ENERGY AUDITING REPORT

"Improving Boiler Energy Efficiency“

OVERVIEW

- INTRODUCTION
- COMPANY DESCRIPTION
- BOILER LAYOUT
- METHODOLOGY
- DESCRIPTION LOSSES FOUND BY RESEARCH
- CALCULATIONS
- STRATEGIES TO REDUCE LOSSES
- CONCLUSION & RECOMMENDATION
- FUTURE SCOPE
- REFERENCES

Introduction

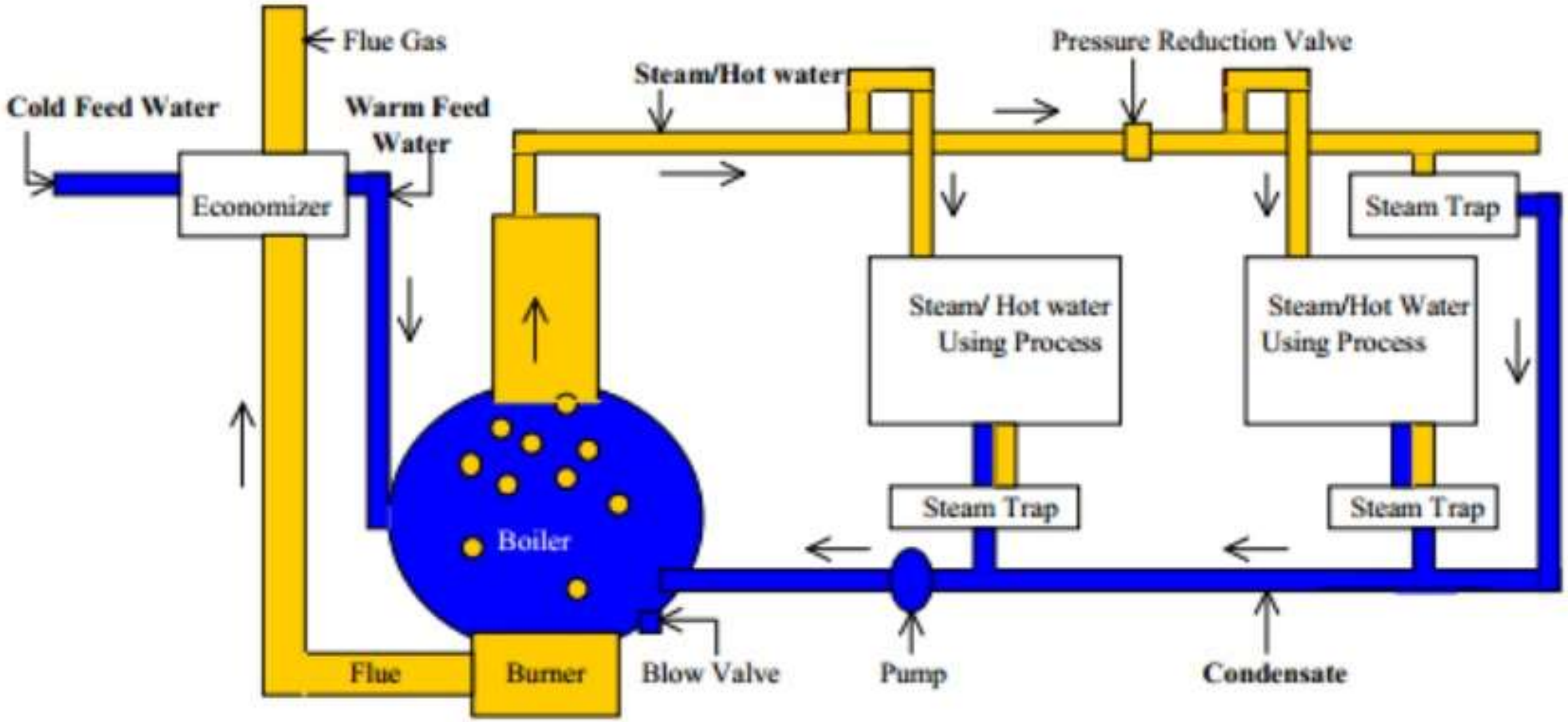
- The primary aim of this project is to enhance efficiency and reduce energy losses within boiler systems.
- Attention is directed towards mitigating heat losses, which contribute significantly to decreased efficiency, particularly through the boiler itself, air pre-heaters, and economizers.
- The project is conducted within a biomass-fueled plant, specifically utilizing rice peel as the biomass fuel.
- Providing an overview of energy audit processes and their role in identifying cost-effective energy-saving measures.

