

**EVALUATING THE HEAT RECOVERY OPTIONS
FROM THE GENERATED OILY SLUDGE IN
THERMAL POWER PLANTS**

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Degree of Master of Engineering

Department of Mechanical Engineering

University of Moratuwa

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Dissertation submitted in partial fulfillment of the requirements for the degree Master
of Engineering

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Declaration

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Abstract:

Oily sludge is a process waste of thermal power plants that use heavy fuel oil for power generation. At present, the oily sludge is sold or incinerated from the power stations belonging to Ceylon Electricity Board. Since the waste heat generated from the incineration process is disposed to the environment without harnessing for effective work, the operation and maintenance cost of incineration is not cost-effective. In this study, the waste heat recovery options were considered based on the sludge treatment methods used in thermal power stations.

The possibility of using the sludge as fuel for micropower generation, hot water generation, and waste heat recovery from the oily sludge incineration was investigated. The study was carried out to determine the potential of recovering the waste heat of the oily sludge incineration process and to investigate the design parameters for a suitable heat recovery steam generator. Furthermore, the calorific value and the constituents in the sludge sample were investigated. As a result of this study, Heat Recovery Steam Generator was found as the most suitable heat recovery method.

The proposed HRSG was modeled, simulated, and optimized using the Engineers Equation Solver (EES) software. From the trial runs, the maximum power output that could be recovered from HRSG is 96.04 kW of energy at a rate of 222.1 kg/h sludge incinerating. Considering the steam mass flow rate for commercially available steam turbines, implementing a micropower generation plant with a capacity of 93.63kW is a feasible project with a payback period of 2.70 years to recover the cost of the investment. Furthermore, the feasibility of the sludge using as a fuel to a sludge fired boiler for power generation and hot water generation were investigated. 107.0 kW of power could be harnessed by burning of sludge at a rate of 204.48 kg/h and 13.36 kg/h of hot water could be generated by burning sludge at a rate of 1kg/h.

Waste heat recovery, Oily Sludge, Micropower generation, HRSG, EES.

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List of abbreviations

| | |
|-------|--|
| CEB | - Ceylon Electricity Board |
| PHC | - Polycyclic aromatic hydrocarbons |
| UJPS | - Uthuru Janani Power Station |
| HFO | - Heavy Fuel Oil |
| LFO | - Diesel fuel |
| OEM | - Original Equipment Manufacturer |
| CPC | - Ceylon Petroleum Corporation |
| CPSTL | - Ceylon Petroleum Storage Terminals Limited |
| EES | - Engineering Equation Solver software package |
| HRSG | - Heat Recovery Steam Generator |
| ITI | - Industrial Technology Institute |
| EGT | - Exhaust gas temperature |

Subscript

| | |
|-----|--------------------------|
| apr | -Approach point |
| shs | -Superheated steam |
| gs | -Flue gas |
| sw | -Saturated water |
| go | -Gas out |
| gi | -Gas in |
| st | -Steam |
| f | -Fuel |
| g | -Gas |
| t | -Temperature |
| pt | -Pinch point temperature |

Nomenclature

| | |
|--------------|---|
| Q | -Heat content(J) |
| V | -Flowrate of the matter(m^3/s) |
| m_f | -Mass of the required fuel (kg) |
| Q_g | -Energy absorbed (kJ) |
| t_{go} | -Flue gas out temperature ($^{\circ}C$) |
| m_{st} | -Mass flow rate of steam (kg/s) |
| t_{g1} | -Flue gas in temperature of HRSG ($^{\circ}C$) |
| t_{pt} | -Pinch point temperature difference ($^{\circ}C$) |
| t_{g2} | -Economizer exit temperature ($^{\circ}C$) |
| h_{apr} | -Enthalpy - approach point (kJ/kg) |
| h_{sw} | -Feed water enthalpy (kJ/kg) |
| h_{shs} | -Enthalpy – superheated steam (kJ/kg) |
| h_{ouis} | -Isentropic enthalpy of steam (kJ/kg) |
| Q_e | -Heat required (kJ) |
| C_f | -Calorific value of sludge |
| η_{stm} | -Turbine mechanical efficiency |
| h_{sw} | -Enthalpy of saturated water (kJ/kg) |
| t_s | -Saturation temperature of the water |
| Δt | -Temperature difference in the substance |
| h_{s2} | -Enthalpy of steam evaporator(kJ/kg) |
| h_{ou} | -Enthalpy of steam at turbine out (kJ/kg) |
| Q_{ex} | -Extracted energy percentage |
| h_{lo} | -Heat loss from the HRSG |
| P_{stm} | -Steam turbine power output (kW) |
| η_{Is} | -Turbine - isentropic efficiency |
| ρ | -Density of flue gas (kg/m^3) |
| C_{pg} | - Value of specific heat - flue gas |
| h_{shs} | -Turbine inlet enthalpy (kJ/kg) |

| | |
|-------------|---|
| η_b | -Efficiency of the boiler |
| t_{gi} | -Flue gas in temperature ($^{\circ}\text{C}$) |
| \dot{m}_f | -Mass flow rate of sludge (kg/h) |
| m_g | -Mass flow rate of flue gas (kg/s) |
| m_{gs} | -Mass flow rate of gas (kg/s) |
| t_{g1} | -Temperature - flue gas in ($^{\circ}\text{C}$) |
| t_{g4} | -HRSG exit temperature ($^{\circ}\text{C}$) |
| t_{g3} | -Evaporator exit temperature ($^{\circ}\text{C}$) |