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APPENDICES

APPENDIX A

DETAILS OF SYNTHETIC FIBRE PLANT COGENERATION MODEL

1. objective function

The objective function to be minimized represents the total net cost required to cogenerate process steam and electricity, as follows.

(Total net cost) = (cost of make - up boiler feed water)
+ (cost of fuel oil consumption)
+ (cost of purchsed electricity)
+ (cost of blow steam)
+ (income from steam sale)

In mathematical symbols, the objective function becomes

$$PHI = CW * x(7) + CF * x(6) + CE * x(4) + CB * x(3) - CS * FS$$

1.1 cost of fuel oil consumption

Cost of fuel oil consumption mainly depends on the amount of superhested steam produced in the boiler.

Cost of fuel oil consumption = CF * x(6)

when CF is the unit price of fuel oil 2500 RW 1 which is 2.62 Baht/litre (May, 1987) and x(6) is the rate of fuel oil consumption by mains boiler (l/h)

1.2 cost of purchased electricity

The electricity cost consists of the following components

a) Demand * 170 Bath/KW

b) Energy * 1.22 Bath/KWH

c) Discount 4%

d) Bonus = Demand * 90 Bath/KW (1- 0.85/PO)

when - Demand here is the maximum value of purchased electricity in that month

Demand = x(4)/0.85

- o.85 is the desired power factor ,

- PO is the actual power factor

- Bonus is a discount given by the Provincial Electric Authority. However,it will be negligible here.

Therefore, the cost of purchased electricity

= (demand * 170 + energy * 1.22) * 0.96

= [x(4)/0.85] * 170 + x(4) * 30 * 24 * 1.22) * 0.96

= 1035.26*x(4)

Since the above is electricity purchase cost per month.

So, electricity purchase cost per hour = 1035.26*x(4)/(30*24)

= 1.438*x(4)

1.3 costs of steam

Steam of a different pressure is assigned a different associated cost because its energy content (enthalpy) and the work content (exergy) are not the same.

1.3.1 cost of 100K superheated steam

From the steam-oil ratio relation based on actual boiler operation, 3590 l/h of fuel oil is consumed to generate 50 T/H of steam, whereas 5330 l/h of fuel oil generates 75 T/h of steam. So on the average, 4460 l/h of fuel oil is reguired to produce 62.5T/h of steam. And the average steam oil ratio is 0.014 T/l fuel oil.

Since the fuel cost, CF, is 2.62 Baht/l, the cost of 100K superheated steam = 2.62/0.014 = 186.97 Baht/T

1.3.2 Cost of 17K steam

The definition of exergy is

$$e = (h - h_o) - T_o (s - s_o) \quad \text{(A-1)}$$

e - exergy of steam (kcal/kg)

h - enthalpy of steam (kcal/Kg)

h_o - enthalpy of steam at dead state

t_o - dead state temperature 25°C or 298°K

s - entropy of steam (kcal/kg°K)

s_o - entropy of steam at dead state

The properties of steam are taken from the steam table

h (17K,240°C) = 692.46 (kcal/kg)

h (3K,180°C) = 656.52 (kcal/kg)

h (100K,500°C) = 806.2 (kcal/kg)

h_o = 25.07 (kcal/kg)

s_o = 0.087 (kcal/kg)

s (17K,240°C) = 1.59 (kcal/kg°K)

s (3K,180°C) = 1.72 (kcal/kg°K)

s (100K,500°C) = 1.586 (kcal/kg°K)

Next the above values are substituted into equation (A-1) to obtain the exergy of steam at each condition.

$e\ (100K, 500^{o}C) = (806.2 - 25.07) - 298\ (1.586 - 0.087)$

$= 781.13 - 446.46$

$= 334.67$ kcal/kg

$e\ (17K, 240^{o}C) = (692.46 - 25.07) - 298\ (1.59 - 0.087)$

$= 667.79 - 447.6$

$= 219.79$ kcal/kg

$e\ (3K, 180^{o}C) = (656.52 - 25.07) - 298\ (1.72 - 0.087)$

$= 631.45 - 488.42$

$= 143.03$ kcal/kg

Cost of 17K steam $= [e(17K,240^{o}C)/e(100K,500^{o}C)]$

x(Cost of 100K steam)

$= (219.79/334.67)\ (CF/0.014)$

= 46.90 CF or 122.90 Baht/T

1.3.3 Cost of 3K steam

Similarly, cost of 3K steam $= [e(3K,180^{o}C)/e(100K,500^{o}C)]$

x(Cost of 100K steam)

$= 143.03/334.67)\ (CF/0.014)$

= 30.52 CF or 79.98 Baht/T

1.4 <u>Cost of make - up boiler feed water</u>

By experience, the cost of make - up boiler feed water is taken as 10 Baht/T

1.5 <u>Sale price of 17K steam</u>

The steam for sale was 17K steam. Here its sale price was taken to be the same as the production cost of 17K steam.

2. Inequality constraints

In this section the physical meaning of each inequality constraint is explained and the equation form is shown.

2.1 Bustie electricity must be less than purchased electricity

$$x(5) < x(4)$$

$$g(1) = x(5) - x(4) < 0$$

2.2 100K by - passed steam must be greater than or equal to 0.5 T/h

$$g(2) = x(8)+0.5-((EN1-EN2)/(EN1-EN5))*(X(9)+RC*x(1))<0$$

2.3 The 17K steam to the boiler burners must be less than 0.04*RC*x(1) by experience

$$g(3) = 0.96*RC*x(1)-x(11)<0$$

2.4 The 17K steam to the burners must be greater than 0.010 T/h

$$g(4) = 0.10+x(11)-RC(x(1)<0$$

2.5 Temperature of the outlet steam from the high pressure heater must be higher than $140^{\circ}C$

$$g(5) = 140-(((CON+x(7)+X(11)+TODT*EN5$$
$$-((CON+x(7))*x(12)*1000+TODT*EN4))/x(11))*1.0E-3)<0$$

The second term of constraint g(5) was the temperature of the outlet steam from the high pressure heater. Details of the relation has been shown in the example of calculation in Appindex C.

2.6 Temperature of the outler steam from the high pressure heater must be less than $170^{\circ}C$.

$$g(6) = -170+(((CON+x(7)+x(11)+TODT)*EN5$$
$$-((CON+x(7))*x(12)1000+TODT*EN4))/x(11)*1.0E-3<0$$

3. Equality constraints

First the nomenclature used in the derivation of the model will be shown here.

Abbreviation of Words

HPH - High Pressure Heater

BFP - Boiler Feed Pump

DT - Deaeration Tank

DFP - Deaerator Feed Pump

PWT - Purified Water Tank (This tank contained with the make-up boiler feed water)

FOH - Fuel oil Heater

APH - Air Preheater

Parameters

TOAT - 17K atomizing steam to boiler (for atomizing fuel oil) (T/h)

TODT - 3K steam to deaeration tank (T/h)

TOAPH - 3K steam to air preheater (T/h)

TOFOH - 3K steam to fuel oil heater (T/h)

BP1 - 100K steam by - passed from boiler to 17K steam line (T/h)

BP2 - 100K steam by - passed from boiler to 3K steam line (T/h)

D1 - Desuperheating water for mixing with by-pased steam to 17K steam line (T/h)

D2 - Desuperheating water for mixing with by-passed steam to 3K steam line (T/h)

FDE1 - Desuperheating water for 17K extracted steam (FDE1=BP1+D1)(T/h)

FDE2 - Desuperheating water fo 3K extracted steam (FDE2=BP2+D2)(T/h)

BB - blow down from boiler bottom (T/h)

Constants

TSUP - Temperature of superheated steam produced from boiler. In this work TSUP is 500°C

EN1 - Enthalpy of 17K steam extracted from turbogenerater

EN1 = 437.714 * TSUP + 513866

= 732723 kcal/T

EN2 - Enthalpy of 17K saturated steam (after desuperheating)

EN2 = 691000 kcal/T

EN3 - Enthalpy of 13K steam exhausted from turboglnerator

EN3 = 727.5 * TSUP + 326323

= 690073 kcal/T

EN4 - Enthalpy of 3K saturated steam (after desuperheating)

EN4 = 675000 kcal/T

EN5 - Enthalpy of desuperheating water

EN5 = 142,000 kcal/T

EN6 - Enthalpy of superheated 100K steam (500°C) from boiler

EN6 = 700 * TSUP + 456643

= 806643 kcal/T

RC - Fixed fraction of 17K steam sent back to boiler as house service. By experiment RC is 0.092

RD - Fixed fraction of 3K steam sent back to boiler as house sevice. By experiment RD was 0.12.

RE - Correction factor of 3K house service steam. By experiment RE is 1.0.

CPOIL - Speaific heat of fuel oil.
CPOIL = 0.538 kcal/kg^{o}C

CPAIR - Speaific of air.
CPAIR = 0.237 kcal/kg ^{o}C

DENAIR - Density of air
DENAIR = 1.29 kg/m^3

DENOIL - Density of fuel oil
DENOIL = 0.9465 kg/l

3.1 Energy balance around the turbogenerator

Define A1 = 1 - RC (EN2-EN5)/(EN1-EN5)
- RD (EN4-EN5)/(EN3-EN5)

A2 = [EN6-RC.EN1(EN2-EN5)/(EN1-EN5)
- RD.EN3(EN2-EN5)/(EN3-EN5)]/A1

From the law of energy conservation.

(heat input of steam from boiler)-(heat output of 17K extracted steam)-(heat output of 3K exhaust steam)-(heat output of blow steam)-(work or electricity generated) = 0

h(1) = (x(2)*860)*(1(.1699*(x(2)**.195)))*(1/A2-EN3))
-((A2-EN1)/(A2-EN3))*((EN2-EN5)/(EN1-EN5))*x(9)
-((EN4-EN5)/(EN3-EN5))*(x(10)+2.3*RE)-X(3) = 0

The derivation of the equation is made by the factory.

3.2 Electricity balance

(Purchased electricity) + (generated electricity) = (Total electricity required by process)

x(4) +x(2) = AB

h(2) = x(4) + x(2) - AB = 0

3.3 Fuel oil consumption and steam produced

Fuel oil consumption depends on steam production ascording to the following empirical equation

x(6) = (x(1) * 1000)/(13.9198+(x(1)-45)*5E-03)

h(3) = x(6)-(x(1) * 1000 /(13.9198+x(1)-45)*5E-03)) = 0

3.4 Overall steam mass balance around big loop

(100K steam generated by boiler)+(desuperheating water)

= (17K steam sent to process plus 17K steam for sale)+ (3K steam sent to process)+(3K steam blow off)+(17K steam house service)+(3K steam house service)

h(4) = x(9(+x(10)+x(3)+RC*x(1)+(RD*x(1)+2.3* RE)

- x(1) -x(8) = 0

3.5 Mass balance (Steam and Water) around HPH and DT

(Steam to HPH) + (3K steam house service)+(make-up feed water)+(Recovered condensate) = (boiler feed water)+(desuperheating water)+(TOFOH)+(TOAPH)

TOFOH and TOAPH are calculated simply from heat balances, as follows.

Calculation of TOFOH

3K steam is used to heat fuel oil from 60°C to 90°C and it becomes condensate at 100°C.

$TOFOH * (EN4-o.1 * 10^6) = CPOIL *(\triangle T)_{oil} (Q_{oil})$

$TOFOH * (EN4 - 0.1 * 10^6) = CPOIL * (90-60) * x(6) * DENOIL$

TOFOH = CPOIL * (90-60) * x(6) * DENOIL/(EN4-100,000)

Calculation of TOAPH

3K steam is used to preheat combustion air from 35°C to 122°C and it becomes condensate at 100° C

$TOAPH * EN4 = CPAIR(\triangle T)_{air} (Q_{air})$

$Q_{air} = m.Q_{air\ theory}$

In this case assume that m is 1.3.

$Q_{air\ theory}$ = function (heating value of oil) (see Boie's formula)

$= 12.38(HL-1,100)/1,000 \quad m^3/kg_{oil}$

In this case HL was 9,300(kcal/kg)

$Q_{air\ theory} = 12.38(9300-1100)/1,000$

$= 10.15 \quad m^3/kg_{oil}$

$Q_{air} = 1.3\ Q_{air\ theory}$

$= 1.3 * 10.15$

$= 13.19 \quad m^3/kg_{oil}$

$TOAPH * EN4 = CPAIR(\triangle T)_{air}\ Q_{air}$

= CPAIR * (122-35)*13.19*DENAIR*x(6)*DENOIL

TOAPH = CPAIR * (122-35)*13,19DENAIR*x(6)*DENOIL/EN4 h(5) = x(11) + (RD * x(1) + 2.3 * RE) + x(7) + CON

- 1.01 * x(1) - x(8) - (CPOIL * (90-60) * x(6) * DENOIL)/

(EN4-100,000) - CPAIR * (122-35) * 13.19 * DENAIR *

x(6) * DENOIL/EN4 = 0

3.6 Overall water balance

(Make-up feed water)+(Condensate water)=(boiler feed water)

=(steam to air preheater) + (steam to fuel oil heater)

+(steam fo atomizing fuel oil + Bottom blow down from boiler)+(17K steam sent to process plus steam for sale) + (3K steam sent to process) + (3K steam blow off to atmosphere)

h(6) = CPAIR * (122-35) * 13.19 * DENAIR * x(6) * DENOIL/EN4 + (CPOIL * (90-60) * x(6) DENOIL)/(EN4-100,000) + RC * x(1) - x(11) + 0.01 * x(1) + x(9) +x(10) + x(3) - x(7) - CON = 0

3.7 Process Steam Requirement

(17K steam sent to process plus steam for sale) + (3K steam sent to process)

=(Total repuirement of steam by proces plus steam for sale)

h(7) = x(9) + x(10) - PTOTAL = 0

3.8 Heat balance around HPH, BFP and DT

(heat from TOHPH) + (heat from TODT) + (heat from PWT) =

(heat of boiler feed water)

h(8) = (x(11) * EN2 + (RD * x(1) + 2.3 * RE) * EN4

-EN4 * (CPOIL * (90-60) * x(6) * DENOIL)/(EN4-100,000)

-CPAIR * (122-35) * 13.19 * DENAIR * x(6) * DENOIL

+ (CON + x(7) * x(12) * 1000 - 1.01 * x(1) * 0.19E6 -x(8) *

EN5) * 1.0E - 07 = 0

3.9 Heat balance around PWT and DFP

(heat of condensate) + (heat from pure water tank) =(heat out)

h(9) = (CON * x (13) * 1000 + x (7) * 0.03 E6 - (CON +

x(7)) * x(12) * 1000) * 1.0E - 07 = 0

APPENDIX B

DETAIL OF UPPER AND LOWER BOUND OF VARIABLE FOR COGENERATION MODEL OF SYNTHETIC FIBRE PLANT

The upper bounds (UB) and lower bounds (LB) of the 13 variables in the present cogeneration model of the fibre synthetic plant are shown and explained here.

Variable		Physical Meaning	Remark
x(1)	UB = 80.0	Maximum boiler load is 80 T/h	
	LB = 50.0	The minimum boiler load is set at 50.0 T/h in order to maintain good boiler efficiency.	
x(2)	UB = 9,000.0	Maximum electricity generation capacity of turbogenerator is 9000.0 KW.	
	LB = 6,500	Minimum electricity generation capacity of turbogenerator is 6500.0 KW.	

Variable		Physical Meaning	Remark
x(3)	UB = 20	The maximum allowable blow of 3K steam is 20.0 T/h.	
	LB = 0.0	3 K blow steam cannot be negative.	
x(4)	UB = 12000.0	Maximum electricity purchase is 12000.0 KW.	
	LB = 2010.0	Purchase electricity is set by contrat at 2010.0 KW.	
x(5)	UB = 12000.0	Maximum bus-tie electricity is 12000.0 KW.	
	LB = 0.0	Bus-tie electricity cannot be negative.	
x(6)	UB = 5675.0	Maximum fuel oil consumption is 5675.0 l/h (based on 80 T/h steam).	
	LB = 3580.0	Minimum fuel oil consumption is 3580.0 l/h (based on 50 T/h steam).	

Variable		Physical Meaning	Remark
x(7)	UB = 80	Maximum make-up boiler feed water is 80 T/h. (no condensate recovery).	
	LB = 2.40	Minimum make-up boiler feed water is 3% of maximum boiler load (80 T/h), since it is necessary to carry out bottom blow.	
x(8)	UB = 3.45	Maximum desuperheating water is 3.45 T/h.	
	LB = 0.0	Desuperheating water must not be negative.	
x(9)	UB = 43.0	Maximum 17 K steam sent to process plus steam for sale must not exceed total requirement of process steam plus 17 K steam for sale (PTOTAL).	
	LB = 20.0	Minimum 17 K steam sent to process plus steam for sale should not be less than P17K min (Minimum process requirement of 17 K steam plus steam for sale). This numerical value is for the standard case.	

Variable		Physical Meaning	Remark
x(10)	UB = 40.0	Maximum 3 K steam sent to process is 40.0 T/h. This is determined by the exhaust steam from the turbogenerator	
	LB = 15.0	Minimum 3 K steam sent to process is 15.0 T/h. That is determined by the characteristics of turbogenerator.	
x(11)	UB = 7.36	Maximum 17 K steam to high pressure heater is 7.36 T/h.	
	LB = 5.24	Minimum 17 K steam to high pressure heater is 5.24 T/h.	
x(12)	UB = 90.0	Maximum temperature of mixing condensate and make-up water is 90°C	
	LB = 55.0	Minimum temperature of mixing condensate and make-up water is. 55.0°C.	

	Variable	Physical Meaning	Remark
x(13)	UB = 100.0	Maximum temperature of condensate in condensate tank at atmospheric pressure is 100°C.	
	LB = 60.0	Minimum temperature of condensate water in condensate tank is set at 60°C.	

APPENDIX C

DETAIL OF HEAT AND MASS BALANCES

To ensure the validity of the model, as well as the optimization results heat and mass balances were made each major piece of equipment or section in the fiber synthesis plant.

Appendix C indicates the pieces of equipment and sections where heat and mass balances were made, and show examples of calculation, including the computer print outs for both the starting point and optimal point.

The FORTRAN IV sub-program for carrying out these calculations is shown concluded in Appendix D as part of the listed subroutines.

1. Location of heat and mass balances

Heat and mass balances were made around in following pieces of equipment and sections.

<u>Balance 1</u>. Around the section enclosed by loop P.1 in Fig.C.1

The input streams of the section enclosed by loop P.1 were steam from the boiler house and desuperheating water sent from the boiler feed water pump. The output streams were electricity generated, 3K blow steam, 17K steam supplied to the process plus 17K steam for sale, 3K steam supplied to the process, 17K steam for house service and 3K steam for house service.