Company Description

- Established: 2002, Ahmedabad, Gujarat, India
- Business: Manufacturer, Exporter, Wholesaler
- Products: Mild Steel Barrels, Stainless Steel Barrels, MS Composite Barrels, MS Composite Drums, etc.
- Manufacturing: Follows industry standards, uses high-quality materials and advanced technology.

- Competitive Advantages: Pocket-friendly prices, timely delivery, rigorous quality control.
- Infrastructure: State-of-the-art facility with dedicated production, quality testing, warehousing & packaging units.
- Team: Experienced professionals including engineers, technicians, quality controllers, R&D personnel, administration staff, and skilled laborers.
- Focus: Meeting customer needs efficiently while delivering high-quality products.

BOILER LAYOUT



Methodology

Inventory & Documentation

- Compile list of boiler components and condition.
- Review operational records, maintenance logs, and incident reports.
- Conduct thorough inspection of boiler components for compliance with safety standards.

Efficiency Evaluation

- Perform combustion analysis (flue gas composition and temperature).
- Calculate heat losses (direct or indirect method).
- Benchmark boiler performance against industry standards.

Additional Considerations

- Review water treatment program for adequacy.
- Evaluate boiler operation practices (burner settings, blowdown).
- Perform cost-benefit analysis of potential upgrades.

Compile Audit Report

- Include findings from safety assessment, efficiency evaluation, and additional considerations.-
- Provide recommendations for improvement.

Descriptive Losses found by research

- A. Heat given by fuel
- B. Loss estimation in flue gas
- C. Losses due to moisture
- D. Losses due to fuel moisture
- E. Radiation losses

A. Heat given by fuel

- The standard fuel used by these companies generally is “Rice Husk”. Even though the fuel seems economical at first, the scale at which this company is working makes this less economical.
- Using Pet coke as an alternative to this seems a more feasible option. Pet coke has already been used as an alternative in many industries as fuel , with recent examples such as cement industries.
- Even though the cost might be a little on the higher side , when compared to its calorific value , is overall unit contribution is cheaper as shown.

Calculation

Using pet coke alternatively of rice husk :

1 ton of rice husk produces = 3.2 ton of steam

Steam produced from rice husk = 1297 ton per day

1297 ÷ 3.2 = 398.75 tons of rice husk used daily

Cost of 1 ton of rice husk = Rs 4,300

So, 398.75 × 4300 = Rs 17,97,675.2 per day

Now, pet coke;

1 ton of pet coke produces = 8.6 ton of steam

1297 ÷ 8.6 = 150.8139 tons of pet coke will be used daily to produce same amount of steam.

Cost of 1 ton of pet coke = Rs 8,100 So, 150.8139 × 8100 = Rs 12,21,592.59 per day

Savings = Rs. 17,97,675.2 – 12,21,592.59 = Rs 5,76,082.61 per day

B. Loss estimation in flue gas

Air Preheaters:

- Reduced Fuel Consumption: By preheating the combustion air entering the boiler, less heat is required from the burning fuel to reach the desired combustion temperature. This translates to burning less fuel to achieve the same boiler output, leading to significant cost savings.
- Improved Boiler Efficiency: Preheating the air reduces the temperature difference between the incoming air and the hot flue gases. This minimizes heat loss to the flue gases, improving overall boiler efficiency.
- Lower Flue Gas Temperatures: Cooler flue gases exiting the boiler can simplify the design and potentially reduce the cost of the exhaust stack.

