INNOVATIVE CONCEPTS FOR WTE AND NATURAL GAS TURBINE POWER PLANTS – AN ECONOMICALLY FEASIBLE SOLUTION FOR RIO DE JANEIRO.

Dr. Sergio Guerreiro

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FINAL DESTINATION OF WASTE IN RIO GRAMACHO LANDFILL →8,000 TON/D

WILL CLOSE SOON

PROBLEM→NEW PACIENCIA LANDFILL WAS CANCELLED DUE TO DIFFICULTIES WITH ENVIRONMENTAL LICENSE

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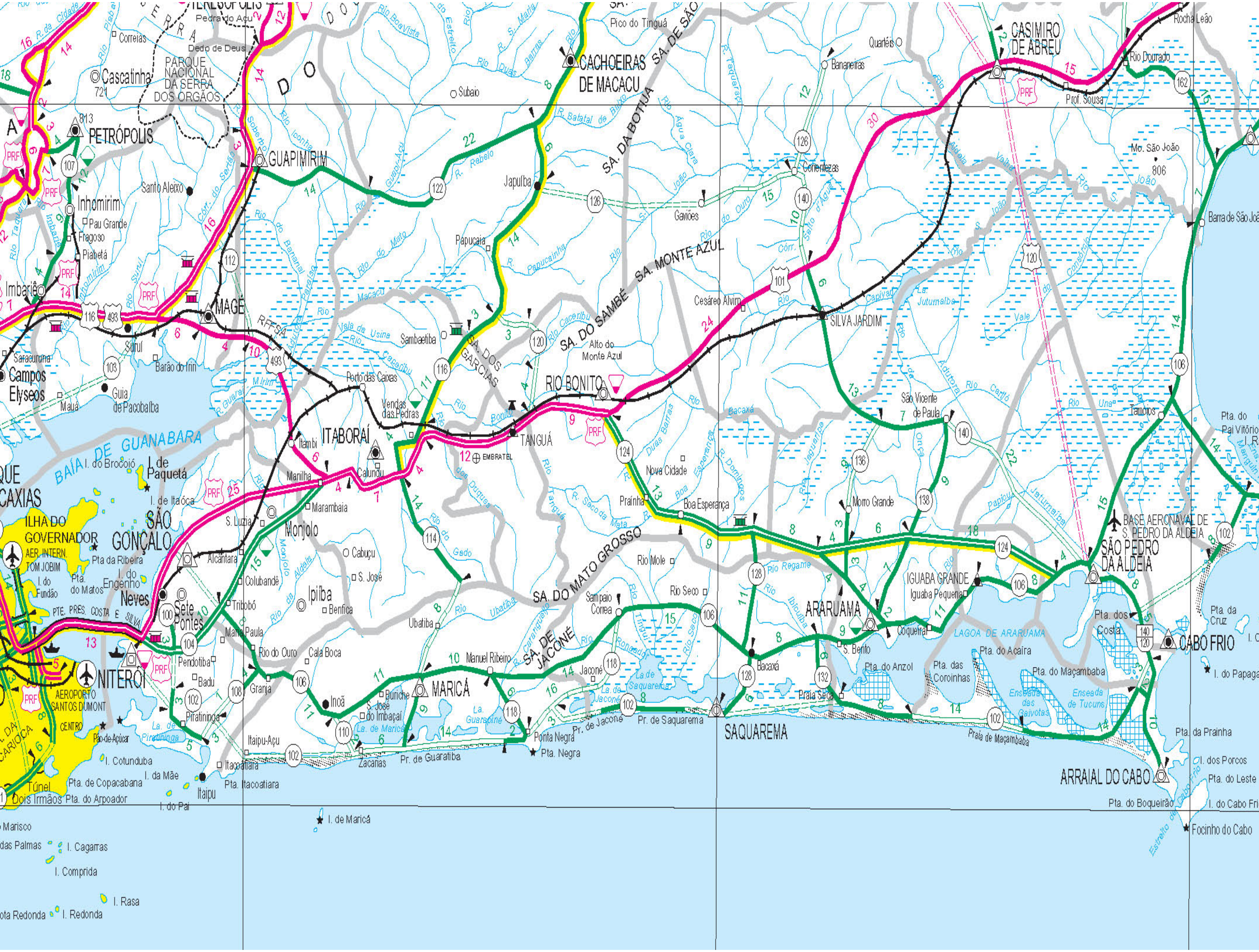

Pedra do Açu
Pico do Tinguá
CASIMIRO DE ABREU
Rocha Leão
Quartéis
Correias
Dedo de Deus
Cascatinha
721
PARQUE NACIONAL DA SERRA DOS ORGÃOS
CACHOEIRAS DE MACACU
Subaio
Bananeiras
Rio Dourado
Prof. Sousa
PETRÓPOLIS
813
GUAPIMIRIM
Japuíba
Santo Aleixo
Inhomirim
Pau Grande
Fragoso
Piabetá
Imbariê
Corrientezas
Gaviões
Mo. São João
806
Barra de São João
Papucaia
SA. DA BOTIJA
SA. MONTE AZUL
SA. DO SAMBÉ
Cesáreo Alvim
SILVA JARDIM
MAGÉ
Suruí
RFFSA
Saracuruna
Campos Elyseos
Barão do Irin
Guia de Pacobaíba
Mauá
Sambaetiba
SA. DOS GARCIAS
Alto do Monte Azul
RIO BONITO
São Vicente de Paula
Tamoios
Porto das Caixas
Vendas das Pedras
ITABORAÍ
Itambi
TANGUÁ
EMBRATEL
BAÍA DE GUANABARA
I. do Brocoió
I. de Paquetá
Manilha
Calundu
Nova Cidade
Morro Grande
Prainha
Boa Esperança
BASE AERONAVAL DE S. PEDRO DA ALDEIA
SÃO PEDRO DA ALDEIA
CAXIAS
I. de Itaóca
SÃO GONÇALO
S. Luzia
Marambaia
Monjolo
ILHA DO GOVERNADOR
AER. INTERN. TOM JOBIM
Pta da Ribeira
Alcântara
Cabuçu
S. José
SA. DO MATO GROSSO
Rio Mole
IGUABA GRANDE
Iguaba Pequena
I. do Fundão
Pta. do Matos
I. do Engenho
Neves
Colubandê
Ipiiba
Benfica
Rio Seco
Sampaio Correa
ARARUAMA
PTE. PRES. COSTA E SILVA
Sete Pontes
Tribobó
Ubatiba
LAGOA DE ARARUAMA
Coqueiral
Pta. da Cruz
Pta. dos Costa
CABO FRIO
Maria Paula
Rio do Ouro
Cala Boca
Manuel Ribeiro
SA. DE JACONÉ
S. Bento
Pta. do Acaíra
NITERÓI
Pendotiba
Badu
Granja
Inoã
Buriche
MARICÁ
Jaconé
La. de Jaconé
La. de Saquarema
Bacaxá
Pta. do Anzol
Pta. das Coroinhas
Pta. do Maçambaba
I. do Papagaio
AEROPORTO SANTOS DUMONT
CENTRO
Piratininga
S. José do Imbaçaí
La. de Maricá
La. Guarapina
Praia Seca
Enseada das Gaivotas
Enseada de Tucuns
Pão-de-Açúcar
La. de Piratininga
Itaipu-Açu
Ponta Negra
Pr. de Jaconé
Pr. de Saquarema
SAQUAREMA
Praia de Maçambaba
Pta. da Prainha
I. Cotunduba
Itacoatiara
Zacarias
Pr. de Guaratiba
Pta. Negra
I. dos Porcos
Pta. do Leste
Pta. de Copacabana
I. da Mãe
Itaipu
Pta. Itacoatiara
ARRAIAL DO CABO
Túnel
Dois Irmãos
Pta. do Arpoador
I. do Pai
Pta. do Boqueirão
I. do Cabo Frio
Estreito do Cabo Frio
I. de Maricá
Marisco
das Palmas
I. Cagarras
Focinho do Cabo
I. Comprida
I. Rasa
ota Redonda
I. Redonda
PRF

