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THERMACT-Effective Remedial Solution for Removal of Slag and Clinker in Power Plant Boilers

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Abstract: ***Boiler slagging and clinker formation are persistent challenges in coal-fired power plants, adversely impacting heat transfer, boiler efficiency, and overall plant availability. Conventional mechanical cleaning techniques often require costly shutdowns and offer limited efficacy. This paper presents THERMACT, a multifunctional combustion catalyst developed by Abhitech Energycon Ltd. in collaboration with IIT Bombay, as an effective remedial solution to mitigate slag and clinker formation without additional capital investment. Through catalytic enhancement of combustion, THERMACT reduces activation energy, improves flame stability, and optimizes heat distribution. Field applications demonstrate significant reductions in flue gas exit temperature, unburnt carbon, auxiliary power consumption, and tube metal temperatures. Analytical tools such as furnace temperature mapping, ash fusion temperature analysis and scanning electron microscopy (SEM) confirm the improved combustion characteristics and ash behaviour. This paper consolidates operational insights, performance benefits, and scientific evaluations of THERMACT, establishing it as a proven solution for enhancing boiler reliability and efficiency across diverse coal blends. This product is being used by coal fired power plant of 210 MW to 830 MW capacity in India as well as overseas for more than 15 years.***

Keywords: Clinker, Slag, Combustion catalyst, Activation energy, Unburnt carbon, Boiler efficiency, Ash fusion temperature, Deformation Temperature (DT), Softening Temperature (ST), Hemispherical Temperature (HT), Flow Temperature (FT)

1. Introduction

Establishment of best practices, enhancement of Knowledge, Proactive initiatives are indispensable and Key attributes for overall improvement to gain expertise in Standardized O&M systems. Effective O&M Practices is one of the most cost-effective methods for ensuring reliability, safety, and energy efficiency.

Reducing fouling & slagging in the furnace improves the effective heat transfer in overall furnace and helps in maintaining the flue gas exit temperature thus helps in maintaining improved boiler performance and availability of the plant. Generally, plant operation takes shutdown for controlling & removing the clinkers which can be avoided by use of suitable cost-effective boiler additives. Typical problems like S-panel bridging, heavy clinker dislodging in boiler, furnace pressure fluctuation issues, increased boiler tube metal temperatures, bottom ash hopper refractory damage etc. cause heavy tangible and intangible losses to the power plants.

THERMACT, a multifunctional combustion catalyst developed by Abhitech Energycon Limited in collaboration with IIT, Mumbai, is a groundbreaking product utilized in the power plants world over to efficiently tackle the slag and clinkering issues in the power plant boilers.

The paper highlights the features of the THERMACT and the associated benefits. The product is thoroughly tested for safety and does not cause any detrimental effects in the boilers.

2. Root Causes of Slag and Clinker Issues

Deposition and slagging in coal fired boilers can be a major cause for poor performance and low availability of the unit. Slagging of ash refers to accumulation of semi-fluid ash over the furnace wall tubes and, in some cases, on the superheaters, reheaters located in the high temperature zone. Fouling occurs in low temperature zones (after FSH), wherein the elemental composition present in ash in combination with sulphur content, condense to create a fouling effect.

There are two basic forms of ash deposits, molten ash and alkali salts. The molten deposits are called slag and occur primarily in the furnace area of the boiler. Alkali salts generally occur in the convection or cooler portions of the boiler and duct.

When dealing with deposition or slagging in coal fired boilers, the following factors need to be considered:
- Coal and Ash analysis
- Composition and properties of Slag and Clinker
- Vaporization and condensation of ash
- Heat transfer phenomenon
- GCV of coal
- Combustion mechanism.

2.1 Impact of Slag and Clinker:

Accumulation of Ash Deposits (slag) on the platen Super heater & Reheater results in Reduced Heat transfer that would cause overheating of exposed tubes which may lead to tube damage. Dislodgement of Clinkers & slag would damage the Furnace Hopper and S panels.

The formation of slag and clinker is dependent on the composition of the coal ash and the boiler operating conditions. Based on the ash composition, Ash Fusion temperature of coal varies and is influenced by the process conditions in the furnace. The zone wise slag accumulation, its location, and the hardening index of the slag is thus dependent on the combustion profile in the boiler.

