BOILER & HRSG PERFORMANCE EVALUATION

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Thermal performance analysis is an important aspect of boiler and HRSG evaluation. Many problems faced by the operators of boilers and HRSGs can be understood and often resolved by evaluating its thermal performance. Problems such as:

- Steam capacity not attainable or fuel input to generate the desired steam in the HRSG is more than envisaged
- Efficiency is lower than that predicted. Boiler or HRSG exit gas temperature is very high
- Fouling inside and or outside boiler tubes
- Steam temperature either lower or higher than predicted ; spray water flow high
- Superheater tube failures due to overheating, poor flow distribution due to low steam side pressure drop or carryover of solids from drum
- Boiler circulation problems resulting in repeated tube failures in some specific areas due to circulation stagnation or reverse flows
- Gas/steam side pressure drops significantly different from proposal data increasing the fan/pump power consumption or too low causing flow distribution problems
- In multiple pressure HRSGs, HP or LP steam differ from predicted values
- Surface areas seem high but boiler is not performing well

The solution to these problems lies in evaluating the thermal design of the boiler/HRSG (by engaging a consultant if in house capability is absent in this area.)

During the last several years as a boiler/hrsg consultant I have seen many boilers and HRSGs with compromised or poor design being sold and purchased. (I know of a few cases where designs developed 50 years ago have been sold as design details, drawings are readily available!). While anyone in the plant is capable of questioning the paint colour or the weight of the components or refractory thickness or materials used or piping layout , valve information or Code welding details etc etc, few are capable of analyzing the thermal performance and checking if the design provided was good. If the boiler works well, then fine else if any of the above issues crop up, the end user first contacts the boiler supplier who will try to defend the design and may blame the issues on operation and may suggest some modifications which may work and often do not. Keep in mind that the end user has to live with this beast for several decades!

When a doctor advises a patient to undergo surgery for a problem, the patient does not immediately agree to the suggestion. He contacts another doctor for a second opinion and it may turn out that the disease can be cured by simpler medication unless the patient was in a really poor state of health.

One of my services is evaluating the thermal design and performance checking of any boiler or HRSG (new, to be bought or existing) and verifying the claims made in the proposal using tools (software) developed by me over the years. It is advisable to do

this evaluation BEFORE the order for the boiler/hrsg is placed. Serious errors if any can be rectified early else the end user is stuck with a sick baby for twenty to thirty years.
I have also seen that boiler and HRSG suppliers do not provide much information on the boiler thermal design and performance aspects, while information on paints, refractory, casing, stack, piping, valves, controls, Code aspects etc etc are provided as these are components or topics many end users are familiar with. (Parkinson's law!). How many in the end user's camp know if the boiler circulation is proper? Whether the steam velocity used in the superheater tubes is appropriate considering the maximum and minimum loads? Is the fin density used appropriate for the superheater? Does the surface area mean much? What is the furnace heat flux? What is likely to be actual tube wall temperature in various components of the boiler (or superheater) at full or part load? Is the baffling inside the drum properly to ensure good circulation? Many end users have no clue to evaluating these points. Of course they are not there to perform these types of studies.

Hence I suggest to anyone planning to invest millions of dollars in a new boiler/hrsg, please have the thermal design evaluated by an independent consultant who can suggest improvements to the design BEFORE you order the equipment. He can also obtain the data required for any future evaluation from the boiler supplier. Many boiler suppliers do not provide the basic data required for the thermal design evaluation and hence in the case of any serious problem at a later date, it becomes difficult to do a boiler thermal performance analysis. I have seen this in many situations. Many boiler suppliers take advantage of the end user's lack of knowledge in the above mentioned thermal design issues and do not provide all the data or bare minimum information and drawings.

If the boiler/hrsg is already bought and you have problems, then you will be approaching the boiler supplier in case of any problem and probably get a biased analysis which may or may not solve the problem. If you would like an independent consultant to review the design, then the following information must be provided:

1.Performance of boiler/hrsg as suggested in the proposal. Data such as feed water temperature, pressure of steam, steam flow, gas/steam temperature profiles at various heating surfaces should be available and flue gas flow and analysis (in case of a waste heat boiler or HRSG). In addition tube geometry data should be provided. Many boiler suppliers do not provide these data to their customers (and the customer does not know what data to ask for) and as a result, when some performance issue crops up, the boiler supplier is able to make excuses and get away clean. This article will enable the potential boiler user to ask the right questions to the boiler/Hrsg supplier before purchasing the unit.

2.Field data is a must to ensure that the model is reliable. Correction factors can be simulated for each surface which can fine tune the model to match the field data and then one can see if the original proposal was reasonable. Say a HRSG is operating at part load. The thermal model can be simulated using the existing field data from which one can extrapolate to any other set of gas conditions and ensure the original offering was good.

TUBE AND BOILER GEOMETRY DETAILS

Before you order your boiler or HRSG, obtain data from the supplier in the following format, which enables one to do a thermal performance analysis later if necessary. This data is for the heating surfaces as the gas flows from the hot to the cold end. If it is a steam generator, the furnace dimensions should be available along with fuel ultimate analysis, ash melting temperatures used and burner excess air. If more surfaces are used, data for each in the format shown below in Table 1 is required.