USUAL WTE DIFFICULTIES

1. HIGH INVESTMENT

2. BOILER CORROSION <-> LOW EFFICIENCY

3.HIGH O&M COSTS

3.LOW ENERGY / TON OF MSW

4. LOW TIP FEE IN MANY PLACES (BRAZIL)

5. CARBON CREDITS CAN HELP

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ADVANTAGES OF WTE

1.ONLY VIABLE ALTERNATIVE TO LANDFILLS

2. ENVIRONMENTALLY SUSTAINABLE

3. MATERIALS AND ENERGY RECOVERY

4. CAN BE COMPLETELY CONTROLLED

5. WE CAN AND SHOULD MONITOR EMISSIONS

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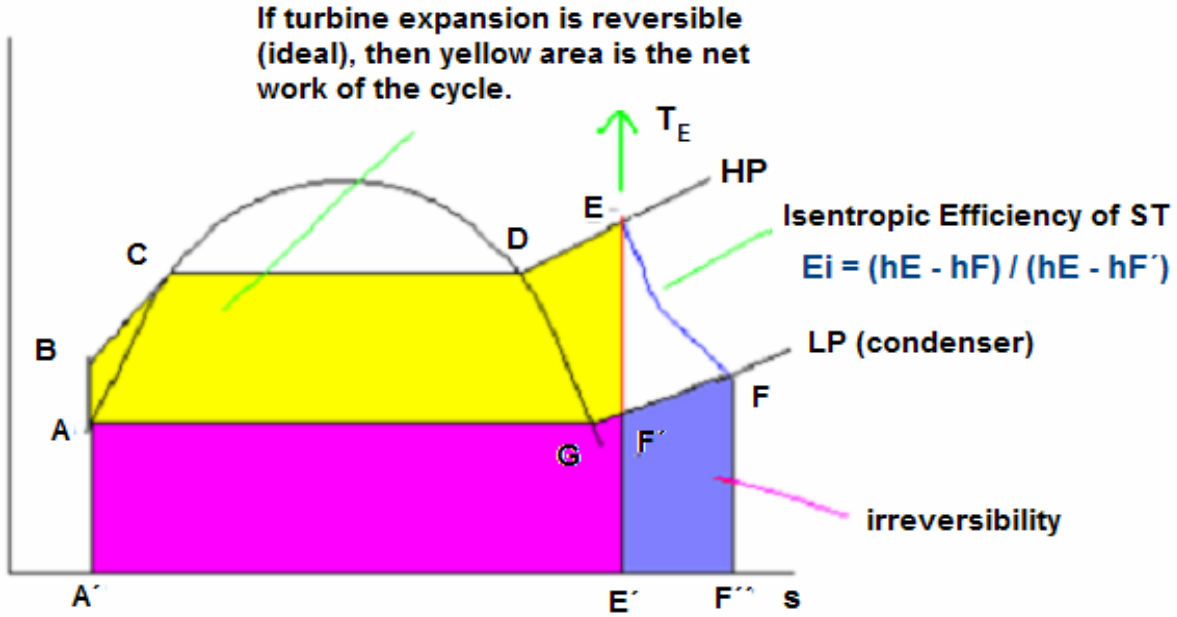
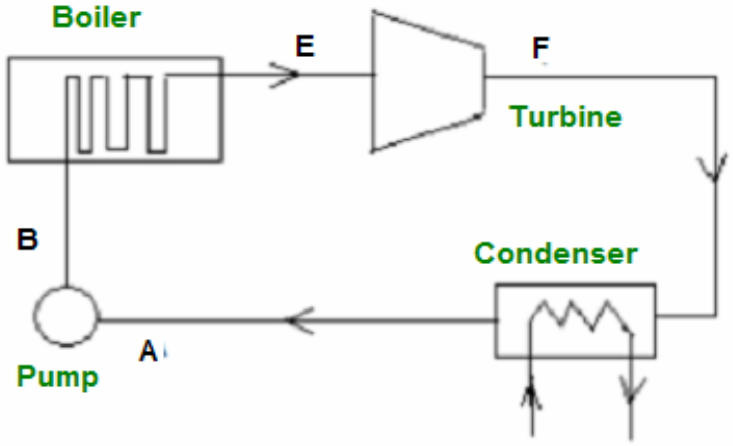
STEAM CYCLE EFFICIENCY

W(net) = Q(in) - Q(out) = (A´- B-C-D-E-E´- A´) - (A´-A-G-F-F´´ - A´) = (■ + ■) - (■ + ■) = ■ - ■

dQ = T ds



Efficiency = W(net) / Q(in) = (■ - ■) / (■ + ■)



TO INCREASE EFFICIENCY

Qin = constant = (■ + ■) = Fuel

■ ↓ ■ ↓ constant ■

superheater

HP ↑ T_E ↑

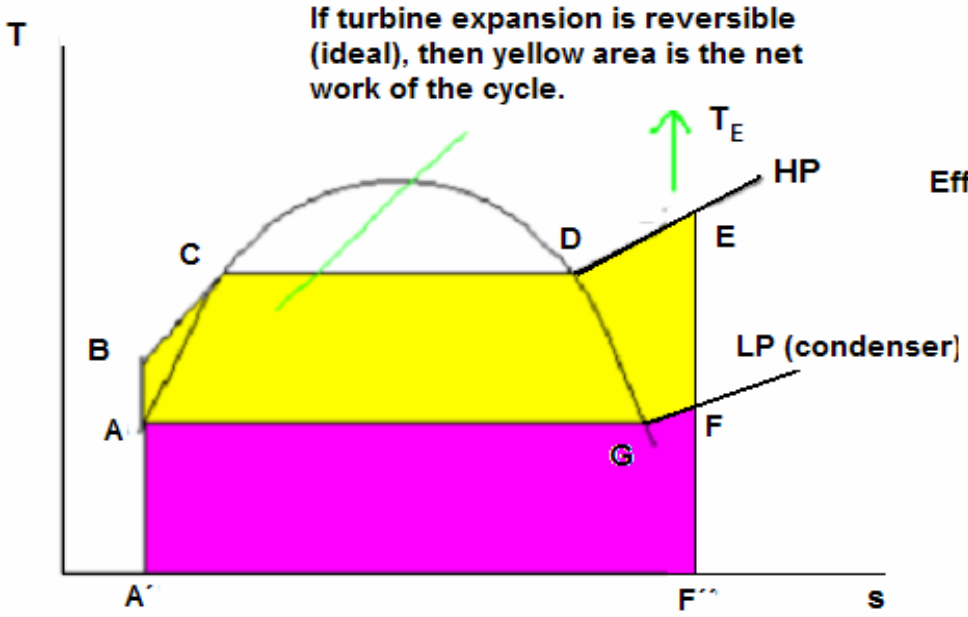
LP ↓

condenser

STEAM CYCLE EFFICIENCY (IDEAL)

W(net) = Q(in) - Q(out) = (A´- B-C-D-E-F´´-A´) - (A´-A-G-F-F´´ -A´) = (■ + □) - (■) = □

dQ = T ds

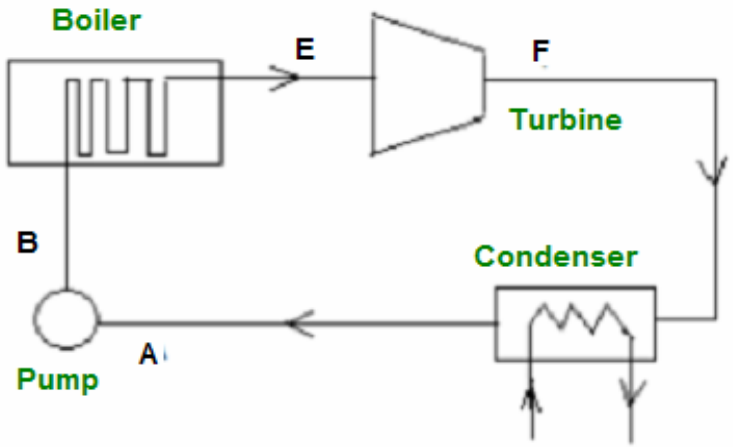


Efficiency = W(net) / Q(in) = (□) / (■ + □)

