH(I,K) eq 2;
1594  SCK(J,K)$(ORD(K) NE CARD(K)) = SSPC(J,K)$SSPC(J,K) eq 2;
1595
1596  SH1(I) = SUM(K$(ORD(K) NE CARD(K)), SSPH(I,K)$SSPH(I,K) eq 2);
1597  SC1(J) = SUM(K$(ORD(K) NE CARD(K)), SSPC(J,K)$SSPC(J,K) eq 2);
1598
1599  SCK3(J,K)$(ORD(K) NE CARD(K)) = SSPC(J,K)$SSPC(J,K) eq 3;
1600
1601  SC13(J) = SUM(K$(ORD(K) NE CARD(K)), SSPC(J,K)$SSPC(J,K) eq 3);
1602
1603  DISPLAY SSPH, SSPC, SPH1, SPC1, SHK, SCK, SH1, SC1, SCK3, SC13;
1604
1605  PARAMETER SSC1(K),  SSC2(K), SSC3(K), SSC4(K);
1606
1607  LOOP(K,
1608   LOOP(J,
1609     LOOP(I $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
1610        if(sc1(j) eq 1 and sck(j,k) eq 1,
1611           if(sspc(j,k) eq 2 and ssph(i,k) eq 2,
1612            if(ssph(i+1,k) eq 1,
1613            SSC1(k)  = 1;
1614            );
1615            if(sspc(j-1,k) eq 1,
1616            SSC2(k)  = 1;
1617            );
1618           );
1619           if(sspc(j,k) eq 2 and ssph(i,k) eq 1,
```

```
1620            if(ssph(i-1,k) eq 2,
1621            SSC3(k)  = 1;
1622            );
1623            if(sspc(j-1,k) eq 1,
1624            SSC4(k)  = 1;
1625            );
1626           );
1627          );
1628      );
1629    );
1630  );
1631  DISPLAY SSC1, SSC2, SSC3, SSC4;
1632
1633  PARAMETERS LC10, BS, EXNY, LC5;
1634  FILE RES16 /si/;
1635  PUT RES16 "#COLD SPLIT"/;
1636  PUT RES16;
1637  EXNY  = 0;
1638  LOOP(K,
1639  LC5  = 0;
1640   LOOP(J,
1641   LC10 = 0;
1642   BS   = 0;
1643     LOOP(I $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
1644        EXNY = EXNY + 1;
1645        if(sc1(j) ne 1 and sc1(j) ne 2,
1646        PUT RES16 "0";
1647        PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
1648        PUT RES16 ""(EXM):5:2;
1649        PUT RES16 "     "(NC - ORD(J) + 1):5:2//;
1650        );
            if(sc1(j) eq 1 and sck(j,k) eq 1,
               PUT RES16 "0";
               PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
               PUT RES16 ""(EXNY - 1/3 - BS):5:2;
               PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
               PUT RES16 ""(EXNY - BS):5:2;
               PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
               if(sspc(j,k) eq 2 and ssph(i,k) eq 2,
                if(ssph(i+1,k) eq 1,
                 PUT RES16 ""(EXNY + 2  - BS):5:2;
                 PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                 PUT RES16 ""(EXNY + 2 + 1/3 - BS):5:2;
                 PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                );
                if(ssph(i+1,k) ne 1,
                 PUT RES16 ""(EXNY + 1  - BS):5:2;
                 PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                 PUT RES16 ""(EXNY + 1 + 1/3 - BS):5:2;
                 PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                );
               );
               if(sspc(j,k) eq 2 and ssph(i,k) eq 1,
                if(ssph(i-1,k) ne 2,
                  PUT RES16 ""(EXNY + 1  - BS):5:2;
                  PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                  PUT RES16 ""(EXNY + 1 + 1/3 - BS):5:2;
                  PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                );
               if(ssph(i-1,k) eq 2,
                  PUT RES16 ""(EXNY + 2 - BS):5:2;
                  PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                  PUT RES16 ""(EXNY + 2 + 1/3 - BS):5:2;
```

```
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
               );
              );
              PUT RES16 ""(EXM):5:2;
              PUT RES16 "     "(NC - ORD(J) + 1):5:2//;
            );
1691        if(sc1(j) eq 1 and sck(j,k) eq 1,
               PUT RES16 "0";
               PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
               PUT RES16 ""(EXNY - 1/3 - BS):5:2;
               PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
               PUT RES16 ""(EXNY - BS):5:2;
               PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
               if(ssc1(k) eq 1  and ssc3(k) eq 1 and ssc2(k) eq 0 and ssc4(k) eq 0,
                PUT RES16 ""(EXNY + 2  - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                PUT RES16 ""(EXNY + 2 + 1/3 - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
               );
               if(ssc1(k) eq 1  and ssc3(k) eq 1 and ssc2(k) eq 1 and ssc4(k) eq 1,
                PUT RES16 ""(EXNY + 1  - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                PUT RES16 ""(EXNY + 1 + 1/3 - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
               );
               if(ssc1(k) eq 0  and ssc3(k) eq 0 and ssc2(k) eq 0 and ssc4(k) eq 0,
                PUT RES16 ""(EXNY + 1  - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                PUT RES16 ""(EXNY + 1 + 1/3 - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
               );
              PUT RES16 ""(EXM):5:2;
              PUT RES16 "     "(NC - ORD(J) + 1):5:2//;
            );
1719        if(sc1(j) eq 2 and sck(j,k) eq 1,
             if(sspc(j,k) eq 2,
              if (ssph(i,k) eq 2,
                PUT RES16 ""(EXNY  - 1 - 1/3):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                PUT RES16 ""(EXNY  - 1/3 - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                PUT RES16 ""(EXNY - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                PUT RES16 ""(EXNY + 2 - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                PUT RES16 ""(EXNY + 2 + 1/3 - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                PUT RES16 ""(EXNY + 2 + 1/3):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                PUT RES16 ""(EXNY + 3 - 1/3):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2//;
               );
              if (ssph(i,k) eq 1,
                PUT RES16 ""(EXNY  - 1/3 - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                PUT RES16 ""(EXNY - BS):5:2;
                PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                if(ssph(i-1,k) ne 2,
                 PUT RES16 ""(EXNY + 1 - BS):5:2;
                 PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
                 PUT RES16 ""(EXNY + 1 + 1/3 - BS):5:2;
                 PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
                );
```

```
1748             if(ssph(i-1,k) eq 2,
1749              PUT RES16 ""(EXNY + 2 - BS):5:2;
1750              PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2/;
1751              PUT RES16 ""(EXNY + 2 + 1/3 - BS):5:2;
1752              PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
1753             );
1754              PUT RES16 ""(EXNY + 1 + 1/3):5:2;
1755              PUT RES16 "     "(NC - ORD(J) + 1):5:2//;
1756            );
1757          );
1758        );
1759        if(sc13(j) eq 1 and sck3(j,k) eq 1,
1760            PUT RES16 ""(EXNY  - 1/3 - BS):5:2;
1761            PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
1762            PUT RES16 ""(EXNY - BS):5:2;
1763            PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC5):5:2/;
1764            PUT RES16 ""(EXNY + 2 - BS):5:2;
1765            PUT RES16 "     "(NC - ORD(J) + 1 + 1/4 - LC5):5:2/;
1766            PUT RES16 ""(EXNY + 2 + 1/3 - BS):5:2;
1767            PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
1768            PUT RES16 ""(EXNY + 1 + 1/3):5:2;
1769            PUT RES16 "     "(NC - ORD(J) + 1):5:2//;
1770        );
1771        LC10 = LC10 + 1/2;
1772        BS   = BS   + 1;
1773        LC5  = LC5  + 1/4;
1774      );
1775    );
1776  );
1777  LOOP(J$(SPC1(J) EQ 0 or SPC1(J) LT 1),
1778  PUT RES16 "0";
1779  PUT RES16 "     "(NC - ORD(J) + 1):5:2/;
1780  PUT RES16 ""(EXM):3:0;
1781  PUT RES16 "     "(NC - ORD(J) + 1):5:2//;
1782  );
1783
1784  PARAMETERS LCE2,LOC1, LCE3, HS;
1785  FILE RES17 /fi/;
1786  PUT RES17 "#HOT SPLIT"/;
1787  PUT RES17;
1788  EXN  = 0;
1789  LOOP(K$(ORD(K) NE CARD(K)),
1790  LCE2 = NE + 0.25;
1791  LOC1 = NE ;
1792   LOOP(I,
1793   HS   = 0;
1794   LCE3 = 0;
1795    LOOP(J $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
1796    EXN  = EXN +1;
1797         if(sh1(i) ne 1 and sh1(i) ne 2,
1798          PUT RES17 "0";
1799          PUT RES17 "     "LOC1:5:2/;
1800          PUT RES17 ""(EXM):5:2;
1801          PUT RES17 "     "(LOC1):5:2//;
1802          );
1803         if(sh1(i) eq 1 and shk(i,k) eq 1,
1804          PUT RES17 "0";
1805          PUT RES17 "     "LOC1:5:2/;
1806          PUT RES17 ""(EXN - 1/3 - HS):5:2;
1807          PUT RES17 "     "(LOC1):5:2/;
1808          PUT RES17 ""(EXN - HS):5:2;
1809          PUT RES17 "     "(LCE2 - LCE3):5:2/;
1810          PUT RES17 ""(EXN + 1 - HS):5:2;
```

```
1811          PUT RES17 "     "(LCE2 - LCE3):5:2/;
1812          PUT RES17 ""(EXN + 1 + 1/3 - HS):5:2;
1813          PUT RES17 "     "(LOC1):5:2/;
1814          PUT RES17 ""(EXM):5:2;
1815          PUT RES17 "     "(LOC1):5:2//;
1816         );
1817         if(sh1(i) eq 2 and shk(i,k) eq 1,
1818          PUT RES17 ""(EXN - 1 - 1/3):5:2;
1819          PUT RES17 "     "LOC1:5:2/;
1820          PUT RES17 ""(EXN - 1/3 - HS):5:2;
1821          PUT RES17 "     "(LOC1):5:2/;
1822          PUT RES17 ""(EXN - HS):5:2;
1823          PUT RES17 "     "(LCE2 - LCE3):5:2/;
1824          PUT RES17 ""(EXN + 1 - HS):5:2;
1825          PUT RES17 "     "(LCE2 - LCE3):5:2/;
1826          PUT RES17 ""(EXN + 1 + 1/3 - HS):5:2;
1827          PUT RES17 "     "(LOC1):5:2/;
1828          PUT RES17 ""(EXN + 1 + 1/3):5:2;
1829          PUT RES17 "     "(LOC1):5:2//;
1830          );
1831          LCE3 = LCE3 + 1/2;
1832          HS   = HS + 1;
1833       );
1834       LCE2 = LCE2 - 1;
1835       LOC1 = LOC1 - 1;
1836     );
1837  );
1838  LOOP(I$(SPH1(I) EQ 0 or SPH1(I) LT 1),
1839  PUT RES17 "0";
1840  PUT RES17 "     "(NE - ORD(I) + 1):5:2/;
1841  PUT RES17 ""(EXM):3:0;
1842  PUT RES17 "     "(NE - ORD(I) + 1):5:2//;
1843  );
1844
1845  PARAMETERS AY, LOCE1, LOCE2, LOC10, LOCE3, LC1, LC10;
1846  FILE RES6 /ei/;
1847  PUT RES6;
1848  EXN = 0;
1849  LOOP(K,
1850  AY = 0;
1851  LOCE1 = NE;
1852  LOCE2 = NE + 0.25;
1853  LOC10 = 0;
1854  LC10  = 0;
1855  LC1   = 0;
1856   LOOP(I,
1857    LOCE3 = 0;
1858    LOOP(J $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
1859    EXN = EXN +1;
1860    if (ssph(i,k) eq 1,
1861      if(sspc(j,k) eq 1,
1862       PUT RES6 ""(EXN):3:0;
1863       PUT RES6 "     "(LOCE1):5:2/;
1864       PUT RES6 ""(EXN):3:0;
1865       PUT RES6 "     "(NC - ORD(J) + 1):2:0//;
1866      );
1867      if(sspc(j,k) eq 2,
1868       PUT RES6 ""(EXN):5:2;
1869       PUT RES6 "     "(LOCE1):5:2/;
1870       PUT RES6 ""(EXN):5:2;
1871       PUT RES6 "     "(NC - ORD(J) + 1 + 1/4 - LOC10 + LC1):5:2//;
1872      );
1873      if(sspc(j,k) eq 3,
```

