

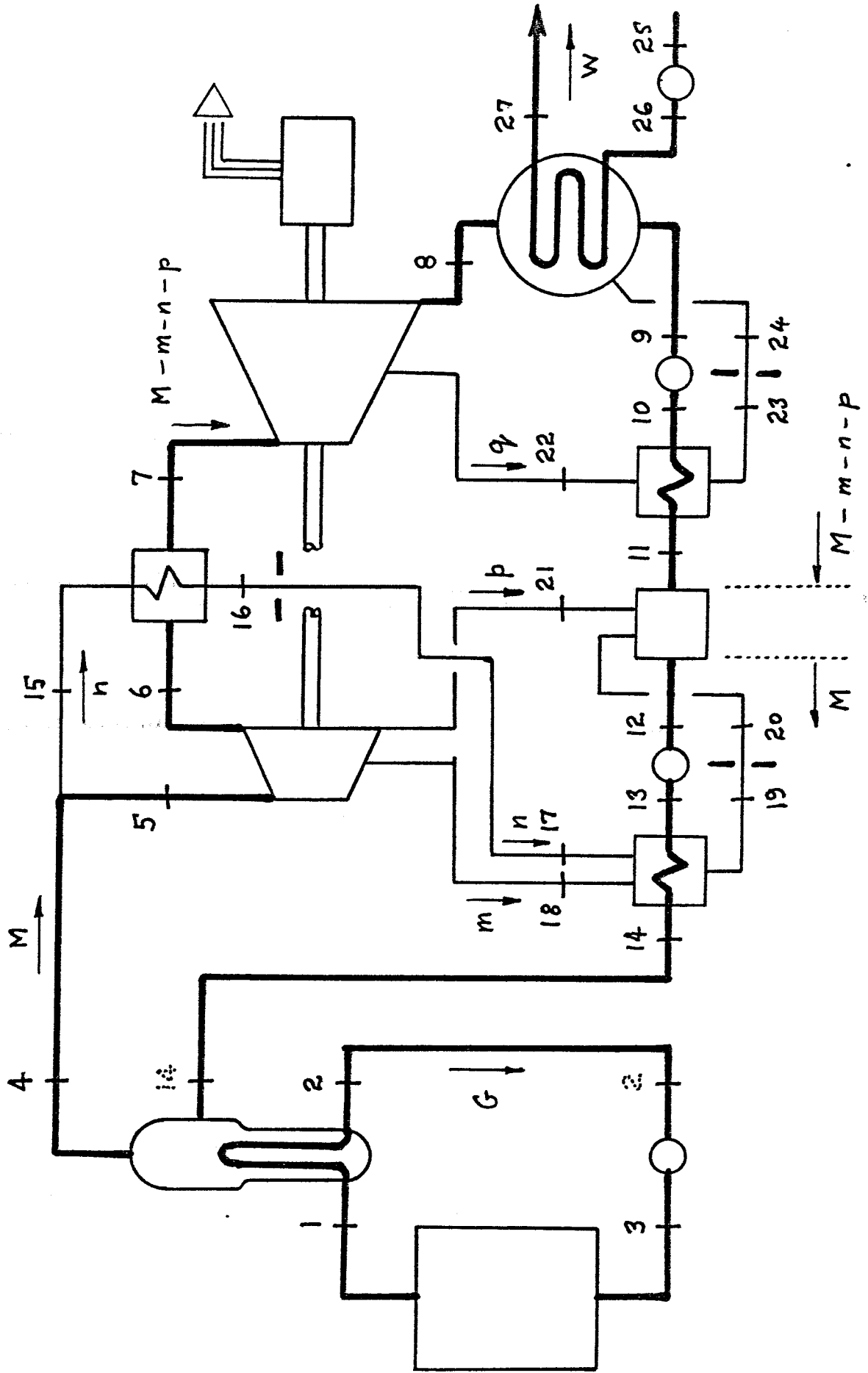
900 MW PWR EXAMPLE

SIMPLIFIED 900 MW PWR SYSTEM

SIMPLIFICATIONS AND ASSUMPTIONS

- ① THE DRAIN COOLER AND LP1, LP2 + LP3 FEEDWATER HEATERS HAVE BEEN REPLACED BY ONE SURFACE HEATER. SIMILARLY THE HPS + HP6 FEEDWATER HEATERS HAVE BEEN REPLACED BY A SINGLE SURFACE HEATER.
- ② THE LP4 FEEDWATER HEATER AND DRAIN RECOVERY SYSTEM HAVE BEEN REPLACED BY A DEAERATOR OR DIRECT CONTACT HEATER.
- ③ ALL AUXILIARY SYSTEMS OF BOTH THE NUCLEAR REACTOR AND TURBINE GENERATOR HAVE BEEN ELIMINATED.
- ④ THE STEAM DRIVEN FEEDWATER PUMPS HAVE BEEN REPLACED BY ELECTRICALLY DRIVEN FEEDWATER PUMPS.
- ⑤ BLED STEAM EXTRACTION POINTS HAVE BEEN ADAPTED TO SUIT THE MODIFIED ARRANGEMENT OF FEEDWATER HEATERS.
- ⑥ THE SYSTEM PRIMARY, SECONDARY + TERTIARY FLOWS HAVE BEEN ADJUSTED TO ENSURE COMPATIBILITY WITH THE MODIFIED SYSTEM.
- ⑦ THE FEEDWATER SYSTEM PUMPS OPERATE BETWEEN THE CORRESPONDING BLED STEAM EXTRACTION PRESSURES. THERE ARE NO PRESSURE LOSSES NOR STATIC HEADS IN THE SYSTEM.
- ⑧ THE SURFACE HEATERS HAVE A TERMINAL TEMPERATURE DIFFERENCE OF 5°C ON THE STEAM SIDE. THESE HEATERS OPERATE UNDER SATURATION CONDITIONS AND HAVE NO DRAIN COOLING.
- ⑨ THE TEMPERATURE OF HEAT REJECTION IS 13°C WHICH IS THE TEMPERATURE OF INCOMING SEA WATER.

