CHAPTER II
BACKGROUND AND LITERATURE SURVEY

2.1 Pinch Technology

Pinch technology has been developed for two decades as a systematic methodology for analysis of chemical process and the surrounding utility systems. The prime objective of pinch analysis is to achieve financial savings by process heat integration (maximizing process-to-process heat recovery and reducing the external utility loads).

The concept was first developed by two independent research groups (Flower and Linnhoff, 1978 and Umeda *et al.*, 1979), based on the applied thermodynamics concepts. The term 'Pinch Analysis' is often used to represent the application of the tools and algorithms of Pinch Technology for studying industrial process. Developments of rigorous software programs have proved to be very useful in pinch analysis of complex industrial process with speed and efficiency.

Pinch technology analyzes chemical processes and the surrounding utility systems with the help of the first and second laws of Thermodynamics. The hot stream can be cooled to a temperature difference defined by the 'temperature approach' of the heat exchanger which is the minimum allowable temperature difference (ΔTmin) in the stream temperature profiles, for the heat exchanger unit. The temperature level at which ΔTmin is observed in the process is referred to as "pinch point" or "pinch condition". The pinch defines the minimum driving force allowed in the exchanger unit.

2.2 Step in Pinch Analysis for Heat Exchanger Network (HEN) Design

In any Pinch Analysis problem, whether a new project or a retrofit situation, a well-defined stepwise procedure is followed. It should be noted that these steps are not necessarily performed on a once-through basis, independent of one another. Additional activities such as re-simulation and data modifications occur as the analysis proceeds and some iteration between the various steps is always required, as shown in Figure 2.1.

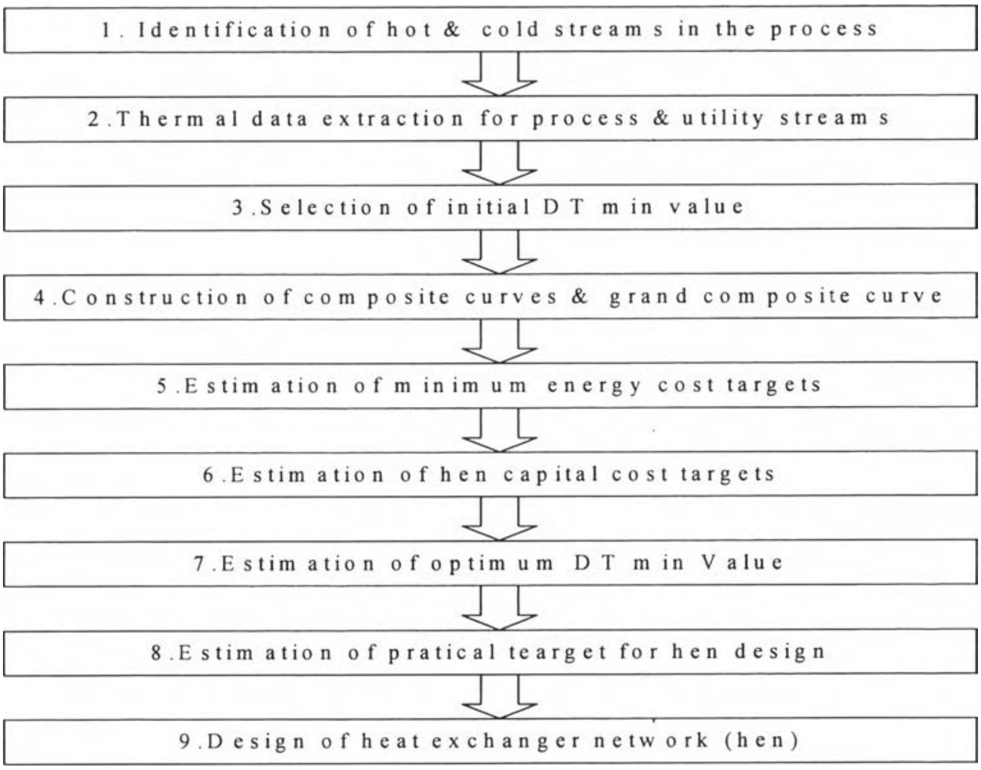


Figure 2.1 Steps of Pinch Analysis (Linnhoff and Hindmarsh, 1983).

2.2.1 Identification of the Hot, Cold and Utility Streams in the Process

Hot Streams are those that must be cooled or available to be cooled. e.g. product cooling before storage. Cold Streams are those that must be heated e.g. feed preheat before a reactor. Utility Streams are used to heat (hot utilities) or cool (cold utilities) process streams, when heat exchange between process streams is not practical or economic. The identification of streams needs to be done with care as sometimes, despite undergoing change in temperature, the stream is not available for heat exchange such as the stream that temperature rises because of the conversion of mechanical energy into heat.

2.2.2 Thermal Data Extraction for Process & Utility Streams

Hot streams are referred to streams that required cooling i.e. the supply temperature (TS) is higher than the target temperature (TT). The cold streams are referred to those required heating, i.e. the target temperature is higher than the supply temperature. Therefore, in thermodynamic law, it must have heat exchanging between hot and cold streams.