```
1874       PUT RES6 ""(EXN):5:2;
1875       PUT RES6 "     "(LOCE1):5:2/;
1876       PUT RES6 ""(EXN):5:2;
1877       PUT RES6 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2//;
1878      );
1879    );
1880    if (ssph(i,k) eq 2,
1881      if(sspc(j,k) eq 3,
1882       PUT RES6 ""(EXN - AY):5:2;
1883       PUT RES6 "     "(LOCE2 - LOCE3):5:2/;
1884       PUT RES6 ""(EXN - AY):5:2;
1885       PUT RES6 "     "(NC - ORD(J) + 1 + 1/4 - LC10):5:2//;
1886      );
1887      if(sspc(j,k) eq 2,
1888       PUT RES6 ""(EXN - AY):5:2;
1889       PUT RES6 "     "(LOCE2 - LOCE3):5:2/;
1890       PUT RES6 ""(EXN - AY):5:2;
1891       PUT RES6 "     "(NC - ORD(J) + 1 + 1/4 - LOC10 + LC1):5:2//;
1892      );
1893      if(sspc(j,k) eq 1,
1894       PUT RES6 ""(EXN - AY):5:2;
1895       PUT RES6 "     "(LOCE2 - LOCE3):5:2/;
1896       PUT RES6 ""(EXN - AY):5:2;
1897       PUT RES6 "     "(NC - ORD(J) + 1):2:0// ;
1898      );
1899    );
1900    LOCE3 = LOCE3 + 1/2;
1901    LC10  = LC10  + 1/4;
1902    LOC10 = LOC10 + 1/2;
1903    LC1   = LOC10 - 1/2;
1904    );
1905    LOCE1 = LOCE1 - 1;
1906    LOCE2 = LOCE2 - 1;
1907   );
1908   AY = AY + 1/4;
1909  );
1910
1911  PARAMETERS L1, L2;
1912  FILE RES7 /ci/;
1913  PUT RES7;
1914  L1 = NE - NH;
1915  LOOP(J,
1916    PUT RES7 "0";
1917    PUT RES7 "     "(L1):6:2/;
1918    PUT RES7 "0.05";
1919    PUT RES7 "     "(L1+0.03):6:2//;
1920    PUT RES7 "0";
1921    PUT RES7 "     "(L1):6:2/;
1922    PUT RES7 "0.05";
1923    PUT RES7 "     "(L1-0.03):6:2//;
1924    L1 = L1 - 1;
1925  );
1926
1927  FILE RES8 /hi/;
1928  PUT RES8;
1929  L2 = NE;
1930  LOOP(I,
1931    PUT RES8 ""(EXN+1):3:0;
1932    PUT RES8 "     "(L2):6:2/;
1933    PUT RES8 ""(EXN+1-0.05):7:2;
1934    PUT RES8 "     "(L2+0.03):6:2//;
1935    PUT RES8 ""(EXN+1):3:0;
1936    PUT RES8 "     "(L2):6:2/;
```