Balance 2. Around the turbogenerator (enclosed by loop P.2)

The only input stream was super-heated steam from the boiler excluding the part which was by-passed for desuperheating. The output streams were 17K extract steam from the turbo enerator, 3K exhaust steam, and 3K blow steam.

Balance 3. Around the desuperheater for 3K exhaust steam (enclosed by loop P.3)

Part of the exhaust steam from the turbogenerator was blown off to the atmosphere. Then it was desuperheated by mixing with hot water at 142°C, so that the temperature of the exhaust steam mixture was reduced from 200°C to be 180°C. After desuperheating the steam was sent to the process while a part of it was returned to the boiler as house service steam.

Balance 4. Around the desuperheater for 17K extract steam. (enclosed by loop P.4)

The extract steam from the turbogenerator was desuperheated by mixing with hot water at 142°C, so that the temperature of the extract steam was reduced from 300°C to be 240°C. After desuperheating the steam was sent to the process and also for sale, while a part of it was returned to the boiler as house service steam.

Balance 5. Around the section enclosed by loop P.5

The input streams to this section were steam from the boiler excluding the part which was by - passed for desuperheating, desuperheating water for the 17K extract steam and desuperheating water for the 3K exhaust steam. The output streams were electricity generated, 3K blow steam, 17K steam sent to the process plus steam for sale, 17K steam for house service, 3K steam sent to the process and 3K steam for house service.

Balance 6. Around the section enclosed by loop P.6

Part of the superheated steam from the boiler was by-passed and split. The pressures of the split streams were next reduced from 100 kg/cm^2 to 17 kg/cm^2 and 3 kg/cm^2 while heat losses caused their temperatures to become 190°C and 133°C, respectively. Then the two streams were each mixed with a part of the mixture of condensate and make-up water to become desuperheating water for the 17K extract steam (FDE1) and for the 3K exhaust steam (FDE2), respectively.

Thus the input streams were 17K by-passed steam, 3K by-passed steam and a part of the mixture between condensate and make-up water.

The output streams were the two streams of desuperheating water for the 17K extract steam with enthalpy of about 142,000 kcal/T and for the 3K exhaust steam with enthalpy of about 142,000 kcal/T.

Balance 7. Around the section enclosed by loop P.7

As superheated steam from the boiler flowed to the turbogenerator, part of it was by-passed and its pressure was further reduced, as described in Balance 6 above.

Here the input stream was superheated steam from the boiler. The output streams were steam to the turbogenerator and by - passed steam.

Balance 8. Around the spliting point of 17K exhaust steam (enclosed by loop P.8)

At first the extract steam from the turbogenerator was desuperheated by mixing with 17K desuperheating water (FDE 1).

Then it was split into two streams, one flowing to house service and the other to the process.

Here the input stream was the desuperheated 17K steam. The output streams were 17K house service steam and 17K steam to the process plus steam for sale.

Balance 9. Around the splitting point of 3K steam (enclosed by loop P.9)

At first part of the 3K exhaust steam was blown off to the atmosphere. Then it was mixed with desuperheating water (FDE2) and split into two streams, one flowing to house service and the other to the process.

Here the input stream was the desuperheated 3K steam. The output streams were 3K house service steam and 3K steam to the process.

Balance 10. Around the blow-off point of 3K steam (enclosed by loop P.10)

A part of the 3K exhaust steam was blown off in order to adjust the rate of electricity generation at will even though the 3K process steam requirement was low.

Here the input stream was 3K exhaust steam from the turbogenerator and the output steams were 3K blow-off steam and 3K steam sent to the process.

Balance 11. Around the splitting point of 17K house service steam (enclosed by loop P.11)

Here the point the input stream was 17K house service steam. The output streams were 17K steam to the high pressure heater and 17K steam to boiler for atomizing fuel oil.

Balance 12. Around the splitting point of 3K house service (enclosed by loop P.12).

Here the input stream was 3K house service steam.

The output streams were 3K steam to the deaeration tank and 3K steam to the fuel oil heater and air preheater.

Balance 13. Around the splitting point of 3K heating steam (enclosed by loop P.13).

Here the input stream was 3K heating steam. The output streams were 3K steam to the fuel oil heater and 3K steam to the air preheater.

Balance 14. Around the section enclosed by loop P.14.

The section consisted of the high pressure feed water heater, boiler feed pump and deaeration tank. The input streams were 17K steam to the high pressure heater, 3K steam to the deaeration tank and boiler feed water from the deaeration feed pump. The output streams were boiler feed water and desuperheating water.

Balance 15. Around the boiler (enclosed by loop P.15)

Here the input streams were combustion air, fuel oil, 17K steam for atomizing fuel oil and boiler feed water. The ouput streams were 100K superheated steam from the boiler, hot flue gas exhausted air and bottom blow down from the boiler.

Balance 16. Around the deaeration tank (enclosed by loop P.16)

Here the input streams were 3K steam to the deaeration tank, incoming water from the deaeration feed pump and condensate from the high pressure heater. The output stream was deaerated water to the boiler feed pump.

Balance 17. Around the boiler feed pump (enclosed by loop P.17)

Here the input stream was deaerated water from the deaeration tank. The output streams were desuperheating water and boiler feed water.

Balance 18. Around the high pressure heater (enclosed by loop P.18)

Here the input streams were boiler feed water at about $140^{o}C$ and 17K steam to the high pressure heater at about $240^{o}C$.The output streams were heated boiler feed water whose temperature was raised up to be about $195^{o}C$ and condensate from the high pressure heater at about $160^{o}C$.

Balance 19. Around the fuel oil heater (enclosed by loop P.19)

Here the input streams were fuel oil and 3K heating steam to the fuel oil heater. The output streams were heated fuel oil and condensate.

Balance 20. Around the preheater (enclosed by loop P.20).

Here the input streams were cold combustion air and 3K heating steam to the air preheater.

The output streams were condensate and hot combustion air to the boiler.

Balance 21. Around the pure (boiler feed) water tank (enclosed by loop P.21).

Here the input streams were treated make-up water and returned condensate. The output stream was water to the deaeration tank.

At all the above balance points, the total amounts of mass in, mass out, heat in and heat out were calculated. Then relative errors of mass and heat balance were estimated as follows :

$$\text{Relative error} = \frac{[(\text{mass or heat in}) - (\text{mass or heat out})]}{(\text{mass or heat in})} \times 100\ (\%)$$

Typical results of these heat and mass balances and their relative errors were shown in Appendix C.

2. Formulas and Examples of Calculation

The values of the variables at the starting point of the standard case were used here to demonstrate the calculations. This set of values represented the recent operating condition in the plant. When heat and mass balances were calculated, all the relative errors were found to be less than 1 percent.

Balance 1. Around the section enclosed by loop P.1

mass in :

boiler load	7.13	T/h
desuperheating water	2.04	T/h
Total	75.17	T/h

mass out :

17K steam sent to the process plus steam for sale	20	T/h
3K steam sent to the process	23	T/h
3K house service steam	11.07	T/h
17K house service steam	6.72	T/h
3K blow-off steam	14.38	T/h
Total	75.17	T/h

heat in :

heat of 1ooK steam from the boiler 73.13 * 806,000 = 58.94 x 10^6 kcal/h

heat of desuperheating water 2.04 * 142,000 = 0.29 x 10^6 kcal/h

Total 59.23 x 10^6 kcal/h

Let G be the amount of electricity

and RB be turbogenerator efficiency,

then RB = .1699 * (G**.195)

In this case we have

G = 8536 KW and RB = .993

So heat of generated electricity = (G x 860)/RB

= 7.39 kcal/h

heat out :

heat of generated electricity	=	7.39 * 10^6	kcal/h
heat of 17K extract steam 20 * 691,000	=	13.82 * 10^6	kcal/h
heat of 3K exhaust steam 23 * 675,000	=	15.52 * 10^6	kcal/h
heat of 3K house service steam 11.17 * 675,000	=	7.47 * 10^6	kcal/h
heat of 17K house service steam 6.72 * 691,000	=	4.64	kcal/h
heat of 3K blow off steam, 14.38 * 690,073	=	9.92	kcal/h
Total		58.76	kcal/h

Balance 2. Around the turbogenerator

Define TUR - inlet steam to the turbogenerator T/h

FEXT - extract steam from the turbogenerator T/h

FEXH - exhaust steam from the turbogenerator T/h

HS - 17K steam to the process plus steam for sale T/h

LS - 3K steam to the process T/h

BS - 3K blow-off steam T/h

FDE1 - desuperheating steam for the extract steam T/h

FDE2 - desuperheating steam for the exhaust steam T/h

mass in :

TUR = FEXT + FEXH

FEXT = 17k house service steam + HS - FDE1

= 0.092 * 73.13 + 20 - 1.87

= 24.85 T/h

FEXH = 3K house service steam + LS - FED2 + BS

= 11.07 + 23 - 0.92 + 14.38

= 47.53 T/h

TUR = 24.85 + 47.53 T/h

= 72.38 T/h

Total mass in = 72.38 T/h

mass out :

Total mass out = 72.38 T/h

heat in :

Total heat in = TUR * EN6

= 72.38 * 806643

= $58.38 * 10^6$ kcal/h

heat out :

Total heat out = FEXT * EN1 + FEXH * EN3 + heat of generted electricity

= $24.85 * 732723 + 47.53 * 690773 + 7.41 * 10^6$

= $18.2 * 10^6 + 32.8 * 10^6 + 7.41 * 10^6$

= $58.41 * 10^6$ kcal/h

Balance 3. Around the desuperheater for 3K exhaust steam

mass in :

FDE2 = (RD * x(1) + 2.3 * RE + x(10) * (EN3-EN4)/(EN3-EN5)

= (0.12 * 73.13 + 2.3 + 23) * (690073-675000)/

(690073-142000)

= 34.07 * 0.0275

= 0.936 T/h

Total mass in = FEXH - x(3) + FDE2

= 47.53 - 14.38 + 0.936

= 34.086 T/h

mass out :

Total mass out = x(10) + RD * x(1) + 2.3 * RE

= 23 + 0.12 * 73.13 + 2.3

= 34.076 T/h

heat in :

Total heat in = (FEXH - x(3)) * EN3 + FDE2 * EN5

= (47.53 - 14.38) * 690073 + 0.936 * 142000

= $22.87 * 10^6 + 0.133 * 10^6$ kcal/h

= $23.0 * 10^6$ kcal/h

heat out :

Total heat out = mass out * EN4

= 34.076 * 675000 kcal/h

= $23.0 * 10^6$ kcal/h

<u>Balance 4.</u> Around the desuperheater for 17K extract steam.

mass in :

FDE1 = (RC * x(1) + x(9) * (EN1-EN2)/(EN1-EN5)

= (0.092 * 73.13 + 20) * (732723-691000)/ (732723-142000)

= 26.72 * 0.07 T/h

= 1.88 T/h

Total mass in = FEXT + FDE1

= 24.85 + 1.88 T/h

= 26.73 T/h

mass out :

Total mass out = RC * x(1) + x(9)

= 0.092 * 73.13 + 20

= 6.728 + 20 T/h

= 26.728 T/h

heat in :

Total heat in = FEXT * EN1 + FDE1 * EN5

= 24.85 * 732723 + 1.88 * 142000

= $18.2 * 10^6 + 0.26 * 10^6$ kcal/h

= $1.846 * 10^6$ kcal/h

heat out :

Total heat out = mass out * EN2

= 26.728 * 691000

= $1.846 * 10^6$ kcal/h

Balance 5. Around the section enclosed by loop P.5

mass in :

Total mass in = TUR + FDE1 + FDE2 .

= 72.38 + 1.88 + 0.936

= 75.196 T/h

mass out :

Total mass out = RC * x(1) + x(9) + RD * x(1) + 2.3 + x(3)

= 6.72 + 20 + 11.07 + 23 + 14.38

= 75.17 T/h

heat in :

Total heat in = TUR * EN6 + FDE1 * ENR FDE2 * EN5

= 72.38 * 806643 + 1.88 * 142000 + 0.936 * 142000

= $58.38 * 10^6 + 0.266 * 10^6 + 0.133 * 10^6$

= $58.78 * 10^6$ kcal/h

heat out :

Total heat out = x(2) * 860/RB + x(3) * EN3 + RC * x(1) * EN2

+(RD * x(1) + 2.3 * RE) * EN3

= $7.41 * 10^6$ + 14.38 * 690073 + 26.72 * 691000

+ 34.07 * 675000

= $7.41 * 10^6 + 9.92 * 10^6 + 18.46 * 10^6$

$+ 22.99 * 10^6$

= $58.78 * 10^6$ kcal/h

Balance 6. Around the section enclosed by loop P.6

Define EN7 - enthalpy of 17K steams at 198°C

EN7 = 19800 kcal/T

EN8 - enthalpy of 3K steam at 133°C

EN8 = 133000 kcal/T

BP1 - by - passed steam whose pressure was reduced to 17K T/h

BP2 - by - passed steam whose pressure was reduced to 3K T/h

D1 - Desuperheating water for BP1 T/h

D2 - Desuperheating water for BP2 T/h

BP - 100K by - passed steam

$$BP = x(1) - TUR$$

BP1 and D1 can be calculated from the heat balance.

$$FEE1 * EN5 = BP1 * EN7 + D1 * EN5 \qquad \ldots(a)$$

$$FDE2 * EN5 = (BP - BP1) * EN8 + (x(8) - D1) * EN5 \qquad \ldots(b)$$

from (b)

$$FDE2 * EN5 = BP * EN8 - BP1 * EN8 + x(8) * EN5 - D1 * EN5 \qquad \ldots(c)$$

(a) + (c)

$$(FDE1 + FDE2) * EN5 = BP1 * (EN7 - EN2) + BP * EN8 + x(8) * EN5$$

$$BP1 = \frac{(FDE1 + FDE2) * EN5 - BP * EN8 - x(8) * EN5}{EN7 - EN8}$$

$$BP2 = BP - BP1$$

$$D1 = \frac{FDE1 * EN5 - BP1 * EN7}{EN5}$$

$$D2 = x(8) - D1$$

After substituting the known values, we get

BP1 = 0.03 T/h

BP2 = 0.72 T/h

D1 = 1.788 T/h

D2 = 0.252 T/h

mass in :

Total mass is = BP + x(8)

= 0.75 + 2.04 T/h

= 2.79 T/h

mass out :

Total mass out = FDE1 + FDE2

= 1.88 + 0.936 T/h

= 2.81 T/h

heat in :

Total heat in = BP1 * EN7 + BP2 * EN8 + x(8) * EN5

= 0.030 * 19800 + 0.72 * 133000 + 2.04 * 142000

= 5940 + 95760 + 289680

= $0.39 * 10^6$ kcal/T

heat out :

Total heat out = (FDE1 + FDE2) * EN5

= 2.81 * 142000

= $0.399 * 10^6$ kcal/T

<u>Balance 7</u>. Around the section enclosed by loop P.7

mass in :

Total mass in = x(1)

= 73.13 T/h

mass out :

Total mass out = TUR + BP

= 72.38 + 0.75

= 73.13 T/h

heat in :

Total heat in = x(1) * EN6

= 73.13 * 806643

= $58.98 * 10^6$ kcal/T

heat out :

Total heat out = TUR * EN6 + BP * EN6

= 72.38 * 806643 + 0.75 * 806643

= $58.38 * 10^6 + 0.6 * 10^6$

= $58.98 * 10^6$ kcal/T

Balance 8. Around the splitting point of 17K exhaust steam.

mass in :

Total mass in = FEXT + FDE1

= 24.85 + 1.88

= 26.73 T/h

mass out :

Total mass out = RC * x(1) + x(9)

= 0.092 * 73.13 + 20

= 26.727 T/h

heat in :

Total heat in = (FEXT + FDE1) * EN2

= 26.73 * 69100

= $18.47 * 10^6$ kcal/T

heat out :

Total heat out = (RC * x(1) + x(9) * EN2

= 26.727 * 691000

= $18.47 * 10^6$ kcal/T

Balance 9. Around the splitting point of 3K steam

mass in :

Total mass in = FEXH - x(3) + FDE2

= 47.53 - 14.38 + 0.936

= 34.086 T/h

mass out

Total mass out = x(10) + x(1) * RD + 2.3 * RE

= 23 + 73.13 * 0.12 + 2.3

= 34.07 T/h

heat in :

Total heat in = [FEXH - x(3) + FDE2] * EN4

= 34.086 * 675000

= $23.00 * 10^6$ kcal/h

heat out :

Total heat out = [x(10) + x(1) * RD + 2.3 * RE] * EN4

= 34.07 * 675000

= $22.99 * 10^6$ kcal/h

Balance 10. Around the blow-off point of 3K steam.

mass in :

Total mass in = FEXH

= 47.53 T/h

mass out :

Total mass out = RD * x(1) + 2.3 * RE + x(10) - FDE2 + x(3)

= 0.12 * 73.13 + 2.3 + 23 - 0.936 + 14.38

= 47.52 T/h

heat in :

Total heat in = FEXH * EN3

= 47.53 * 690073

= $32.79 * 10^6$ kcal/h

heat out :

Total heat out : = mass out * EN3

= 47.52 * 690073

= 32.79×10^6t kcal/h

Balance 11. Around the splitting point of 17K house service steam.

mass in :

Total mass in = x(1) * RC

= 73.13 * 0.092

= 6.72 T/h

mass out :

Total mass out = TOAT + X(11)

= 0.044 + 6.676 T/h

= 6.72 T/h

heat in :

Total heat in = mass in * EN2

= 6.72 * 691000

= $4.648 * 10^6$ kcal/T

heat out :

Total heat out = mass out * EN2

= 6.72 * 691000

= $4.648 * 10^6$ kcal/T

Balance 12. Around the splitting point of 3K house service steam

mass in :

Total mass in = RD * x(1) + 2.3 * RE

= 0.12 * 73.13 + 2.3

= 8.776 + 2.3

= 11.076 T/h

mass out :

Total mass out = TODT + TOAPH + TOFOH

TOFOH

$TOFOH * (EN4-0.1*10^6) = CPOIL (T)_{oil} Q_{oil}$

$TOFOH * (EN4-0.1*10^6) = 0.538\ kcal /kg^oC * (90-60) C * 5201 l/h * 0.9465 kg/l$

