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# *Program User Manual*

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## 1. Introduction to AHED

Welcome to AHED. AHED is a powerful calculation program for the design and evaluation of shell and tube heat exchangers. Shell and the heat exchangers are the most common heat exchange type used the process industry today. AHED offers a technical calculation solution for anyone that needs to evaluate existing designs or installs of shell and tube heat exchangers or needs to design from scratch. This software offer is intended to offer solutions for many types of users:

- Students
- University professors
- Process engineers / chemical engineers
- Maintenance engineers
- Heat exchanger manufacturers
- End users.

AHED can be used for evaluating designs for all types of industries:

- Chemical process industry
- Petrochem
- Oil and gas
- Wastewater and environmental industry
- Pharmaceutical industry
- Food industry

AHED is a software for thermal design exclusively. It does not cover any topic related to mechanical design of shell and tube heat exchangers. The design inputs and outputs (heat exchanger dimensions: shell sizes, tube size, wall thickness, operational pressure, design pressure) of AHED can form the basis for mechanical design evaluations, but for mechanical design calculations we refer to other software solutions available in the market.

AHED calculates for shell and tube heat exchangers with smooth inner tubes only. Enhanced tube options (such as tubes with inserts, corrugated tubes) are not supported neither are other heat exchanger types such as plate heat exchangers, shell-and-plate heat exchangers etc.

### 1.1. Program features.

AHED consist of several program modules that work in conjunction:

#### *Fluids*

Allows to the user to define fluid physical properties in table format or generate a physical properties table from the AHED pure fluids database, using the Mixing Assistant.

### Heat Balance

Once the shell and tube side fluid are selected, the flowrate, inlet and outlet temperatures are calculated here. Also, the physical properties for the gas and/or liquid streams are calculated at inlet and outlet temperatures. These values form the basis for the final heat transfer calculation.

### Geometry

This is where the dimensions of the heat exchanger are defined: shell and inner tube dimensions, nozzle sizes, materials of constructions, orientation etc. Based on the input data, the amount of tubes that can fit in the shell and other important parameters are calculated. The results of this module are needed as inputs for the heat transfer calculation.

### Baffles

Baffle dimension must be properly defined for heat transfer calculation on the shell side of the heat exchanger. The information provided here is essential as well for evaluation of vibrational risk.

### Overall Calculation Module

With the information provided in the previous modules, tube side, shell side and overall heat transfer coefficients, heat transfer area, and pressure drops are calculated here.

### Batch

Often, shell and tube heat exchangers are used in batch operations. This module makes it possible to calculate batch heating or cooling times based on the previously calculated heat transfer parameters.

### Graphs

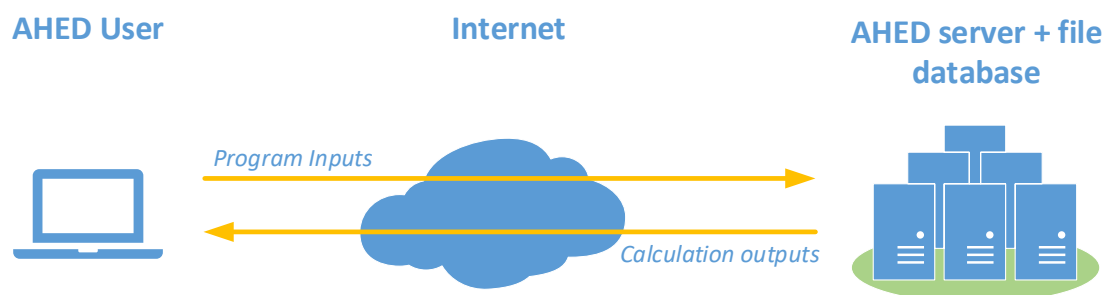
Temperature profiles along the length of the heat exchanger and heat transfer parameters are displayed in a graphical format here.

### Reports

Various types of reports can be generated here, all displayed in Microsoft Excel Format.

## 1.2. Program structure.

AHED is setup as a cloud-based software solution. This means that the software that is installed on the user's computer only serves as a vehicle for defining the input parameters for each design and for receiving the results of each calculation. The heat transfer calculations that AHED performs are done on external AHED calculations servers. An active internet connection is therefore required to be able to work with the program.



Calculation projects are stored on the central AHED database servers. This is done for a specific reason: Any AHED project can be shared with any other registered user, wherever their location is. User groups can be defined, so teams with members that are not working in the same physical space have the possibility to view and share AHED designs without the need for sending program files via email or other.

Another advantage of the cloud-based setup is that all program updates are performed automatically. Each time the program is started it checks for any latest release and installs this automatically.

### 1.3. Calculation types.

The following types of heat transfer processes can be calculated in AHED:

- Fluid types: liquids and gases only. Heat transfer on solids is not supported by AHED
- Sensible heat: heating and cooling.
- Condensation.
- Desuperheating and subcooling with condensation.
- Partial condensation.

These processes can be applied to the three heat exchanger types that are supported by the program:

- Tube in tube (single inner tube).
- Multi tube.
- Triple tube (three concentric tubes).

Evaporation / boiling applications are not yet supported by AHED. We hope to add these options in future releases of the program.

### 1.4. Features according to license.

Several license types are available for AHED and the number of features available increases with license type. The following table shows what features are available with each license type:

License type:	Trial	Bronze	Silver	Gold	Platinum
<b>Fluids</b>					
User defined	•	•	•	•	•
AHED Database	•			•	•
<b>Geometries</b>					
Tube in tube	•	•	•	•	•
Multi tube	•	•	•	•	•
Triple tube	•			•	•
Single pass	•	•	•	•	•
Multi pass	•		•	•	•
<b>Heat transfer processes</b>					
Sensible heat	•	•	•	•	•
Condensation	•	•	•	•	•
Desuperheating/subcooling	•			•	•
Partial condensation	•			•	•
Batch calculation	•		•	•	•
<b>User options</b>					
Multiple calculations per project	•		•	•	•
Preset options	•			•	•
User group					•
Project copy share	•			•	•
<b>Other features</b>					
Vibration analysis	•			•	•
Graphs module	•			•	•
Reporting	•			•	•
Helpdesk support					•

Moving from bronze to platinum license more and more features are added to the program. The bronze license can be viewed as a license for educational purposes whereas the platinum license is a full license for a thermal engineering or heat exchanger professional.

The trial license contains all features (except helpdesk support and access to online resources) so it allows the user to verify all program options before making a purchase decision.

For pricing information for the various license type we refer to the AHED web page: [www.hrs-ahed.com/en/licensing](http://www.hrs-ahed.com/en/licensing)

## 2. Getting started – Installation.

AHED is designed to run under the Windows 10 operating system and the files for installation can be run from here:

<https://www.hrs-ahed.com/app/download>

To install AHED, it should be checked that the computer meets the [system requirements](#) and click on “Get the app” to download and install it.

Once the installation has completed, the program icon has become available in the Windows start Menu under HRS-AHED and the program can be launched.

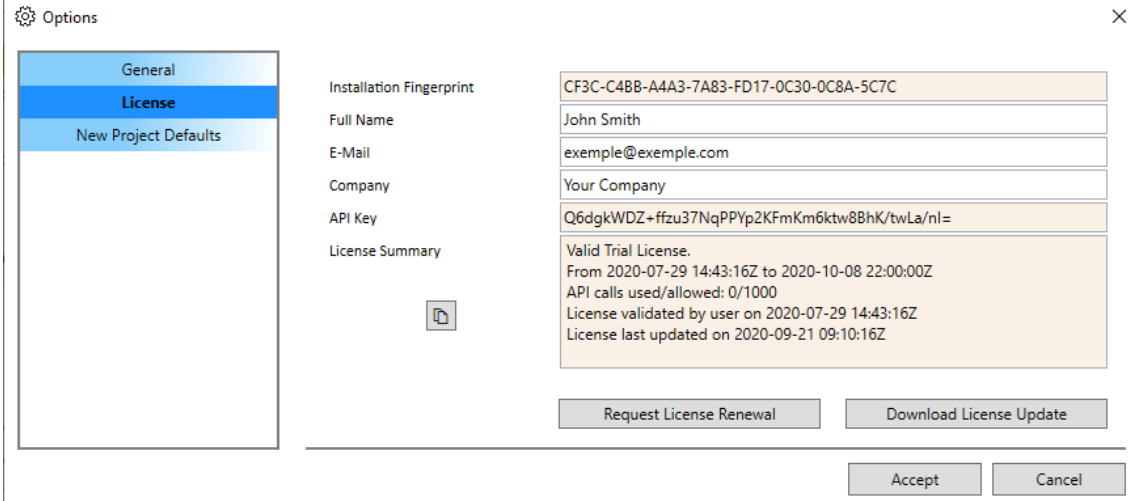
In the program, under **TOOLS>OPTIONS>LICENSE** the user must fill in the following data:

- Full name
- Email address
- Company or organization name

After clicking **REQUEST LICENSE** our servers will process the information. First time users need to confirm and validate their email address. For such a purpose they will receive an email with instructions. The user will be granted access to the features of his ordered license once the payment has been fulfilled. Until then, the program can be accessed but under the condition of a trial license only, which expires after 15 days. If no payment is received after the 15 day period, no further calculation can be made until receiving of the payment.

In case of problem with license activation the user is recommended to consult via an email to [info@hrs-ahed.com](mailto:info@hrs-ahed.com).

To check if the license is active simply go to **TOOLS>OPTIONS>LICENSE** and check the **LICENSE SUMMARY** field where the status of the license is displayed:



The screenshot shows the 'Options' dialog box with the 'License' tab selected. The 'License' tab is highlighted in blue. The 'New Project Defaults' section is visible below the 'License' tab. The 'License Summary' field displays the following information:

Installation Fingerprint	CF3C-C4B8-A4A3-7A83-FD17-0C30-0C8A-5C7C
Full Name	John Smith
E-Mail	exemple@exemple.com
Company	Your Company
API Key	Q6dgkWDZ+ffzu37NqPPYp2KFmKm6ktw8BhK/twLa/nl=
License Summary	Valid Trial License. From 2020-07-29 14:43:16Z to 2020-10-08 22:00:00Z API calls used/allowed: 0/1000 License validated by user on 2020-07-29 14:43:16Z License last updated on 2020-09-21 09:10:16Z

At the bottom of the dialog, there are two buttons: 'Request License Renewal' and 'Download License Update'. At the very bottom, there are 'Accept' and 'Cancel' buttons.



### 3. AHED User Interface

Upon launching AHED, the following user interface appears:

DateTime	Severity	Message
2020-07-14 15:02:03	Information	No App updates available. You are running the latest version.
2020-07-14 15:01:58	Information	Your license is valid until 2020-09-30 and you have used 4.88% of your API calls (4885 out of 100000).

Each element of the user interface will be explained in more details now:

#### 3.1. File menu

The following features are available here:

##### *New:*

Opens a new project. The user will be prompted to save the current project.

##### *Manage:*

Used for opening / managing projects, fluids, or geometries. The list of projects, fluids or geometries is presented. The user can choose to open any of these picking from the list. Search options are included to quickly find the item needed. Right clicking on any project, fluid or geometry in the list gives the following options:

- **Open:** to open the item to be used for calculation.
- **Delete:** will delete the item from the list (permanently).
- **Edit** (fluids only): allows the user to edit the fluids file.
- **Share with:** makes it possible to share the item with any of the user groups available.
- **Send copy to:** by introducing an email address of a validated AHED license, the recipient will receive a copy of the selected item to be used in his/her personal database.

**Save:**

Used for saving any project, fluid, or geometry when a change is made.

**Saves as:**

Used for saving any project, fluid, or geometry under a different name when a change is made.

**Recent projects:**

Gives a list of the latest projects for quicker access.

**Exit:**

To exit and close AHED.

### 3.2. Tools menu

The Tools menu is a drop-down menu in AHED's main tool bar. Dropping down the menu, we find

- Select Presets
- Group Manager
- Temperature Pressure Water/Steam
- Options

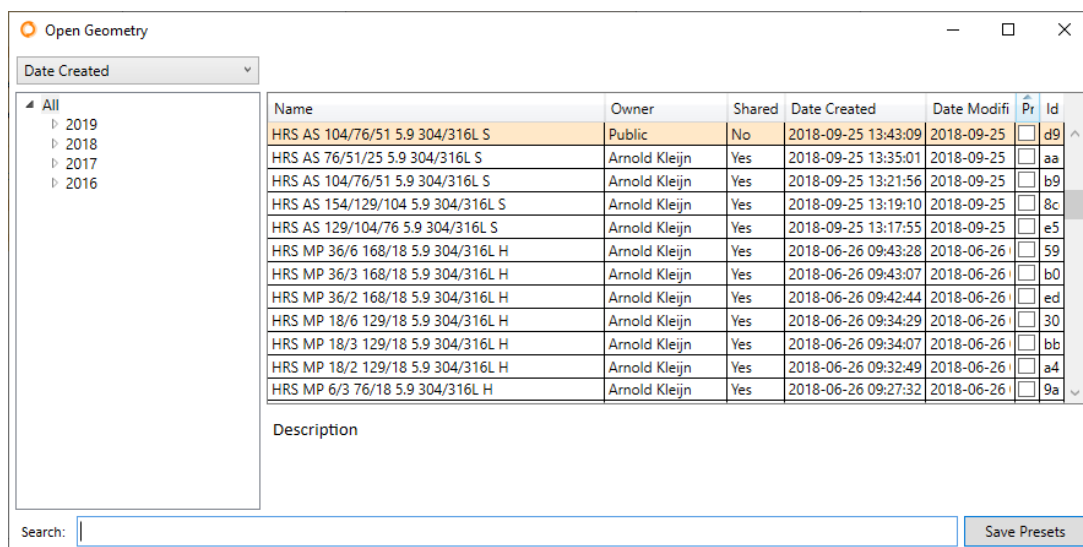
#### 3.2.1. Select Presets

Select Presets is a drop-down menu where types of presets are available:

- Geometry Presets
- Fluid Presets
- Material Presets

**Geometry Presets**

This window has the following appearance:



A list of defined geometries is displayed. Ticking the checkbox in the **Presets** column, the geometry in question is added to the Preset list and becomes directly available as a quick selection item in the **Geometry** calculation. Make sure to click **Save Presets** to make sure any change in the tick boxes is saved.