```
1937    PUT RES8 ""(EXN+1-0.05):7:2;
1938    PUT RES8 "     "(L2-0.03):6:2//;
1939    L2 = L2 - 1;
1940  );
1941
1942  FILE RES9 /ui/;
1943  PUT RES9;
1944  PUT RES9 "#COLD UTILITY"/;
1945  LOOP(I$(QCOLD.L(I) NE 0),
1946    PUT RES9 ""(EXN+0.7):5:2;
1947    PUT RES9 "     "(NE - ORD(I) + 1):2:0/;
1948    );
1949
1950  FILE RES11 /ai/;
1951  PUT RES11;
1952  PUT RES11 "#COLD UTILITY"/;
1953  LOOP(I$(QCOLD.L(I) NE 0),
1954    PUT RES11 ""(EXN+0.7):5:2;
1955    PUT RES11 "     "(NE - ORD(I) + 1 - 0.2):6:2/;
1956    PUT RES11 ""(EXN+0.7):5:2;
1957    PUT RES11 "     "(NE - ORD(I) + 1 + 0.2):6:2//;
1958    PUT RES11 ""(EXN+0.73):5:2;
1959    PUT RES11 "     "(NE - ORD(I) + 1 - 0.1):6:2/;
1960    PUT RES11 ""(EXN+0.7):5:2;
1961    PUT RES11 "     "(NE - ORD(I) + 1 - 0.2):6:2//;
1962    PUT RES11 ""(EXN+0.67):5:2;
1963    PUT RES11 "     "(NE - ORD(I) + 1 - 0.1):6:2/;
1964    PUT RES11 ""(EXN+0.7):5:2;
1965    PUT RES11 "     "(NE - ORD(I) + 1 - 0.2):6:2//;
1966  );
1967
1968  FILE RES10 /yi/;
1969  PUT RES10;
1970  PUT RES10 "#HOT UTILITY"/;
1971  LOOP(J$(QHOT.L(J) NE 0),
1972    PUT RES10 "0.3";
1973    PUT RES10 "     "(NC - ORD(J) + 1):2:0/;
1974  );
1975
1976  FILE RES12 /bi/;
1977  PUT RES12;
1978  PUT RES12 "#HOT UTILITY"/;
1979  LOOP(J$(QHOT.L(J) NE 0),
1980    PUT RES12 "0.3";
1981    PUT RES12 "     "(NC - ORD(J) + 1 - 0.2):6:2/;
1982    PUT RES12 "0.3";
1983    PUT RES12 "     "(NC - ORD(J) + 1 + 0.2):6:2//;
1984    PUT RES12 "0.33";
1985    PUT RES12 "     "(NC - ORD(J) + 1 + 0.1):6:2/;
1986    PUT RES12 "0.3";
1987    PUT RES12 "     "(NC - ORD(J) + 1 + 0.2):6:2//;
1988    PUT RES12 "0.27";
1989    PUT RES12 "     "(NC - ORD(J) + 1 + 0.1):6:2/;
1990    PUT RES12 "0.3";
1991    PUT RES12 "     "(NC - ORD(J) + 1 + 0.2):6:2//;
1992  );
1993
1994  PARAMETERS LOC4, LOC51, LOC5, LOCE52, LOCE53, LOC7, LOC52, AYN, LOC21,
1995             LOC22, AYK, AYM, LOC7, AYN, LOC15, LOC6, LOCE5, LOC13,
1996             LOC8, LC2, LC15, LC13, is, js, LOC131;
1997  FILE RES5 /synheat.dem/;
1998  PUT RES5;
1999  PUT RES5 "set noborder"/;
```

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2000  *PUT RES5 "set terminal windows"/;
2001  PUT RES5 "set noyzeroaxis"/;
2002  PUT RES5 "set noxzeroaxis"/;
2003  PUT RES5 "set noxtics"/;
2004  PUT RES5 "set noytics"/;
2005  PUT RES5 "set nokey"/;
2006  PUT RES5 "set nogrid"/;
2007  PUT RES5 "set yrange [ 0 : ";
2008  PUT RES5 " "(NE+1):2:0;
2009  PUT RES5 " ]"/;
2010  PUT RES5 "set xrange [ 0";
2011  PUT RES5 " : "(EXN+1):3:0;
2012  PUT RES5 " ]"/;
2013  PUT RES5 "set style line 1 lt 1 lw 1 lc rgb 'red'" /;
2014  PUT RES5 "set style line 2 lt 1 lw 1 lc rgb 'blue'" /;
2015  PUT RES5 "set style line 3 lt 1 lw 1 lc rgb 'black'" /;
2016  LOC4 = NE + 0.15;
2017  LOOP(I,
2018  PUT RES5 "set label";
2019  PUT RES5 " '"TIIN.L(I):6:1;
2020  PUT RES5 "'";
2021  PUT RES5 " at 0";
2022  PUT RES5 " , "LOC4:6:3;
2023  PUT RES5 " left"/;
2024  PUT RES5 "set label";
2025  PUT RES5 " '"TIOUT.L(I):6:1;
2026  PUT RES5 "'";
2027  PUT RES5 " at "(EXN+1):3:0;
2028  PUT RES5 " , "LOC4:6:3;
2029  PUT RES5 " right"/;
2030  LOC4 = LOC4 - 1;
2031  );
2032  LOC51 = NE - 0.15;
2033  LOOP(I,
2034  PUT RES5 "set label";
2035  PUT RES5 " '"FCI(I):8:1;
2036  PUT RES5 "'";
2037  PUT RES5 " at 0";
2038  PUT RES5 " , "LOC51:6:3;
2039  PUT RES5 " left"/;
2040  LOC51 = LOC51 - 1;
2041  );
2042  EXN = 0;
2043  LOOP(K,
2044   AYM = 0;
2045   LOC5 = NE + 0.15;
2046   LOCE52 = NE + 0.3;
2047   LOOP(I,
2048    LOCE53 = 0;
2049    is = 0;
2050    LOOP(J $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
2051    EXN = EXN +1;
2052    is  = is  +1;
2053     IF(SPLH EQ 0,
2054       if(TKI.L(I,K+1) NE TIIN.L(I) AND TKI.L(I,K+1) NE TIOUT.L(I),
2055       PUT$(ssph(i,k) eq 1) RES5 "set label";
2056       PUT$(ssph(i,k) eq 1) RES5 " '"TKI.L(I, K+1):6:1;
2057       PUT$(ssph(i,k) eq 1) RES5 "'";
2058       PUT$(ssph(i,k) eq 1) RES5 " at "(EXN + 0.5):5:2;
2059       PUT$(ssph(i,k) eq 1) RES5 " , "LOC5:6:3;
2060       PUT$(ssph(i,k) eq 1) RES5 " center"/  ;
2061       );
2062       PUT$(ssph(i,k) eq 2) RES5 "set label";
```

```
2063       PUT$(ssph(i,k) eq 2) RES5 " '"TKI.L(I, K+1):6:1;
2064       PUT$(ssph(i,k) eq 2) RES5 "'";
2065       PUT$(ssph(i,k) eq 2) RES5 " at "(EXN + 0.35 - AYM):5:2;
2066       PUT$(ssph(i,k) eq 2) RES5 " , "(LOCE52-LOCE53 + 0.05):6:3;
2067       PUT$(ssph(i,k) eq 2) RES5 " center"/;
2068
2069       PUT$(ssph(i,k) eq 2) RES5 "set label";
2070       PUT$(ssph(i,k) eq 2) RES5 " '"TKI.L(I, K):6:1;
2071       PUT$(ssph(i,k) eq 2) RES5 "'";
2072       PUT$(ssph(i,k) eq 2) RES5 " at "(EXN - 0.35 - AYM):5:2;
2073       PUT$(ssph(i,k) eq 2) RES5 " , "(LOCE52-LOCE53 + 0.05):6:3;
2074       PUT$(ssph(i,k) eq 2) RES5 " center"/;
2075
2076       if(is eq 2 and ssph(i,k) eq 2 and TKI.L(I,K+1) NE TIIN.L(I) and TKI.L(I,K+1) NE TIO
UT.L(I),
2077       PUT RES5 "set label";
2078       PUT RES5 " '"TKI.L(I, K+1):6:1;
2079       PUT RES5 "'";
2080       PUT RES5 " at "(EXN + 0.5 - AYM):5:2;
2081       PUT RES5 " , "(LOC5):6:3;
2082       PUT RES5 " center"/;
2083       );
2084
2085      );
2086     IF(SPLH EQ 1,
2087        if(TH.L(I,J,K) NE TIIN.L(I) AND TH.L(I,J,K) NE TIOUT.L(I),
2088       PUT$(ssph(i,k) eq 1) RES5 "set label";
2089       PUT$(ssph(i,k) eq 1) RES5 " '"TH.L(I,J,K):6:1;
2090       PUT$(ssph(i,k) eq 1) RES5 "'";
2091       PUT$(ssph(i,k) eq 1) RES5 " at "(EXN - 2):5:2;
2092       PUT$(ssph(i,k) eq 1) RES5 " , "LOC5:6:3;
2093       PUT$(ssph(i,k) eq 1) RES5 " center"/;
2094        );
2095       PUT$(ssph(i,k) eq 2) RES5 "set label";
2096       PUT$(ssph(i,k) eq 2) RES5 " '"TH.L(I,J,K):6:1;
2097       PUT$(ssph(i,k) eq 2) RES5 "'";
2098       PUT$(ssph(i,k) eq 2) RES5 " at "(EXN + 0.7 - AYM):5:2;
2099       PUT$(ssph(i,k) eq 2) RES5 " , "(LOCE52-LOCE53 + 0.05):6:3;
2100       PUT$(ssph(i,k) eq 2) RES5 " center"/;
2101
2102       PUT$(ssph(i,k) eq 2) RES5 "set label";
2103       PUT$(ssph(i,k) eq 2) RES5 " '"TKI.L(I, K):6:1;
2104       PUT$(ssph(i,k) eq 2) RES5 "'";
2105       PUT$(ssph(i,k) eq 2) RES5 " at "100:5:2;
2106       PUT$(ssph(i,k) eq 2) RES5 " , "(LOCE52-LOCE53 + 0.05):6:3;
2107       PUT$(ssph(i,k) eq 2) RES5 " center"/;
2108
2109       if(is eq 2 and ssph(i,k) eq 2 and TKI.L(I,K+1) NE TIIN.L(I) and TKI.L(I,K+1) NE TIO
UT.L(I),
2110       PUT RES5 "set label";
2111       PUT RES5 " '"TKI.L(I,K+1):6:1;
2112       PUT RES5 "'";
2113       PUT RES5 " at "(EXN + 0.5 - AYM):5:2;
2114       PUT RES5 " , "(LOC5):6:3;
2115       PUT RES5 " center"/;
2116       );
2117
2118      );
2119      LOCE53 = LOCE53 + 1/2;
2120     );
2121    LOC5 = LOC5 - 1;
2122    LOCE52 = LOCE52 - 1;
2123   );
```

```
2124    AYM = AYM + 1/4;
2125  );
2126  LOC7 = NE;
2127  LOOP(I,
2128  PUT RES5 "set label";
2129  PUT RES5 " ’ H"ORD(I):2:0;
2130  PUT RES5 "’";
2131  PUT RES5 " at 0.01";
2132  PUT RES5 " , "LOC7:6:3;
2133  PUT RES5 " right"/;
2134  LOC7 = LOC7 - 1;
2135  );
2136  EXN = 0;
2137  LOOP(K,
2138   AYN = 0;
2139   LOC52 = NE + 0.15;
2140   LOC21 = NE + 0.35;
2141   LOOP(I,
2142    LOC22 = 0;
2143    LOOP(J $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
2144    EXN = EXN +1;
2145    IF(ssph(i,k) eq 1,
2146     PUT RES5 "set label";
2147     PUT RES5 " ’"Q.L(I,J,K):7:1;
2148     PUT RES5 " kW’";
2149     PUT RES5 " at "(EXN):5:2;
2150     PUT RES5 " , "(LOC52):6:2;
2151     PUT RES5 " center"/;
2152    );
2153    if(ssph(i,k) eq 2,
2154     PUT RES5 "set label";
2155     PUT RES5 " ’"Q.L(I,J,K):7:1;
2156     PUT RES5 " kW’";
2157     PUT RES5 " at "(EXN - AYN):5:2;
2158     PUT RES5 " , "(LOC21 - LOC22):6:2;
2159     PUT RES5 " center"/;
2160    );
2161   LOC22 = LOC22 + 1/2;
2162   );
2163  LOC52 = LOC52 - 1;
2164  LOC21 = LOC21 - 1;
2165   );
2166  AYN = AYN + 1/4;
2167  );
2168  EXN = 0;
2169  LOOP(K,
2170   AYK = 0;
2171   LOC15 = 0;
2172   LC2   = 0;
2173   LC15  = 0;
2174   LOOP(I,
2175    LOOP(J $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
2176    EXN = EXN +1;
2177    if(sph(i,k) eq 1 and sspc(j,k) eq 1,
2178    PUT RES5 "set label";
2179    PUT RES5 " ’"A(I,J,K):7:1;
2180    PUT RES5 " m2’";
2181    PUT RES5 " at "(EXN):5:2;
2182    PUT RES5 " , "(NC - ORD(J) + 1 - 0.15):6:2;
2183    PUT RES5 " center"/;
2184    );
2185    if(sph(i,k) eq 1 and sspc(j,k) eq 2,
2186    PUT RES5 "set label";
```

```
2187    PUT RES5 " ’"A(I,J,K):7:1;
2188    PUT RES5 " m2’";
2189    PUT RES5 " at "(EXN):5:2;
2190    PUT RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC15 + LC2 - 0.15):6:2;
2191    PUT RES5 " center"/;
2192    );
2193    if(sph(i,k) eq 1 and sspc(j,k) eq 3,
2194    PUT RES5 "set label";
2195    PUT RES5 " ’"A(I,J,K):7:1;
2196    PUT RES5 " m2’";
2197    PUT RES5 " at "(EXN):5:2;
2198    PUT RES5 " , "(NC - ORD(J) + 1 + 1/4 - LC15 - 0.15):6:2;
2199    PUT RES5 " center"/;
2200    );
2201    if(sph(i,k) eq 2 and sspc(j,k) eq 1,
2202    PUT RES5 "set label";
2203    PUT RES5 " ’"A(I,J,K):7:1;
2204    PUT RES5 " m2’";
2205    PUT RES5 " at "(EXN - AYK):5:2;
2206    PUT RES5 " , "(NC - ORD(J) + 1 - 0.15):6:2;
2207    PUT RES5 " center"/;
2208    );
2209    if(sph(i,k) eq 2 and sspc(j,k) eq 2,
2210    PUT RES5 "set label";
2211    PUT RES5 " ’"A(I,J,K):7:1;
2212    PUT RES5 " m2’";
2213    PUT RES5 " at "(EXN - AYK):5:2;
2214    PUT RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC15 + LC2 - 0.15):6:2;
2215    PUT RES5 " center"/;
2216    );
2217    LOC15 = LOC15 + 1/2;
2218    LC2   = LOC15 - 1/2;
2219    LC15  = LC15  + 1/4;
2220     );
2221   );
2222   AYK = AYK + 1/4;
2223  );
2224  LOOP(I$(QCOLD.L(I) NE 0),
2225  PUT RES5 "set label";
2226  PUT RES5 " ’W’";
2227  PUT RES5 " at "(EXN+0.7):5:2;
2228  PUT RES5 " , "(NE - ORD(I) + 1 + 0.4):6:2;
2229  PUT RES5 " center"/;
2230  );
2231  LOOP(J$(QHOT.L(J) NE 0),
2232  PUT RES5 "set label";
2233  PUT RES5 " ’S’";
2234  PUT RES5 " at 0.3";
2235  PUT RES5 " , "(NC - ORD(J) + 1 - 0.3):6:2;
2236  PUT RES5 " center"/;
2237  );
2238  LOOP(I$(QCOLD.L(I) NE 0),
2239  PUT RES5 "set label";
2240  PUT RES5 " ’"QCOLD.L(I):6:1;
2241  PUT RES5 " kW’";
2242  PUT RES5 " at "(EXN+0.7):5:2;
2243  PUT RES5 " , "(NE - ORD(I) + 1 - 0.3):6:2;
2244  PUT RES5 " center"/;
2245  );
2246  LOOP(J$(QHOT.L(J) NE 0),
2247  PUT RES5 "set label";
2248  PUT RES5 " ’"QHOT.L(J):6:1;
2249  PUT RES5 " kW’";
```

```
2250  PUT RES5 " at 0.3";
2251  PUT RES5 " , "(NC - ORD(J) + 1 + 0.4):6:2;
2252  PUT RES5 " center"/;
2253  );
2254  LOC6 = NE - NH + 0.15;
2255  LOOP(J,
2256  PUT RES5 "set label";
2257  PUT RES5 " '"TJIN.L(J):6:1;
2258  PUT RES5 "'";
2259  PUT RES5 " at "(EXN+1):3:0;
2260  PUT RES5 " , "LOC6:6:3;
2261  PUT RES5 " right"/;
2262  PUT RES5 "set label";
2263  PUT RES5 " '"TJOUT.L(J):6:1;
2264  PUT RES5 "'";
2265  PUT RES5 " at 0";
2266  PUT RES5 " , "LOC6:6:3;
2267  PUT RES5 " left"/;
2268  LOC6 = LOC6 - 1;
2269  );
2270  LOCE5 = NE - NH - 0.15;
2271  LOOP(J,
2272  PUT RES5 "set label";
2273  PUT RES5 " '"FCJ(J):8:1;
2274  PUT RES5 "'";
2275  PUT RES5 " at "(EXN+1):3:0;
2276  PUT RES5 " , "LOCE5:6:3;
2277  PUT RES5 " right"/;
2278  LOCE5 = LOCE5 - 1;
2279  );
2280  EXN = 0;
2281  LOOP(K,
2282   js = 0;
2283   LOC13  = 0;
2284   LC13   = 0;
2285   LOC131 = 0;
2286   LOOP(I,
2287    LOOP(J $((Z.L(I,J,K) EQ 1) AND (Q.L(I,J,K) NE 0)),
2288    EXN = EXN +1;
2289    js = js + 1;
2290    IF(SPLC EQ 0,
2291        if(TKJ.L(J,K) NE TJIN.L(J) AND TKJ.L(J,K) NE TJOUT.L(J),
2292       PUT$(sspc(j,k) eq 1) RES5 "set label";
2293       PUT$(sspc(j,k) eq 1) RES5 " '"TKJ.L(J, K):6:1;
2294       PUT$(sspc(j,k) eq 1) RES5 "'";
2295       PUT$(sspc(j,k) eq 1) RES5 " at "(EXN - 0.5):5:2;
2296       PUT$(sspc(j,k) eq 1) RES5 " , "(NC - ORD(J) + 1 + 0.15):6:3;
2297       PUT$(sspc(j,k) eq 1) RES5 " center"/;
2298         );
2299       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 "set label";
2300       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " '"TKJ.L(J, K):6:1;
2301       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 "'";
2302       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " at "(EXN - 0.25):5:2;
2303       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC131
 + 0.07):6:3;
2304       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " center"/;
2305
2306       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 "set label";
2307       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " '"TKJ.L(J, K+1):6:1;
2308       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 "'";
2309       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " at "(EXN + 0.25):5:2;
2310       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC131
