Consider the Bigger Picture During Energy Audit to Maximise Energy Savings

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ABSTRACT

This article describes the significance of addressing energy management in the context of an overall process system, i.e. the "bigger picture" in order to maximise energy savings. Towards this end, it presents Pinch Technology as an effective solution to address the core of energy efficiency problems. Results from the application of Pinch Technology for the retrofit of a palm oil refinery have been highlighted to demonstrate how some simple graphical tools and rules of Pinch Technology can be translated into practical solutions to maximise energy savings.

Keywords: Composite Curves, Grand Composite Curves, Minimum Energy Targets, Pinch Technology, Retrofit

INTRODUCTION

Efforts to increase plant energy efficiency have intensified with the recent increase in fuel prices and the global concern on environmental emissions. As new processes and technologies emerge, existing processes are under pressure to increase efficiency and to maintain profitability in order to remain competitive. Many existing installations have focused on energy efficiency upgrading in order to increase profitability. Energy efficiency measures employed in the Malaysian industry, particularly by the small and medium size industrial sector (SMIs), are generally confined to measures such as the employment of good housekeeping techniques, demand side management, the upgrading of boilers, steam systems, chillers, hot oil circuit, power motors (e.g. compressors and pumps), refrigeration and cooling circuits. A key point to note is that these are primarily measures for improving a process' service facility, i.e. the utility system. Very few of the companies are willing to venture deep into process operations to further reduce energy consumption. As a result, benefits that can be derived from an energy audit exercise can be very limited. Measures for utilities are, undoubtedly, important short-term energy management options. However, utilities should not be the main focus, let alone the ultimate priority in energy management for two main reasons:

1. Utility system is merely part of an overall process. So, don't forget the bigger picture

A crucial point to remember is that energy management must consider the *"bigger picture"*. It is most vital that energy management be conducted in the context of an overall plant. Failure to do so could, at best, result in marginal energy savings, and, at worst, cause wasted capital expenditure. An example, by [4], describes a blunder in the integration of a co-generation system due to the fact that the integration did not consider the overall process system. Figure 1 shows the schematic of a typical process plant. Utility system is usually the smaller part of a general plant infrastructure even though it is one of the key components to take into account during energy audit. There is also the process (manufacturing section) as well as the waste treatment system to consider besides utilities. Note that utility and waste treatment sections are essentially a plant's service facilities.

Typically, the process, which may include equipment like reactors, separators, heat exchangers, compressors, turbo-expanders, kilns, furnaces and dryers, is the heart of a plant, and is therefore the most important section to consider. As in the case of utility system, there are energy contents, losses and inefficiencies associated with the input and output streams in the process section.

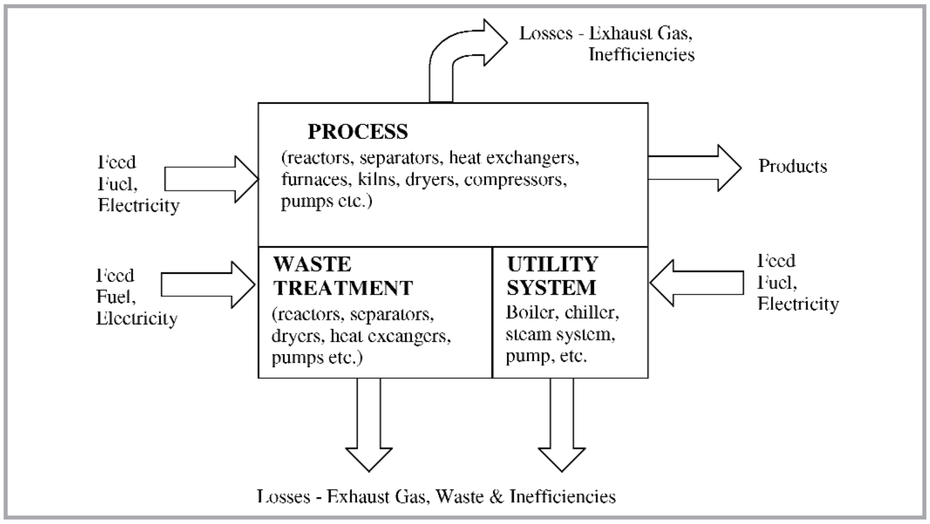

Figure 1: An overall process plant typically consists of process, waste treatment and utility system

2. Higher utility consumption and inefficient utility system are merely the symptoms, not the core of energy efficiency problem

It is important to recognise if an illness is a symptom of a more serious ailment so that the right remedy is given to cure the illness. For example, it is quite well known that migraine is the symptom of stress. Yet, many people still rely on pain relief and spend little effort to manage and eliminate stress. If nothing is done to relieve the core of the problem (stress), the symptom (migraine) tends to become more chronic, usually leaving the victim dependent on increased dosage of pain relief. The notion on symptom and core for an illness is a fitting analogy for effective process improvement including energy management.

