INSTED Plate-Fin Tutorial

TTC INSTED Ver. 9.2

TTC TECHNOLOGIES, INC.

August 20, 2018

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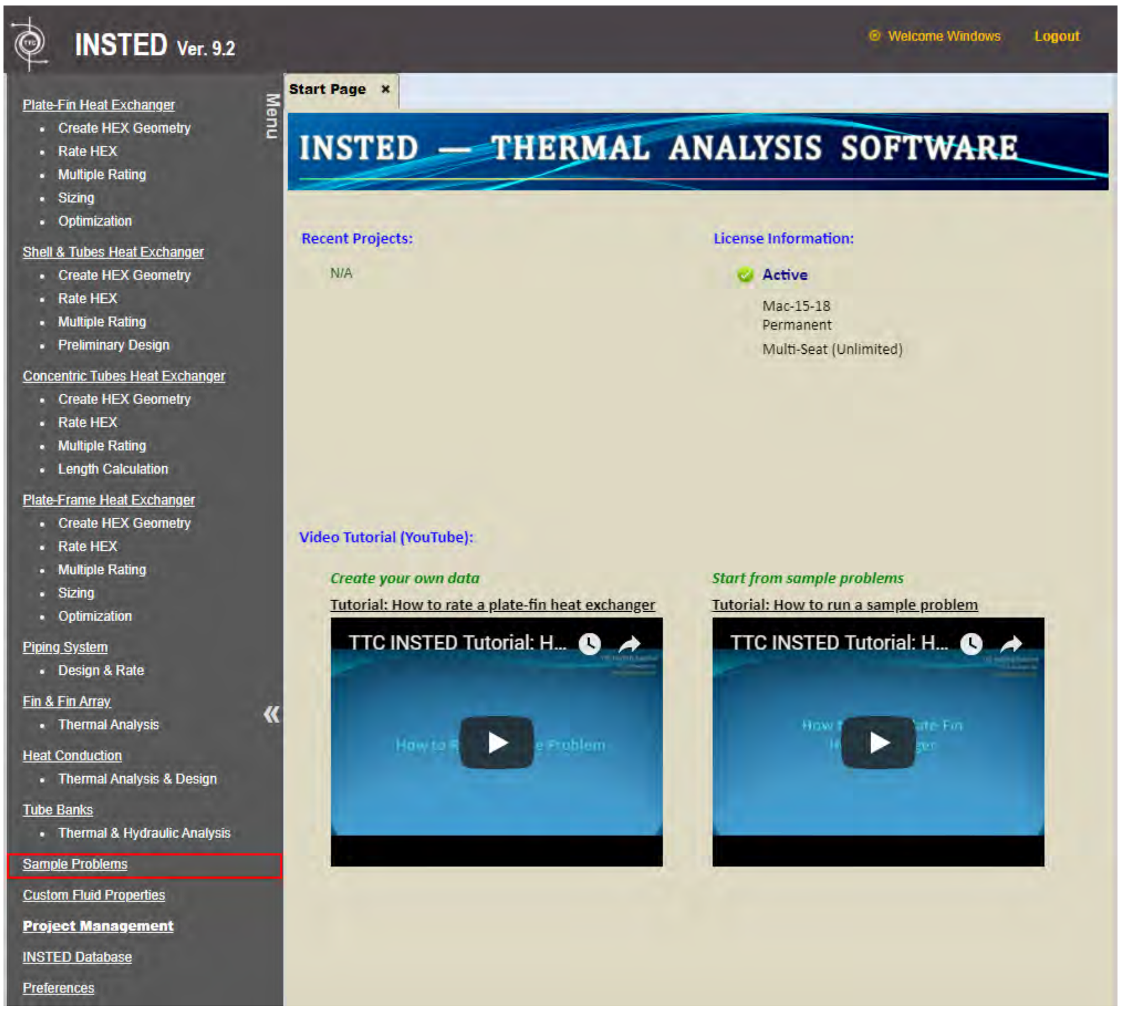
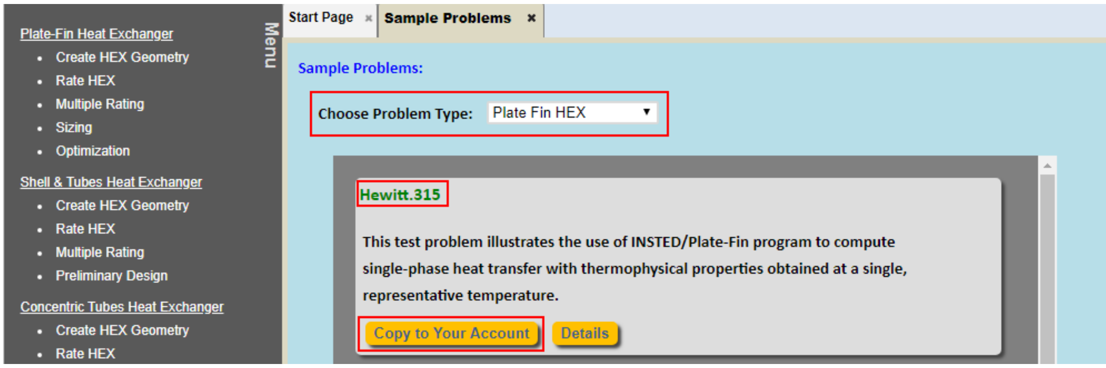
1. QuickStart: Running a Plate-Fin Sample Problem

This tutorial will teach you how to quickly run a Plate-Fin sample problem that has been previously generated and archived in INSTED. Please follow the steps below.

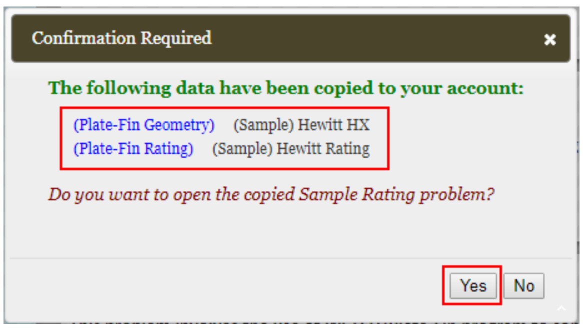
(1) Click "Sample Problem" from the menu panel shown on the left-side of the screen shot



(2) After the "Sample Problems" tab has been loaded, ensure that "Plate-Fin HEX" is displayed for "Choose Problem Type." As a sample problem, locate "Hewitt.315" from the list of available Plate-Fin sample problems, and then click the "Copy to Your Account" button.

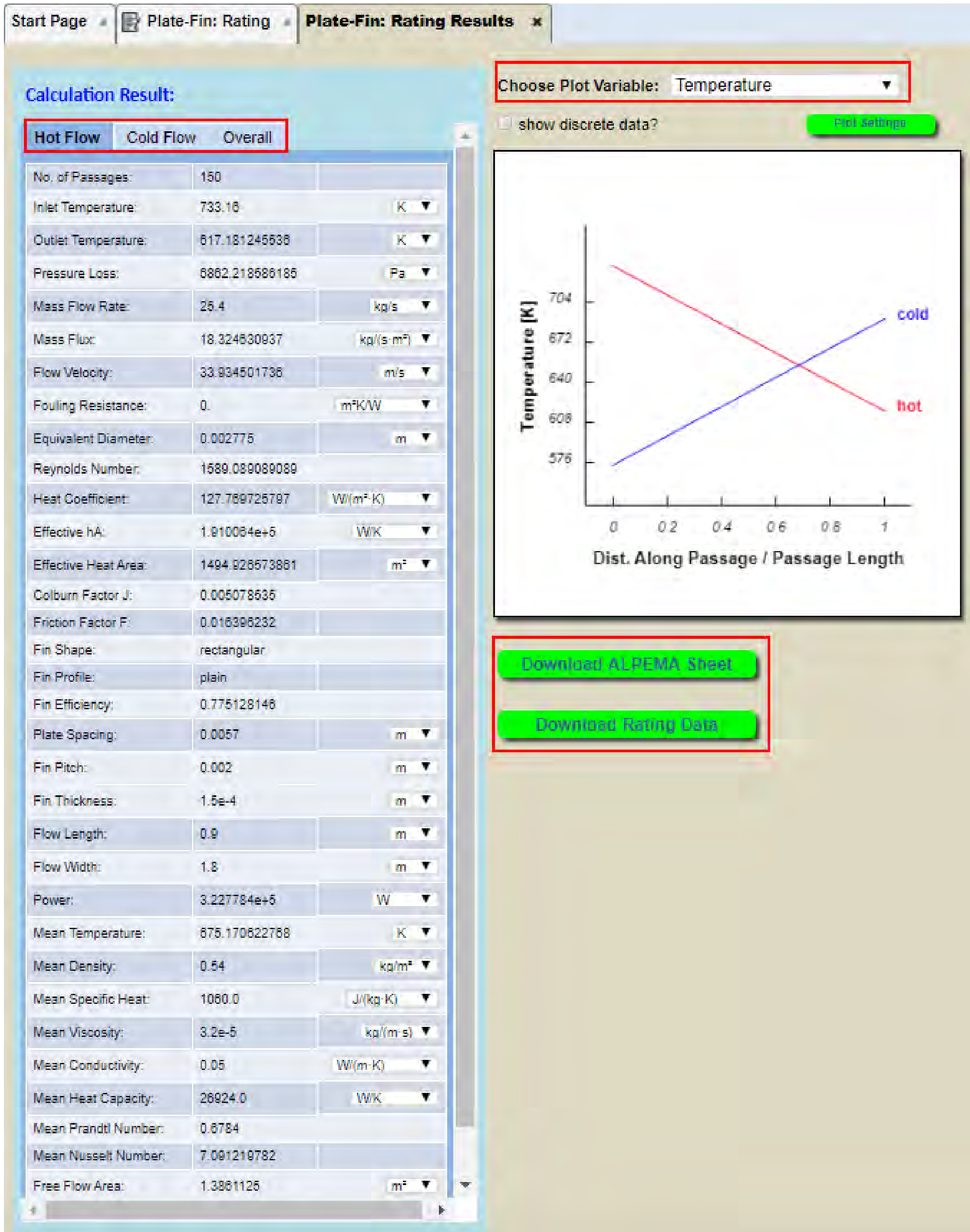


(3) A popup window will show up to confirm the sample problem has been copied to your account. Note that two projects are created: "(Sample) Hewitt HX" for the heat exchanger Geometry module and "(Sample) Hewitt Rating" for the heat exchanger Rating module. Click "OK" to view the rating project.



(4) The interface for the Plate-Fin rating module will be displayed. Note that the "Rate HEX" menu is highlighted in the menu panel to indicate the working project is for the Plate-Fin Rating module. Also note that "(Sample) Hewitt HX" is selected for "Choose Heat Exchanger Geometry to Rate", which is the heat exchanger geometry project that was copied in Step (3) above. Click the "Compute" button to start the Rating calculation.

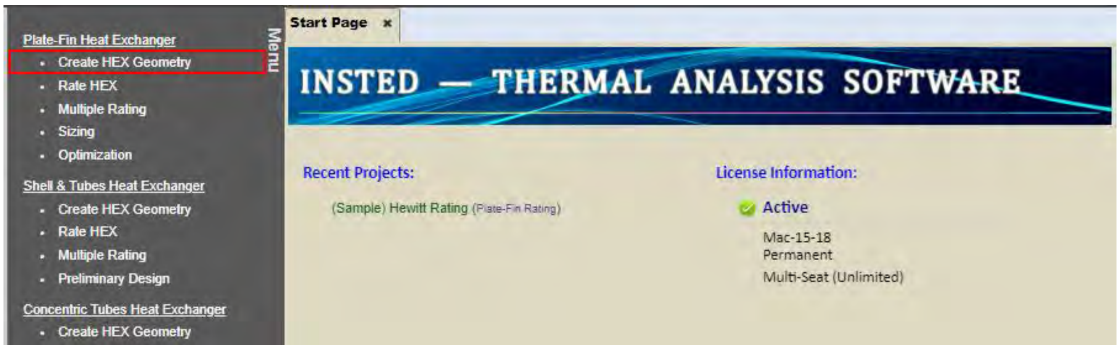
(5) Wait until the calculation has finished, after which the calculation results will be displayed. Click "Hot Flow / Cold Flow / Overall" to view the results for the hot stream, cold stream, or the overall results. You can choose a different variable to plot using "Choose Plot Variable." Click the "Download ALPEMA Sheet" button to display the calculation results in ALPEMA sheet format or click the "Download Rating Data" button to download the calculation results in a Microsoft Excel file format.


Start Page
Plate-Fin: Rating
Plate-Fin: Rating Results
Calculation Result:
Hot Flow
Cold Flow
Overall
No. of Passages: 150
Inlet Temperature: 733.15 K
Outlet Temperature: 617.181245538 K
Pressure Loss: 6862.218686185 Pa
Mass Flow Rate: 25.4 kg/s
Mass Flux: 18.324630937 kg/(s·m²)
Flow Velocity: 33.934501736 m/s
Fouling Resistance: 0. m²K/W
Equivalent Diameter: 0.002775 m
Reynolds Number: 1589.089089089
Heat Coefficient: 127.769725797 W/(m²·K)
Effective hA: 1.910064e+5 W/K
Effective Heat Area: 1494.926573861 m²
Colburn Factor J: 0.005078535
Friction Factor F: 0.016396232
Fin Shape: rectangular
Fin Profile: plain
Fin Efficiency: 0.775128146
Plate Spacing: 0.0057 m
Fin Pitch: 0.002 m
Fin Thickness: 1.5e-4 m
Flow Length: 0.9 m
Flow Width: 1.8 m
Power: 3.227784e+5 W
Mean Temperature: 675.170622768 K
Mean Density: 0.54 kg/m³
Mean Specific Heat: 1060.0 J/(kg·K)
Mean Viscosity: 3.2e-5 kg/(m·s)
Mean Conductivity: 0.05 W/(m·K)
Mean Heat Capacity: 26924.0 W/K
Mean Prandtl Number: 0.6784
Mean Nusselt Number: 7.091219782
Free Flow Area: 1.3861125 m²
Choose Plot Variable: Temperature
show discrete data?
Plot Settings
Temperature [K]
704
672
640
608
576
cold
hot
0
0.2
0.4
0.6
0.8
1
Dist. Along Passage / Passage Length
Download ALPEMA Sheet
Download Rating Data

2. QuickStart: Creating a Plate-Fin Geometry

This tutorial will teach you how to manually create a Plate-Fin heat exchanger geometry.

(1) Click the "Create Hex Geometry" button under "Plate-Fin Heat Exchanger" from the menu panel

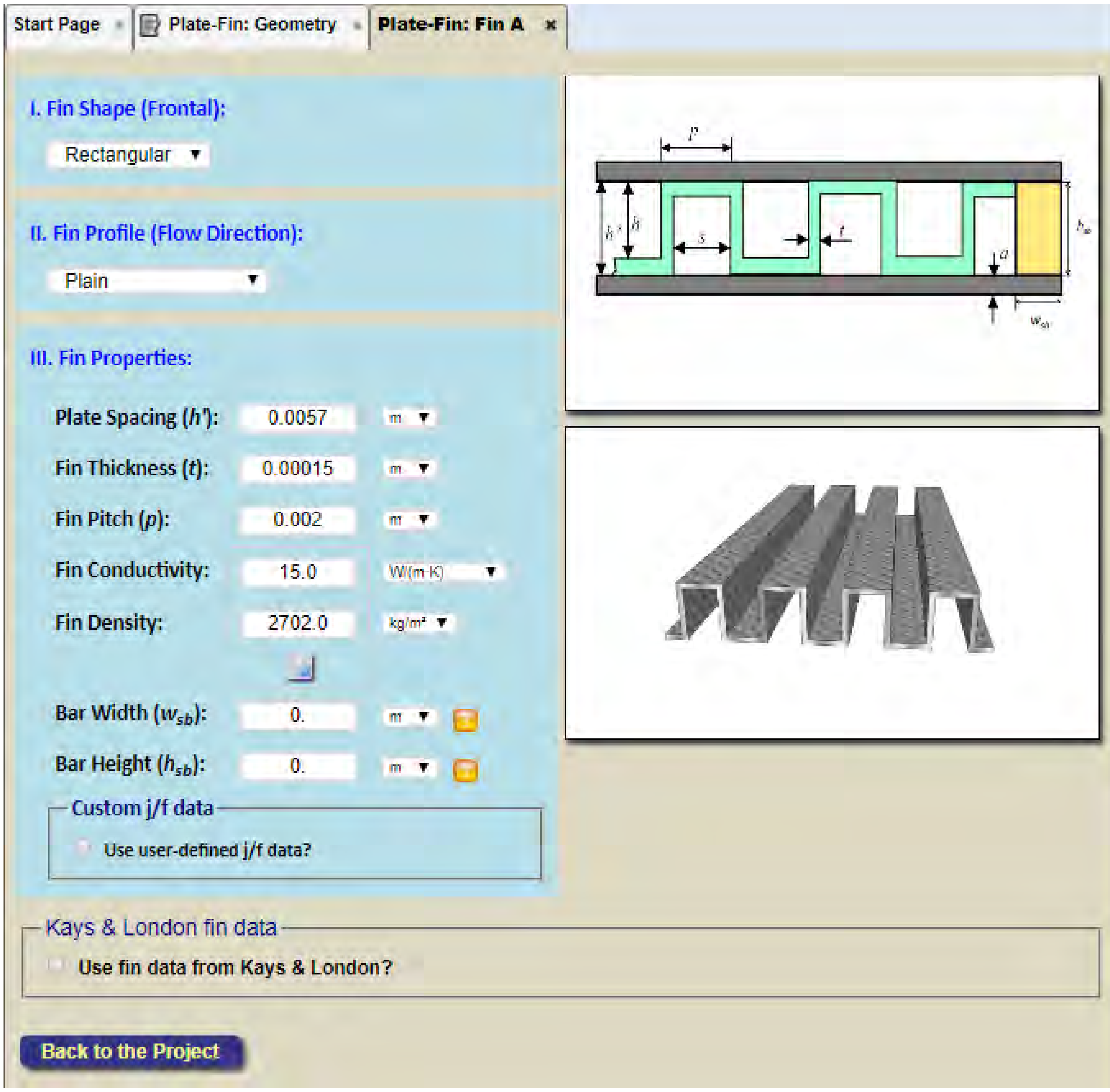


(2) After "Plate-Fin: Geometry" tab has been loaded, input the following data as a sample heat exchanger geometry:

a. Input "Hewitt HX" in "Heat Exchanger Geometry Name:"
b. Select "Cross" for "Flow Arrangement:"
c. Choose "150" for "No. of Passages" for both "Fluid A" and "Fluid B".
d. Choose "1" for "No. of Flow Passes" for both fluids.
e. Choose "1" for "No. of Partitions" for both fluids.
f. Select "Single" for "Banking Type"
g. Input "0.9 [m]" for "L" (heat exchanger length)
h. Input "1.8 [m]" for "W" (heat exchanger width)
i. Input "0.0003 [m]" for "Plate Thickness"
j. Input "0.0003 [m]" for "End Plate Thickness"
k. Input "15.0 [W/m.K]" for "Plate Conductivity"
l. Input "2700 [kg/m^3]" for "Plate Density"

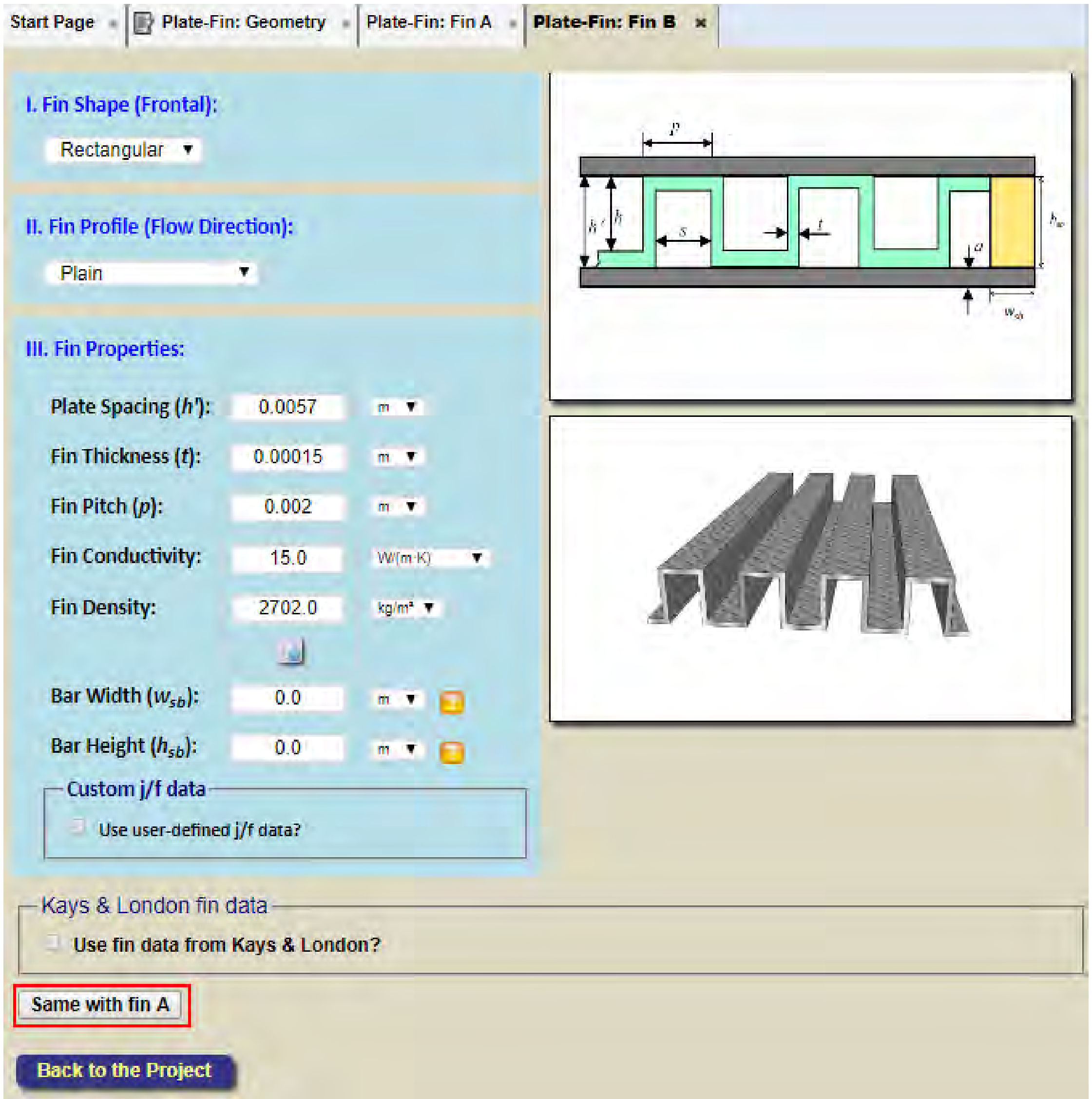
(3) Click “Enter Fin Data for Flow A” button. The “Plate-Fin: Fin A” tab will be displayed.

a. Choose “Rectangular” for “Fin Shape (Frontal)”
b. Choose “Plain” for “Fin Profile (Flow Direction)”
c. Input “0.0057 [m]” for “Plate Spacing”
d. Input “0.00015 [m]” for “Fin Thickness”
e. Input “0.002 [m]” for “Fin Pitch”
f. Input “15.0 [W/m.K]” for “Fin Conductivity”
g. Input “2702.0 [kg/m^3]” for “Fin Density”
h. Input “0.0” for both “Bar Width” and “Bar Height’ (See the sketch below for the definition of these parameters. The bar is shown in yellow color.)
i. Confirm “Use user-defined j/f data?” is unchecked
j. Confirm “Use fin data from Kays & London?” is unchecked



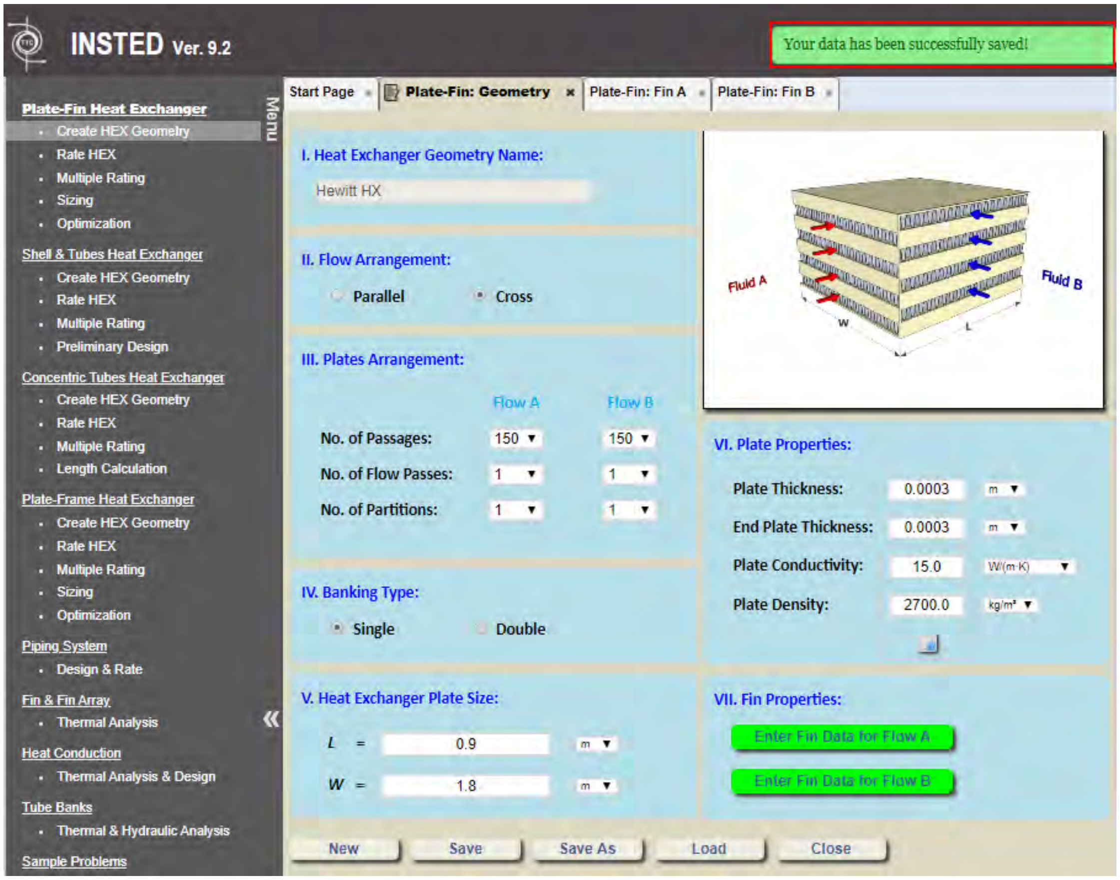
(4) Click "Back to the Project" button at the bottom of "Plate-Fin: Fin A" tab to return to the "Plate-Fin: Geometry" tab. Click "Enter Fin Data for Flow B" button. The "Plate-Fin: Fin B" tab will be displayed.

a. For this illustration problem, the same fins are used for both streams. Click the "Same with Fin A" button so that all previously inputted data for "Fin A" will automatically be used for "Fin B."

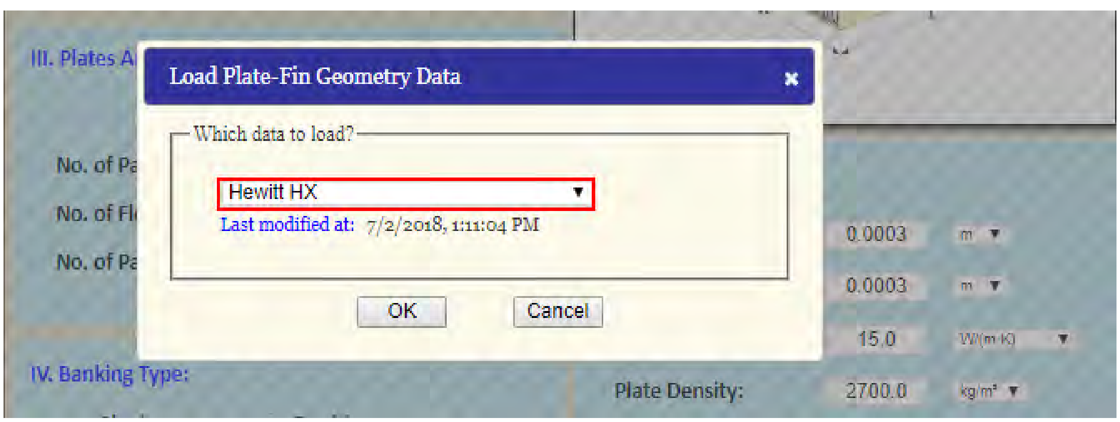


(5) Click the "Back to the Project" button at the bottom of the "Plate-Fin: Fin B" tab to return to the "Plate-Fin: Geometry" tab. Click "Save" button to save current project.

(6) A notification "Your data has been successfully saved!" will be displayed to confirm that the project has been saved.



(7) Note that the saved project can be loaded back by clicking the "Load" button. The geometry name is used to distinguish different saved Plate-Fin geometry projects.

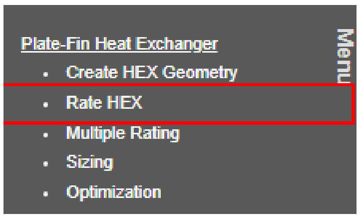


(8) Continue to the next tutorial to learn how to rate this newly created heat exchanger geometry.

3. QuickStart: Rating a Plate-Fin Geometry

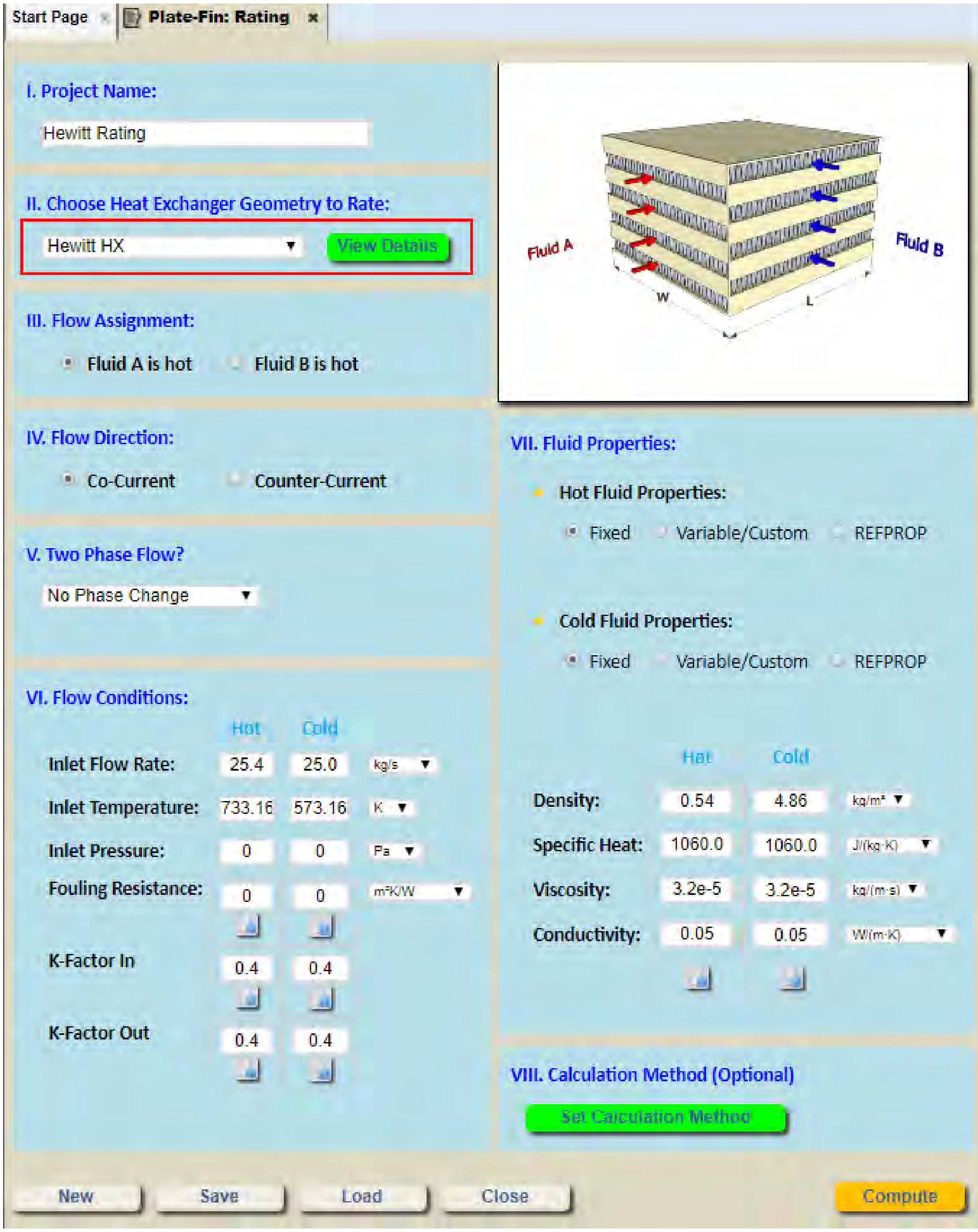
This tutorial will teach you how to manually create a Plate-Fin rating project to rate the heat exchanger geometry created in the previous tutorial.

