TRENDS IN STEAM PARAMETERS FOR STEAM TURBINES

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SYNOPSIS

Steam parameters adopted for steam turbines at various stages of history till date are briefed in this paper. General trends in these parameters for Indian industry are also elaborated with respect to attainable gains. Special emphasis was given for the changing trend in inlet steam parameters and power ratings for sugar co-generation application for understanding the future market demands.

INITIAL STEAM PARAMETERS

Steam Turbines are used for industrial applications as well as Power Plant (Utility) applications. During initial days of development, i.e., before 1950s, the steam turbines with parameters of 13 Kg/cm² and 176°C were quite common in power plants also with a plant heat rate of 8750 KCal/KW-Hr apart from Industrial Applications against today's common plant heat rates of (2075) KCal/KW-Hr with 246 Bar/540°C applications in double reheat turbines.

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SUPER CRITICAL STEAM PARAMETERS

During 1950s, super critical turbines with 325 Bar / 650°C were developed and put in operation both in power plants and industrial applications. But, due to economical, operational and thermal flexibility problems with the associated Austenitic steels for high temperature parts, there was a slackening with respect to super critical applications.

OIL CRISIS AND ITS EFFECTS

The Fuel-Oil crisis of 1970s led to economic recession and emergence of new technologies that have improved the efficiency of end user appliances and new directions in the manufacturing sector. So, to improve economical viability, achieving higher efficiencies had again become the corner stone for further developments. In this process, new approaches came into existence. With the existing metallurgy at that point of time, the maximum steam temperature was chosen as 540°C for which, ferritic steels are sufficient with which, metallurgy was more or less perfect. Simultaneous developmental plans were drawn for improved blade profiles. Increased inlet sizes and outlet (low pressure) portions reduced the frictional losses and a gain of 2.5% was achieved. Then, base load turbines are converted into variable pressure models from constant pressure models. In these models, gains in part load heat rates like 2.4% at 25% loads are achieved in power plants.

REINTRODUCTION OF SUPER CRITICAL STEAM PARAMETERS

Presently, many achievements are recorded in metallurgical improvements of high temperature materials. In pursuit for higher efficiencies, using martensitic rotor materials, the steam temperatures are increased to 593°C in single reheat and double reheat turbines and achieved a gain of 6 to 8% relative thermal efficiencies based on 540°C. The utilisation of fossil fuels is brought down. This has also led to reduction in harmful pollutants like SO_2, No_x and CO_2 , to atmosphere, per unit of power generated. In the coming next 10 years, the inlet steam temperatures of 650°C are aimed at. For the associated benefits with higher temperatures, please refer (a) Figure – 1 for change of steam temperature in large rating units and (b) Table – 1 for gains with high temperatures :