Calculation

Ψ_1 = initial energy of the products = $(h_1 – h_o) – T_o \times (s_1 - s_o) = C_{pg} \times (T_{g1} – T_o) – T_o \times C_{pg} \times \ln T_{g1}/T_o$

Where;

$T_{g1} = 290$, $T_o = 18$, $C_{pg} = 1.073$ (from steam table) $= 1.073 \times (562 – 291) – 291 \times 1.073 \times \ln 562/291 = 85.83$ kJ/kg

Ψ_2 = initial energy of the products = $(h_2 – h_o) – T_o \times (s_2 - s_o) = C_{pg} \times (T_{g2} – T_o) – T_o \times C_{pg} \times \ln T_{g2}/T_o$

Where;

$T_{g2} = 190$, $T_o = 18$, $C_{pg} = 1.073$ (from steam table) $= 1.073 \times (462 – 291) – 291 \times 1.073 \times \ln 462/291 = 49.419$ kJ/kg

Decrease in energy of the products = $\Psi_1 – \Psi_2 = 36.411$ kJ/kg

Increase in energy of air = $m_a \times [(h_2 – h_1) - T_o \times (s_2 - s_1 – R \times \ln P_2/P_1)] = m_a \times C_{pa} (T_{a2} – T_{a1}) – T_o \times (C_{pa} \times \ln T_{a2}/T_{a1} – R \times \ln P_2/P_1)]$

Where;

$T_{a2} = 142$, $T_{a1} = 18$, $T_o = 18$, $C_{pa} = 1.005$, $P_1 = 811$ mm of WC,

$P_2 = 713$ mm of WC, $R = 0.274$, $m_a = 11.66$ kg/sec (from steam table) = 364 kW

Initial energy of steam

specific enthalpies of the steam at the exit (Tg1)

specific enthalpies of the steam at reference state (To)

specific entropies of the steam at the exit

specific entropies of the steam at reference state

Cpg is the specific heat capacity of the steam at constant pressure

Tg1 is the exit temperature of the steam from the boiler.

$\Psi 1$ = initial energy of the products = $(h1 - ho) - To \times (s1 - so) = Cpg \times (Tg1 - To) - To \times Cpg \times \ln Tg1/To$

To is the reference temperature (often ambient temperature)

Where;

$Tg1 = 290$, $To = 18$, $Cpg = 1.073$ (from steam table) $= 1.073 \times (562 - 291) - 291 \times 1.073 \times \ln 562/291 = 85.83$ kJ/kg

$\Psi 2$ = Initial Energy of Steam After Expansion = $(h2 - ho) - To \times (s2 - so) = Cpg \times (Tg2 - To) - To \times Cpg \times \ln Tg2/To$

Where;

$Tg2 = 190$, $To = 18$, $Cpg = 1.073$ (from steam table) $= 1.073 \times (462 - 291) - 291 \times 1.073 \times \ln 462/291 = 49.419$ kJ/kg

Decrease in energy of the products = $\Psi 1 - \Psi 2 = 36.411$ kJ/kg

Increase in energy of air = $ma \times [(h2 - h1) - To \times (s2 - s1 - R \times \ln P2/P1)] = ma \times Cpa\ (Ta2 - Ta1) - To \times (Cpa \times \ln Ta2/Ta1 - R \times \ln P2/P1)]$

Where;

$Ta2 = 142$, $Ta1 = 18$, $To = 18$, $Cpa = 1.005$, $P1 = 811$ mm of WC,

$P2 = 713$ mm of WC, $R = 0.274$, $ma = 11.66$ kg/sec (from steam table) = 364 kW

Installing Economizers for Energy Saving

- Economizers: Utilize Waste Heat: Economizers capture heat from the exiting flue gases, which would otherwise be wasted, and use it to preheat the feedwater entering the boiler.
- Reduced Fuel Consumption: Preheated feedwater requires less energy from the boiler to reach its boiling point. This translates to lower fuel consumption for the same steam output.
- Improved Boiler Efficiency: By recovering waste heat and using it to preheat the feedwater, the economizer contributes to a more efficient boiler system.
- Reduced Emissions: Lower fuel consumption due to both air preheaters and economizers leads to a reduction in pollutant emissions from the boiler.
- The water gains heat from the flue gases which are at a temperature of around 390. The economizer has 25 numbers of tubes. Inside the tubes water at 120 is flowing. The diameter of the tubes which are present within the economizer is 25 mm and the thickness of the tubes is 3.5mm. The economizer is decently insulated which prevents the heat loss from the economizer walls.