Supply temperature (TS, °C) : the temperature at which the stream is available.
Target temperature (TT, °C) : the temperature the stream must be taken to.
Heat capacity flow rate (CP, kW/°C) : the product of flow rate (m) in kg/sec and specific heat ($\hat{C}_p$, kJ/kg °C).

$$CP = \dot{m} \times \hat{C}p \quad (2.1)$$

Enthalpy Change (ΔH) associated with a stream passing through the exchanger is given by the First Law of Thermodynamics without mechanical work:

$$\text{Enthalpy change, } \Delta H = CP \times (TS - TT) \quad (2.2)$$

** Here the specific heat values have been assumed to be temperature independent within the operating range.

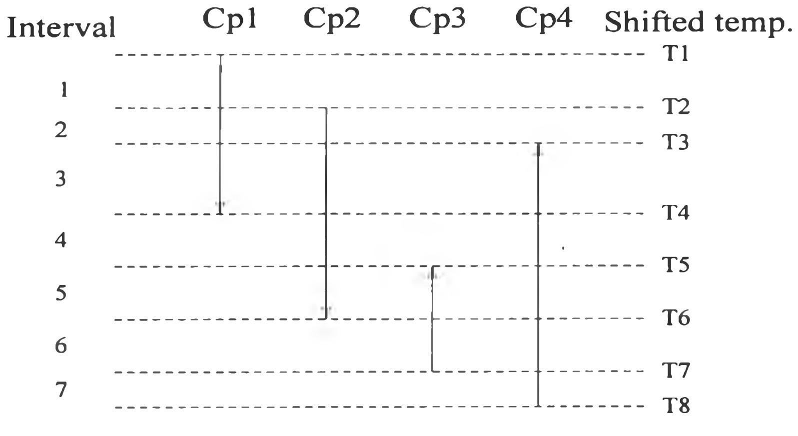


Figure 2.2 Set up intervals.

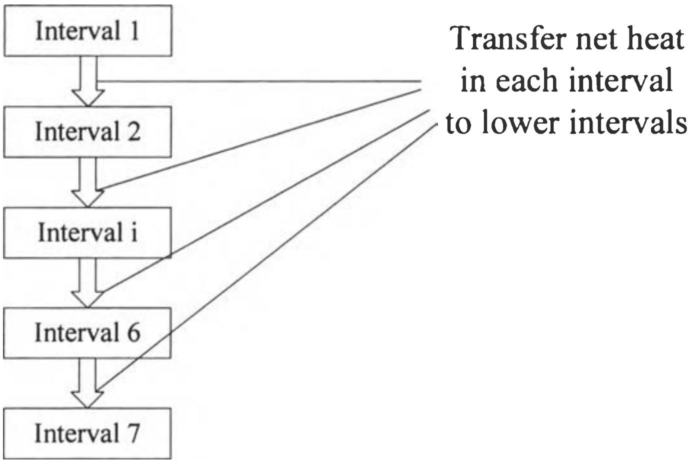


Figure 2.3 Cascade heat surpluses (Linnhoff and Hindmarsh, 1983).

Figures 2.2 and 2.3 show how to consider heat exchanging when performing pinch analysis. It must be settled in intervals first and then go to find heat which transfers from one interval to other interval.

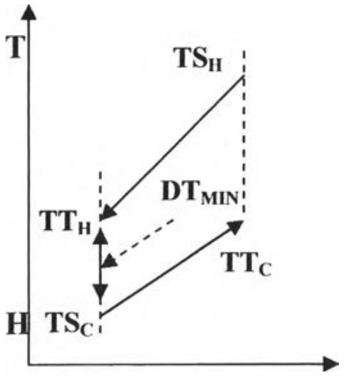
The stream data and their potential effect on the conclusions of pinch analysis should be considered during all steps of the analysis. Any erroneous or incorrect data can lead to false conclusion. In order to avoid mistakes, the data extraction is based on certain qualified principles.

2.2.3 Selection of Initial ΔT_{min} Value

The temperature of the hot and cold streams at any point in the exchanger must always have a minimum temperature difference (ΔT_{min}). This ΔT_{min} value represents the bottleneck in the heat recovery. Thus, at any point in the exchanger

Hot stream Temp. (T_H) – (T_C) Cold stream Temp. $\geq$ ΔTmin

The value of ΔT_{min} is determined by the overall heat transfer coefficient (U) and the geometry of the heat exchanger. In network design, the type of the heat exchanger will determine the practical ΔTmin for the network, for example, an initial selection for shell and tubes may be 3-5 °C. The heat transfer equation, which relates Q, U, A and ΔT_{LM} (Log Mean temperature Difference) is depicted in Figure 2.4.



$$\boxed{\text{LMTD} = \frac{(TS_H - TT_C) - (TT_H - TS_C)}{\ln[(TS_H - TT_C)/(TT_H - TS_C)]}}$$

$$\boxed{Q = U \times A \times \Delta T_{LM}}$$

Figure 2.4 Heat transfer equation.

For a given value of heat transfer load (Q), if smaller values of ΔTmin are chosen, the area requirements increase which make the heat recovery in exchanger increases and demand of external utilities decreases. Thus, the selection of ΔTmin value has implications for both capital and energy costs.