(3) Click “Rate HEX” under “Plate-Fin Heat Exchanger” from the menu panel



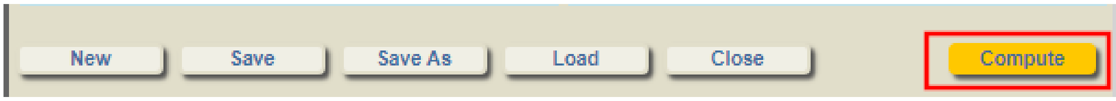
(4) After the “Plate-Fin: Rating” tab has been loaded, follow the steps below:

a. Input “Hewitt Rating” for “Project Name”
b. Choose the name of the Plate-Fin heat exchanger geometry created in the previous tutorial (“Hewitt HX”) in “Choose Heat Exchanger Geometry to Rate”
c. Choose “Fluid A is hot” in “Flow Assignment”
d. Choose “Co-Current” in “Flow Direction”
e. Choose “No Phase Change” in “Two Phase Flow?”
f. Input “25.4”, “25.0” for hot and cold stream “Inlet Flow Rate” and choose “kg/s” as the flow rate unit
g. Input “733.16”, “573.16” for hot and cold stream “Inlet Temperature” and choose “K” as the temperature unit
h. Input “0”, “0” for hot and cold stream “Inlet Pressure”
i. Input “0.4”, “0.4” for hot and cold stream “K-Factor In”
j. Input “0.4”, “0.4” for hot and cold stream “K-Factor Out”
k. For “Fluid Properties”, choose “Fixed” for both hot and cold stream
l. Input “0.54”, “4.86” for hot and cold stream fluid “Density” and choose “kg/m^3” as the density unit
m. Input “1060.0”, “1060.0” for hot and cold stream “Specific Heat” and choose “J/(kg·K)” as the specific heat unit
n. Input “3.2e-5”, “3.2e-5” for hot and cold stream “Viscosity” and choose “kg/(m·s)” as the viscosity unit
o. Input “0.05”, “0.05” for hot and cold stream “Conductivity” and choose “W/(m·K)” as the conductivity unit



(5) Click the “Save” button to save the project.

(6) Click the “Compute” button to begin the rating calculations.



(7) Wait until the calculation has finished and some calculation results shown. Click "Hot Flow / Cold Flow / Overall" to view the "overall" results. Select any variables you might want to plot by clicking on the "Choose Plot Variable" button. Click on "Download ALPEMA Sheet" if you want to view the calculation results in ALPEMA format or click "Download Rating Data" to view them in a Microsoft Excel file.

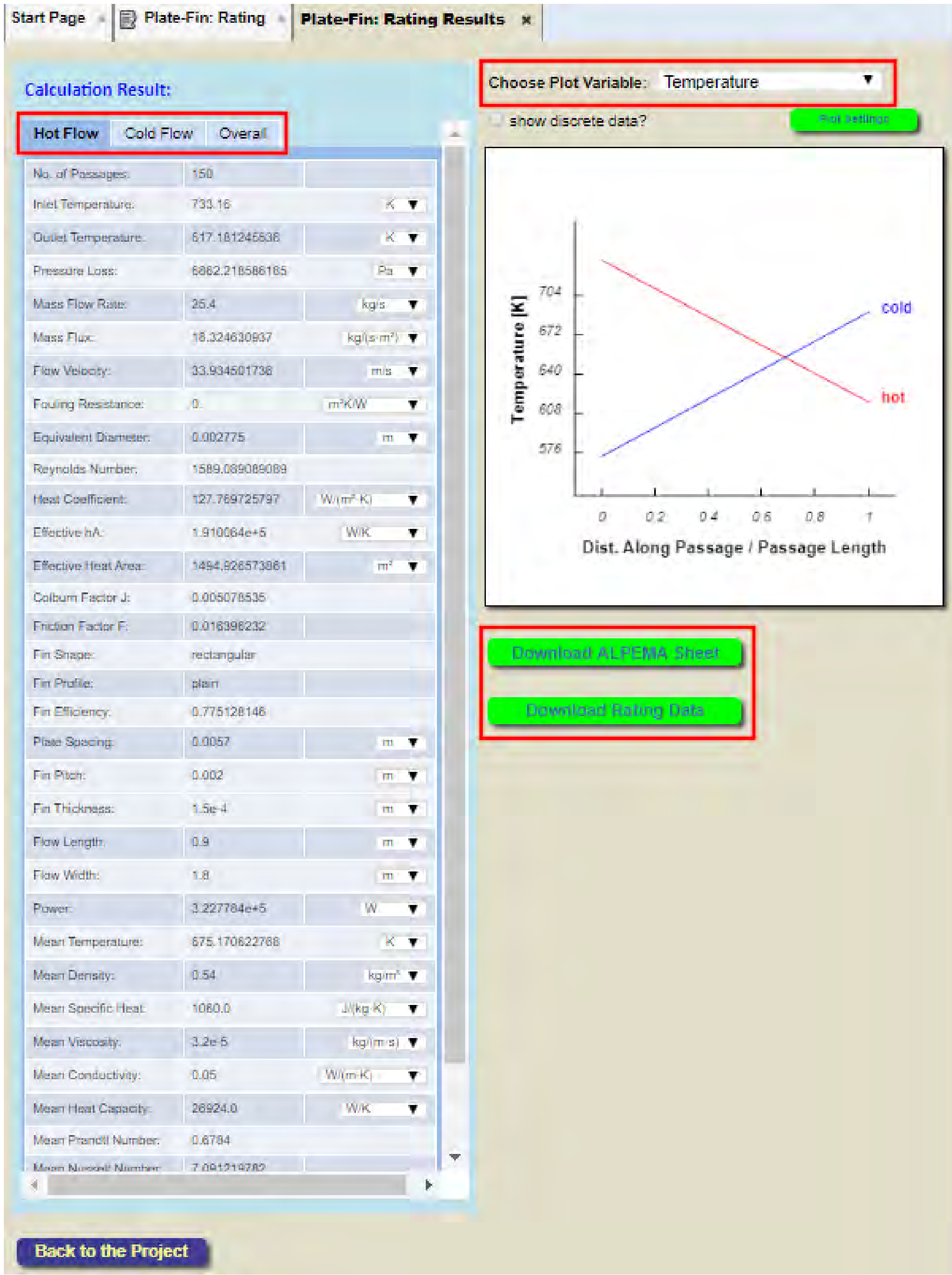

Start Page
Plate-Fin: Rating
Plate-Fin: Rating Results
Calculation Result:
Hot Flow
Cold Flow
Overall
No. of Passages: 150
Inlet Temperature: 733.16 K
Outlet Temperature: 617.181245536 K
Pressure Loss: 6862.218586185 Pa
Mass Flow Rate: 25.4 kg/s
Mass Flux: 18.324630937 kg/(s·m²)
Flow Velocity: 33.934601738 m/s
Fouling Resistance: 0 m²K/W
Equivalent Diameter: 0.002775 m
Reynolds Number: 1589.089089089
Heat Coefficient: 127.769725797 W/(m²·K)
Effective hA: 1.910064e+5 W/K
Effective Heat Area: 1494.926573861 m²
Colburn Factor J: 0.005078535
Friction Factor F: 0.016398232
Fin Shape: rectangular
Fin Profile: plain
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Plate Spacing: 0.0057 m
Fin Pitch: 0.002 m
Fin Thickness: 1.5e-4 m
Flow Length: 0.9 m
Flow Width: 1.8 m
Power: 3.227784e+5 W
Mean Temperature: 675.170622768 K
Mean Density: 0.54 kg/m³
Mean Specific Heat: 1060.0 J/(kg·K)
Mean Viscosity: 3.2e-5 kg/(m·s)
Mean Conductivity: 0.05 W/(m·K)
Mean Heat Capacity: 26924.0 W/K
Mean Prandtl Number: 0.6784
Choose Plot Variable: Temperature
show discrete data?
Temperature [K]
704
672
640
608
576
cold
hot
0
0.2
0.4
0.6
0.8
1
Dist. Along Passage / Passage Length
Download ALPEMA Sheet
Download Rating Data
Back to the Project

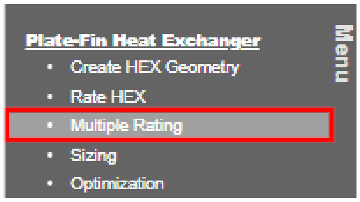
4. QuickStart: Creating & Running a Multiple Rating Project

In the Multiple Rating module, INSTED allows you to successively run multiple Plate-Fin rating calculations by changing the values of one or more geometry or flow parameters based on an existing regular Plate-Fin rating project. This is basically a parameter sweep analysis.

This tutorial will teach you how to create a Plate-Fin Multiple Rating project so that the hot stream inlet mass flow rate is varied over a given range. The rating project created in the previous tutorial will be used for the illustration.

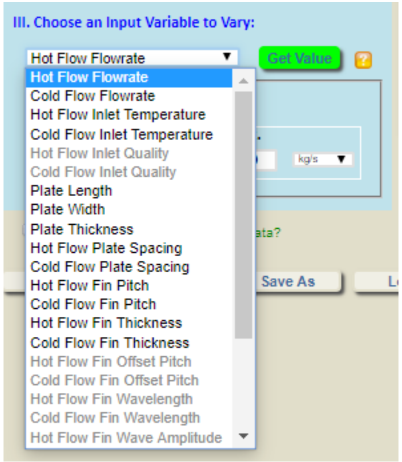
Note that this tutorial only demonstrates how to change one geometry/flow parameter in Multiple Rating project. To change more than one geometry/flow parameters simultaneously, please refer to the Tutorial "*23. Advanced Topics: Custom Multiple Rating*".

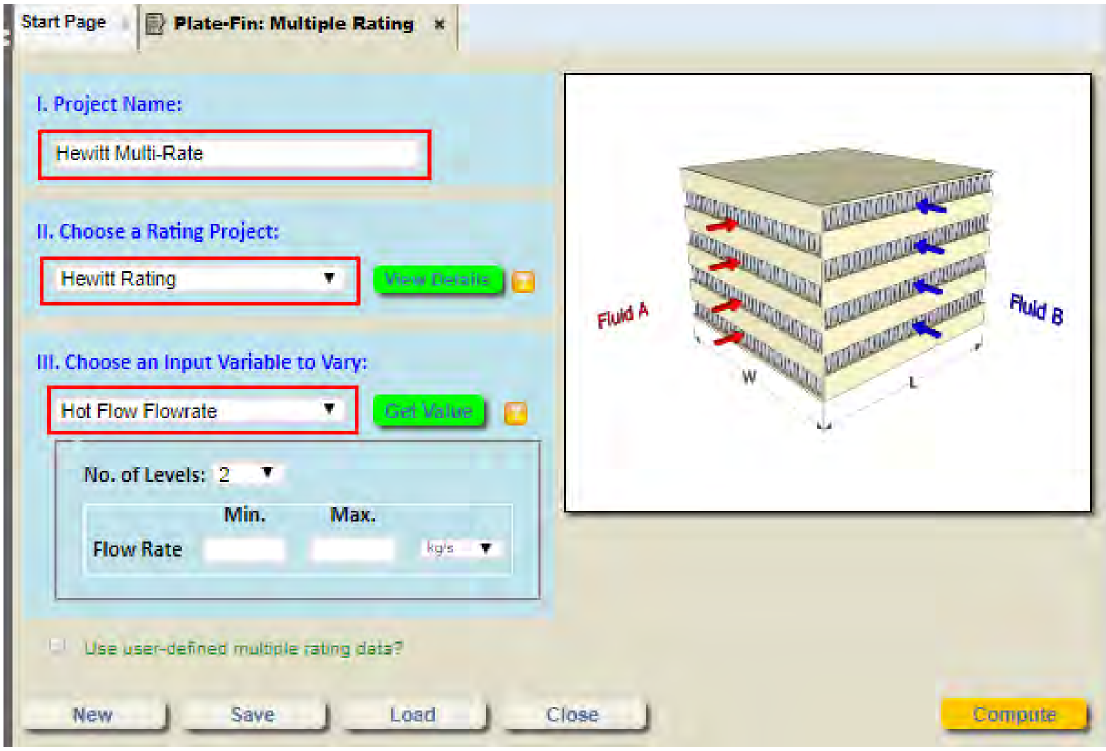
(1) Click "Rate HEX" under "Plate-Fin Heat Exchanger" in the main menu panel



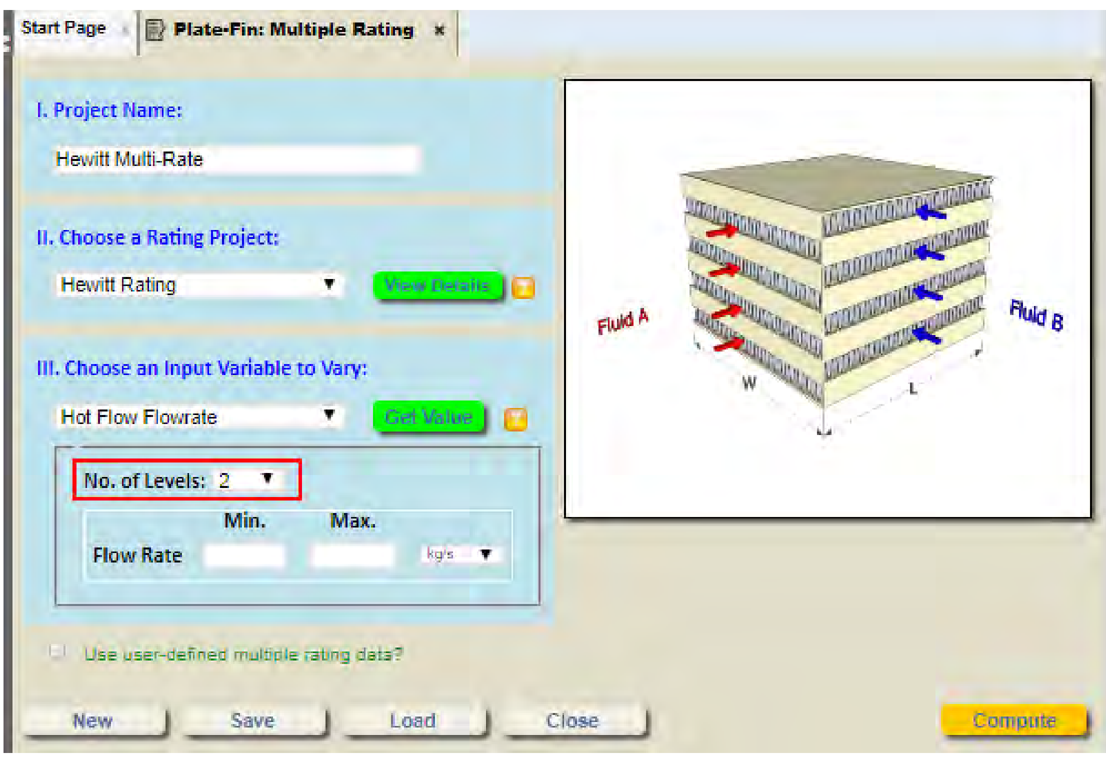
(2) After the "Plate-Fin: Multiple Rating" tab has been loaded, following the steps below:

a. Input "Hewitt Multi-Rate" for "Project Name"
b. Choose the name of the Plate-Fin Rating Project created in previous tutorial "Hewitt Rating" in "Choose a Rating Project." Note that the details of the selected Rating Project can be viewed by clicking on the "View Details" button.
c. Choose "Hot Flow Flowrate" in the "Choose an Input Variable to Vary" dropdown list. Note that a couple of geometry/flow parameters are allowed to vary, but we will only vary the hot stream flow rate in this example.

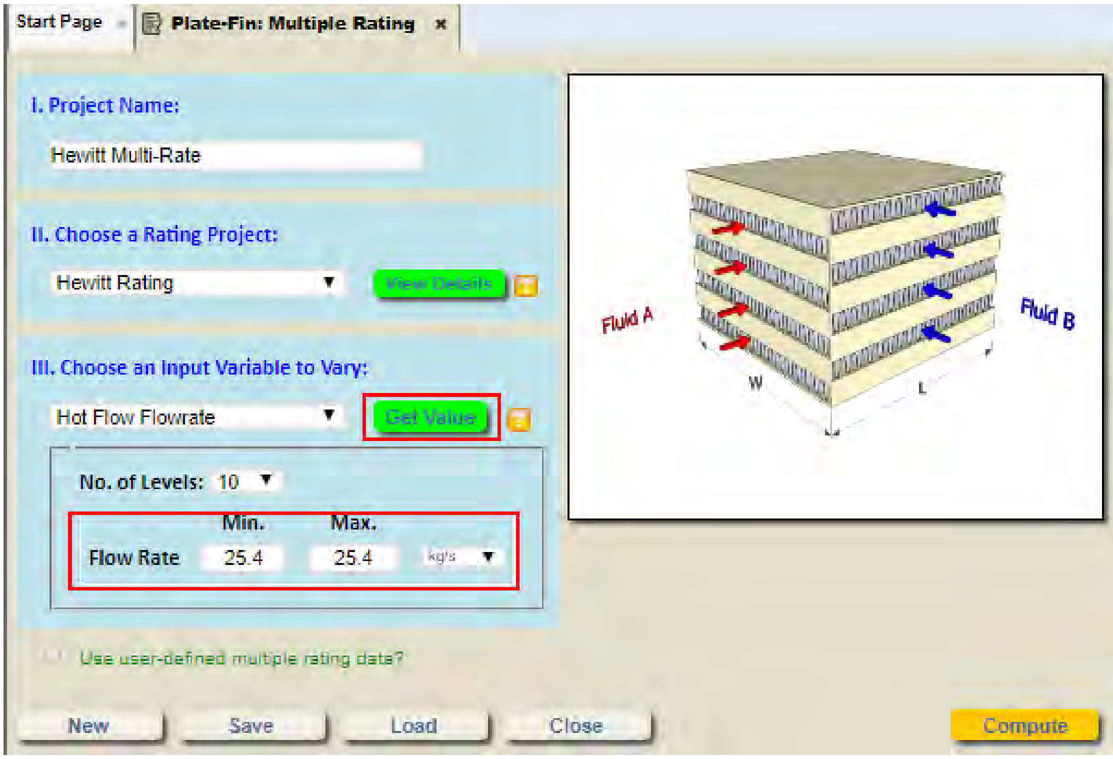




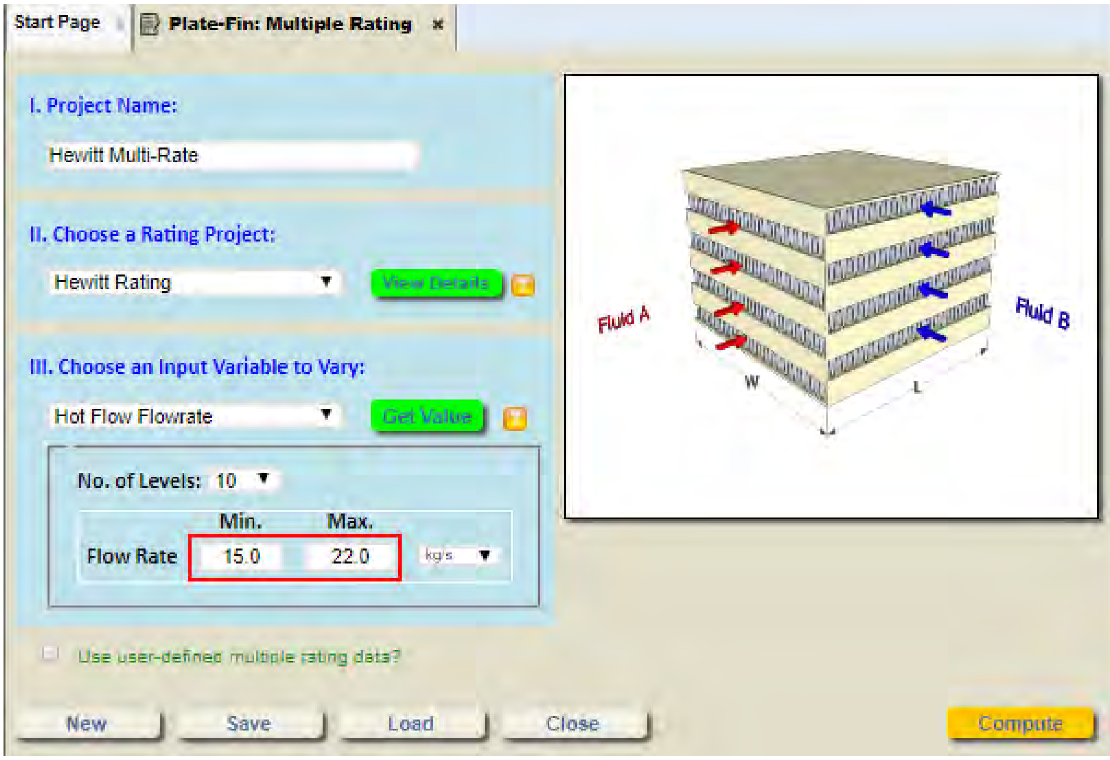
(3) Change "No. of Levels" to 10, which indicates 10 rating calculations will be carried out.



(4) Click the "Get Value" button so that the value of the original hot stream mass flowrate will be shown in the "Min./Max. Flow Rate" textboxes.



(5) Change the "Min." value to 15.0 and the "Max." value to "22.0." This indicates that 10 rating calculations will be carried out for hot stream flowrate between 15.0 kg/s and 22.0 kg/s.

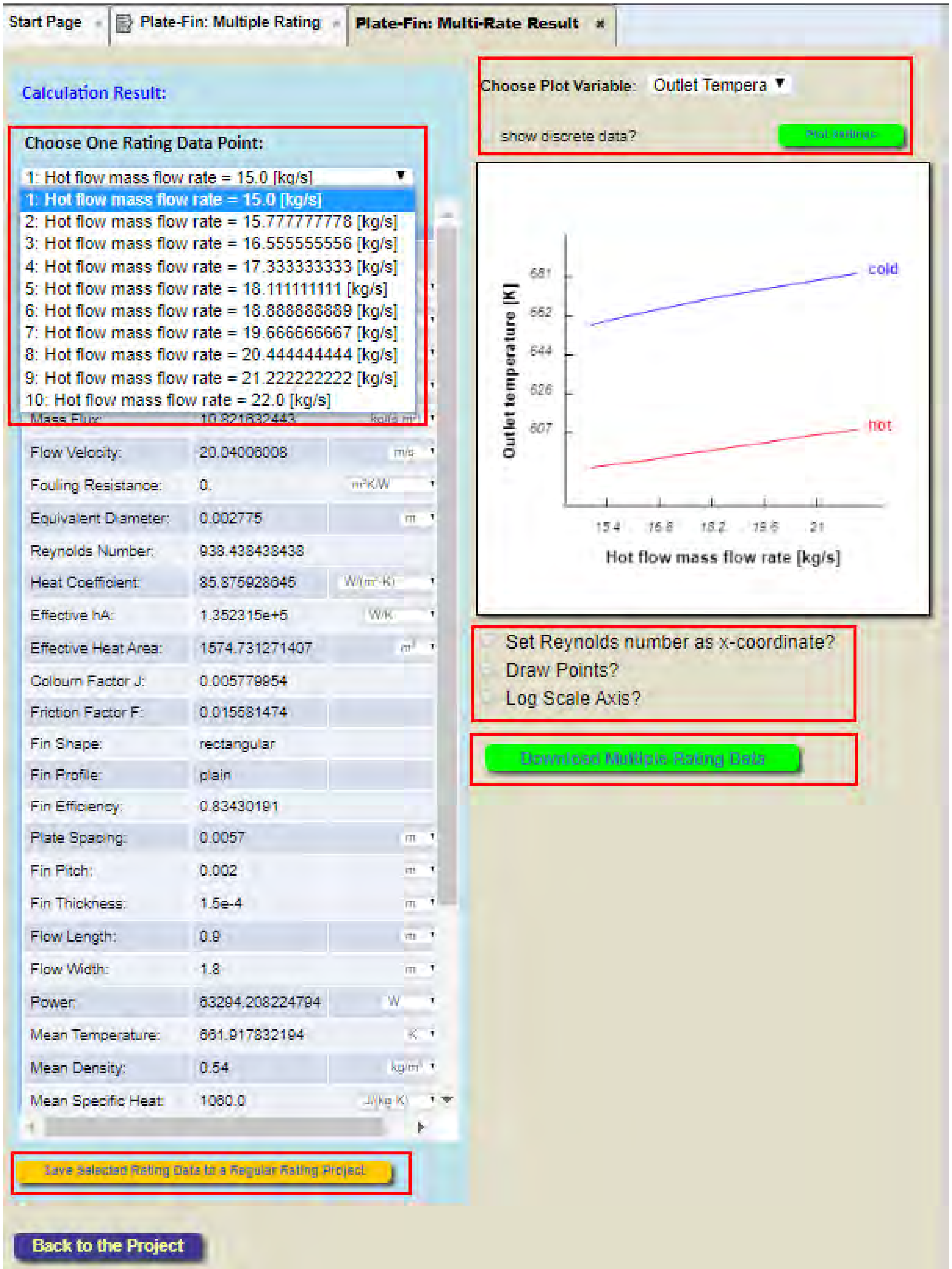


(6) Click the “Save” button to save the project.

(7) Click the “Compute” button to begin the Multiple Rating calculations.

(8) Wait until the calculation has been completed, and the calculation results displayed:

a. Under “Choose One Rating Point” dropdown list, you can choose a specific rating point to view its results
b. Click the “Save Selected Rating Data to a Regular Rating Project” button to save the selected rating point into a regular Plate-Fin Rating Project
c. Click on “Choose Plot Variable” to select a variable to plot. Note that the “X-axis” represents the variable that is being varied (the hot stream flowrate in this case)
d. Additional options are available for plot settings.
e. Click on "Download Multiple Rating Data" to view calculation results in a Microsoft Excel file.

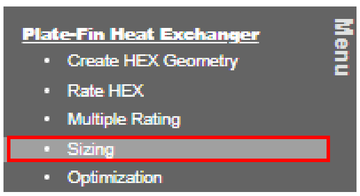

Start Page
Plate-Fin: Multiple Rating
Plate-Fin: Multi-Rate Result
Calculation Result:
Choose One Rating Data Point:
1: Hot flow mass flow rate = 15.0 [kg/s]
1: Hot flow mass flow rate = 15.0 [kg/s]
2: Hot flow mass flow rate = 15.777777778 [kg/s]
3: Hot flow mass flow rate = 16.555555556 [kg/s]
4: Hot flow mass flow rate = 17.333333333 [kg/s]
5: Hot flow mass flow rate = 18.111111111 [kg/s]
6: Hot flow mass flow rate = 18.888888889 [kg/s]
7: Hot flow mass flow rate = 19.666666667 [kg/s]
8: Hot flow mass flow rate = 20.444444444 [kg/s]
9: Hot flow mass flow rate = 21.222222222 [kg/s]
10: Hot flow mass flow rate = 22.0 [kg/s]
Flow Velocity: 20.04006008 m/s
Fouling Resistance: 0.
Equivalent Diameter: 0.002775 m
Reynolds Number: 938.438438438
Heat Coefficient: 85.875928645
Effective hA: 1.352315e+5 W/K
Effective Heat Area: 1574.731271407
Colourn Factor J: 0.005779854
Friction Factor F: 0.015581474
Fin Shape: rectangular
Fin Profile: plain
Fin Efficiency: 0.83430191
Plate Spacing: 0.0057 m
Fin Pitch: 0.002 m
Fin Thickness: 1.5e-4 m
Flow Length: 0.9 m
Flow Width: 1.8 m
Power: 63294.208224794 W
Mean Temperature: 661.917832194 K
Mean Density: 0.54
Mean Specific Heat: 1060.0
Save Selected Rating Data to a Regular Rating Project
Back to the Project
Choose Plot Variable: Outlet Tempera
show discrete data?
Outlet temperature [K]
681
662
644
626
607
cold
hot
15.4
16.8
18.2
19.6
21
Hot flow mass flow rate [kg/s]
Set Reynolds number as x-coordinate?
Draw Points?
Log Scale Axis?
Download Multiple Rating Data

5. QuickStart: Creating & Running a Sizing Project

In the Sizing module, INSTED tries to find a Plate-Fin heat exchanger geometry that satisfies a design target (target heat transfer rate). This is done by changing several heat exchanger geometry parameters in an existing rating project (reference rating project).

This tutorial will teach you how to create a Plate-Fin sizing project. The Rating Project created in the previous tutorial will be used.

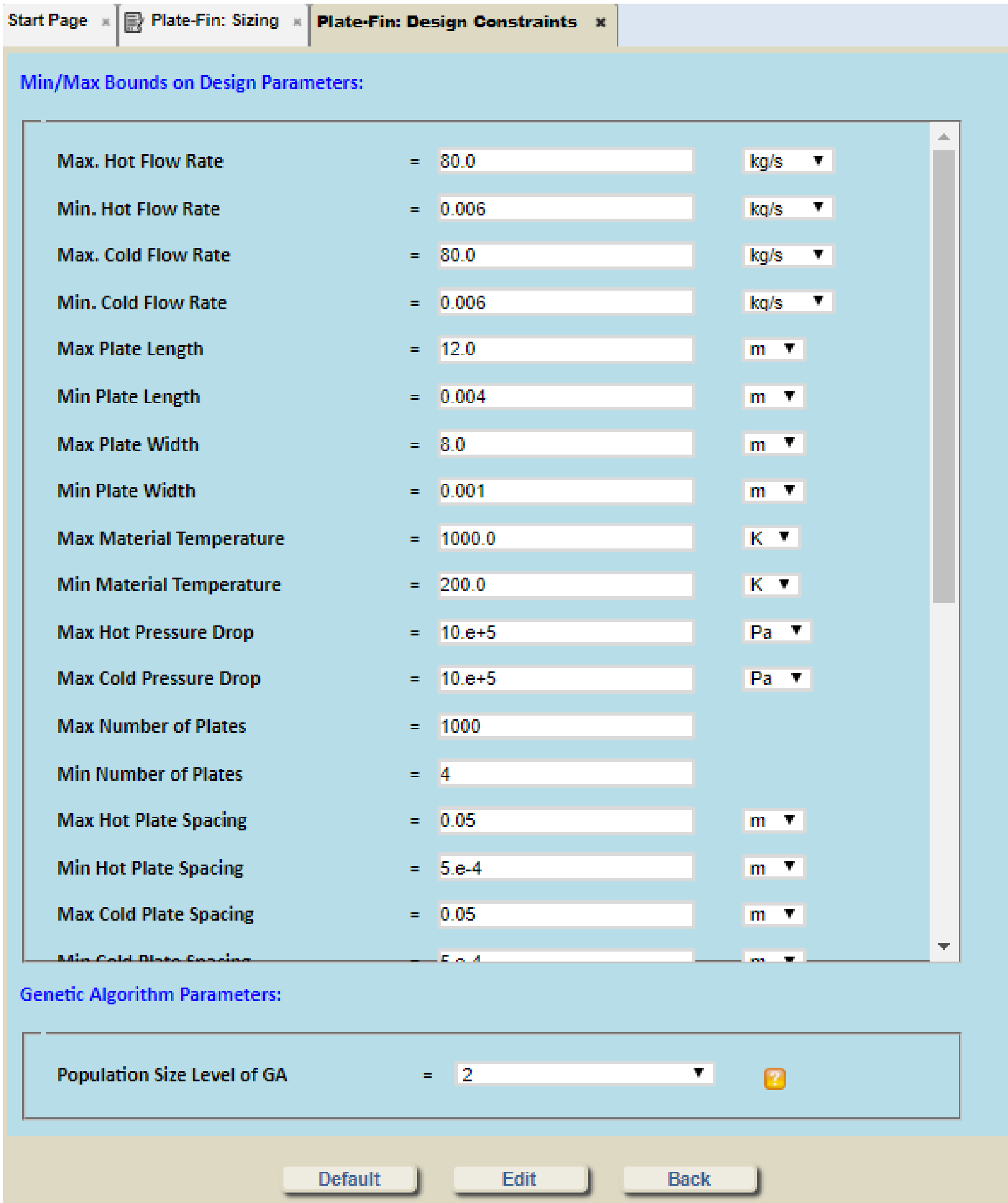
(1) Click “Sizing” under “Plate-Fin Heat Exchanger” from the menu panel



(2) After the “Plate-Fin: Sizing” tab has loaded, follow the steps below:

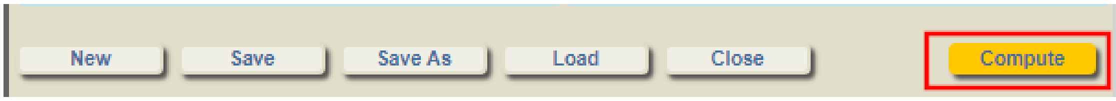
a. Input “Hewitt Sizing” for “Project Name”
b. Select the name of the Plate-Fin rating project created in the previous tutorial ("Hewitt Rating") in "Choose a Rating Project." Note that the details of the selected Rating Project can be viewed by clicking the “View Details” button.
c. Note that the total heat transfer rate of the original “Hewitt Rating” project is “3.122612 E+6 W.” In this sizing calculation, specify “3.5E+6 W” for “Target Heat Transfer Rate.”
d. The “Sizing Criteria” controls the parameters that are allowed to change in the referenced Rating Project during the Sizing calculations. In this case, only allow plate length and width to change.

(3) Click the “Set Bounds” button; the “Plate-Fin: Design Constraints” tab will be displayed. The range of the design parameters that are allowed to change can be set here. For this illustration, leave the default values unchanged. Click the “Back” button to go back to the “Plate-Fin: Sizing” tab.

