

Release Notes: Plate-Frame Module

INSTED Ver. 9.0



TTC TECHNOLOGIES, INC.

June 20, 2017

Release Features

INSTED Ver. 9.0

The most recent version of INSTED (Ver. 9.0) includes significant re-design, enhancements, and changes to the Plate-Frame module in INSTED. The new features include the following:

Improved Support for Multi-Pass Plate-Frame Calculations

In INSTED 9.0, a new parameter “Flow Inlet Location” has been added to help define the different configurations of multi-pass flows in a plate frame heat exchanger (PHE). Together with the “Flow Inlet Direction,” different multi-pass configurations can be defined. Details can be found in the Appendix of this Release Notes. The definition of these parameters is as follows.

Flow Inlet Direction	Parallel	Stream inlets are both located at the top or bottom of the heat exchanger
	Counter	One stream inlet is located at the top and the other at the bottom of the heat exchanger
Flow Inlet Location	Same Side	Stream inlets are both located at the left or at the right side of the heat exchanger
	Opposite Sides	One stream inlet is located at the left side and the other at the right side of the heat exchanger

Note that the PHE module currently does not support flow maldistribution from port to channel. Therefore, some configurations are mathematically identical and will return the same calculation results.

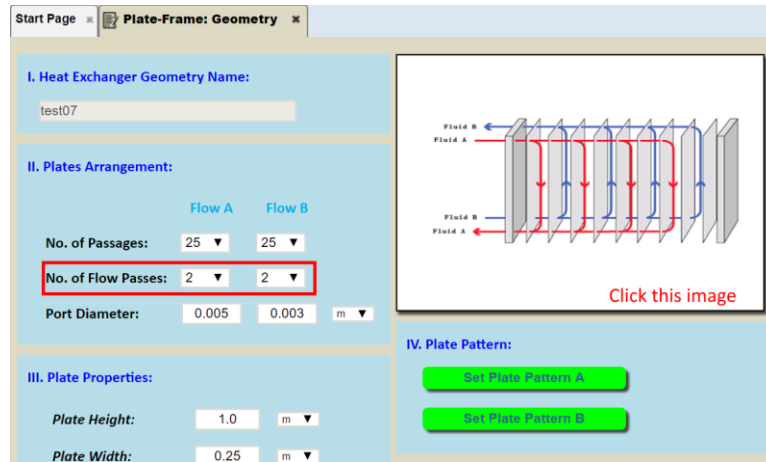
The GUI looks like the one below:

The screenshot displays the INSTED software interface for configuring a Plate-Frame Heat Exchanger. The interface is organized into several sections:

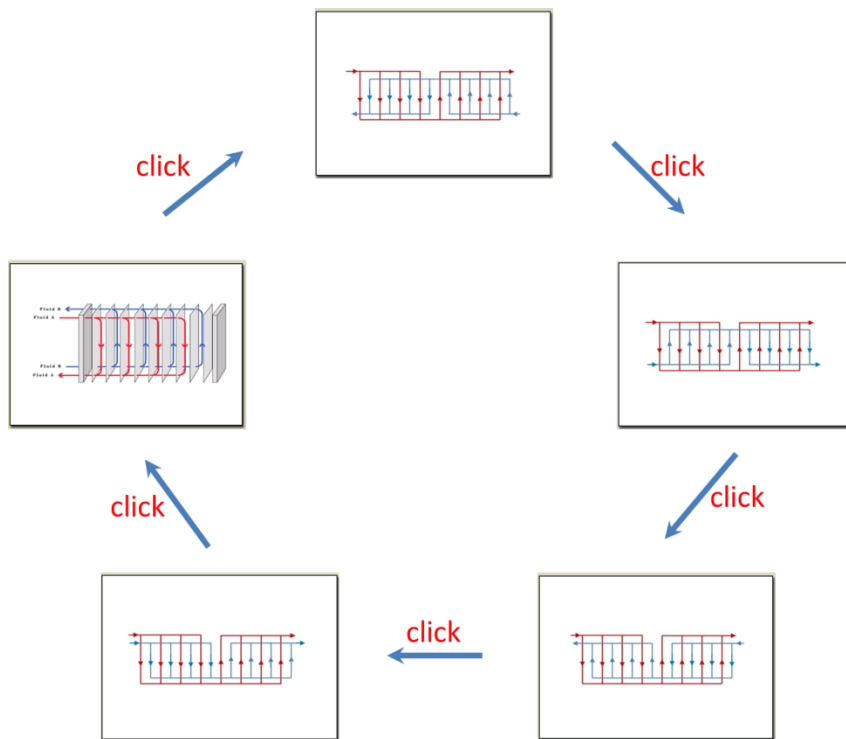
- I. Project Name:** A text input field.
- II. Choose Heat Exchanger Geometry to Rate:** A dropdown menu with "Please choose" and a "View Details" button.
- III. Flow Assignment:** Radio buttons for "Fluid A is hot" (selected) and "Fluid B is hot".
- IV. Flow Direction:** Radio buttons for "Parallel" (selected) and "Counter".
- V. Flow Inlet Location:** Radio buttons for "Same Side" (selected) and "Opposite Side".
- VI. Flow Conditions:** Radio buttons for "Hot" and "Cold".
- Flow Rate:** An "Inlet Flow Rate" input field with units in kg/s.
- VII. Fluid Properties:** Radio buttons for "Fixed", "Variable/Custom", and "REFPROP" for both Hot and Cold fluids.