Geometry Presets in **Geometry** window:

**Calculate**

Geometry presets: --Select Geometry--

**Tube & Shell Geometry**

Heat Exchanger Type: Tube/Shell

	Tubes Side	Shell Side
Name	HRS S&T 0 0/0 3.0 304/316L H	
Outer Diameter	mm 0.00	0.00
Thickness	mm 0.00	0.00
Inner Diameter	mm 0.00	0.00
Material	AISI 316L	AISI 304
Number of Tubes	0	
Tube Inner Length (Lti)	mm 3000.00	

**Tubeplate Layout**

By selecting a geometry from the Geometry Presets dropdown, all its parameters will be inserted in the Geometry calculation. Normally, the background colour will change to green that the selected geometry is correctly validated. Any parameter value can be changed now, but the user should hit the calculate button to check if the changes made give a valid result.

### Fluid Presets

This window has the following appearance:

Open Fluid

Date Created

☒ All  
☐ 2020  
☐ 2019  
☐ 2018  
☐ 2017  
☐ 2016

Name	Owner	Shared	Date Created	Date Modified	Preset	Id
Barbeque sauce	Public	No	2016-04-26 13:49:48	2016-04-26 13:49:48	<input type="checkbox"/>	d8
Rapeseed oil	Public	No	2016-04-26 13:49:49	2016-04-26 13:49:49	<input type="checkbox"/>	52
Skim milk 20% wt solids	Public	No	2016-04-26 13:49:49	2016-04-26 13:49:49	<input type="checkbox"/>	d2
Skim milk 15% wt solids	Public	No	2016-04-26 13:49:49	2016-04-26 13:49:49	<input type="checkbox"/>	16
Skim milk 10% wt solids	Public	No	2016-04-26 13:49:49	2016-04-26 13:49:49	<input type="checkbox"/>	53
Propylene Glycol 30%	Public	No	2016-04-26 13:49:49	2016-04-26 13:49:49	<input checked="" type="checkbox"/>	a5

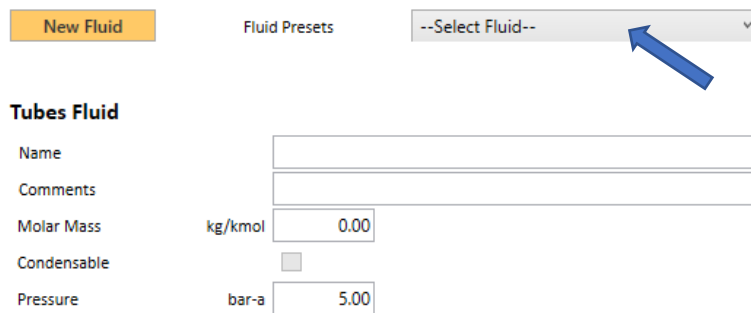
Description

Search:

**Save Presets**

A list of defined fluids is displayed. Ticking the checkbox in the **Presets** column, the fluid in question is added to the Preset list and becomes directly available as a quick selection item in the **Heat Balance** calculation. Make sure to click **Save Presets** to make sure any change in the tickboxes is saved.

Fluid presets in the **Fluids** window:



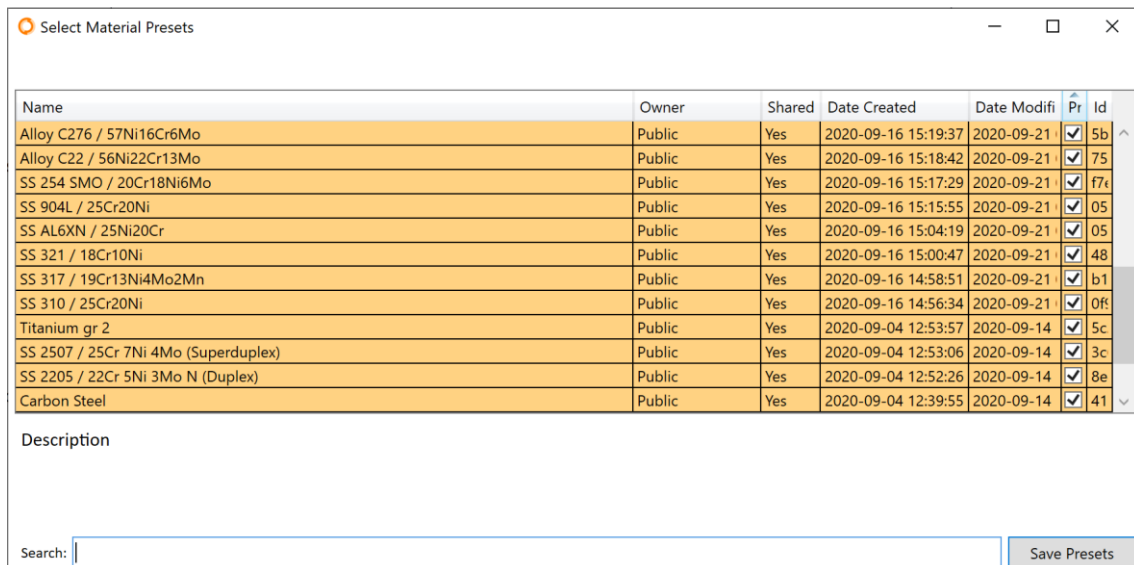
The screenshot shows the 'Fluids' window. At the top, there is a 'New Fluid' button and a 'Fluid Presets' dropdown menu with the text '--Select Fluid--'. A blue arrow points to the dropdown menu. Below this, the 'Tubes Fluid' section contains several input fields: 'Name' (text box), 'Comments' (text box), 'Molar Mass' (text box with 'kg/kmol' unit and value '0.00'), 'Condensable' (checkbox), and 'Pressure' (text box with 'bar-a' unit and value '5.00').

By selecting a fluid from the Fluid Presets dropdown, all the fluid parameters will be inserted. Normally, the background colour will change to green that the selected fluid is correctly validated. Any parameter value in the Fluid window can be changed now.

### Material Presets

Materials works slightly different. Starting AHED for the first time, the user has some materials selected by default. Those materials are the only possible selection in a new geometry. If user consider to use other materials, it can be changed in Material Presets window.

This window has the following appearance:



The screenshot shows the 'Select Material Presets' window. It contains a table with the following columns: Name, Owner, Shared, Date Created, Date Modified, Presets, and Id. The table lists various materials, including Alloy C276, Alloy C22, SS 254 SMO, SS 904L, SS AL6XN, SS 321, SS 317, SS 310, Titanium gr 2, SS 2507, SS 2205, and Carbon Steel. Each row has a checkbox in the 'Presets' column and an 'Id' value. Below the table is a 'Description' section and a 'Search:' input field. A 'Save Presets' button is located at the bottom right.

Name	Owner	Shared	Date Created	Date Modified	Pr	Id
Alloy C276 / 57Ni16Cr6Mo	Public	Yes	2020-09-16 15:19:37	2020-09-21	<input checked="" type="checkbox"/>	5b
Alloy C22 / 56Ni22Cr13Mo	Public	Yes	2020-09-16 15:18:42	2020-09-21	<input checked="" type="checkbox"/>	75
SS 254 SMO / 20Cr18Ni6Mo	Public	Yes	2020-09-16 15:17:29	2020-09-21	<input checked="" type="checkbox"/>	f7c
SS 904L / 25Cr20Ni	Public	Yes	2020-09-16 15:15:55	2020-09-21	<input checked="" type="checkbox"/>	05
SS AL6XN / 25Ni20Cr	Public	Yes	2020-09-16 15:04:19	2020-09-21	<input checked="" type="checkbox"/>	05
SS 321 / 18Cr10Ni	Public	Yes	2020-09-16 15:00:47	2020-09-21	<input checked="" type="checkbox"/>	48
SS 317 / 19Cr13Ni4Mo2Mn	Public	Yes	2020-09-16 14:58:51	2020-09-21	<input checked="" type="checkbox"/>	b1
SS 310 / 25Cr20Ni	Public	Yes	2020-09-16 14:56:34	2020-09-21	<input checked="" type="checkbox"/>	0f
Titanium gr 2	Public	Yes	2020-09-04 12:53:57	2020-09-14	<input checked="" type="checkbox"/>	5c
SS 2507 / 25Cr 7Ni 4Mo (Superduplex)	Public	Yes	2020-09-04 12:53:06	2020-09-14	<input checked="" type="checkbox"/>	3c
SS 2205 / 22Cr 5Ni 3Mo N (Duplex)	Public	Yes	2020-09-04 12:52:26	2020-09-14	<input checked="" type="checkbox"/>	8e
Carbon Steel	Public	Yes	2020-09-04 12:39:55	2020-09-14	<input checked="" type="checkbox"/>	41

A list of defined materials is displayed. Ticking the checkbox in the **Presets** column, the material in question is added to the Preset list and becomes directly available as a selection item in the **Geometry** calculation. Make sure to click **Save Presets** to make sure any change in the tickboxes is saved.

Material presets in the **Geometry** window:

**Calculate**

Geometry presets: --Select Geometry--

**Tube & Shell Geometry**

Heat Exchanger Type: Tube/Shell

		Tubes Side	Shell Side
Name		HRS S&T 0 0/0 3.0 304/316L H	
Outer Diameter	mm	0.00	0.00
Thickness	mm	0.00	0.00
Inner Diameter	mm	0.00	0.00
Material		AISI 316L	AISI 304

By selecting a material from the material dropdown, all the material parameters will be inserted in the proper side.

Open a project with a material with is not in the user presets list will add the material to the list until you close AHED. Also, user cannot unselect a material preset if it is using on the current project or if it is selected as a default material.

### 3.2.2. Group Manager (platinum license only)

Clicking on the **Group Manager** button in the Tools drop-down menu, the Group Manager window pops up.

Gestor de Grupos

**Group 1**

Grupos: **Borrar Grupo** **Nuevo Grupo** **Editar Grupo** **Guardar Grupo**

**Nombre:** \* Group 1 \* Requerido

**País:** \* UK

**Descripción:** Just a test

**Usuarios** **Añadir Usuario**

Nombre	Correo-e	Compañía	Compartir nuevos recursos por defecto	Es Administrador	Puede leer	Puede escribir	Puede eliminar
John Smith	example@example.com	Your Company	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Buscar:  **Cerrar**

A **Group** is a selection of AHED licensed users, that can share fluids, geometries and projects. A user can only share with groups to which he/she is added as a user. By right clicking on any item in the fluid, geometry or project database, the option is given to share the item with any group

### Existing Groups

By clicking on an existing group in the left field, the list of the group members appears, together with select/deselect boxes for assigning the rights of each user:

- Admin rights
- Can read
- Can write
- Can overwrite

These rights are managed by the creator of the group that who obtains admin rights by default.

### New Group

By clicking on the **New Group** button, a group can be created. Name and country should be inserted, a description is optional. **Save Group** should be clicked to confirm. The next step is to add members to the group. Click **Add User** and type the email of the user. This email should be the exact same email address that the user in question used for applying for the AHED account. For each user, the right admin rights should be defined. Even admin rights can be selected for an added user, so more than one member can have admin rights.

### Edit Group

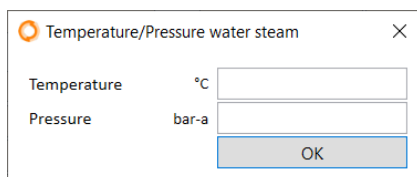
By clicking Edit Group any group can be edited to which the user has admin rights. This option should be used to change names, description, delete users, add users or change admin rights.

### Delete Group

By clicking this button, the group is deleted. This is only allowed for admin members.

### 3.2.3. Temperature/Pressure water steam

Clicking Temperature/Pressure water steam in the Tools drop-down menu shows this window:

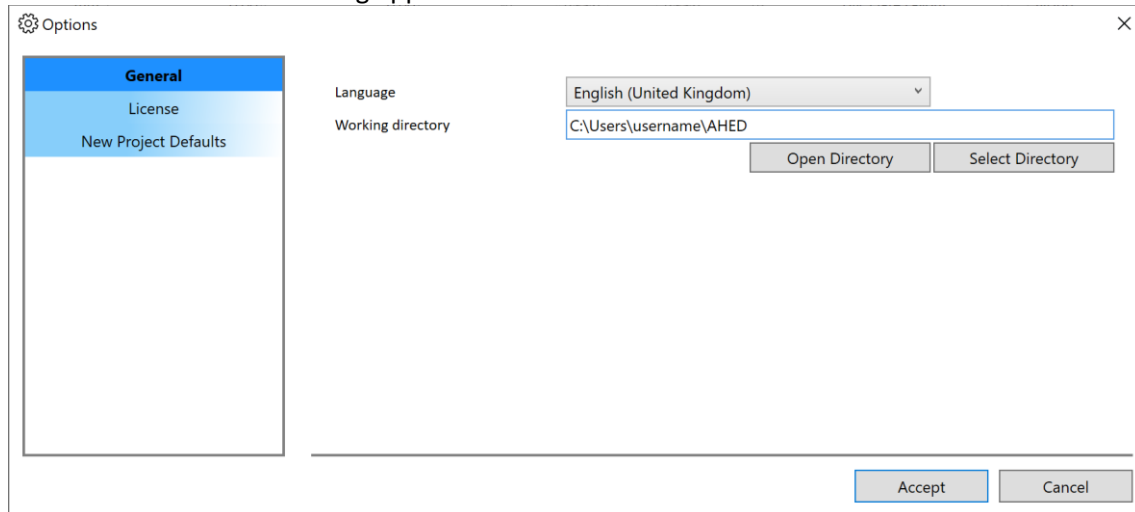


The dialog box is titled "Temperature/Pressure water steam" and contains two input fields. The first field is labeled "Temperature" with a unit of "°C". The second field is labeled "Pressure" with a unit of "bar-a". Below these fields is an "OK" button.

