Contents

INTRODUCTION

The procedures for executing INSTED®/Plate-Fin program are presented in this section. The input file options, primary tasks, required data, and the results are discussed, as are the online utilities that are available within the program environment.

This program performs single-phase and two-phase calculations for multi-pass or multi-partitioned cores. In addition, the program performs sizing and optimization calculations for single-phase problems in cross-flow or parallel arrangements.

INSTED®/Plate-Fin program supports rectangular, triangular, wavy, and trapezoidal fin types with plain, serrated, or herringbone profiles. The program also allows you to specify the *j/f* data for fin types not included in INSTED.

INSTED®/Plate-Fin program is intended for realistic systems. Consequently, this program may not be very suitable for textbook examples on plate-fin heat exchangers. As a result, most of the sample problems that are included with the program were obtained from realistic plate-fin problems provided by several valued INSTED/Plate-Fin users.

RUNNING INSTED®/Plate-Fin Program

Starting the Program

Follow this procedure to execute INSTED®/Plate-Fin program.

1. Click on the Windows **Start** button
2. Select **Program**
3. Select **INSTED 3.0**
4. Select the **Plate-Fin Heat Exchanger** icon.
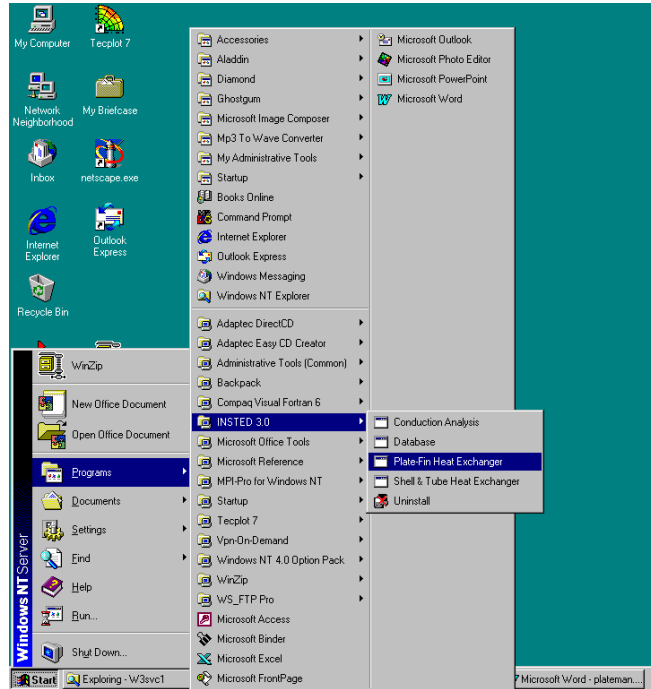
The Restart File

The Plate-Fin Heat Exchanger program automatically loads the previous analysis if the program was terminated normally in the previous session. This is to allow previous sessions to continue naturally. However, to initialize all input fields, select the "New Project" option from the 'Project Admin' dialog box. This feature is explained in more details later in this manual.

