NOMENCLATURE FOR REFERENCE EQUATIONS (SI UNITS)

A	Flow area, Surface area	m^2
c_p	Specific heat at constant pressure	J/kg°C
c_v	Specific heat at constant volume	J/kg°C
d	diameter	m
D	Diameter	m
E	Energy	J
g	Gravitational acceleration	m/s^2
h	Specific enthalpy	J/kg
h	Heat transfer coefficient	$J/m^2°Cs$
k	Ratio of specific heats	
k	Conductivity	J/m°Cs
L	Length	m
M	Mass flow rate	kg/s
p	Pressure	$Pa(N/m^2)$
q	Heat transfer rate	J/s
q	Heat transferred	J/kg
Q	Heat	J
R	Specific gas constant	J/kg K
s	Entropy	J/kg K
T	Temperature	K
u	Specific internal energy	J/kg
U	Overall heat transfer coefficient	$J/m^2°Cs$
v	Specific volume	m^3/kg
V	Velocity	m/s
w	Specific work	J/kg
W	Work	J
x	Length	m
z	Elevation	m
η	Efficiency	
μ	Dynamic viscosity	Ns/m^2
ν	Kinematic viscosity	m^2/s
ρ	Density	kg/m^3
τ	Thrust	N
θ	Temperature Difference	°C

GENERAL CONSTANTS

Acceleration due to gravity: $g = 9.81\ m/s^2$
Atmospheric pressure: $p_{atm} = 100\ kPa$
Density of water: $\rho_{water} = 1000\ kg/m^3$

Specific heat of air: $c_p = 1.005\ kJ/kg°C$
Specific heat of air: $c_v = 0.718\ kJ/kg°C$

THERMODYNAMICS REFERENCE EQUATIONS

Basic Thermodynamics

First Law:	$dE = \delta Q - \delta W$
Enthalpy:	$h = u + pv$
Continuity:	$\rho VA = \text{constant}$
Flow Work:	$w = \Delta(pv)$
Energy Equation:	$zg + V^2/2 + u + pv + \Delta w + \Delta q = \text{constant}$
Entropy:	$\Delta s = \Sigma \delta q / T$ (reversible conditions)

Ideal Gas Relationships

Gas Law:	$pv = RT$
Specific Heat at Constant Pressure:	$c_p = \Delta h / \Delta T$
Specific Heat at Constant Volume:	$c_v = \Delta u / \Delta T$
Gas Constant:	$R = c_p - c_v$
Specific Heat Ratio:	$k = c_p / c_v$
Isentropic Relations:	$p_1 / p_2 = (v_2 / v_1)^k = (T_1 / T_2)^{k/(k-1)}$

FLUID MECHANICS REFERENCE EQUATIONS

Fluid Mechanics

Continuity Equation: $\rho_1 V_1 A_1 = \rho_2 V_2 A_2 = M$

Bernoulli's Equation: $p_1/\rho g + z_1 + V_1^2/2g = p_2/\rho g + z_2 + V_2^2/2g$

Momentum Equation: $F = p_1 A_1 - p_2 A_2 - \rho V A (V_2 - V_1)$ (one dimensional)

Steam Turbines

Nozzle Equation: $h_1 - h_2 = (V_2^2 - V_1^2) / 2$

Work: $W = M[(V_{1\,absolute}^2 - V_{2\,absolute}^2) + (V_{2\,relative}^2 - V_{1\,relative}^2)] / 2$

Gas Turbines

State Equation: $pv = RT$

Isentropic Equation: $(T_2/T_1) = (p_2/p_1)^{(k-1)/k}$

Enthalpy Change: $h_1 - h_2 = c_p(T_1 - T_2)$ (ideal gas)

Nozzle Equation: $h_1 - h_2 = (V_2^2 - V_1^2) / 2$

Jet Propulsion

Thrust: $\tau = M(V_{jet} - V_{aircraft})$

Thrust Power: $\tau V = M(V_{jet} - V_{aircraft}) V_{aircraft}$

Jet Power: $P = M(V_{jet}^2 - V_{aircraft}^2) / 2$

Propulsion Efficiency: $\eta_p = 2V_{aircraft}/(V_{jet} + V_{aircraft})$

Wind Turbine

Maximum Ideal Power: $P_{max} = 8 \rho A V_1^3 / 27$

Symbols Used in Tables

c_{po} specific heat capacity at constant pressure for zero pressure, kilojoules per kilogram kelvin, kJ/(kg·K).*
c_{oo} specific heat capacity at constant volume for zero pressure, kilojoules per kilogram kelvin, kJ/(kg·K).
h specific enthalpy, kilojoules per kilogram, kJ/kg.
h_o specific enthalpy at zero pressure, kilojoules per kilogram, kJ/kg.
k isentropic exponent, $-(\partial \log p/\partial \log v)_s$.
p pressure, megapascals, MPa.
p_r relative pressure, pressure of semiperfect vapor at zero entropy multiplied by 10^{-6}, megapascals, MPa.
s specific entropy, kilojoules per kilogram kelvin, kJ/(kg·K).
s_1 specific entropy of semiperfect vapor at 0.1 MPa; kilojoules per kilogram kelvin, kJ/(kg·K).
t thermodynamic temperature, degrees Celsius, °C.
T thermodynamic temperature, kelvin, K.
u specific internal energy, kilojoules per kilogram, kJ/kg.
u_o specific internal energy at zero pressure, kilojoules per kilogram, kJ/kg.
v specific volume, cubic meters per kilogram, m^3/kg.
v_r relative specific volume, specific volume of semiperfect vapor at zero entropy multiplied by 10^{10}, cubic meters per kilogram, m^3/kg.
ζ_1 specific Gibbs free energy of semiperfect vapor at 0.1 MPa, kilojoules per kilogram, kJ/kg.
ψ_1 specific Helmholtz free energy of semiperfect vapor at 0.1 MPa, kilojoules per kilogram, kJ/kg.