TO INCREASE EFFICIENCY

1) Qin = constant = (■ + □) = Fuel

■ ↓ LP ↓ condenser

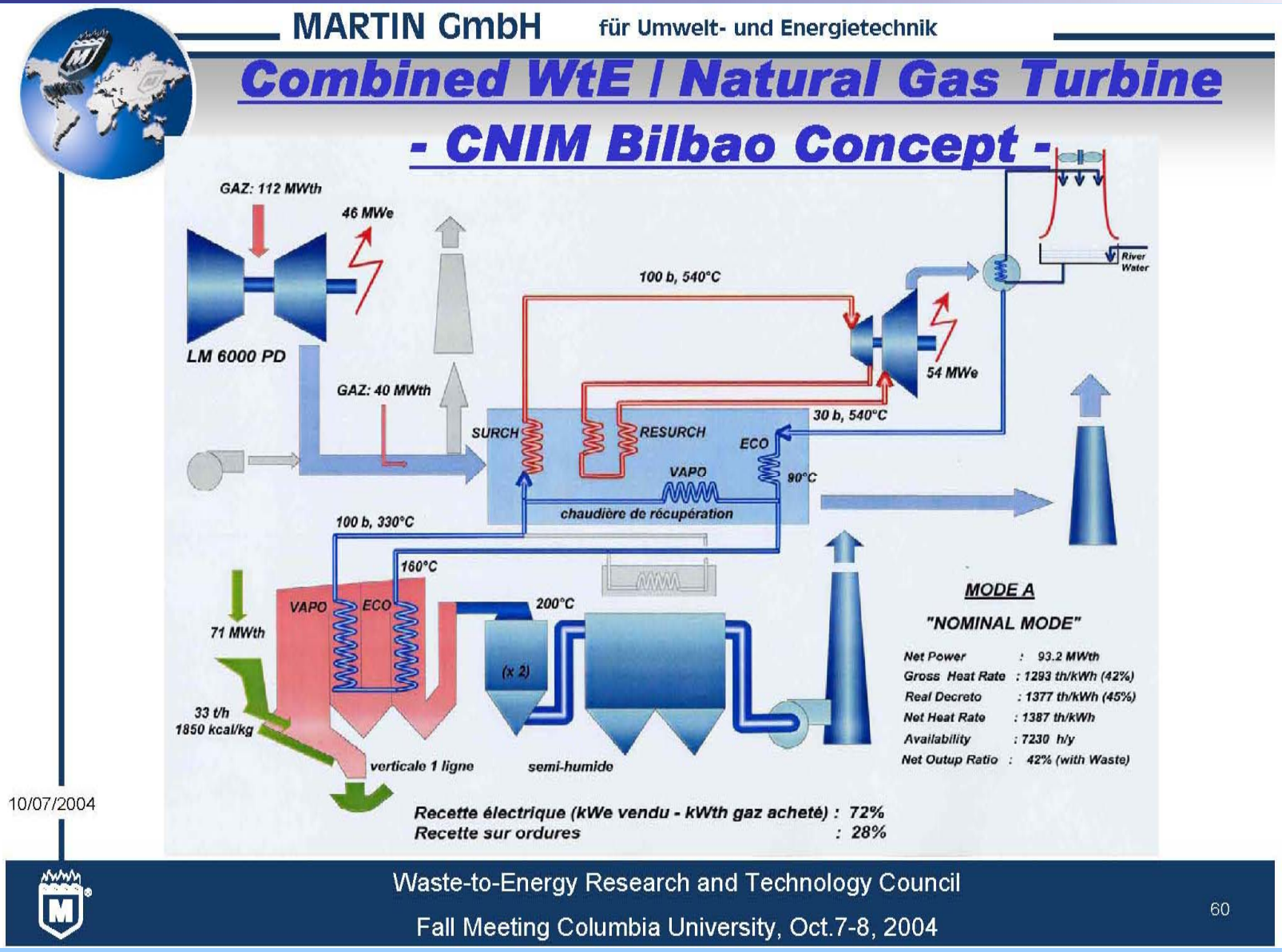


2) constant ■ □ ↑

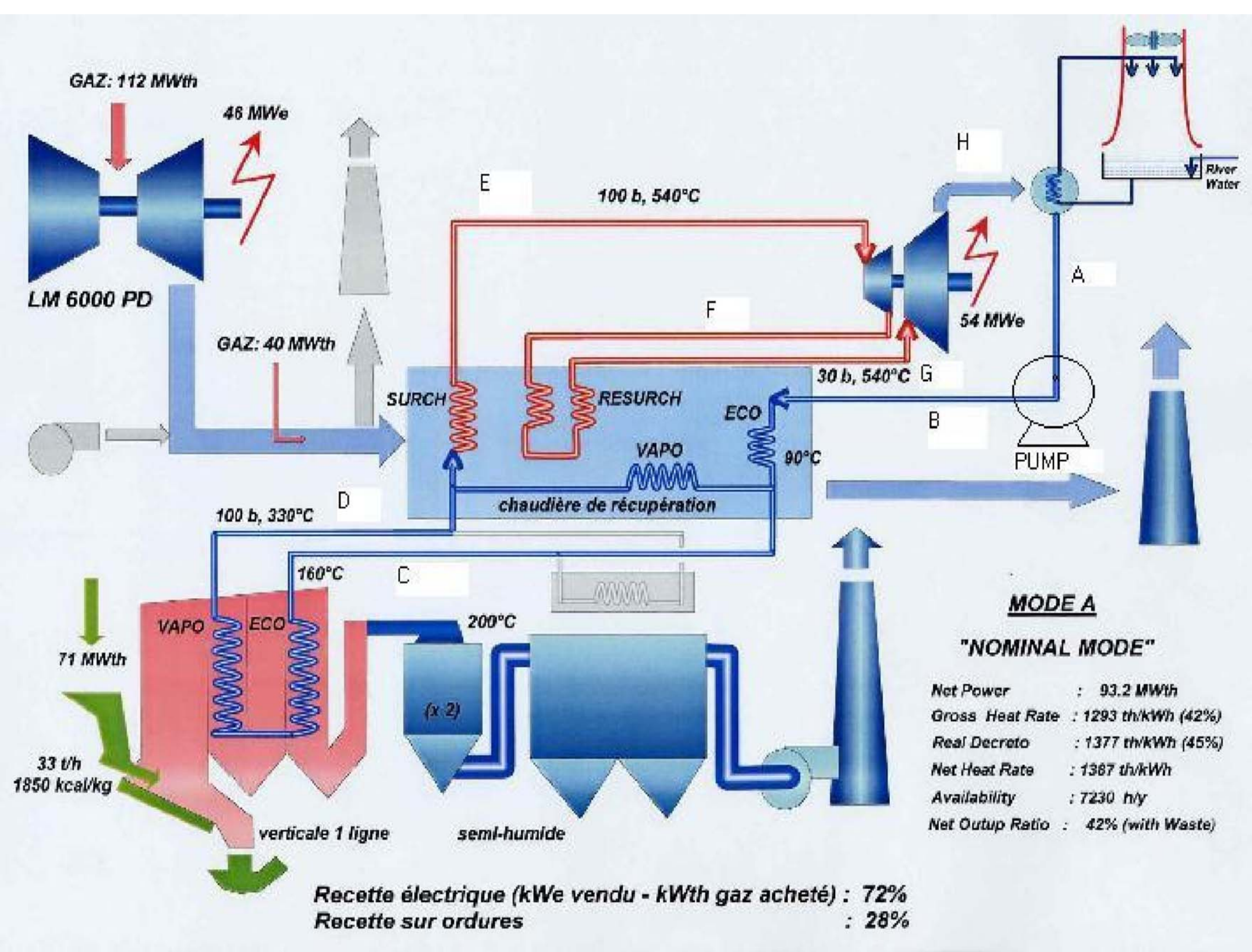
HP ↑ T_E ↑ superheater

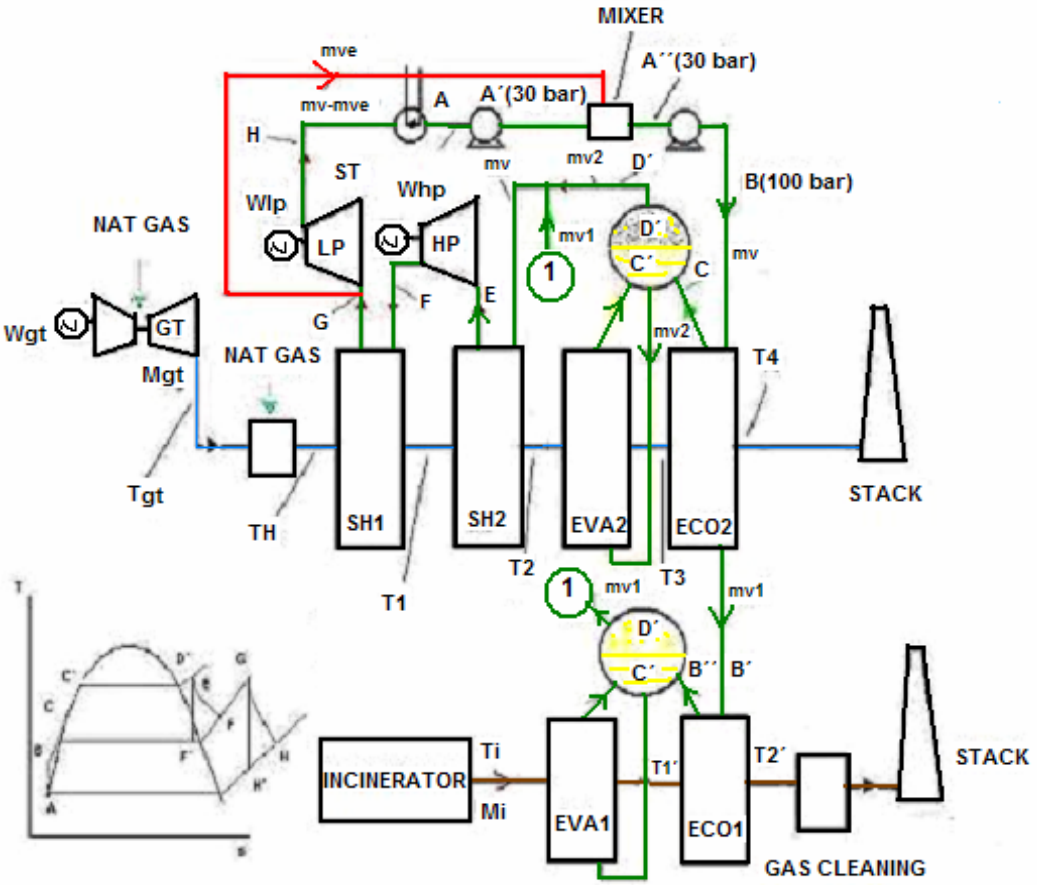
WtE Facility Bilbao, Spain

EXEMPLOS – INCINERAÇÃO ZABALGARBI, ESPANHA




CNIM


GAZ: 112 MWth
46 MWe
LM 6000 PD
GAZ: 40 MWth
E
100 b, 540°C
H
River Water
A
F
54 MWe
30 b, 540°C
G
SURCH
RESURCH
ECO
VAPO
90°C
B
PUMP
chaudière de récupération
D
100 b, 330°C
160°C
C
200°C
VAPO
ECO
71 MWth
(x 2)
33 t/h
1850 kcal/kg
verticale 1 ligne
semi-humide
MODE A
"NOMINAL MODE"
Net Power : 93.2 MWth
Gross Heat Rate : 1293 th/kWh (42%)
Real Decreto : 1377 th/kWh (45%)
Net Heat Rate : 1367 th/kWh
Availability : 7230 h/y
Net Outup Ratio : 42% (with Waste)
Recette électrique (kWe vendu - kWth gaz acheté) : 72%
Recette sur ordures : 28%