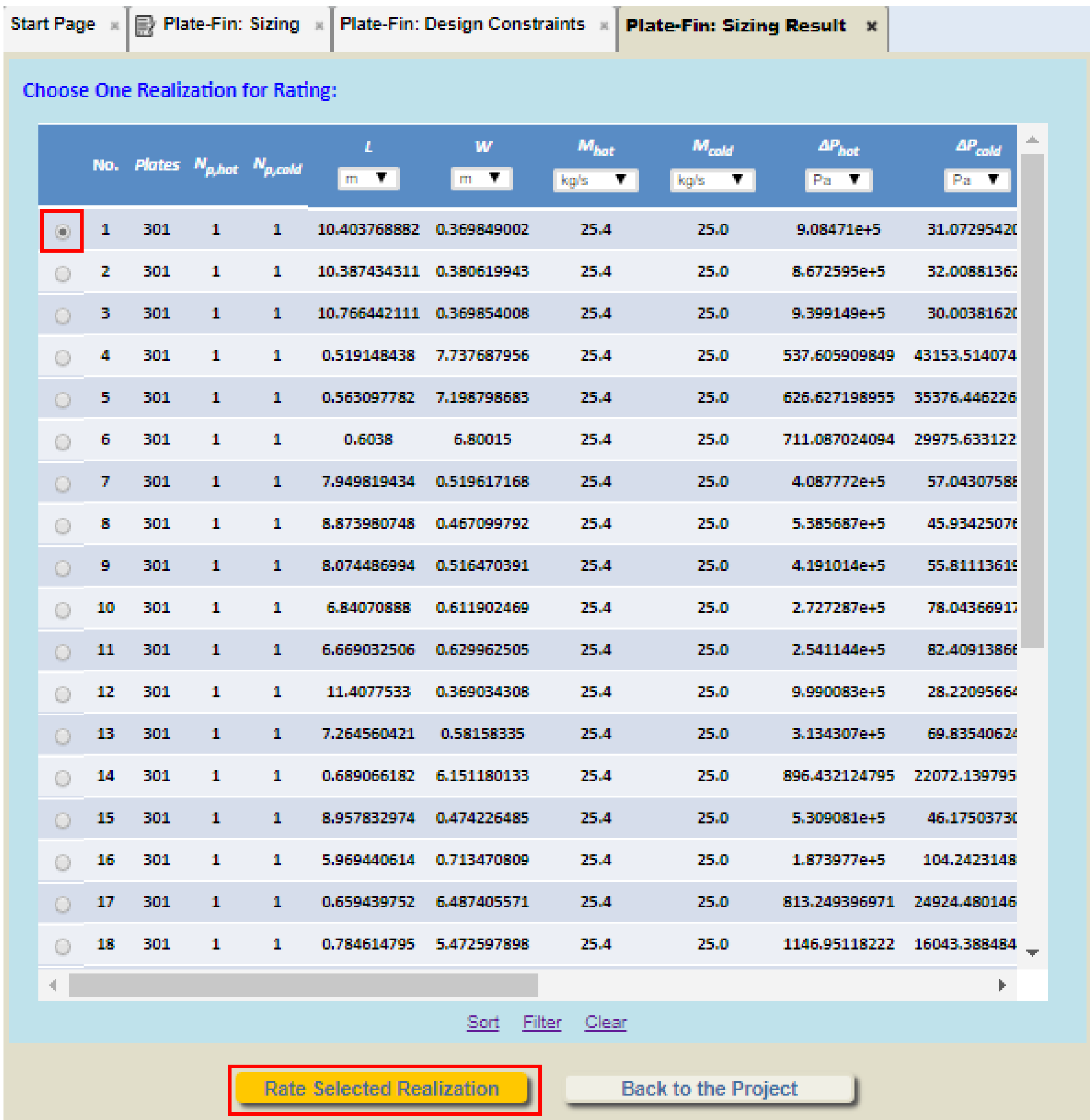


(4) Click the "Save" button to save the project.

(5) Click the "Compute" button to begin the sizing calculations. Depending on the settings, the calculation may take several minutes.



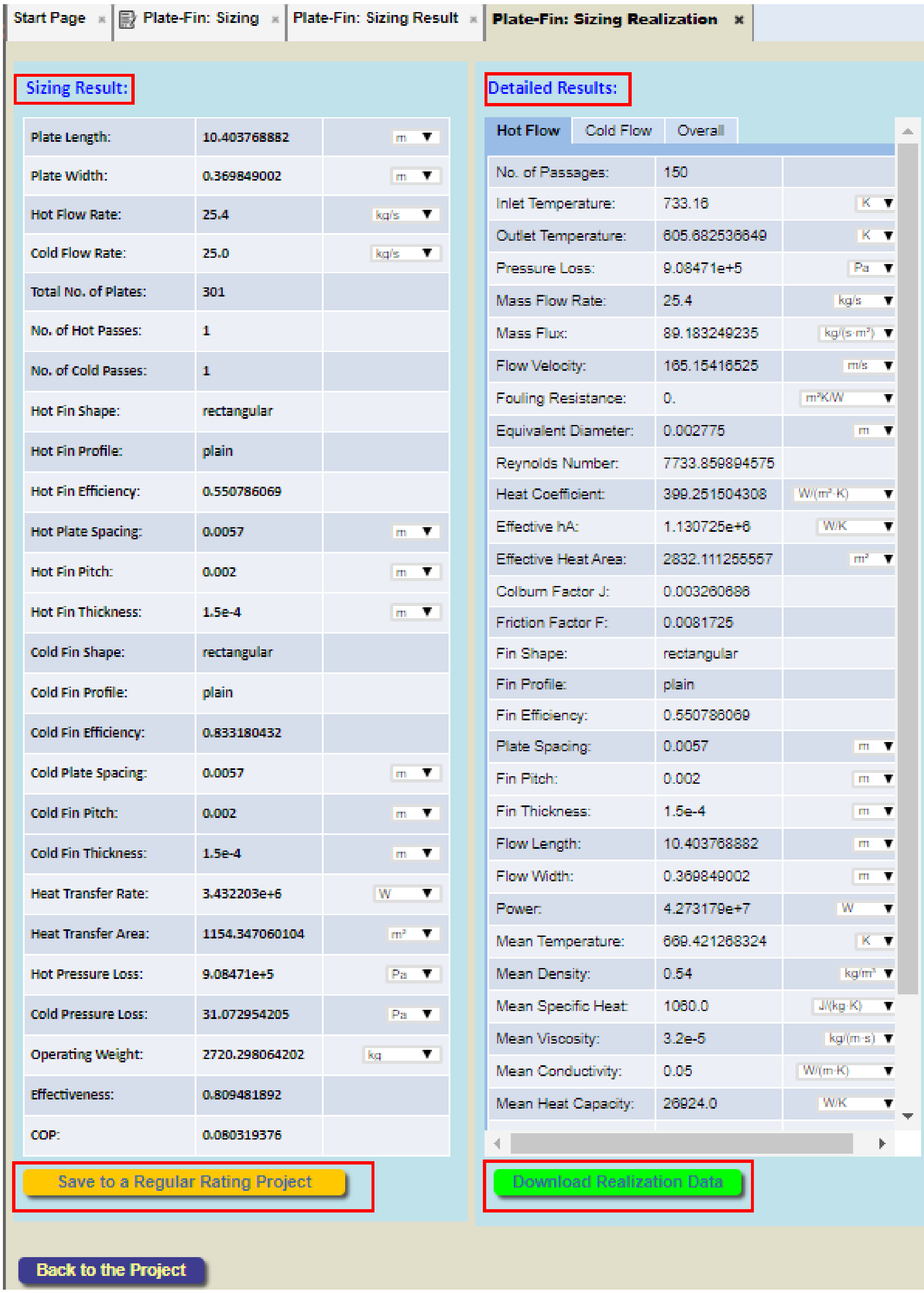
(6) Wait until the sizing calculation has finished; a list of possible design realizations will be displayed. You may select a particular realization from the table and then click the “Rate Selected Realization” button to view the details of the realization.



No.	Plates	$N_{p,hot}$	$N_{p,cold}$	L (m)	W (m)	M_{hot} (kg/s)	M_{cold} (kg/s)	ΔP_{hot} (Pa)	ΔP_{cold} (Pa)
1	301	1	1	10.403768882	0.369849002	25.4	25.0	9.08471e+5	31.0729542
2	301	1	1	10.387434311	0.380619943	25.4	25.0	8.672595e+5	32.0088136
3	301	1	1	10.766442111	0.369854008	25.4	25.0	9.399149e+5	30.0038162
4	301	1	1	0.519148438	7.737687956	25.4	25.0	537.605909849	43153.514074
5	301	1	1	0.563097782	7.198798683	25.4	25.0	626.627198955	35376.446226
6	301	1	1	0.6038	6.80015	25.4	25.0	711.087024094	29975.633122
7	301	1	1	7.949819434	0.519617168	25.4	25.0	4.087772e+5	57.0430758
8	301	1	1	8.873980748	0.467099792	25.4	25.0	5.385687e+5	45.9342507
9	301	1	1	8.074486994	0.516470391	25.4	25.0	4.191014e+5	55.8111361
10	301	1	1	6.84070888	0.611902469	25.4	25.0	2.727287e+5	78.0436691
11	301	1	1	6.669032506	0.629962505	25.4	25.0	2.541144e+5	82.4091386
12	301	1	1	11.4077533	0.369034308	25.4	25.0	9.990083e+5	28.2209566
13	301	1	1	7.264560421	0.58158335	25.4	25.0	3.134307e+5	69.8354062
14	301	1	1	0.689066182	6.151180133	25.4	25.0	896.432124795	22072.139795
15	301	1	1	8.957832974	0.474226485	25.4	25.0	5.309081e+5	46.1750373
16	301	1	1	5.969440614	0.713470809	25.4	25.0	1.873977e+5	104.2423148
17	301	1	1	0.659439752	6.487405571	25.4	25.0	813.249396971	24924.480146
18	301	1	1	0.784614795	5.472597898	25.4	25.0	1146.95118222	16043.388484

(7) The details of the selected realization will be shown in the “Plate-Fin: Sizing Realization” tab

a. The results of the sizing calculation are shown under “Sizing Result”
b. The rating results for the selected realization will be shown under “Detailed Results”
c. Clicking the “Save to a Regular Rating Project” button allows you to save the realization into a regular Plate-Fin rating project
d. Click "Download Realization Data" to view the realization results in a Microsoft Excel file.

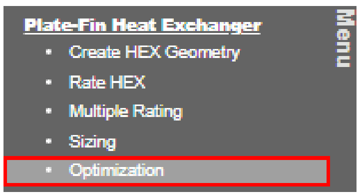

Start Page
Plate-Fin: Sizing
Plate-Fin: Sizing Result
Plate-Fin: Sizing Realization
Sizing Result:
Plate Length: 10.403768882 m
Plate Width: 0.369849002 m
Hot Flow Rate: 25.4 kg/s
Cold Flow Rate: 25.0 kg/s
Total No. of Plates: 301
No. of Hot Passes: 1
No. of Cold Passes: 1
Hot Fin Shape: rectangular
Hot Fin Profile: plain
Hot Fin Efficiency: 0.550786069
Hot Plate Spacing: 0.0057 m
Hot Fin Pitch: 0.002 m
Hot Fin Thickness: 1.5e-4 m
Cold Fin Shape: rectangular
Cold Fin Profile: plain
Cold Fin Efficiency: 0.833180432
Cold Plate Spacing: 0.0057 m
Cold Fin Pitch: 0.002 m
Cold Fin Thickness: 1.5e-4 m
Heat Transfer Rate: 3.432203e+6 W
Heat Transfer Area: 1154.347060104 m²
Hot Pressure Loss: 9.08471e+5 Pa
Cold Pressure Loss: 31.072954205 Pa
Operating Weight: 2720.298064202 kg
Effectiveness: 0.809481892
COP: 0.080319376
Save to a Regular Rating Project
Detailed Results:
Hot Flow
Cold Flow
Overall
No. of Passages: 150
Inlet Temperature: 733.16 K
Outlet Temperature: 605.682536849 K
Pressure Loss: 9.08471e+5 Pa
Mass Flow Rate: 25.4 kg/s
Mass Flux: 89.183249235 kg/(s·m²)
Flow Velocity: 165.15416525 m/s
Fouling Resistance: 0. m²K/W
Equivalent Diameter: 0.002775 m
Reynolds Number: 7733.859894575
Heat Coefficient: 399.251504308 W/(m²·K)
Effective hA: 1.130725e+6 W/K
Effective Heat Area: 2832.111255557 m²
Colburn Factor J: 0.003260686
Friction Factor F: 0.0081725
Fin Shape: rectangular
Fin Profile: plain
Fin Efficiency: 0.550786069
Plate Spacing: 0.0057 m
Fin Pitch: 0.002 m
Fin Thickness: 1.5e-4 m
Flow Length: 10.403768882 m
Flow Width: 0.369849002 m
Power: 4.273179e+7 W
Mean Temperature: 669.421268324 K
Mean Density: 0.54 kg/m³
Mean Specific Heat: 1060.0 J/(kg·K)
Mean Viscosity: 3.2e-5 kg/(m·s)
Mean Conductivity: 0.05 W/(m·K)
Mean Heat Capacity: 26924.0 W/K
Download Realization Data
Back to the Project

6. QuickStart: Creating & Running an Optimization Project

In the Optimization module, INSTED attempts to find the best Plate-Fin heat exchanger geometry that satisfies stipulated objective functions and constraints. The constraints could include a specified value of the heat transfer rate in an existing Rating project (or Reference rating project).

This tutorial will teach you how to create a Plate-Fin optimization project. The rating project created in the previous tutorial will be used.

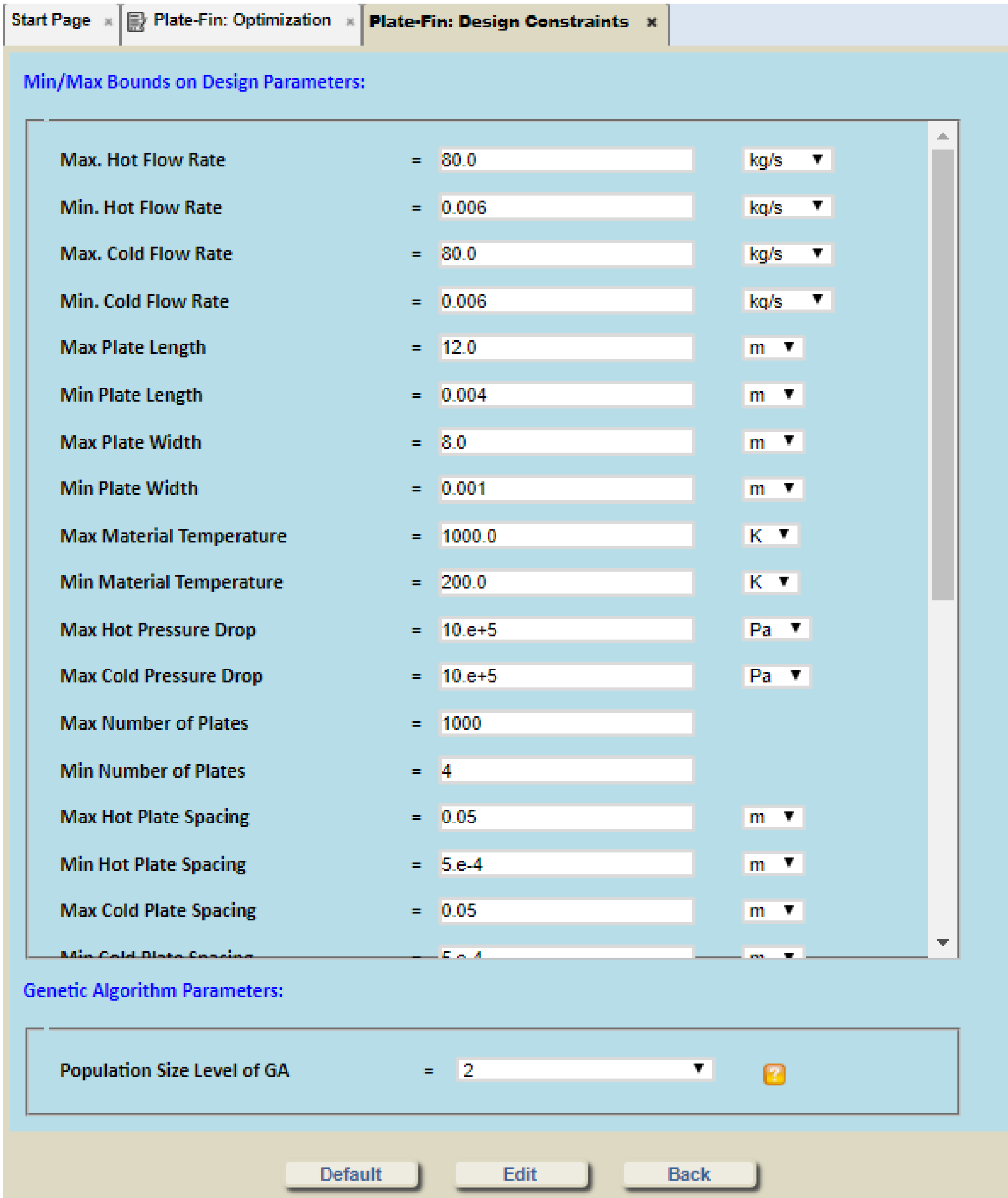
(1) Click the "Optimization" button under "Plate-Fin Heat Exchanger" from the menu panel



(2) After "Plate-Fin: Optimization" tab has been loaded, follow the steps below:

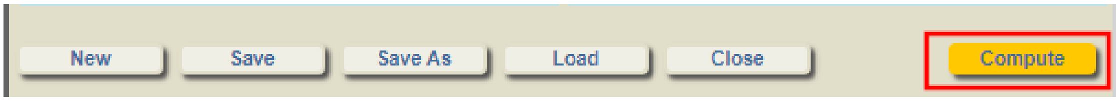
a. Write "Hewitt Optimization" for "Project Name"
b. Choose the name of the Plate-Fin Rating Project created in the previous tutorial ("Hewitt Rating") in "Choose a Rating Project." Note that the details of the selected Rating Project can be viewed by clicking on the "View Details" button.
c. The "Optimization Objective Functions" tab controls the optimization objectives. In the present illustration problem, we want to determine the heat exchanger geometry that uses the minimum number of plates and provides the highest overall effectiveness. To specify these objectives, check "Minimize No. of Plates" and "Maximize Effectiveness" in "Optimization Objective Functions"
d. "Optimization Criteria" controls the parameters that are allowed to change in the reference Rating project during the optimization calculation. For this problem we allow only the plate length and width to change.

(3) Click the "Set Bounds" button; the "Plate-Fin: Design Constraints" tab will be displayed. The range of the design variables that are allowed to change can be specified here. For the sample problem, use the default values. Click the "Back" button to return to the "Plate-Fin: Optimization" tab.

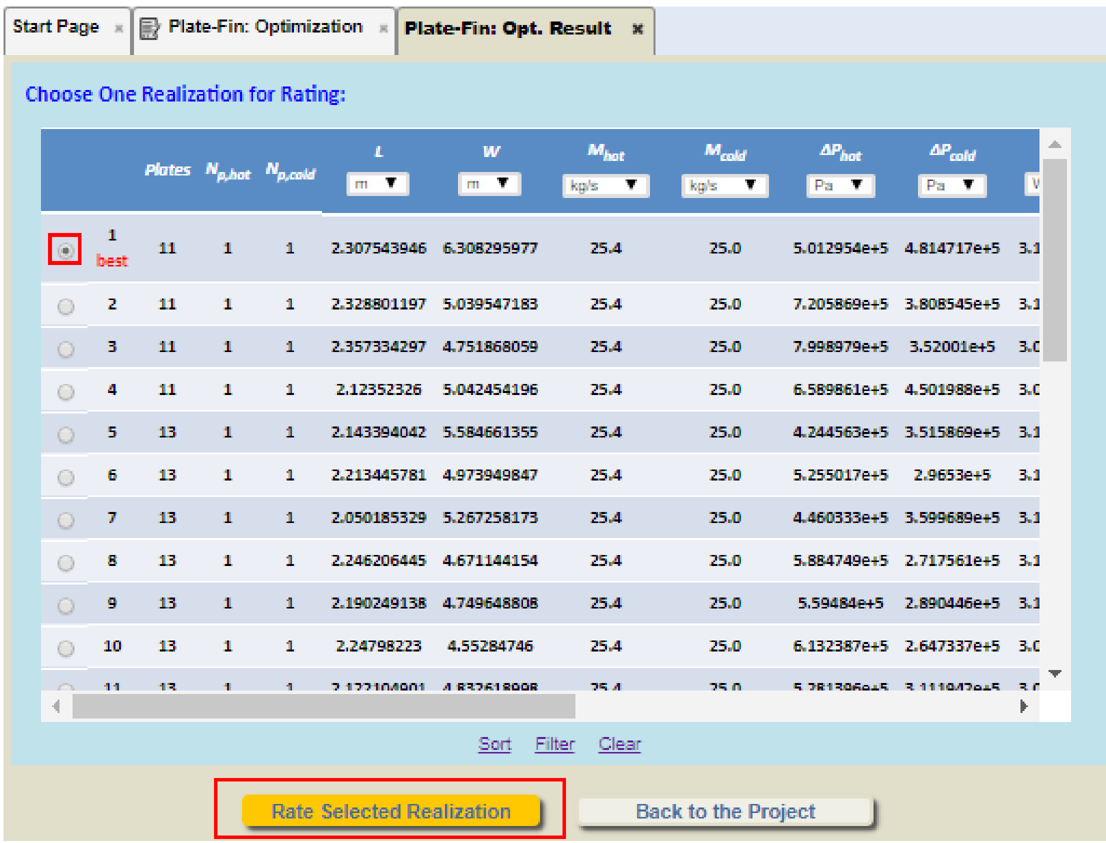


(4) Click the “Save” button to save the project.

(5) Click the “Compute” button to begin the Optimization calculations. Depending on the problem settings, the calculations may take several minutes.

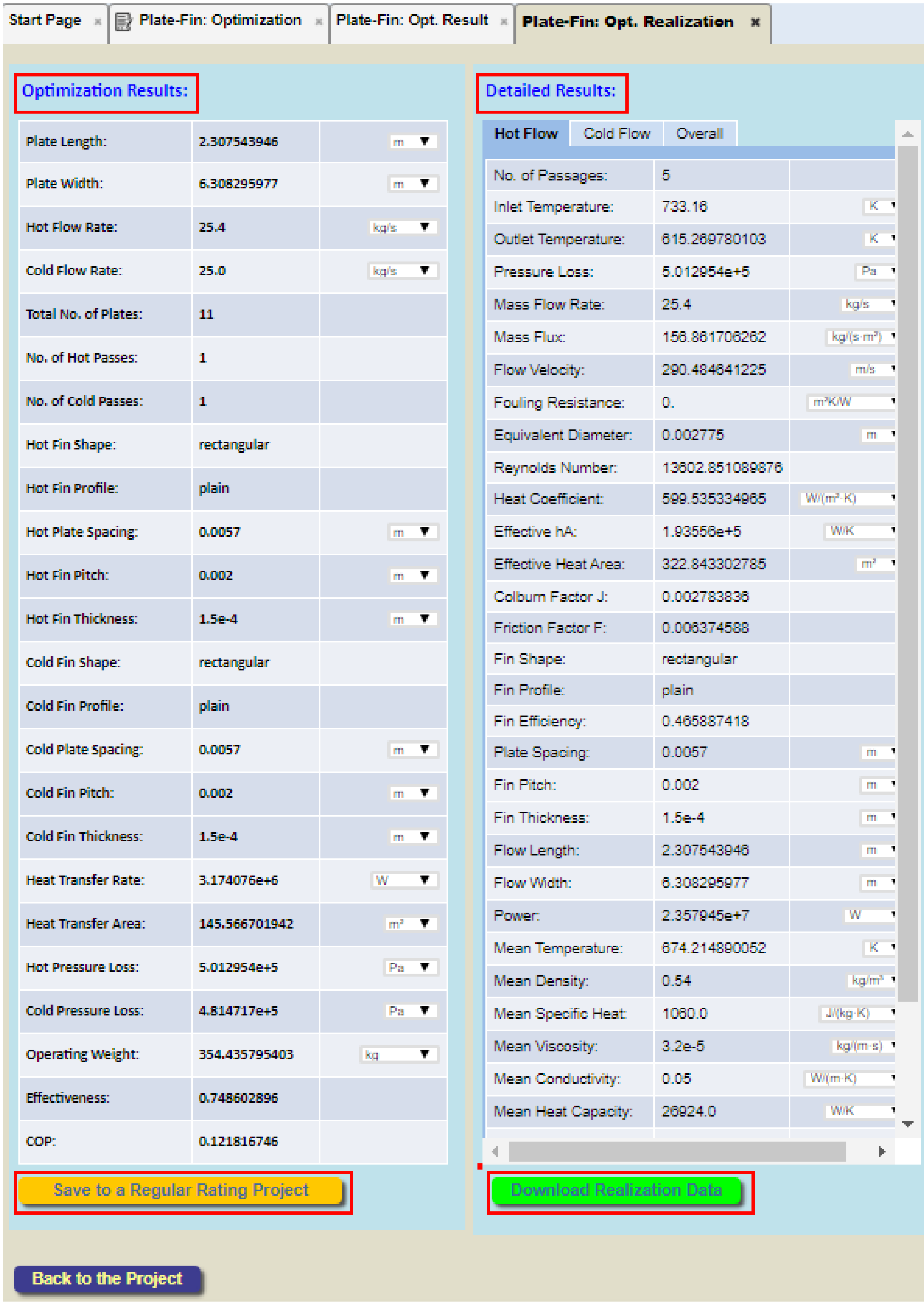


(6) Wait until the optimization calculations have been completed; a list of possible design realizations will be displayed. You can select one of the realizations and click the “Rate Selected Realization” button to view the details of the selected realization. Note that the list of the realizations is ordered in decreasing order of the best result based on the objective function.



(7) The details of the selected realization will be shown when you select the “Plate-Fin: Optimization Realization” tab:

a. The values of the optimization parameters will be shown under “Optimization Result”
b. The Rating Results of the selected realization will be shown under “Detailed Results”
c. Clicking on “Save to a Regular Rating Project” allows you to save a selected realization into a regular (single-point)Plate-Fin Rating project
d. Click on "Download Realization Data" to view the realization results in a Microsoft Excel file.



Optimization Results:

Plate Length:	2.307543946	m
Plate Width:	6.308295977	m
Hot Flow Rate:	25.4	kg/s
Cold Flow Rate:	25.0	kg/s
Total No. of Plates:	11	
No. of Hot Passes:	1	
No. of Cold Passes:	1	
Hot Fin Shape:	rectangular	
Hot Fin Profile:	plain	
Hot Plate Spacing:	0.0057	m
Hot Fin Pitch:	0.002	m
Hot Fin Thickness:	1.5e-4	m
Cold Fin Shape:	rectangular	
Cold Fin Profile:	plain	
Cold Plate Spacing:	0.0057	m
Cold Fin Pitch:	0.002	m
Cold Fin Thickness:	1.5e-4	m
Heat Transfer Rate:	3.174076e+6	W
Heat Transfer Area:	145.566701942	m²
Hot Pressure Loss:	5.012954e+5	Pa
Cold Pressure Loss:	4.814717e+5	Pa
Operating Weight:	354.435795403	kg
Effectiveness:	0.748602896	
COP:	0.121816746	

Detailed Results: Hot Flow

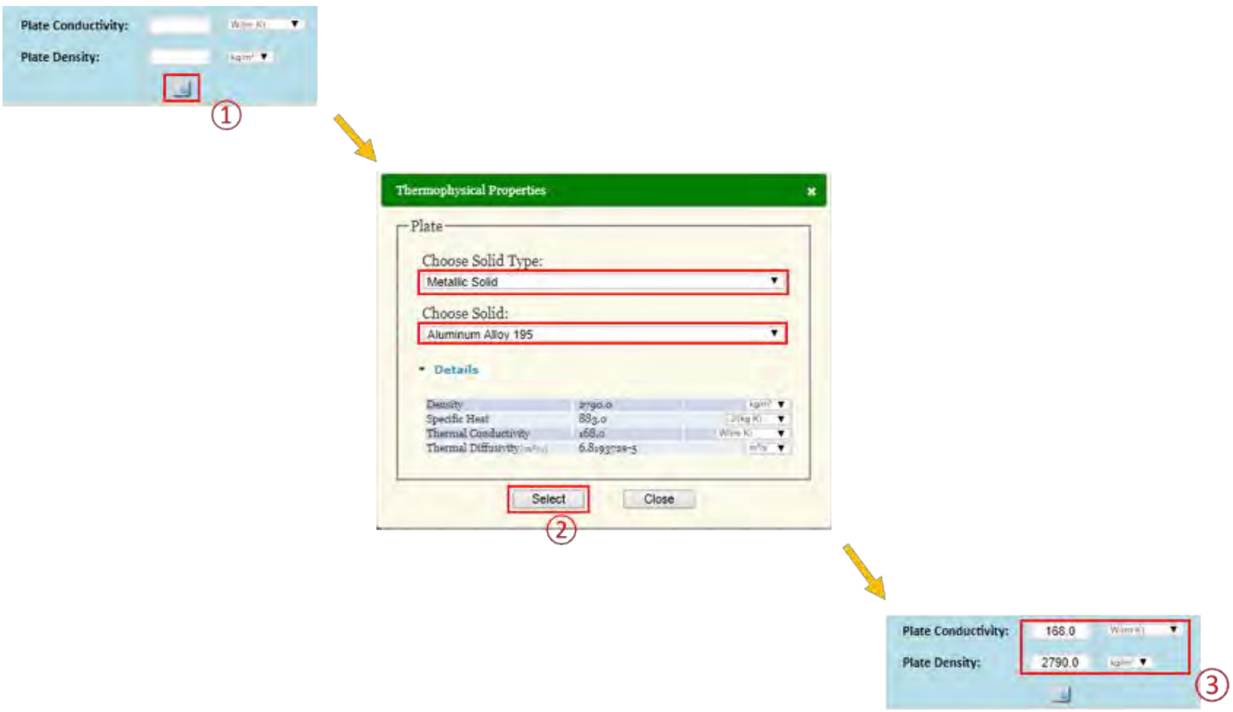
No. of Passages:	5	
Inlet Temperature:	733.16	K
Outlet Temperature:	615.269780103	K
Pressure Loss:	5.012954e+5	Pa
Mass Flow Rate:	25.4	kg/s
Mass Flux:	156.881706262	kg/(s·m²)
Flow Velocity:	290.484641225	m/s
Fouling Resistance:	0.	m²K/W
Equivalent Diameter:	0.002775	m
Reynolds Number:	13602.851089876	
Heat Coefficient:	599.535334965	W/(m²·K)
Effective hA:	1.93556e+5	W/K
Effective Heat Area:	322.843302785	m²
Colburn Factor J:	0.002783836	
Friction Factor F:	0.006374588	
Fin Shape:	rectangular	
Fin Profile:	plain	
Fin Efficiency:	0.465887418	
Plate Spacing:	0.0057	m
Fin Pitch:	0.002	m
Fin Thickness:	1.5e-4	m
Flow Length:	2.307543946	m
Flow Width:	6.308295977	m
Power:	2.357945e+7	W
Mean Temperature:	674.214890052	K
Mean Density:	0.54	kg/m³
Mean Specific Heat:	1060.0	J/(kg·K)
Mean Viscosity:	3.2e-5	kg/(m·s)
Mean Conductivity:	0.05	W/(m·K)
Mean Heat Capacity:	26924.0	W/K

7. Tips: Accessing Integrated Database

In INSTED, the database is integrated into the GUI and can be accessed by clicking the buttons. More details of the database in INSTED are provided below.

