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PinCH
www.pinch-analyse.ch

PinCH
An analysis and design tool for process integration

Version 1.5

User Manual

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Preface

PinCH is a user-friendly software for the practical implementation of pinch-analysis in the industry. The software has been developed at the Competence Centre Thermal Energy Systems and Process Engineering at the Lucerne School of Engineering and Architecture. The development team thanks the Swiss Federal Office of Energy (SFOE) and Energie-Agentur Der Wirtschaft (EnAW)for the financial support. In addition, the team thanks the experts from Helbling Beratung + Bauplanung AG and PLANAIR SA Ingenieurs Conseils SIA for the valuable technical advice and support in writing this documentation.

Information about the software PinCH including the current versions of the software and manual is available at *www.pinch-analyse.ch*.

Summary

The use of energy in the world today and in the future is of utmost importance for governments and citizens alike due to its central role in everyday life. Without access to affordable and highly concentrated sources of energy much of today's economic and innovation progress would be reduced. As a result, concerns prevail related to the increasing shortage of resources presently used for meeting the energy demands of the world's economies. In addition, CO_2 emissions targets are legislated with the goal of reducing the amount of CO_2 and other greenhouse gases emitted to below 1990 levels in countries that have ratified the Kyoto protocol. Nevertheless, the world's economies require energy to meet the everyday needs of citizens and provide opportunities for new innovation and economic growth in both western and developing nations. One of the keys to meeting this challenge is to improve energy efficiency throughout the industrial infrastructure. This approach has the combined effect of reducing energy demand as well as CO_2 emissions. The Swiss Federal Office of Energy (SFOE) has estimated that from 30 to 50% reduction in energy needs of domestic industrial processes can be achieved though improved efficiency and energy utilization. Improvements in efficiency are a way to the future.

A cornerstone technology increasingly used for improving industrial energy efficiency is pinch analysis method. The pinch method is a major part of the more generalized and broader area of process integration. It plays a central role in the integrated or holistic approach in process synthesis and design and has been shown to provide significant improvements in the energy utilization of industrial facilities of various levels of complexity and size. The method is based on a relatively practical interpretation of the second law of thermodynamics and places a considerable amount of responsibility on the user to fully understand the process they are trying to optimize. This action in itself provides a strong basis for the adoption of such a technology as the design engineer speaks in terms of his or her process on a practical concrete level of understanding. The results from a pinch analysis study provide the thermodynamically feasible targets for the industrial process being studied. The technology seeks to distinguish between avoidable and inevitable losses. Therefore, given a certain economic and energy trade-off the energy targets encompassing only the inevitable losses can be calculated. These targets provide a powerful incentive in the design or retrofitting project phase to ensure the maximum amount of energy is recovered leading to the minimum amount of required external energy. However, it must be noted that they are

to be seen as a guidelines and not absolutes forcing the design engineer to balance constraints, economics and controllability issues with the targeted minimum energy requirement.

Due to the large amount of information and details that can arise during an analysis for medium to large processes, a computer based tool is typically needed to support a pinch analysis study. Today several commercial applications exist; however, one version of a pinch analysis tool was developed in the Ecole Polytechnique Fédérale de Lausanne (EPFL) in the early 1990's ("PinchLENI", Prof. Dr. Daniel Favrat, Laboratoire d'énergétique industrielle LENI). This tool has allowed students and engineers to learn and apply the method in the praxis successfully. However, the software is no longer being developed and maintained and is not capable of running on the newer Macintosh operating system. PinchLENI has been a useful product over the years, but the decision was made to upgrade the entire code base to new technology and include additional new features within the field of process integration that were not developed in the original software. This new software is called **PinCH** and has been documented in this user manual. PinCH maintains the user friendliness of its predecessor in allowing the design engineer to easily create the stream table for the process in question followed by targeting analysis to determine the the ΔT_{min}, pinch temperature and associated thermodynamically feasible minimum utility requirements. These requirements or targets provide the basis for the final project stage of heat exchanger network design and synthesis.

In conclusion, the new PinCH software is an exciting new simulation tool focussed on the optimization of industrial processes as its central goal. The realization of this central goal will allow the continued promotion of the pinch analysis method enabling progress and leadership in the area of process integration and a more holistic system design approach to minimizing society's energy needs.

Contents

Chapter 1

Welcome to PinCH

1.1 Introducing PinCH

Welcome to PinCH - a complete solution for energy analysis of industrial processes. To help promote the use of the pinch analysis method, this software tool called PinCH (CH stands for the Latin name “Confoederatio Helvetic”, i.e. Switzerland) has been developed to provide a sound basis for the application and support of the pinch method and process integration.

- PinCH is sophisticated calculation software that supports process integration studies focussed on the pinch analysis method.
- Pinch is a framework for handling multiple scenarios and process structures in targeting calculations.
- PinCH is a dynamic and powerful heat exchanger network design tool.

See “What Features are in PinCH” for a list of the features included in this release of PinCH.
For update-to-date release information, please go to: *www.pinch-analyse.ch*

1.2 About This Manual

This manual assumes that you know how to use Microsoft Windows operating system, Microsoft Excel, a word processor and the mouse. For

help on these topics, consult your computer owner's manual.
Within the PinCH program itself are several ways to execute commands. Primarily the program is context menu driven based on context-sensitive right click on specific text fields. In addition, there is a main menu as well standard keyboard shortcuts available on the workbench.

Note: This user manual will be periodically updated. Please check the PinCH website for the latest version at *www.pinch-analyse.ch*.

1.3 What Features Are In PinCH

PinCH provides for some of the following features (only as an overview):

- Analysis of continuous and batch processes
- Coupling of several processes (Process Management)
- Dynamic stream table capabilities
- Flexible functions for investment and energy costs
- Technical and economic case studies (Scenario Management)
- Present situation analysis of processes and heat exchanger networks
- Graphical design of heat exchanger networks
- Optimization of utility systems
- Integration of heat pumps, combined heat and power (CHP) systems, mechanical vapour recompression units, etc.
- Physical property data for refrigerants, water/steam and humid air systems
- Comprehensive data import/export capabilities

Chapter 2

Installing And Upgrading PinCH

2.1 PinCH Program Requirements

Please read this section before proceeding with the installation.

PinCH can be installed as a trial version that will run in a limited capacity for a short trial period. The trial can be extended upon request or an activation key can be purchased. Please go to our website for latest pricing information at *www.pinch-analyse.ch*.
In addition, information on how to obtain PinCH via a download is available on the website.

System Requirements:
In order to use the software the Microsoft.Net Framework 3.5 SP1 must be installed. Administrator rights will be needed in order to do so and may require the assistance of your information technology department to complete the install. PinCH runs under the following operating systems:

- Windows XP, with Service Pack 3 (Microsoft .Net Framework 3.5 SP1)
- Window Vista
- Window 7

Hardware Requirements:

- Processor: 1 GHz Pentium processor or equivalent (Recommended)
- RAM: 1024 MB (Recommended)
- Hard Disk: Up to 25 MB of available space may be required
- Display: 1680 x 1050 high colour, 32-bit (Recommended)

2.2 PinCH Installation

Follow these instructions to install the PinCH program.
→ If you are upgrading to a newer version, please see "Upgrading To A Newer Version".
→ Please see "Using PinCH On A Network" for information about using PinCH on a network and the limitations at this time.

PinCH is available in three versions - A free trial, an extended trial and a full purchased version.

Note: Please ensure you have a full administrator rights in order to be able to make insertions in the Windows operating global registry. These rights are particularly important for installing on Windows Vista and Windows 7.

To install PinCH:

1. Login to the machine with administrator rights or as a user with program installation privileges.
2. Ensure you have obtained the most recent version of PinCH by checking for latest information on *www.pinch-analyse.ch.*
3. Unzip the compressed installer file to your computer and double click the installer file to start the PinCH setup program.
4. Follow the instructions on the screen to complete the installation. Use the Next button to move forward between these wizard dialogs:

a. Welcome: Thank you for using PinCH!

b. Licence Agreement: Review the licensing agreement and choose to accept or not.

c. Select Installation Folder: PinCH must be installed using administrator rights. As a result, the install will by default make the program available for all users. Finally the disk cost can be checked and the install location can be modified as required.

d. Confirm Installation: Installation will proceed and necessary changes completed.

e. Installation Complete: Close the wizard.

5. After installing PinCH start the program and the Trial/Activation dialog will appear.

6. After selecting the Request Activation button, fill in the customer information and press the Create Request button to generate the key. (**Note:** the CustomerId is generated automatically and does not need to be entered).

7. Copy and paste the machine specific serial number into an email and send to pinch@hslu.ch (**Note:** please ensure the Begin and End Software Activation Request attributes are included)

8. After an Activation UnlockKey has been created and sent in return via email, start the PinCH program and select Activate Software and copy the Activation UnlockKey into the text area. The program will then be automatically activated and ready for use. (**Note:** this step will be automatically skipped if the Activation UnlockKey is already copied to the clip board before the PinCH program is started).

9. The PinCH program will now start and be ready for use. In order to check the licence status, information is displayed in the Help/About menu item. The licence information and expiry date are listed.

Fig. 2.1: Software Activation Dialog

The same process can be used to request a trial extension if more time is needed to assess the program before deciding to purchase.

2.3 Upgrading To A Newer Version

Before upgrading PinCH, back up any project files or the custom layout file that you have created. We recommend that you uninstall any previous version of PinCH that has been installed before upgrading. If during the setup an earlier version is detected then PinCH will either ask you to remove the program first or will automatically remove the program depending if a major or minor release.

Note: There are two types of upgrades - i) upgrade to a minor release or ii) upgrade to a major release. In the case i) the newer version can simply be installed and the orginal Unlock key will be used. However, in case ii) a new request key will need to be created resulting a new Unlock key to be used.

Install the upgrade just as you would a new install as detailed above in section “PinCH Installation”.

2.4 Using PinCH

Even though PinCH can be accessed across a network, it was not designed with specific networking cabilities at this time and does not support hardware nor software product activation servers. The product can be accessed via terminal services subject to the number of activation keys purchased.

2.5 Uninstalling PinCH

Before uninstalling PinCH, back up any project files or the custom layout file that you have created.

To uninstall PinCH:

1. Login to the machine with administrator rights or as a user with program installation privileges.
2. From the Windows *Start* menu, select *Control Panel*, or choose Settings and then *Control Panel*.
3. Select *Add or Remove Programs*.
4. In the list of currently installed programs, select *PinCH Engineering Tool*.
5. Select the *Remove* button.

Chapter 3

PinCH Guided Tour

3.1 Process Types And Their Modelling Needs

Industrial processes are typically distributed and dynamic in nature. As a result, a real world industrial plant often involves several production processes, possibly operated independently of each other, in one or several buildings or areas. They can be characterized into continuous as well as batch operation with various other scheduling opportunities spread between. In addition, even in cases when only one process is operated, it may feature some changes in the operating conditions over the year, either because of change in the climate conditions, or because of changes in the feed being processed and corresponding adjustments in the production recipes (e.g. flakes made from corn or from wheat, different colour of paint, etc.).

PinCH has been designed to allow such real world problem specificities to be taken into account, and modelled in a basic time scheduled manner. It provides the user with flexible tools to define these specifications, to decide which processes must be heat integrated together, and how to integrate them.

The following base process scheduling types are supported in PinCH:

3.1.1 Single Process Continuous

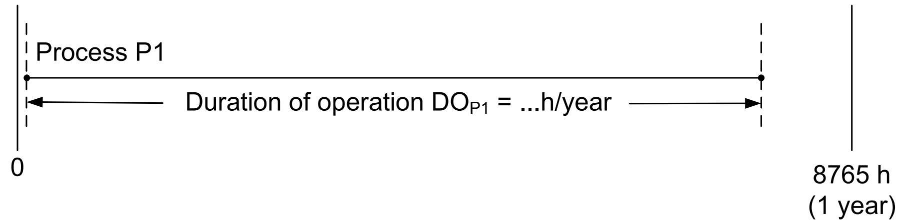


Fig. 3.1: Diagram Illustrating a Single Continuous Process

This is the simplest process type commonly found in industry: constant process conditions of process P1 over the whole duration of operation of the process DO_{P1}. Note that since there is only one process the schedule has no influence.

3.1.2 Multiple Processes, Continuous And Synchronous

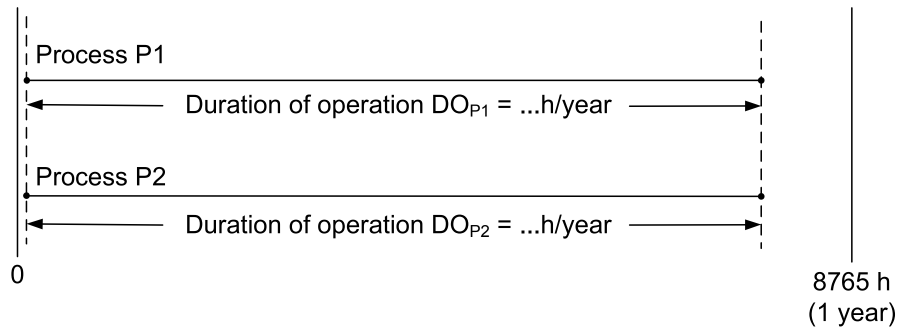


Fig. 3.2: Diagram Illustrating Multiple Processes, Continuous, and Synchronous

This case includes two or more synchronous processes, e.g. linked continuous processes contributing to the production of one or more products. A priori, the processes are not grouped in a single overall process because typically they are not close enough to each other on the site to allow direct heat integration between streams of the different processes. As for the case described for singe continuous, the processes start at an arbitrary time point of 0 and the schedule has no influence on the result as long as the processes are synchronous.

3.1.3 Multiple Processes, Continuous, Not Overlapped

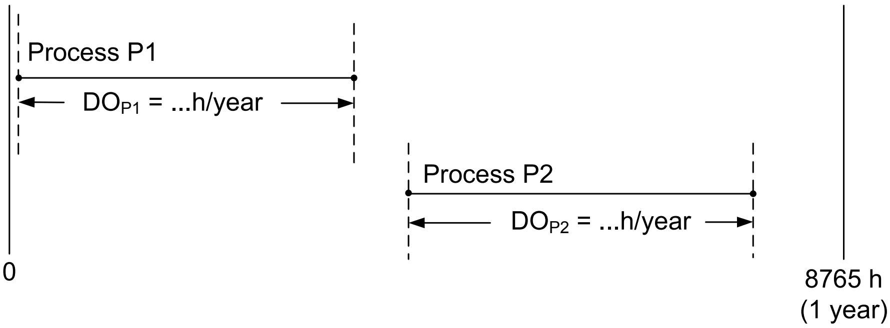


Fig. 3.3: Diagram Illustrating Multiple Processes, Continuous, Not Overlapped

This case includes two or more continuous processes, not overlapped. The time difference between the end of P1 and the beginning of P2 may be variable. Therefore, it is assumed that heat integration between P1 and P2 is either not feasible, or uneconomic. As a consequence, the heat integration of P1 and P2 may be analysed independently of each other.

However, the above reasoning does not hold anymore, if P1 and P2 are processes organised on a weekly basis (often found in food industry), i.e. P1 operated at the beginning of each week, while P2 would follow during the second part of the week. In this case:

- heat integration through intermediate heat storage may be possible if the process pinch of P1 is significantly different from that of P2, and potentially profitable;
- the base period considered to define the schedule should not be one year, but one week (to correctly take the number of heat storage cycles into account; an important issue for the profitability), and the user should then define the number of weeks per year this schedule is repeated.

As for the case described previously, the process may start at 0 as well, the schedule has no influence on the result as long as the processes are not overlapped.

Note: If the processes different periods for the same processes then the opportunity to design a heat exchanger network valid for all the base cases must be done

3.1.4 Multiple Processes, Continuous, Overlapped

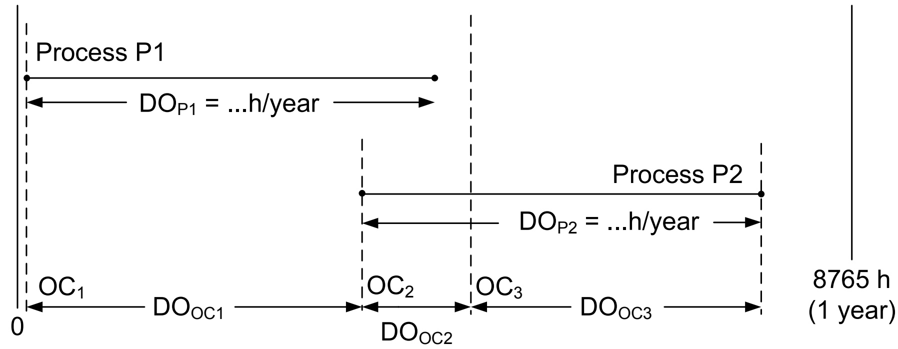


Fig. 3.4: Diagram Illustrating Multiple Processes, Continuous, Overlapped

This case includes two or more continuous processes, partially overlapped, defining operating cases (here OC_1, OC_2, and OC_3, of duration DO_{OC1}, DO_{OC2}, and DO_{OC3}, respectively). OC_2 introduces (as far as the heat integration between P1 and P2 is feasible and profitable), a link of the optimization possibilities based on the heat integration of both processes. The significance of this link depends, among other things, on the duration DO_{OC2} and the associated improvement of the heat recovery target compared to that involving only the heat integration of P1 and P2 separately.

3.1.5 Single Process, Multiple Base Cases

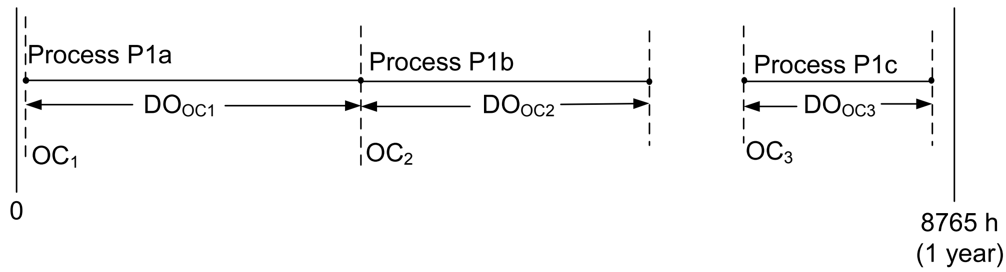


Fig. 3.5: Diagram Illustrating a Single Continuous Process, Multiple Base Case

This process type scheduling can consists of several continuous processes following closely after each other sequentially. These types of multiple base cases (MBC) can occur due to season changes that affect operation even though the process is the same product. It is assumed that heat integration between P1a, P1b and P1c is either not feasible, or uneconomic. As a consequence, the heat integration of P1a, P1b and P1c may be analysed independently of each other. However, the above reasoning does not hold if P1a, P1b and P1c are processes organised on a weekly basis (often found in food industry), i.e. P1a operated at the beginning of each week, while P1b would follow during the second part of the week. In this case:

- heat integration through intermediate heat storage may be possible if the process pinch of P1 is significantly different from that of P2, and potentially profitable;
- the base period considered to define the schedule should not be one year, but one week (to correctly take the number of heat storage cycles into account; an important issue for the profitability), and the user should then define the number of weeks per year this schedule is repeated.