$= 0.079 * 10^6$ kcal/h

$TOFOH = (0.079 * 10^6)/(0.575x10^6)$

= 0.1374 T/h

TOAPH

$TOAPH * EN4 = CPAIR (T)_{air} Q_{air}$

$= 0.237\ kcal/kg^oC * (122-35)^oC * 13.19 m^3/kg_{oil} * 1.29 kg/m^3$

$= 351.0\ kcal/kg_{oil}$

= 351.0 * 5201 l/h * 0.9465 kg/l

$= 1.73 * 10^6$ kcal/h

$TOAPH = 1.72 * 10^6/0.675 * 10^6$

= 2.56 T/h

<u>TODT</u>

TODT = mass in - TOFOH - TOAPH

= 11.076 - 0.1374 - 2.56

= 8.378 T/h

Total mass out = 8.378 + 2.56 + 0.1374

= 11.076 T/h

heat in :

Total heat in = mass in * EN4

= $11.076 * 0.675 * 10^6$

= $7.47 * 10^6$ kcal/h

heat out :

Total heat out = mass out * EN4

= $11.076 * 0.675 * 10^6$

= $7.47 * 10^6$ kcal/h

<u>Balance 13</u>. Around the splitting point of 3K heating steam.

mass in :

Total mass in = RC * x(1) + 2.3 * RE - TODT

= 0.12 * 73.13 + 2.3 - 8.38

= 11.07 - 8.38

= 2.69 T/h

mass out :

Total mass out = TOFOH + TOAPH

= 0.11 + 2.56

= 2.69 T/h

heat in :

Total heat in = mass in * EN4

= $2.69 * 0.675 * 10^6$

= $1.82 * 10^6$ kcal/h

heat out :

Total heat out = mass out * EN4

= $2.69 * 0.675 * 10^6$

= $1.82 * 10^6$ kcal/h

<u>Balance</u> <u>14</u>. Around the section enclosed by loop P.14

mass in :

Total mass in = CON + x(7) + x(11) + RD * x(1) + 2.3

= 35 + 26.07 + 6.676 + 11.076

= 78.82 T/h

mass out :

Total mass out = TOFOH + TOAPH + x(8) + 1.01 * x(1)

= 0.137 + 2.56 + 2.04 + 73.86

= 78.592 T/h

heat in :

Total heat in = CON * x(13) * 1000 + X(7) * 0.03 * 10^6 + x(11) * EN2 + (RD * x(1) + 2.3) * EN4

= $35 * 0.095 * 10^6 + 26.07 * 0.03 * 10^6 + 6.67 * 0.691 * 10^6 + 11.07 * 0.675 * 10^6$

= $3.325 * 10^6 + 0.78 * 10^6 + 4.61 * 10^6 + 7.47 * 10^6$

= $16.18 * 10^6$ kcal/h

heat out :

Total heat out = (TOFOH + TOAPH) * EN4 + x(8) * 0.14 * 10^6

+ 1.01 * x(1) *0.19 * 10^6

= 2.697 * 0.675 * 10^6 + 2.04 * 0.14 * 10^6

+ 1.01 * 73.13 * 0.19 * 10^6

= 1.82 * 10^6 + 0.28 * 10^6 + 14.03 * 10^6

= 16.13 * 10^6 kcal/h

<u>Balance</u> <u>15</u>. Around the boiler

mass in :

Total mass in = 1.01 * x(1)

= 1.01 * 73.13

= 73.86 T/h

mass out :

Total mass out = x(1) + 0.01 * x(1)

= 73.13 + 0.073

= 73.86 T/h

heat in :

Total heat in = (heat from air) + (heat from oil) +

(heat from feed water) + (heat of combustion)

+ (heat of atomizing steam)

heat from air = CPAIR $(\triangle T)_{air}$ Q_{air}

= 0.237 kcal/kg°C (22-25)°C * 13.19 m^3/kg_{oil}

* 1.29 kg/m^3

= 391.16 $kcal/kg_{oil}$

= 391.16 $kcal/kg_{oil}$ * 5201 l/h * 0.9465 kg/l

= 1.925 * 10^6 kcal/h

heat from oil = CPOIL $(\triangle T)_{oil}\ Q_{oil}$

= 0.538 kcal/kg^{o}C (90-25)^{o}C * 5201 l/h * 0.9465 kg/l

= 0.172 * 10^{6} kcal/h

heat from feed water = 1.01 * x(1) * 0.19 * 10^{6} kcal/h

= 1.01 * 73.13 * 0.19 * 10^{6} kcal/h

= 14.03 * 10^{6} kcal/h

heat of combustion = heating value * x(6)

= 9294.63 kcal/l * 5201 l/h

= 48.34 * 10^{6} kcal/h

heat of atomizing steam = [RC * x(1) - x(11)] * EN2

= (6.72 - 6.676) * 0.691 * 10^{6}

= 0.03 * 10^{6} kcal/h

Total heat in = 1.925 * 10^{6} + 0.172 * 10^{6} + 14.03 * 10^{6} + 48.34 * 10^{6} + 0.03 * 10^{6}

= 64.494 * 10^{6} kcal/h

heat out :

Total heat out = (heat of superheated steam) + (heat of flue gas) + (heat in blow down) + (heat losses)

heat of superheated = x(1) * 0.806 * 10^{6} kcal/h

= 73.13 * 0.806 * 10^{6} kcal/h

= 58.94 * 10^{6} kcal/h

heat of flue gas = CPAIR $(\ \ T)_{air}\ Q_{air}$

= 0.237 kcal/kg^{o}C (195-25) * 13.19 m^{3}/kg_{oil} * 1.29 kg/m^{3}

= 685.54 kcal/kg_{oil}

= 685.54 kcal/kg_{oil} * 5201 l/h * 0.9465 kg/l

= $3.37 * 10^6$ kcal/h

heat in blow down = $0.01 * x(1) * 0.5 * 10^6$ kcal/h

= $0.01 * 73.13 * 0.5 * 10^6$

= $0.36 * 10^6$ kcal/h

heat losses = $64.494 * 10^6 - 58.94 * 10^6 - 3.37 * 10^6$

$- 0.36 * 10^6$

= $1.82 * 10^6$ kcal/h

% heat loss = $[(1.82 * 10^6/(64.49 * 10^6)] * 100$

= 2.82%

Total heat out = $58.94 * 10^6 + 3.37 * 10^6 + 0.36 * 10^6$

$+ 1.82 * 10^6$

= $64.49 * 10^6$ kcal/h

<u>Balance</u> <u>16</u>. Around the dealration tank

mass in :

Total mass in = CON + make-up water + x(11) + TODT

= 35 + 26.07 + 6.676 + 8.378

= 76.124 T/h

mass out :

Total mass out = 75.93 T/h

heat in :

Total heat in = (CON + make-up water) * x(12) * 1000

$+ x(11) * 0.16 * 10^6$ + TODT * EN4

= $61.07 * 0.067 * 10^6 + 6.676 * 0.16 * 10^6$

$+ 8.37 * 0.675 * 10^6$

= 4.09 + 1.07 + 5.65 kcal/h

= 10.81 kcal/h

heat out :

Total heat out = mass out * 0.142 * 10^6

= 75.93 * 0.142 * 10^6 kcal/h

= 10.78 kcal/h

Balance 17. Around the boiler feed pump

mass in :

Total mass in = CON + make-up water + x(11) + TODT)

= 35 + 26.07 + 6.676 + 8.37

= 76.12 T/h

mass out :

Total mass out = 1.01 * x(1) -x(8)

= 73.86 + 2.04 T/h

= 75.90 T/h

heat in :

Total heat in = mass in * 0.142 * 10^6

= 76.12 * 0.142 * 10^6

= 10.81 * 10^6 kcal/h

heat out :

Total heat out = mass out * 0.142 * 10^6

= 75.9 * 0.142 * 10^6

= 10.77 * 10^6 kcal/h

Balance 18. Around the high pressure heater

mass in :

Total mass in = 1.01 * x(1) + x(11)

= 73.86 + 6.676 T/h

= 80.536 T/h

mass out :

Total mass out $= 1.01 * x(1) + x(11)$

$= 73.86 + 6.676$

$= 80.536$ T/h

heat in :

Total heat in $= 1.01 * x(1) * 0.142 * 10^6 + x(11)$ EN2

$= 73.86 * 0.142 * 10^6 + 6.676 * 0.691 * 10^6$

$= 10.49 * 10^6 + 4.61 * 10^6$

$= 15.10 * 10^6$ kcal/h

heat out :

total heat out $= 1.01 * x(1) * 0.19 * 10^6 + x(11) * 0.16 * 10^6$

$= 73.86 * 0.19 * 10^6 + 6.676 * 0.16 * 10^6$

$= (14.03 + 1.07) * 10^6$

$= 15.10 * 10^6$ kcal/h

<u>Balance</u> <u>19</u>. Around the fuel oil heater

mass in :

Total mass in = TOFOH

$= 0.117$ T/h

mass out :

Total mass out = mass in

$= 0.117$ T/h

heat in :

Total heat in = TOFOH * EN4 + CPOIL $(\Delta T)_{oil}\ Q_{oil}$

$= 0.137 * 0.675 * 10^6 + 0.538\ (60-25) * 5201$

$* 0.9465$

$= 0.092 * 10^6 + 0.0927 * 10^6$

$= 0.185 * 10^6$ kcal/h

heat out :

total heat out = TOFOH * 0.1 * 10^6 + CPOIL $(\Delta T)_{oil}$ Q_{oil}

= 0.137 * 0.1 * 10^6 + 0.538 (90-25) * 5201 * 0.9465

= 0.0137 * 10^6 + 0.172 * 10^6

= 0.185 * 10^6 kcal/h

Balance 20. Around the air preheater

mass in :

Total mass in = TOAPH

= 2.56 T/h

mass out :

total mass out = mass in

= 2.56 T/h

heat in :

Total heat in = TOAPH * EN4 + CPAIR $(\Delta T)_{air}$ Q_{air}

= 2.56 * 0.675 * 10^6 + 0.237 (35-25) * 13.19 * 1.29 * 5201 * 0.9465

= 1.73 * 10^6 + 0.198 * 10^6

= 1.928 * 10^6 kcal/h

heat out :

total heat out = CPAIR $(\Delta T)_{air}$ Q_{air}

= 0.237 (122-25) * 13.19 * 1.29 *5201 * 0.9465

= 1.925 * 10^6 kcal/h

Balance 21. Around the pure water tank

mass in :

Total mass in = CON + make-up water

= 35 + 26.07 T/h

= 61.07 T/h

mass out :

total mass out = mass in

= 61.07 T/h

heat in :

total heat in = CON * x(13) * 1000 + BFW * 0.03 * 10^6

= 35 * 0.095 * 10^6 + 26.07 * 0.03 * 10^6

= 3.325 * 10^6 + 0.782 * 10^6

= 4.107 * 10^6 kcal/h

heat out :

total heat out = (CON + BFW) * x(12) * 1000

= 61.07 * 0.067 * 10^6

= 4.09 * 10^6 kcal/h

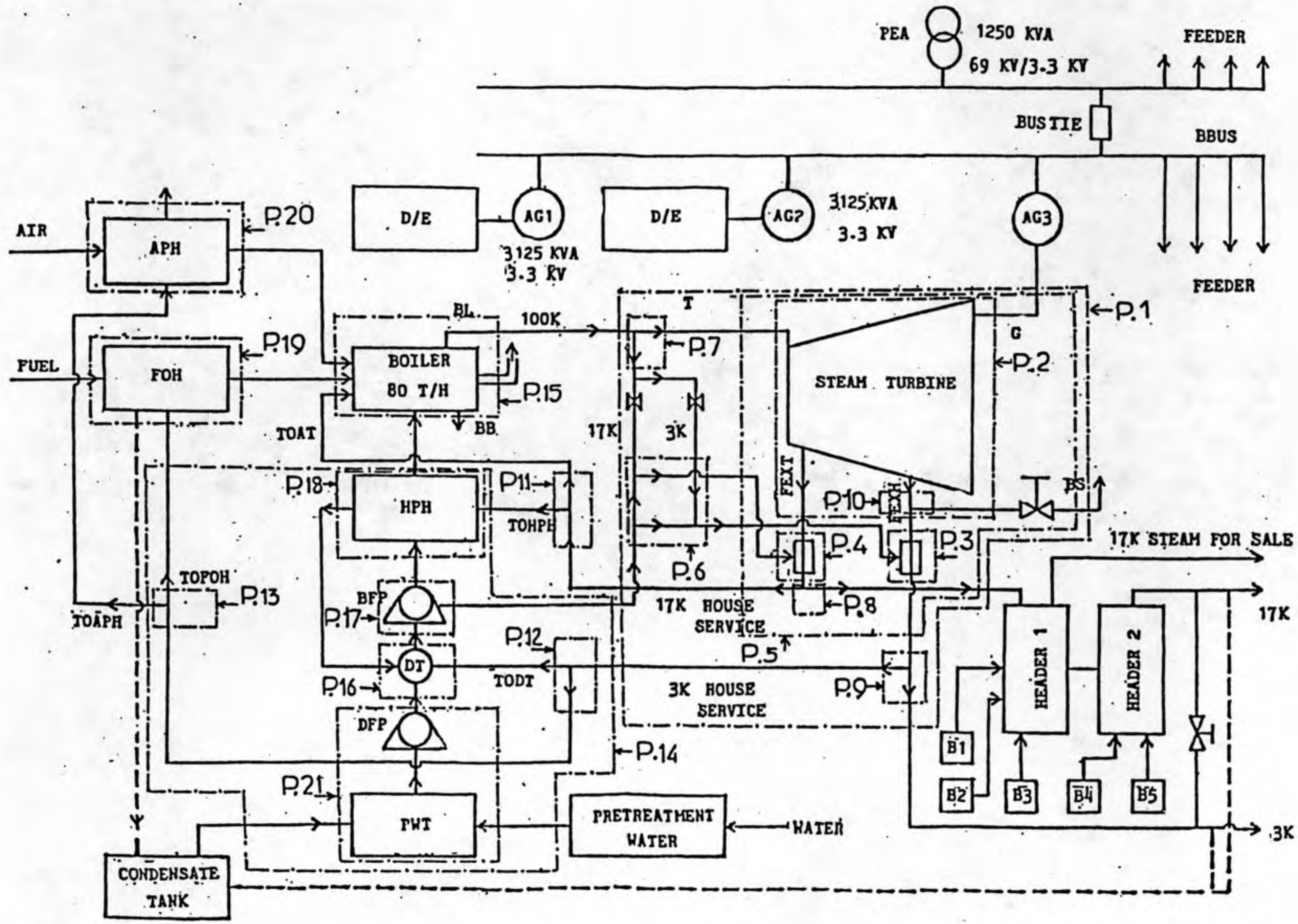

Fig C.1 Location of Heat and Mass Balance

3. Computer print out for both starting point and optimal point.

```
PARAMETRES

NV         13
NIN         6
NEG         9
NEVL       20
NTO         6
ITET       20
ICCNJ       1
IDIAG       0
ITMAX      20
KFIL        1
KLIN        0
NCO        15
ITSOR       1
ISOLSUR    20
EPSIL      0.1E+00
EPSIL0     0.1E-03
EPSIL1     0.1E-03
EPSIL2     0.1E-03
PC         0.0E+00


INITIA REMARK TEST        NO SCALE AT JACOBIAN



COGENERATION PROBLEM
REMARK DAY 5TH APRIL NORMAL RUN

COST OF MATERIAL

FUEL COST (BATH/LITRE)       2.620     ELECTRIC COST (BATH/KW)      1.438
CW; COST OF BOILER FEED WATER    BATH/LITRE     10.000
CS; COST OF 17K STEAM FOR SALE   BATH/LITRE    122.878
CB; COST OF 3K BLOW STEAM        BATH/LITRE     79.962

PROCESS REQUIREMENT

TOTAL REQUIREMENT OF ELECTRIC KWH  12000.000
TOTAL REQUIREMENT OF STEAM     T/H     60.200
CONDENSATE WATER               T/H     35.000
STEAM FOR SALE                 T/H      6.000
```

SUMMARY CF INDEPENDENT VARIABLE

BOILER LOAD T/H AT 100 KG/CM**2		73.130
PRODUCED ELECTRIC	KWH	8536.000
3K BLOW STEAM	T/HR	14.380
PURCHASE ELECTRIC	KWH	2464.000
ABUS ELECTRIC	KWH	2463.000
FUEL OIL CONSUMTION	L/H	5201.000
BOILER FEED WATER	T/H	-26.070
DESUPERHEAT WATER	T/H	2.040
17K STEAM GENERATION	T/H	20.000
3K STEAM GENERATION	T/H	23.000

INTERESTING VARIABLE

TURBINE AND GENERATOR EFFICIENCY		0.993
17K PROCESS REQUIREMENT	T/H	28.000
3K PROCESS REQUIREMENT	T/H	32.200
17K HOUSE SERVICE	T/H	6.728
3K HOUSE SERVICE	T/H	11.076
BUSTIE ELECTRIC	KWH	-1.000
BBUS ELECTRIC	KWH	9537.000

INTERESTING HEAT BALANCE
OBJECTIVE FUNCTION VALUE

FUEL COST	BATH/HR	13626.619
ELECTRIC COST	BATH/HR	3543.231
BOILER FEED WATER COST	BATH/HR	260.700
SALE STEAM COST	BATH/HR	737.268
3K BLOW STEAM COST	BATH/HR	1149.859
TOTAL COST	BATH/HR	17843.142

HEAT AND MASS BALANCE

POINT 1. MASS BALANCE AROUND BIG LOOP

SUM CF MASS IN	75.170	T/H	SUM OF MASS OUT	75.184	T/H	% RELATIVE ERROR	-0.018
HEAT BALANCE AROUND BIG LOOP							
SUM OF HEAT IN	.59279D+08	KCAL/H	SUM CF HEAT OUT	.58789D+08	KCAL/H	% RELATIVE ERROR	0.828