SIMPLIFIED 900 MW PWR SYSTEM



SIMPLIFIED 900 MW PWR SYSTEM

ASSUMPTIONS : NO PRESSURE DROPS IN SYSTEM
 TERMINAL TEMPERATURE DIFFERENCE IN HEATERS = 5°C

POINT	FLOW (kg/s)	TEMPERATURE (°C)	PRESSURE (MPa)	ENTHALPY (kJ/kg)	ENTROPY (kJ/kg°C)	AVAILABILITY (kJ/kg)
1	12625	325	15			
2	12625	286	15			
3	12625	-	15			
4	1513	270	5.5			
5	M-n	270	5.5			
6	M-m-n-p	186 _w	1.15			
7	M-m-n-p	252	1.15			
8	M-m-n-p-q	30 _w	0.0043			
9	M-m-n-p	30	0.0043			
10	M-m-n-p	-	1.15			
11	M-m-n-p	106	1.15			
12	1513	186	1.15			
13	1513	-	5.5			
14	1513	219	5.5			
15	n	270	5.5			
16	n	270	5.5			
17	n	-	2.5			
18	m	224 _w	2.5			
19	m+n	224	2.5			
20	m+n	-	1.15			
21	p	186 _w	1.15			
22	q	111 _w	0.15			
23	q	111	0.15			
24	q	-	0.0043			
25	47000	13	0.1			
26	47000	-	0.1			
27	47000	24	0.1			

W = WET STEAM

TURBINE ENTHALPIES

HP η = 83% (SPECIFIED)
 LP η = 81% (SPECIFIED)

$h_5 = 2790 \text{ kJ/kg}$
 $h_7 = 2941 \text{ kJ/kg}$

$S_5 = 5.930 \text{ kJ/kg}^\circ\text{C}$
 $S_7 = 6.860 \text{ kJ/kg}^\circ\text{C}$

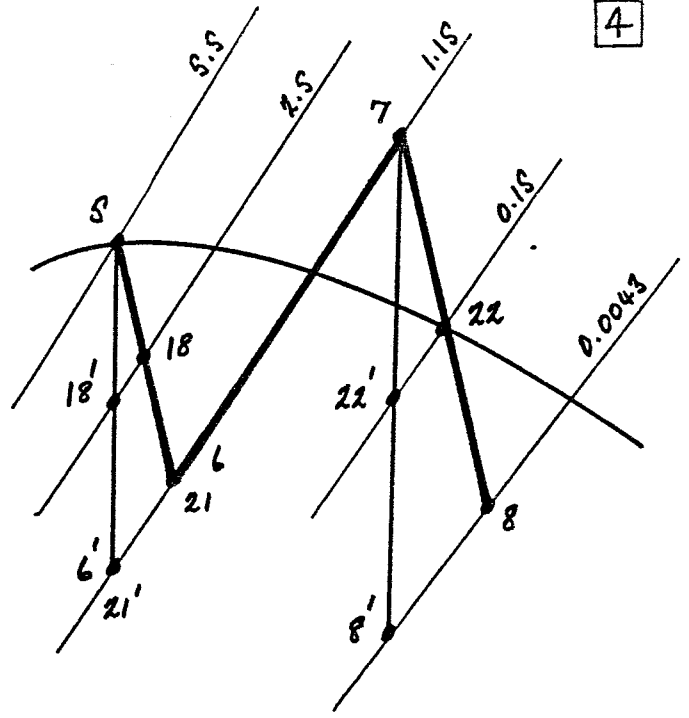
$S_{18'} = S_f + x_{18'} S_{fg}$
 $5.930 = 2.555 + x_{18'} 3.703$
 $x_{18'} = (5.930 - 2.555) / 3.703 = 0.911$
 $h_{18'} = h_f + x_{18'} h_{fg}$
 $h_{18'} = 962 + 0.911 (1841) = 2640 \text{ kJ/kg}$

$\eta = (h_5 - h_{18}) / (h_5 - h_{18'})$
 $0.83 = (2790 - h_{18}) / (2790 - 2640)$
 $h_{18} = 2790 - 0.83 (150) = 2666 \text{ kJ/kg}$

$S_{6'} = S_f + x_{6'} S_{fg}$
 $5.930 = 2.198 + x_{6'} 4.340$
 $x_{6'} = (5.930 - 2.198) / 4.340 = 0.860$
 $h_{6'} = h_f + x_{6'} h_{fg}$
 $h_{6'} = 790 + 0.860 (1993) = 2504 \text{ kJ/kg}$