PROGRAM ORGANIZATION

The INSTED®/Plate-Fin Program is organized into nine dialog boxes: the Main, Project Administration, Fin Properties, Process Conditions, Problem Description, Edit j/f Data, More Plots, Material Limit and the Sizing/Optimization dialog boxes. The dialog boxes are launched from the Main dialog box. Result presentation is done also via the Main dialog box. A detailed description of each dialog box is presented later in this manual. The figure below shows the program interface at start up.
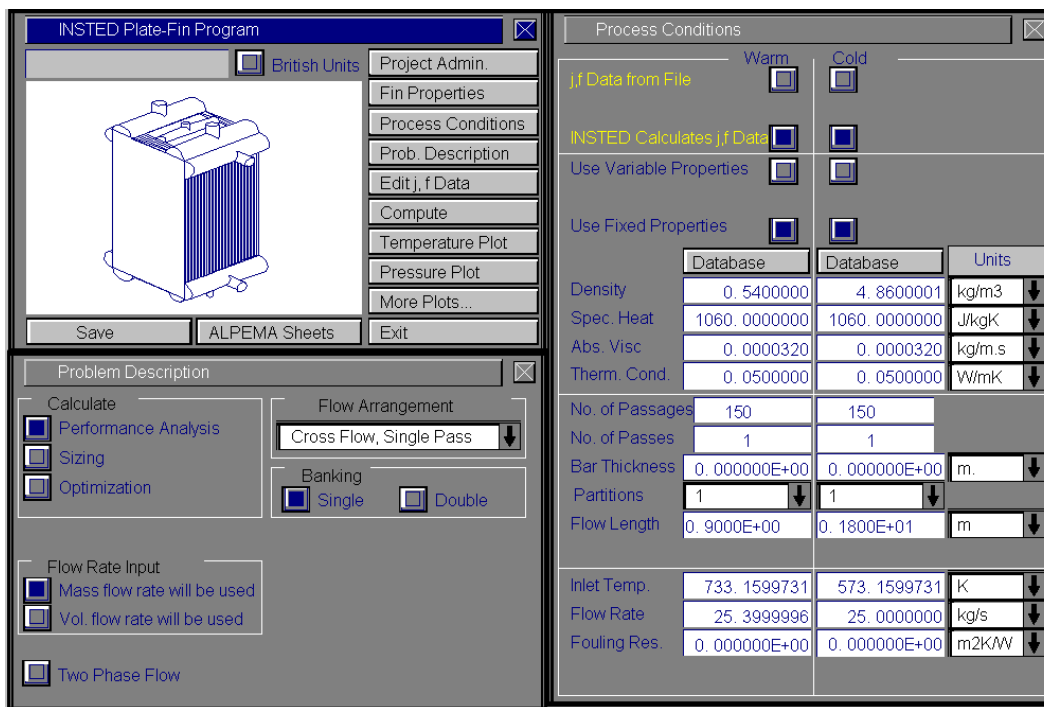
Tasks

INSTED®/Plate-Fin program can be used to carry out the following tasks:
- Rating (Performance Calculations)
- Sizing
- Optimization

Input Required for Single-Phase Rating Analysis

The minimum data required for analysis are:
- Inlet temperatures for both fluids
- Specification of the flow configuration.
- Specification of the banking arrangement.
- Thermophysical properties (specific heat, density, absolute viscosity, and thermal conductivity) for both fluids. These data may be supplied directly or obtained seamlessly through the INSTED Database program.
- Number of passages for both fluid streams
- Number of passes
- Number of partitions
- Separator bar thickness
- Flow length of both streams
- Fouling resistance of both streams
- Fin type, profile, thickness, height in passage and material conductivity for both fluid streams
- Plate thickness and conductivity

Data That May be Required

- *j* and *f* performance curves will be required if you choose to use custom j/f data.
- Flow width may be required for parallel flow arrangements
- Offset pitch may be required for fin types with non-plain profiles

Input Required for Two-Phase Rating Analysis

In addition to the above data, the following data may also be required for a two-phase calculation:
- Inlet quality
- Saturation temperature and/or dew point
- Surface tension
- Two-phase thermophysical properties
- Critical temperature and pressure
- Latent heat of condensation or vaporization
- Molecular weight

Results from Rating Analysis

- Total heat transfer rate
- Total heat transfer area
- U, UA
- Effectiveness
- Mean temperature difference
- NTU
- Outlet temperatures and temperature profile along passage
- Total pressure loss and pressure loss profile along passage
- Outlet quality for two-phase calculation and quality profile along passage
- Colburn and friction factors
- Reynolds number
- Single-phase or two-phase pressure drops