This is used for calculating the saturated steam temperature or pressure for pure water. Fill in the temperature and put the cursor in the pressure field to obtain the corresponding pressure. Also, the pressure value can be inserted, by then clicking in the temperature field, the corresponding pressure to that temperature is given. Click **OK** to close this window

### 3.2.4. Options

This window has the following appearance:



#### *General*

Here the program language and working directory for saving reports can be defined. The change will take place after restarting the program.

#### *License*

Here the license information summary is displayed. A button for license renewal request is available here

#### *New Project Defaults*

Here the default settings for the program engineering units can be defined, the number of decimals to be displayed can be inserted and default materials for new geometries for tubes side and shell side.

### 3.3. Help Menu

The Help Menu gives the following options:

*Manual:*

Clicking leads to a Manual page on the AHED web. By clicking F1 or on any of the parameters in AHE, the user is redirected to the AHED internet Manual page where the parameters are explained.

*Report problem:*

Makes it possible to inform AHED of any problem encountered while using the program. A clear description should be given in the text field. By clicking "Allow us to check the current project", a copy of the project is uploaded to the AHED helpdesk for further investigation (recommended if the problem is related to that project).

*About:*

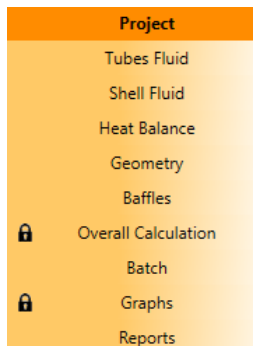
Information about the AHED program version.

*Release notes:*

Leads to the AHED website with release notes of all current and previous releases.

### 3.4. Navigation Window

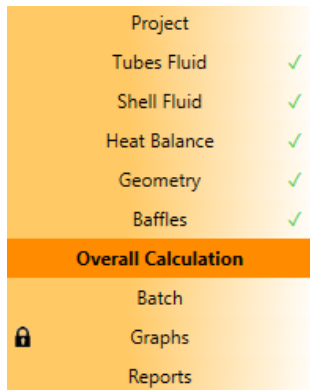
Located on the left-hand side with the following appearance:



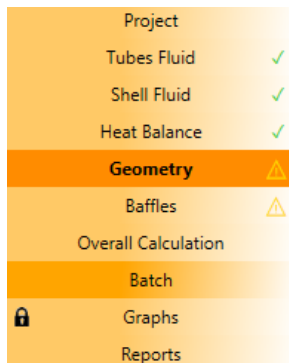
This window is organized in a sequential order. To start, the necessary **Project** information must be given. Then the **Tubes Fluid** and the **Shell Fluid** must be defined. Then the **Heat Balance** must be defined and calculation. After that the **Geometry** and **Baffle** information (dimensions) of the heat exchanger must be defined and calculated. If all these steps are completed, the **Overall Calculation** can be performed. A **Batch** calculation is optional from this point. If the Overall Calculation is performed correctly, the **Graphs** become available for viewing. **Reports** become available as each step is executed.

The sequential workflow of AHED means that a certain step cannot be executed if the previous ones are not completed. In the image above, a lock symbol appears next to Overall Calculation indicating that something is missing. The correct situation would look like this:





The green ticks indicate that **Tubes Fluid** and **Shell Fluid** are defined correctly, and the **Heat Balance** and **Geometry / Baffle** calculations are correctly done. The lock symbol next to **Overall Calculation** has disappeared meaning that this calculation can now be done. The lock symbol still appears next to **Graphs**, indicating that the **Overall Calculation** has not been successfully completed.



In case calculations have come to conclusion but with warnings, then this is indicated with the appearance of a warning symbol next to the step. In the situation above the **Geometry** and **Baffle** calculation show a warning, but the user can proceed in doing the **Overall Calculation**. The user is always advised to not ignore the warning messages and check in the **Log Window** to find out what could be the reason for the program to issue the warning.

### 3.5. Log Window.

The Log Window is located at the bottom of the program interface. This window displays message concerning the calculation that has been executed. Three type of messages are displaying according a colour code.

#### White:

DateTime	Severity	Message
2019-12-10 08:29:10	Information	Heat Balance calculation finished successfully.
2019-12-10 08:29:10	Information	Heat Balance calculation started.

Confirming the start or end of a calculation. In case the calculation has completed correctly without any errors or warning, its colour will be white.

**Yellow:**

DateTime	Severity	Message
2019-12-10 08:31:23	Warning	Baffles calculation finished with warnings.
2019-12-10 08:31:23	Warning	Unsupported plain tube span exceeds TEMA recommendations Lb,max=3175 (±5%)

A yellow message notifies warnings. The calculation may have completed but the user is advised of certain important events.

**Red:**

DateTime	Severity	Message
2019-12-10 08:32:21	Error	Heat Balance calculation finished with errors.
2019-12-10 08:32:21	Error	Tubes Flow value must be positive
2019-12-10 08:32:21	Error	Inlet and Outlet Temperatures must be different (there must be a $\Delta T$ ) when Sensible Heat is selected.
2019-12-10 08:32:21	Error	Inlet and Outlet Temperatures must be different (there must be a $\Delta T$ ) when Sensible Heat is selected.

A message in red notifies of an error that prohibits the calculation to complete. If possible, the fields in the calculation related to the error will be highlighted in red, pointing the users towards the matter that needs to be resolved. See the example below where an incorrect temperatures definition leads to a log message in red: "Invalid Temperatures LMTD".

	Tubes Side		Shell Side	
	Inlet	Outlet	Inlet	Outlet
--Select Fluid--	v		v	
	Water (IAPWS-IF97)		Water (IAPWS-IF97)	
	Sensible Heat		Condensation	
kg/hr		42193.74	<input checked="" type="radio"/>	6273.76
°C	<input type="text" value="30.00"/>	<input type="text" value="110.00"/>	<input type="radio"/>	<input type="text" value="100.00"/>
kcal/hr		3381237.76		-3381237.76
bar-a	<input type="text" value="5.00"/>		<input type="text" value="1.01"/>	

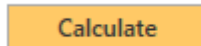
Over time, the Log Window can become cluttered with messages. Using the **Clear Log** button on the left-hand side of the **Log Window**, all messages will be removed:

Clear Log

### 3.6. Calculation colour schemes.

To the right of the **Navigation Window** we have the main project field where all the calculations take place. On the top left you will find the calculation button. The bar behind this button will change colour based on the status of the calculation:

#### White:

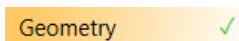


While parameters are being added or changed the background colour will remain white.

#### Green:



A green colour indicates that a calculation has completed free of warnings and errors. In the **Navigation Window**, this will be indicated as well by appearing the green tick next to calculation that was just done:



#### Yellow:



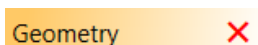
A yellow background colour indicates that a calculation has completed but a warning has been emitted (see log window). In the **Navigation Window** this will be indicated with the warning symbol next to the item in question:



#### Red:



A red background colour indicates that an error has been produced. The field with error in question will be highlighted. In the **Navigation Window**, a red cross indicates that the calculation has an error and is not completed:




The user is advised to check the Log Window for yellow and red cases. Corrective action may/will be needed to improve the result and complete the calculation free of warnings.

## 4. Project


A project in AHED is a place where several heat exchanger calculations can be defined and calculated. When clicking **Project**, the following interface appears:

**Project**

Id	bb0c46a5-af78-43ac-8dfc-77cca3b63188		Revision	0
Name				
Customer				
Description				
Units	Metric	Number of decimals	2	

**Project Processes**

default

**Advanced Properties** 


**Id** is an internal AHED parameter, used for locating the project in database of projects. This parameter cannot be changed. **Revision** is for allocating a revision number to the project. Changing this number will not create a new revision of the project. The project remains unique and is only one entry in the project database. A project **Name** and **Customer** can be inserted. In the **Description** field and kind of relevant information can be inserted. If the “wand” symbol is clicked, a small description of each calculation in the project is inserted (giving information about fluids, flows and temperatures for tube and shell side). In **Units** the user can select between Metric, Si or British engineering units. In **Number of decimals**, the user can assign the numbers of decimals for each field with a numeric value.

Below this general information, the users will find the **Project Processes** field. Each item of the list is a Process, or heat exchanger calculation, with its own tube and shell side fluid definition, heat balance, geometry, baffles, overall calculation section etc. Each process can be selected by clicking it and the names can be overwritten. As many processes as needed can be created in a single project. A new process can be added by clicking on the last blank line and inserting a name. Right clicking any process gives options cloning (meaning creating a copy), deleting and reordering the processes.

For changing between processes in a project, two ways can be used: either going back to the Project tan and selecting the desired process or using the keyboard shortcuts *Ctrl + PgUp* or *Ctrl + PgDown* to move though the list of processes. The keyboard shortcut works in every section. For example: Viewing the tube side fluid properties of one process, clicking *Ctrl + PgDown* leads to the tube side fluid properties of the next process in the list.

### Advanced properties

Advanced properties are by default hidden but when clicked appear:

**Advanced Properties** 

Created		Modified	
User Email	<input type="text" value="exemple@exemple.com"/>	User Email	<input type="text" value="exemple@exemple.com"/>
Company	<input type="text" value="Your Company"/>	Company	<input type="text" value="Your Company"/>
Date	<input type="text" value="2020-09-21 11:03:32"/>	Date	<input type="text" value="2020-09-21 11:03:32"/>
Number of Saves	<input type="text" value="0"/>	Shared in groups:	
Category	<input type="text"/>	Not shared	
Keywords	<input type="text"/>		
Comments	<input type="text"/>		

The following, **User email, Company, Date, Number of Saves, User email, Company** and **Date** are just for information cannot be changed. In the fields **Category, Keywords** and **Comments** any other kind of relevant information can be added by the user.

Under **Shared in groups** a list of groups appears in which this project is shared.

## 5. Fluids

For correct thermal design, fluid physical properties are vital. The following four parameters must be defined in detail over the temperature range in which the fluid is applied:

- Density
- Specific heat
- Thermal conductivity
- Viscosity

Viscosity is defined in AHED with two parameters:

- Consistency index (centipoises, Pa.s etc)
- Flow behaviour index (dimensionless)

This is done as to be able to work with non-Newtonian fluids where the shear rate influences the apparent viscosity level. In appendix A of this manual you will find a reference to the model that is applied for the calculation of the apparent viscosity. What is important here is to understand that for Newtonian fluids the flow behaviour index is equal to 1 and the apparent viscosity is the same as the value of the consistency index. For non-Newtonian liquids, the consistency index can be viewed as the apparent viscosity when the shear rate is reduced to 0. With increasing shear rate the apparent viscosity decreases as a function of the flow behaviour index. The lower the flow behaviour index ( $0 < \text{flow behaviour index} < 1$ ), the sharper the decrease in viscosity (the more non-Newtonian the liquid becomes).

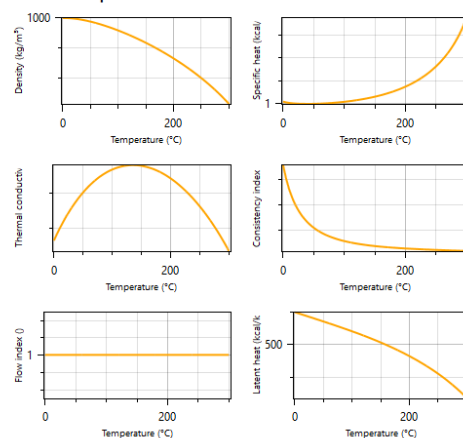
AHED works with fluid property tables. For a series of temperatures, values must be given for all property parameters mentioned above. AHED performs interpolation calculations for each temperature that lies between two temperatures defined in the fluid property table. By working this way, the more temperature data points are given, the more accurate the calculation becomes. Temperature points must be defined to cover the range of temperatures that are defined in the heat transfer calculation. If the temperature of the calculation exceeds what is defined in the property table, then AHED will issue a warning and the last value found in the table is used for any temperature outside of the table range. Below shows the interface of the property table.

### Tubes Fluid

Name	Water (IAPWS-IF97)	
Comments	0 to 300 °C	
Molar Mass	kg/kmol	18.00
Saturated	<input checked="" type="checkbox"/>	
Pressure	bar-a	NaN

Liquid Phase		Gas Phase	Mixing Assistant			
Temp. °C	Dens. kg/m³	Sp. heat kcal/kg·°C	Th. cond. kcal/m·hr·°C	C. ind. cP	F. ind.	dH kcal/kg
0	999.793	1.0079	0.4832	1.792	1	597.3373
5	999.918	1.0044	0.4921	1.5183	1	594.4995
10	999.654	1.0022	0.5004	1.306	1	591.6712
15	999.055	1.0006	0.5081	1.1376	1	588.845
20	998.161	0.9996	0.5155	1.0016	1	586.0204
25	997.004	0.9989	0.5223	0.89	1	583.1905
30	995.609	0.9984	0.5288	0.7972	1	580.3561
35	993.996	0.9982	0.5348	0.7191	1	577.5139
40	992.183	0.9981	0.5405	0.6527	1	574.663
45	990.183	0.9981	0.5458	0.5958	1	571.8002
50	988.009	0.9983	0.5507	0.5465	1	568.9247

### Tubes Fluid Graphs



As can be seen, the values of the table are presented as graphs. An odd value in the table would show up in the graph as a spike so any errors can be easily detected by reviewing the graphs.

### 5.1. Pure fluid database

Three tabs appear above the fluid table:

Liquid Phase	Gas Phase	Mixing Assistant
Temp. °C	Dens. kg/m <sup>3</sup>	Sp. heat kcal/kg·°C

Liquid phase and has phase properties go into the corresponding tab. The third tab, Mixing Assistant, can be used for defining the physical properties of mixes of pure components, using the AHED standard fluid database (Gold license and higher) that contains 53 pure components.

Next, we will explain in detail the use of the Mixing Assistant - AHED standard fluid database:

To generate the mix, first a name, the temperature range, temperature increment and pressure should be given.