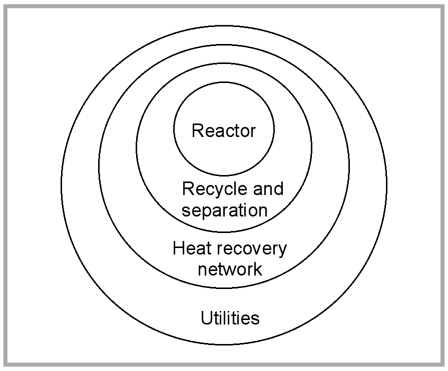

Figure 2: Onion model for process design and improvement (Foo and Manan, 2005)

The idea is best understood by referring to the onion model for process design and improvement shown in Figure 2 [1]. Creation of a process begins from the core of the onion (i.e. the reactor) outwards. Temperature, pressure and composition at the reactor affect the product distribution and, hence, the structure as well as the utility requirements for separation and recycle systems. Reactor, recycle and separator design influence the overall heat recovery potential. Finally, utility system is designed to supply the remaining heating and cooling needs for the reaction and separation systems that cannot be satisfied through process heat recovery. Note that the choice, the integrity and the efficiency of process design and structure at the inner layers are the key factors that dictate the utility needs of a process plant.

For example, a reaction route that requires extreme process conditions may need a high-pressure boiler that is prone to more losses compared to a competing route that requires mild operating conditions. A high-pressure distillation column may need high-pressure steam or thermal oil heating compared to the use of an extractor. On the other hand, poor heat recovery from the process will increase the demand for external utilities no matter how high the efficiency of a plant's boiler and steam system. Clearly, excessive utility requirements and inefficiencies at the outer layer are merely the symptoms of bigger problems at the core of the process. Putting more emphasis on improvement of utilities and less on the process is akin to relying on pain relief to cure migraine. In the light of the hierarchy for process design and improvement, utilities can be considered as the end-of-pipe solution to energy management. Addressing the core of the problems from the inner layers of the onion diagram during energy audit is expected to yield greater savings.

THE SOLUTION - ENERGY OPTIMISATION USING PINCH TECHNOLOGY

Well-established techniques are available to address energy efficiency problems from the core of process. Pinch Technology is one of the most effective analysis tools that have been used in developed countries since the early Eighties. Pinch Technology is a systematic procedure for the design and retrofit (improvement) of process systems for optimum energy and resource utilisation. Until the last decade, energy was the main focus of new developments in the area. Now, it has been used to optimise solvent, water as well as hydrogen utilisation networks [1, 2, 10].

Pinch application for process energy optimisation begins with the setting up of the minimum energy targets based on the thermodynamics of a process under study. The true minimum energy targets for a given section of a plant can be obtained from a plot of the enthalpy (energy) aggregate for the hot and cold streams of a process on a temperature vs. enthalpy diagram as shown in Figure 3. The pair of "composite curves" represents the overall process heat availability and requirement. The shaded region on the plot, where the hot and cold composites overlap, indicates the maximum possible heat recovery from the process streams. The overshoots of both the hot and the cold curves represent the minimum hot and cold utility requirements, or the energy targets for the process. The point of closest approach that occurs at the smallest temperature difference between the hot and cold composites is referred to as the *pinch* that represents the bottleneck for process heat recovery.

The pinch divides a process into two thermodynamically separate systems, each of which is in enthalpy balance with its relevant utility. It follows that the hot utility (e.g. steam heating) is the only required utility for the process above the pinch. On the other hand only the cold

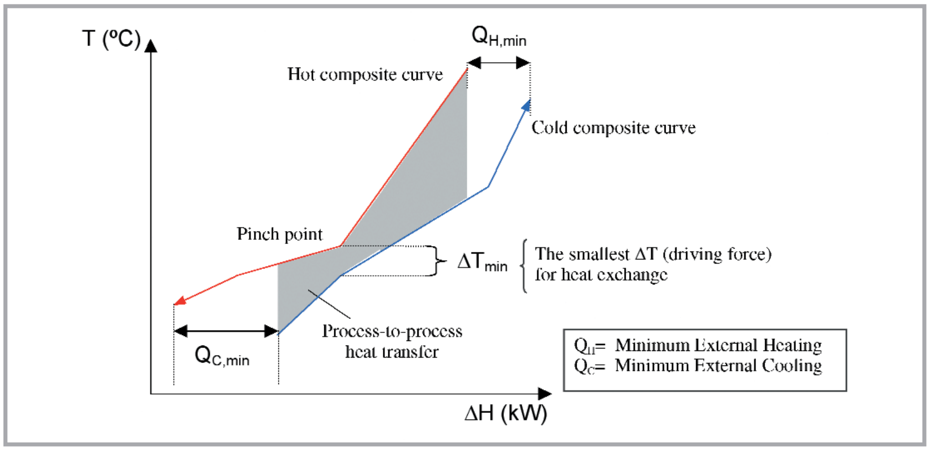

Figure 3. The composite curves represent the overall process heat availability and requirement and the energy targets

utility (e.g. cooling water) is required below the pinch. In order to avoid excess utility consumption, three fundamental rules must be observed during the design and retrofit of processes:

1. Keep the systems above and below the pinch independent from one another. Never allow heat to be transferred across the pinch.
2. Below the pinch, only cold utility is needed. Therefore, hot utility is irrelevant.
3. Above the pinch, only hot utility is needed. Therefore, cold utility is irrelevant.

The composite curves provide profound insights for the design and retrofit of thermodynamically efficient systems. They have proven useful in representing the overall process streams heat quality and quantity, and in generating the true minimum energy targets and in assessing process inefficiencies. With the notion of design targets made available through Pinch Analysis, a technologist would be less likely to settle for a marginal improvement and would strive to achieve the minimum target. He is also able to screen promising projects from marginal ones and assess if further improvement is worthwhile simply by comparing the performance gap between an existing design and the minimum energy targets obtained from the composite curves.

The power of Pinch Technology hinges on the fact that it was designed to address the bigger picture. Pinch analysis is beyond heat recovery. In any design or retrofit work, pinch could provide guidance for a designer from the core of the process all the way to the utility system through the use of some user-friendly graphical targeting tools such as the composite and grand composite curves (see Figures 3 and 4). At the core of the onion in Figure 2, the graphical visualisation tools allow a user to select the best reactor configuration to minimise utility needs for a given product specifications. For a design or retrofit project, a user could visualise how some small changes in reactor or separator pressure and temperature could affect the process energy requirement while the product composition and rate are maintained. Once the equipment conditions are fixed, the minimum utility requirements for the entire process can be computed using the composite curves. Thereafter, the heat recovery system would be designed to achieve the minimum energy targets. Utility system is designed to supply the remaining heating and cooling needs for the reaction and separation systems that cannot be satisfied through process heat recovery. The scope for integration between process and utility can be assessed for example when considering the installation of cogeneration system [7, 11]. All the analysis work can now be rapidly and efficiently done with the aid of Pinch Analysis software such as Heat-MATRIX [9].

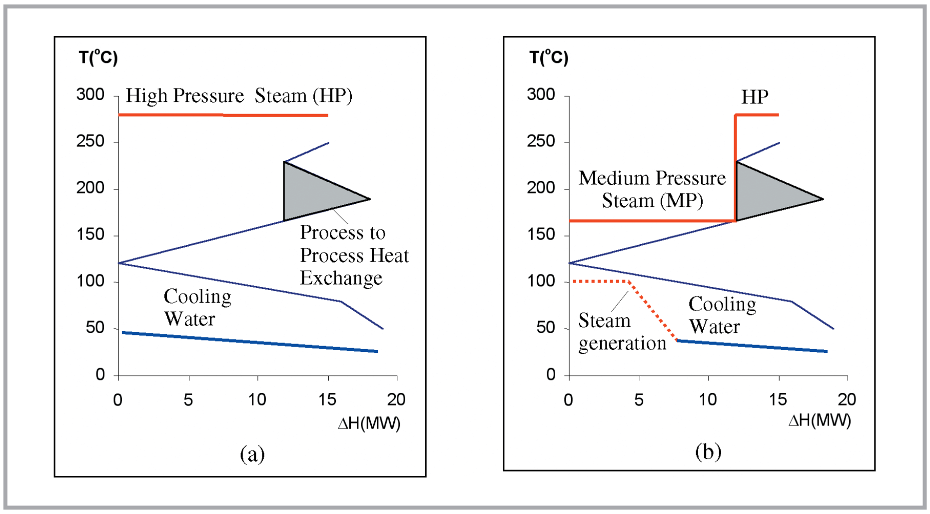

Figure 4: The grand composite curve provides an interface for the optimum selection of multiple utility levels (a) one hot and one cold utility scenario (b) multiple utilities

USING PINCH RULES TO IDENTIFY HEAT LOSSES – APPLICATION TO A PALM OIL REFINERY [8]

It can be said that one of the most important activities in Heat Exchanger Network (HEN) synthesis is retrofit as opposed to grassroots design. This is due to the fact that most process plants will undergo at least one major revamp in their plant lifetime to take advantage of process technology to improve energy efficiency or to increase the plant's throughput. For an existing plant, three common types of heat recovery network inefficiencies may occur in existing plants. The inefficiencies may be due to three types of key faults in process flow design:

1. Hot utility supplied at the cold end (lower temperature part) of a process (heating below the pinch).
2. Cold utility supplied at the hot end (higher temperature part) of a process (cooling above the pinch).
3. Heat exchange mismatch between process streams ("cross-pinch" heat transfer).