2.2.4 Construction of Composite Curves and Grand Composite Curves

COMPOSITE CURVES: Temperature – Enthalpy (T-H) plots have been used for many years to set energy targets ahead of design. They consist of temperature (T)-enthalpy (H) profiles of heat availability in the process (the hot composite curve) and heat demands in the process (the cold composite curve) together in the graphical representation. In general any stream with a constant heat capacity (CP) value is represented on a T - H diagram by a straight line running from stream supply temperature to stream target temperature. When there are a number of hot and cold streams, the construction of hot and cold composite curves simply involves the addition of the enthalpy changes of the streams in the respective temperature intervals. An example of hot composite curve construction is shown in Figures 2.5(a) and 2.5(b).

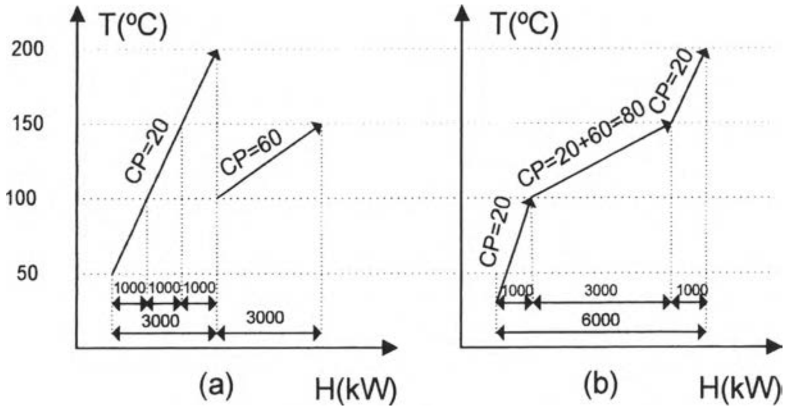


Figure 2.5 Temperature-enthalpy relations used to construct composite curves (Linnhoff, 1982).

For heat exchange to the hot stream cooling curve must lie above the cold stream-heating curve. Because of the kinked nature of the composite curves (Figure 2.6), they approach each other most closely at one point defined as the minimum approach temperature (ΔT_{min}). This point of minimum temperature difference represents a bottleneck in heat recovery and is commonly referred to as the Pinch. At a particular ΔTmin value, the overlap shows the maximum possible scope for heat recovery within the process. The hot end and cold end overshoots indicate minimum hot utility requirement (Q_{Hmin}) and minimum cold utility requirement (Q_{Cmin}), of the process for the chosen ΔT_{min}.

To summarize, the composite curves provide overall energy targets but do not clearly indicate how much energy must be supplied by different utility levels. The utility mix is determined by the Grand Composite Curve.

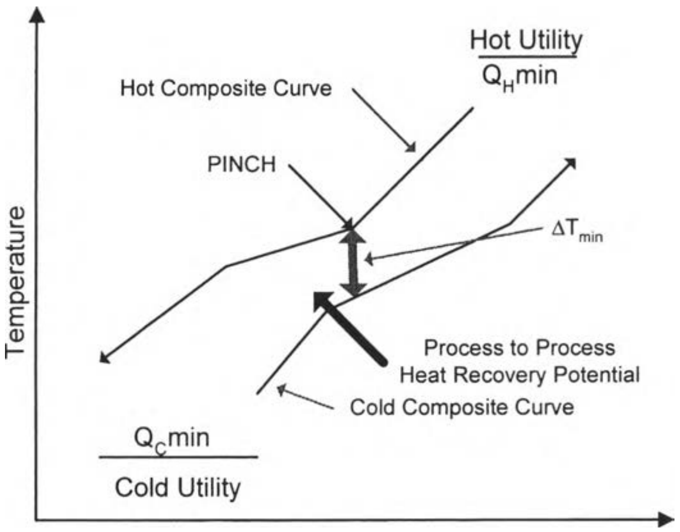


Figure 2.6 Combined Composite Curves.

GRAND COMPOSITE CURVE (GCC) : The introduction of a new tool, the Grand Composite Curve (GCC), was introduced in 1982 by Itoh, Shiroko and Umeda. The GCC (Figure 2.7) shows the variation of heat supply and demand within the process. Using this diagram the designer can find which utilities are used. The designer aims to maximize the use of the cheaper utility levels and minimize the use of the expensive utility levels.

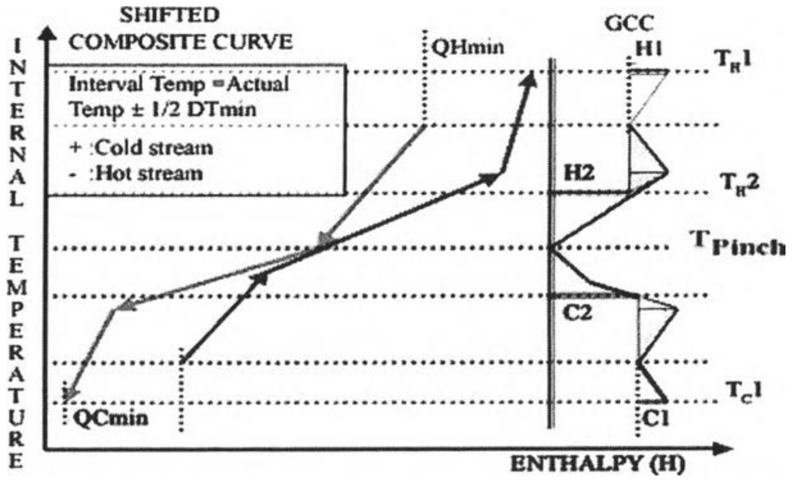


Figure 2.7 Grand Composite Curve.