Note: Indirect heat integration capabilities are not included in this version PinCH.

3.1.6 Single Process, Batch

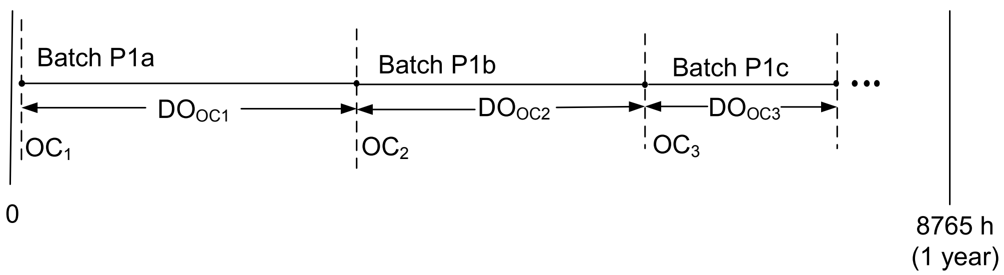


Fig. 3.6: Diagram Illustrating a Sequential Batch Process

This type of process consists of several batch processes following sequentially after each other. Direct heat integration between the batches P1a, P1b and P1c is not feasible. However, indirect heat integration would be a possible means to exchange energy between the time slices of each batch. In this case:

- heat integration through intermediate heat storage may be possible if the process pinch of P1 is significantly different from that of P2, and potentially profitable;
- the base period considered to define the schedule should not be one year, but one week (to correctly take the number of heat storage cycles into account -an important issue for the profitability), and the user should then define the number of weeks per year this schedule is repeated.

Note: Indirect heat integration capabilities are not included in this version PinCH.

3.2 PinCH Processing Steps

In order to begin the guided tour of the PinCH software several important aspects of the pinch analysis study should be reviewed. The application of the pinch method is manual in nature; however, it provides a systematic and structured approach to the difficult problem of overall system design [1]. The method places a considerable amount of responsibility on the user to fully understand the process they are focused on optimizing. However, this action in itself provides a strong benefit as the design engineer speaks in terms of his or her process on a practical concrete level of understanding. Fig. 3.7 shows the project flow diagram for a typical pinch study in industry [2]. The flow involves 3 major phases 1) mass and energy balance validation, 2) pinch method calculations and 3) new design change recommendations. The PinCH software mainly focuses on supporting the second phase involving targeting and heat exchanger network design calculations. The skills involved in the first and third steps can only be minimally supported and require the design engineer to develop the necessary skills in process engineering and unit operation design through learning and experience.

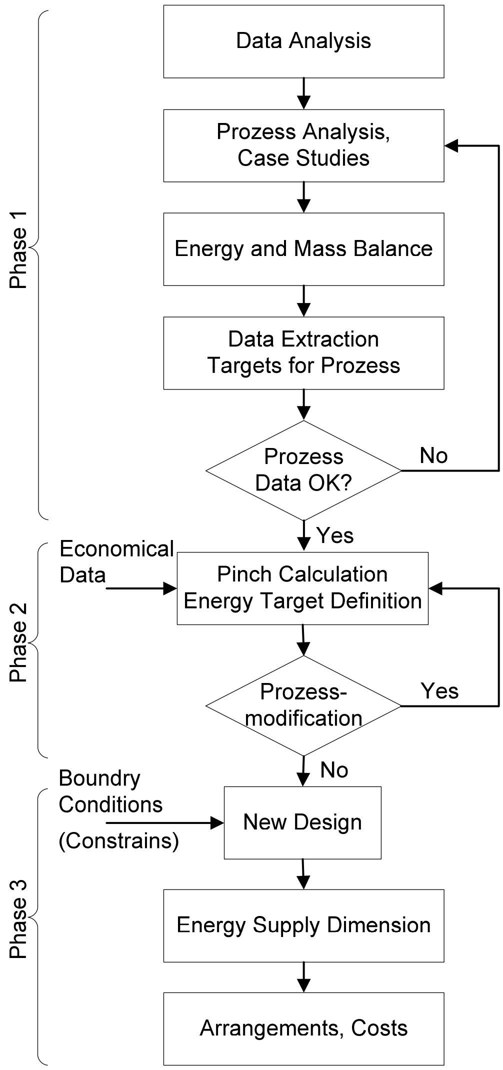


Fig. 3.7: Pinch Study Process

However, within the context of the pinch study calculations, ten major processing steps were identified that are typically done and are directly supported in the PinCH software. They are as follows:

1. Entering Stream Data
2. Creating Processes
3. Assigning Streams to Processes
4. Setting Economic Data (Global and Utility Stream Specific)

5. Creating an Operating Cases Schedule
6. Creating a Target Group
7. Calculating a Target Result (e.g. Separate Design or Time Average Model (TAM) Design)
8. Calculating Target Results Based on Variations of ΔT_{min} Values or other parameters (e.g. economic data and scheduling data)
9. Adding Energy Conversion Units
10. Creating Heat Exchanger Network (HEN) Designs for Specific Target Results

Note: Please see Help / First Steps menu item in PinCH for a diagram of the 10 steps. The first step is clearly focussed on supporting phase 1 of the pinch study process in order to allow easy inputting of stream data and process requirements. However, steps 2, 3, 4 and 5 are unique in that they allow the complete definition of the process(es) from a static perspective. This definition allows the flexibility to manage different scenarios and variability studies involved in the pinch analysis calculations.

Steps 6, 7, 8 and 9 allow the configuration of result scenarios used in performing heat integration Targeting calculations. Finally, step 10 encapsulates the detailed design requirement for the HEN exchanger network based on the targeting results. This transition supports one of the golden rules of pinch analysis:

Targets Before Design

The structured set of steps and the support given in the PinCH software ease the challenge of cyclically analyzing the different options that can result in a study due to better information and understanding through to identified process changes. Each of these options require the repeating of the targeting and new HEN designs. PinCH manages each of these steps through the use of graphical user interface object visualizers. The key features include the ability to create complex plant design scenarios for the analysis of single continuous, multiple base case and single product batch processes. Once standard targeting calculations are complete detailed heat exchanger network grid diagrams can be created to produce minimum energy or relaxed designs. Some of these features will be introduced next.

3.2.1 Major Graphical Components Of PinCH

When you open PinCH the application Workbench will be displayed. The following Fig. 3.8 shows a calculated result. In order to view these major graphical components shown please open a project case as follows:

1. Select *File / Open Project* on the main menu (see Fig. 3.8 point 1).
2. In the Open project dialog navigate to *(install directory)/Hochschule Luzern/PinCH Engineering Tool/Examples* and select the project FourStreamEx2.xml.
3. Select to expand the *New Target Group* node shown in the Target Explorer.
4. Select the *Results* tree node and right click to bring up the context menu and select Calculate Target Result with... > Separate Design Tool.
5. Select the check box under *Costs* in the Filter Panel of the resulting Target Result graphical result visualizer.

PinCH workbench should now show the target result calculated for the given process.

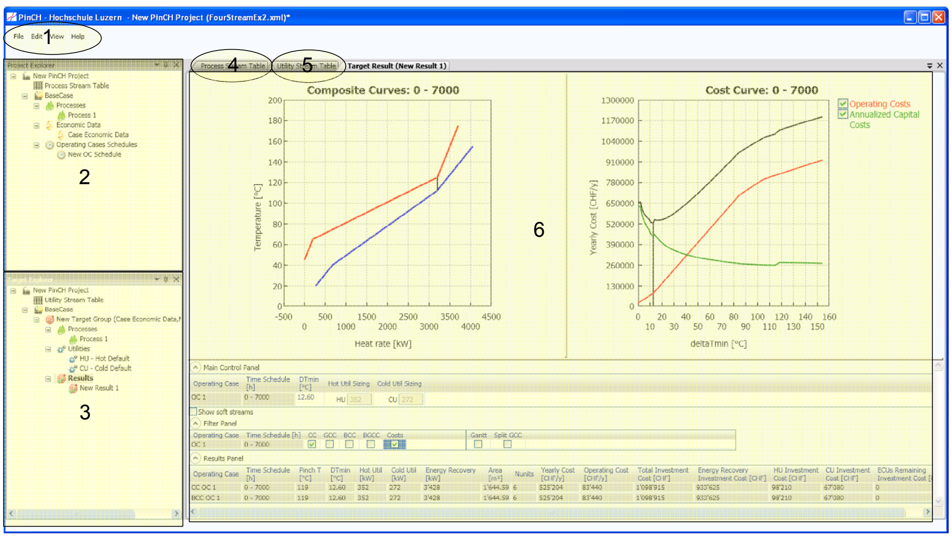


Fig. 3.8: PinCH Workbench and Major Graphical Components

Referring to Fig. 3.8 the major components included are the following:

1. Main menu bar.
2. Project Explorer - used to define static information related to processes and their scheduling as well as global economic data.
3. Target Explorer - used to configure and manage the generation of results that are based on the information supplied in the project explorer.
4. Process Stream Table - data grid used to hold all stream related information derived from the data extraction process and used in calculating the targets and building HEN designs.
5. Utility Stream Table - data grid to hold all utility stream related information used in designing and optimizing the utility systems for a given target result.
6. Target Result Visualizer - used to encapsulate all results related to a particular targeting calculation. Results include the following:

   a. composite curves
   b. grand composite curve
   c. balance composite curve
   d. balance grand composite curve
   e. cost curves
   f. process gantt chart
   g. split grand composite curve
   h. main control panel to set target for a specific ΔT_{min} and size utilities
   i. filter panel to control viewing combinations
   j. results panel to view targeting results in a grid format

An additional base graphical component is the HEN grid as shown in the following figure.

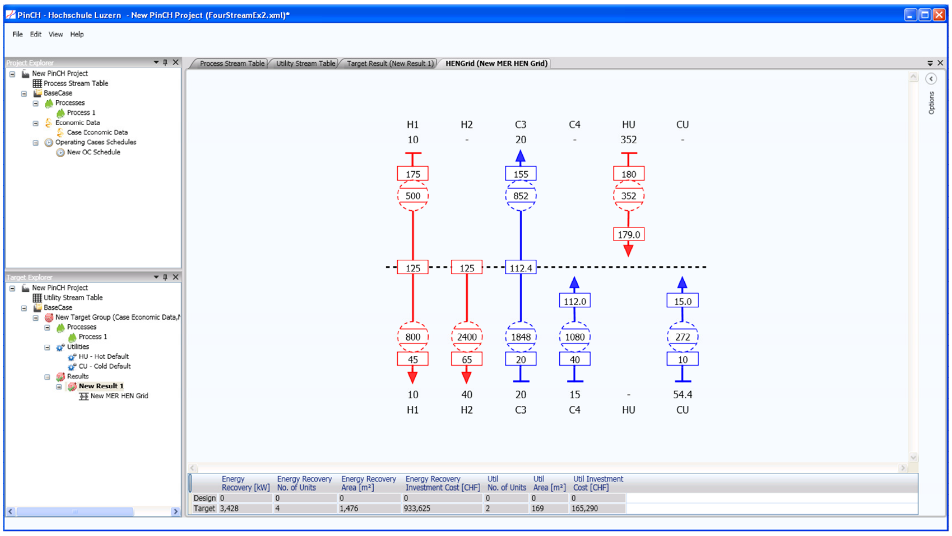


Fig. 3.9: PinCH Workbench Showing a HEN Grid

In order to create and view the HEN please do the following:

1. Use the same open project file as used in creating Fig. 3.9.
2. Right click on the **New Result 1** created for the target result to view the context menu.
3. Select context menu *Add HEN* > *Add MER HEN*

The HEN grid for the particular minimum temperature difference will be displayed. Design can now begin to place heat exchange matches starting at the pinch line to ensure the minimum energy requirement network is achieved. The details of each of the components are presented in subsequent sections. In addition, the reader is encouraged to read and learn about the principles of the pinch method in the several references listed at the end of this document.

Chapter 4

Using The Process Stream Table

4.1 Importance Of Proper Data Extraction

Data extraction is a very important activity in the overall pinch analysis project process. This project phase (see Fig. 3.7) involves a large effort to analyze an industrial process and derive the necessary stream information needed for a pinch analysis. In this first phase, the engineer is responsible for analyzing the entire boundary of operation of a given industrial process and to breakdown the structure into appropriate time and space dimensions. The assumptions made in organizing the structure is important to ensure an adequate level of modelling complexity is maintained, yet being certain to not exceed the necessary amount of details for an adequate analysis (i.e. attain a manageable level but still incorporate the key features for heat integration studies). As a result, the engineer will typically have to first identify the type of processes present, their location on the site relative to each other, any limits on interfacing these distinct processes, the range of products (recipes) and their different production lines (conditions and schedule) and finally include any special side processes (e.g. HVAC). Each of these process characteristics will generate different target results. More generally, it is often observed in practice that these charateristics influence the manner in which the process streams (or process requirements) are identified for use in the pinch analysis depending on what can be assumed to be modifiable and what can not. This process stream analysis is a very challenging aspect of a pinch analysis, yet it provides immediate benefits even before the pinch calculations are performed.

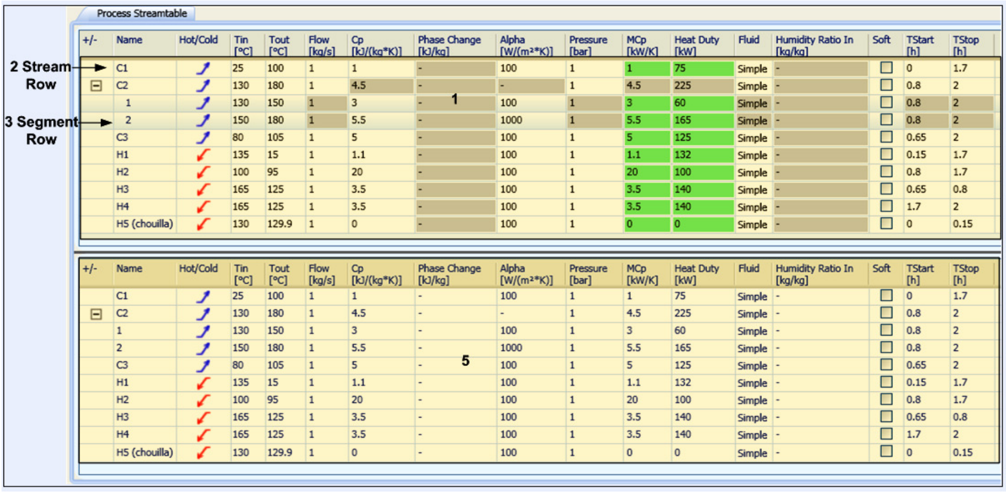
Given the importance of data extraction, the PinCH program provides a convenient data grid component to allow the easy entering or importing of stream data and other features to aid the engineer in ensuring the data is complete and of high quality. The next sections provide details related to using the functionality available in the Process and Utility Stream Tables where the core process requirements are entered.

4.2 The Stream Table (Process Requirements)

The Process Stream Table contains the process requirements (stream data) established during the data extraction phase. In pinch analysis, these requirements are represented through the common definition of **Hot Streams to be cooled down and Cold Streams to be heated up** in a system.

It is assumed the physical properties of a stream remain relatively constant in most circumstances. However, this is not always true (e.g. crude oil or humid air) and a stream can be divided into one or more segments in order to provide improved accuracy in calculating the pinch analysis target values.

Each stream and its associated segments are stored along with the specific parameters such as temperature, pressure, mass flow, etc. in the project file. These values are read upon opening the project file and displayed as shown in Fig. 4.1.



+/-	Name	Hot/Cold	Tin [°C]	Tout [°C]	Flow [kg/s]	Cp [kJ/(kg*K)]	Phase Change [kJ/kg]	Alpha [W/(m²*K)]	Pressure [bar]	MCp [kW/K]	Heat Duty [kW]	Fluid	Humidity Ratio In [kg/kg]	Soft	TStart [h]	TStop [h]
	C1		25	100	1	1	-	100	1	1	75	Simple	-	☐	0	1.7
⊟	C2		130	180	1	4.5	-	-	1	4.5	225	Simple	-	☐	0.8	2
	1		130	150	1	3	-	100	1	3	60	Simple	-	☐	0.8	2
	2		150	180	1	5.5	-	1000	1	5.5	165	Simple	-	☐	0.8	2
	C3		80	105	1	5	-	100	1	5	125	Simple	-	☐	0.65	2
	H1		135	15	1	1.1	-	100	1	1.1	132	Simple	-	☐	0.15	1.7
	H2		100	95	1	20	-	100	1	20	100	Simple	-	☐	0.8	1.7
	H3		165	125	1	3.5	-	100	1	3.5	140	Simple	-	☐	0.65	0.8
	H4		165	125	1	3.5	-	100	1	3.5	140	Simple	-	☐	1.7	2
	H5 (chouilla)		130	129.9	1	0	-	100	1	0	0	Simple	-	☐	0	0.15

+/-	Name	Hot/Cold	Tin [°C]	Tout [°C]	Flow [kg/s]	Cp [kJ/(kg*K)]	Phase Change [kJ/kg]	Alpha [W/(m²*K)]	Pressure [bar]	MCp [kW/K]	Heat Duty [kW]	Fluid	Humidity Ratio In [kg/kg]	Soft	TStart [h]	TStop [h]
	C1		25	100	1	1	-	100	1	1	75	Simple	-	☐	0	1.7
⊟	C2		130	180	1	4.5	-	-	1	4.5	225	Simple	-	☐	0.8	2
	1		130	150	1	3	-	100	1	3	60	Simple	-	☐	0.8	2
	2		150	180	1	5.5	-	1000	1	5.5	165	Simple	-	☐	0.8	2
	C3		80	105	1	5	-	100	1	5	125	Simple	-	☐	0.65	2
	H1		135	15	1	1.1	-	100	1	1.1	132	Simple	-	☐	0.15	1.7
	H2		100	95	1	20	-	100	1	20	100	Simple	-	☐	0.8	1.7
	H3		165	125	1	3.5	-	100	1	3.5	140	Simple	-	☐	0.65	0.8
	H4		165	125	1	3.5	-	100	1	3.5	140	Simple	-	☐	1.7	2
	H5 (chouilla)		130	129.9	1	0	-	100	1	0	0	Simple	-	☐	0	0.15

Fig. 4.1: Process Stream Table

As shown in Fig. 4.1 the major components included are the following:

1. Main Process Stream Table - A complete listing of streams and segments.
2. Stream Row - A summary of the major parameters associated with the bulk stream properties.
3. Segment Row - The specific parameters associated with the section of the stream where either a major change in C_p or a change in phase occurs.
4. Process Stream Table Context Sensitive Menu - This context menu is the key entry point to execute commands against the stream table. The menu listing can be shown by **right clicking** on a row in the Process Stream Table. The commands are as follows:

    a. Add Process Stream
    b. Add Process Stream Segment
    c. Copy Process Stream
    d. Remove Process Stream
    e. Remove Process Stream Segment

5. Working Stream Table - This table displays the streams assigned to a particular process grouping (please see section 5).

