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INLET FOGGING OF GAS TURBINE ENGINES DETAILED CLIMATIC ANALYSIS OF GAS TURBINE EVAPORATIVE COOLING POTENTIAL IN THE USA

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ABSTRACT

Inlet fogging of gas turbine engines has attained considerable popularity due to the ease of installation and the relatively low first cost compared to other inlet cooling methods. With increasing demand for power and with shortages envisioned especially during the peak load times during the summers, there is a need to boost gas turbine power. There is a sizable evaporative cooling potential throughout the world when the climatic data is evaluated based on an analysis of *coincident wet bulb and dry bulb information*. This data is not readily available to plant users. In this paper, a detailed climatic analysis is made of 122 locations in the US to provide the hours of cooling that can be obtained by direct evaporative cooling. This data will allow gas turbine operators to easily make an assessment of the economics of evaporative cooling. The paper also covers an introduction to direct evaporative cooling and the methodology and data analysis used to derive the cooling potential in different regions of the US. Simulation runs have been made for gas turbine simple cycles using a reference plant based on a GE Frame 7111EA gas turbine at the 122 locations studied in the US to provide a feel for the sensitivity of operation with inlet fogging.

NOMENCLATURE

ECDH	Equivalent Cooling Degree Hours
GPM	Gallons/minute
DB	Dry Bulb Temp
WB	Wet Bulb Temp
WG	Water Gauge

1. INTRODUCTION

Gas Turbine output is a strong function of the ambient air temperature with power output dropping by 0.3-0.5 % for every 1°F rise in ambient temperature. On several heavy frame gas turbines, power output drops of around 20% can be experienced when ambients reach 95°F (35°C), coupled with a heat rate increase of about 5%. Aeroderivative gas turbines exhibit even a greater sensitivity to ambient conditions. Figure 1 derived by examining several turbines provides a representation of the power boost capability for different types of gas turbines. This was derived using GTPRO[1] software over a range of turbines. This loss in output presents a significant problem to utilities, cogenerators and IPPs when electric demands are high during the hot summer months. In the petrochemical and process industries, the reduction in output of mechanical drive gas turbines often curtails plant output. For example, at some LNG plants, production may have to be curtailed during the hot afternoons when the refrigeration capacity is limited by gas turbine driver power. One way to counter this drop is to cool the inlet air. While there are several cooling technologies available, fogging has seen large-scale application because of the advantage of low first cost when compared to other techniques including media evaporative cooling and refrigeration technologies[2].

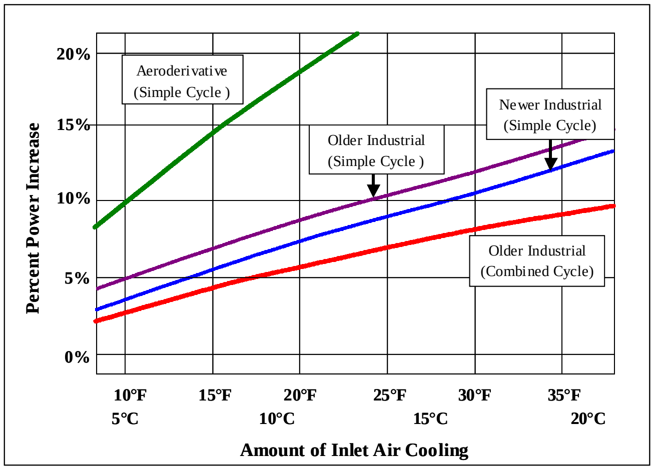

Figure 1. Representation of power boost possible by inlet cooling.

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[1] Program by Thermoflow Inc.
[2] Cost ratios are about 5:1 but can vary based on project specifics.

One obstacle faced by gas turbine users in analyzing the potential for fog evaporative cooling is that there is sparse climatic data available in a form that users can make a decision on the benefits of evaporative cooling. The obstacle may be broken into two factors:

[1] Operators cannot easily locate the appropriate weather data for their site. Much of the data is available at a plant site may be based on ***average*** data points with no representation of the values of *coincident* dry and wet bulb temperatures. This data is invaluable when evaluating any evaporative cooling solution.

[2] Even when some appropriate data is available through web sites or other sources, the data tables and information are not in a format to enables an operator to rapidly access the potential of evaporative cooling. The data has often to be considerably massaged and collated before any meaningful estimate can be made of cooling potential at the site.

This paper will provide a detailed analysis of multiple locations in the US providing useful climatic data which allows users to evaluate the power augmentation potential available. To our knowledge, this is the first attempt to consolidate this data in a form that users can use easily. It is planned to extend this analysis in a later paper, to sites located at several locations in the world.

McNeilly (2000) has provided an excellent study on the importance of accurate climatic data when evaluating gas turbine inlet cooling projects. The relative potential of different gas turbines to capacity increase due to inlet cooling has been evaluated by Kitchen et al (1995).