Figure – 1

Change in Temperature in Large Rating Units

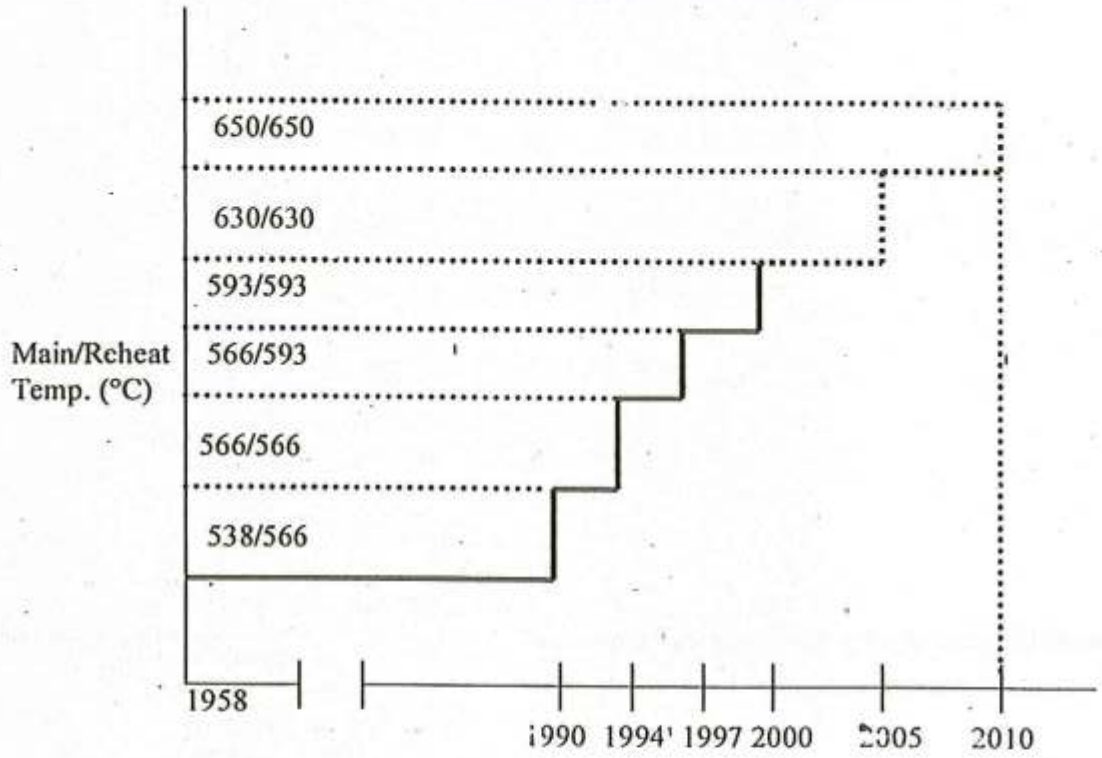

Table – 1

Gains with High Temperature

	CONVENTIONAL PLANT	AIMS FOR ADVANCED 1000 MW PLANTS	
		STAGE – I	*STAGE – II*
Steam Pr. (Bar)	241	314	343
Steam Temp. (°C)	538 / 538	593/593/593	649/593/593
Thermal Effi. – Total %	41.5	44.0	44.8
Relative Efficiency improvement %	Base	6.0	8.0
Coal Savings – 10^3 Tons Per Year	Base	130	170
Reduced Emissions, M^3, S.T.P / Year	Base	897×10^6	1173×10^6

INTRODUCTION TO COMBINED CYCLE PLANTS

As further improvements in steam turbines may not result in much changes in efficiencies beyond 50% (at 650°C); simultaneously, combined cycle plants (Brayton + Rankine cycles combined for gas turbine with steam turbine) are developed and presently, they are demonstrating total efficiencies of the order of 60% with firing temperatures of gas turbines as high as 1280°C. For these cycles, the inlet steam temperatures for steam turbines are as high as 565 to 585°C.

INDUSTRIAL SECTOR OPTING FOR HIGHER STEAM TEMPERTURES

Most of the industries moved upto 140 Bar / 540°C parameters. In some cases, they approached 180 Bar / 565°C. Table – 2 shows relative efficiency improvements with respect to steam parameters. An improvement in Isentropic efficiency of 9% can be seen with 100 Bar / 520°C over a parameter of 43 Bar / 435°C with an expected saving of 5.8% fuel.

With 140 Bar / 540°C, the Isentropic efficiency improvement is 13% and fuel saving is about 8.5%.

Table – 2

Efficiency Improvement and Fuel Savings with High Inlet Steam Parameters

INLET STEAM PRESSURE / TEMP. (BAR / °C)	IMPROVEMENT IN ISENTROPIC ENTHALPY IN %	SAVING OF FUEL IN %	ANNUAL SAVINGS (RS. IN CRORES)
43 / 435	Base	Base	----------
63 / 490	2.2	1.4	Base
87 / 520	8.1	5.2	1.11 to 1.48
100 / 520	9.0	5.8	----------
120 / 535	12.0	7.8	----------
140 / 540	13.0	8.5	----------

Example : ***Annual saving by using 87 Bar / 520°C instead of 63 Bar / 490°C***

For 63 Bar / 490°C case, the inlet steam required for a 20 MW Straight Condensing case is approximately 78 TPH at the rate of 3.9 Kg/KW-Hr.

- The isentropic enthalpy gain from 63 Bar / 490°C to 87 Bar / 520°C is 16.85 KCal/Kg.
- Taking thermal efficiency factor of 80%, the enthalpy available for power generation is :

  16.85 x 0.8 x 0.98 x 0.96 = 12.8 KCal/Kg.
- Total extra power that can be generated is :

$$\frac{12.8 \times 78000}{860} = 1160 \text{ KW}$$

- Power generation cost / KW-Hr = Rs. 1.4 to 1.6
  On an average, it is Rs. 1.5/KW-Hr
- Power sale cost = Rs. 2.7 to Rs. 3.1/KW-Hr
- Based on minimum sale cost, the annual savings from extra power :

  (2.7 – 1.5) x 1160 x 8000 Hrs = **Rs. 1.11 Crores**
- Based on maximum sale cost, the savings = **Rs. 1.48 Crores**

TRENDS IN SUGAR CO-GENERATION

Presently, co-generation in sugar industry is catching up with higher power ratings, as selling of power is giving higher income. Accordingly, viability of sugar industry is directly dependent upon efficiency in power generation. As higher steam parameters are offering higher efficiencies resulting in reduction of unit power generating cost, sugar industry is looking up for higher steam parameters. From Table – 2 it may be inferred that, every 10°C increase in steam temperature, increases efficiency by about 0.5% and an increase of 10 Bar of steam pressure increases the efficiency by about 0.2% with respect to fuel consumption.

Presently, sugar plants are under operation are familiar with lower steam parameters like 43 Bar / 435°C. The sugar plants under upgradation, renovation, etc., and new sugar plants are aware of requirement to go in for higher rating sugar co-generation plants with higher steam inlet parameters like 65 Bar / 490°C; 87 Bar / 520°C and 100 Bar / 520°C. Consultants and financial institutes are also advocating for higher steam parameters. In some regions, the plants are opting for optimised rating co-generation units with their own bagasse and in some regions, the plants are opting for higher rating co-generation plants by planning for purchasing of other bio-mass fuels from the nearby localities.

