Heat Engines:
Thermodynamics,
Cycles, and
Performance Curves
...just the figures for those who got the B&W version...

by D. James Benton

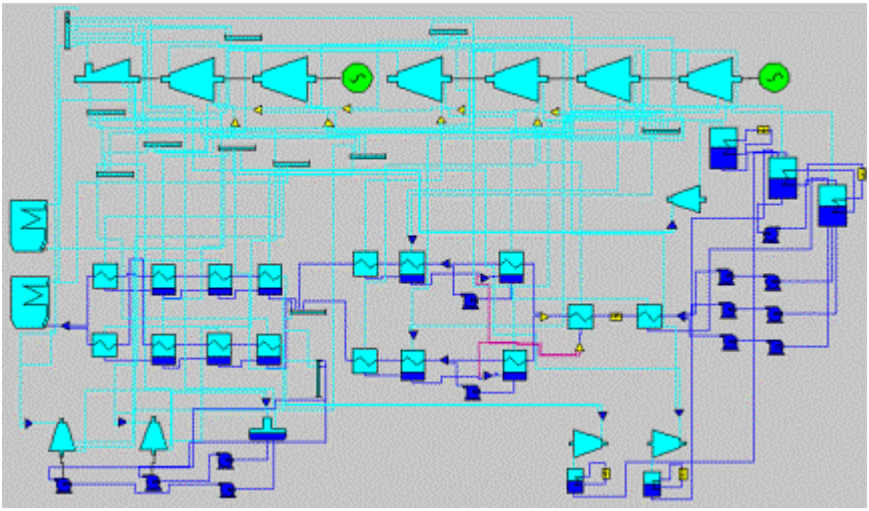

Figure 1. TVA's Paradise Unit 3 (Coal-Fired)

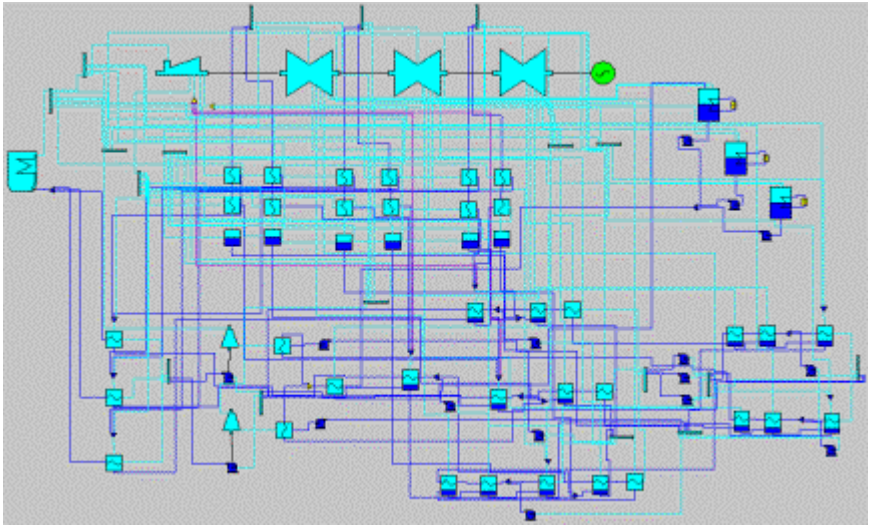

Figure 2. TVA's Sequoyah Nuclear Plant

Figure 3. Steam Turbine Rotor

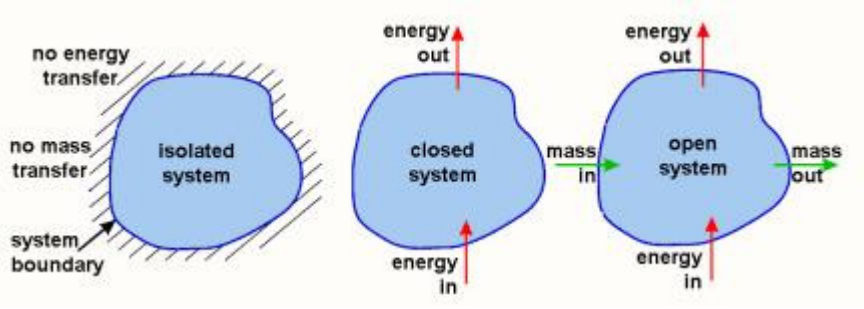

Figure 4. Types of Systems

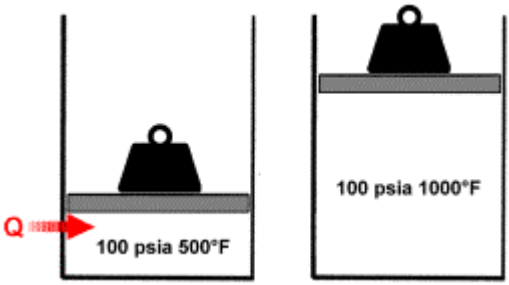

Figure 5. Work on a Closed System

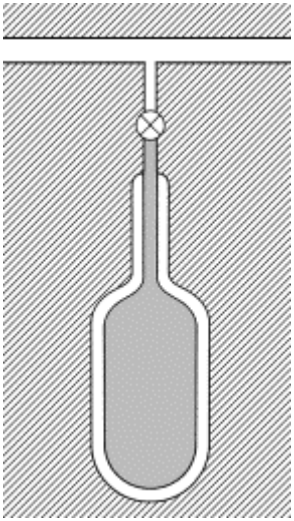

Figure 6. Filling a Tank

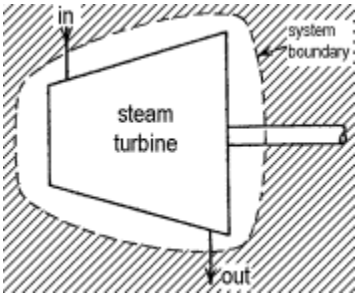

Figure 7. Steam Turbine System Boundary

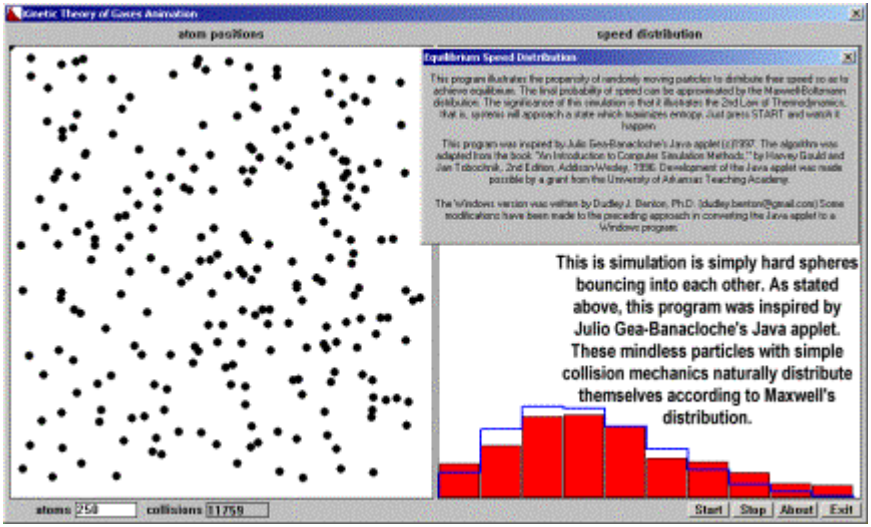

Figure 8. Molecules Collide

	A	B
1	Maxwell-Boltzmann Speed Distribution	
2	cβ	f(cβ)
3	0.0	0.0000
4	0.1	0.0099
5	0.2	0.0384
6	0.3	0.0823
7	0.4	0.1363
8	0.5	0.1947
9	0.6	0.2512
10	0.7	0.3002
11	0.8	0.3375
12	0.9	0.3603
13	1.0	0.3679
14	1.1	0.3608
15	1.2	0.3412
16	1.3	0.3118
17	1.4	0.2761
18	1.5	0.2371
19	1.6	0.1979
20	1.7	0.1606
21	1.8	0.1269

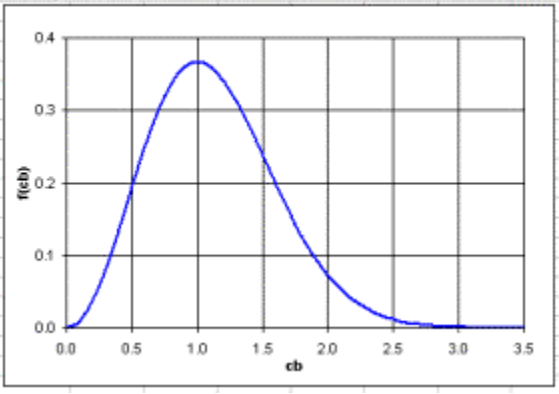

Figure 9. Maxwellian Velocity Distribution

	A	B	C
1	Speed Distributions for Argon		
2	39.948 MW [gm/mole]		
3	6.02E+23 N (Avogadro's number) [atoms/mole]		
4	6.63E-23 μ (mass of one atom) [gm]		
5	1.38E-23 k (Boltzmann's constant) [J/°K/atom]		
6	T	Crms	
7	°K	m/s	
8	100	250	
9	200	353	
10	300	433	
11	400	500	
12	500	559	
13	600	612	
14	700	661	
15	800	707	
16	900	750	
17	1000	790	
18	1100	829	
19	1200	866	
20	1300	901	
21	1400	935	
22	1500	968	
23	1600	1000	
24	1700	1030	
25	1800	1060	

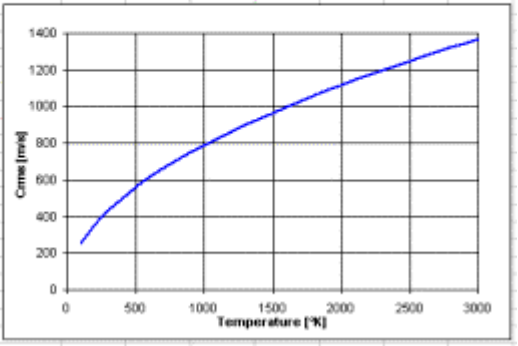

Figure 10. Mean Atomic Speed

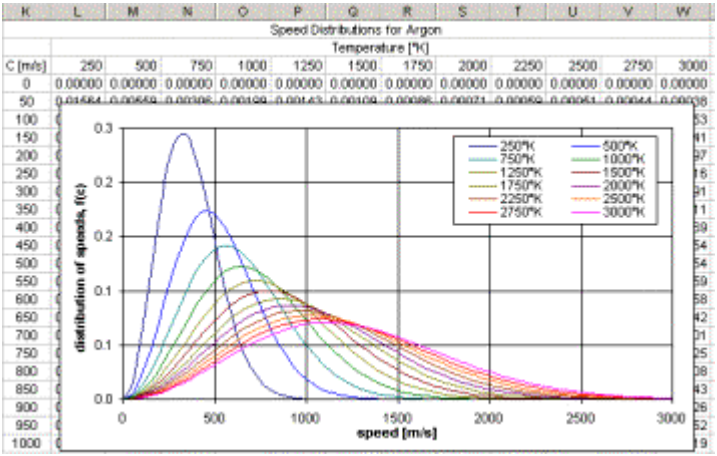

Figure 11. Speed Distributions

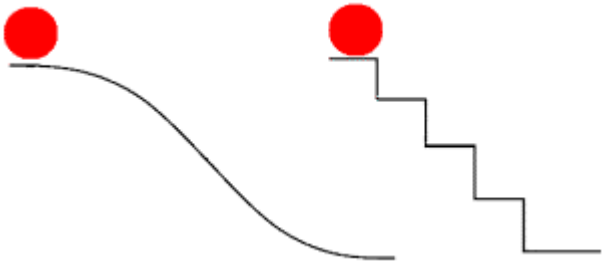

Figure 12. Conceptual Energy Levels

	A	B	C	D	E
1	NASA Glenn Gases				
2	Constant Pressure Specific Heat, Cp				
3	T [°K]	Argon	N2	Methane	Methanol
4	200	0.52	1.04	2.09	1.13

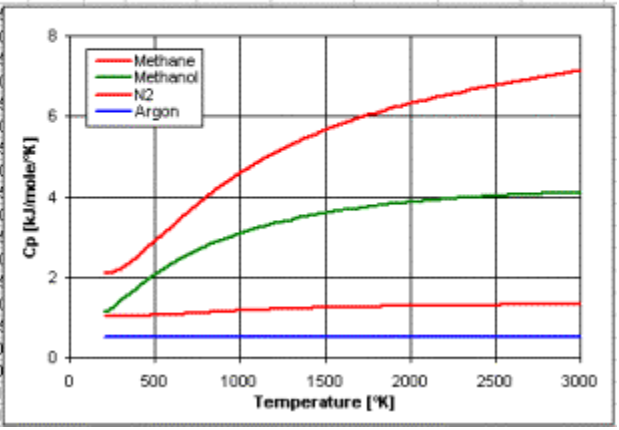

Figure 13. Specific Heats

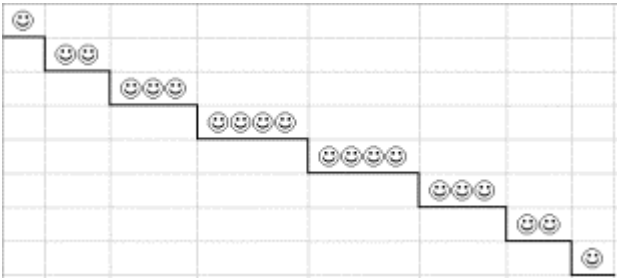

Figure 14. Energy Levels 1

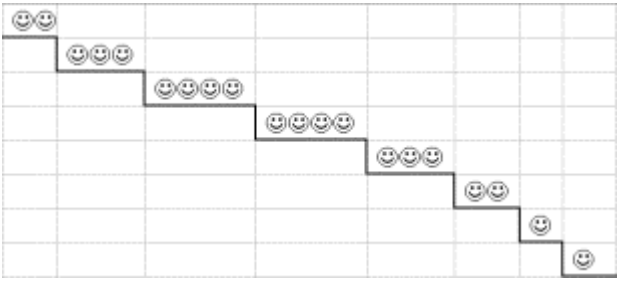

Figure 15. Energy Levels 2

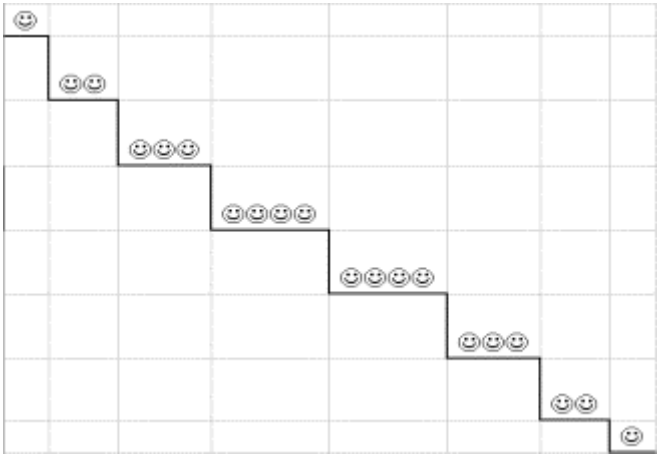

Figure 16. Energy Levels 3

Figure 17. Partitioning 1

Figure 18. Partitioning 2

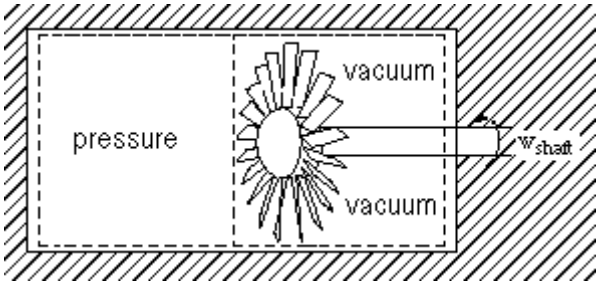

Figure 19. Work on an Insulated System

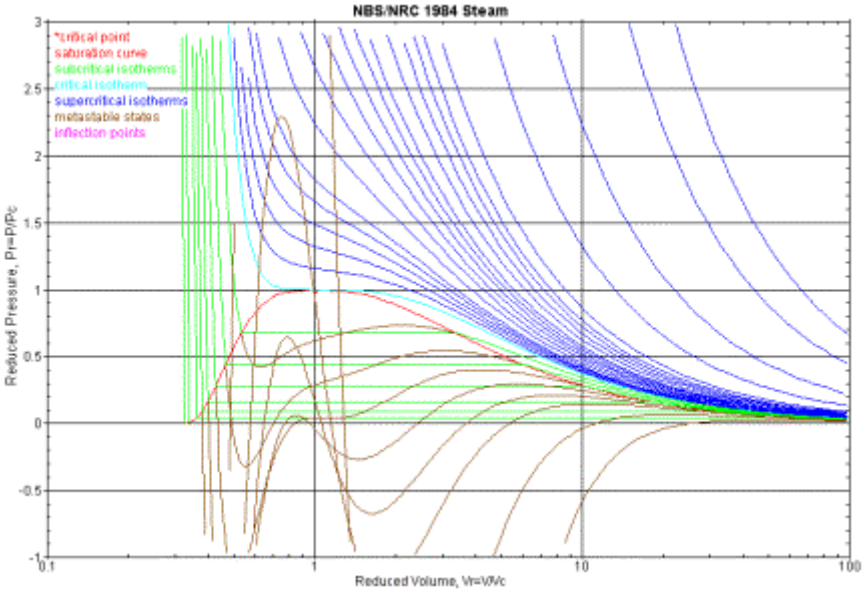

Figure 20. Steam Reduced Pressure vs. Reduced Volume

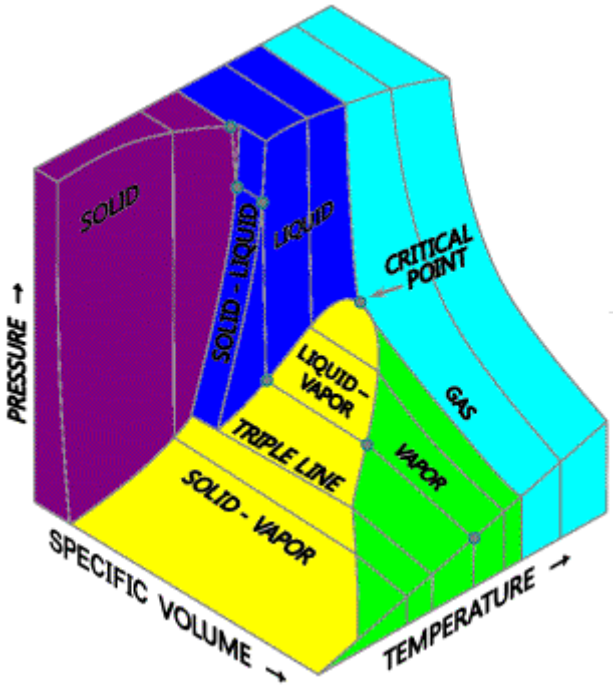

Figure 21. States of Water

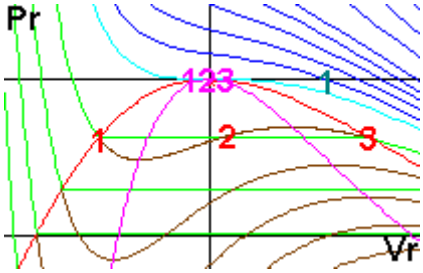

Figure 22. Near the Critical Point

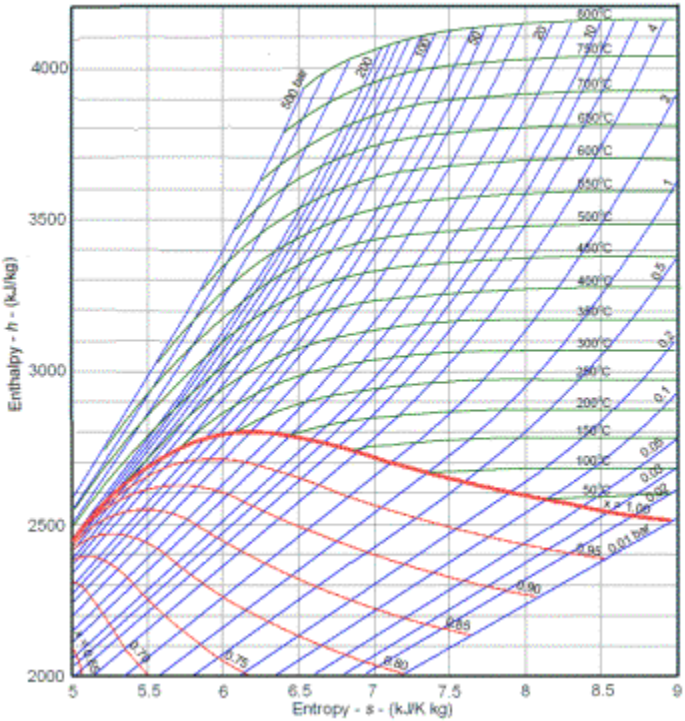

Figure 23. Mollier Diagram for Water

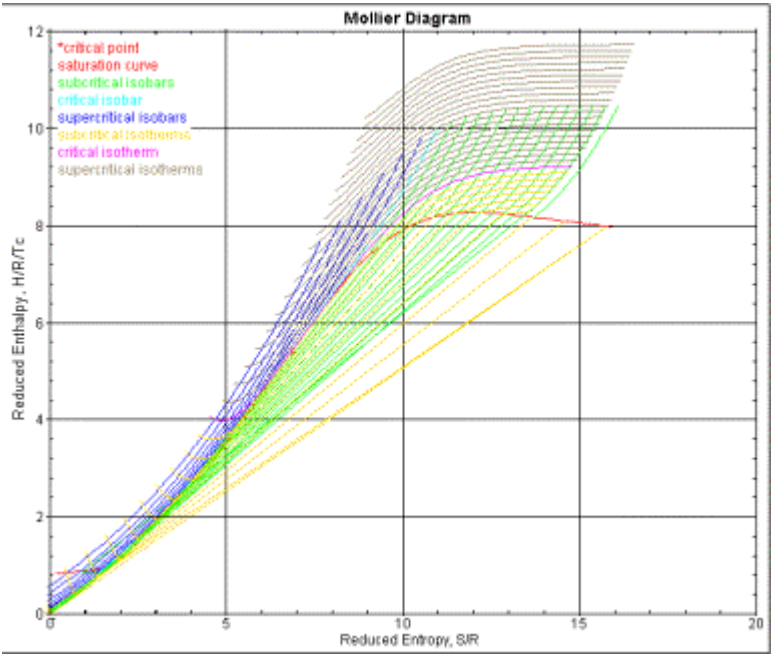

Figure 24. Extended Mollier Diagram

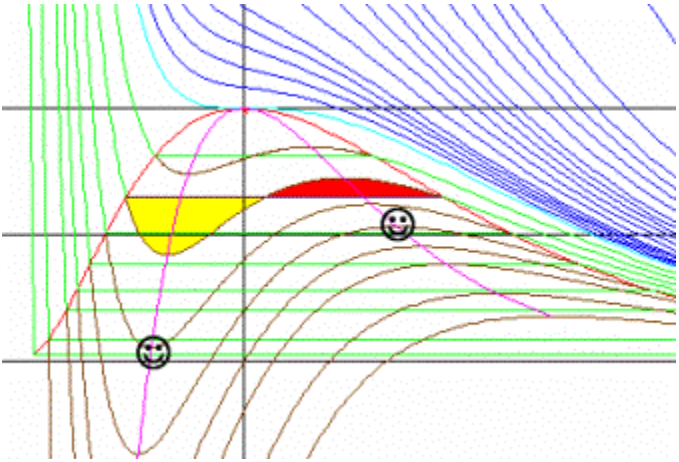

Figure 25. Maxwell's Equal Areas

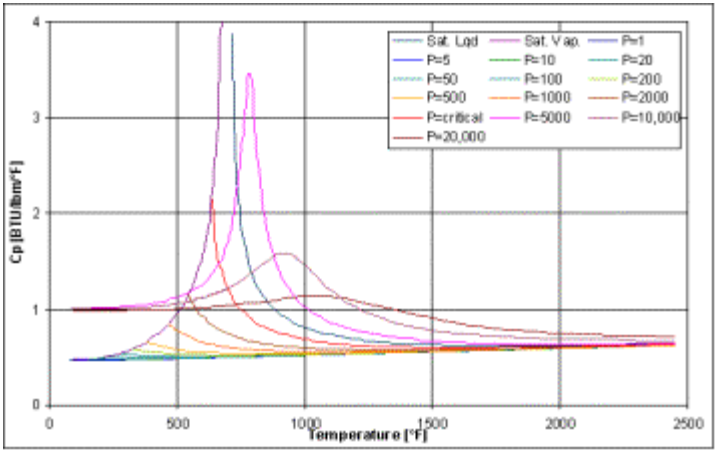

Figure 26. Specific Heat of Water

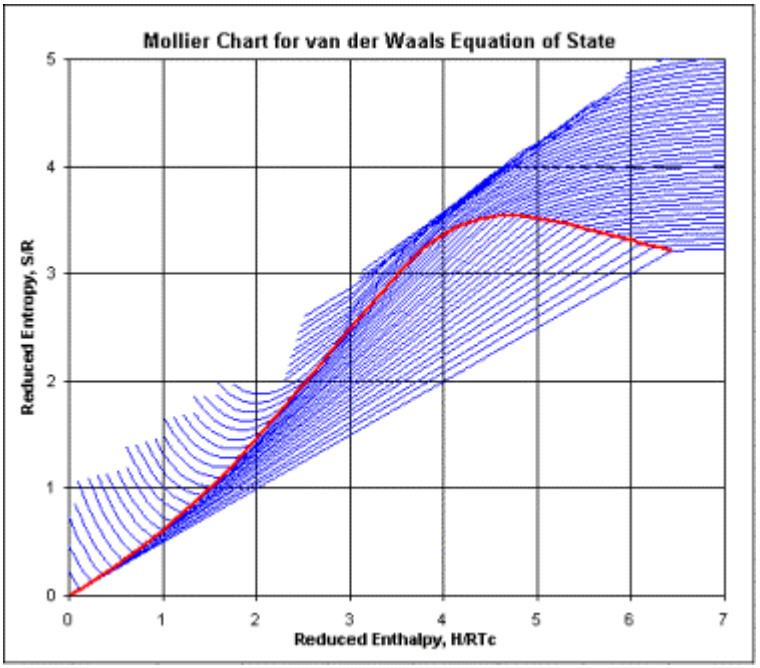

Figure 27. Reduced Entropy vs. Reduced Enthalpy

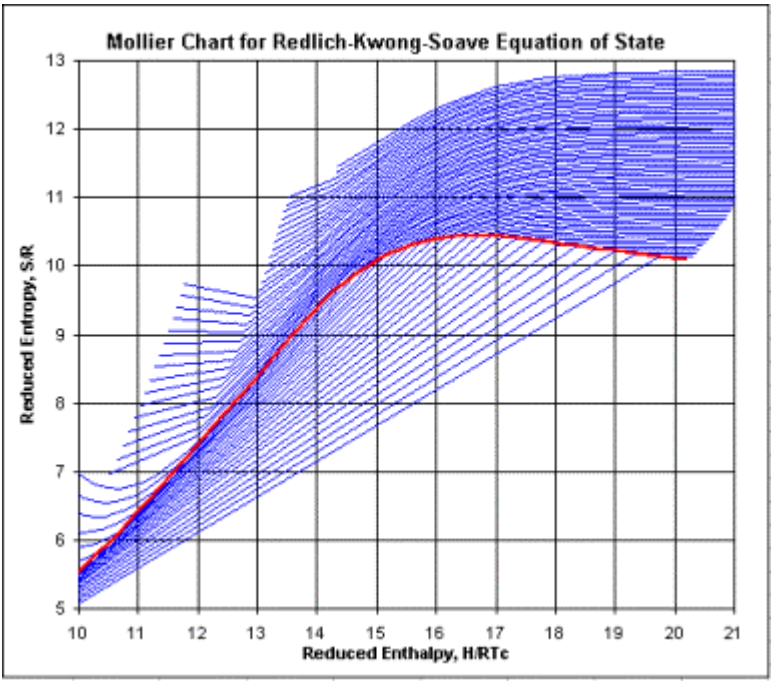

Figure 28. RKS Mollier Chart

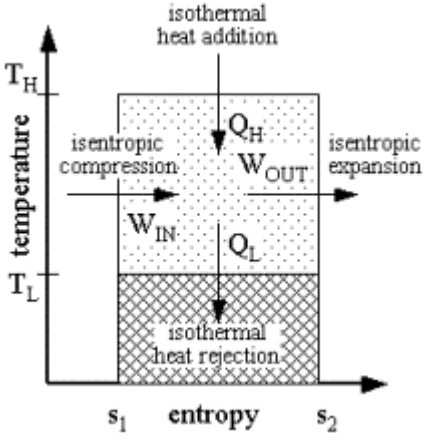

Figure 29. Carnot Cycle

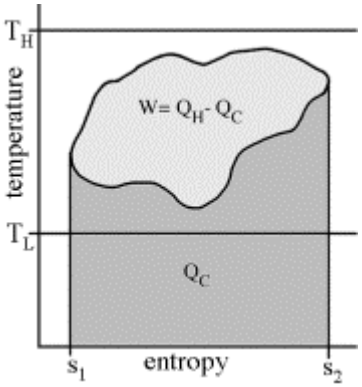

Figure 30. Arbitrary Cycle

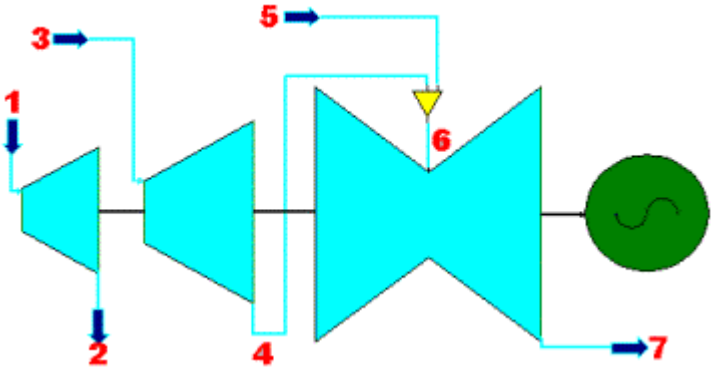

Figure 31. Cascaded Steam Turbines

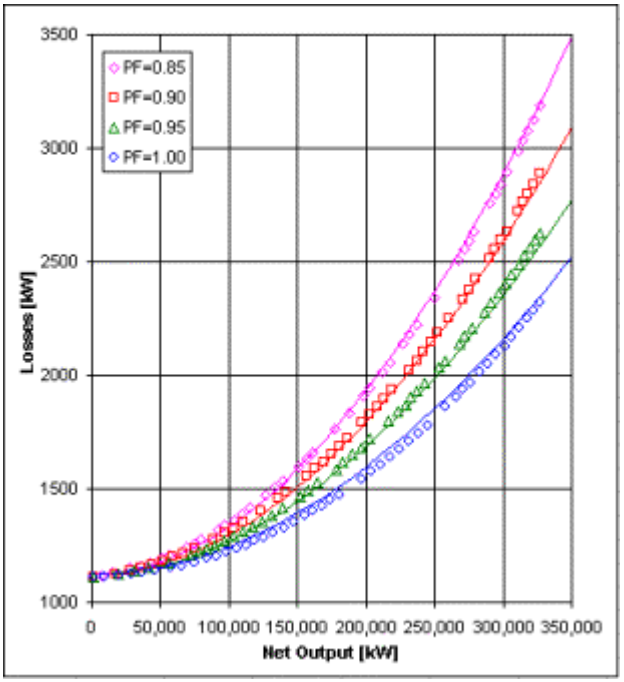

Figure 32. Typical Power Factor Curves

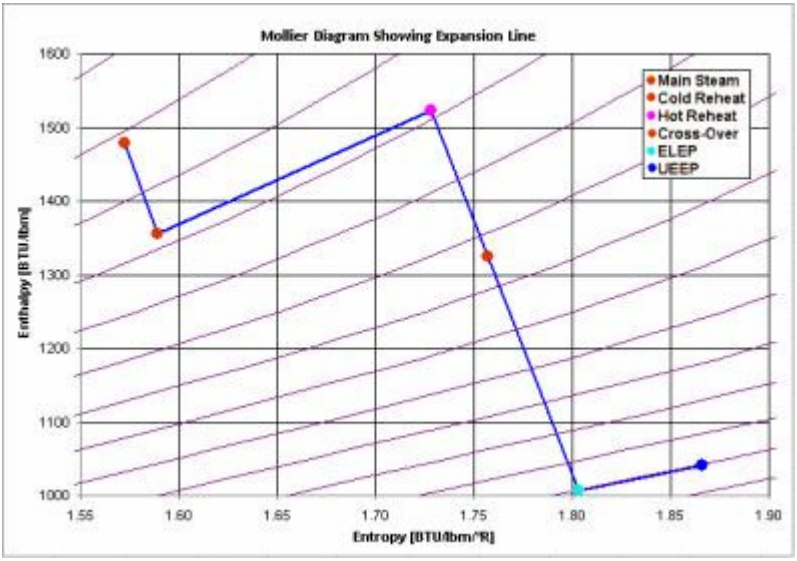

Figure 33. Typical Steam Turbine Expansion Line

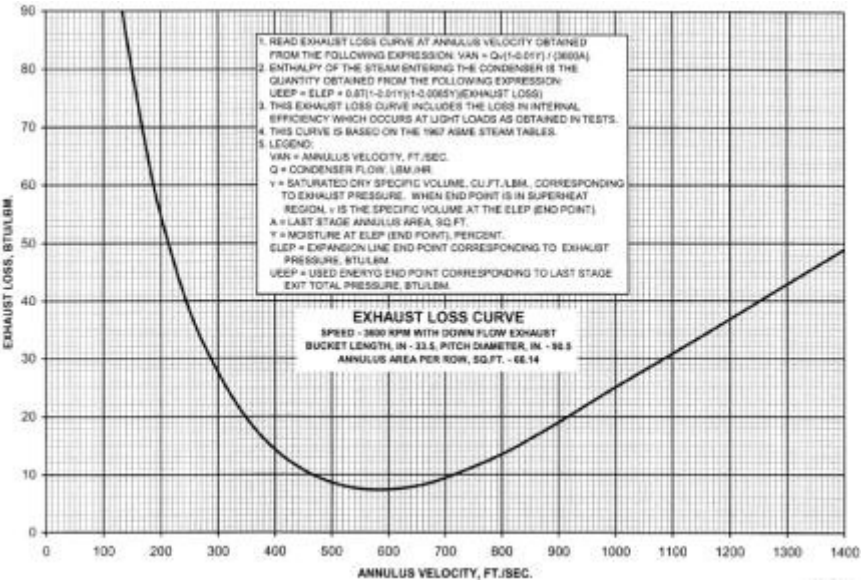

Figure 34. Typical Steam Turbine Exhaust Loss Curve

	A	B	C	D	E	F	G	H	I	J	K
1	design					Area [sq.ft.]	66.14				
2	measured					Vg	342.2952				
3	calculated					x	0.936523				
4	iterative					Van	1264.862				
5	solve					loss	42.17177	35.22332			
6	description	main steam	cold reheat	hot reheat	IPT exit	LPT inlet	exp.lin.end	used energ	IPT isentr.	LP admis.	LPT isentr.
7	point	1	2	3	4	6	ELEP	UEEP	4s	5	7s
8	flow		1778199		1812039	1874969				62930	
9	pressure	1820.9	618.6	551.7	97.32	97.32	0.9728	0.9729	97.32	97.32	0.97
10	temperatur	997.1	710.5	1006.2	590.5	589.5			531.3	558.2	100.8
11	enthalpy	1478.8	1356.0	1522.8	1324.9	1324.4	1006.1	1041.3	1295.3	1308.8	979.9
12	entropy	1.5727	1.5888	1.7282	1.7573	1.7567	1.8034	1.8663	1.7282	1.7417	1.7567
13	kW		64021.9		109082.1			155532.3			
14				slope, dh/ds	-6815	-6815	shaft	324635.4			
15			for method 1 adjust until this is zero			0	PF	0.999224			
16				efficiency	86.96%	92.40%	loss	2318			
17			for method 2 adjust until this is zero			5.42%	net calc	322318			
18							net meas	322318			
19				adjust until this is zero for either method				0			

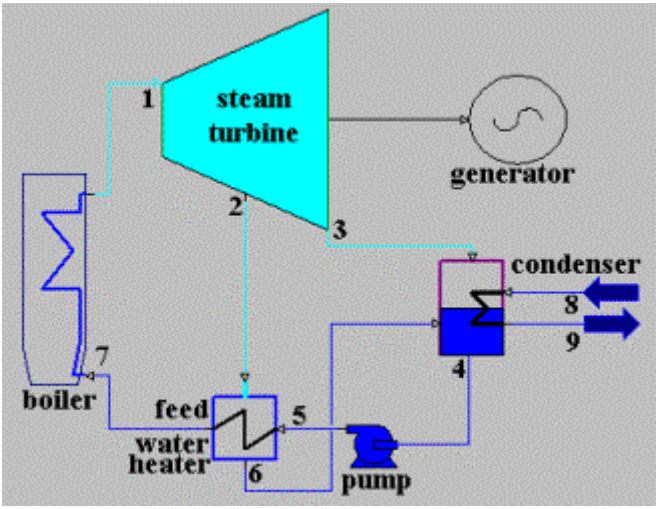

Figure 35. Simple Rankine Cycle

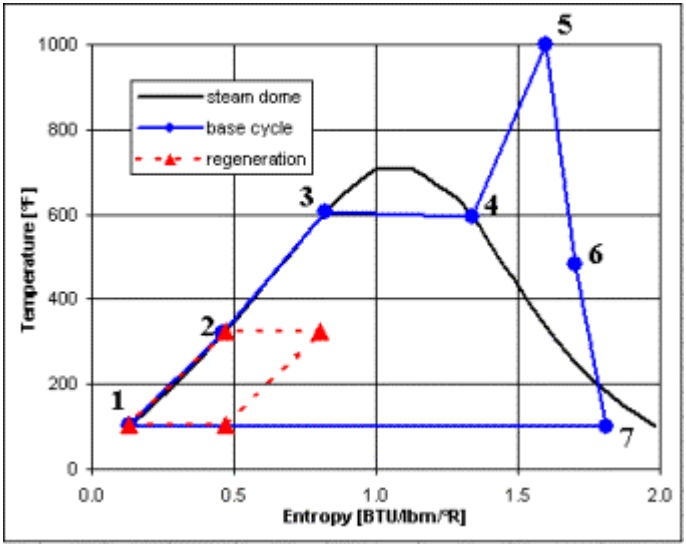

Figure 36. Rankine Cycle with Regeneration

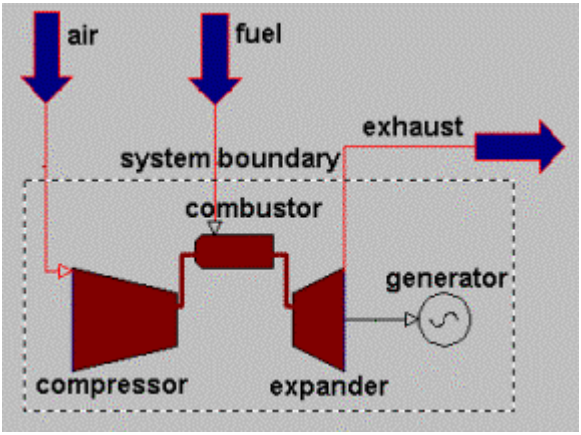

Figure 37. Combustion Turbine System Boundary

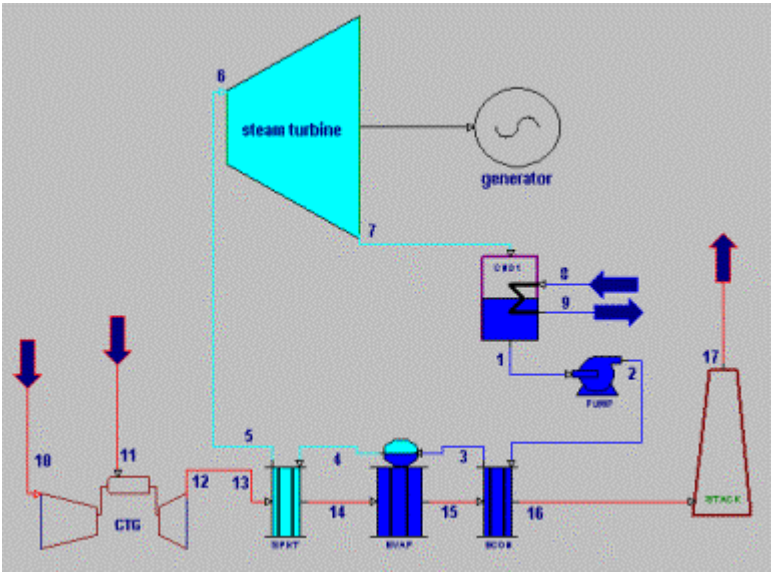

Figure 38. Simple Combined Cycle

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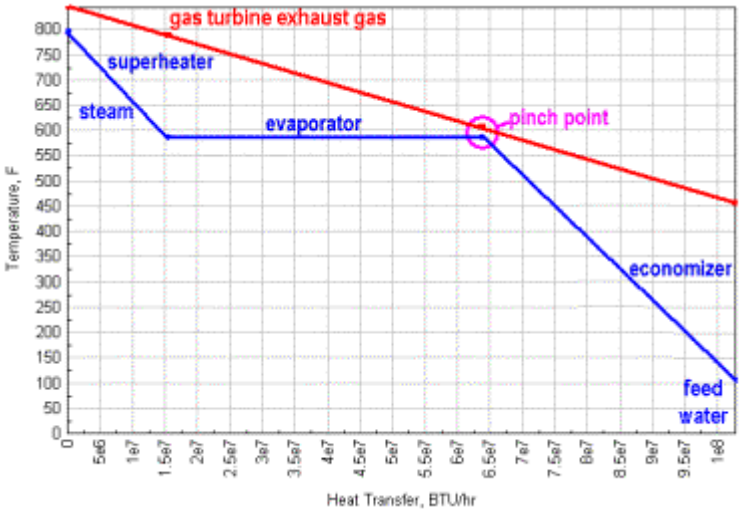