2. OVERVIEW OF EVAPORATIVE COOLING TECHNOLOGY

2.1 Traditional Evaporative Cooling

Traditional media based evaporative coolers have been widely used in the gas turbine industry especially in hot arid areas. The basic principle of evaporative cooling is that as water evaporates, it consumes 1,160 BTUs of heat (latent heat of vaporization) and in doing so reduces the ambient air temperature.

Traditional Evaporative Coolers are described in detail by Johnson, (1988).

Evaporative cooler effectiveness is given by:

$$E = \frac{T_{1DB} - T_{2DB}}{T_{1DB} - T_{2WB}} \qquad (1)$$

Where,

T_1 = inlet temperature

T_2 = exit temperature of evaporative cooler

DB = dry bulb

WB = wet bulb

A typical value for effectiveness is 85-90% which means that the Wet bulb temperature can never be attained.

The temperature drop is given by:

$$\Delta T_{DB} = 0.9(T_{1DB} - T_{2WB}) \qquad (2)$$

A psychometric chart can be used to obtain the values. The exact power increase depends on the particular machine type, site altitude and ambient conditions.

The presence of a media type evaporative cooler inherently creates a pressure drop which results in a drop in turbine output. As a rough rule of thumb, a 1" WG increase in inlet duct losses will result in a 0.48% drop in power and a 0.12% increase in heat rate. These numbers would be somewhat higher for an aeroderivative machine. Increases in inlet duct differential pressure will cause a reduction of compressor mass flow and engine operating pressure. Increase in inlet differential pressure results in a reduction of the turbine expansion ratio.

The inherent loss of efficiency and increased inlet pressure loss in a traditional evaporative cooling system never allows for the maximum cooling effect to be attained. Water quality requirements are, however, less stringent than those required for direct fog cooling systems and this may be an important factor in some site locations when demineralized water is not easily available or is expensive.

2.2 Inlet Fogging

Direct inlet fogging is a method of cooling where demineralized water is converted into a fog by means of special atomizing nozzles operating at 2000 psi. This fog provides cooling when it evaporates in the air inlet duct of the gas turbine. This technique allows 100% effectiveness in terms of attaining 100 percent relative humidity at the gas turbine inlet and thereby gives the lowest temperature possible without refrigeration (the wet bulb temperature). Direct high pressure inlet fogging can also be used to create a compressor intercooling effect by allowing excess fog into the compressor, thus boosting the power output considerably. In this paper, consideration is only made of *evaporative* fogging alone, with no discussion of fog intercooling being considered. A photograph showing a typical high pressure fogging skid is shown in Figure 2.

Figure 2. Typical high pressure fogging skid. The feed lines from the high pressure pumps to the inlet system can be seen here.

This consists of a series of high pressure reciprocating pumps providing demineralized water to an array of high pressure fogging nozzles located after the air filter elements. The nozzles create a large number of micron size droplets which evaporate cooling the inlet air to wet bulb conditions. A photo of a nozzle array fogging an inlet duct for a large frame machine is shown in Figure 3.

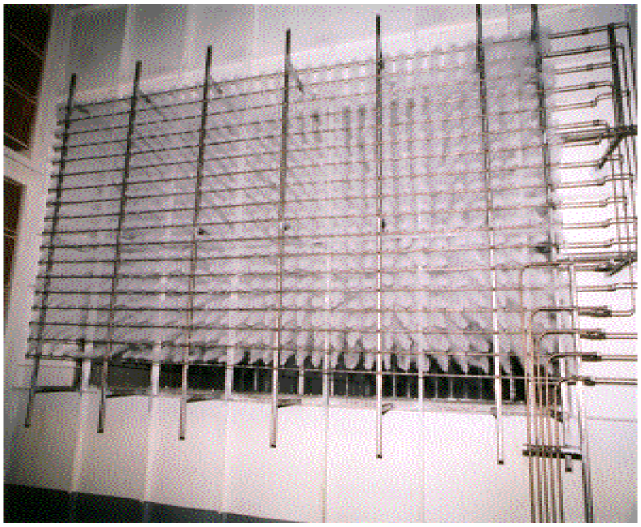

Figure 3. High pressure fogging skid in operation for a heavy-duty gas turbine.

2.2.1 Control of Inlet Fogging Systems and the Importance of Climatic Data. The control system incorporates a programmable logic controller (PLC), which is mounted on the high-pressure pump skid. Sensors are provided to measure relative humidity and dry bulb temperature. Programming algorithms within the PLC use these measured parameters to compute the ambient wet bulb temperature and the wet bulb depression (i.e., the difference between the dry bulb and wet bulb temperature) to quantify and control the amount of evaporative cooling that is possible at the prevailing ambient conditions. The system turns on (or off) fog cooling stages to match the ability of the ambient air conditions to absorb water vapor. The software would then be configured to adjust the amount of fog injected in proportion to the inlet air mass flow.

By choosing pump displacements (i.e., flow in gpm) it is possible to derive multiple cooling stages with the utilization of different pump combinations.

Obviously, the control of the skid is based on climatic conditions and so the overall utilization of the fogging system at any location, is a strong function of the climatic conditions. It is this reason that makes an accurate understanding of the variations in climatic conditions an imperative.