2.2. Probable locations of slag accumulation:

- Water Wall Slag
- Hanging Tubes Slag, and
- Convection Pass Fouling

3. Remedial Solution

The following practices of troubleshooting are well accepted among the users:
- Steam operated soot blower
- Use of sonic horns
- Use of water cannons
- Use of fireside additive

Sonic horns are fitted in the inspection doors in the first pass and second pass. Steam operated soot blowers are provided as per the design of the boilers. Various additives have been tried and used for many years to prevent fouling and corrosion.

4. THERMACT: A Multifunctional Combustion Catalyst

The catalytic action of THERMACT helps in lowering the activation energy (Figure 1) of the coal during the combustion process. This results in an optimized combustion process, leading to overall improvement in efficiency.

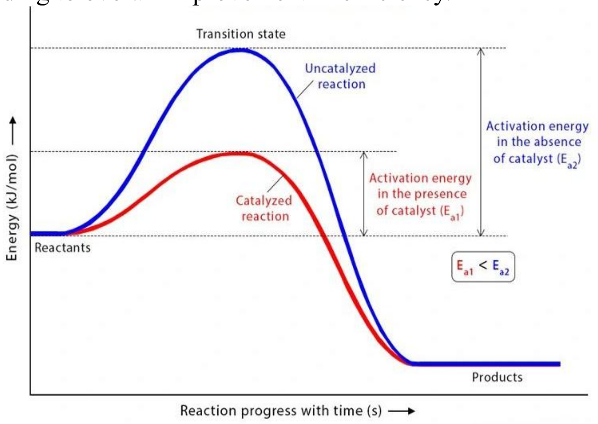

Figure 1: Activation Energy

4.1. Benefits of THERMACT:

Detailed analyses were carried out with continuous use of THERMACT, and the following benefits were observed:
- Reduction in Slag & Clinker (Figure 2 & 3)
- Bright flame indicating improved combustion
- Reduction in Secondary Air requirement thus increased fuel residence time in furnace

4.2. Visual Results after use of THERMACT:

4.2.1. Bottom Ash:

Figure 2: (A, C, E) Before Thermact

- Better heat transfer in the water wall zone (Figure 4,6,7,9,12 & 13)
- Reduction in flue gas exit temperature (Figure 5) and Increase in Combustion Efficiency
- Reduction in Unburnt Carbon in Ash (Figure 10 & 11)
- Reduction in fugitive emissions (SPM) (Figure 8)
- Reduction in Auxiliary Power Consumption
- Uniform heat gradient leading to reduced tube failures which improves forced outage rate

Figure 3: (B, D, F) After Thermact

As per our experience with Operations of subcritical and Supercritical units, to have an optimal cost of generation, different types of Coal blends are being used at Thermal Power Stations. With these coal blends, ash properties will change, leading to variable amount of slagging and fouling in boiler.

In some cases, unit shutdown becomes unavoidable to remove the dislodged heavy clinker from the boiler. It is also observed that the accumulation of slag and clinker results in heavy bridging in the bottom ash hopper, hindering the passage in the flue gas path. In this scenario the use of Boiler additive provides a quick fix CAPEX free solution. With the use of THERMACT, it has been made possible to run the unit with different types of coal blends without hampering the normal boiler operation.