POINT 2. MASS BALANCE AROUND TURBOGENERATOR

SUM CF MASS IN	72.359	T/H	SUM OF MASS OUT	72.359	T/H	% RELATIVE ERROR	0.000
HEAT BALANCE AROUND TURBOGENERATOR							
SUM OF HEAT IN	.58369D+08	KCAL/H	SUM OF HEAT OUT	.58388D+08	KCAL/H	% RELATIVE ERROR	-0.034

```
POINT 3. MASS BALANCE AT DESUP POINT OF 3K
SUM OF MASS IN          34.076    T/H      SUM OF MASS OUT        34.076    T/H     % RELATIVE ERROR       -0.000
          HEAT BALANCE AT DESUP POINT OF 3K
SUM OF HEAT IN       .23001D+08   KCAL/H     SUM OF HEAT OUT     .23001D+08   KCAL/H      % RELATIVE ERROR        0.000

POINT 4. MASS BALANCE AT DESUP POINT OF 17K
SUM OF MASS IN          26.728    T/H      SUM OF MASS OUT        26.728    T/H     % RELATIVE ERROR       -0.000
          HEAT BALANCE AT DESUP POINT OF 17K
SUM OF HEAT IN       .18469D+08   KCAL/H     SUM OF HEAT OUT     .18469D+08   KCAL/H      % RELATIVE ERROR        0.000
FUE1=      1.888     FUE2=      0.937

POINT 5. MASS BALANCE AT SECOND LOOP
SUM OF MASS IN          75.184    T/H      SUM OF MASS OUT        75.184    T/H     % RELATIVE ERROR       -0.000
          HEAT BALANCE AT SEPARATE OF DECAL
SUM OF HEAT IN       .58769D+08   KCAL/H     SUM OF HEAT OUT     .59302D+08   KCAL/H      % RELATIVE ERROR       -0.908

POINT 6. MASS BALANCE AT DESUP AND 3P
SUM OF MASS IN           2.811    T/H      SUM OF MASS OUT         2.825    T/H     % RELATIVE ERROR       -0.482
          HEAT BALANCE AT DESUP AND 3P
SUM OF HEAT IN       .40114D+06   KCAL/H     SUM OF HEAT OUT     .40114D+06   KCAL/H      % RELATIVE ERROR        0.000
BP1=0.136       BP2=0.635       D1=1.698        D2=0.342

POINT 7. MASS BALANCE AT 3L AND BP
SUM OF MASS IN          73.130    T/H      SUM OF MASS OUT        73.130    T/H     % RELATIVE ERROR        0.000
          HEAT BALANCE AT BL AND BP
SUM OF HEAT IN       .58990D+08   KCAL/H     SUM OF HEAT OUT     .58990D+08   KCAL/H      % RELATIVE ERROR        0.000

POINT 8. MASS BALANCE AT SEPARATE OF 17K
SUM OF MASS IN          26.728    T/H      SUM OF MASS OUT        26.728    T/H     % RELATIVE ERROR       -0.000
          HEAT BALANCE AT SEPAREATE OF 17K
SUM OF HEAT IN       .18469D+08   KCAL/H     SUM OF HEAT OUT     .18469D+08   KCAL/H      % RELATIVE ERROR        0.000

POINT 9. MASS BALANCE AT SEPARATE OF  3K
SUM OF MASS IN          34.076    T/H      SUM OF MASS OUT        34.076    T/H     % RELATIVE ERROR       -0.000
          HEAT BALANCE AT SEPAREATE OF  3K
SUM OF HEAT IN       .23001D+08   KCAL/H     SUM OF HEAT OUT     .23001D+08   KCAL/H      % RELATIVE ERROR       -0.000

POINT 10. MASS BALANCE AT BLCK  3K
SUM OF MASS IN          47.518    T/H      SUM OF MASS OUT        47.518    T/H     % RELATIVE ERROR        0.000
          HEAT BALANCE AT SEPAREATE OF  3K
SUM OF HEAT IN       .32791D+08   KCAL/H     SUM OF HEAT OUT     .32791D+08   KCAL/H      % RELATIVE ERROR        0.000

POINT 11. MASS BALANCE AT 17K TO AT
XINHPH=      6.676     TOAT=      0.052
SUM OF MASS IN           6.728    T/H      SUM OF MASS OUT         6.728    T/H     % RELATIVE ERROR        0.000
          HEAT BALANCE AT 17K TO AT
SUM OF HEAT IN       .46490D+07   KCAL/H     SUM OF HEAT OUT     .46490D+07   KCAL/H      % RELATIVE ERROR        0.000

POINT 12. MASS BALANCE AT  3K TO DT
TOFUH=.13818D+00
TOAPH=.25586D+01
TODT =.83788D+01
SUM OF MASS IN          11.076    T/H      SUM OF MASS OUT        11.076    T/H     % RELATIVE ERROR        0.000
          HEAT BALANCE AT  3K TO DT
SUM OF HEAT IN       .74760D+07   KCAL/H     SUM OF HEAT OUT     .74760D+07   KCAL/H      % RELATIVE ERROR        0.000
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POINT 13. MASS BALANCE AT  3K TO FOH
SUM CF MASS IN          2.697   T/H      SUM OF MASS OUT          2.697    T/H      % RELATIVE ERROR        0.000
         HEAT BALANCE AT  3K TO DT
SUM OF HEAT IN      .18203D+07   KCAL/H      SUM OF HEAT OUT     .18203D+07   KCAL/H      % RELATIVE ERROR        0.000

POINT 14. MASS BALANCE AT  LOWER LOOP
SUM OF MASS IN          79.822   T/H      SUM OF MASS OUT          78.598    T/H      % RELATIVE ERROR        0.284
         HEAT BALANCE AT LOWER LOOP
SUM OF HEAT IN      .16219D+08   KCAL/H      SUM OF HEAT OUT     .16144D+08   KCAL/H      % RELATIVE ERROR        0.411

POINT 15. MASS BALANCE AROUND BOILER
SUM OF MASS IN          73.861   T/H      SUM OF MASS OUT          73.861    T/H      % RELATIVE ERROR        0.000
         HEAT BALANCE AROUND BOILER
HEAT FROM AIR=      .19256D+07
HEAT FROM OIL=      -.17215D+06
HEAT FROM WATER INLET=      .14034D+08
HEAT OF COMBUSTION=      .48341D+08
HEAT OF TOAT=      .35905D+05

HEAT FROM STEAM=      .58990D+09
HEAT FROM AIR OUTLET=      .33747D+07
HEAT OF BLOW DOWN=      .36565D+06
HEAT LOST=      .17785D+07
% HEAT LOST=      .27569D+01
SUM OF HEAT IN      .64509D+08   KCAL/H      SUM OF HEAT OUT     .64509D+08   KCAL/H      % RELATIVE ERROR        0.000

POINT 16. MASS BALANCE AROUND DT
SUM OF MASS IN          76.125   T/H      SUM OF MASS OUT          76.125    T/H      % RELATIVE ERROR        0.000
         HEAT BALANCE AROUND DT
TOUTHP = 159.12834
SUM OF HEAT IN      .10619D+08   KCAL/H      SUM OF HEAT OUT     .10778D+08   KCAL/H      % RELATIVE ERROR        0.294

POINT 17. MASS BALANCE AROUND BFP
SUM OF MASS IN          75.125   T/H      SUM OF MASS OUT          75.701    T/H      % RELATIVE ERROR        0.294
         HEAT BALANCE AROUND BFP
SUM OF HEAT IN      .10319D+08   KCAL/H      SUM OF HEAT OUT     .10778D+08   KCAL/H      % RELATIVE ERROR        0.294

POINT 18. MASS BALANCE AROUND HPH
SUM OF MASS IN          80.537   T/H      SUM OF MASS OUT          80.537    T/H      % RELATIVE ERROR        0.000
         HEAT BALANCE AROUND HPH
SUM OF HEAT IN      .15401D+08   KCAL/H      SUM OF HEAT OUT     .15096D+08   KCAL/H      % RELATIVE ERROR        0.036

POINT 19. MASS BALANCE AROUND FOH
SUM OF MASS IN          0.138   T/H      SUM OF MASS OUT          0.138    T/H      % RELATIVE ERROR        0.000
         HEAT BALANCE AROUND FOH
SUM OF HEAT IN      .18597D+06   KCAL/H      SUM OF HEAT OUT     .18597D+06   KCAL/H      % RELATIVE ERROR        0.000

POINT 20. MASS BALANCE AROUND APH
SUM OF MASS IN          2.559   T/H      SUM OF MASS OUT          2.559    T/H      % RELATIVE ERROR        0.000
         HEAT BALANCE AROUND APH
SUM OF HEAT IN      .19255D+07   KCAL/H      SUM OF HEAT OUT     .19256D+07   KCAL/H      % RELATIVE ERROR        0.000

POINT 21. MASS BALANCE AROUND PHT
SUM OF MASS IN          61.070   T/H      SUM OF MASS OUT          61.070    T/H      % RELATIVE ERROR        0.000
         HEAT BALANCE AROUND PHT
SUM OF HEAT IN      .41211D+07   KCAL/H      SUM OF HEAT OUT     .40917D+07   KCAL/H      % RELATIVE ERROR        0.714
```

GRADIENT REDUIT GENERALISE

NOMBRE DE VARIABLES NATURELLES 13

NOMBRE TOTAL DE VARIABLES 28
NOMBRE DE CONTRAINTES 15

EPSILON DE NEWTON 0.1000E-03
EPSILON TEST GRADIENT 0.1000E-03

FONCTION ECONOMIQUE -0.17343142278928D+05

	BORNE INFERIEURE		VARIABLE NATURELLE		BORNE SUPERIEURE
XI(1)	0.500000000000000D+02	X(1)	0.751300000000000D+02	XS(1)	0.750000000000000D+02
XI(2)	0.650000000000000D+04	X(2)	0.853500000000000D+04	XS(2)	0.900000000000000D+04
XI(3)	0.000000000000000D+00	X(3)	0.143800000000000D+02	XS(3)	0.150000000000000D+02
XI(4)	0.201000000000000D+04	X(4)	0.246400000000000D+04	XS(4)	0.120000000000000D+05
XI(5)	0.100000000000000D-05	X(5)	0.246300000000000D+04	XS(5)	0.120000000000000D+05
XI(6)	0.358000000000000D+04	X(6)	0.520100000000000D+04	XS(6)	0.533000000000000D+04
XI(7)	0.240000000000000D+01	X(7)	0.260700000000000D+02	XS(7)	0.750000000000000D+02
XI(8)	0.100000000000000D-01	X(8)	0.204000000000000D+01	XS(8)	0.345000000000000D+01
XI(9)	0.200000000000000D+02	X(9)	0.200000000000000D+02	XS(9)	0.400000000000000D+02
XI(10)	0.150000000000000D+02	X(10)	0.230000000000000D+02	XS(10)	0.400000000000000D+02
XI(11)	0.000000000000000D+00	X(11)	0.667500000000000D+01	XS(11)	0.736000000000000D+01
XI(12)	0.550000000000000D+02	X(12)	0.670000000000000D+02	XS(12)	0.900000000000000D+02
XI(13)	0.600000000000000D+02	X(13)	0.954000000000000D+02	XS(13)	0.100000000000000D+03

```
VALEUR DES CONTRAINTES

C(  1)    -0.1000000000000000D+01
C(  2)    -0.2349464988555230D+00
C(  3)    -0.2171560087462500D+00
C(  4)    -0.4196055629949400D-01
C(  5)    -0.1912833995434240D+02
C(  6)    -0.1087166105657600D+02
C(  7)     0.2777122100341600D+00
C(  8)    -0.1000000000000000D+04
C(  9)    -0.1138454639049100D+00
C( 10)     0.1356109738349700D-01
C( 11)     0.2234840427333100D+00
C( 12)    -0.2099401636059700D+00
C( 13)    -0.1719999694824200D+02
C( 14)    -0.3716676019423900D-02
C( 15)     0.2941006661289700D-02

IT  1   PHI-0.660406562954750D+08   DIR.GRAD.  NO  4   YN 0.440D+07  DELTAFI 0.770D+09  ETA 0.62E+09  NCDB 0  NCN 2  NITN 2
IT  2   PHI-0.660446154727980D+08   ITERATION  SPECIALE  BASE  DEGENEREE                                NCDB 1  NCN 1  NITN 0
IT  3   PHI-0.660098022317970D+08   DIR.GRAD.  NO  5   YN 0.300D+06  DELTAFI 0.660D+09  ETA 0.62E+09  NCDB 2  NCN 4  NITN 6
IT  4   PHI-0.660017759674160D+08   DIR.GRAD.  NO  8   YN 0.170D+06  DELTAFI 0.650D+09  ETA 0.62E+09  NCDB 4  NCN 3  NITN 6
IT  5   PHI-0.660007080636160D+08   DIR.GRAD.  NO  5   YN 0.180D+06  DELTAFI 0.650D+09  ETA 0.62E+09  NCDB 5  NCN 2  NITN 6
IT  6   PHI-0.659480368115370D+08   DIR.GRAD.  NO  8   YN 0.170D+06  DELTAFI 0.650D+09  ETA 0.62E+09  NCDB 1  NCN 4  NITN 6
IT  7   PHI-0.626916123728580D+08   DIR.GRAD.  NO  9   YN 0.110D+06  DELTAFI 0.650D+09  ETA 0.62E+09  NCDB 1  NCN 3  NITN 5
IT  8   PHI-0.626504774030850D+08   DIR.GRAD.  NO  9   YN 0.480D+06  DELTAFI 0.650D+09  ETA 0.31E+16  NCDB 1  NCN 6  NITN 6
IT  9   PHI-0.591727484896470D+08   DIR.GRAD.  NO 10   YN 0.950D+05  DELTAFI 0.650D+09  ETA 0.43E+14  NCDB 2  NCN 9  NITN 20
IT 10   PHI-0.504050454845040D+08   DIR.GRAD.  NO 10   YN 0.140D+08  DELTAFI 0.650D+09  ETA 0.11E+18  NCDB 1  NCN 2  NITN 6
IT 11   PHI-0.419589769111220D+08   DIR.GRAD.  NO 10   YN 0.140D+08  DELTAFI 0.620D+09  ETA 0.62E+09  NCDB 1  NCN 10  NITN 20
IT 12   PHI-0.574549058673920D+05   DIR.GRAD.  NO 12   YN 0.170D+06  DELTAFI 0.620D+09  ETA 0.62E+09  NCDB 1  NCN 3  NITN 3
IT 13   PHI-0.256088964319340D+05   DIR.GRAD.  NO 11   YN 0.290D+04  DELTAFI 0.560D+05  ETA 0.56E+05  NCDB 1  NCN 9  NITN 10
IT 14   PHI-0.191601018626240D+05   DIR.GRAD.  NO 12   YN 0.280D+04  DELTAFI 0.240D+05  ETA 0.24E+05  NCDB 1  NCN 3  NITN 6
        PHI-0.191801018626240D+05                      YN 0.000D+00  DELTFI 0.000D+00   ETA 0.00E+00

IMPOSSIBILITE D OBTENIR UN POINT REALISABLE
ESSAYEZ DE MODIFIER LES PENALITES SUR LES VARIABLES ARTIFICIELLES DONT VOICI LA LISTE ,

X( 20) =  0.000000000000000D+00   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE   7
X( 21) =  0.000000000000000D+00   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE   8
X( 22) =  0.000000000000000D+00   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE   9
X( 23) = -0.170413430549130D-04   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE  10
X( 24) =  0.000000000000000D+00   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE  11
X( 25) =  0.000000000000000D+00   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE  12
X( 26) =  0.000000000000000D+00   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE  13
X( 27) =  0.000000000000000D+00   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE  14
X( 28) =  0.000000000000000D+00   VARIABLE  ARTIFICIELLE  RELATIVE  A  LA CONTRAINTE  15

DANS LE S/P CALC,(APRES LA LIGNE 127), IMPOSEZ A LA VARIABLE PENAL UNE VALEUR DIFFERENTE DE    0.648655286755980D+05
```

```
DIRECTION  DE  DEPLACEMENT
Y(  1)  0.000000000000000D+00    Y(  2)  0.000000000000000D+00    Y(  3) -0.799624077011100D+02    Y(  4)  0.000000000000000D+00
Y(  5)  0.000000000000000D+00    Y(  6)  0.000000000000000D+00    Y(  7)  0.000000000000000D+00    Y(  8)  0.000000000000000D+00
Y(  9)  0.000000000000000D+00    Y( 10)  0.000000000000000D+00    Y( 11)  0.000000000000000D+00    Y( 12)  0.000000000000000D+00
Y( 13)  0.000000000000000D+00    Y( 14)  0.000000000000000D+00    Y( 15)  0.000000000000000D+00    Y( 16)  0.000000000000000D+00
Y( 17)  0.000000000000000D+00    Y( 18)  0.000000000000000D+00    Y( 19)  0.000000000000000D+00    Y( 20)  0.000000000000000D+00
Y( 21)  0.000000000000000D+00    Y( 22)  0.000000000000000D+00    Y( 23)  0.000000000000000D+00    Y( 24)  0.000000000000000D+00
Y( 25)  0.000000000000000D+00    Y( 26)  0.000000000000000D+00    Y( 27)  0.000000000000000D+00    Y( 28)  0.000000000000000D+00


        VARIABLE  NATURELLE                                    VARIABLE  DUALE  ASSOCIEE

X(  1) =  0.749918140527170D+02                                V(  1) =  0.
X(  2) =  0.806089777340940D+04                                V(  2) =  0.
X(  3) =  0.100000000317110D-29                                V(  3) = -0.799624077011100D+02
X(  4) =  0.393910222659160D+04                                V(  4) =  0.
X(  5) =  0.246300000000000D+04                                V(  5) =  0.000000000000000D+00
X(  6) =  0.533000000000000D+04 = XS(  6)                      V(  6) =  0.223113738665600D+02
X(  7) =  0.287237028784870D+02                                V(  7) =  0.
X(  8) =  0.340643108100950D+01                                V(  8) =  0.
X(  9) =  0.336872426035130D+02                                V(  9) =  0.
X( 10) =  0.265127542827290D+02                                V( 10) =  0.
X( 11) =  0.688914751855000D+01                                V( 11) =  0.
X( 12) =  0.883089081150900D+02                                V( 12) =  0.
X( 13) =  0.997481570811050D+02                                V( 13) =  0.
```

CONTRAINTE		VARIABLE DUALE ASSOCIEE
CONTRAINTE 1	-0.14761022265515D+04	U(1) = 0.00000000000000D+00
CONTRAINTE 2	-0.10000000474975D-03	U(2) = 0.21624925228550D+04
CONTRAINTE 3	-0.26587004720567D+00	U(3) = 0.00000000000000D+00
CONTRAINTE 4	-0.10000000474975D-03	U(4) = 0.99999999999867D+01
CONTRAINTE 5	-0.23270836636287D+02	U(5) = 0.00000000000000D+00
CONTRAINTE 6	-0.67291633637626D+01	U(6) = 0.00000000000000D+00
CONTRAINTE 7	0.31149540262732D-05	U(7) = 0.28859793978980D+03
CONTRAINTE 8	-0.90949470177293D-12	U(8) = -0.14375997253418D+01
CONTRAINTE 9	0.00000000000000D+00	U(9) = -0.24936558907209D+02
CONTRAINTE 10	0.17041343051583D-04	U(10) = 0.64865528675598D+05
CONTRAINTE 11	-0.33306690738755D-14	U(11) = -0.62703036152743D+05
CONTRAINTE 12	0.00000000000000D+00	U(12) = -0.62693036152743D+05
CONTRAINTE 13	-0.35527136788005D-14	U(13) = -0.18323590928661D+04
CONTRAINTE 14	-0.19514019999561D-08	U(14) = 0.00000000000000D+00
CONTRAINTE 15	0.19514019797801D-08	U(15) = 0.00000000000000D+00