Liquid Phase	Gas Phase	Mixing Assistant
Database	AHED© fluids	Save Save As Load
Name		
Description		
Temperatures (min, max)	°C	ΔT
Pressure	bar-a	Saturated <input type="checkbox"/>

Then from the drop-down list components can be added using the + symbol or deleted using the x symbol (or searched). To each component the correct mass % or molar % should be inserted.

Chemical Compound	Formula	IUPAC Name	CAS Number
Acetone	C3H6O	Propan-2-one	67-64-1
Acetylene	C2H2	Ethyne	74-86-2
Air	-	-	132259-10-0
Ammonia	NH3	Azane	7664-41-7
Aniline	C6H5NH2	Benzenamine	62-53-3
Argon	Ar	Argon	7440-37-1

Search

+

>

Chemical Compound	Molecular Weig	Molar %	Mass %
Air	28.96	20	14
Water	18.015	40	17.42
Chlorine	70.905	40	68.58

Calculate

In case one component's concentration is changed, the other concentrations are automatically recalculated to generate a 100% total.

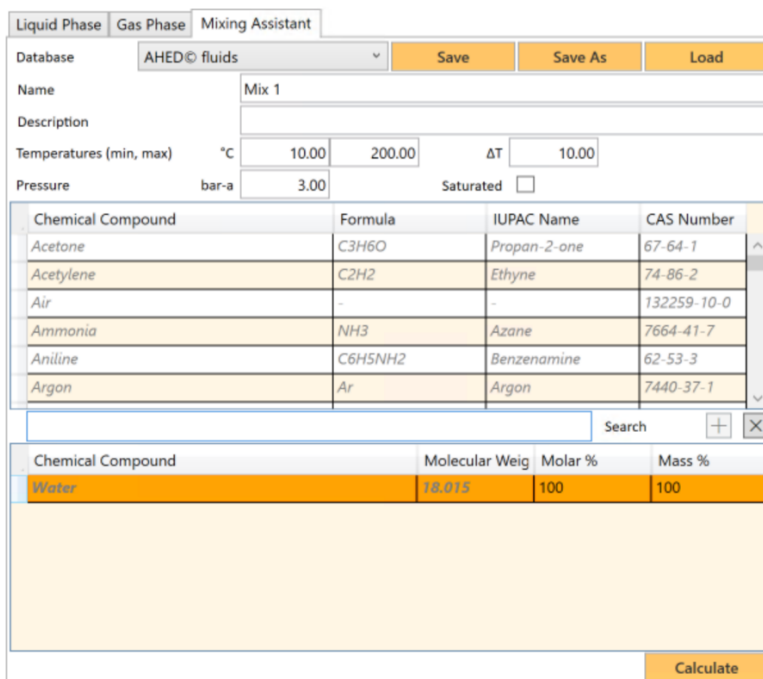
By clicking **Calculate** AHED works out if in the temperature range a gas-liquid transition change occurs. It then presents a table of liquid properties from the minimum temperature to the transition temperature and a table of gas properties from the transition temperature to the maximum temperature. You should click on the tabs **Liquid Phase** or **Gas Phase** to access the calculated properties. For a mix of two or more components it will check for partial condensation: in the gas table the vapor fraction appears for each temperature point.

There is also a tick box called **Saturated**. This box can be checked for a single component mix only and will consider that the fluid always enters and exits at saturation conditions for condensation calculations. In this case liquid and gas properties are calculated for each temperature point including the vapour pressure.

In the heat balance calculation, by inserting the operating inlet pressure, AHED automatically inserts the correct inlet temperature based on the derived vapor pressure values.

## 5.2. Desuperheating and subcooling

The adding of the AHED pure component database makes it possible to calculate desuperheating (cooling of a gas to condensation point) and subcooling (cooling of a 100% condensed fluid to a lower temperature). For this option to check box **Saturated** must be unmarked always. Here is an example of defining water in the correct way so that a desuperheating calculation can be made:



The screenshot shows the 'Mixing Assistant' tab in the AHED software. The 'Database' is set to 'AHED fluids'. The 'Name' is 'Mix 1'. The 'Temperatures (min, max) °C' are 10.00 and 200.00, with a 'ΔT' of 10.00. The 'Pressure bar-a' is 3.00, and the 'Saturated' checkbox is unchecked. A table of chemical compounds is shown, with 'Water' highlighted. The 'Calculate' button is at the bottom right.

Chemical Compound	Formula	IUPAC Name	CAS Number
Acetone	C <sub>3</sub> H <sub>6</sub> O	Propan-2-one	67-64-1
Acetylene	C <sub>2</sub> H <sub>2</sub>	Ethyne	74-86-2
Air	-	-	132259-10-0
Ammonia	NH <sub>3</sub>	Azane	7664-41-7
Aniline	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	Benzenamine	62-53-3
Argon	Ar	Argon	7440-37-1

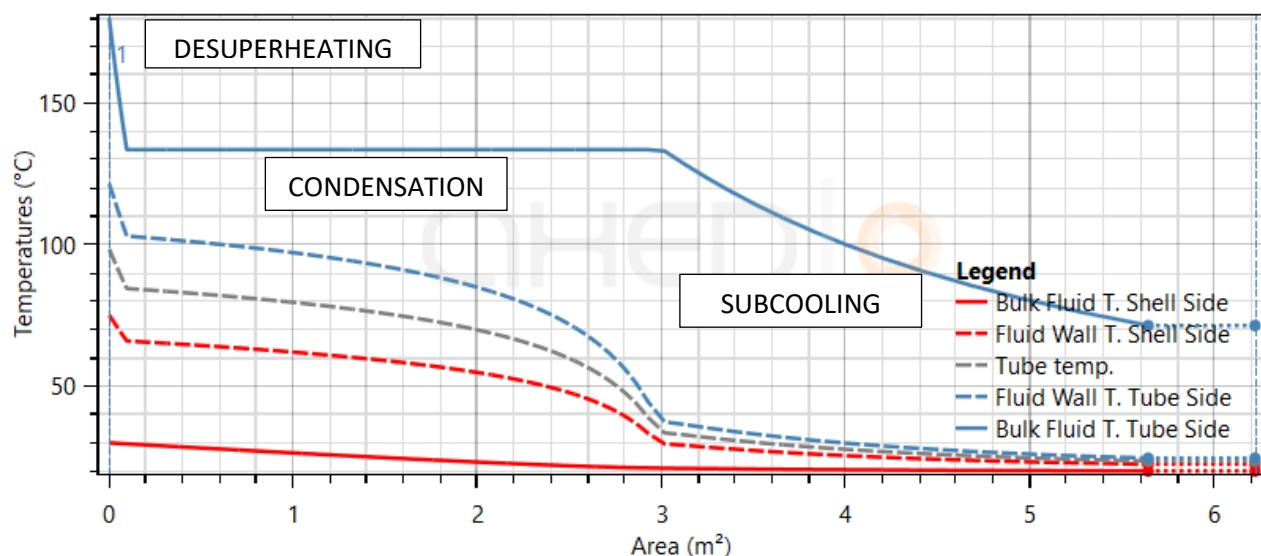
Chemical Compound	Molecular Weight	Molar %	Mass %
Water	18.015	100	100

After performing the heat exchanger calculation, the process of desuperheating, condensation and subcooling clearly appears in the temperature – area graph. See the example below of water steam in at 180 °C / 3 bara and exiting at 65 °C:



## Temperatures

☒ Show modules

☒ Show legend


It is recommendable to keep the desuperheating and subcooling temperature ranges not too high to assure good working heat exchangers.

### [Save, Save As and Load.](#)

Pure component mixtures can be saved and loaded using these buttons. Any pure component mix is also saved within the project when clicking **Save Project**.

### **IMPORTANT NOTE OF ADVICE:**

The Mixing Assistant should be used with care. The physical properties are derived using chemical engineering formulas and mixing rules. In many cases, the calculated result will be a very good approximation of the real mix physical properties, but the result is not always 100% exact. Special care should be taken with mixes of polar fluids. They are calculated well individually but when mixed deviations occur. One example is water – glycol mixes where the calculated mix viscosity can differ from reality. For those cases we refer to the water glycol mixes that are in the standard fluid database inside AHED.

From the file menu, fluids can be opened and saved.

## 6. Heat Balance

The heat balance calculation section has the following appearance:

Calculate

Swap Fluids

Flow Type ☒ Counter current ☐ Co-current

### Heat Balance

	Tubes Side		Shell Side	
	Inlet	Outlet	Inlet	Outlet
Fluid Presets	--Select Fluid--		--Select Fluid--	
Fluid Name	Water (IAPWS-IF97)		Water (IAPWS-IF97)	
Process	Sensible Heat		Condensation	
Flow	kg/hr	42193.74	<input checked="" type="radio"/> 781.50	
Temperature	°C	30.00    40.00	<input type="radio"/> 100.00 <input type="radio"/> 100.00	
Duty	kcal/hr	421188.49	-421188.49	
Pressure	bar-a	5.00    4.95	1.01    1.01	
<b>Liquid Phase</b>				
Density	kg/m³	995.61    992.18		958.35
Specific heat	kcal/kg-°C	1    1		1.01
Thermal conductivity	kcal/m-hr-°C	0.53    0.54		0.58
Consistency index	cP	0.8    0.65		0.28
Flow index		1.00    1.00		1.00
Latent heat	kcal/kg	580.36    574.66		538.95
<b>Gas Phase</b>				
Density Gas	kg/m³		0.6	

At the top of the screen the flow type inside the heat exchanger must be selected. The flow can either be counter-current or co-current.

Tube and shell side fluids can be selected using the **Fluid Presets** button (for quick selection) or in the proper tube and shell side sections. Then the heat transfer **Process** on each side must be selected:

- Sensible heat: no phase change in the fluid.
- Condensation: for condensing fluids or partially condensing fluids.

The tube side flow and inlet temperatures must now be inserted, as well as the inlet pressure of the fluid. For the shell side two out of three input parameters (flow, inlet and outlet temperature: two of these) must be defined together with the inlet pressure. By clicking **Calculate**, the program calculates first the heat transfer duty based on the tube side values. The free parameter on the shell side is fitted in such a way that the shell side duty equals the tube side duty. This way the heat balance is closed. The duty for a heating process is displayed as a positive number, a cooling or condensing duty gives a negative number. The heat balance is closed when the sum of the shell and tube side duty is equal to zero. The outlet pressure values will be inserted when the overall (heat transfer) calculation is performed. At that moment the pressure drops on tube and shell side are calculated and the outlet pressures can be calculated and inserted in the heat balance window.

Within the tube side and shell side sections, two columns are shown. These indicate the values of the variables which the heat exchanger has at the inlet or at the outlet.

The next step is to calculate the physical properties of the shell and tube side fluid at inlet and conditions (density, specific heat, thermal conductivity, consistency index, flow behaviour and latent heat). These values must be calculated as they later become input parameters for the overall heat transfer calculation. When the process takes in the liquid phase, the values appear in the liquid phase column. For gas phases processes, the values will appear in the gas phase column. So, for a phase change process, such as condensation, the inlet values will be in gas phase column, the outlet values will be in the liquid column. See the example below:

#### Liquid Phase

Density	kg/m <sup>3</sup>	995.61	992.18		958.35
Specific heat	kcal/kg-°C	1	1		1.01
Thermal conductivity	kcal/m-hr-°C	0.53	0.54		0.58
Consistency index	cP	0.8	0.65		0.28
Flow index		1.00	1.00		1.00
Latent heat	kcal/kg	580.36	574.66		538.95

#### Gas Phase

Density Gas	kg/m <sup>3</sup>			0.6	
Specific heat gas at constant pressure (Cp)	kcal/kg-°C			0.5	
Thermal Conductivity Gas	kcal/m-hr-°C			0.02	
Dynamic viscosity gas	cP			0.01	
Vapour pressure	bar-a			1.01	
Vapour Fraction	%	0.00	0.00	1.00	0.00

Also note that for condensation calculation, only the steam inlet temperature is needed as an input, for closing the heat balance. Alternatively, the inlet pressure can be given, and AHED will automatically adapt the inlet temperature according the saturated steam T-P curve of the liquid.

In case of partial condensation both gas phase and liquid phase properties will be displayed in the same column.

Next to the Calculation button there is a Swap Fluids button. This will move the shell side liquid to the tube side and vice versa. When this is done, the heat balance must be recalculated (calculation bar changes to white again) so press Calculate again.

## 7. Geometry

Prior to the **Overall Calculation**, the **Geometry Calculation** must be performed to make sure the heat exchanger has a correct dimensional definition. For the **Overall Calculation** parameters such as the flow section cross areas and hydraulic diameters are needed, and these are derived during the **Geometry Calculation**.

**Calculate**

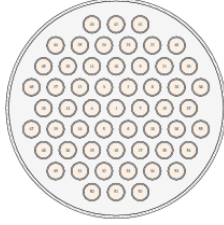
Geometry presets: --Select Geometry--

**Tube & Shell Geometry**

Heat Exchanger Type: Tube/Shell

	Tubes Side	Shell Side
Name		
Outer Diameter	mm 18.00	219.10
Thickness	mm 1.00	3.00
Inner Diameter	mm 16.00	213.10
Material	AISI 316L	AISI 304
Number of Tubes	55	
Tube Inner Length (Lti)	mm 939.00	
Orientation	Horizontal	
Wetted Perimeter (per pass)	mm 2764.6	3779.65
Hydraulic Diameter	mm 16	22.93
Area / Module	m² 2.92	
Volume / Module	l 10.38	20.35
Tube Profile	Hard corrugation	
Roughness (ε)	μm 0.80	0.80
Bundle Type	<input checked="" type="radio"/> Fixed <input type="radio"/> Removable	
	<input type="checkbox"/> Roller Expanded	

**Tubeplate Layout**



Tube Pitch: mm 24.00

Tube Layout: Triangular Centered (30°)

Number of Passes: 1

Div. Plate Layout: None

Div. Plate Thickness: mm 5.00

TubePlate Thickness (Lts): mm 27.00

Shell Cross Section: m² 0.02

Tubes Cross Section (per pass): m² 0.01

Perimeter: mm 669.47

Max. Nr. Tubes: 55

Tube Distribution: {55}

Tube-Tube Spacing: mm 6.00

Geometries can be selected from predefined Presets (top of the screen) or defined from scratch inserting initially:

- Heat exchanger type.
- Shell and tube diameters and wall.
- Shell and tube material.
- Number of tubes.
- Tube length.
- Orientation (horizontal or vertical)
- Shell and tube roughness (needed for pressure drop calculation).
- Bundle type (needed for applying correct tolerances).
- Roller expanded (if marked, tube pitch limited to minimum 1,25 x tube diameter)

### Heat exchanger type:

Two types are possible:

Tube / Shell: a normal bundle containing one or more inner tubes.