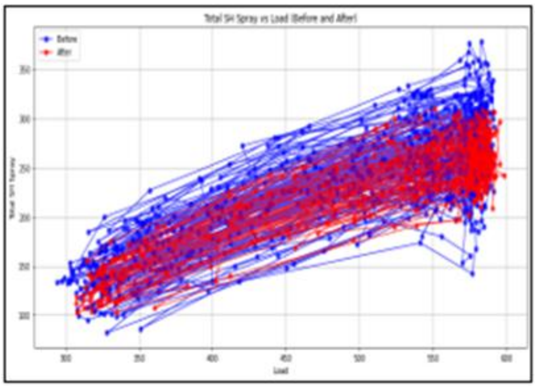

Figure 4: SH Spray Reduction

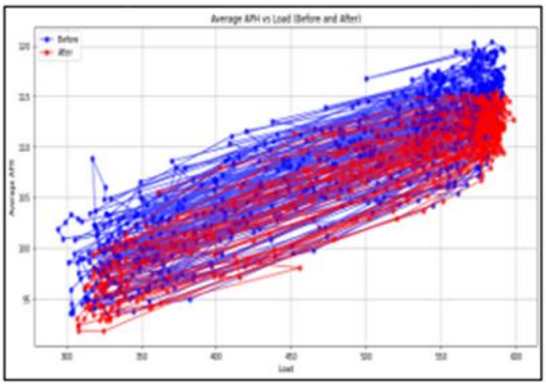

Figure 5: FG Temperature Reduction at APH O/L

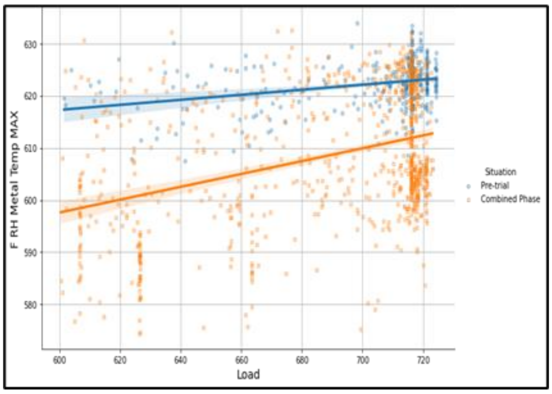

Figure 6: Reduction in Final RH Tube Metal Temp

5. Results and discussions after use of THERMACT at power plants:

5.1 Effect on Boiler Parameters:

Any fouling & Slagging in boiler will impact heat transfer and results in increase of Flue gas exit temperature (Figure 5) of the Boiler. Many thermal power plants operate with very high flue gas exit temperature and loosing boiler efficiency. (Every 10 ^{0}C rise in FGET results in 0.54% drop in boiler efficiency)

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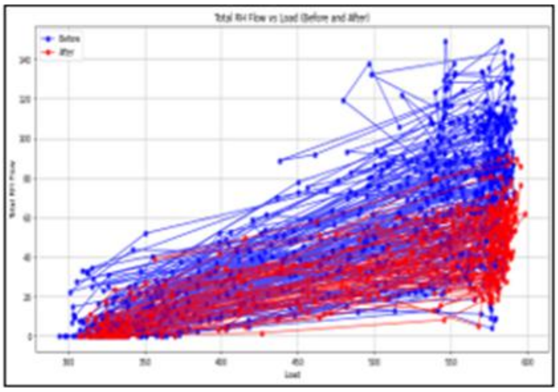

Figure 7: RH Spray Reduction

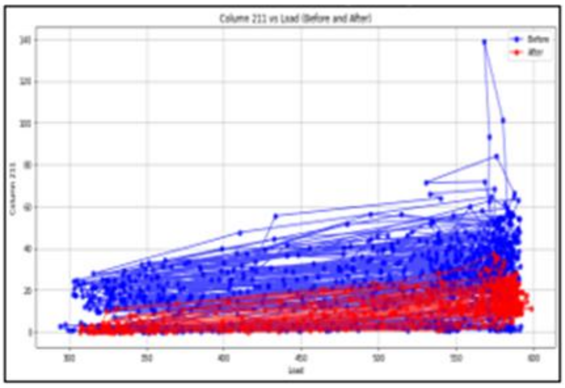

Figure 8: Reduction in Opacity

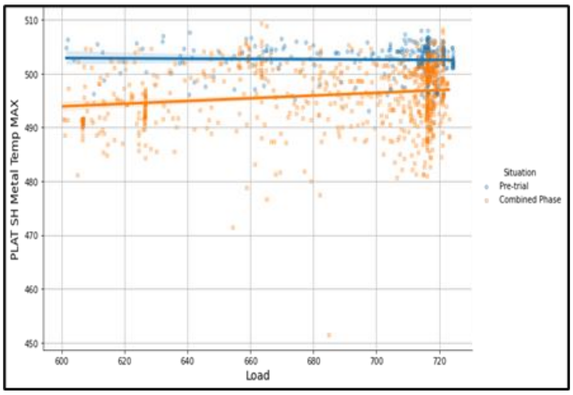

Figure 9: Reduction in Platen SH Tube Metal Temp.