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NIVEAU DE SORTIE    1

NOMBRE D ITERATIONS    14

NOMBRE D APPELS DU S/P CALCULANT LES CONTRAINTES   159

NOMBRE D APPELS DU S/P CALCULANT LA FONCTION ECONOMIQUE   113

NOMBRE D APPELS DU S/P CALCULANT LE GRADIENT DE LA FONCTION ECONOMIQUE    60

NOMBRE D APPELS DU S/P CALCULANT L INVERSE AVEC BASE DONNEE   115
NOMBRE D APPELS DU S/P CALCULANT L INVERSE AVEC RECHERCHE DE BASE    3

NOMBRE D APPELS DU S/P EFFECTUANT LES CHANGEMENTS DE BASE   22

NOMBRE D APPELS DU S/P CALCULANT LE JACOBIEN DES CONTRAINTES   20

NOMBRE D APPELS DU S/P EFFECTUANT UNE RECHERCHE DE MAX SANS DICHOTOMIE    0
NOMBRE D APPELS DU S/P EFFECTUANT UNE RECHERCHE DE MAX AVEC DICHOTOMIE    0
                                                                              NOMBRE TOTAL D ITERATIONS   102
NOMBRE D APPELS DU S/P EFFECTUANT LA RENTREE DANS LE DOMAINE   61


BASE
  14    3   16   11   18   19   10    4    1   23    7    9    2   12   13


HORS-BASE
   3    5    6   13   17   20   21   22   24   25   26   27   28


INVERSE DE BASE
 0.10000D+01  -0.15038D+04   0.00000D+00  -0.33392D-12   0.00000D+00   0.00000D+00  -0.20069D+03   0.10000D+01
 0.17342D+02   0.00000D+00  -0.15038D+04  -0.15038D+04   0.12673D+04   0.00000D+00   0.00000D+00
 0.00000D+00  -0.26645D-14   0.00000D+00  -0.22204D-15   0.00000D+00   0.00000D+00   0.13878D-16   0.00000D+00
 0.11391D-01   0.00000D+00  -0.10000D+01  -0.10000D+01   0.10000D+01   0.00000D+00   0.00000D+00
 0.00000D+00   0.00000D+00   0.10000D+01   0.10000D+01   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00

 0.53194D-04   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00   0.00000D+00   0.00000D+00   0.10000D+01   0.00000D+00   0.00000D+00   0.00000D+00

 0.13299D-02   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00   0.53339D-15   0.00000D+00   0.76603D+02   0.10000D+01   0.00000D+00   0.14336D-15

 0.14913D-03   0.00000D+00   0.23612D+02   0.18974D-13  -0.19318D-13  -0.14516D+04   0.00000D+00   0.00000D+00
 0.00000D+00  -0.53339D-15   0.00000D+00  -0.76603D+02   0.00000D+00   0.10000D+01  -0.14336D-15
 0.14913D-03   0.00000D+00  -0.23612D+02  -0.18974D-13   0.19318D-13   0.14516D+04   0.00000D+00   0.00000D+00
 0.00000D+00   0.23186D+02   0.00000D+00   0.51484D-14   0.00000D+00   0.00000D+00   0.00000D+00

 0.26739D+00   0.00000D+00   0.23186D+02   0.23186D+02  -0.21549D+02   0.00000D+00   0.00000D+00   0.10000D+01
 0.00000D+00  -0.15038D+04   0.00000D+00  -0.33392D-12   0.00000D+00   0.00000D+00  -0.20069D+03
 0.17342D+02   0.00000D+00  -0.15038D+04  -0.15038D+04   0.12673D+04   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00
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 0.14455D-01   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00  -0.13862D-14   0.00000D+00  -0.22204D-15   0.00000D+00   0.00000D+00   0.00000D+00
 0.32848D-08   0.10000D+01  -0.10000D+01  -0.10000D+01   0.14021D-14   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00  -0.26645D-14   0.00000D+00  -0.10000D+01   0.00000D+00   0.00000D+00   0.13878D-16

 0.14455D-03   0.00000D+00  -0.26645D-14  -0.10000D+01   0.10000D+01   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00  -0.23186D+02   0.00000D+00  -0.51484D-14   0.00000D+00   0.00000D+00   0.22204D-15
 0.26739D+00   0.00000D+00  -0.23186D+02  -0.23186D+02   0.22549D+02   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00   0.15038D+04   0.00000D+00   0.33392D-12   0.00000D+00   0.00000D+00   0.20069D+03