The method involves shifting (along the temperature [Y] axis) of the hot composite curve down by ½ ΔT_{min} and that of cold composite curve up by ½ ΔT_{min}. The Grand Composite Curve is then constructed from the enthalpy (horizontal) differences between the shifted composite curves at different temperatures. On the GCC, the horizontal distance separating the curve from the vertical axis at the top of the temperature scale shows the overall hot utility consumption of the process.

Figure 2.7 shows that it is not necessary to supply the hot utility at the top temperature level. The GCC indicates that we can supply the hot utility over two temperature levels T_H1 (HP steam) and T_H2 (LP steam). Recall that, when placing utilities in the GCC, intervals, and not actual utility temperatures, should be used. The total minimum hot utility requirement remains the same: Q_{Hmin} = H1 (HP steam) + H2 (LP steam). The points T_H2 and T_C2 where the H2 and C2 levels touch the grand composite curve are called the "Utility Pinches." The shaded pockets represent the process-to-process heat exchange.

2.2.5 Estimation of Minimum Energy Cost Targets

From the minimum requirements of composite curves and the utility levels selected from GCC, the total energy cost can be calculated if the unit cost of each utility is known by using the energy equation given below.(Linnhoff and Polley, 1988)

$$\text{Total energy cost} \quad = \quad \sum_{U=1}^{U} Q_U * C_U \qquad (2.3)$$

Where Q_U = Duty of utility U ,kw

C_U = Unit cost of utility U ,$kw,yr

U = Total number of utilities used

2.2.6 Estimation of Heat Exchanger Network (HEN) Capital Cost Targets

The capital cost of a heat exchanger network is dependent upon:

- the number of exchangers
- the overall network area,
- the distribution of area between the exchangers

- **AREA TARGETING** A Composite curve can tell how much area will be necessarily used. Minimum area requirement can be achieved by vertical heat transfer between hot and cold composites.

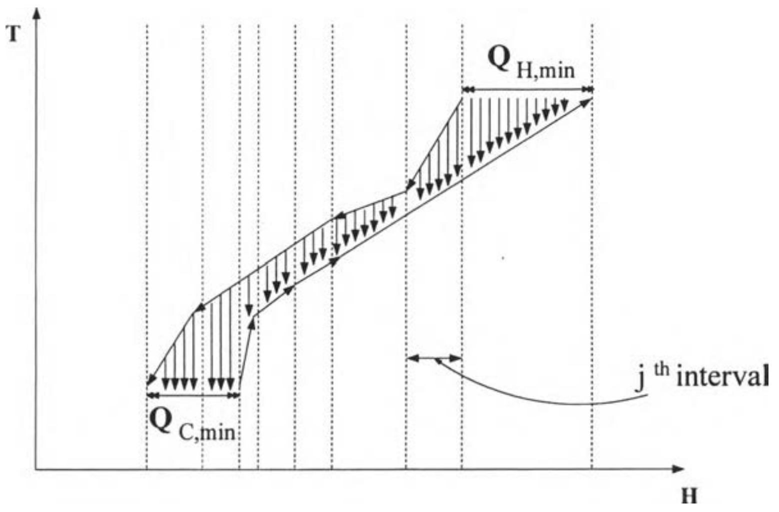


Figure 2.8 General expression for network area target.

$$\text{Area interval} = \sum_{j}^{\text{interval}}(1/\Delta T_{lm}) * \sum_{i}^{\text{stream}}(Qi/hi) \qquad (2.4)$$

This equation gives the minimum area required for heat recovery network if heat transfer coefficients of all streams are uniform. But it is still acceptable if heat transfer coefficients are not much different with one another. However if there are large differences in heat transfer coefficients, criss-cross matching may give better area prediction than vertical heat transfer.

To the calculation easier, it should be divided into intervals. The area of each interval should be determined and then summed up to get heat exchange area as shown in Figure 2.8. Since the hot and cold composite curves do not have change in slope, the heat exchange is assumed to be vertical (pure counter-current heat exchange). The hot stream in any enthalpy interval, at any point, exchanges heat with cold stream at the temperature vertically below it. The actual HEN total area required is generally within 10% of the area target as calculated above. With inclusion of temperature correction factors area targeting can be extended to non counter-current heat exchange as well.