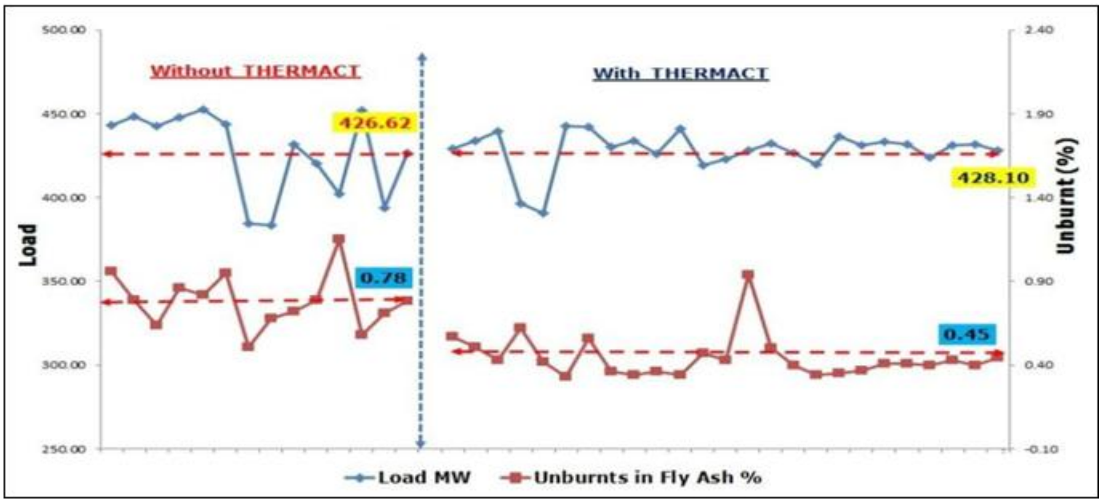

Figure 10: Unburnt Carbon Fly Ash

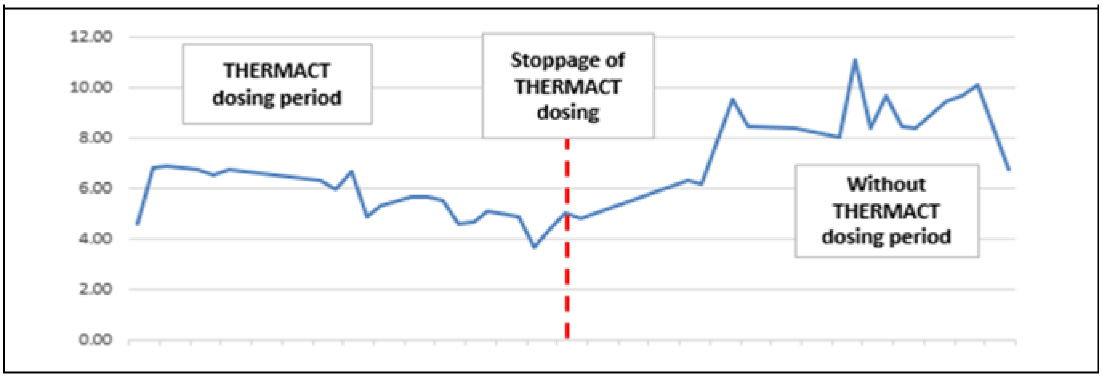

Figure 11: Unburnt Carbon Bottom Ash

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5.2 Furnace Temperature Mapping profiles:

As seen from the furnace temperature mapping profiles, usage of THERMACT has helped to lower the furnace temperatures. This reduced temperature profile along with improved heat transfer due to cleaned water wall surfaces help improve the boiler operating performance.