Figures 5 (a) and (b) represent a section of a palm oil refinery being retrofitted. Figure 5(a) shows that the refined, bleached and deodorised palm oil (RBDPO) at 160ºC and steam heater (H1) is used to heat the crude palm oil feed (CPO) at the cold end of the process. Another steam heater (H2) is used to heat the degassed oil from 104ºC to 124ºC. A careful observation of the stream conditions reveals that all three types of inefficiencies mentioned above exist in the refinery. First, there is a heat exchange mismatch between RBDPO and CPO streams. This occurs due to the use of high-temperature RBDPO to heat CPO feed which is one of the streams with the lowest temperature in the process. This heat exchange match prematurely brings down the temperature of RBDPO to 95ºC thereby degrading the potential for RBDPO to supply heat to streams at temperatures higher than 95ºC, for example, to the degassed oil. The mismatch ultimately results in loss of the bulk of available heat in RBDPO and the need for heater H1 to raise CPO feed temperature to 97ºC. The mismatch is a

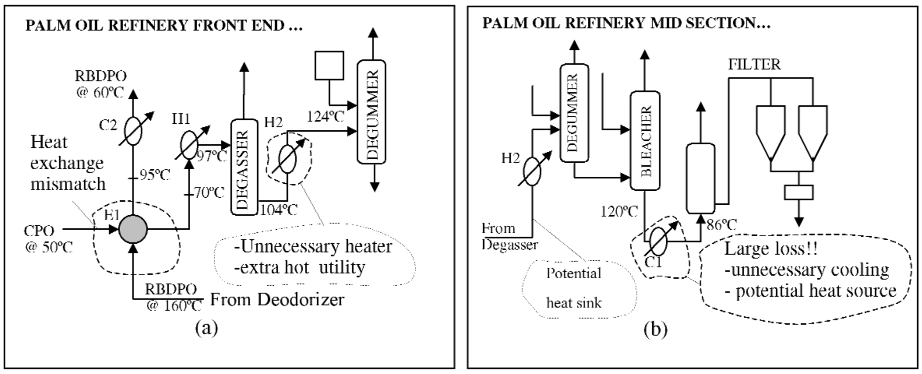

Figure 5: (a) Heating below the pinch & cross-pinch heat transfer (b) Cooling above the pinch.

manifestation of cross-pinch heat transfer (type-3 fault). On the other hand, H1 amounts to heating below the pinch (type-1 fault). Retrofit by re-routing RBDPO to enable heat exchange between RBDPO and the degasser exit stream prior to using RBDPO for CPO feed preheating would save the heat duty not only for heater H2 but also for H1. This has been made possible simply through better process flow design, i.e., proper matching among process streams.

Figure 5(b) shows heat being rejected from an apparently valuable heat source, i.e. the bleacher exit at 120°C, directly to cooling water via cooler C1. The exchange is a manifestation of type-2 fault-cooling above the pinch. This fault degrades the potential for the bleacher exit to supply heat to other process streams. The fault results in a loss of valuable heat source and in unnecessary use of cooling water. Note that the three types of faults cost the plant dearly in terms of fuel, water bills and extra gaseous emissions due to inefficient fuel consumption. Detailed heat exchanger network retrofit performed by [6] has shown that a maximum savings of 66% steam and 48% cooling water are possible with a projected payback period on investment of less than five months. Pinch retrofit procedures [5,7] enable the cross-pinch matches to be detected and corrected to eliminate extra utility consumption and hence, reduced emissions.

CONCLUSION

Clearly, Pinch Technology offers a solution not only by addressing the bigger picture, but also by dealing with the core of energy efficiency problems. As such, the difference between Pinch Technology and other approaches is fundamental. It is therefore not surprising that significant reductions in terms of energy usage as well as effluent discharge have been reported. The experiences of multi-national petrochemical corporations like Shell, Exxon, BP, Dow, Mitsubishi, JGC and Union Carbide in Europe, USA and Japan have shown that Pinch Analysis has led to energy savings in the range of 15-90%, and capital savings of up to 30% [3]. Examples from relatively recent developments in the application of water pinch analysis have led to water savings of between 15-25% from simple piping and control changes. Improvements related to process modifications and selective wastewater regeneration savings are greater, often exceeding 50% [4]. ■

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