Results from Sizing Analysis

- A design realization, showing the number of plates, heat transfer rate, pressure losses, flow rates, and dimensions satisfying the sizing requirements.
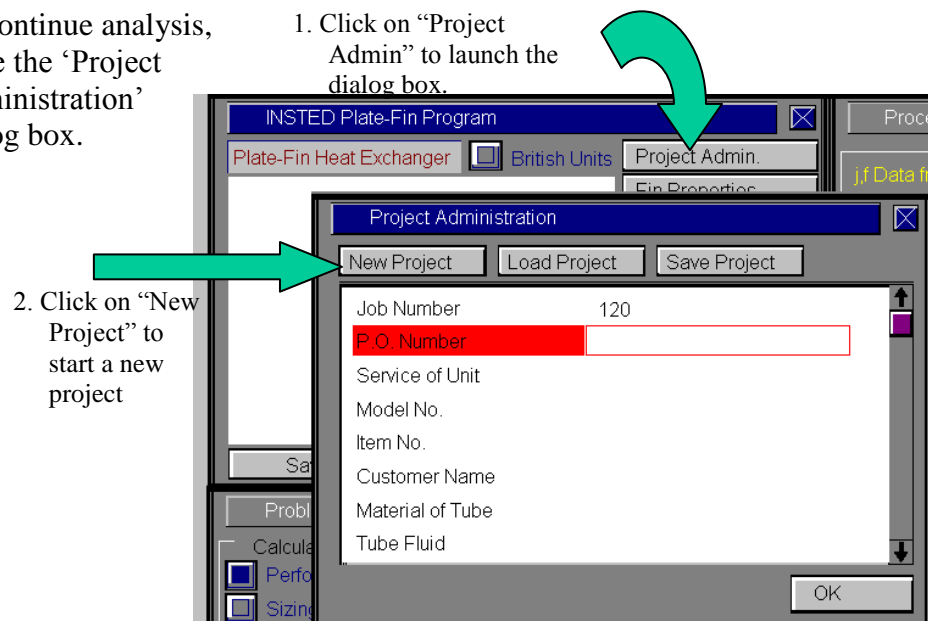
Results from Optimization Analysis

▪ Several plausible design realizations, showing the number of plates, heat transfer rate, pressure drop, flow rates, and the dimensions satisfying the constraints and the optimization criteria.
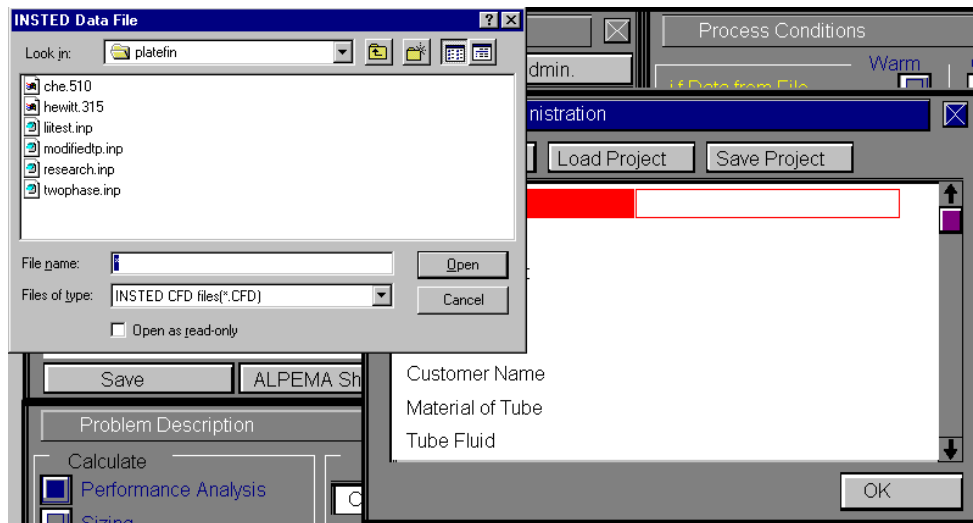
Starting a New Project

To start a new project:
1. Click the "Project Admin." button on the Main dialog box.
2. Click "New Project" on the 'Project Administration' dialog box.
3. Fill in the administrative data for the editbox on the Project Administration dialog if desired. Some of the information will be echoed on the ALPEMA result sheet.
4. To continue analysis, close the 'Project Administration' dialog box.

1. Click on "Project Admin" to launch the dialog box.

2. Click on "New Project" to start a new project

INSTED Plate-Fin Program		Proce
Plate-Fin Heat Exchanger ☐ British Units	Project Admin.	
	Fin Proportion	j,f Data fr

Project Administration

New Project	Load Project	Save Project

Job Number	120
P.O. Number	
Service of Unit	
Model No.	
Item No.	
Customer Name	
Material of Tube	
Tube Fluid	

OK

Sa

Probl

Calcula
Perfo
Sizing

Loading an Old Project

To load an old project:
1. Click the "Project Admin." button on the Main dialog box.
2. Click on the "Load Project" button.
3. Change directory to the "Samples" subdirectory of the "plate" folder.
4. Type *.* in the file name text box on the Windows file menu which comes up.
5. Press the Enter key.
6. Select the file you wish to open by clicking on it in the Windows file open dialog box. This dialog box is shown below.