3. CLIMATIC AND PSYCHROMETRIC ASPECTS OF INLET FOGGING

3.1 Modeling of Climatic Data

There are numerous problems and traps when modeling climatic data- several of which derive from the concept of "averaging" of data. One example of this is using data such as shown in Figure 4. This figure provides a correlation of dry bulb and wet bulb averages at a certain site. The graph shows that the linear behavior may lead one to conclude that at a dry bulb temperature of 25°C, the expected wet bulb is 20°C allowing a wet bulb depression of 5°C. (i.e., a measure of evaporative cooling potential). This is totally erroneous as the data was derived by taking the *average* WB temperature and the *average* DB temperature and plotting the curve. Consequently, the graph does *not* reflect *coincident* WB and DB conditions and will therefore indicate a much reduced cooling potential. This sort of error is very common. There is also a tendency of engineers to specify operating conditions that represent the "worst case" in terms of temperature and humidity. This is done in an attempt to derive an installation that will provide required capacity under the most stringent conditions, but in most cases, these extreme conditions can never exist in nature. The result is that plants may end up more expensive than they need to be[3].

This philosophy also pervades the definition of site conditions for power generation and mechanical drive applications. More than often the capacity conditions are defined at a very high temperature in combination with a high or average relative humidity. This often leads to more expensive plant construction than is needed (McNeilly, 2000).

It is advisable that the site's temperature profile for a full year of hourly data with the 20-30 year average wet and dry bulb coincident temperatures be considered in the analysis. These data can be used to generate "evaporative cooling degree hour" (ECDH) numbers for each hour of the year and allow a turbine operator to make a very detailed and accurate analysis of potential power gain from inlet fogging.

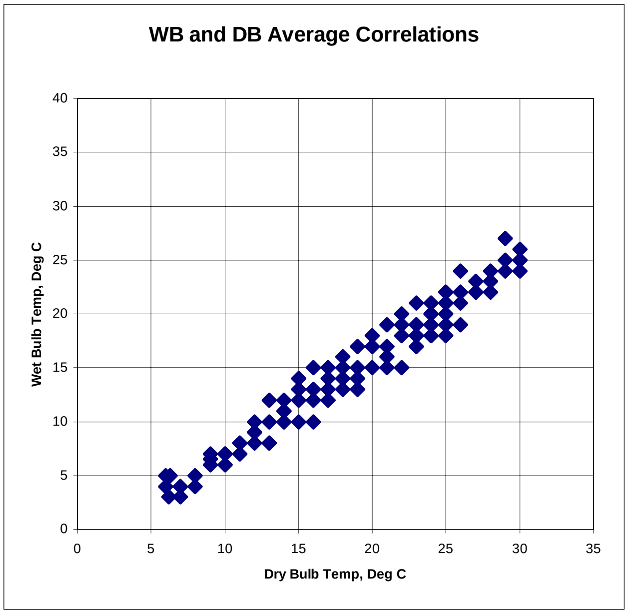

Figure 4. Correlation of WB and DB temperatures- averaged data.

High relative humidity conditions do not occur with high dry bulb temperatures. A typical pattern of variation of dry bulb and wet bulb temperature over a day is depicted in Figure 5. As can be seen, during the afternoon hours, there is a considerable difference between the wet bulb and dry bulb temperatures. It is this spread that allows the use of fog evaporative cooling. .

A common mistake made by potential users is to take the reported high relative humidity and temperature for a given month and base the design on these. The problem is that the high relative humidity generally occurs time-coincident with the lowest temperature and the lowest relative humidity occurs with the highest temperature. This mistake results in the erroneous conclusion that very little evaporative cooling can be accomplished and has

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[3] The problem is compounded as the EPC contractor for the plant who is held to a guarantee, enforces the extreme climatic conditions on the turbine manufacture possibly. resulting in an oversized turbine.

historically been the underlying cause of the maxim that evaporative cooling is not possible in “high humidity regions”.

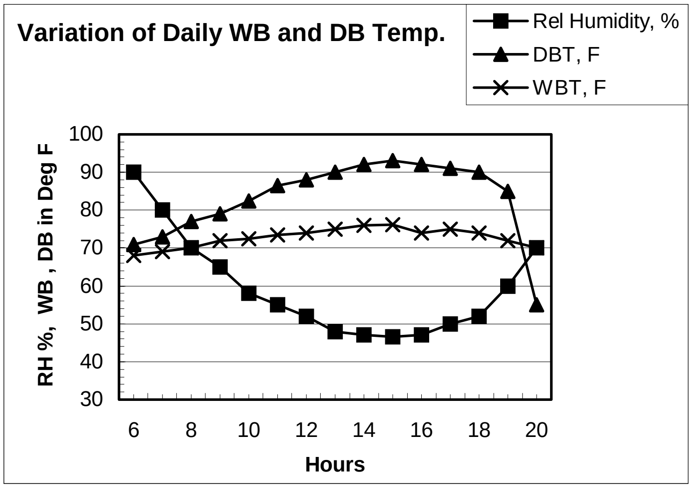

Figure 5. Daily variation of dry bulb and wet bulb temperatures.