- **NUMBER OF UNITS TARGETING**: In designing for the minimum energy requirement (MER), no heat transfer is allowed across the pinch. Thus, a realistic target for the minimum number of units (NminMER) is the sum of the targets evaluated both above and below the pinch separately. (Linnhoff and Polley, 1988)

$$N_{minMER} = [N_h + N_c + N_u - 1]_{AP} + [N_h + N_c + N_u - 1]_{BP} \qquad (2.5)$$

Where Nh = Numbers of hot streams

Nc = Number of cold streams

Nu = Number of utility streams

AP = Above Pinch

BP = Below Pinch

- **HEN TOTAL CAPITAL COST TARGETING**

Capital cost of single exchanger (Linnhoff and Polley, 1988)

$$\text{Cost} = A + B(\text{Area})^{C} \qquad (2.6)$$

Where A = Installation cost

B = Materials cost

C = Scale factor

Capital cost target of a network;

$$\text{Cost}_{network} = N_{min}(A + B(A_{target}/N_{min})^{C}) \qquad (2.7)$$

Annualised capital cost

Since capital cost is not defined per year so it needs to be annualized as follows. (Linnhoff and Polley, 1988)

Energy cost : $/annum

Capital cost : $

To combine these costs,capital cost needs to be 'annualized'

Annualized capital cost = (C.A.F.) × (Capital cost) (2.8)

Where C.A.F. = Capital annualized factor

$$\text{C.A.F.} = (I(I+1)^{n}) / (I+1)^{n-1}) \qquad (2.9)$$

Where I = Interest rate per annum

n = Plant life(year)

2.2.7 Estimation of Optimum ΔT_{min} Value by Energy-Capital Trade off

To arrive at an optimum ΔT_{min} value, the total annual cost is plotted at varying ΔTmin values. Three key observations can be made from Figure 2.9:

a. An increase in ΔT_{min} value results in higher energy cost and lower capital costs.

b. A decrease in ΔT_{min} value results in lower energy cost and higher capital costs.

c. An optimum ΔT_{min} exists where sum of total annual cost of energy and capital cost is minimized.

Thus, by systematically varying the temperature approach we can determine the optimum heat recovery level or the $\Delta T_{min,OPTIMUM}$ for the process.

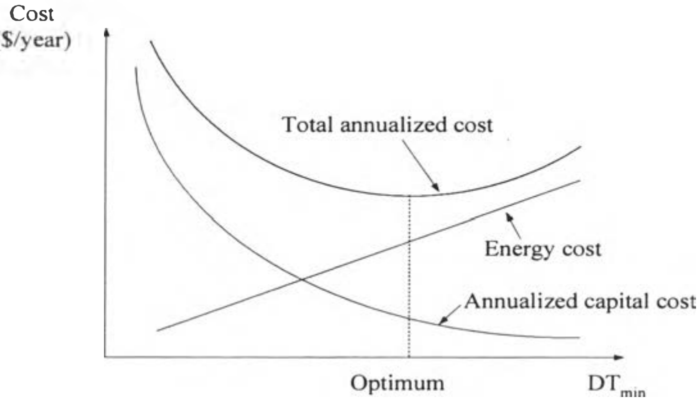


Figure 2.9 Energy-capital cost trade off (Optimum ΔT_{min}).

2.2.8 Estimation of Practical Targets for HEN Design

The heat exchanger network designed on the basis of the estimated optimum ΔT_{min} value is not always the most appropriate design. A very small ΔT_{min} value, perhaps 8 ^{0}C, can lead to a very complicated network design with a large total area due to low driving forces. The designer, in practice, selects a higher value (15 ^{0}C) and calculates the marginal increases in utility duties and area requirements. If the marginal cost increase is small, the higher value of ΔT_{min} is selected as the practical pinch point for the HEN design.

Recognizing the significance of the pinch temperature allows energy targets to be realized by design of appropriate heat recovery network. The pinch divides the process into two separate systems each of which is in enthalpy balance with the utility. The pinch point is unique for each process. Above the pinch, only the hot utility is required. Below the pinch, only the cold utility is required, hence, for an optimum design, no heat should be transferred across the pinch. This is known as the key concept in pinch technology.

To summarize, Pinch technology gives three rules that form the basis for practical network design.

- No external heating below the pinch
- No external cooling above the pinch
- No heat transfers across the pinch

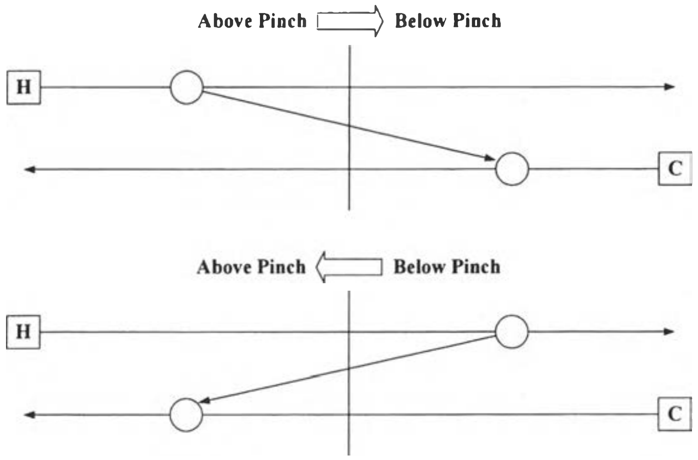


Figure 2.10 Cross pinch on grid diagram.