Saving a New Project

To save a new project:
1. Click the "Project Admin." button on the Main dialog box.
2. Click on the "Save Project" button.

$\Rightarrow$ A Windows 'File Save' dialog box will appear.
3. Select the path in which you wish to save the file.
4. Type a name for the new project file.

DESCRIPTION OF THE DIALOG BOXES

The following section describes the function of each dialog box in INSTED®/Plate-Fin Program.

The Main Program Dialog Box

This dialog box contains twelve buttons and a radio button. The radio button, if selected, indicates that all input data and results would be based on the British units, by default. Leaving this button unselected will use SI units for all calculations, input and results. The functions of the buttons are described below:

Project Admin

This button opens the Project Administration dialog box. The dialog box performs administrative functions including loading and saving the session data, initializing all data fields for starting a new project and recording project data.

Fin Properties

This button opens the Fin Properties dialog box, which contains the description of the fins in each plate passage. This includes the fin type, height, thickness, pitch and material properties such as thermal conductivity and roughness. It also includes the description of the plate thickness and conductivity.
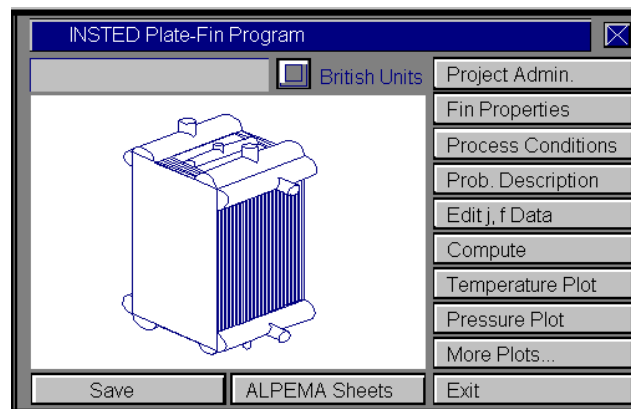
Process Conditions

This button opens the Process Conditions dialog box. This dialog box contains information about the fluid thermophysical properties, the method of calculating j and f data, the number of passages and passes for each stream, as well as the inlet conditions, such as the temperature and the quality of each stream.

Problem Description

This button opens the Problem Description dialog box. This dialog box contains a description of the problem such as information about the fluid arrangement in the core, and a selection of the task to perform. It also contains access to the sizing and optimization dialog boxes.

Edit j/f Data

INSTED/ Plate-Fin allows you to specify the j and f data. This is accomplished in the dialog box opened by clicking this button.

Compute

The Compute button tells INSTED to compute the results. This assumes that all required input data for the task have been specified. If this is not the case, the computation may be unsuccessful and the missing input is indicated, via a (warning) message box.

Temperature & Pressure Plots

Pressing these buttons provides the temperature and pressure plots for the most recent rating or performance calculation.

More Plots

This opens the 'More Plots' dialog box which contains buttons to display and print the quality and the heat flux charts.

To Save

Click on the "Save" button, which is conveniently situated on the Main dialog box. To safeguard work done in the session, it is advisable to intermittently perform a save operation. Note that an error occurs if no project has been loaded previously or saved using the "Save Project" button in the 'Project Administration' dialog box. The procedure for saving a new project has been described in a previous section of this manual.

ALPEMA Sheets

The "ALPEMA" button prints the result on a sheet formatted in the ALPEMA style. The ALPEMA sheet is presented in either SI or British units, depending on the global unit that is selected in the Main dialog box. Once the ALPEMA sheet is presented, clicking on 'File/Print' will print the sheet. Clicking anywhere on the sheet will return the program to the program's interface.

Exit

Press this button to close the program and end the current session. All session data are stored and are automatically retrieved on restarting the program.