Table 1 shows a sample calculation that computes degrees F of evaporative cooling potential for a site based on DOE climatic data. This table provides one months worth of data and a summary for the year’s operation. The total indicated is the total annual degree F – hours of cooling potential by the use of fog. A bar chart showing composite data considering all the months of the year from another site (Orlando, Florida) is depicted in Figure 6.

DB [F]	**Hrs**	**Avg Coincident WB [F]**	**WB Depression [F]**	**Evap Cool Potential F-hrs**
110-86	0	0	0	0
85	1	71	14	14
84	1	70	14	14
83	0	0	0	0
82	2	72	11	21
81	7	73	8	55
80	9	73	7	61
79	9	73	6	55
78	13	72	6	73
77	10	72	5	53
76	22	69	7	154
75	29	69	6	163
74	37	70	4	140
73	41	68	5	203
72	38	66	6	221
71	62	66	5	281
70	76	66	4	286
			TOTAL:-	**1794**

Table 1. Data taken for a typical month .

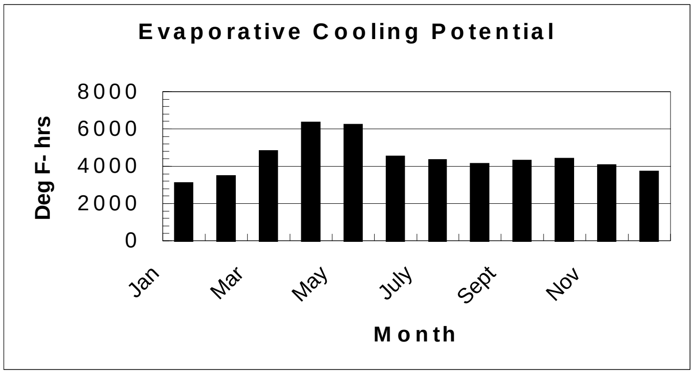

Figure 6. Evaporative Cooling Potential for a year.

3.2 Fog Evaporative Cooling in High Humidity Regions.

Even the most humid environments allow for up to 15°F of evaporative cooling during the hotter part of the day. The term “Relative Humidity” refers to the moisture content in the air “relative” to what the air could hold at that temperature. In contrast “Absolute Humidity,” is the absolute amount of water vapor in the air (normally expressed in unit mass of water vapor per unit mass of air).

The moisture-holding capacity of air depends on its temperature. Warmer air can hold more moisture than cooler air. Consequently, relative humidity is highest during the cool morning and evening hours and lowest in the hot afternoon hours. Since inlet air fogging systems cause a very small pressure drop in the inlet air stream, and are relatively inexpensive to install, they have been successfully applied in areas with very high summer time humidity such as the Texas Gulf Coast region in the USA.

4. METHODOLOGY AND ANALYSIS TO CREATE THE US DATABASE FOR EVAPORATIVE COOLING DEGREE HOURS.

Data was obtained from a DOE climatic database. The climatic data was primarily obtained from both National Climatic Data Center and the California Energy Commission. The goal of the analysis was to determine the Equivalent Cooling Degree Hours (ECDH) for a variety of locations in the USA. The ECDH is defined as a number that provides the total amount of cooling that can be derived for a given time period. The total ECDH is arrived at by summing the ECDHs derived for the 12 months at a location. For example, in the tabulation in Appendix C, the total ECDH for Atlanta GA, is derived by summing the numbers in that row, from January to December.

The database consists of two types of files:

[1] TMY Files- These are typical meteorological year data generated by selecting long-term data gathered over approximately 20 years. The Typical year is a combination of twelve typical months chosen form the entire long-term database. Consequently, the typical year can be composed of 12 months from up to 12 different years. This data includes DB and WB temperature, barometric pressure, and other climatic data. TMY files were used for the analysis in this paper as they

represent the most typical conditions and would provide the best estimate of future trends.

[2] TRY Files- This is a Test Reference Year by selecting data from a long term database by a process of elimination wherein years that have months with extreme temperatures are eliminated until only one year remains. The final remaining year becomes the Test Reference year.

After data was collated from the above data files, a cross check was performed with ASHRE data. Finally, the data was placed in a spread sheet and then a tabulation provided in the Appendix was derived. The ECDH was chosen with a lower limit of 45°F (7.2 °C). This was considered a prudent number to avoid any possibility of inlet icing.

A Map of the USA provided in Appendix B, provides a pictorial depiction of the available cooling degree hours in major US cities. A detailed list of 122 cities covering all the states of the USA has been provided in Appendix C with a month by month calculation of the cooling hours (ECDH) available. If the ECDH number is used to compute MW-hr boost over the year, it is important to note that this would imply that fogging is employed whenever there is even a 1°F depression. In reality there may be a delay set in the control system to trigger the first stage of cooling and also the cooling degrees per stage, would have to be larger than the depression. Typical stage cooling is 2-3°F.