(1) Solid Properties database

In the Plate-Fin Geometry module, the plate and fin solid material conductivity and density can be obtained directly from the built-in solid thermophysical properties database in INSTED:



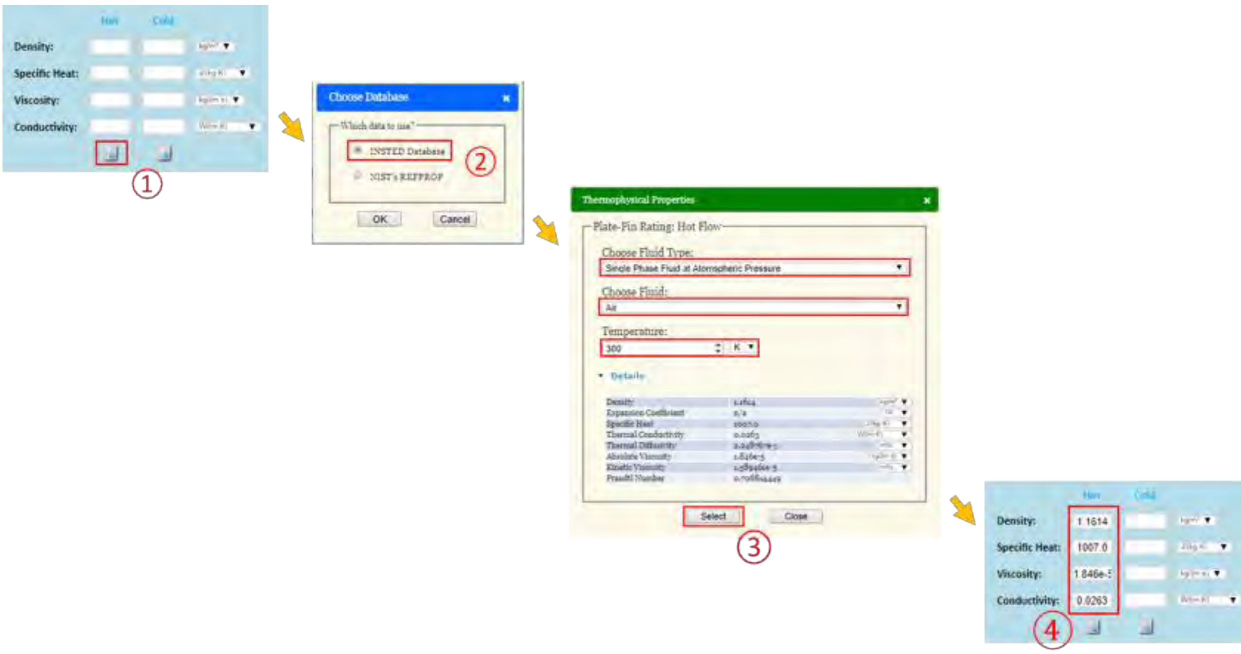
(2) Fluid Properties database

In the Plate-Fin Rating module, the fluid density, heat capacity, viscosity, and thermal conductivity can be obtained directly from the built-in fluid thermophysical properties database in INSTED. INSTED includes two kinds of Fluid Properties database:

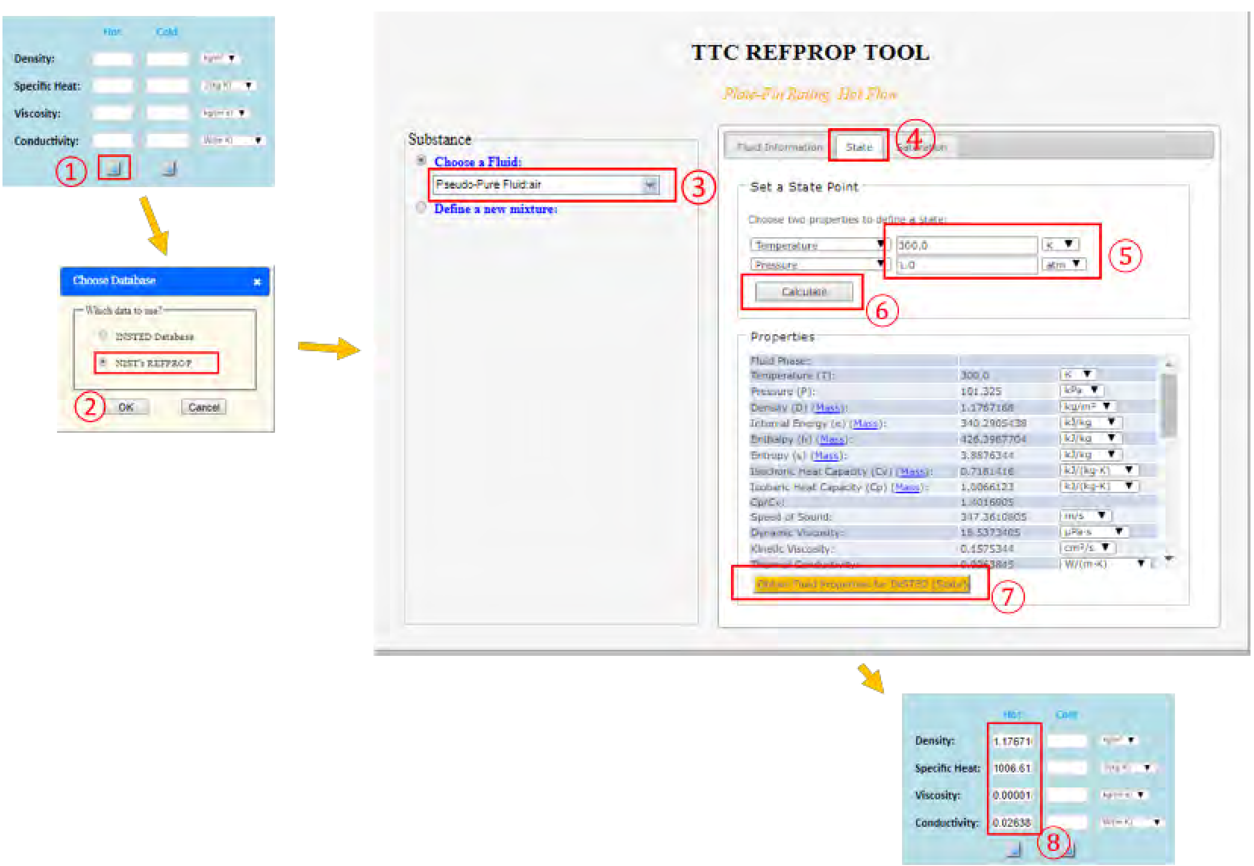
- INSTED Fluid database
- NIST'S REFPROP database

Note that the fluid properties you obtain from clicking the button is single-point only. To obtain variable properties please refer to Sections "*14. Fluid Properties: Using NIST's REFPROP Database*" and "*15. Fluid Properties: User Defined Fluid Properties.*"

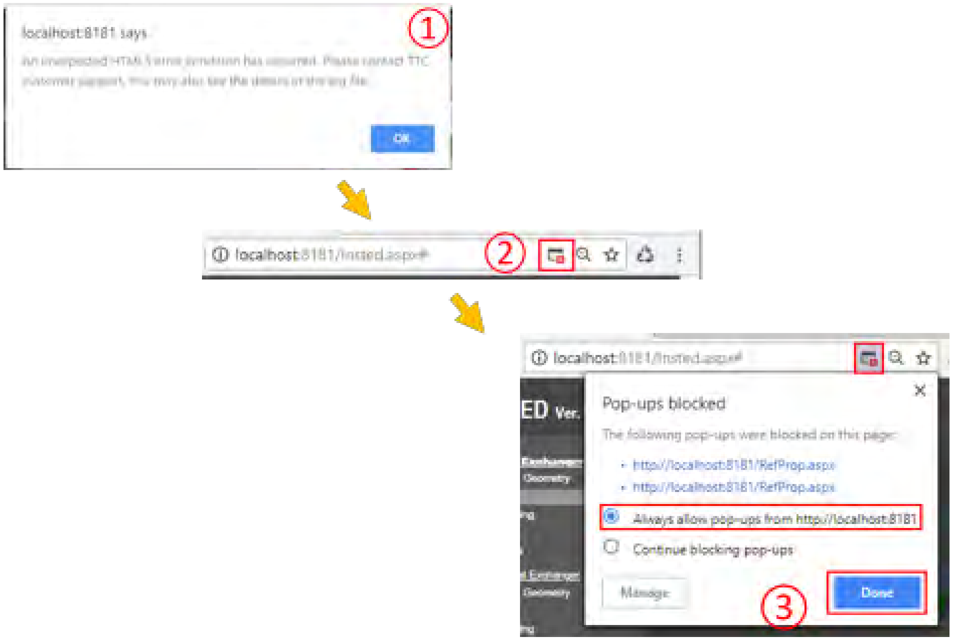
INSTED Fluid Database



NIST's REFPROP Database

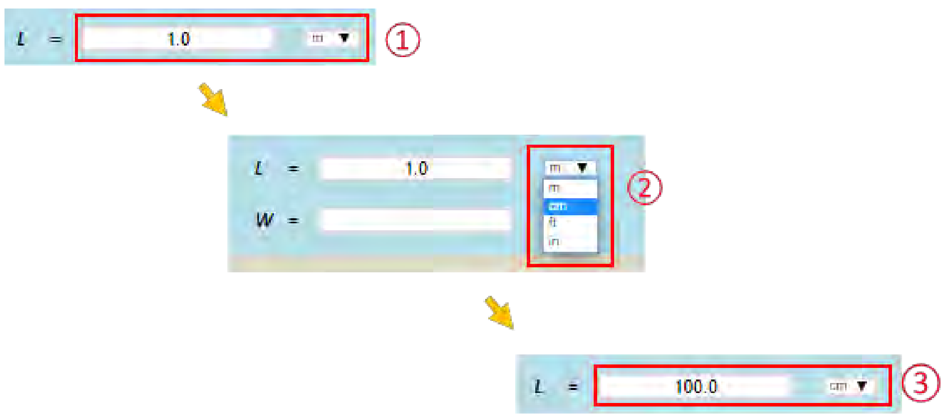


Note that REFPROP will be opened in a new web page in the browser. If the “popup blocker” is enabled you may see the error message in the screen shot below. In this case, you should enable the page to popup, and then retry to access the REFPROP database.

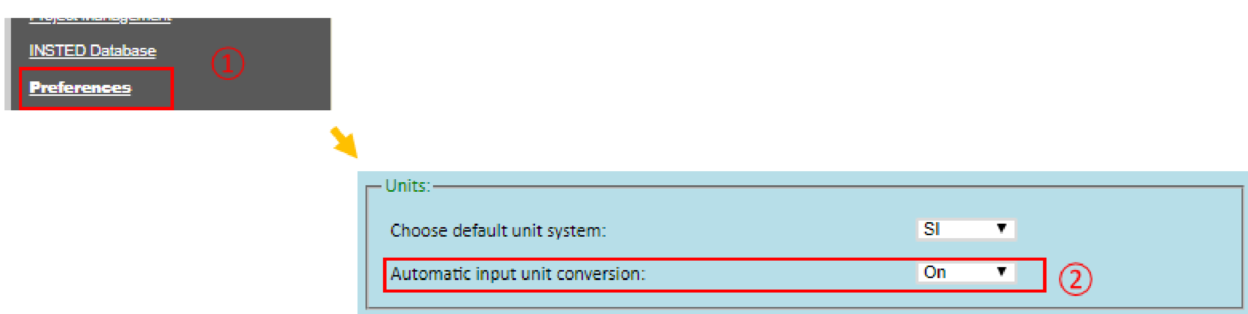


8. Tips: Using Integrated Unit Conversion

The Unit Conversion capability is integrated with INSTED GUI. When changing the unit of a variable, the value of the variable will be automatically changed consistent with the new unit selected.



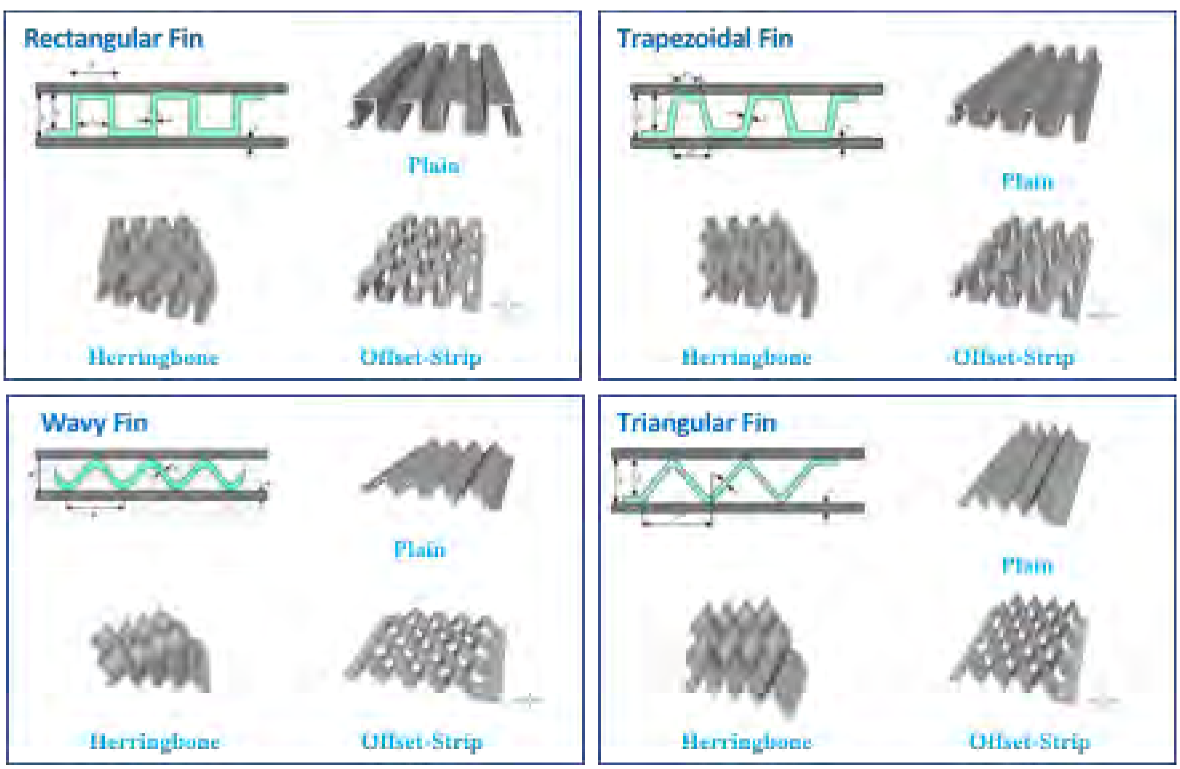
Note that the “automatic input unit conversion” can be disabled in “Preferences -> Automatic input unit conversion” from the main menu panel.



9. Fins: Natively Supported Fins

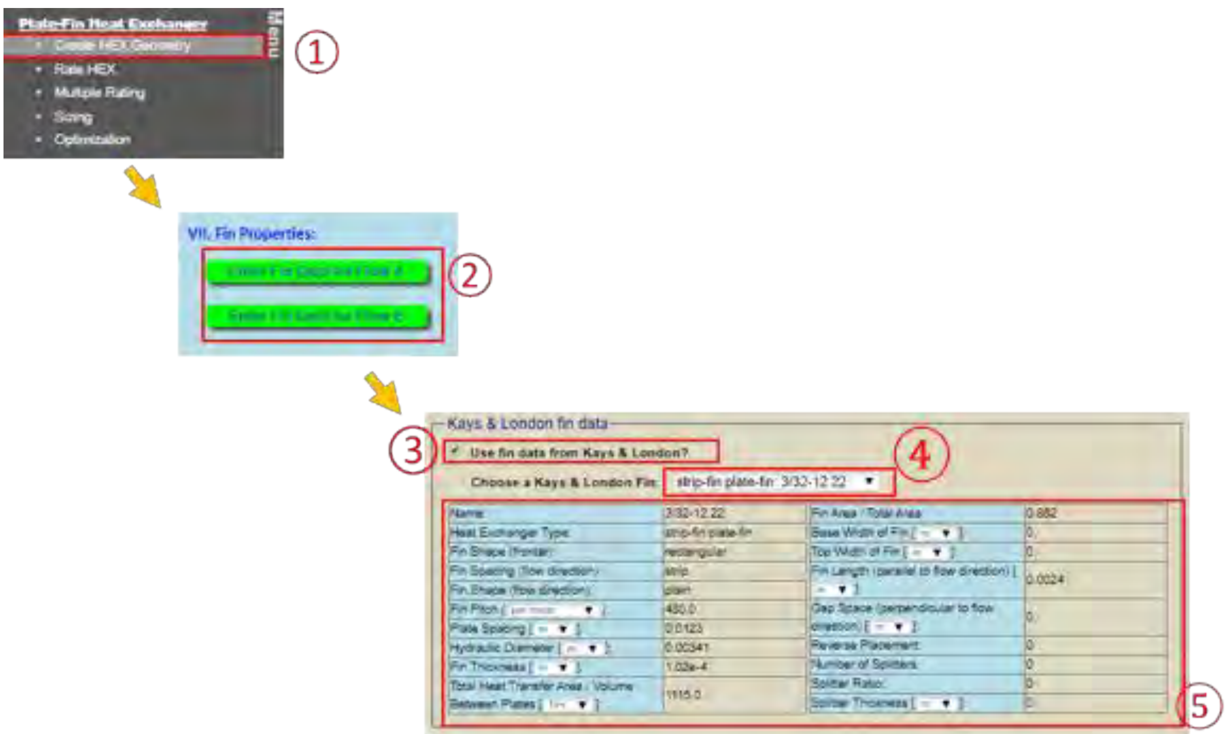
The INSTED Plate-Fin module natively supports the following fin types for the frontal shape and the profile in the flow direction:

- Frontal shape
  - rectangular
  - trapezoidal
  - triangular
  - wavy
- Flow Direction profiles
  - plain
  - offset-strip
  - herringbone



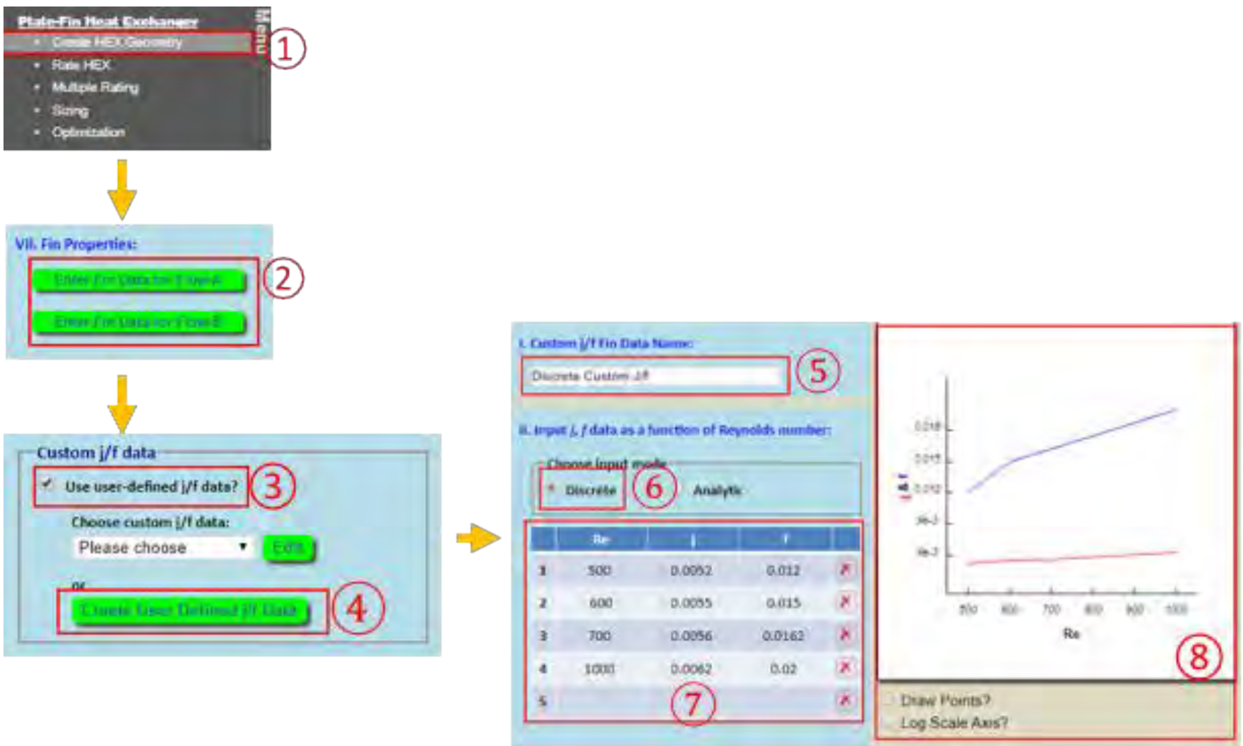
10. Fins: Using Kays & London Fins

Fifty six (56) Kays & London fins are integrated into the INSTED Plate-Fin program. They can be accessed from the main menu panel: Create HEX Geometry > Enter Fin Data for Flow A/B > Use find data from Kays & London? as shown below:



11. Fins: Custom J/F Data – Discrete Mode

You can provide your own J/F data to override the built-in J/F correlations contained in INSTED Plate-Fin. You can do this in two ways: Discrete approach and Analytic approach. In the discrete approach, the J/F data can only be entered as a function of the Reynolds number, and can be entered in a discrete lookup table form. Follow the steps in the screen shots below.

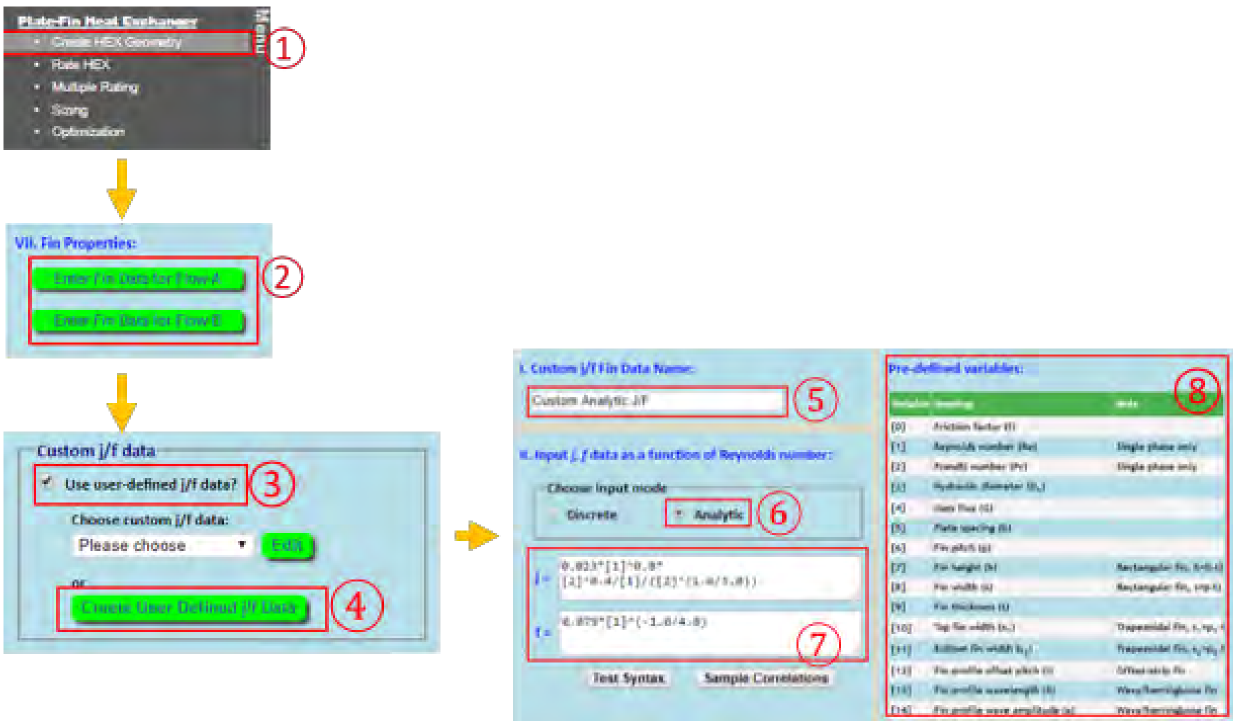


Note:

- Existing custom J/F data can be modified by clicking the "Edit" button
- The discrete J/F data points must be entered in the table in increasing order of the Reynolds number

12. Fins: Custom J/F Data – Analytic Mode

In the Analytic Approach for specifying your custom J/F data, you can provide the data by simply typing the analytical expressions for J and F directly on the keyboard. INSTED will interpret (parse) the typed expressions and evaluate the J and F values at runtime. More details about how the parser works can be found in "*INSTED J/F Equation Interpreter Syntax Reference Manual.*"

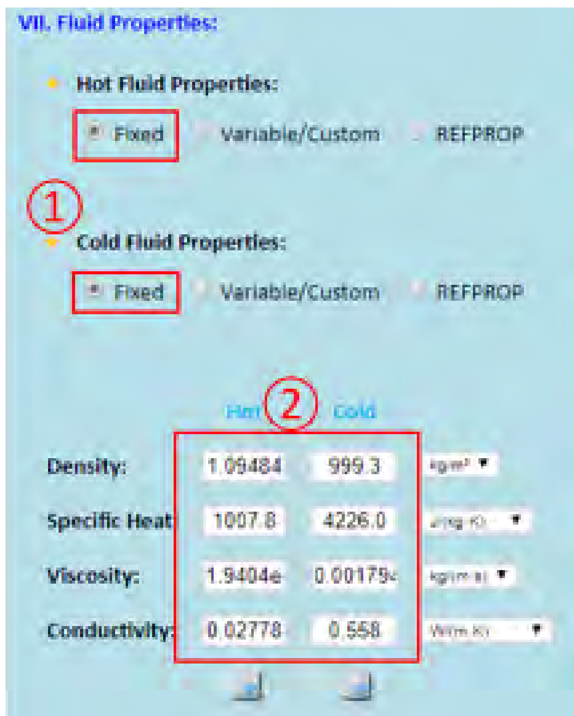


13. Fluid Properties: Fixed (Single-Point) Thermo-Physical Fluid Properties

In the Plate-Fin Rating Module, several options are available for obtaining single-point thermal physical properties of the (hot and cold) fluids:

- Fixed
- Variable/Custom
- REFPROP

When "Fixed" is chosen, you need to provide the (single) values of density, heat capacity, viscosity, and thermal conductivity for the fluids.

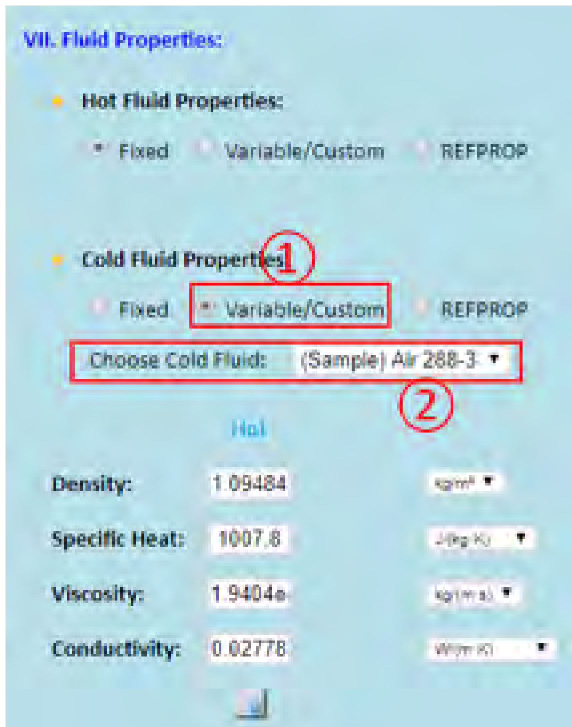


14. Fluid Properties: Using NIST's REFPROP Database

When "REFPROP" is chosen, you need to select the name of the fluid from a dropdown list.

15. Fluid Properties: User Defined Fluid Properties

When the “Variable/Custom” button is selected, you need to select the fluid from the list of previously-generated custom fluid properties.



The “Variable/Custom fluid data” capability has been provided for the following purposes:

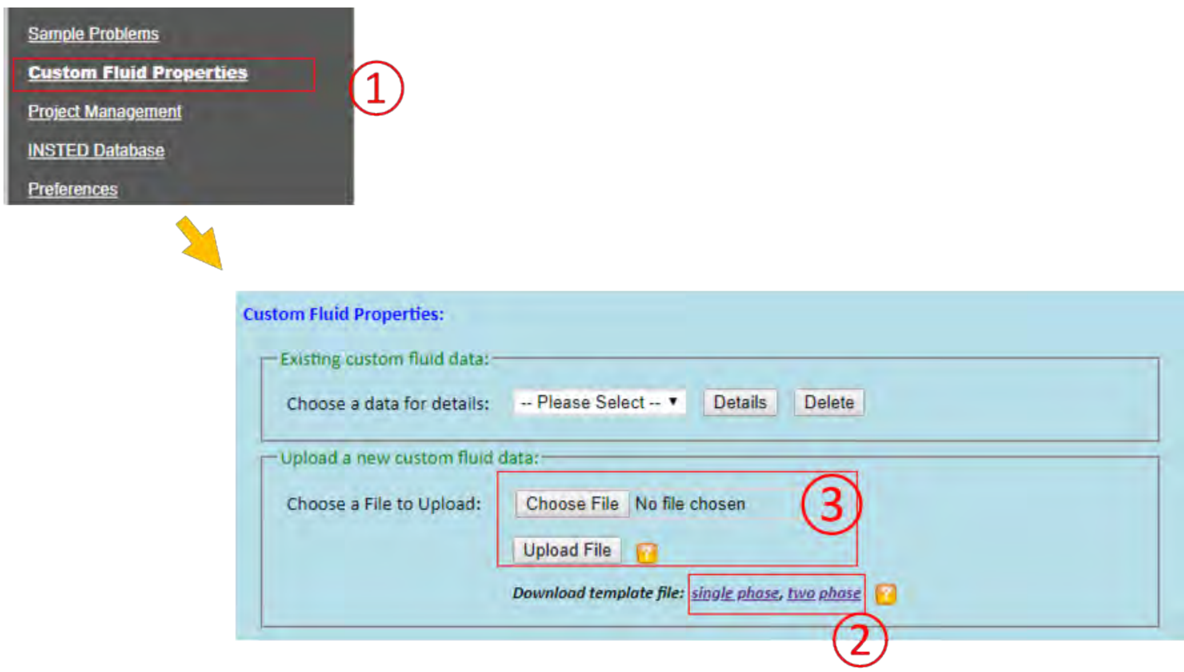
- To allow you to use your own thermophysical fluid data
- To allow you to provide variable thermophysical fluid data, i.e. the fluid thermophysical properties can be a function of the local temperature and pressure.

To use this capability, you need to first create the "Variable/Custom fluid data." This is done by uploading a Microsoft Excel file with the "correct" format. This can easily be done by downloading the sample Excel template file in INSTED and modifying them directly.

Two template files are available:

- Single-phase fluid Excel template
- Two-phase fluid Excel template

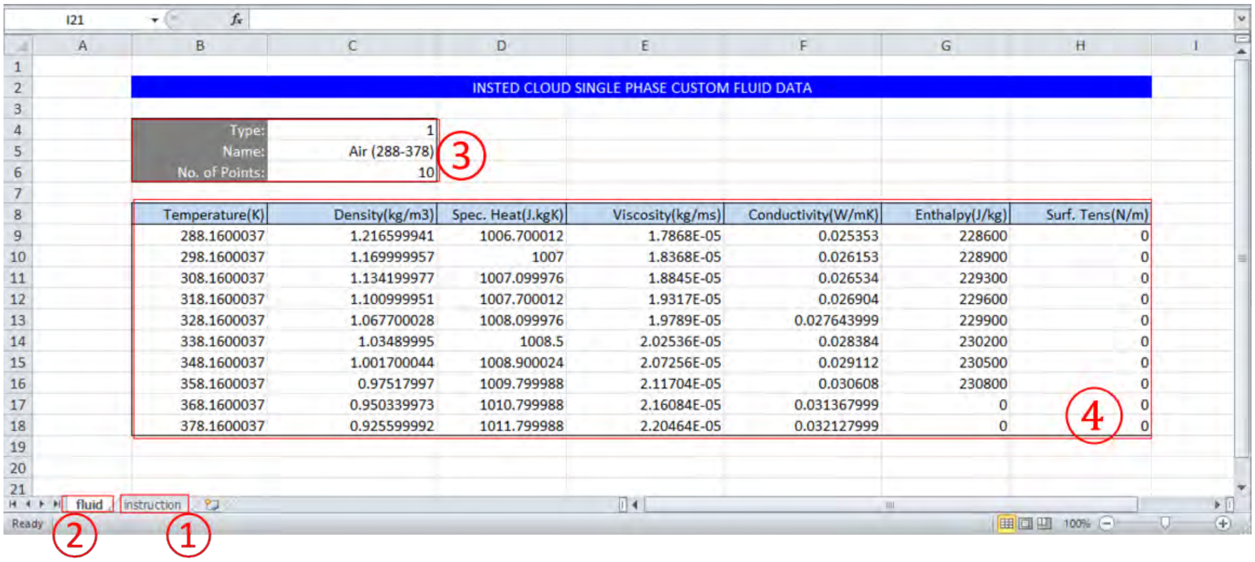
The capability to create a "Variable/Custom fluid data" can be accessed from "Custom Fluid Properties" menu in the main menu panel.