A diagram on the right side of the interface shows a cross-section of a plate heat exchanger with multiple plates. Red arrows indicate the flow path of Fluid A, and blue arrows indicate the flow path of Fluid B. The diagram illustrates a multi-pass configuration where Fluid A flows through the top and bottom channels, and Fluid B flows through the middle channels.

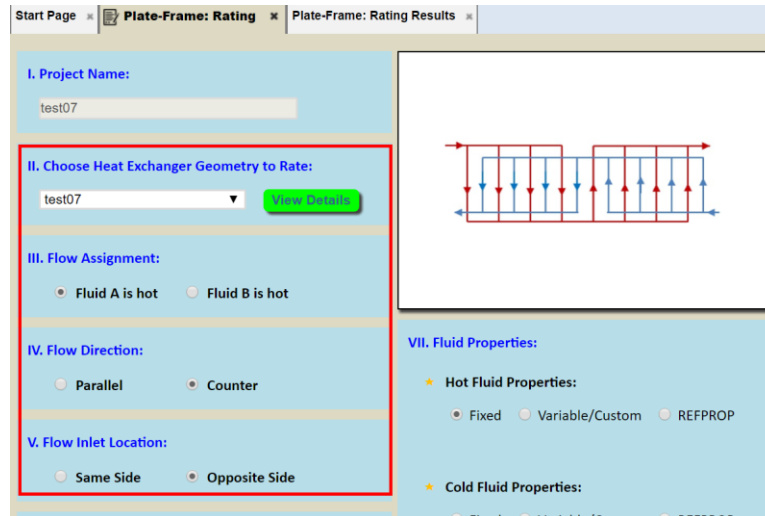
When defining the heat exchanger geometry, the number of flow passes can be defined:



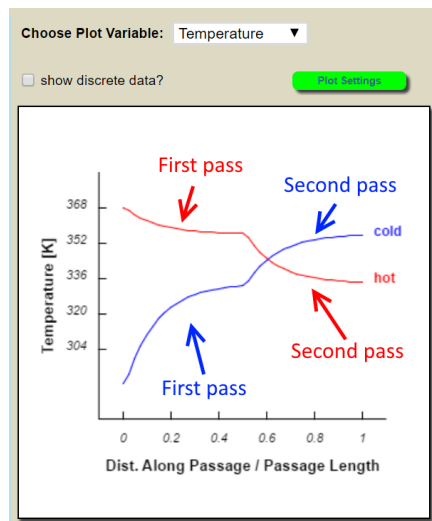
By repeatedly clicking the heat exchanger image in the GUI, all the supported multi-pass PHE configurations will be shown:



When rating a PHE, after choosing particular heat exchanger geometry, the GUI for entering the parameters required for the configuration will be shown (below).



In the results for the Rating task, the effects of having a multi-pass configuration can be observed in the plots of the distribution of certain variables, such as temperature, along the flow passage. This is evident in the figure below.



Sizing & Optimization using the Genetic Algorithm

In INSTED 9.0, Sizing and Optimization functionalities have been added to the PHE module. Similar to the Plate-Fin module, both the Sizing and Optimization solvers are based on the generic algorithm. During calculation, design realizations will be suggested to you by the code based on your specified design targets and bounds.

