CHE526: PINCH TECHNOLOGY

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Objectives of Pinch Analysis

- The temperature level at which ΔT_{min} 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.
- Pinch Analysis is used to identify energy cost and heat exchanger network (HEN) capital cost targets for a process and recognizing the pinch point:
  - first, the minimum requirements of external energy, network area, and the number of units for a given process at the pinch point is predicted ahead of design.
  - Next a heat exchanger network design that satisfies these targets is synthesized.
  - Finally the network is optimized by comparing energy cost and the capital cost of the network so that the total annual cost is minimized.
- Thus, the prime objective of pinch analysis is to achieve financial savings by better process heat integration (**maximizing process-to-process heat recovery and reducing the external utility loads**).

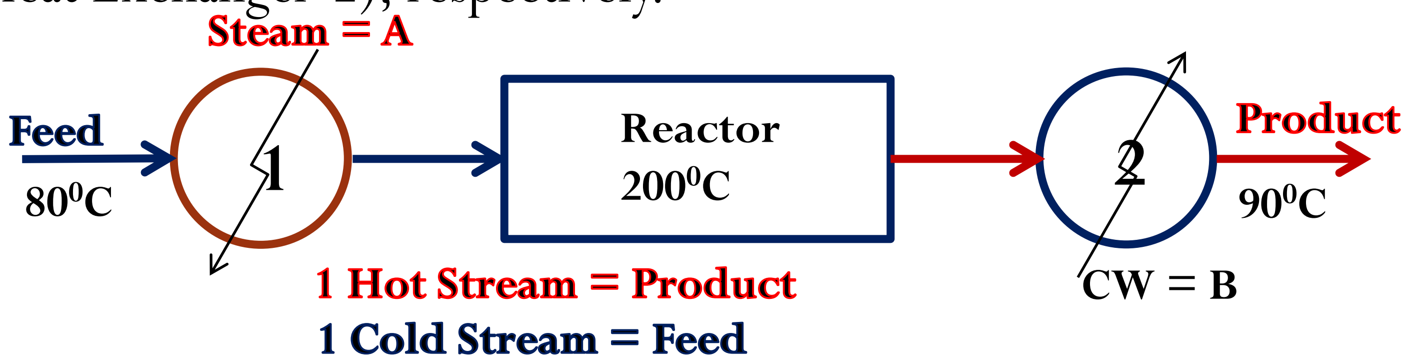
Basic Concepts of Pinch Analysis

- Industrial processes involve transfer of heat either from one process stream to another process stream (interchanging) or from a utility stream to a process stream. In the present energy crisis scenario all over the world, the target in any industrial process design is to maximize the process-to-process heat recovery and to minimize the utility (energy) requirements.
- To meet the goal of maximum energy recovery or minimum energy requirement (MER) an appropriate heat exchanger network (HEN) is required.
- The design of such a network is not an easy task considering the fact that most processes involve a large number of process and utility streams.
- A summary of the key concepts, their significance, and the nomenclature used in pinch analysis is given below:
- Combined (Hot and Cold) Composite Curves: Used to predict targets for
  - Minimum energy (both hot and cold utility) required,
  - Minimum network area required, and
  - Minimum number of exchanger units required.