Calculation

- Ψ_1 = initial energy of the products = $(h_1 – h_o) – T_o \times (s_1 - s_o)$= $C_{pg} \times (T_{g1} – T_o) – T_o \times C_{pg} \times \ln T_{g1}/T_o$(Assume constant velocity of water at inlet and outlet of economizer tubes)
- Where;
- T_{g1} = 390, T_o = 18 , C_{pg} = 1.073 (from steam table)= 1.073 × (663 – 291) – 291 × 1.073 × ln 663/291= 142.046 kJ/kg
- Ψ_2 = initial energy of the products = $(h_2 – h_o) – T_o \times (s_2 - s_o)$ = $C_{pg} \times (T_{g2} – T_o) – T_o \times C_{pg} \times \ln T_{g2}/T_o$ (Assume velocity of water at inlet and outlet of economizer tubes to be constant.)
- Where;
- T_{g2} = 290, T_o = 18 , C_{pg} = 1.073(from steam table)= 1.073 × (563 – 291) – 291 × 1.073 × ln 563/291 = 85.79 kJ/kg
- Decrease in energy of the products = $\Psi_1 – \Psi_2$ = 56.256 kJ/kg
- Increase in energy of water= $m_w \times [(h_2 – h_1) – T_o \times (s_2 – s_1)]$
- Where;
- m_w = 15kg/sec, h_2 = 990.3 kJ/kg, h_1 = 503.7 kJ/kg, T_o = 18, s_2 = 2.610 kJ/kg K, s_1 = 1.528 kJ/kg K (from steam table) = 2576.08 kJ/kg

C. Losses due to moisture

- The fuel is kept in open inside the plant as a result it absorbs a small quantity of moisture from the atmosphere. So more heat has to be given to the fuel which leads to the decrease in efficiency Water is formed due to the oxidation of hydrogen present in the fuel into water which is estimated by the following equation.
- $h_{wc} = W_c \times L$ $h_{wc} = 0.56 \times 2100 = 1176.28$ kW whereW_c = Weight of moisture formed in kg per kg of dry fuel L = Latent heat of vaporization at the dew point of flue gas, kJ/kg h_{wc} = Heat loss due to water of combustion, kW
- This much of energy can be saved if we can reduce moisture.

D. Losses due to fuel moisture

- Moisture present in the fuel is also gone to the atmosphere from the chimney. This is given by the following equation. This loss designates the amount of excess heat given to the fuel due to the moisture present in the fuel. The more good quality the fuel is the less moisture will be present per kg of fuel.

  $hw = W \times L$

  $hw = 0.165 \times 2100 \times 3.42 = 1185.03$ kW

  WhereW = Weight of moisture present in kg per kg of dry fuel

  L = Latent heat of vaporization at the dew point of flue gas, kJ/kg

  hw = Heat loss due to water present in fuel, kW

Strategies to Reduce Losses:

- Select drier fuels.
- Store fuel properly.
- Dry fuel (if applicable).
- Optimize combustion air.
- Control flue gas temperature.
- Utilize waste heat (economizers)Perform boiler blowdownControl leaks

Radiation Loss Reduction

- To reduce radiation losses , we can insulate the boiler by aluminium sheets and Glass wool.
- The sample boiler has a dimension of Diameter= 2.6m, height=6.1m
- The following shows the cost of insulation:

  Given Information:
- Boiler Dimensions:
- Diameter: 2.6 m Height: 6.1 m Insulation: Metal Sheet: 2.1 mm thick Glass Wool: 9.1 cm thick
- Material Rates: Glass Wool: ₹80/sq.ft (for 20 mm thickness)
- Aluminum Sheet (assuming used instead of metal sheet): ₹100/sq.m (for 2 mm thickness)