In addition to the Process Stream Table, there is also the Utility Stream Table. This table is similar to the Process Stream table, but contains only the necessary information to calculate the required mass flowrate of utility for a given duty. Since each *Target Result* (see section 6) calculates its required hot and cold duty requirements, only the physical properties necessary to define the utility are needed. It should be noted a stream is considered a utility if it supplies or removes energy over a system boundary, but itself can be replaced easily with another utility stream. In this case it is not to be considered as part of the process and should be placed into the Utility Stream Table.

4.3 Defining Of Streams

The definition of streams and their associated segments consist primarily of two main types: *Simple* and *Fluid*. The most basic yet most important is a Simple stream that can be defined in a flexible and direct manner based on either the streams heat capacity flowrate (MC_p) or the heat of vapourization/condensation (phase change). Fluid stream are based on internally calculated physical property calculations for *water, common refrigerants (e.g. R134a)* and *humid air*. By simply choosing the required fluid under the Fluid column (Fig. 4.1), *PinCH* will automatically calculate the necessary physical property data and segment the stream according to the phases present [3 - 4]. The base stream parameters are defined in the following tables for both the Process and Utility Stream Tables:

Tab. 4.1: Process Stream Table Properties

Process Stream Parameters	**Description**	**Units**
Name	Stream or segment name	
Hot / Cold	Designation if stream is hot or cold	
T_{in}	The starting temperature of a stream	°C
T_{out}	The ending temperature of a stream	°C
Flow	The mass flow of a stream	kg/s
C_p	Stream or segment heat capactiy	kJ/kg K
Phase Change	Heat of vapourization or condensation (simple streams only)	kJ/kg
α	Heat transfer coefficient	$\mathrm{W/K\,m^2}$
Pressure p	Absolute stream pressure	bar
MC_P	Heat capacity flow rate	kW/K
Heat Duty	Total heat rate of a stream or segment	kW
Fluid	A selection list to choose between simple, water, refrigerant or humid air stream types	
Humidity Ratio In	The water content of an air stream at its inlet conditions	kg H_2O / kg Dry Air
Soft	Designation if a stream can be included optionally into the targeting calculation	
t_{Start}	Stream existence start time (absolute)	hour
t_{Stop}	Stream existence end time (absolute)	hour

Tab. 4.2: Utility Stream Table Properties

Utility Stream parameters	**Description**	**Units**
Name	Stream or segment name	
Hot / Cold	Designation if stream is hot or cold	
T_{in}	The starting temperature of a stream	°C
T_{out}	The ending temperature of a stream	°C
Flow	The mass flow of a stream	kg/s
C_p	Stream or segment heat capactiy	kJ/kg K
Phase Change	Heat of vapourization or condensation (simple streams only)	kJ/kg
α	Heat transfer coefficient	$W/K\,m^2$
Pressure p	Absolute stream pressure	bar
Utility Cost	Specific cost of the utility stream	CHF/kWh
Heat Duty	Total heat rate of a stream or segment	kW
Fluid	A selection list to choose between simple, water, refrigerant or humid air stream types	
Humidity Ratio In	The water content of an air stream at its inlet conditions	kg H_2O / kg Dry Air

Specifying Streams:

In order to fully specify a stream to allow calculation of the heat duty necessary in the pinch analysis calculations, not all information must be set. The Stream Tables **automatically check the degrees of freedom** to see if enough information is already available to calculate the remaining energy related variables (MC_p, Heat Duty, C_p, Mass Flow). Each stream or segment row is entirely flexible in the combinations that can be supplied. However, the most common is to provide the **mass flow and the** C_p (for *sensible* heat streams or segments). However, the heat duty or the MC_p values can also be directly given.

Streams or segments that experience a phase change such as *condensation or evaporation*, the **mass flow and phase change** are most commonly entered. However, the heat duty can be directly entered if known.

4.4 Configuring Fluid Types

The Fluid column shown in the Stream Tables allows the user to select a specific component in order to automatically calculate the representative streams and segments. The following table lists the components that are available:

The calculation of the water and refrigerant components are handled internally using the listed calculation procedures.

The humid air partial condensation process is modeled by assuming ideal conditions. In the first step, the gas is assumed to be cooled completely to the dew point. The second divides the remaining temperature range into equal segments and calculates the average C_p in each interval for the combined air and condensate mixture. Simply by selecting humid air and setting appropriate pressure and temperature levels can the segmented stream be calculated.

Tab. 4.3: Fluid Types

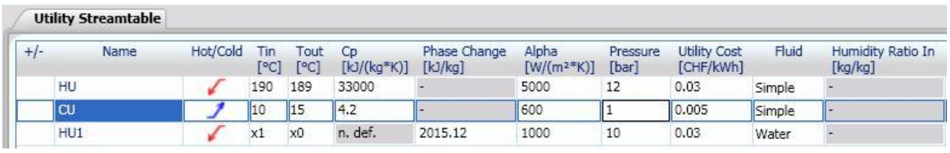
Fluid Type	**Name**	**Calculation Basis**
Water	H_2O	Stream properties calculated using the Steam Tables
Humid Air		Stream properties calculated for an air stream that experiences partial condensation
R134a	1.1.1.2-tetrafluoroethane	Properties calculated using the Lee and Kesler [4] equation of state
R245ca	1.1.2.2.3-pentafluoropropane	Properties calculated using the Lee and Kesler [4] equation of state
R245fa	1.1.1.3.3-tpentafluoropropane	Properties calculated using the Lee and Kesler [4] equation of state
R404A	R125 / 143a 134a (44/52/4)	Properties calculated using the Lee and Kesler [4] equation of state using pseudo mixture properties
R407C	R32 / 125 134a (23/25/52)	Properties calculated using the Lee and Kesler [4] equation of state using pseudo mixture properties
R410A	R32 / 125 (50/50)	Properties calculated using the Lee and Kesler [4] equation of state using pseudo mixture properties
R600	N-Butane	Properties calculated using the Lee and Kesler [4] equation of state
R600a	Iso-Butane	Properties calculated using the Lee and Kesler [4] equation of state
R601	N-Pentane	Properties calculated using the Lee and Kesler [4] equation of state
R717	NH_3 Ammonia	Properties calculated using the Lee and Kesler [4] equation of state
R718 Water	H_2O	Properties calculated using the Lee and Kesler [4] equation of state
R723	NH_3 Dimethyl-ether (60/40)	Properties calculated using the Lee and Kesler [4] equation of state using pseudo mixture properties
R744	CO_2	Properties calculated using the Lee and Kesler [4] equation of state

4.5 Configuring Utility Streams

In PinCH, process streams and utility streams are considered separately. A utility is defined as a stream that is used to provide the necessary energy requirements for heating and cooling the process being analyzed. Most significantly these are streams that are *not* necessary for the process to produce the product. A corollary to this statement is that a utility stream is one that can be replaced by any other utility stream as it is not part of the process.

A typical site utility is steam that can be used to exchange energy in a heat exchanger with other process streams. However, steam could be injected directly into a distillation column to replace the function of a reboiler in addition to providing additional stripping effects. In this case, the steam is more commonly considered as a process stream and not a utility.

Definition of utility streams is done on a separate window from the standard process streams. These streams are characterized by the fact that *no mass flow nor heat duty* can be entered (as it is in the Process Stream Table). The reason is that utility streams belong to a particular target result (see section 6) and the corresponding composite curve. Their heat duty is calculated directly based on the selected ΔT_{min} of the composite curves resulting in the direct determination of the required mass flow for the given heat capacity or phase change value. These calculations are handled internally and the user only needs to supply the state properties of the utilities they require (see Fig. 4.2)


Utility Streamtable

+/-	Name	Hot/Cold	Tin [°C]	Tout [°C]	Cp [kJ/(kg*K)]	Phase Change [kJ/kg]	Alpha [W/(m²*K)]	Pressure [bar]	Utility Cost [CHF/kWh]	Fluid	Humidity Ratio In [kg/kg]
	HU		190	189	33000	-	5000	12	0.03	Simple	-
	CU		10	15	4.2	-	600	1	0.005	Simple	-
	HU1		x1	x0	n. def.	2015.12	1000	10	0.03	Water	-

Fig. 4.2: Utility Stream Table Showing Multiple Utilities. Mass Flow and Heat Duty Are Not Given

4.6 Configuring Soft Streams

The concept of a soft stream relates to the fact the some process streams often are left on their own to equilibrate with the conditions of the environment. Examples include streams that are sent directly to tanks and can cool

or exhaust air vent to atmosphere. However, it may be beneficial to use a portion of such streams for additional energy recovery. Therefore, it is of value to assess in a process integration study if it is worthwhile to use a portion of this energy. As a result, the *Soft* parameter is included with process streams to allow the ability to easily check for energy integration possibilities with such soft parts of streams.
Within the target result (see section 6) the part of the stream that is considered hard or soft is taken into consideration in the targeting calculation where the soft part of the stream is excluded. On the process Stream Table the selection of the parameter soft only indicates the stream can potentially be used as a soft stream. The designation of how much of the stream is soft is done in the target result window (see section 6).

4.7 Importing And Exporting

The importance of being able to import from such spread sheeting software such as Excel is important for many engineers and technical employees as they often use such software for storing and calculating process related information. As a result, the Process Stream Table can be imported from a simple csv formatted file to allow easy insertion into the PinCH Process Stream Table regardless of the source. Given the prevalance of Excel in the marketplace the following example illustrates how to export and then import to this commercial software tool.

Exporting From the Process Stream Table:

1. Select *File / Open Project* and then open the 4StreamEx.xml located in the Example directory
2. Select the Process Stream Table tab
3. Select *File / Export Stream Table* to show the *Export Stream Table To...* dialog
4. Name and store the Comma Separated Values (csv) format file on to your desktop
5. Start Excel and select *File / Open*
6. In the Open Dialog, change the file type to **All Types**

7. In the Open Dialog, navigate to the desktop and select the saved csv format file that was exported in step 3

The process Stream Table information should now be displayed along with the headers showing the column names and units. Even though the data has been saved in a csv format, the saved format can be easily changed using the File / Save As menu item in Excel.

Note: Fluid streams are exported with only their bulk stream properties. As a result, any custom entered segment specific properties (e.g. α) will not be stored.

Importing To The Process Stream Table:

In order to import the Process Stream Table into PinCH from Excel, the format as seen after exporting will need to be used. *Therefore, by simply exporting the data to see the format, can the data be easily set up in Excel and then Imported using the following steps.*

1. Select *File / New Project*
2. Select *File / Import Stream Table* to show the Please choose a Stream Table to import dialog
3. Ensure the csv file that you wish to import is **not open in another program** before proceeding
4. Navigate to the desktop and select the saved csv that was exported previously

The data stored in the csv will be automatically loaded into the Process Stream Table and ready to be used in completing the pinch analysis calculations.

Note: Importing of stream data from a csv file will appended to the end of existing streams already entered into the stream table.

Chapter 5

Defining And Configuring Processes (Project Explorer)

5.1 Introduction

During the data extraction phase (see Fig. 3.7) a structured breakdown of individual processes within an industrial site can be identified. This structure defines the time and space boundaries as well as any limitations to interlinking between these boundaries and other constraints. PinCH supports the configuration and modeling of such structures through the definition of Processes. Processes contain the assignment of the stream requirements that are identified to be encapsulated within a single process. In addition, the scheduling on a time basis can be set in order to perform studies such as multiple base case analysis.

Finally, sets of global economic data can be defined that will be applied across all groupings of processes. These sets contain specific power law cost equation parameters for different heat exchangers as well as general site investment and operational cost parameters. Combined together with the processes as well as the scheduling, the energy-capital trade-off through heat recovery using a heat exchanger network can be calculated before any detailed design (see Section 6).

5.2 How To Create Processes And Assign Streams

Create a new process by using the PinCH Project Explorer dockable window. The project explorer encapsulates all the necessary functionality used to define the necessary static information for an industrial site (Fig. 5.1). The most critical first step is to create the processes defined as subsystems of the site and then assign streams.

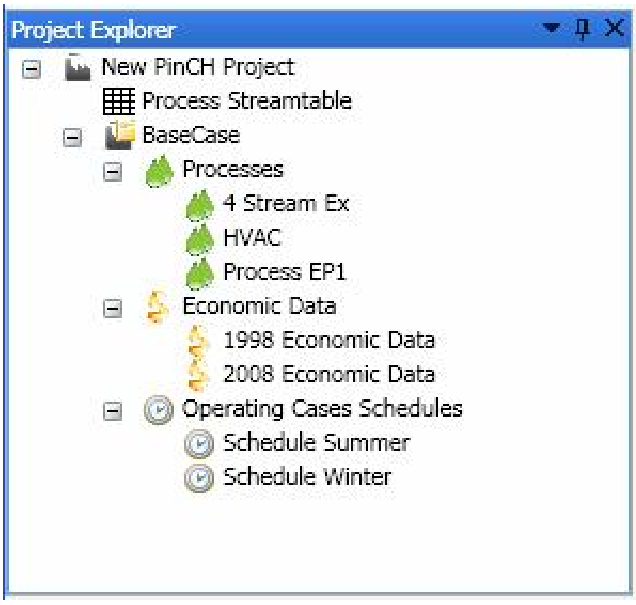


Fig. 5.1: Project Explorer

To create a Process:

1. Select and highlight the *Processes* node in the *Project Explorer*
2. Right click on the *Processes* node to view the context menu and select *Add Process*
3. Select the newly created process listed under the *Processes* node and press *F2*
4. Rename the node as required

To Assign Streams to a Process

1. Ensure to first select and highlight a created process listed under the *Processes* node (see Fig. 4.1)
2. Select the Process Stream Table tab
3. Select a stream in the upper Stream Table
4. Click with the left mouse button on the stream and hold and drag downwards to the working Stream Table
5. Release the mouse button to assign the stream to the process
6. Repeat for the number of streams to be assigned to the process

5.3 How To Create And Configure Global Economic Data

The Project Explorer can also be used to define different versions or sets of the global economic data as shown in Fig. 5.2.

On this entry dialog are given the heat exchanger power law equation parameters for process-process, cold utility-process and hot utility-process stream matching. In addition, the global energy prices as well as general site wide operational and investment cost are given. These cost parameters are used together in deriving the targeting cost result based on the area and number of units distributions as shown in appendix A1.

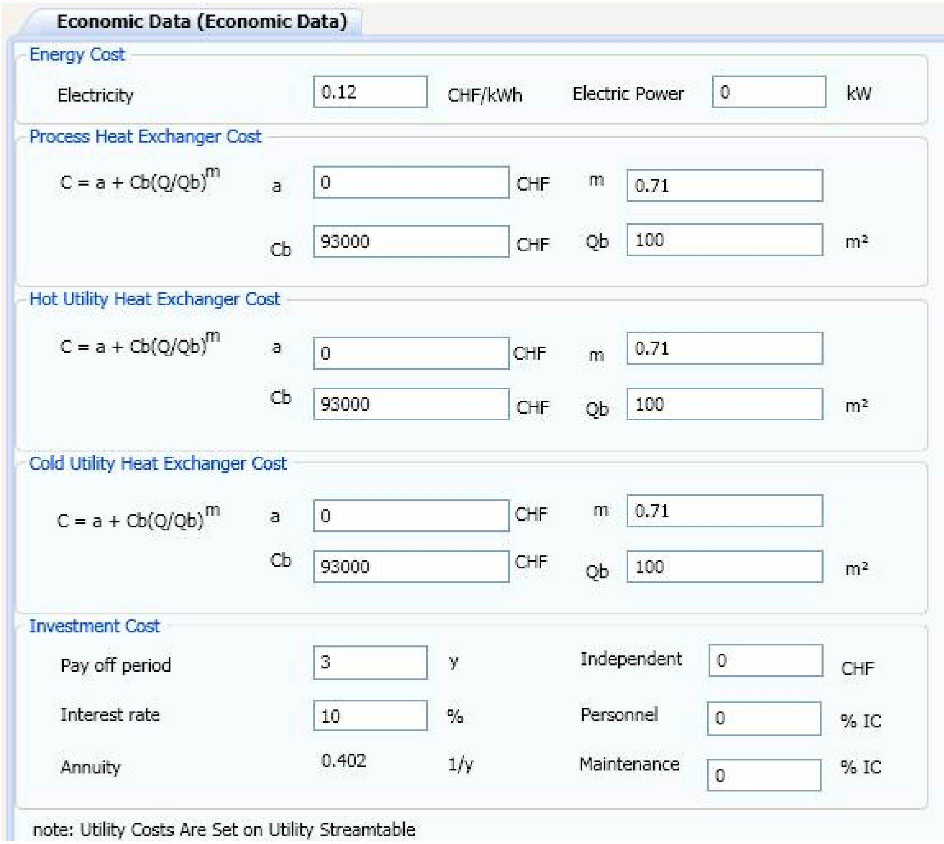


Fig. 5.2: Global Economic Data

To create a New Global Economic Data:

1. Select and highlight the *Economic Data* node in the *Project Explorer*
2. Right click on the *Economic Data* node to view the context menu and select *Add Economic Data*
3. Select the newly created economic data listed under the *Economic Data* node and press *F2*
4. Rename the node as required
5. Change the parameters as required

Note: The annuity factor is calculated and updated automatically once a new *Pay off Period* or *Interest Rate* is entered.