$\eta = (h_5 - h_6) / (h_5 - h_{6'})$
 $0.83 = (2790 - h_6) / (2790 - 2504)$
 $h_6 = 2790 - 0.83 (286) = 2553 \text{ kJ/kg}$

$h_{21} = h_6 \quad h_{21} = 2553 \text{ kJ/kg}$



$$\begin{aligned}
 S_{22}' &= S_f + x_{22}' S_{fg} \\
 6.860 &= 1.434 + x_{22}' 5.790 \\
 x_{22}' &= (6.860 - 1.434) / 5.790 = 0.937 \\
 h_{22}' &= h_f + x_{22}' h_{fg} \\
 h_{22}' &= 467 + 0.937 (2226) = 2553 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 \eta &= (h_7 - h_{22}) / (h_7 - h_{22}') \\
 0.81 &= (2941 - h_{22}) / (2941 - 2553) \\
 h_{22} &= 2941 - 0.81 (388) = 2627 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 S_{g'} &= S_f + x_{g'} S_{fg} \\
 6.860 &= 0.440 + x_{g'} (8.009) \\
 x_{g'} &= (6.860 - 0.440) / 8.009 = 0.802 \\
 h_{g'} &= h_f + x_{g'} h_{fg} \\
 h_{g'} &= 127 + 0.802 (2430) = 2076 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 \eta &= (h_7 - h_g) / (h_7 - h_{g'}) \\
 0.81 &= (2941 - h_g) / (2941 - 2076) \\
 h_g &= 2941 - 0.81 (865) = 2240 \text{ kJ/kg}
 \end{aligned}$$

ENTHALPIES

h_5	=	2790	kJ/kg
h_6	=	2553	kJ/kg
h_7	=	2941	kJ/kg
h_8	=	2240	kJ/kg
h_{18}	=	2666	kJ/kg
h_{21}	=	2553	kJ/kg
h_{22}	=	2627	kJ/kg

PUMP ENTHALPIES

REACTOR COOLANT (PRIMARY) PUMPS (3 IN SERVICE)

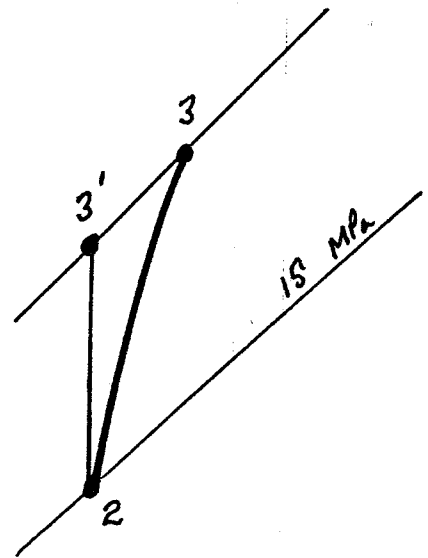
INLET PRESSURE = 15 MPa (FROM TABLE)
 INLET TEMPERATURE = 286 °C (FROM TABLE)
 PUMP HEAD = 92 m (SPECIFIED)
 OVERALL EFFICIENCY = 0.72 (FROM HEAD/FLOW/POWER RELATIONSHIP)
 MOTOR EFFICIENCY = 0.96 (ASSUMED)
 PUMP EFFICIENCY = 0.75 (0.72 = 0.75 x 0.96)
 SPECIFIC VOLUME = 0.0013290 m³/kg
 PRESSURE RISE = 92 x 9.81 / 0.0013290
 = 679097 N/m²
 = 0.679 MPa

$p_2 = 15 \text{ MPa}$
 $t_2 = 286 \text{ °C}$
 $h_2 = 1263.7 \text{ kJ/kg}$
 $s_2 = 3.0953 \text{ kJ/kg °C}$

$s_{3'} = 3.0953 \text{ kJ/kg °C}$
 $p_{3'} = 15.679 \text{ MPa}$

	15.0 MPa	15.679 MPa	17.5 MPa
280 °C	3.0393	3.0373	3.0319
300 °C	3.2260	3.2234	3.2163
280 °C	1232.1	1231.9	1231.3
300 °C	1337.3	1336.7	1335.2

$\Delta s = 0.1861$
 $\delta s = 0.0580$
 $\Delta h = 104.8$
 $\delta h = 104.8 (0.0580 / 0.1861) = 32.7$
 $h_{3'} = 1264.6 \text{ kJ/kg}$



$$\eta = (h_3' - h_2) / (h_3 - h_2)$$

$$0.75 = (1264.6 - 1263.7) / (h_3 - 1263.7)$$

$$h_3 - 1263.7 = 0.9 / 0.75$$

$$h_3 = 1263.7 + 1.2$$

$$h_3 = 1264.9 \text{ kJ/kg}$$

$$\Delta h = 104.8$$

$$\delta h = 33.0$$

$$\Delta S = 0.1861$$

$$\delta S = 0.1861 (33.0 / 104.8) = 0.0586$$

$$S_3 = 3.0959 \text{ kJ/kg } ^\circ\text{C}$$

FEEDWATER PUMPS (ELECTRIC) (2 IN SERVICE)