Sizing

For Sizing, after choosing a reference Rating Project which provides a template for the problem to be sized, you can specify a target heat transfer rate with some additional design criteria. The GUI for this is shown below.

The screenshot shows the 'Plate-Frame: Sizing' GUI. It includes a flow diagram in the top right showing a multi-pass heat exchanger configuration with red and blue arrows indicating flow directions. The main interface has several sections:

- I. Project Name:** PFM Size
- II. Choose a Reference Rating Project:** test01a (Single phase calculation only)
- III. Design Target:** Target Heat Transfer Rate: 1.5e+6 W
- IV. Sizing Criteria:**
 - Fix Plate Length?
 - Fix Plate Width?
 - Fix Hot Flow Rate?
 - Fix Cold Flow Rate?
 - Fix No. of Flow Passes?
 - Fix No. of Plates?
 - Fix Hot Flow Frame Pattern?
 - Fix Hot Flow Frame Corrugation Angle?
 - Fix Cold Flow Frame Pattern?
 - Fix Cold Flow Frame Corrugation Angle?
 - Fix Effectiveness?
 - Fix COP?
- V. Min/Max Bounds on Design Parameters:** Set Bounds

Difference between sizing and rating:

	Rating	Sizing
Inputs	Plate Height Plate Width No. of Flow Pass (Hot) No. of Flow Pass (Cold) Mass Flow Rate (Hot) Mass Flow Rate (Cold) Frame Pattern (Hot) Frame Pattern (Cold)	Target Heat Transfer Rate
Outputs	Heat Transfer Rate	Plate Height ; Plate Width ; No. of Flow Pass (Hot) ; No. of Flow Pass (Cold) ; Mass Flow Rate (Hot) ; Mass Flow Rate (Cold) ; Frame Pattern (Hot) ; Frame Pattern (Cold) ;

! If not fixed for sizing calculation.

Buttons at the bottom: New, Save, Save As, Load, Close, Compute

You can specify the bounds on the design parameters by clicking the “Set Bounds” button. The GUI is shown below.

Start Page | Plate-Frame: Sizing | **Plate-Frame: Design Constraints**

Min/Max Bounds on Design Parameters:

Max. Hot Flow Rate	=	80.0	kg/s
Min. Hot Flow Rate	=	0.006	kg/s
Max. Cold Flow Rate	=	80.0	kg/s
Min. Cold Flow Rate	=	0.006	kg/s
Max Plate Height	=	8.0	m
Min Plate Height	=	0.004	m
Max Plate Width	=	8.0	m
Min Plate Width	=	0.001	m
Max Material Temperature	=	1000.0	K
Min Material Temperature	=	200.0	K
Max Hot Pressure Drop	=	36000.0	Pa
Max Cold Pressure Drop	=	36000.0	Pa
Max Corrugation Angle	=	89.0	°
Min Corrugation Angle	=	1.0	°
Max Number of Plates	=	1000	

Genetic Algorithm Parameters:

Population Size Level of GA	=	2	?
-----------------------------	---	---	---

Default Back

After you have clicked on “Compute” button, the code will begin execution, and, upon completion, will list all the possible design realizations that satisfy the design target. The dialog box containing the list of realizations is shown below.

Start Page | Plate-Frame: Sizing | Plate-Frame: Design Constraints | **Plate-Frame: Sizing Result**

Choose One Realization for Rating:

No.	Plates	$N_{p,hot}$	$N_{p,cold}$	H	W	M_{hot}	M_{cold}	ΔP_{hot}	ΔP_{cold}	
				m	m	kg/s	kg/s	Pa	Pa	
<input type="radio"/>	1	100	1	1	1.0	0.25	10.0	5.0	3409.736258242	1233.0618533
<input type="radio"/>	2	100	1	1	1.110722801	0.23500582	10.0	5.0	4171.13694074	1492.5601796
<input type="radio"/>	3	100	1	1	0.615723955	0.550507883	10.0	5.0	665.346745157	272.6928984
<input type="radio"/>	4	100	1	1	0.496640487	1.03189379	10.0	5.0	238.146621525	105.2889962
<input type="radio"/>	5	100	1	1	0.419094447	1.355358515	10.0	5.0	144.549593947	65.5294712
<input type="radio"/>	6	100	1	1	0.300929266	2.064761678	10.0	5.0	63.763700377	29.79363603
<input type="radio"/>	7	100	1	1	0.394475322	1.581221154	10.0	5.0	113.515230608	52.09175604
<input type="radio"/>	8	100	1	1	0.283598825	2.672918147	10.0	5.0	45.035996353	21.3433385
<input type="radio"/>	9	100	1	1	0.207637937	3.667509498	10.0	5.0	23.351440292	11.21876454
<input type="radio"/>	10	100	1	1	0.226589931	3.541735818	10.0	5.0	26.461095669	12.69585419
<input type="radio"/>	11	100	1	1	0.184051929	4.541133325	10.0	5.0	16.465159847	7.96834231

Rate Selected Realization Back to the Project

You can choose any design realization from this table and click the “Rate the Selected Realization” button in order to rate the selected realization.

Sizing Result:

Plate Height:	1.110722801	m
Plate Width:	0.23500582	m
Hot Flow Rate:	10.0	kg/s
Cold Flow Rate:	5.0	kg/s
Total No. of Plates:	100	
No. of Hot Passes:	1	
No. of Cold Passes:	1	
Hot Pattern Type:	chevron_herringbone	
Hot Plate Spacing:	0.005	m
Hot Contact Pitch:	0.0020583	m
Hot Pattern Angle:	30.0	
Cold Pattern Type:	chevron_herringbone	
Cold Plate Spacing:	0.005	m
Cold Contact Pitch:	0.0020583	m
Cold Pattern Angle:	30.0	
Heat Transfer Rate:	1.529721e+6	W
Heat Transfer Area:	26.102632311	m ²
Hot Pressure Loss:	4171.13694074	Pa
Cold Pressure Loss:	1492.560179661	Pa

Detail Result:

No. of Passages:	50	
Inlet Temperature:	368.16	K
Outlet Temperature:	331.593711289	K
Pressure Loss:	4171.13694074	Pa
Mass Flow Rate:	10.0	kg/s
Mass Flux:	170.208550343	kg/(s·m ²)
Flow Velocity:	0.172765479	m/s
Fouling Resistance:	0.	m ² K/W
Equivalent Diameter:	0.01	m
Reynolds Number:	3370.466343431	
Heat Coefficient:	7295.517796586	W/(m ² ·K)
Effective hA:	95216.109281091	W/K
Colburn Factor j:	0.022528909	
Friction Factor f:	0.6385287	
Flow Length:	1.110722801	m
Flow Width:	0.23500582	m
Plate Pattern:	chevron_herringbone	
Plate Spacing:	0.005	m
Contact Pitch:	0.0020583	m
Chevron Angle:	30.0	
Power:	42.337971384	W
Mean Temperature:	355.069036956	K

You may save the selected realization into a regular Rating project by clicking the “Save to a Regular Rating Project” button. The results of rating may be exported into a downloadable Excel file by clicking on the “Download Realization Data” button.