STEAM CYCLE EFFICIENCY = 36.1%

ST POWER = 144.2 * 0.361 = 52.06 MWe

TOTAL POWER = 46 + 52.06 = 98.06 MWe

OVERALL EFF. = 98.06 / (152+71) =43.97%

PAID FUEL EFF. = 98.06 / 152 = 64.51%

NG EFF. = 76.76 / 152 = 50.50%

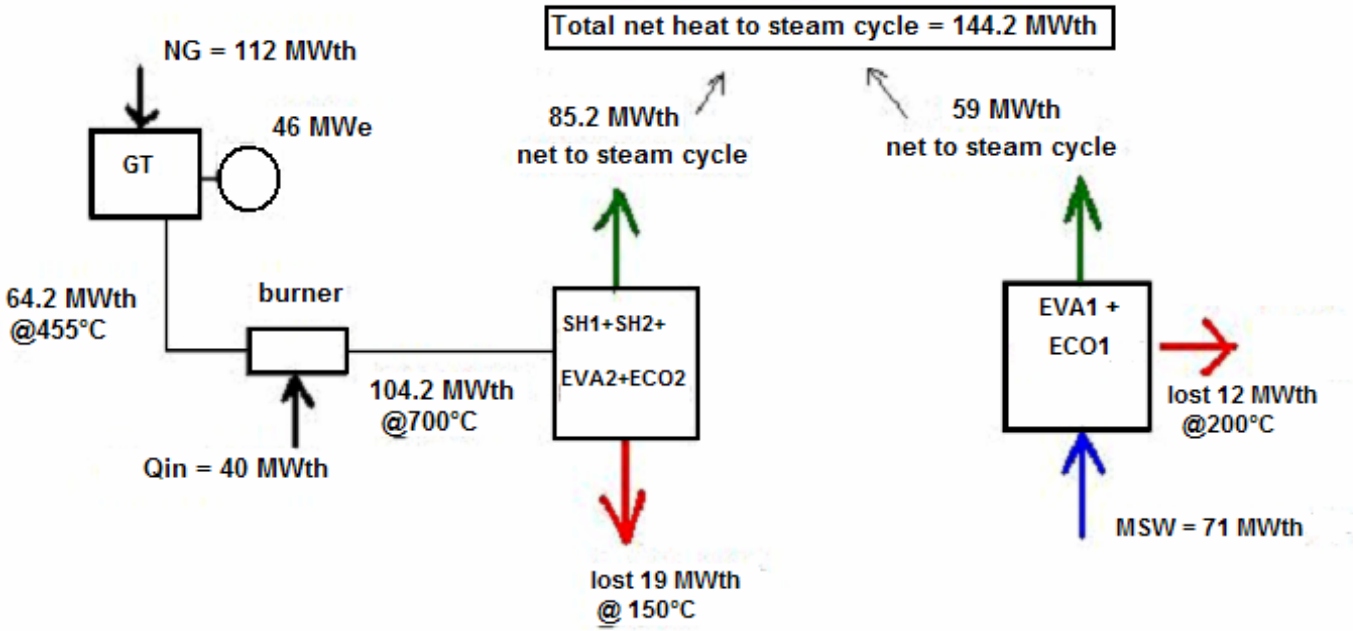
WASTE EFF. = 21.3 / 71 = 30%

WASTE CONTRIBUTION

21.30 / 98.06 = 21.72% OF TOTAL ENERGY

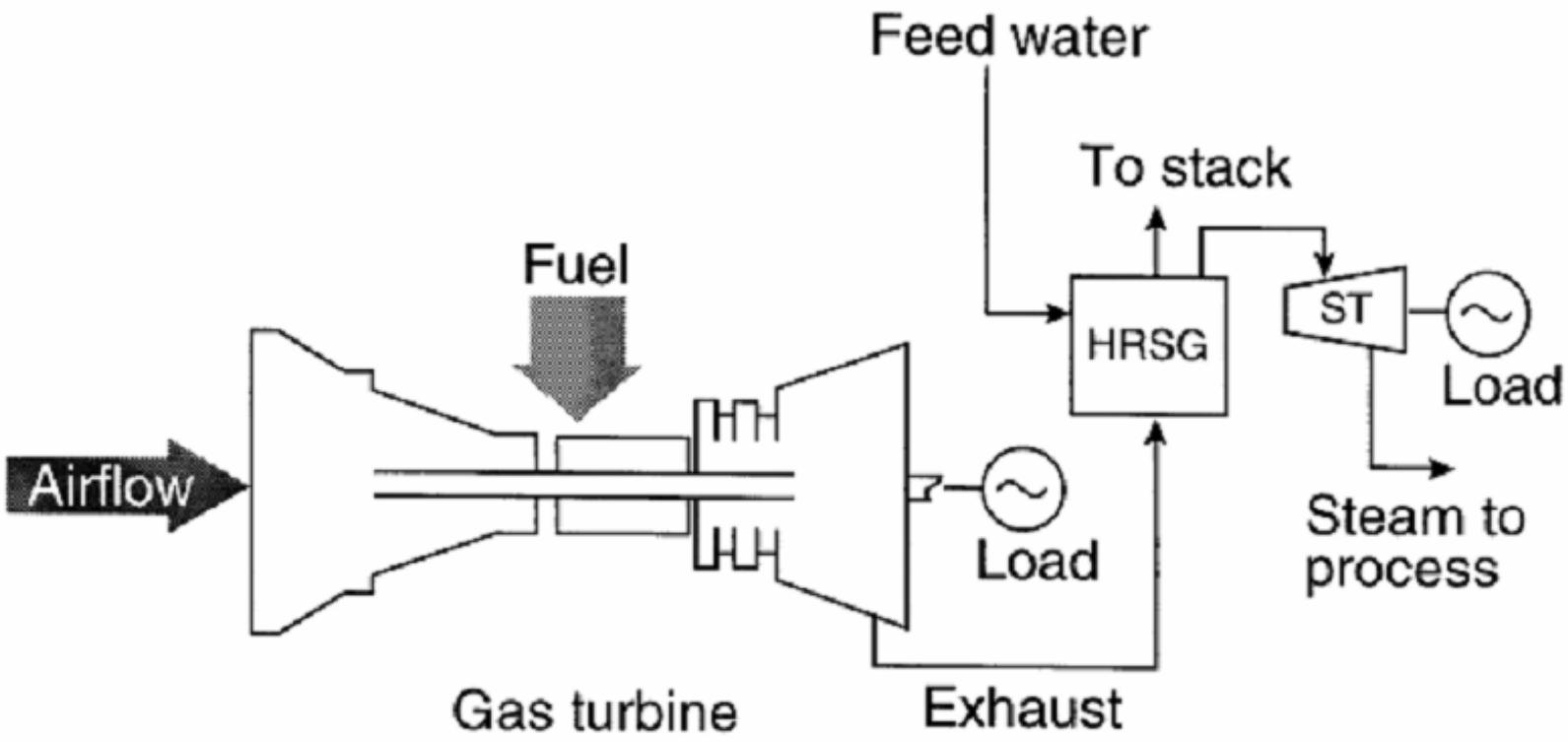
MWth / TON = 21.3 / 33 = 0.64 (1,850 Kcal/Kg)

MWth / TON = 21.3 / 33 = 0.84 (2,400 Kcal/Kg)

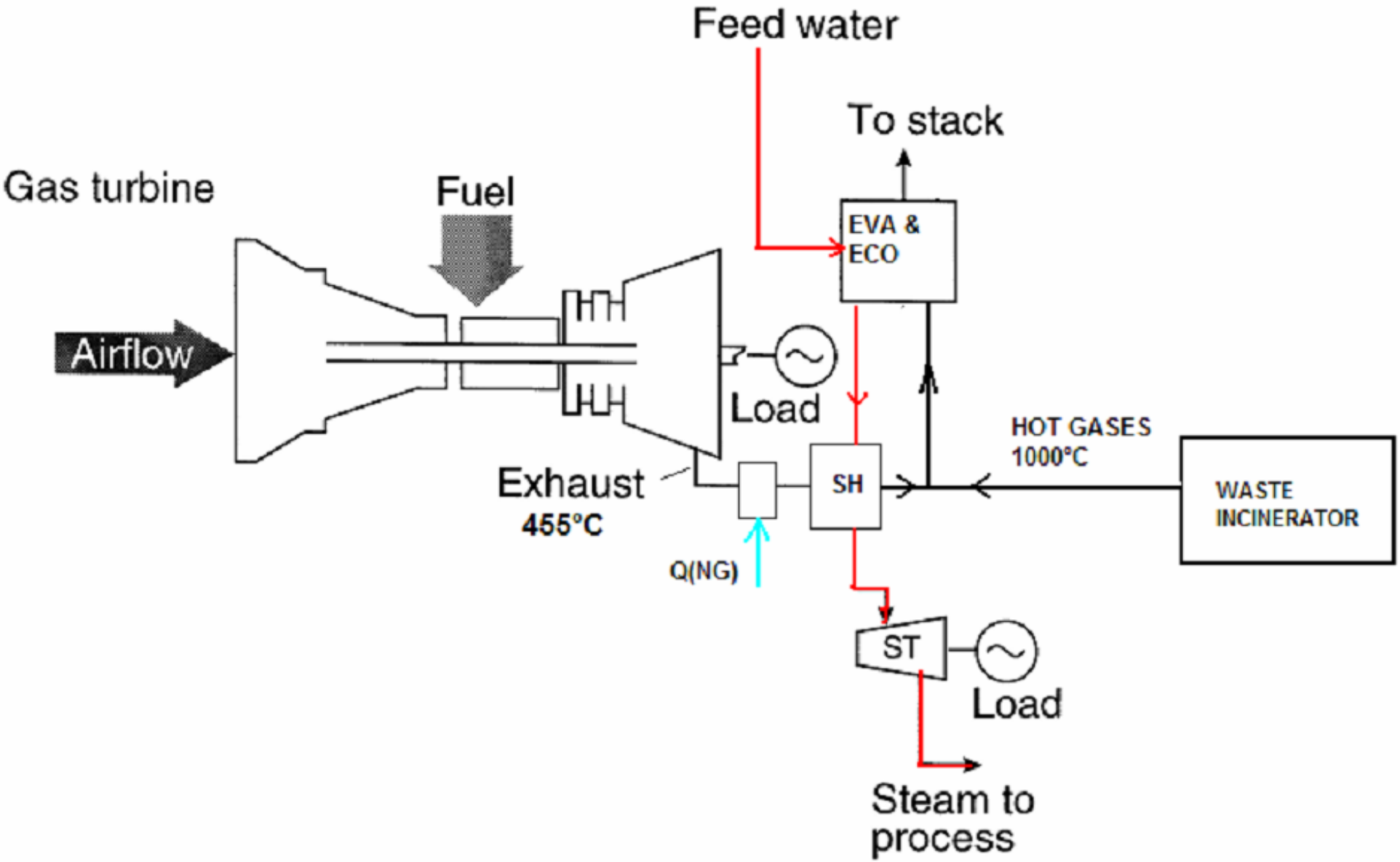


ZABALGARBI ORIGINAL

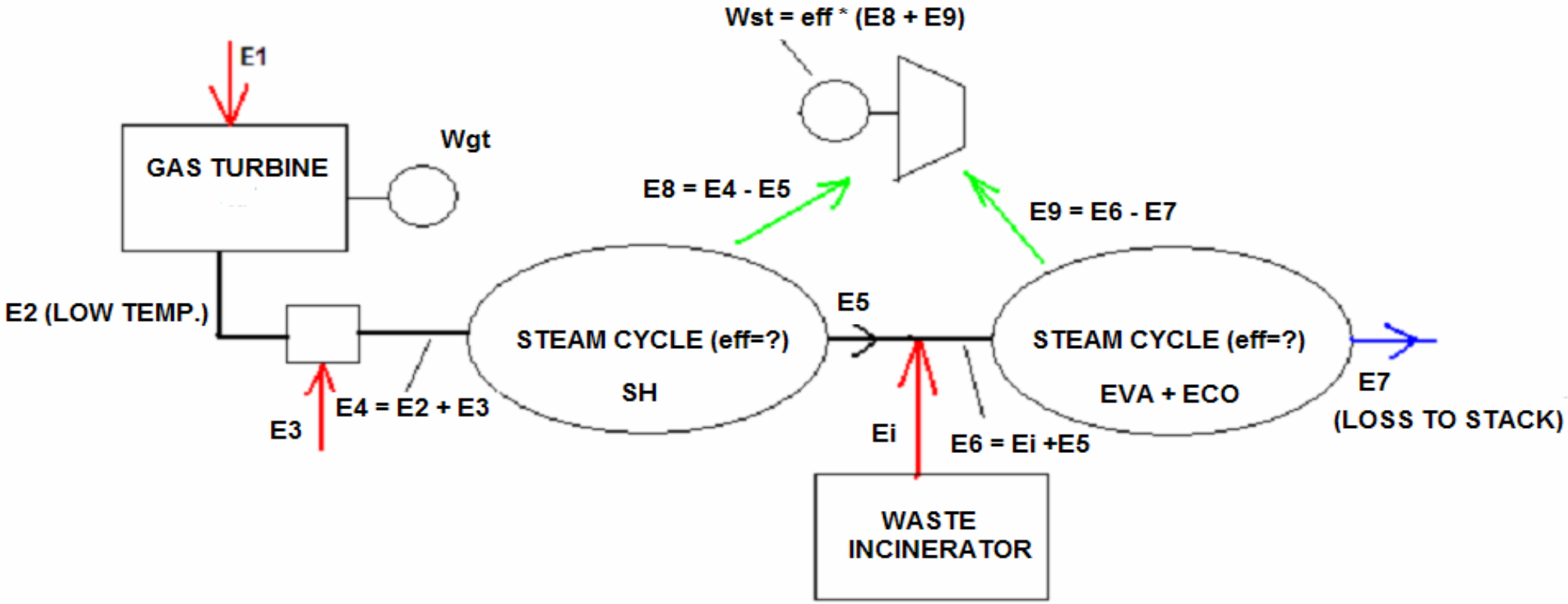
GAS TURBINE WITH STANDARD COMBINED CYCLE