Violation of any of the above rules results in higher energy requirements above the minimum requirements.

2.2.9 Design of Heat Exchanger Network

Using the Pinch Design Method (PDM) the design of network examines which hot streams can be matched to cold streams via heat recovery. This can be achieved by employing tick off heuristics to identify the heat loads on the pinch exchanger. Every match brings one stream to its target temperature. As the pinch divides the heat exchange system into two thermally independent regions, HENs for both above and below pinch regions are designed separately. When the heat recovery is maximized the remaining thermal needs must be supplied by hot utility. The graphical method of representing flow streams and heat recovery matches is called a grid diagram (Figure 2.11). The design of a network is based on certain guidelines like the CP inequality rule, stream splitting, driving force plot and remaining problem analysis.

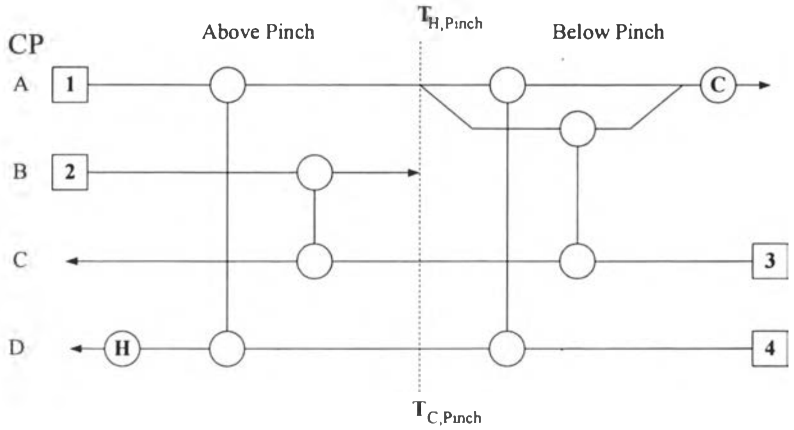


Figure 2.11 Grid diagram (Linnhoff and Hindmarsh, 1983).

Having made all the possible matches, the two designs above and below the pinch are then brought together and usually refined to further minimize the capital cost. After the network has been designed according to the pinch rules, it can be further subjected to energy optimization. Optimizing the network involves both topological and parametric changes of the initial design in order to minimize the total cost.

2.3 Retrofitting by Pinch Technology

Energy saving retrofit project differs from those involving the design of new plants into two important aspects. First, with grass-root project it is possible to obtain a reasonably accurate prediction of the relationship between capital expenditure and heat recovery without undertaking any design work. In the retrofit, the opportunities cannot be identified without undertaking some design calculations. Thus, in retrofit project, the aim of applying economic analysis to the basic stream data is the identification of energy saving opportunities. Evaluation of these opportunities involves combination of design calculation and economic analysis.

Second, the economic analysis applied in retrofit differs from that used in grass-root projects. In the case of grass-root project the economics is evaluated in terms of capital cost and return on investment. With retrofits the economics are usually evaluated in terms of payback time and capital investment.

2.3.1 Identification of energy saving opportunities

The algorithm for the pinch technology described above can be used to determine the energy consumption and the network area as a function of ΔT_{min} as shown in Figure 2.12.

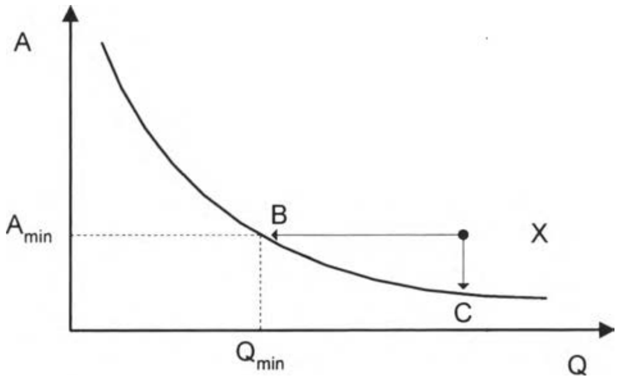


Figure 2.12 Ideal relationships between area-energy. (Tjoe and Linnhoff, 1986).

The existing system, positioned at point X, is found to make quite poor use of the installed heat recovery area. Given the quantity of heat consumed the surface area given by point C is required. With the quantity of surface actually installed, the system could be operated with a quantity of energy associated with point B.

In practice, the investment is required for changing the existing network, thus increasing area. Therefore, the retrofit path is the most important in the identification of saving opportunity. Many approaches have been proposed, the assumption that is used for setting retrofit path is to follow the path parallel to the ideal area/energy relationship. This path can be translated into saving/investment plot as shown in Figure 2.13.