4.1 Use of the Table

Any gas turbine operator can immediately see the potential for evaporative cooling per month in his or her location based on a long term historical database The results can be directly read off the tabulation and it is relatively easy to compute the MW-hours of capacity available by the use of evaporative fogging. In order to do this the ECDH number would be multiplied by the turbine specific MW/°F cooling number. This can be obtained from the gas turbine OEM's curves. An economic evaluation can then be developed on a month-by-month basis knowing the site-specific economic criteria.

ECDH data can also be looked at more closely to account for differences in energy market values at different times of the year. For example, examination of data could provide an estimate of the revenue stream during the hot summer months alone.

5. GAS TURBINE SIMULATION

In order to put the entire situation into perspective, a GTPRO simulation was made using a Frame 7111EA gas turbine in simple cycle configuration (fueled by natural gas) as a reference plant. Salient particulars of this gas turbine are provided in Table 2. A schematic showing the thermodynamic parameters is shown in Figure 7 in Appendix A.

ENGINE MODEL	GE 7111EA
RPM	3600
Power	84920 kWe
Pressure Ratio	12.4:1
TIT	2020 F
EGT	981 F
Mass flow rate of air	646 lbs/sec
Heat Rate	10,212 BTU/kWhr
Thermal Eff	32%

Table 2. Salient features of gas turbine engine used for simulation.

The procedure used followed the following steps:

[1] GTPRO was used to define the MW vs. temperature relationship for the particular engine. This was done by assuming three different wet bulb depressions of approx 35F, 21F and 6F, and then by simulating the engine output for the different wet bulb conditions using GTPRO. From this the MW/Deg F sensitivity for the engine could be determined for the different extents of cooling. (as opposed to just taking a linear relationship or utilizing a rule of thumb) In the case of the Frame 7111EA the relationship was found to be linear and so a value of 0.28MW/Deg F was used

[2] Using the tabulated ECDH data, the MW-hrs that can be augmented on a Frame 7 EA gas turbine is provided in the last column. (See tabulation of Appendix C).

6. Economic Criteria for Inlet Cooling

The specific decision to utilize inlet evaporative fogging technology is an economic one and the total project cost must be evaluated over the life cycle. Because of the varying economic situation in different parts of the country, no economic analysis is presented here. Dominating factors which should be taken into account in doing a study are:

- Climatic Profile (discussed above)
- Installed cost of the cooling system in terms of $ /incremental power increase
- Amount of power gained by means of inlet air cooling. This should take into account parasitic power used, and the effect of increased inlet pressure drop. With fogging systems, the maximum parasitic power is in 50-80 kW for larger turbines when the maximum wet bulb depression has to be derived. The inlet pressure drop is almost nil due to the configuration and design of the nozzle array.
- Fuel and demin water costs, and costs of incremental power- i.e., what benefit is attained by the power boost.
- Projected O&M costs for the system
- Environmental impact
- For cogeneration applications, the time of use electric rates and the PPA have to be carefully considered
- Potential impact on existing emission licenses

Economic analysis for inlet cooling systems may be found in Utamura et al (1996), Ondryas (1990), van Der Linden, and Guinn (1993).

In this paper, the emphasis is more on the climatological aspects as opposed to the economic analysis due to the fact that the economic conditions are very site specific in terms of a deregulating market that exists at this time in the US market.

7. CLOSURE

The paper has provided a tool to easily enable operators in the USA to determine the degree of evaporative cooling potential in terms of evaporative cooling degree hours. The tabulation provides a tool that any gas turbine operator can use to determine feasibility of the application of evaporative cooling to specific applications. Further, the data provided would reduce the effort that is needed to make an economic analysis of the potential of evaporative cooling.