TABLE 1: TUBE GEOMETRY DATA SHEET(typical)

GEOMETRY	screen	suphtr	suphtr	evap	Econ
tube OD-in	2.000	2.000	2.000	2.000	2.000
tube ID-in	1.770	1.644	1.644	1.770	1.770
fins/in	0.00	0.00	0.00	4.00	5.00
fin height-in	0.00	0	0.00	0.75	0.75
fin thk-in	0.00	0	0.00	0.075	0.05
fin width-in	0.00	0	0	0.00	0.17
fin conductivity	0.00	0	20.00	25	25.00
tubes/row	15.00	14.00	14.00	15.00	10.00
no deep	4.00	22.00	42.00	11.00	12.00
Eff length-ft	8.60	6.50	6.50	8.60	8.00
tr pitch-in	4.50	4.	4.5	4.50	4.50
long pitch	4.00	5.00	5.00	4.00	4.50
streams	0.00	14.00	14.00	0.00	3.00
parl=0,countr=1	0.00	1.00	1.00	0.00	1.00
arrangement	inline	inline	inline	inline	staggered
tube material	sa192	T91/T22	T11	sa192	sa192
Surf area	*****	******	*****	******	*******
fin material					

1.If this is a HRSG then the thermal performance can be obtained as shown in Table 2.
2.If this is a steam generator, provide furnace dimensions, fuel analysis, excess air.
3.scheme showing how steam enters each stage of superheater is also required.

TABLE 2: THERMAL PERFORMANCE (typical only)

(Gas flow, inlet gas temperature,% vol co2,h2o,n2,o2,so2 etc of the flue gases should be available to perform this analysis. The analysis shown below can be obtained at various gas flow, inlet gas temperature conditions also if the tube geometry is known.)

surface	**Screen**	**Suphtr**	**suphtr**	**evap**	**econ**
gas temp in ±10F	1865	1599	1143	701	609
gas temp out-±10F	1599	1143	701	609	288
gas sp ht-Btu/lbF	0.3233	0.3114	0.2948	0.2846	0.2770
duty-MM Btu/h	4.82	7.97	7.33	1.45	4.99
U -Btu/ft2hF	14.47	15.28	13.17	12.51	7.00
surface Area-ft2	270	1048	2001	743	5381
LMTD-F	1232	498	278	156	133
gas pr drop-in wc	0.19	1.64	2.29	0.29	0.85

max gas vel-ft/s	61	72	56	31	32
tube wall temp ±10F	543	1140	827	501	241
fin tip temp ±10F	543	1140	827	501	257
weight-lb	1293	7512	14342	3555	7068
fluid temp in-F	356	692	495	356	230
fluid temp out ±10F	494	1051	778	494	356
pr drop-psi	0.00	14.49	19.26	0.00	6.40
fluid velocity-ft/s	0.0	64.5	46.9	0.0	3.8
fluid ht tr coefft	2000	180	186	2000	1339
foul factor-gas	0.0010	0.0010	0.0010	0.0010	0.0010
foul factor-fluid	0.0010	0.0010	0.0010	0.0010	0.0010
spray-lb/h	1,649				

Steam generation is also obtained based on inlet gas conditions.

The above information is only to show that type of information that can be generated for the boiler/HRSG. Boiler circulation is analyzed by a separate program. One can check the gas/steam profiles, tube wall temperatures of various surfaces and the heat fluxes from the above data. From these data one can infer if some problems are likely in any particular area by performing a more critical evaluation or row by row analysis.

For example if in a HRSG for the given gas flow and inlet gas temperature, one expects say 288F exit gas temperature for a feed water temperature of 230F but in actual operation sees say 320F or so, then we can infer that the sizing is not done right or needs to be investigated for fouling. Thats why the proposal should show these details and not simply a paragraph saying the HRSG will generate so much steam. An independent analysis can then check the original design. If the tube wall temperatures of the superheater are much higher than the values shown above then there is likelihood of deposits inside the tubes or the boiler supplier did not even evaluate or provide them. Steam purity may be checked. If steam purity is fine, one may look into the gas or steam flow distribution.. Poor ducting to the HRSG or poor header arrangements for steam can cause flow to individual tubes to vary.

Thus some insight into the boiler critical performance may be obtained which can help us to modify the design if absolutely required or see where the problems are.It can also tell if the original design was compromised or adequate or not.

This type of analysis is also useful even if the boiler is performing well. If the plant wants to change the fuel used in the boiler at a later date or change the inlet gas flow, temperature or analysis to the HRSG, the boiler or HRSG performance should be evaluated to ensure no problems arise. Changing to a low BTU fuel increases the flue gas quantities and the gas pressure drop can affect the fan operation. One may also perform this evaluation to see if there is scope for improving the boiler efficiency or energy recovery from the HRSG. If the plant wants to increase the capacity of the boiler by 10%,one can immediately check if the pressure drops in the superheater are reasonable and the drum pressure does not approach the design pressure assuming tube wall temperatures are reasonable .If the superheater is replaced with tubes of a different diameter at some point, how should the streams (number of tubes carrying the steam flow) be adjusted to ensure reasonable steam velocity or pressure drop?

In summary, thermal performance evaluation provides valuable information on several aspects of the boiler performance and identifies potential problem areas. To ensure that the model is reasonable, the author uses correction factors based on field data. Hence if the plant has enough field data and the tube geometry data, the boiler/HRSG performance can be predicted for any set of conditions or variations in feed water temperature, steam pressure, flue gas flow, analysis etc etc.