Figure 39. Typical HRSG Process Lines

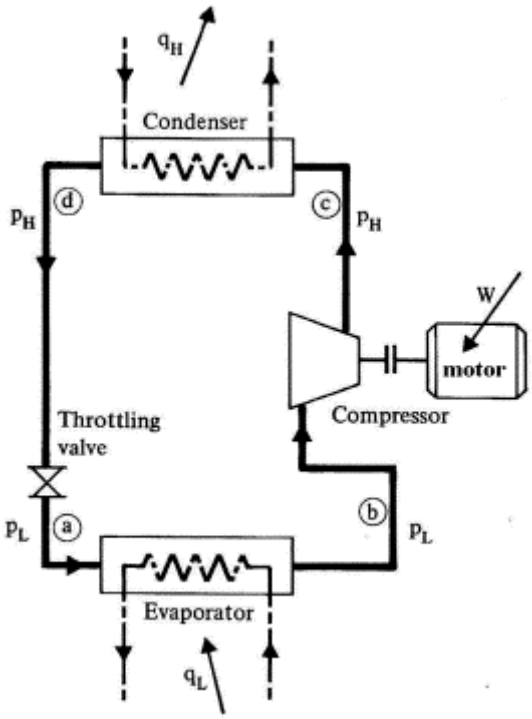


Figure 40. Simple Refrigeration Cycle

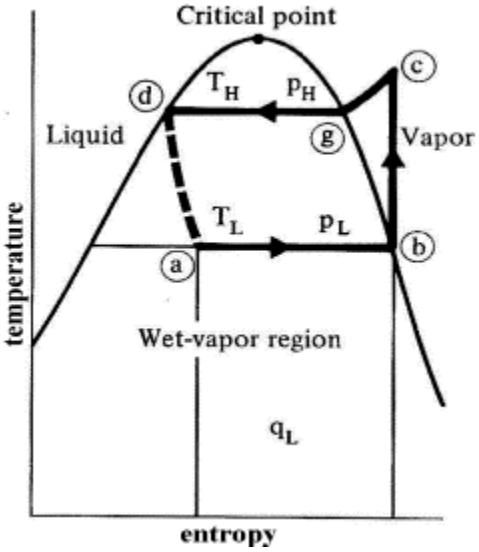


Figure 41. Refrigeration Cycle

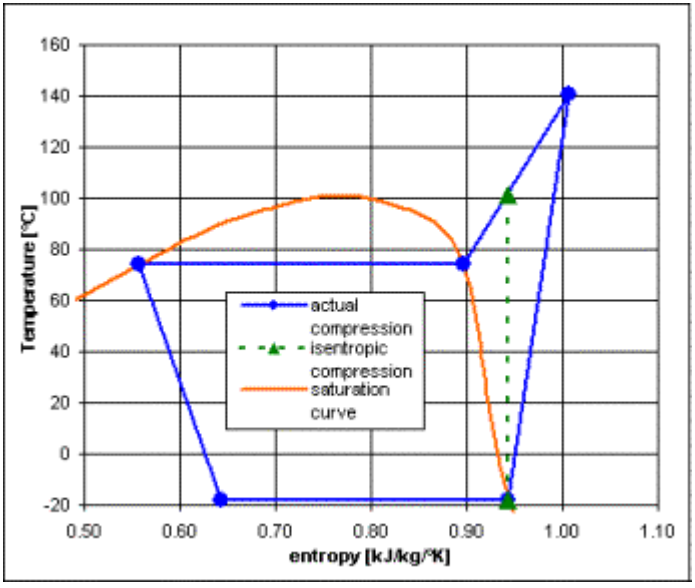


Figure 42. Refrigeration T-S Diagram

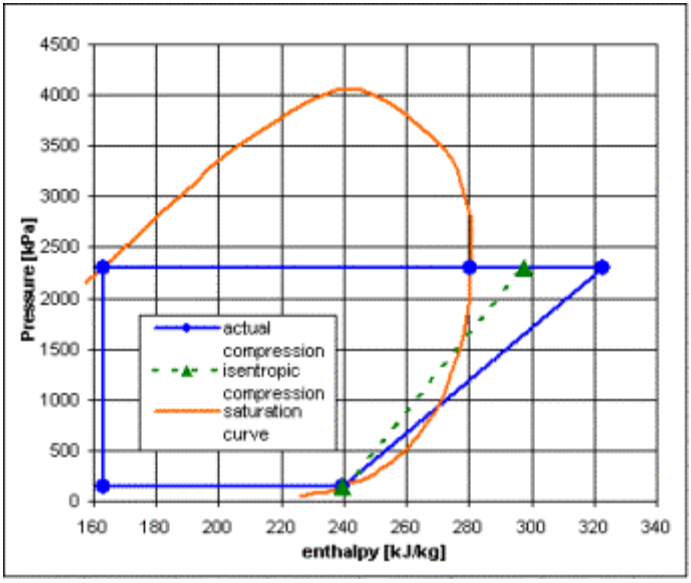


Figure 43. Refrigeration P-H Diagram

Otto Cycle					
User Inputs					
compression ratio			9.5		
compression eff.			90%		
expansion efficiency			90%		
combustion temp.			1500	°C	
k=Cp/Cv			1.4	-	
Cp			1.1	kJ/kg°C	
R			0.314	kJ/kg°C	
point	P	T	v	h	s
units	kPa	°C	m³/kg	kJ/kg	kJ/kg°C
1	101	25	0.925	0	0.000
1.1	138	55	0.746	33	0.008
1.2	183	85	0.614	66	0.015
1.3	238	115	0.513	99	0.021
1.4	302	145	0.434	132	0.027
1.5	378	175	0.372	164	0.033
1.6	466	204	0.322	197	0.038
1.7	568	234	0.281	230	0.043
1.8	684	264	0.247	263	0.048
1.9	815	294	0.219	296	0.052
2	963	324	0.195	329	0.057
2.1	1152	442	0.195	458	0.198
2.2	1342	559	0.195	588	0.317
2.3	1531	677	0.195	717	0.421
2.4	1721	794	0.195	846	0.513
2.5	1910	912	0.195	976	0.595
2.6	2100	1030	0.195	1105	0.669

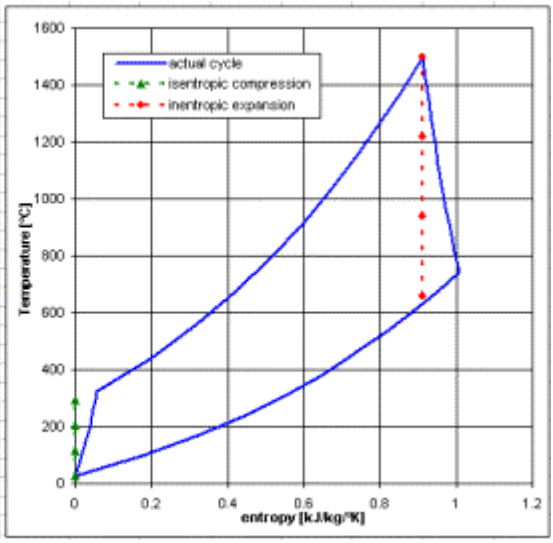


Figure 44. Otto Cycle T-S Diagram

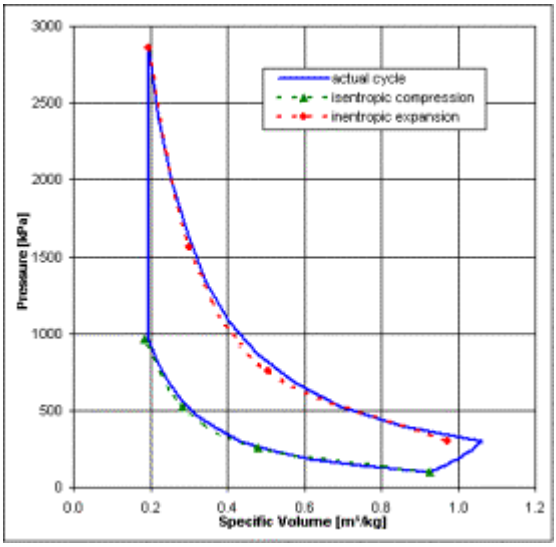


Figure 45. Otto Cycle P-V Diagram

Diesel Cycle

User Inputs

compression ratio	16.5	
compression eff.	90%	
expansion efficiency	90%	
combustion temp.	1000	°C
k=Cp/Cv	1.4	-
Cp	1.1	kJ/kg*C
R	0.314	kJ/kg*C

point	P	T	v	h	s
units	kPa	°C	m³/kg	kJ/kg	kJ/kg*C
1	101	25	0.925	0	0.000
1.1	154	66	0.693	45	0.010
1.2	222	106	0.536	89	0.018
1.3	310	147	0.426	134	0.026
1.4	419	188	0.346	179	0.033
1.5	552	228	0.286	224	0.040
1.6	711	269	0.240	268	0.045
1.7	900	310	0.204	313	0.051
1.8	1121	350	0.175	358	0.056
1.9	1378	391	0.152	403	0.061
2	1672	432	0.133	447	0.065
2.1	1672	489	0.143	510	0.151
2.2	1672	545	0.154	572	0.230
2.3	1672	602	0.165	635	0.304
2.4	1672	659	0.175	697	0.373
2.5	1672	716	0.186	760	0.438
2.6	1672	773	0.197	822	0.499

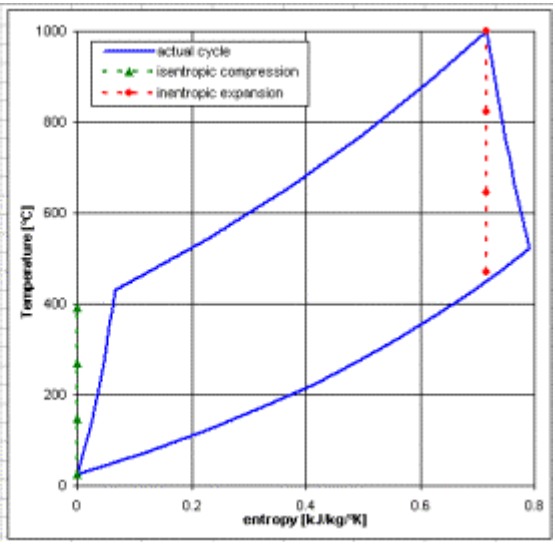


Figure 46. Diesel Cycle T-S Diagram

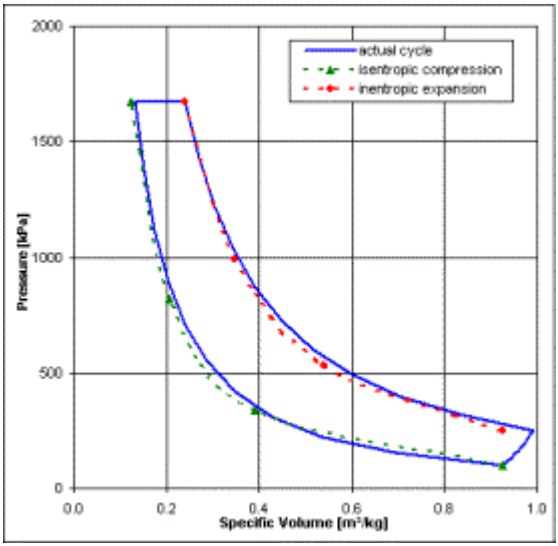


Figure 47. Diesel Cycle P-V Diagram

Brayton Cycle

User Inputs

compression ratio	5.9		
compression eff.	90%		
expansion efficiency	90%		
combustion temp.	1000	°C	
k=Cp/Cv	1.4	-	
Cp	1.1	kJ/kg°C	
R	0.314	kJ/kg°C	

point	P	T	v	h	s
units	kPa	°C	m³/kg	kJ/kg	kJ/kg°C
1	101	25	0.925	0	0.000
1.1	127	47	0.791	24	0.006
1.2	157	68	0.683	48	0.012
1.3	192	90	0.595	72	0.017
1.4	231	112	0.523	96	0.022
1.5	276	134	0.463	120	0.027
1.6	327	155	0.412	144	0.031
1.7	383	177	0.369	167	0.036
1.8	446	199	0.333	191	0.040
1.9	516	221	0.301	215	0.044
2	593	242	0.273	239	0.047
2.1	593	318	0.314	323	0.198
2.2	593	394	0.354	406	0.331
2.3	593	470	0.394	489	0.449
2.4	593	545	0.434	573	0.556
2.5	593	621	0.474	656	0.653
2.6	593	697	0.514	739	0.743

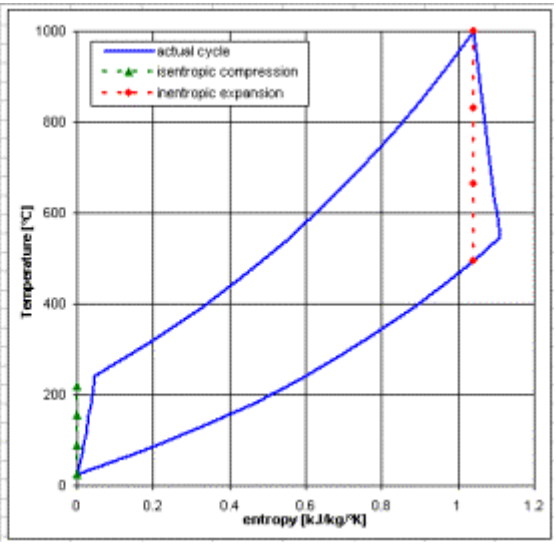


Figure 48. Brayton Cycle T-S Diagram

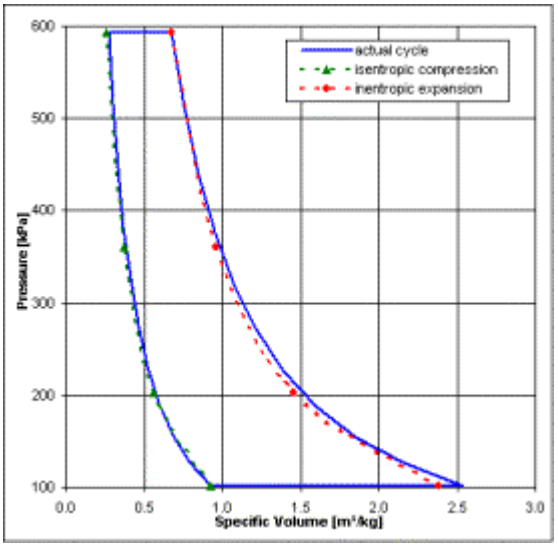


Figure 49. Brayton Cycle P-V Diagram

Chapter 21. Lenoir Cycle

Lenoir Cycle

User Inputs

expansion efficiency	90%		
combustion temp.	958	°C	
k=Cp/Cv	1.4	-	
Cp	1.1	kJ/kg°C	
R	0.314	kJ/kg°C	

point	P	T	v	h	s
units	kPa	°C	m³/kg	kJ/kg	kJ/kg°C
1	101	25	0.925	0	0.000
1.1	133	118	0.925	102	0.212
1.2	164	210	0.925	204	0.379
1.3	196	303	0.925	305	0.517
1.4	227	395	0.925	407	0.634
1.5	259	488	0.925	509	0.736
1.6	290	580	0.925	611	0.826
1.7	321	673	0.925	712	0.907
1.8	353	765	0.925	814	0.980
1.9	384	858	0.925	916	1.047
2	416	950	0.925	1018	1.109
2.1	368	913	1.012	977	1.114
2.2	325	877	1.111	937	1.118
2.3	286	840	1.223	897	1.123
2.4	251	804	1.351	857	1.128
2.5	218	767	1.497	817	1.133
2.6	189	731	1.665	776	1.139
2.7	163	694	1.860	736	1.144
2.8	140	658	2.086	696	1.150

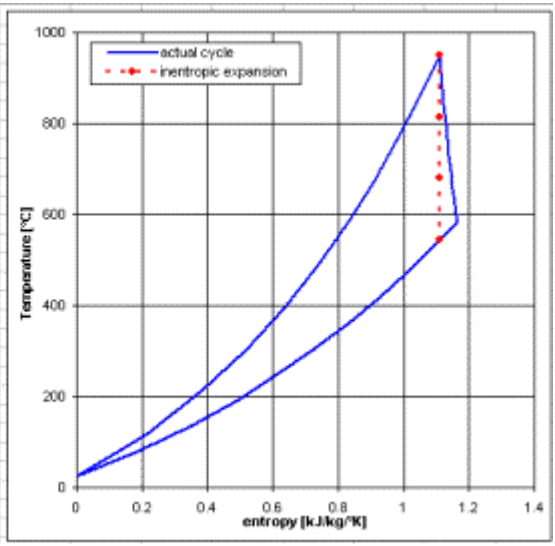


Figure 50. Lenoir Cycle T-S Diagram

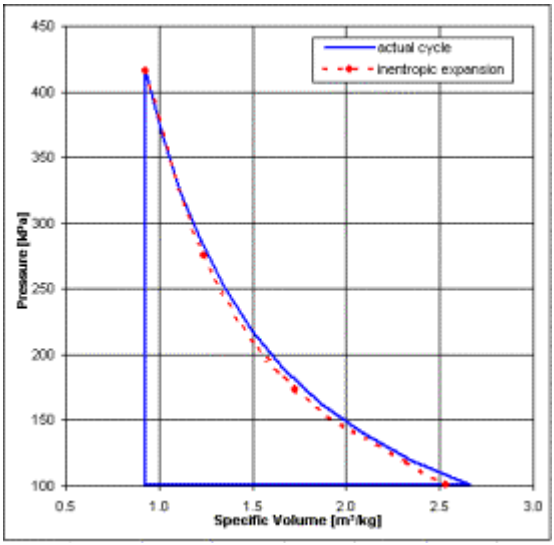


Figure 51. Lenoir Cycle P-V Diagram

Stirling Cycle

User Inputs

compression ratio	9.5		
combustion temp.	950	°C	
k=Cp/Cv	1.4	-	
Cp	1.1	kJ/kg/°C	
R	0.314	kJ/kg/°C	

point	P	T	v	h	s
units	kPa	°C	m³/kg	kJ/kg	kJ/kg/°C
1	101	25	0.925	0	0.000
1.1	127	25	0.738	0	-0.071
1.2	159	25	0.590	0	-0.142
1.3	199	25	0.471	0	-0.212
1.4	249	25	0.376	0	-0.283
1.5	312	25	0.300	0	-0.354
1.6	391	25	0.240	0	-0.425
1.7	490	25	0.191	0	-0.495
1.8	614	25	0.153	0	-0.566
1.9	769	25	0.122	0	-0.637
2	963	25	0.097	0	-0.708
2.1	1261	118	0.097	102	-0.495
2.2	1560	210	0.097	204	-0.326
2.3	1859	303	0.097	305	-0.191
2.4	2157	395	0.097	407	-0.074
2.5	2456	488	0.097	509	0.028
2.6	2754	580	0.097	611	0.119
2.7	3053	673	0.097	712	0.199
2.8	3352	765	0.097	814	0.273

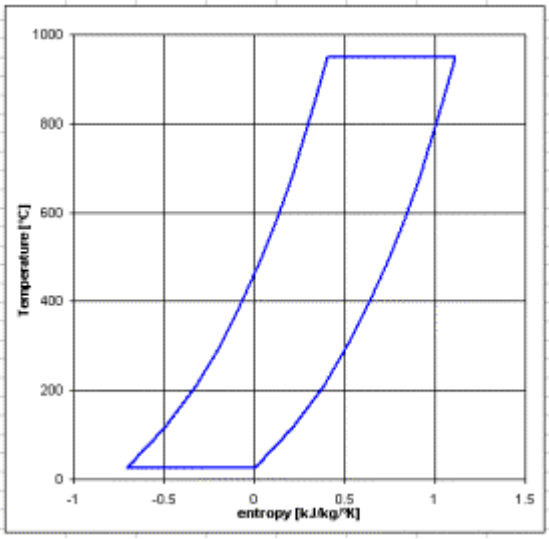


Figure 52. Sterling Cycle T-S Diagram

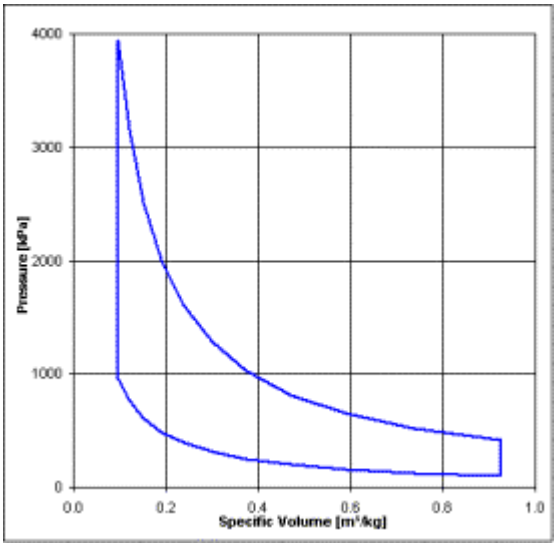


Figure 53. Sterling Cycle P-V Diagram

Ericsson Cycle

User Inputs

compression ratio	9.5		
combustion temp.	950	°C	
k=Cp/Cv	1.4	-	
Cp	1.1	kJ/kg/°C	
R	0.314	kJ/kg/°C	

point	P	T	v	h	s
units	kPa	°C	m³/kg	kJ/kg	kJ/kg/°C
1	101	25	0.925	0	0.000
1.1	127	25	0.738	0	-0.071
1.2	159	25	0.590	0	-0.142
1.3	199	25	0.471	0	-0.212
1.4	249	25	0.376	0	-0.283
1.5	312	25	0.300	0	-0.354
1.6	391	25	0.240	0	-0.425
1.7	490	25	0.191	0	-0.495
1.8	614	25	0.153	0	-0.566
1.9	769	25	0.122	0	-0.637
2	963	25	0.097	0	-0.708
2.1	963	118	0.128	102	-0.410
2.2	963	210	0.158	204	-0.177
2.3	963	303	0.188	305	0.016
2.4	963	395	0.218	407	0.180
2.5	963	488	0.248	509	0.323
2.6	963	580	0.279	611	0.449
2.7	963	673	0.309	712	0.562
2.8	963	765	0.339	814	0.665

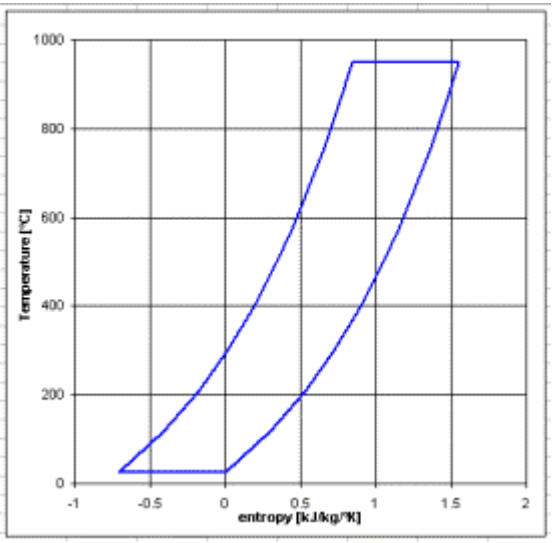


Figure 54. Ericsson Cycle T-S Diagram

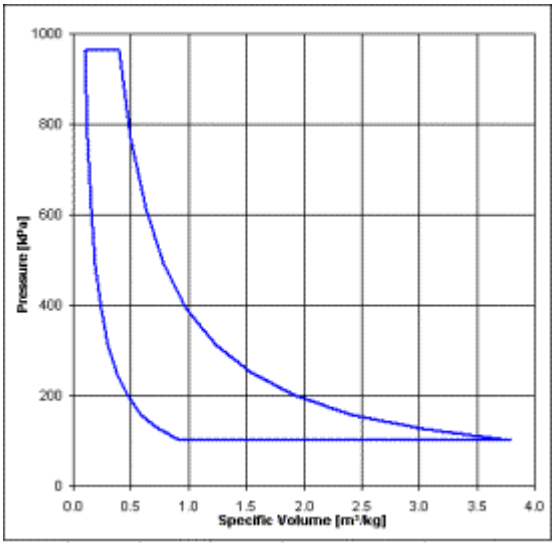


Figure 55. Ericsson Cycle P-V Diagram

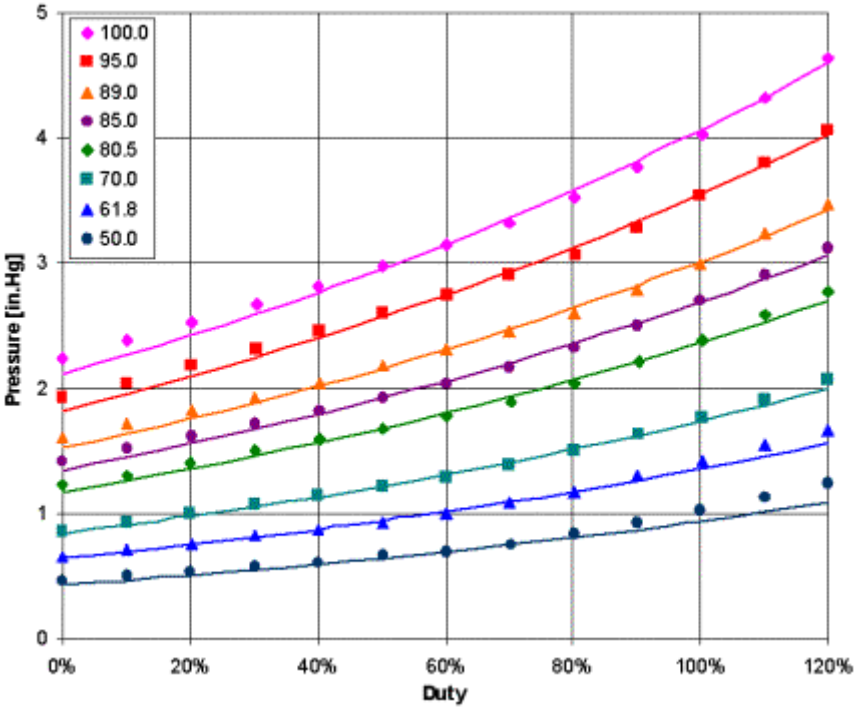


Figure 56. Typical WCC Curves

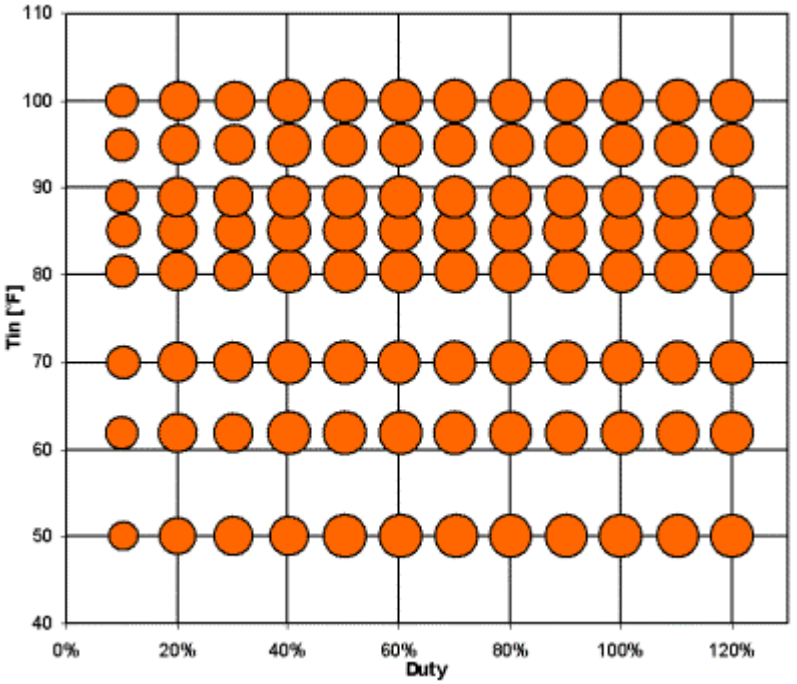


Figure 57. WCC Duty Points

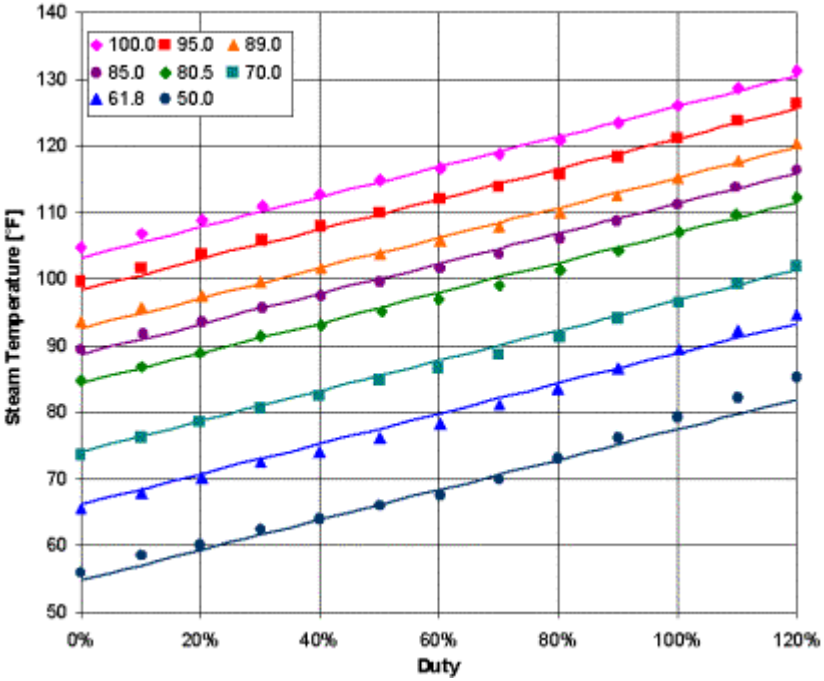


Figure 58. WCC Transform Curves

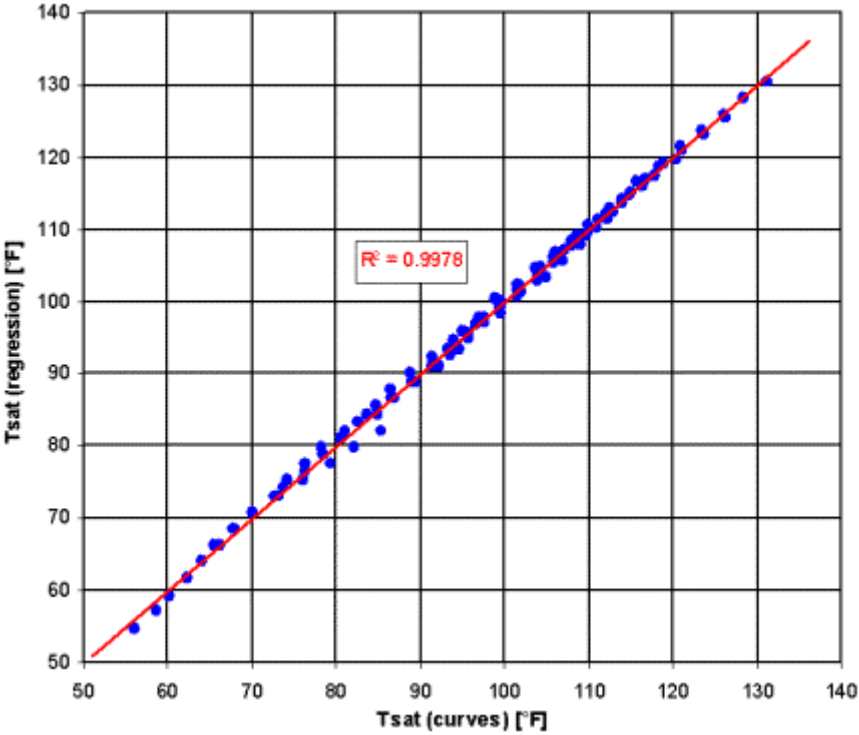
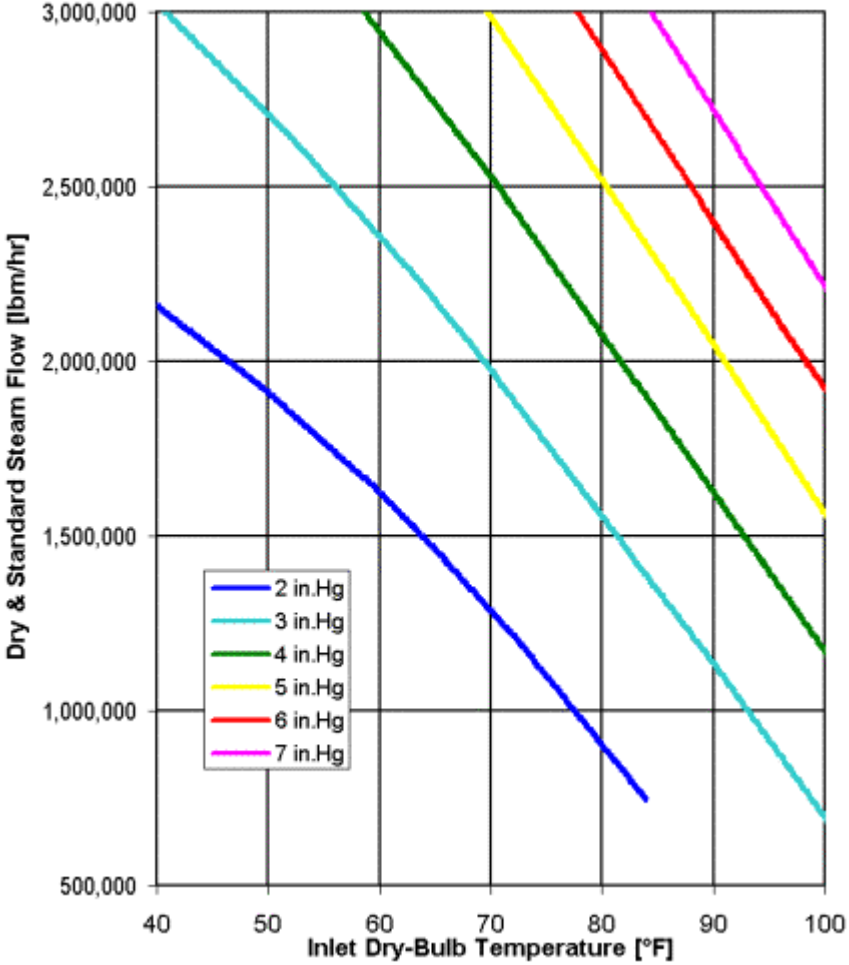


Figure 59. WCC Curve Regession


3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
Dry & Standard Steam Flow [lbm/hr]
40
50
60
70
80
90
100
Inlet Dry-Bulb Temperature [°F]
2 in.Hg
3 in.Hg
4 in.Hg
5 in.Hg
6 in.Hg
7 in.Hg