GAS TURBINE WITH SPECIAL COMBINED CYCLE INCLUDING WASTE



ENERGY FLOW FOR WASTE / NG SYSTEMS

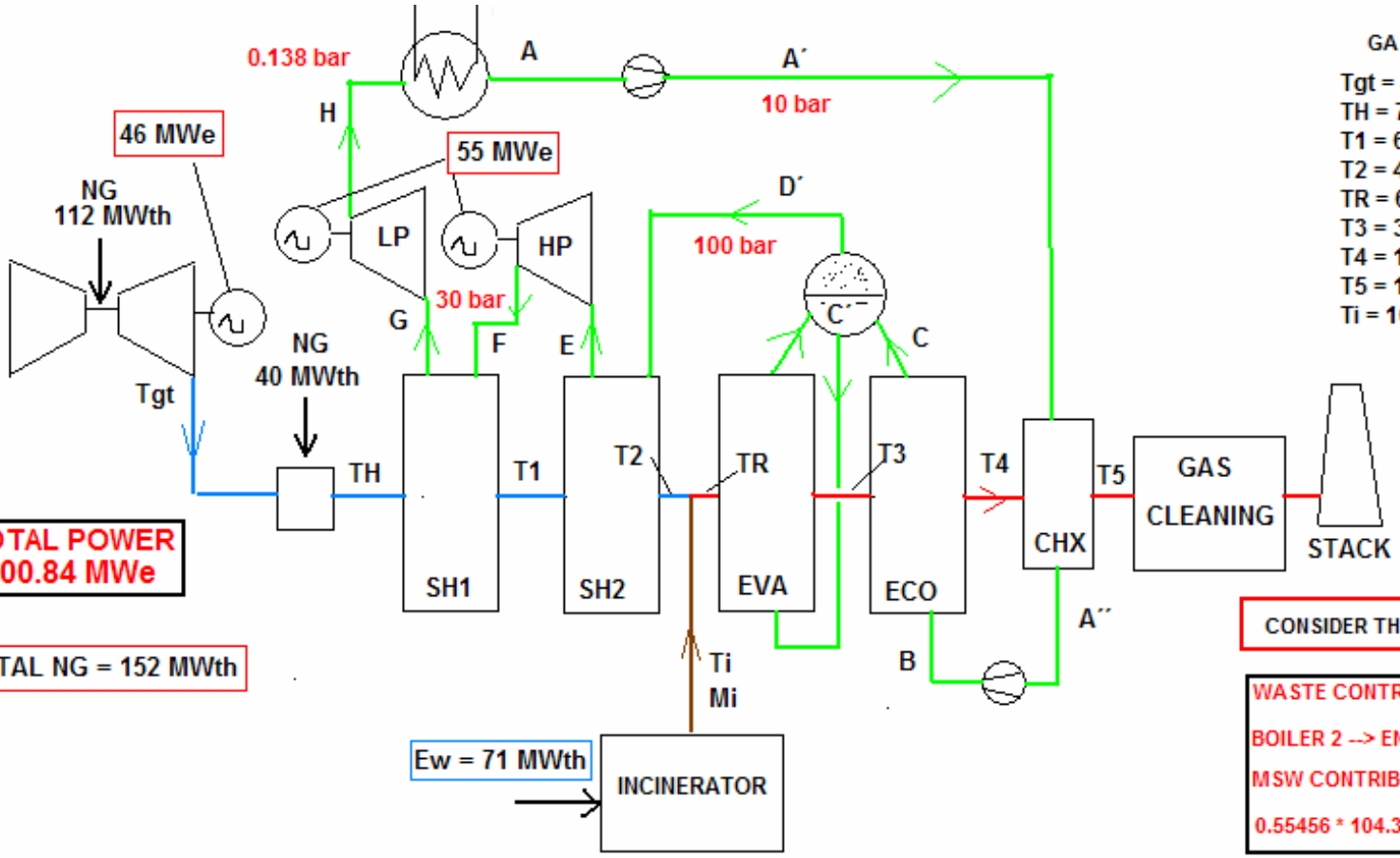


1. WHEN WE "HANG" THE WTE PLANT BETWEEN THE SUPERHEATER AND THE EVAPORATOR WE AVOID CORROSION IN SUPERHEATER SINCE THE GAS IS CLEAN.

2. EVAPORATOR SUBJECTED TO LOWER TEMPERATURE AND CLEANER GAS. METAL TEMPERATURE BELOW 400°C.

3. THE HIGHER THE STEAM CYCLE EFFICIENCY THE BETTER. CAN USE SPECIAL MATERIALS (INCONEL, STAINLESS) TO USE ADVANCED STEAM CYCLES TO REACH EFFICIENCIES CLOSE TO 50%.

4. TO MINIMIZE THE ENERGY LOSS TO THE STACK (E7) WE MUST LOWER THE EXHAUST GAS TEMPERATURE. USING A CONDENSER HEAT EXCHANGER (CHX) - TEFLON COATED TUBES IN COLDER SECTION OF ECONOMIZER WE CAN INCREASE THE OVERALL EFFICIENCY LOWERING THE EXIT TEMPERATURE OF THE FLUE GAS.



GAS	WATER	PROCESS
Tgt = 455°C	TA = TA´ = 52°C	mGT = 298 lbm/s
TH = 710°C	TA´´ = 121°C	mR = 431.5 lbm/s
T1 = 609°C	TB = 122°C	
T2 = 407°C	TC = 300°C	mi = 133.5 lbm/s
TR = 602°C	TC´= 311°C	
T3 = 346°C	TD´= 311°C	
T4 = 187°C	TE = 540°C	
T5 = 129°C	TF = 368°C	
Ti = 1000°C	TG = 540°C	
	TH = 52°C	

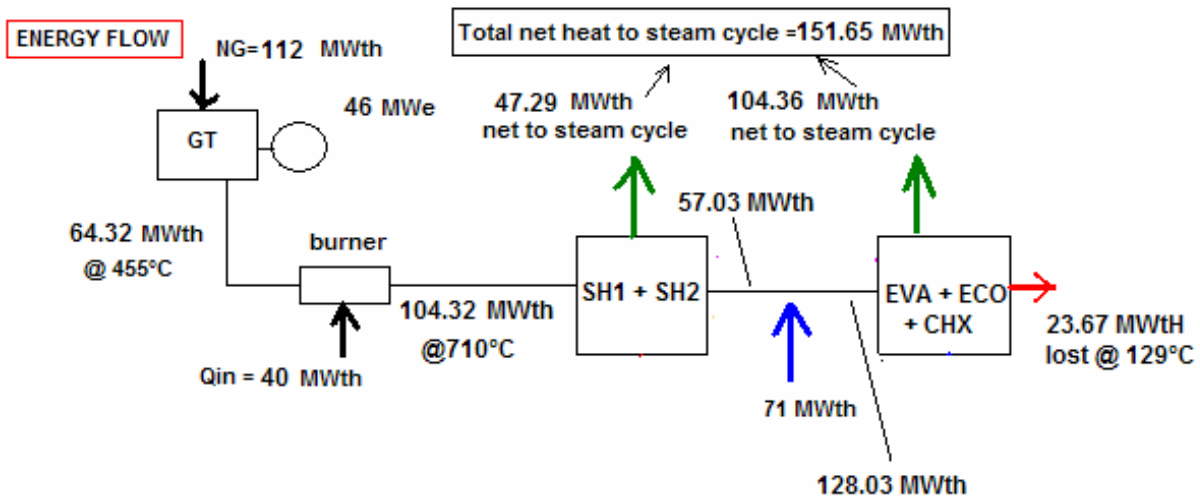
CONSIDER THE STEAM CYCLE EFFICIENCY 36.164%

WASTE CONTRIBUTION

BOILER 2 --> ENERGY INPUT FROM MSW = 55.456%

MSW CONTRIBUTION TO TOTAL POWER =

0.55456 * 104.36 * 0.36164 = 20.93 MWe or 20.75% OF TOTAL



ST POWER = 151.65 * 0.36164 = 54.84 MWe

TOTAL POWER OF PLANT = 46 + 54.84 = 100.84 MWe

OVERALL EFFIC. = 100.84 / (112 + 40 +71) = 45.22%

PAID FUEL EFFIC. = 100.84 / (112 + 40) = 66.34%

NG EFFIC. = (100.84 - 20.93) / (112 + 40) = 52.57%

WASTE EFFIC. = 20.93 / 71 = 29.48%

WASTE APPAR. POWER = 100.84 - (112 + 40) * 0.51

= 23.32 MWe (23.12% of total)