Annular space (gold license or higher): also known as triple tube, meaning three concentric tubes. Here the product flows through the annulus and the service flows in the outer and inner space. When this option is chosen, an extra column appears for defining all three tubes:

Heat Exchanger Type	Annular Space		
	Inner Side	Tubes Side	Shell Side
Name			
Outer Diameter	mm 0.00	0.00	0.00
Thickness	mm 0.00	0.00	0.00
Inner Diameter	mm 0.00	0.00	0.00

On the top right-hand side, the tube pitch, tube layout, number of passes, division plate layout, division plate thickness and tube plate thickness must be defined. In the lower part, diameters and wall thickness for shell and tube side nozzles must be inserted.

Nozzles			
In Outer Diam.	mm	114.30	141.30
In Thickness	mm	3.00	3.40
In Inner Diam.	mm	108.30	134.50
Out Outer Diam.	mm	114.30	60.30
Out Thickness	mm	3.00	2.70
Out Inner Diam.	mm	108.30	54.90
Number of Parallel Lines		1	1
Number of modules per block		1	
Shell Nozzle Orientation	<input checked="" type="radio"/> Opposite Side <input type="radio"/> Same Side		

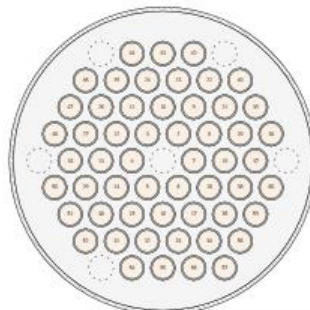
If all the requested information is given, the calculation can be performed. Two calculations are performed simultaneously:

- The maximum number of inner tubes that can fit within the shell is derived. The image depicts the maximum number of tubes.
- The wetted perimeter, hydraulic diameter, area per module, shell and tube module volumes, shell, and tube side flow sections areas (internal parameters, not shown) and the nozzle flow section area (also internal parameters) are calculated. For this calculation, the number of inner tubes considered is the number on the left-hand side:

Number of Tubes	55
-----------------	----

This numbers should be  $\geq 1$  and  $\leq$  maximum number of tubes that can fit. The image of the tube bundle shows the maximum number of tubes and the fitted number of tubes:

#### Tubeplate Layout



Max. Nr. Tubes	61
Tube Distribution	{55}
Tube-Tube Spacing	mm 4.00

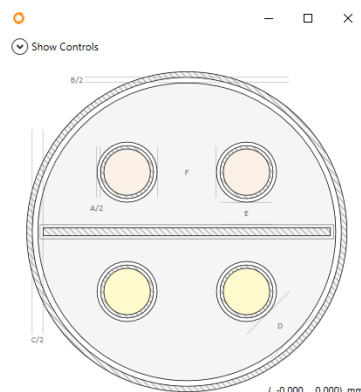
In this example, 55 tubes are fitted in a bundle where a maximum of 61 tubes can be contained. Double clicking this image will open it in a separate window for a more detailed look.

In case a calculation gives an erroneous result, the background colour around the calculation button changes accordingly. The parameter responsible for the error will be highlighted and the log window will provide further information to the nature of the error.

### *Clearances and spacing:*

#### Clearances & Spacing

Tube to tubeplate (A)	mm	0.20
Tubeplate to shell (B)	mm	0.00
Division plate to shell (C)	mm	0.00
Minimum tube hole to tubeplate edge (D)	mm	3.00
Actual tube hole to tubeplate edge (D)	mm	9.45
Min. tube hole to division plate groove (E)	mm	3.00
Actual tube hole to tube hole (F)	mm	3.80
Division plate to tubeplate (groove)	mm	1.00
Minimum tube-in-tube spacing (G)	mm	3.00
		<b>Restore Defaults</b>
		<b>Show Template</b>



Under clearances and spacing (normally hidden) a series of tolerance values are defined which are needed for designing shell and tube heat exchangers correctly. A series of AHED default values can be restored by clicking the button **Restore Defaults**. Clicking **Show Template** will show a layout where each parameter is indicated.

## 8. Baffles

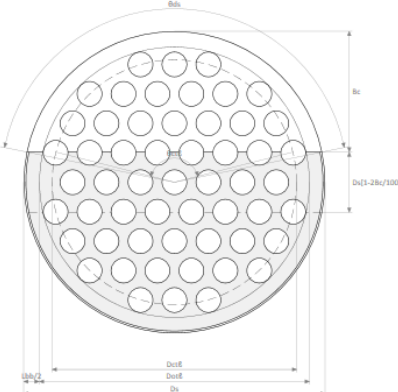
Shell and tube heat exchangers use baffles for supporting the inner tubes and enhancing the heat transfer on shell side. In AHED three types of calculation options for baffles can be chosen:

- **NO Baffles:** no baffles are placed, and tubes are only supported between the two tubeplates. Heat transfer is calculated as fluid in a straight channel. This only should be applied for very short tube lengths.
- **Standard heat transfer with SUPPORT baffles only:** This option is to be used for longer tube lengths (so tube support is necessary) but the distance between adjacent baffles (baffle spacing) is much longer than the shell inner diameter. Heat transfer is calculated as fluid in a straight channel, but the baffles geometry is considered for the pressure drop calculation on shell side.
- **FULL baffles heat transfer calculation:** This option is to be used for longer tube lengths and a baffle spacing equal or less than the shell inner diameter. For this situation, the shell side flow is considered as cross flow over a tube bank. The Delaware method is applied for calculation the correction factors applied to the crossflow heat transfer coefficient.

Calculate

NO baffles

**Basic Baffle Geometry Relations**



**Baffle Geometry Parameters**

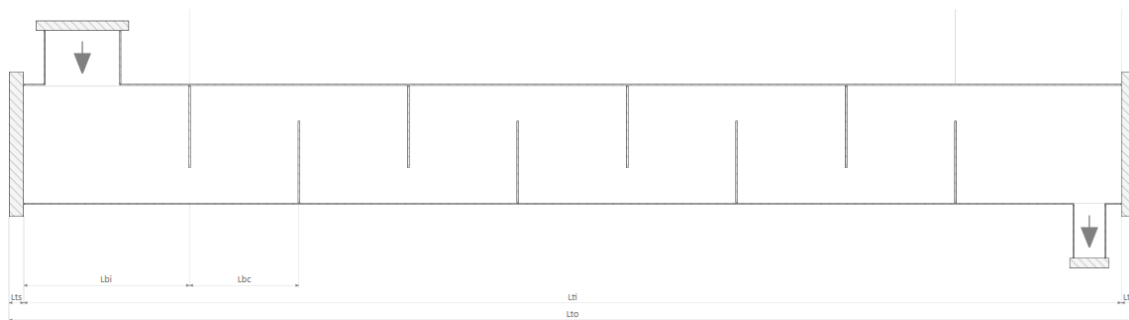
Type	Single segmental
Shell inner diameter (Ds)	mm 213.10
Tubes outer diameter (Dt)	mm 18.00
Baffle cut (Bc)	% 30.00
Baffle cut direction	Horizontal
Pairs of sealing strips (Nss)	0
Shell diameter angle (Bds)	° 132.84
Center tube angle (θctδ)	° 120.99
Diameter to tube center (Dctδ)	mm 173.07
Diameter to tube outer side (Dotδ)	mm 191.07
Bypass lanes (Lt)	mm 0
Inner shell to outer tube bypass clearance (Lt)	mm 22.03

Show Template

The following parameters should be defined for a correct calculation of SUPPORT baffles (second option) or FULL heat transfer baffles (third option):

- Baffle cut
- Number of pairs of sealing strips
- Inlet baffle spacing
- Outlet baffle spacing
- Number of baffles
- Baffle thickness

Clicking on the left hand side image shows a close up of the baffle shape and parameters. These **Baffle Distribution Parameters** should be entered under the heat exchanger image



### Baffle Distribution Parameters

TubePlate Thickness (Lts)	mm	27.00
Tube Inner Length (Lti)	mm	2000.00
Tube Outer Length (Lto)	mm	2054.00
Inlet baffle spacing (Lbi)	mm	300.00
Central baffle spacing (Lbc)	mm	195.43
Outlet baffle spacing (Lbo)	mm	300.00
Number of baffles (Nb)		8
Baffle thickness	mm	4.00

The top image shows how the baffles are distributed over the shell length according to the parameters defined below.

Sealing strips (if chosen) are displayed as well. Sealing strips can be used for redirecting the shell side flow towards the tube bank and keeping heat transfer high.

The J correction factor (according the Delaware method) are only calculated for the third option: FULL heat transfer baffles. The first two correction factors, Jc (cut effect) and JI (leakage effect) are calculated at the moment of defining the baffle geometry. The remaining correction factors, and the net shell side heat transfer coefficient are derived after completion of the **Overall Calculation**. After performing the **Overall Calculation**, the user is recommended to return to the **Baffle Calculation** window the review the calculated correction factors and heat transfer coefficients:

### Baffle Effects and Factors

	Inlet	Outlet
Cut Effect (Jc)	0.96	0.96
Leakages Effect (JI)	0.84	0.84
Bundle bypass effect (Jb)	NaN	NaN
Adverse Temperature Gradient (Jr)	NaN	NaN
Uneven Baffle Spacing (Js)	NaN	NaN
Combined Effects (JT)	NaN	NaN
Colburn Correction Factor (Ji)	NaN	NaN
Heat Trans. Coeff. Pure Cross-flow Ideal (Hccix) kcal/hr-m <sup>2</sup> -°C	NaN	NaN
Shell-Side Heat Transfer Coefficient (Hcc) kcal/hr-m <sup>2</sup> -°C	NaN	NaN

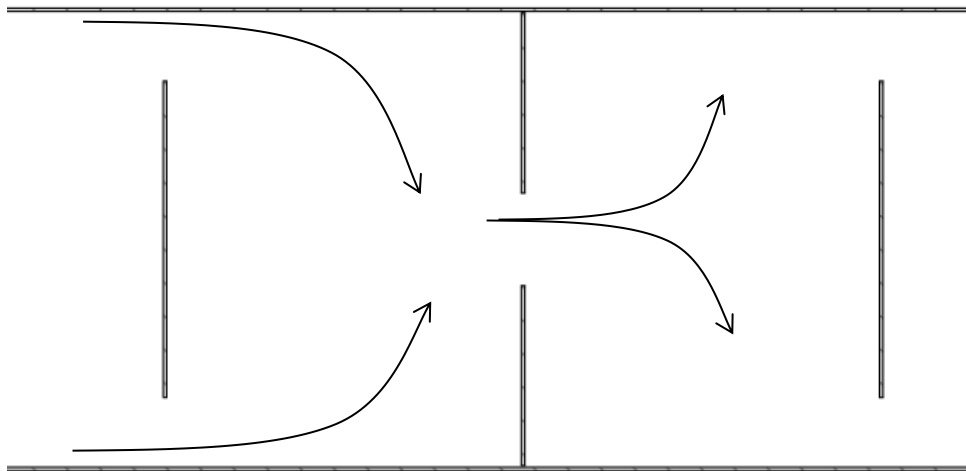


Baffle clearances and spacing can be defined at the bottom of the window. By clicking **Restore Defaults** the program inserts the AHED default values.

**Baffles Clearances & Spacings** ^

Diametral Clearance Shell-Baffle ( $\delta_{sb}$ )	mm	<input type="text" value="3.00"/>
Diametral Clearance Tube-Baffle ( $\delta_{tb}$ )	mm	<input type="text" value="0.60"/>
<input type="button" value="Restore Defaults"/>		

Apart from default single segmental baffles, AHED allows to use **Double Segmental Baffles**. These baffles split the shell side flow in two currents around each second baffle. This way a reduction in velocity is obtained. In general, this will lead to a reduction in pressure drop and a reduced vibrational risk. The next image shows the principle of double segmental baffles and how they split the flow around a baffle that is placed in the centre. The next baffle consists of two outer segments where the two currents are joined again in a central window.



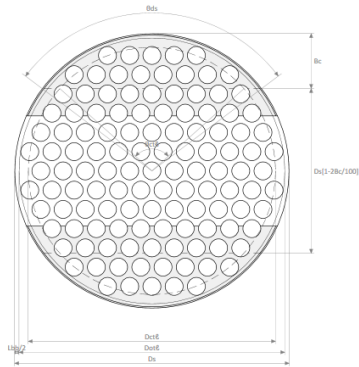
The reduction in flow velocity influences the rate of heat transfer. Normally, heat transfer is increased less with double segmental baffles than with single segmental baffles. But in general, double segmental baffles will give an improvement over a design with zero or very few baffles.

Double segmental baffles must be designed with a small overlap between the centre baffle and the split baffle. This overlap must be large enough to house a minimum of one tube row. Because of this requisite, double segmental baffles will be less useful with small tube bundles and work better with larger ones.