 + 0.07):6:3;
```

```
2311       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " center"/;
2312
2313       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 "set label";
2314       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " '"TKJ.L(J, K):6:1;
2315       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 "'";
2316       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " at "(EXN - 0.25):5:2;
2317       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC13
+ 0.07):6:3;
2318       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " center"/;
2319
2320       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 "set label";
2321       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " '"TKJ.L(J, K+1):6:1;
2322       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 "'";
2323       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " at "(EXN + 0.25):5:2;
2324       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC13
+ 0.07):6:3;
2325       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " center"/;
2326
2327       if(js eq 1 and TKJ.L(J, K) NE TJOUT.L(J) and TKJ.L(J, K) NE TJIN.L(J),
2328       PUT$(sspc(j,k) eq 2) RES5 "set label";
2329       PUT$(sspc(j,k) eq 2) RES5 " '"TKJ.L(J, K):6:1;
2330       PUT$(sspc(j,k) eq 2) RES5 "'";
2331       PUT$(sspc(j,k) eq 2) RES5 " at "(EXN - 0.5):5:2;
2332       PUT$(sspc(j,k) eq 2) RES5 " , "(NC - ORD(J) + 1 + 0.15):6:3;
2333       PUT$(sspc(j,k) eq 2) RES5 " center"/;
2334         );
2335       if(js eq 1 and TKJ.L(J, K) NE TJOUT.L(J) and TKJ.L(J, K) NE TJIN.L(J),
2336       PUT$(sspc(j,k) eq 3) RES5 "set label";
2337       PUT$(sspc(j,k) eq 3) RES5 " '"TKJ.L(J, K):6:1;
2338       PUT$(sspc(j,k) eq 3) RES5 "'";
2339       PUT$(sspc(j,k) eq 3) RES5 " at "(EXN - 0.5):5:2;
2340       PUT$(sspc(j,k) eq 3) RES5 " , "(NC - ORD(J) + 1 + 0.15):6:3;
2341       PUT$(sspc(j,k) eq 3) RES5 " center"/;
2342         );
2343       PUT$(sspc(j,k) eq 3) RES5 "set label";
2344       PUT$(sspc(j,k) eq 3) RES5 " '"TKJ.L(J, K):6:1;
2345       PUT$(sspc(j,k) eq 3) RES5 "'";
2346       PUT$(sspc(j,k) eq 3) RES5 " at "(EXN - 0.25):5:2;
2347       PUT$(sspc(j,k) eq 3) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LC13 + 0.07):6:3;
2348       PUT$(sspc(j,k) eq 3) RES5 " center"/;
2349
2350       PUT$(sspc(j,k) eq 3) RES5 "set label";
2351       PUT$(sspc(j,k) eq 3) RES5 " '"TKJ.L(J, K+1):6:1;
2352       PUT$(sspc(j,k) eq 3) RES5 "'";
2353       PUT$(sspc(j,k) eq 3) RES5 " at "(EXN + 0.25):5:2;
2354       PUT$(sspc(j,k) eq 3) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LC13 + 0.07):6:3;
2355       PUT$(sspc(j,k) eq 3) RES5 " center"/;
2356
2357       );
2358    IF(SPLC EQ 1,
2359       if(TC.L(I,J,K) NE TJIN.L(J) AND TC.L(I,J,K) NE TJOUT.L(J),
2360       PUT$(sspc(j,k) eq 1) RES5 "set label";
2361       PUT$(sspc(j,k) eq 1) RES5 " '"TC.L(I,J,K):6:1;
2362       PUT$(sspc(j,k) eq 1) RES5 "'";
2363       PUT$(sspc(j,k) eq 1) RES5 " at "(EXN - 0.5):5:2;
2364       PUT$(sspc(j,k) eq 1) RES5 " , "(NC - ORD(J) + 1 + 0.15):6:3;
2365       PUT$(sspc(j,k) eq 1) RES5 " center"/;
2366        );
2367       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 "set label";
2368       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " '"TC.L(I,J,K):6:1;
2369       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 "'";
2370       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " at "100:5:2;
2371       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC131
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 + 0.07):6:3;
2372       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " center"/;
2373
2374       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 "set label";
2375       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " '"TKJ.L(J, K+1):6:1;
2376       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 "'";
2377       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " at "(EXN + 0.25):5:2;
2378       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC131
 + 0.07):6:3;
2379       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) ne 2) RES5 " center"/;
2380
2381       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 "set label";
2382       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " '"TC.L(I,J,K):6:1;
2383       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 "'";
2384       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " at "(EXN - 0.25):5:2;
2385       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC13
+ 0.07):6:3;
2386       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " center"/;
2387
2388       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 "set label";
2389       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " '"TKJ.L(J, K+1):6:1;
2390       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 "'";
2391       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " at "(EXN + 0.25):5:2;
2392       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LOC13
+ 0.07):6:3;
2393       PUT$(sspc(j,k) eq 2 and ssph(i-1,k) eq 2) RES5 " center"/;
2394
2395       if(js eq 1 and TKJ.L(J, K) NE TJOUT.L(J) and TKJ.L(J, K) NE TJIN.L(J),
2396       PUT$(sspc(j,k) eq 2) RES5 "set label";
2397       PUT$(sspc(j,k) eq 2) RES5 " '"TKJ.L(J, K):6:1;
2398       PUT$(sspc(j,k) eq 2) RES5 "'";
2399       PUT$(sspc(j,k) eq 2) RES5 " at "(EXN - 0.5):5:2;
2400       PUT$(sspc(j,k) eq 2) RES5 " , "(NC - ORD(J) + 1 + 0.15):6:3;
2401       PUT$(sspc(j,k) eq 2) RES5 " center"/;
2402       );
2403       if(js eq 1 and TKJ.L(J, K) NE TJOUT.L(J) and TKJ.L(J, K) NE TJIN.L(J),
2404       PUT$(sspc(j,k) eq 3) RES5 "set label";
2405       PUT$(sspc(j,k) eq 3) RES5 " '"TKJ.L(J, K):6:1;
2406       PUT$(sspc(j,k) eq 3) RES5 "'";
2407       PUT$(sspc(j,k) eq 3) RES5 " at "(EXN - 0.5):5:2;
2408       PUT$(sspc(j,k) eq 3) RES5 " , "(NC - ORD(J) + 1 + 0.15):6:3;
2409       PUT$(sspc(j,k) eq 3) RES5 " center"/;
2410         );
2411       PUT$(sspc(j,k) eq 3) RES5 "set label";
2412       PUT$(sspc(j,k) eq 3) RES5 " '"TC.L(I,J,K):6:1;
2413       PUT$(sspc(j,k) eq 3) RES5 "'";
2414       PUT$(sspc(j,k) eq 3) RES5 " at "(EXN - 0.25):5:2;
2415       PUT$(sspc(j,k) eq 3) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LC13 + 0.07):6:3;
2416       PUT$(sspc(j,k) eq 3) RES5 " center"/;
2417
2418       PUT$(sspc(j,k) eq 3) RES5 "set label";
2419       PUT$(sspc(j,k) eq 3) RES5 " '"TKJ.L(J, K+1):6:1;
2420       PUT$(sspc(j,k) eq 3) RES5 "'";
2421       PUT$(sspc(j,k) eq 3) RES5 " at "(EXN + 0.25):5:2;
2422       PUT$(sspc(j,k) eq 3) RES5 " , "(NC - ORD(J) + 1 + 1/4 - LC13 + 0.07):6:3;
2423       PUT$(sspc(j,k) eq 3) RES5 " center"/;
2424       );
2425      LOC131 = LOC131 + 1/2;
2426      LC13  = LC13  + 1/4;
2427      );
2428     LOC13 = LOC13 + 1/2;
2429    );
2430  );
```

```
2431  LOC8 = NE - NH;
2432  LOOP(J,
2433  PUT RES5 "set label";
2434  PUT RES5 " 'C"ORD(J):2:0;
2435  PUT RES5 "'";
2436  PUT RES5 " at ";
2437  PUT RES5 " "(EXN+1):6:3;
2438  PUT RES5 " , "LOC8:6:3;
2439  PUT RES5 " left"/;
2440  LOC8 = LOC8 - 1;
2441  );
2442  PUT RES5 "set label";
2443  PUT RES5 " 'Total Network Cost ($/yr)  = "(TOT):12:2;
2444  PUT RES5 " '";
2445  PUT RES5 " at "((EXN+1)/2):6:2;
2446  PUT RES5 " , "(NE + 0.8):6:2;
2447  PUT RES5 " center"/;
2448  *PUT RES5 "plot 'ci' w l 3,'si' w l 3,'fi' w l 1,";
2449  PUT RES5 "plot 'ci' w l ls 2,'si' w l ls 2,'fi' w l ls 1,";
2450  *PUT RES5 "'ui' w p 3 3,'yi' w p 1 3,";
2451  PUT RES5 "'ui' w p, 'yi' w p ls 1,";
2452  *PUT RES5 "'ai' w l 3,'bi' w l 1,";
2453  PUT RES5 "'ai' w l ls 2,'bi' w l ls 1,";
2454  *PUT RES5 "'hi' w l 1,'ei' w linespoints 6 3"/;
2455  PUT RES5 "'hi' w l ls 1,'ei' w linespoints ls 3"/;
2456  PUT RES5 "pause 0 ' ' "/;
2457  PUT RES5 "pause 0 ' ' "/;
2458  PUT RES5 "pause 0 ' ' "/;
2459  *PUT RES5 "pause -1 '                                    Press Return ' "/;
2460  *PUT RES5 "set terminal postscript color solid 'Times-Roman' 5"/;
2461  PUT  RES5 "set terminal png"/;
2462  PUT RES5 "set nogrid"/;
2463  PUT RES5 "unset timestamp"/;
2464  PUT RES5 "set noborder"/;
2465  PUT RES5 "set noyzeroaxis"/;
2466  PUT RES5 "set noxzeroaxis"/;
2467  PUT RES5 "set noxtics"/;
2468  PUT RES5 "set noytics"/;
2469  PUT RES5 "set nokey"/;
2470  PUT RES5 "set output '../../synheat/synheat.png' "/;
2471  PUT RES5 "replot";
2472
2473
2474  SET II /1*100/;
2475  PARAMETER HI;
2476  HI = 2*CARD(I);
2477  DISPLAY HI;
2478
2479  PARAMETERS TQMAX, TQMIN, THQ(II), QHQ(II), TH1Q(II), TH0Q(II);
2480  TQMAX = SMAX(I, TIIN.L(I));
2481  TQMIN = SMIN(I, TIOUT.L(I));
2482
2483  THQ(II) = 0;
2484  TH1Q(II) = 0;
2485  TH0Q(II) = 0;
2486  LOOP(II$(ORD(II) LE HI),
2487   if(ord(ii) ge 2,
2488   TH1Q(II)$(TH1Q(II) LE TQMAX) = SMIN(I$(TIIN.L(I) GT THQ(II-1)), TIIN.L(I));
2489   TH0Q(II)$(TH0Q(II) LE TQMAX) = SMIN(I$(TIOUT.L(I) GT THQ(II-1)), TIOUT.L(I));
2490   THQ(II)$(THQ(II) LE TQMAX)   = MIN(TH1Q(II)$(TH1Q(II) GT 0), TH0Q(II)$(TH0Q(II) GT 0));
2491   );
2492   if(ord(ii) eq 1,
2493   THQ(II) = SMIN(I, TIOUT.L(I));
```

```
2494   );
2495  );
2496
2497  QHQ(II) = 0;
2498  LOOP(II$(ORD(II) LE HI),
2499   if(ord(ii) ge 2,
2500   QHQ(II) = QHQ(II-1) + SUM(I$(TIOUT.L(I) LT THQ(II) AND TIIN.L(I) GE THQ(II)),FCI(I)*(TH
Q(II) - THQ(II-1)));
2501   );
2502   if(ord(ii) eq 1,
2503   QHQ(II) = 0;
2504   );
2505  );
2506  DISPLAY THQ, QHQ;
2507
2508  FILE RES18 /phi/;
2509  PUT RES18;
2510  LOOP(II$(ORD(II) LE HI),
2511    if(QHQ(II) lt INF and THQ(II) lt INF,
2512    PUT RES18 ""QHQ(II):10:2;
2513    PUT RES18 "     "THQ(II):8:2/;
2514    );
2515  );
2516
2517  PARAMETERS QQMAX, QQMIN;
2518
2519  QQMAX = SMAX(II$(ORD(II) LE HI), QHQ(II));
2520  QQMIN = SMIN(II$(ORD(II) LE HI), QHQ(II));
2521
2522  DISPLAY TQMAX, TQMIN, QQMAX, QQMIN;
2523
2524
2525  SET JJ /1*100/;
2526
2527  PARAMETER CJ;
2528  CJ = 2*CARD(J);
2529  DISPLAY CJ;
2530
2531  PARAMETERS TQJMAX, TQJMIN, TCQ(JJ), QCQ(JJ), TC1Q(JJ), TC0Q(JJ);
2532  TQJMAX = SMAX(J, TJOUT.L(J));
2533  TQJMIN = SMIN(J, TJIN.L(J));
2534
2535  TCQ(JJ) = 0;
2536  TC1Q(JJ) = 0;
2537  TC0Q(JJ) = 0;
2538  LOOP(JJ$(ORD(JJ) LE CJ),
2539   if(ord(jj) ge 2,
2540   TC1Q(JJ)$(TC1Q(JJ) LE TQJMAX) = SMIN(J$(TJOUT.L(J) GT TCQ(JJ-1)), TJOUT.L(J));
2541   TC0Q(JJ)$(TC0Q(JJ) LE TQJMAX) = SMIN(J$(TJIN.L(J) GT TCQ(JJ-1)), TJIN.L(J));
2542   TCQ(JJ)$(TCQ(JJ) LE TQJMAX)   = MIN(TC1Q(JJ)$(TC1Q(JJ) GT 0), TC0Q(JJ)$(TC0Q(JJ) GT 0))
;
2543   );
2544   if(ord(jj) eq 1,
2545   TCQ(JJ) = SMIN(J, TJIN.L(J));
2546   );
2547  );
2548
2549  QCQ(JJ) = 0;
2550  LOOP(JJ$(ORD(JJ) LE CJ),
2551   if(ord(jj) ge 2,
2552   QCQ(JJ) = QCQ(JJ-1) + SUM(J$(TJIN.L(J) LT TCQ(JJ) AND TJOUT.L(J) GE TCQ(JJ)),FCJ(J)*(TC
Q(JJ) - TCQ(JJ-1)));
2553   );
```

```
2554   if(ord(jj) eq 1,
2555   QCQ(JJ) = SUM(I, QCOLD.L(I));
2556   );
2557  );
2558  DISPLAY TCQ, QCQ;
2559
2560  FILE RES19 /pci/;
2561  PUT RES19;
2562  LOOP(JJ$(ORD(JJ) LE CJ),
2563    if(QCQ(JJ) lt INF and TCQ(JJ) lt INF,
2564    PUT RES19 ""QCQ(JJ):10:2;
2565    PUT RES19 "     "TCQ(JJ):8:2/;
2566    );
2567  );
2568
2569  PARAMETERS QQJMAX, QQJMIN;
2570
2571  QQJMAX = SMAX(JJ$(ORD(JJ) LE CJ), QCQ(JJ));
2572  QQJMIN = SMIN(JJ$(ORD(JJ) LE CJ), QCQ(JJ));
2573
2574  PARAMETERS TMAXY, TMINY, QMAXY, QMINY;
2575  TMAXY = MAX(TQMAX, TQJMAX);
2576  TMINY = MIN(TQMIN, TQJMIN);
2577  QMAXY = MAX(QQMAX, QQJMAX);
2578  QMINY = MIN(QQMIN, QQJMIN);
2579
2580  DISPLAY TQJMAX, TQJMIN, QQJMAX, QQJMIN;
2581
2582  FILE RES20 /pinch.dem/;
2583  PUT RES20;
2584  PUT RES20 "set title 'SYNHEAT:  T-Q  CURVE' "/;
2585  PUT RES20 "set xlabel ' Q (kW)' "/;
2586  PUT RES20 "set ylabel ' T (K)' "/;
2587  *PUT RES20 "set terminal windows"/;
2588  PUT RES20 "set nokey"/;
2589  PUT RES20 "set xrange [ 0 :";
2590  PUT RES20 " "(QMAXY+50):10:2;
2591  PUT RES20 " ]"/;
2592  PUT RES20 "set yrange [ ";
2593  PUT RES20 " "(TMINY-10):8:2;
2594  PUT RES20 " : "(TMAXY+10):8:2;
2595  PUT RES20 " ]"/;
2596  PUT RES20 "set style line 1 lt 1 lw 1 lc rgb 'red'" /;
2597  PUT RES20 "set style line 2 lt 1 lw 1 lc rgb 'blue'" /;
2598  *PUT RES20 "plot 'phi' w l, 'pci' w l 3"/;
2599  PUT RES20 "plot 'phi' w l ls 1, 'pci' w l ls 2"/;
2600  PUT RES20 "pause 0 ' ' "/;
2601  PUT RES20 "pause 0 ' ' "/;
2602  PUT RES20 "pause 0 ' ' "/;
2603  *PUT RES20 "pause -1 '                                    Press Return ' "/;
2604  *PUT RES20 "set terminal postscript color solid 'Times-Roman' 5"/;
2605  PUT  RES20 "set terminal png"/;
2606  *PUT RES20 "set output 'pinch.ps' "/;
2607  PUT RES20 "set output '../../synheat/pinch.png' "/;
2608  PUT RES20 "replot";
2609
```