Note:

- You can view details of an existing custom fluid data by clicking the "Details" button
- You can delete an existing custom fluid data by clicking the "Delete" button

Single-Phase template:

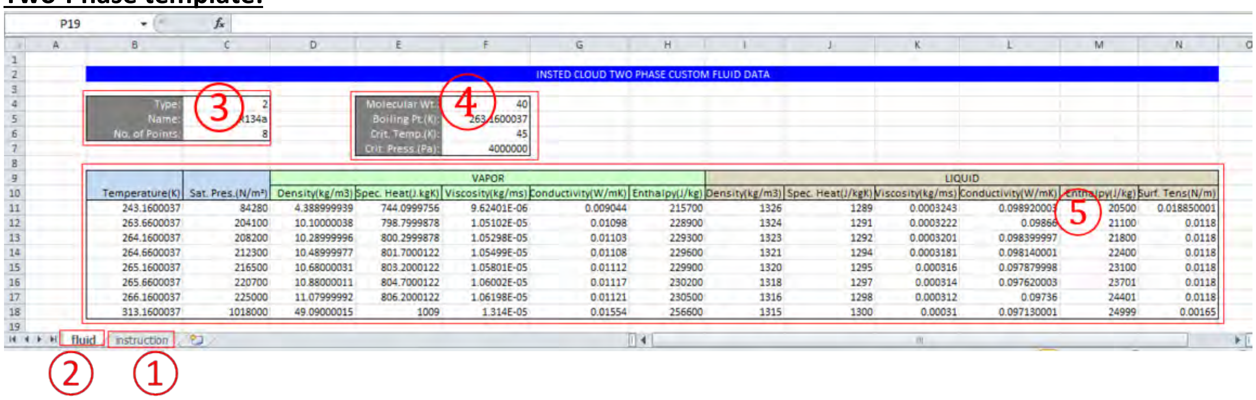


INSTED CLOUD SINGLE PHASE CUSTOM FLUID DATA

Type:	1
Name:	Air (288-378)
No. of Points:	10

Temperature(K)	Density(kg/m3)	Spec. Heat(J.kgK)	Viscosity(kg/ms)	Conductivity(W/mK)	Enthalpy(J/kg)	Surf. Tens(N/m)
288.1600037	1.216599941	1006.700012	1.7868E-05	0.025353	228600	0
298.1600037	1.169999957	1007	1.8368E-05	0.026153	228900	0
308.1600037	1.134199977	1007.099976	1.8845E-05	0.026534	229300	0
318.1600037	1.100999951	1007.700012	1.9317E-05	0.026904	229600	0
328.1600037	1.067700028	1008.099976	1.9789E-05	0.027643999	229900	0
338.1600037	1.03489995	1008.5	2.02536E-05	0.028384	230200	0
348.1600037	1.001700044	1008.900024	2.07256E-05	0.029112	230500	0
358.1600037	0.97517997	1009.799988	2.11704E-05	0.030608	230800	0
368.1600037	0.950339973	1010.799988	2.16084E-05	0.031367999	0	0
378.1600037	0.925599992	1011.799988	2.20464E-05	0.032127999	0	0

Two-Phase template:



INSTED CLOUD TWO PHASE CUSTOM FLUID DATA

Type:	2
Name:	R134a
No. of Points:	8

Molecular Wt.:	40
Boiling Pt.(K):	263.1600037
Crit. Temp.(K):	45
Crit. Press.(Pa):	4000000

		VAPOR					LIQUID					
Temperature(K)	Sat. Pres.(N/m²)	Density(kg/m3)	Spec. Heat(J.kgK)	Viscosity(kg/ms)	Conductivity(W/mK)	Enthalpy(J/kg)	Density(kg/m3)	Spec. Heat(J/kgK)	Viscosity(kg/ms)	Conductivity(W/mK)	Enthalpy(J/kg)	Surf. Tens(N/m)
243.1600037	84280	4.388999939	744.0999756	9.62401E-06	0.009044	215700	1326	1289	0.0003243	0.098920003	20500	0.018850001
263.6600037	204100	10.10000038	798.7999878	1.05102E-05	0.01098	228900	1324	1291	0.0003222	0.09866	21100	0.0118
264.1600037	208200	10.28999996	800.2999878	1.05298E-05	0.01103	229300	1323	1292	0.0003201	0.098399997	21800	0.0118
264.6600037	212300	10.48999977	801.7000122	1.05499E-05	0.01108	229600	1321	1294	0.0003181	0.098140001	22400	0.0118
265.1600037	216500	10.68000031	803.2000122	1.05801E-05	0.01112	229900	1320	1295	0.000316	0.097879998	23100	0.0118
265.6600037	220700	10.88000011	804.7000122	1.06002E-05	0.01117	230200	1318	1297	0.000314	0.097620003	23701	0.0118
266.1600037	225000	11.07999992	806.2000122	1.06198E-05	0.01121	230500	1316	1298	0.000312	0.09736	24401	0.0118
313.1600037	1018000	49.09000015	1009	1.314E-05	0.01554	256600	1315	1300	0.00031	0.097130001	24999	0.00165

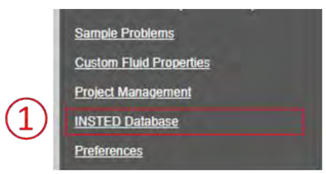
Note:

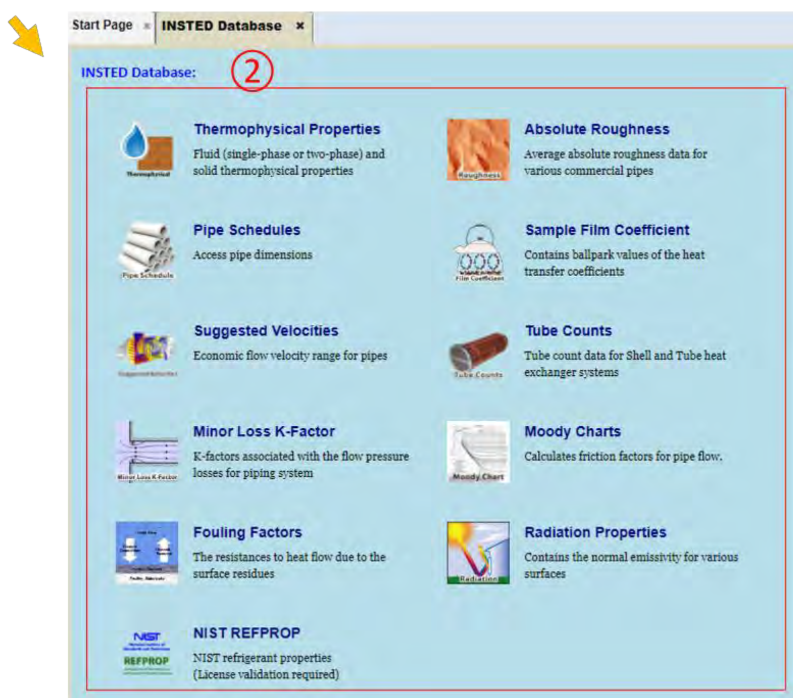
- Click the "Instruction" worksheet in Excel to view instructions
- Need to enable "Macros" to use template
- All fluid data must be in "Fluid" worksheet, do not rename the sheet
- All thermophysical properties must be entered in SI units.

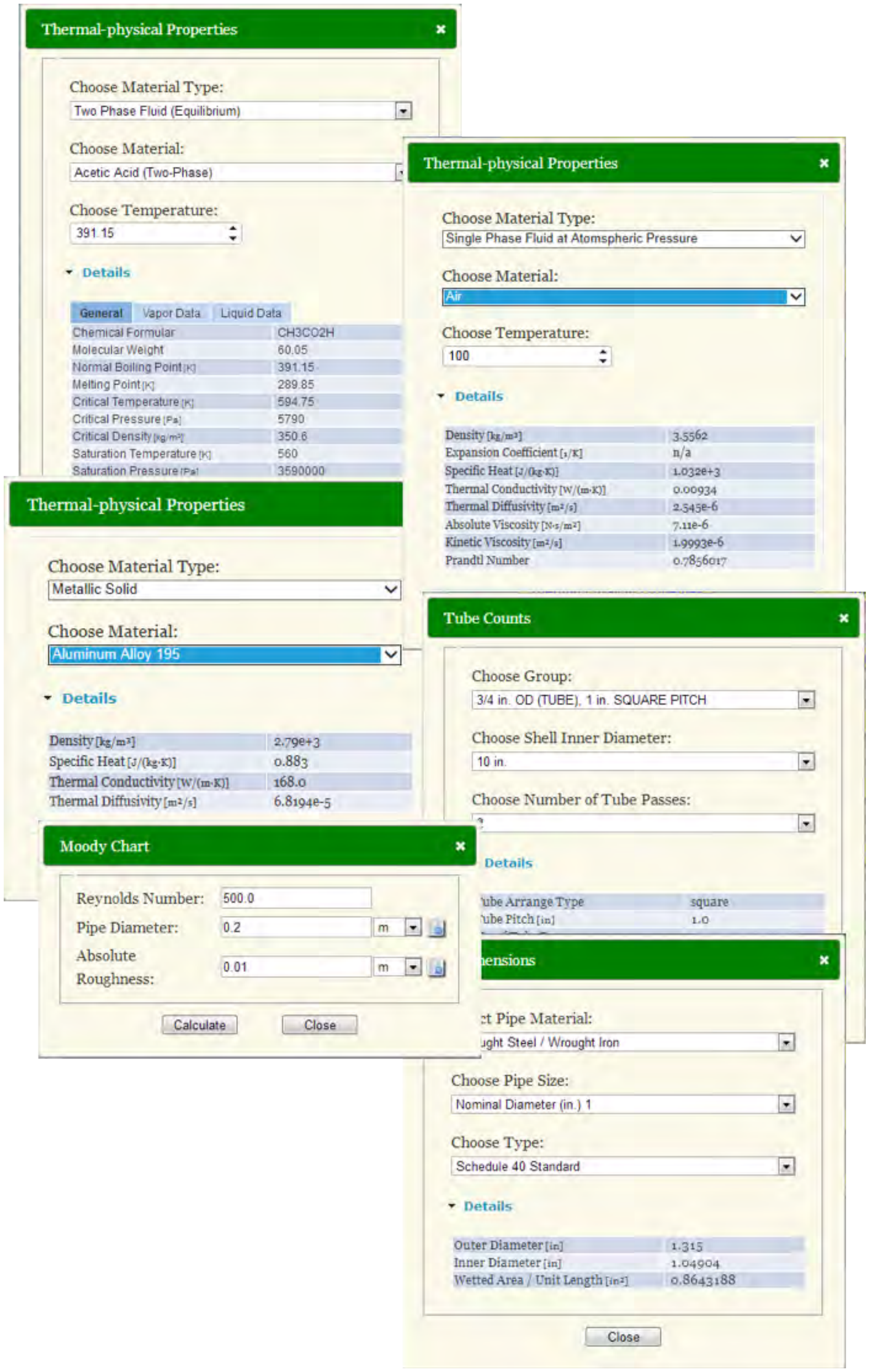
16. Tips: Accessing Standalone Database Interface

The following components are available in the Standalone database in INSTED, which can be accessed by clicking on the "INSTED Database" menu in the menu panel:

- Thermophysical properties of fluids and solids
- Pipe schedules
- Suggested velocities for the flow of various fluids
- Minor loss k-factors
- Fouling factors
- Absolute roughness
- Sample film coefficients
- Tube counts in Shell-and-Tubes
- Moody charts (friction factor calculation)
- Radiation properties
- NIST's REFPROP

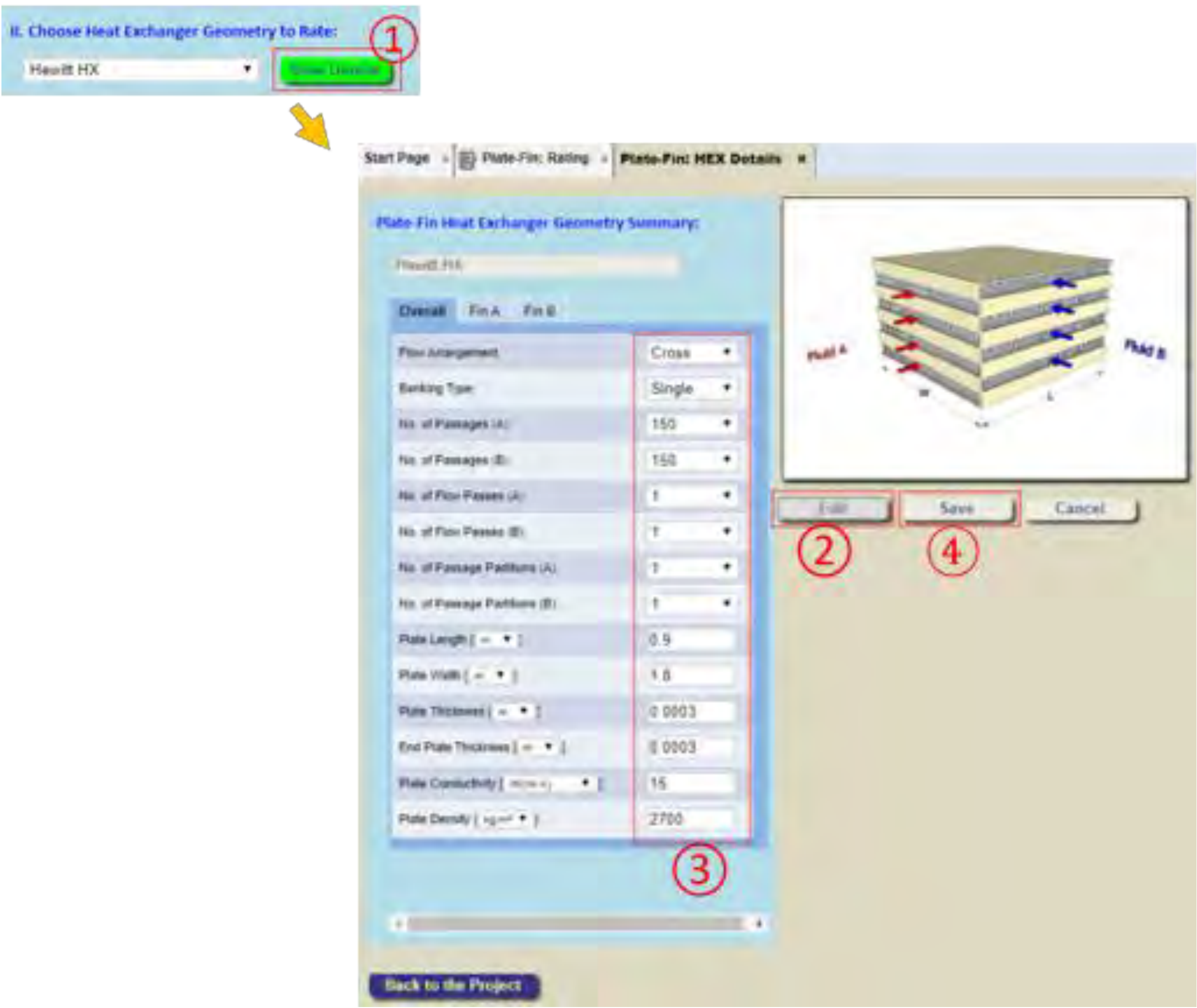





Thermal-physical Properties
Choose Material Type:
Two Phase Fluid (Equilibrium)
Choose Material:
Acetic Acid (Two-Phase)
Choose Temperature:
391.15
Details
General
Vapor Data
Liquid Data
Chemical Formular CH3CO2H
Molecular Weight 60.05
Normal Boiling Point [K] 391.15
Melting Point [K] 289.85
Critical Temperature [K] 594.75
Critical Pressure [Pa] 5790
Critical Density [kg/m³] 350.6
Saturation Temperature [K] 560
Saturation Pressure [Pa] 3590000
Thermal-physical Properties
Choose Material Type:
Single Phase Fluid at Atomspheric Pressure
Choose Material:
Air
Choose Temperature:
100
Details
Density [kg/m³] 3.5562
Expansion Coefficient [1/K] n/a
Specific Heat [J/(kg-K)] 1.032e+3
Thermal Conductivity [W/(m-K)] 0.00934
Thermal Diffusivity [m²/s] 2.545e-6
Absolute Viscosity [N-s/m²] 7.11e-6
Kinetic Viscosity [m²/s] 1.9993e-6
Prandtl Number 0.7856017
Thermal-physical Properties
Choose Material Type:
Metallic Solid
Choose Material:
Aluminum Alloy 195
Details
Density [kg/m³] 2.79e+3
Specific Heat [J/(kg-K)] 0.883
Thermal Conductivity [W/(m-K)] 168.0
Thermal Diffusivity [m²/s] 6.8194e-5
Tube Counts
Choose Group:
3/4 in. OD (TUBE), 1 in. SQUARE PITCH
Choose Shell Inner Diameter:
10 in.
Choose Number of Tube Passes:
Details
Tube Arrange Type square
Tube Pitch [in] 1.0
Moody Chart
Reynolds Number: 500.0
Pipe Diameter: 0.2 m
Absolute Roughness: 0.01 m
Calculate
Close
Choose Pipe Size:
Nominal Diameter (in.) 1
Choose Type:
Schedule 40 Standard
Details
Outer Diameter [in] 1.315
Inner Diameter [in] 1.04904
Wetted Area / Unit Length [in²] 0.8643188
Close

17. Tips: Modifying Heat Exchanger Geometry Data Directly in the Rating Interface

In the Plate-Fin Rating module, if you want to change the HEX geometry parameters, you do not need to close the current Rating project and switch to the geometry module in order to make the modification. There is a "shortcut" in the Rating module which allows you to directly modify the HEX geometry parameters. This is done by clicking the "View Details" button on the right of HEX geometry selection dropdown list and then clicking the "Edit" button in the "Plate-Fin: HEX Details" tab:

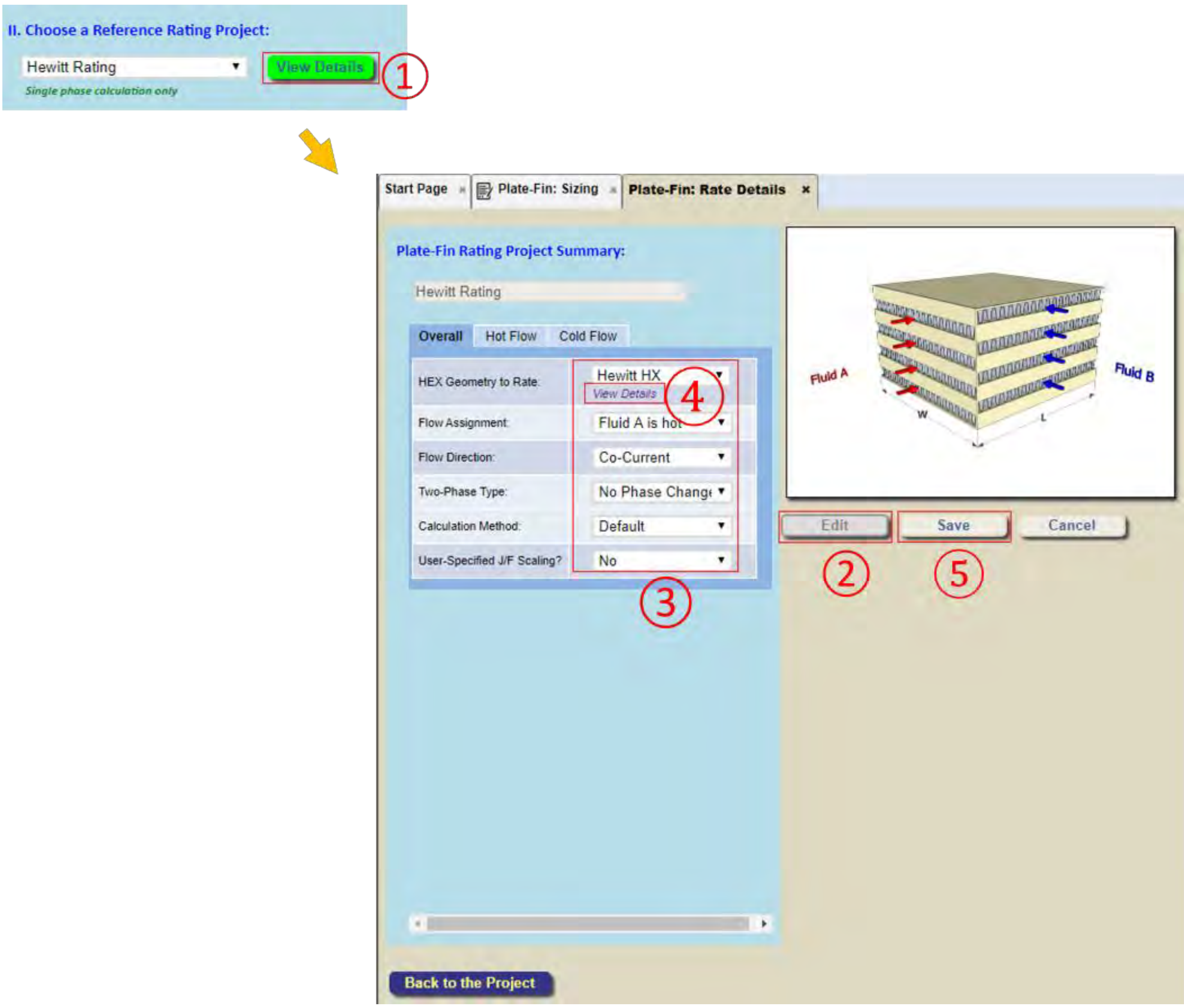


Note:

- The geometry parameters become editable after clicking "Edit" button
- Click the "Save" button to save changes
- All changes will be discarded if the "Cancel" button is clicked

18. Tips: Modifying Heat Exchanger Rating Data Directly in the Interface for Multiple-Rating, Sizing, and Optimization

Similar to the support provided for the editing of Geometry Parameters in the Rating module, there is also a shortcut in Multiple Rating, Sizing, and Optimization modules that allows you to directly change Rating project input data.



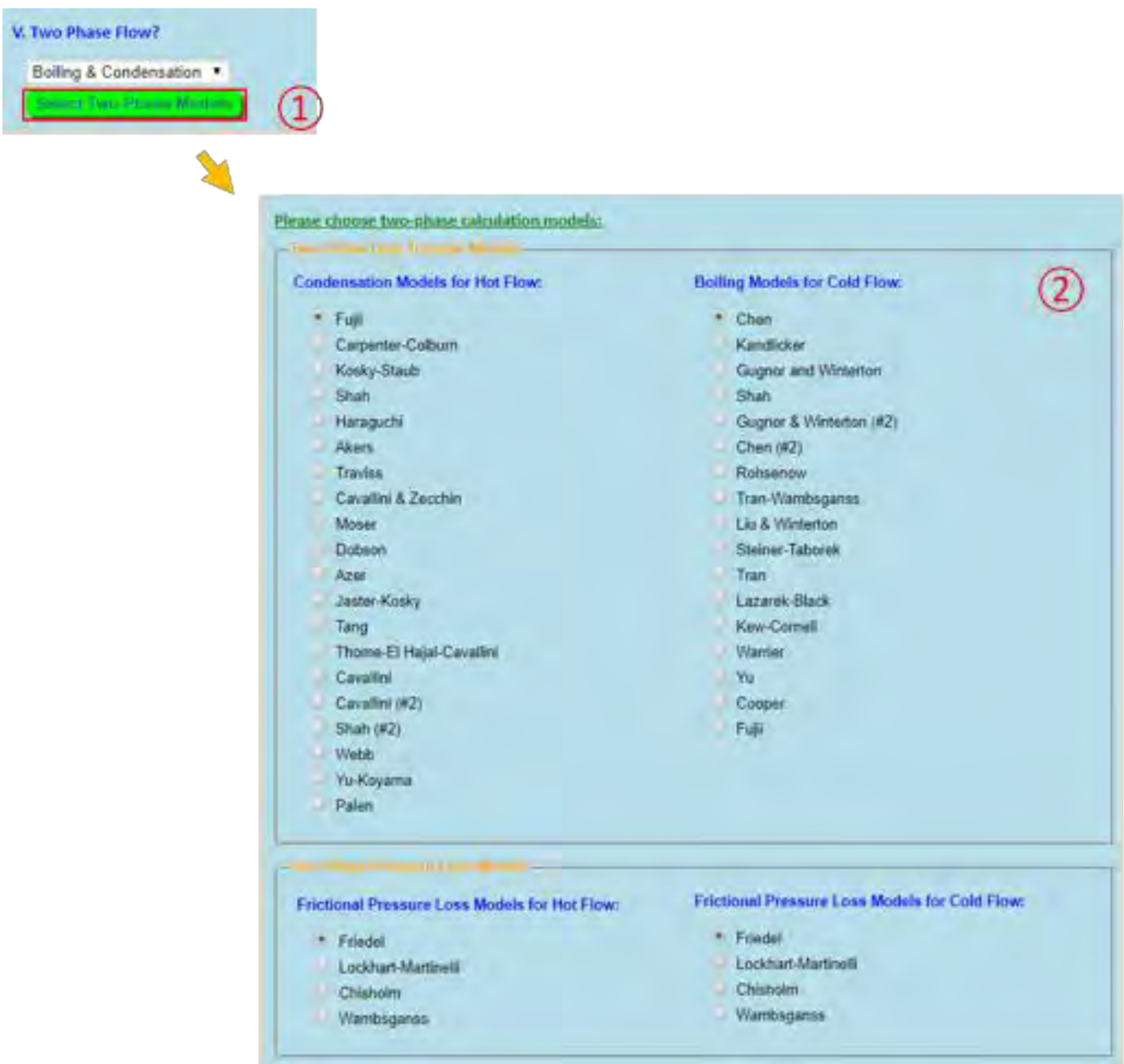
Note:

- The Rating parameters become editable after clicking the “Edit” button
- Click the “Save” button to save changes
- All changes will be discarded if the “Cancel” button is clicked
- The geometry data can also be shown and modified by clicking “View Details” button under the “HEX Geometry to Rate” dropdown list

19. Advanced Topics: Two-Phase Analysis

In the Plate-Fin Rating module, for two-phase analysis, the following models can be selected by clicking the "Select Two Phase Models" button under the "Two Phase Flow?" dropdown list. The following options are available:

- Twenty (20) condensation models for the hot fluid
- Seventeen (17) boiling models for the cold fluid
- Four (4) frictional pressure loss models for the hot stream
- Four (4) frictional pressure loss models for the cold stream



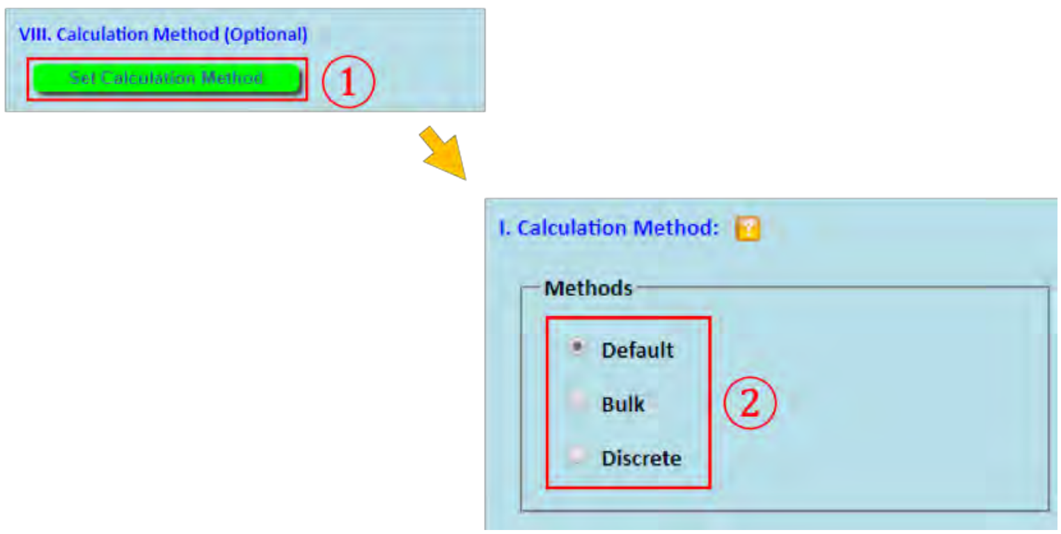
Note that the technical details of the boiling and condensation models supported can be found in section "*37. Technical Details: Two-Phase Models.*"

20. Advanced Topics: Discrete vs. Bulk Methods

INSTED Plate-Fin supports two calculation methods:

- Bulk method, which uses the traditional ε-NTU model
- Discrete method, which uses a low-order, one-dimensional, finite-volume-type numerical integration of the flow and heat transfer equations

You can select the model to use by clicking the “Set Calculation Method” button and selecting the desired “Calculation Method”



Note:

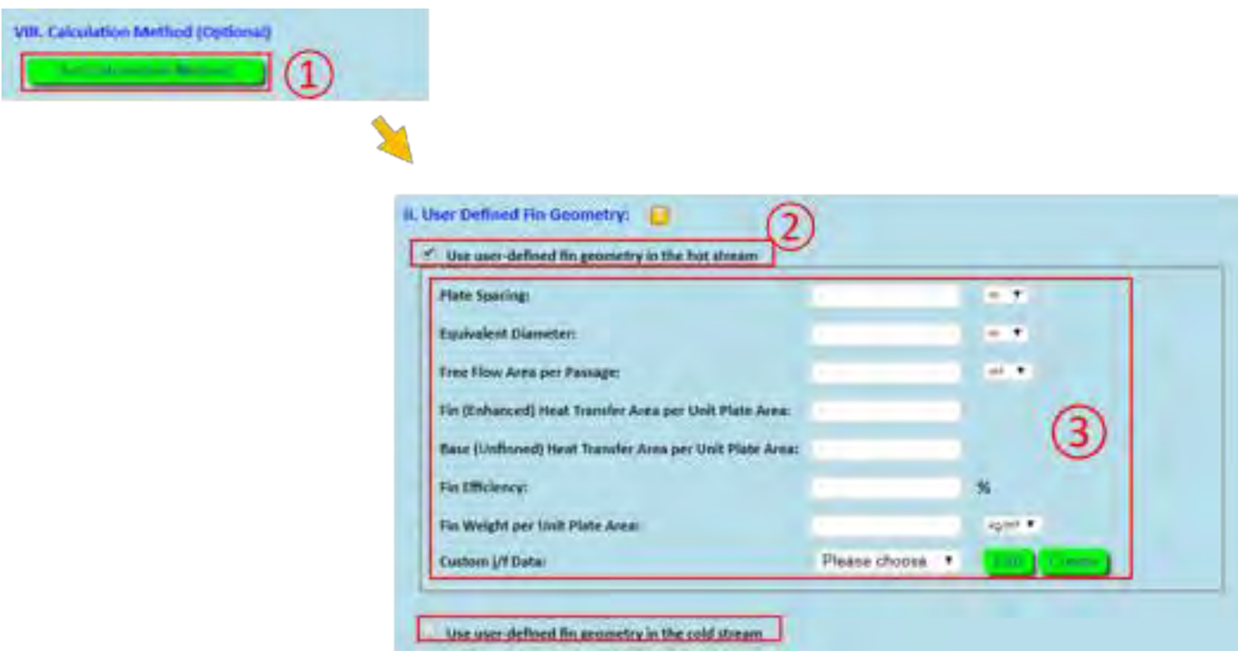
- Problems involving variable fluid thermophysical properties can only be analyzed with the Discrete calculation method
- The Bulk calculation method is currently not available for phase-change problems
- The Bulk calculation method is currently not available for problems involving multi-passes and multi-partitions
- When the “Default” Calculation Method is chosen, INSTED will automatically choose the calculation method based on the setup of the Rating problem:
    - If the problem involves a single-phase fluid with fixed thermophysical properties and there are no multiple passes or multiple partitions, INSTED will choose the Bulk method
    - Otherwise, the “Discrete” Calculation Method will be used.

21. Advanced Topics: User-Defined Fins

In Section *"9. Fins: Natively Supported Fins,"* the natively-supported fin types in INSTED Plate-Fin are listed. If you want to use a fin type that is not currently natively-supported, INSTED provides a feature called "User-Defined Fins" that allows you to use your own fin type, if you can provide the values of the following parameters:

- Plate Spacing
- Equivalent Diameter of the flow passage
- Free Flow Area per Passage
- Finned (Enhanced) Heat Transfer Area per Unit Plate Area
- Base (Un-finned) Heat Transfer Area per Unit Plate Area
- Fin Efficiency
- Fin Weight per Unit Plate Area
- Custom j/f Data

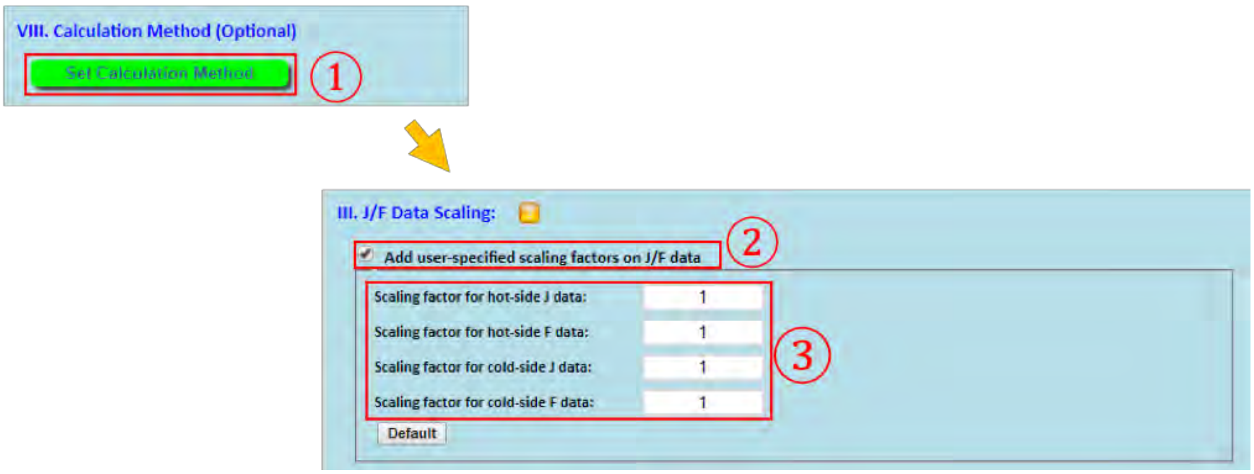
This interesting feature of INSTED can be accessed from the Rating module by clicking on the "Set Calculation Method" button and checking the checkboxes under "User Defined Fin Geometry"



Note that currently the "User-Defined Fin" settings are located inside the Rating module and that the User-Defined fin data will override the fin geometry data that might have been previously defined in "HEX Geometry."