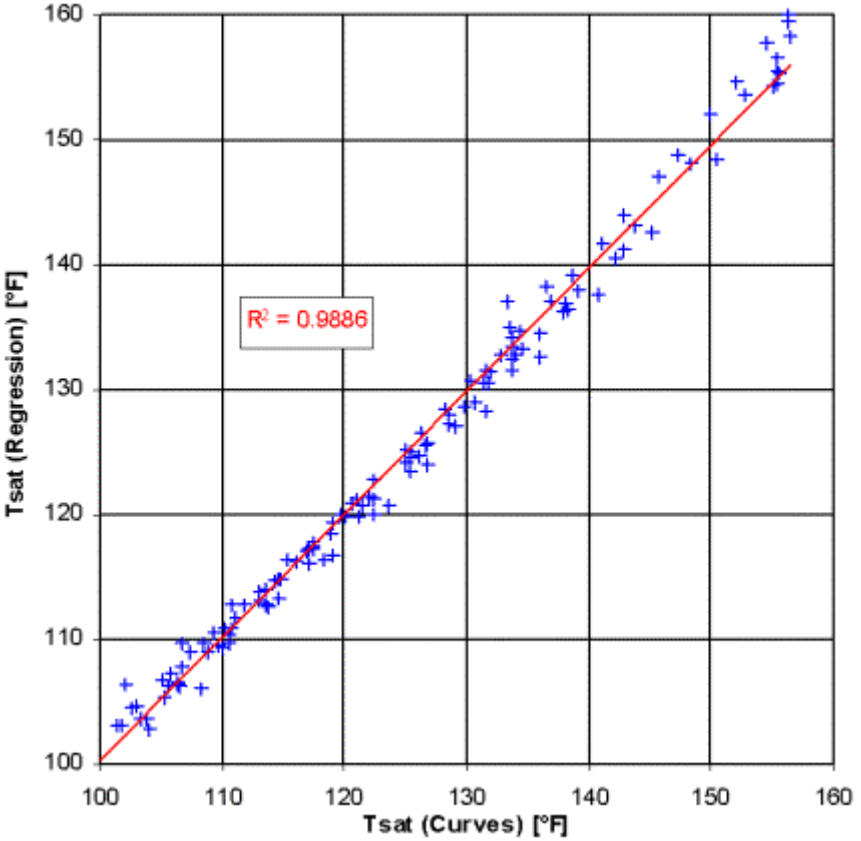


Figure 61. ACC Curve Regression

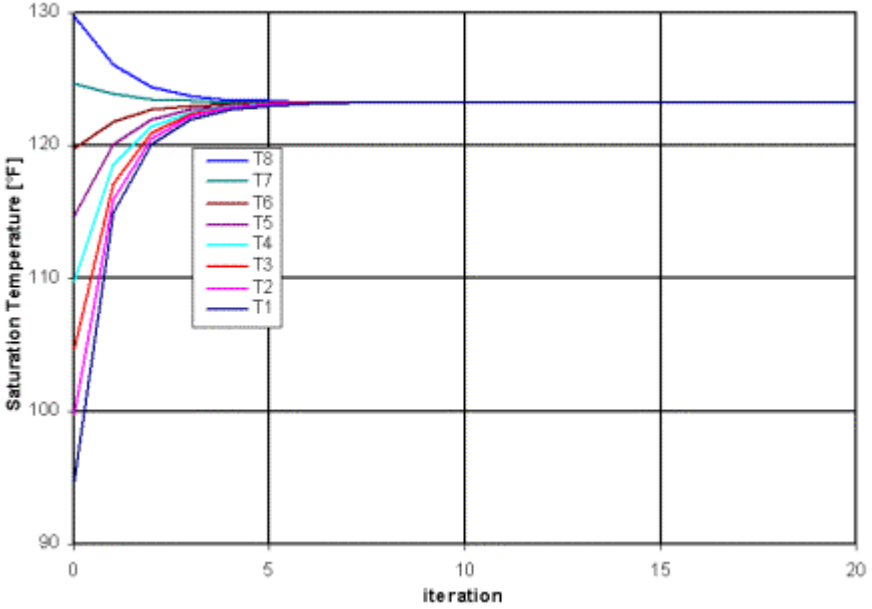


Figure 62. Results of Iteration

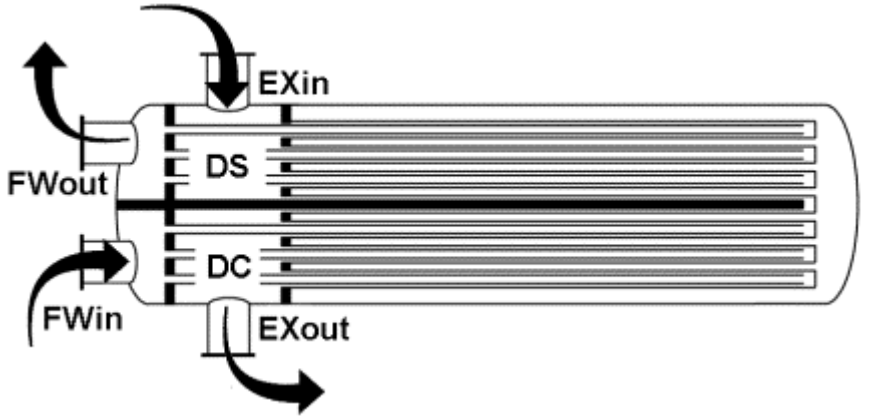


Figure 63. Typical Feedwater Heater

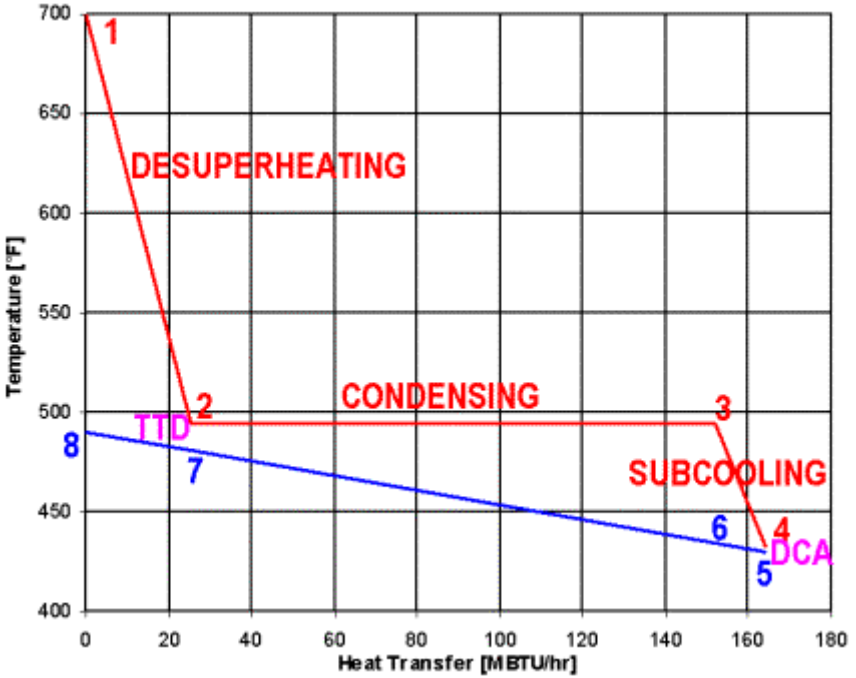


Figure 64. FWH Process Lines (Temperature)

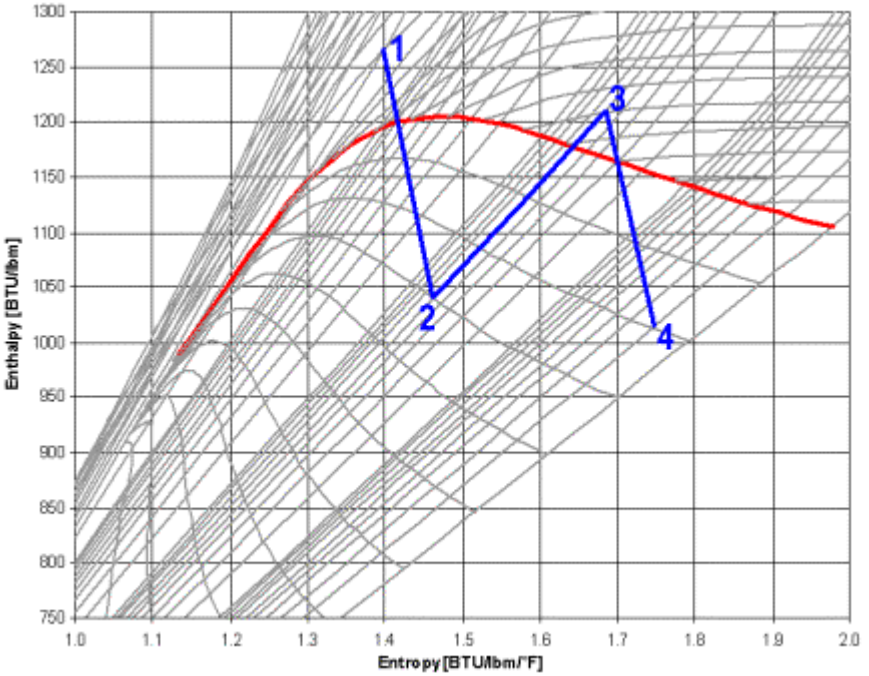


Figure 65. Steam Turbine Expansion Lines (Nuclear)

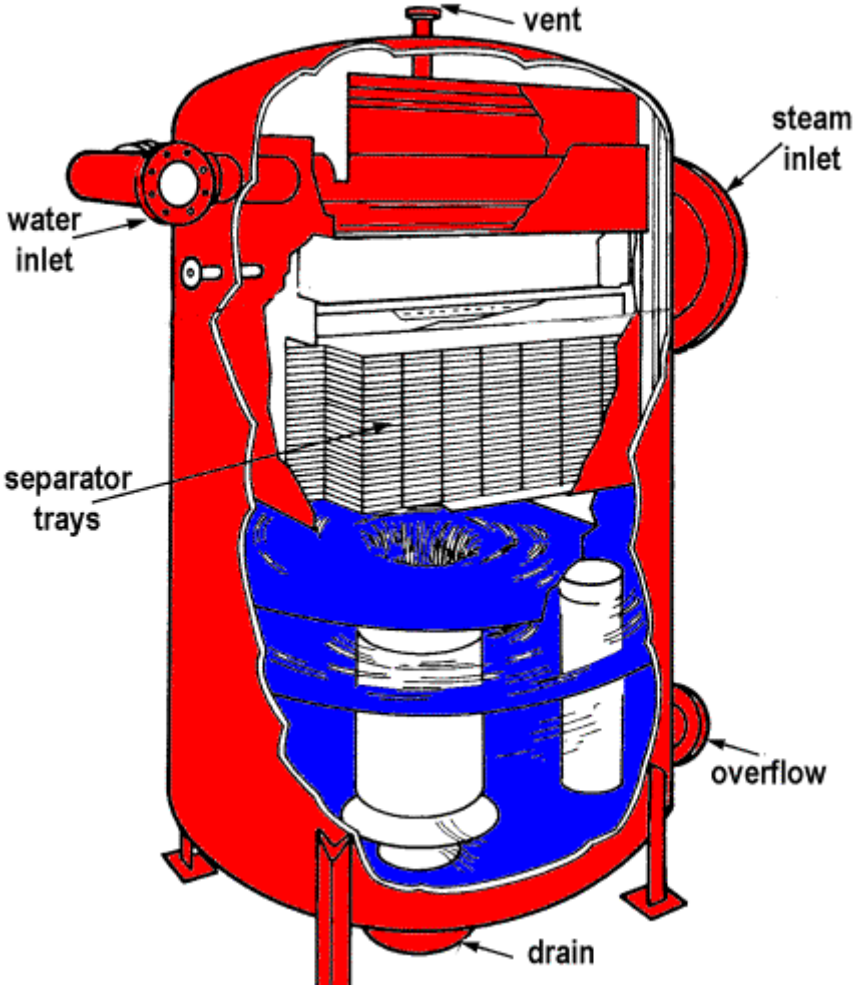


Figure 66. Deaerator

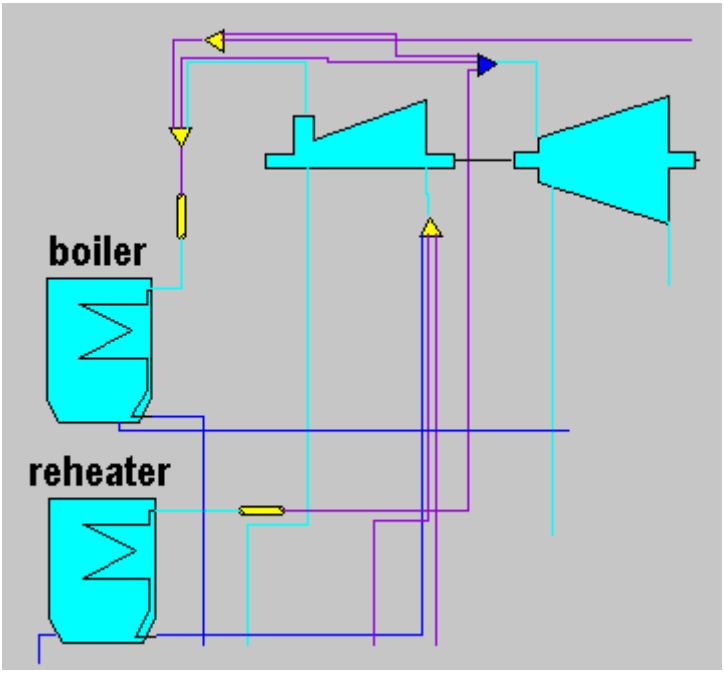


Figure 67. Boiler and Reheater Schematic

Figure 68. Pipes and Valves in a Power Plant

Figure 69. Pumps in a Power Plant

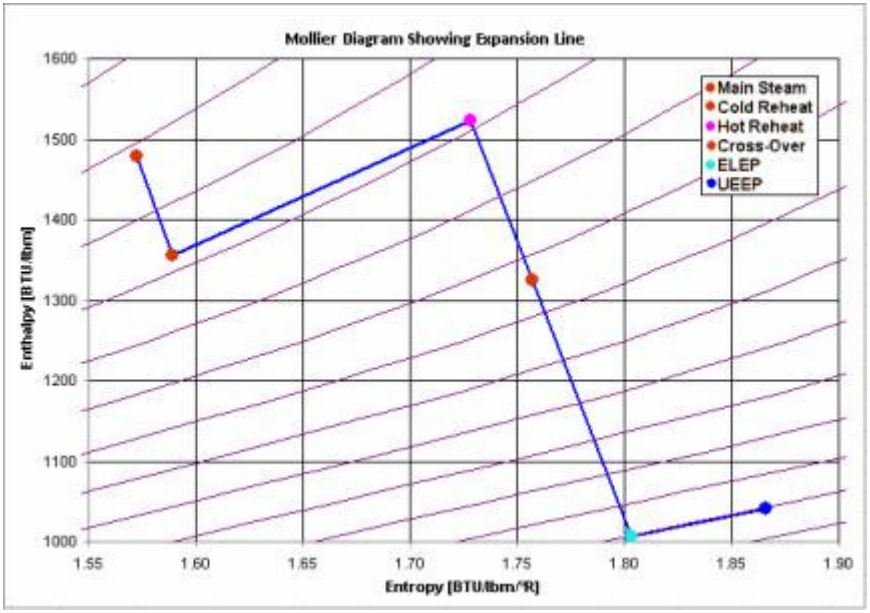


Figure 70. Expansion Line

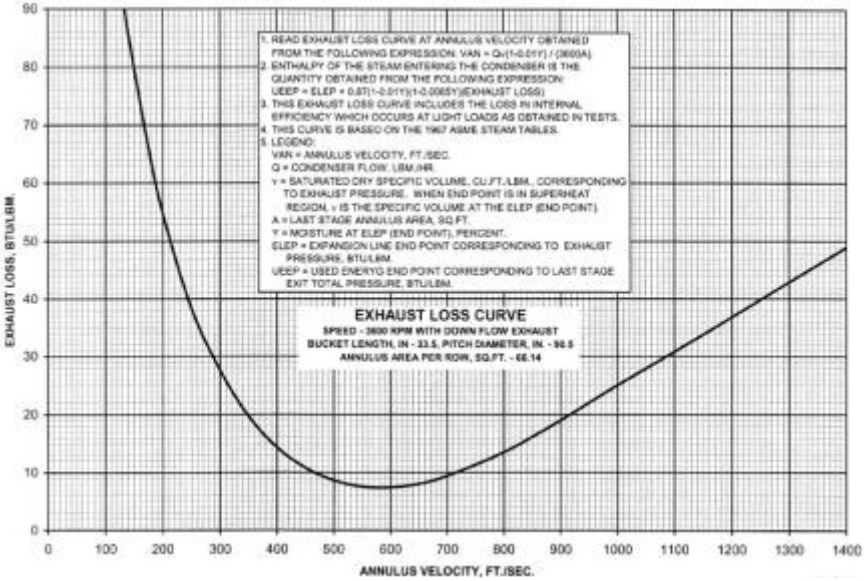


Figure 71. Exhaust Loss Curve

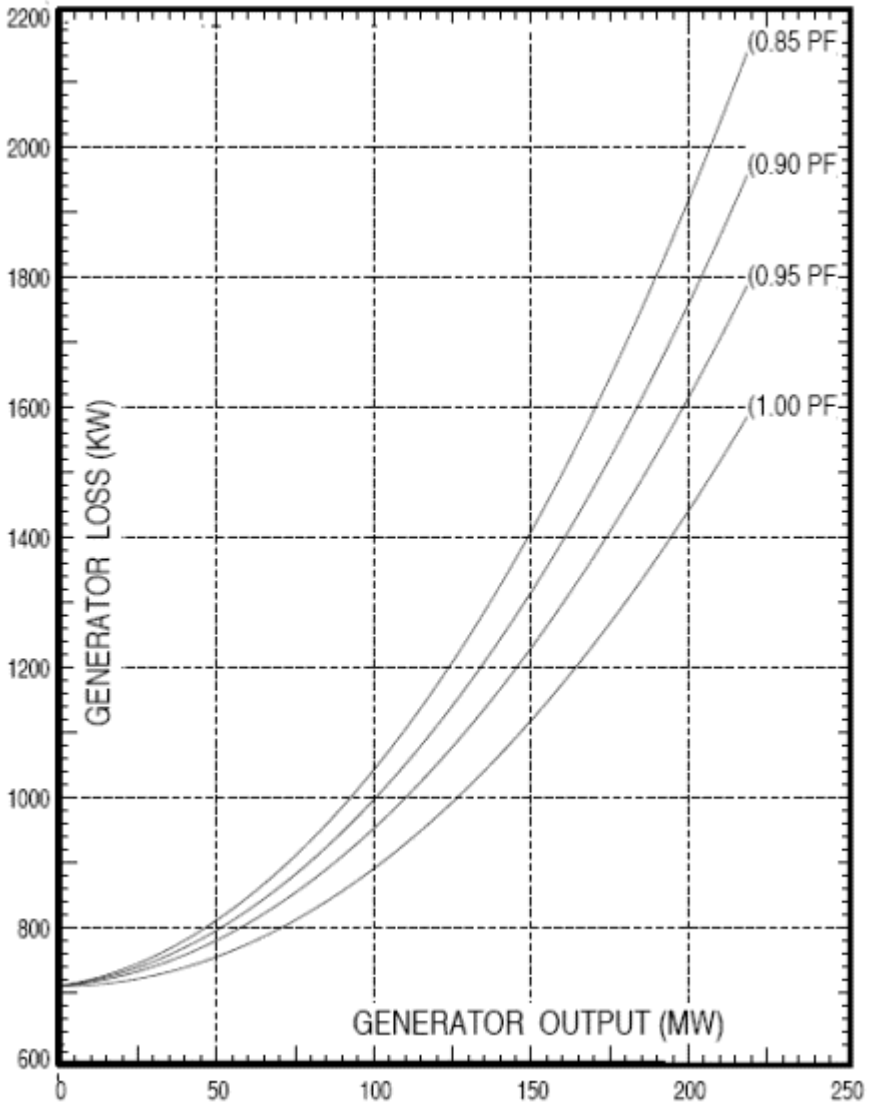


Figure 72. Typical Generator Loss Curves

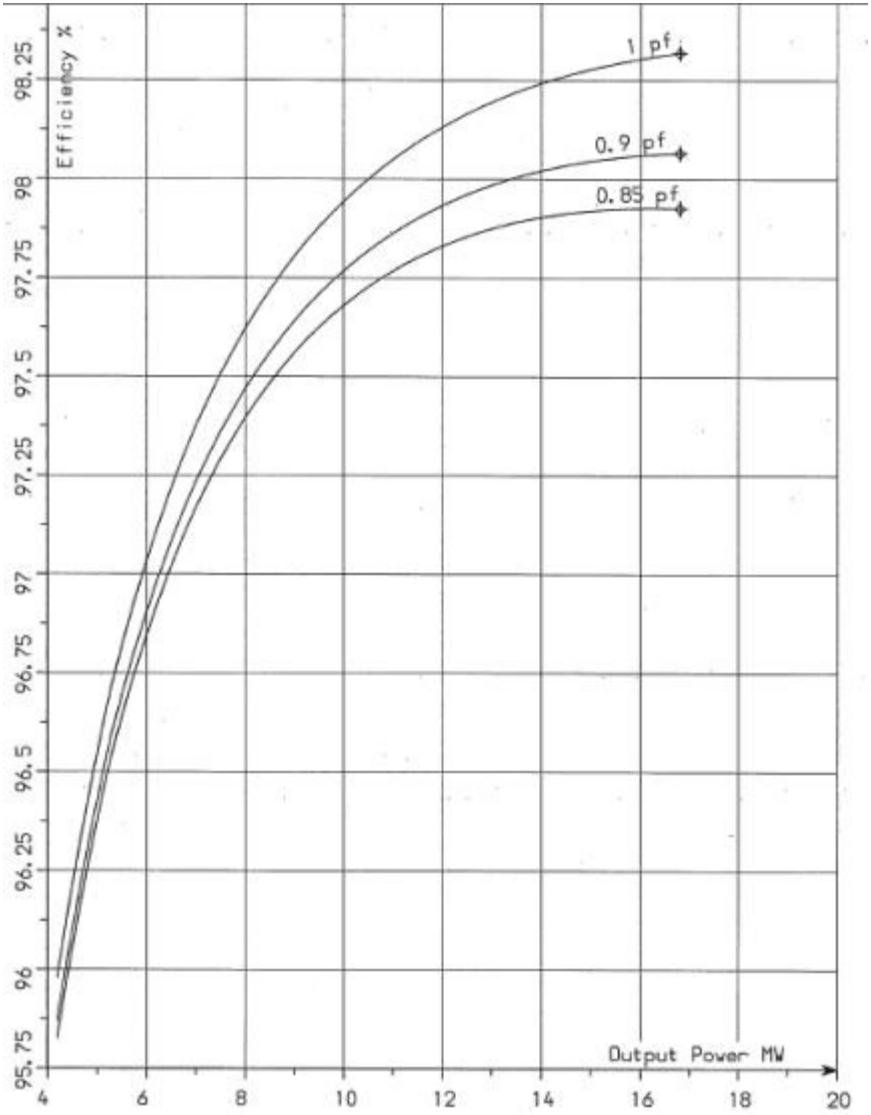


Figure 73. Typical Generator Efficiency Curves

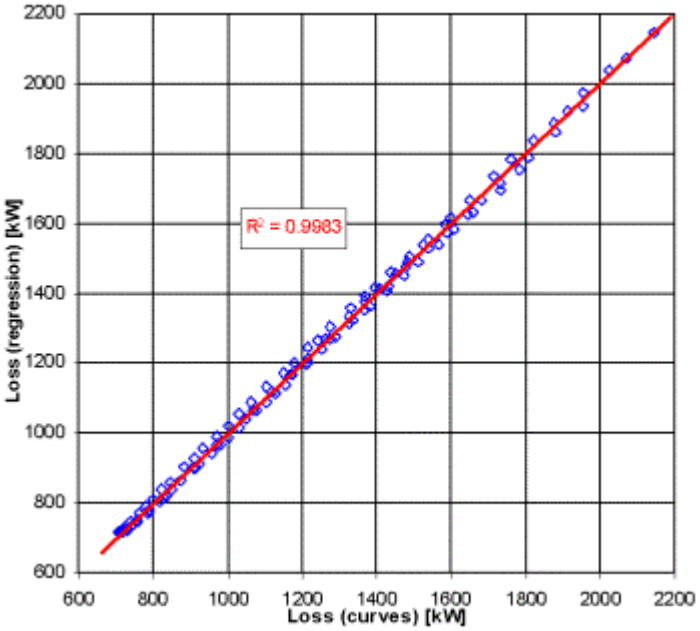


Figure 74. Generator Curve Regression

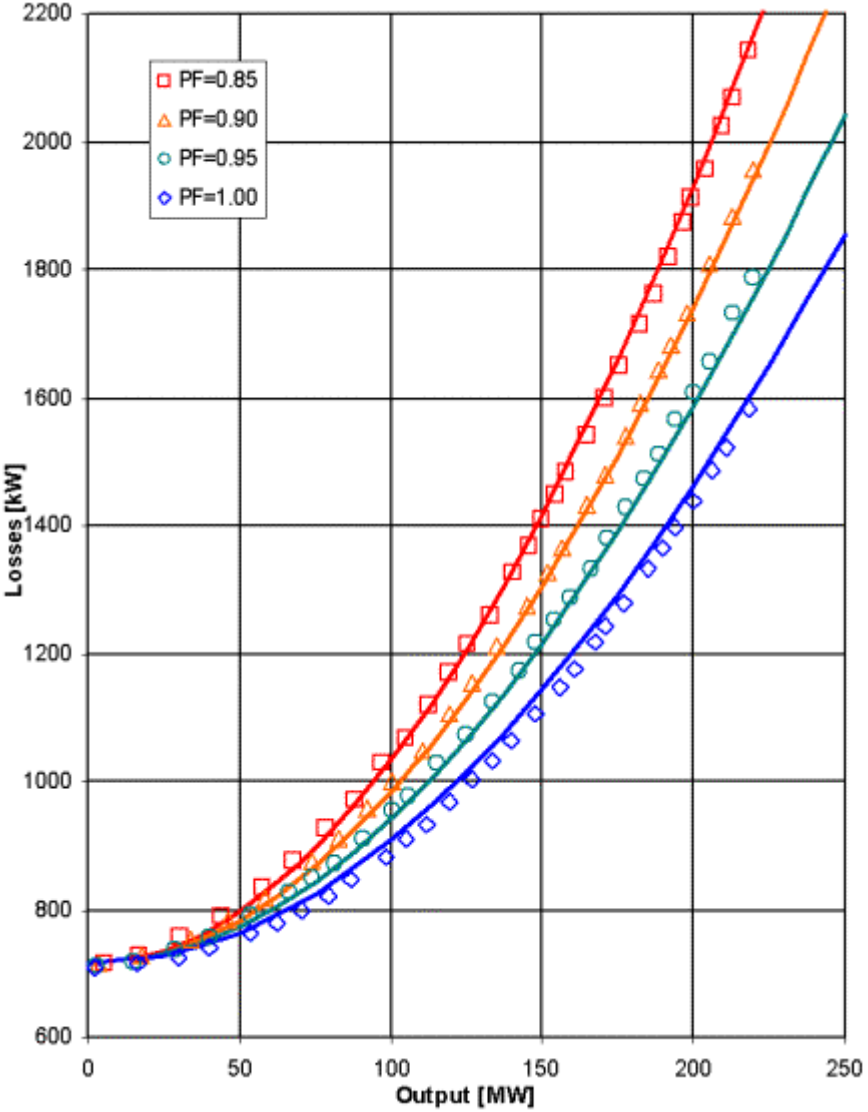


Figure 75. Results of Regression for Losses

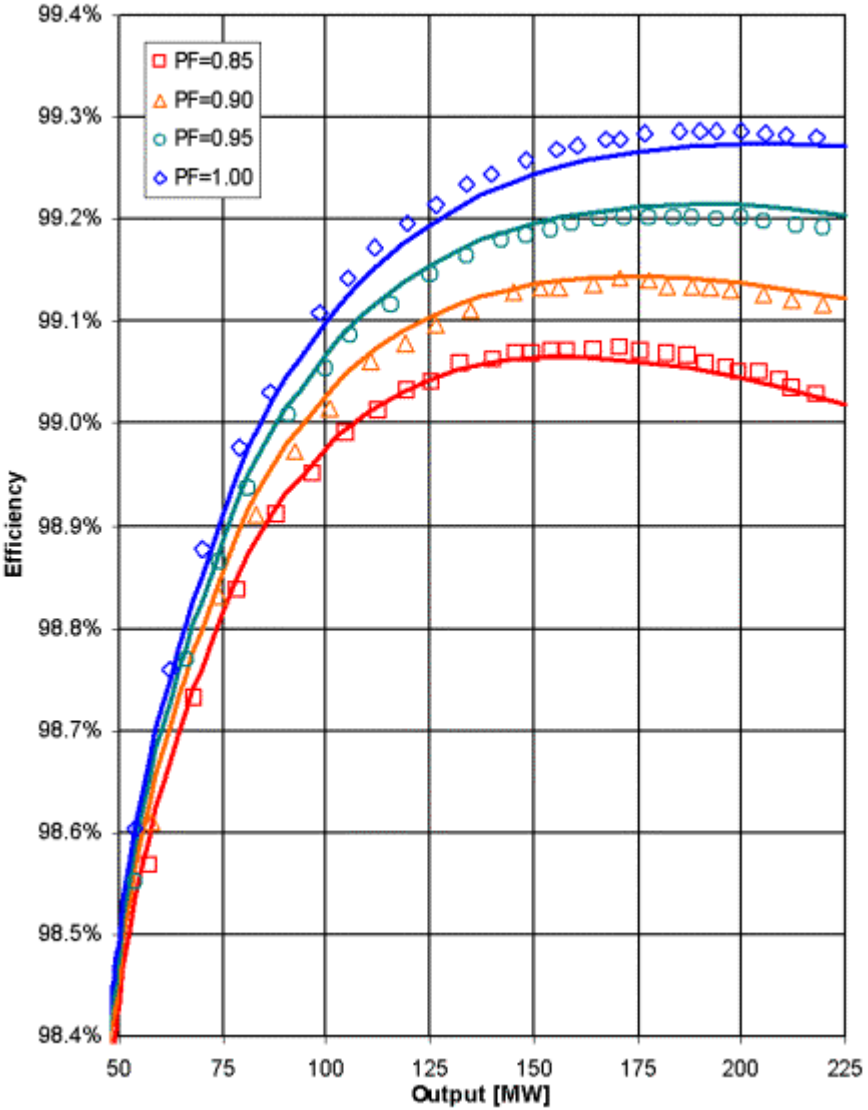


Figure 76. Results of Regression for Efficiency

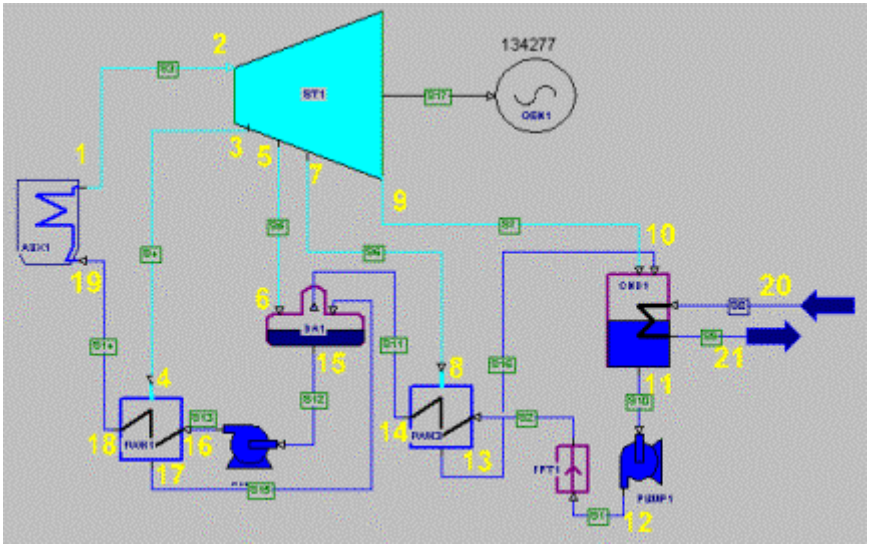


Figure 77. Simple Rankine Cycle

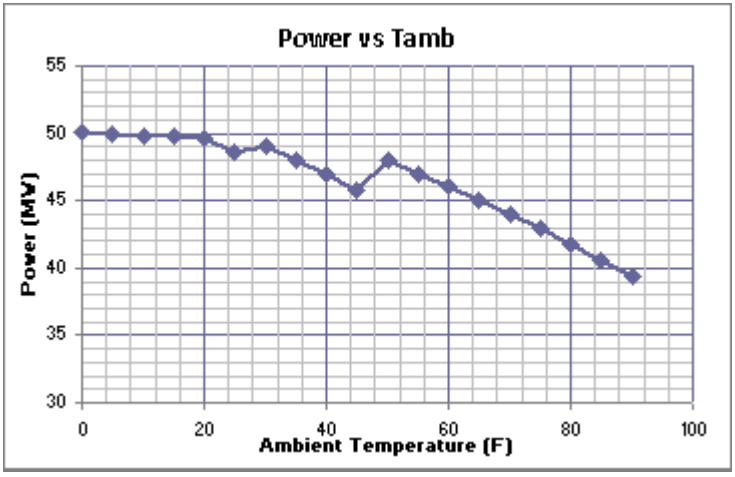


Figure 78. Impact of Ambient Temperature on Power

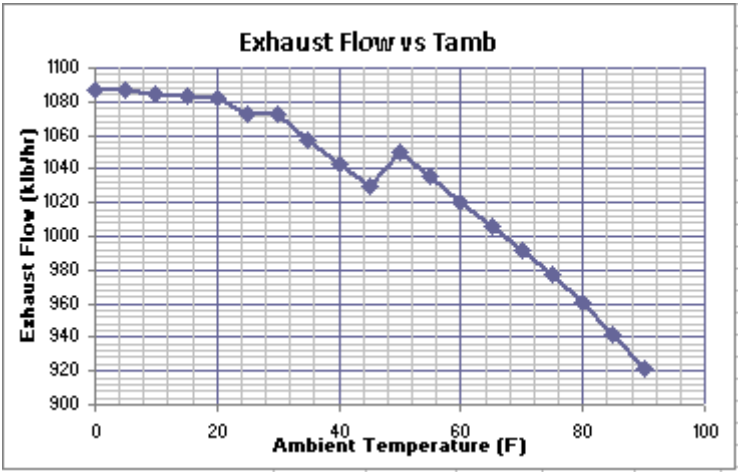


Figure 79. Impact of Ambient Temperature on Exhaust Flow

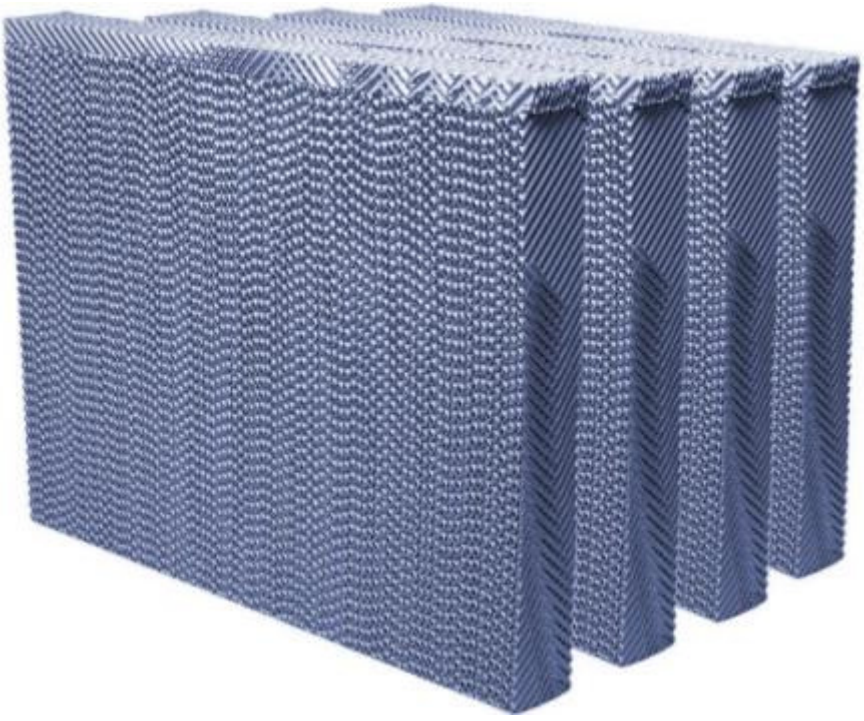


Figure 80. Typical GT Evaporative Cooler

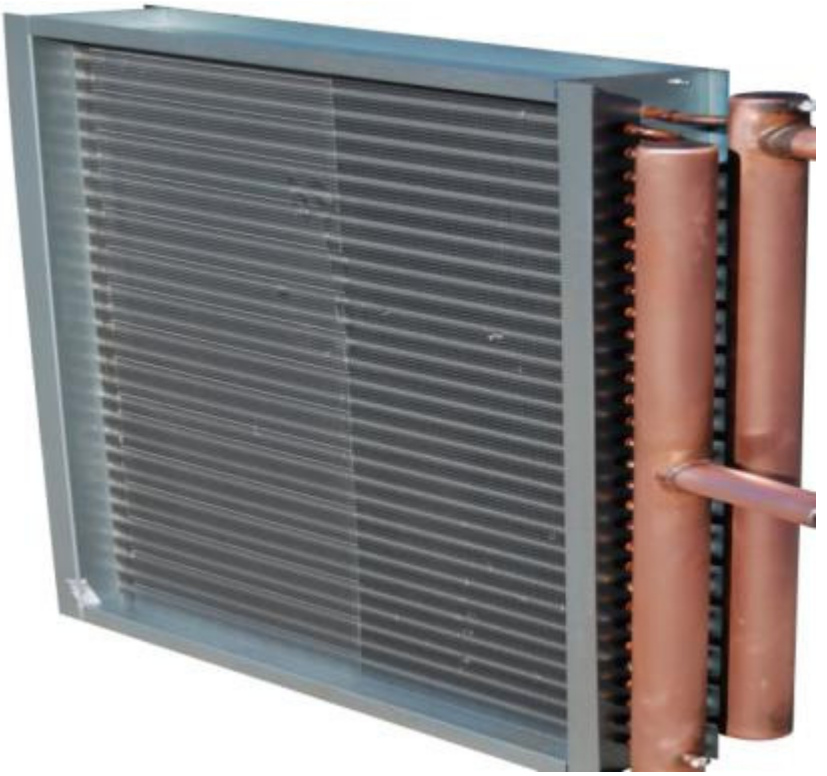


Figure 81. Typical GT Inlet Chiller

.