- INLET PRESSURE = 1.15 MPa
- INLET TEMPERATURE = 186 °C
- OUTLET PRESSURE = 5.5 MPa
- PUMP EFFICIENCY = 0.83 (SPECIFIED)
- COUPLING EFFICIENCY = 0.93 (SPECIFIED)
- MOTOR EFFICIENCY = 0.96 (SPECIFIED)
- OVERALL EFFICIENCY = 0.83 x 0.93 x 0.96 = 0.74

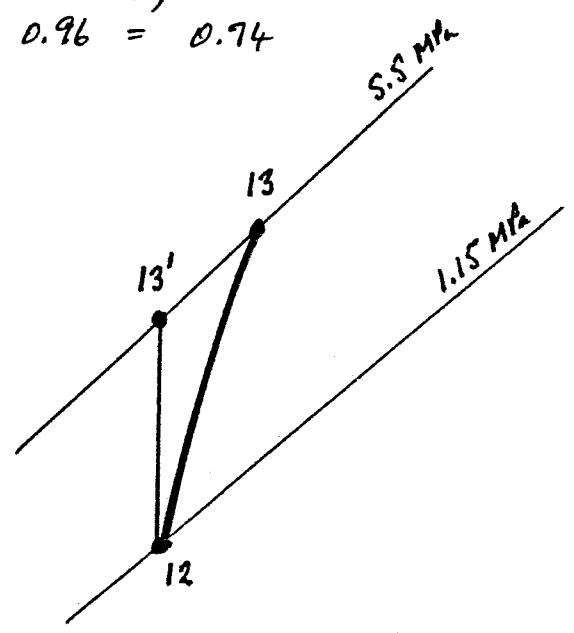
$$p_{12} = 1.15 \text{ MPa}$$

$$t_{12} = 186 \text{ } ^\circ\text{C}$$

	0 MPa	1.15 MPa	2.5 MPa
180 °C	2.1410	2.1394	2.1375
200 °C	2.3334	2.3316	2.3294
180 °C	762.72	763.30	763.97
200 °C	851.80	852.26	852.80

$$h_{12} = 790.00 \text{ kJ/kg}$$

$$S_{12} = 2.1971 \text{ kJ/kg } ^\circ\text{C}$$



$$s_{13}' = 2.1971 \text{ kJ/kg}^\circ\text{C}$$

$$p_{13}' = 5.5 \text{ MPa}$$

	5.0 MPa	5.5 MPa	7.5 MPa
180°C	2.1341	2.1334	2.1308
200°C	2.3255	2.3247	2.3316
180°C	765.25	765.51	766.55
200°C	853.90	854.10	854.90

$$\Delta s = 0.1913$$

$$\delta s = 0.0637$$

$$\Delta h = 88.59$$

$$\delta h = 88.59 (0.0637 / 0.1913) = 29.5$$

$$h_{13}' = 795.01 \text{ kJ/kg}$$

$$\eta = (h_{13}' - h_{12}) / (h_{13} - h_{12})$$

$$0.83 = (795.01 - 790.00) / (h_{13} - 790.00)$$

$$h_{13} - 790.00 = 5.01 / 0.83$$

$$h_{13} = 790.00 + 6.04$$

$$h_{13} = 796.04 \text{ kJ/kg}$$

$$\Delta h = 88.59$$

$$\delta h = 30.53$$

$$\Delta s = 0.1913$$

$$\delta s = 0.1913 (30.53 / 88.59) = 0.0659$$

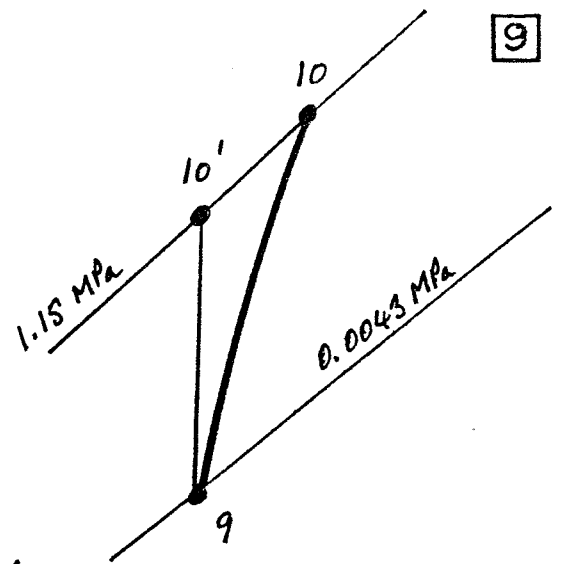
$$s_{13} = 2.1993 \text{ kJ/kg}^\circ\text{C}$$

CONDENSATE (EXTRACTION) PUMPS (2 IN SERVICE)

INLET PRESSURE	=	0.0043 MPa
INLET TEMPERATURE	=	30°C
OUTLET PRESSURE	=	1.15 MPa
PUMP EFFICIENCY	=	0.77 (SPECIFIED)
MOTOR EFFICIENCY	=	0.96 (SPECIFIED)
OVERALL EFFICIENCY	=	0.77 x 0.96 = 0.74

$$\begin{aligned}
 p_9 &= 0.0043 \text{ MPa} \\
 t_9 &= 30 \text{ }^\circ\text{C} \\
 h_9 &= 125.79 \text{ kJ/kg} \\
 s_9 &= 0.4369 \text{ kJ/kg}^\circ\text{C}
 \end{aligned}$$

$$\begin{aligned}
 s_{10'} &= 0.4369 \text{ kJ/kg}^\circ\text{C} \\
 p_{10'} &= 1.15 \text{ MPa}
 \end{aligned}$$