22. Advanced Topics: J/F Data Scaling

Under the "Plate-Fin: Cal. Parameters," there is a feature that allows you to specify scaling factors that can be applied to the default or user-specified J/F data. The feature can be accessed from the Rating module by clicking the "Set Calculation Method" button and checking the checkboxes under "J/F Data Scaling"



Note:

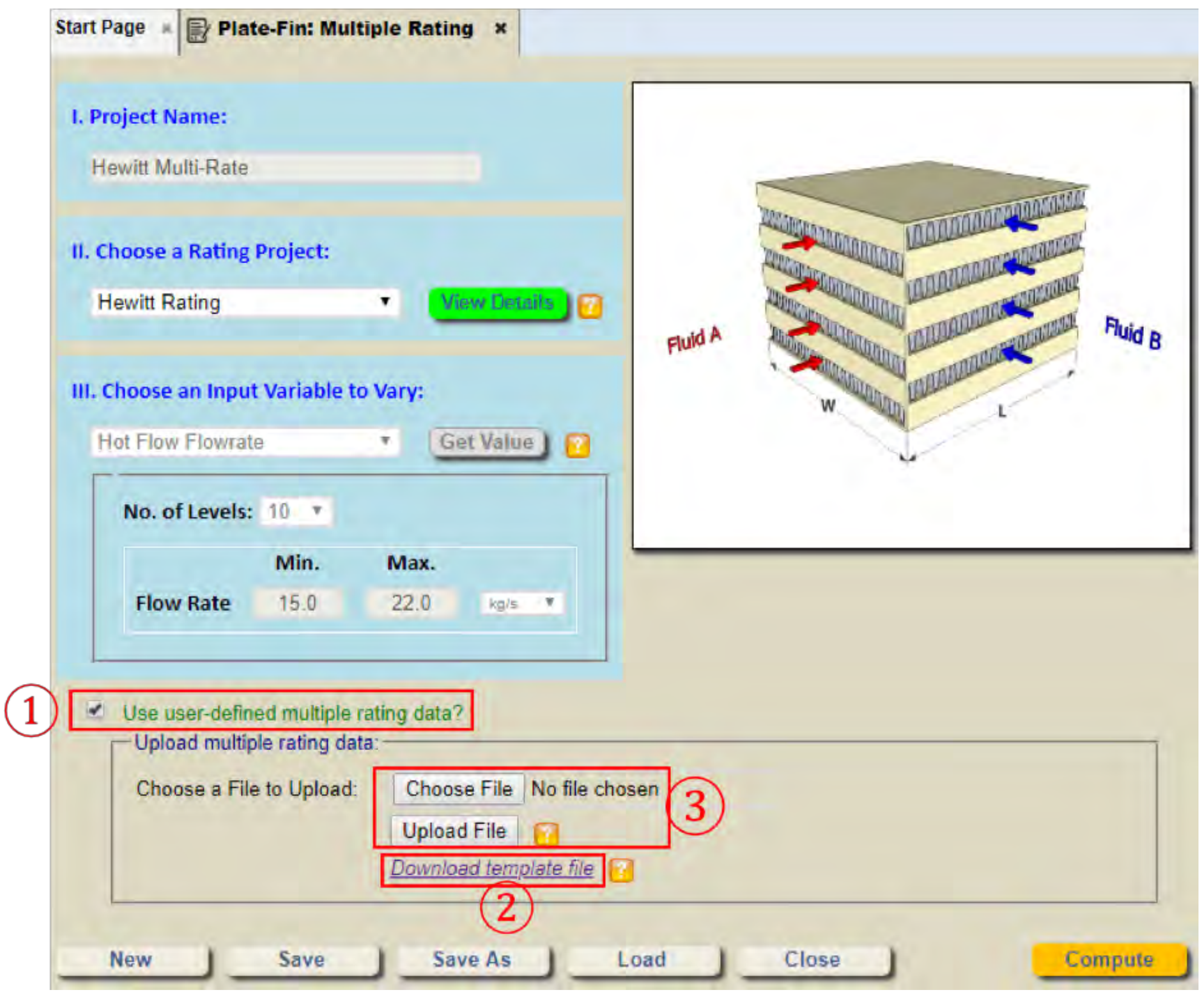
- A factor of unity implies no-scaling
- The J/F scaling factors are currently available only for single-phase analysis

23. Advanced Topics: Custom Multiple Rating

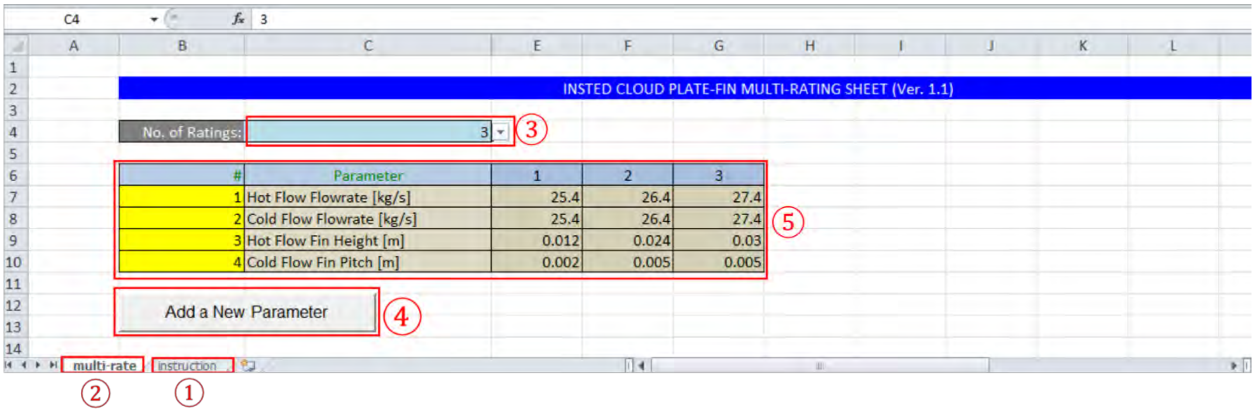
Section "*4. QuickStart: Create & Run a Multiple Rating Project*" shows you how to create a Multiple Rating project by allowing one flow or geometry parameter of a reference Rating project to be varied within a specified range. In this section, we will tell you how to allow more than one flow or geometry parameters to be varied simultaneously in a Multiple Rating project. This feature is called "Custom Multiple Rating."

To use this capability, you need to first create the "Custom Multiple Rating data." This is done by uploading a Microsoft Excel file with the "correct" format. This can be done by downloading Excel sample template files in INSTED and modifying them directly.

The capability can be accessed by checking "Use user-defined multiple rating data?" in the Multiple Rating module.



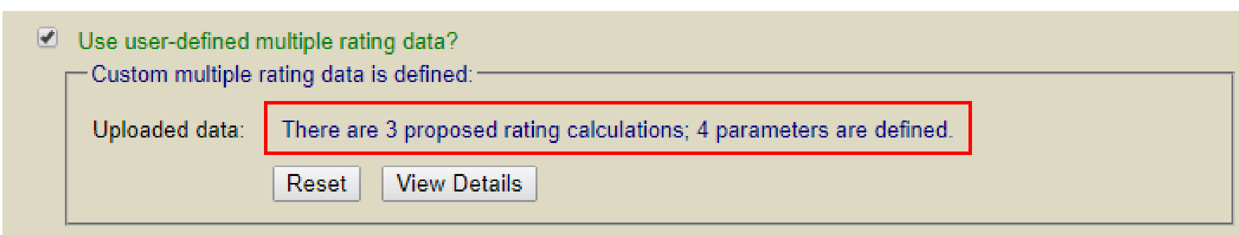
Custom Multiple Rating Templates:



Note:

- Click the "Instruction" worksheet in Excel to view the instructions
- You need to enable "Macros" to use the template
- All fluid data must be in "multi-rate" worksheet, which must not be renamed
- Click the dropdown list on the right of "No. of Ratings:" to change the number of rating calculations to run.
- Click the "Add a new Parameter" button to add a new variable. The variable can be selected from a dropdown list (Column C in the Excel Table)

After the Excel file has been edited and uploaded in INSTED, if there are no errors in the Excel file, INSTED will show the basic information on the uploaded custom Multiple Rating data, as shown in the screen shot below:

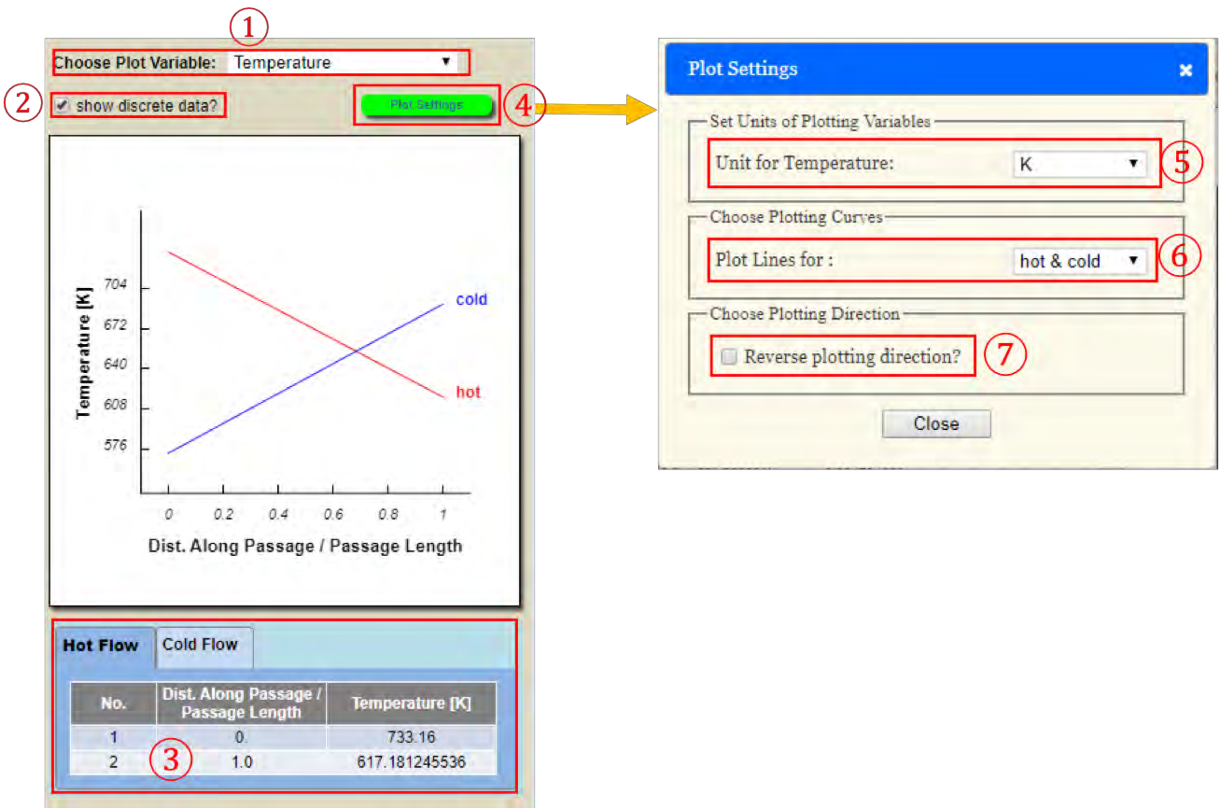


Note:

- Clicking the "Reset" button will remove the current custom Multiple Rating data
- Clicking the "View Details" button will download a new Excel file that contains the custom Multiple Rating data that allows you to view the details.

24. Post-Processing: Line Plots

INSTED provides many tools for customizing the line plots of the results from the Rating and Multiple Rating calculations. Here we use the line plot interface for the results from the Rating calculations to illustrate the various plotting capabilities.

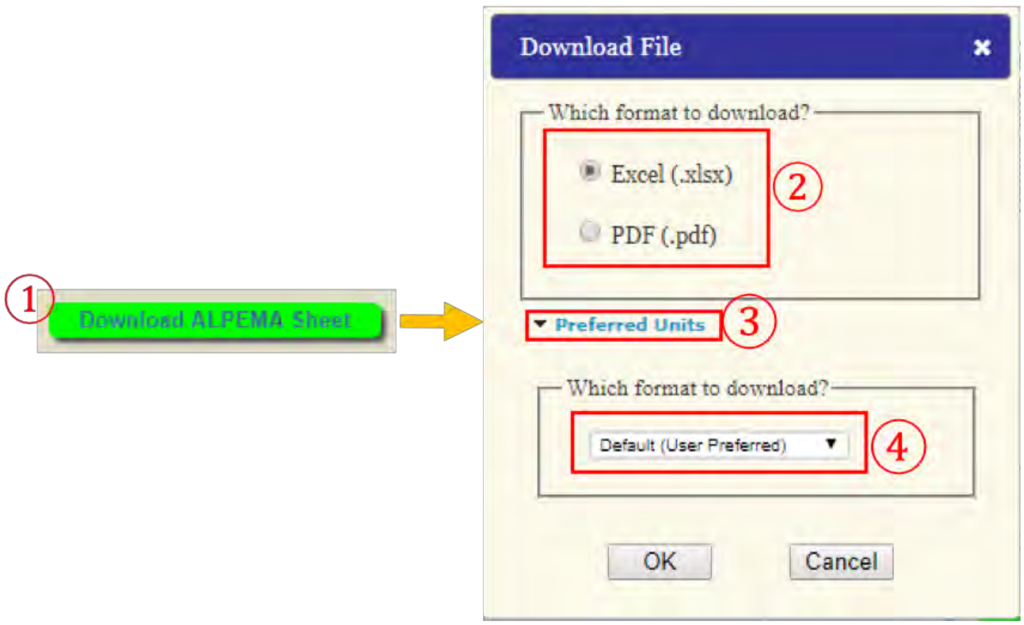


Note:

- Clicking the "Choose Plot Variable" dropdown list will change the variable on the y-axis
- Checking the "show discrete data?" checkbox will display the discrete data points used in a line plot in a table below the plot. You can copy these data and use other plotting tools to regenerate the plot, say for publication quality purposes.
- More Plot settings are available by clicking the "Plot Settings" button:
    - The unit for the y-axis variable can be changed
    - You can plot the distribution of a variable for both the hot and the cold streams or for just one of them
    - You can reverse the plot direction for the hot and/or cold stream. Note that, by default, the curves are plotted along the respective flow directions. "Reversing" the plotting direction is especially useful for parallel counter-flow HEX. By reversing the plotting direction of one stream, you can compare the data for the two streams point-by-point.

25. Post-Processing: ALPEMA Sheets

You can download the Plate-Fin rating results into a file format that follows the ALPEMA sheet standard. The ALPEMA sheet can be downloaded into either Excel format or PDF format. You can also specify the unit system desired for the data contained in the sheet.



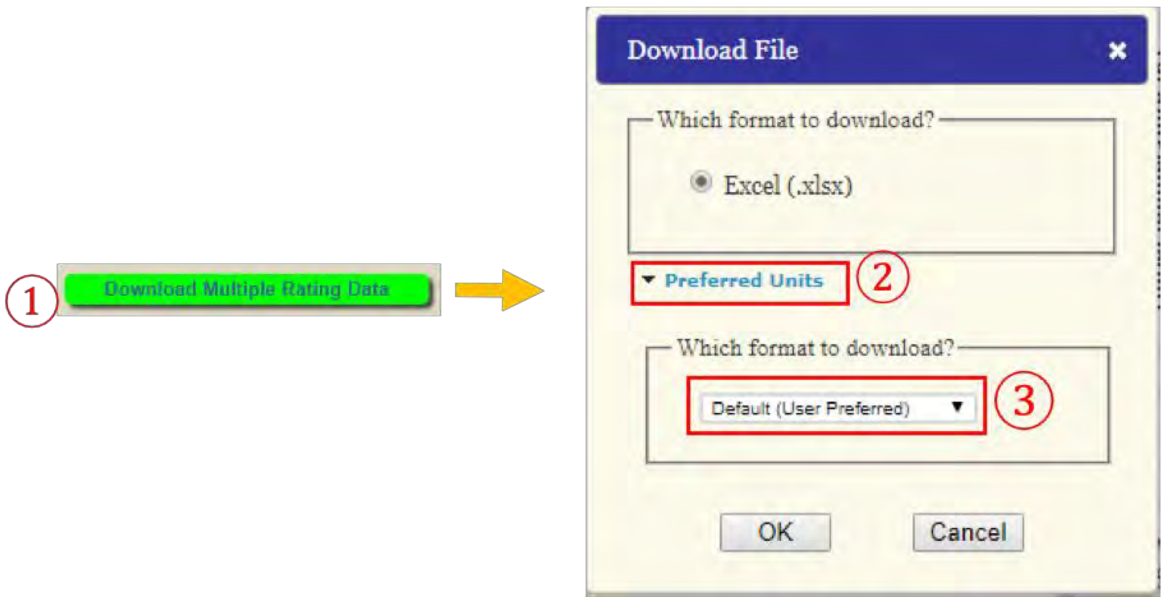
Sample ALPEMA Sheet

BRAZED ALUMINIUM PLATE-FIN HEAT EXCHANGER SPECIFICATION

Customer		Project			Location		
Item numb		Service			Date	8/2/2018	Revision
Stream i.d. / fluid name	Unit	Warm	Cold	C/	D/	E/	F/
Flow rate Total	kg/s	25.4	25				
Vap./Liq. In	kg/s	/	/	/	/	/	/
Vap./Liq. Out	kg/s	/	/	/	/	/	/
Molecular v Vap. In/Out	-	/	/	/	/	/	/
Liq. In/Out	-	/	/	/	/	/	/
Density Vap. In/Out	kg/m³	0.54 /	4.86 /	/	/	/	/
Liq. In/Out	kg/m³	0.54 /	4.86 /	/	/	/	/
Viscosity Vap. In/Out	kg/(m*s)	0.000032 /	0.000032 /	/	/	/	/
Liq. In/Out	kg/(m*s)	0.000032 /	0.000032 /	/	/	/	/
Specific he Vap. In/Out	J/(kg*K)	1060 /	1060 /	/	/	/	/
Liq. In/Out	J/(kg*K)	1060 /	1060 /	/	/	/	/
Thermal co Vap. In/Out	W/(m*K)	0.05 /	0.05 /	/	/	/	/
Liq. In/Out	W/(m*K)	0.05 /	0.05 /	/	/	/	/
Temperatu In/Out	K	733.16 / 617.1812	573.16 / 690.9944	/	/	/	/
Operating pressure In	Pa	0	0				
Allowable frictional pressure drop	Pa						
Heat load	W	3122611.985	3122611.985				
Corrected MTD	K	27.51757655	27.51757655				
Fouling resistance	m²*K/W	0	0				
Design pressure / test pressure	Pa	/	/	/	/	/	/
Design temperatures max / min.	Pa	/	/	/	/	/	/
Number of cores and assemblies	-	In parallel	In series	Number of cores/assembly		Number of assemblies	
Core size	m	Width 1.8	Height 1.8003	Length 0.9			
Flow pattern	-	Counter	Cross-counter		Cross	X Parallel	
Number of layers (including dummy laye	m	Parting sheet thickness:	0.0003	Cap sheet thickness:	0	Side bar width:	0
Approx. weights	kg	Core empty	1138.555845	Core operating 1145.292	Assembly empty	Assembly operating	
Number of layers	-	150	150				
Fin code: Heat transfer fin	-	rectangular	rectangular				
Distributor fin	-	plain	plain				
Effective width	m	1.8	1.8				
Effective thermal length	m	0.9	0.9				
Heat transfer surface/core	m²	486	486				
Core opening size In/Out	m	/	/	/	/	/	/
Nozzle number × size In/Out	m	/	/	/	/	/	/
Manifold pipe size In/Out	m	/	/	/	/	/	/
Calculated frictional pressure drop	Pa	6862.218586	4321.07879				
Stacking arrangement:							
Code and/or regulation:							
Notes							
	User supplied data					Data sheet supplied by ALPEMA	

26. Post-Processing: Downloadable Calculation Results

Instead of the ALPEMA sheet, INSTED also allows you to view the Rating and Multiple Rating calculation results in an Excel file which can be more easily analyzed and modified. The feature is useful for Multiple Rating since it allows you to download all the results into a single file. You can also select a desired unit system for the data contained in the spreadsheet.



Sample Multiple Rating Downloadable Excel File

INSTED Output for HX Sizing and Rating Simulations- Last Rev. [08/29/2016]

Row	Design #	Description (for example, flow arrangement, multipassing, single/two phase flow etc.)	HX Problem Statement: Performance Requirement Q	Δp-hot	Δp-cold	Operating Conditions -Hot: Fluid Type	Flow Rate	Tin	Pin	Operating Conditions -Cold: Fluid Type	Flow Rate	Tin	Pin
6			[kW]	[kPa]	[kPa]	[-]	[kg/s]	[K]	[Pa]	[-]	[kg/s]	[K]	[Pa]
7	**#1: Hot flow mass flow rate = 15 [kg/s]**	Cross-flow, single banking					15	733.16	0		25	573.16	0
8	#2: Hot flow mass flow rate = 15.7777777777778 [kg/s]	Cross-flow, single banking					15.7778	733.16	0		25	573.16	0
9	#3: Hot flow mass flow rate = 16.5555555555556 [kg/s]	Cross-flow, single banking					16.5556	733.16	0		25	573.16	0
10	#4: Hot flow mass flow rate = 17.3333333333333 [kg/s]	Cross-flow, single banking					17.3333	733.16	0		25	573.16	0
11	#5: Hot flow mass flow rate = 18.1111111111111 [kg/s]	Cross-flow, single banking					18.1111	733.16	0		25	573.16	0
12	#6: Hot flow mass flow rate = 18.8888888888889 [kg/s]	Cross-flow, single banking					18.8889	733.16	0		25	573.16	0
13	#7: Hot flow mass flow rate = 19.6666666666667 [kg/s]	Cross-flow, single banking					19.6667	733.16	0		25	573.16	0
14	#8: Hot flow mass flow rate = 20.4444444444444 [kg/s]	Cross-flow, single banking					20.4444	733.16	0		25	573.16	0
15	#9: Hot flow mass flow rate = 21.2222222222222 [kg/s]	Cross-flow, single banking					21.2222	733.16	0		25	573.16	0
16	#10: Hot flow mass flow rate = 22 [kg/s]	Cross-flow, single banking					22	733.16	0		25	573.16	0

Row	HX Core Design Input: t-sp	t-ep	w-sb-hot	h-sb-hot	w-sb-cold	h-sb-cold	HX Core Dimensions: P-L	P-W	L-NF/S	Np-h	Np-c	W	k_{plate}	Hot Side: Type	N-Fin or Channel	H (Plate Spacing)	t-fin	l or λ	2a	d_h	A_c	A_b	A_{eff}	k_{fin}
6	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[-]	[-]	[kg]	[W/(m*K)]	[-]	[1/m]	[m]	[m]	[m]	[m]	[m]	[m²]	[m²]	[m²]	[W/(m*K)]
7	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1574.7	15
8	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1570.3	15
9	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1558.3	15
10	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1552	15
11	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1545.9	15
12	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1539.9	15
13	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1534	15
14	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1528.3	15
15	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1522.8	15
16	0.0003	0.0003	0	0.0057	0	0.0057	0.9	1.8	1.8	150	150	1139	15	rectangular/pl	500	0.0057	0.0002			0.0028	1.3861	243	1517.3	15

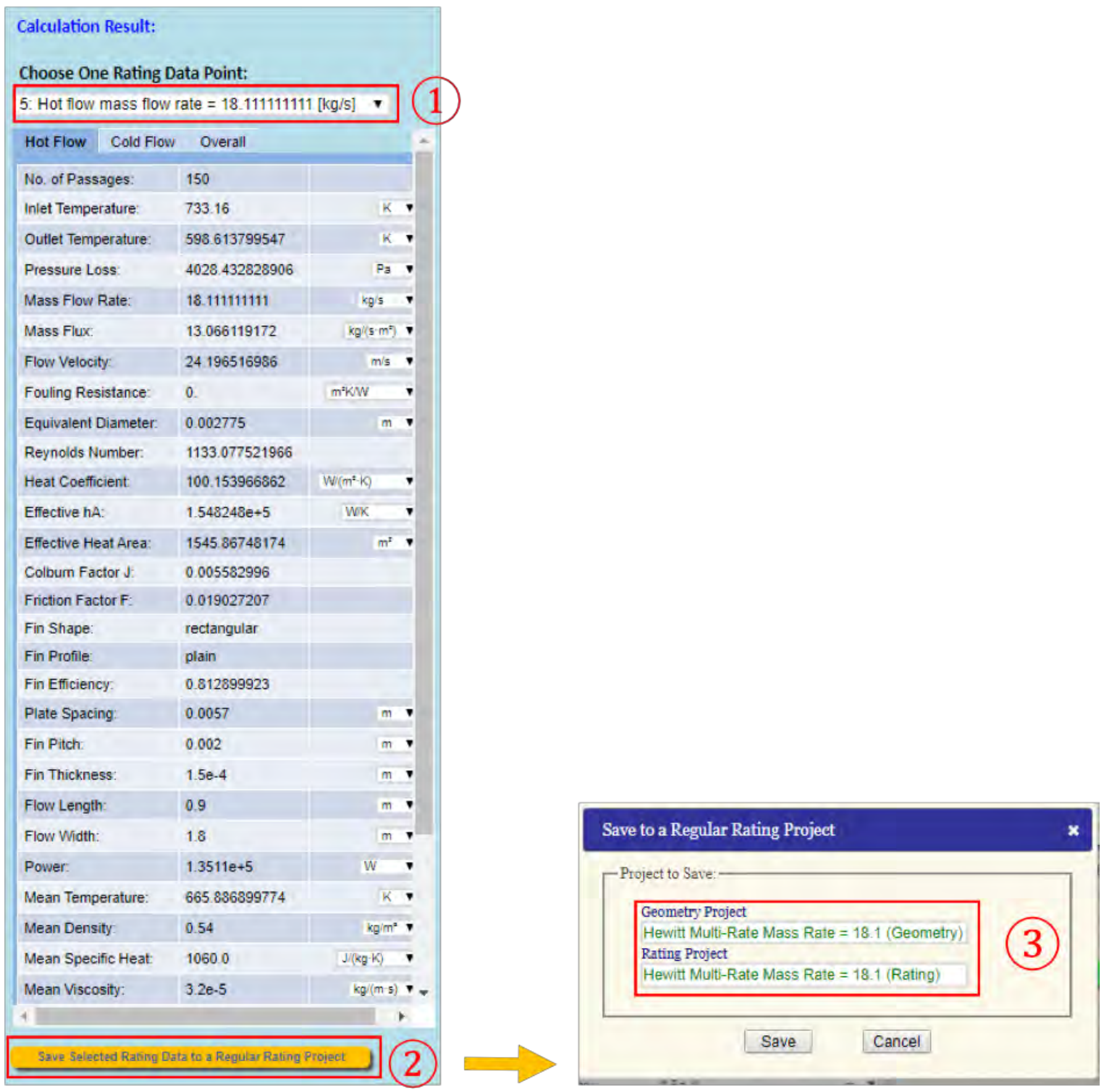
HX Size, Weight and Performance- Output

Row	Cold Side: Type	N-Fin or Channel	H (Plate Spacing)	t	l or λ	2a	d_h	A_c	A_b	A_{eff}	k_{fin}	Hot Side: Tout	T_{mean}	Δp	σΔP	ρ_{mean}	μ_{mean}	$c_{p\text{-}mean}$	$k_{\text{-}mean}$	Re	Pr	Nu	hA_{eff}	Pow
6	[-]	[1/m]	[m]	[m]	[m]	[m]	[m]	[m²]	[m²]	[m²]	W/(m*K)	[K]	[K]	[Pa]	[kPa]	[kg/m³]	kg/(m*s)	J/(kg*K)	W/(m*K)	[-]	[-]	[-]	[W/K]	[W]
7	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	590.68	661.92	2278.6		0.54	3E-05	1060	0.05	938.44	0.6784	4.7661	135232	63294
8	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	592.79	662.98	2319.6		0.54	3E-05	1060	0.05	987.1	0.6784	4.8841	138191	67773
9	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	594.52	663.84	3497.6		0.54	3E-05	1060	0.05	1035.8	0.6784	5.2105	146299	107230
10	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	596.56	664.86	3759.6		0.54	3E-05	1060	0.05	1084.4	0.6784	5.3856	150604	120677
11	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	598.61	665.89	4028.4		0.54	3E-05	1060	0.05	1133.1	0.6784	5.5585	154825	135110
12	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	600.66	666.91	4304.1		0.54	3E-05	1060	0.05	1181.7	0.6784	5.7294	158966	150554
13	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	602.71	667.93	4586.3		0.54	3E-05	1060	0.05	1230.4	0.6784	5.8983	163032	167033
14	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	604.74	668.95	4875.1		0.54	3E-05	1060	0.05	1279.1	0.6784	6.0653	167026	184572
15	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	606.76	669.96	5170.3		0.54	3E-05	1060	0.05	1327.7	0.6784	6.2306	170952	203197
16	rectangular/pla	500	0.0057	0.0002			0.0028	0.6931	243	1375.3	15	608.75	670.96	5471.9		0.54	3E-05	1060	0.05	1376.4	0.6784	6.3942	174814	222929

Row	Cold Side: Tout	T_{mean}	Δp	σΔP	ρ_{mean}	μ_{mean}	$c_{p\text{-}mean}$	$k_{\text{-}mean}$	Re	Pr	Nu	hA_{eff}	Pow	Overall HX Core Performance: EB	C*	ε	Q	NTU	UA	COP
6	[K]	[K]	[Pa]	[kPa]	[kg/m³]	kg/(m*s)	J/(kg*K)	W/(m*K)	[-]	[-]	[-]	[W/K]	[W]	[%]	[-]	[-]	[W]	[-]	[W/K]	[-]
7	658.65	598.02	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.6		0.8905	2E+06	5.7323	91144	26.49
8	661.75	598.54	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.6311		0.8773	2E+06	5.5296	92479	26.084
9	664.97	598.49	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.6622		0.8665	2E+06	5.4728	96041	18.793
10	667.87	598.8	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.6933		0.8537	3E+06	5.3271	97877	17.562
11	670.63	599.08	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.7244		0.8409	3E+06	5.1903	99643	16.417
12	673.27	599.34	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.7556		0.8281	3E+06	5.0615	1E+05	15.354
13	675.78	599.57	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.7867		0.8153	3E+06	4.9398	1E+05	14.369
14	678.18	599.78	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.8178		0.8026	3E+06	4.8248	1E+05	13.457
15	680.46	599.96	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.8489		0.79	3E+06	4.7158	1E+05	12.614
16	682.64	600.13	4321.1		4.86	3E-05	1060	0.05	3128.1	0.6784	11.548	286154	22228	0.88		0.7776	3E+06	4.6123	1E+05	11.834

27. Miscellaneous: Saving Selected Multiple Rating Result into a Regular Rating Project

In the Plate-Fin Multiple Rating module, the selected rating data point can be saved into a regular rating project.

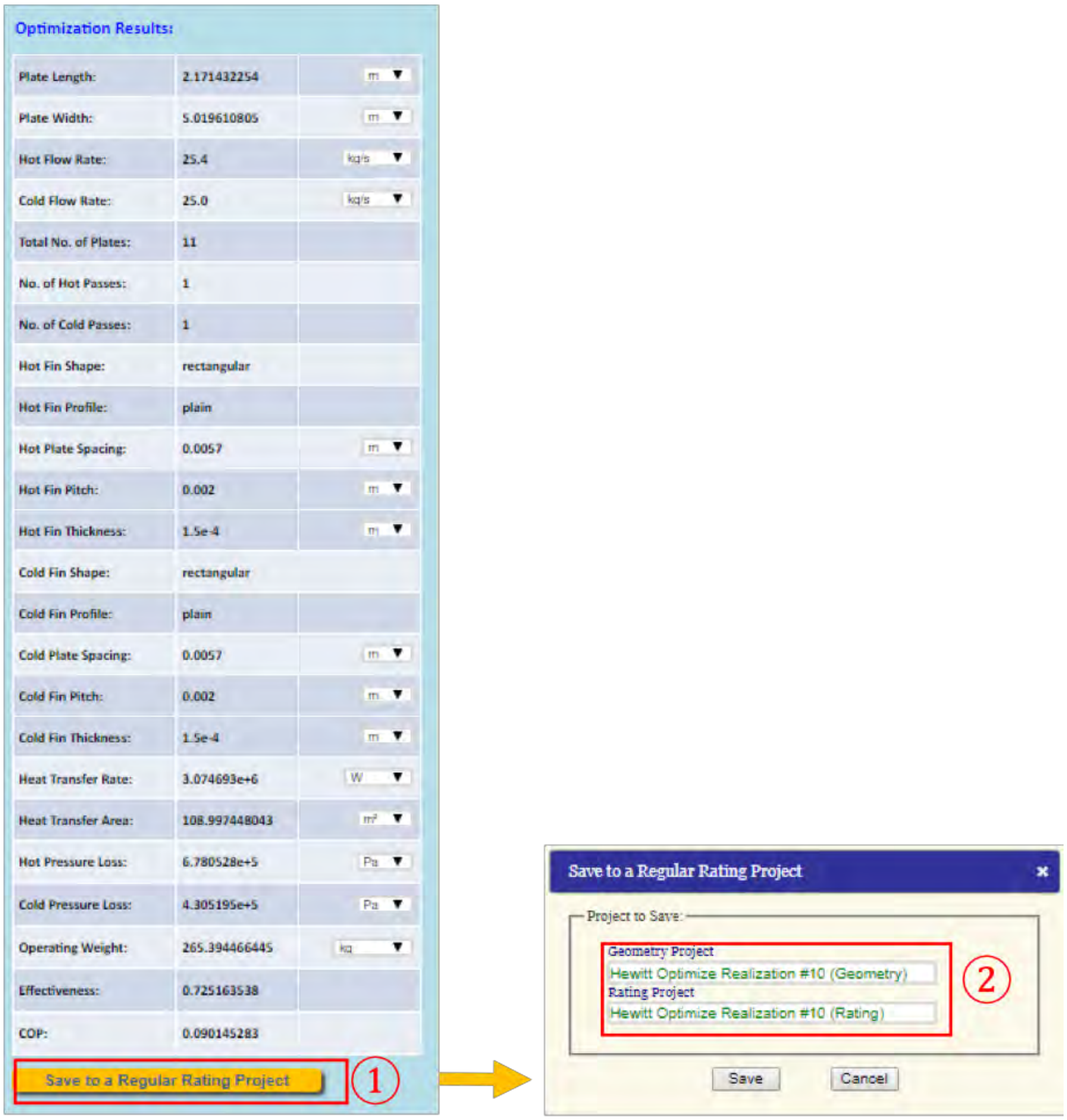


Note:

- The names for the HEX Geometry and Rating projects to be saved need to be specified after the “Save Selected Rating Data to a Regular Rating Project” button has been clicked
- The saved Rating project can be loaded in the Rating module.

28. Miscellaneous: Saving Selected Sizing/Optimization Realization into a Regular Rating Project

In the Plate-Fin Sizing and Optimization modules, a selected realization can be saved into a regular Rating project.