5.4 How To Create And Configure Operating Cases Schedules

To create a schedule or sets of schedules, the project explorer *Operating Cases Schedules* node can be used. On this dialog are given the fields to set the absolute *initialize or start time* of a process and its corresponding *operating time*.

Note: In the future additional fields will be added to allow the detailed scheduling of batch processes that run over multiple periods and can be overlapped.

To create a New Operating Cases Schedule:

1. Select and highlight the *Operating Cases Schedules* node in the *Project Explorer*
2. Right click on the *Operating Cases Schedules* node to view the context menu and select *Add Operating Cases Schedule*
3. Select the newly created schedule listed under the *Operating Cases Schedules* node and press *F2*
4. Rename the node as required
5. Change the time parameters as required

Chapter 6

Configuration And Calculation of Targeting Results (Target Explorer)

6.1 Introduction

Targeting calculations are a central part of a pinch analysis study. The significance of such calculations lies in the fact that a great deal of useful information can be calculated using only the stream based data established in the data extraction and energy modeling efforts. No detailed design needs to be completed at this part of the study which allows for rapid iterations in evaluating energy integration possibilities.
The main goal of the targeting calculations is to establish the minimum cold and hot utility requirements for a given set of process requirements as established during the data extraction phase (see section 4). In addition, the area and number of units distribution can also be established. The thermal, economic and time dependence data configured in the project explorer (see section 5) provide the foundation for these calculations and the link between the thermodynamic requirements with the economic realities. The theory and fundamental equations used in targeting calculations are not covered in the following sections. However, the user is recommended to review the following references for more information: [5 - 10].

In the PinCH software, several new key application components are used for creating and analyzing targeting results. The first is the Target Group where specific economic data, schedules, processes and utilities can be selected to calculate a Target Result. These components provide the basis for creating scenarios necessary in the iterative procedure often necessary for determining the most relevant target result. The details of these and other components are presented in the next sections.

6.2 How To Create And Configure A Target Group

Create a new Target Group using the Target Explorer. The target explorer encapsulates all the necessary functionality used in configuring and calculating the dynamic information used in analysis. (Fig. 6.1). The first step is to create a grouping of processes that are to be analyzed within a Target Group. More than one process can be selected allowing zonal targeting assessment.

Note: Duplicate streams are not allowed in the different processes that are added to the same targeting group.

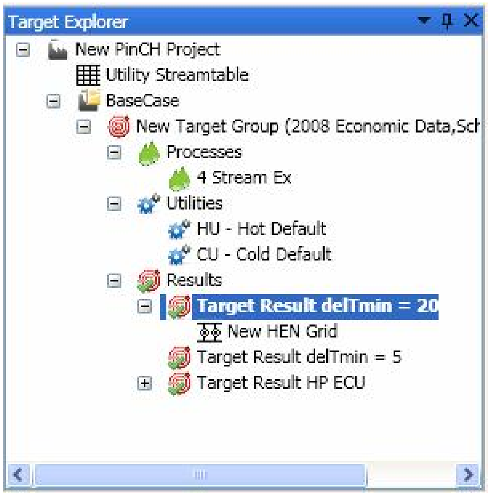


Fig. 6.1: Target Explorer

To create a Target Group:

1. Select and highlight the *BaseCase* node in the *Target Explorer*
2. Right click on the BaseCase node to view the context menu and select *Add Target Group*

3. Select the newly created target group listed under the *Processes* node and press *F2*

4. Rename the node as required

6.3 How To Create A Target Result

A target result is the central calculation object created when calculating the energy, area and unit targets used in performing a pinch analysis. However, as reviewed in section 3, there can exist differences in the time dependent nature of the underlying process streams that can result in two main result types - Continuous and Batch/Multiple Base Case (MBC).

6.3.1 Continuous Target Result

Continuous target results consist primarily of a single process or a grouping of multiple processes that are synchronized in time. All streams exist over the same time duration resulting in the creation of a single composite curve. Analysis is straightforward as it is assumed that each stream can potentially exchange energy with all other streams of the opposite hot or cold designation.

To Create Target Result for a Continuous Process:

1. Create a Target Group

2. Select and highlight the *Target Group* node in the *Target Explorer*

3. Right click on the *Target Group* node to view the context menu and select *Reassign Operating Cases Schedule* and re-assign a schedule as needed.

4. Right click on the *Target Group* node to view the context menu and select *Reassign Economic Data* and re-assign an economic data as needed.

5. Right click on the *Processes* node and select a process to be used in the analysis. Repeat for any additional processes to be combined together for the analysis.

6. Right click on the *Utilities* node and select a default hot and a default cold utility (see note given below)

7. Right click on the *Results* node and select *Separate Design Tool* to create the target result
8. All the nodes can be renamed after pressing F2

Note: It is critical to have created at least one hot and one cold stream in the Utility Stream Table. Please be certain to ensure the respective temperature ranges of these utilities provide enough driving force for the given process streams. These two utilities will need to be assigned as the default hot and cold utility in order to allow the internal energy balance to be closed. This is particularly important in the case of adding multiple utilities used in optimizing such systems.

After completing the above, a window will be created and anchored on the workbench with a tab. This window encapsulates the entire targeting result for the selected tool (in this case the Separate Design Tool) (Fig. 6.2). By selecting check boxes on the filter panel, the *composite curve, grand composite curve, balance composite curve, balanced grand composite curve, cost curve* as well as the *gantt chart* can be selected. Each will display automatically in the upper portion of the window while the specific targeting result for a given ΔT_{min} (entered on the *Main Control Panel*) is shown on the *Results Panel* data grid at the bottom of the window. Both the results for the composite curve (only includes the default hot and cold utility) and the balanced composite curve (includes the default hot and cold utility as well as any additional internal sized utilities) are shown on the Results Panel.

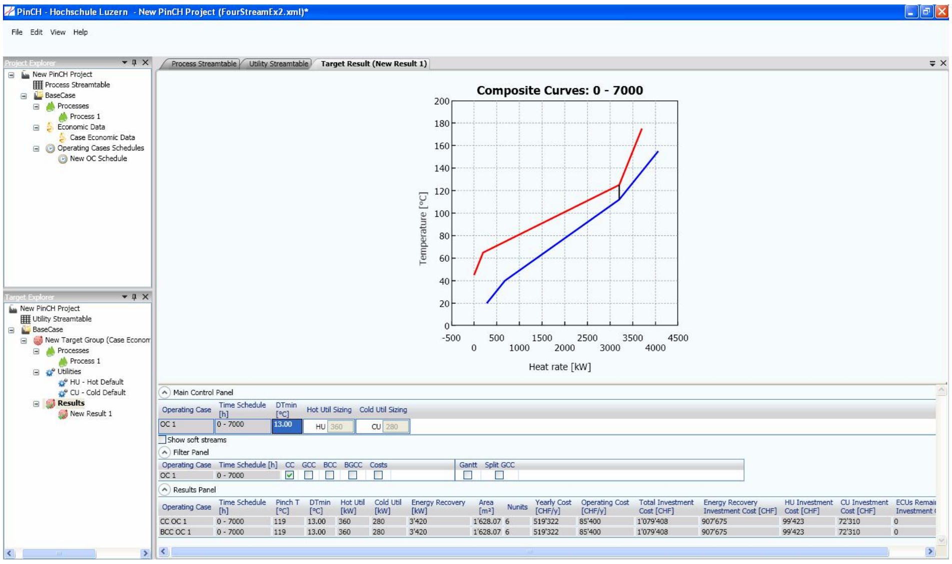


Fig. 6.2: Continuous Process Separate Design Tool Target Result

6.3.2 Batch / Multiple Base Case

Batch and Multiple Base Case target results consist either of a single process with differing stream existence times or of multiple continuous processes that overlap. These results are both characterized by multiple time slices each of which has its own composite curve. Analysis becomes complex as opportunities for energy recovery become bounded due to time constraints and it can not be assumed that each stream can potentially exchange energy with all other streams of opposite hot or cold designation at all times. However, PinCH provides the ability to easily view and compare the results in each time slice helping in the search for opportunities for better process integration.

To Create a Target Result for a Batch:

1. Create a Target Group
2. Select and highlight the *Target Group* node in the *Target Explorer*
3. Right click on the *Target Group* node to view the context menu and select *Reassign Operating Cases Schedule* and re-assign a schedule as needed.
4. Right click on the *Target Group* node to view the context menu and select *Reassign Economic Data* and re-assign an economic data as needed.

5. Right click on the *Processes* node and select a batch process to be used in the analysis. (Ensure the tstart and tstop have been included for each stream in the Process Stream Table beforehand).

6. Right click on the *Utilities* node and select a default hot and a default cold utility (see note given below)

7. Right click on the *Results* node and select *Separate Design Tool* to create the target result

8. All the nodes can be renamed after pressing F2

9. Select the *Results* node and select *Time Average Model Tool* to create a second target result

In this case, there are two tools available for analysis - **Separate Design Tool** and **Time Average Model Tool**. The separate design tool analyzes the *absolute* stream existence times and decomposes the data into separate *time slices* or *operating cases*. Each slice is independent of the other and can be analyzed on its own. However, the time average model simply assumes all the streams exist at the same time and weights them accordingly. This type of analysis represents that absolute minimum energy targets that can be achieved and is only realistic in an ideal sense given perfect energy storage capabilities. Nevertheless, these targets are useful for determining the global pinch and the absolute minimum energy requirements when completing a batch analysis [10].

Note: It is critical to have created at least one hot and one cold stream in the Utility Stream Table. Please be certain to ensure the respective temperature ranges of these utilities provide enough driving force for the given process streams. These two utilities will need to be assigned as the default hot and cold utility in order to allow the internal energy balance to be closed. This is particularly important in the case of adding multiple utilities used in optimizing such systems.

After completing the above, a window will be created and anchored on the workbench with a tab. This window encapsulates the entire targeting result for the selected tool (in this case either the Separate Design Tool or Time Average Model). Fig. 6.3 shows the result for a Separate Design Tool target result for a single batch process.

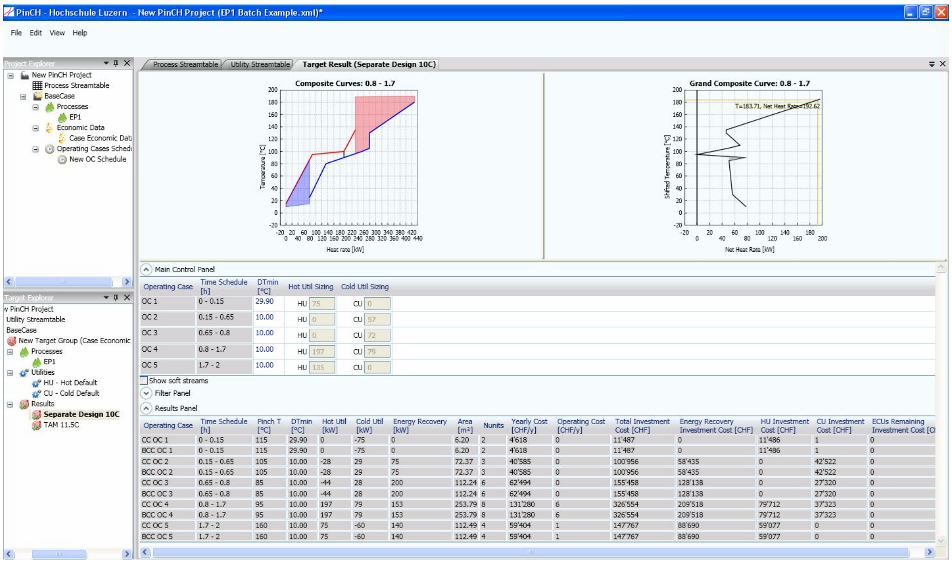


Fig. 6.3: Batch Process Separate Design Tool Target Result

By selecting check boxes on the filter panel, the *composite curve, grand composite curve, balance composite curve, balanced grand composite curve, cost curve as well as the gantt chart* can be selected for viewing. Each will be displayed automatically in the upper portion of the dockable window while the results for a given process ΔT_{min} (entered on the *Main Control Panel*) will be shown on the *Results Panel* data grid at the bottom of the window. The specific results for each time slice can be viewed on the Results Panel data grid. Both the results for the composite curve (only includes the default hot and cold utility) and the balanced composite curve (includes the default hot and cold utility as well as the additional internal sized utilities) are shown. Any multiple operating cases or time slices will also be listed in the data grids each row representing the targeting result for the particular slice.

6.4 How To Manage Targeting Results

One of the key advantages of the targeting explorer is the flexibility it gives in comparing different target results. For any particular target group multiple target results can be created and then automatically saved under the particular target group tree node. A structure of test cases can be saved directly and easily used in comparing the results of each to find the best energy integration option.

Creating Multiple Target Results:

1. Create a Target Result as described for either a Continuous or Batch process.
2. Right click on the same *Results* node and select *Separate Design Tool* to create a second target result.
3. All the nodes can be renamed after pressing F2.
4. Change the ΔT_{min} in the new Target result to a different value.
5. Repeat for required number of different ΔT_{min} values.

Note: Additional target results can be created when an ECU (see section Energy Conversion Units), soft streams or multiple utilities (see section 4) are added.

Comparing Multiple Target Results:

1. Create Multiple Target Results as described earlier.
2. Right click on each of the created target result nodes and select *Calculate and Show Target Result*.
3. Ensure all the target results windows are displayed as tabs in the center docked position.
4. Left click on one of the target result tabs and hold and drag to reposition. The dockable window anchor points will be displayed on the workbench (see Fig. 6.4).
5. Position the cursor while dragging over the right most anchor point.
6. The target result window will be placed beside the other target results still in the original center position (see Fig. 6.5).
7. Reposition the window edges by clicking with the left mouse button to shift the edges.

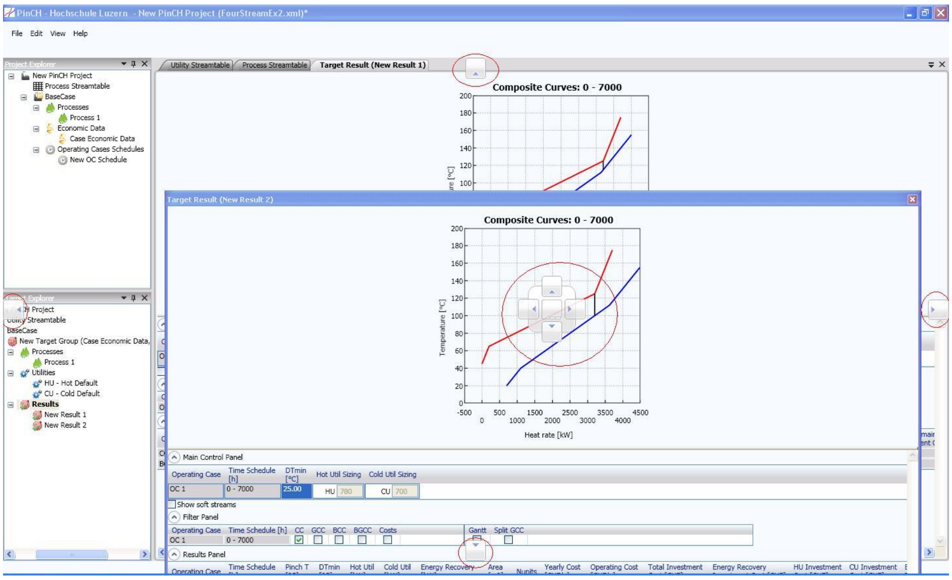


Fig. 6.4: Target Result Window Repositioning. Window Anchor Points are Shown In Red Circles

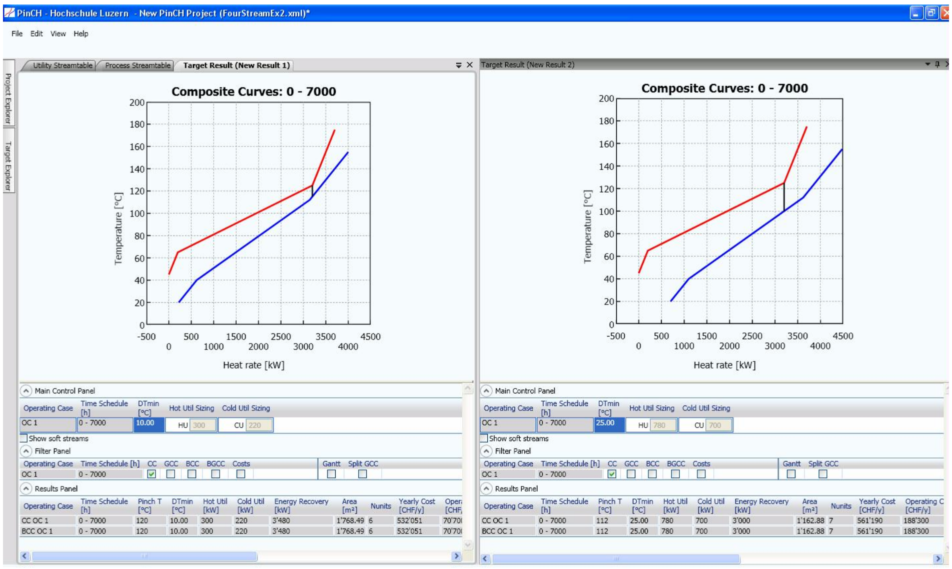


Fig. 6.5: Two Target Result Windows Positioned Side By Side To allow Comparison of Results

The management of target results also includes the handling of changes to the underlying data that affects a result. In PinCH any change such as a stream table parameter change, economic data change or schedule change will result in the previously saved Target Results no longer being synchronized with the changed data. Therefore, *all affected target results* *will be indicated as not synchronized such changes are made. The Target Result can be synchronized by closing and re-opening the Target Result.*

Handling Changes to Data That Effect Target Results:

1. Create a Target Result
2. Change a stream table parameter in the Process Stream Table for one of the streams in the process
3. A message box confirming the change results is displayed (Fig. 6.6). Select Yes
4. The Target Result icon is displayed in red to indicate it is no longer synchronized
5. Ensure the Target Result dockable window is closed and then re-open the Target Result. The icon will no longer be displayed in red and the result is synchronized with change.