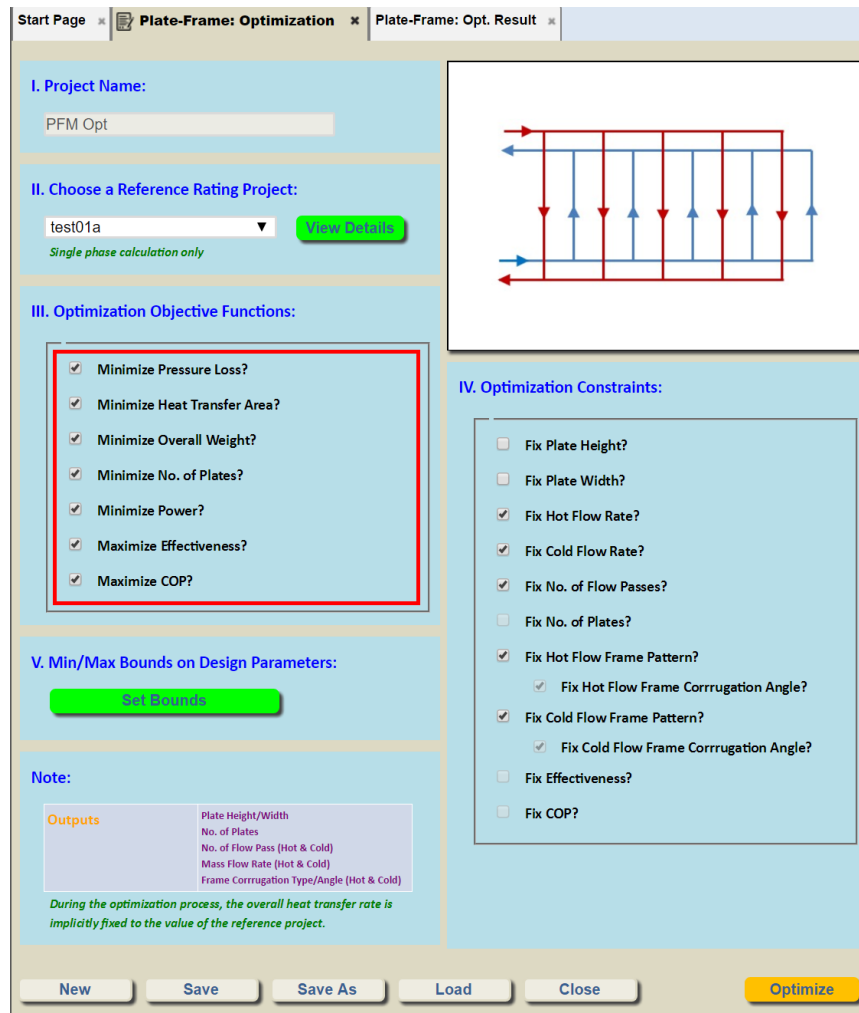
HX Problem Statement													HX Core Dimensions				
Operating Conditions -Hot				Operating Conditions -Cold				HX Core Design Input				HX Core Dimensions					
Fluid Type	Flow Rate	T _{in}	P _{in}	Fluid Type	Flow Rate	T _{in}	P _{in}	t-sp	t-ep	port-dia-hot	port-dia-cold	P-L	P-W	L-NF/S	Np-h	Np-c	W
[-]	[kg/s]	[K]	[Pa]	[-]	[kg/s]	[K]	[Pa]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[-]	[-]	[kg]
	10	368.16	0		5	288.16	0	3E-09	0	0.005	0.005	1.1107	0.25	0.5	50	50	0.0002

Optimization

The procedure for optimization in INSTED PHE is in general similar to that for sizing, However, the former also attempts to find design realizations can achieve the same heat transfer rate as in the reference project, as well as achieving one or more of the following optimization targets:

- Minimize Pressure Loss
- Minimize Heat Transfer Area
- Minimize Overall Weight
- Minimize No. of Plates
- Minimize Power
- Maximize Effectiveness
- Maximize Cop

The relevant GUI for this setting is shown below.



Similar to the Sizing module, after specifying the bounds on the design parameters and choosing the design constraints, you can click the “Compute” button to start the Optimization calculations. When the calculations have been completed, all possible design realizations that satisfy the design target will be listed in a table. The list of the realizations is sorted based on how well the realizations satisfy the optimization targets. The best one is placed at the top of the table.

The dialog box containing the list of realizations is shown below.

Start Page x Plate-Frame: Optimization x Plate-Frame: Opt. Result x

Choose One Realization for Rating:

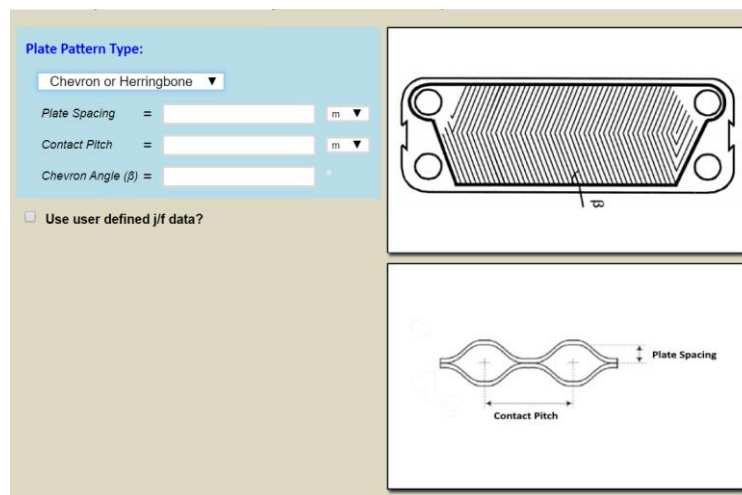
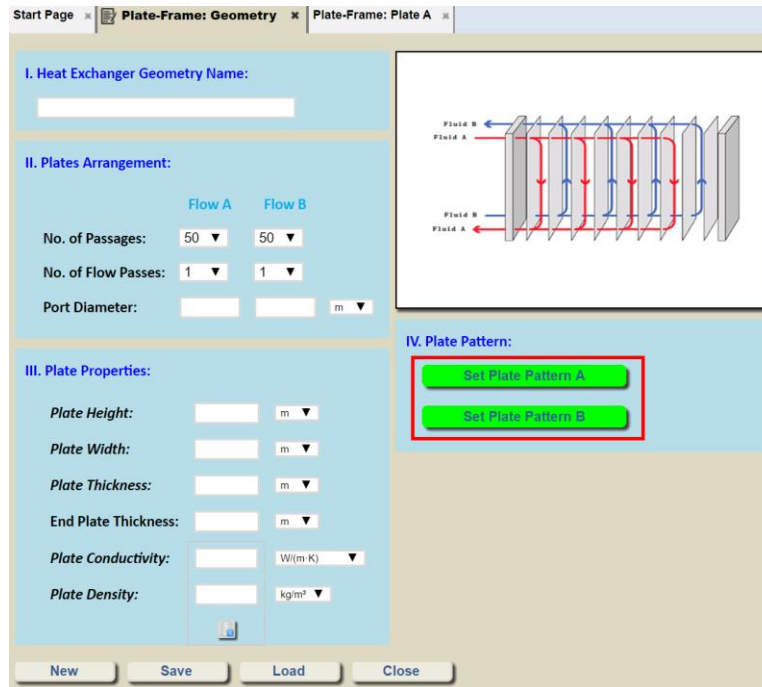
	Plates	$N_{p,hot}$	$N_{p,cold}$	H m	W m	M_{hot} kg/s	M_{cold} kg/s	ΔP_{hot} Pa	ΔP_{cold} Pa
<input checked="" type="radio"/> 1 <i>best</i>	176	1	1	0.106631882	6.333785459	10.0	5.0	3.738142234	1.843654527
<input type="radio"/> 2	128	1	1	1.474515028	5.6287168	10.0	5.0	81.16881461	39.743177829
<input type="radio"/> 3	166	1	1	1.162159512	3.464534089	10.0	5.0	80.983778598	39.451465191
<input type="radio"/> 4	166	1	1	1.365778668	4.696759716	10.0	5.0	69.257141526	33.963162897
<input type="radio"/> 5	158	1	1	1.190558244	2.951495815	10.0	5.0	103.540449468	50.149373468
<input type="radio"/> 6	158	1	1	1.422576131	3.670683168	10.0	5.0	98.258450219	47.876890901
<input type="radio"/> 7	112	1	1	1.846180705	3.670227196	10.0	5.0	183.680058005	88.605563827
<input type="radio"/> 8	158	1	1	2.074155656	3.156487337	10.0	5.0	167.984631024	81.52326343
<input type="radio"/> 9	286	1	1	0.781753738	7.808786455	10.0	5.0	13.49300325	6.700068455
<input type="radio"/> 10	132	1	1	4.145814623	5.660422508	10.0	5.0	219.736762636	107.669123955
<input type="radio"/> 11	190	1	1	3.183997617	6.993210295	10.0	5.0	93.235489234	46.083526747

Rate Selected Realization Back to the Project

Improvements to Chevron Corrugations

In INSTED 9.0, for the PHE with chevron-type corrugation, the following improvements have been made:

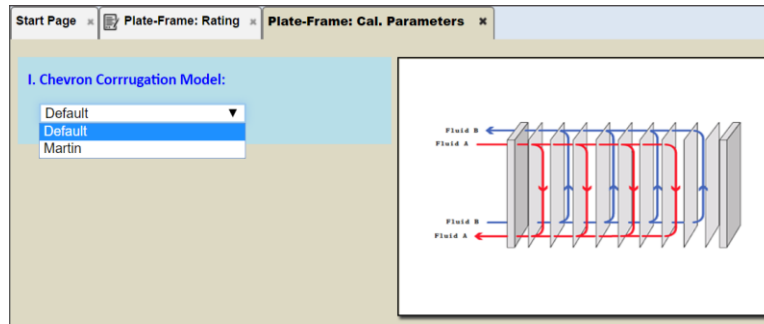
- 1) In the previous version of INSTED, the chevron corrugation must be identical for both streams. In INSTED 9.0, different corrugation parameters, such as the corrugation angle and contact pitch, can be set for each side of the streams. The GUI is shown below.