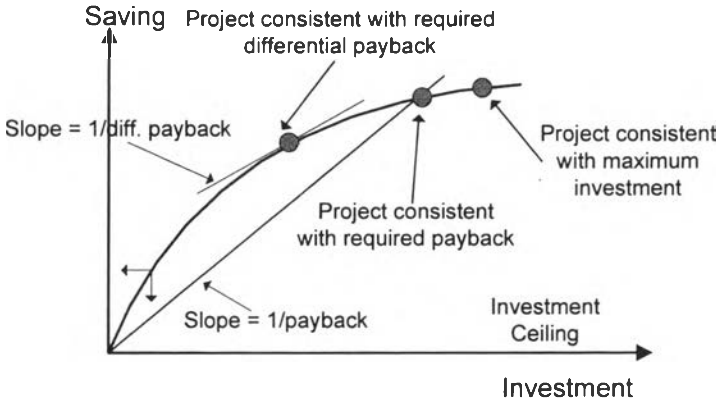


Figure 2.13 Saving-Investment relationships. (Tjoe and Linnhoff, 1986).

When one of the economic criterions, for example, capital expenditure or payback time, is specified the saving opportunity can be obtained directly from the plot. Also, the minimum temperature difference for the retrofit design will be indirectly obtained. Now, the value of saving opportunity and the minimum temperature difference of the project are obtained. Next step is to make change to the existing network to achieve the opportunity.

2.3.2 Retrofit Design

After minimum temperature difference is obtained. The grid diagram for the existing network will be redrawn with the new value of ΔT_{min}. The idea of the retrofit design is to identify the cross-pinch heat exchangers then modify them to minimize the cross-pinch heat transfer.

The steps in retrofit design are as follows:

1) Identify cross-pinch heat exchangers
2) Eliminate cross-pinch heat exchangers from the network.
3) Complete the network by positioning new exchangers using PDM and, where possible, reuse exchangers removed in Step 2.

Evolve improvement by improving compatibility with existing network via heat load loops and paths. Reuse area of existing exchangers as much as possible.

2.4 Literature Survey

2.4.1 Applications of Pinch Technology

Pinch technology (PT) had become more important way for engineers to optimize chemical processes (Stankiewicz, 1993). By allowing engineers to track the heat or pressure flow of all process streams, PT made it easier to integrate plant design. Rearranging equipment, such as reactor evaporators, pumps, distillation columns, and separators, can make unit operations more efficient energy consumption such as heat exchanger networks. It is available to automate the redesign process and PT is set to move beyond energy, into pressure drop optimization and distillation columns sequencing.

Furthermore, the pinch concept is also used to optimize a licensor's design for complex processes with many utilities and unit operations (Trivedi *et al.*, 1996). The procedure included a method to set the marginal cost for various utility levels. It also illustrated how to use composite and grand composite curves to set the level and load of various. In addition, the method optimizes distillation column using the concepts of column grand composite curves.

In addition to the use of PT as a design tool, it can be combined with exergy analysis to develop a method for process modification (Feng and Zhu, 1997). The graphical representation of pinch analysis combines with the power to identify the cause of thermodynamic imperfection was used to represent the whole system. Omega-H diagram was proposed, energy and exergy balance can be represented in this diagram which helps the process analyst to view the performance and set the target for improvement and modification can be located by viewing the imperfection of the existing process. The same idea was also applied to heat exchanger network analysis (Sorin and Paris, 1997). Heat exchanger network was treated as a single unit operation which simplifies the graphical representation of exergy and reduces the computational efforts.

The major area in which the pinch analysis is applied (Hallae, 2001) is Process integration (PI). PI is not only the pinch analysis and energy integration by it had been extended its uses to various applications. The four major areas of PI are 1) efficient use of raw materials 2) energy efficiency 3)emission reduction and 4) process operations. Many applications of pinch technology were discussed, they are used in hydrogen management, total site analysis and integration, heat exchanger networks design and retrofit, column analysis and integration and water management. All of these applications start from generating composite curve, locating pinch point, setting targets and then designing or modifying to achieve the targets.

2.4.2 The Pinch Design Method for New Heat Exchanger Network Design

In pinch analysis, after the designers have set the target for the problem, the next step they have to do is to design a network topology that satisfied the setting target. The first design methodology is called "The pinch design method (PDM)" (Linnhoff and Hindmarsh,1983). The synthesis starts at the pinch and moving away to the remaining parts. The design at the pinch is employed by stream splitting to satisfy pinch principles and the feasibility criteria. The procedure is sped up by tick-off heuristic but this can penalize the energy usage. In the final step, the design topology is trade-off between energy and capital cost by using heat load loop and heat load path.

A simple methodology for the design of near optimum heat exchanger networks with energy-capital trade-off consideration was presented by Linnhoff and Ahmad (1990a). The approach is based on setting cost targets, optimizing these targets prior to the design by using simple capital cost model which gives the results within 5 percent of the optimum solution. The detailed capital cost models, which consider the different in heat transfer coefficient, non-linear heat exchanger cost law, non-counter current exchanger, non-uniform material of construction, pressure rating and exchanger type in the network, gives the more accurate results (Ahmad, Linnhoff and Smith, 1990b).

To make a design economically, most of designers are trying to optimize the use of intermediate utilities. In this situation, the utility pinches are created in the network problems. The PDM describe above is suited for just only one pinch point in the problem. Therefore, the multiple pinches design method was proposed.

Jezowski (1992) reviewed a pinch design method (PDM) for multiple pinches problems. The design is started by defining the inverse pinch point. This point will separate a region between pinches into two sub-regions. The PDM proposed by Linnhoff and Hindmarsh (1983) was used for designing with some guidance. The design is started from both pinches simultaneously. The solutions obtained feature the maximum energy recovery and minimum number of units.