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Appendix A

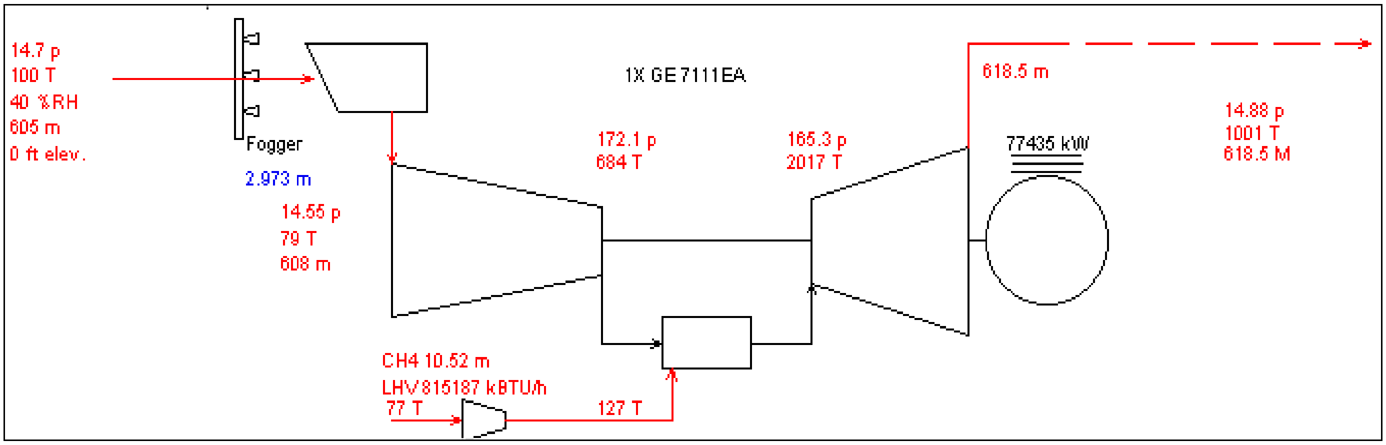

Figure 7. Thermodynamics conditions for Frame 7EA simulation

Appendix B

Map showing representative Evaporative Cooling Degree Hours for sites in the USA

Available Yearly and Monthly Cooling hours in USA Cities.

Appendix C- three pages

Based on Data From: National Climatic Data Center
Gas Turbine: 7111EA , Min WBT=45°F
(MW/F):0.27, Power boost for Frame 7EA (MWh) shown in last column

City	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MWh
Abilene	72264	1567	2131	4478	6230	9964	9080	9535	10544	7414	5182	4167	1972	19676
Albany	32165	0	0	273	2464	5073	5864	5772	5153	4335	2631	573	27	8758
Albuquer	68105	0	54	980	3550	10448	14075	11701	11019	8871	6525	858	24	18544
Allentown	29058	59	0	719	2492	3772	5239	5098	4074	3486	2811	1106	202	7912
Alpena	24353	0	0	159	805	3793	4832	5788	3917	2743	2017	299	0	6631
Amarillo	58691	478	543	2440	6594	9491	7551	8209	8310	6690	6074	2035	276	15981
Apalachi	45800	1942	2188	3194	3879	4766	4395	3862	4090	6103	4979	2977	3425	12471
Ashevill	27310	1114	504	1602	3528	4528	3198	3318	2770	2190	2306	1584	668	7436
Atlanta	42486	1179	1021	2468	5501	5395	4978	4557	4946	3748	4932	2468	1293	11568
Austin	61342	2564	2809	5200	5472	6546	6635	7728	7882	5577	4873	3862	2194	16702
Bakersfi	101101	1556	3444	5712	8093	10569	14076	15137	14529	11349	9399	5009	2228	27528
Baltimor	37600	151	412	1372	2753	5645	6116	5467	5102	5422	3853	1182	125	10238
Bangor	24444	4	0	1	602	3453	4948	5042	4986	3011	2127	270	0	6656
Barbersp	58261	3634	4316	4569	4773	5484	5302	5442	5547	5163	5164	4142	4725	15863
Batonrou	46461	2159	2858	4343	4916	5625	4623	3871	4825	2812	4826	3067	2536	12651
Bismark	31563	0	0	127	1209	4886	5049	6397	7743	4491	1661	0	0	8594
Boise	58653	0	233	301	1207	7277	9020	13885	12880	8835	4279	736	0	15970
Boston	33601	138	218	126	1460	4912	5584	6308	6034	4806	3016	957	42	9149
Buffalo	30524	44	77	331	1957	3898	5513	5987	5099	4199	2494	839	86	8311
Burlina	33079	27	3	737	3054	5705	3786	6035	5047	4448	3145	1092	0	9007
Burlinvt	25160	0	1	118	289	4094	4847	5167	5535	2938	1877	149	145	6851
Cedarcit	58657	42	120	347	1164	6877	11834	12226	12310	9037	4215	485	0	15971
Charlesc	39386	1731	1924	3583	3768	5251	3472	3778	4090	3199	3811	2950	1829	10724
Charlewv	40648	686	370	2115	4466	5558	5742	6407	4079	3537	4150	2334	1204	11068
Charlott	47343	899	1483	2988	5150	5523	6089	5636	5929	5522	4414	2472	1238	12891
Cheyenne	38513	0	0	152	913	4406	6738	8651	8532	6444	2658	19	0	10486
Chicago	37713	1	27	283	2346	4610	6953	7265	6027	5198	3724	1211	68	10269
Cincinna	39644	110	140	1082	3260	5796	7010	6000	6136	4631	3789	1079	611	10794
Colorado	46841	0	76	0	1698	6020	9869	8776	7743	8589	3842	228	0	12754
Columbmo	39794	535	383	991	3811	5666	5178	6061	5707	5531	3666	1976	289	10835
Columbsc	49108	1167	1169	3655	6820	5568	6389	5999	4690	5061	4090	2725	1775	13371
Columbus	35312	105	146	801	2750	5508	5117	6376	5001	4539	3178	1454	337	9615
Concornh	27468	6	115	76	1399	5258	4884	5180	4520	3078	2496	370	86	7479
Corpusch	47096	2775	3176	3122	3134	3544	4011	5939	4904	6043	4647	3512	2289	12823
Daggett	121859	2460	3284	6831	8479	14357	15882	18845	17673	15188	10520	5925	2415	33180
Denver	52132	0	0	704	2685	6502	8576	11739	8986	8749	3458	581	152	14195
Detroit	35170	0	45	417	2007	4922	5965	7177	5291	4869	3425	886	166	9576
Dodgecit	48726	147	136	1466	3845	6488	7770	8335	9121	5292	4339	1596	191	13267