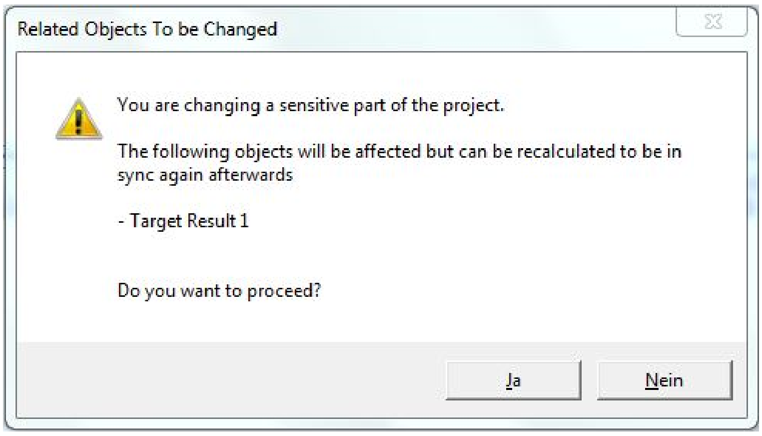


Fig. 6.6: Dialog Confirming Change that Affects All Dependent Target Results

6.5 Analyzing Results

The data derived from a Target Result can be viewed in the *Results Panel* data grid shown at the bottom of the window containing each Target Result (see Fig. 6.2 and Fig. 6.3). Several characteristics are to be noted regarding the display. First there are two rows displayed for a single operating case or time slice. Fig. 6.7 shows the two rows. The first row corresponds to the targeting result information based on the CC graph where only the default hot and cold utilities are added at the end of the composite curve. No other utilities are allowed. However, the second row is based on the BCC (or balanced composite curve) that includes any internal utilities in addition to the default utilities that have been included in the composite curve. It should be noted that the default utilities must always be added to a target result as they are automatically used to ensure the energy balance is complete regardless of the values entered for internal utilities.

Operating Case	Time Schedule [h]	Pinch T [°C]	ΔTmin [K]	Hot Util [kW]	Cold Util [kW]	Energy Recovery [kW]	Area [m²]	Nunits	Yearly Cost [CHF/y]	Operating Cost [CHF/y]	Total Investment Cost [CHF]	Energy Recovery Investment Cost [CHF]	HU Investment Cost [CHF]	CU Investment Cost [CHF]	ECUs Remaining Investment Cost [CHF]
CC OC 1	0 - 7000	75	10.00	148	168	672	162.14	5	166'938	86'184	200'880	171'702	11'061	18'117	0
BCC OC 1	0 - 7000	75	10.00	42	41	905	200.99	7	160'978	56'504	259'886	248'426	4'476	6'984	0

Fig. 6.7: Result Panel For a Continuous Process Target Result With a Single Operating Case And Two Rows For CC and BCC

A second characteristic of the results panel is that results are shown for each operating case or time slice determined to exist over the entire time period of operation of all processes. Fig. 6.8 illustrates the layout of results from a batch process showing the five operating cases and their individual targeting values. In addition, the totals for the targeting values when multiple operating cases or time slices exist are given at the bottom of the data grid.

Operating Case	Time Schedule [h]	Pinch T [°C]	ΔTmin [K]	Hot Util [kW]	Cold Util [kW]	Energy Recovery [kW]	Area [m²]	Nunits	Yearly Cost [CHF/y]	Operating Cost [CHF/y]	Total Investment Cost [CHF]	Energy Recovery Investment Cost [CHF]	HU Investment Cost [CHF]	CU Investment Cost [CHF]	ECUs Remaining Investment Cost [CHF]
CC OC 1	0 - 0.15	110	40.00	10	-65	0	5.11	3	3'705	0	9'216	2	9'214	0	0
BCC OC 1	0 - 0.15	110	40.00	10	-65	0	5.11	3	3'705	0	9'216	2	9'214	0	0
CC OC 2	0.15 - 0.65	115	40.00	5	62	70	67.15	3	35'832	0	89'134	48'536	2'068	38'530	0
BCC OC 2	0.15 - 0.65	115	40.00	5	62	70	67.15	3	35'832	0	89'134	48'536	2'068	38'530	0
CC OC 3	0.65 - 0.8	100	40.00	-12	60	200	112.24	6	62'494	0	155'458	128'138	0	27'320	0
BCC OC 3	0.65 - 0.8	100	40.00	-12	60	200	112.24	6	62'494	0	155'458	128'138	0	27'320	0
CC OC 4	0.8 - 1.7	100	40.00	279	161	71	145.99	7	82'540	8	205'302	56'432	87'281	61'589	0
BCC OC 4	0.8 - 1.7	100	40.00	279	161	71	145.99	7	82'540	8	205'302	56'432	87'281	61'589	0
CC OC 5	1.7 - 2	105	40.00	150	15	125	102.85	4	49'771	1	123'806	75'858	44'477	3'472	0
BCC OC 5	1.7 - 2	105	40.00	150	15	125	102.85	4	49'771	1	123'806	75'858	44'477	3'472	0
CC Total				432	233	467	433.33	23	234'342	10	582'915	308'965	143'040	130'911	
BCC Total				432	233	467	433.33	23	234'342	10	582'915	308'965	143'040	130'911	

Fig. 6.8: Result Panel For a Batch Process Target Result With a Multiple Operating Cases or Time Slices

The targeting values listed in these panels are summarized in the following table:

Tab. 6.1: Results Panel Targeting Values Table

Results Panel Values	**Description**	**Units**
Operating Case	The time slice in which specific stream exist at the same time	
Time Schedule	The absolute start and end time of an operating case or time slice	hour
Pinch T	The pinch temperature represented by the closest approach of the hot and the cold composite curve	°C
ΔT_{min}	The vertical distance between the hot and the cold composite curve at the closest point	K
Hot Util	The minimum amount of hot utility needed for heating based on the specified ΔT_{min} for the given composite curves	kW
Cold Util	The minimum amount of cold utility needed for cooling based on the specified ΔT_{min} for the given composite curves	kW
Energy Recovery	The amount of heat exchange between process-process or internal utility-process streams	kW
Area	The amount of heat exchanger area calculated based on the given composite curves and ΔT_{min} assuming vertical heat transfer for the spaghetti network [12]	m^2
Nunits	The total number of units calculated based on the given composite curve and ΔT_{min}	
Operating cost	The total annual operating cost for the given composite curve and ΔT_{min} (Utility, ECU and Site Electricity, maintenance and personnel)	CHF/ year
Total Investment Cost	The total cost of the required heat exchanger area plus any remaining ECU investment cost (e.g. compressor cost)	CHF

Continuation of table:

Results Panel Values	**Description**	**Units**
Energy Recovery Investment Cost	The heat exchanger investment cost associated with process-process or internal utility-process streams heat exchange	CHF
HU investment cost	The heat exchanger investment cost only associated with the default hot utility-process heat exchange	CHF
CU investment cost	The heat exchanger investment cost only associated with the default cold utility-process heat exchange	CHF
ECUs Remaining Investment Cost	Investment cost for ECUs not including the heat exchanger investment costs for ECUs. (Note: ECU heat exchanger investment costs are included directly in the Energy Recovery Investment cost calculation)	CHF

The results from a Target Result can be analyzed in two ways - i) within the PinCH program itself or ii) exported to another program. The first method is accomplished using the Results Panel and graphics as previously discussed. However, all data grids and graphics can be exported to other programs.

To Export Results Panel Table:

1. Calculate and Show a Target Result.
2. Press the ctrl button.
3. Select several rows in the Results Panel data grid to highlight (Hold the ctrl key to select individual rows).
4. Press ctrl + C to copy the selected rows.
5. Open an editing program such as Excel.
6. Press ctrl + V to paste the results into the program for editing.

To Export Graphics:

1. Calculate and Show a Target Result.
2. Right-click on the composite curve graph and select Save Image As.
3. Navigate to the desired directory location, enter a name for the png file and press save.

Note: All graphics in PinCH can be saved using the *Save Image As* context menu directly on each graphic by right clicking.

To Change Scaling of Graphics:

Each graphic can be analyzed in closer detail by changing the scale of the graphic in order to zoom closer in on a particular graph region. This can be done simply by positioning the mouse cursor over a graph at a required location and then using the mouse wheel to increase or decrease the scaling in the chosen region.

6.6 Energy Conversion Units

The uses of energy conversion units (ECU) are limited to individual target results. These ECUs allow the investigation of integrating such unit operations into the stream population for a given Target Result. In each case either one or more streams are inserted directly as new streams to be included in the target calculation.
Economic calculations for the ECU relate only to any remaining investment costs outside the heat exchanger cost as these are handled directly in the target area calculations. The following tables list the economic parameters and their values [14].

Tab. 6.2: ECU Materials of Construction Economic Factors Table

fm Materials of Construction	**Value**
Carbon steel (default)	1.0
Aluminium	1.3
Stainless steel (low grades)	2.4
Stainless steel (high grades)	3.4
Hastelloy C	3.6
Monel	4.1
Nickel and inconel	4.4
Titanium	5.8

Tab. 6.3: ECU Economic Pressure Factors Table

fp pressure	**Value**
0.01 bar	2.0
0.1 bar	1.3
0.5 to 7 bar (default)	1.0
50 bar	1.5
100 bar	1.9

Tab. 6.4: ECU Economic Temperature Factors Table

ft Temperature	**Value**
0 to 100°C (default)	1.0
300°C	1.6
500°C	2.1

There are four ECUs described in the following sections:

6.6.1 Heat Pump

The heat pump models a standard heat pump cycle that includes a regenerator heat exchanger as shown in appendix 11. After setting the correct parameters for the heat pump, two streams are created and inserted into the target result stream population - a condenser stream and an evaporator stream (see Fig. 6.9). Changes to the parameters automatically update the Target Result immediately unless an infeasible value is entered resulting in non-convergence results (e.g entered condensation temperature above critical temperature).

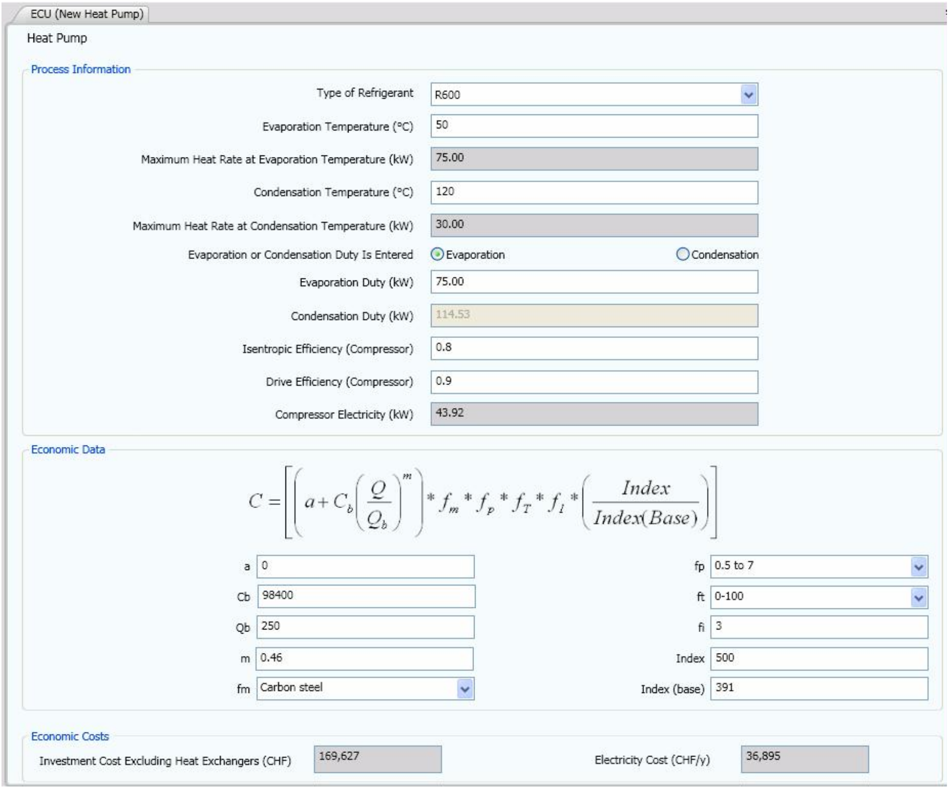


Fig. 6.9: Heat Pump Parameter Dialog

The parameters of the heat pump are described in the following table.

Note: Please see section 9 list of symbols for information regarding the economic data parameters. The base quantity for the heat pump is the **compressor electrical power**.

Tab. 6.5: Heat Pump Parameters

Heat Pump Parameters	**Description**	**Units**
Type of Refrigerant	Refrigerant used in the thermodynamic cycle calculation	
Evaporation Temperature	Temperature in the evaporator at which the refrigerant evaporates	°C
Maximum Heat Rate at Evaporation Temperature	The heat rate measured from the GCC of the *original composite curve* before the ECU is added at the given evaporation temperature	kW
Condensation Temperature	Temperature in the condenser at which the refrigerant condenses	°C
Maximum Heat Rate at Condensation Temperature	The heat rate measured from the GCC of the original composite curve before the ECU is added at the given condensation temperature	kW
Evaporation or Condensation	Flag to set if either the evaporation or condensation duty is entered (Given this value the other is calculated)	
Evaporation Duty	The duty of the heat transferred in the evaporator	kW
Condensation Duty	The duty of the heat transferred in the condenser	kW
Isentropic Efficiency	Efficiency of compressor process	
Drive Efficiency	Efficiency to include mechanical and electrical losses	
Compressor Electricity	Total electrical requirement to operate the compressor	kW
Investment Cost Excluding Heat Exchangers	Total investment cost for heat pump components outside the heat exchanger costs	CHF
Electricity Costs	Costs of electricity based on the price set in the global economic dialog	CHF/ year

6.6.2 Internal Combustion Engine

The internal combustion engine calculation is used for assessing the energy integration effects of a combined heat and power unit (CHP) as reviewed in appendix 11. After setting the correct parameters for the engine three streams are created and inserted into the target result stream population - a water stream, an oil stream and an exhaust air stream (see Fig. 6.10). Changes to the parameters automatically update the target result immediately unless an infeasible value is entered or non-convergence results.

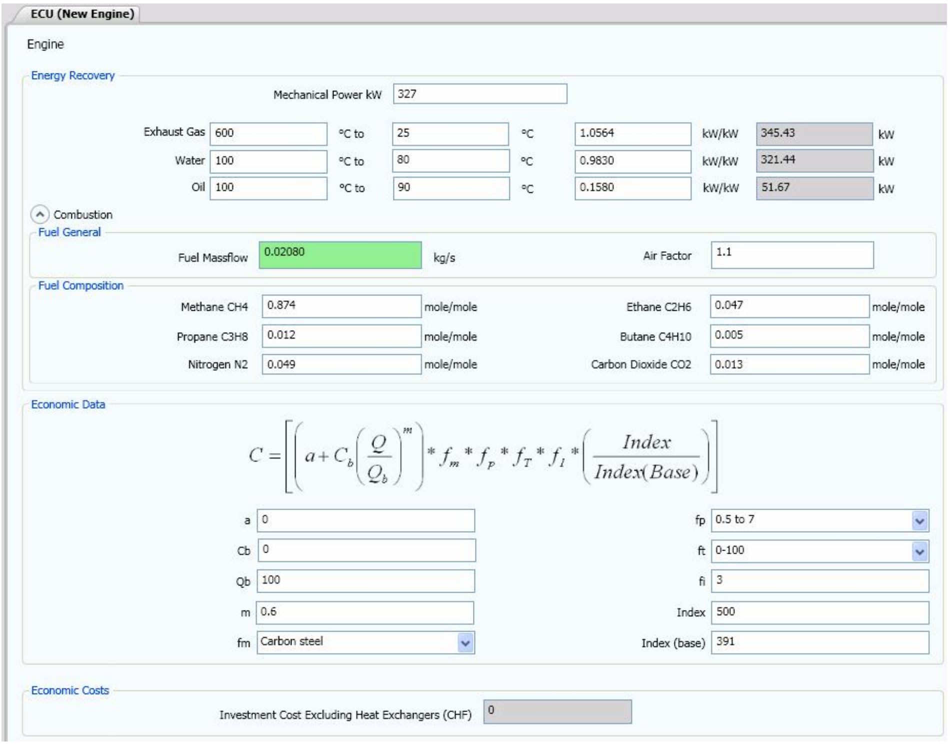


Fig. 6.10: Internal Combustion Engine ECU Parameter Dialog

The parameters of the engine are described in the following table.

Note: Please see section 9 list of symbols for information regarding the economic data parameters. The base quantity for the heat pump is the **mechanical power**.

Tab. 6.6: Internal Combustion Engine Parameters

Engine Parameters	**Description**	**Units**
Mechanical Power	Shaft power of the engine	kW
Exhaust Gas temperature range	Temperature from which the exhaust gas stream is cooled to	°C
Water temperature range	Temperature from which the water strean is cooled to	°C
Oil temperature range	Temperature from which the oil stream is cooled to	°C
Exhaust Gas heat duty load ratio	Heat duty load ratio used to approximate the energy that can be derived from the created water stream	
Water heat duty load ratio	Heat duty load ratio used to calculate the energy that can be derived from the created oil stream	
Oil heat duty load ratio	Heat duty load ratio used to calculate the energy that can be derived from the created oil stream	
Exhaust Gas stream energy recovery	Energy recovery approximated for the exhaust gas stream	kW
Water stream energy recovery	Energy recovery approximated for the water stream	kW
Oil stream energy recovery	Energy recovery approximated for the oil stream	kW
Fuel mass flow	Flow of the gas fuel	kg/s
Air Factor	Ratio of air to fuel flow rate	
Fuel Composition	Mole fractions of methane, ethane, propane and butane in the fuel feed	mole/ mole
Investment Cost Excluding Heat Exchangers	Total investment cost for the engine components outside the heat exchanger costs	CHF

6.6.3 Mechanical Vapour Recompression

The mechanical vapour recompression (MVR) models a standard compression cycle shown in appendix 11 . After setting the correct parameters for the MVR and selecting a *water vapour* stream to be upgraded in the compressor two new streams are created and inserted into the target result stream population (upgraded and reduced). The originally selected stream is removed (see Fig. 6.11) from the stream population. Changes to the parameters automatically update the target result immediately unless an infeasible value is entered or non-convergence results.