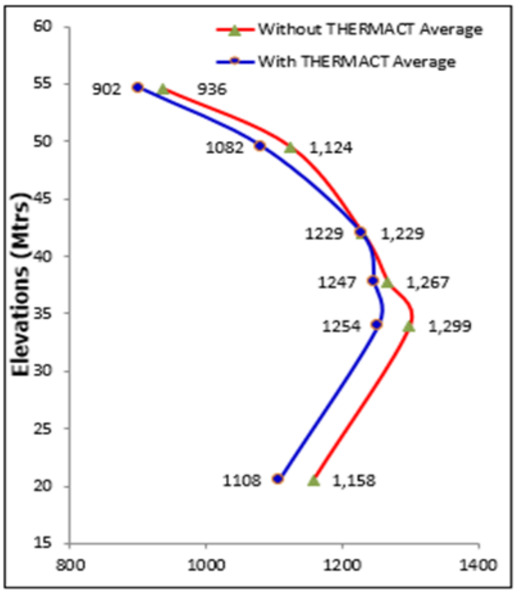

Figure 12: FTM Sample 1

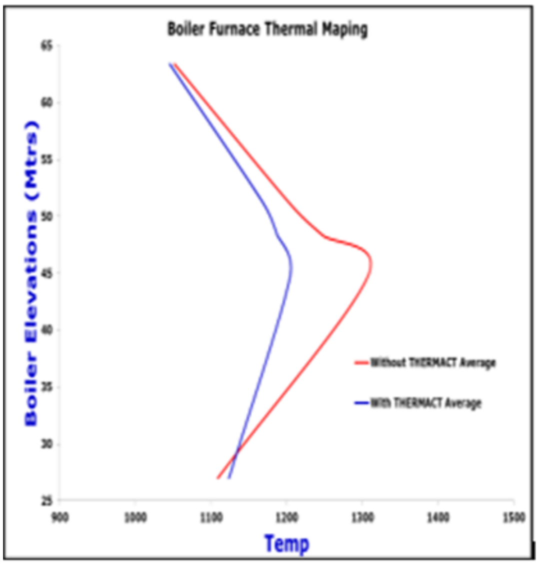

Figure 13: FTM Sample 2

5.3 Ash Fusion Temperature test results:

It has been observed from Ash Fusion characteristics test that the overall fusion temperatures of the ash have improved after the addition of THERMACT.

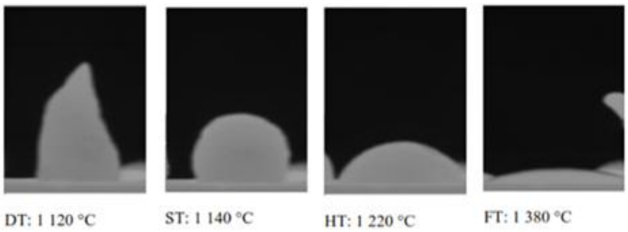

Figure 14: Ash Fusion Temperatures before Thermact

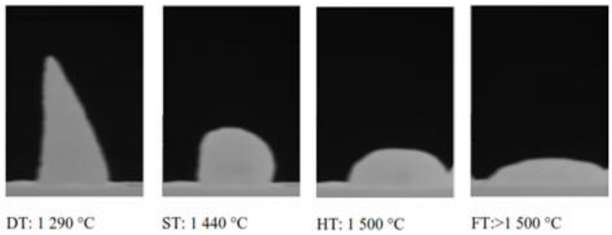

Figure 15: Ash Fusion Temperatures after Thermact

5.4 Scanning Electron Microscopic Study (SEM) of Fly Ash

SEM micrographs show remarkable differences in the microstructure of Fly Ash after usage of THERMACT.

Average particle size of Fly Ash before usage of additives is more as compared to that with THERMACT usage. Also, the particle shape is smoother with Thermact. This high particle size of fly ash is causing abrasive wear on the boiler tubes and hence after usage of this additive it is expected that there will be reduction in Boiler Tube failure rates due to erosion.

There was improvement in the collection of fly ash in ESP second field onwards since fly ash particulate size has reduced.