City	**Year**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**MWh**
Eagle	36914	0	0	0	838	4575	7392	8186	7932	5698	2189	104	0	10051
Eauclair	28907	0	0	0	2084	4937	5817	4924	4919	3280	2756	186	4	7871
Elko	50882	0	0	398	414	6351	8275	13148	11860	7592	2428	419	0	13854
Elpaso	99611	1565	1719	5849	9583	14367	15612	13323	12190	10910	9663	3863	967	27122
Evansvil	38528	267	248	1647	3749	4822	5860	5832	5838	4723	3812	1368	362	10491
Fairbank	21374	0	0	0	0	3522	5831	5944	4366	1697	14	0	0	5820
Fargo	29973	0	0	0	954	4715	5164	5698	6352	3935	3105	50	0	8161
Glasgow	42539	0	0	499	1234	6059	8164	9252	9035	6747	1537	12	0	11583
goodland	44242	310	150	669	2955	5184	6814	8881	8685	6054	4072	468	0	12046
Grandrap	29854	0	0	296	1691	4816	5186	6612	4708	3126	2906	513	0	8129
Greatfal	45702	85	107	0	1133	5272	7943	11359	10461	5937	2882	509	14	12444
Hartford	33072	3	4	302	2376	4899	5956	7038	4571	4034	3269	455	165	9005
Hilo	43545	4494	3870	4238	3407	3890	3633	3440	2932	3404	3505	3304	3428	11857
Honolulu	69101	3952	5427	4780	5112	6470	6263	6719	6588	6630	6189	5591	5380	18815
Houston	49649	2672	2689	4174	4710	4970	4864	5486	5033	4610	4309	4207	1925	13519
Indianap	35055	71	187	815	2860	4699	5804	5585	5272	5453	3401	798	110	9545
Jackson	44811	1122	1885	3522	4355	5439	4428	4918	5390	4106	5086	2988	1572	12201
Jacksonv	47357	2053	3046	4757	5817	6258	5014	4268	4489	3146	4083	2510	1916	12894
Juneau	11641	0	0	0	0	1934	3197	2825	2258	1143	284	0	0	3170
Lasvegas	126551	1137	1679	5628	7222	16670	19990	19891	19484	17383	12847	4450	170	34458
Lewistmt	32967	20	0	61	505	3770	5145	7928	7479	4830	2866	325	38	8976
Lihue	52458	3514	4566	4594	4307	4115	4403	5065	5179	4702	4230	4564	3219	14283
Littlero	45148	786	1181	3509	3957	5527	5577	6078	6393	4331	4234	2345	1230	12293
Longbeac	60525	3820	4241	5010	5448	4888	4463	6184	4614	6351	6133	4847	4526	16480
Losangel	48469	4006	3220	3539	4742	3734	2883	3917	4226	3743	4336	5032	5091	13197
Louisvil	40367	274	322	1495	3617	6085	5259	6090	5187	5754	3830	1453	1001	10991
Lovelock	66234	256	327	1153	1401	7401	10545	16196	14611	9208	4175	909	52	18034
Lufkin	45260	2224	2688	4048	4237	4732	4633	4978	5560	3920	3562	2838	1836	12324
Madison	30367	0	0	63	2198	4902	4930	5360	4874	4647	2932	461	0	8268
Medford	21358	255	454	352	1679	2803	2345	2505	3438	3304	2112	1197	914	5815
Memphis	46250	606	1200	3108	5334	5324	6065	6848	5237	4135	4393	2607	1393	12593
Miami	55668	3920	5210	5027	5582	5109	4404	4051	4615	3628	4263	4830	5029	15157
Minneapo	31109	0	0	0	2256	5158	6466	5670	5225	3877	2243	208	6	8470
Nashvill	42410	834	1276	2773	4416	5045	5848	5154	5103	4463	4112	2496	890	11548
Newarknj	38760	27	133	284	3413	5729	6519	7214	5760	4787	3382	1070	442	10554
Neworlea	43068	2028	2945	3758	4170	4700	4649	3785	5055	3273	4310	2701	1694	11727
Newyorkc	32206	15	0	357	2671	4298	4384	5785	5538	4737	3252	1005	164	8769
Newyorkl	38156	141	0	461	2556	4470	6039	6940	6463	5168	3927	1861	130	10389
Norfolk	39141	755	42	1812	4862	4637	5806	5197	4515	4475	3247	3323	470	10657
Oakland	37442	1495	2411	3299	3254	3376	3335	3188	3759	4357	4118	3171	1679	10195
Oklahoma	53446	662	951	3414	5730	6072	6202	8387	7791	6337	4927	2301	672	14552
Omaha	39277	0	0	927	4465	7095	6482	6543	5008	4251	3309	878	319	10694