*Units are defined and compared in Table 10.

SUBSCRIPTS

f refers to a property of liquid in equilibrium with vapor
g refers to a property of vapor in equilibrium with liquid
i refers to a property of solid in equilibrium with vapor
fg refers to a change by evaporation
ig refers to a change by sublimation

Table 2. Saturation: Pressures

Press. MPa	Temp °C	Specific Volume		Internal Energy			Enthalpy			Entropy		
		Sat. Liquid	Sat. Vapor	Sat. Liquid	Evap.	Sat. Vapor	Sat. Liquid	Evap.	Sat. Vapor	Sat. Liquid	Evap.	Sat. Vapor
p	t	$10^3 v_f$	$10^3 v_g$	u_f	u_{fg}	u_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
.0006113	.01	1.0002	206 136	.00	2375.3	2375.3	.01	2501.3	2501.4	.0000	9.1562	9.1562
.0007	1.89	1.0001	181 255	7.90	2370.0	2377.9	7.91	2496.9	2504.8	.0288	9.0775	9.1064
.0008	3.77	1.0001	159 675	15.81	2364.7	2380.6	15.81	2492.5	2508.3	.0575	8.9999	9.0573
.0009	5.45	1.0001	142 789	22.88	2360.0	2382.9	22.89	2488.5	2511.4	.0829	8.9312	9.0142
.0010	6.98	1.0002	129 208	29.30	2355.7	2385.0	29.30	2484.9	2514.2	.1059	8.8697	8.9756
.0011	8.37	1.0002	118 042	35.17	2351.8	2386.9	35.17	2481.6	2516.8	.1268	8.8140	8.9408
.0012	9.66	1.0003	108 696	40.58	2348.1	2388.7	40.58	2478.6	2519.1	.1460	8.7631	8.9091
.0013	10.86	1.0004	100 755	45.60	2344.7	2390.3	45.60	2475.7	2521.3	.1637	8.7162	8.8799
.0014	11.98	1.0005	93 922	50.31	2341.6	2391.9	50.31	2473.1	2523.4	.1802	8.6727	8.8529
.0015	13.03	1.0007	87 980	54.71	2338.6	2393.3	54.71	2470.6	2525.3	.1957	8.6322	8.8279
.0016	14.02	1.0008	82 763	58.87	2335.8	2394.7	58.87	2468.3	2527.1	.2102	8.5943	8.8044
.0017	14.95	1.0009	78 146	62.80	2333.2	2396.0	62.80	2466.0	2528.8	.2238	8.5586	8.7825
.0018	15.84	1.0010	74 030	66.53	2330.7	2397.2	66.54	2463.9	2530.5	.2368	8.5250	8.7618
.0019	16.69	1.0012	70 337	70.09	2328.3	2398.4	70.10	2461.9	2532.0	.2491	8.4931	8.7422
.0020	17.50	1.0013	67 004	73.48	2326.0	2399.5	73.48	2460.0	2533.5	.2607	8.4629	8.7237
.0021	18.28	1.0014	63 981	76.73	2323.8	2400.6	76.74	2458.2	2534.9	.2719	8.4341	8.7060
.0022	19.02	1.0016	61 226	79.84	2321.7	2401.6	79.85	2456.4	2536.3	.2826	8.4067	8.6892
.0023	19.73	1.0017	58 705	82.83	2319.7	2402.6	82.83	2454.8	2537.6	.2928	8.3804	8.6732
.0024	20.42	1.0019	56 389	85.71	2317.8	2403.5	85.72	2453.1	2538.8	.3026	8.3552	8.6579
.0025	21.08	1.0020	54 254	88.48	2315.9	2404.4	88.49	2451.6	2540.0	.3120	8.3311	8.6432
.0026	21.72	1.0021	52 279	91.16	2314.1	2405.3	91.17	2450.1	2541.2	.3211	8.3079	8.6290
.0027	22.34	1.0023	50 446	93.75	2312.4	2406.1	93.75	2448.6	2542.3	.3299	8.2856	8.6155
.0028	22.94	1.0024	48 742	96.26	2310.7	2407.0	96.27	2447.2	2543.4	.3384	8.2640	8.6024
.0029	23.52	1.0026	47 152	98.69	2309.1	2407.8	98.70	2445.8	2544.5	.3466	8.2432	8.5898
.0030	24.08	1.0027	45 665	101.04	2307.5	2408.5	101.05	2444.5	2545.5	.3545	8.2231	8.5776
.0032	25.16	1.0030	42 964	105.56	2304.4	2410.0	105.57	2441.9	2547.5	.3697	8.1848	8.5545
.0034	26.19	1.0032	40 572	109.83	2301.6	2411.4	109.84	2439.5	2549.3	.3840	8.1488	8.5327
.0036	27.16	1.0035	38 440	113.89	2298.8	2412.7	113.90	2437.2	2551.1	.3975	8.1148	8.5123
.0038	28.08	1.0038	36 527	117.76	2296.2	2414.0	117.77	2435.0	2552.8	.4104	8.0826	8.4930
.0040	28.96	1.0040	34 800	121.45	2293.7	2415.2	121.46	2432.9	2554.4	.4226	8.0520	8.4746
.0042	29.81	1.0043	33 234	124.99	2291.3	2416.3	125.00	2430.9	2555.9	.4343	8.0229	8.4572
.0044	30.62	1.0045	31 806	128.39	2289.1	2417.4	128.39	2429.0	2557.4	.4455	7.9951	8.4406
.0046	31.40	1.0048	30 500	131.64	2286.9	2418.5	131.65	2427.2	2558.8	.4562	7.9686	8.4248
.0048	32.15	1.0050	29 299	134.78	2284.7	2419.5	134.79	2425.4	2560.2	.4665	7.9431	8.4096
.0050	32.88	1.0053	28 192	137.81	2282.7	2420.5	137.82	2423.7	2561.5	.4764	7.9187	8.3951
.0055	34.58	1.0058	25 769	144.94	2277.9	2422.8	144.95	2419.6	2564.5	.4997	7.8616	8.3613
.0060	36.16	1.0064	23 739	151.53	2273.4	2425.0	151.53	2415.9	2567.4	.5210	7.8094	8.3304
.0065	37.63	1.0069	22 014	157.66	2269.3	2426.9	157.67	2412.4	2570.0	.5408	7.7613	8.3020
.0070	39.00	1.0074	20 530	163.39	2265.4	2428.8	163.40	2409.1	2572.5	.5592	7.7167	8.2758
.0075	40.29	1.0079	19 238	168.78	2261.7	2430.5	168.79	2406.0	2574.8	.5764	7.6750	8.2515
.0080	41.51	1.0084	18 103	173.87	2258.3	2432.2	173.88	2403.1	2577.0	.5926	7.6361	8.2287
.0085	42.67	1.0089	17 099	178.69	2255.0	2433.7	178.70	2400.3	2579.0	.6079	7.5994	8.2073
.0090	43.76	1.0094	16 203	183.27	2251.9	2435.2	183.29	2397.7	2581.0	.6224	7.5648	8.1872
.0095	44.81	1.0098	15 399	187.64	2248.9	2436.6	187.65	2395.2	2582.9	.6362	7.5321	8.1682
.010	45.81	1.0102	14 674	191.82	2246.1	2437.9	191.83	2392.8	2584.7	.6493	7.5009	8.1502
.011	47.69	1.0111	13 415	199.66	2240.8	2440.4	199.67	2388.3	2588.0	.6738	7.4430	8.1168
.012	49.42	1.0119	12 361	206.91	2235.8	2442.7	206.92	2384.1	2591.1	.6963	7.3900	8.0863
.013	51.04	1.0126	11 465	213.66	2231.2	2444.9	213.67	2380.2	2593.9	.7172	7.3412	8.0584
.014	52.55	1.0134	10 693	219.98	2226.9	2446.9	219.99	2376.6	2596.6	.7366	7.2959	8.0325
.015	53.97	1.0141	10 022	225.92	2222.8	2448.7	225.94	2373.1	2599.1	.7549	7.2536	8.0085
.016	55.32	1.0147	9433	231.54	2219.0	2450.5	231.56	2369.9	2601.4	.7720	7.2140	7.9860
.017	56.59	1.0154	8910	236.86	2215.3	2452.2	236.89	2366.8	2603.7	.7882	7.1767	7.9649
.018	57.80	1.0160	8445	241.93	2211.8	2453.8	241.95	2363.8	2605.8	.8035	7.1416	7.9451
.019	58.96	1.0166	8027	246.76	2208.5	2455.3	246.78	2361.0	2607.8	.8181	7.1082	7.9263
.020	60.06	1.0172	7649	251.38	2205.4	2456.7	251.40	2358.3	2609.7	.8320	7.0766	7.9085
.021	61.12	1.0178	7307	255.81	2202.3	2458.1	255.83	2355.7	2611.6	.8452	7.0464	7.8916
.022	62.14	1.0183	6995	260.06	2199.4	2459.4	260.08	2353.2	2613.3	.8579	7.0176	7.8756
.023	63.12	1.0189	6709	264.15	2196.6	2460.7	264.18	2350.8	2615.0	.8701	6.9901	7.8602
.024	64.06	1.0194	6446	268.09	2193.8	2461.9	268.12	2348.5	2616.6	.8818	6.9637	7.8455