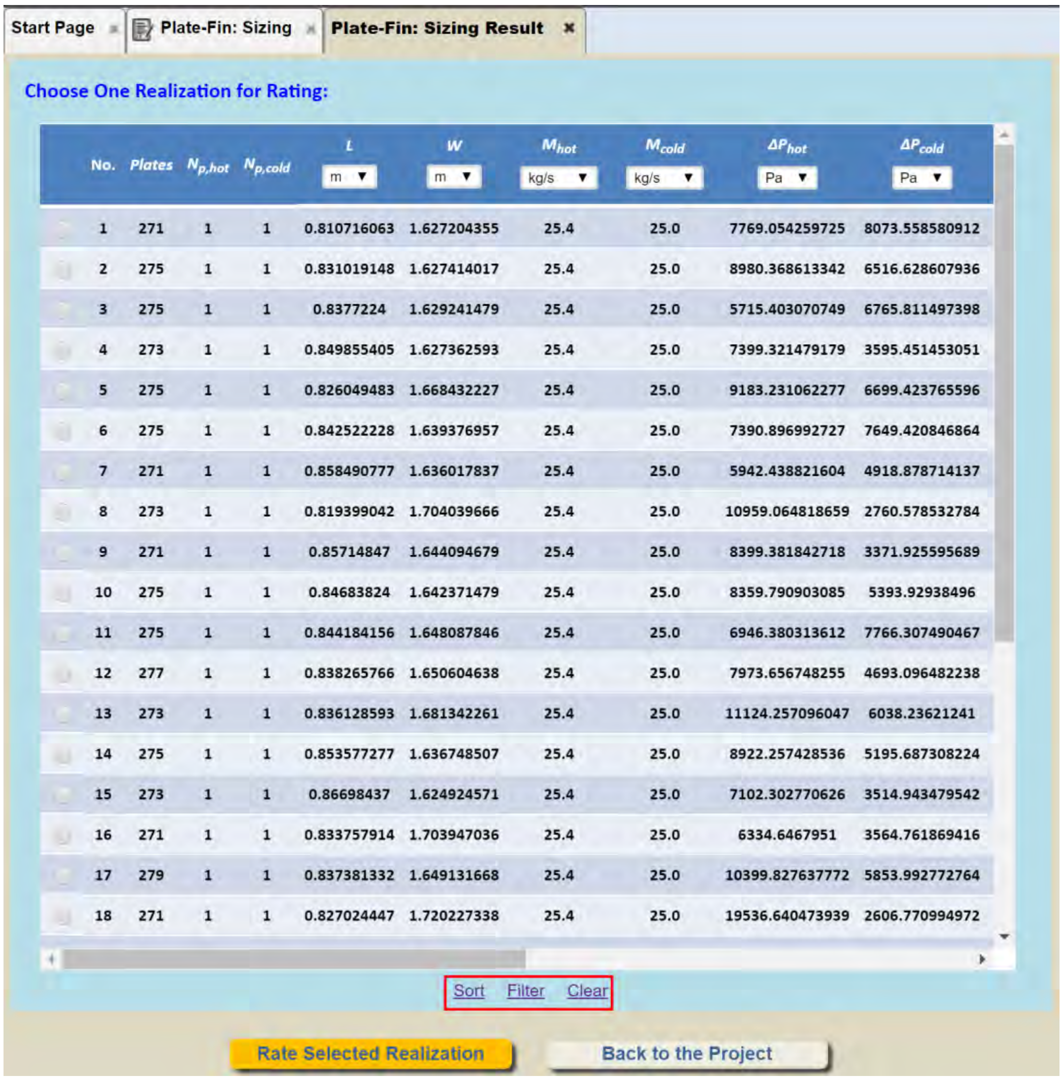


Note:

- The names of the HEX Geometry and Rating projects to be saved need to be specified after the "Save Selected Rating Data to a Regular Rating Project" button has been clicked
- The saved Rating project can be loaded in the Rating module.

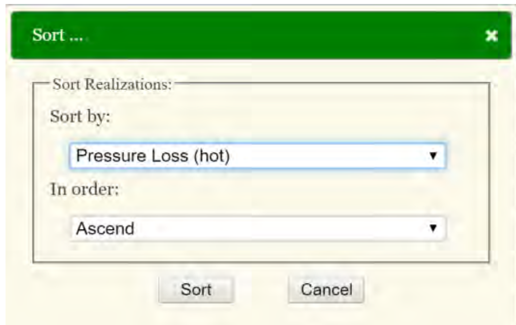
29. Miscellaneous: Sorting and Filtering Sizing/Optimization Realizations

The realizations from Sizing and Optimization analysis are presented in a tabular form. INSTED provides a tool for sorting and filtering these realizations, which can be accessed by clicking the “Sort/Filter/Clear” buttons located at the bottom of the dialog box containing the realization table.



No.	Plates	$N_{p,hot}$	$N_{p,cold}$	L (m)	W (m)	M_{hot} (kg/s)	M_{cold} (kg/s)	ΔP_{hot} (Pa)	ΔP_{cold} (Pa)
1	271	1	1	0.810716063	1.627204355	25.4	25.0	7769.054259725	8073.558580912
2	275	1	1	0.831019148	1.627414017	25.4	25.0	8980.368613342	6516.628607936
3	275	1	1	0.8377224	1.629241479	25.4	25.0	5715.403070749	6765.811497398
4	273	1	1	0.849855405	1.627362593	25.4	25.0	7399.321479179	3595.451453051
5	275	1	1	0.826049483	1.668432227	25.4	25.0	9183.231062277	6699.423765596
6	275	1	1	0.842522228	1.639376957	25.4	25.0	7390.896992727	7649.420846864
7	271	1	1	0.858490777	1.636017837	25.4	25.0	5942.438821604	4918.878714137
8	273	1	1	0.819399042	1.704039666	25.4	25.0	10959.064818659	2760.578532784
9	271	1	1	0.85714847	1.644094679	25.4	25.0	8399.381842718	3371.925595689
10	275	1	1	0.84683824	1.642371479	25.4	25.0	8359.790903085	5393.92938496
11	275	1	1	0.844184156	1.648087846	25.4	25.0	6946.380313612	7766.307490467
12	277	1	1	0.838265766	1.650604638	25.4	25.0	7973.656748255	4693.096482238
13	273	1	1	0.836128593	1.681342261	25.4	25.0	11124.257096047	6038.23621241
14	275	1	1	0.853577277	1.636748507	25.4	25.0	8922.257428536	5195.687308224
15	273	1	1	0.86698437	1.624924571	25.4	25.0	7102.302770626	3514.943479542
16	271	1	1	0.833757914	1.703947036	25.4	25.0	6334.6467951	3564.761869416
17	279	1	1	0.837381332	1.649131668	25.4	25.0	10399.827637772	5853.992772764
18	271	1	1	0.827024447	1.720227338	25.4	25.0	19536.640473939	2606.770994972

If you click the “Sort” button, a new dialog box will appear that enables you to select the variable on which the sorting should be based. For example, the following setting will order the list of realizations in ascending order of the hot stream pressure drop:

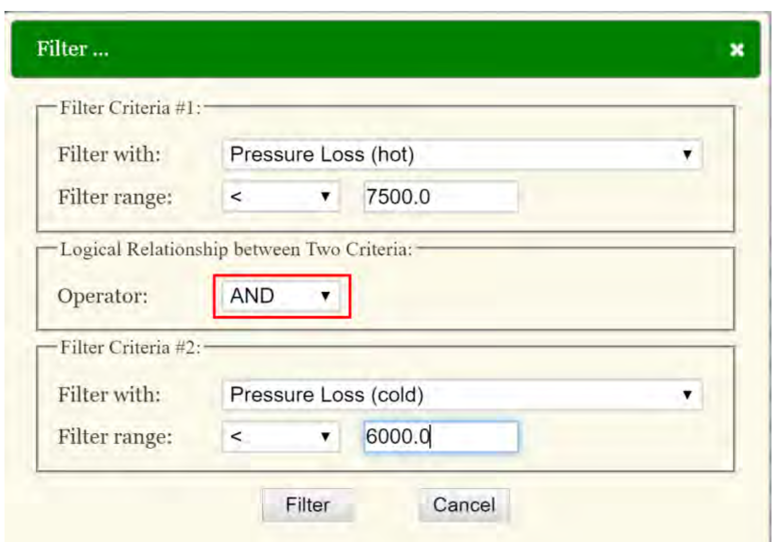


No.	Plates	$N_{p,hot}$	$N_{p,cold}$	L (m)	W (m)	M_{hot} (kg/s)	M_{cold} (kg/s)	ΔP_{hot} (Pa)	ΔP_{cold} (Pa)
3	275	1	1	0.8377224	1.629241479	25.4	25.0	5715.403070749	6765.811497398
7	271	1	1	0.858490777	1.636017837	25.4	25.0	5942.438821604	4918.878714137
27	271	1	1	0.859279963	1.666356581	25.4	25.0	6162.996553583	4681.977484485
25	271	1	1	0.832534785	1.717483063	25.4	25.0	6309.722165268	3438.135032869
16	271	1	1	0.833757914	1.703947036	25.4	25.0	6334.6467951	3564.761869416
11	275	1	1	0.844184156	1.648087846	25.4	25.0	6946.380313612	7766.307490467
15	273	1	1	0.86698437	1.624924571	25.4	25.0	7102.302770626	3514.943479542
6	275	1	1	0.842522228	1.639376957	25.4	25.0	7390.896992727	7649.420846864
4	273	1	1	0.849855405	1.627362593	25.4	25.0	7399.321479179	3595.451453051
30	271	1	1	0.859830913	1.668139042	25.4	25.0	7598.398144587	5415.810918932
21	271	1	1	0.867283203	1.645169037	25.4	25.0	7727.496655303	3798.572333389
1	271	1	1	0.810716063	1.627204355	25.4	25.0	7769.054259725	8073.558580912
12	277	1	1	0.838265766	1.650604638	25.4	25.0	7973.656748255	4693.096482238
22	275	1	1	0.856791838	1.641991539	25.4	25.0	8152.60041813	6868.838909232
10	275	1	1	0.84683824	1.642371479	25.4	25.0	8359.790903085	5393.92938496
9	271	1	1	0.85714847	1.644094679	25.4	25.0	8399.381842718	3371.925595689
29	273	1	1	0.866172901	1.642353637	25.4	25.0	8548.547812272	4999.735058987
23	273	1	1	0.852980764	1.662478217	25.4	25.0	8681.859237757	7240.373090178

If you click the “Filter” button, a new dialog box will appear to enable you to set filter conditions. Only the realizations for which the filter conditions are satisfied will be displayed. For example, the following setting will cause the GUI to display only the realizations for which the hot stream pressure drop is smaller than 7500 Pa.

No.	Plates	$N_{p,hot}$	$N_{p,cold}$	L (m)	W (m)	M_{hot} (kg/s)	M_{cold} (kg/s)	ΔP_{hot} (Pa)	ΔP_{cold} (Pa)	W
3	275	1	1	0.8377224	1.629241479	25.4	25.0	5715.403070749	6765.811497398	3.15
7	271	1	1	0.858490777	1.636017837	25.4	25.0	5942.438821604	4918.878714137	3.14
27	271	1	1	0.859279963	1.666356581	25.4	25.0	6162.996553583	4681.977484485	3.16
25	271	1	1	0.832534785	1.717483063	25.4	25.0	6309.722165268	3438.135032869	3.15
16	271	1	1	0.833757914	1.703947036	25.4	25.0	6334.6467951	3564.761869416	3.13
11	275	1	1	0.844184156	1.648087846	25.4	25.0	6946.380313612	7766.307490467	3.13
15	273	1	1	0.86698437	1.624924571	25.4	25.0	7102.302770626	3514.943479542	3.14
6	275	1	1	0.842522228	1.639376957	25.4	25.0	7390.896992727	7649.420846864	3.1
4	273	1	1	0.849855405	1.627362593	25.4	25.0	7399.321479179	3595.451453051	3.1

Note that in the current version of INSTED, a maximum 2 filter conditions are allowed. You can choose the logical operation (AND or OR) between the two filter conditions. For example, the following settings will show only the realizations for which the hot stream pressure drop is smaller than 7500 Pa and the cold stream pressure drop is smaller than 6000 Pa.

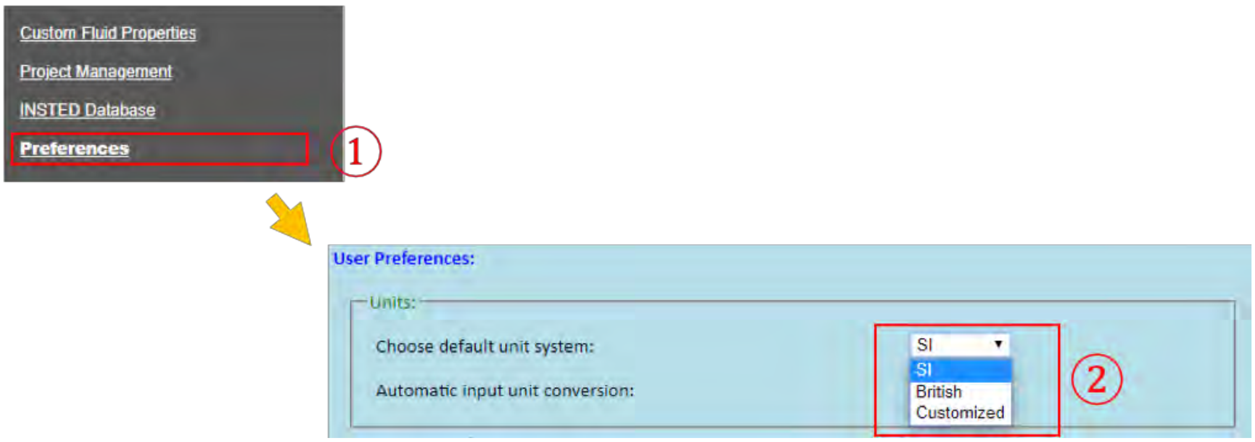


No.	Plates	$N_{p,hot}$	$N_{p,cold}$	L (m)	W (m)	M_{hot} (kg/s)	M_{cold} (kg/s)	ΔP_{hot} (Pa)	ΔP_{cold} (Pa)	W
7	271	1	1	0.858490777	1.636017837	25.4	25.0	5942.438821604	4918.878714137	3.14
27	271	1	1	0.859279963	1.666356581	25.4	25.0	6162.996553583	4681.977484485	3.16
25	271	1	1	0.832534785	1.717483063	25.4	25.0	6309.722165268	3438.135032869	3.15
16	271	1	1	0.833757914	1.703947036	25.4	25.0	6334.6467951	3564.761869416	3.13
15	273	1	1	0.86698437	1.624924571	25.4	25.0	7102.302770626	3514.943479542	3.14
4	273	1	1	0.849855405	1.627362593	25.4	25.0	7399.321479179	3595.451453051	3.1

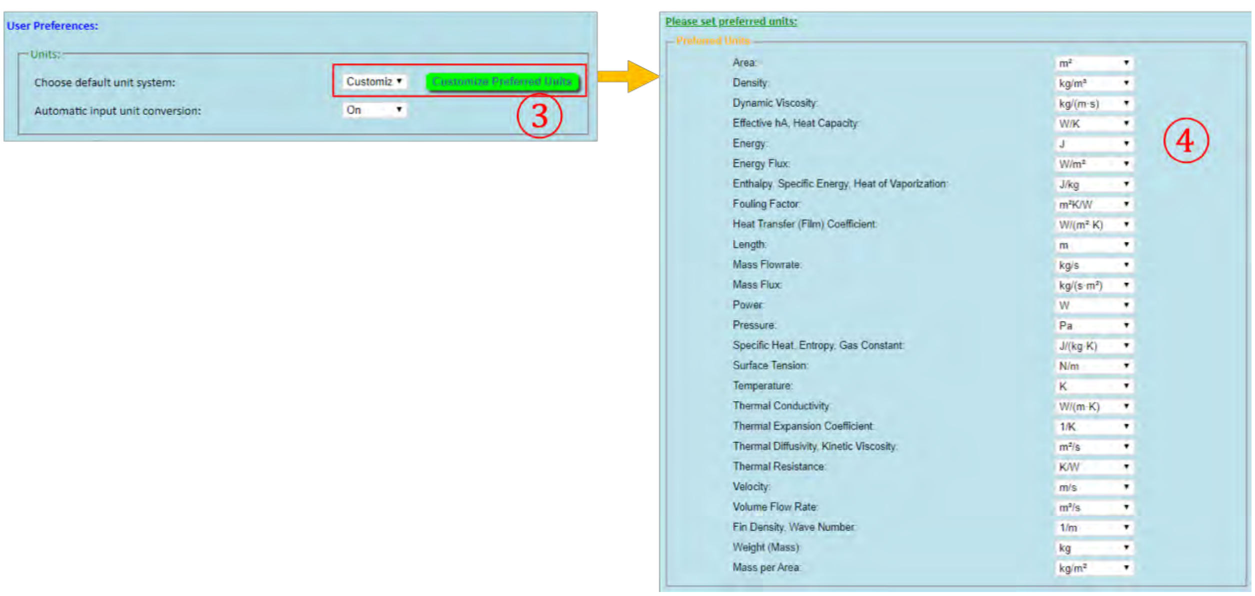
By clicking the “Clear” button, the filter settings will be removed and the list of realizations will appear in the default order.

30. Miscellaneous: Changing the Default Unit System

You can change the default unit system that you want to use for your analysis by selecting "Preferences" in the main menu panel.

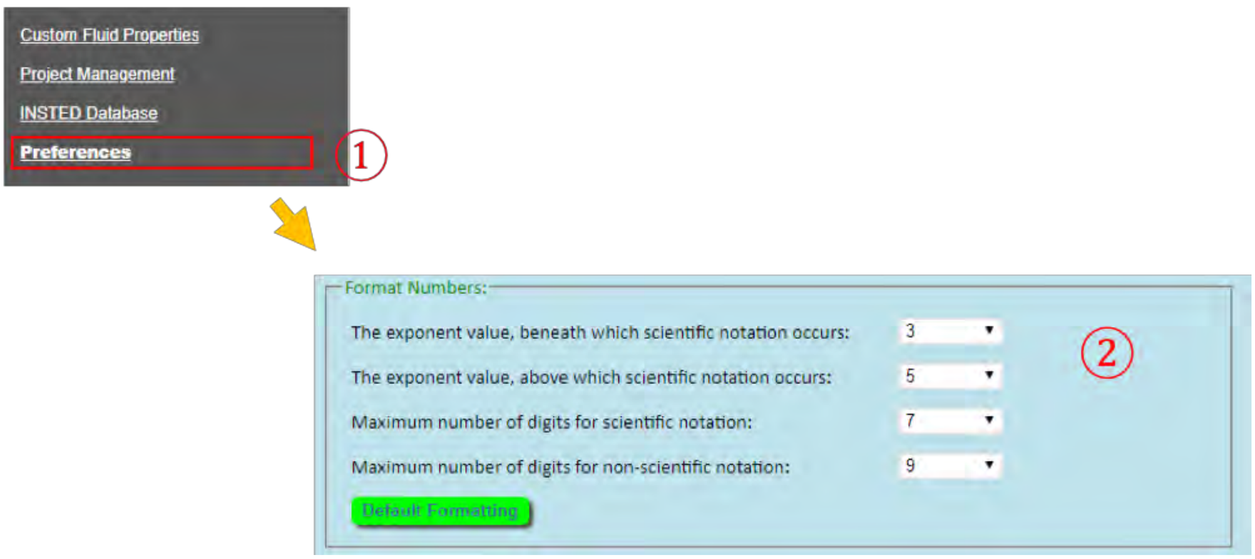


You can select either "SI," "British," or "Customized" unit systems as your default unit system in INSTED. If "Customized" is chosen, you will need to specify the default unit for each variable type. You do this by clicking on the "Customize Preferred Units" button.



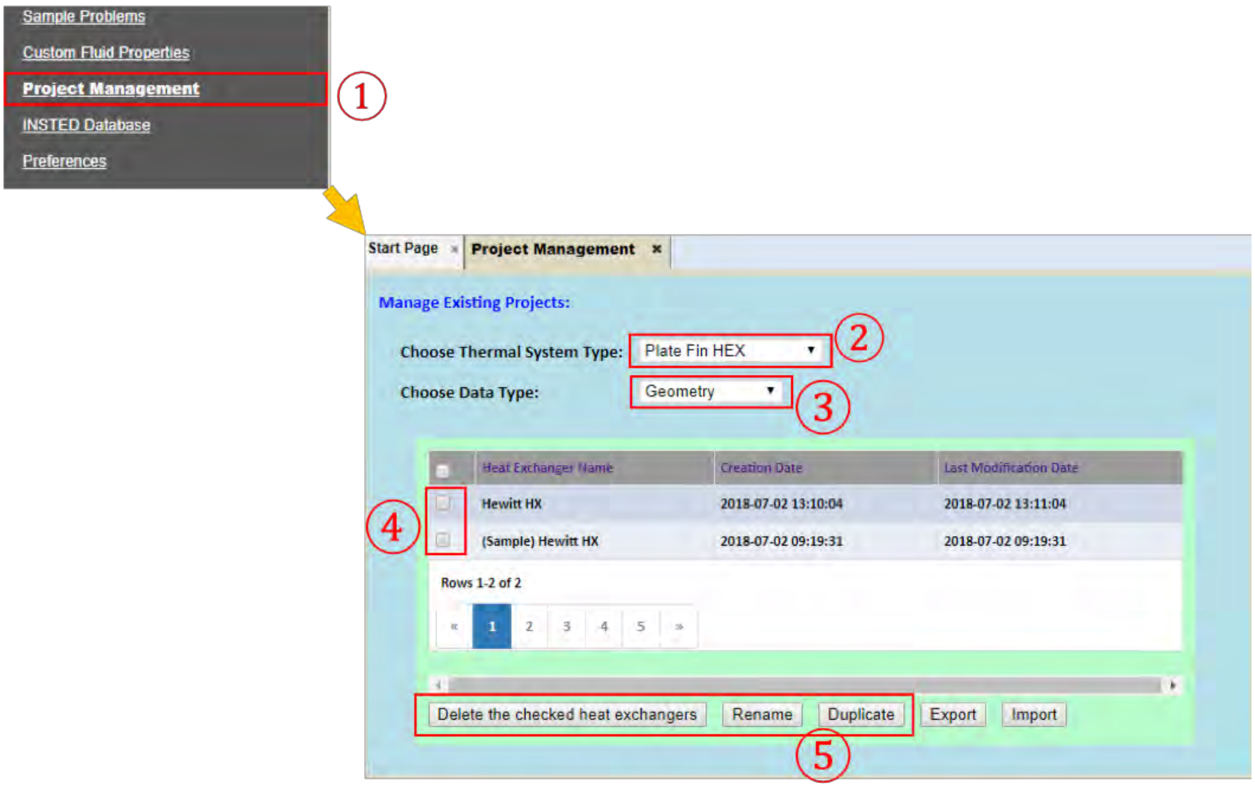
31. Miscellaneous: Changing the Precisions of Output Floating Number

You can change the default floating number output precision and format in “User Preferences.”



32. Miscellaneous: Renaming/Deleting/Duplicating Existing Projects

In INSTED, existing project data can be managed using the "Project Management" tool, which can be accessed by clicking the "Project Management" button in the menu panel.



Note:

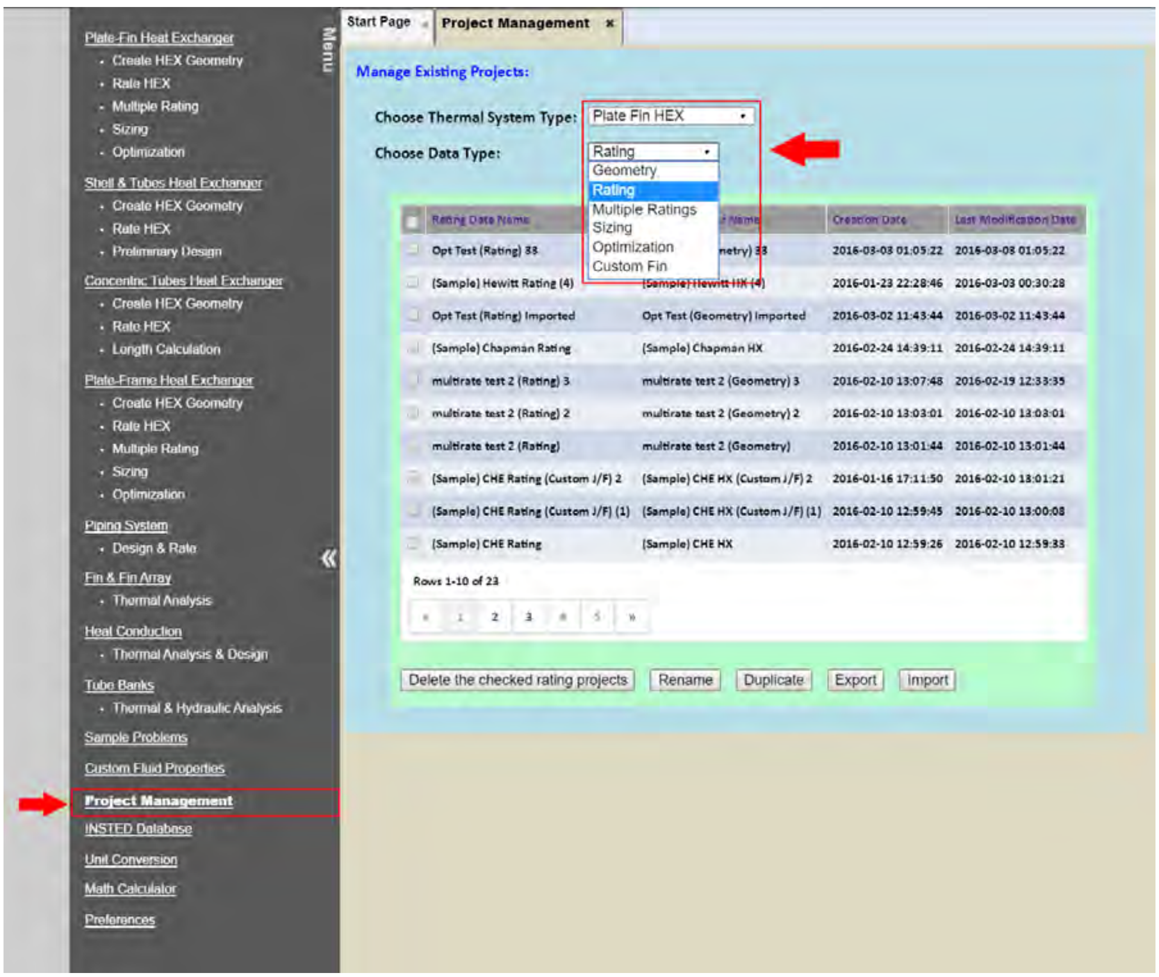
- Make sure the correct data type ("Geometry," "Rating," "Multiple Ratings," "Sizing," or "Optimization") is selected.
- To rename or duplicate a project, select a project by checking the checkbox and then clicking the "Rename/Duplicate" buttons. A new dialog will be displayed to enable you to specify the new project name.
- For deletion, multiple projects can be selected at once.
- When deleting a Rating project, the Delete operation will fail if the Rating project is also used by a Multiple Rating, Sizing, or Optimization project. You need to delete the Multiple Rating, Sizing, and Optimization projects first before deleting the Rating project.
- When deleting a HEX Geometry project, the Delete operation will fail if the Geometry project is also used by a Rating project. You need to delete the corresponding Rating project first before deleting the Geometry project.

33. Miscellaneous: Exporting an Existing Project into an XML File

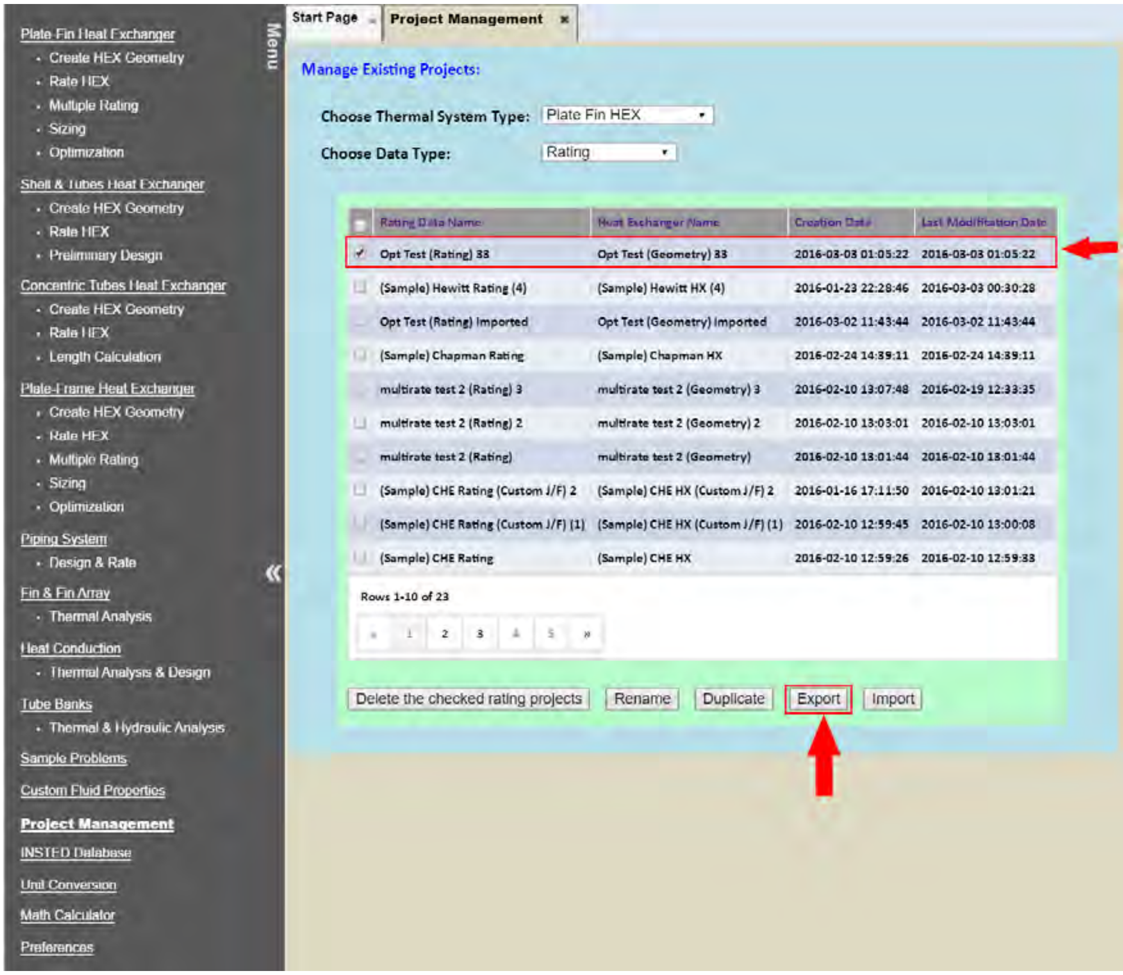
In INSTED, a project data can be exported into an XML text file, which can be imported back later. The feature serves two purposes:

- Backing up of project data
- Sharing of project between INSTED users

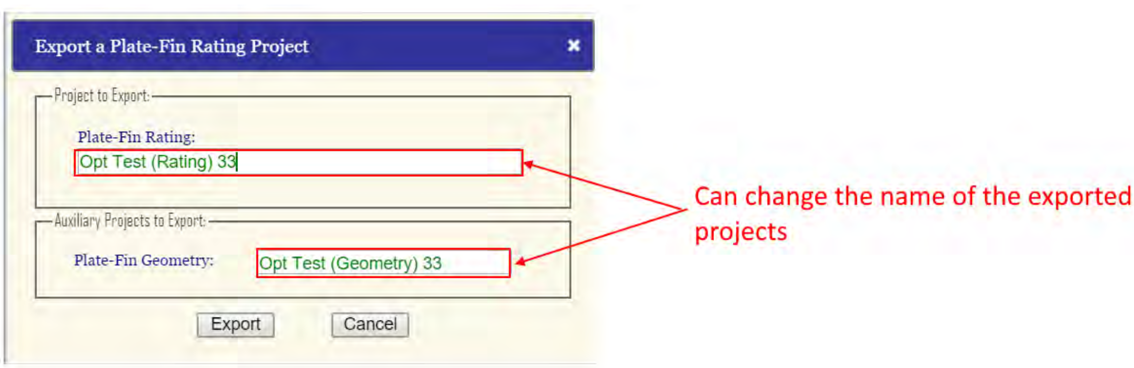
Under “Project Management” in the menu panel choose “Thermal System Type” and “Data Type”



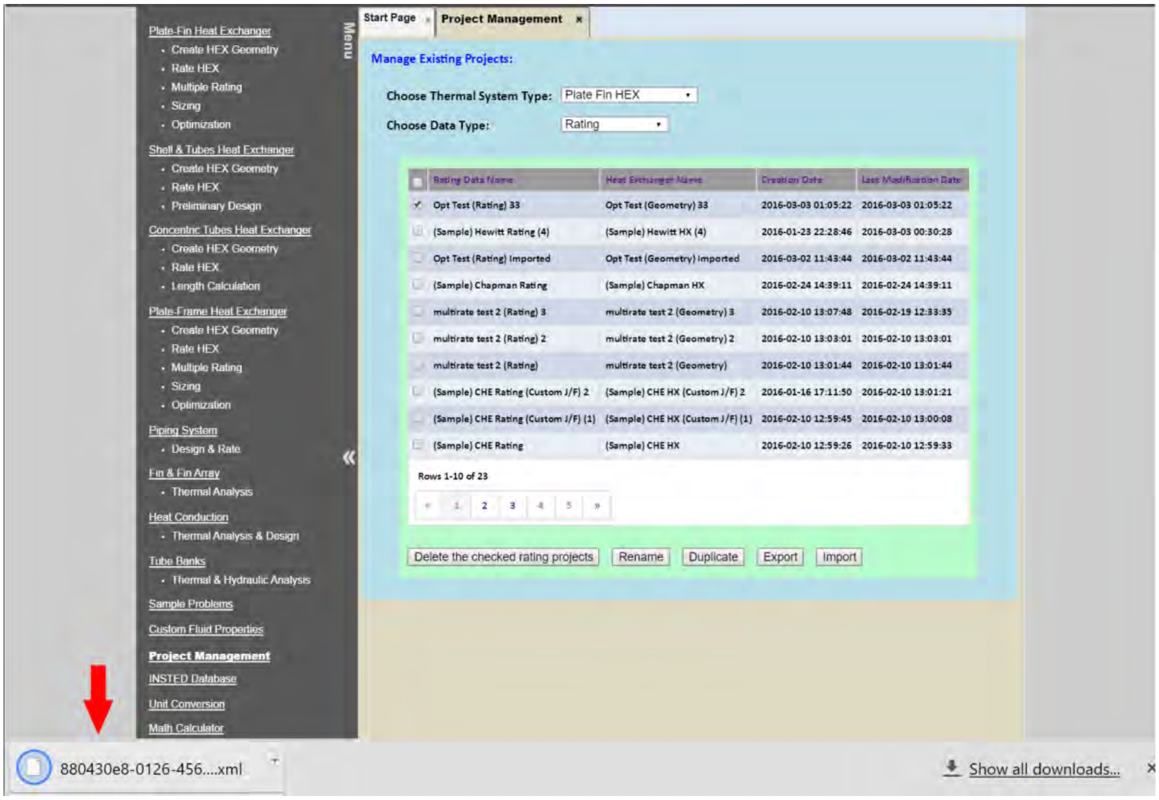
Check the “checkbox” corresponding to the project (file) you want to export and click the “Export” button.