City	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MWh
Orlando	53342	3093	3473	4798	6342	6210	4507	4308	4125	4283	4376	4055	3772	14524
Philadel	35968	144	79	1089	2146	6067	5289	5649	5893	4673	3471	1192	276	9793
Phoenix	138281	4739	4703	8852	11468	17155	18715	17407	16494	15276	12408	7132	3932	37652
Pierre	41313	16	0	82	2919	5481	4777	8048	9302	6340	4110	238	0	11249
Pittsbur	35130	114	248	885	2779	6221	5530	5911	5238	3992	2763	1027	422	9565
Pocatell	51530	0	0	231	596	6388	8050	12970	11701	8352	3242	0	0	14031
Portlame	22555	5	0	313	769	3467	4127	4630	3924	2637	2323	360	0	6141
Portlaor	35143	254	606	1821	2196	4605	5483	6584	4375	5108	2443	1339	329	9569
Providen	31127	85	73	192	1661	4778	4717	6050	5126	3972	3403	800	270	8475
Pueblo	67024	129	968	2058	3201	9168	11178	11744	10812	9426	6712	1213	415	18249
Raleigh	38699	1231	1398	2715	4395	4499	5503	3903	4343	4807	3005	2262	638	10537
Reno	55619	0	473	1465	2028	5631	10025	11301	11886	8006	3514	1290	0	15144
Richmond	39275	441	1628	2051	5208	4986	4422	4455	5776	3645	2836	2676	1151	10694
Rochesmn	26119	0	0	59	1863	4464	5144	4102	4459	2976	2703	337	12	7112
Sacramen	63093	679	2147	3241	4587	6876	8294	9158	8991	7994	6227	3778	1121	17179
Saltlake	63306	0	95	206	2332	7306	9477	15259	13983	9491	4097	1060	0	17237
Sanangel	77667	2379	3560	5461	7025	9537	9302	11218	9321	7647	4775	4060	3382	21147
Sandiego	54447	4960	4106	4359	4088	5524	3942	3189	4447	4462	6325	4961	4084	14825
Sanfranc	39427	1703	2212	2974	3501	3796	3638	3600	3872	4746	4775	2601	2009	10735
Sanjuan	52301	4577	4798	4662	6004	5614	3927	4011	4125	3342	3723	3416	4102	14241
Savannah	43778	2248	2206	3740	5086	5275	5578	3861	3986	3061	4453	2558	1726	11920
Scottsbl	44674	49	215	531	2790	5942	7962	8879	8276	6548	3098	384	0	12164
Seattle	27480	119	465	990	915	3516	4071	5191	5550	3380	1916	1071	296	7482
Sheridan	38523	0	74	213	1193	4920	5009	8602	9707	5988	2720	76	21	10489
Siouxcit	33806	0	47	541	3128	6164	5067	5242	4740	3789	4256	465	367	9205
Siouxfal	32572	0	47	393	1668	5163	6496	5972	5497	3059	3909	368	0	8869
Spokane	44205	0	39	0	1035	5664	6547	10243	11357	7103	2201	16	0	12036
Stlouis	39267	469	641	1794	4312	5776	5126	5722	4636	4628	4673	1205	285	10692
Sunnyval	43725	2174	2619	3777	4317	3636	4451	3799	4583	4377	4146	3439	2407	11906
Syracuse	30545	23	24	378	2574	3787	5356	5702	4891	3990	2734	833	253	8317
Tallahas	44479	2095	2641	3572	5003	5069	5493	4103	3543	3797	4413	3118	1632	12111
Tampa	51181	3005	3317	4333	5746	5796	3689	4553	4615	3601	4773	4287	3466	13936
Tonopah	61177	190	0	587	2372	5793	12198	13275	13280	9458	3804	220	0	16657
Truthorc	79274	186	382	3216	5699	12238	15245	12389	9851	10950	7323	1795	0	21585
Tucson	120601	4162	3179	7319	10613	15654	18715	13828	11623	12599	11822	7105	3982	32838
Tucumcar	66163	319	1559	2649	5972	9966	9658	9932	9780	7180	5882	2527	739	18015
Tulsa	48478	744	991	3394	5277	4789	5306	7278	7970	4590	5073	2212	854	13200
Waco	63849	1809	2714	4835	6067	6591	7126	9671	8492	5121	6007	3479	1937	17385
Washingt	34812	198	263	1134	3873	5787	4190	4948	5624	3883	2936	1818	158	9479
Wilmingt	34911	56	65	918	2705	4795	5471	6499	5379	4673	3194	850	306	9506
Winslow	69648	0	134	1674	2746	9399	14358	12449	11937	9615	5898	1401	37	18964
Yuccafla	80779	72	562	528	4087	9199	14265	16733	15257	11296	6451	2216	113	21995
Yuma	143952	5552	7091	10790	13900	16506	18043	15921	14783	13805	12568	9949	5044	39196