Note: The water vapour stream to be upgrade must be defined as R718 fluid which uses the equation of state given in [4].

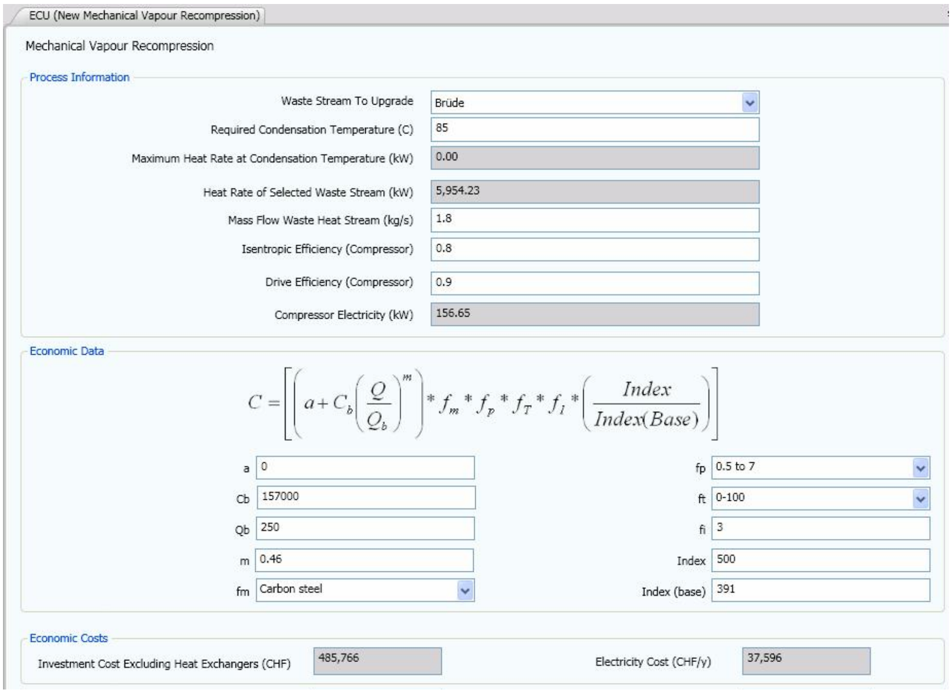


Fig. 6.11: Mechanical Vapour Recompression ECU Parameter Dialog

The parameters of the MVR are described in the following table.

Note: Please see section 9 list of symbols for information regarding the economic data parameters. The base quantity for the MVR is the compressor **electrical power**.

Mechanical Vapour Recompression Parameters	**Description**	**Units**
Vapour Stream to Upgrade	Water vapour stream to be upgraded by passing through the compressor (**limited to refrigerant R718 water fluid**)	
Condensation Temperature	Temperature at which the upgrade vapour stream it to condense at	°C
Maximum heat rate at condensation temperature	The heat rate measured from the GCC of the *original composite curve* before the ECU is added at the given condensation temperature	kW
Heat rate of selected waste heat stream	The heat rate taken directly from the selected waste heat stream	kW
Mass flow rate of selected waste heat stream	Flow rate portion of the waste heat stream to be upgraded in the compressor	kg/s
Isentropic Efficiency	Efficiency of the compressor process	
Drive Efficiency	Efficiency to include mechanical and electrical losses	
Investment cost excluding heat exchangers	Total investment cost for MVR components outside the heat exchanger costs	CHF
Electricity Cost	Cost of electricity based on the price set in the global economic dialog	CHF/ year

6.6.4 Thermal Vapour Recompression

The thermal vapour recompression (TVR) models a standard ejector as shown in appendix 11. After setting the correct parameters for the TVR and selecting the water vapour stream to be upgraded by steam injection, two new streams are created and inserted into the target result stream population (upgraded and reduced). The originally selected stream is removed (see Fig. 6.12) from the stream population. Changes to the parameters automatically update the target result immediately unless an infeasible value is entered or non-convergence results.

Note: The water vapour stream to be upgrade must be defined as R718 fluid which uses the equation of state given in [4].

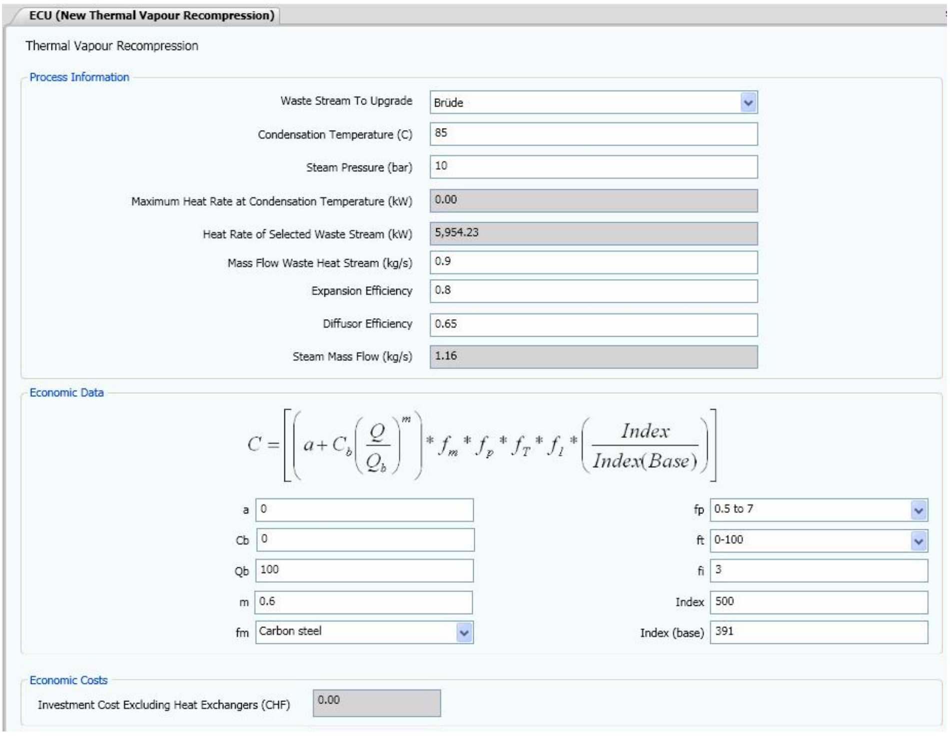


Fig. 6.12: Thermal Vapour Recompression ECU Parameter Dialog

The parameters of the TVR are described in the following table.

Note: Please see section 9 list of symbols for information regarding the economic data parameters. The base quantity for the MVR is the **steam flow rate**.

Thermal Vapour Recompression Parameters	**Description**	**Units**
Vapour Stream to Upgrade	Water vapour stream to be upgraded by passing through the compressor (**limited to refrigerant R718 water fluid**)	
Condensation temperature	Temperature at which the upgraded vapour stream is to condense at	°C
Steam Pressure	Pressure of saturated steam used to upgrade the water vapour stream to the required condensations temperature	bar
Maximum Heat Rate at Condensation Temperature	The heat rate measured from the GCC of the original composite curve before the ECU is added at the given condensation temperature	kW
Heat Rate of Selected Waste Heat Stream	The heat rate taken directly from the selected waste heat vapour stream	kW
Required Mass Flow of Vapour Stream To Upgrade	Flow rate of waste heat vapour stream to be upgraded in the compressor	kg/s
Expansion Efficiency	Efficiency of the expansion process	
Drive Efficiency	Efficiency to include mechanical and electrical losses	
Steam Mass Flow	Calculated mass flow rate of required steam to upgrade the waste heat stream to the required condensation temperature	kg/s
Investment Cost Excluding Heat Exchangers	Total investment cost for TVR components outside the heat exchanger Costs	CHF

6.7 Targeting Analysis Support Tools

Several tools presently exist to support the analysis of target results. The first is the Split Grand Composite Curve (Fig. 6.13). This graphic allows the display of two separate grand composite curves in separate Target Groups and Target Results in order to provide the ability to investigate the possibility of integrating the two processes. In addition, it can be used to assess indirect heat integration between time slices of a single batch process.

Note: The second selected grand composite curve is mirrored relative to the other grand composite curve.

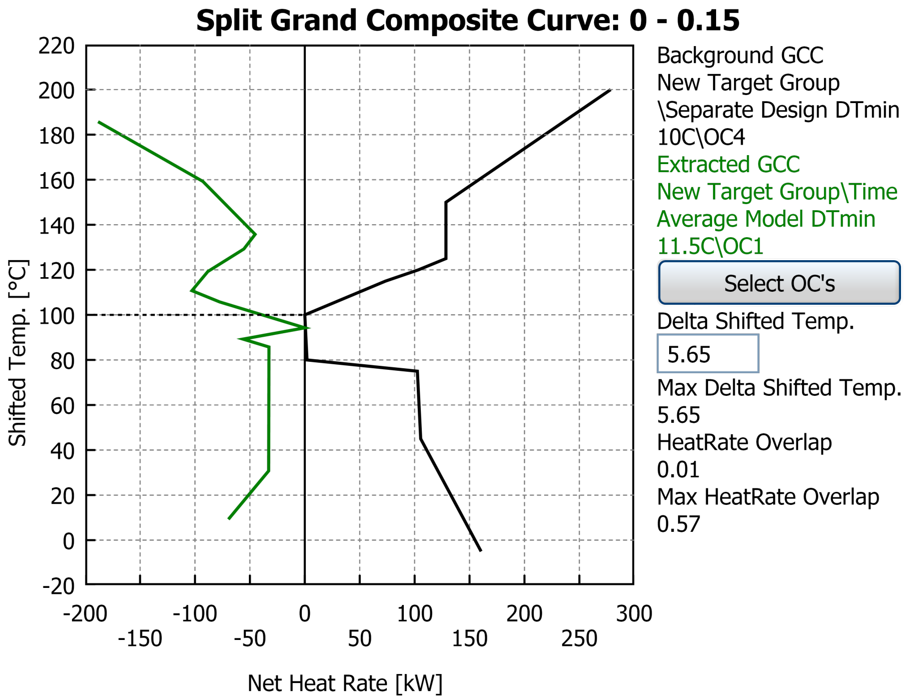


Fig. 6.13: Split Grand Composite Curve

The second tool is the Gantt chart. This graphic displays the processes assigned to the target group and their schedule on an *absolute* basis. In addition, the individual streams absolute positions can also be displayed by selecting the small button on the left end of the process bar (Fig. 6.14).

A third tool is an interaction tool or cross-hairs implemented for the Grand Composite Curve (GCC). This tool provides the ability to measure the net

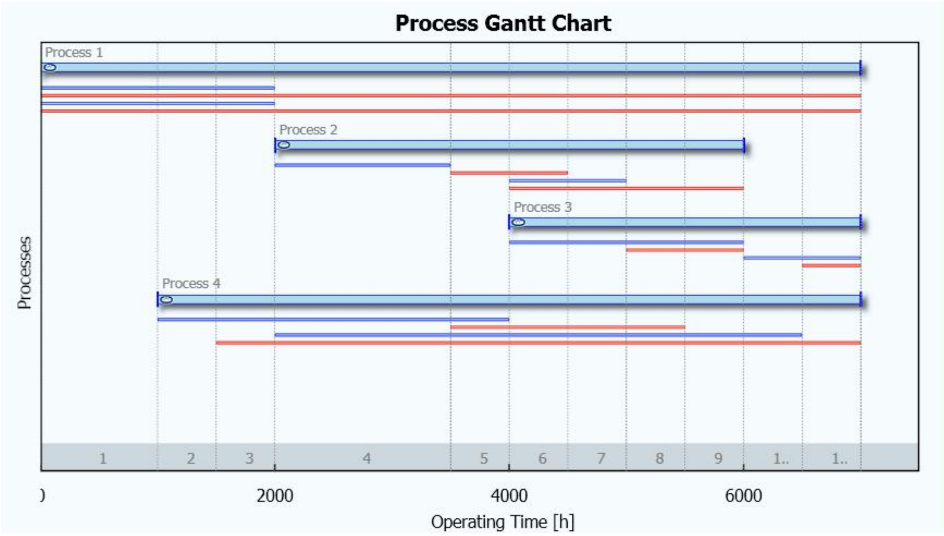


Fig. 6.14: Gantt Chart

heat rate at a given shifted temperature or conversely the shifted temperature for a given net heat rate (Fig. 6.15). In addition, if a stream consists of a phase change, then this segment can be directly selected. This action allows the setting of the quality value and displays the corresponding shifted temperature and heat rate portion. This functionality is primarily used for sizing internal utilities heat rates when performing a utility system optimization (see section 4).

Finally, the internal matchwise are calculation results can be exported for each Target Result. Thie results are exported based on a range of ΔT_{min} values and are saved as a comma-separated values forma file. This file can be easily opened in any editing or mathematical program such as Matlab.

To Export Area Matrices:

1. Create a Target Result
2. Right-click on the created Target Result node and select *Export > Export Matchwise Result Matrices*
3. Select the operating case to vary the ΔT_{min}
4. Enter a range of ΔT_{min} values to calculate the matchwise matrices
5. Select *Export* button and enter name and location
6. Press *Save*

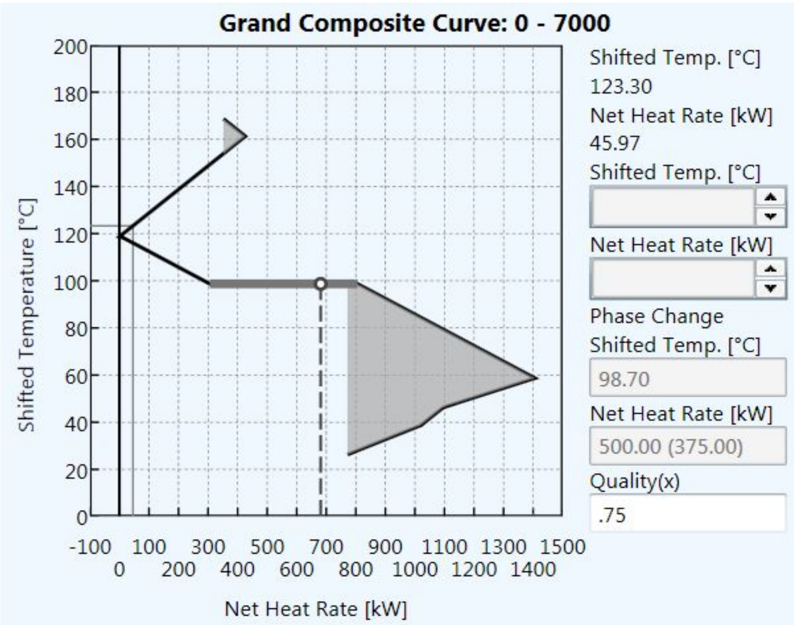


Fig. 6.15: Grand Composite Curve Interaction Tools

Chapter 7

Configuration And Calculation Of Detailed HEN Designs

7.1 Introduction

Following the calculation of a Target Result as discussed in section 6, a detailed heat exchanger network (HEN) design can be developed. This last step (step 10 - section ??) of the PinCH process requires substantial effort as there can be many possible solutions that need to be evaluated and compared. Also, in the case of retrofitting an existing process, the user will be required to balance the need to derive a network that achieves the calculated energy and cost targets with the realities and constraints of existing capital expenditure. It is a difficult process; however, the HEN design capabilities of PinCH provide an easy framework to rapidly develop new designs and to compare them. In PinCH there are three main types of HEN grids:

1. MER HEN Grid
2. Relaxed HEN Grid
3. HEN Grid which Includes Soft Stream Parts

In all cases can either a fully balanced HEN grid, which includes all intermediate utilities, or a grid with the just the default hot and cold utilities be created.

In order to create a heat exchanger network with maximum energy recovery (MER), the network is divided into two separate parts by the pinch temperature (a part that is entirely above the pinch line and a part that is entirely below as shown in Fig. 7.1. This figure highlights many of the key user interface graphical components available on the PinCH HEN grid before beginning to build the network. As can be seen in the diagram, two completely independent thermodynamic systems are formed that can be evaluated independently from each other (one above the pinch temperature and one below the pinch temperature). This division aids in reducing the complexity of the design problem and maintains one of the key pinch design rules of ensuring not to transfer heat across the pinch. The theory and documentation of the pinch design rules are not covered in this manual and the reader is recommended to review references [1 - 2],[5 - 10] and [14].

7.2 How To Create A HEN Grid

A HEN grid is bound to a particular Target Result and its corresponding ΔT_{min} for the given composite curve. Therefore, upon creating a HEN grid the pinch temperature and the associated utility values and streams are used to initialize the streams on the HEN grid.

To Create a MER HEN Grid:

1. Create a Target Result (see section 6).
2. Right click on the node of the created Target Result and select *Add HEN -> Add MER HEN.*

Note: If multiple utilities have been included in the Target Result a message box will appear asking if you would like to create either a balanced grid, which includes all the internal utilities, or a standard MER HEN grid where only the default Hot and Cold Utility are included.