- 2) Martin's new j/f correlation model is now supported in the solver.

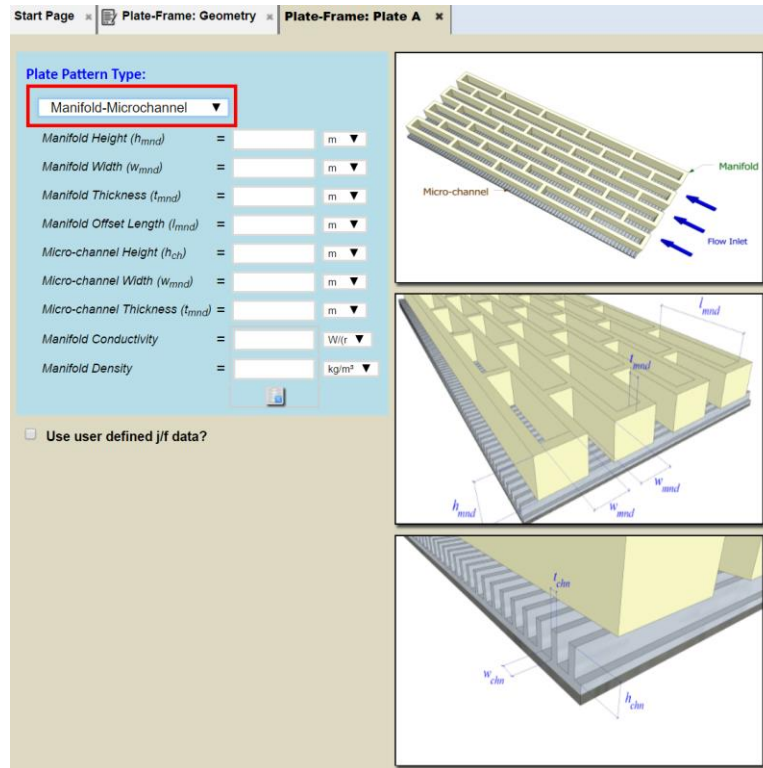
Reference: Martin, Holger, "A theoretical approach to predict the performance of chevron-type plate heat exchangers." *Chemical Engineering and Processing: Process Intensification* 35, no. 4 (1996), pp. 301-310.

You can choose the j/f correlation model to use from the “Set Calculation Parameters” button in the rating project.



Support for Manifold-Microchannel Fins Model

In INSTED 9.0, a new type of plate heat exchanger: Manifolds-Microchannel PHE exchanger is now supported for rating, multiple rating, sizing, and optimization calculations. The GUI where you define the manifolds-microchannel is shown below.



More Sample Validation Problems:

In INSTED 9.0, new sample problems have been added for plate-frame module. You may copy the sample problems into your account and run them to get familiar with the new plate-frame module in INSTED and validate the code.

Sample Problems:

Choose Problem Type:

Hewitt.341

A plate heat exchanger has 99 plates, each 1 m high and 0.25 m wide, with a gap between them of 5 mm. Cold water, initially at 15°C is fed into the heat exchanger at a rate of 5 kg/s and flows through half the passages in counter current flow to hot water, initially at 95°C, flowing at a rate of 10 kg/s. What is the exit temperature of the cold stream?

