TURBINE TIPS
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Subject: Determining Turbine Inlet (Firing) Temperature, T_F
Applies to: All GE gas turbines (and other turbine marques too)

Have you recently received your copy of ***Turbomachinery Handbook 2009*** in the mail?

Reading through it at lunch one November day, I came upon the section that deals with **Electrical Generation Specifications**. I thumbed through to page 92 for the GE specifications and notice that GE ***still*** does not provide the Turbine Inlet (Firing) Temperature (***TF***) for the models listed. Glancing around, I noticed that most of the other OEMs do not either; guarding this information as if it was the ***Holy Grail.***

Electrical Generation Specifications

GE Energy

MODEL	POWER RATING ISO Base Load (MW)	HEAT RATE Lower Heating Value (LHV) (Btu/kWh)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD Turbine Inlet Temp. (°C)	Exhaust Flow (kg/sec)	Exhaust Temp[1] (°C)
Oil & Gas								
GE10-1	11 250	10 892	11000	15.5	1 can--		47.5	482
PGT16	13 740	9 750	7900	20.2	1 annular	--	47.3	493
PGT20	17 464	9 706	6500	15.7	1 annular	--	62.5	475
PGT25	22 455	9 389	6500	17.9	1 annular	--	68.9	522
PGT25+	30 274	8 599	6100	21.5	1 annular	--	84.3	499
PGT25+G4	32 737	8 704	6100	23.0	1 annular	--	89.7	512
LM6000PD	42 319	8 317	3600	28.0	1 annular	--	124.7	455
LMS100	98 902	7 676	3600	40.0	1 annular	--	207.6	416
MS5001	27 232	11 813	5094	10.6	10	--	125.2	482
MS5002E	30 881	9 799	5714	17.0	6	--	102.2	508
MS6001B	42 382	10 502	5163	12.5	10	--	148.1	546
MS7001EA	86 889	10 395	3600	12.8	10	--	302.3	535
MS9001E	126 621	10 015	3000	12.7	14	--	421.0	540
Heavy Duty								
PG6581(B)	42.1	10,642	5,163	12.2	10	—	141	548
PG6591(C) (50 Hz)	45.4	9,315	7,100	19.6	6	—	122	581
PG6591(C) (60 Hz)	45.3	9,340	7,100	19.6	6	—	122	581
PG6111(FA) 50 Hz	77.1	9,760	5,231	15.6	6	—	203	603
PG6111(FA) 60 Hz	77.1	9,795	5,254	15.7	6	—	204	603
PG7121(EA)	85.1	10,430	3,600	12.7	10	—	294	536
PG7241(FA)	171.7	9,360	3,600	16.0	14	—	445	601
PG7251(FB)	184.4	9,215	3,600	18.4	14	—	454	624
PG9171(E)	126.1	10,100	3,000	12.6	14	—	418	543
PG9351(FA)	255.6	9,250	3,000	17.0	18	—	641	602
PG9371(FB)	279.2	9,016	3,000	18.3	18	—	655	629

Fig. 1: Electrical Generation Specifications – Turbomachinery Handbook 2009, Page 92

Years ago, I was asked by a client to determine the turbine inlet (firing) temperature for one of their ***older*** GE gas turbines (a model no longer offered by GE so not listed in the ***TH*** publication). However, I went to the ***TH*** on my desk for that year and looked up the GE information. As luck would have it, John Brown Engineering (a GE manufacturing associate at the time) listed the firing temperatures for all the GE models made in Scotland. Good information but it didn't provide what I needed for an older model turbine.

I went to my bookshelf and found a relic from my college days (***Thermodynamics*** by George F. Babits, Copyright 1963). In that book on page 194, I found a formula for calculating turbine inlet temperature; however, I still had a "missing link." I didn't know one value needed to plug into the equation. My dilemma, as any engineering student knows, you can't solve a problem with **two** unknowns. Since the client I was working for was in the USA, I used Fahrenheit for temperature data. Then I discovered that the temperatures had to be referenced to absolute zero (you need to add 460 to all Fahrenheit temperature values). The thermo book gave me the following formula:

$$T_F = (T_X + 460)\,(PR)^{(k-1)/k} - 460$$

With all the JBE data, however, I could use the following to solve for the ratio of specific heats (symbol ***k***) that I needed to do the calculations on the older model GE gas turbine. From the properties of gases in the same text, the value of ***k***, is the ratio of specific heats at constant pressure (***CP***) divided by the specific heat at constant volume (***Cv***). That is, $k = C_p / C_v$. For air, the value of $k = 1.4$. But my question was: what is the value of ***k*** for an air-fuel mixture like that consumed in a gas turbine? From the ***TH***, I used for several calculations, solving for the value of ***k.***

- Compressor pressure ratio, (***PR***)
- Average turbine exhaust temperature, (***Tx***).
- Turbine Firing Temperature, ***(TF)***.

Therefore, I could solve for the constant value of ***(k-1)/k*** needed in the thermodynamics formula, giving me the value of **.206.** I could then find the value of ***k = 1.26.***

Then I booted up my computer and used ***Microsoft Excel*** to set up the calculations needed. Every time I did the calculation on my scientific calculator (my old ***K&E*** slide rule wouldn't have worked), I came up with approximately the same value for, specifically: ***k = 1.26.*** Thus, the ratio became ***(k-1/k) = .206***

Plugging the data into the equation, I calculated the turbine firing temperature for the **GEMS7001B** gas turbine:

$$^{o}T_F = (950 + 460)\,(10)^{.206} - 460$$

$$T_F = 1807.6\ ^{o}F$$

Excel Spread Sheet:

Average Turbine Exhaust Temperature, Tx	**Average Turbine Exhaust Temperature, (Tx + 460)**	**Axial-flow Compressor Press Ratio (Pcd / Pin), both in psia.**	**Ratio of Specific Heats for air-gas fuel mixture, *k***	**Power *(k-1)/k***	**General Electric Gas Turbine Inlet (Firing) Temperature, TF**
^{o}F	**^{o}R**	**PR**	**Cp/Cv**		**^{o}F**
950	***1410***	***10.0***	***1.26***	***0.206***	***1807.6***

I used with the average value for the ratio of specific heats, ***k***. Also, I set up five columns on my Microsoft Xcel spread sheet as follows:

1. Compressor pressure ratio (***PR***). In this case, 10.0.
2. Average turbine exhaust temperature (***Tx + 460***). Converts to degrees Rankin.
3. Ratio of specific heats for the combustion gas, ***k = 1.26***
4. I decided to use ***k*** as an adjustable value, so I set up a column with the calculation ***(k-1)/k = .206.*** That allowed me to adjust the values ***k*** slightly, if needed (say to ***k*** = 1.258 or ***k*** = 1.263) for "fine tuning" my calculations.
5. Finally, I wrote the equation to solve for: Turbine Firing Temperature (***TF - 460***)

Behold, I was able to now use an Excel spread sheet to calculate turbine firing temperature ***(TF)*** for any gas turbine. In this case, a GE MS7001B gas turbine "fires" at approximately **1807 ºF.**

Mystery solved! GE can't deceive us by not publishing firing temperature values.

Discovering the GE and JBE on the same page in the ***Turbomachinery Handbook*** was pure luck. I earned a few bucks from my client too. More good fortune.

I guess I'd rather be lucky than good!

For more information on this subject, contact Dave Lucier of PAL Engineering on 518-371-1971 or email: dave@pondlucier.com