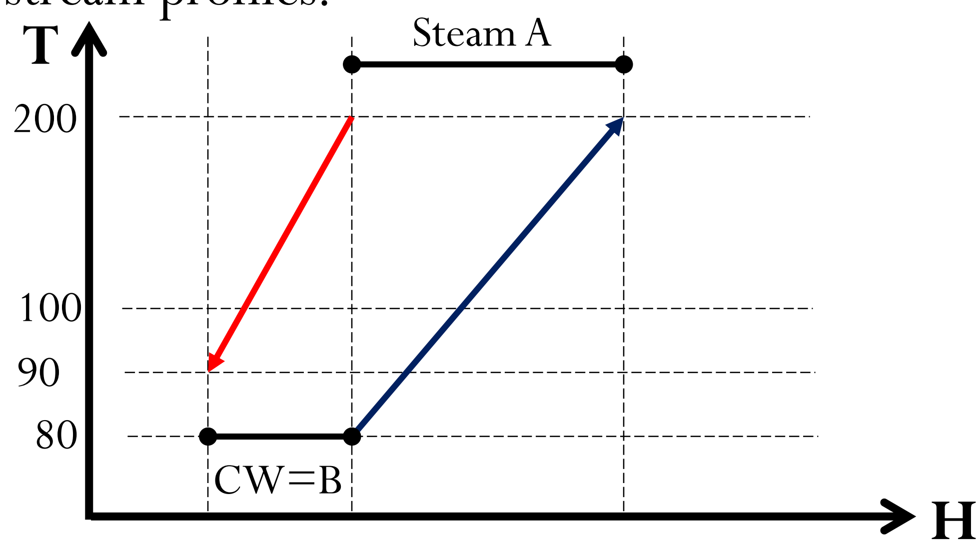
Basic Concepts

- ΔT_{min} and Pinch Point : The ΔT_{min} value determines how closely the hot and cold composite curves can be 'pinched' (or squeezed) without violating the Second Law of Thermodynamics (no temperature crossover).
- Grand Composite Curve: Used to select appropriate levels of utilities (maximize cheaper utilities) to meet over all energy requirements.
- Energy and Capital Cost Targeting : Used to calculate total annual cost of utilities and capital cost of HEN.
- Total Cost Targeting: Used to determine the optimum level of heat recovery or the optimum ΔT_{min} value, by balancing energy and capital costs.
- Plus/Minus and Appropriate Placement Principles: The "Plus/Minus" Principles provide guidance regarding how a process can be modified in order to reduce associated utility needs and costs. The Appropriate Placement Principles provide insights for proper integration of key equipment like distillation columns, evaporators, furnaces, heat engines, heat pumps etc. in order to reduce the utility requirements of the combined system.
- Total Site Analysis : This concept enables the analysis of the energy usage for an entire plant site that consists of several processes served by a central utility system

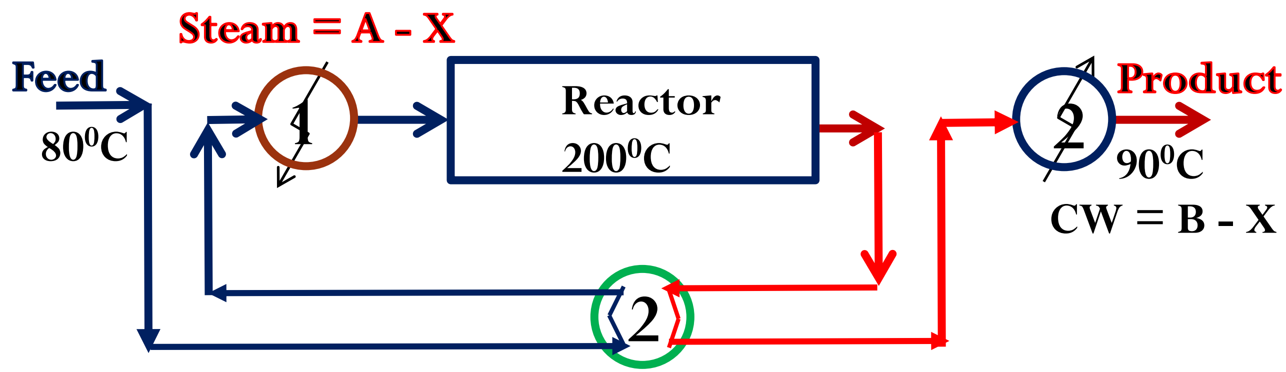
- Consider the following simple process where the feed stream to a reactor is heated before inlet to a reactor and the product stream from the reactor is to be cooled. The heating and cooling are done by use of steam (Heat Exchanger-1) and cooling water (Heat Exchanger-2), respectively.