	0 MPa	1.15 MPa	2.5 MPa
20 °C	0.2966	0.2964	0.2961
40 °C	0.5725	0.5720	0.5715
20 °C	83.95	88.03	86.30
40 °C	167.56	168.58	169.77

$$\begin{aligned}
 \Delta s &= 0.2756 \\
 \delta s &= 0.1405 \\
 \Delta h &= 83.55 \\
 \delta h &= 83.55 (0.1405 / 0.2756) = 42.59 \\
 h_{10'} &= 127.62 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 \eta &= (h_{10'} - h_9) / (h_{10} - h_9) \\
 0.77 &= (127.62 - 125.79) / (h_{10} - 125.79) \\
 h_{10} - 125.79 &= 1.83 / 0.77 \\
 h_{10} &= 125.79 + 2.38 \\
 h_{10} &= 128.17 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 \Delta h &= 83.55 \\
 \delta h &= 43.14 \\
 \Delta s &= 0.2756 \\
 \delta s &= 0.2756 (43.14 / 83.55) = 0.1423 \\
 s_{10} &= 0.4387 \text{ kJ/kg}^\circ\text{C}
 \end{aligned}$$

$$\begin{aligned} \Delta s &= 0.2967 \\ s_s &= 0.1929 \\ \Delta h &= 83.96 \\ s_h &= 83.96 (0.1929 / 0.2967) = 54.59 \\ h_{26}' &= 54.79 \end{aligned}$$

$$\begin{aligned} \eta &= (h_{26}' - h_{25}) / (h_{26} - h_{25}) \\ 0.88 &= (54.79 - 54.65) / (h_{26} - 54.65) \\ h_{26} - 54.65 &= 0.14 / 0.88 \\ h_{26} &= 54.65 + 0.16 \\ h_{26} &= 54.81 \text{ kJ/kg} \end{aligned}$$

$$\begin{aligned} \Delta h &= 83.96 \\ s_h &= 54.61 \\ \Delta s &= 0.2967 \\ s_s &= 0.1967 (54.61 / 83.96) = 0.1930 \\ s_{26} &= 0.1929 \text{ kJ/kg} \end{aligned}$$

CIRCULATING WATER OUTLET

$$\begin{aligned} p_{27} &= 0.1 \text{ MPa} \\ t_{27} &= 24^\circ\text{C} \end{aligned}$$

	0 MPa	0.1 MPa	2.5 MPa
20°C	0.2966	0.2966	0.2961
40°C	0.5725	0.5725	0.5715
20°C	83.95	84.04	86.30
40°C	167.56	167.65	169.77

$$\begin{aligned} h_{27} &= 100.76 \text{ kJ/kg} \\ s_{27} &= 0.3318 \text{ kJ/kg}^\circ\text{C} \end{aligned}$$

ENTHALPIES

h_2	=	1263.7 kJ/kg
h_3	=	1264.9 kJ/kg
h_{12}	=	790.00 kJ/kg
h_{13}	=	796.04 kJ/kg
h_9	=	125.79 kJ/kg
h_{10}	=	128.17 kJ/kg
h_{25}	=	54.65 kJ/kg
h_{26}	=	54.81 kJ/kg
h_{27}	=	100.76 kJ/kg

ENTROPIES

S_2	=	3.0953 kJ/kg °C
S_3	=	3.0959 kJ/kg °C
S_{12}	=	2.1971 kJ/kg °C
S_{13}	=	2.1993 kJ/kg °C
S_9	=	0.4369 kJ/kg °C
S_{10}	=	0.4387 kJ/kg °C
S_{25}	=	0.1928 kJ/kg °C
S_{26}	=	0.1929 kJ/kg °C
S_{27}	=	0.3518 kJ/kg °C

HEATER FLOWS

ENERGY BALANCE EQUATIONS

REHEATER : $(M - m - n - p)(h_7 - h_6) = n(h_{15} - h_{16})$
 $(M - m - n - p)(2941 - 2553) = n(2790 - 1185)$
 $(M - m - n - p) 388 = n 1605$
 $388 M = 388 m + 1993 n + 388 p \dots\dots\dots ①$

HP HEATER : $M(h_{14} - h_{13}) = m(h_{18} - h_{19}) + n(h_{17} - h_{19})$
 $M(940 - 796) = m(2666 - 962) + n(1185 - 962)$
 $144 M = 1704 m + 223 n \dots\dots\dots ②$

DEAERATOR : $(M - m - n - p)(h_{12} - h_{11}) = (m + n)(h_{20} - h_{12}) + p(h_{21} - h_{12})$
 $(790 - 445)(M - m - n - p) = (m + n)(962 - 790) + p(2593 - 790)$
 $345(M - m - n - p) = 172m + 172n + 1763p$
 $345 M = 172 m + 172 n + 1763 p + 345 m + 345 n + 345 p$
 $345 M = 517 m + 517 n + 2108 p \dots\dots\dots ③$