[Copy 1-pass by 1-pass Parallel/Counter Flow Sample](#)

[Copy 2-pass by 1-pass Parallel/Counter Flow Sample](#)

[Copy 1-pass by 2-pass Parallel/Counter Flow Sample](#)

[Copy 2-pass by 2-pass Parallel/Counter Flow Sample](#)

[Details](#)

Pike

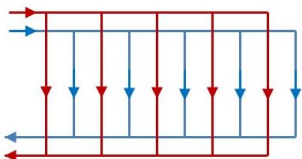
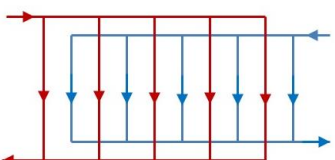
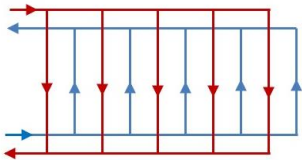
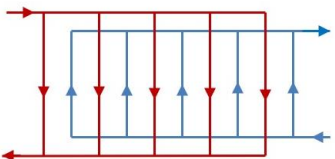
This test problem is designed to validate the INSTED Plate-Frame rating module. The heat exchanger is of the chevron type and has a chevron angle of 40 degrees. Martin's correlations are used to evaluate the heat transfer and pressure drop of the flows through chevron plates.

[Copy to Your Account](#) [Details](#)

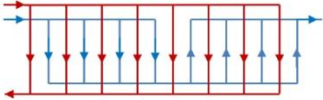
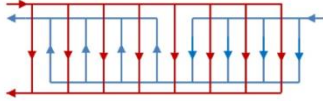
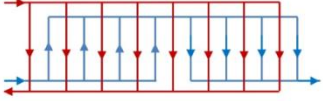
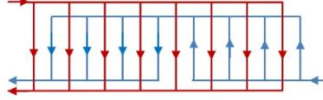
Salman

Appendix: Illustration of Multi-Pass Configurations

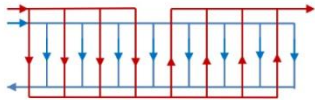
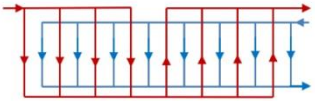
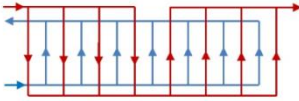
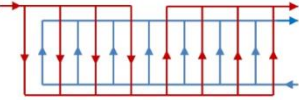
1-by-1

	Hot Passes	Cold Passes	Inlet Flow Direction	Inlet Location	PHE Configuration
#1	1	1	Parallel	Same side	
#2	1	1	Parallel	Opposite side	
#3	1	1	Counter	Same side	
#4	1	1	Counter	Opposite side	

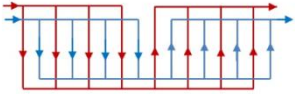
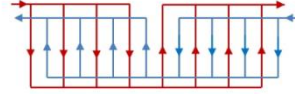
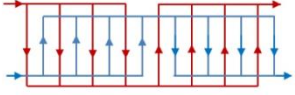
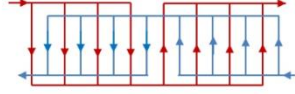
1-by-2

	Hot Passes	Cold Passes	Inlet Flow Direction	Inlet Location	PHE Configuration
#1	1	2	Parallel	Same side	
#2	1	2	Parallel	Opposite side	
#3	1	2	Counter	Same side	
#4	1	2	Counter	Opposite side	

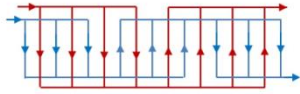
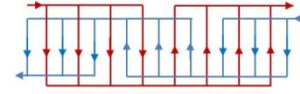
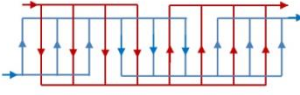
2-by-1

	Hot Passes	Cold Passes	Inlet Flow Direction	Inlet Location	PHE Configuration
#1	2	1	Parallel	Same side	
#2	2	1	Parallel	Opposite side	
#3	2	1	Counter	Same side	
#4	2	1	Counter	Opposite side	

2-by-2

	Hot Passes	Cold Passes	Inlet Flow Direction	Inlet Location	PHE Configuration
#1	2	2	Parallel	Same side	
#2	2	2	Parallel	Opposite side	
#3	2	2	Counter	Same side	
#4	2	2	Counter	Opposite side	

M-by-N

	Hot Passes	Cold Passes	Inlet Flow Direction	Inlet Location	PHE Configuration
#1	2	3	Parallel	Same side	
#2	2	3	Parallel	Opposite side	
#3	2	3	Counter	Same side	
#4	2	3	Counter	Opposite side	