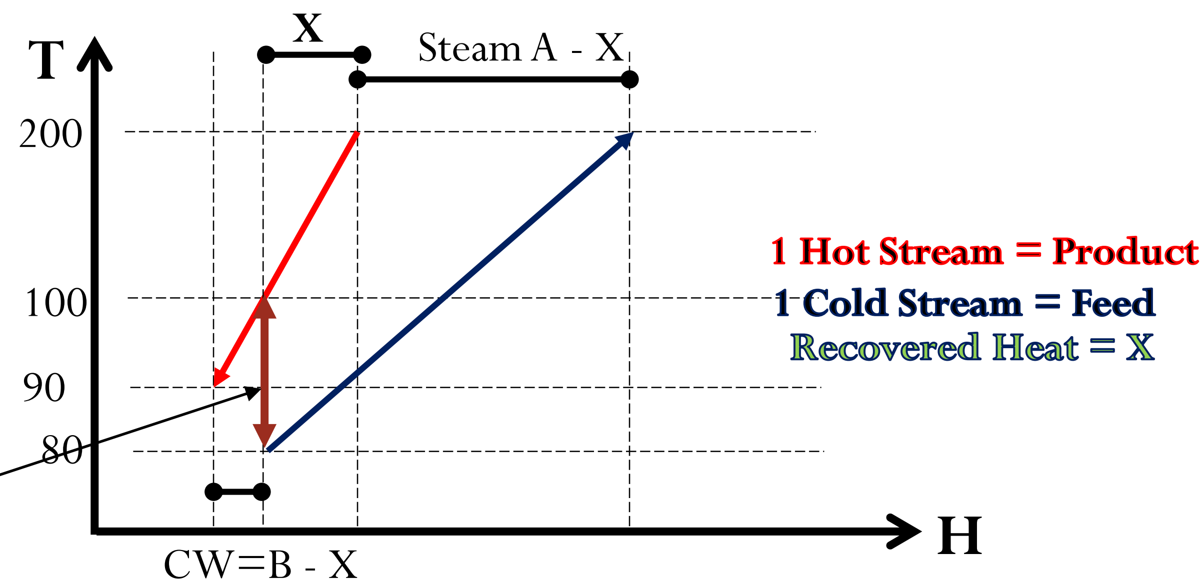


- The Temperature (T) vs. Enthalpy (H) plot for the feed and product streams depicts the hot (Steam) and cold (CW) utility loads when there is no vertical overlap of the hot and cold stream profiles.



- Alternatively, an improved scheme where the addition of a new 'Heat Exchanger–3' recovers product heat (X) to preheat the feed. The steam and cooling water requirements get reduced by the same amount (X).