A dialog box will be displayed to show the name of the Rating project to be exported and its associated "Geometry." To give the project and/or its geometry a different name, simply write over the current name of the project and/or its geometry, as shown below.



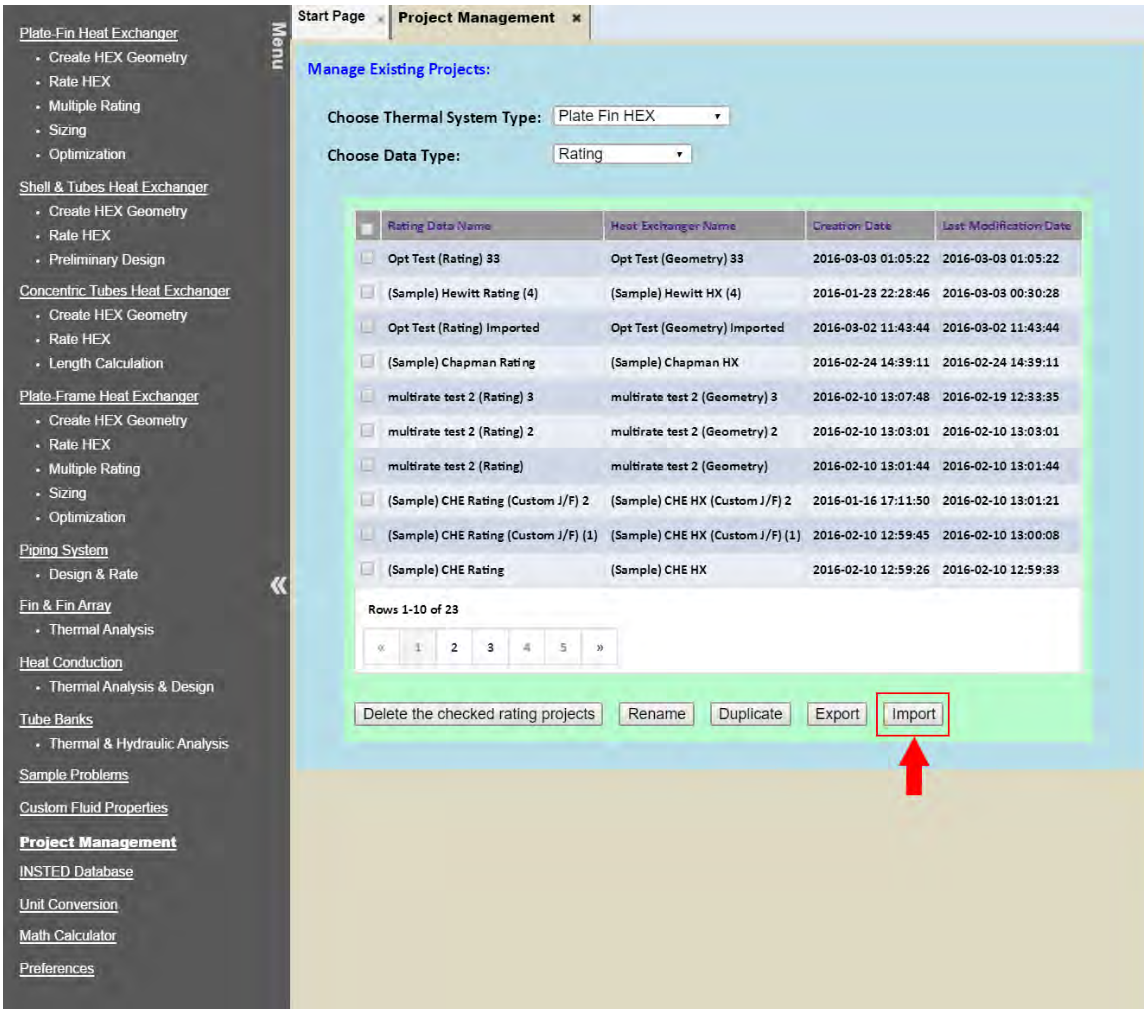
Clicking the "Export" will cause a project file to be generated and downloaded into the default Download folder of your browser. This means that you need to know the location of the Download folder in your computer. Your system administrator should be able to help you obtain this bit of information.


Start Page
Project Management
Manage Existing Projects:
Choose Thermal System Type: Plate Fin HEX
Choose Data Type: Rating
Delete the checked rating projects
Rename
Duplicate
Export
Import
880430e8-0126-456....xml
Show all downloads...

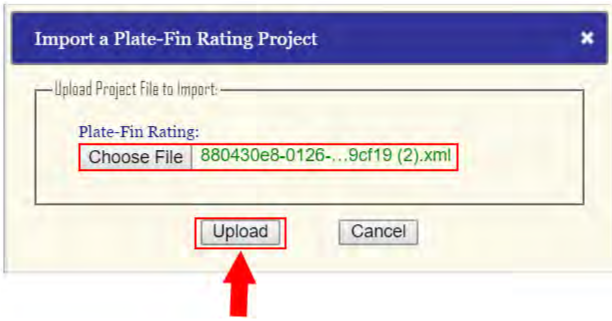
34. Miscellaneous: Importing a Project from an XML File

The following instruction contains the procedures for importing a project from an XML text file.

Under “Projects Management” in the menu panel, choose the type of task for which you want to import a project and click the “Import” button.



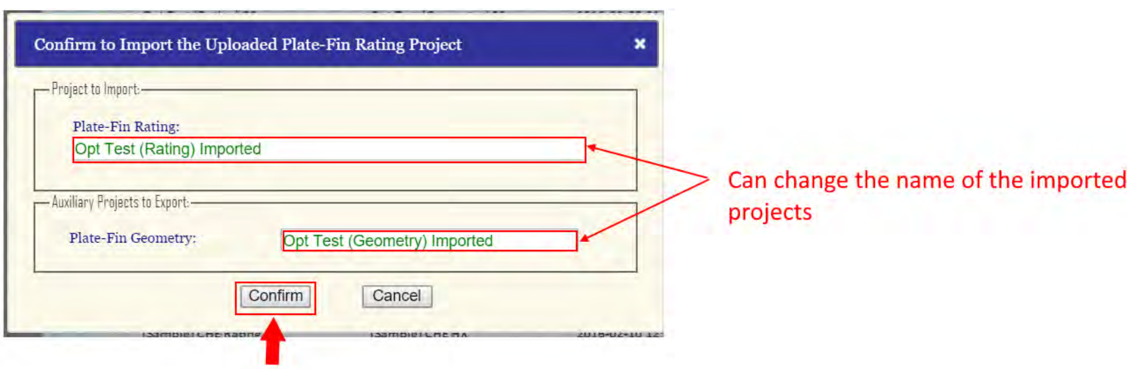
A dialog box will be displayed.



Choose the file you want to upload and click the “Upload” button.

A dialog box containing the details of the imported project will be displayed. You also have the option of changing the name (descriptions) of the imported project.

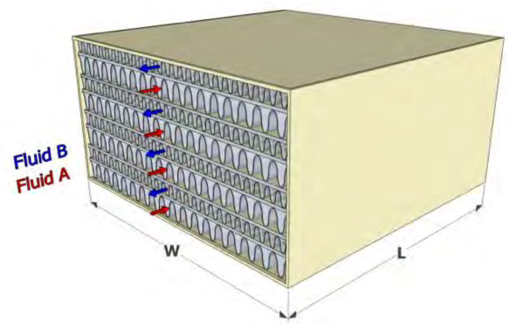
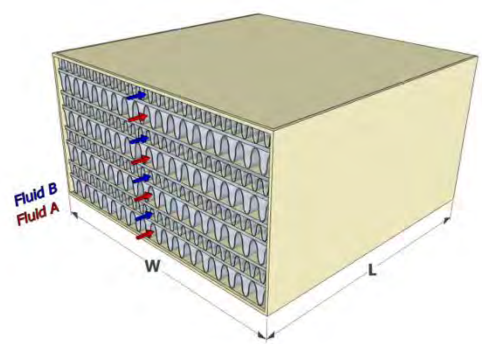
Important Information: Please note that your project files are downloaded into your browser default download folder. This is where to look when you want to export the file to other INSTED users.

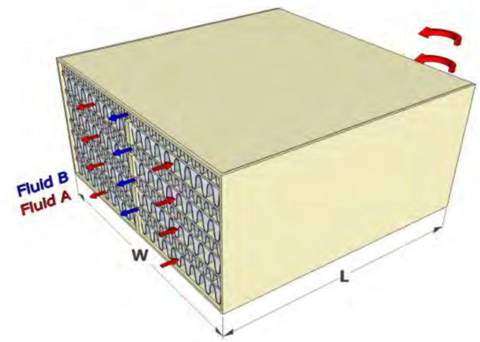
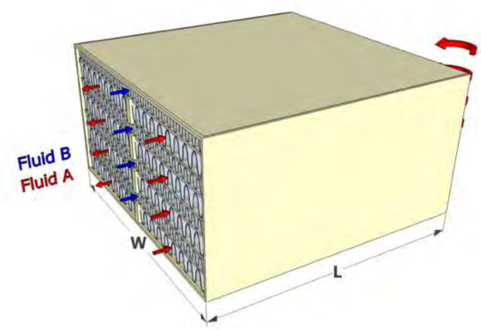
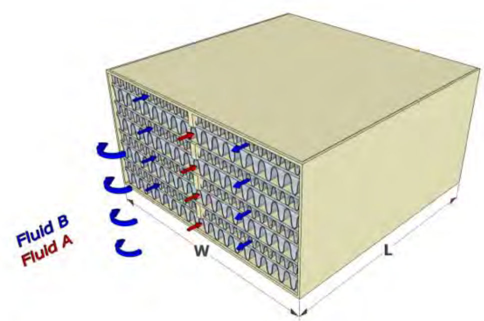


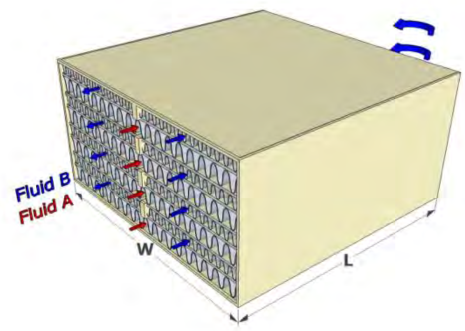
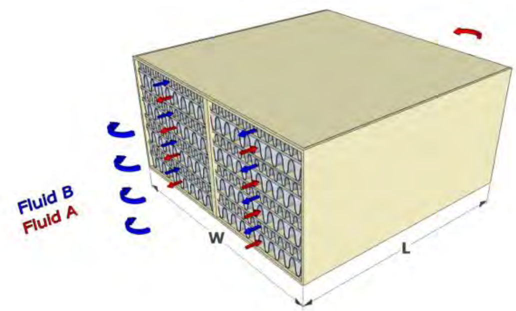
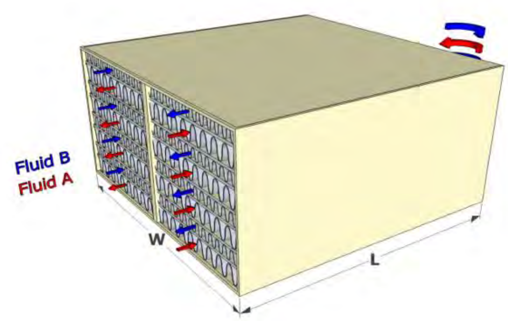
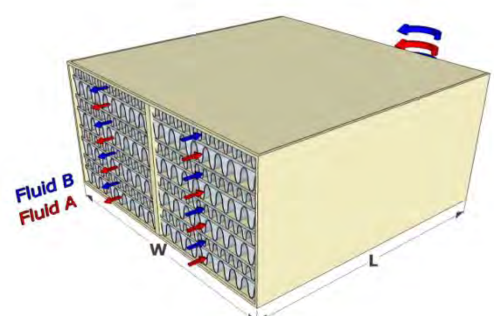
Click the “Confirm” button to import the project.

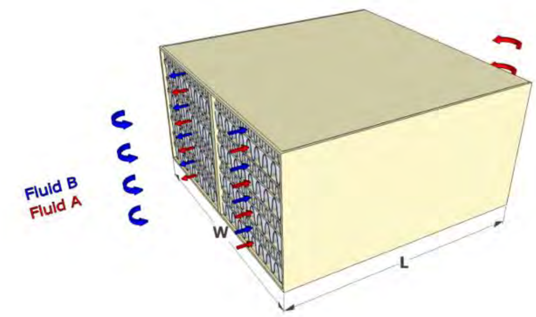
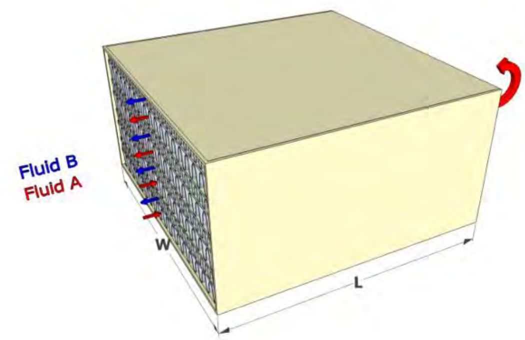
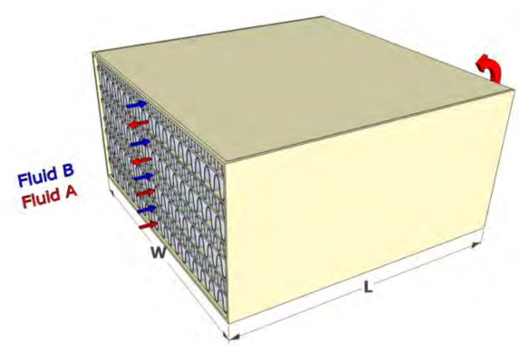
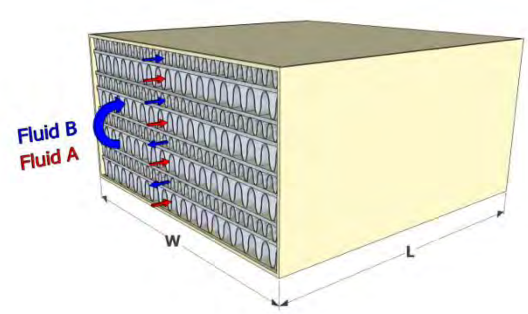
35. Flow Configurations: Parallel Flow vs. Cross Flow, Multiple Passes vs. Multiple Partitions, Counter-Current vs. Co-Current

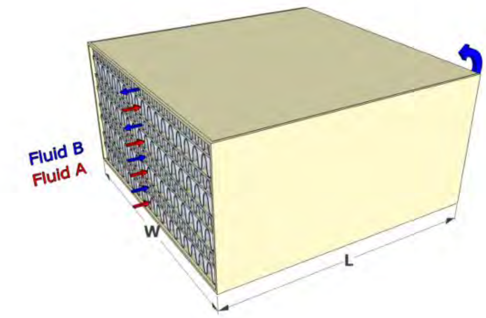
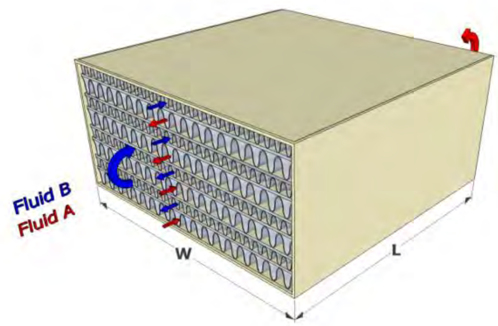
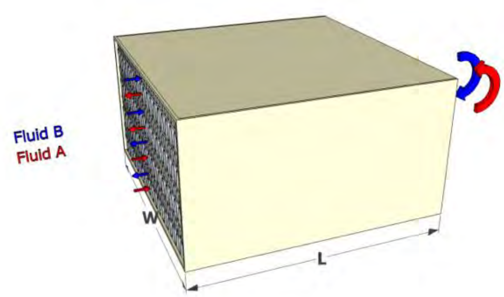
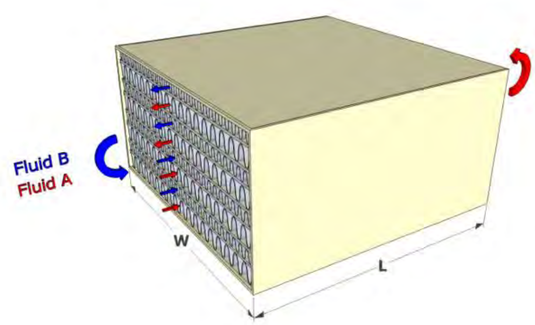
The following table contains the flow configurations supported in the INSTED Plate-Fin module:

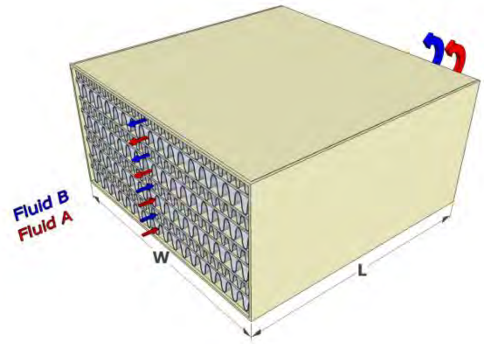
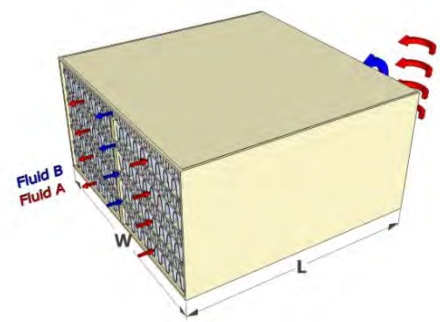
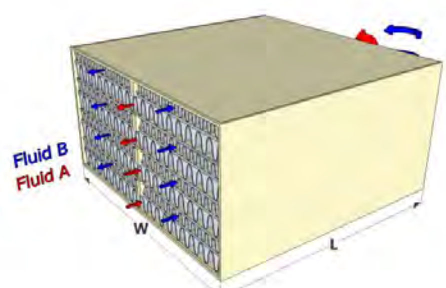
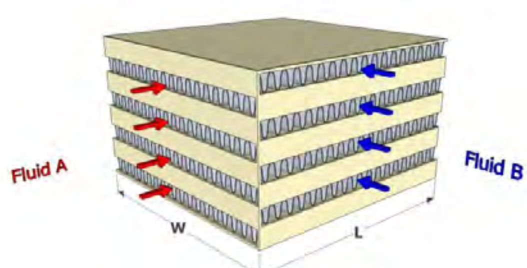
Flow Assignment	Flow Passes (hot-cold)	Flow Partitions (hot-cold)	Flow Direction	Illustration
Parallel	1-1	1-1	Counter-current	
Parallel	1-1	1-1	Co-current	

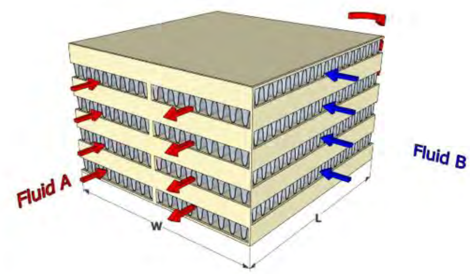
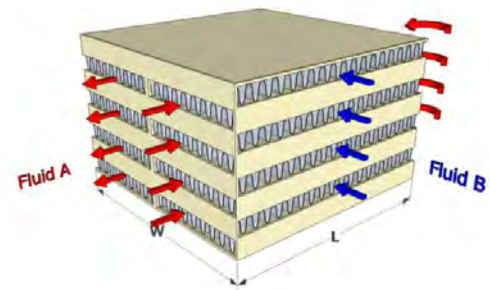
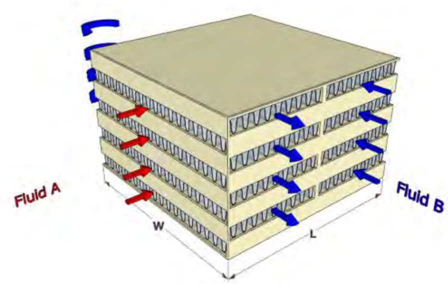
Parallel	2-1	1-1	counter-current	
Parallel	2-1	1-1	co-current	
parallel	1-2	1-1	counter-current	

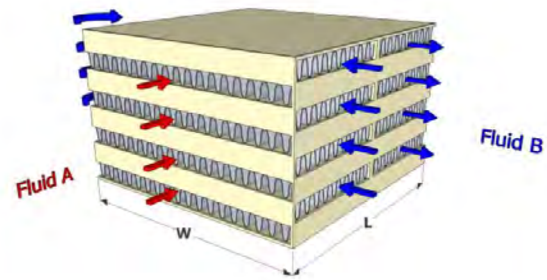
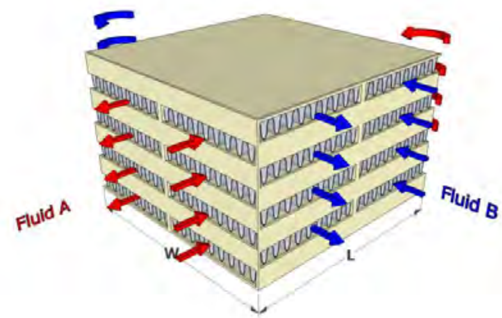
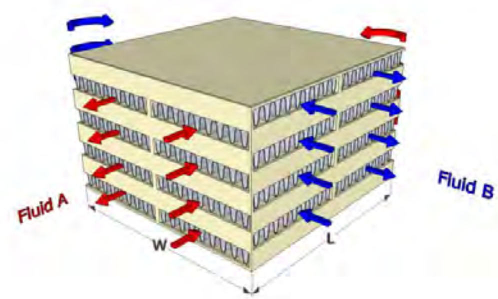
parallel	1-2	1-1	co-current	
parallel	2-2	1-1	counter-current	
parallel	2-2	1-1	co-current	

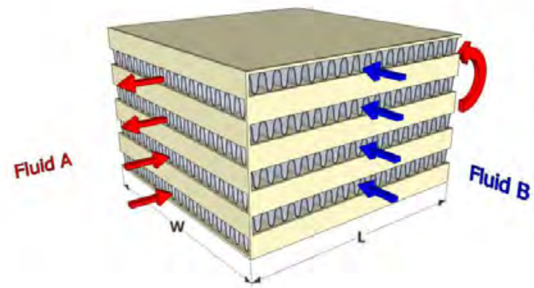
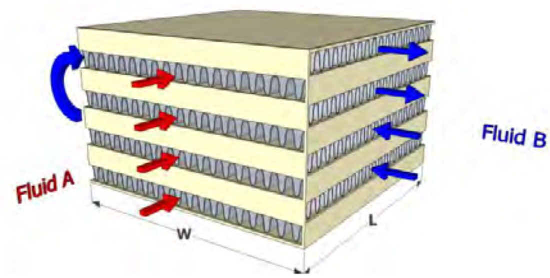
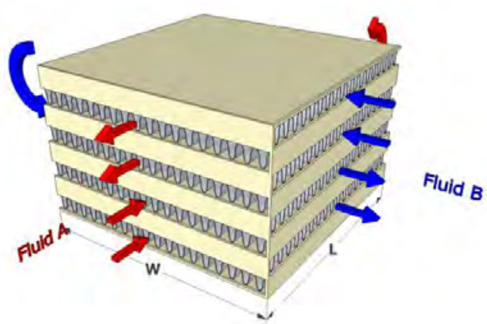
				
parallel	1-1	2-1	counter-current	
parallel	1-1	2-1	co-current	
parallel	1-1	1-2	counter-current	

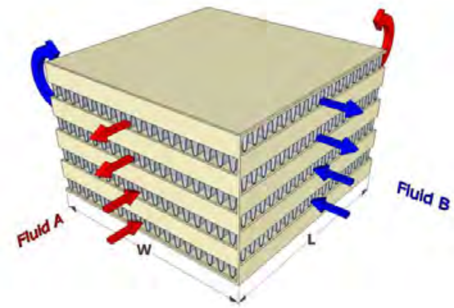
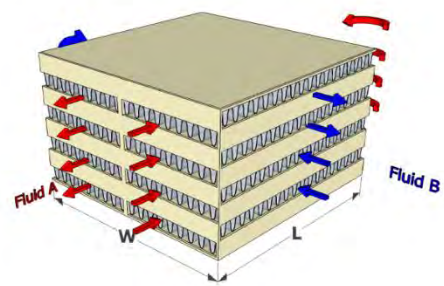
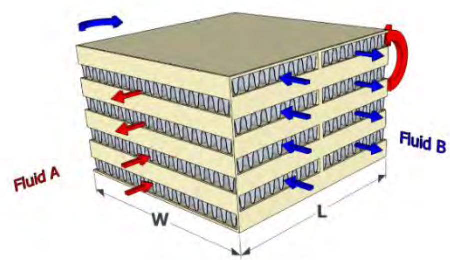
parallel	1-1	1-2	co-current	
parallel	1-1	2-2	counter-current	 
parallel	1-1	2-2	co-current	

				
parallel	2-1	1-2	n/a	
parallel	1-2	2-1	n/a	
Cross	1-1	1-1	n/a	

Cross	2-1	1-1	counter-current	
Cross	2-1	1-1	co-current	
Cross	1-2	1-1	counter-current	

Cross	1-2	1-1	co-current	
Cross	2-2	1-1	counter-current	
Cross	2-2	1-1	co-current	

Cross	1-1	2-1	n/a	
Cross	1-1	1-2	n/a	
Cross	1-1	2-2	counter-current	

Cross	1-1	2-2	co-current	
Cross	2-1	1-2	n/a	
Cross	1-2	2-1	n/a	

36. Technical Details: Built-in J/F Correlations for Various Fins

In INSTED Plate-Fin, the following built-in J/F correlations are used for the different types of fins:

Plain Fins

TTC's internal proprietary J/F correlations are used for plain fins. The correlations have been obtained from joint work with TTC customers and from the literature, such as the Kays and London correlations [1].

Offset-Strip Fins

For the offset-strip type of fins, Bergles and Manglik's model [2] is used.

Herringbone Fins

For herringbone/wavy fins (flow direction), Award's model [3] is used.

Note that you can always use your own customized J/F correlations in place of the built-in correlations. Please refer to Section "*12. Fins: Custom J/F Data – Analytic Mode*" for instructions on how to specify your own j/f data.

Reference:

[1] Kays, William Morrow, and Alexander Louis London. "Compact heat exchangers." (1984).

[2] Bergles, R. M., and A. E. Manglik. "The thermal-hydraulic design of the rectangular offset-strip-fin compact heat exchanger." Compact Heat Exchangers: A Festschrift for AL London 123 (1990).

[3] Awad, M., and Yuri S. Muzychka. "Models for pressure drop and heat transfer in air cooled compact wavy fin heat exchangers." Journal of Enhanced Heat Transfer 18, no. 3 (2011).

37. Technical Details: Two-Phase Models

The various boiling and condensation models supported in INSTED Plate-Fin were obtained from the literature where they have mostly been developed for flow in circular pipes or ducts. A list of the two-phase models is shown in the table below. TTC has modified these models to make them applicable to extended fin surfaces. The details of the procedure to do this can be found in a paper from TTC's [1]. Note that this paper can be downloaded from TTC's website under "Publications.".

Reference:

[1] Li, W., Alabi, K. and Ladeinde, F., "Comparison of 30 Boiling and Condensation Correlations for Two-Phase Flows in Compact Plate-Fin Heat Exchangers," ASME Paper HT2017-4907, July 2017.

Note that each of the two-phase models listed in the table below is valid for only a certain flow regime and conditions. Some information on the validity of the various models are contained in the table.

Boiling Models:

No.	Correlation	Channel Geometry	Boiling Mechanism	Fluids
1	Chen (1966)	Horizontal tubes	Nucleate boiling and forced convective boiling	Water, Methanol, Pentane, Heptane, Benzene, etc.
2	Shah (1982)	Horizontal and vertical tubes D_h=5.0-15.8 mm	Nucleate boiling and forced convective boiling	R11, R12, R22, R502, etc.
3	Gungor and Winterton (1986)	Horizontal and vertical tubes D_h=2.95-32 mm	Nucleate boiling and forced convective boiling	Water, R11, R12, R113, etc.
4	Gungor and Winterton (1987)	Horizontal and vertical tubes D_h=2.95-32 mm	Nucleate boiling and forced convective boiling	Water, R11, R12, R113, etc.
5	Kandlikar (1990)	Horizontal and vertical tubes D_h=4.6-32 mm	Nucleate boiling and forced convective boiling	Water, R11, R12, R22, R113, Nitrogen, etc.
6	Liu and Winterton (1991)	Horizontal and vertical tubes D_h=2.95-32 mm	Nucleate boiling and forced convective boiling	Water and refrigerants
7	Steiner and Taborek (1992)	Horizontal tubes D_h=1-32 mm	Nucleate boiling and forced convective boiling	Water, refrigerants, cryogenics
8	Kattan (1998)	Microfin tube	Nucleate boiling and forced convective boiling	R134a, R123, R402a, R404a, R502
9	Rohsenow (1951)	Horizontal tubes	Nucleate boiling	Water, CCl4, Benzene, n-Pentane, Ethyl alcohol, etc.
10	Cooper (1984)	Pool boiling	Nucleate boiling	Water, refrigerants, organic fluids, cryogens
11	Koyama (1995)	Microfin tube	Nucleate boiling	Refrigerants
12	Tran (1996)	Horizontal tubes D_h=2.4-2.92 mm	Nucleate boiling	R12, R113
13	Kew and Cornwell (1997)	Horizontal tubes D_h=1.39-3.69 mm	Nucleate boiling	R141b
14	Warrier (2002)	Horizontal tubes D_h=0.75 mm	Nucleate boiling	FC-84
15	Yu (2002)	Horizontal tubes D_h=2.98 mm	Nucleate boiling (moderate convective boiling maybe included)	Water

Condensation Models:

No.	Correlation	Channel Geometry	Condensation Regime	Fluids
1	Carpenter and Colburn (1951)	Horizontal tubes	Annular flow	Steam
2	Kosky and Staub (1971)	Horizontal tubes	Annular flow	Steam
3	Cavallini and Zechin (1974)	Horizontal tubes	Annular flow	Steam
4	Jaster and Kosky (1976)	Horizontal tubes D_h=12.5 mm	Stratified flow	Steam
5	Shah (1979)	Horizontal tubes D_h=7-40 mm	Annular flow	Water, R11, R12, R22, R113, methanol, ethanol, benzene, etc.
6	Haraguchi (1994)	Horizontal tubes D_h=8.4 mm	Annular flow	R22, R134a, R123
7	Fujii (1995)	Horizontal tubes D_h=8.4 mm	Gravity and shear flows	R22, R134a, R123
8	Yu and Koyama (1998)	Microfin tubes	Gravity and shear flows	R22, R134a, R123
9	Moser (1998)	Horizontal tubes D_h=3.14-20 mm	Annular flow	Steam
10	Dobson and Chato (1998)	Horizontal tubes D_h=3.14-7.04 mm	Annular and stratified-wavy flows	R12, R22, R134a, etc.
11	Webb (1998)	Horizontal tubes D_h=1-7 mm	Annular flow	R12
12	Cavallini (2002)	Horizontal tubes D_h=8 mm	Annular, annular-stratified, and stratified-slug flows	R22, R134a, R125, R236ea, R32, R410A
13	Thome (2003)	Horizontal tubes D_h=8 mm	Annular, stratified-wavy, and wavy flows	R22, R134a, R125, R236ea, R32, R410A
14	Cavallini (2006)	Horizontal tubes D_h=8 mm	ΔT-dependent and ΔT-independent flows	R22, R134a, R125, R236ea, R32, R410A
15	Shah (2009)	Horizontal/vertical tubes	Laminar, transitional, and turbulent flows	Water, halocarbon refrigerants, hydrocarbon refrigerants, and organics