A *Relaxed HEN Grid* allows the evaluation and analysis of an existing or retrofit network in order to compare with the MER HEN grid designs. Cross

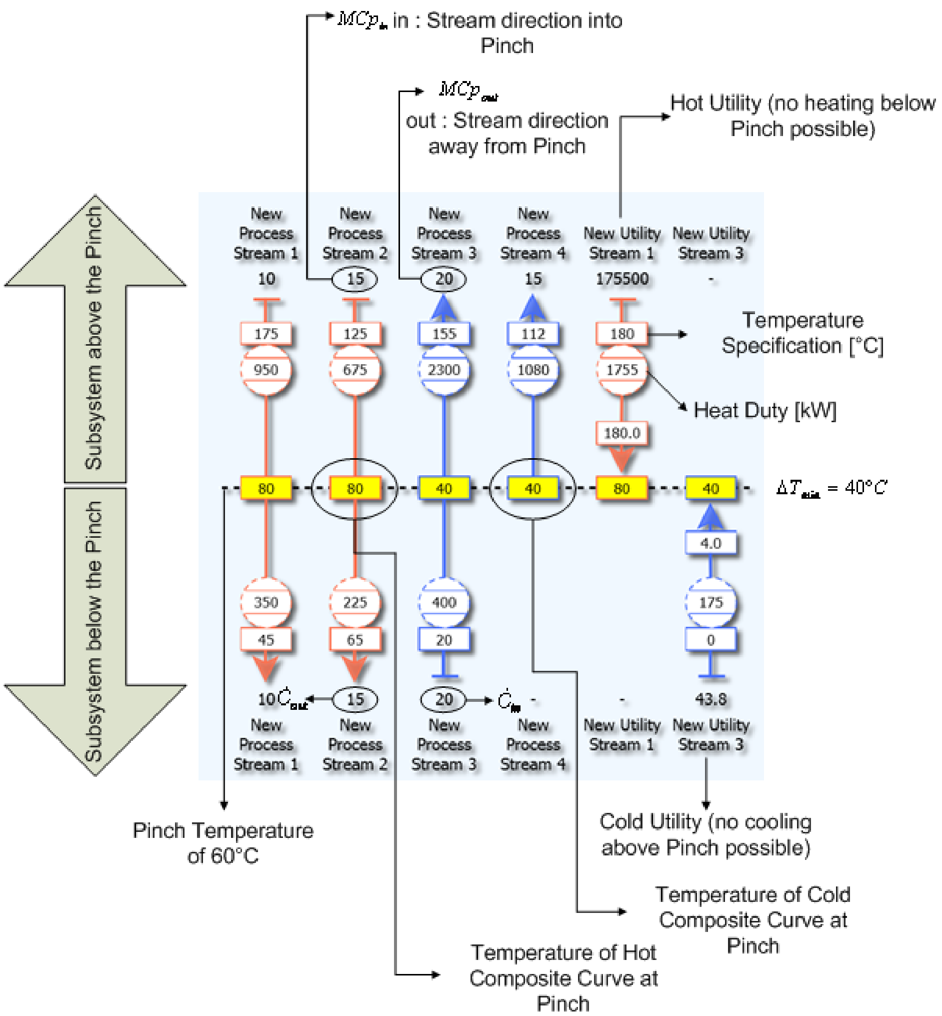


Fig. 7.1: Heat Exchanger Network Grid Parts

pinch heat transfer is represented by a diagonal line connecting a hot and cold stream heat exchanger (whereas non-cross pinch heat transfer is always shown with horizontally placed heat exchangers). In addition, ΔT_{min} is allowed to be *not be respected* permitting heat exchanger connection to be made where this value is less than that specified in the Target Result.

To create a Relaxed HEN Grid:

1. Create a Target Result (see section 6).
2. Right click on the node of the created Target Result and select *Add HEN -> Add Relaxed HEN.*

A *HEN Grid with Soft Stream Parts* allows the design of HEN grids which include the soft stream parts that were excluded in the Targeting calculation (see sections 4 and 6). The soft energy that was excluded is shown in a *Soft Pool* graphical object which allows the exceeding of the calculated MER values for the hot and cold utilities. This ensures the HEN grid energy balance can be completed, yet provides the flexibility for the user to create HEN designs that use the soft parts when necessary.

Note: This functionality is only recommended for expert users as a considerable amount of knowledge and experience is necessary in order to make the correct decision when to violate the MER design and use such soft streams directly.

7.3 Adding An Heat Exchanger

Heat exchanger matches can be easily added to the HEN grid using drag and drop functionality. The connection of two streams is limited by several key rules:

- Only a hot and a cold stream can be matched together
- Temperature crosses are not allowed
- The process ΔT_{min} must be respected (except for a Relaxed HEN Grid)
- The energy balance must be maintained

Fig. 7.2 illustrates an heat exchanger network grid with several heat exchangers added to a MER HEN design.

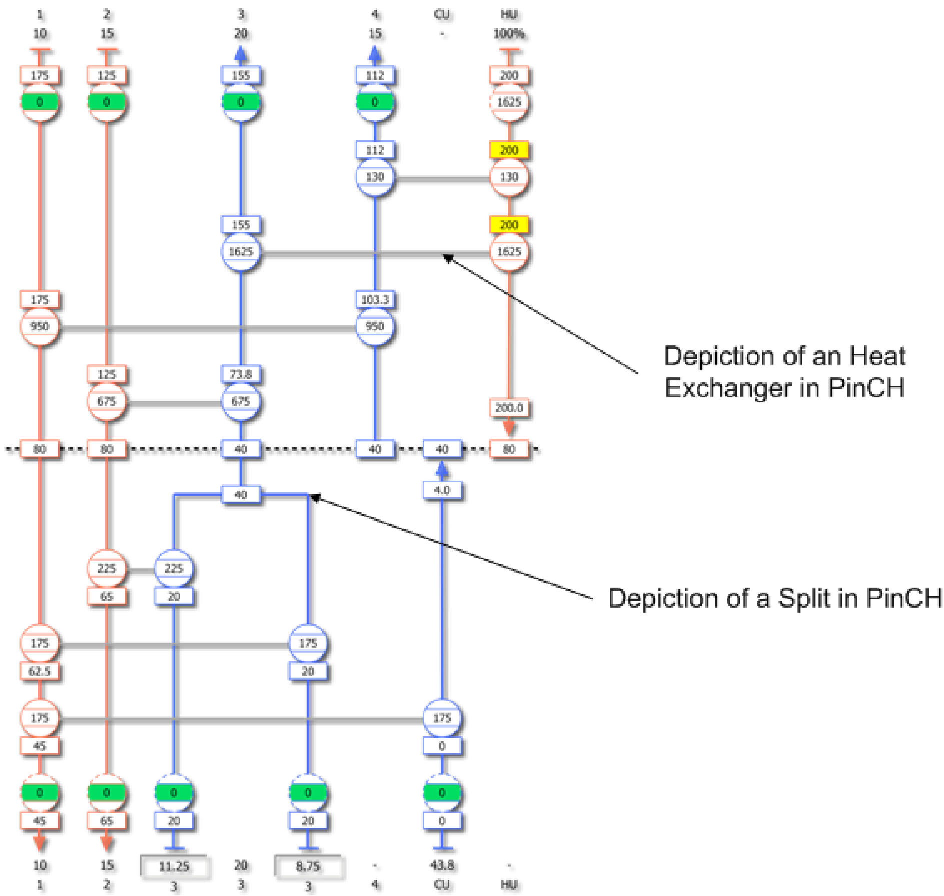


Fig. 7.2: Depiction of Heat Exchangers and Stream Split on HEN Grid

Note: PinCH will allow an HEX to exceed its energy balance limitation, but will mark the heat exchanger in red.

How to Add an Heat Exchanger:

1. Create a HEN Grid
2. Left click on a hot stream to add a *stream part*
3. Left click on a cold stream to add a stream part (Note: Ensure the MC_p rule based on the *Pinch Design Method* is maintained - MC_p of a stream going in a direction away from the pinch is greater than the MC_p of a stream going towards the pinch)
4. Left click on one of the newly added stream parts and *hold and drag* to the other stream part (ensure both stream parts are on the same vertical row as diagonal placement is not allowed for non-cross pinch heat exchange)

5. Release the left mouse button to create the match.

6. Double click in the HEX duty box to *tick-off* the entire duty of one of the stream (Note: According to the Pinch Design Method, it is recommended to always use the entire duty of one of the streams in a match)

7. Optionally, the temperature coming out of the stream parts can be directly specified

Note: PinCH will automatically check for the pinch design rules and ensure the energy balance is maintained. If the pinch design rules are not met then *matching stream parts will be disabled.* In addition, if an exchanger becomes pinched internally PinCH will only tick-off the duty up to the point of maintaining the ΔT_{min}.

7.4 Splitting And Merging

The ability to split a stream is very important in order to be able complete a HEN design and not be limited by the MC_p values of the streams above and below the pinch. The rules of when to split a stream are not covered in this document. However, the user is encourage to review the following references for more information [1 - 2],[5] and [10].

How to Split a Stream:

1. Create a MER HEN Grid

2. Left click on either a hot stream or a cold stream and select Split Stream

3. Select the MC_p box associated with one of the branches and enter a new MC_p value

Note: PinCH will automatically update the other MCp value and adjust the energy duties in each branch. Connections to other appropriate streams can now be made (see Fig. 7.3).

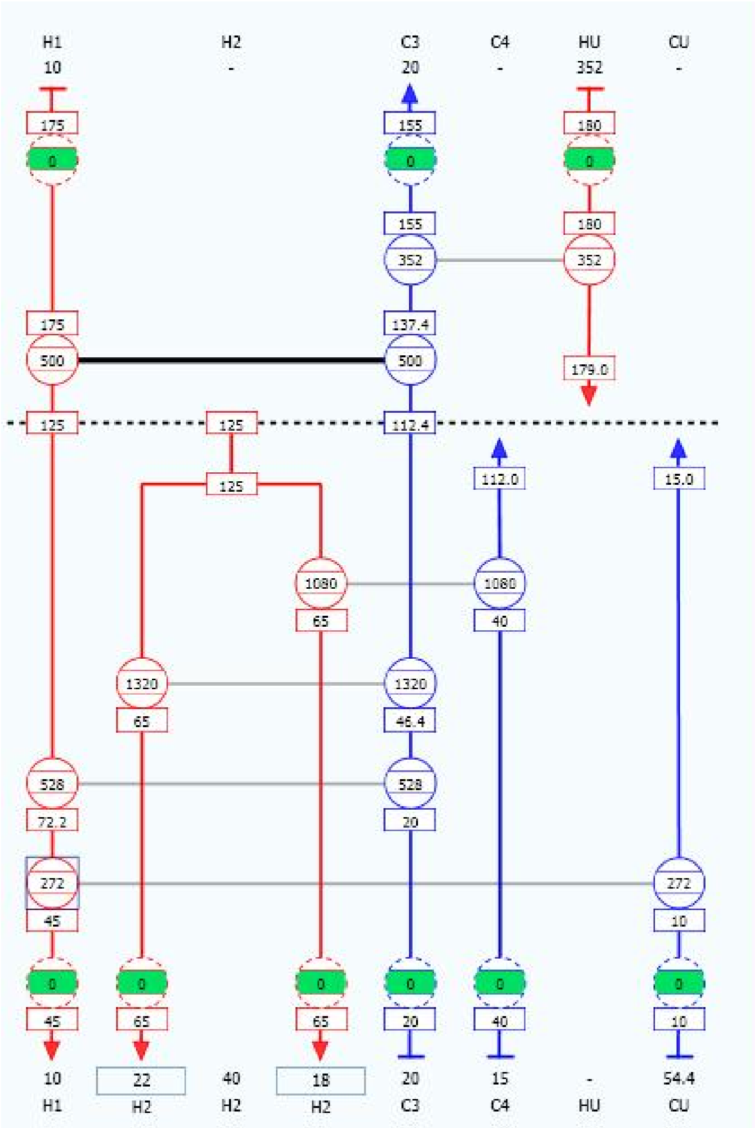


Fig. 7.3: Completed MER HEN Design Showing a Split

Merging is limited to *single streams that were originally split*. The merge must be isothermal and require the placing of a stream part on each split branch before merging.

How to Merge Stream Branches:

1. Create a MER HEN Grid
2. Split a stream

3. Add a stream part to each created stream branch
4. Left click on either branch and select Merge Branches
5. Select the MCp box associated with one of the branches and enter a new MCp value as required

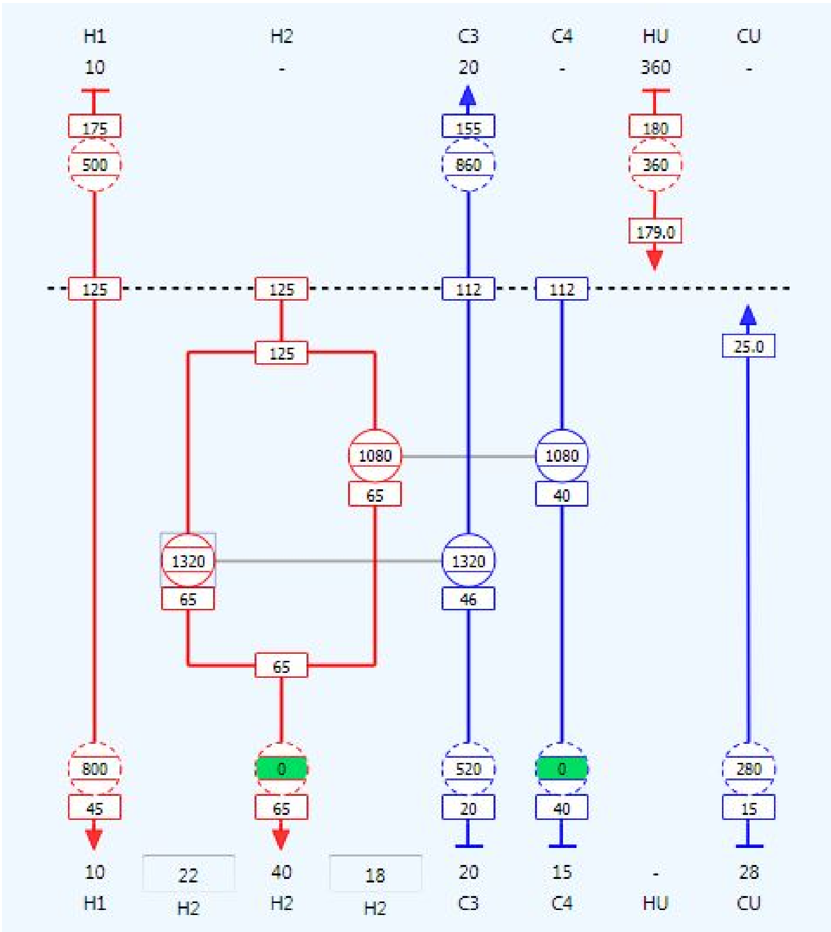


Fig. 7.4: HEN Grid With a Stream Merge

Note: Heat exchanger parts will be automatically added to each branch if a merge is made to a split that does not contain any manually added heat exchanger parts.

7.5 Analyzing Results

There are several graphical objects that can be used to analyze the results of a HEN grid design. The first is the *HEN Table*. This table displays upon initialization the Targeting Result data. The data is conveniently broken out into energy recovery values and utility values. As heat exchangers are added to the HEN grid then the design values are automatically added to the Design row in the table. This provides a convenient layout for comparing the design with targets in helping determine if the design is appropriate or not. Fig. 7.5 shows the completed result for the HEN design given previously in Fig. 7.3 and shows how close the target and design values are.

	Energy Recovery [kW]	Energy Recovery No. of Units	Energy Recovery Area [m²]	Energy Recovery Investment Cost [CHF]	Util No. of Units	Util Area [m²]	Util Investment Cost [CHF]
Design	3,428	4	1,746	997,512	2	168	163,061
Target	3,428	4	1,476	933,625	2	169	165,290

Fig. 7.5: HEN Table for Completed HEN Design

A second method of analyzing results is to use the *HEX table* (see Fig. 7.6). On this table is displayed the specific information for each placed HEX on the HEN Grid. The information includes the hot and cold streams properties and well as the HEX area, LMTD, k-value, cost and type selected. This data grid conveniently allows the analysis and comparison of each exchanger with the others.

How to Open the HEX Table:

1. Create a MER HEN Grid
2. Add an Heat Exchanger
3. Select the line joining the two heat exchanger part (Note: the line should be highlighted in black)
4. Double click the black highlighted line to open the HEX Table.

Finally, the HEX can easily be used to calculated the total real cost of the design by adding up the cost column values. This can be simply accomplished by *copy and paste* of data grid information into a spread sheet program such Microsoft Excel.

The individual HEXs are calculated by default assuming *counter current* heat exchange. However, it is possible to change the form factor used in the UA

Name	Heat Load [kW]	Hot Stream	Hot TIn [°C]	Hot TOut [°C]	Hot Mass Flow [kg/s]	Hot Cp [kJ/(kg*K)]	Hot MCp [kW/K]	Cold Stream	Cold TIn [°C]	Cold TOut [°C]	Cold Mass Flow [kg/s]	Cold Cp [kJ/(kg*K)]	Cold MCp [kW/K]	LMTD [°C]	Area [m²]	Cost [CHF]	HEX Type
H1 - C3	500	H1	175.00	125.00	1.00	10.00	10.00	C3	112.40	137.40	1.00	20.00	20.00	22.87	219	162,077	Counter Current
HU - C3	352	HU	180.00	179.00	0.01	30,000.00	352.00	C3	137.40	155.00	1.00	20.00	20.00	32.6	108	98,210	Counter Current
H2 - C4	1,080	H2	125.00	65.00	0.45	40.00	18.00	C4	40.00	112.00	1.00	15.00	15.00	18.35	589	327,356	Counter Current
H2 - C3	1,320	H2	125.00	65.00	0.55	40.00	22.00	C3	46.40	112.40	1.00	20.00	20.00	15.41	857	427,401	Counter Current
H1 - C3	528	H1	125.00	72.20	1.00	10.00	10.00	C3	20.00	46.40	1.00	20.00	20.00	64.5	82	80,678	Counter Current
H1 - CU	272	H1	72.20	45.00	1.00	10.00	10.00	CU	10.00	15.00	18.13	3.00	54.40	45.19	60	64,851	Counter Current

Fig. 7.6: HEX Table for Complete HEN Design

calculation to better represent a non-ideal situation in a real plant setting. Fig. 7.7 shows the options available for changing the parameters that affect the area and cost calculation of the individual heat exchanger. The film heat transfer coefficient (α) values are initialized from the stream table; however, they can be overwritten in the *Heat Transfer Coefficient boxes*. The same is true for the *Heat Exchanger Cost* parameters. Finally the calculated form factor correlations are derived from [11].

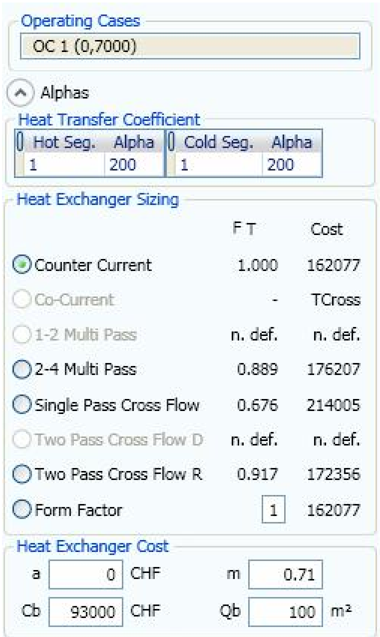


Fig. 7.7: HEN Sizing Options Dialog

7.6 HEN Design Support Tools

Two tools presently exist to support the analysis of heat exchanger networks and heat exchangers. The first is the *Driving Force Plot* (see Fig. 7.8).