As a first step in going for higher steam parameters, many plants had chosen 65 Bar / 490°C and many plants are running with these parameters. Example: Shamnur Sugars, Bannari Amman, Gem Sugars, etc., with power ratings ranging from 16 to 22 MW. Some plants are presently opting for 87 Bar / 520°C. Example : Bannari Amman expansion and Balarampur with power ratings ranging from 18 MW to 24 MW. Some enquiries demand 100 Bar / 520°C also, but the demand as on date is small.

Units with 65 Bar / 490°C had already stabilised. Units with 87 Bar / 520°C have to stabilise. Looking at the process of stabilisation with 65 Bar / 490°C which has taken about 5 years and their continued demand even now, one can safely estimate that, demand for 87 Bar / 520°C application may be there for coming 5 to 8 years. For this range, our main competitor M/s Bharat Heavy Electricals Ltd does not have cost effective module. M/s BHEL has got cost effective and efficient modules for steam parameters of 65 Bar / 490°C, 100 Bar / 510°C and 140 Bar / 540°C. Accordingly, it may well be predicted that, if M/s Triveni develops turbines for 87 Bar / 520°C in the range of 16 to 22 MW with cost effective and good efficiency features, there exists a good marketing potentiality for coming 5 to 8 years. Based on the trend analysis by our Marketing Department, demand is there for 5 to 10 MW with 65 Bar / 490°C and 10 to 30 MW with 87 Bar / 520°C. However, based on higher growth potentiality, priority may be given on 16 – 22 MW range with 87 Bar / 520°C.

If sugar industry switches over to 100 Bar / 520°C and beyond, BHEL can be the leader as an indigenous OEM.

TRENDS IN INDEPENDENT POWER PLANTS

The same trend may be there in IPPs also. But, the rate of change may be lower than in sugar applications, since most of the IPPs for which we are offering our modules are bio-mass based and upto 6 MW with 65 Bar / 490°C. It may be noted that, financing agencies like IREDA are encouraging for higher inlet steam parameters by offering some incentives for bio-mass plants.

PARAMETER RANGE FOR COMBINED CYCLE PLANTS

In combined cycle plants, the steam parameters that may stabilise are 80 Bar / 510°C for steam turbine ratings upto 35 MW (Ex : 206 CCP Plants with dual pressure). For higher range turbines beyond 60 MW, the steam parameters may stabilise at 100 Bar / 520°C (Ex : 109E CCP Plants with triple pressure).

If one looks at the speed of gas turbine developments by GE, even these parameters may go upto 120 Bar / 565°C where martensitic steel is to be used for rotor forgings with associated changes in the blade material, etc. GE has already established F-Technology with exhaust temperature of 590°C. It is trying with G & H Technologies which will take CCP cycle efficiencies as high as 60%. Here, the steam turbine inlet parameters may go upto 120 Bar/ 585°C with single reheat and triple pressure operation.

This high temperature technology is already available with M/s Bharat Heavy Electricals Ltd, Hyderabad, having supplied a 17 MW back pressure turbine with steam temperature of 565°C to TCL, Mithapur. The has resulted in an efficiency gain about 6.25% against 540°C application.

PARAMETER RANGE FOR FERTILIZER PLANTS

In case of fertilizer plants, steam parameters of 140 Bar / 540°C are already stabilised for synthesis gas and CO_2 compressor drive and captive power applications with high speeds.

For a 1350 TPD plant, the steam turbine power requirement for synthesis gas drive compressors will be about 30 MW at 10,000 to 11,000 RPM. For CO_2 drive applications, the power requirement will be about 18 – 20 MW. These capacities keep on changing with the size of fertilizer plant.

PARAMETERS RANGE FOR CEMENT, PAPER, STEEL, TEXTILE, SPONGE IRON & CARBON INDUSTRIES

In cement industry, presently running steam parameters are 65 Bar / 490°C which is likely to sustain for a long time with ratings from 12 MW to 25 MW. As on date, cement itself is the primary product for profits in cement.

In paper industry also, the steam parameters are 65 Bar / 490°C for quite a long time with ratings of 8 – 16 MW. The difference between sugar industry and the other paper & cement industry is that, in sugar industry, power is becoming the primary source for ROI than sugar itself; whereas in cement and paper industry, cement and paper are the primary source of income.

In small steel industry, the trend is for 65 Bar / 490°C parameters with ratings of 10 – 20 MW. In case of integrated steel plants, steam parameters of 140 Bar / 540°C are already stabilised with power ratings of 60 – 120 MW.

In textile industry, 65 Bar / 490°C may work for a quite long time, since the initiation to power development using steam turbines has started of late.

In sponge iron and carbon industries, it is likely that, 65 Bar / 490°C may still run for quite a long time.

CONCLUSION

There exist a good market for steam turbines with steam parameters of 87 Bar / 520°C for the coming 5 to 8 years, especially in sugar co-generation application. The power ratings widely vary from 5 to 30 MW with a greater demand between 16 to 22 MW with these parameters.