 0.17342D+02   0.00000D+00   0.15038D+04   0.15038D+04  -0.12673D+04   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00  -0.31306D-14   0.00000D+00  -0.97717D+01   0.00000D+00   0.00000D+00   0.85071D-17
 0.14801D-01   0.00000D+00  -0.22284D+01  -0.11564D+01   0.11564D+01   0.15693D+03   0.00000D+00   0.00000D+00
 0.00000D+00  -0.84238D-14   0.00000D+00  -0.19886D+02   0.00000D+00   0.00000D+00   0.30577D-16
 0.26790D-01   0.00000D+00  -0.40571D+01  -0.32000D+01   0.32000D+01   0.28571D+03   0.28571D+03
```

JACOBIEN DES CONTRAINTES

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LIGNE DE RANG  1
 0.00000D+00   0.00000D+00   0.00000D+00  -0.10000D+01   0.10000D+01   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00

LIGNE DE RANG  2
-0.97982D-02   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.10000D+01

 0.70630D-01  -0.27562D-01   0.00000D+00   0.00000D+00   0.00000D+00

LIGNE DE RANG  3
 0.88320D-01   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00   0.00000D+00  -0.10000D+01   0.00000D+00   0.00000D+00

LIGNE DE RANG  4
-0.92000D-01   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00
 0.00000D+00   0.00000D+00   0.10000D+01   0.00000D+00   0.00000D+00

LIGNE DE RANG  5
 0.92842D+01   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00  -0.40117D-01  -0.10697D+02   0.00000D+00
 0.00000D+00   0.00000D+00   0.30876D+01   0.92499D+01   0.00000D+00

LIGNE DE RANG  6
-0.92842D+01   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.40117D-01   0.10697D+02   0.00000D+00
 0.00000D+00   0.00000D+00  -0.30876D+01  -0.92499D+01   0.00000D+00

LIGNE DE RANG  7
 0.00000D+00   0.49827D-02   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00   0.00000D+00
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0.649330+00    -0.972500+00    0.000000D+00    0.000000D+00    0.000000+00

LIGNE  DE  RANG   8
 0.000000D+00    0.100000+01    0.000000D+00    0.100000D+01    0.000000D+00    0.000000D+00    0.000000D+00    0.000000D+00
0.000000D+00    0.000000+00    0.000000D+00    0.000000D+00    0.000000+00

LIGNE  DE  RANG   9
-0.69180D+02    0.000000+00    0.000000+00    0.000000D+00    0.000000D+00    0.10000D+01    0.000000D+00    0.000000D+00
0.000000D+00    0.000000+00    0.000000D+00    0.000000D+00    0.000000+00

LIGNE  DE  RANG  10
-0.78000D+00    0.000000D+00    0.000000+00    0.000000+00    0.000000D+00    0.000000D+00    0.000000D+00    -0.100000+01
0.100000D+01    0.100000+01    0.000000D+00    0.000000D+00    0.000000+00

LIGNE  DE  RANG  11
-0.89000D+00    0.000000+00    0.000000+00    0.000000+00    0.000000D+00    -0.51852D-03    0.10000D+01    -0.10000D+01
0.000000D+00    0.000000+00    0.100000D+01    0.000000D+00    0.000000+00

LIGNE  DE  RANG  12
 0.102000D+00    0.000000+00    0.000000D+00    0.000000D+00    0.000000D+00    -0.51852D-03    -0.10000D+01    0.000000D+00
0.10000D+01    0.100000+01    -0.100000D+01    0.000000D+00    0.000000+00

LIGNE  DE  RANG  13
 0.000000D+00    0.000000+00    0.000000D+00    0.000000D+00    0.000000D+00    0.000000D+00    0.000000D+00    0.000000D+00
0.10000D+01    0.100000+01    0.000000D+00    0.000000D+00    0.000000D+00

LIGNE  DE  RANG  14
-0.11090D-01    0.000000+00    0.000000D+00    0.000000D+00    0.000000+00    -0.35000D-04    0.68309D-02    -0.14200D-01
0.000000D+00    0.000000+00    0.69100D-01    0.637240-02    0.000000+00

LIGNE  DE  RANG  15
 0.000000D+00    0.000000+00    0.000000D+00    -0.000000D+00    -0.000000D+00    0.000000D+00    -0.38309D-02    0.000000D+00
0.000000D+00    0.000000+00    0.000000D+00    -0.63724D-02    0.35000D-02


ORDRE  DES  CONTRAINTES
   1      2      3      4      5      6      7      8      9     10     11     12     13     14     15
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	VARIABLES D ECART		VARIABLES ARTIFICIELLES	
CONTRAINTE 1	X(14)	0.14751021265916D+04		
CONTRAINTE 2	X(15)	0.00000000000000D+00		
CONTRAINTE 3	X(16)	0.26577004720092D+00		
CONTRAINTE 4	X(17)	0.00000000000000D+00		
CONTRAINTE 5	X(18)	0.23270733803660D+02		
CONTRAINTE 6	X(19)	0.67290661983310D+01		
CONTRAINTE 7			X(20)	0.00000000000000D+00
CONTRAINTE 8			X(21)	0.00000000000000D+00
CONTRAINTE 9			X(22)	0.00000000000000D+00
CONTRAINTE 10			X(23)	-0.17041343054913D-04
CONTRAINTE 11			X(24)	0.00000000000000D+00
CONTRAINTE 12			X(25)	0.00000000000000D+00
CONTRAINTE 13			X(26)	0.00000000000000D+00
CONTRAINTE 14			X(27)	0.00000000000000D+00
CONTRAINTE 15			X(28)	0.00000000000000D+00

COGENERATION PROBLEM
REMARK DAY 5TH APRIL NORMAL RUN

COST OF MATERIAL

FUEL COST (BATH/LITRE)	2.620	ELECTRIC COST (BATH/KW)	1.430
CW; COST OF BOILER FEED WATER	BATH/LITRE	10.000	
CS; COST OF 17K STEAM FOR SALE	BATH/LITRE	-122.878	
CB; COST OF 3K BLOW STEAM	BATH/LITRE	79.962	

PROCESS REQUIREMENT

TOTAL REQUIREMENT OF ELECTRIC	KWH	12000.000
TOTAL REQUIREMENT OF STEAM	T/H	60.200
CONDENSATE WATER	T/H	35.000
STEAM FOR SALE	T/H	6.000

SUMMARY OF INDEPENDENT VARIABLE

BOILER LOAD T/H AT 100 KG/CM**2		74.992
PRODUCED ELECTRIC	KWH	8060.898
3K BLOW STEAM	T/HR	0.000
PURCHASE ELECTRIC	KWH	3939.102
ABUS ELECTRIC	KWH	2463.000
FUEL OIL CONSUMTION	L/H	5330.000
BOILER FEED WATER	T/H	28.724
DESUPERHEAT WATER	T/H	3.406
17K STEAM GENERATION	T/H	33.687
3K STEAM GENERATION	T/H	26.513

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INTERESTING VARIABLE
TURBINE AND GENERATOR EFFICIENCY          0.982
17K PROCESS REQUIREMENT      T/H         28.000
3K PROCESS REQUIREMENT       T/H         32.200
17K HOUSE SERVICE            T/H          6.899
3K HOUSE SERVICE             T/H         11.299
BUSTIE ELECTRIC              KWH       1476.102
BBUS   ELECTRIC              KWH       9537.000


INTERESTING HEAT BALANCE
OBJECTIVE FUNCTION VALUE

FUEL COST                 BATH/HR     13964.599
ELECTRIC COST             BATH/HR      5664.428
BOILER FEED WATER COST    BATH/HR       281.237
SALE STEAM COST           BATH/HR       737.268
3K BLOW STEAM COST        BATH/HR         0.000
                          -------     ---------
TOTAL COST                BATH/HR     19178.995


HEAT AND MASS BALANCE


POINT 1. MASS BALANCE AROUND BIG LOOP
SUM OF MASS IN          78.398    T/H      SUM OF MASS OUT       78.398     T/H      % RELATIVE ERROR     -0.000
         HEAT BALANCE AROUND BIG LOOP
SUM OF HEAT IN     .60975D+08    KCAL/H      SUM OF HEAT OUT    .606300D+08   KCAL/H      % RELATIVE ERROR       0.566

POINT 2. MASS BALANCE AROUND TURBOGENERATOR
SUM OF MASS IN          74.492    T/H      SUM OF MASS OUT       74.492     T/H      % RELATIVE ERROR      0.000
         HEAT BALANCE AROUND TURBOGENERATOR
SUM OF HEAT IN     .60089D+08    KCAL/H      SUM OF HEAT OUT    .600760D+08   KCAL/H      % RELATIVE ERROR       0.021

POINT 3. MASS BALANCE AT DESUP POINT OF 3K
SUM OF MASS IN          37.812    T/H      SUM OF MASS OUT       37.812     T/H      % RELATIVE ERROR     -0.000
         HEAT BALANCE AT DESUP POINT OF 3K
SUM OF HEAT IN     .25523D+08    KCAL/H      SUM OF HEAT OUT    .255230D+08   KCAL/H      % RELATIVE ERROR       0.000

POINT 4. MASS BALANCE AT DESUP POINT OF 17K
SUM OF MASS IN          40.586    T/H      SUM OF MASS OUT       40.586     T/H      % RELATIVE ERROR     -0.000
         HEAT BALANCE AT DESUP POINT OF 17K
SUM OF HEAT IN     .28045D+08    KCAL/H      SUM OF HEAT OUT    .280450D+08   KCAL/H      % RELATIVE ERROR       0.000
FDE1=     2.837     FDE2=     1.040

POINT 5. MASS BALANCE AT SECOND LOOP
SUM OF MASS IN          78.398    T/H      SUM OF MASS OUT       78.398     T/H      % RELATIVE ERROR     -0.000
         HEAT BALANCE AT SEPARATE OF DECAL
SUM OF HEAT IN     .60643D+08    KCAL/H      SUM OF HEAT OUT    .612000D+08   KCAL/H      % RELATIVE ERROR      -0.919
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POINT 6. MASS BALANCE AT DESUP AND BP
SUM OF MASS IN          3.907    T/H      SUM OF MASS OUT        3.907   T/H     % RELATIVE ERROR      -0.000
         HEAT BALANCE AT DESUP AND BP
SUM OF HEAT IN      .554730+06   KCAL/H      SUM OF HEAT OUT    .554730+06   KCAL/H     % RELATIVE ERROR      0.000
BP1=0.065     BP2=0.431     C1=2.770     D2=0.636

POINT 7. MASS BALANCE AT BL AND BP
SUM OF MASS IN         74.992    T/H      SUM OF MASS OUT       74.992   T/H     % RELATIVE ERROR       0.000
         HEAT BALANCE AT BL AND BP
SUM OF HEAT IN      .604920+08   KCAL/H      SUM OF HEAT OUT    .604920+08   KCAL/H     % RELATIVE ERROR      0.000

POINT 8. MASS BALANCE AT SEPARATE OF 17K
SUM OF MASS IN         40.586    T/H      SUM OF MASS OUT       40.586   T/H     % RELATIVE ERROR      -0.000
         HEAT BALANCE AT SEPAREATE OF 17K
SUM OF HEAT IN      .280450+08   KCAL/H      SUM OF HEAT OUT    .280450+08   KCAL/H     % RELATIVE ERROR     -0.000

POINT 9. MASS BALANCE AT SEPARATE OF  3K
SUM OF MASS IN         37.812    T/H      SUM OF MASS OUT       37.812   T/H     % RELATIVE ERROR      -0.000
         HEAT BALANCE AT SEPAREATE OF  3K
SUM OF HEAT IN      .255230+08   KCAL/H      SUM OF HEAT OUT    .255230+08   KCAL/H     % RELATIVE ERROR     -0.000

POINT 10. MASS BALANCE AT BLOW  3K
SUM OF MASS IN         36.772    T/H      SUM OF MASS OUT       36.772   T/H     % RELATIVE ERROR       0.000
         HEAT BALANCE AT SEPAREATE OF  3K
SUM OF HEAT IN      .253750+08   KCAL/H      SUM OF HEAT OUT    .253750+08   KCAL/H     % RELATIVE ERROR      0.000

POINT 11. MASS BALANCE AT 17K TO AT
XINHPH=     6.889      TCAT=      0.010
SUM OF MASS IN          6.899    T/H      SUM OF MASS OUT        6.899   T/H     % RELATIVE ERROR       0.000
         HEAT BALANCE AT 17K TO AT
SUM OF HEAT IN      .476740+07   KCAL/H      SUM OF HEAT OUT    .476740+07   KCAL/H     % RELATIVE ERROR      0.000

POINT 12. MASS BALANCE AT  3K TO DT
TOFCH=.141610+00
TOAPH=.262210+01
TODT =.353530+01
SUM OF MASS IN         11.299    T/H      SUM OF MASS OUT       11.299   T/H     % RELATIVE ERROR       0.000
         HEAT BALANCE AT  3K TO DT
SUM OF HEAT IN      .762680+07   KCAL/H      SUM OF HEAT OUT    .762680+07   KCAL/H     % RELATIVE ERROR      0.000

POINT 13. MASS BALANCE AT  3K TO FOH
SUM OF MASS IN          2.764    T/H      SUM OF MASS OUT        2.764   T/H     % RELATIVE ERROR       0.000
         HEAT BALANCE AT  3K TO DT
SUM OF HEAT IN      .186550+07   KCAL/H      SUM OF HEAT OUT    .186550+07   KCAL/H     % RELATIVE ERROR      0.000

POINT 14. MASS BALANCE AT  LOWER LOOP
SUM OF MASS IN         81.912    T/H      SUM OF MASS OUT       81.912   T/H     % RELATIVE ERROR       0.000
         HEAT BALANCE AT LOWER LOOP
SUM OF HEAT IN      .167400+08   KCAL/H      SUM OF HEAT OUT    .167400+08   KCAL/H     % RELATIVE ERROR      0.000
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POINT 15. MASS BALANCE AROUND BOILER
SUM OF MASS IN          75.742   T/H      SUM OF MASS OUT       75.742   T/H      % RELATIVE ERROR      0.000
          HEAT BALANCE AROUND BOILER
HEAT FROM AIR=      .19733D+07
HEAT FROM OIL=      .17643D+08
HEAT FROM WATER INLET=      .14791D+08
HEAT OF COMBUSTION=      .49540D+08
HEAT OF TOAT=      .69791D+04

HEAT FROM STEAM=      .60492D+08
HEAT FROM AIR OUTLET=      .34594D+07
HEAT OF BLOW DOWN=      .37496D+06
HEAT LOST=      .17630D+07
% HEAT LOST=      .26677D+01
SUM OF HEAT IN      .66069D+08    KCAL/H      SUM OF HEAT OUT      .66038D+08   KCAL/H      % RELATIVE ERROR      0.000

POINT 16. MASS BALANCE AROUND DT
SUM OF MASS IN          79.148   T/H      SUM OF MASS OUT       79.148   T/H      % RELATIVE ERROR      0.000
          HEAT BALANCE AROUND DT
TOUTHP = 163.27084
SUM OF HEAT IN      .11239D+08    KCAL/H      SUM OF HEAT OUT      .11239D+08   KCAL/H      % RELATIVE ERROR      -0.000

POINT 17. MASS BALANCE AROUND BFP
SUM OF MASS IN          79.148   T/H      SUM OF MASS OUT       79.148   T/H      % RELATIVE ERROR      0.000
          HEAT BALANCE AROUND BFP
SUM OF HEAT IN      .11239D+08    KCAL/H      SUM OF HEAT OUT      .11239D+08   KCAL/H      % RELATIVE ERROR      0.000

POINT 18. MASS BALANCE AROUND HPH
SUM OF MASS IN          82.631   T/H      SUM OF MASS OUT       82.631   T/H      % RELATIVE ERROR      0.000
          HEAT BALANCE AROUND HPH
SUM OF HEAT IN      .15516D+08    KCAL/H      SUM OF HEAT OUT      .15516D+08   KCAL/H      % RELATIVE ERROR      0.000

POINT 19. MASS BALANCE AROUND FCH
SUM OF MASS IN           0.142   T/H      SUM OF MASS OUT        0.142   T/H      % RELATIVE ERROR      0.000
          HEAT BALANCE AROUND FCH
SUM OF HEAT IN      .19058D+06    KCAL/H      SUM OF HEAT OUT      .19058D+06   KCAL/H      % RELATIVE ERROR      -0.000

POINT 20. MASS BALANCE AROUND APH
SUM OF MASS IN           2.622   T/H      SUM OF MASS OUT        2.622   T/H      % RELATIVE ERROR      0.000
          HEAT BALANCE AROUND APH
SUM OF HEAT IN      .19733D+07    KCAL/H      SUM OF HEAT OUT      .19733D+07   KCAL/H      % RELATIVE ERROR      -0.000

POINT 21. MASS BALANCE AROUND SWT
SUM OF MASS IN          63.724   T/H      SUM OF MASS OUT       63.724   T/H      % RELATIVE ERROR      0.000
          HEAT BALANCE AROUND SWT
SUM OF HEAT IN      .43529D+07    KCAL/H      SUM OF HEAT OUT      .43529D+07   KCAL/H      % RELATIVE ERROR      0.000
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APPENDIX D
THE LISTED SUBROUTINES

Subroutines for cogeneration problem in a synthetic fibre plant is shown as follows.

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C*****SUBPROGRAM AFTER THIS LINE IS PUT BY USER
C*****WITH NUMERICAL DIFFERENTIATE;FIRST DATE 24 MAY 1988
C*****THIS IS SUBPROGRAM FOR TEJIN CO. ,COGENERATION PROBLEM
C*****SUBR.A  13 VARIABLE 9 EQUALITY CONSTRAINS/MODEL OF FACTORY
C*****COMPLETE 5 AUG 1988  2 INEQUALITY CONSTRAINS
C*****P17K AND P3K ARE VARIABLE
      SUBROUTINE PHIX
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      REAL *4 PC
      DIMENSION XC(150),XI(150),XS(150),C(150),VC(50)
      DIMENSION X(150)
      DIMENSION A(50,100),ALFA(50,50)
      DIMENSION IBAS(50),Y(150),IHB(100),IVC(50),IVA(150)
      COMMON/GREG0/NLVL,NTO,ITET,ICONJ,IDIAG,ITMAX,KFIL,KLIN,NCO,ITSOR
      COMMON/GREG1/ISOLSR,EPSIL,EPSIL0,EPSIL1,EPSIL2,PC
      COMMON/GREG2/XC,XI,XS,C,VC
      COMMON/GREG3/X,PHI,NV,NIN,NEG,NC
      COMMON/GREG4/A,ALFA,IBAS,Y,IHB,IVC,IVA
      COMMON/GREG5/IVB,NK,NTV,NV1,NEV,NIN1,NIN2,NIN3,NIN4,NVNIN1,YSCRT
      COMMON/GREG6/NVNIN2,NVNIN3,INDEX,II,IR,IR1,IS,IS1,IT,IBP,ICOD,LC
      COMMON/GREG7/JCDB,KCDB,KREN,KD,FI1,PSI,PSI3,TB,TC,TD,KFONC,KGRAD
      COMMON/GREG8/KCONT,KINV1,KINV2,KCDBA,KJACO,KMAX1,KMAX2,KREN1,JKO
      COMMON/GREG9/KREN2,KINV,KCDBA1,KREN11,KREN21,IDIREC,DELTFI,ETA
C  ENERGY COST (BAHT/HR)
C  FUEL OIL COST PLUS PURCHASED ELECTRICAL COST
C
CFE1  DATA CF/2.56/,CE/1.544/
CFE2  DATA CF/2.94/,CE/1.438/
CFE3  DATA CF/3.01/,CE/1.438/
CC    DATA CF/1.50/,CE/1.438/
      DATA CF/2.620/,CE/1.438/
C
      DATA CW/10.00/,FS/6.0/
CC    DATA CW/0.00/,FS/6.0/,CS/0.0/,CB/0.0/
      CS=40.90*CF
CC    CS=220.0
      CB=30.52*CF
C
C     CW IS COST OF MAKE-UP WATER     (B/T)
C     CF IS COST OF FUEL OIL          (B/L)
C     CE IS COST OF PURCHASED ELECTRIC(B/KW)
C     CS IS COST OF SELLING STEAM     (B/T)
C     FS STEAM TO SELL                (T/HR)
C     CB IS COST OF 3K BLOW STEAM     (B/T)
C
C     TOTAL COST = MAKE-UP WATER COST + FUEL COST
C                  +PURCHASED ELECTRIC COST
C                  +3K BLOW STEAM COST - STEAM SALE PRICE
C
      PHI= -(CW*XC(7)+CF*XC(6)+CE*XC(4)-CS*FS+CB*XC(3))
      RETURN
      END
      SUBROUTINE GRADFI
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      REAL *4 PC
      DIMENSION XC(150),XI(150),XS(150),C(150),VC(50)
      DIMENSION X(150)
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```
      DIMENSION A(50,100),ALFA(50,50)
      DIMENSION IBAS(50),Y(150),IHB(100),IVC(50),IVA(100)
      COMMON/GREG0/NEVL,NTO,ITET,ICONJ,IDIAG,ITMAX,KFIL,KLIN,NCU,ITSOR
      COMMON/GREG1/ISOLSR,EPSIL,EPSIL0,EPSIL1,EPSIL2,PC
      COMMON/GREG2/XC,XI,XS,C,VC
      COMMON/GREG3/X,PHI,NV,NIN,NEG,NC
      COMMON/GREG4/A,ALFA,IBAS,Y,IHB,IVC,IVA
      COMMON/GREG5/IVB,NK,NTV,NV1,NEV,NIN1,NIN2,NIN3,NIN4,NVNIN1,YSORT
      COMMON/GREG6/NVNIN2,NVNIN3,INDEX,II,IP,IR1,IS,IS1,IT,IBP,ICDB,LC
      COMMON/GREG7/JCDB,KCDB,KREN,KD,FI1,PSI,PSI3,TB,TC,TD,KFONC,KGRAD
      COMMON/GREG8/KCONT,KINV1,KINV2,KCDBA,KJACO,KMAX1,KMAX2,KREN1,JKO
      COMMON/GREG9/KREN2,KINV,KCDBA1,KREN11,KREN21,IDIREC,DELTFI,ETA
C
CFL1  DATA CF/2.58/,CE/1.544/
CFL2  DATA CF/2.94/,CE/1.438/
CFL3  DATA CF/3.01/,CE/1.438/
CC    DATA CF/1.50/,CE/1.438/
      DATA CF/2.620/,CL/1.438/
C
      DATA CH/10.00/,FS/6.0/
CC    DATA CH/0.00/,FS/6.0/,CS/0.0/,CD/0.0/
      CS=46.90*CF
CC    CS=110.0
      CS=30.52*CF
C
      C(1)=0.0
      C(2)=0.0
      C(3)=-CB
      C(4)=-CL
      C(5)=0.
      C(6)=-CF
      C(7)=-CH
      C(9)= 0.
      C(10)=0.
      C(11)=0.
      C(12)=0.
      C(13)=0.
      RETURN
      END
      SUBROUTINE CPHI
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      REAL *4 PC
      DIMENSION XC(150),XI(150),XS(150),C(150),VC(50)
      DIMENSION X(150)
      DIMENSION A(50,100),ALFA(50,50)
      DIMENSION IBAS(50),Y(150),IHB(100),IVC(50),IVA(100)
      COMMON/GREG0/NEVL,NTO,ITET,ICONJ,IDIAG,ITMAX,KFIL,KLIN,NCU,ITSOR
      COMMON/GREG1/ISOLSR,EPSIL,EPSIL0,EPSIL1,EPSIL2,PC
      COMMON/GREG2/XC,XI,XS,C,VC
      COMMON/GREG3/X,PHI,NV,NIN,NEG,NC
      COMMON/GREG4/A,ALFA,IBAS,Y,IHB,IVC,IVA
      COMMON/GREG5/IVB,NK,NTV,NV1,NEV,NIN1,NIN2,NIN3,NIN4,NVNIN1,YSORT
      COMMON/GREG6/NVNIN2,NVNIN3,INDEX,II,IR,IR1,IS,IS1,IT,IBP,ICDB,LC
      COMMON/GREG7/JCDB,KCDB,KREN,KD,FI1,PSI,PSI3,TB,TC,TD,KFONC,KGRAD
      COMMON/GREG8/KCONT,KINV1,KINV2,KCDBA,KJACO,KMAX1,KMAX2,KREN1,JKO
      COMMON/GREG9/KREN2,KINV,KCDBA1,KREN11,KREN21,IDIREC,DELTFI,ETA
C
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```
      DATA AB/11000.0/,P17K/28.33/,P3K/33.16/
      DATA PTOTAL/62.0/,CON/33.00/
C
      DATA RA/0.966/,RC/0.092/,RD/0.12/,RE/1.0/
      DATA TSUP/500.0/
C
C POLYESTER PLANT
C VARIABLE = DESCRIPTION(UNITS)
C XC(1)        BOILER LOAD (T/H) AT 100 KG/CM**2
C XC(2)        ELECTRIC GENERATION        (KWH)
C XC(3)        3K BLOW STEAM              (T/HR)
C XC(4)        PURCHASED ELECTRIC         (KWH)
C XC(5)        ABUS ELECTRIC              (KWH)
C XC(6)        FUEL OIL CONSUMPTION       (L/H)
C XC(7)        MAKE-UP     WATER          (T/HR)
C XC(8)        DESUPERHEAT WATER          (T/HR)
C XC(9)        17K STEAM GENERATION       (T/H)
C XC(10)       3K  STEAM GENERATION       (T/H)
C XC(11)       17K THROUGH HPH            (T/H)
C XC(12)       TEMP OF WATER FROM DFP     ( C )
C XC(13)       TEMP OF CONDENSATE         ( C )
C DEFINITION OF CONSTANTS
C
C AB           TOTAL REQUIREMENT OF ELECTRIC LOAD (KW)
C PTOTAL       TOTAL REQUIREMENT OF STEAM ELECTRIC LOAD (T/H)
C P17K         17K WORK PROCESS(T/H)
C P3K          3K WORK PROCESS(T/H)
C CON          CONDENSATE WATER RECOVER
C
C ENTHALPY OF EACH POINT
       EN1 =437.714*TSUP+513866
       EN2 =691600
       EN3 =727.5*TSUP+326323
       EN4 =675000
       EN5 =142000
       EN6 =700.0*TSUP+456643
C
       CPOIL=0.536
       CPAIR=0.237
       DENAIR=1.29
       DENOIL=0.9465
C      HL=9300
       TOFOH=(CPOIL*(90-60)*XC(6)*DENOIL)/(EN4-100000)
       TOAPH=CPAIR*(122-35)*13.19*DENAIR*XC(6)*DENOIL/EN4
       TODT=RD*XC(1)+2.3-TOFOH-TOAPH
C
       A1=1-RC*(EN2-EN5)/(EN1-EN5)-RD*(EN4-EN5)/(EN3-EN5)
       A2=(EN6-RC*EN1*(EN2-EN5)/(EN1-EN5)-RD*EN3*(EN4-EN5)/(EN3-EN5))/A1
C
C*THIS IS INEQUALITY CONSTRAIN VC(1).LE.0
C ELECTRIC BALANCE
C PURCHASE ELECTRIC = ABUS ELECTRIC + BUSTILE ELECTRIC
       [illegible]
C
C*THIS IS INEQUALITY CONSTRAIN VC(2).LE.0
C DESUP.LE.DECAL
       VC(2)=XC(8)+0.5-((EN1-EN2)/(EN1-EN5))*(XC(9)+RC*XC(1))
```

```
      $-((EN3-EN4)/(EN3-EN5))*(XC(10)+RD*XC(1)+2.3*RE)
C
C*THIS IS INEQUALITY CONSTRAIN VC(3).LE.0
C IDAT NOT.GT.0.04*RC*XC(1)
      VC(3)=0.96*RC*XC(1)-XC(11)
C
C IDAT.GT. 0.01
      VC(4)= 0.01+XC(11)-RC*XC(1)
C
      VC(5)=140-(((CON+XC(7)+XC(11)+TODT)
     $*EN5-((CON+XC(7))*XC(12)*1000+TODT*EN4))/XC(11))*1.0E-3
C
C
C IDUTHP NOT.GT.170 C VC(6).LE.0
      VC(6)=-170+(((CON+XC(7)+XC(11)+TODT)
     $*EN5-((CON+XC(7))*XC(12)*1000+TODT*EN4))/XC(11))*1.0E-3
C
CC HEAT BALANCE AROUND TURBINE
      VC(7)=(XC(2)*860)*(1/(.1899*(XC(2)**.1951)))*(1/(A2-EN3))
     $-((A2-EN1)/(A2-EN3))*((EN2-EN5)/(EN1-EN5))*XC(9)
     $-((EN4-EN5)/(EN3-EN5))*(XC(10)+2.3*RE)-XC(3)
C
C     PRODUCED ELECTRIC + PURCHASED ELCTRIC = GIVEN ELECTRIC LOAD
      VC(8)= XC(2)+XC(4)-AB
C
C  OIL CONSUMTION AND STEAM PRODUCED
C
      VC(9)= XC(6)-(XC(1)*1000/(13.9190+(XC(1)-45)*5E-03))
C
C CALCULATION OF BOILER LOAD .
C STEAM FROM BOILER + WATER FOR DESUPERHEAT = 17K TO PROCESS
C + 3K TO PROCESS +3K BLOW OFF +17K HOUSE SERVICE +3K HOUSE SERVICE
C
C
      VC(10)=XC(9)+XC(10)+XC(3)+RC*XC(1)+(RD*XC(1)+2.3*RE)-XC(1)-XC(8)
C
CC WATER MASS BALANCE AROUND HPH AND DT
C
C           TO HPH +3K HOUSE SERVICE +BFW +CON = BOILER INLET +DESUP
C           +TOFOH+TOAPH
      VC(11)=XC(11)+(RD*XC(1)+2.3*RE)+XC(7)+CON
     $-1.01*XC(1)-XC(8)-(CPOIL*(90-60)*XC(6)*DENOIL)/(EN4-100000)
     $-CPAIR*(122-35)*13.19*DENAIR*XC(5)*DENOIL/EN4
C
C OVERALL WATER BALANCE
C      BFW+CON =FOH +APH +AT+BB+HS+LS+BS
C
C
      VC(12) =CPAIR*(122-35)*13.19*DENAIR*XC(6)*DENOIL/EN4
     $+(CPOIL*(90-60)*XC(6)*DENOIL)/(EN4-100000)
     $+RC*XC(1)-XC(11)+0.01*XC(1)+XC(9)+XC(10)+XC(3)-XC(7)-CON
C STEAM REQUIRED IN PROCESS
C 17K STEAM +3K STEAM = STEAM REQUIREMENT
      VC(13)= XC(9)+XC(10)-PTOTAL
C HEAT BALANCE AROUND HPH,BFP AND DT
C HEAT FROM TOHPH + HEAT FROM TODT + HEAT FROM PWT= HEAT OF BOILER INLET
      VC(14)=(XC(11)*EN2+(RD*XC(1)+2.3*RE)*EN4
```

```
      $-EN4*(CPOIL*(90-60)*XC(5)*DENOIL)/(EN4-100000)
      $-CPAIR*(122-35)*13.19*DENAIR*XC(6)*DENOIL
      $+(CON+XC(7))*XC(12)*1000-1.01*XC(1)*.1956-XC(8)*EN5)*1.0E-07
C HEAT BALANCE AROUND PHT AND DFP
C HEAT FROM CON + HEAT FROM PHT= HEAT OUT
      VC(15)=(CON*XC(13)*1000
      $+XC(7)*0.03E6-(CON+XC(7))*XC(12)*1000)*1.0E-07
      RETURN
      END
      SUBROUTINE CP(Z,V)
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      REAL *4 PC
      DIMENSION Z(1),V(1)
C
      DATA AB/11000.0/,P17K/28.83/,P3K/33.16/
      DATA PTOTAL/62.0/,CON/35.00/
C
      DATA RA/0.986/,RC/0.092/,RD/0.12/,RE/1.0/
      DATA TSUP/500.0/
C
C POLYESTER PLANT
C VARIABLE = DESCRIPTION(UNITS)
C Z(1)       BOILER LOAD (T/H) AT 100 KG/CM**2
C Z(2)       ELECTRIC GENERATION          (KWH)
C Z(3)       3K BLEW STEAM                (T/HR)
C Z(4)       PURCHASED ELECTRIC           (KWH)
C Z(5)       ABUS ELECTRIC                (KWH)
C Z(6)       FUEL OIL CONSUMPTION         (L/H)
C Z(7)       BOILER FEED WATER            (T/HR)
C Z(8)       DESUPERHEAT WATER            (T/HR)
C Z(9)       17K STEAM GENERATION         (T/H)
C Z(10)      3K  STEAM GENERATION         (T/H)
C Z(11)      17K THROUGH HPH              (T/H)
C Z(12)      TEMP OF WATER FROM DFP       ( C )
C Z(13)      TEMP OF CONDENSATE           ( C )
C DEFINITION OF CONSTANTS
C
C AB          TOTAL REQUIREMENT OF ELECTRIC LOAD (KW)
C PTOTAL      TOTAL REQUIREMENT OF STEAM ELECTRIC LOAD (T/H)
C P17K        17K WORK PROCESS(T/H)
C P3K         3K WORK PROCESS(T/H)
C CON         CONDENSATE WATER RECOVER
C
C ENTHALPY OF EACH POINT
      EN1 =437.714*TSUP+513865
      EN2 =691000
      EN3 =727.5*TSUP+326323
      EN4 =675000
      EN5 =142000
      EN6 =700.0*TSUP+4556+3
C
      CPOIL=0.536
      CPAIR=0.237
      DENAIR=1.29
      DENOIL=0.9465
      TOFUA=(CPOIL*(90-60)*Z(5)*DENOIL)/(EN4-100000)
      TOAPA=CPAIR*(122-35)*13.19*DENAIR*Z(6)*DENOIL/EN4+
```

```
      TODT=RD*Z(1)*2.3-TOFOH-TOAPH
C
      A1=1-RC*(EN2-EN5)/(EN1-EN5)-RD*(EN4-EN5)/(EN3-EN5)
      A2=(EN6-RC*EN1*(EN2-EN5)/(EN1-EN5)-RD*EN3*(EN4-EN5)/(EN3-EN5))/A1
C
C*THIS IS INEQUALITY CONSTRAIN V(1).LE.0
C ELECTRIC BALANCE
C PURCHASE ELECTRIC =ABUS ELECTRIC + BUSTILE ELECTRIC
      V(1)= -Z(4)+Z(5)
C
C DESUP.LE.DECAL
      V(2)=Z(8)+0.5-((EN1-EN2)/(EN1-EN5))*(Z(9)+RC*Z(1))
     $-((EN3-EN4)/(EN3-EN5))*(Z(10)+RD*Z(1)+2.3*RE)
C
C*THIS IS INEQUALITY CONSTRAIN VC(3).LE.0
C TOAT NOT.GT.0.04*RC*XC(1)
      V(3)=0.96*RC*Z(1)-Z(11)
C
C TOAT.GT. 0.01
      V(4)=0.01+Z(11)-RC*Z(1)
C
      V(5)=140-(((CON+Z(7)+Z(11)+TODT)
     $*EN5-((CON+Z(7))*Z(12)*1000+TODT*EN4))/Z(11))*1.0E-3
C
      V(6)=-170+(((CON+Z(7)+Z(11)+TODT)
     $*EN5-((CON+Z(7))*Z(12)*1000+TODT*EN4))/Z(11))*1.0E-3
CC HEAT BALANCE AROUND TURBINE
      V(7)=(Z(2)*860)*(1/(.1699*(Z(2)**.195)))*(1/(A2-EN3))
     $-((A2-EN1)/(A2-EN3))*((EN2-EN5)/(EN1-EN5))*Z(9)
     $-((EN4-EN5)/(EN3-EN5))*(Z(10)+2.3*RE)-Z(3)
C
C     PRODUCED ELECTRIC + PURCHASED ELCTRIC = GIVEN ELECTRIC LOAD
      V(8)= Z(2)+Z(4)-AB
C
C  OIL CONSUMTION AND STEAM PRODUCED
C
      V(9)= Z(6)-(Z(1)*1000/(13.9173+(Z(1)-45)*5E-03))
C
C CALCULATION OF BOILER LOAD
C STEAM FROM BOILER + WATER FOR DESUPERHEAT = 17K TO PROCESS
C + 3K TO PROCESS +3K BLOW OFF +17K HOUSE SERVICE +3K HOUSE SERVICE
C
C
      V(10)=Z(9)+Z(10)+Z(3)+RC*Z(1)+(RD*Z(1)+2.3*RE)-Z(1)-Z(8)
C
C          10 HPH +3K HOUSE SERVICE +DFH +CON = BOILER INLET +DESUP
C          + TOFOH+TOAPH
      V(11)=Z(11)+(RD*Z(1)+2.3*RE)+Z(7)+CON
     $=1.01*Z(1)=Z(3)=(CPOIL*(90-60)*Z(6)*DENOIL)/(EN4=100000)
     $-CPAIR*(122-35)*13.19*DENAIR*Z(6)*DENOIL/EN4
C
C OVERALL WATER BALANCE
C     DFH+CON =APH +FOH+AT+BB+HS+LS+B3
C
      V(12) =CPAIR*(122-35)*13.19*DENAIR*Z(6)*DENOIL/EN4
     $+(CPOIL*(90-60)*Z(6)*DENOIL)/(EN4-100000)
     $+RC*Z(1)-Z(11)+0.01*Z(1)+Z(9)+Z(10)+Z(3)-Z(7)-CON
```

```
C STEAM REQUIRED IN PROCESS
C 17K STEAM +3K STEAM = STEAM REQUIREMENT
      V(13)= Z(9)+Z(10)-PTOTAL
C HEAT BALANCE AROUND HPH,DFP AND DT
C HEAT FROM TOHPH + HEAT FROM TODT + HEAT FROM PHT= HEAT OF BOILER INLET
      V(14)=(Z(11)*EN2+(RD*Z(1)+2.3*RE)*EN4
     $-EN4*(CPOIL*(90-80)*Z(6)*DENOIL)/(EN4-100000)
     $-CPAIR*(122-35)*13.19*DENAIR*Z(6)*DENOIL
     $+(CON+Z(7))*Z(12)*1000-1.01*Z(1)*.19E6-Z(8)*EN5)*1.0E-07
C HEAT BALANCE AROUND PHT AND DFP
C HEAT FROM CON + HEAT FROM PHT= HEAT OUT
      V(15)=(CON*Z(13)*1000+Z(7)*0.73E6-(CON+Z(7))*Z(12)*1000)*1.0E-07
      RETURN
      END
      SUBROUTINE INITIA
C THIS IS SUBROUTINE FOR PRINT INITIAL CONDITION
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      REAL *4 PC
      DIMENSION XC(150),XI(150),XS(150),C(150),VC(50)
      DIMENSION X(150)
      DIMENSION A(50,100),ALFA(50,50)
      DIMENSION IBAS(50),Y(150),IHB(100),IVC(50),IVA(100)
      COMMON/GREG0/NLVL,NTO,ITET,ICONJ,IDIAG,ITMAX,KFIL,KLIN,NCJ,ITSGR
      COMMON/GREG1/ISOLSR,EPSIL,EPSILO,EPSIL1,EPSIL2,PC
      COMMON/GREG2/XC,XI,XS,C,VC
      COMMON/GREG3/X,PHI,NV,NIN,NEG,NC
      COMMON/GREG4/A,ALFA,IBAS,Y,IHB,IVC,IVA
      COMMON/GREG5/IVB,NK,NTV,NV1,NEV,NIN1,NIN2,NIN3,NIN4,NVNIN1,YSORT
      COMMON/GREG6/NVNIN2,NVNIN3,INDEX,II,IR,IR1,IS,IS1,IT,IBP,ICDB,LC
      COMMON/GREG7/JCDB,KCO3,KREN,KT,FI1,PSI,PSI3,TB,TC,TD,KFONC,KGRAD
      COMMON/GREG8/KCONT,KINV1,KINV2,KCOBA,KJACO,KMAX1,KMAX2,KREN1,JKO
      COMMON/GREG9/KREN2,KINV,KCOBA1,KREN11,KREN21,IDIREC,DELTFI,ETA
      COMMON/BBGAS/ IDUM(14),IFLAG
C
C
C*****
      DO 1 I=1,NV
      XC(I)=X(I)
    1 CONTINUE
C*****
      WRITE(6,5)
    5 FORMAT(///,1X,'INITIA REMARK TEST        NO SCALE AT JACOBIAN')
      CALL RESULT
      RETURN
      END
      SUBROUTINE RESULT
C THIS IS SUBROUTINE FOR PRINT OPTIMAL CONDITION
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      REAL *4 PC
      DIMENSION XC(150),XI(150),XS(150),C(150),VC(50)
      DIMENSION X(150)
      DIMENSION A(50,100),ALFA(50,50)
      DIMENSION IBAS(50),Y(150),IHB(100),IVC(50),IVA(100)
      COMMON/GREG0/NLVL,NTO,ITET,ICONJ,IDIAG,ITMAX,KFIL,KLIN,NCJ,ITSGR
      COMMON/GREG1/ISOLSR,EPSIL,EPSILO,EPSIL1,EPSIL2,PC
      COMMON/GREG2/XC,XI,XS,C,VC
      COMMON/GREG3/X,PHI,NV,NIN,NEG,NC
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      COMMON/GREG4/A,ALFA,IBAS,Y,IH3,IVC,IVA
      COMMON/GREG5/IVB,NK,NTV,NV1,NEV,NIN1,NIN2,NIN3,NIN4,NVNIN1,YSOPT
      COMMON/GREG6/NVNIN2,NVNIN3,INDEX,II,IR,IR1,IS,ISL,IT,IBP,ICDS,LL
      COMMON/GREG7/JLDB,KCDB,KREN,KJ,FII,PSI,PSI3,FU,FC,FD,KFDNC,KGRAD
      COMMON/GREG8/KCONT,KINV1,KINV2,KCD3A,KJACO,KMAX1,KMAX2,KREN1,JKD
      COMMON/GREG9/KREN2,KINV,KCD3A1,KREN11,KREN21,IDIREC,DELTHI,ETA
      COMMON/BBBAS/ IDUM(14),IFLAG
C
CFL1  DATA CF/2.56/,CE/1.544/
CFL2  DATA CF/2.94/,CE/1.438/
CFL3  DATA CF/3.01/,CE/1.438/
CC    DATA CF/1.50/,CE/1.438/
      DATA CF/2.820/,CE/1.438/
C
CC    DATA CW/0.00/,FS/6.0/,CS/0.0/,CB/0.0/
      DATA CW/10.00/,FS/6.0/
      CS=40.90*CF
CC    CS=110.0
      CB=30.52*CF
C
      DATA AB/11000.0/,P17K/23.83/,P3K/33.16/
      DATA FTOTAL/42.0/,CON/35.00/
C
      DATA RA/0.986/,RC/0.092/,RD/0.12/,RE/1.0/
      DATA TSUP/509.0/
C
C
C ENTHALPY OF EACH POINT
      EN1 =437.714*TSUP+513365
      EN2 =691000
      EN3 =727.5*TSUP+326323
      EN4 =675000
      EN5 =142000
      EN6 =700.0*TSUP+456643
C
C
      A1=1-RC*(EN2-EN5)/(EN1-EN5)-RD*(EN4-EN5)/(EN3-EN5)
      A2=(EN6-RC*EN1*(EN2-EN5)/(EN1-EN5)-RD*EN3*(EN4-EN5)/(EN3-EN5))/A1
C
      WRITE(6,5)
    5 FORMAT(1X,'                    ',//////)
      WRITE(6,10)
   10 FORMAT(1X,'COGENERATION PROBLEM')
      WRITE(6,20)
   20 FORMAT(1X,'REMARK DAY 5TH APRIL NORMAL RUN',//)
C
      WRITE(6,30)
   30 FORMAT(1X,'COST OF MATERIAL',/)
      WRITE (6,40) CF,CE
   40 FORMAT(1X,'FUEL COST (BAHT/LITRE)',F10.3,5X,'ELECTRIC COST (BAHT/K
     *WH)',F10.3)
      WRITE(6,50)CW
      WRITE(6,60)CS
      WRITE(6,70)CB
   50 FORMAT(1X,'CW: COST OF MAKE-UP    WATER      BAHT/T     ',F10.3)
   60 FORMAT(1X,'CS: COST OF 17K STEAM FOR SALE  BAHT/T     ',F10.3)
   70 FORMAT(1X,'CB: COST OF 3K BLOW STEAM       BAHT/T     ',F10.3,/)
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C
      WRITE(6,170)
      WRITE(6,180)AB
      WRITE(6,190)PTOTAL
      WRITE(6,200)CON
      WRITE(6,210)FS
  170 FORMAT(1X,'PROCESS REQUIREMENT',/)
  180 FORMAT(1X,'TOTAL REQUIREMENT OF ELECTRIC KWH ',F10.3)
  190 FORMAT(1X,'TOTAL REQUIREMENT OF STEAM    T/H ',F10.3)
  200 FORMAT(1X,'CONDENSATE WATER              T/H ',F10.3)
  210 FORMAT(1X,'STEAM FOR SALE                T/H ',F10.3,//)
C
      WRITE(6,330)
      WRITE(6,340)XC(1)
      WRITE(6,350)XC(2)
      WRITE(6,360)XC(3)
      WRITE(6,370)XC(4)
      WRITE(6,380)XC(5)
      WRITE(6,390)XC(6)
      WRITE(6,400)XC(7)
      WRITE(6,410)XC(8)
      WRITE(6,420)XC(9)
      WRITE(6,430)XC(10)
  330  FORMAT(1X,'SUMMARY OF INDEPENDENT VARIABLE')
  340  FORMAT(1X,'BOILER LOAD   T/H  AT 100 KG/CM**2',F10.3)
  350  FORMAT(1X,'PRODUCED ELECTRIC              KWH ',F10.3)
  360  FORMAT(1X,'3K BLOW STEAM                 T/HR ',F10.3)
  370  FORMAT(1X,'PURCHASE ELECTRIC              KWH ',F10.3)
  380  FORMAT(1X,'ABUS      ELECTRIC             KWH ',F10.3)
  390 FORMAT(1X,'FUEL OIL CONSUMATION           L/H ',F10.3)
  400 FORMAT(1X,'MAKE-UP      WATER             T/H ',F10.3)
  410 FORMAT(1X,'DESUPERHEAT WATER              T/H ',F10.3)
  420 FORMAT(1X,'17K STEAM GENERATION           T/H ',F10.3)
  430 FORMAT(1X,'3K STEAM GENERATION            T/H ',F10.3,//)
C
      WRITE(6,500)
  500 FORMAT(1X,'INTERESTING VARIABLE')
      RB=.1699*(XC(2)**.195)
      WRITE(6,510)RB
  510 FORMAT(1X,'TURBINE AND GENERATOR EFFICIENCY  ',F10.3)
      WRITE(6,520)P17K
      WRITE(6,530)P3K
      XHS =RC*XC(1)
      XLS =RD*XC(1)+2.3*RE
      XBT =XC(4)-XC(5)
      XBB =AB-XC(5)
      WRITE(6,540) XHS
      WRITE(6,550) XLS
      WRITE(6,560) XBT
      WRITE(6,570) XBB
  520 FORMAT(1X,'17K PROCESS REQUIREMENT     T/H  ',F10.3)
  530 FORMAT(1X,'3K PROCESS REQUIREMENT      T/H  ',F10.3)
  540 FORMAT(1X,'17K HOUSE SERVICE           T/H  ',F10.3)
  550 FORMAT(1X,'3K HOUSE SERVICE            T/H  ',F10.3)
  560 FORMAT(1X,'BUSTTE ELECTRIC             KWH  ',F10.3)
  570 FORMAT(1X,'BBUS   ELECTRIC             KWH  ',F10.3,//)
C
```

```
      WRITE(6,2000)
 2000 FORMAT(1X,'INTERESTING HEAT BALANCE')
      WRITE(6,600)
  600 FORMAT(1X,'OBJECTIVE FUNCTION VALUE',/)
      XCF=CF *XC(6)
      XCE=CE*XC(4)
      XCW=CW*XC(17)
      XCS=CS*FS
      XCB=CB *XC(3)
      WRITE(6,610) XCF
      WRITE(6,620) XCE
      WRITE(6,630) XCW
      WRITE(6,640) XCS
      WRITE(6,650) XCB
      XTOTAL=XCF+XCE+XCW+XCB-XCS
      WRITE(6,660) XTOTAL
  610 FORMAT(1X,'FUEL COST                BAHT/HR     ',F10.3)
  620 FORMAT(1X,'ELECTRIC COST            BAHT/HR     ',F10.3)
  630 FORMAT(1X,'MAKE-UP      WATER COST  BAHT/HR     ',F10.3)
  640 FORMAT(1X,'SALE STEAM COST          BAHT/HR     ',F10.3)
  650 FORMAT(1X,'3K BLOW STEAM COST       BAHT/HR     ',F10.3,/)
  660 FORMAT(1X,'TOTAL COST               BAHT/HR     ',F10.3)
C*****
      WRITE(6,3000)
 3000 FORMAT(///,1X,'HEAT AND MASS BALANCE',///)
C
C DESCRIPTION IN THIS SUBSET
C GENERAL FORMAT OF MASS BALANCE
 3020 FORMAT(1X,'SUM OF MASS IN',5X,F10.3,3X,'T/H',5X,
     $          'SUM OF MASS OUT',4X,F10.3,3X,'T/H',5X,
     $          '% RELATIVE ERROR',3X,F10.3)
C GENERAL FORMAT OF HEAT BALANCE
 3030 FORMAT(1X,'SUM OF HEAT IN',5X,E10.5,3X,'KCAL/H',5X,
     $          'SUM OF HEAT OUT',4X,E10.5,3X,'KCAL/H',5X,
     $          '% RELATIVE ERROR',3X,F10.3)
C
      WRITE(6,3010)
 3010 FORMAT(/,1X,'POINT 1. MASS BALANCE AROUND BIG LOOP')
      XMAIN= XC(1)+XC(8)
      XMAOUT =XC(3)+XC(5)+XC(10)+XHS +XLS
      REERM= ((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3040)
 3040 FORMAT(1X,'             HEAT BALANCE AROUND BIG LOOP')
      XHEIN=XC(1)*EN6+XC(8)*EN3
      XHEOUT=XC(3)*EN3+XC(7)*EN2+XC(10)*EN4+XHS*EN2+XLS*EN4+XC(2)*860/RB
      REERH= ((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3050)
 3050 FORMAT(/,1X,'POINT 2. MASS BALANCE AROUND TURBOGENERATOR')
      FDE1=((EN1-EN2)/(EN1-EN5))*(RC*XC(1)+XC(9))
      FDE2=((EN3-EN4)/(EN3-EN5))*(RD*XC(1)+2.3*XC(10))
      FEXI=RC*XC(1)+XC(9)-FDE1
      FEXH=RD*XC(1)+2.3*XC(10)+XC(3)-FDE2
```