Definitions of symbols on page 1.

Table 2. Saturation: Pressures

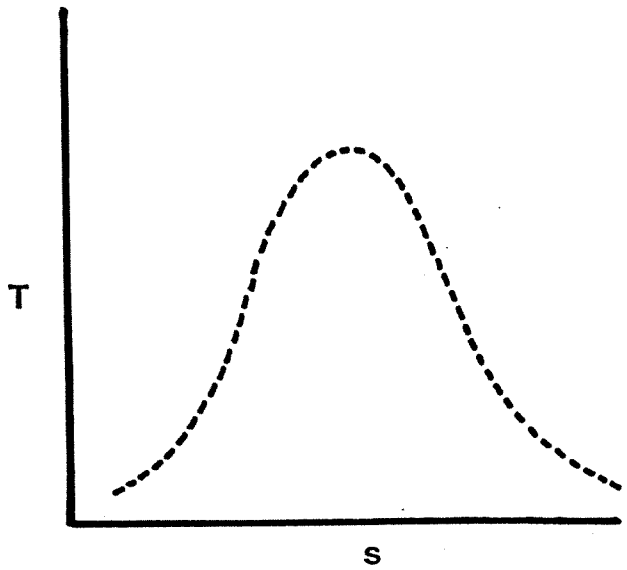
Press. MPa	Temp °C	Specific Volume		Internal Energy			Enthalpy			Entropy		
		Sat. Liquid	Sat. Vapor	Sat. Liquid	Evap.	Sat. Vapor	Sat. Liquid	Evap.	Sat. Vapor	Sat. Liquid	Evap.	Sat. Vapor
p	t	$10^3 v_f$	$10^3 v_g$	u_f	u_{fg}	u_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
2.00	212.42	1.1767	99.63	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.05	213.67	1.1789	97.25	912.11	1688.6	2600.7	914.52	1885.5	2800.0	2.4590	3.8728	6.3318
2.10	214.90	1.1810	94.98	917.67	1683.4	2601.0	920.15	1880.3	2800.5	2.4704	3.8524	6.3229
2.15	216.10	1.1831	92.81	923.15	1678.2	2601.4	925.69	1875.2	2800.9	2.4817	3.8325	6.3141
2.20	217.29	1.1852	90.73	928.53	1673.2	2601.7	931.14	1870.2	2801.3	2.4927	3.8129	6.3056
2.25	218.45	1.1872	88.75	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.30	219.60	1.1893	86.85	939.04	1663.2	2602.3	941.77	1860.2	2802.0	2.5141	3.7749	6.2890
2.35	220.72	1.1913	85.02	944.17	1658.4	2602.5	946.97	1855.4	2802.3	2.5245	3.7564	6.2809
2.40	221.83	1.1933	83.27	949.22	1653.5	2602.8	952.09	1850.5	2802.6	2.5347	3.7382	6.2729
2.45	222.92	1.1953	81.59	954.21	1648.8	2603.0	957.13	1845.7	2802.9	2.5448	3.7204	6.2651
2.5	223.99	1.1973	79.98	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
2.6	226.09	1.2013	76.92	968.73	1634.7	2603.5	971.85	1831.6	2803.5	2.5740	3.6685	6.2425
2.7	228.12	1.2051	74.09	978.09	1625.6	2603.7	981.34	1822.4	2803.8	2.5927	3.6353	6.2280
2.8	230.10	1.2090	71.45	987.20	1616.7	2603.9	990.59	1813.4	2804.0	2.6109	3.6030	6.2139
2.9	232.02	1.2127	68.99	996.10	1607.9	2604.0	999.61	1804.5	2804.1	2.6285	3.5717	6.2002
3.0	233.90	1.2165	66.68	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.1	235.72	1.2202	64.52	1013.26	1590.9	2604.1	1017.04	1787.1	2804.1	2.6624	3.5116	6.1740
3.2	237.51	1.2239	62.49	1021.56	1582.5	2604.1	1025.47	1778.6	2804.1	2.6787	3.4827	6.1614
3.3	239.24	1.2275	60.57	1029.68	1574.3	2604.0	1033.72	1770.2	2803.9	2.6946	3.4544	6.1491
3.4	240.94	1.2311	58.77	1037.63	1566.3	2603.9	1041.82	1761.9	2803.7	2.7101	3.4269	6.1370
3.5	242.60	1.2347	57.07	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
3.6	244.23	1.2382	55.45	1053.07	1550.4	2603.5	1057.53	1745.6	2803.1	2.7401	3.3737	6.1138
3.7	245.82	1.2418	53.92	1060.58	1542.7	2603.3	1065.17	1737.6	2802.8	2.7546	3.3479	6.1025
3.8	247.38	1.2453	52.47	1067.95	1535.0	2603.0	1072.68	1729.7	2802.4	2.7688	3.3227	6.0915
3.9	248.91	1.2487	51.09	1075.19	1527.5	2602.6	1080.05	1721.8	2801.9	2.7828	3.2980	6.0807
4.0	250.40	1.2522	49.78	1082.31	1520.0	2602.3	1087.31	1714.1	2801.4	2.7964	3.2737	6.0701
4.2	253.31	1.2590	47.33	1096.20	1505.3	2601.5	1101.48	1698.8	2800.3	2.8229	3.2266	6.0495
4.4	256.12	1.2658	45.10	1109.66	1490.9	2600.6	1115.22	1683.8	2799.0	2.8485	3.1811	6.0296