SIMULTANEOUS OPTIMIZATION FOR HEN SYNTHESIS (Yee and Grossmann, 1989)
Include File Summary

SEQ	GLOBAL	TYPE	PARENT	LOCAL	INCLVL	FILENAME

```
     1        1 INPUT          0       0       0  /var/www/html/interfaces/cgi-bin/synheat/mod
el.gms
     2        1 INCLUDE        1       1       1  /var/www/html/interfaces/cgi-bin/synheat/ex1
.dat
     3      234 INCLUDE        1       2       1  /var/www/html/interfaces/cgi-bin/synheat/var
iables.inc
     4      246 INCLUDE        3      12       2  /var/www/html/interfaces/cgi-bin/synheat/min
lp.inc
     5      961 INCLUDE        3      13       2  /var/www/html/interfaces/cgi-bin/synheat/rep
minlp.inc
     6     1557 INCLUDE        3      14       2  /var/www/html/interfaces/cgi-bin/synheat/spl
ot.inc


COMPILATION TIME     =        0.004 SECONDS      3 MB  52.5.0 9bc771bf LEX-LEG
GAMS 52.5.0  9bc771bf Jan 28, 2026          LEX-LEG x86 64bit/Linux - 07/17/26 11:59:38 Page 4
SIMULTANEOUS OPTIMIZATION FOR HEN SYNTHESIS (Yee and Grossmann, 1989)
Equation Listing    SOLVE MIXED Using MINLP From line 768


---- STRENBH  =E=  STREAM ENERGY BALANCE OF HOT STREAM

STRENBH(1)..  10*TIIN(1) - 10*TIOUT(1) - QCOLD(1) - Q(1,1,1) - Q(1,1,2) - Q(1,2,1) - Q(1,2,2)
=E= 0 ; (LHS = -6700, INFES = 6700 ****)

STRENBH(2)..  20*TIIN(2) - 20*TIOUT(2) - QCOLD(2) - Q(2,1,1) - Q(2,1,2) - Q(2,2,1) - Q(2,2,2)
=E= 0 ; (LHS = -6700, INFES = 6700 ****)


---- STRENBHI  =E=  STREAM ENERGY BALANCE OF HOT STREAM ISOTERMIC

               NONE


---- STRENBC  =E=  STREAM ENERGY BALANCE OF COLD STREAM

STRENBC(1)..  - 15*TJIN(1) + 15*TJOUT(1) - QHOT(1) - Q(1,1,1) - Q(1,1,2) - Q(2,1,1) - Q(2,1,2)
 =E= 0 ; (LHS = -9200, INFES = 9200 ****)

STRENBC(2)..  - 13*TJIN(2) + 13*TJOUT(2) - QHOT(2) - Q(1,2,1) - Q(1,2,2) - Q(2,2,1) - Q(2,2,2)
 =E= 0 ; (LHS = -5850, INFES = 5850 ****)


---- STRENBCI  =E=  STREAM ENERGY BALANCE OF COLD STREAM ISOTERMIC

               NONE


---- LOADHM  =E=  LOAD OF HOT SIDE MATCH IN INTERVAL K

LOADHM(1,1)..  10*TKI(1,1) - 10*TKI(1,2) - Q(1,1,1) - Q(1,2,1) =E= 0 ; (LHS = -4750, INFES = 4
750 ****)

LOADHM(1,2)..  10*TKI(1,2) - 10*TKI(1,3) - Q(1,1,2) - Q(1,2,2) =E= 0 ; (LHS = -4750, INFES = 4
750 ****)

LOADHM(2,1)..  20*TKI(2,1) - 20*TKI(2,2) - Q(2,1,1) - Q(2,2,1) =E= 0 ; (LHS = -5550, INFES = 5
550 ****)

REMAINING ENTRY SKIPPED


---- LOADCM  =E=  LOAD OF COLD SIDE MATCH IN INTERVAL K
```

LOADCM(1,1).. 15*TKJ(1,1) - 15*TKJ(1,2) - Q(1,1,1) - Q(2,1,1) =E= 0 ; (LHS = -6400, INFES = 6
400 ****)

LOADCM(1,2).. 15*TKJ(1,2) - 15*TKJ(1,3) - Q(1,1,2) - Q(2,1,2) =E= 0 ; (LHS = -6400, INFES = 6
400 ****)

LOADCM(2,1).. 13*TKJ(2,1) - 13*TKJ(2,2) - Q(1,2,1) - Q(2,2,1) =E= 0 ; (LHS = -3900, INFES = 3
900 ****)

REMAINING ENTRY SKIPPED

---- TIINTK =E= TIIN=TKI1

TIINTK(1).. TIIN(1) - TKI(1,1) =E= 0 ; (LHS = 0)

TIINTK(2).. TIIN(2) - TKI(2,1) =E= 0 ; (LHS = 0)

---- TJINTK =E= TJIN=TKJLAST

TJINTK(1).. TJIN(1) - TKJ(1,3) =E= 0 ; (LHS = 0)

TJINTK(2).. TJIN(2) - TKJ(2,3) =E= 0 ; (LHS = 0)

---- TKICON =G= CONSTRAINT ON TKI

TKICON(1,1).. TKI(1,1) - TKI(1,2) =G= 0 ; (LHS = 0)

TKICON(1,2).. TKI(1,2) - TKI(1,3) =G= 0 ; (LHS = 0)

TKICON(2,1).. TKI(2,1) - TKI(2,2) =G= 0 ; (LHS = 0)

REMAINING ENTRY SKIPPED

---- TKICONA =E= CONSTRAINT ON TKI FOR ISOTERMIC STREAM

NONE

---- TKJCON =G= CONSTRAINT ON TKJ

TKJCON(1,1).. TKJ(1,1) - TKJ(1,2) =G= 0 ; (LHS = 0)

TKJCON(1,2).. TKJ(1,2) - TKJ(1,3) =G= 0 ; (LHS = 0)

TKJCON(2,1).. TKJ(2,1) - TKJ(2,2) =G= 0 ; (LHS = 0)

REMAINING ENTRY SKIPPED

---- TKJCONA =G= CONSTRAINT ON TKJ FOR ISOTERMIC STREAM

NONE

---- TCON1 =L= CONSTRAINT ON TIOUT

TCON1(1).. TIOUT(1) - TKI(1,3) =L= 0 ; (LHS = -280)

```
TCON1(2)..  TIOUT(2) - TKI(2,3) =L= 0 ; (LHS = -220)

---- TCON2  =G=  CONSTRAINT ON TJOUT

TCON2(1)..  TJOUT(1) - TKJ(1,1) =G= 0 ; (LHS = 240)

TCON2(2)..  TJOUT(2) - TKJ(2,1) =G= 0 ; (LHS = 150)

---- LOADQC  =E=  HEAT LOAD COLD UTILITY WITH HOT I

LOADQC(1)..  - 10*TIOUT(1) - QCOLD(1) + 10*TKI(1,3) =E= 0 ; (LHS = 2800, INFES = 2800 ****)

LOADQC(2)..  - 20*TIOUT(2) - QCOLD(2) + 20*TKI(2,3) =E= 0 ; (LHS = 4400, INFES = 4400 ****)

---- LOADQH  =E=  HEAT LOAD HOT UTILITY WITH COLD J

LOADQH(1)..  15*TJOUT(1) - QHOT(1) - 15*TKJ(1,1) =E= 0 ; (LHS = 3600, INFES = 3600 ****)

LOADQH(2)..  13*TJOUT(2) - QHOT(2) - 13*TKJ(2,1) =E= 0 ; (LHS = 1950, INFES = 1950 ****)

---- LOGCOND  =L=  LOGICAL CONSTRAINTS FOR UNIT ASSIGNMENT

LOGCOND(1,1,1)..  - 2800*Z(1,1,1) + Q(1,1,1) =L= 0 ; (LHS = 2800, INFES = 2800 ****)

LOGCOND(1,1,2)..  - 2800*Z(1,1,2) + Q(1,1,2) =L= 0 ; (LHS = 2800, INFES = 2800 ****)

LOGCOND(1,2,1)..  - 1950*Z(1,2,1) + Q(1,2,1) =L= 0 ; (LHS = 1950, INFES = 1950 ****)

REMAINING 5 ENTRIES SKIPPED

---- LOGCU  =L=  LOGICAL CONSTRAINTS FOR COOLERS

LOGCU(1)..  - 2800*ZCU(1) + QCOLD(1) =L= 0 ; (LHS = 0)

LOGCU(2)..  - 4400*ZCU(2) + QCOLD(2) =L= 0 ; (LHS = 0)

---- LOGHU  =L=  LOGICAL CONSTRAINTS FOR HEATERS

LOGHU(1)..  - 3600*ZHU(1) + QHOT(1) =L= 0 ; (LHS = 0)

LOGHU(2)..  - 1950*ZHU(2) + QHOT(2) =L= 0 ; (LHS = 0)

---- DTCON  =L=  DRIVING FORCE FOR INLET STAGE K

DTCON(1,1,1)..  280*Z(1,1,1) - TKI(1,1) + TKJ(1,1) + DT(1,1,1) =L= 280 ; (LHS = 0)

DTCON(1,1,2)..  280*Z(1,1,2) - TKI(1,2) + TKJ(1,2) + DT(1,1,2) =L= 280 ; (LHS = 0)

DTCON(1,2,1)..  300*Z(1,2,1) - TKI(1,1) + TKJ(2,1) + DT(1,2,1) =L= 300 ; (LHS = 0)

REMAINING 5 ENTRIES SKIPPED

---- DTCONA  =L=  DRIVING FORCE FOR OUTLET STAGE NOK

DTCONA(1,1,1)..  280*Z(1,1,1) - TKI(1,2) + TKJ(1,2) + DT(1,1,2) =L= 280 ; (LHS = 0)
```

```
DTCONA(1,1,2)..  280*Z(1,1,2) - TKI(1,3) + TKJ(1,3) + DT(1,1,3) =L= 280 ; (LHS = 0)

DTCONA(1,2,1)..  300*Z(1,2,1) - TKI(1,2) + TKJ(2,2) + DT(1,2,2) =L= 300 ; (LHS = 0)

REMAINING 5 ENTRIES SKIPPED

---- DTHUCON  =L=  DETERMINING DRIVING FORCE FOR HEATERS

DTHUCON(1)..  TKJ(1,1) + DTHU(1) =L= 680 ; (LHS = 680)

DTHUCON(2)..  TKJ(2,1) + DTHU(2) =L= 680 ; (LHS = 680)

---- DTCUCON  =L=  DETERMINING DRIVING FORCE FOR COOLERS

DTCUCON(1)..  - TKI(1,3) + DTCU(1) =L= -320 ; (LHS = -320)

DTCUCON(2)..  - TKI(2,3) + DTCU(2) =L= -320 ; (LHS = -320)

---- SPLITH  =L=  SPLIT OF HOT STREAMS

               NONE

---- SPLITC  =L=  SPLIT OF COLD STREAMS

               NONE

---- REQUIRED  =E=  REQUIRED MATCHES BETWEEN HOT AND COLD STREAMS

               NONE

---- HUTILFX  =E=  HOT UTILITY HEAT LOAD FIXED

               NONE

---- CUTILFX  =E=  COLD UTILITY HEAT LOAD FIXED

               NONE

---- HUTILUP  =L=  HOT UTILITY HEAT LOAD UPPER BOUND

               NONE

---- CUTILUP  =L=  COLD UTILITY HEAT LOAD UPPER BOUND

               NONE

---- OBJMINLP  =E=  OBJECTIVE FUNCTION FOR MINLP

OBJMINLP..  (0)*TIOUT(1) + (0)*TIOUT(2) + (0)*TJOUT(1) + (0)*TJOUT(2) - 1000*Z(1,1,1) - 1000*Z
(1,1,2) - 1000*Z(1,2,1) - 1000*Z(1,2,2) - 1000*Z(2,1,1) - 1000*Z(2,1,2) - 1000*Z(2,2,1) - 1000
*Z(2,2,2) - 1000*ZCU(1) - 1000*ZCU(2) - 1000*ZHU(1) - 1000*ZHU(2) - (19.5633994168703)*QCOLD(1
) - (20.1506855876612)*QCOLD(2) - (89.2735917465639)*QHOT(1) - (86.8430901096068)*QHOT(2) - (3
```