Calculate

FULL baffles heat transfer calculation

## Basic Baffle Geometry Relations



## Baffle Geometry Parameters

Type	Double segment: ▾	
Shell inner diameter (Ds)	mm	267.10
Tubes outer diameter (Dt)	mm	18.00
Central Baffle cut (Bc1)	%	40.00
Overlap	mm	26.71
Side Baffle cut (Bc2)	%	40.00
Baffle cut direction	Horizontal ▾	
Pairs of sealing strips (Nss)		0
Shell diameter angle (θ <sub>s</sub> )	°	156.93
Center tube angle (θ <sub>ct</sub> )	°	154.34
Diameter to tube center (D <sub>ct</sub> )	mm	240.53
Diameter to tube outer side (D <sub>ot</sub> )	mm	258.53
Bypass lanes (L <sub>p</sub> )	mm	0
Inner shell to outer tube bypass clearance (L <sub>b</sub> )	mm	8.57
Avg. Tubes in Double Baffle Windows		50.7
<a href="#">Show Template</a>		

The **Central Baffle Cut** parameter defines the opening (in % of shell diameter) around the centre baffle. The **Side Baffle Cut** parameter defines the opening (in % of shell diameter) of the space confined between the baffles that has two segments. From this definition it should be clear that any cut  $\geq 50\%$  will not allow for any overlap between the two baffles and an error will inform you of this. The overlap parameter indicates the overlap distance in mm. Use this value as a guide in the design process.

Double segmental baffles should always be designed with an uneven number of baffles. The first and last baffle must be a split baffle. This avoids preferential flows at the shell side inlet and outlet position.

Try to work with the double segmental option for cases where single segmental fail to give a workable solution. Where a lot of single segmental baffles can give an excessive pressure drop, double segmental baffles can provide the alternative.

## 9. Overall Calculation

The overall calculation can be performed when all previous steps needed have been completed free of errors (heat balance, geometry, and baffle calculation). The overall calculation module consists of three separate steps:

- Calculation of heat transfer area
- Calculation of shell and tube side pressure drops
- Vibration analysis

We will look at each step individually in more detail now.

### 9.1. Heat transfer area calculation

The basis of the heat exchanger area calculation is the calculation of the three important heat transfer numbers for shell and tube side:

- Reynolds number
- Prandtl number
- Nusselt number

It is beyond the scope of this manual to explain the physical background of each number. However, in the annex at the end of this manual a list of scientific paper references is given. This list of scientific work forms the mathematical background of the AHED software.

The three heat transfer numbers are related in a mathematical relationship:

$$Nu = f(Re, Pr) = \frac{K_{side} \cdot \text{Hydraulic diameter}}{\text{Fluid thermal conductivity}}$$

So knowing the Nusselt number (calculated from the Re,Pr relationship) on shell and tube side means knowing  $K_{side}$  for shell and tube side. The  $K_{side}$  and the overall heat transfer coefficient  $K_{fouled}$  are related in the following manner:

$$K_{fouled} = \frac{1}{\frac{1}{K_{shell}} + \frac{D_{out}}{D_{in} \cdot K_{tube}} + \frac{D_{out} \ln\left(\frac{D_{out}}{D_{in}}\right)}{2\lambda} + FF_{shell} + \frac{D_{out} \cdot FF_{tube}}{D_{in}}}$$

$D_{out}$ :	Tube outer diameter
$D_{in}$ :	Tube inner diameter
$K_{fouled}$ :	Overall heat transfer coefficient
$K_{shell}, K_{tube}$ :	Shell and tube side local heat transfer coefficients
$\lambda$ :	Tube material thermal conductivity
$FF_{shell}, FF_{tube}$ :	Fouling factors tube and shell side

Once  $K_{fouled}$  is known, the area needed for heat transfer is calculated using this equation:

$$Area\ needed = \frac{Duty}{K_{fouled} \cdot LMTD}$$

LMTD is the log mean temperature difference between shell and tube side inlet and outlet temperatures. The LMTD is calculated directly from these temperatures as they were established during the heat transfer calculation.

The calculation order for obtaining the heat transfer area is as follows:

*From the heat transfer calculation results:*

⇒ *Pr number calculations*

*Next, using geometry and physical property calculation results:*

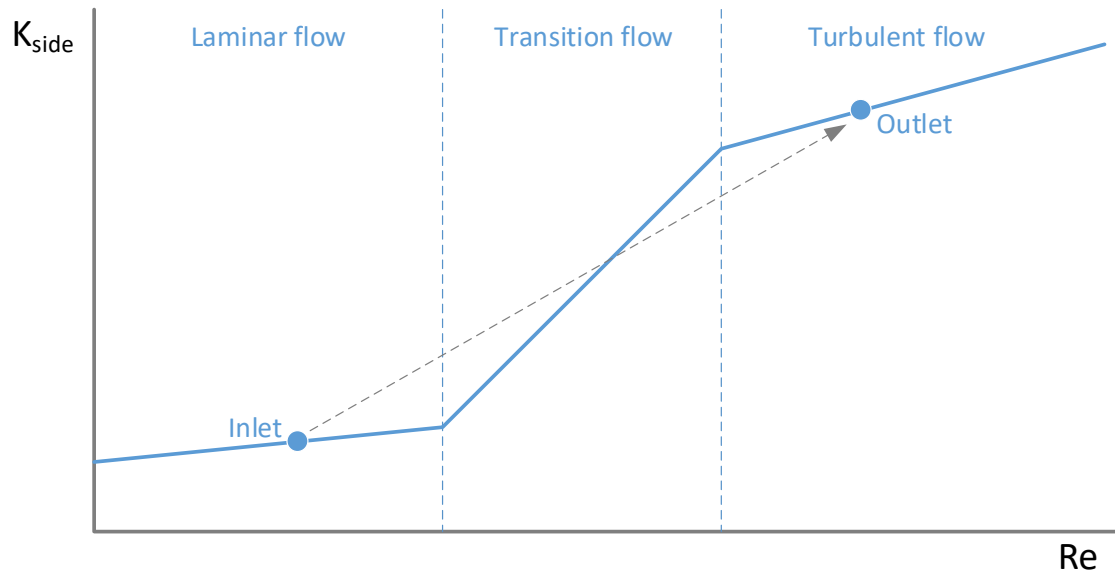
- ⇒ *Fluid velocity and apparent viscosity calculations*
- ⇒ *Re number calculations*
- ⇒ *Nu number calculations*
- ⇒  *$K_{side}$  calculations*
- ⇒  *$K_{fouled}$  calculation*
- ⇒ *Area calculation*

## 9.2. Wall temperature iteration

AHED corrects the side coefficients  $K_{side}$  for wall temperature effects. In heating applications, the fluids temperature near the tube wall is higher than in the bulk of the fluid. This means that the viscosity (for most liquids) near the tube wall is also less than in the bulk. This effect of reduced viscosity towards the tube wall will increase the side coefficient. The wall temperature and wall viscosity depend on the value of the corrected  $K_{side}$  in comparison to the overall coefficient  $K_{fouled}$ . But to know  $K_{fouled}$ , we must know the corrected  $K_{side}$  for shell and tube side first and for that the wall temperature must be known which is not calculated yet. This dilemma of missing information can only be solved by an iterative procedure. At that start wall temperatures are assumed and values of  $K_{side}$  and  $K_{fouled}$  are calculated. Based on these  $K_{side}$  and  $K_{fouled}$  new values for the wall temperatures are derived and  $K_{side}$  and  $K_{fouled}$  values are calculated again. This process continues until the values of  $K_{side}$  and  $K_{fouled}$  have converged.

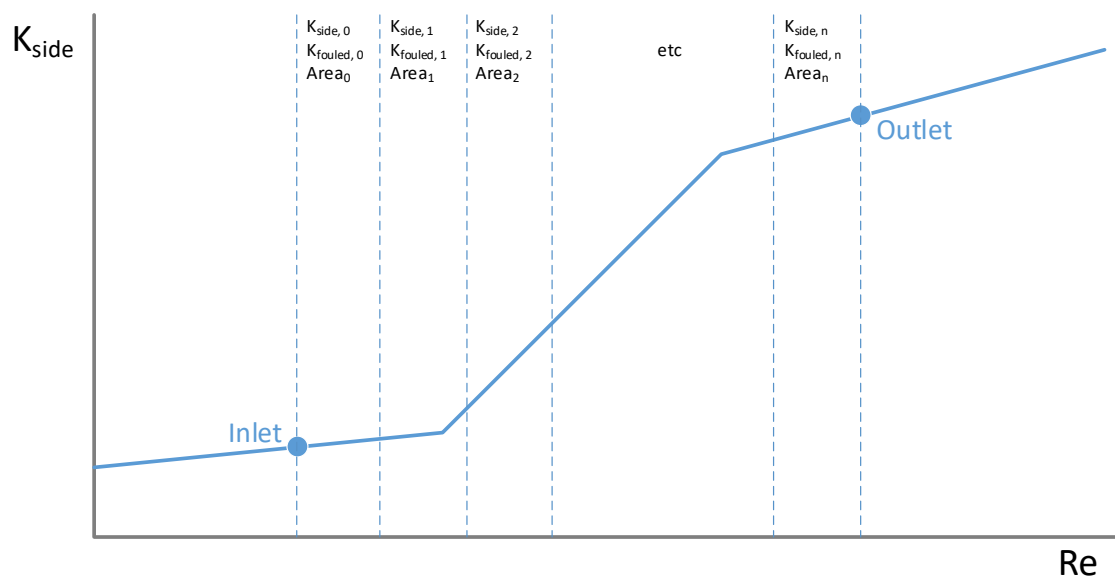
## 9.3. Heat transfer steps iteration (AHED-OPT procedure)

Many heat exchanger design programs calculate values of  $K_{side}$  at the inlet and outlet of the heat exchanger. Then on both sides  $K_{fouled}$  is calculated and the average value is taken for deriving the calculation of the needed heat transfer area. Other programs use the so-called mid temperature method meaning that  $K_{side}$  and  $K_{fouled}$  are calculated at the average temperature between inlet and outlet for shell and tube side. While for many cases this can give a satisfactory result, a great risk lies hidden in these ways of calculating. This is explained with the help of the following graph:



Heat transfer coefficient vary greatly depending on the flow regime they're in, as the figure shows. Imagine a fluid with a large variation in physical properties. At the inlet of the heat exchanger it may flow under laminar flow conditions and at the outlet under transition flow or even turbulent flow conditions. An average-method (or mid-point) calculation would lead to large errors: An average would be taken on inlet (low  $K_{side}$ ) and outlet (high  $K_{side}$ ) values. However, the reality shows that a low heat transfer coefficient at the inlet would mean a much larger heat transfer area is needed for the first part (transfer of laminar to transition) then for the last part (transition to turbulent). The average-method would not take this effect into account. Heat exchanger designed in this way run the risk of being calculated with not enough heat transfer area and would lead to underperformance of the unit.

To compensate for this calculation error the **AHED-OPT** routine is implemented in the programs code. **AHED-OPT** divides the heat exchanger calculation in several separate sections, see the figure below:

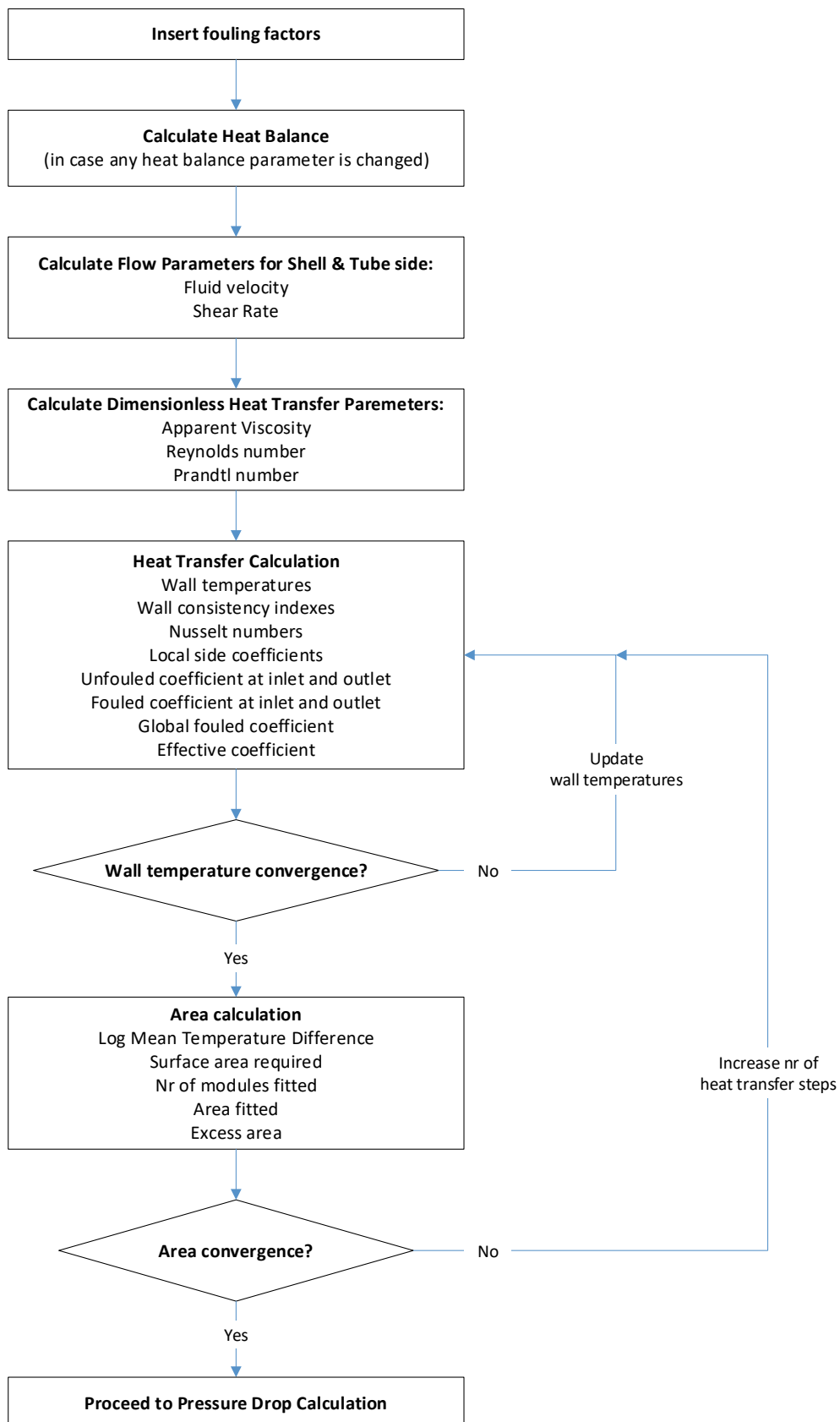


For each individual section, a heat transfer calculation is made where the heat transfer area needed is calculated just for that part of the overall duty. The overall heat transfer area needed is calculated by summing the parts:

$$Total\ area = \sum_0^n A_n$$

The **AHED-OPT** technology greatly enhances the accuracy of the heat exchanger design and is essential for working with fluids that show a great variation in the physical property values over their temperature range in the heat exchanger. **AHED-OPT** is by default used in all heat exchangers calculation in AHED.

