Fig. 1. CDU crude preheat train flow scheme.

and light hydrocarbon gases from the crude oil. The vapour is risen up to pre-flash overhead distillate and the liquid flows downward to the bottom. The preflash column bottom is further heated by heat exchanger E13 before entering furnace at design temperature of 215 °C. The preheated crude oil enters furnace at furnace inlet temperature (FIT). In a furnace, the heat source is provided by the burning fuel with air at theoretical flame temperature (TFT). The heat from the burning of fuel with air is transferred to the crude oil [12]. Then, the heated crude oil enters the crude distillation column at tower inlet temperature (TIT). The remaining heat in the furnace leaves through furnace stack at stack temperature (*T* stack).

2.2. Exergy analysis

Fig. 2 shows an exergy composite curve. The upper line is the hot composite curve and the lower line is the cold composite curve. The area under the hot composite curve is the amount of exergy source (ΔE_H) and the area under the cold composite curve is the amount of exergy sink (ΔE_C). Note that ΔE_H is partly covered by ΔE_c in Fig. 2. The gap between hot composite curve and cold composite curve is the exergy loss which is $\Delta Ex_{loss} = \Delta E_H - \Delta E_C$ [13].

The exergy source in a system is provided by hot process streams that transfer heat and is calculated as follows:

$$\Delta Ex_{source} = (H_{h2} - H_{h1}) - T_o(S_{h2} - S_{h1}) \quad (1)$$

On the other hand, the cold process stream that receives heat is the exergy sink:

$$\Delta Ex_{sink} = (H_{c2} - H_{c1}) - T_o(S_{c2} - S_{c1}) \quad (2)$$

Exergy is never conserved in real processes. Exergy will degrade and will be lost. Exergy loss reflects the irreversibility in the heat transfer process. Exergy loss can be calculated from an exergy balance as follows:

$$\Delta Ex_{loss} = \sum \Delta Ex_{sources} - \sum \Delta Ex_{sinks} = T_o(\Delta S_c - \Delta S_h) \quad (3)$$

where ΔS_c is change in entropy for cold streams and ΔS_h is change in entropy for hot streams.

2.3. Generation of possible fuel reduction strategies

Fig. 3 shows a typical exergy composite curve for furnace. *T* stack is located at the initial point of hot composite curve while TFT is located at the end point of hot composite curve. FIT is located at the initial point of cold composite curve while TIT is located at the end point of cold composite curve.

The fuel reduction strategies are generated from exergy composite curve analysis. As shown in Fig. 3, amount of exergy loss is represented by the gap between hot and cold composite curve. Thus, the idea to minimize exergy loss of the system is to obtain closer gap between hot and cold composite curve. The closer gap between hot and cold composite curve can be obtained by:

a) Reducing theoretical flame temperature (TFT)
b) Reducing stack temperature (*T* stack)
c) Increasing tower inlet temperature (TIT)
d) Increasing furnace inlet temperature (FIT)

These four options are the possible fuel reduction strategies for CDU. Two options are chosen to be implemented in this study which are reducing *T* stack and increasing FIT. The proposed options for fuel reduction strategies in this study are reduction of heat loss from furnace stack and overall cleaning schedule of CPT. The first

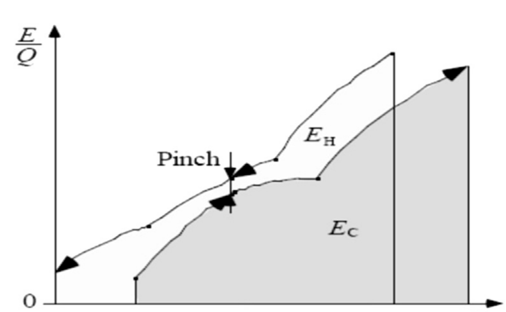

Fig. 2. Exergy composite curve.