Almost two decades of development, the analysis of the PDM problems was seen by many research groups. Polley and Heggs (1999) showed the problems of the pinch design method (PDM). Firstly, the designs obtained can be non-optimal designs. Secondly, the nature of process streams is not accounted. Thirdly, it does not consider the impact of network on plant piping and process flow. Finally, the software involved usually complicated and they can not give an optimal design. A problem decomposition analysis is used for the design instead of PDM. The design obtained is a network in local which is easily to operate and low cost. The procedure is started from problem simplification, identified the process changes, setting the final problem, decomposition analysis based on flow-sheet and decomposition on a thermal basis.

2.4.3 The Pinch Design Method for Heat Exchanger Network Retrofit

The above discussion is made only to the grass-root design. In practice, there are many petrochemical plants that have been invested for the exchangers. The discussion above is not appropriate for this case, since many of invested heat exchangers have to be eliminated to achieve the energy target. The approach has been developed about the same period as for the grass-root one. The development of method for retrofitting plants based on pinch analysis is discussed below.

Tjoe and Linnhoff (1986) presented a method that used pinch design method for process retrofits. The assumption in this method is a good retrofit will make the process similar to optimum grass-root design. The first step is to set the target by using area-energy curve. The design was done by assuming that the new area will have the same efficiency as the existing one. The minimum temperature and energy savings are set under a specified payback time or investment. The retrofit is to identify the cross-pinch exchangers and modify them. The method was also applied for ethylene plant retrofit (Linnhoff and Witherell, 1986)

The parameter concerning with the cost of matching was considered in a new approach for heat exchanger network retrofit (Carlsson, Franck and Berntsson, 1993). The criss-cross matching was believed to give a lower cost solution comparing to the vertical matching. In this approach, the cost of match includes the effect of other parameters. The match cost matrices was proposed. The matrices show the type of matching, cost of matching. The designers will select the match and the new matrices will be calculated for the remaining part. The networks cost is the sum of these chosen matches.

Polley and Amidpour (2000) showed the procedure for retrofitting industrial heat exchanger networks. They indicated that the capital investment and payback time are the important economic indicators for process retrofit. The saving-investment plot was used to determine the retrofit target. The retrofit analysis was started by comparing the performance of the existing unit with the ideal relationship via area efficiency. The analysis is based on assumption that any new area has at least the same efficiency as the existing one. In conventional method, the cross-pinch exchangers were identified and then modified them. They also indicated the disadvantages of the existing method. At the same time, they proposed the new procedure by identifying the structure of the revamped units in the first stage and then energy-investment trading-off will be done to size and modify the exchangers.

2.4.4 Process Heat Integration

A process heat integration is concerned about the integration of heat engines, heat pumps, distillation columns with the background processes to achieve as high as benefits over stand alone one. A criterion for placement of heat engines and heat pumps in process networks was first presented by Townsend and Linnhoff (1983a). The criterion proposed is based on the process network pinch. The appropriate placement is the placement at which we can get advantages over the stand alone engines or pumps. For the heat engines, they showed that an appropriate placement is to place them at either above or below pinch but not across process pinch. The situation for heat pumps is opposite. The appropriate placement in this case is to place them across the pinch. They also showed that to get the 100 percent efficiency using the real engines, we have to use a large number of engines connected in series. In addition, they discussed that in practical, we can never achieve a fully appropriate integration due to the heat has to cross the pinch to the ambient. With this development, an application to distillation column was developed in a next few months.

Townsend and Linnhoff (1983b) applied the used of the criterions proposed above for selection the best practical technology for any design systems. The process source/sink profile was introduced in this procedure. The procedure is based on the pinch analysis. This method can always form a point of reference and take account of practical design constraints. The procedure can be used to evaluate options at the preliminary design stage and to identify the preferred configuration for chemical and other processes involving integrated heat recovery and power generation. The procedure represents a breakthrough in the general area of process synthesis that takes into account the fundamental importance of the heat recovery pinch.

As mentioned before, the heat engine placement was lead to the development of a criterion to place distillation columns into process streams. The discussion was first given by Linnhoff, Dunford and Smith (1983). They discussed about the placement of columns and got the interesting conclusions. First, if the good integration between columns and process is achieved, the columns can be run with free of utility charges. Second, they found that the conventional column integration methods, e.g., multiple effect columns, can prevent the good integration. They showed that the good integration is obtained by placing column in one side of pinch, i.e. not go across the pinch and either the re-boiler or condenser being integrated with the process. If these criteria can be met, energy cost of distillation column can effectively be zero.

The development of an approach for shaft-work targeting directly from process data using pinch analysis (PA) was important in designing low-temperature process (Linnhoff and Dhole, 1992). The approach bypasses the design of both heat exchanger network (HEN) and refrigeration system. The combination of PA and exergy concepts was used in developing the method. Comparison with the existing method, in which shaft-work is determined from the refrigeration load, the proposed approach is simpler. It provides a strong tool for understanding and assisting the designer to find the best HEN and refrigeration system simultaneously.