The following flow sheet summarises the complete procedure for heat exchanger area calculation:



## 9.4. Pressure drop calculation

Pressure drops in fluid channels are calculated according in AHED using the following (Darcy-Weisbach) equation:

$$\Delta P = f_d \frac{\rho}{2} \cdot \frac{v^2}{D_h} \cdot L$$

$f_d$ : Darcy friction factor  
 $\rho$ : Density  
 $V$ : Fluid velocity  
 $D_h$ : Hydraulic diameter  
 $L$ : Channel length

The Darcy friction factor is a function of the Reynolds number, the hydraulic diameter, and the tube roughness. The friction factor is an internal AHED parameter and is not displayed in the program's interface. All these variables needed for pressure drop calculation are known once the area calculation is completed. Therefore, pressure drops are calculated after the area calculation has come to completion without any errors. Fluid pressure drop is created in tube and shell side inlet and outlet nozzles. So, these head losses are considered also and included in the pressure drop calculation.

**Pressure Drop** ☒ Use Viscosity Correction

**Tubes Side**

	v	m/s	c·v <sup>2</sup>	kg/m·s <sup>2</sup>	ΔP	bar-a
Modules		19.258				0.006
Inlet Nozzles		8.910		60.143		4.511E-4
Outlet Nozzles		7.903		53.348		4.001E-4
Bends		8.407				0.000
<b>Total</b>						0.007

**Shell Side**

	v	m/s	c·v <sup>2</sup>	kg/m·s <sup>2</sup>	ΔP	bar-a
Modules		0.659				0.000
Inlet Nozzles		1.287		1570.537		0.012
Outlet Nozzles		1.288		1571.773		0.012
Pressure drop in all central baffle spaces (ΔPc)						0.002
Pressure drop in all baffle windows (ΔPw)						0.011
Pressure drop in the entrance and exit baffle spaces (ΔPe)						0.017
<b>Total</b>						0.053

The tick box "Use viscosity correction" should always be marked during heat exchanger calculation. This way, wall effects (change of viscosity near the wall due to changes of wall temperature with respect to the bulk temperature) are considered. By unchecking this box, the pressure drop calculation can be used for pipe flow calculation in non-heat transfer situations.



For baffled heat exchanger the channel pressure drop is divided into losses in the central baffle spaces, inlet and outlet spaces and baffle windows. These pressure drops are calculated according the Delaware method and together with nozzle losses become the total shell side pressure drop.

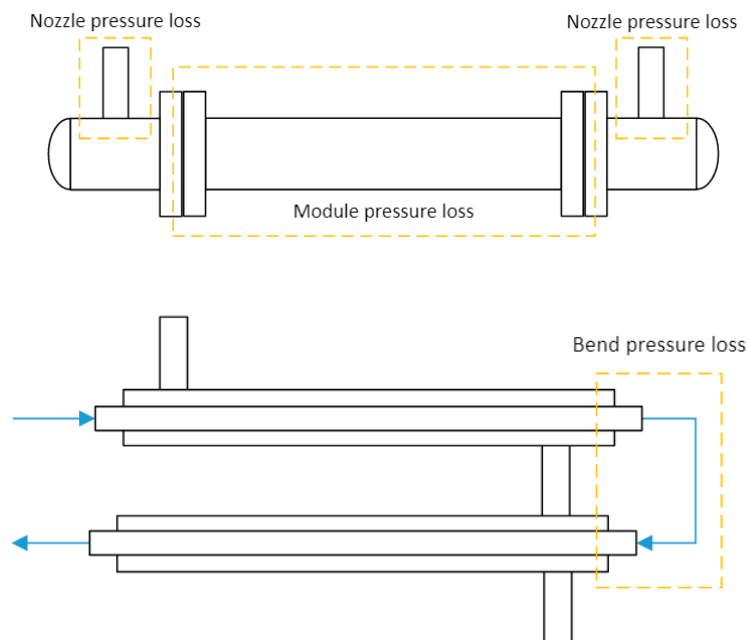
For the tube side pressure drop calculation the following should be noted:

**Modules pressure drop:** this is the pressure drop inside the inner tube plus the pressure drop for entering and exiting through the tube sheets.

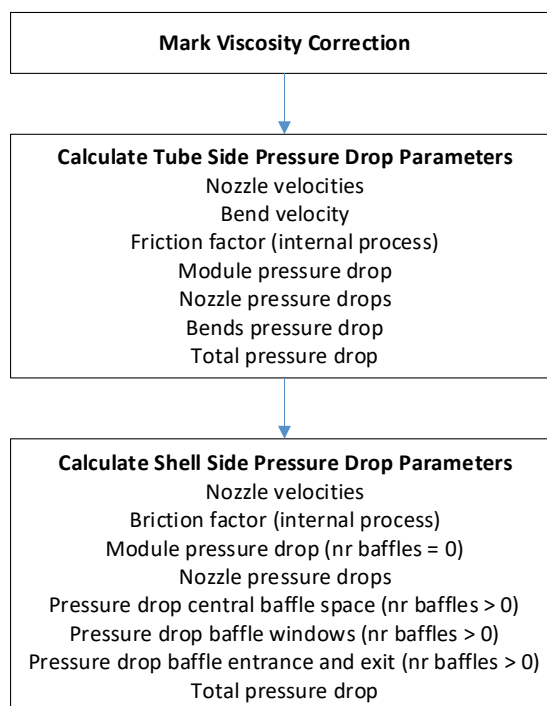
**Inlet and outlet nozzles pressure drops:** These are the pressure drops through these connections as they are fitted on bonnets.

**Bends pressure drop:** this is the pressure through 180 ° interconnecting bends in case they are applied for interconnecting multiple heat exchanger modules. This is typical for tube in tube heat exchanger modules interconnected. For the bend pressure drop calculation, the bend diameter considered is equal to the size of the exit nozzle definition.

The images below explain the differences between the various pressure drops.



The flowsheet below summarises the pressure drop calculation procedure:



### 9.5. $\rho v^2$

The value of density  $\times$  velocity<sup>2</sup> is a measure of the kinetic energy of a moving liquid. TEMA sets specified values for  $\rho v^2$  that should need be exceeded in inlet and outlet nozzles. For this reason, the  $\rho v^2$  are calculated in AHED and displayed next to nozzle pressure drop calculation. Warning messages (yellow) will be issued by AHED in case  $\rho v^2$  exceed maximum levels.

### 9.6. Vibration analysis

The flow of a fluid through a heat exchanger can cause heat exchanger tubes to vibrate. Mechanical failure due to excessive tube vibration can occur, for that reason a vibration analysis is included in AHED. The physics and mathematics behind tube vibration is highly complex and the details of this are beyond the scope of this manual. The method for vibration analysis applied in AHED is the method that is recommended by TEMA. In the literature annex the link is provided to the TEMA publication where this method is explained.

The most important parameters that come into play for vibration analysis are tube side fluid and its physical properties (density), tube (unsupported) span length and shell fluid flow and its physical properties. Failure due to tube vibrations can take place in all kinds of locations in the heat exchanger shell. The main areas of concern are usually long unsupported tube spans and high shell flow rates. The mitigation of tube vibration risk usually involves changes for one or both concerns. These can be changes like change in flow rates, tube lengths, tube layout and changes in the number of baffles and baffle cut.

The image below summarises the vibration analysis procedure:

**Vibration Parameters Calculation**

For inlet, center and outlet location:

Span length

Span length / Tema length ratio

Tubes natural frequency

Shell acoustic frequency

Cross flow velocity

Critical velocity

Cross flow velocity ratio

Vortex shedding ratio

Turbulent buffeting ratio

Vibration risk criteria

Acoustic vibration check

**Final vibration risk evaluation**

The parameters marked in blue are critical for the vibration risk evaluation and maximum recommended values of these are displayed in the interface. See the next image with clear yellow highlights:

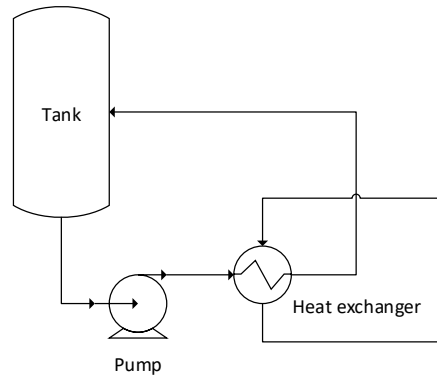
**Vibrations**

		Inlet	Central	Outlet	
Span Length	mm	562.22	524.44	562.22	
Span Length / TEMA Lb,max		0.39	0.36	0.39	< 1.0
Tubes Natural Frequency	Hz	190.44	218.76	151.88	
Shell Acoustic Frequency (gases)	Hz				
<b>Fluidelastic Instability</b>					
Cross Flow Velocity	m/s	18.52	10.6	0.01	
Critical Velocity	m/s	117.83	95.78	4.8	
Average Cross Flow Velocity Ratio		0.16	0.11	2.41E-3	< 0.8
<b>Vibration Amplitude</b>					
Vortex Shedding Ratio		0.02	0.01	1.11E-5	< 1.0
Turbulent Buffeting Ratio		0.00	0.00	0.00	< 1.0
<b>Acoustic Vibrations (gases)</b>					
Acoustic Vibration Exists		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Vibration Exists		<input type="checkbox"/>			

A final vibration risk statement is given. If the checkbox “Vibration exists” is marked, the user is recommended to make changes in the design to eliminate the vibration risk. Ignoring so can result in a design with severe risk of mechanical failure.

## 10. Batch

This section can be used to calculate batch heating and cooling times when a heat exchanger is used to heat or cool the contents of a tank:



The **Batch Calculation** section has the following appearance:

Calculate

**Batch**

Batch mass	kg	<input type="text"/>	Shell Inlet Temp.	°C	<input type="text"/>
Tubes Flow	kg/hr	<input type="text"/>	Shell flow	kg/hr	<input type="text"/>
Tubes Spec. Heat	kcal/kg·°C	<input type="text"/>	Shell spec. heat	kcal/kg·°C	<input type="text"/>
Batch start temp.	°C	<input type="text"/>	Isothermal Service Fluid	<input type="checkbox"/>	
Batch end temp.	°C	<input type="text"/>	Heat exchanger area	m²	<input type="text"/>
Duty Limitation	kcal/hr	<input type="text"/>	Heat transfer coeff	kcal/hr·m²·°C	<input type="text"/>

System mass	kg	<input type="text"/>
System spec. heat	kcal/kg·°C	<input type="text"/>

Batch time	hh:mm:ss	<input style="background-color: #f4a460;" type="text"/>
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**Batch Temperatures**

It can be accessed from the Navigation Window and by clicking the button **Batch Calculation** in the **Overall Calculation** section. When accessing through the Overall Calculation section several parameters of the heat transfer calculation are copied into the batch module:

- Tube Flow rate
- Tube Spec. Heat
- Shell Inlet Temp.
- Shell flow rate
- Shell spec. heat
- Heat exchanger area
- Heat transfer coefficient

But all parameters can be set manually as well without using any computed value from the overall calculation.

If the service fluid is isothermal (fluids with phase change such as condensing steam) the “Isothermal Service Fluid” box must be ticked which causes “Shell flow” and “Shell spec. heat” fields to be shaded out as these don’t need to be inputted in this case.

To perform a batch calculation, the user must input the “Batch mass”, “Batch start temp.”, “Batch end temp.”, “System mass” and “System spec. heat” as these won’t be inputted automatically. The batch mass is the total amount of product to be heated or cooled. The system mass is the total amount of system material that is in contact with the fluid. It will absorb heat and therefore its effect in the batch calculation must be considered.

The “Duty limitation” does not have to be defined to perform a batch calculation but is a useful tool when you need to limit the duty of each pass. This field is ideal for ensuring that no more duty can be absorbed then can be delivered by the services available. The typical example us to specify a maximum boiler capacity for example.

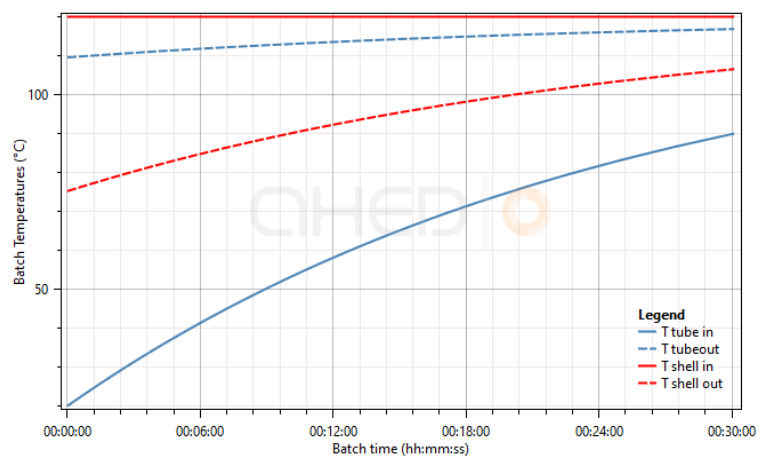
Once all the aforementioned fields have been filled in, click the **Calculate** button. This will perform the batch calculation which yields a “Batch Time” and a “Batch Graph”. The “Batch Graph” shows you the inlet and outlet temperatures of both the tube side and shell side fluids throughout the batch process.