.16684022498858)*Q(1,1,1) - (3.16684022498858)*Q(1,1,2) - (2.53347783327697)*Q(1,2,1) - (2.533
47783327697)*Q(1,2,2) - (4.22244148609346)*Q(2,1,1) - (4.22244148609346)*Q(2,1,2) - (3.1668402
2498858)*Q(2,2,1) - (3.16684022498858)*Q(2,2,2) + (18.4730499134203)*DT(1,1,1) + (36.946099826
8406)*DT(1,1,2) + (18.4730499134203)*DT(1,1,3) + (8.23372062012056)*DT(1,2,1) + (16.4674412402
411)*DT(1,2,2) + (8.23372062012056)*DT(1,2,3) + (42.223992616786)*DT(2,1,1) + (84.447985233571
9)*DT(2,1,2) + (42.223992616786)*DT(2,1,3) + (12.865159761132)*DT(2,2,1) + (25.7303195222639)*
DT(2,2,2) + (12.865159761132)*DT(2,2,3) + (0)*DTHU(1) + (0)*DTHU(2) + (0)*DTCU(1) + (0)*DTCU(2
) + COST =E= 0 ; (LHS = -70367.1289470446, INFES = 70367.1289470446 ****)

SIMULTANEOUS OPTIMIZATION FOR HEN SYNTHESIS (Yee and Grossmann, 1989)
Column Listing SOLVE MIXED Using MINLP From line 768

---- TIIN SUPPLY TEMP. OF HOT STREAM

TIIN(1)
(.LO, .L, .UP, .M = 650, 650, 650, 0)
10 STRENBH(1)
1 TIINTK(1)

TIIN(2)
(.LO, .L, .UP, .M = 590, 590, 590, 0)
20 STRENBH(2)
1 TIINTK(2)

---- TIOUT TARGET TEMP. OF HOT STREAM

TIOUT(1)
(.LO, .L, .UP, .M = 370, 370, 370, 0)
-10 STRENBH(1)
1 TCON1(1)
-10 LOADQC(1)
(0) OBJMINLP

TIOUT(2)
(.LO, .L, .UP, .M = 370, 370, 370, 0)
-20 STRENBH(2)
1 TCON1(2)
-20 LOADQC(2)
(0) OBJMINLP

---- TJIN SUPPLY TEMP. OF COLD STREAM

TJIN(1)
(.LO, .L, .UP, .M = 410, 410, 410, 0)
-15 STRENBC(1)
1 TJINTK(1)

TJIN(2)
(.LO, .L, .UP, .M = 350, 350, 350, 0)
-13 STRENBC(2)
1 TJINTK(2)

---- TJOUT TARGET TEMP. OF COLD STREAM

TJOUT(1)
(.LO, .L, .UP, .M = 650, 650, 650, 0)
15 STRENBC(1)
1 TCON2(1)

```
       15       LOADQH(1)
       (0)      OBJMINLP

TJOUT(2)
                (.LO, .L, .UP, .M = 500, 500, 500, 0)
       13       STRENBC(2)
        1       TCON2(2)
       13       LOADQH(2)
       (0)      OBJMINLP


---- Z

Z(1,1,1)
                (.LO, .L, .UP, .M = 0, 0, 1, 0)
    -2800       LOGCOND(1,1,1)
      280       DTCON(1,1,1)
      280       DTCONA(1,1,1)
    -1000       OBJMINLP

Z(1,1,2)
                (.LO, .L, .UP, .M = 0, 0, 1, 0)
    -2800       LOGCOND(1,1,2)
      280       DTCON(1,1,2)
      280       DTCONA(1,1,2)
    -1000       OBJMINLP

Z(1,2,1)
                (.LO, .L, .UP, .M = 0, 0, 1, 0)
    -1950       LOGCOND(1,2,1)
      300       DTCON(1,2,1)
      300       DTCONA(1,2,1)
    -1000       OBJMINLP

REMAINING 5 ENTRIES SKIPPED

---- ZCU

ZCU(1)
                (.LO, .L, .UP, .M = 0, 0, 1, 0)
    -2800       LOGCU(1)
    -1000       OBJMINLP

ZCU(2)
                (.LO, .L, .UP, .M = 0, 0, 1, 0)
    -4400       LOGCU(2)
    -1000       OBJMINLP


---- ZHU

ZHU(1)
                (.LO, .L, .UP, .M = 0, 0, 1, 0)
    -3600       LOGHU(1)
    -1000       OBJMINLP

ZHU(2)
                (.LO, .L, .UP, .M = 0, 0, 1, 0)
    -1950       LOGHU(2)
    -1000       OBJMINLP


---- QCOLD  CONSUMPTION OF COLD UTILITY FOR HOT STREAM I
```

```
QCOLD(1)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
       -1       STRENBH(1)
       -1       LOADQC(1)
        1       LOGCU(1)
     (-19.5634) OBJMINLP

QCOLD(2)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
       -1       STRENBH(2)
       -1       LOADQC(2)
        1       LOGCU(2)
     (-20.1507) OBJMINLP


---- QHOT  CONSUMPTION OF HOT UTILITY FOR COLD STREAM J

QHOT(1)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
       -1       STRENBC(1)
       -1       LOADQH(1)
        1       LOGHU(1)
     (-89.2736) OBJMINLP

QHOT(2)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
       -1       STRENBC(2)
       -1       LOADQH(2)
        1       LOGHU(2)
     (-86.8431) OBJMINLP


---- TKI  STAGE BOUNDARY TEMP. OF HOT STREAM I

TKI(1,1)
                (.LO, .L, .UP, .M = 370, 650, 650, 0)
       10       LOADHM(1,1)
       -1       TIINTK(1)
        1       TKICON(1,1)
       -1       DTCON(1,1,1)
       -1       DTCON(1,2,1)

TKI(1,2)
                (.LO, .L, .UP, .M = 370, 650, 650, 0)
      -10       LOADHM(1,1)
       10       LOADHM(1,2)
       -1       TKICON(1,1)
        1       TKICON(1,2)
       -1       DTCON(1,1,2)
       -1       DTCON(1,2,2)
       -1       DTCONA(1,1,1)
       -1       DTCONA(1,2,1)

TKI(1,3)
                (.LO, .L, .UP, .M = 370, 650, 650, 0)
      -10       LOADHM(1,2)
       -1       TKICON(1,2)
       -1       TCON1(1)
       10       LOADQC(1)
       -1       DTCONA(1,1,2)
       -1       DTCONA(1,2,2)
       -1       DTCUCON(1)
```

REMAINING 3 ENTRIES SKIPPED

---- TKJ STAGE BOUNDARY TEMP. OF COLD STREAM J

TKJ(1,1)
(.LO, .L, .UP, .M = 410, 410, 650, 0)
15 LOADCM(1,1)
1 TKJCON(1,1)
-1 TCON2(1)
-15 LOADQH(1)
1 DTCON(1,1,1)
1 DTCON(2,1,1)
1 DTHUCON(1)

TKJ(1,2)
(.LO, .L, .UP, .M = 410, 410, 650, 0)
-15 LOADCM(1,1)
15 LOADCM(1,2)
-1 TKJCON(1,1)
1 TKJCON(1,2)
1 DTCON(1,1,2)
1 DTCON(2,1,2)
1 DTCONA(1,1,1)
1 DTCONA(2,1,1)

TKJ(1,3)
(.LO, .L, .UP, .M = 410, 410, 650, 0)
-15 LOADCM(1,2)
-1 TJINTK(1)
-1 TKJCON(1,2)
1 DTCONA(1,1,2)
1 DTCONA(2,1,2)

REMAINING 3 ENTRIES SKIPPED

---- Q HEAT LOAD OF MATCH BETWEEN I AND J IN STAGE K

Q(1,1,1)
(.LO, .L, .UP, .M = 0, 2800, +INF, 0)
-1 STRENBH(1)
-1 STRENBC(1)
-1 LOADHM(1,1)
-1 LOADCM(1,1)
1 LOGCOND(1,1,1)
(-3.1668) OBJMINLP

Q(1,1,2)
(.LO, .L, .UP, .M = 0, 2800, +INF, 0)
-1 STRENBH(1)
-1 STRENBC(1)
-1 LOADHM(1,2)
-1 LOADCM(1,2)
1 LOGCOND(1,1,2)
(-3.1668) OBJMINLP

Q(1,2,1)
(.LO, .L, .UP, .M = 0, 1950, +INF, 0)
-1 STRENBH(1)
-1 STRENBC(2)
-1 LOADHM(1,1)
-1 LOADCM(2,1)
1 LOGCOND(1,2,1)

```
      (-2.5335) OBJMINLP

REMAINING 5 ENTRIES SKIPPED

---- DT  DRIVING FORCE OF BOUNDARY OF INTERVAL K

DT(1,1,1)
                (.LO, .L, .UP, .M = 10, 240, +INF, 0)
        1       DTCON(1,1,1)
      (18.473)  OBJMINLP

DT(1,1,2)
                (.LO, .L, .UP, .M = 10, 240, +INF, 0)
        1       DTCON(1,1,2)
        1       DTCONA(1,1,1)
      (36.9461) OBJMINLP

DT(1,1,3)
                (.LO, .L, .UP, .M = 10, 240, +INF, 0)
        1       DTCONA(1,1,2)
      (18.473)  OBJMINLP

REMAINING 9 ENTRIES SKIPPED

---- DTHU  DRIVING FORCE FOR HEATERS

DTHU(1)
                (.LO, .L, .UP, .M = 10, 270, +INF, 0)
        1       DTHUCON(1)
       (0)      OBJMINLP

DTHU(2)
                (.LO, .L, .UP, .M = 10, 330, +INF, 0)
        1       DTHUCON(2)
       (0)      OBJMINLP


---- DTCU  DRIVING FORCE FOR COOLERS

DTCU(1)
                (.LO, .L, .UP, .M = 10, 330, +INF, 0)
        1       DTCUCON(1)
       (0)      OBJMINLP

DTCU(2)
                (.LO, .L, .UP, .M = 10, 270, +INF, 0)
        1       DTCUCON(2)
       (0)      OBJMINLP


---- COST  HEN AND UTILITY COST

COST
                (.LO, .L, .UP, .M = -1000, 0, +INF, 0)
        1       OBJMINLP
```