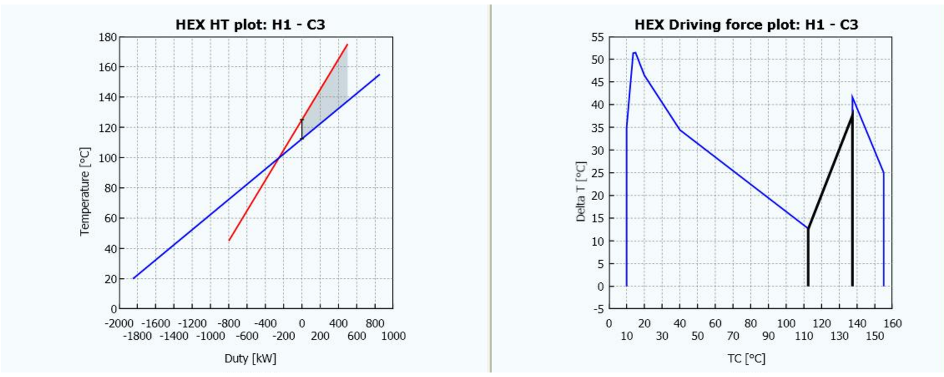


Fig. 7.8: Enthalpy versus Temperature Plot and Driving Force Plot

This graphic is useful for assessing how well a particular heat exchanger approximates the vertical heat transfer model. The plot is created by calculating the differences in terminal temperatures of a counter-current heat exchanger versus the Driving Force Plot derived from the composite curve. The driving force plot is simply the temperature difference at the inflection points of the composite curve versus the cold temperature at the same point. The application and analysis of the driving force plot is reviewed in [1].

The second support tool is the *Enthalpy versus Temperature Plot* (HT Plot - see Fig. 7.8). This plot provides an effective means of checking the driving force of the selected heat exchanger relative to the given ΔT_{min}. This plot is very effective at quickly visualizing the driving forces within a heat exchanger, in particular the LMTD which has a significant impact on the required area. In addition, an internal heat exchanger pinch can be identified if multiple segments are used that result in a point within the heat exchanger where the ΔT_{min} occurs (and not at the end of the exchanger).

Chapter 8

Menus, Preferences And Keyboard Commands

The PinCH menus display equivalent key commands next to many of the commands, so you can execute commands directly from the keyboard.

It should be noted that all commands are not always available and depend on the state of the program or action being executed. The classic example is that the Save menu will be disabled when no changes have been made to a project. If a change has been made then this menu item is enabled and the program title is appended with **"*"** to indicate that changes have been made and must be saved or they will be lost. Upon closing you will be asked to confirm this situation.

The following tables list the commands presently available in this version and any associated key board shortcut that exists.

Tab. 8.1: File Menu Commands

File Menu Command	**Key Board Command**
New Project	CTRL + N
Open Project	CTRL + O
Close Project	
Save Project	CTRL + S
Save Project As...	
Import Stream Table	
Export Stream Table	
Exit	

Tab. 8.2: Edit Menu Commands

Edit Menu Command	**Key Board Command**
Undo	CTRL + Z
Redo	CTRL + Y
Copy	CTRL + C
Paste	CTRL + V

Tab. 8.3: View Menu Commands

View Menu Command	**Key Board Command**
Save Custom Layout	
Load Custom Layout	
Restore Initial Layout	

Tab. 8.4: Help Menu Commands

Help Menu Command	**Key Board Command**
First Steps	
PinCH Home	
Help	F1
About	

Workbench and Dockable Windows:

The workbench is composed of dockable windows that can be moved and repositioned throughout the workbench. This allows easy comparison of results or data that has been entered (see Fig. 6.5). However, the situation may arise whereby you want to automatically return to a simpler default layout of the windows. As shown above under the *View* commands it is possible to use either the default initial layout or to save your own layout and *restore the layout* as needed.

Chapter 9

List of Symbols And Acronyms

9.1 Symbols

A	Heat exchanger surface area	m^2
a	Fixed investment cost component	CHF
C	Investment Cost	CHF
Cb	Base Cost	CHF
Cp	Specific heat capacity (at constant pressure)	kJ/kg K
fm	Materials of construction factor	[-]
fp	Pressure factor	[-]
ft	Temperature factor	[-]
fi	Installation faction	[-]
Index	Cost Index (e.g. default values CE Plant Cost Index)	[-]
Qb	ECU cost *base quantity* for an ECU	kW, kg/s
ΔT	Minimum temperature difference	K
X	Humidity ratio	kg H2O / kg Dry Air
ϕ	Relative humidity	[%]
A_{min}	Minimum area target for an entire network	m^2
$A_{min,L}$	Minimum area contribution of exchanger specification	m^2
i	Hot stream	[-]
j	Cold stream	[-]
k	Enthalpy interval	[-]
L	Exchanger specification	[-]
Ni	Number of enthalpy intervals	[-]
NE	Number of different exchanger specification	[-]
NHL	Number of hot streams with exchanger specification L	[-]
NCL	Number of cold streams with exchanger specification L	[-]

Q(i,j)	Heat rate between hot stream i and cold stream j	W
α	Film heat transfer coefficient	W/m^2 K
k	Overall heat transfer coefficient	W/m^2 K
m_T	Mass flow *steam* stream (Treibstoff)	kg/s
m_F	Mass flow waste heat vapour stream (Forderstrom)	kg/s
ξ_{Tr}	Entrainment (reversible)	[-]
ξ_T	Entrainment (irreversible)	[-]
h_F	Specific enthalpy waste heat vapour stream	kJ/kg
$hmix$	Specific enthalpy mixture	kJ/kg
h_T	Specific enthalpy *steam* stream (Treibstoff)	kJ/kg
η_D	Diffusor efficiency	[-]
η_E	Expander efficiency	[-]

9.2 Acronyms

BCC	Balanced Composite Curve
BGCC	Balanced Grand Composite Curve
CC	Composite Curve
csv	Comma Separated Values format
CU	Cold Utility
ECU	Energy Conversion Unit
GCC	Grand Composite Curve
HVAC	Heating Ventilation Air Conditioning
HEX	Heat Exchanger
HEN	Heat Exchanger Network
HP	Heat Pump
HU	Hot Utility
MER	Minimum Energy Requirement, Maximum Energy Recovery
MVR	Mechanical Vapour Recompression
MBC	Multiple Base Case
png	portable network graphics file
Split GCC	Split Grand Composite Curve
TVR	Thermal Vapour Recompression

Chapter 10

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Chapter 11

Appendix

A1: Area And Number Of Units

The internal calculations used for targeting are based on the approach published in [12]. This approach extends the traditional Uniform Bath formula to give the flexibility to apply different heat exchanger cost formulas for a given stream. In PinCH different cost formulas can be defined for either hot or cold utility exchangers or for process-process heat exchangers. In order to accomplish this differentiation in heat exchanger type, the area calculation is changed to provide a matchwise area distribution. The reader is encouraged to read the original paper for details for more information on the derivation of the following formula.

$$A_{min\,L} = \sum_{k=1}^{N_i} \frac{1}{LMTD,k} \sum_{i=1}^{NHL} \sum_{j=1}^{NCL} Q_{(i,j)\,k,L} \left(\frac{1}{\alpha_{i,j}} + \frac{1}{\alpha_{j,i}} \right)$$

Given an area distribution for each heat exchanger match, it becomes imperative to establish the number of units that can be attributed to each type of heat exchanger specification. Like the area distribution, it is insufficient to assume an equal distribution as done in early targeting calculations; therefore, a unit distribution must be calculated. The chosen method for calculating a unit distribution is to start with the known number of matches above and below the pinch temperature assuming the "spaghetti" design vertical heat transfer model. Next, for each heat exchanger specification the number of matches above and below the process pinch can also be determined. These values can be then be used to weight the number of units calculated in a standard manner to provide the number of units for a specific exchanger specification as shown in the following equation.

$$Nunit, L = (Na - 1)\,\frac{Va, L}{Va} + (Nb - 1)\,\frac{Vb, L}{Vb}$$

A2: Heat Pump Energy Conversion Unit

The heat pump energy conversion unit operation model provides a simplified representation of a heat pump with an internal regenerator. This model provides the energy integration streams associated with the condenser and the evaporator that can be included in the stream population for a particular targeting result. The required heat loads for both the condenser and the evaporator are ideally sized using the grand composite curve for the original targeting result and must be properly placed relative to the pinch. The key calculation for the heat pump thermodynamic cycle is the isentropic calculation across the compressor. An isentropic efficiency entered in the heat pump dialog is used to simply calculate the actual enthalpy requirement across the compressor. The calculation uses an internal fluid phase flash calculations based on the equation of state in [4] to calculate the specific enthalpy exiting the compressor. Once this state is known the rest of the cycle can be solved. The schemas of the heat pump as well as the thermal cycle are shown in the following figures.

Note: The Mechanical Vapour Recompression (MVR) ECU uses the same compressor calculation as the heat pump.

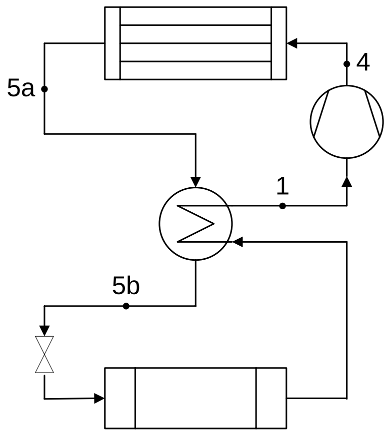

Fig. 11.1: Heat Pump Energy Conversion Unit with Regenerator

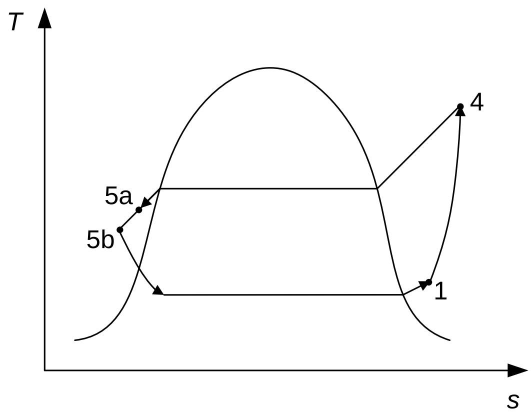

Fig. 11.2: T, s-diagram of Heat Pump Cycle

A3: Internal Combustion Engine Energy Conversion Unit

The Engine calculation is used for assessing the energy integration effects of including a combined heat and power unit (CHP). The engine ECU incorporates a standard combustion calculation as well as heat load ratios. The result is the creation of three separate streams that are used as additional process streams and are automatically included in the stream population on the level of the Target Result. They are as follows:

1. Water flow stream
2. Engine oil stream
3. Exhaust Gas stream

The first two streams are calculated using a simple engine heat load calculation based on the factors already displayed on the engine dialog. These factors are based on standard ratios of waste heat energy to mechanical power generated. These ratios can be edited as needed.

The displayed Exhaust Gas heat load factor is only to provide an indication of the possible heat load that can be recovered. The *actual amount of exhaust gas waste heat is calculated internally based on a standard combustion calculation* as listed in the following steps:

1. An air stream at 50% humidity and 15 C is assumed to be mixed and burned with the fuel with given composition as entered on the Engine Dialog.
2. The mole fractions of N_2, O_2 and H_2O in air stream are calculated.
3. The ratio for moles of Air/moles of fuel and moles of exhaust air/moles of fuel are calculated based on the stoichimetric quantities and the given air to fuel ratio.
4. The moles of O_2, N_2, CO_2, H_2O / mole of fuel are calculated.
5. The mole fractions of N_2, O_2, CO_2 and H_2O in exhaust gas are calculated.
6. The mass fractions N_2, O_2, CO_2 and H_2O in exhaust gas are the calculated.
7. The mass fractions N_2, O_2, CO_2 and H_2O in exhaust gas on a dry basis are calculated
8. The dry basis mass fractions are then used to calculate enthalpies at inlet and outlet conditions by simply summing the enthalpy contributions of each exhaust gas component over the given cooling temperature range. The water enthalpy contribution is handled in a similar manner with the addition of the heat of condensation.
9. Given the inlet and outlet enthalpy data calculated in step 8, the stream segments are then calculated assuming an average C_p per segment temperature range.

A4: Mechanical Vapour Recompression Energy Conversion Unit

The mechanical vapour recompression energy conversion unit operates with the similar goal as the thermal vapour recompression unit. However, this unit utilizes a compressor to achieve the temperature lift necessary to reach the required condensation temperature. The MVR is also in principle a heat pump, yet is an open system that takes an existing stream and upgrades it to a higher pressure and condensation temperature. The following figure illustrates the operation of an MVR. Note: The selection of the water vapour stream is limited to the fluid **R718 (water)** based on the equation of state given in [4].

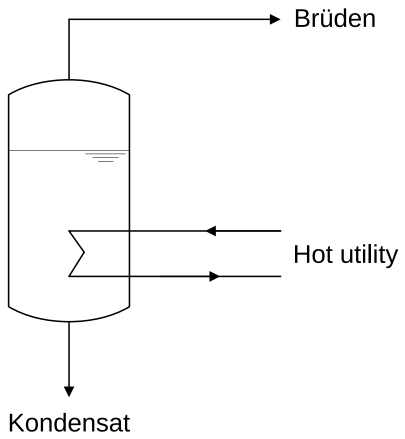

Fig. 11.3: Simple Evaporator Unit

The stream selected is limited to a water vapour stream that is subcooled. The amount of this stream to upgrade is set in the MVR dialog allowing the same compressor calculation as listed in Appendix 11 (see Heat Pump Energy Conversion Unit) to determine the state at the outlet of the compressor. The electrical power requirements incorporating thermal and drive efficiencies can then be calculated and used in the cost calculation for the compressor.

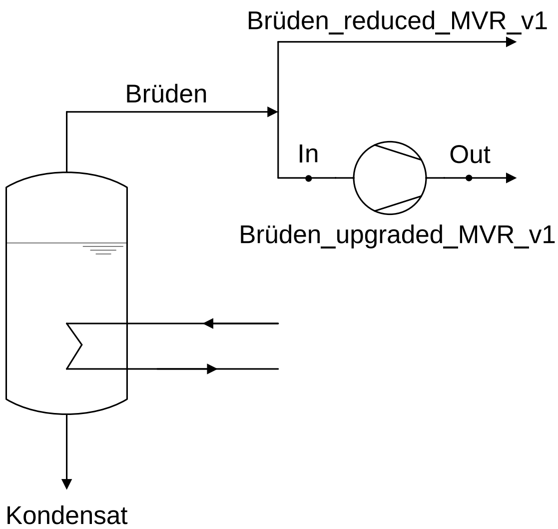

Fig. 11.4: Simple Evaporator Unit with a Mechanical Vapour Recompression (MVR) Energy Conversion Unit

A5: Thermal Vapour Recompression Energy Conversion Unit

The thermal vapour recompression (TVR) energy conversion unit (ECU) operates with the similar goal as the mechanical vapour recompression unit. However, this unit utilizes medium to high pressure steam to achieve the temperature lift necessary to reach the required condensation temperature. The TVR is also in principle a heat pump, yet is an open system that takes an existing stream and upgrades it to a higher pressure and condensation temperature. The following figure illustrates the principle of a TVR. Note: The selection of the water vapour stream is limited to the fluid **R718 (water)** based on the equation of state given in [4].

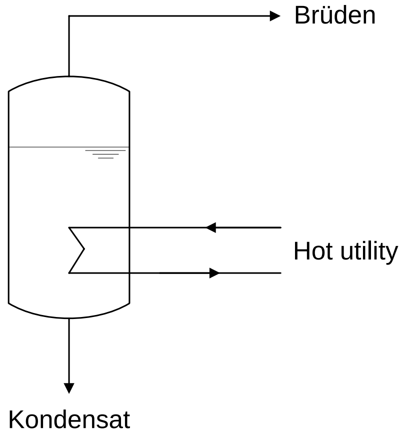

Fig. 11.5: Simple Evaporator Unit

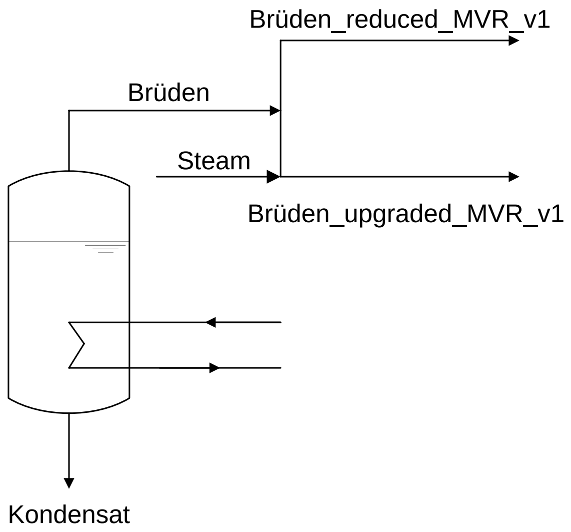

Fig. 11.6: Simple Evaporator Unit With A Thermal Vapour Recompression Energy Conversion Unit

The calculation of the amount of steam required to upgrade the selected waste heat stream is the main calculation for the ECU. Inefficiencies in the nozzle are handled internally to account for the irreversible nature of the expansion and diffusion process that occur with in the nozzle. The following equation is based on the overall energy balance around the nozzle assuming reversible expansion and diffusion processes [13]:

$$\xi_{Tr} = \frac{m_T}{m_T + m_F} = \frac{h_F - h_{mix}}{h_F - h_T}$$

In order to account for the irreversible nature of the processes in the diffuser and the expansion sections, specific diffusor and expansion efficiencies can be entered on the TVR dialog. They are used in the following equation to determine the amount of steam, m_T, necessary to achieve the increase in condensation temperature of the water vapour.

$$\xi_T = \sqrt{\frac{\xi_{Tr}}{\eta_D \, \eta_E}}$$

The amount of steam required in the irreversible case can be easily calculated using the following equation: