National Environment Agency Singapore

Measurement & Verification of Heating Systems

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1 Hot Oil Heater System

The objective of a hot oil system is to provide heat to various processes through a centralized system (i.e. fired heater) where the heating medium is a hydrocarbon stream (defined as hot oil).

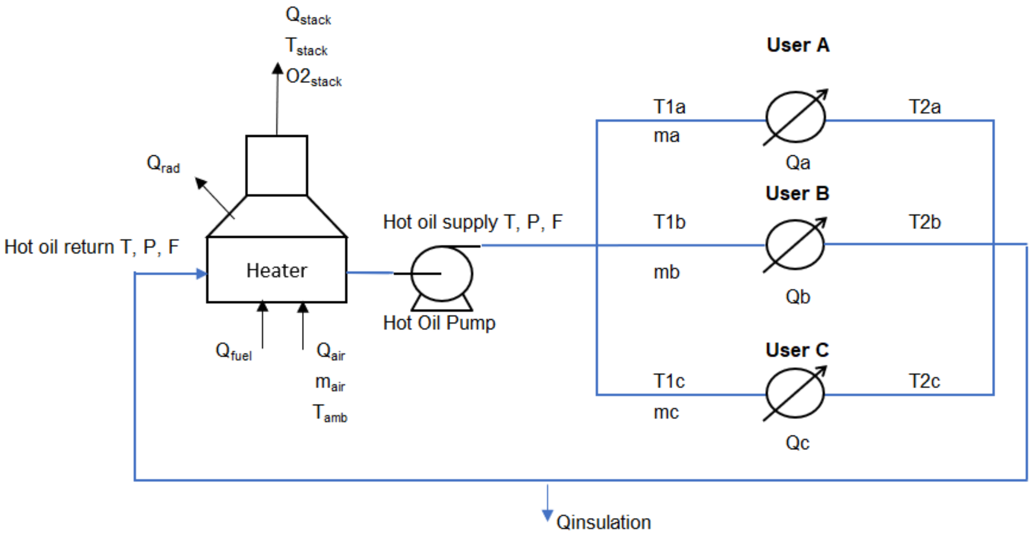

Figure 1: Main considerations for assessing the performance of hot oil systems

Table 1: **Key energy metrics for hot oil heaters**

Energy System	Hierarchy	Metric	Method
Heater equipment only	Energy performance indicator	Thermal efficiency (%)	Calculated
	Energy influencing variable	Stack temperature (°C)	Measured
	Energy influencing variable	Stack oxygen (%)	Measured
	Energy influencing variable	Hot oil supply temperature (°C)	Measured
	Energy influencing variable	Hot oil return temperature (°C)	Measured
Hot oil system	Energy performance indicator	Hot oil pump specific energy consumption (kW/unit throughput)	Calculated

Energy performance indicators: these are calculated values that allow the management and engineering team to track the overall performance of an equipment, process or even the whole site.

Energy influencing variables: these items represent elements within the system that can be manipulated to improve the efficiency of the equipment or process.

Figure 1 shows a schematic diagram of a typical hot oil heater system. Table 1 shows a list of key metrics for a hot oil heater system.

This measurement and verification (M&V) plan serves to outline the methodology for quantifying the energy performance improvement before and after the implementation of energy conservation measures relating to the hot oil system.

2 Assessment of Baseline Energy Performance

2.1 Heater thermal efficiency

The thermal efficiency of the hot oil heater can be computed using the following methodology.

$$Heat\ Input = m_{fuel} \times LHV_{fuel} \qquad \text{Eqn. 1}$$

$$Useful\ Heat\ Output_{baseline} = m_{hot\ oil} \times C_{p,avg} \times (T_{supply} - T_{return}) \qquad \text{Eqn. 2}$$

$$E_{baseline} = \frac{Useful\ Heat\ Output}{Heat\ Input} \times 100\% \qquad \text{Eqn. 3}$$

Where:

$E_{baseline}$	:	Baseline thermal efficiency of hot oil heater (%)
Heat Input	:	Fired duty of heater (MJ/h)
Useful Heat Output$_{baseline}$	:	Useful heat absorbed by hot oil (MJ/h)
m_{fuel}	:	Mass flow rate of fuel (t/h)
LHV_{fuel}	:	Lower heating value of fuel (kJ/kg)
$m_{hot\ oil}$	:	Mass flow rate of hot oil stream (t/h)
$C_{p,avg}$	:	Specific heat capacity of hot oil (kJ/kg.°C)
T_{supply}, T_{return}	:	Hot oil supply and return temperatures (°C)

Note: If the heater has an air preheater that uses an external heat source, the heat duty of the preheater should be included as heat input into the heater and so added to Eqn 1. If the air preheater uses stack gases, this is not necessary as the air preheater is recovering energy from the heater itself.

2.2 Hot oil pump specific energy consumption

The power consumption of pumps can be determined by one of the following methods

- Use of readings from existing power meters

  Power consumption of pumps can be measured through the use of existing power meters or ammeters. If power meters are available, then power consumption information will be available for applying Eqn. 4 below.

- Plot baseline operation on the pump curve

  Using the operating flow data of the pump, the pump curve can be used to determine the pump power consumption.

Specific energy consumption (SEC) of a pump can be computed by the following formula.

$$SEC_{baseline} = \frac{Pump\ Power_{baseline}}{Unit\ throughput} \qquad \textit{Eqn. 4}$$

Where:

$SEC_{baseline}$	:	Baseline specific energy consumption of pump (kWh/t)
$Pump\ Power_{baseline}$	:	Baseline power consumption of pump (kW)
$Unit\ throughput_{baseline}$	:	Baseline hot oil flow rate (t/h)

3 Assessment of Post-Implementation Energy Performance

The assessment of post-implementation energy performance of hot oil heater systems follows the same approach as detailed in Section 2 above.

4 Quantification of Energy Performance Improvements and Cost Savings

Energy performance improvements to the hot oil heater efficiency can be quantified as follow.

$$Energy\ performance\ improvement = Useful\ Heat\ Output_{post} \times \left(\frac{1}{E_{baseline}} - \frac{1}{E_{post}}\right) \quad \text{Eqn. 5}$$

$$Annual\ energy\ performance\ improvement = Energy\ performance\ improvement \times Op\ hrs \quad \text{Eqn. 6}$$

$$Annual\ cost\ savings = Annual\ energy\ performance\ improvement \times Fuel\ cost \quad \text{Eqn. 7}$$

Where:

E_{post}	:	Post-implementation thermal efficiency of hot oil heater (%)
Useful heat $output_{post}$	:	Post-implementation useful heat absorbed by hot oil (MJ/h)
Op hrs	:	Number of operating hours in a year (hrs /yr)
Energy performance improvement	:	Energy performance improved compared to baseline (MJ/h)
Annual energy performance improvement	:	Energy performance improvement for a year (MJ/yr)
Fuel Cost	:	Cost of fuel (SGD/MJ)
Annual cost savings	:	Cost savings in a year (SGD/yr)

Pump energy performance improvements can be computed as follow.

$$Pump\ energy\ performance\ improvement = Unit\ throughput_{post} \times \left(SEC_{baseline} - SEC_{post}\right) \qquad \text{Eqn. 8}$$

$$Annual\ energy\ performance\ improvement = Pump\ energy\ performance\ improvement \times Op\ hrs \qquad \text{Eqn. 9}$$

$$Annual\ cost\ savings = Annual\ energy\ performance\ improvement \times Tariff \qquad \text{Eqn. 10}$$

Where:

SEC_{post}	:	Post-implementation specific energy consumption of pump (kWh/t)
Unit $throughput_{post}$	:	Post-implementation hot oil flow rate (t/h)
Pump energy performance improvement	:	Pump power reduction compared to baseline (kW)
Op hrs	:	Number of operating hours in a year (hrs/yr)
Annual energy performance improvement	:	Energy performance improvement for a year (kWh/yr)
Tariff	:	Electricity tariff (SGD/kWh)
Annual cost savings	:	Cost savings in a year (SGD/yr)

5 Typical Scenarios Applicable to Hot Oil Heater Systems

Generally, there are two types of projects that would affect the performance of hot oil heater system, namely:

- Modifications to hot oil heater
- Changes in the process heat requirements

Modifications to hot oil heater

Energy efficiency projects relating to modifying the hot oil heater generally targets the main source of heat loss, which is through the flue gas. Improvements to heat recovery from stack flue gas, or the trimming of excess oxygen content in flue gas leads to better thermal efficiencies.

As these modifications only affect the thermal performance of the heaters (and do not lead to any change to the downstream demand of the heat energy), the baseline and post-implementation thermal efficiencies can be calculated using heat balance or empirical formula on the fired heater, with measurement of the stack oxygen content, temperature of stack flue gas and inlet combustion air. This approach is detailed in the Assessment Framework for hot oil heaters.

Changes in the process heat requirements

Changes to process heat demand can be a result of increased process to process heat recovery, changes to process operations or product slates. These changes can be observed through the temperature profile of the supply and return hot oil and the heater duty. The performance of both the hot oil heater and hot oil pump may be affected.

The previous sections have provided information on how to establish the base line and quantify energy performance improvements and cost savings for these cases.

6 Instrumentation Requirements

The following section describes the list of critical parameters that should be measured using permanent instruments. The availability of these data will allow for continuous monitoring of hot oil heater efficiency.

- Fuel system
  - Fuel flow to each individual heater
- Heater
  - Stack temperature
  - Stack oxygen content
- Hot oil
  - Hot oil flow rate
  - Hot oil supply temperature
  - Hot oil return temperature
- Pump
  - Power

Other parameters such as the specific heat capacity of hot oil and lower heating value of fuel can be obtained from design data or laboratory test results.

As per NEA guidelines, a 2-week measurement period is used when calculating the baseline or post-implementation heating system efficiency. The resolution of the collected data should be at least on an hourly basis.