LP HEATER : $(M - m - n - p)(h_{11} - h_{10}) = q(h_{22} - h_{23})$
 $(445 - 128)(M - m - n - p) = q(2627 - 467)$
 $317(M - m - n - p) = 2160 q$
 $317 M - 317 m - 317 n - 317 p = 2160 q$
 $317 M = 317 m + 317 n + 317 p + 2160 q \dots\dots\dots ④$

STEAM FLOW : $M = 1513 \text{ kg/s}$

Equation ① and Equation ③

$$\begin{array}{r} 388(1513) = 388 m + 1993 n + 388 p \\ \times 2108 / 1000 \quad 1237489 = 818 m + 4201 n + 818 p \\ 345(1513) = 517 m + 517 n + 2108 p \\ \times 388 / 1000 \quad 202530 = 201 m + 201 n + 818 p \\ \text{first - second} \quad 1034959 = 617 m + 4000 n \dots\dots\dots ⑤ \end{array}$$

Equation ② and ③

$$\begin{array}{rcl}
 144 (1513) & = & 1704 m + 223 n \\
 \times 4000 / 1000 & & 871488 = 6816 m + 892 n \\
 & & 1034959 = 617 m + 4000 n \\
 \times 223 / 1000 & & 230796 = 138 m + 892 n \\
 \text{first} - \text{second} & & 640692 = 6678 m \quad \dots \dots \dots \textcircled{6}
 \end{array}$$

Equation ⑥

$$\begin{array}{rcl}
 640692 & = & 6678 m \\
 m & = & 640692 / 6678 \\
 m & = & 96 \text{ kg/s}
 \end{array}$$

Equation ③

$$\begin{array}{rcl}
 144 M & = & 1704 m + 223 n \\
 144 (1513) & = & 1704 (96) + 223 n \\
 223 n & = & 217872 - 163584 \\
 n & = & 54288 / 223 \\
 n & = & 243 \text{ kg/s}
 \end{array}$$

Equation ①

$$\begin{array}{rcl}
 388 M & = & 388 m + 1993 n + 388 p \\
 388 (1513) & = & 388 (96) + 1993 (243) + 388 p \\
 388 p & = & 587044 - 39248 - 484299 \\
 p & = & 65497 / 388 \\
 p & = & 169 \text{ kg/s}
 \end{array}$$

Equation ④

$$\begin{array}{rcl}
 317 M & = & 317 m + 317 n + 317 p + 2160 q \\
 317 (1513) & = & 317 (96) + 317 (243) + 317 (169) + 2160 q \\
 479621 & = & 30432 + 77031 + 53573 + 2160 q \\
 2160 q & = & 479621 - 30432 - 77031 - 53573 \\
 q & = & 318885 / 2160 \\
 q & = & 147 \text{ kg/s}
 \end{array}$$

FLOWS

m	=	96 kg/s
n	=	243 kg/s
p	=	169 kg/s
q	=	147 kg/s

SIMPLIFIED 900 MW PWR SYSTEM

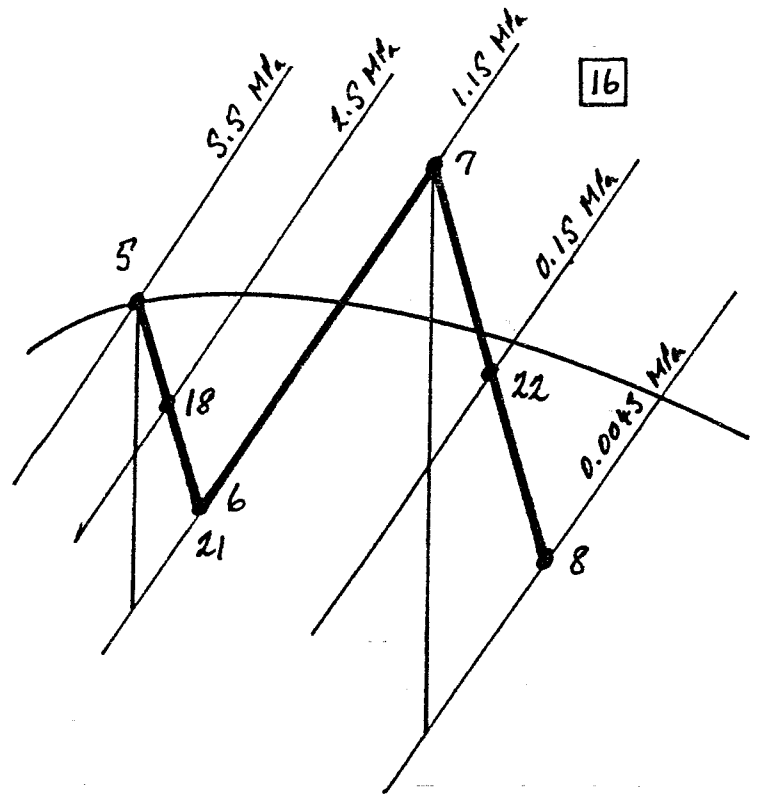
ASSUMPTIONS : NO PRESSURE DROPS IN SYSTEM
 TERMINAL TEMPERATURE DIFFERENCE IN HEATERS = 5°C