RANGE STATISTICS (ABSOLUTE NON-ZERO FINITE VALUES)

```
RHS       [min, max] : [ 2.400E+02, 6.800E+02] - Zero values observed as well
Bound     [min, max] : [ 1.000E+00, 1.000E+03] - Zero values observed as well
Matrix    [min, max] : [ 1.000E+00, 4.400E+03] - Zero values observed as well

GAMS 52.5.0  9bc771bf Jan 28, 2026          LEX-LEG x86 64bit/Linux - 07/17/26 11:59:38 Page 7
SIMULTANEOUS OPTIMIZATION FOR HEN SYNTHESIS (Yee and Grossmann, 1989)
Model Statistics    SOLVE MIXED Using MINLP From line 768


MODEL STATISTICS

BLOCKS OF EQUATIONS          31     SINGLE EQUATIONS           65
BLOCKS OF VARIABLES          16     SINGLE VARIABLES           61
NON ZERO ELEMENTS           245     NON LINEAR N-Z             32
CODE LENGTH                 202     CONSTANT POOL              26     DISCRETE VARIABLES
   12


GENERATION TIME      =        0.001 SECONDS      4 MB  52.5.0 9bc771bf LEX-LEG
GAMS 52.5.0  9bc771bf Jan 28, 2026          LEX-LEG x86 64bit/Linux - 07/17/26 11:59:38 Page 8
SIMULTANEOUS OPTIMIZATION FOR HEN SYNTHESIS (Yee and Grossmann, 1989)
Solution Report     SOLVE MIXED Using MINLP From line 768


               S O L V E      S U M M A R Y

     MODEL   MIXED               OBJECTIVE  COST
     TYPE    MINLP               DIRECTION  MINIMIZE
     SOLVER  DICOPT              FROM LINE  768

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      8 Integer Solution
**** OBJECTIVE VALUE           200246.7706

 RESOURCE USAGE, LIMIT          0.030   1000000.000
 ITERATION COUNT, LIMIT       205       1000000
 EVALUATION ERRORS              0             0
------------------------------------------------------------------------------
Dicopt 2         52.5.0 9bc771bf Jan 28, 2026          LEG x86 64bit/Linux
------------------------------------------------------------------------------


    C O N O P T   version 4.39.0
    Copyright (C) GAMS Software GmbH
                  GAMS Development Corporation

    Will use up to 4 threads.


    The user model has 65 constraints and 61 variables
    with 245 Jacobian elements, 32 of which are nonlinear.
    The Hessian of the Lagrangian has 32 elements on the diagonal,
    36 elements below the diagonal, and 32 nonlinear variables.

    The pre-triangular part of the model has 12 constraints and variables.
    The post-triangular part of the model has 1 constraints and variables.

    Preprocessed model has 52 constraints and 48 variables
    with 152 Jacobian elements, 0 of which are nonlinear.

 ** Optimal solution. Reduced gradient less than tolerance.
```

```
 CONOPT time Total                            0.002 seconds
   of which: Function evaluations             0.000 =  0.0%
             1st Derivative evaluations       0.001 = 50.0%
             2nd Derivative evaluations       0.000 =  0.0%
             Directional 2nd Deriv(Hess)      0.000 =  0.0%
             Interval derivative evals        0.000 =  0.0%

--- GAMS/CPLEX licensed for continuous and discrete problems.
--- GMO setup time: 0.00s
--- GMO memory 0.51 Mb (peak 0.52 Mb)
--- Dictionary memory 0.00 Mb
--- Cplex 22.1.2.0 link memory 0.00 Mb (peak 0.01 Mb)
--- Starting Cplex


--- MIP status (101): integer optimal solution.
--- Cplex Time: 0.01sec (det. 2.05 ticks)

--- Returning a primal only solution to GAMS (marginals all set to NA).
--- Fixing integer variables and solving final LP...


--- Fixed MIP status (1): optimal.
--- Cplex Time: 0.00sec (det. 0.10 ticks)


Proven optimal solution
MIP Solution:       124975.914373    (79 iterations, 0 nodes)
Final Solve:        124975.914373    (11 iterations)

Best possible:      124975.914373
Absolute gap:           -0.000000
Relative gap:           -0.000000

--- DICOPT: Setting up next NLP


    C O N O P T   version 4.39.0
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                  GAMS Development Corporation

    Will use up to 4 threads.


    The user model has 65 constraints and 61 variables
    with 245 Jacobian elements, 32 of which are nonlinear.
    The Hessian of the Lagrangian has 32 elements on the diagonal,
    36 elements below the diagonal, and 32 nonlinear variables.

    The pre-triangular part of the model has 40 constraints and 38 variables.
    The post-triangular part of the model has 1 constraints and variables.
    There are 7 definitional constraints and defined variables.

    Preprocessed model has 17 constraints and 15 variables
    with 35 Jacobian elements, 0 of which are nonlinear.

 ** Optimal solution. Reduced gradient less than tolerance.


 CONOPT time Total                            0.001 seconds
   of which: Function evaluations             0.000 =  0.0%
             1st Derivative evaluations       0.000 =  0.0%
             2nd Derivative evaluations       0.000 =  0.0%
```

```
             Directional 2nd Deriv(Hess)      0.000 =  0.0%
             Interval derivative evals        0.000 =  0.0%

--- GMO Resort Time 0ms
--- GAMS/CPLEX licensed for continuous and discrete problems.
--- GMO setup time: 0.00s
--- GMO memory 0.52 Mb (peak 0.52 Mb)
--- Dictionary memory 0.00 Mb
--- Cplex 22.1.2.0 link memory 0.00 Mb (peak 0.01 Mb)
--- Starting Cplex


--- MIP status (101): integer optimal solution.
--- Cplex Time: 0.01sec (det. 5.50 ticks)

--- Returning a primal only solution to GAMS (marginals all set to NA).
--- Fixing integer variables and solving final LP...


--- Fixed MIP status (1): optimal.
--- Cplex Time: 0.00sec (det. 0.13 ticks)


Proven optimal solution
MIP Solution:       130222.772941    (98 iterations, 0 nodes)
Final Solve:        130222.772941    (16 iterations)

Best possible:      130222.772941
Absolute gap:            0.000000
Relative gap:            0.000000

--- DICOPT: Setting up next NLP


    C O N O P T   version 4.39.0
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                  GAMS Development Corporation

    Will use up to 4 threads.


    The user model has 65 constraints and 61 variables
    with 245 Jacobian elements, 32 of which are nonlinear.
    The Hessian of the Lagrangian has 32 elements on the diagonal,
    36 elements below the diagonal, and 32 nonlinear variables.

    The pre-triangular part of the model has 39 constraints and 37 variables.
    The post-triangular part of the model has 1 constraints and variables.

    Preprocessed model has 25 constraints and 23 variables
    with 57 Jacobian elements, 0 of which are nonlinear.

 ** Optimal solution. Reduced gradient less than tolerance.


 CONOPT time Total                            0.001 seconds
   of which: Function evaluations             0.000 =  0.0%
             1st Derivative evaluations       0.000 =  0.0%
             2nd Derivative evaluations       0.000 =  0.0%
             Directional 2nd Deriv(Hess)      0.000 =  0.0%
             Interval derivative evals        0.000 =  0.0%

--- DICOPT: Stopped on NLP worsening
```

The search was stopped because the objective function
of the NLP subproblems started to deteriorate.

--- DICOPT: Best integer solution found: 200246.770565

---- EQU STRENBH STREAM ENERGY BALANCE OF HOT STREAM

	LOWER	LEVEL	UPPER	MARGINAL
1	.	.	.	.
2	.	.	.	.

---- EQU STRENBHI STREAM ENERGY BALANCE OF HOT STREAM ISOTERMIC

NONE

---- EQU STRENBC STREAM ENERGY BALANCE OF COLD STREAM

	LOWER	LEVEL	UPPER	MARGINAL
1	.	-4.54747E-13	.	.
2	.	.	.	-29.9603

---- EQU STRENBCI STREAM ENERGY BALANCE OF COLD STREAM ISOTERMIC

NONE

---- EQU LOADHM LOAD OF HOT SIDE MATCH IN INTERVAL K

	LOWER	LEVEL	UPPER	MARGINAL
1.1	.	.	.	53.5063
1.2	.	.	.	4.0148
2.1	.	.	.	28.4148
2.2	.	.	.	-2.3493

---- EQU LOADCM LOAD OF COLD SIDE MATCH IN INTERVAL K

	LOWER	LEVEL	UPPER	MARGINAL
1.1	.	.	.	-77.6835
1.2	.	.	.	-14.9224
2.1	.	.	.	.
2.2	.	.	.	12.9831

---- EQU TIINTK TIIN=TKI1

	LOWER	LEVEL	UPPER	MARGINAL
1	.	.	.	737.9892
2	.	.	.	568.2962

---- EQU TJINTK TJIN=TKJLAST

	LOWER	LEVEL	UPPER	MARGINAL
1	.	.	.	-116.7568
2	.	.	.	-453.2548

---- EQU TKICON CONSTRAINT ON TKI

	LOWER	LEVEL	UPPER	MARGINAL
1.1	.	65.9905	+INF	.
1.2	.	195.0000	+INF	.
2.1	.	.	+INF	.
2.2	.	114.2177	+INF	.

---- EQU TKICONA CONSTRAINT ON TKI FOR ISOTERMIC STREAM

NONE

---- EQU TKJCON CONSTRAINT ON TKJ

	LOWER	LEVEL	UPPER	MARGINAL
1.1	.	43.9937	+INF	.
1.2	.	152.2903	+INF	.
2.1	.	.	+INF	.
2.2	.	150.0000	+INF	.

---- EQU TKJCONA CONSTRAINT ON TKJ FOR ISOTERMIC STREAM

NONE

---- EQU TCON1 CONSTRAINT ON TIOUT

	LOWER	LEVEL	UPPER	MARGINAL
1	-INF	-19.0095	.	.
2	-INF	-105.7823	.	.

---- EQU TCON2 CONSTRAINT ON TJOUT

	LOWER	LEVEL	UPPER	MARGINAL
1	.	43.7160	+INF	.
2	.	.	+INF	.

---- EQU LOADQC HEAT LOAD COLD UTILITY WITH HOT I

	LOWER	LEVEL	UPPER	MARGINAL
1	.	.	.	-25.9352
2	.	.	.	-22.0916

---- EQU LOADQH HEAT LOAD HOT UTILITY WITH COLD J

	LOWER	LEVEL	UPPER	MARGINAL
1	.	.	.	-94.3860
2	.	.	.	EPS

---- EQU LOGCOND LOGICAL CONSTRAINTS FOR UNIT ASSIGNMENT

	LOWER	LEVEL	UPPER	MARGINAL
1.1.1	-INF	-2140.0948	.	.
1.1.2	-INF	.	.	-2.6846
1.2.1	-INF	.	.	.
1.2.2	-INF	.	.	.

2.1.1	-INF	.	.	-41.8257
2.1.2	-INF	-1315.6459	.	.
2.2.1	-INF	.	.	.
2.2.2	-INF	.	.	-17.1398

---- EQU LOGCU LOGICAL CONSTRAINTS FOR COOLERS

	LOWER	LEVEL	UPPER	MARGINAL
1	-INF	-2609.9052	.	.
2	-INF	-2284.3541	.	.

---- EQU LOGHU LOGICAL CONSTRAINTS FOR HEATERS

	LOWER	LEVEL	UPPER	MARGINAL
1	-INF	-2944.2594	.	.
2	-INF	.	.	.