WASTE APPAR. EFFIC. = 23.32 / 71 = 32.84%

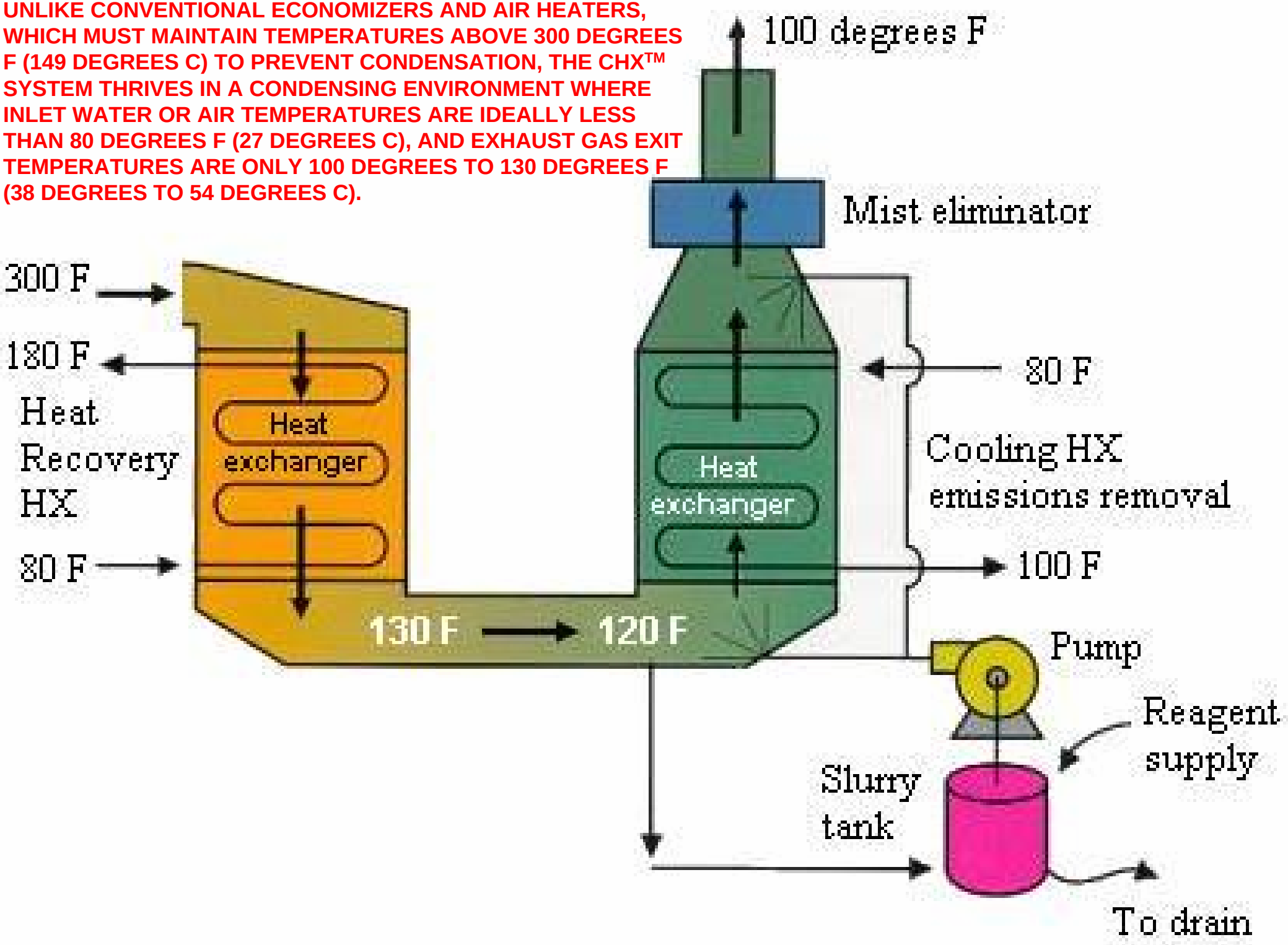
FULL MIXING WITH CHX

CHX

TRADITIONALLY, RECOVERING HEAT FROM EXHAUST GAS HAS BEEN ECONOMICALLY VIABLE ONLY AT TEMPERATURES ABOVE THE ACID DEW POINT OF THE GAS. BELOW THIS POINT, COLD-END CORROSION WAS INEVITABLE, RESULTING IN PREMATURE EQUIPMENT REPLACEMENT COSTS.

CONDENSING HEAT EXCHANGER
900 COMMERCE DRIVE, CLIFTON PARK, NY 12065
PHONE: (518) 877-8805 FAX: (518) 877-8686
E-MAIL: sps@capital.net

UNLIKE CONVENTIONAL ECONOMIZERS AND AIR HEATERS, WHICH MUST MAINTAIN TEMPERATURES ABOVE 300 DEGREES F (149 DEGREES C) TO PREVENT CONDENSATION, THE CHX™ SYSTEM THRIVES IN A CONDENSING ENVIRONMENT WHERE INLET WATER OR AIR TEMPERATURES ARE IDEALLY LESS THAN 80 DEGREES F (27 DEGREES C), AND EXHAUST GAS EXIT TEMPERATURES ARE ONLY 100 DEGREES TO 130 DEGREES F (38 DEGREES TO 54 DEGREES C).



CHX

SINCE THE HEAT EXCHANGER TUBE SURFACE AND THE EXHAUST AREA OF THE HEAT EXCHANGER ARE AT A TEMPERATURE WELL BELOW THE DEW POINT OF THE WATER VAPOR, A RAIN OF CONDENSATE IS PRODUCED THROUGH DROPWISE CONDENSATION OF THE WATER VAPOR. THIS CONDENSATE PASSES AROUND THE TUBE ARRAY, CARRYING PARTICULATES AND ACIDS WHICH HAVE BEEN SCRUBBED FROM THE GAS AND WASHED FROM THE TUBES.

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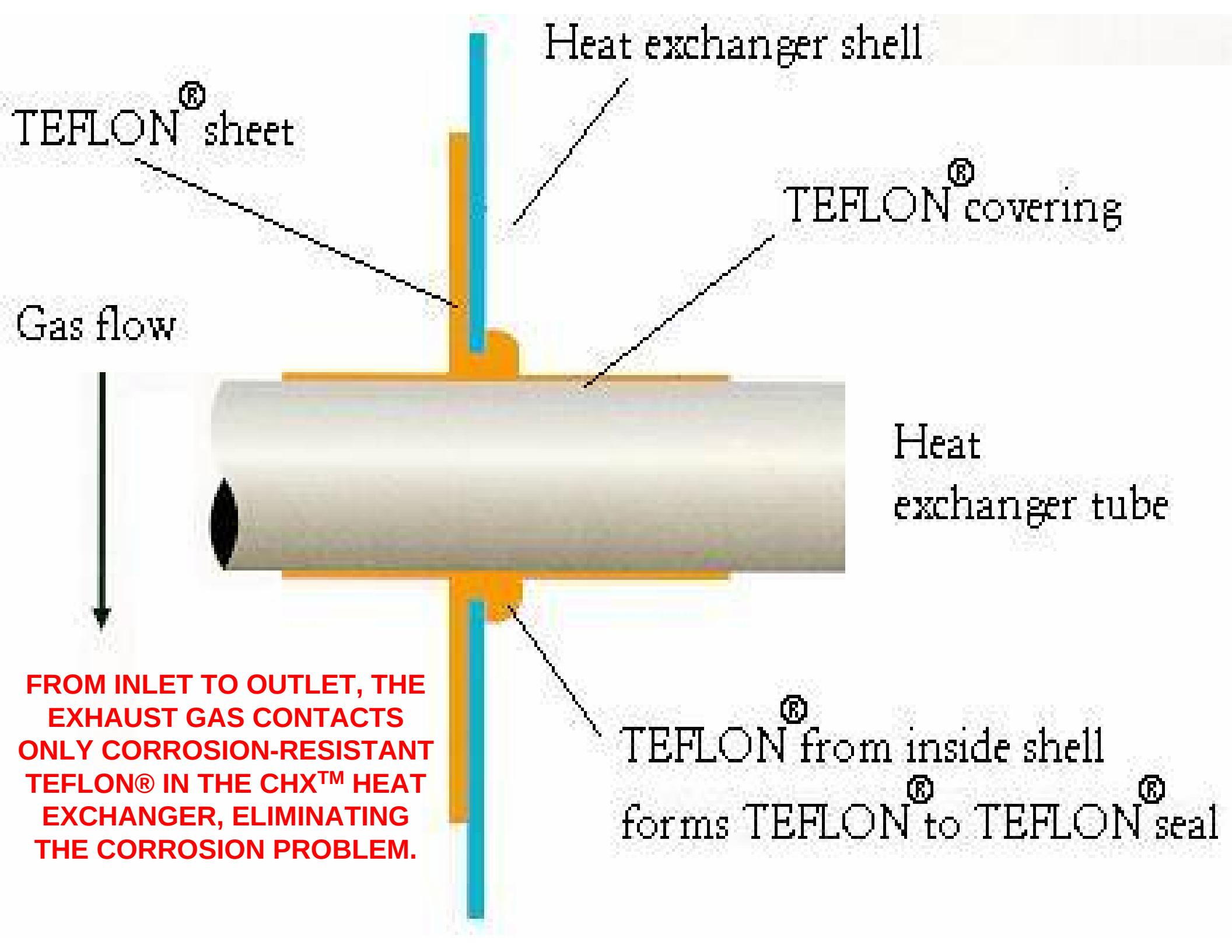
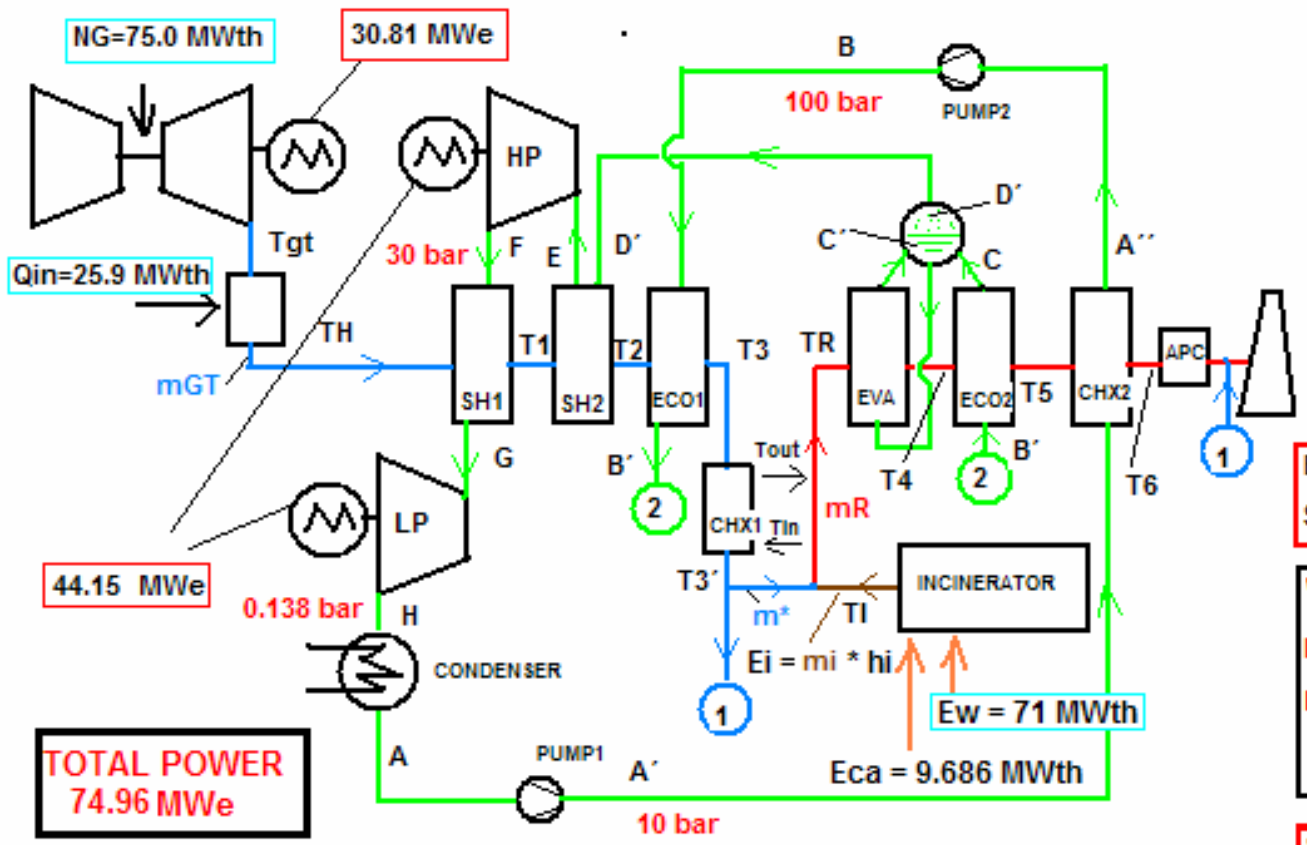