4.6	258.83	1.2726	43.06	1122.73	1476.8	2599.5	1128.58	1669.0	2797.6	2.8732	3.1371	6.0103
4.8	261.45	1.2792	41.18	1135.43	1462.9	2598.4	1141.57	1654.5	2796.0	2.8970	3.0945	5.9916
5.0	263.99	1.2859	39.44	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
5.2	266.45	1.2925	37.83	1159.87	1435.9	2595.8	1166.58	1626.0	2792.6	2.9427	3.0131	5.9557
5.4	268.84	1.2991	36.34	1171.65	1422.8	2594.4	1178.66	1612.0	2790.7	2.9645	2.9740	5.9385
5.6	271.17	1.3056	34.95	1183.16	1409.8	2592.9	1190.46	1598.2	2788.6	2.9858	2.9359	5.9217
5.8	273.43	1.3122	33.65	1194.41	1396.9	2591.3	1202.02	1584.5	2786.5	3.0065	2.8988	5.9052
6.0	275.64	1.3187	32.44	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
6.2	277.78	1.3252	31.30	1216.25	1371.7	2588.0	1224.46	1557.6	2782.1	3.0464	2.8270	5.8734
6.4	279.88	1.3317	30.23	1226.85	1359.4	2586.2	1235.37	1544.3	2779.7	3.0657	2.7923	5.8580
6.6	281.93	1.3382	29.22	1237.26	1347.1	2584.4	1246.09	1531.2	2777.2	3.0845	2.7583	5.8428
6.8	283.93	1.3448	28.27	1247.49	1335.0	2582.5	1256.63	1518.1	2774.7	3.1030	2.7249	5.8279
7.0	285.88	1.3513	27.37	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
7.2	287.79	1.3578	26.52	1267.44	1311.0	2578.5	1277.21	1492.2	2769.4	3.1389	2.6600	5.7989
7.4	289.67	1.3644	25.71	1277.18	1299.2	2576.4	1287.28	1479.4	2766.7	3.1563	2.6284	5.7847
7.6	291.50	1.3710	24.94	1286.78	1287.5	2574.3	1297.19	1466.6	2763.8	3.1734	2.5973	5.7707
7.8	293.30	1.3776	24.21	1296.24	1275.8	2572.1	1306.98	1453.9	2760.9	3.1902	2.5666	5.7569
8.0	295.06	1.3842	23.52	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
8.2	296.79	1.3908	22.86	1314.78	1252.7	2567.5	1326.18	1428.7	2754.9	3.2230	2.5067	5.7297
8.4	298.49	1.3975	22.22	1323.87	1241.3	2565.2	1335.61	1416.2	2751.8	3.2391	2.4773	5.7164
8.6	300.16	1.4042	21.62	1332.86	1229.9	2562.8	1344.93	1403.7	2748.7	3.2549	2.4484	5.7032
8.8	301.80	1.4110	21.04	1341.73	1218.6	2560.3	1354.14	1391.3	2745.4	3.2704	2.4197	5.6902
9.0	303.40	1.4178	20.48	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6772
9.2	304.99	1.4246	19.95	1359.19	1196.0	2555.2	1372.29	1366.5	2738.8	3.3009	2.3635	5.6644
9.4	306.54	1.4315	19.44	1367.78	1184.8	2552.6	1381.23	1354.1	2735.4	3.3159	2.3358	5.6517
9.6	308.07	1.4384	18.95	1376.28	1173.6	2549.9	1390.08	1341.8	2731.9	3.3306	2.3084	5.6391
9.8	309.58	1.4454	18.48	1384.70	1162.5	2547.2	1398.86	1329.5	2728.3	3.3452	2.2813	5.6265
10.0	311.06	1.4524	18.026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141
10.2	312.52	1.4595	17.588	1401.31	1140.3	2541.6	1416.19	1304.8	2721.0	3.3739	2.2278	5.6017
10.4	313.96	1.4667	17.167	1409.51	1129.2	2538.7	1424.76	1292.5	2717.3	3.3880	2.2014	5.5894
10.6	315.38	1.4739	16.760	1417.64	1118.2	2535.8	1433.26	1280.2	2713.5	3.4020	2.1752	5.5771
10.8	316.77	1.4812	16.367	1425.71	1107.1	2532.8	1441.70	1267.9	2709.6	3.4158	2.1491	5.5649

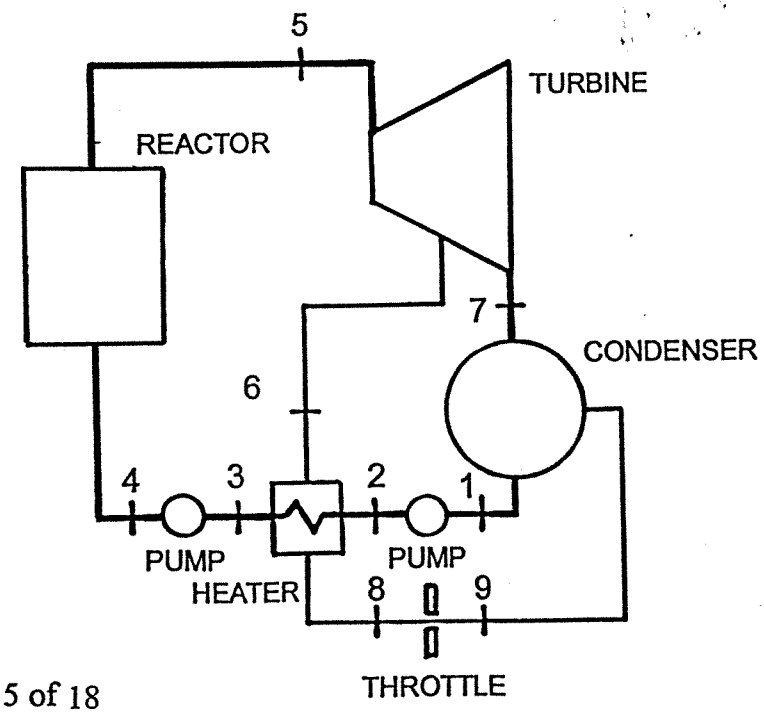
Definitions of symbols on page 1.