---- EQU DTCON DRIVING FORCE FOR INLET STAGE K

	LOWER	LEVEL	UPPER	MARGINAL
1.1.1	-INF	280.0000	280.0000	-202.9265
1.1.2	-INF	-1.06581E-13	280.0000	.
1.2.1	-INF	300.0000	300.0000	EPS
1.2.2	-INF	300.0000	300.0000	-168.7808
2.1.1	-INF	280.0000	280.0000	EPS
2.1.2	-INF	280.0000	280.0000	-615.2827
2.2.1	-INF	240.0000	240.0000	EPS
2.2.2	-INF	240.0000	240.0000	.

---- EQU DTCONA DRIVING FORCE FOR OUTLET STAGE NOK

	LOWER	LEVEL	UPPER	MARGINAL
1.1.1	-INF	280.0000	280.0000	-326.1342
1.1.2	-INF	280.0000	280.0000	EPS
1.2.1	-INF	-2.84217E-14	300.0000	.
1.2.2	-INF	300.0000	300.0000	-284.4740
2.1.1	-INF	-1.10134E-13	280.0000	.
2.1.2	-INF	280.0000	280.0000	-340.5923
2.2.1	-INF	240.0000	240.0000	EPS
2.2.2	-INF	240.0000	240.0000	EPS

---- EQU DTHUCON DETERMINING DRIVING FORCE FOR HEATERS

	LOWER	LEVEL	UPPER	MARGINAL
1	-INF	680.0000	680.0000	-47.6116
2	-INF	510.0000	680.0000	.

---- EQU DTCUCON DETERMINING DRIVING FORCE FOR COOLERS

	LOWER	LEVEL	UPPER	MARGINAL
1	-INF	-320.0000	-320.0000	-15.0252
2	-INF	-320.0000	-320.0000	-54.2524

---- EQU SPLITH SPLIT OF HOT STREAMS

NONE

---- EQU SPLITC SPLIT OF COLD STREAMS

NONE

---- EQU REQUIRED REQUIRED MATCHES BETWEEN HOT AND COLD STREAMS

NONE

NONE

---- EQU HUTILFX (EMPTY)
---- EQU CUTILFX (EMPTY)
---- EQU HUTILUP (EMPTY)
---- EQU CUTILUP (EMPTY)
---- EQU OBJMINLP . . . 1.0000

HUTILFX HOT UTILITY HEAT LOAD FIXED
CUTILFX COLD UTILITY HEAT LOAD FIXED
HUTILUP HOT UTILITY HEAT LOAD UPPER BOUND
CUTILUP COLD UTILITY HEAT LOAD UPPER BOUND
OBJMINLP OBJECTIVE FUNCTION FOR MINLP

---- VAR TIIN SUPPLY TEMP. OF HOT STREAM

	LOWER	LEVEL	UPPER	MARGINAL
1	650.0000	650.0000	650.0000	-737.9892
2	590.0000	590.0000	590.0000	-568.2962

---- VAR TIOUT TARGET TEMP. OF HOT STREAM

	LOWER	LEVEL	UPPER	MARGINAL
1	370.0000	370.0000	370.0000	-274.2346
2	370.0000	370.0000	370.0000	-535.4243

---- VAR TJIN SUPPLY TEMP. OF COLD STREAM

	LOWER	LEVEL	UPPER	MARGINAL
1	410.0000	410.0000	410.0000	116.7568
2	350.0000	350.0000	350.0000	63.7713

---- VAR TJOUT TARGET TEMP. OF COLD STREAM

	LOWER	LEVEL	UPPER	MARGINAL
1	650.0000	650.0000	650.0000	1503.9572
2	500.0000	500.0000	500.0000	389.4836

---- VAR Z

	LOWER	LEVEL	UPPER	MARGINAL
1.1.1	.	1.0000	1.0000	149137.0001
1.1.2	.	.	1.0000	-6517.0159
1.2.1	.	.	1.0000	1000.0000
1.2.2	.	1.0000	1.0000	136976.4516
2.1.1	.	.	1.0000	-149572.6557
2.1.2	.	1.0000	1.0000	268645.0007

2.2.1	.	.	1.0000	1000.0000
2.2.2	.	.	1.0000	-32422.6269

---- VAR ZCU

	LOWER	LEVEL	UPPER	MARGINAL
1	.	1.0000	1.0000	1000.0000
2	.	1.0000	1.0000	1000.0000

---- VAR ZHU

	LOWER	LEVEL	UPPER	MARGINAL
1	.	1.0000	1.0000	1000.0000
2	.	.	1.0000	1000.0000

---- VAR QCOLD CONSUMPTION OF COLD UTILITY FOR HOT STREAM I

	LOWER	LEVEL	UPPER	MARGINAL
1	.	190.0948	+INF	.
2	.	2115.6459	+INF	.

---- VAR QHOT CONSUMPTION OF HOT UTILITY FOR COLD STREAM J

	LOWER	LEVEL	UPPER	MARGINAL
1	.	655.7406	+INF	.
2	.	.	+INF	63.2555

---- VAR TKI STAGE BOUNDARY TEMP. OF HOT STREAM I

	LOWER	LEVEL	UPPER	MARGINAL
1.1	370.0000	650.0000	650.0000	.
1.2	370.0000	584.0095	650.0000	.
1.3	370.0000	389.0095	650.0000	.
2.1	370.0000	590.0000	590.0000	.
2.2	370.0000	590.0000	590.0000	.
2.3	370.0000	475.7823	590.0000	.

---- VAR TKJ STAGE BOUNDARY TEMP. OF COLD STREAM J

	LOWER	LEVEL	UPPER	MARGINAL
1.1	410.0000	606.2840	650.0000	.
1.2	410.0000	562.2903	650.0000	.
1.3	410.0000	410.0000	650.0000	.
2.1	350.0000	500.0000	500.0000	.
2.2	350.0000	500.0000	500.0000	.
2.3	350.0000	350.0000	500.0000	.

---- VAR Q HEAT LOAD OF MATCH BETWEEN I AND J IN STAGE K

	LOWER	LEVEL	UPPER	MARGINAL
1.1.1	.	659.9052	+INF	.
1.1.2	.	.	+INF	.
1.2.1	.	.	+INF	27.0628
1.2.2	.	1950.0000	+INF	.
2.1.1	.	.	+INF	.
2.1.2	.	2284.3541	+INF	.

```
2.2.1          .              .            +INF            0.7577
2.2.2          .              .            +INF             .

---- VAR DT  DRIVING FORCE OF BOUNDARY OF INTERVAL K

             LOWER          LEVEL          UPPER         MARGINAL

1.1.1        10.0000        43.7160        +INF             .
1.1.2        10.0000        21.7192        +INF           EPS
1.1.3        10.0000       259.0095        +INF             .
1.2.1        10.0000       450.0000        +INF             .
1.2.2        10.0000        84.0095        +INF             .
1.2.3        10.0000        39.0095        +INF             .
2.1.1        10.0000       263.7160        +INF             .
2.1.2        10.0000        27.7097        +INF           EPS
2.1.3        10.0000        65.7823        +INF             .
2.2.1        10.0000       330.0000        +INF             .
2.2.2        10.0000       330.0000        +INF             .
2.2.3        10.0000       365.7823        +INF             .

---- VAR DTHU  DRIVING FORCE FOR HEATERS

         LOWER          LEVEL          UPPER         MARGINAL

1        10.0000        73.7160        +INF             .
2        10.0000        10.0000        +INF           EPS

---- VAR DTCU  DRIVING FORCE FOR COOLERS

         LOWER          LEVEL          UPPER         MARGINAL

1        10.0000        69.0095        +INF             .
2        10.0000       155.7823        +INF             .

                          LOWER          LEVEL          UPPER         MARGINAL

---- VAR COST           -1000.0000    200246.7706        +INF             .

  COST  HEN AND UTILITY COST


**** REPORT SUMMARY :        0     NONOPT
                             0 INFEASIBLE
                             0  UNBOUNDED
                             0     ERRORS
GAMS 52.5.0  9bc771bf Jan 28, 2026          LEX-LEG x86 64bit/Linux - 07/17/26 11:59:38 Page 9
SIMULTANEOUS OPTIMIZATION FOR HEN SYNTHESIS (Yee and Grossmann, 1989)
E x e c u t i o n


----    824 PARAMETER A  AREA CALCULATED WITH LOG MEAN

              1           2

1.1       41.971
1.2                   66.484
2.1                  103.748


----    824 PARAMETER AL  AREA FOR EXCHANGER FOR MATCH IJ IN INTERVAL K (Chen approx.)

              1           2
```

```
1.1      41.986
1.2                66.517
2.1               103.828


----    824 PARAMETER ACU  AREA COOLERS

1  5.470,    2 39.482


----    824 PARAMETER AHU  AREA HEATERS

1 16.197


----    825 PARAMETER COSTHEAT            =    55737.954  COST OF HEATING
            PARAMETER COSTCOOL            =    34586.109  COST OF COOLING

----    826 PARAMETER INVCOST             =   109922.708  INVESTMENT COST

----    848 PARAMETER SPH

            1           2

1       1.000       1.000
2                   1.000


----    848 PARAMETER SPC

            1           2

1       1.000       1.000
2                   1.000


----   1603 PARAMETER SSPH

            1           2

1       1.000       1.000
2                   1.000


----   1603 PARAMETER SSPC

            1           2

1       1.000       1.000
2                   1.000


----   1603 PARAMETER SPH1

1 2.000,    2 1.000


----   1603 PARAMETER SPC1

1 2.000,    2 1.000


----   1603 PARAMETER SHK
```

(ALL 0.000)

---- 1603 PARAMETER SCK

(ALL 0.000)

---- 1603 PARAMETER SH1

(ALL 0.000)

---- 1603 PARAMETER SC1

(ALL 0.000)

---- 1603 PARAMETER SCK3

(ALL 0.000)

---- 1603 PARAMETER SC13

(ALL 0.000)

---- 1631 PARAMETER SSC1

(ALL 0.000)

---- 1631 PARAMETER SSC2

(ALL 0.000)

---- 1631 PARAMETER SSC3

(ALL 0.000)

---- 1631 PARAMETER SSC4

(ALL 0.000)

---- 2477 PARAMETER HI = 4.000

---- 2506 PARAMETER THQ

1 370.000, 2 590.000, 3 650.000, 4 +INF

---- 2506 PARAMETER QHQ

2 6600.000, 3 7200.000, 4 7200.000

---- 2522 PARAMETER TQMAX = 650.000
PARAMETER TQMIN = 370.000

```
            PARAMETER QQMAX                =     7200.000
            PARAMETER QQMIN                =        0.000

----   2529 PARAMETER CJ                   =        4.000

----   2558 PARAMETER TCQ

1 350.000,    2 410.000,    3 500.000,    4 650.000


----   2558 PARAMETER QCQ

1 2305.741,    2 3085.741,    3 5605.741,    4 7855.741


----   2580 PARAMETER TQJMAX               =      650.000
            PARAMETER TQJMIN               =      350.000
            PARAMETER QQJMAX               =     7855.741
            PARAMETER QQJMIN               =     2305.741

**** REPORT FILE SUMMARY

RES1 /var/www/html/interfaces/synheat/output.html
RES16 /var/www/html/interfaces/cgi-bin/synheat/si
RES17 /var/www/html/interfaces/cgi-bin/synheat/fi
RES6 /var/www/html/interfaces/cgi-bin/synheat/ei
RES7 /var/www/html/interfaces/cgi-bin/synheat/ci
RES8 /var/www/html/interfaces/cgi-bin/synheat/hi
RES9 /var/www/html/interfaces/cgi-bin/synheat/ui
RES11 /var/www/html/interfaces/cgi-bin/synheat/ai
RES10 /var/www/html/interfaces/cgi-bin/synheat/yi
RES12 /var/www/html/interfaces/cgi-bin/synheat/bi
RES5 /var/www/html/interfaces/cgi-bin/synheat/synheat.dem
RES18 /var/www/html/interfaces/cgi-bin/synheat/phi
RES19 /var/www/html/interfaces/cgi-bin/synheat/pci
RES20 /var/www/html/interfaces/cgi-bin/synheat/pinch.dem


EXECUTION TIME       =        0.056 SECONDS     11 MB  52.5.0 9bc771bf LEX-LEG


USER: Floating Network License                       G260106+0003Ac-GEN
      Carnegie Mellon University Dept. of Chemical Engineering /DCE5111
      License for teaching and research at degree granting institutions


**** FILE SUMMARY

Input      /var/www/html/interfaces/cgi-bin/synheat/model.gms
Output     /var/www/html/interfaces/cgi-bin/synheat/model.lst
```