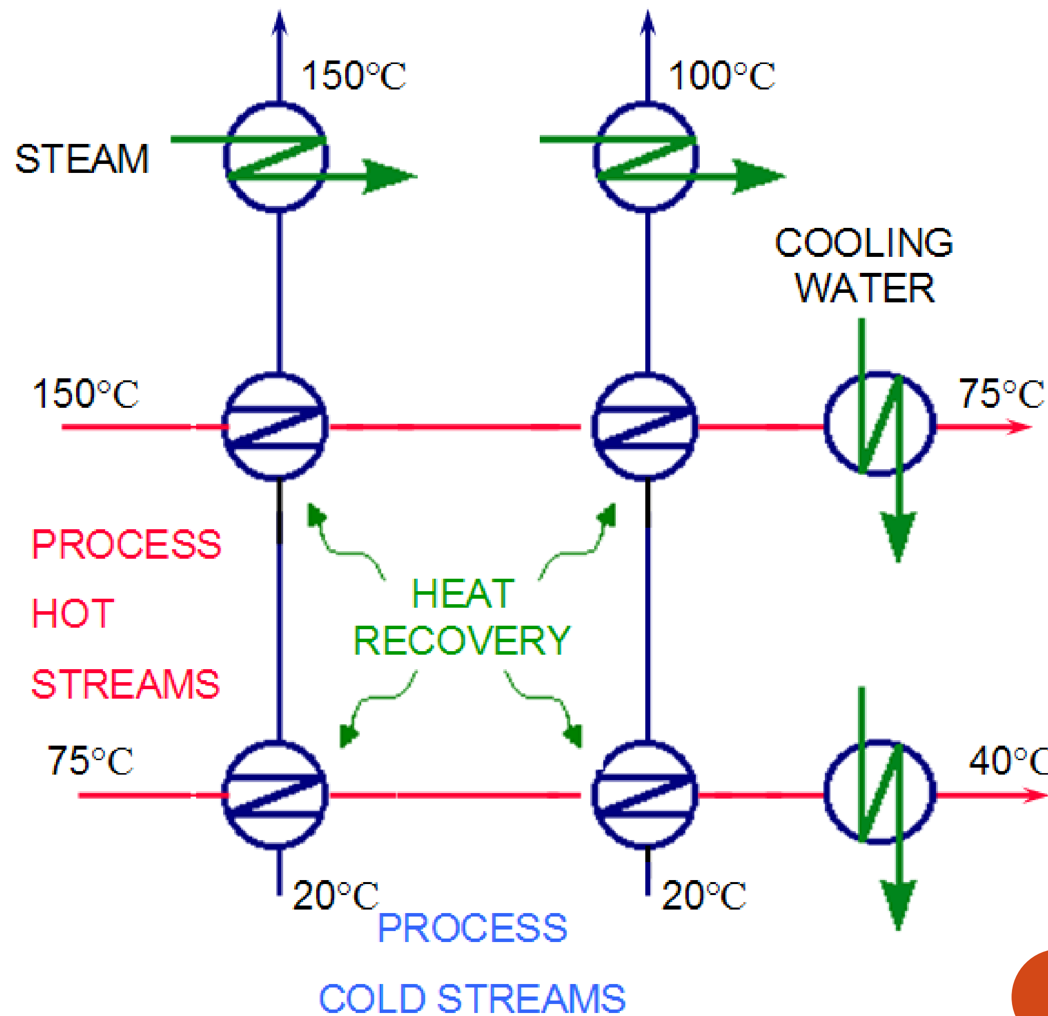




Curves are "shifted" horizontally towards each other till they are vertically apart by 20⁰C.

- The amount of heat recovered (X) depends on the 'minimum approach temperature' allowed for the new exchanger.

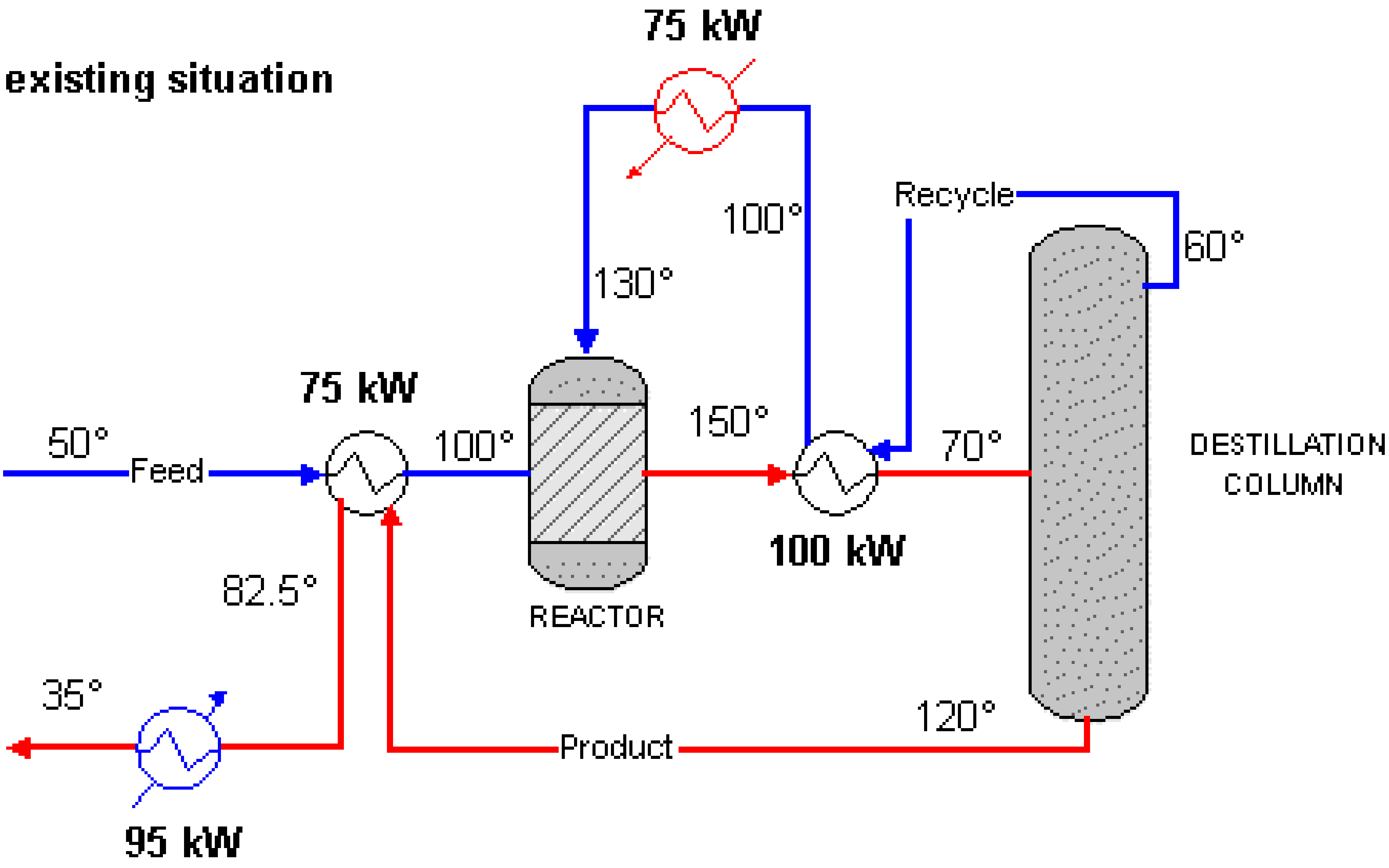
- The minimum temperature approach between the two curves on the vertical axis is ΔT_{min} and the point where this occurs is defined as the "pinch".
- From the T-H plot, the X amount corresponds to a ΔT_{min} value of 20°C.
- Increasing the ΔT_{min} value leads to higher utility requirements and lower area requirements.
- A typical process heating and cooling scheme:



- What is maximum heat recovery possible?
- What is minimum steam needed?
- Best arrangement for heat recovery?

- Pinch Technology answers these and many other questions

existing situation



Steps of Pinch Analysis

1. **Identification of the Hot, Cold and Utility Streams in the Process**
   - 'Hot Streams' are those that must be cooled or are 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 or cool process streams, when heat exchange between process streams is not practical or economic, e.g. hot utilities (steam, hot water, flue gas, etc.) and cold utilities (cooling water, air, refrigerant, etc.).
   - care must be taken of stream that is not available for heat exchange, despite undergoing changes in temperature, e.g. when a gas stream is compressed the stream temperature rises due to the conversion of mechanical energy into heat and not by fluid to fluid heat exchange.
2. **Thermal Data Extraction for Process & Utility Streams**
   - For each hot, cold and utility stream identified, the following thermal data is extracted from the process material and heat balance flow sheet:

PINCH ANALYSIS

- Supply temperature (T_S): the temperature at which the stream is available.
- Target temperature (T_T): the temperature the stream must be taken to.
- Heat capacity flow rate (CP): the product of flow rate (m) in kg/sec and specific heat (C_P, kJ/kg^{0}C). $CP = m \times C_P$
- Enthalpy Change (ΔH) associated with a stream passing through the exchanger is given by the First Law of Thermodynamics: $\Delta H = Q \pm W$
- In a heat exchanger, no mechanical work is being performed: $W = 0$
- The above equation simplifies to: $\Delta H = Q$, where Q represents the heat supply or demand associated with the stream. It is given by the relationship: $Q = CP \times (T_S - T_T)$.
- Enthalpy Change, $H = CP \times (T_S - T_T)$

A TYPICAL STREAM DATA

Stream No.	Stream Name	Supply Temp., ^{0}C	Taregt Temp, ^{0}C	Heat Cap. Flow, kJ/kg^{0}C	Enthalpy change, kW
1	Feed	60	205	20	2900
2	Reactor out	270	160	18	1980
3	Product	220	70	35	5250
4	Recycle	160	210	50	2500

3. Selection of Initial ΔT_{min} value

- A minimum allowable temperature difference ΔT_{min} must be specified which prohibits any temperature crossover between the hot and the cold stream
- the temperature of the hot and cold streams at any point in the exchanger must always have a minimum temperature difference (ΔT_{min}).
- i.e. Hot stream Temp. $T_H - T_C = \Delta T_{min}$
- This ΔT_{min} value represents the bottleneck in the heat recovery.
- The value of ΔT_{min} is determined by the overall heat transfer coefficients (U) and the geometry of the heat exchanger.
- In a network design, the type of heat exchanger to be used at the pinch will determine the practical ΔT_{min} for the network. For example, an initial selection for the ΔT_{min} value for shell and tubes may be 3-5^{0}C (at best) while compact exchangers such as plate and frame often allow for an initial selection of 2-3^{0}C.

$$Q = UA\,\Delta T$$

$$\Delta T_{lm} = \frac{(T_{Hin} - T_{Cout}) - (T_{Hout} - T_{Cin})}{\ln \dfrac{(T_{Hin} - T_{Cout})}{(T_{Hout} - T_{Cin})}}$$

HHB

Typical ΔT_{min} values for various types of process

No	Industrial Sector	ΔT_{min}
1	Oil Refining	20-40°C
2	Petrochemical	10-20°C
3	Chemical	10-20°C
4	Low Temperature Processes	3-5°C

- For a given value of heat transfer load (Q), if smaller values of ΔT_{min} are chosen, the area requirements rise. If a higher value of ΔT_{min} is selected the heat recovery in the exchanger decreases and demand for external utilities increases.
- Thus, the selection of ΔT_{min} value has implications for both capital and energy costs.


Thank You!