98-MEC-B3 ENERGY CONVERSION AND POWER GENERATION
EXAMINATION PAPER ATTACHMENTS

DECEMBER 2002 **NAME** _____

QUESTION 1 STEAM CYCLE EFFICIENCY





Vestas

V80 – 1.8 MW

Pitch regulated wind turbine with OptiSlip® and OptiTip®

ROTOR	
Diameter:	80 m
Swept area:	5,027 m²
Speed of revolution:	15.7 RPM
Number of blades:	3
Power regulation:	Pitch + OptiSlip®
Air brake:	3 separate pitch settings
TOWER:	
Hub height (approx.):	60 – 67 – 78 m
OPERATIONAL DATA:	
Cut-in wind speed:	4 m/s
Nominal wind speed:	16 m/s
Stop wind speed:	25 m/s
GENERATOR:	
Type:	Asynchronous with OptiSlip®
Nominal output:	1.8 MW
Operational data:	60 Hz 690V 1,800 -1,980 RPM
GEARBOX:	
Type:	Planet/parallel gear
CONTROL:	
Type:	Microprocessor-based control of all turbine functions with the option of remote monitoring. OptiSlip® output regulation and OptiTip® pitch regulation of the blades.

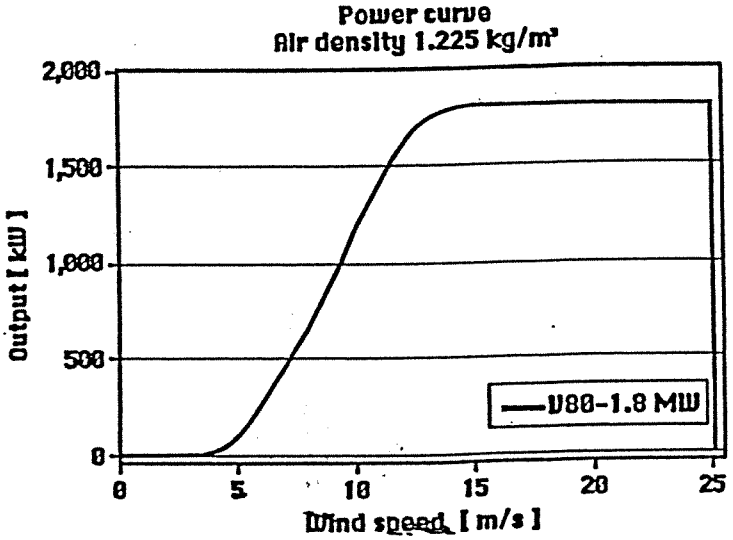
WEIGHT: (APPROX.)	(60 m)	(67 m)	(78 m)
Nacelle:	63 t	63 t	63 t
Rotor:	38 t	38 t	38 t

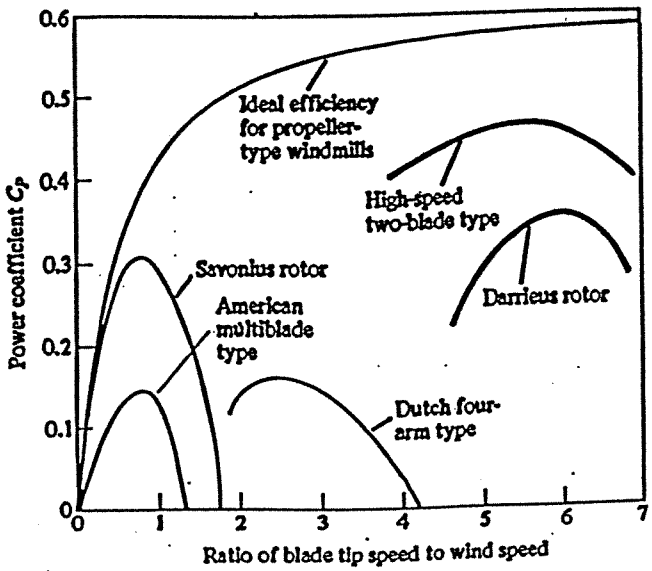
Ideal for moderate wind conditions

The V80-1.8 MW is particularly well suited for installation in areas with moderate to high wind conditions, and thanks to OptiSlip®, the turbine can adapt to wind conditions in almost any location. In this way, Vestas continues to strive for excellence by taking firm steps towards the full exploitation of wind energy.