FROM INLET TO OUTLET, THE EXHAUST GAS CONTACTS ONLY CORROSION-RESISTANT TEFLON® IN THE CHX™ HEAT EXCHANGER, ELIMINATING THE CORROSION PROBLEM.



GAS	WATER	PROCESS
Ttg = 455°C	TA = TA´= 52°C	mGT = 199.57 lbm/s
TH = 700°C	TA´´ = TB = 105°C	m* = 33.542 lbm/s
T1 = 578°C	TB´= 194°C	mR = 185.28 lbm/s
T2 = 333°C	TC = 300°C	mi = 151.737bm/s
T3 = 205°C	TC´ = 311°C	
T3´=104°C	TD´ = 311°C	Tin = 16°C
TR = 850°C	TE = 540°C	Tout = 176°C
T4 = 395°C	TF = 368°C	
T5 = 214°C	TG = 540°C	
T6 = 134°C	TH = 52°C	
TI = 1000°C		

Extra energy in hot combustion air = 9.686 MWth

STEAM CYCLE EFFIC. (NEGLECT PUMP WORK)=36.164%

WASTE CONTRIBUTION

BOILER 2 --> ENERGY INPUT FROM MSW = 86.48%

MSW CONTRIBUTION TO TOTAL POWER =

.8648*71.351*0.36164 = 22.31 MWe or 29.8% OF TOTAL

TOTAL NG=100.9 MWth

TOTAL MSW = 71 MWth

ST POWER = 122.102 * 0.36164 = 44.15 MWe

TOTAL POWER OF PLANT = 30.81 + 44.15 = 74.96 MWe

OVERALL EFFIC. = 74.96 / (75.0 + 25.9 + 71) = 43.6%

PAID FUEL EFFIC. = 74.96 / (75.0 + 25.9) = 74.29%

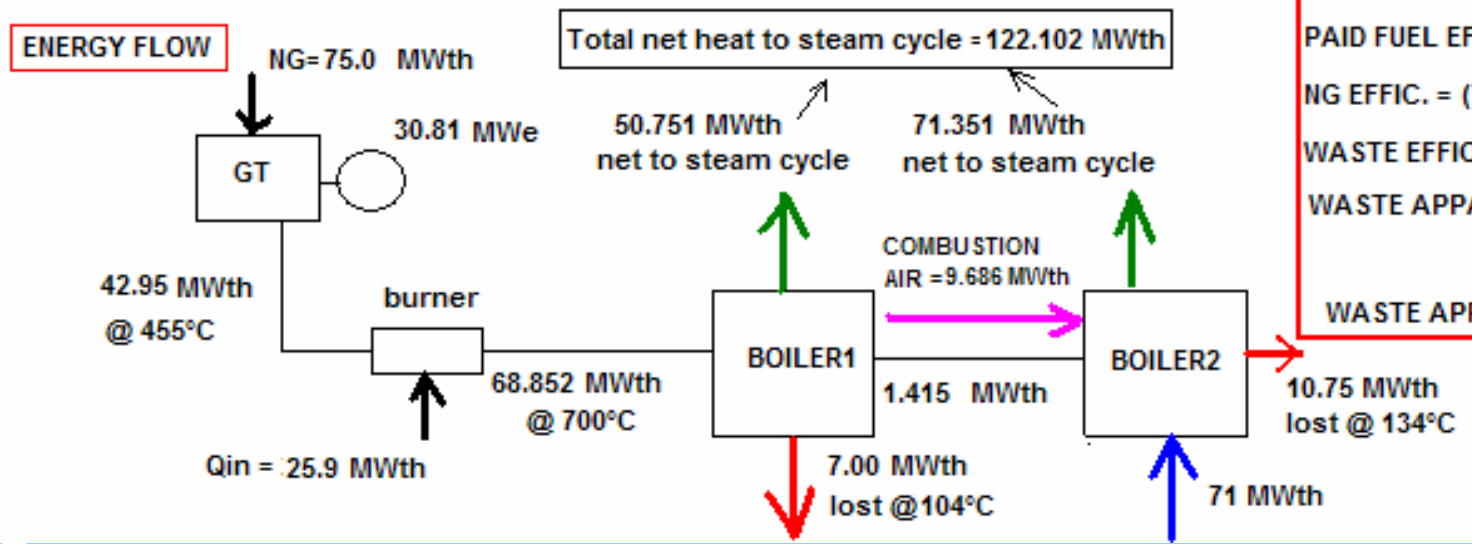
NG EFFIC. = (74.96-22.31) / (75.0+25.9) = 52.18%

WASTE EFFIC. = 22.31/71 = 31.42%

WASTE APPAR. POWER = 74.96 - (75.0 + 25.9) * 0.51

= 23.501 MWe (31.35% total)

WASTE APPAR. EFFIC. = 23.501 /71 = 33.1%



SPLIT ECONOMIZER WITH CHX

SUMMARY

THERMAL POWER FROM WASTE = 71 MWth

STEAM CYCLE EFFICIENCY = 36%

SCHEME	TOTAL POWER (MW)	POWER FROM MSW (MW)	%	POWER FROM NG (MW)	%	OVERALL EFFICIENCY %	MSW EFFICIENCY %	NG EFFICIENCY %	MWh/ton 1850 7.7	2400 10 (Kcal/Kg) (MJ/Kg)
BILBAO (ZABALGARBI)	98.06	21.30	21.7	76.76	78.3	44.0	30.0	50.50	0.64	0.84
FULL MIXING	100.84	20.93	20.8	79.91	79.2	45.2	29.50	52.57	0.63	0.82
SPLIT ECONOMIZER	74.96	22.31	29.8	52.65	70.2	43.6	31.4	52.18	0.68	0.88

USINAVERDE POWER UPGRADE PROJECT – UNIVERSITY OF BRASIL CAMPUS

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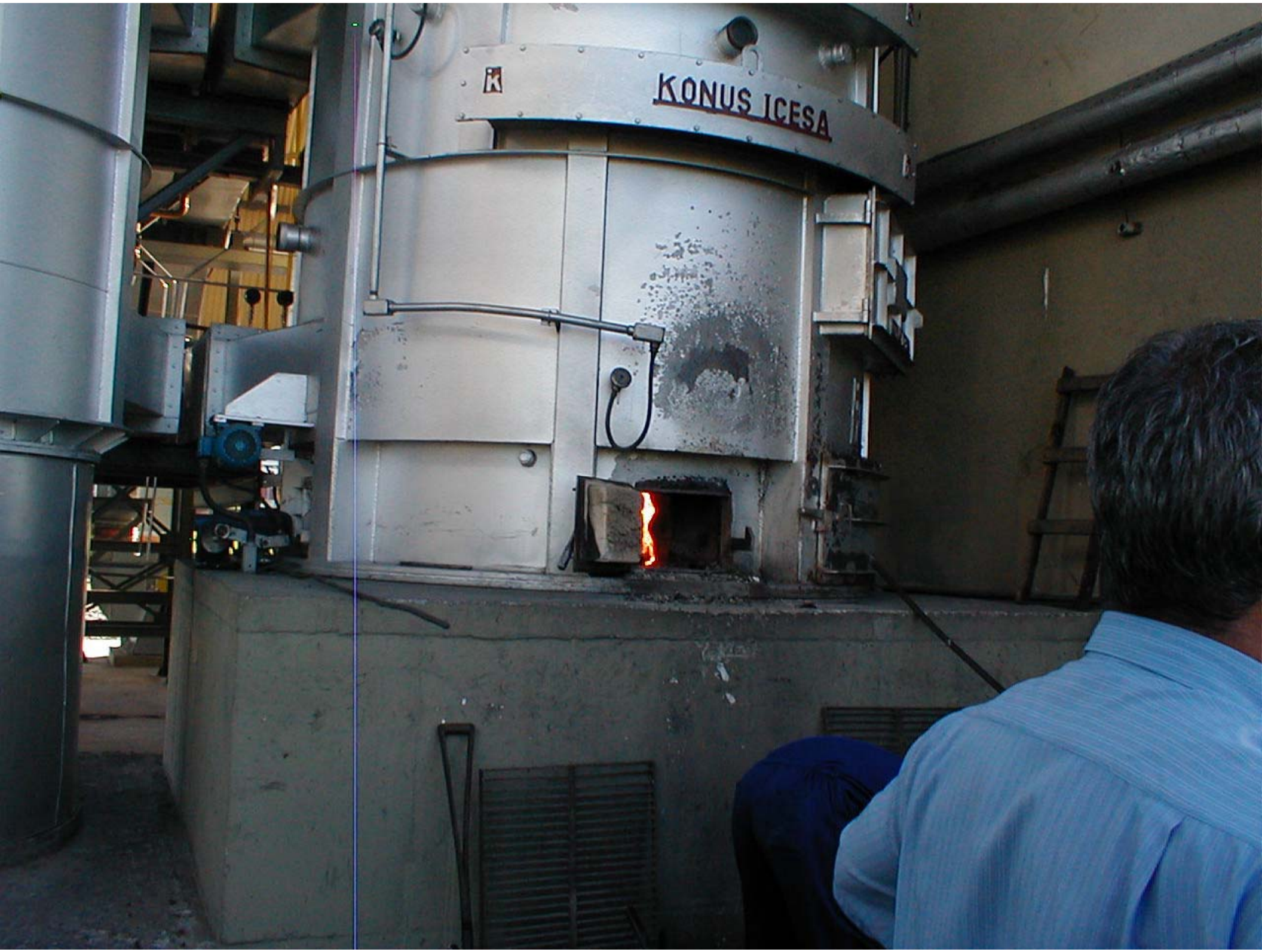
KONUS ICESA

PROJECT DESCRIPTION

PARTNERS → COPPE, BR-DISTRIBUIDORA, PETROBRAS, USINAVERDE.