POINT	FLOW (kg/s)	TEMPERATURE (°C)	PRESSURE (MPa)	ENTHALPY (kJ/kg)	ENTROPY (kJ/kg°C)	AVAILABILITY (kJ/kg)
1	12625	325	15	1486 ^Δ		
2	12625	286	15	1263.7 [○]		
3	12625	-	15	1264.9 [○]		
4	1513	270	5.5	2790 ^Δ		
5	1270 [○]	270	5.5	2790 [○]		
6	1005 [○]	186	1.15	2553 [○]		
7	1005 [○]	252	1.15	2941 [○]		
8	858 [○]	30	0.0043	2240 [○]		
9	1005 [○]	30	0.0043	125.79 [○]		
10	1005 [○]	-	1.15	128.17 [○]		
11	1005 [○]	106	1.15	445 ^Δ		
12	1513	186	1.15	790.00 [○]		
13	1513	-	5.5	796.04 [○]		
14	1513	219	5.5	940 ^Δ		
15	243 [○]	270	5.5	2790 ^Δ		
16	243 [○]	270	5.5	1185 ^Δ		
17	243 [○]	-	2.5	1185 [*]		
18	96 [○]	224 ^w	2.5	2666 [○]		
19	339 [○]	224	2.5	962 ^Δ		
20	339 [○]	-	1.15	962 [*]		
21	169 [○]	186 ^w	1.15	2553 [○]		
22	147 [○]	111 ^w	0.15	2627 [○]		
23	147 [○]	111	0.15	467 ^Δ		
24	147 [○]	-	0.0043	467 [*]		
25	47000	13	0.1	54.65 [○]		
26	47000	-	0.1	54.81 [○]		
27	47000	24	0.1	100.76 [○]		

W = WET STEAM Δ = FROM TABLES ○ = CALCULATED (TURBINE)
 * = CONSTANT ENTHALPY PROCESS ○ = CALCULATED (PUMPS)

TURBINE ENTROPIES

16



$$S_5 = 5.930 \text{ kJ/kg}^\circ\text{C}$$

$$S_7 = 6.860 \text{ kJ/kg}^\circ\text{C}$$

$$h_{18} = h_f + x_{18} h_{fg}$$

$$2666 = 962 + x_{18} (1841)$$

$$x_{18} = (2666 - 962) / 1841$$

$$S_{18} = 0.926$$

$$S_{18} = S_f + x_{18} S_{fg}$$

$$S_{18} = 2.555 + 0.926 (3.703)$$

$$S_{18} = 5.982 \text{ kJ/kg}^\circ\text{C}$$

$$h_6 = h_f + x_6 h_{fg}$$

$$2553 = 790 + x_6 (1993)$$

$$x_6 = (2553 - 790) / 1993 = 0.885 \quad (11.5\% \text{ wet})$$

$$S_6 = S_f + x_6 S_{fg}$$

$$S_6 = 2.198 + 0.885 (4.340) = 6.037 \text{ kJ/kg}^\circ\text{C}$$

$$S_{21} = S_6$$

$$S_{21} = 6.037 \text{ kJ/kg}^\circ\text{C}$$

$$h_{22} = h_f + x_{22} h_{fg}$$

$$2627 = 467 + x_{22} (2226)$$

$$x_{22} = (2627 - 467) / 2226 = 0.970$$

$$S_{22} = S_f + x_{22} S_{fg}$$

$$S_{22} = 1.434 + 0.970 (5.790) = 7.052 \text{ kJ/kg}^\circ\text{C}$$

$$h_8 = h_f + x_8 h_{fg}$$

$$2240 = 127 + x_8 (2430)$$

$$x_8 = (2240 - 127) / 2430 = 0.870 \quad (13.0\% \text{ wet})$$

$$S_8 = S_f + x_8 S_{fg}$$

$$S_8 = 0.440 + 0.870 (8.009) = 7.404 \text{ kJ/kg}^\circ\text{C}$$

ENTROPIES

S_5	=	5.930	$\text{kJ/kg}^\circ\text{C}$
S_6	=	6.037	$\text{kJ/kg}^\circ\text{C}$
S_7	=	6.860	$\text{kJ/kg}^\circ\text{C}$
S_8	=	7.404	$\text{kJ/kg}^\circ\text{C}$
S_{18}	=	5.982	$\text{kJ/kg}^\circ\text{C}$
S_{21}	=	6.037	$\text{kJ/kg}^\circ\text{C}$
S_{22}	=	7.052	$\text{kJ/kg}^\circ\text{C}$

THROTTLE ENTROPIES

REHEATER DRAIN

$$\begin{aligned}
 p_{16} &= 5.5 \text{ MPa} \\
 h_{16} &= 1185 \text{ kJ/kg} \\
 s_{16} &= 2.975 \text{ kJ/kg}^\circ\text{C}
 \end{aligned}$$

$$\begin{aligned}
 p_{17} &= 2.5 \text{ MPa} \\
 h_{17} &= 1185 \text{ kJ/kg} \\
 h_{17} &= h_f + x_{17} h_{fg} \\
 1185 &= 962 + x_{17} 1841 \\
 x_{17} &= (1185 - 962) / 1841 = 0.121 \\
 s_{17} &= s_f + x_{17} s_{fg} \\
 s_{17} &= 2.535 + 0.121 (3.703) \\
 s_{17} &= 3.004 \text{ kJ/kg}^\circ\text{C}
 \end{aligned}$$