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```
      XMAIN=FEXT+FEXH
      XMAOUT=FEXT+FEXH
      TUR=XMAIN
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3060)
 3060 FORMAT(1X,'            HEAT BALANCE AROUND TURBOGENERATOR')
      XHEIN=XMAIN*EN6
      XHEOUT=FEXT*EN1+FEXH*EN3+XC(2)*860/RB
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3070)
 3070 FORMAT(/,1X,'POINT 3. MASS BALANCE AT DESUP POINT OF 3K')
      XMAIN=FEXH-XC(3)+FDE2
      XMAOUT=XC(10)+FD*XC(1)+2.3*RE
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3080)
 3080 FORMAT(1X,'            HEAT BALANCE AT DESUP POINT OF 3K')
      XHEIN=(FEXH-XC(3))*EN3+FDE2*EN5
      XHEOUT=XMAOUT*EN4
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3090)
 3090 FORMAT(/,1X,'POINT 4. MASS BALANCE AT DESUP POINT OF 17K')
      XMAIN=FEXT+FDE1
      XMAOUT=XC(9)+RC*XC(1)
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3100)
 3100 FORMAT(1X,'            HEAT BALANCE AT DESUP POINT OF 17K')
      XHEIN=FEXT*EN1+FDE1*EN5
      XHEOUT=XMAOUT*EN2
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
      WRITE(6,3105)FDE1,FDE2
 3105 FORMAT(1X,'FDE1=',F10.3,3X,'FDE2=',F10.3)
C
C
      WRITE(6,3110)
 3110 FORMAT(/,1X,'POINT 5. MASS BALANCE AT SECOND LOOP')
      XMAIN=TUR+FDE1+FDE2
      XMAOUT= XC(9)+RC*XC(1)+XC(10)+RD*XC(1)+2.3*RE+XC(3)
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3120)
 3120 FORMAT(1X,'            HEAT BALANCE AT SECOND LOOP')
      XHEIN=TUR*EN6+FDE1*EN5+FDE2*EN5
```

```
      XHEOUT=XC(2)*360/RB+XC(3)*E13+RC*XC(1)*EN2+(RO*XC(1)+2.3)*EN3
      XHEOUT=XHEOUT+XC(9)*EN2+XC(10)*EN3
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3130)
 3130 FORMAT(/,1X,'POINT 6. MASS BALANCE AT DESUP AND BP')
      EN7=159000
      EN8=133000
      BP=XC(1)-TUR
      BP1=((FDE1+FDE2)*EN5-BP*EN8-XC(8)*EN5)/(EN7-EN8)
      BP2=BP-BP1
      D1=(FDE1*EN5-BP1*EN7)/EN5
      D2=XC(8)-D1
      XMAIN=BP+XC(8)
      XMAOUT=FDE1+FDE2
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3140)
 3140 FORMAT(1X,'           HEAT BALANCE AT DESUP AND BP')
      XHEIN=BP1*EN7+BP2*EN8+XC(8)*EN5
      XHEOUT=(FDE1+FDE2)*EN5
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
      WRITE(6,3145)BP1,BP2,D1,D2
 3145 FORMAT(1X,'BP1=',F5.3,5X,'BP2=',F5.3,5X,'D1=',F5.3,5X,'D2=',F5.3)
C
C
      WRITE(6,3150)
 3150 FORMAT(/,1X,'POINT 7. MASS BALANCE AT BL AND BP')
      XMAIN=XC(1)
      XMAOUT=TUR+BP
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3160)
 3160 FORMAT(1X,'           HEAT BALANCE AT BL AND BP')
      XHEIN=XC(1)*EN6
      XHEOUT=XMAOUT*EN6
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3170)
 3170 FORMAT(/,1X,'POINT 8. MASS BALANCE AT SEPARATE OF 17K')
      XMAIN=FEXT+FDE1
      XMAOUT=XC(9)+XC(1)*RC
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3180)
 3180 FORMAT(1X,'           HEAT BALANCE AT SEPARATE OF 17K')
      XHEIN=XMAIN*EN2
      XHEOUT=XMAOUT*EN2
```

```
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3190)
 3190 FORMAT(/,1X,'POINT 9. MASS BALANCE AT SEPARATE OF  3K')
      XMAIN=FEXH-XC(3)+FDE2
      XMAOUT=XC(10)+XC(1)*RD+2.3*RE
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3200)
 3200 FORMAT(1X,'              HEAT BALANCE AT SEPARATE OF  3K')
      XHEIN=XMAIN*EN4
      XHEOUT=XMAOUT*EN4
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3210)
 3210 FORMAT(/,1X,'POINT 10. MASS BALANCE AT BLOW  3K')
      XMAIN=FEXH
      XMAOUT=XC(10)+RD*XC(1)+2.3*RE-FDE2+XC(3)
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3220)
 3220 FORMAT(1X,'              HEAT BALANCE AT SEPARATE OF  3K')
      XHEIN=XMAIN*EN3
      XHEOUT=XMAOUT*EN3
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3230)
 3230 FORMAT(/,1X,'POINT 11. MASS BALANCE AT 17K TO AT')
C
      TOAT=XC(1)*RC-XC(11)
      WRITE(6,3235)XC(11),TOAT
 3235 FORMAT(1X,'XINHPH=',F10.3,5X,'TOAT=',F10.3)
      XMAIN=XC(1)*RC
      XMAOUT=XC(11)+TOAT
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3240)
 3240 FORMAT(1X,'              HEAT BALANCE AT 17K TO AT')
      XHEIN=XMAIN*EN2
      XHEOUT=XMAOUT*EN2
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3250)
 3250 FORMAT(/,1X,'POINT 12. MASS BALANCE AT  3K TO DT')
      XMAIN=XLS
      CPOIL=0.536
```

```
      CPAIR=0.237
      DENAIR=1.29
      DENOIL=0.9465
      HL=9500
      TOFOH=(CPOIL*(90-60)*XC(6)*DENOIL)/(EN4-100000)
      TOAPH=CPAIR*(122-35)*13.19*DENAIR*XC(6)*DENOIL/EN4
      TODT=RD*XC(1)+2.3-TOFOH-TOAPH
      XMAOUT=TODT+TOFOH+TOAPH
      WRITE(6,3255)TOFOH,TOAPH,TODT
 3255 FORMAT(1X,'TOFOH=',E10.5,
     &/1X,'TOAPH=',E10.5,
     &/1X,'TODT =',E10.5)
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3260)
 3260 FORMAT(1X,'          HEAT BALANCE AT  3K TO DT')
      XHEIN=XMAIN*EN4
      XHEOUT=XMAOUT*EN4
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3270)
 3270 FORMAT(/,1X,'POINT 13. MASS BALANCE AT  3K TO FOH')
      XMAIN=XLS-TODT
      XMAOUT=TOFOH+TOAPH
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3280)
 3280 FORMAT(1X,'          HEAT BALANCE AT  3K TO DT')
      XHEIN=XMAIN*EN4
      XHEOUT=XMAOUT*EN4
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3290)
 3290 FORMAT(/,1X,'POINT 14. MASS BALANCE AT  LOWER LOOP')
      XMAIN=CON+XC(7)+XC(11)+RD*XC(1)+2.3
      XMAOUT=TOFOH+TOAPH+XC(3)+1.01*XC(1)
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3300)
 3300 FORMAT(1X,'          HEAT BALANCE AT LOWER LOOP')
      XHEIN= CON*XC(13)*1000+XC(7)*0.03E5+XC(11)*EN2+(RD*XC(1)+2.3)*EN4
      XHEOUT=((TOFOH+TOAPH)*EN4+XC(3)*EN3+1.01*XC(1)*0.1926
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3310)
 3310 FORMAT(/,1X,'POINT 15. MASS BALANCE AROUND BOILER')
      XMAIN=1.01*XC(1)
      XMAOUT=XC(1)+0.01*XC(1)
```

```
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
C
      WRITE(6,3320)
 3320 FORMAT(1X,'          HEAT BALANCE AROUND BOILER')
C     HEAT IN = HEAT FROM AIR+HEAT FROM OIL+HEAT FROM WATER INLET
C               +HEAT OF COMBUSTION+HEAT OF TOAT
      XHEIN1=CPAIR*(122-25)*13.19*XC(6)*DENOIL*DENAIR
      XHEIN2=CPOIL*(90-25)*XC(6)*DENOIL
      XHEIN3=1.01*XC(1)*0.19E6
      XHEIN4=9294.63*XC(6)
      XHEIN5=(RC*XC(1)-XC(11))*EN2
      XHEIN=XHEIN1+XHEIN2+XHEIN3+XHEIN4+XHEIN5
C     HEAT OUT= HEAT FROM STEAM+HEAT FROM AIR OUTLET
C               +HEAT OF BLOW DOWN+HEAT LOSS
      XHOUT1=XC(1)*EN6
      XHOUT2= CPAIR*(195-25)*13.19*XC(6)*DENOIL*DENAIR
      XHOUT3=0.01*XC(1)*0.5E6
      XHOUT4=XHEIN-XHOUT1-XHOUT2-XHOUT3
      XHEOUT=XHOUT1+XHOUT2+XHOUT3+XHOUT4
C
      WRITE(6,3330) XHEIN1,XHEIN2,XHEIN3,XHEIN4,XHEIN5
 3330 FORMAT(1X,'HEAT FROM AIR=',5X,E10.5,/
     &1X,'HEAT FROM OIL=',5X,E10.5,/
     &1X,'HEAT FROM WATER INLET=',5X,E10.5,/
     &1X,'HEAT OF COMBUSTION=',5X,E10.5,/
     &1X,'HEAT OF TOAT=',5X,E10.5)
      WRITE(6,3340) XHOUT1,XHOUT2,XHOUT3,XHOUT4
 3340 FORMAT(/,1X,'HEAT FROM STEAM=',5X,E10.5,/
     &1X,'HEAT FROM AIR OUTLET=',5X,E10.5,/
     &1X,'HEAT OF BLOW DOWN=',5X,E10.5,/
     &1X,'HEAT LOST=',5X,E10.5)
      REHL=XHOUT4/XHEIN*100
      WRITE(6,3350) REHL
 3350 FORMAT(1X,'% HEAT LOST=',5X,E10.5)
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3360)
 3360 FORMAT(/,1X,'POINT 15. MASS BALANCE AROUND DT')
      XMAIN=CON+XC(7)+XC(11)+TJDT
      XMAOUT=XMAIN
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
      WRITE(6,3370)
 3370 FORMAT(1X,'          HEAT BALANCE AROUND DT')
C TOUTHP=TEMP OF XC(11) OUT FROM HP1
      TOUTHP=(XMAOUT*EN5-((CON+XC(7))*XC(12)*1000+TJDT*EN4))/XC(11)
      TOUTHP=TOUTHP*1.0E-3
      WRITE(6,3375) TOUTHP
 3375 FORMAT(1X,'TOUTHP =',F10.5)
      XHEIN=(CON+XC(7))*XC(12)*1000+XC(11)*TOUTHP*1000+TJDT*EN4
      XHEOUT=(1.01*XC(1)+XC(8))*EN5
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
```

```
      WRITE(6,3380)
 3380 FORMAT(/,1X,'POINT 17. MASS BALANCE AROUND BFP')
      XMAIN=CON+XC(7)+XC(11)+TOD1
      XMAOUT=1.01*XC(1)+XC(8)
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
      WRITE(6,3390)
 3390 FORMAT(1X,'             HEAT BALANCE AROUND BFP')
      XHEIN=XMAIN*EN5
      XHEOUT=XMAOUT*EN5
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3400)
 3400 FORMAT(/,1X,'POINT 18. MASS BALANCE AROUND HPH')
      XMAIN=1.01*XC(1)+XC(11)
      XMAOUT=XMAIN
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
      WRITE(6,3410)
 3410 FORMAT(1X,'             HEAT BALANCE AROUND HPH')
      XHEIN =1.01*XC(1)*EN5+XC(11)*EN2
      XHEOUT=1.01*XC(1)*0.1966+XC(11)*TOUTHP*1000
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
C
      WRITE(6,3420)
 3420 FORMAT(/,1X,'POINT 19. MASS BALANCE AROUND FOH')
      XMAIN=TOFOH
      XMAOUT=XMAIN
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
      WRITE(6,3430)
 3430 FORMAT(1X,'             HEAT BALANCE AROUND FOH')
      XHEIN =TOFOH*EN4+CPOIL*(60-25)*XC(5)*DENOIL
      XHEOUT= CPOIL*(90-25)*XC(5)*DENOIL+TOFOH*0.126
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
C
      WRITE(6,3440)
 3440 FORMAT(/,1X,'POINT 20. MASS BALANCE AROUND APH')
      XMAIN=TOAPH
      XMAOUT=XMAIN
      REERM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,REERM
      WRITE(6,3450)
 3450 FORMAT(1X,'             HEAT BALANCE AROUND APH')
      XHEIN =TOAPH*EN4+CPAIR*10*13.19*1.29*XC(6)*DENOIL
      XHEOUT=CPAIR*(122-25)*13.19*XC(6)*DENOIL*DENAIR
      REERH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,REERH
      WRITE(6,3460)
 3460 FORMAT(/,1X,'POINT 21. MASS BALANCE AROUND PHT')
      XMAIN=CON+XC(7)
```

```
      RECRM=((XMAIN-XMAOUT)/XMAIN)*100
      WRITE(6,3020)XMAIN,XMAOUT,RECRM
      WRITE(6,3470)
 3470 FORMAT(1X,'              HEAT BALANCE AROUND PHT')
      XHEIN=CON*XC(13)*1000+XC(7)*0.93E6
      XHEOUT=(CON+XC(7))*XC(12)*1000
      RECRH=((XHEIN-XHEOUT)/XHEIN)*100
      WRITE(6,3030)XHEIN,XHEOUT,RECRH
      RETURN
      END
      SUBROUTINE JACOB
      IMPLICIT REAL*8 (A-D,F-H,J-Z)
      REAL *4 PC
      DIMENSION XC(150),XI(150),XS(150),C(150),VC(50)
      DIMENSION X(150)
      DIMENSION A(50,100),ALFA(50,50)
      DIMENSION IBAS(50),Y(150),IHB(100),IVC(50),IVA(100)
      COMMON/GREG0/NEVL,NTO,ITET,ICONJ,IDIAG,ITMAX,KFIL,KLIN,NCU,ITSOR
      COMMON/GREG1/ISOLSR,EPSIL,EPSILO,EPSIL1,EPSIL2,PC
      COMMON/GREG2/XC,XI,XS,C,VC
      COMMON/GREG3/X,PHI,NV,NIN,NEG,NC
      COMMON/GREG4/A,ALFA,IBAS,Y,IHB,IVC,IVA
      COMMON/GREG5/IVB,NK,NTV,NV1,NEV,NIN1,NIN2,NIN3,NIN4,NVNIN1,YSORT
      COMMON/GREG6/NVNIN2,NVNIN3,INDEX,II,IR,IR1,IS,IS1,IT,IUP,ICDB,LC
      COMMON/GREG7/JCDB,KCDB,KREN,KO,FI1,PSI,PSI3,TU,TC,TD,KFUNC,KSRAD
      COMMON/GREG8/KCONT,KINV1,KINV2,KCDBA,KJACO,KMAX1,KMAX2,KRLN1,JKO
      COMMON/GREG9/KREN2,KINV,KCDBA1,KREN11,KREN21,IDIREC,DELTFI,ETA
      DIMENSION FNUMDF(500)
      CALL NUMDIF(XC,FNUMDF,NV,NC)
C RESET TO BE MATRIX
      K=1
      DO 110 I=1,NC
      DO 110 J=1,NV
      A(I,J)=FNUMDF(K)
      K=K+1
  110 CONTINUE
      RETURN
      END
      SUBROUTINE NUMDIF(ZZ,F,NV,NC)
      IMPLICIT REAL*8 (A-D,F-H,J-Z)
      REAL *4 PC
C FOR MANY CONSTRAIN
      DIMENSION ZZ(1),ZFOR(150),ZBAC(150),RE(50,100),F(500)
      DIMENSION VZF(50),VZB(50)
C
C
C SET VALUE OF H
      H=.001
C SET VALUE OF X (RENAMED)
      DO 69 I=1,NV
      ZFOR(I)=ZZ(I)
   69 ZBAC(I)=ZZ(I)
C
      DO 70 IX=1,NV
      ZFOR(IX)=ZZ(IX)+H*ZZ(IX)
      ZBAC(IX)=ZZ(IX)-H*ZZ(IX)
      CALL CP(ZFOR,VZF)
```

```
      CALL CP(ZBAC,VZB)
      DO 71 J=1,NC
C
C
      IF (ZZ(IX).LE.1.0E-30) ZZ(IX)=1.0E-30
C
C
      KE(J,IX)=(VZF(J)-VZB(J))/(2*H*ZZ(IX))
   71 CONTINUE
      ZFOR(IX)=ZZ(IX)
      ZBAC(IX)=ZZ(IX)
   70 CONTINUE
C CHANGE TO ARGUMENT AND SENT
      K=1
      DO 3 I=1,NC
      DO 3 J=1,NV
      F(K)=KE(I,J)
    3 K=K+1
      RETURN
      END
/*
//GO.SYSIN   DD *
      13        5        9       20        6       20        1
       0       20        1        9       15        1       20
     0.1   0.0001   0.0001   0.0001      0.0
  75.150   8530.0    14.33   2464.0   2463.0   5201.0    25.07
    2.04    20.00     23.0    6.676     67.0    -95.4
    50.0   6500.0      0.0   2010.0 0.000001   3500.0     2.40
    0.01    28.93     15.0     5.24     55.0     60.0
    50.0   9000.0     20.0  12000.0  12000.0   5675.0    75.00
    3.45    62.0      40.0     7.35     90.0    130.0
/*
//
```

VITA

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