Here is an example:

#### Batch

Batch mass	kg	<input type="text" value="1000.00"/>	Shell Inlet Temp.	°C	<input type="text" value="120.00"/>
Tubes Flow	kg/hr	<input type="text" value="3000.00"/>	Shell flow	kg/hr	<input type="text" value="6000.00"/>
Tubes Spec. Heat	kcal/kg·°C	<input type="text" value="1.00"/>	Shell spec. heat	kcal/kg·°C	<input type="text" value="1.00"/>
Batch start temp.	°C	<input type="text" value="20.00"/>	Isothermal Service Fluid	<input type="checkbox"/>	
Batch end temp.	°C	<input type="text" value="90.00"/>	Heat exchanger area	m²	<input type="text" value="10.00"/>
Duty Limitation	kcal/hr	<input type="text"/>	Heat transfer coeff	kcal/hr·m²·°C	<input type="text" value="1000.00"/>
System mass	kg	<input type="text" value="1000.00"/>			
System spec. heat	kcal/kg·°C	<input type="text" value="0.12"/>			
Batch time	hh:mm:ss	<input type="text" value="00:30:06"/>			

#### Batch Temperatures



This calculation can be exported to excel in the Reports tab (Section XX). Guidelines to the correct design of batch heating and cooling heat exchangers can be found here:

<https://www.hrs-heatexchangers.com/case-study/correct-design-batch-heat-exchanger-systems/>

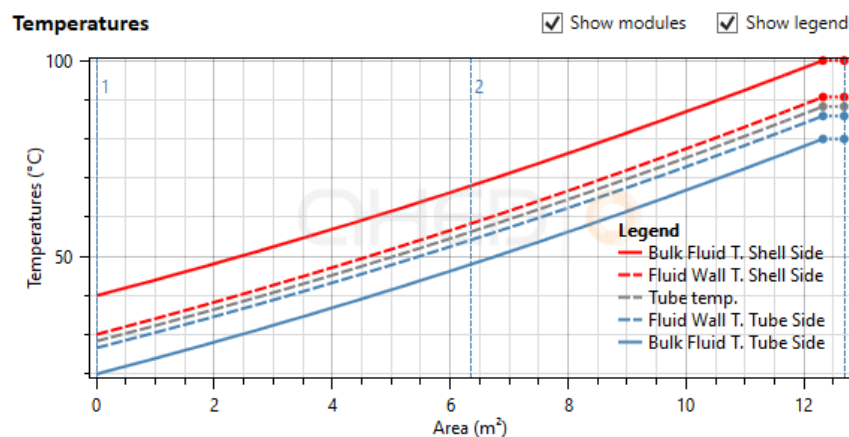
## 11. Graphs

In the graph section, AHED displays three kinds of graphs:

### 11.1. Temperature vs Area Graph

The horizontal axis displays the heat exchanger area. The starting point (zero point) corresponds to the tube side inlet. The vertical axis are the temperature values:

- Shell side fluid bulk temperature
- Shell side fluid wall temperature
- Tube temperature
- Tube side fluid wall temperature
- Tube side fluid bulk temperature



The temperature lines end at 100% value of the needed heat transfer area. After that point, the lines continue in horizontal to end at the total installed area. The number of heat transfer modules in series (in case there are more than one) are indicated with grey numbers in top part of graph. The tick boxes above the graph allow for showing / hiding of the number of modules and graph legend.

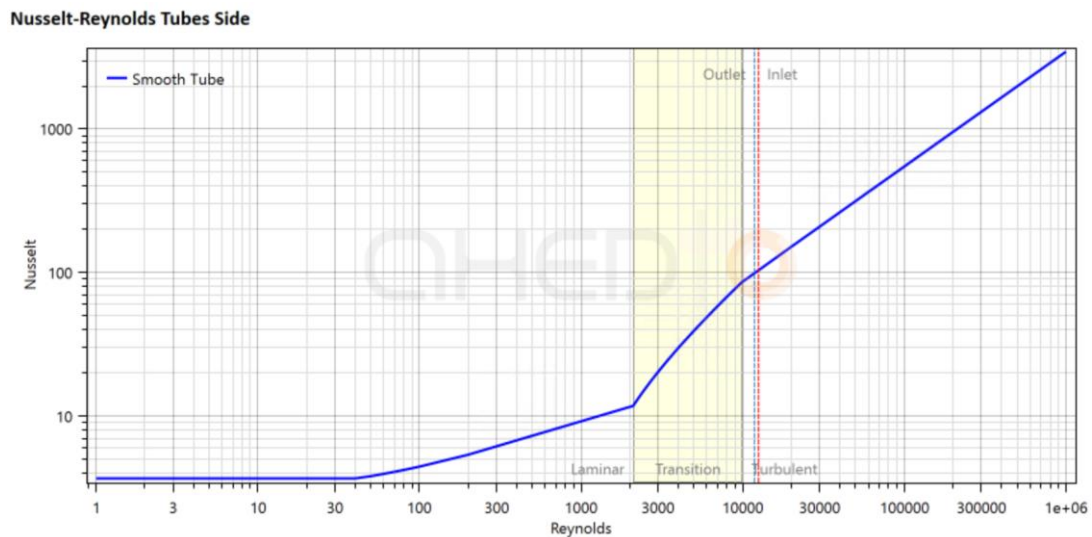
The graph is interactive: Hovering the mouse over the graph lines will show local values. Using the mouse wheel, the user can zoom in and out to certain parts of the graph.

Fluid wall temperatures (the temperature of a fluid molecule in contact with the tube wall) are displayed as they can be of interest for several reasons:

- When temperature dependent corrosion may be an issue (e.g. for fluids with chlorides).
- When temperature dependent fouling is a concern (e.g. for products with proteins in heating applications)
- For cooling applications with fluids with strong increase in viscosity at low temperatures.

### 11.2. Nusselt vs Reynolds Graph Tube Side

This graph shows the Nusselt number (vertical axis) against the Reynolds number (horizontal axis). The tube side Nusselt number is proportional to the tube side heat transfer coefficient. Its value is displayed over the whole range, from low Reynolds number ( $Re = 1$ ) in laminar flow to high Reynolds number ( $Re > 10000$ ) in turbulent flow.



With vertical lines in the graph the conditions of the tube inlet and outlet are shown. As the heat transfer coefficient is proportional to the Nusselt number, and the Reynolds number is proportional to viscosity and to flow velocity, the graph allows for assessment of positive or adverse effects that changes in product viscosity or flow rate may have on the heat exchanger's performance. It is especially helpful to verify potentially dangerous design: in case any of the vertical lines (any of the inlet or outlet conditions) are close to the transfer point from turbulent to laminar flow (Reynolds = 2100), Any decrease in fluid velocity, or increase in product viscosity will decrease the Reynolds number. This can lead to a big reduction in heat transfer and can lead to underperforming designs. It is advisable that for design with fluctuating process conditions these Nusselt Reynolds graph is checked. The transition flow regime, between laminar and turbulent flow, is indicated as a yellow band.

As with the temperature graph, hovering the mouse over the graph lines displays the values and with the mouse wheel the user can zoom in and out.

### 11.3. Nusselt vs Reynolds Graph Shell Side

This graph is identical in functionality to the tube side Nusselt Reynolds graph.



## 12. Reports

AHED allows for export of the simulations to .xlsx files. These files are stored into a pre-established folder, which can be personalized changing “Working directory” in “Options” (in the “Tools” drop down menu).

The units and number of decimals in the reports are the same as those used in the simulation. The following reports can be generated by clicking **Report**:

File	Tools	Help
Project		Phys Prop Report
Tubes Fluid	✓	Heat Balance Report
Shell Fluid	✓	Geometry Report
Heat Balance	✓	Baffles Report
Geometry	✓	Heat Transfer Report
Baffles	✓	Graphs Report
Overall Calculation	✓	Batch report
Batch		TEMA Report
Graphs		Full Report
<b>Reports</b>		

The reports highlighted in orange are available for exporting. The ones in grey are not available. This can be for two reasons:

- The report is not part of the calculation: In the example above no batch calculation was performed.
- The calculation has not completed correctly.

### *Physical Properties Report*

This report sums up the tube- and shell side’s physical and rheological properties that were used for the **Heat Balance** and **Overall Calculation**

### *Heat Balance Report*

This report sums up the main process and property data for the simulation, including the fluids’ physical and rheological properties at the inlets and outlets.

### *Geometry Report*

This report sums up the geometry data of the heat exchanger, such as:

- Shell and tube dimensions.
- Number of tubes, tube pitch.
- Wetted perimeter, hydraulic diameter for tube and shell side.
- Horizontal or vertical mounting.
- Tube layout parameters.
- Nozzle parameters.
- Baffle parameters.

NOTE: The “Clearances & Spacing” drop down data in the program’s Geometry page are not exported to the report.

### *Baffles Report*

This report presents detailed baffle design data, including.

- Baffle geometry parameters.
- Baffle clearances and spacing parameters.
- Baffle distribution parameters.
- Baffle J factors

NOTE: AHED's evaluation and comments of the baffle design, which appear in the interactive window when using the program, do not appear in the report.

The baffle report is only available after successful completion of the baffle calculation.

### *Heat Transfer Report*

This report sums up the **Overall Calculation** and includes:

- Shell and tube side flow parameters for liquid and gas phases including viscosity, Reynolds and Prandtl numbers.
- Heat transfer data: wall temperature, Nusselt numbers and heat transfer coefficients for shell and tube side.
- Overall heat transfer coefficients: unfouled, fouled and effective.
- Areas and number of modules.
- LMTD data.
- Pressure drop data.
- Vibration analysis parameters.

### *Batch Report*

This report shows all the batch calculation parameters, and includes the temperature vs time graph, as described in the **Graphs** section.

### *TEMA report*

This report gives a summary of the most important calculation parameters in a TEMA sheet format.

### *Full Report*

This document sums up the previously mentioned reports in one single .xlsx file. Baffle report and batch report are only included when considered in the simulations.

## A. Calculation methods.

For all methods of calculation applied AHED, links are given here to the corresponding scientific literature.

### **Fluid parameter mixing rules.**

#### *Liquid density:*

Calculated as weighted harmonic mean of density of each compound.

#### *Gas density:*

Calculated with the EOS Soave-Redlich-Kwong (SRK) method.

#### *Specific heat:*

Calculated as weighted arithmetic mean of specific heat of each compound.

#### *Latent heat:*

Calculated as weighted arithmetic mean of specific heat of each compound.

#### *Liquid thermal conductivity:*

Li Method: "Thermal Conductivity of Liquid Mixtures" Li 1976.

#### *Gas thermal conductivity:*

Mason–Saxena–Wassiljewa method: "The Properties of Gases and Liquids" Fifth Edition. Bruce E. Poling, John M. Prausnitz, John P. O'Connell. 2001

#### *Liquid viscosity:*

Calculated by sum of the viscosity logarithm weighted by mass concentration.

#### *Gas viscosity:*

Wilke method: "A Viscosity Equation for Gas Mixtures" C.R. Wilke 1949.

#### *Vapour fractions:*

Calculated with Raoult's law.

**Baffle calculation.**

Delaware method as explained in Serth's textbook:

Process Heat Transfer – Principles and Applications, Robert W. Serth, Elsevier Science & Technology Books, 2014 Edition.

**Laminar Flow Heat Transfer Calculation.**

Sieder Tate correlation:

Ind. Eng. Chem. 1936, 28, 12, 1429-1435

**Transition Flow Heat Transfer Calculation.**

Calculated as a linear interpolation between last laminar and first turbulent result.

**Turbulent Flow Heat Transfer Calculation.**

Sieder Tate correlation:

Ind. Eng. Chem. 1936, 28, 12, 1429-1435

**Mixed Convection Calculation.**

Oliver method:

Chemical Engineering science, Volume 17, Issue 5, 1962, Pages 335-350

**Condensation Calculation***Tube side vertical:*

As explained in Serth's textbook:

Process Heat Transfer – Principles and Applications, Robert W. Serth, Elsevier Science & Technology Books, 2014 Edition.

*Tube side horizontal:*

HRS propriety method.

*Shell side vertical:*

As explained in Serth's textbook:

Process Heat Transfer – Principles and Applications, Robert W. Serth, Elsevier Science & Technology Books, 2014 Edition.

*Shell side horizontal:*

As explained in Serth's textbook:

Process Heat Transfer – Principles and Applications, Robert W. Serth, Elsevier Science & Technology Books, 2014 Edition.

**Pressure Drop Calculation***Straight channel:*

Darcy Weissbach method:

The History of the Darcy-Weissbach Equation for Pipe Flow Resistance, Brown, Glenn, Proc. Environ. Water Resour. Hist., Vol. 38, 2002/10/17

[https://www.researchgate.net/publication/242138088\\_The\\_History\\_of\\_the\\_Darcy-Weissbach\\_Equation\\_for\\_Pipe\\_Flow\\_Resistance](https://www.researchgate.net/publication/242138088_The_History_of_the_Darcy-Weissbach_Equation_for_Pipe_Flow_Resistance)

**Friction factor:**

Laminar flow, calculated as:  $F = 64 / Re$

Turbulent Flow, calculated with the Goudar-Sonnad method:

Goudar, C. T; Sonnad, J. R. (2008). "Comparison of the iterative approximations of the Colebrook-White equation: Here's a review of other formulas and a mathematically exact formulation that is valid over the entire range of Re values". Hydrocarbon Processing. 87 (8)

**Pressure drop in headers, tube plate inlet/outlets, bends etc:**

As explained in Serth's textbook:

Process Heat Transfer – Principles and Applications, Robert W. Serth, Elsevier Science & Technology Books, 2014 Edition.

**Partial Condensation Calculation**

Calculated with the Bell and Ghaly method:

Bell KJ, Ghaly MA. An approximate generalized design method for multicomponent / partial condensers. AIChE Symposium Series 1972;69(No. 131):72–9.

**Vibration Analysis**

Calculated with the TEMA method:

"Standards of the tubular exchanger manufacturer association, Tenth edition", Richard C. Byrne, [www.tema.org](http://www.tema.org)

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