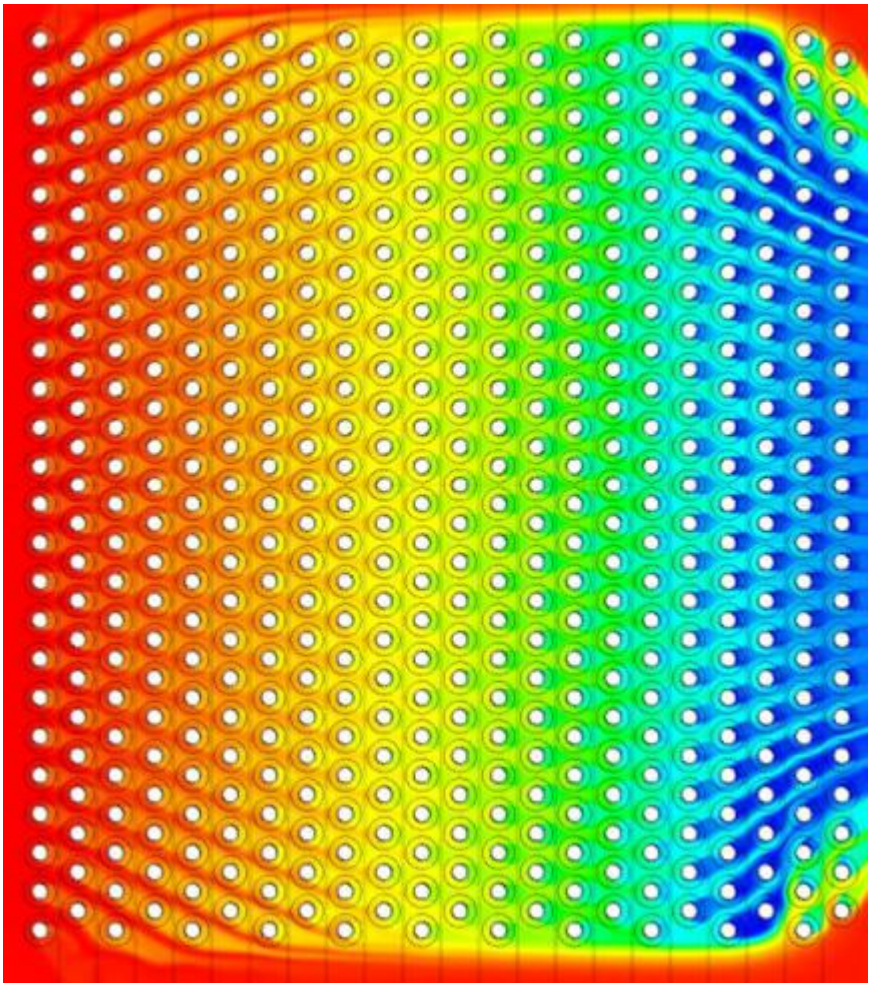


Figure 82. Temperature Distribution in an Economizer

Figure 83. Typical Enhanced Surface Tubes

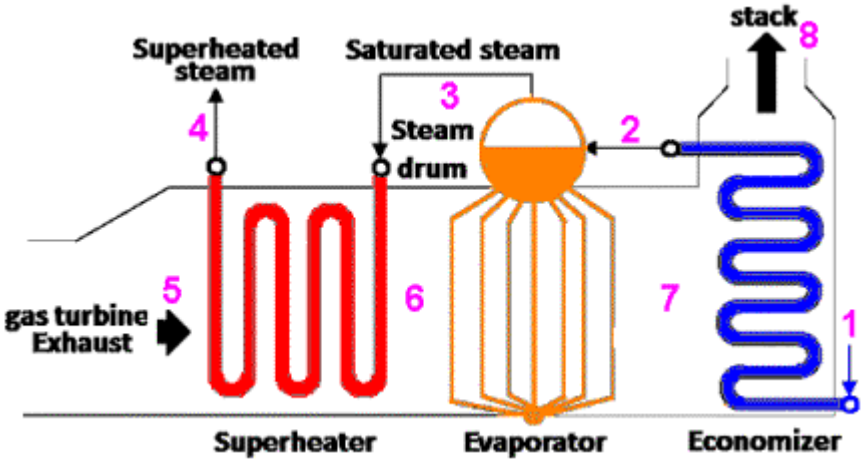


Figure 84. Typical HRSG Evaporator Schematic

Figure 85. Typical HRSG Superheater Tubes Showing Ageing

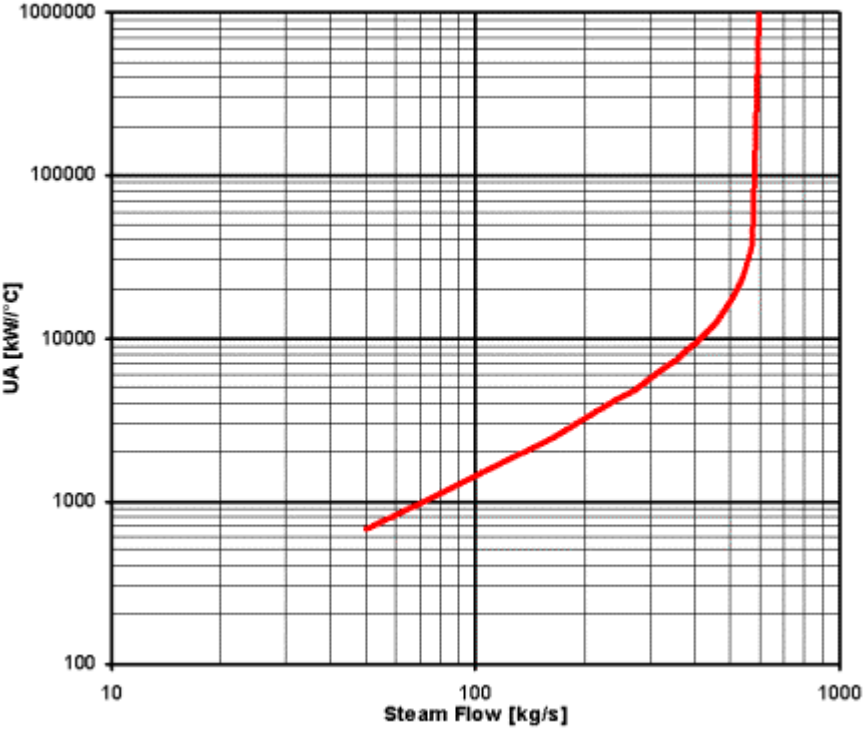


Figure 86. Overall Conductance vs. Steam Flow

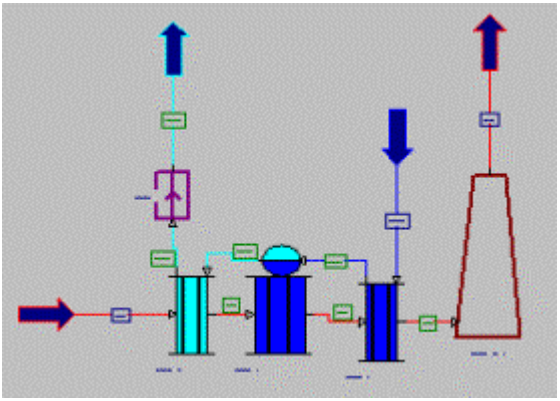


Figure 87. Minimal HRSG Components

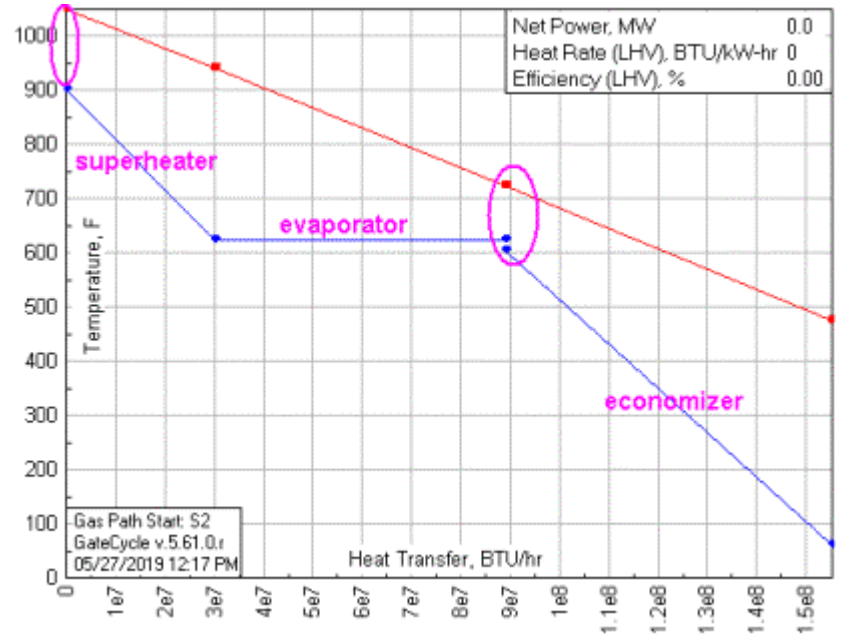


Figure 88. Heat Release Diagram

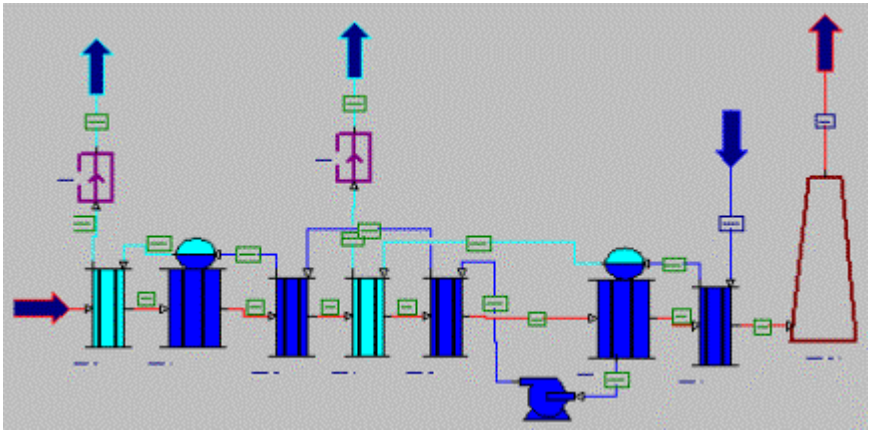


Figure 89. Two-Pressure HRSG Schematic

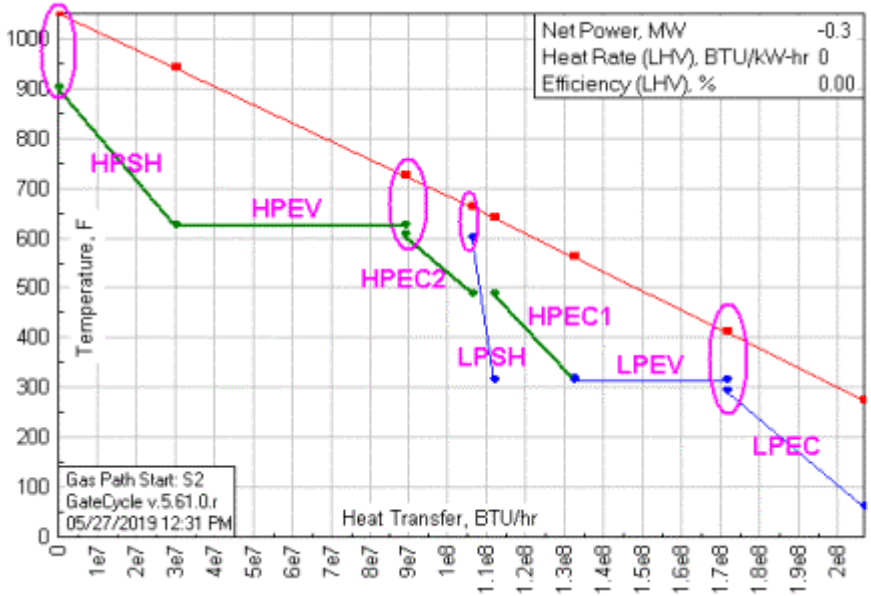


Figure 90. Two-Pressure HRSG Heat Release Diagram

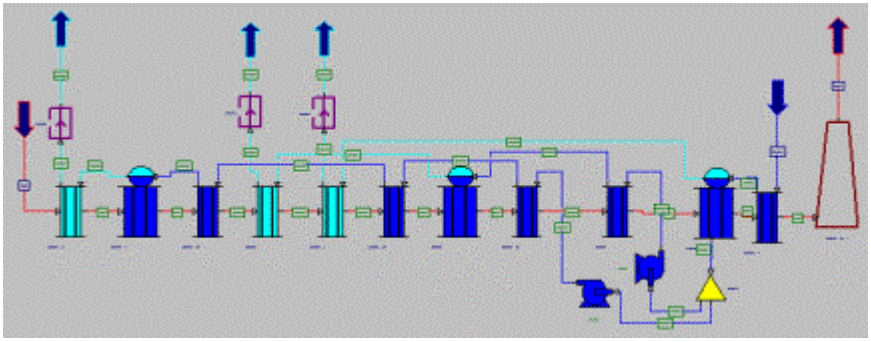


Figure 91. Three-Pressure HRSG Schematic

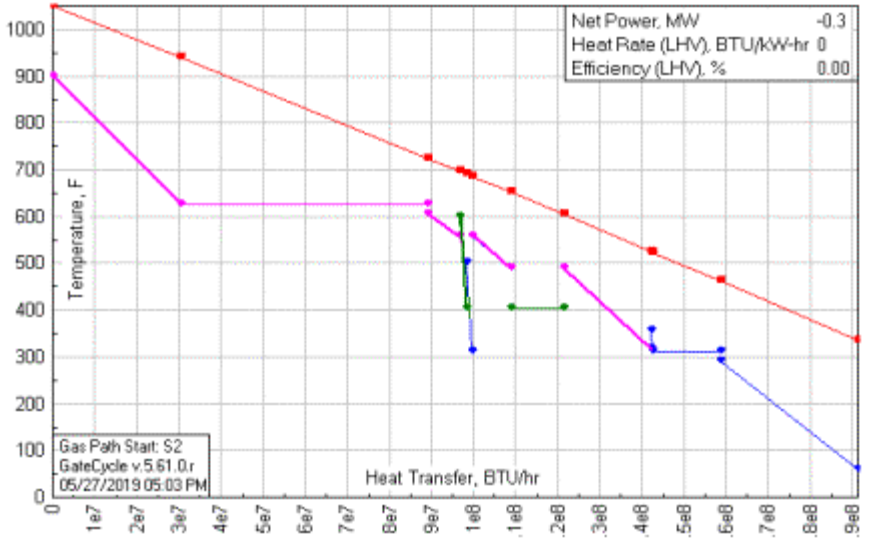


Figure 92. Three-Pressure HRSG Heat Release Diagram

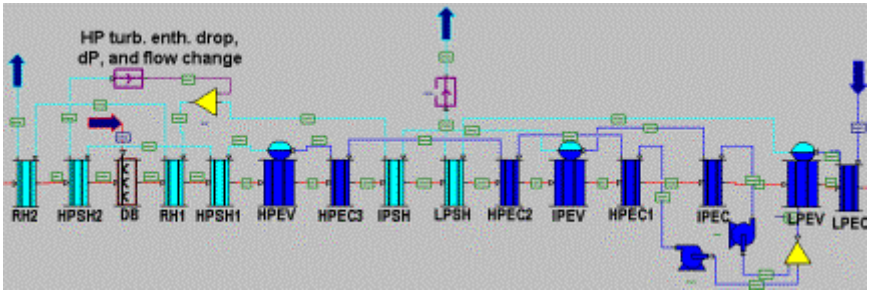


Figure 93. Schematic Showing Reheater and Duct Burner

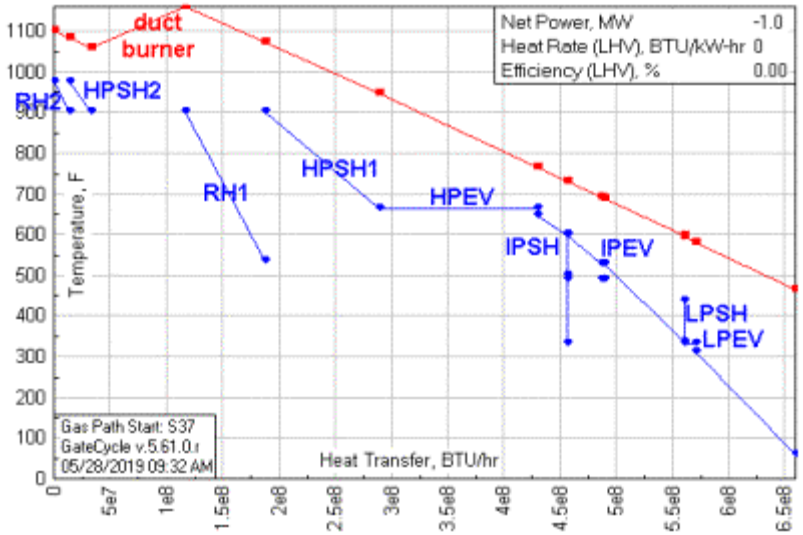


Figure 94. Heat Release Diagram Showing Reheater and Duct Burner

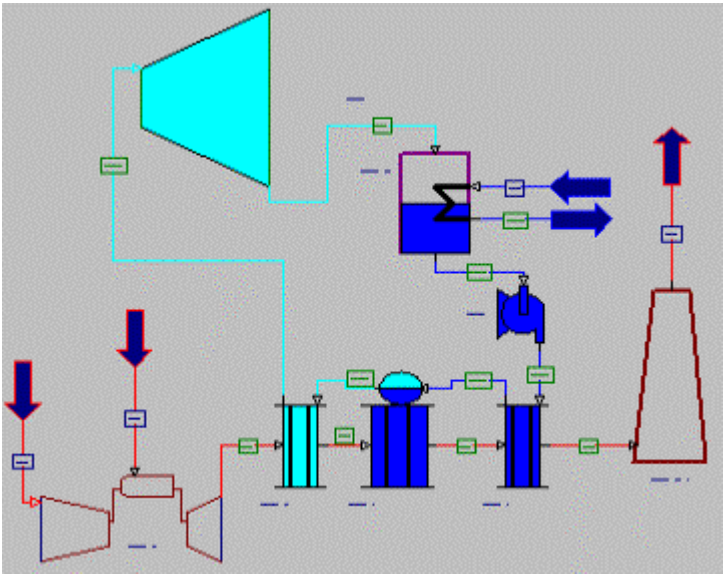


Figure 95. Simple Cycle Schematic

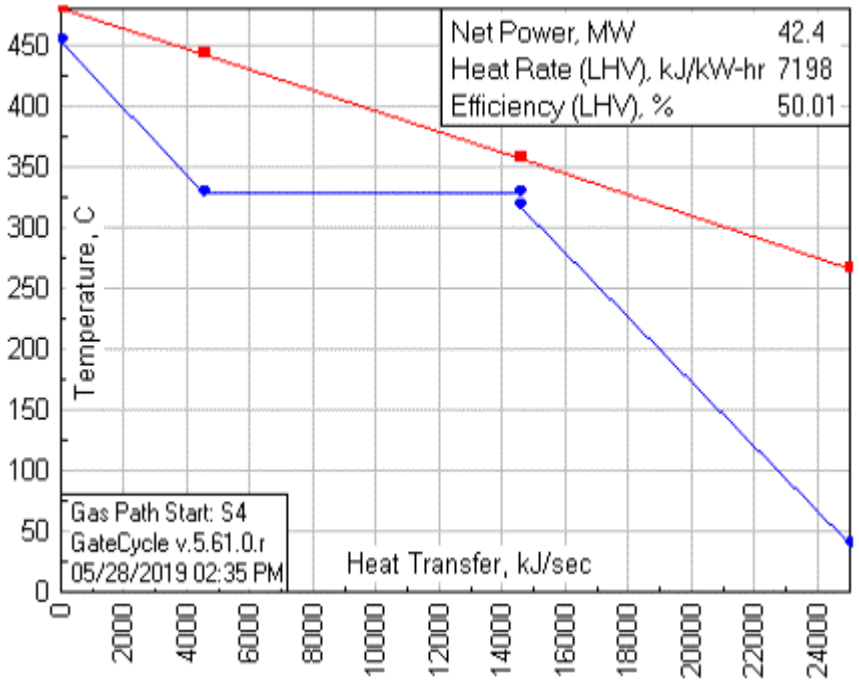


Figure 96. Simple Cycle Heat Release Diagram

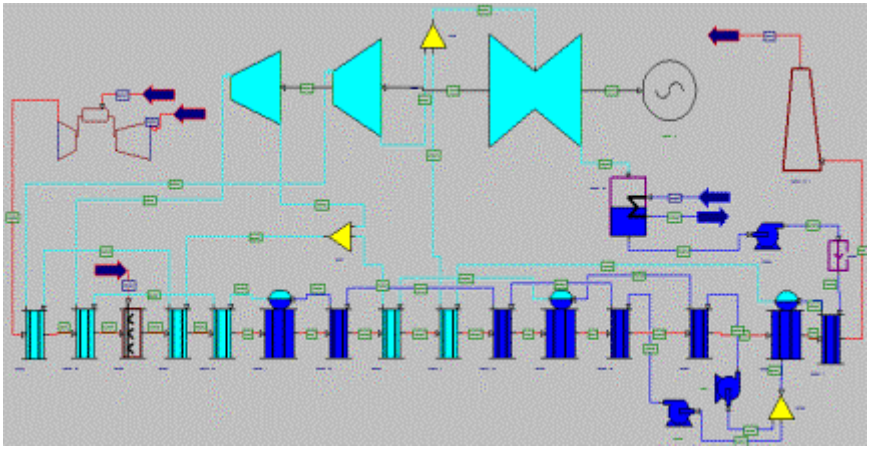


Figure 97. System Schematic

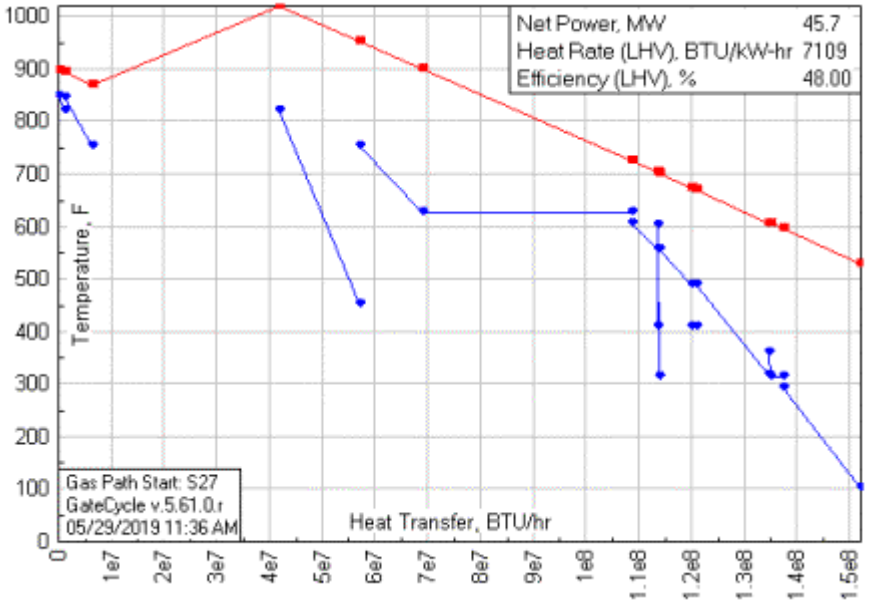


Figure 98. Heat Release Diagram

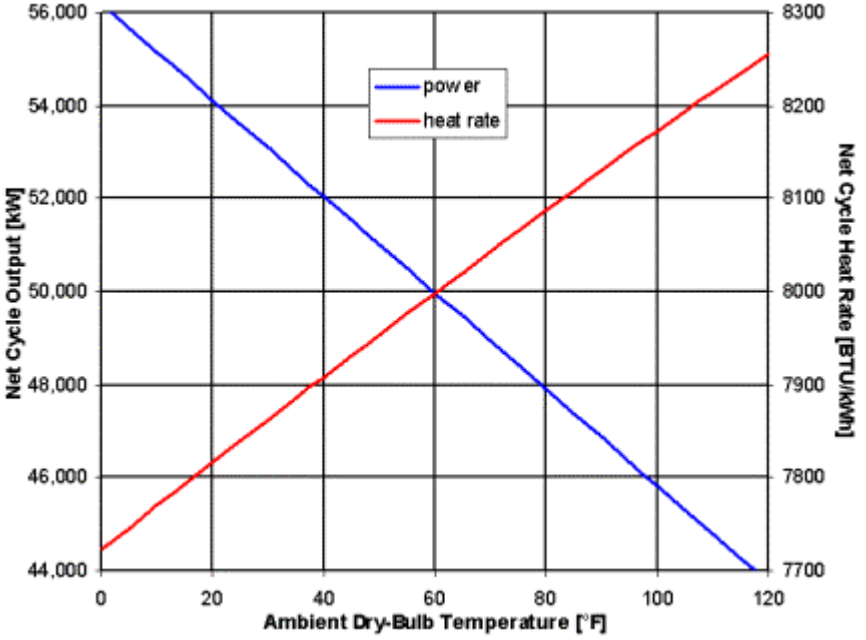


Figure 99. Temperature Correction Curves

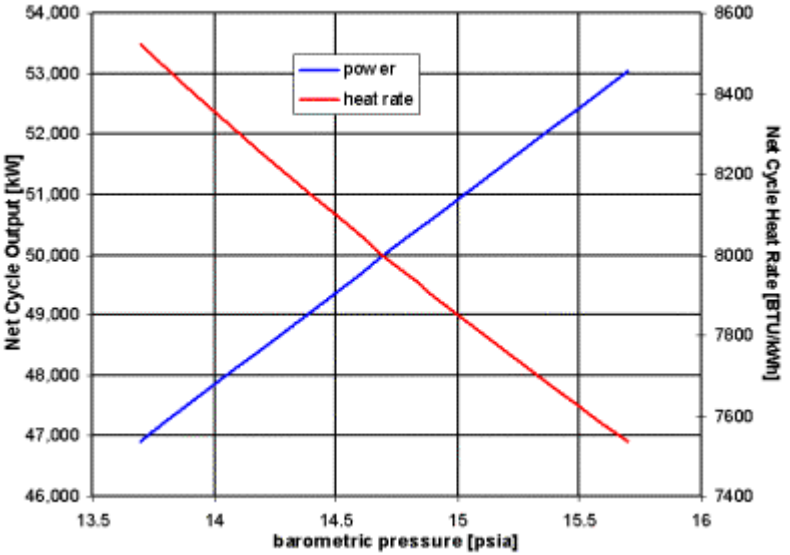


Figure 100. Pressure Correction Curves

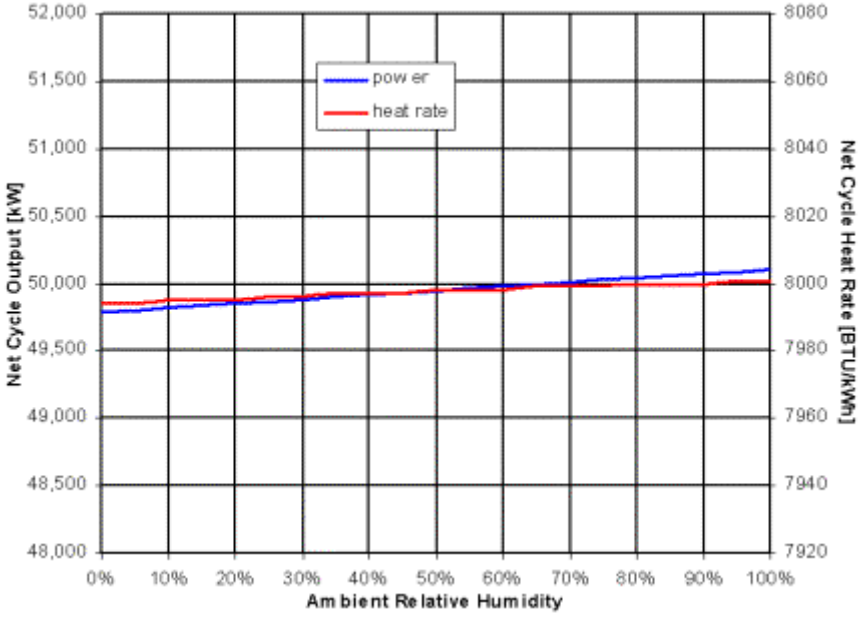


Figure 101. Impact of Relative Humidity

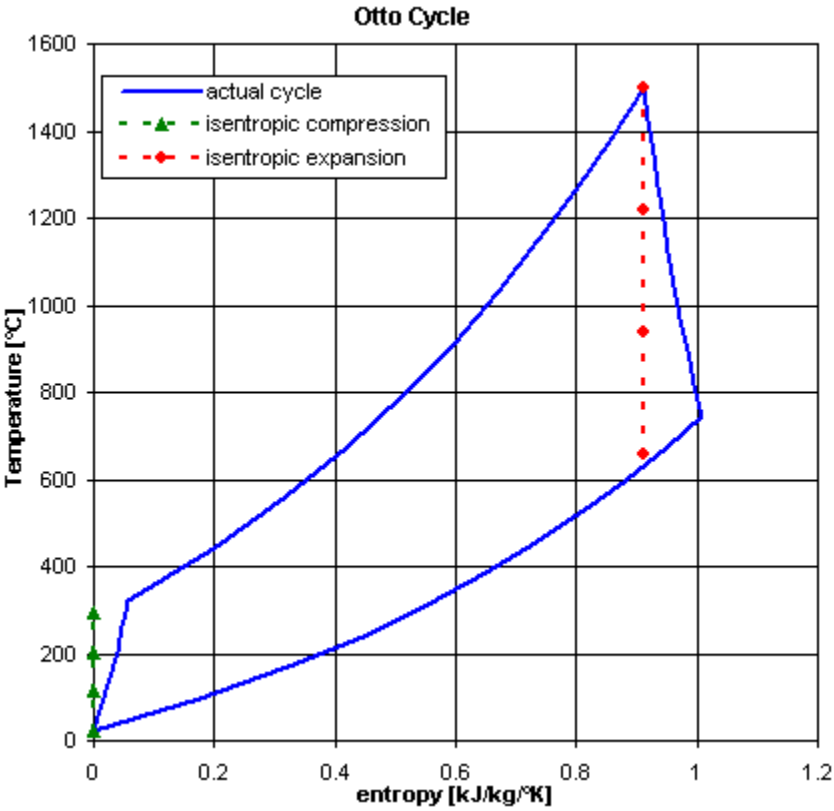


Figure 102. Otto Cycle T-S Diagram

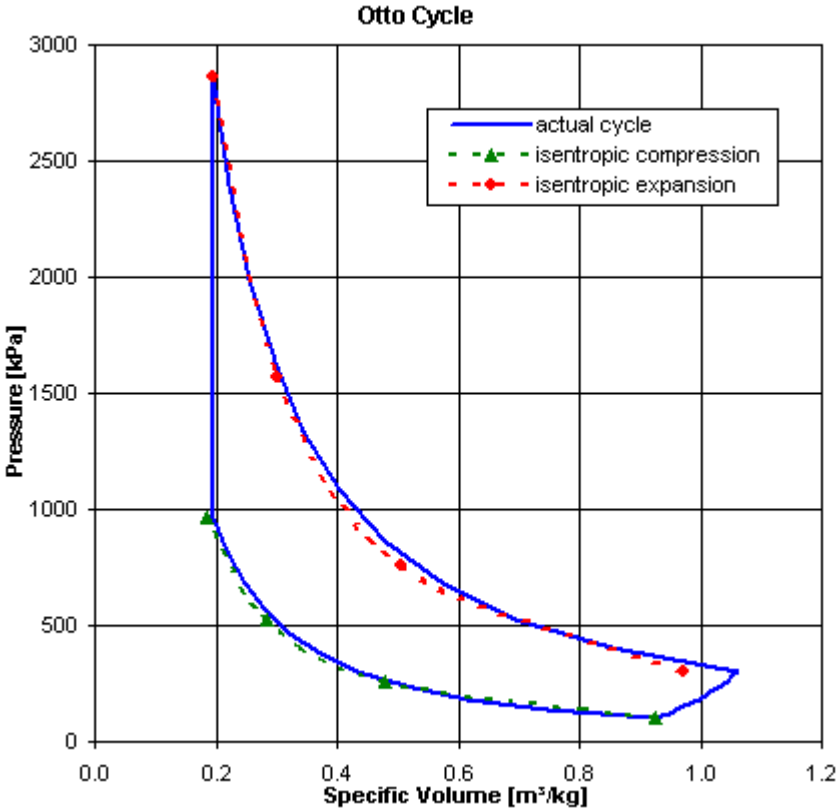


Figure 103. Otto Cycle P-V Diagram

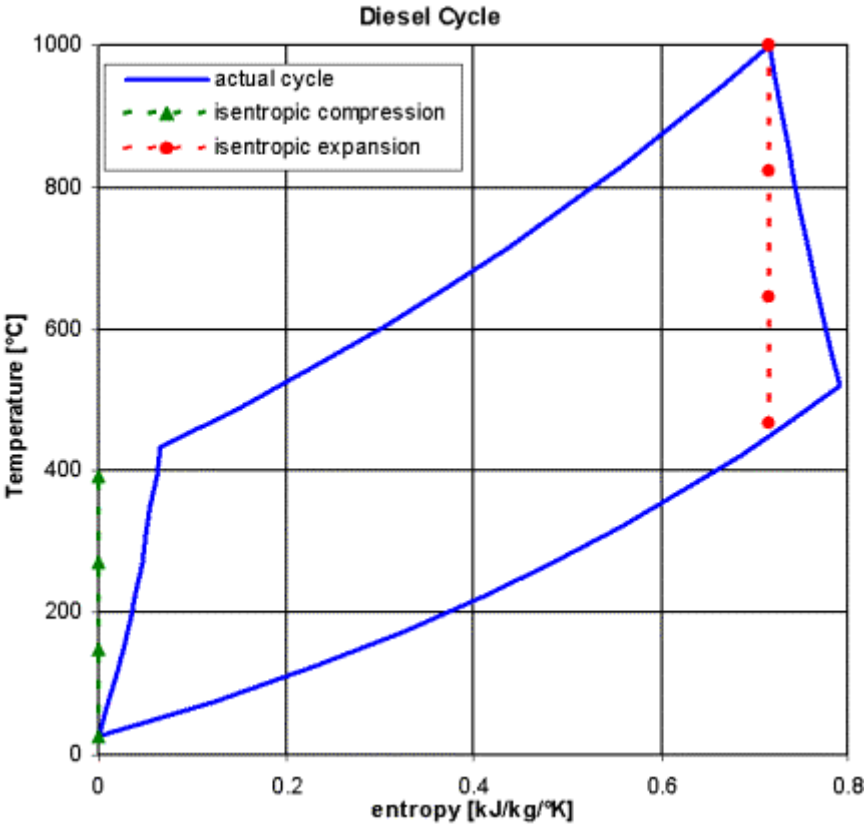


Figure 104. Diesel Cycle T-S Diagram

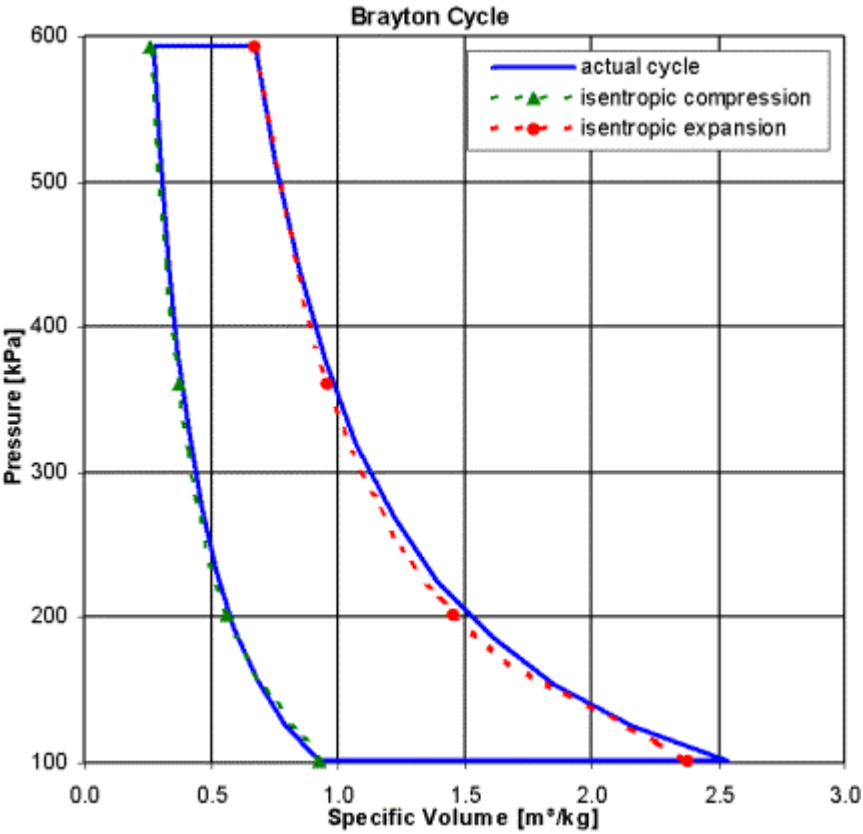


Figure 105. Brayton Cycle P-V Diagram

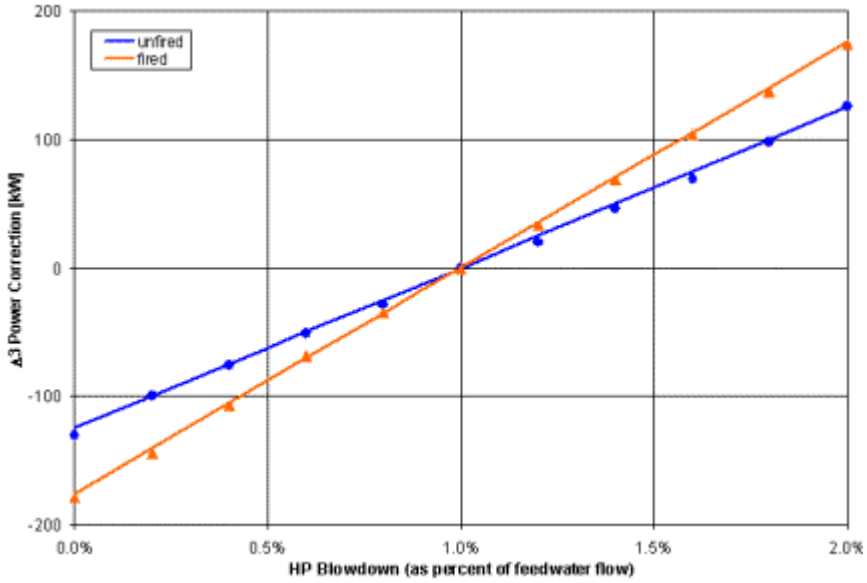


Figure 106. Typical CCPP Delta3 Correction

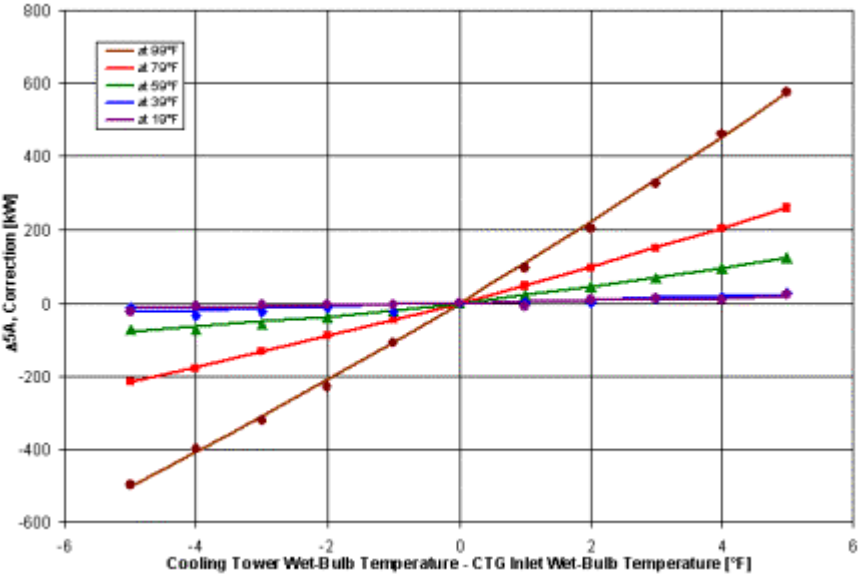


Figure 107. Typical CCPP Delta5A Correction

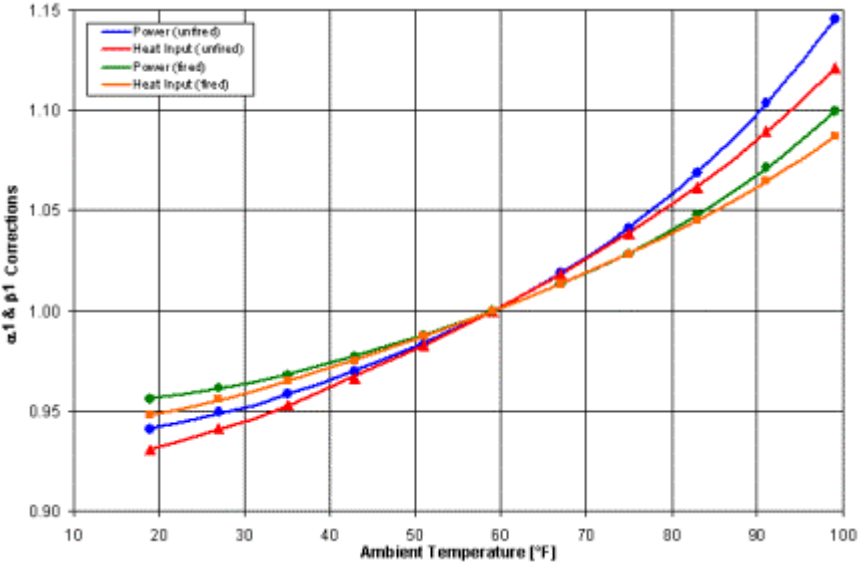


Figure 108. Typical CCPP Alpha1 and Beta1 Corrections

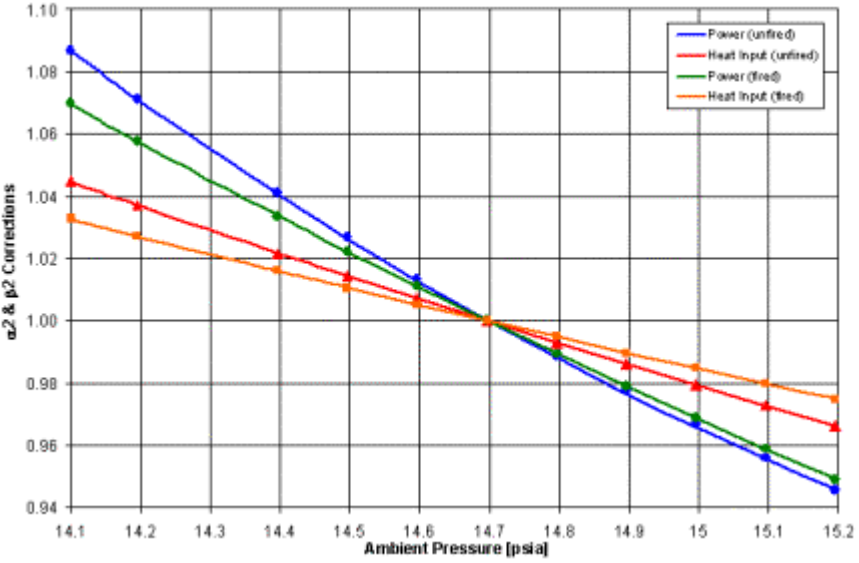


Figure 109. Typical CCPP Alpha2 and Beta2 Corrections

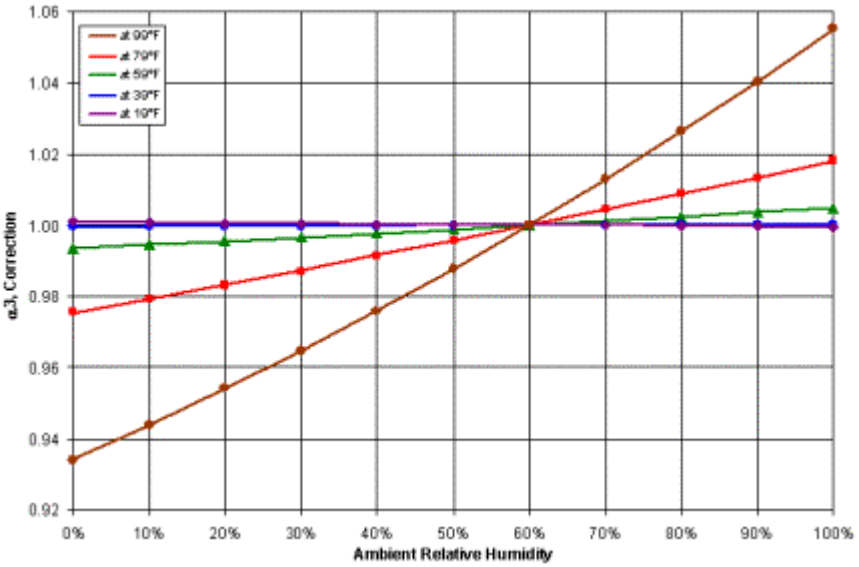


Figure 110. Typical CCPP Alpha3 Correction

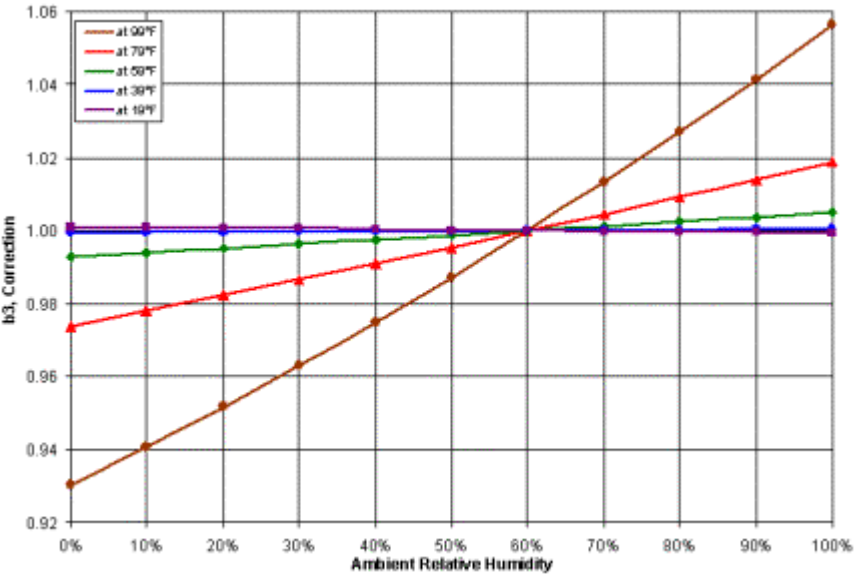


Figure 111. Typical CCPP Beta3 Correction

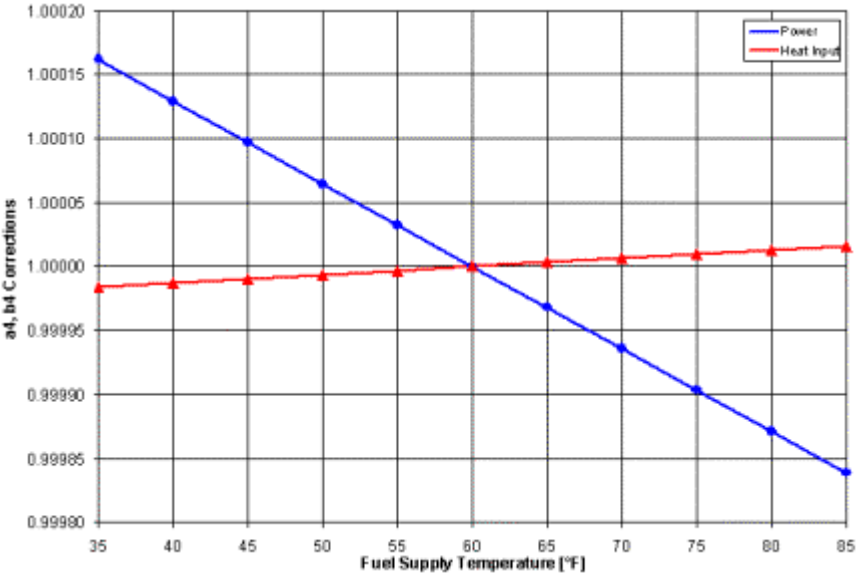


Figure 112. Typical CCPP Alpha4 and Beta4 Corrections

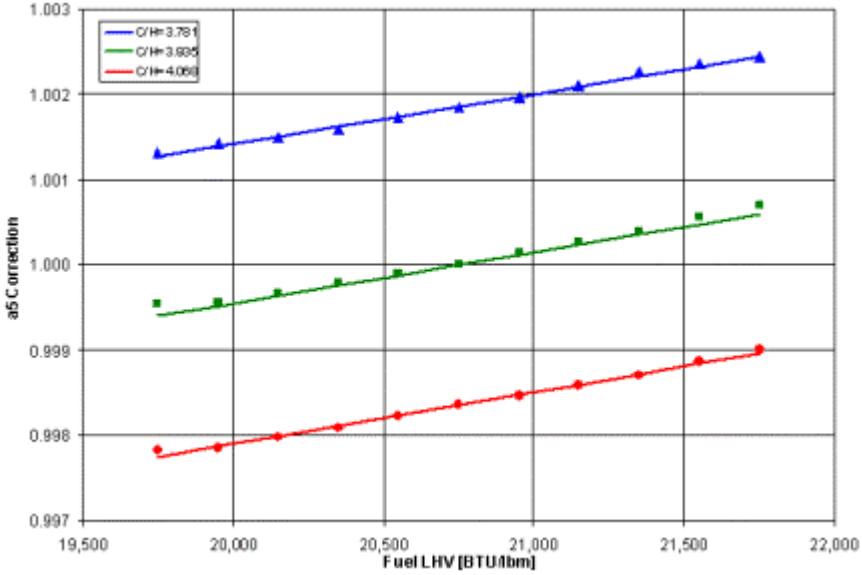


Figure 113. Typical CCPP Alpha5 Correction

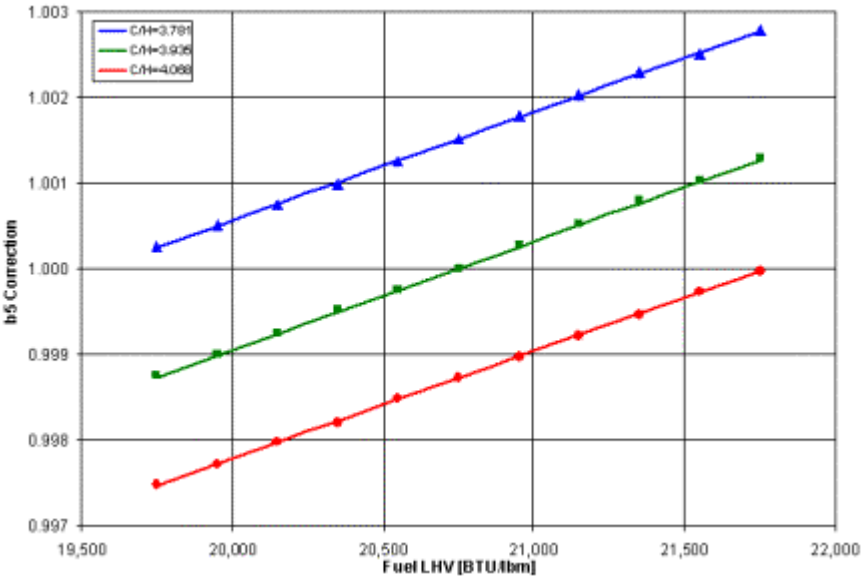


Figure 114. Typical CCPP Beta5 Correction

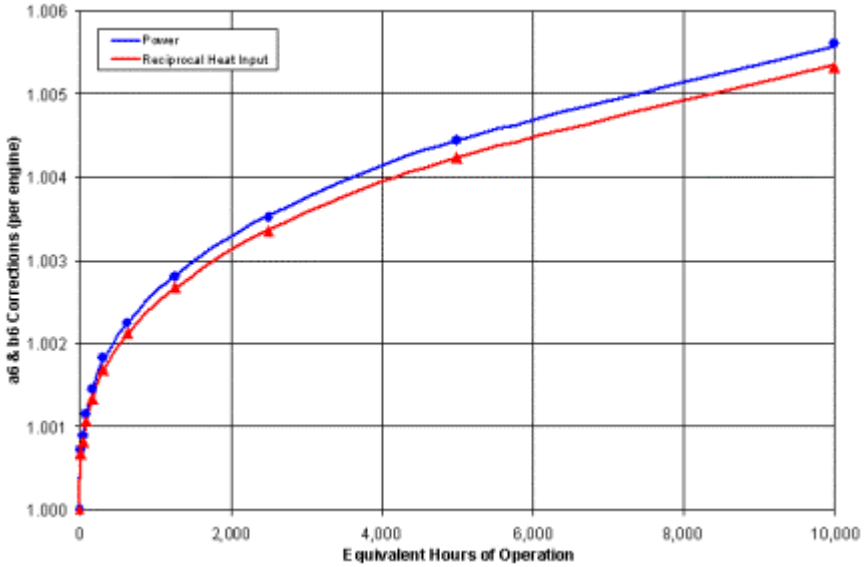


Figure 115. Typical CCPP Alpha6 and Beta6 Corrections

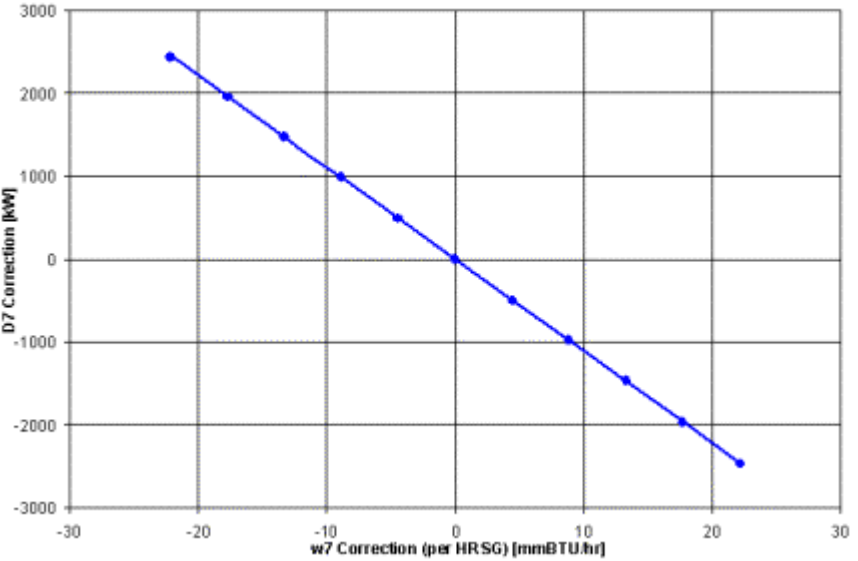


Figure 116. Typical Delta7/Omega7 Duct Firing Correction

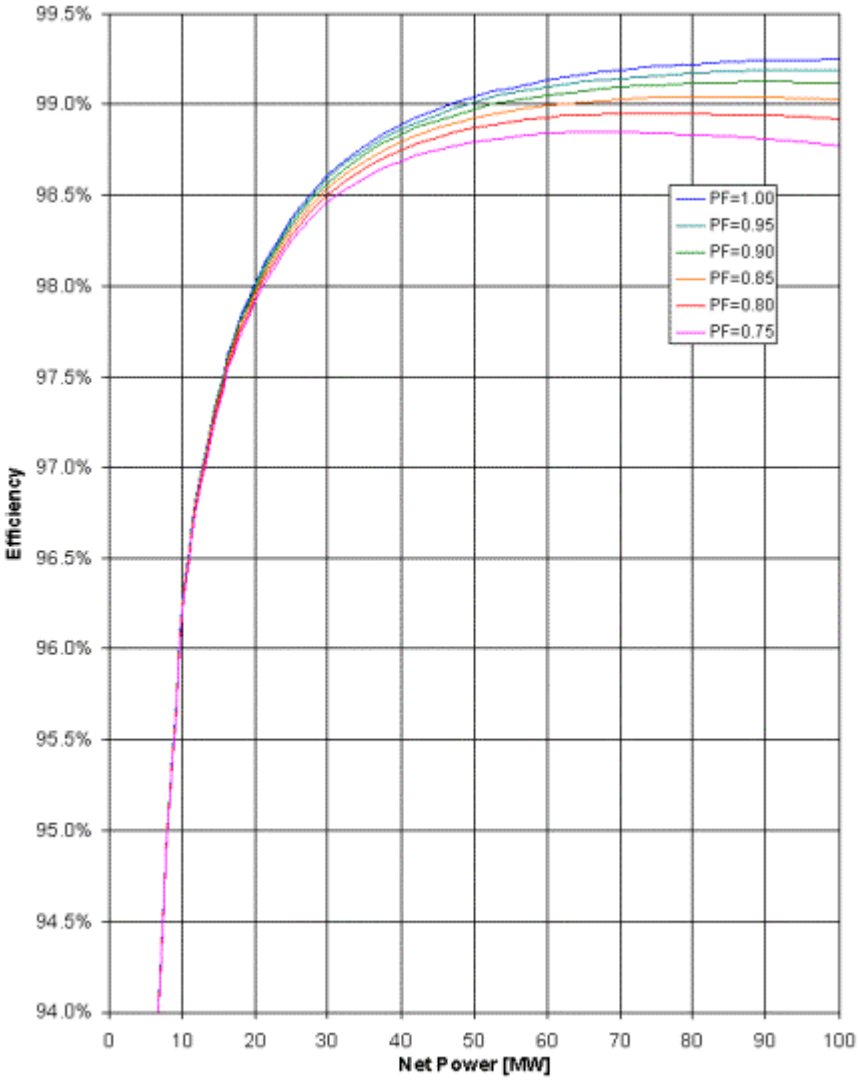


Figure 117. Typical Generator Efficiency Curves

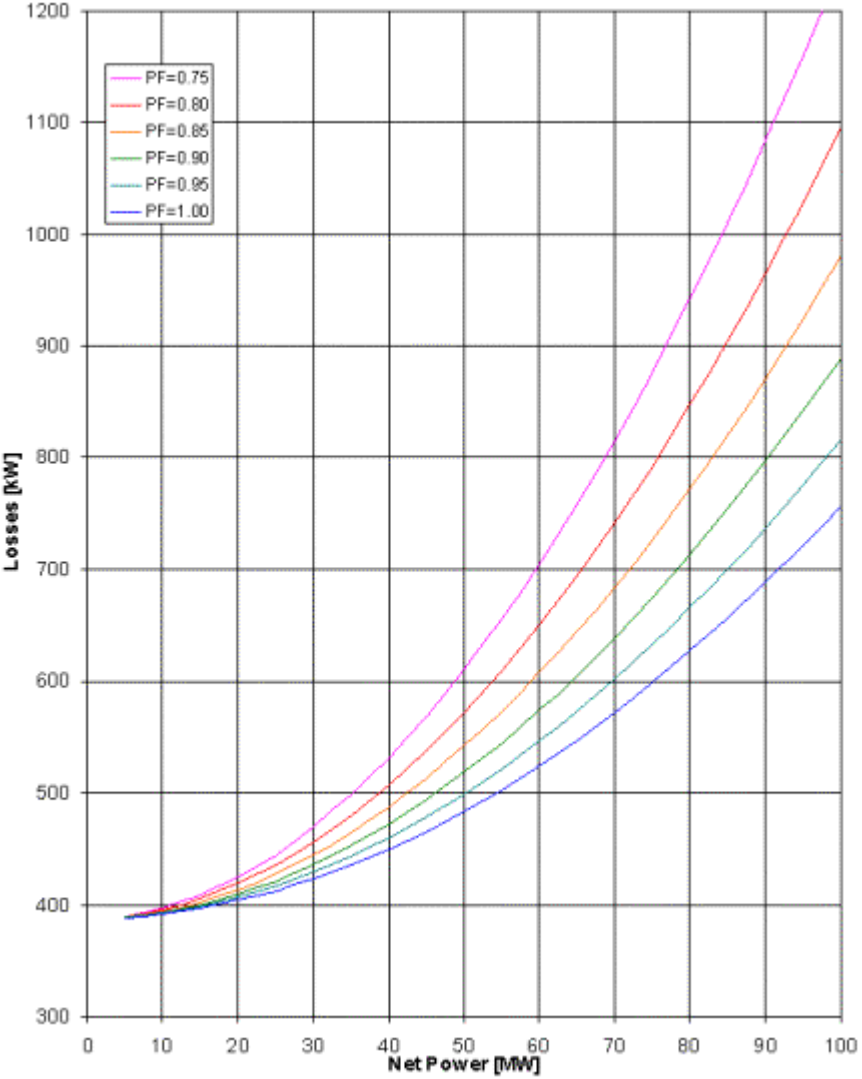


Figure 118. Typical Generator Loss Curves

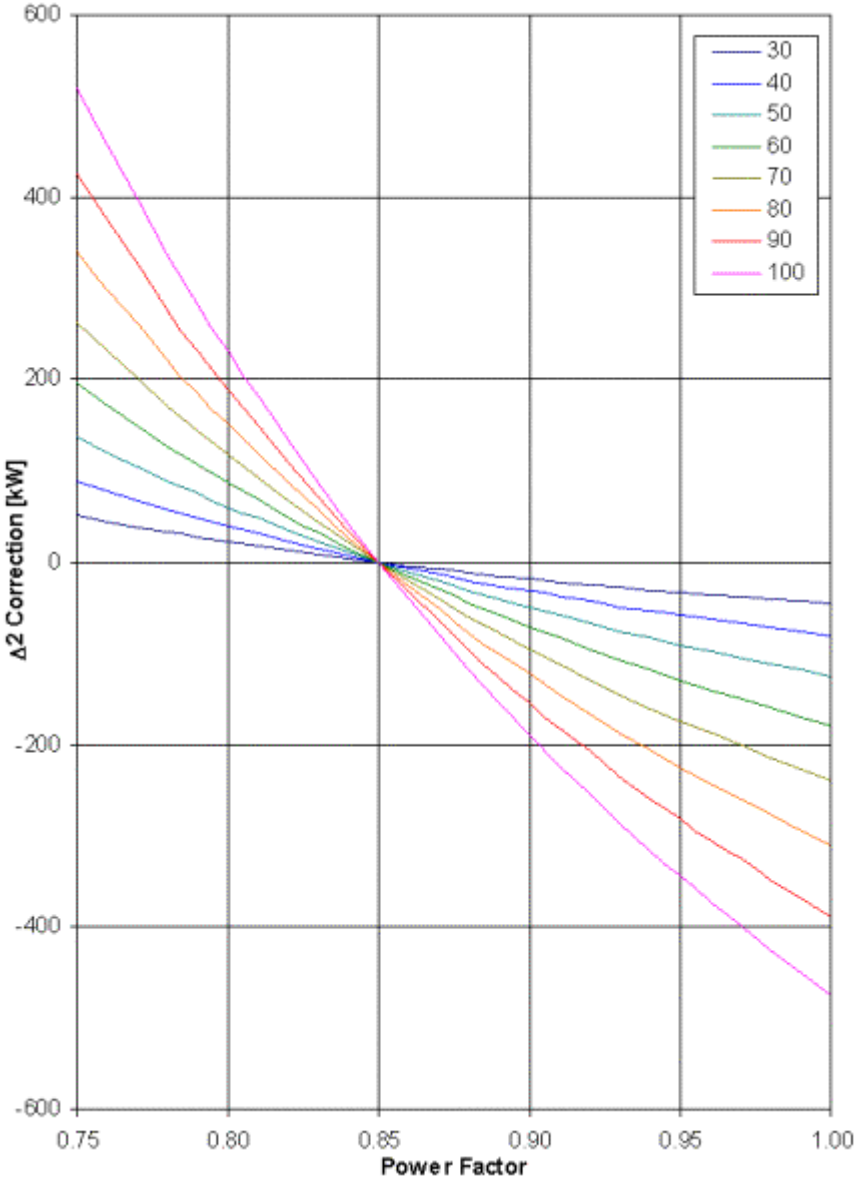


Figure 119. Typical Type 1 Power Factor Correction

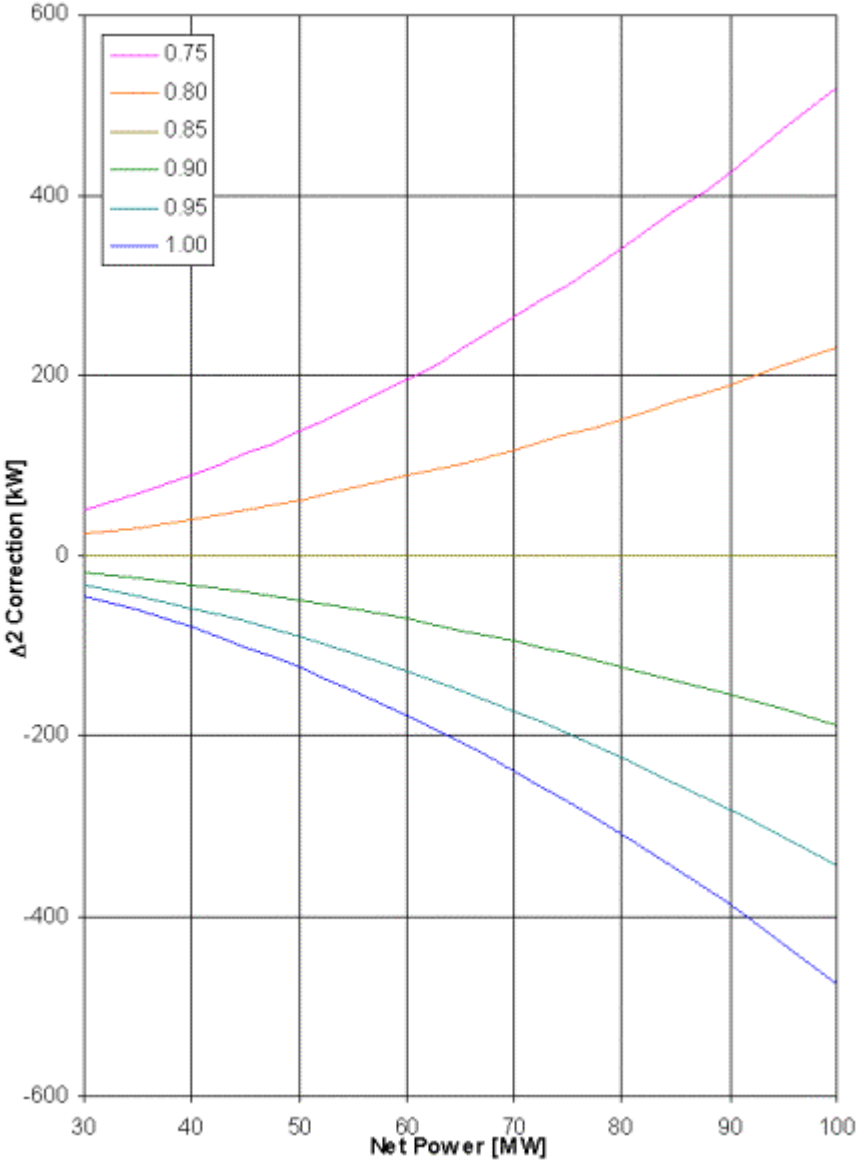


Figure 120. Typical Type 2 Power Factor Correction

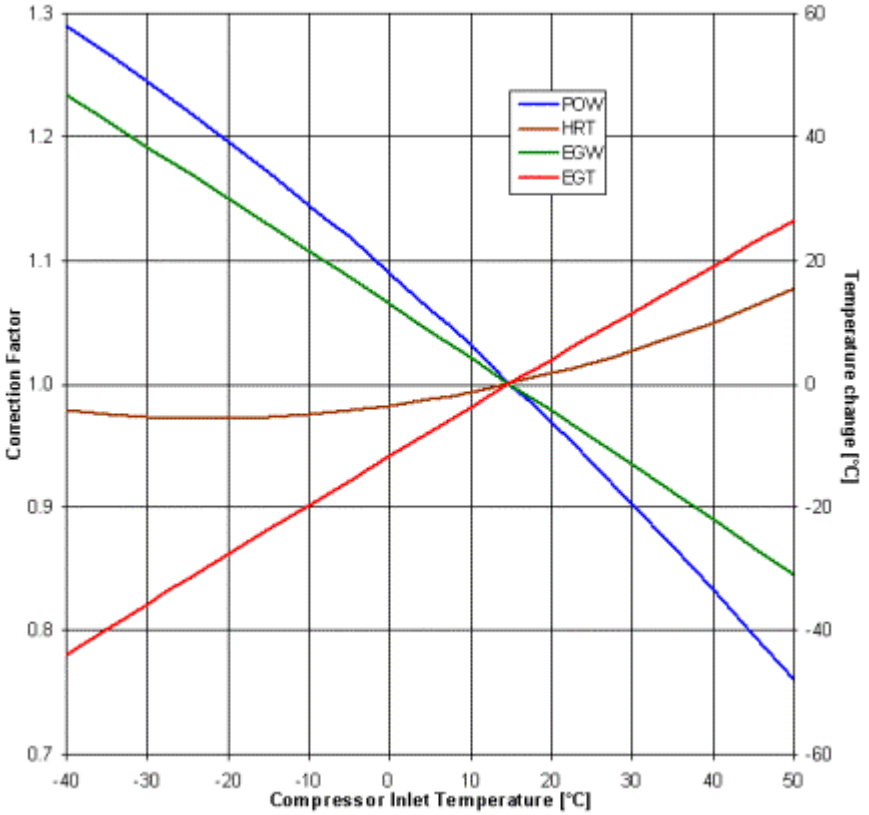


Figure 129. Typical Gas Turbine Curves for Inlet Temperature

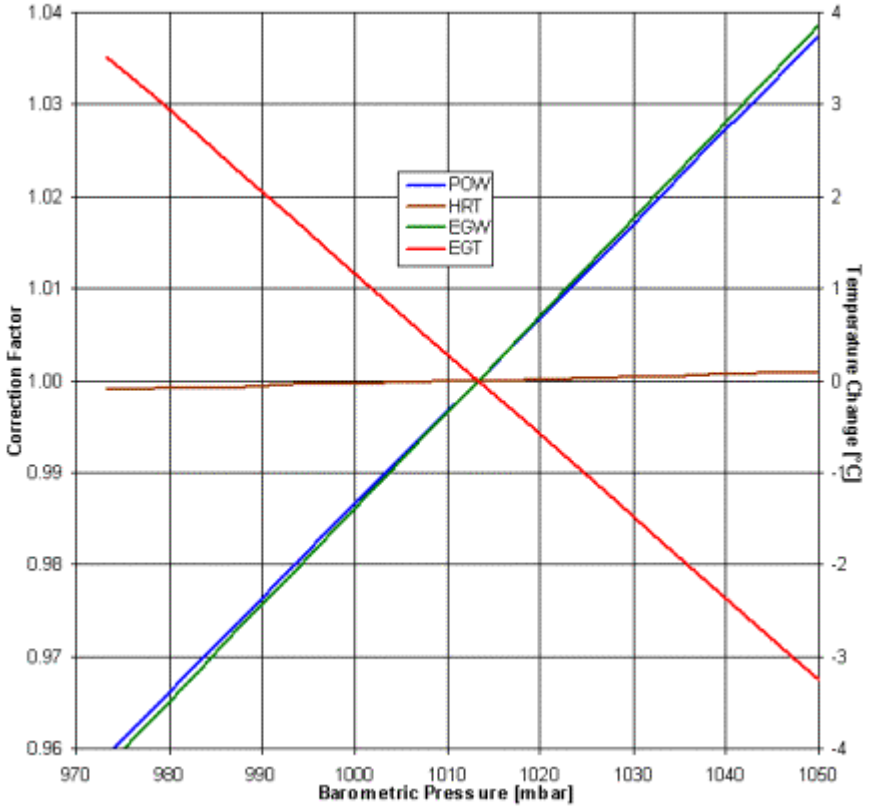


Figure 130. Typical Gas Turbine Curves for Barometric Pressure

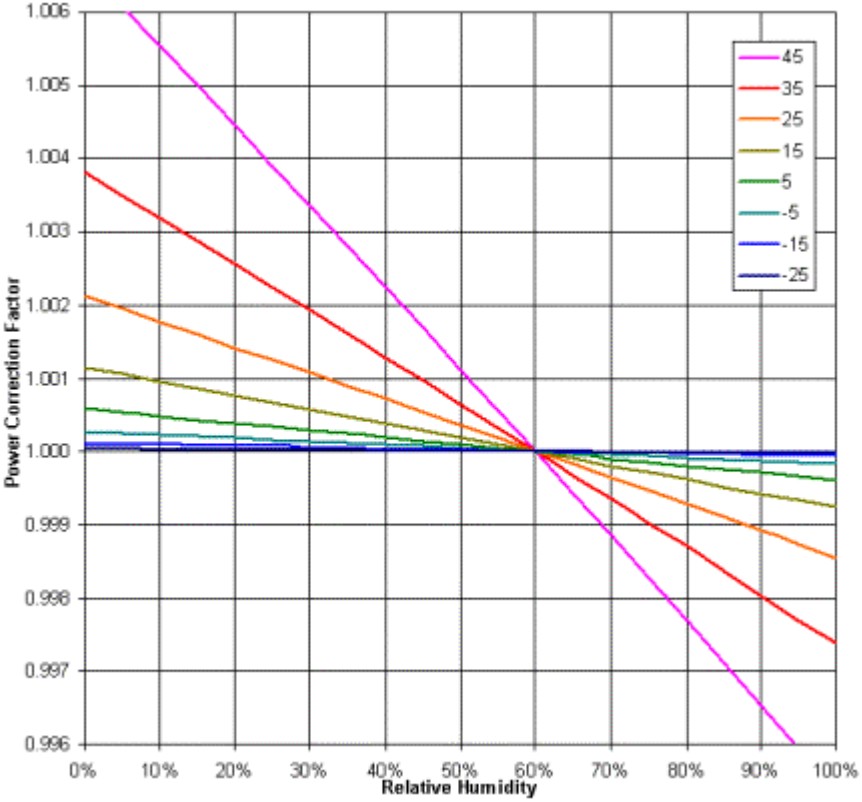


Figure 131. Typical GT Power Correction for Relative Humidity

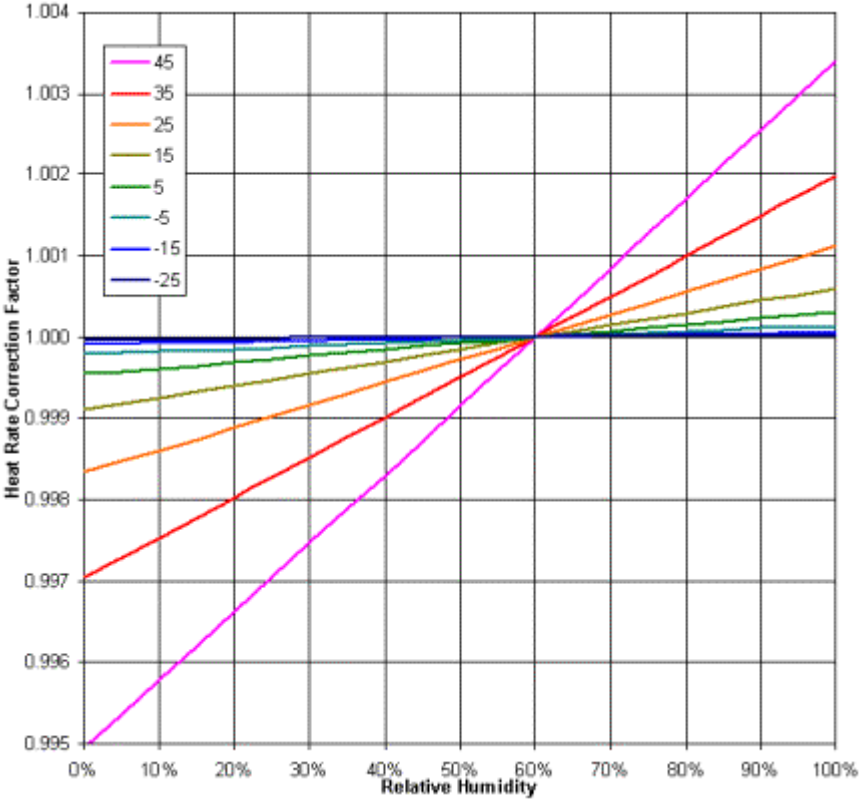


Figure 132. Typical GT Heat Rate Correction for Relative Humidity

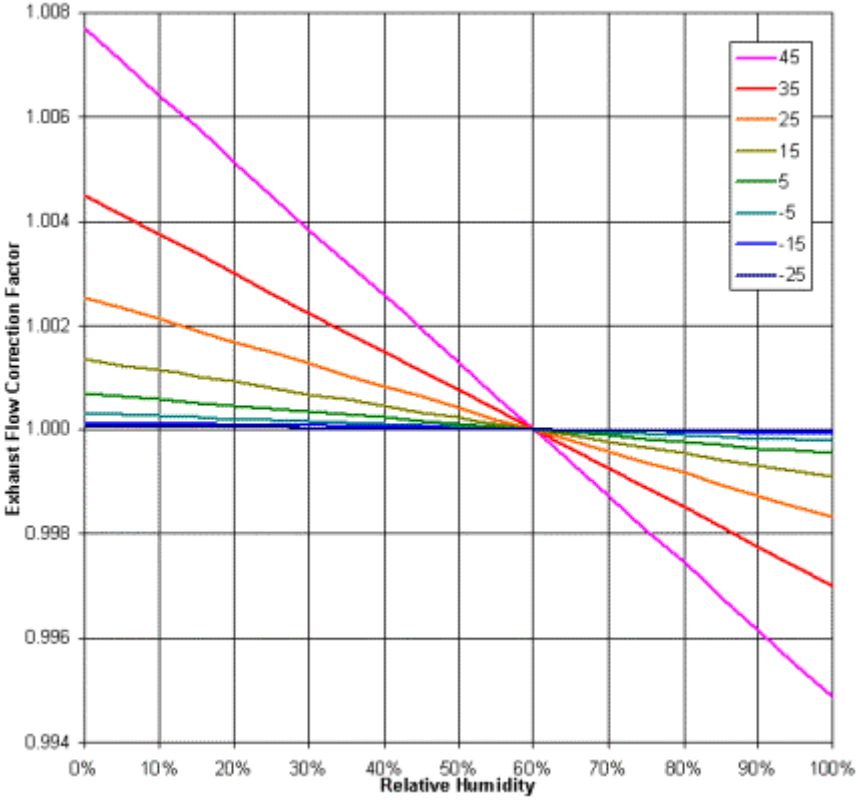


Figure 133. Typical GT Exhaust Flow Correction for Relative Humidity

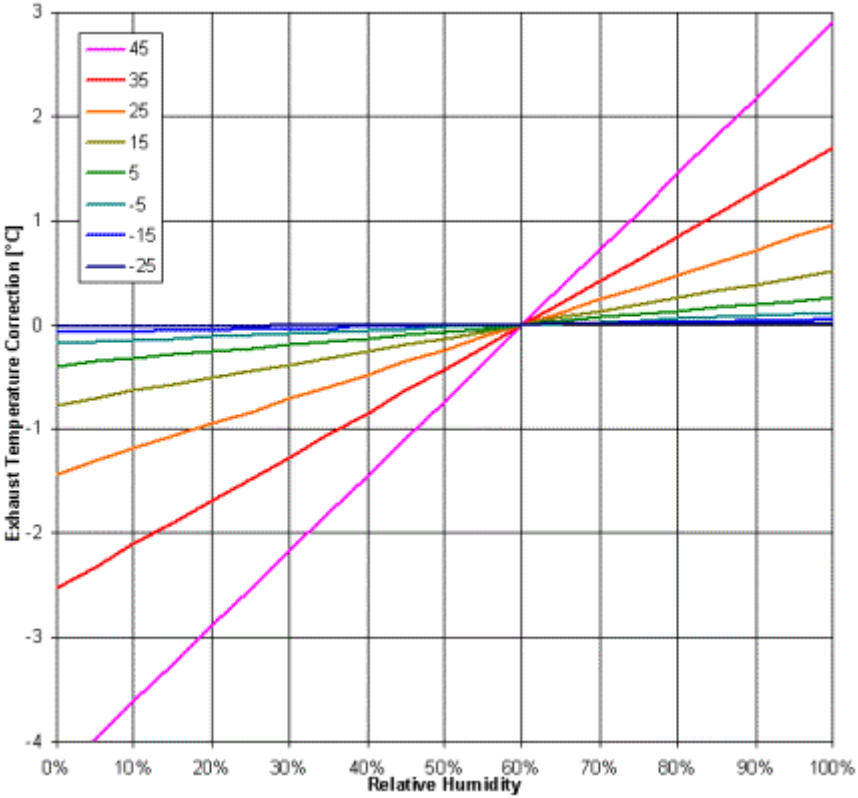


Figure 134. Typical GT Exhaust Temperature Correction for RH

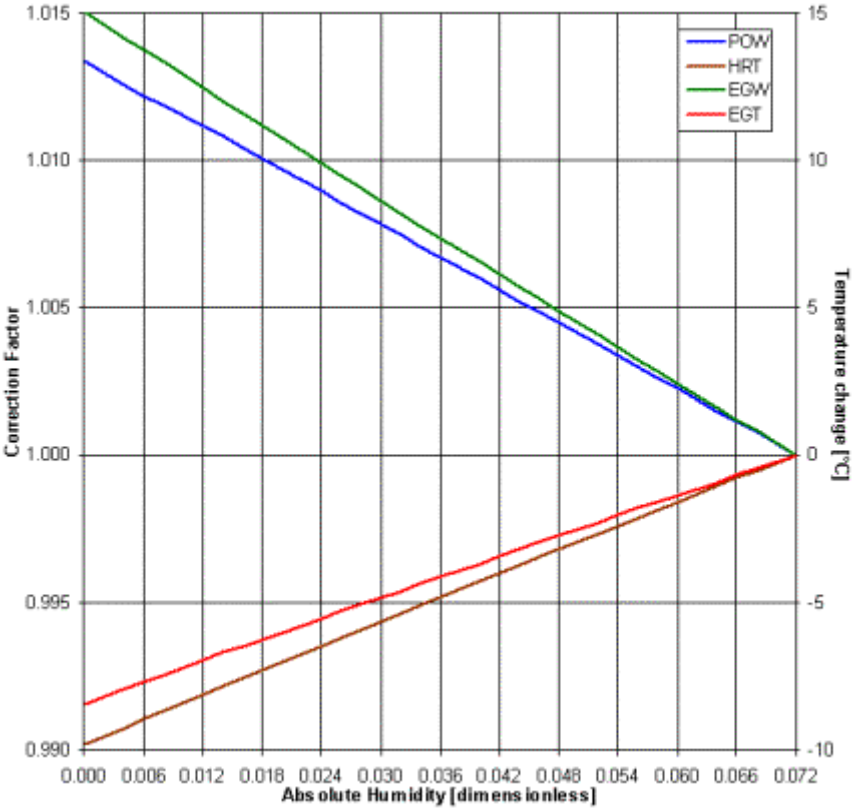


Figure 135. Absolute Humidity Corrections

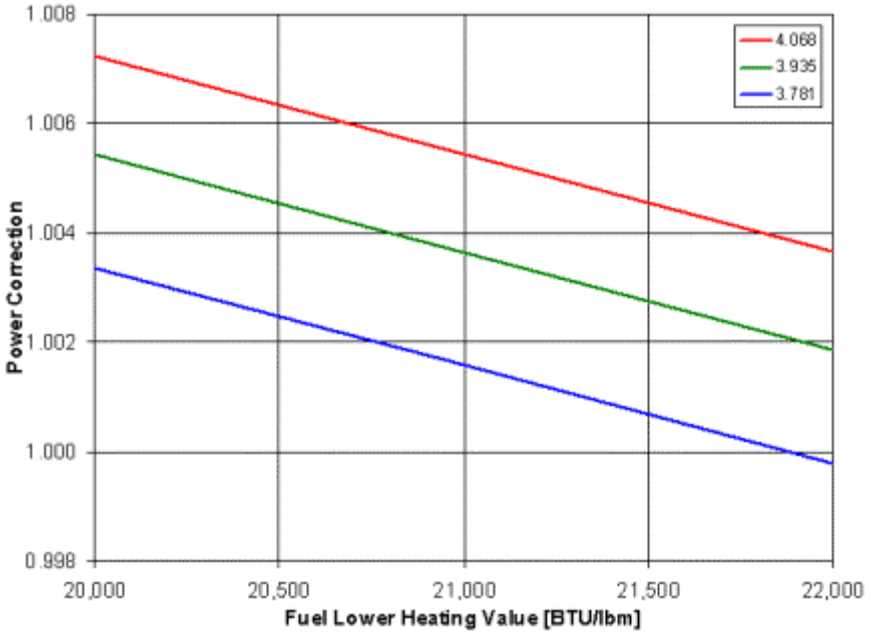


Figure 140. GT Power Correction for Fuel Composition

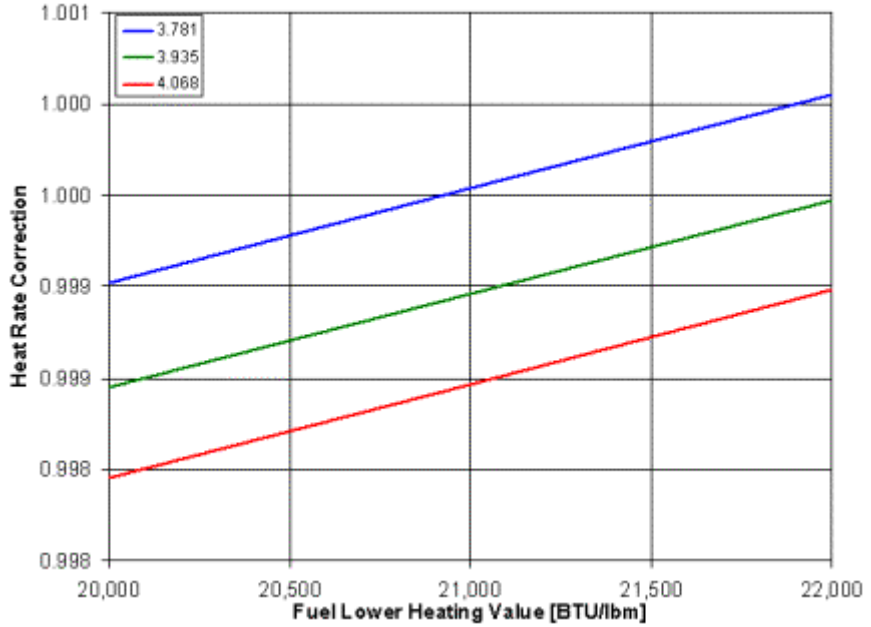


Figure 141. GT Heat Rate Correction for Fuel Composition

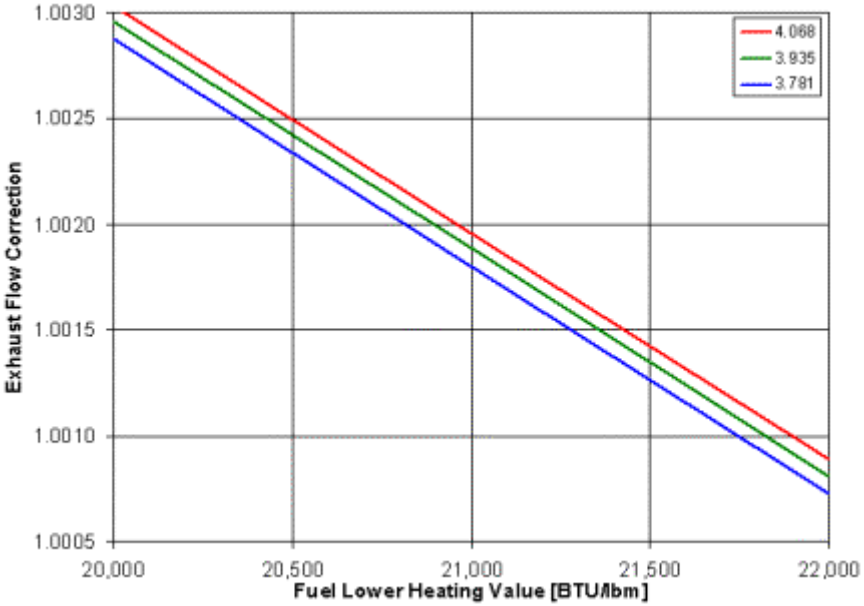


Figure 142. GT Exhaust Flow Correction for Fuel Composition

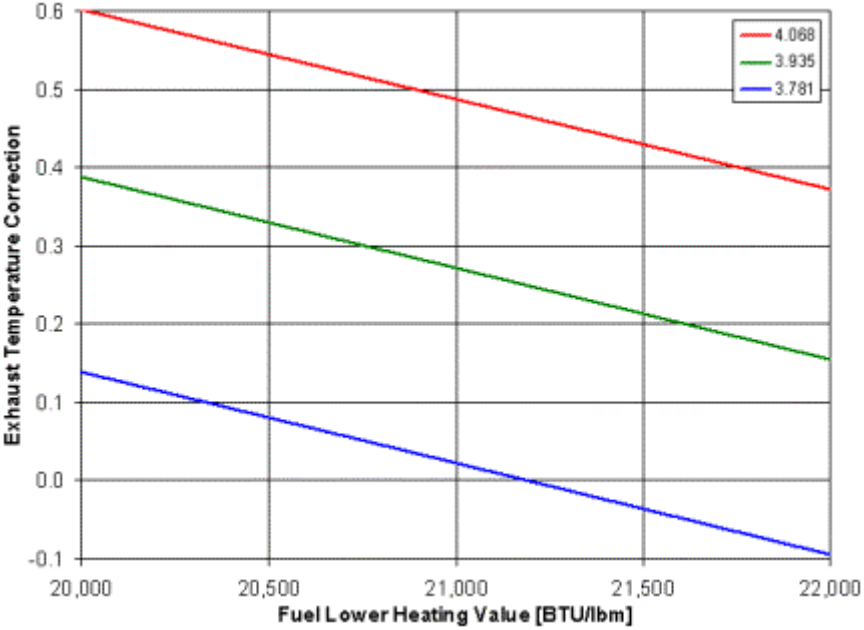


Figure 143. GT Exhaust Temperature Correction for Fuel Composition

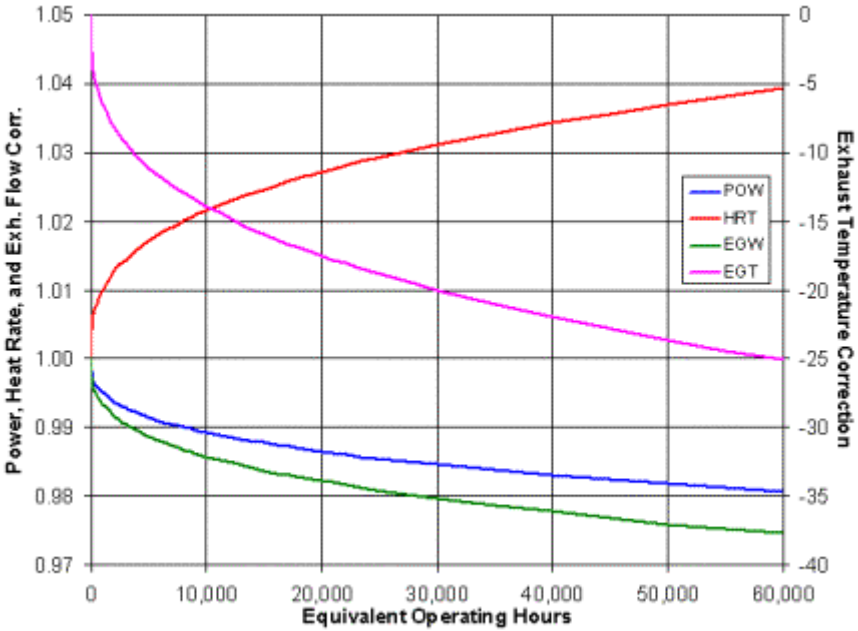


Figure 144. GT Corrctions for Ageing

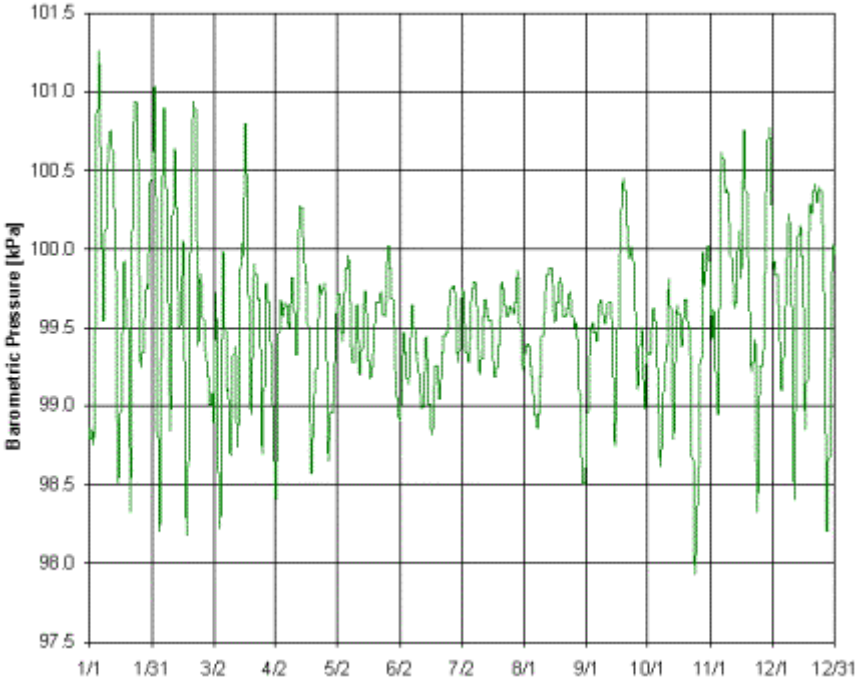


Figure 147. Hourly Values of Barometric Pressure

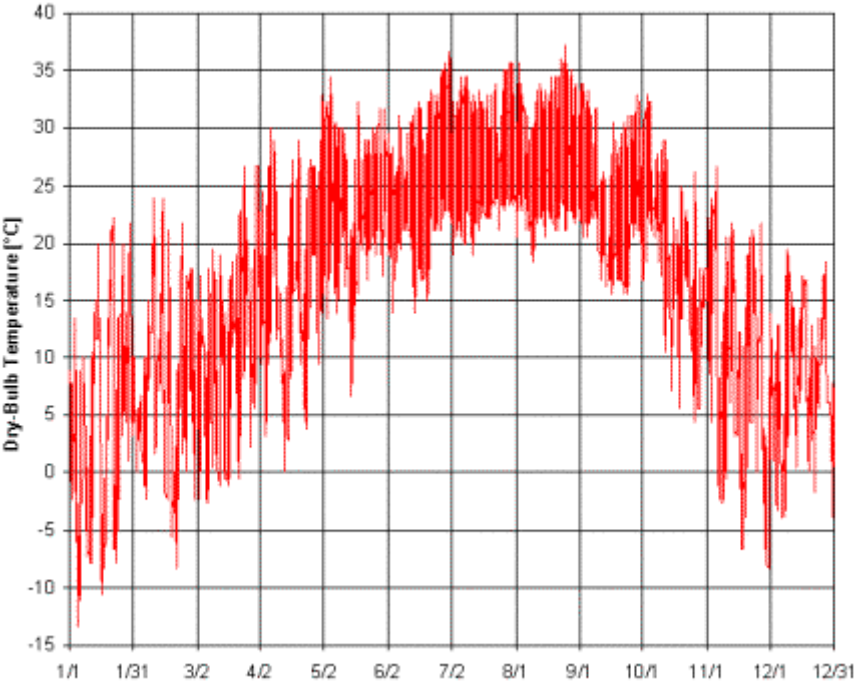


Figure 148. Hourly Values of Dry-Bulb Temperature

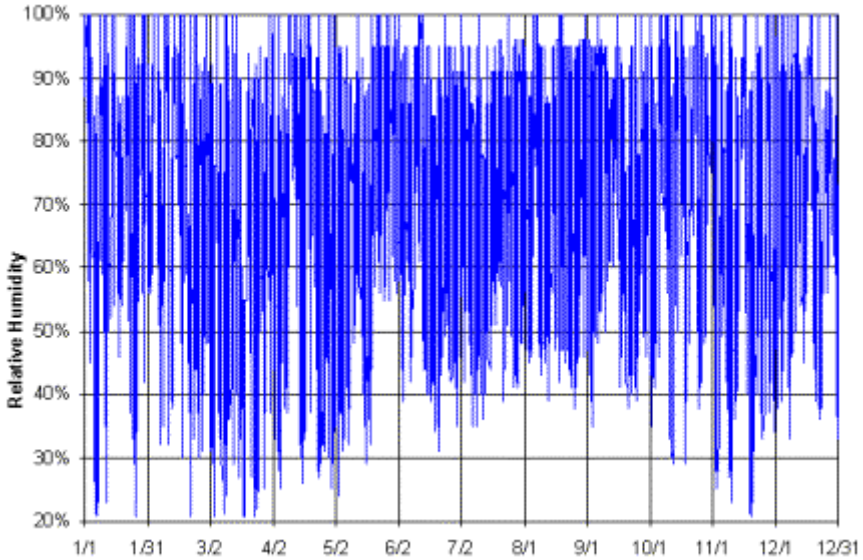


Figure 149. Hourly Values of Relative Humidity

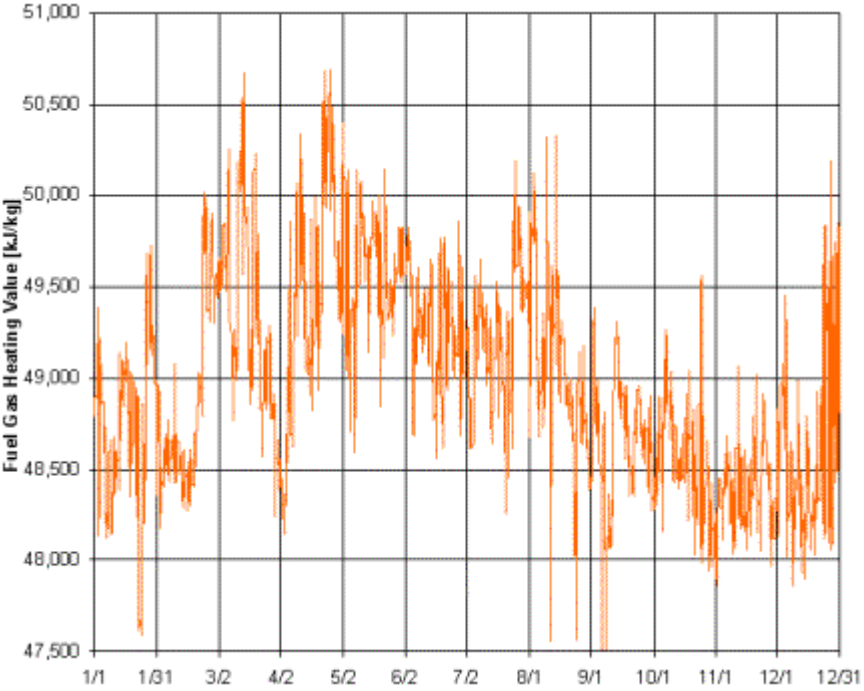


Figure 150. Hourly Values of Heating Value from Online GG

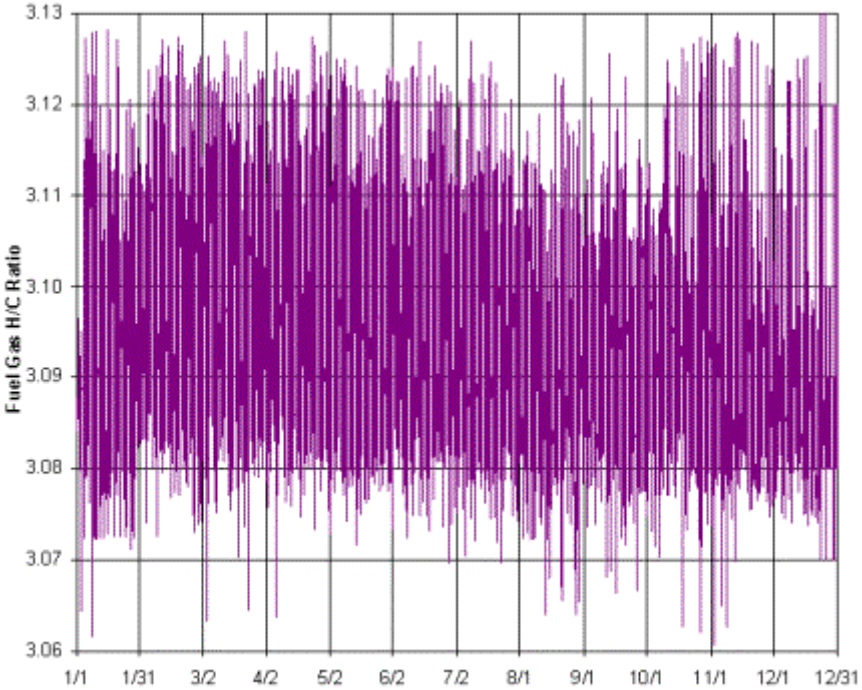


Figure 151. Hourly Values of C/H Ratio from Online GC

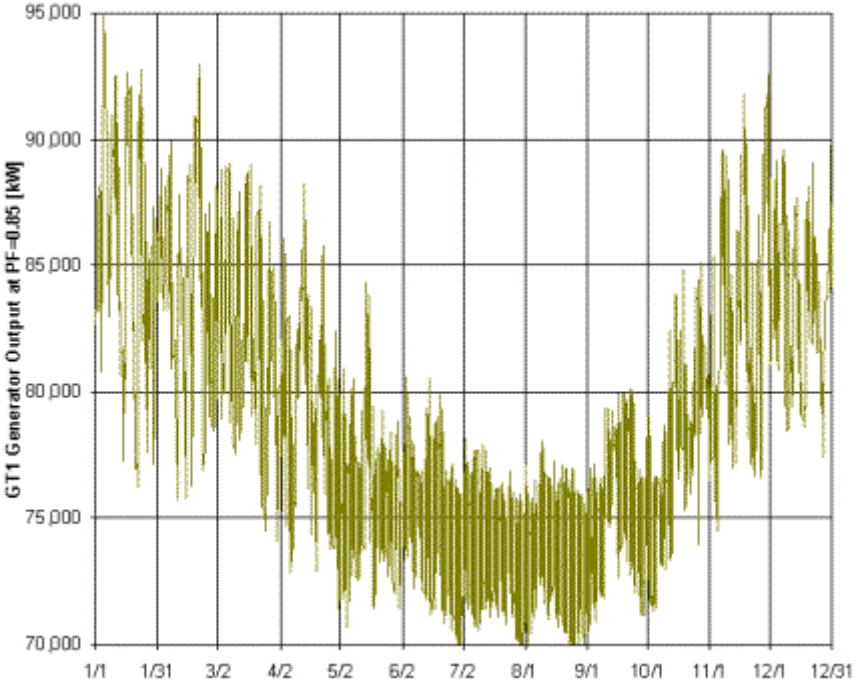


Figure 153. Expected GT1 Capacity throughout the Year

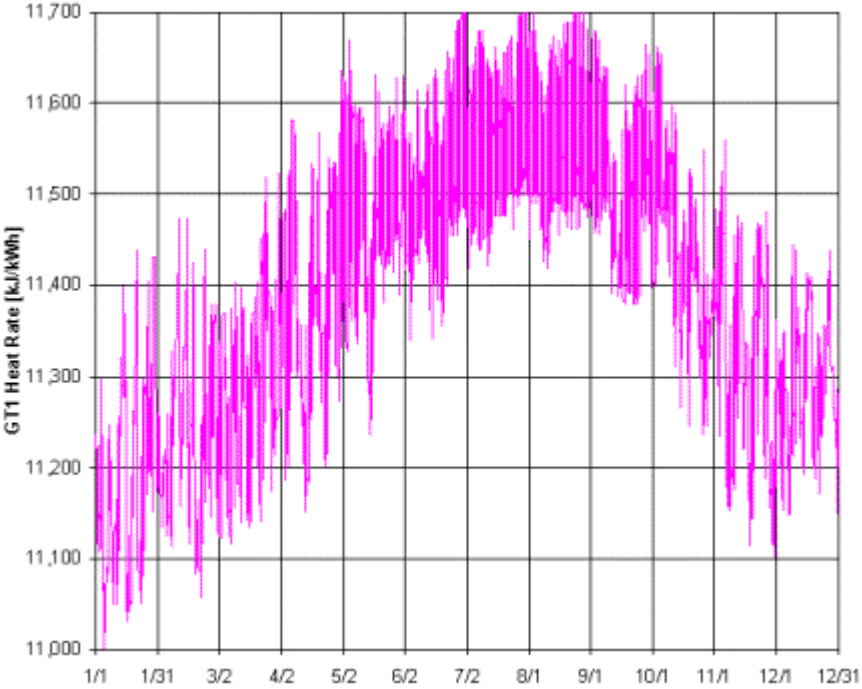


Figure 154. Expected GT1 Heat Rate throughout the Year

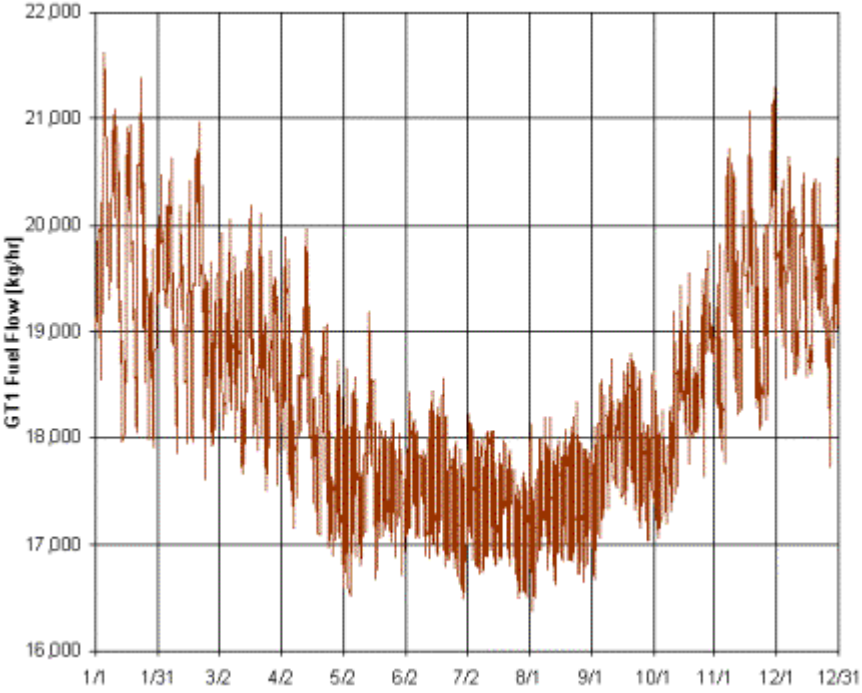


Figure 155. Expected GT1 Fuel Flow throughout the Year

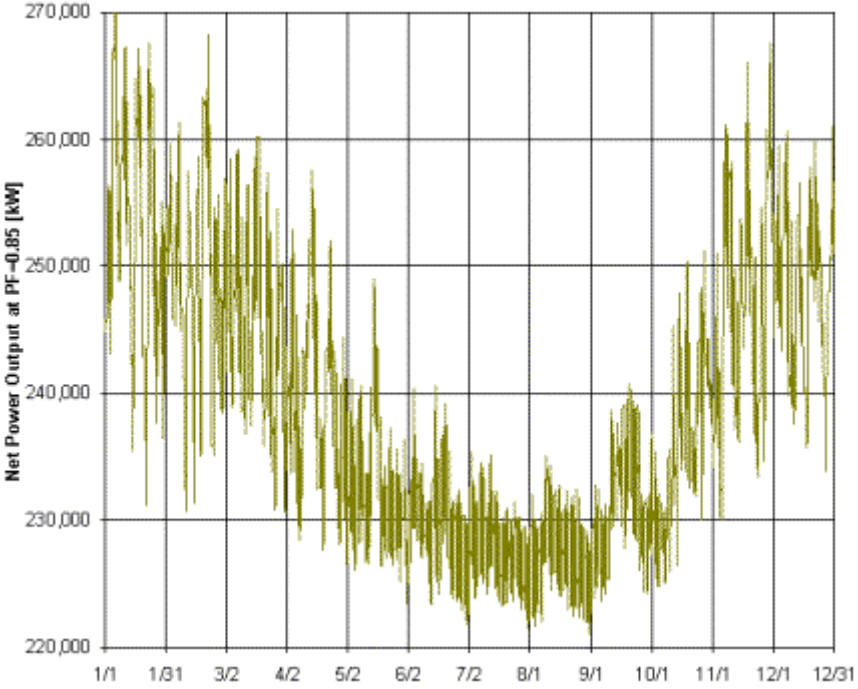


Figure 157. 2x1 CCPP Capacity without Duct Firing

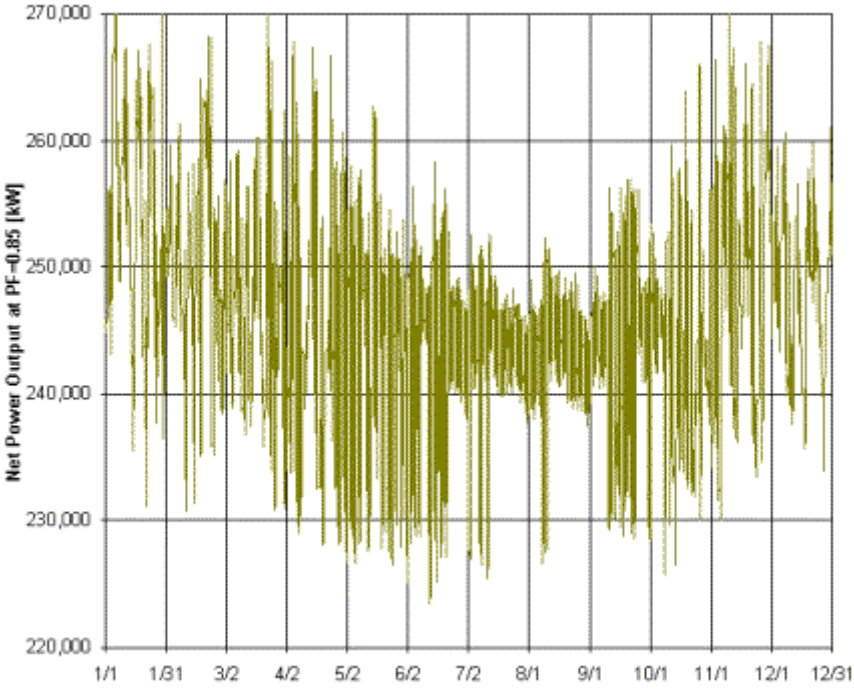


Figure 158. 2x1 CCPP Capacity with Seasonal Duct Firing

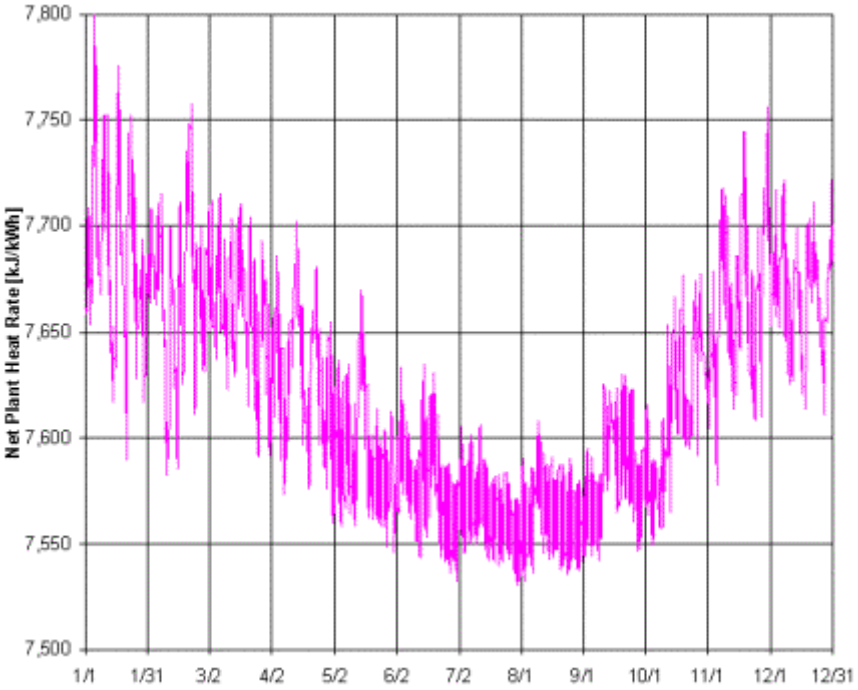
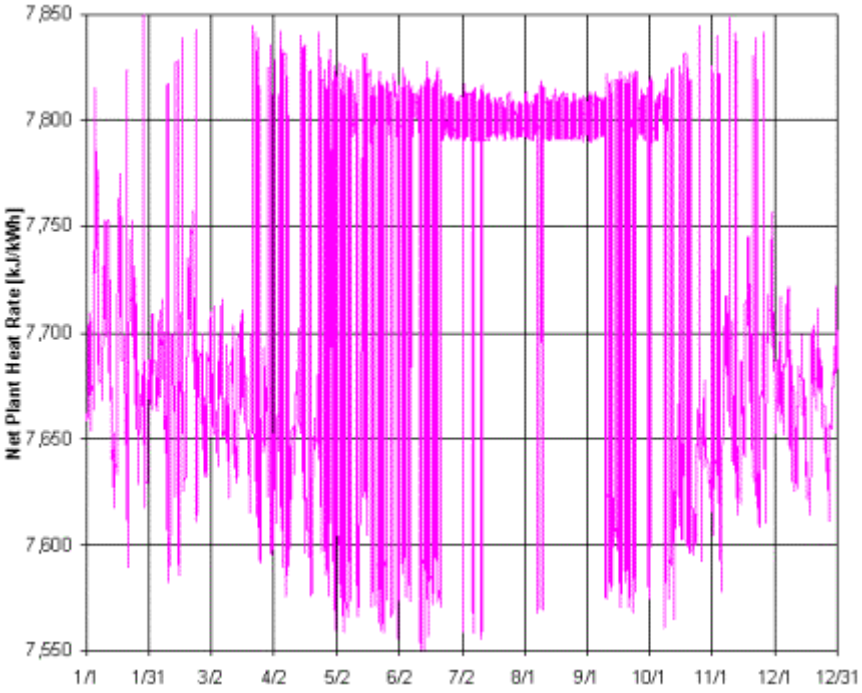


Figure 159. 2x1 CCPP Heat Rate without Duct Firing


Net Plant Heat Rate [kJ/kWh]
7,850
7,800
7,750
7,700
7,650
7,600
7,550
1/1
1/31
3/2
4/2
5/2
6/2
7/2
8/1
9/1
10/1
11/1
12/1
12/31

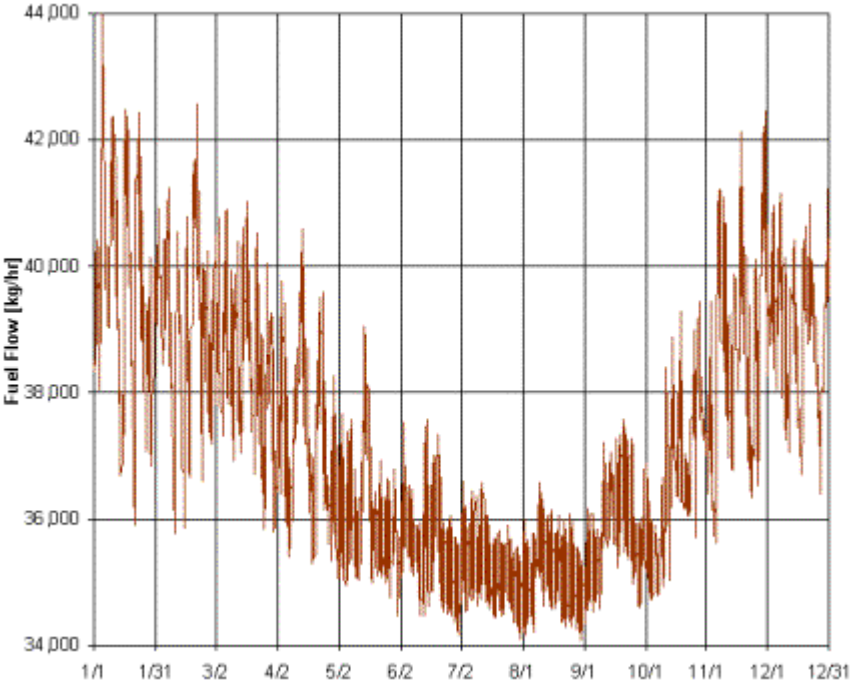


Figure 161. 2x1 CCPP Fuel Flow without Duct Firing

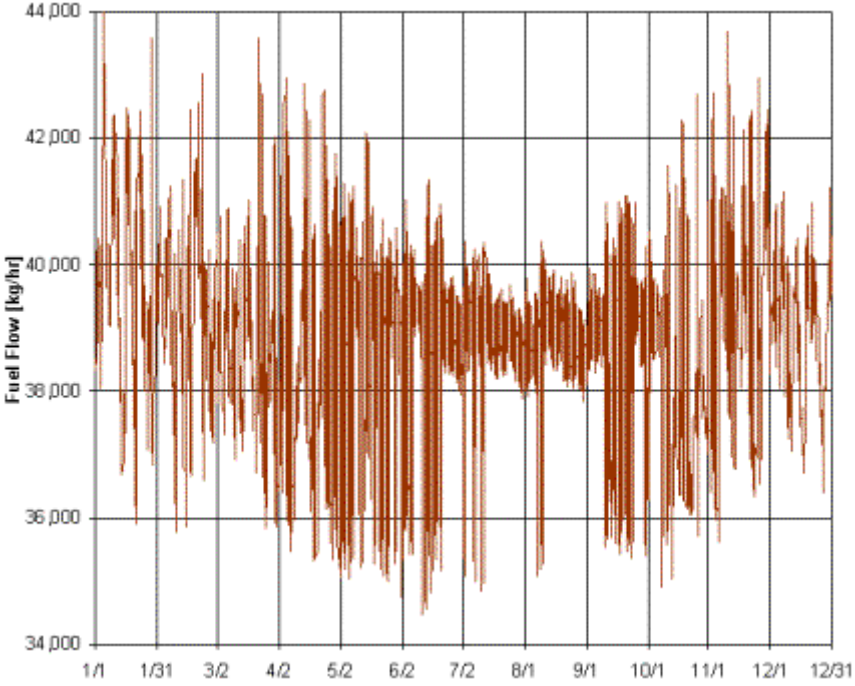


Figure 162. 2x1 CCPP Fuel Flow with Seasonal Duct Firing

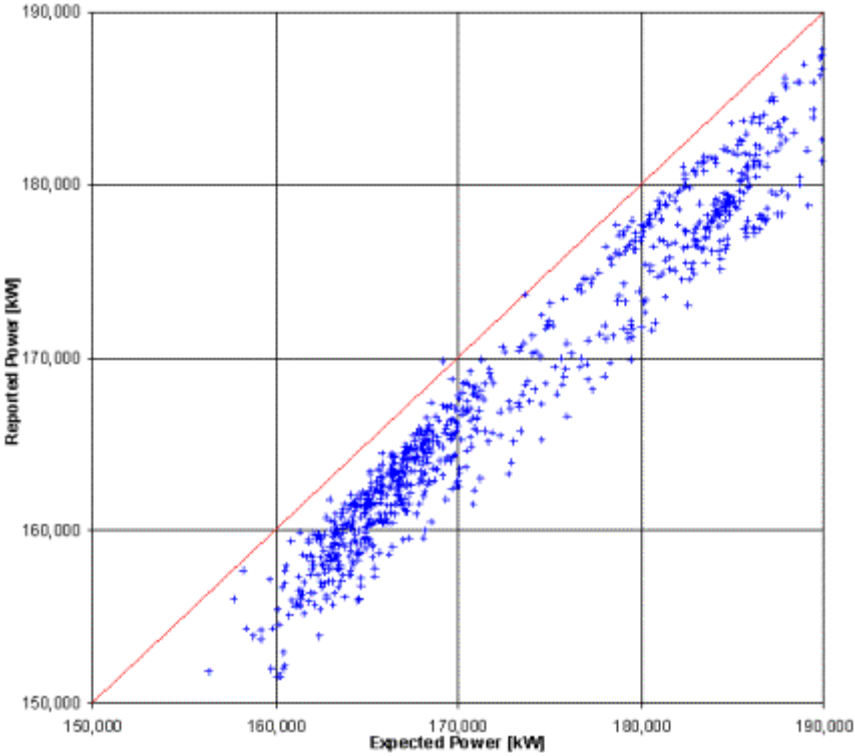


Figure 163. Reported vs. Expected GT Power

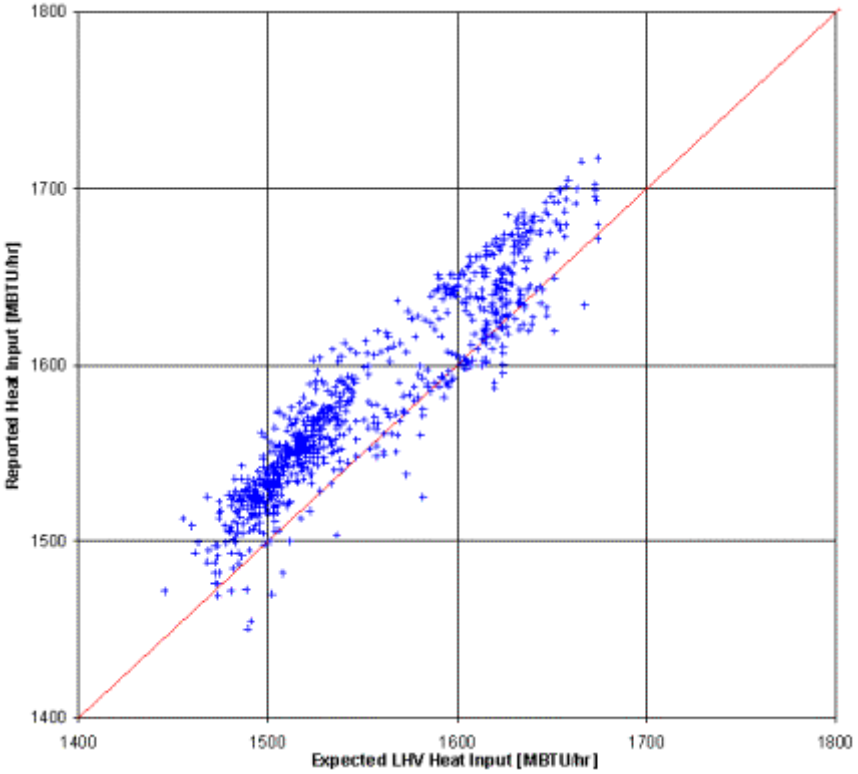


Figure 164. Reported vs. Expected Heat Input

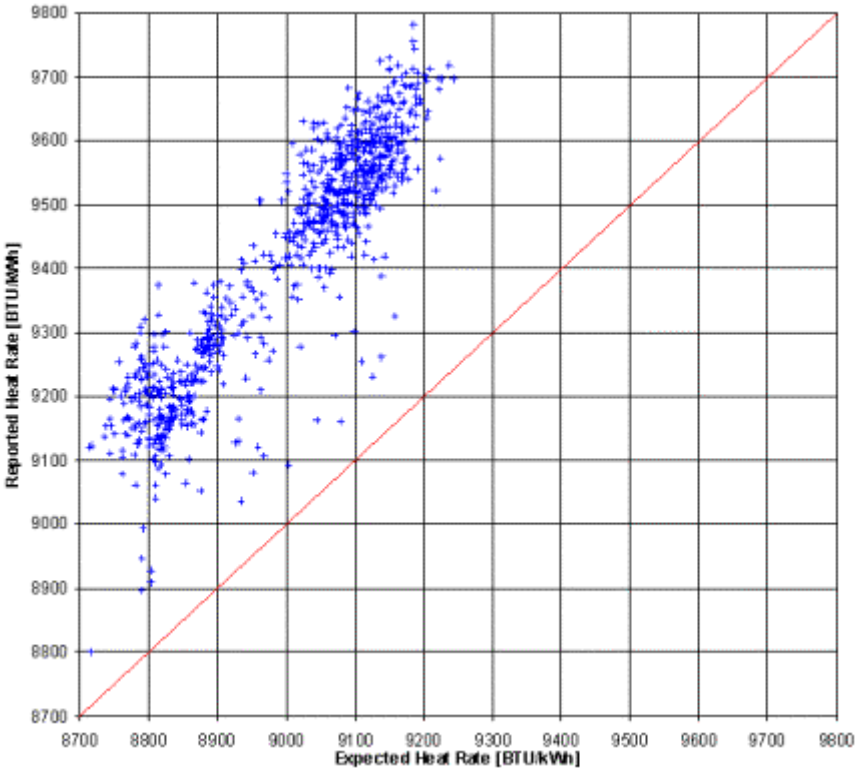


Figure 165. Reported vs. Expected Heat Rate

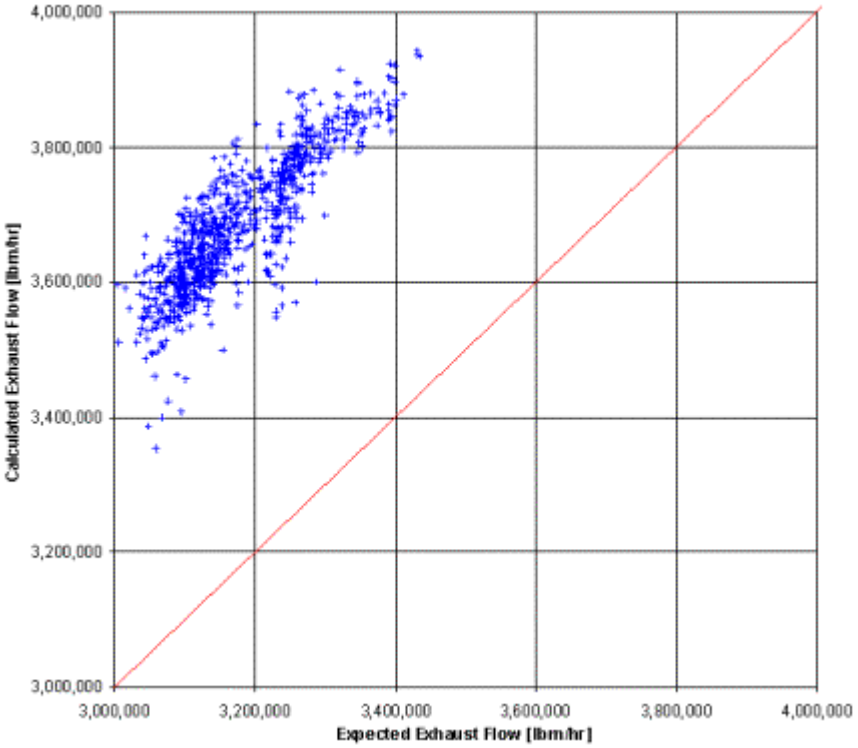


Figure 166. Reported vs. Expected GT Exhaust Flow

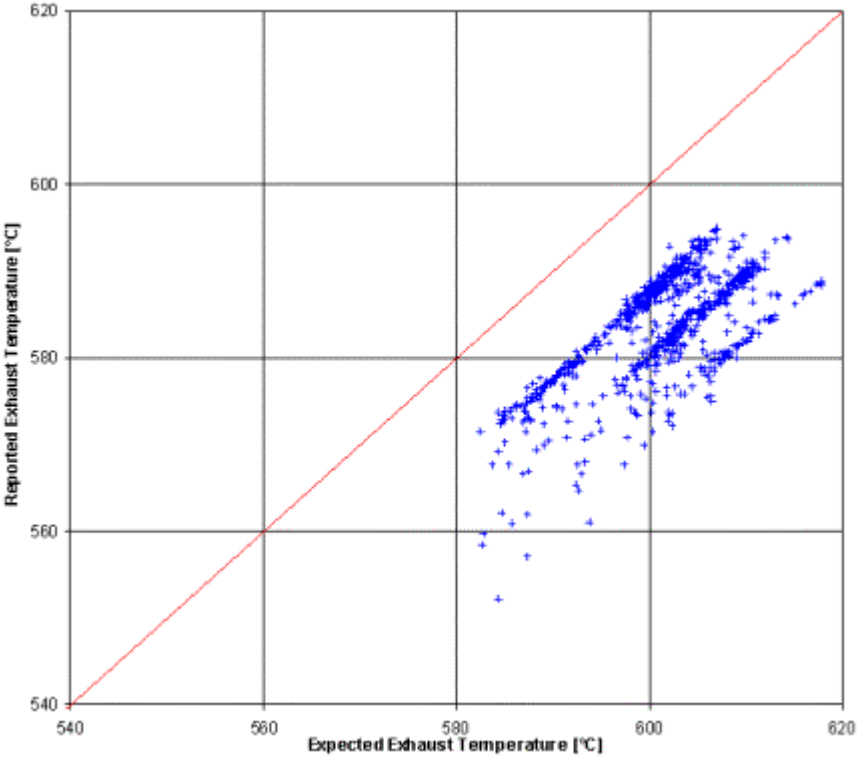


Figure 167. Reported vs. Expected GT Exhaust Temperature

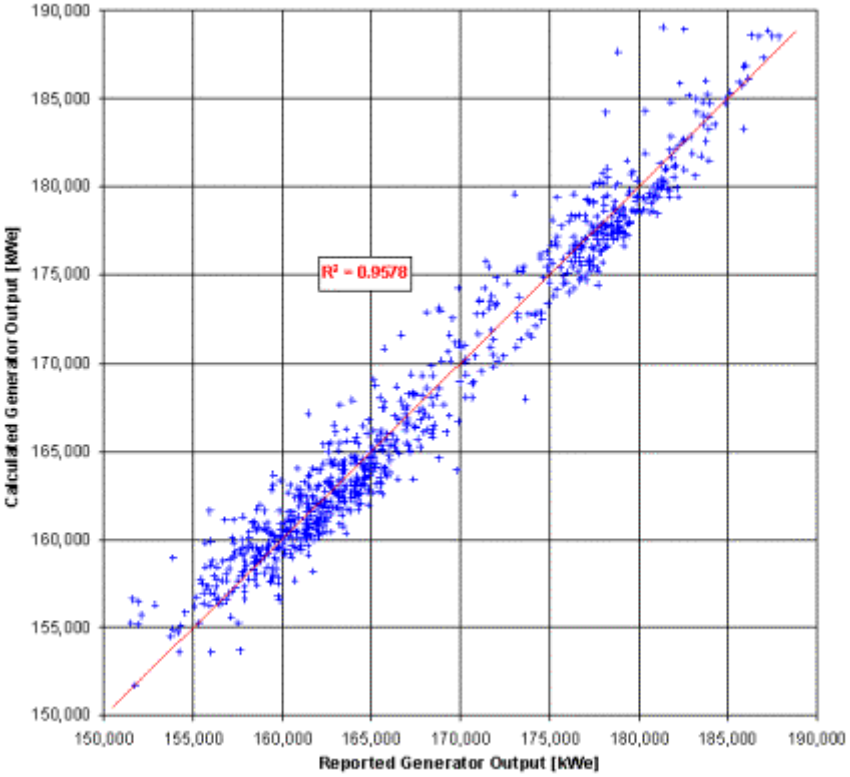


Figure 168. Results of Power Regression

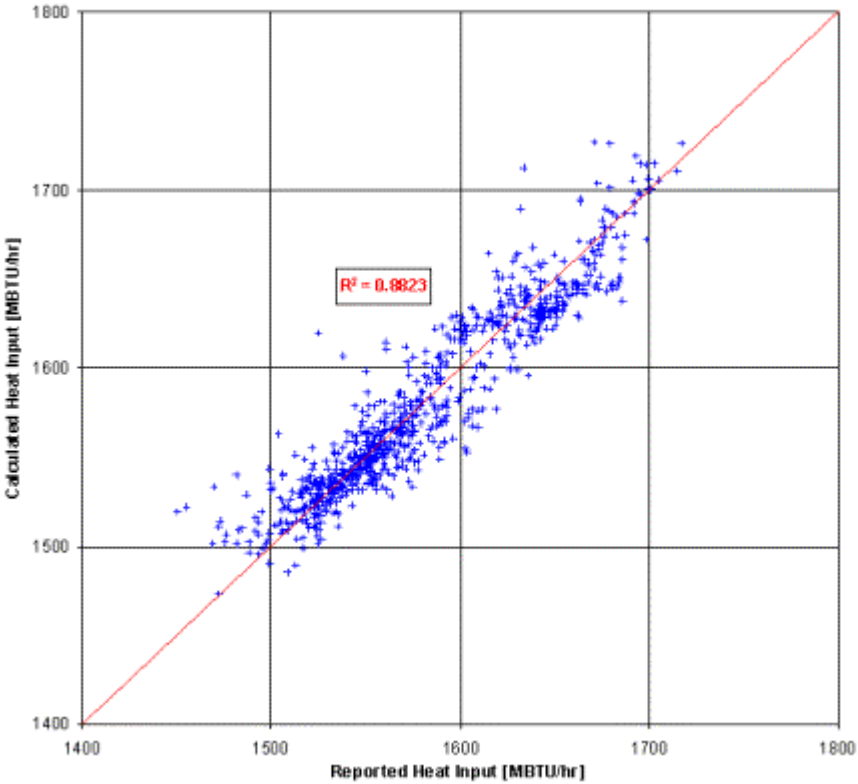


Figure 169. Results of Heat Input Regression

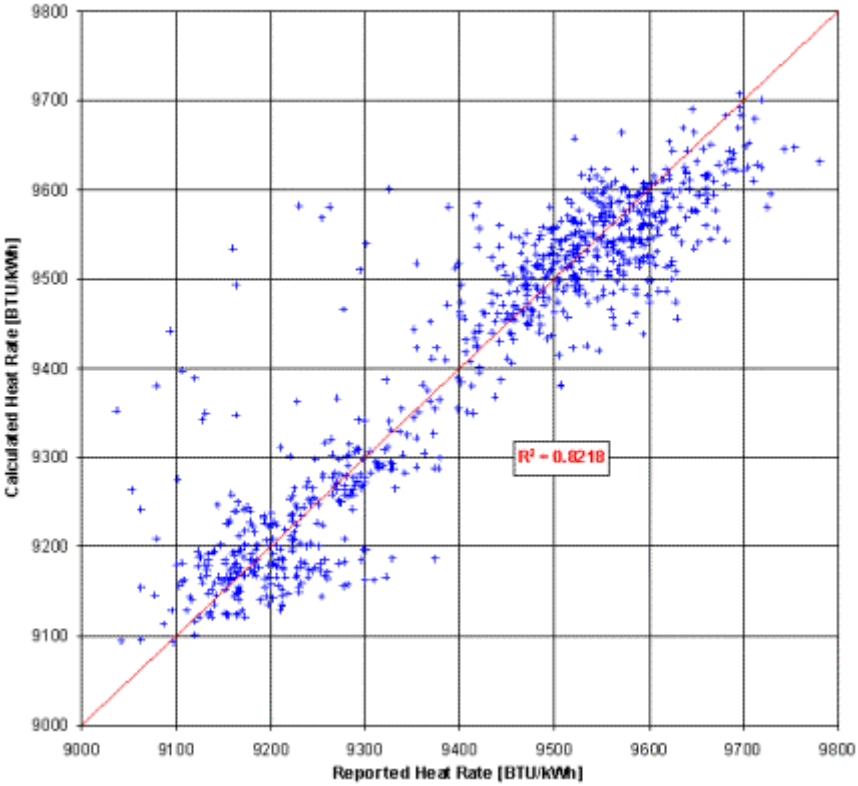


Figure 170. Results of Heat Rate Regression

Figure 171. Results of Exhaust Flow Regression

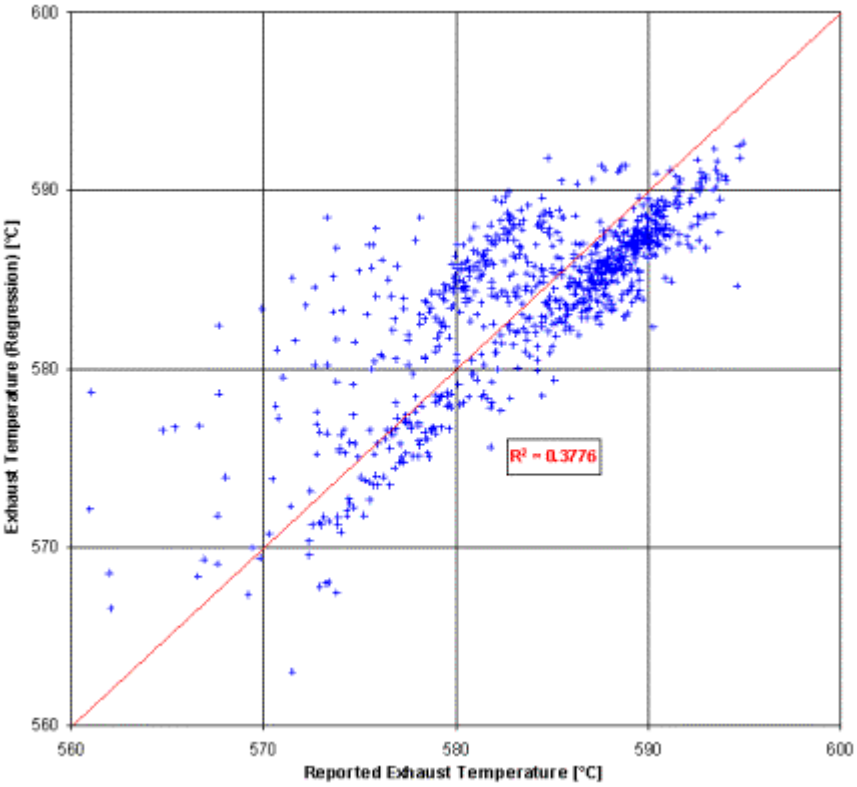


Figure 172. Results of Exhaust Temperature Regression

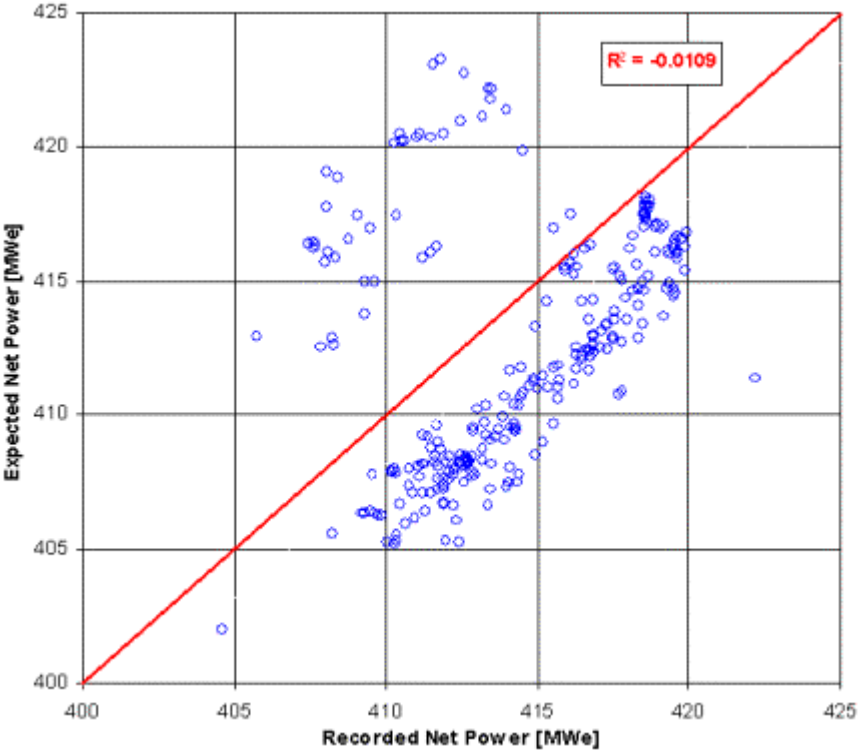


Figure 173. Recorded vs. Expected Full-Load Net Power Output

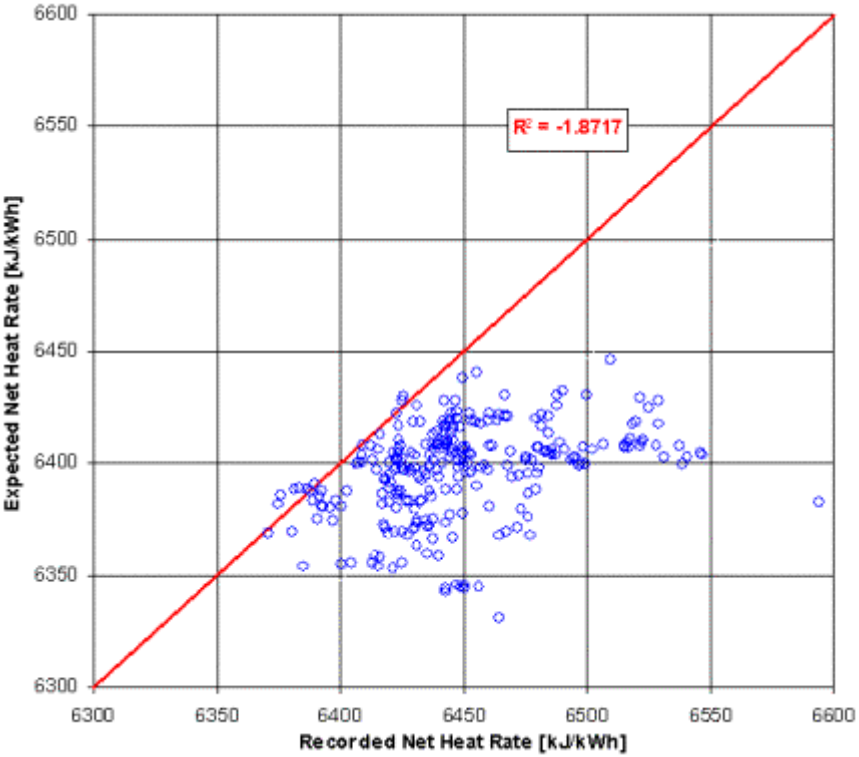


Figure 174. Recorded vs. Expected Full-Load Net Plant Heat Rate

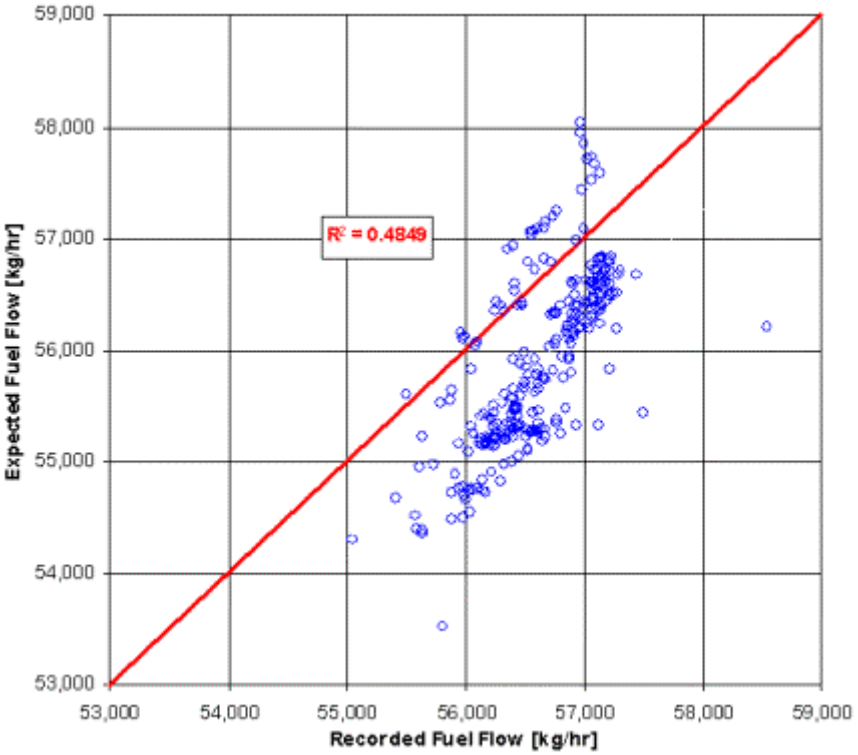


Figure 175. Recorded vs. Expected Fuel Flow at Full Load

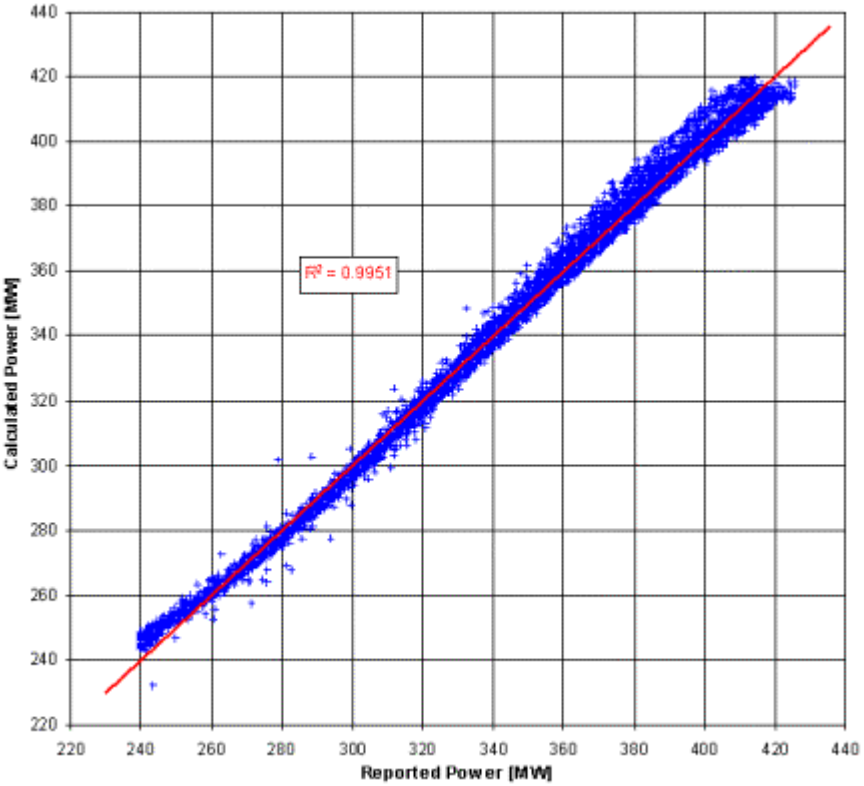


Figure 176. Revised Net Power Comparison

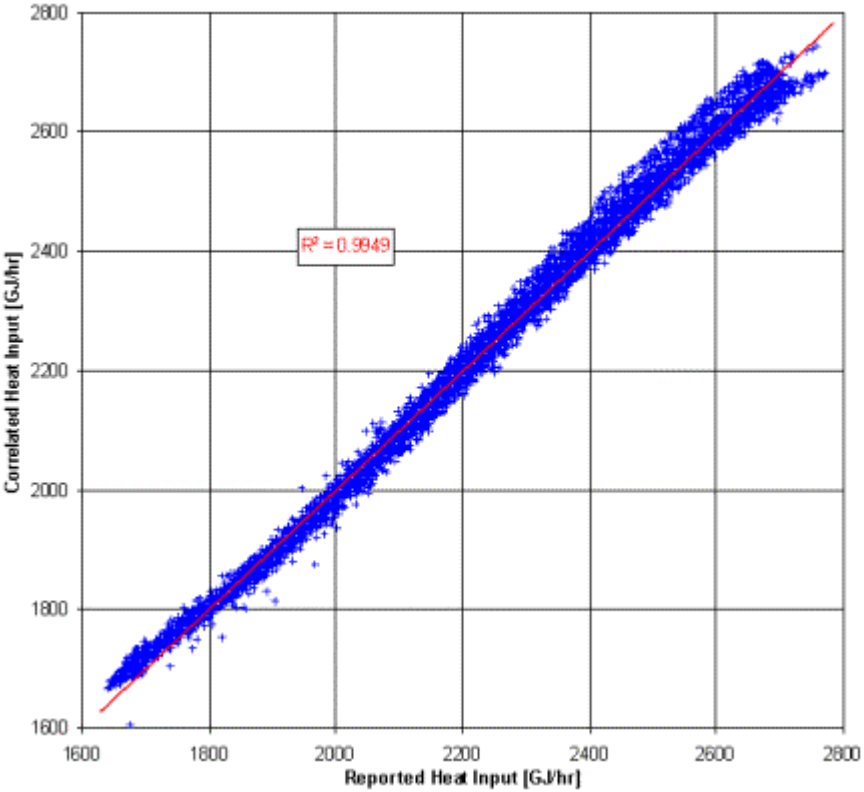


Figure 177. . Revised Heat Input Comparison

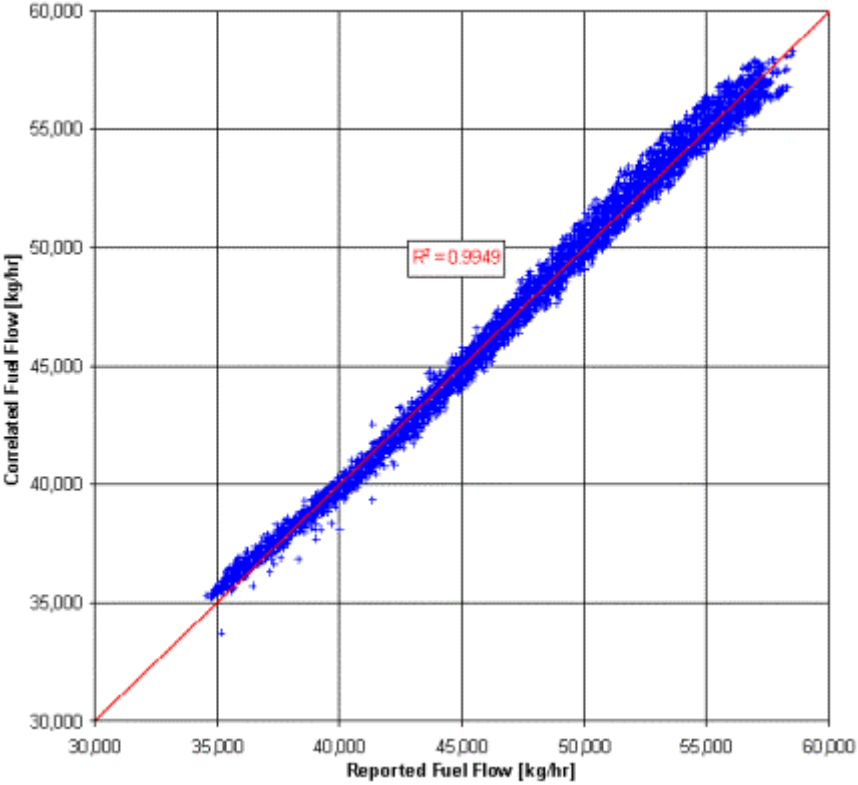


Figure 178. Revised Fuel Flow Comparison

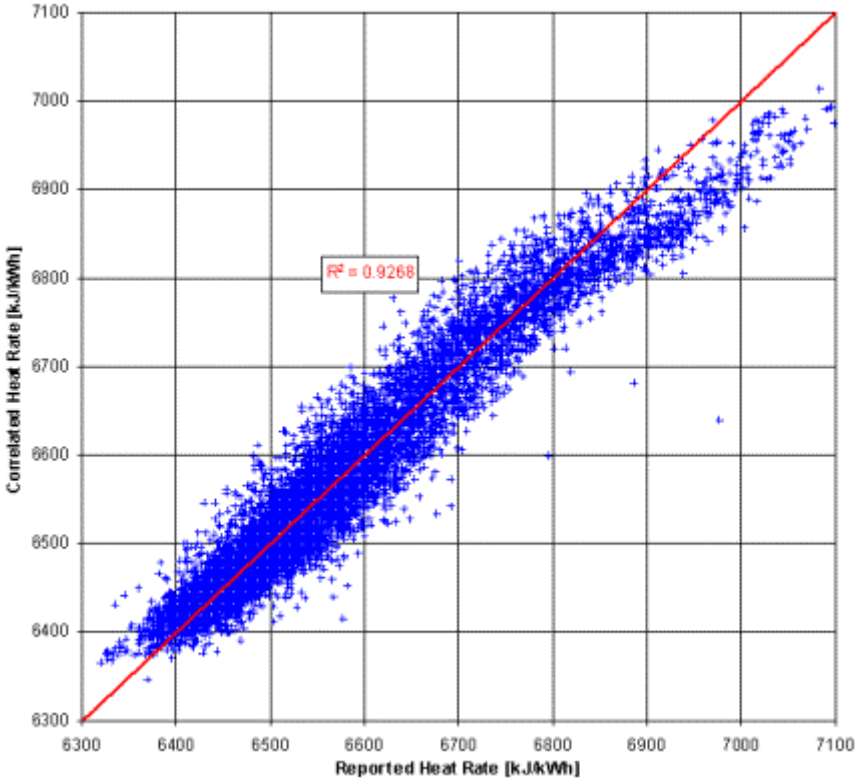


Figure 179. Revised Heat Rate Comparison

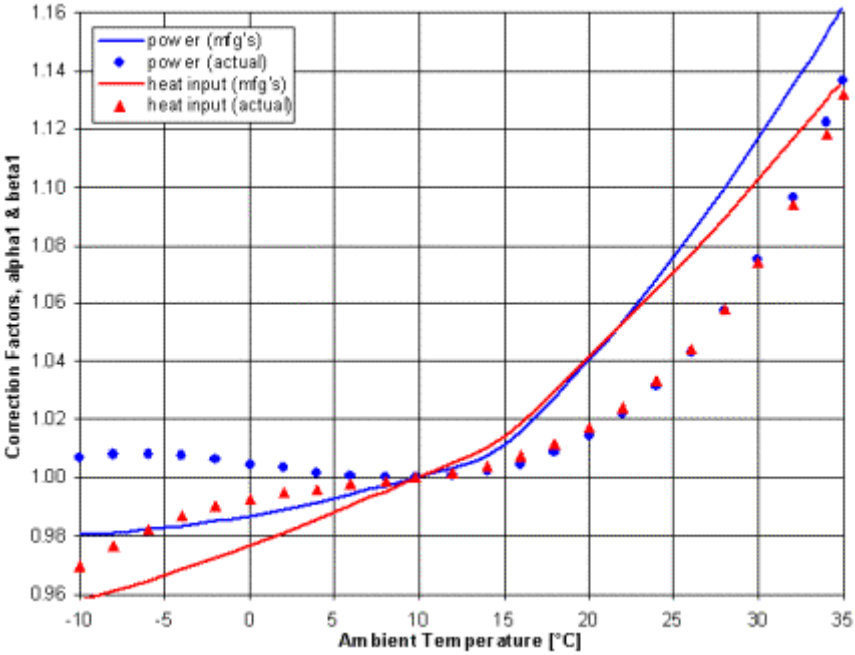


Figure 180. Temperature Corrections, alpha1 & beta1

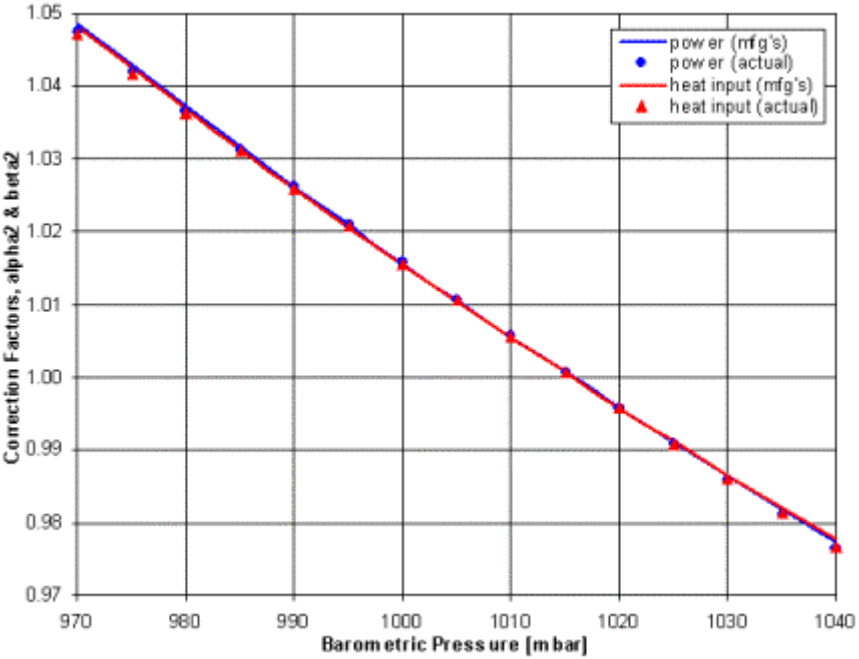


Figure 181. Barometric Pressure Corrections, alpha2 & beta2

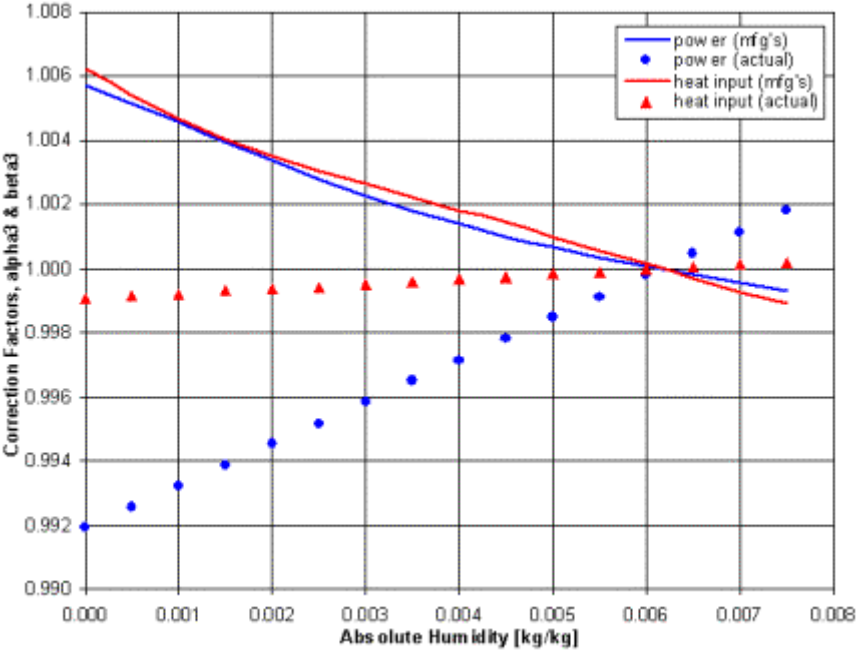


Figure 182. Humidity Corrections, alpha3 & beta3

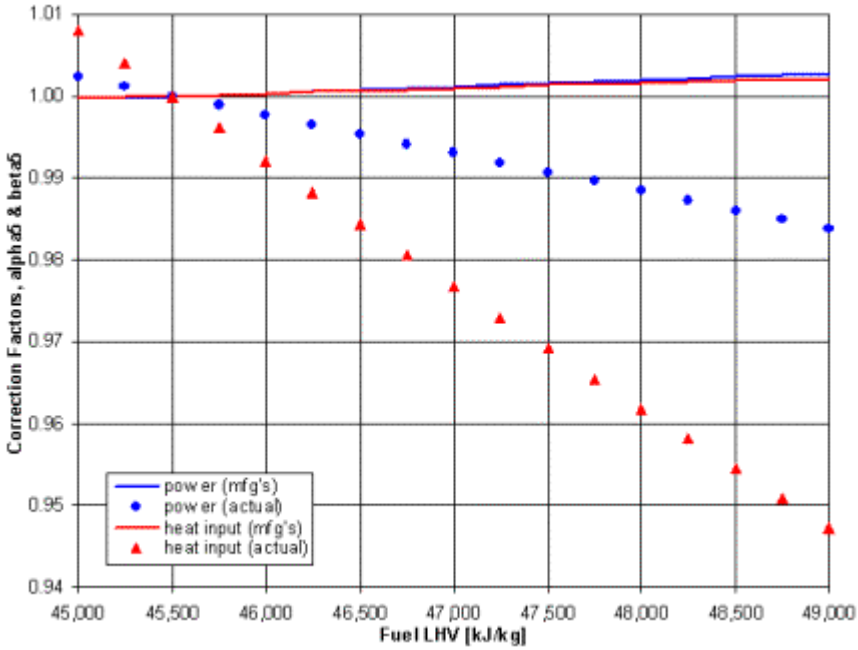
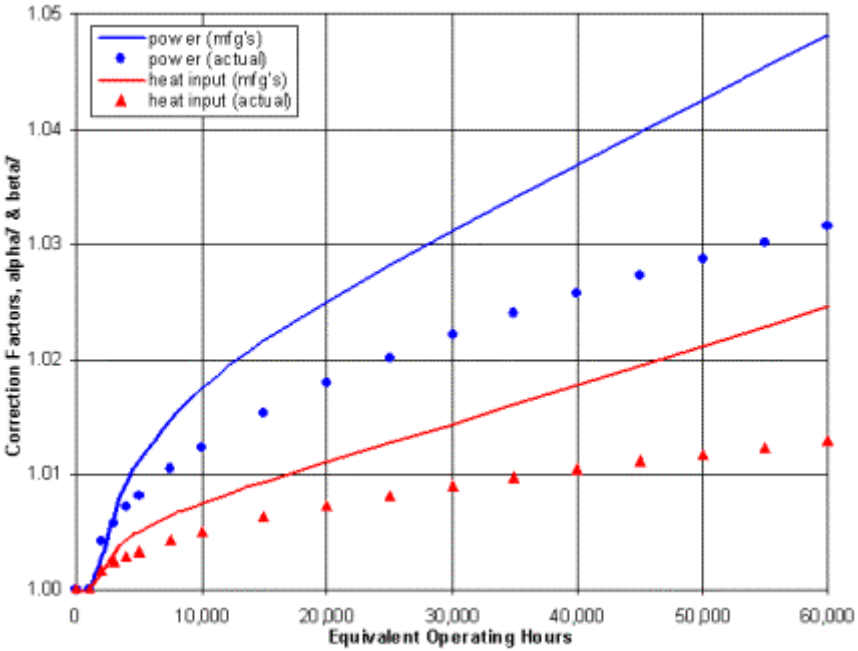


Figure 183. Fuel Composition Corrections, alpha5 & beta5



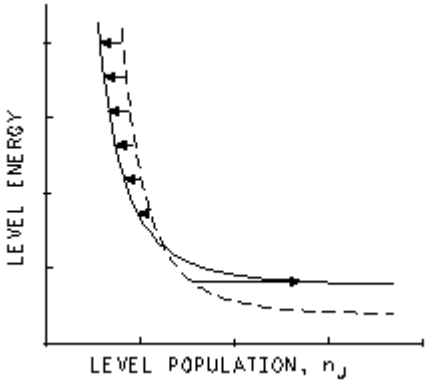


Figure A1. Change in Level Populations

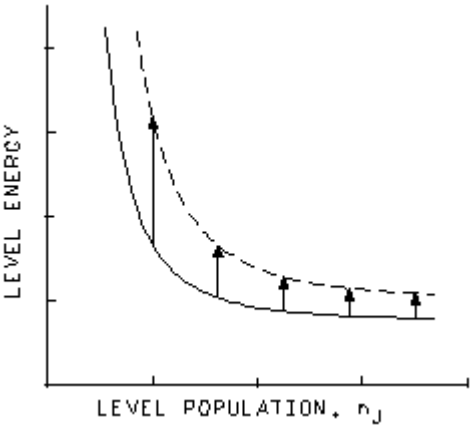


Figure A2. Change in Energy Levels

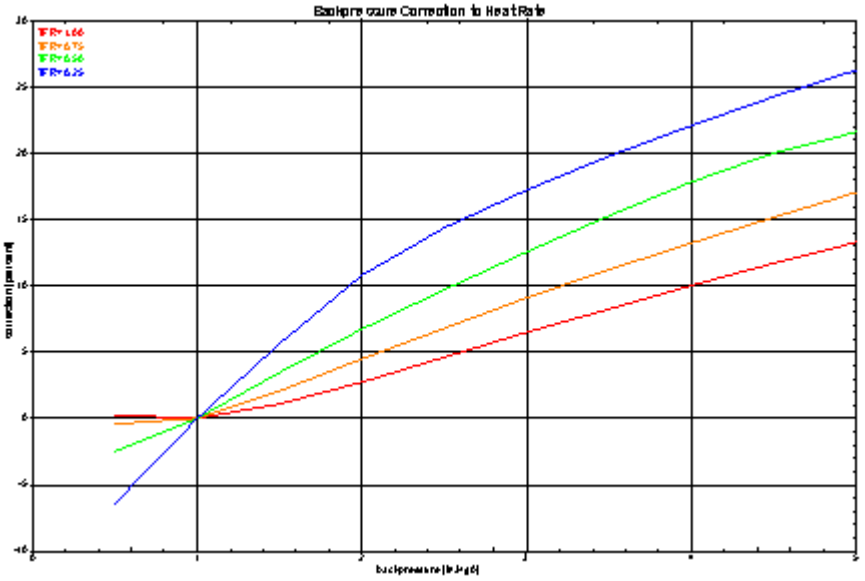


Figure 184. Backpressure Correction to Heat Rate

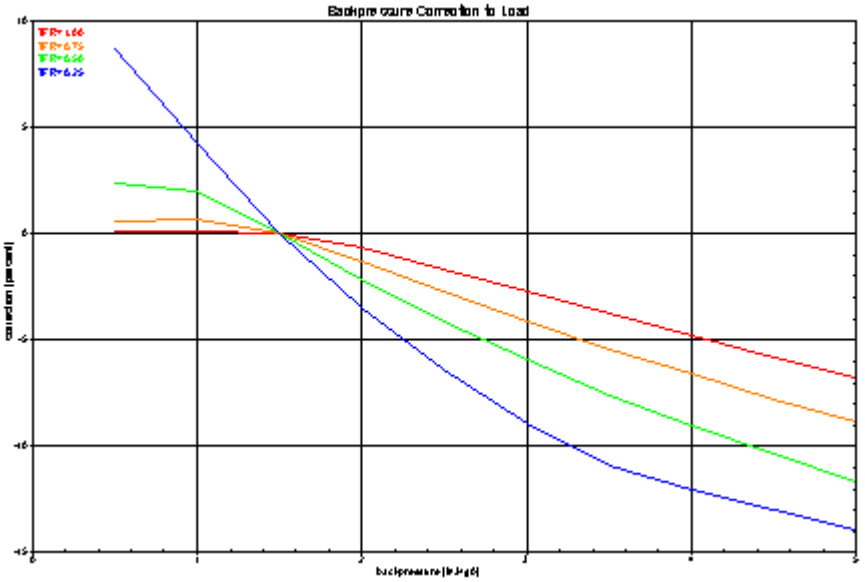


Figure 185. Backpressure Correction to Load

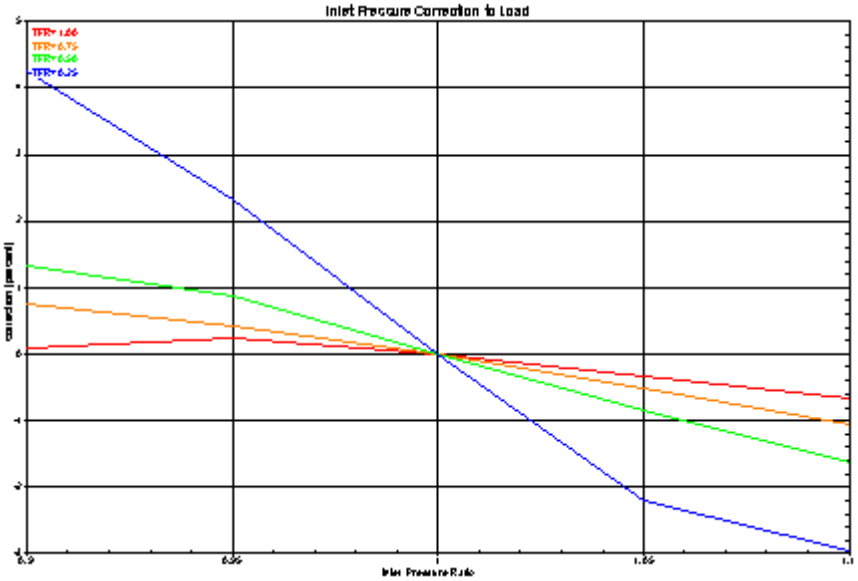


Figure 186. Steam Pressure Correction to Load

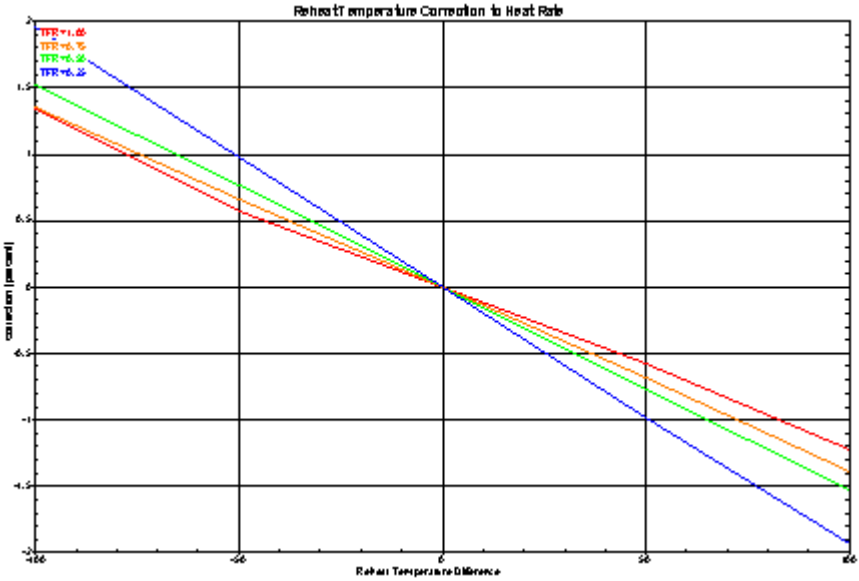


Figure 187. Reheat Temperature Correction to Heat Rate

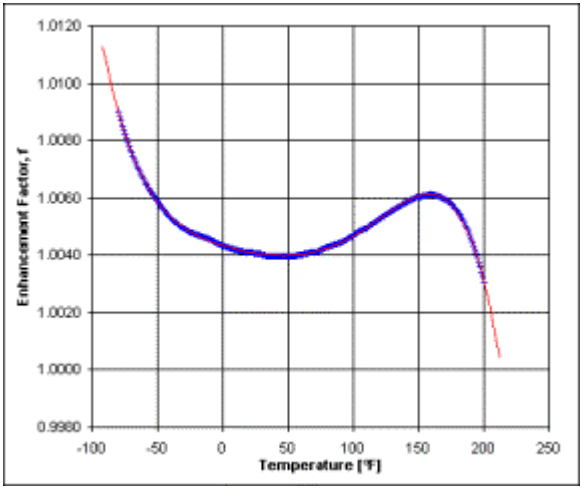


Figure 188. Enhancement Factor

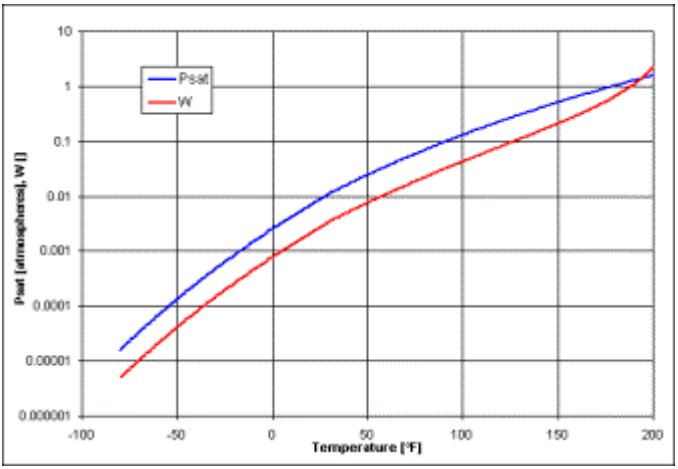


Figure 189. Saturation Pressure vs. Humidity Ratio

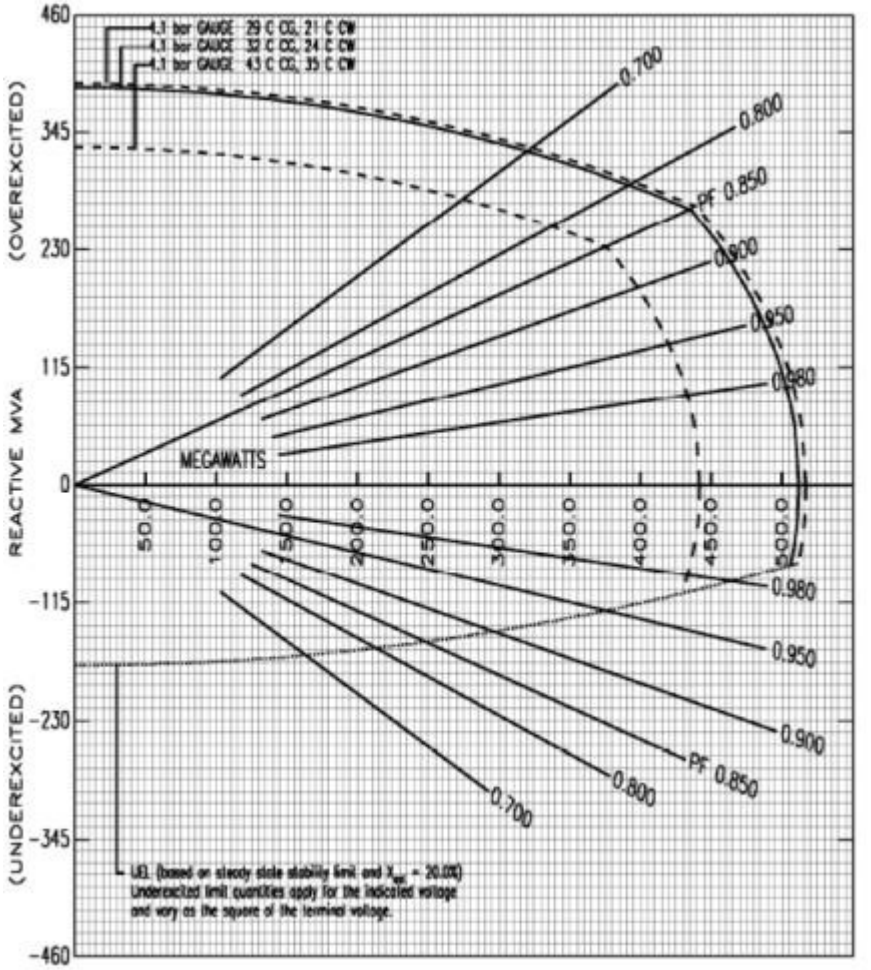


Figure 190. Typical Reactive Capability Curves

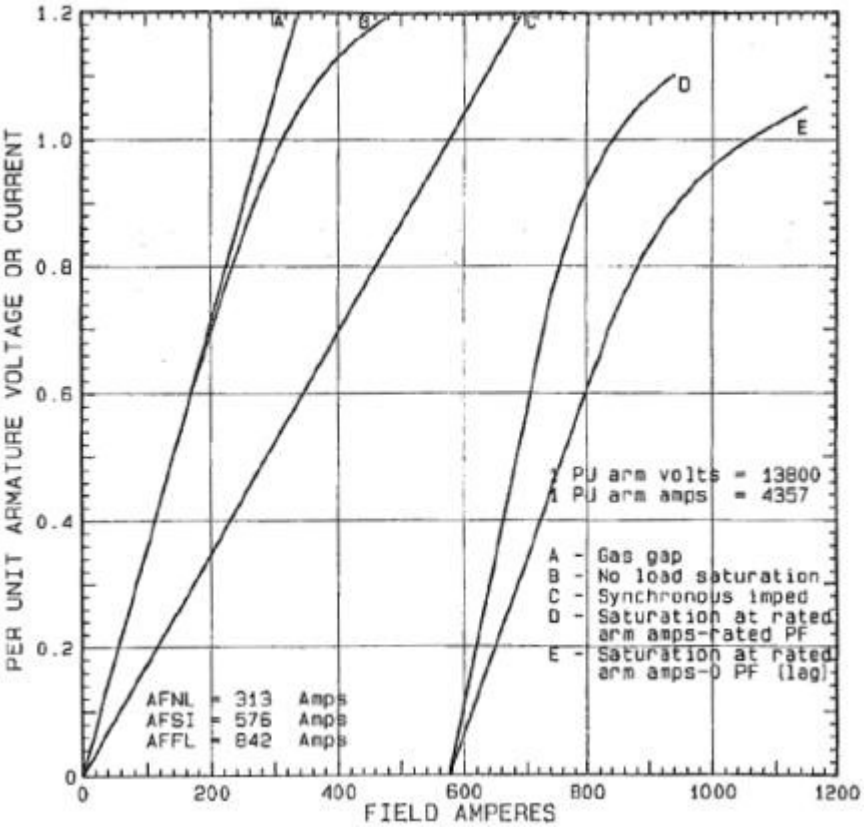


Figure 191. Typical Synchronous Impedance Curves

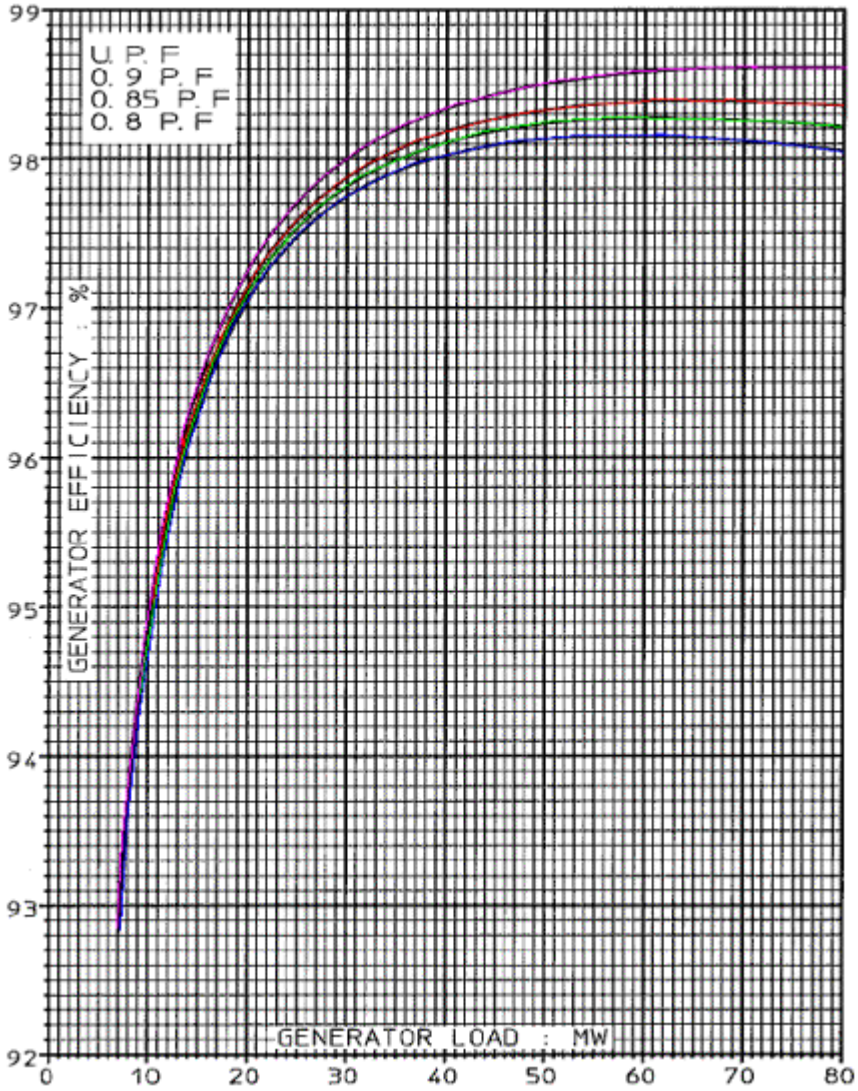


Figure 192. Typical Efficiency Curves

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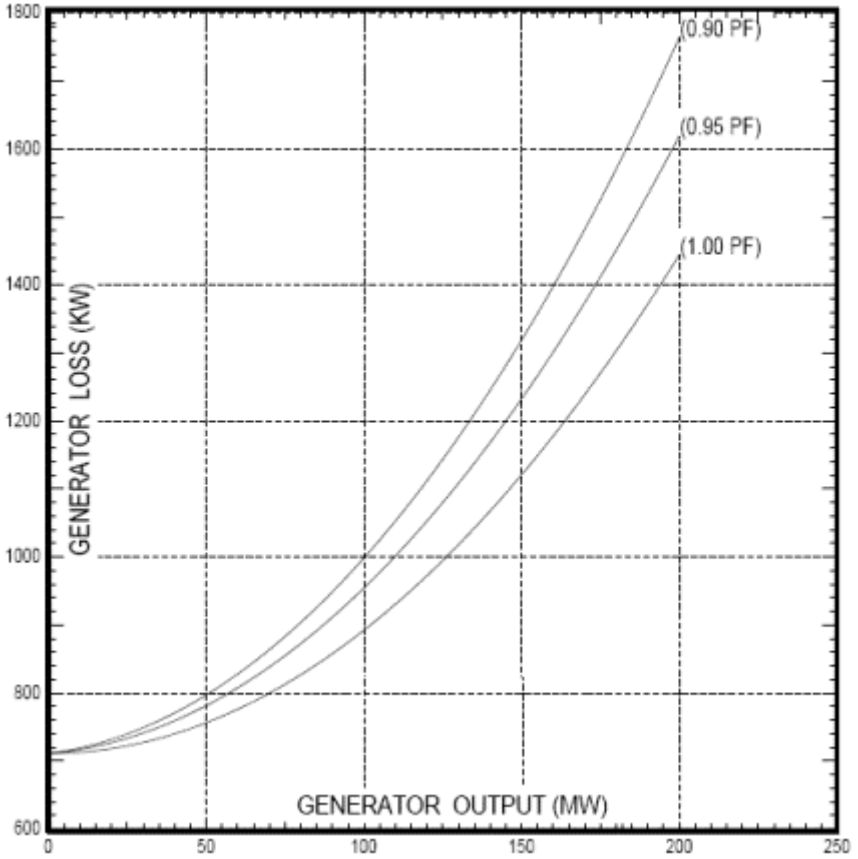


Figure 193. Typical Generator Loss Curves

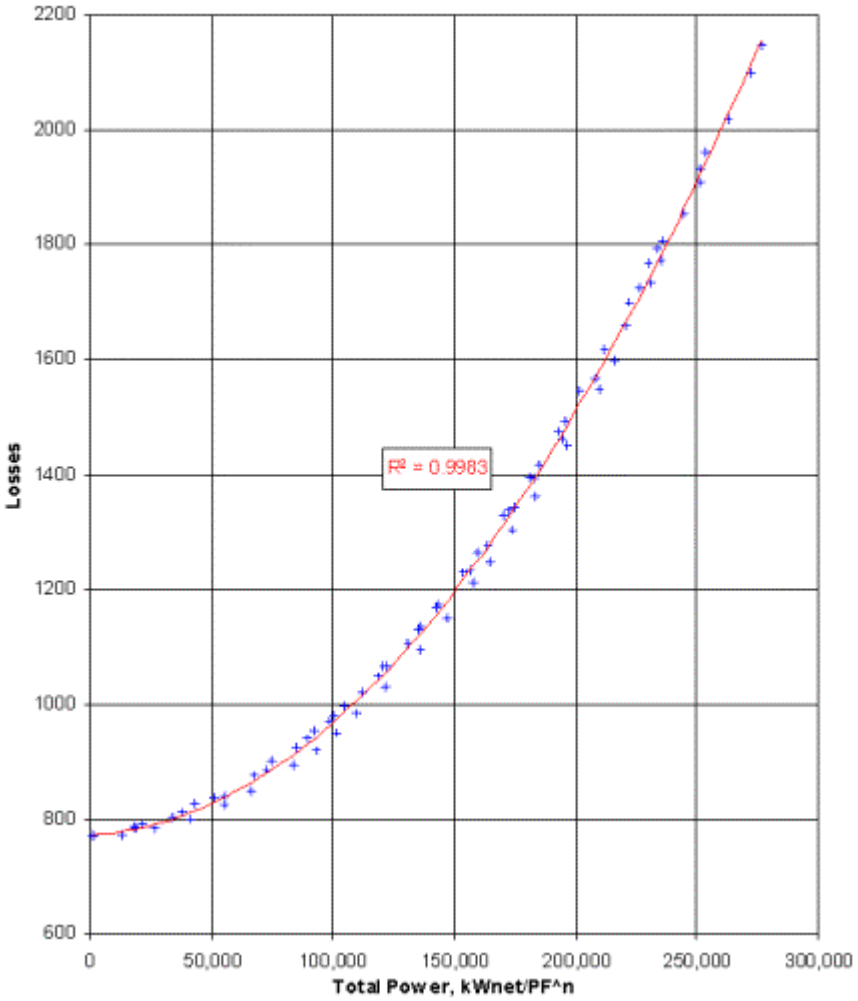


Figure 194. Multiple Loss Curves Collapse to Single Curve

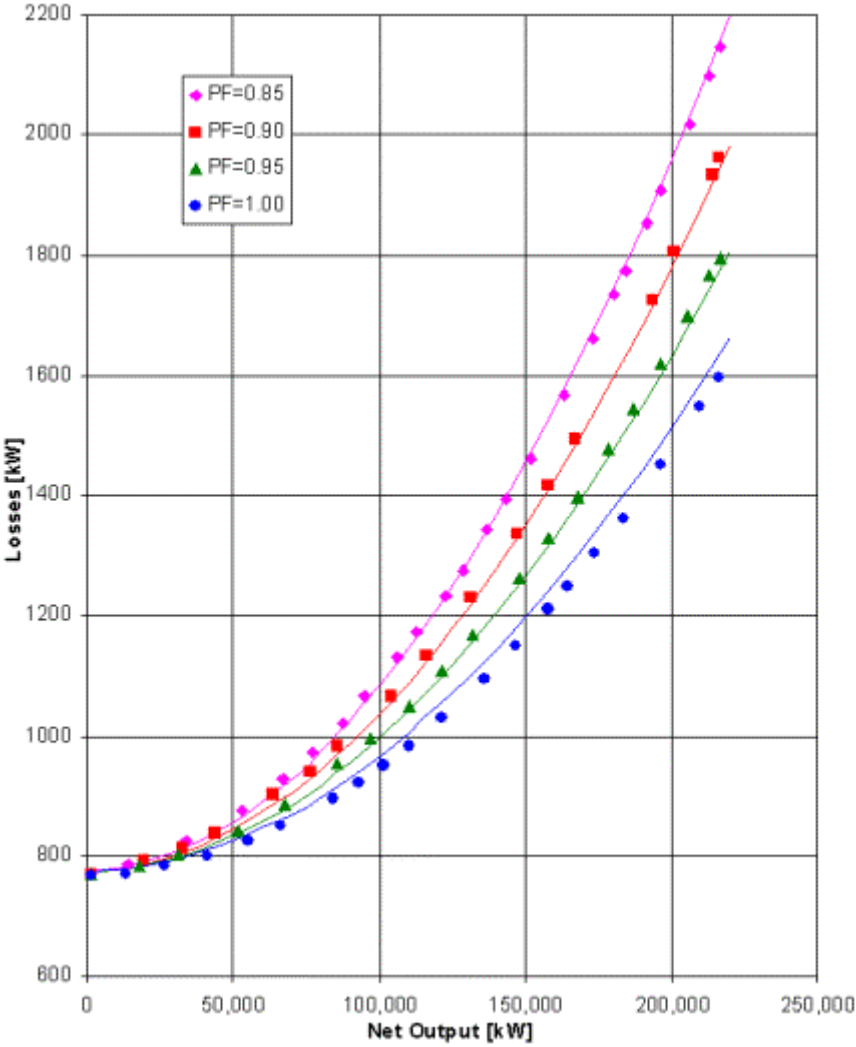
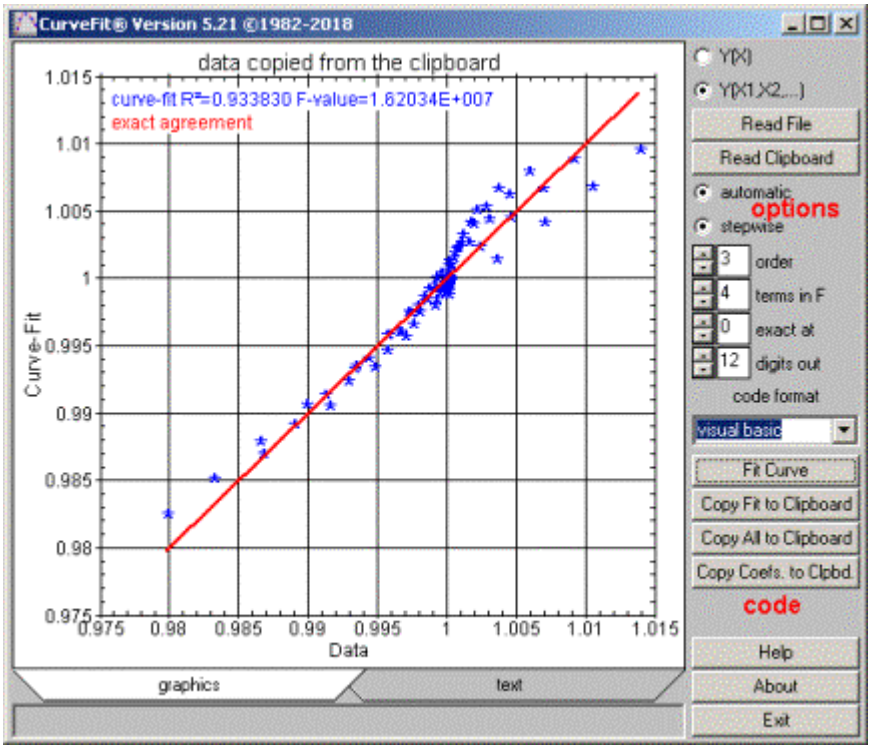


Figure 195. Typical Generator Loss Curve Regression Results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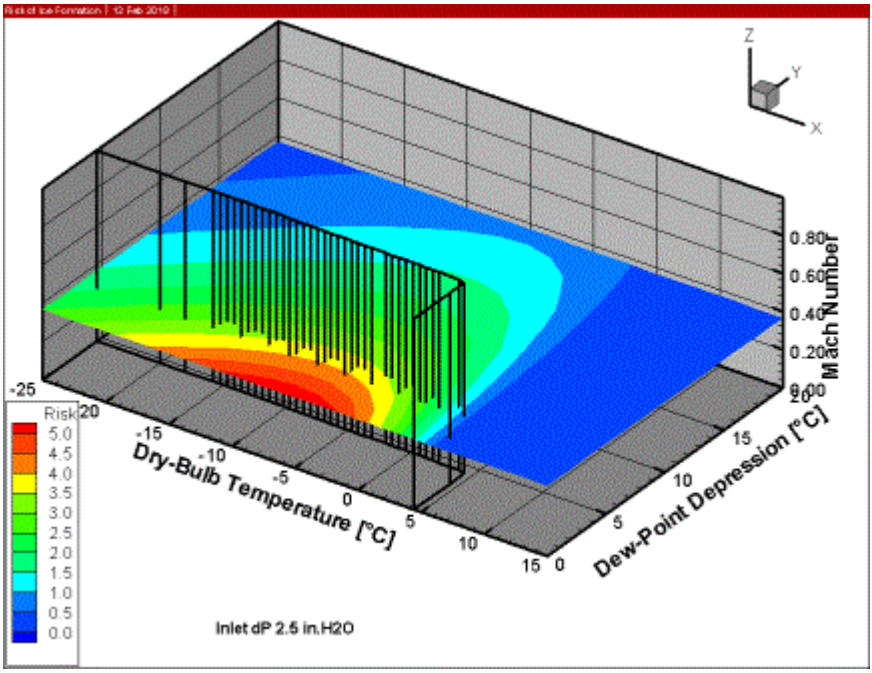

Figure 196. Risk of Icing

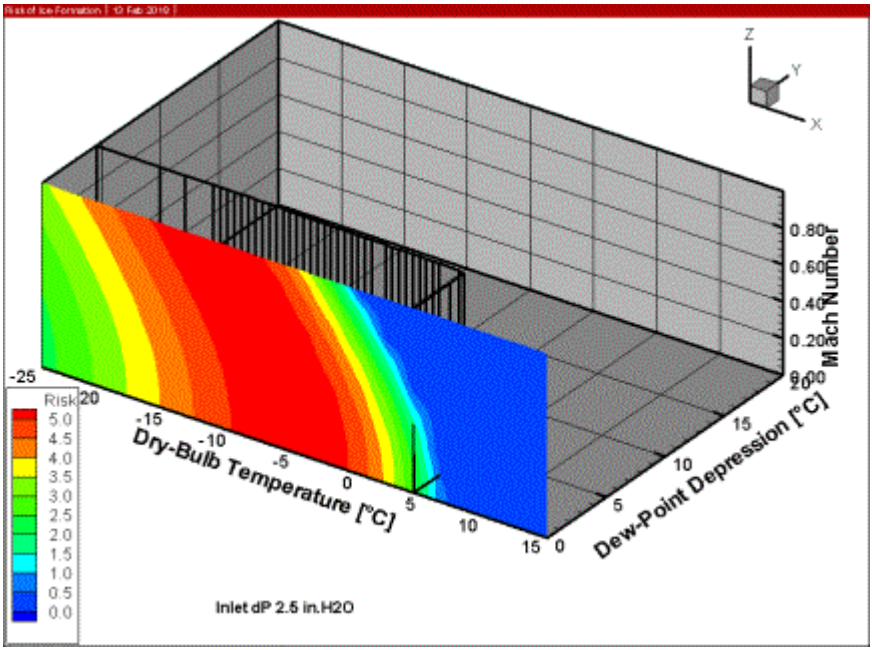

Figure 197. Risk Factor Slicing 1

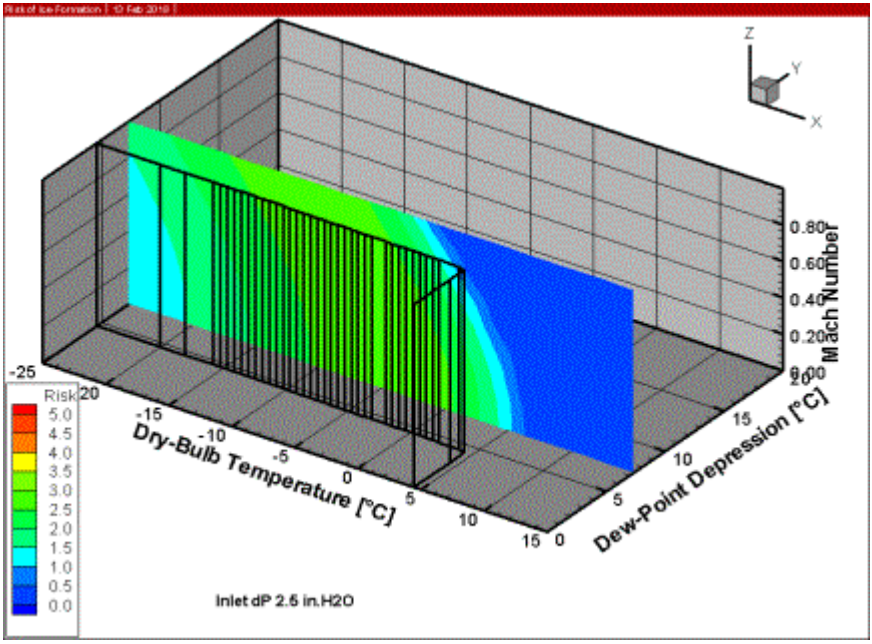

Figure 198. Risk Factor Slicing 2

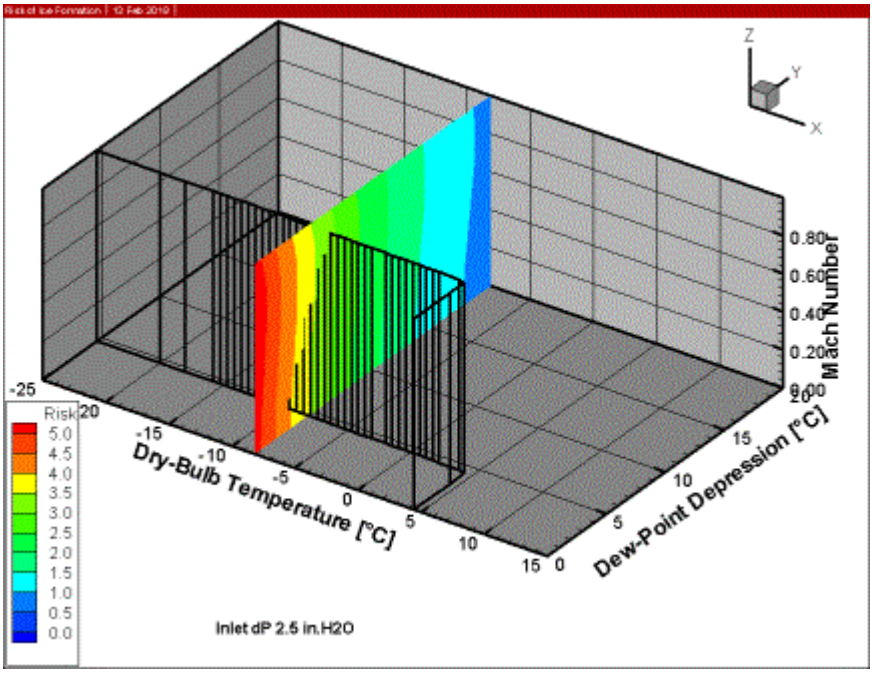

Figure 199. Risk Factor Slicing 3

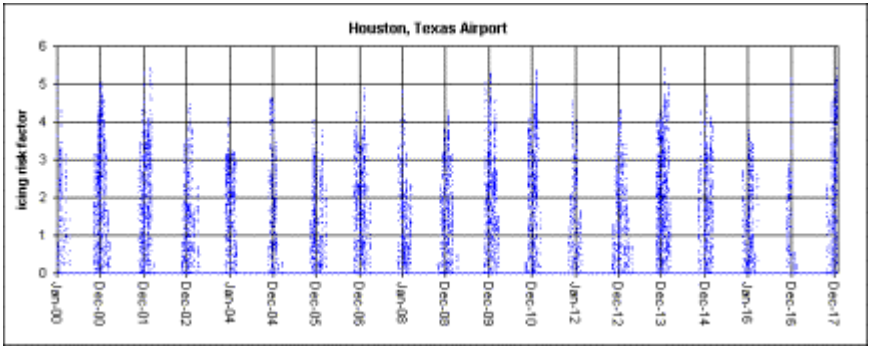

Figure 200. Risk of Icing for Houston, TX

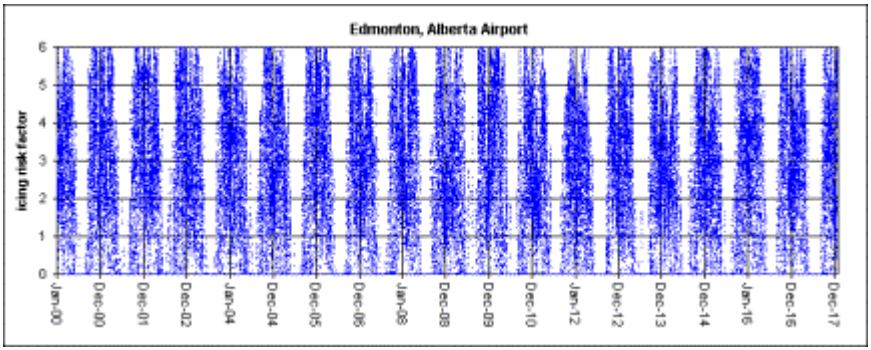

Figure 201. Risk of Icing for Edmonton, Alberta

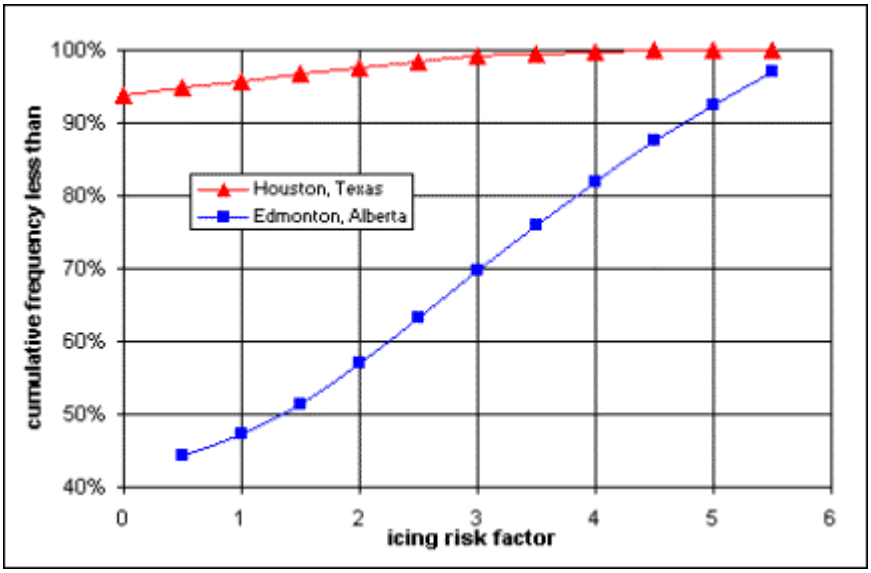

Figure 202. Icing Risk Cumulative Probability Curves

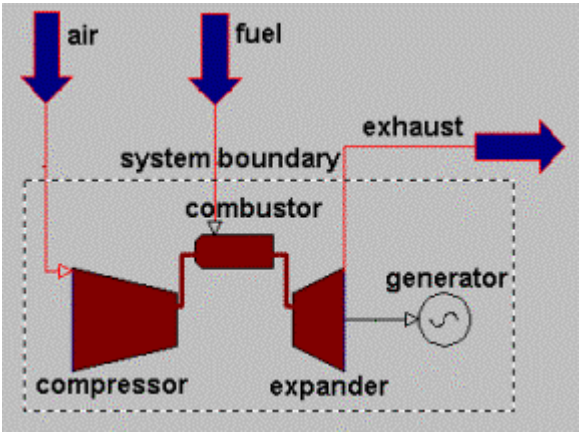

Figure 203. Combustion Turbine System Boundary

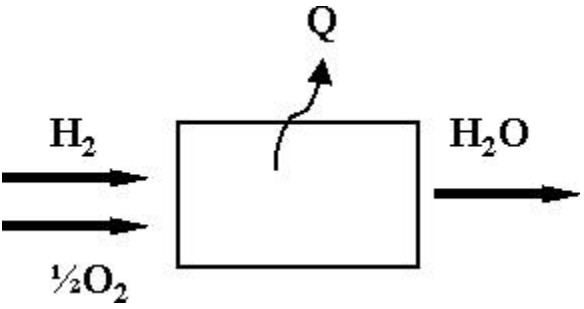

Figure 204. Combustion Schematic