Advanced Vestas technology

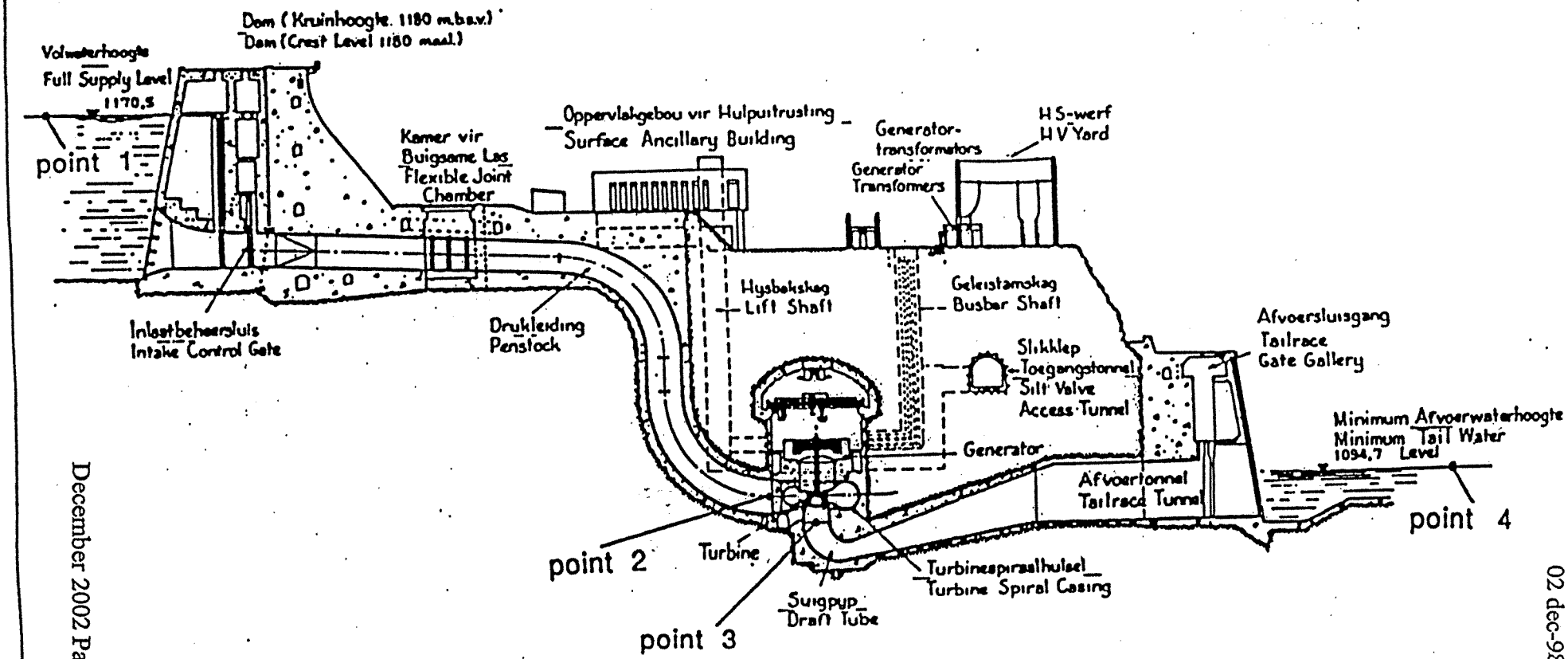
The Vestas V80-1.8 MW is based on the well-known technology from the V66-1.65 MW turbine. The turbine is a three blade 60 Hz pitch-regulated wind turbine with OptiSlip® and OptiTip®. The turbine's rotor diameter is 80 meters – and the turbine can be delivered with tower heights of up to 78 meters.