HP HEATER DRAIN

$$\begin{aligned} p_{19} &= 2.5 \text{ MPa} \\ h_{19} &= 962 \text{ kJ/kg} \\ s_{19} &= 2.555 \text{ kJ/kg}^\circ\text{C} \end{aligned}$$

$$\begin{aligned} p_{20} &= 1.15 \text{ MPa} \\ h_{20} &= 962 \text{ kJ/kg} \\ h_{20} &= h_f + x_{20} h_{fg} \\ 962 &= 790 + x_{20} 1993 \\ x_{20} &= (962 - 790) / 1993 = 0.086 \\ s_{20} &= s_f + x_{20} s_{fg} \\ s_{20} &= 2.198 + 0.086 (4.340) \\ s_{20} &= 2.571 \text{ kJ/kg}^\circ\text{C} \end{aligned}$$

LP HEATER DRAIN

$$\begin{aligned} p_{23} &= 0.15 \text{ MPa} \\ h_{23} &= 467 \text{ kJ/kg} \\ s_{23} &= 1.434 \text{ kJ/kg} \end{aligned}$$

$$\begin{aligned} p_{24} &= 0.0043 \text{ MPa} \\ h_{24} &= 467 \text{ kJ/kg} \\ h_{24} &= h_f + x_{24} h_{fg} \\ 467 &= 127 + x_{24} 2430 \\ x_{24} &= (467 - 127) / 2430 = 0.140 \\ s_{24} &= s_f + x_{24} s_{fg} \\ s_{24} &= 0.440 + 0.140 (8.009) \\ s_{24} &= 1.561 \text{ kJ/kg}^\circ\text{C} \end{aligned}$$

ENTROPIES

s_{17}	=	3.004	kJ/kg $^\circ\text{C}$
s_{20}	=	2.571	kJ/kg $^\circ\text{C}$
s_{24}	=	1.561	kJ/kg $^\circ\text{C}$

AVAILABILITIES

AVAILABILITY AT ANY POINT IS GIVEN BY

$$a = (h - h_0) - T(s - s_0)$$

TEMPERATURE OF HEAT SINK (INCOMING SEA WATER) = 13°C

$$t_0 = 13^\circ\text{C}$$

$$T_0 = 286^\circ\text{K}$$

$$h_0 = 54.65 \text{ kJ/kg (AT } 0.1 \text{ MPa)}$$

$$s_0 = 0.1928 \text{ kJ/kg (AT } 0.1 \text{ MPa)}$$

$$a = (h - 54.65) - 286(s - 0.1928)$$

THIS MAY BE ROUNDED OFF TO MAINTAIN CONSISTANT ACCURACY

SIMPLIFIED 900 MW PWR SYSTEM

ASSUMPTIONS : NO PRESSURE DROPS IN SYSTEM
 TERMINAL TEMPERATURE DIFFERENCE IN HEATERS = 5°C
 TEMPERATURE OF HEAT REJECTION = 13°C = 286°K

POINT	FLOW (kg/s)	TEMPERATURE (°C)	PRESSURE (MPa)	ENTHALPY (kJ/kg)	ENTROPY (kJ/kg°C)	AVAILABILITY (kJ/kg)
1	12625	325	15	1486	3.463 ^Δ	496
2	12625	286	15	1263.7	3.0953 [○]	379.0
3	12625	-	15	1264.9	3.0959 [○]	380.0
4	1513	270	5.5	2790	5.930 ^Δ	1094
5	1270	270	5.5	2790	5.930 [•]	1094
6	1005	186	1.15	2553	6.037 [•]	827
7	1005	252	1.15	2941	6.860 [•]	979
8	858	30	0.0043	2240	7.404 [•]	123
9	1005	30	0.0043	125.79	0.4369 [○]	1.33
10	1005	-	1.15	128.17	0.4387 [○]	3.19
11	1005	106	1.15	445	1.372 ^Δ	53
12	1513	186	1.15	790.00	2.1971 [○]	162.12
13	1513	-	5.5	796.04	2.1993 [○]	167.53
14	1513	219	5.5	940	2.499 ^Δ	225
15	243	270	5.5	2790	5.930 ^Δ	1094
16	243	270	5.5	1185	2.975 ^Δ	334
17	243	-	2.5	1185	3.004 [*]	326
18	96	224	2.5	2666	5.982 [•]	955
19	339	224	2.5	962	2.555 ^Δ	231
20	339	-	1.15	962	2.571 [*]	227
21	169	186	1.15	2553	6.037 [•]	827
22	147	111	0.15	2627	7.052 [•]	610
23	147	111	0.15	467	1.434 ^Δ	57
24	147	-	0.0043	467	1.561 [*]	21
25	47000	13	0.1	54.65	0.1928 [○]	0.00
26	47000	-	0.1	54.81	0.1929 [○]	0.13
27	47000	24	0.1	100.76	0.3518 [○]	0.64

Δ = FROM TABLES • = CALCULATED (TURBINE)
 * = CALCULATED (THROTTLES) ○ = CALCULATED (PUMPS)