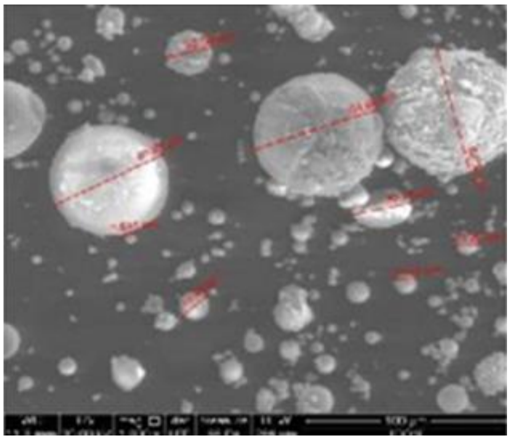

Figure 16: SEM of Fly Ash before Thermact

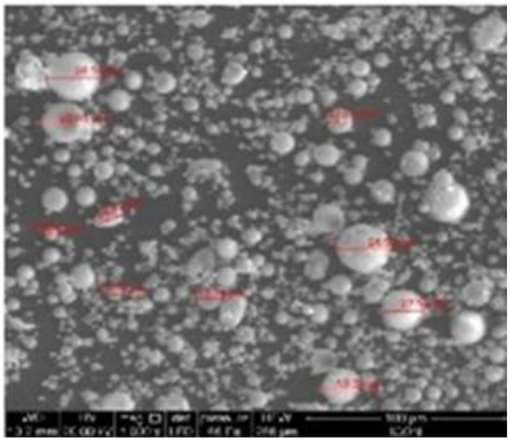

Figure 17: SEM of Fly Ash after Thermact

5.5 Scanning Electron Microscopic Study (SEM) of Bottom Ash:

With usage of Thermact, porosity of bottom ash clinkers is observed to increase as compared to that of without Thermact, as shown in the SEM images at 1000x magnification. As a result, the clinker is porous and hence easy to remove and grind. Thus, the energy required for grinding reduces significantly.

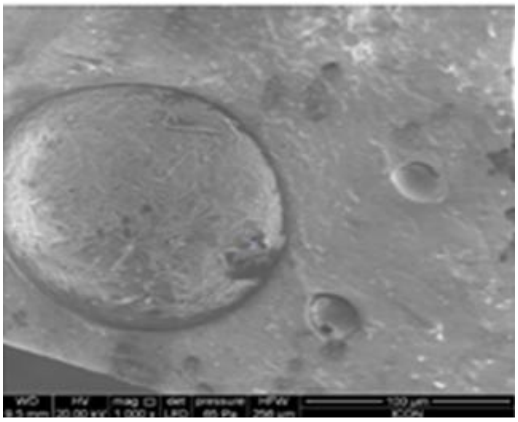

Figure 18: SEM of Bottom Ash before Thermact

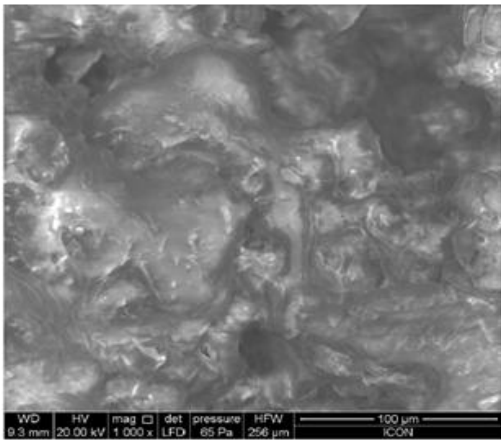

Figure 19: SEM of Bottom Ash after Thermact

5.6 Sieve analysis and particle size distribution (PSD) of Fly Ash

The samples were tested for both particle size distribution and sieve analysis. The PSD results show mean particle diameter (D50) of 56 micron and 53 micron for without Thermact and with Thermact, respectively.

The sieve analysis shows inconclusive trends with particles retained on 75 µm screen increasing in case of collector A and D, while decreasing for collector B and D. Similarly, for 250 µm screen, particles retained increasing for collectors B and C, while decreasing for collectors A and D. However, for 150 µm screen, there is general decreasing trend in particles retained on the screen, except for the collector C.

6. Conclusions

The following conclusions have been drawn after analyzing the impact of THERMACT usage in various power plants.

1) Significant reduction in Flue Gas Exit temperature, Superheat and Reheat Sprays, Unburnt Carbon in Fly ash and Bottom Ash, Opacity etc. were observed leading to improved boiler performance.
2) Reduction in tube metal temperatures enhancing the life of superheaters and reheaters.
3) Based on visual observations and test results, significant reduction was found in slag and clinker formation.

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Author Profile

The author has 40 years of experience in operation, maintenance, and commissioning of subcritical and supercritical thermal power plants in India as well as abroad. He was associated with ESKOM, Tata Power, GMDC, STEAG, Uptime AI and has in depth knowledge and experience in evaluating and troubleshooting challenges faced during boiler operation.