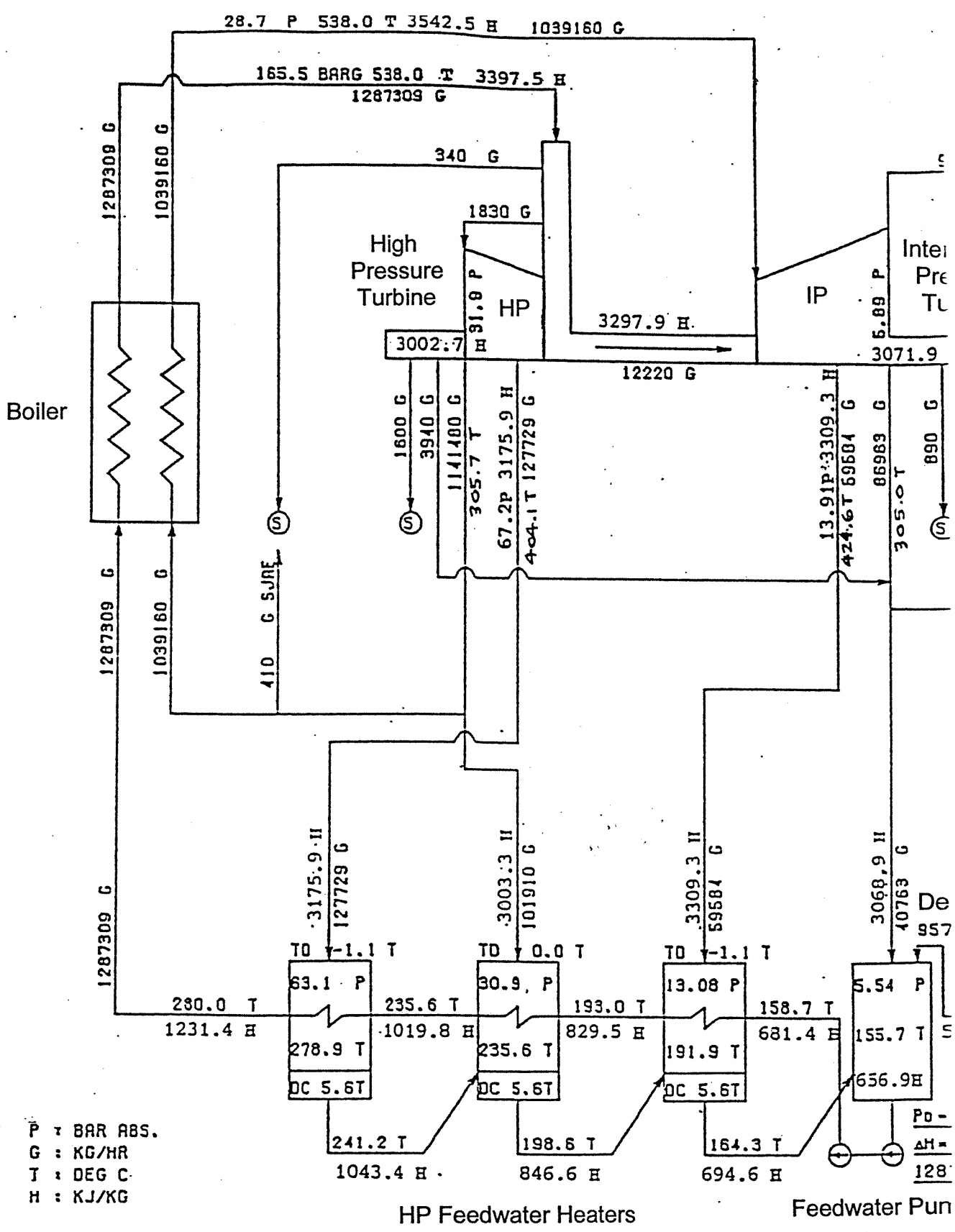




QUESTION 4 II HYDRO POWER PLANT

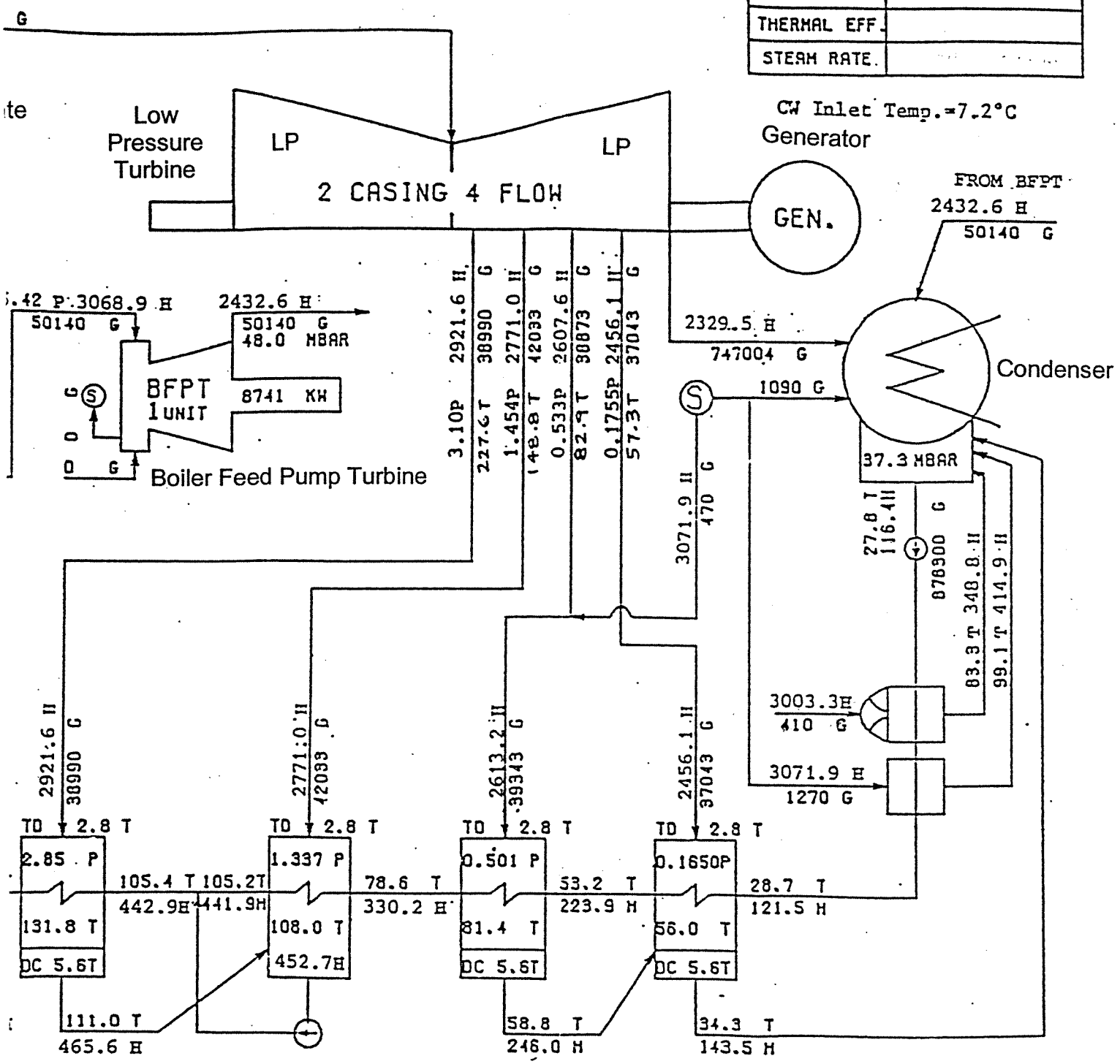
Cross-section through Power Station Waterways/Dwarsdeursnit van Kragstasie-Afvoerkanale





QUESTION 2 BELLEDUNE HEAT BALANCE

GEN.OUTPUT	430000 KW
CONDITION	37.3 MBAR 0.0%MU
M.PRES.PF	412kPa(g) 0.85PF
HEAT RATE	
THERMAL EFF.	
STEAM RATE.	



LP Feedwater Heaters

RAM

APPROVED BY		MESSRS. BELLEDUNE GENERATING STATION UNIT-2 NBEPC. CANADA(600MVA GEN.)	430000 KW REHEAT TURBINE
CHECKED BY			HEAT BALANCE DIAGRAM
DESIGNED BY		TOSHIBA CORPORATION	3KH001731