Calculations for Boiler Insulation

1. Area Calculation: We need to calculate the total surface area of the boiler that needs insulation. This will involve the curved surface area of the cylinder and the top and bottom ends (assuming they are circular).

a) Curved Surface Area:

Formula for cylinder curved surface area: 2 * π * r * h

r (radius) = diameter / 2 = 2.6 m / 2 = 1.3 m

h (height) = 6.1 m * Curved surface area = 2 * π * 1.3 m * 6.1 m ≈ 24.9 sq.m

b) Top and Bottom End Area:Formula for circle area: π * r^2 * Area per end = π * (1.3 m)^2 ≈ 1.69 sq.m* Total area for top and bottom ends (assuming both are circular): 2 * 1.69 sq.m ≈ 3.38 sq.m

c) Total Surface Area for Insulation: Total area = Curved surface area + Top and bottom end area. Total area = 24.9 sq.m + 3.38 sq.m ≈ 28.28 sq.m

2. Glass Wool Cost:**a) Adjust Glass Wool Thickness:The given rate is for 20 mm thickness, but we need the cost for 9.1 cm (91 mm) thickness.

b) Cost per unit area adjustment:We need to calculate the cost per square meter since the total area is in square meters and the rate is given per square foot.

Conversion factor: 1 sq.ft = 0.0929 sq.m Cost per sq.m for 20 mm glass wool = ₹80/sq.ft * (1 sq.m / 0.0929 sq.ft) ≈ ₹861.80/sq.m

Estimate based on assumption:Assuming a linear cost increase with thickness, we can roughly estimate the cost: Cost per mm for 20 mm = ₹861.80 / 20 mm ≈ ₹43.09/mm Estimated cost for 91 mm = ₹43.09/mm * 91 mm ≈ ₹3923.69/sq.m

3. Aluminum Sheet Cost (assuming used instead of metal sheet): Total surface area for insulation (from step 1c): 28.28 sq.m Aluminum sheet rate: ₹100/sq.m* Cost of aluminum sheet = 28.28 sq.m * ₹100/sq.m = ₹2828

Summary: Total surface area for insulation: 28.28 sq.m* Glass wool cost (needs supplier confirmation): Using estimated cost: ₹3923.69/sq.m * 28.28 sq.m ≈ ₹110,533.75* Aluminum sheet cost: ₹2828

Conclusion and Recommendation

- Tank lacks insulation, causing heat loss. Insulation maintains temperature, prevents heat loss, and improves efficiency in energy use.
- Replace rice husk by Pet coke for better efficiency.
- Installation of Air Preheaters and economizer for energy loss prevention, hence increasing the boiler efficiency.
- Reducing moisture in fuel so as to stop the fuel wastage for raising fuel temperature.

FUTURE SCOPE

- This report explains how to conserve energy in an 8.5 MW cogeneration plant. In the future, we can compare similar plants using newer technologies like organic Rankin cycle, ash water rehabilitation, decentralized air systems, and high-pressure roller mills.
- (i) To decrease the heat loss through the furnace walls by proper insulation.
- (ii) Standard controls should be establish on the boilers which give correct reading on even very small variations so that the boiler operation can be incised losses can be minimized.
- (iii) Timely maintenance of the air pre-heater so that air leakage can be forbade and efficiency of the boiler can be improved.

REFERNCES

- Saidur R., Ahamed J.U. and Masjuki H.H. (2010).Energy, energy and economic analysis of industrial boilers. Energy Policy. 38: 2188-2197.
- Kaya D., Eyidogan M. and Kilic F.C. (2014).Energy saving and emission reduction opportunities in mixed fueled industrial boilers. Environmental progress and sustainable energy 1(7):
- Liao Z. and Dexter A.L. (2004).The potential for energy saving in heating systems through improving boiler controls. Energy and buildings. 36: 261-271.
- Kumar A. T.,Chandramouli R. and Jothikumar K. (2014). Exergy analysis of a coal based 63 MW circulating fluidised bed boiler. Applied Sciences. 14(14): 1514-1521

THANK YOU