OBJECTIVE → GENERATE 4 MWe TO CAMPUS (BASE)

FINANCING → FINEP, BR

TOTAL TIME → 2 YEARS

WASTE EFFICIENCY → 0,74 MWh / TON (2.000 KCAL / KG)

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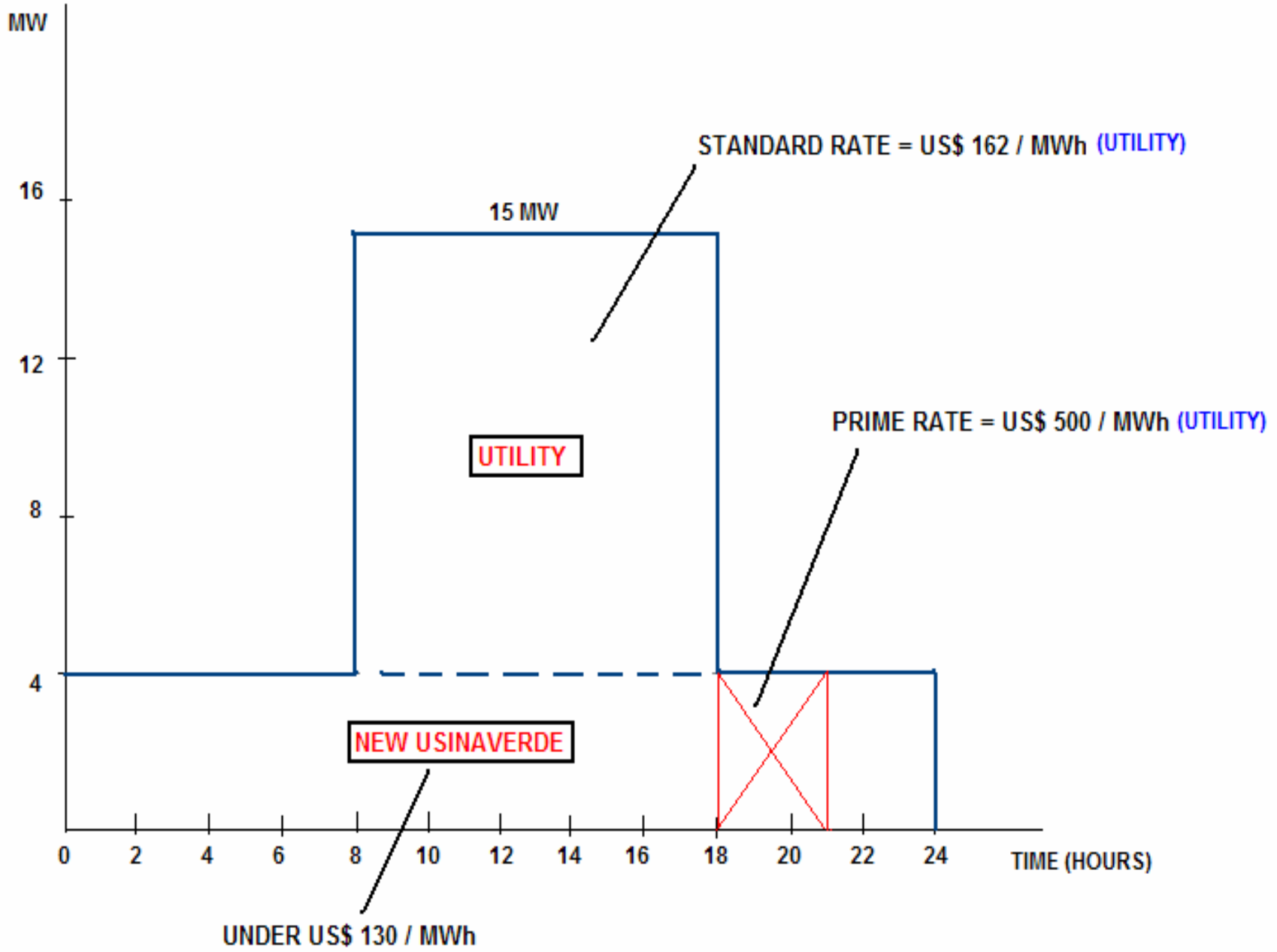
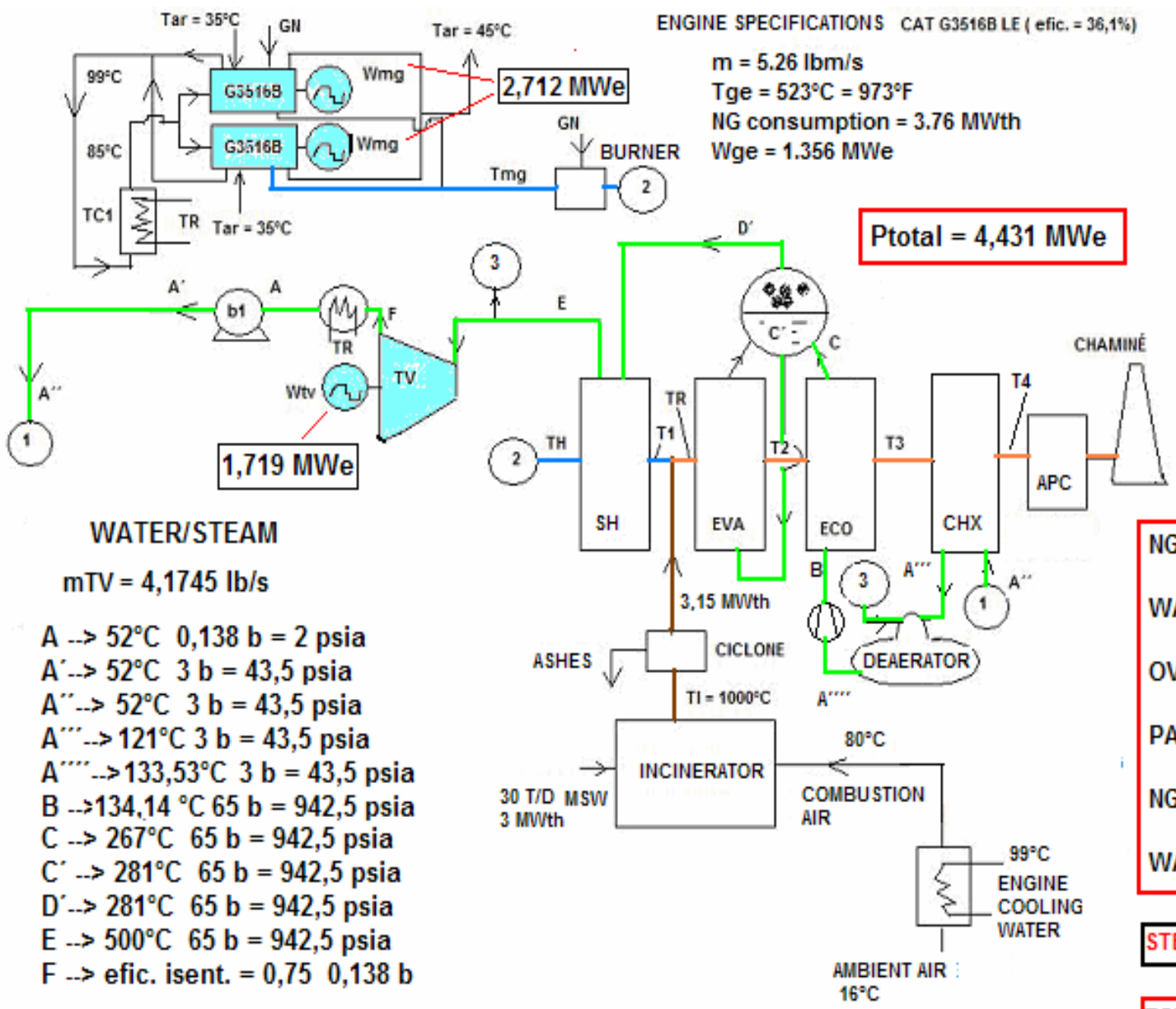
UNIVERSITY OF BRASIL POWER CONSUMPTION - TYPICAL WEEK DAY





ENGINE SPECIFICATIONS CAT G3516B LE (efic. = 36,1%)

m = 5.26 lbm/s
Tge = 523°C = 973°F
NG consumption = 3.76 MWth
Wge = 1.356 MWe

WATER/STEAM

mTV = 4,1745 lb/s

A --> 52°C 0,138 b = 2 psia
A´--> 52°C 3 b = 43,5 psia
A´´--> 52°C 3 b = 43,5 psia
A´´´--> 121°C 3 b = 43,5 psia
A´´´´-->133,53°C 3 b = 43,5 psia
B -->134,14 °C 65 b = 942,5 psia
C --> 267°C 65 b = 942,5 psia
C´ --> 281°C 65 b = 942,5 psia
D´--> 281°C 65 b = 942,5 psia
E --> 500°C 65 b = 942,5 psia
F --> efic. isent. = 0,75 0,138 b

NG POWER = 3.5 MWe

WASTE POWER = 0.931 MWe

OVERALL EFF. = 38.43%

PAID FUEL EFF. = 51.95%

NG EFF. = 41.03%

WASTE EFF. = 31.03%

STEAM CYCLE EFF. = 28.17%

TOTAL NG CONS. = 8.53 MWth

GASES

TH = 704°C
T1 = 483°C
TR = 688°C
T2 = 326°C
T3 = 183°C
T4 = 114°C

Mmg = 10,52 lb/s (total)
MR = 16,45 lb/s
MI = 5,93 lb/s

USINAVERDE POWER
UPGRADE - RIO DE JANEIRO