## The Project Administration Dialog Box

The Project Administration dialog box provides the environment for loading an existing project, saving a new project, or starting a new project.
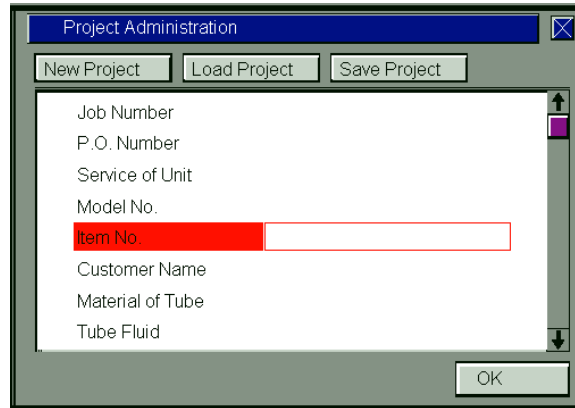
The Project Administration dialog box also contains a description of the project, including job number, customer names etc. This dialog box is the same in all the INSTED programs and data from it are shared during an integrated session with several programs of the INSTED suite of engineering programs.

The Problem Description Dialog Box

This dialog box contains a top-level description of the problem. Choose the main task by selecting one of the options under 'Calculate'. The flow arrangement also has to be selected. INSTED supports Cross Flow, Cross Counter Current Flow, Cross Co-Current Flow, Parallel Counter-Current and Parallel Co-Current arrangements.
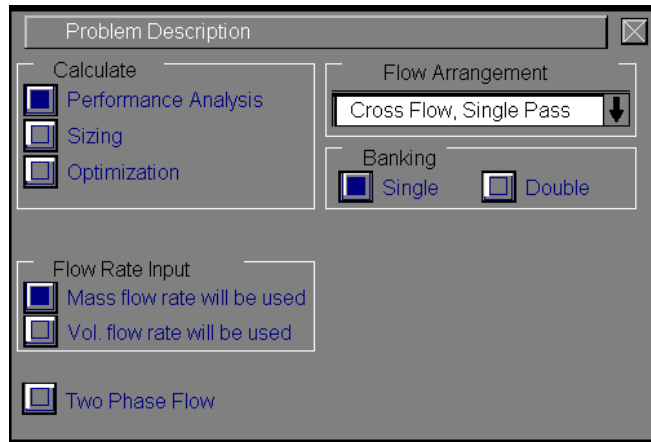

The cross co-current and cross counter -current flow arrangements are illustrated below.

(a) Cross Co-Current Flow   (b) Cross Counter-Current Flow
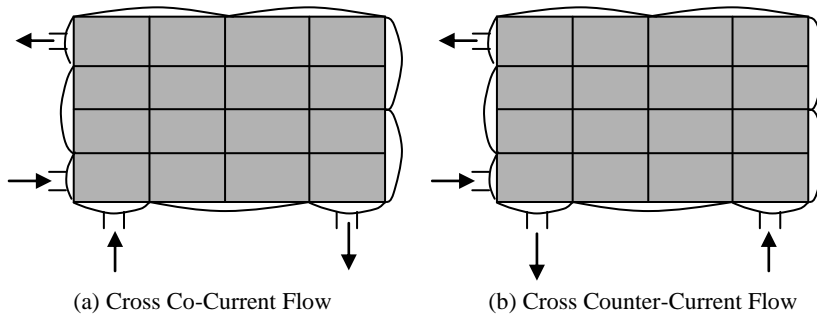
Note that both the cross counter-current and cross co-current arrangements degenerate to the simple cross flow arrangement when the number of passes is one for both streams.

Banking Arrangement

The banking arrangements supported by INSTED are illustrated in the figure below. The required option is selected by clicking the appropriate button in the group box labeled 'Banking'.
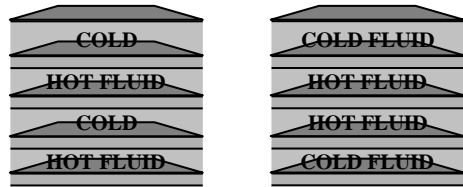
(a) Single Banking Flow   (b) Double Banking Flow Arrangement

Two-Phase Flow

Selecting the two-phase option button indicates a desire to perform two-phase calculations. Input boxes for quality are presented in the 'Process Conditions' dialog box. The specific two-phase options are

- Boiling of the heated fluid, single-phase of the cooled fluid
- Condensation of the cooled fluid, single-phase of the heated fluid
- Boiling of the heated fluid, condensation of the cooled fluid

The Sizing and Optimization Dialog Boxes

The Sizing and Optimization dialog boxes are child dialogs of the Problem Description dialog box. They can be accessed by selecting either the 'Sizing' or 'Optimization' task.
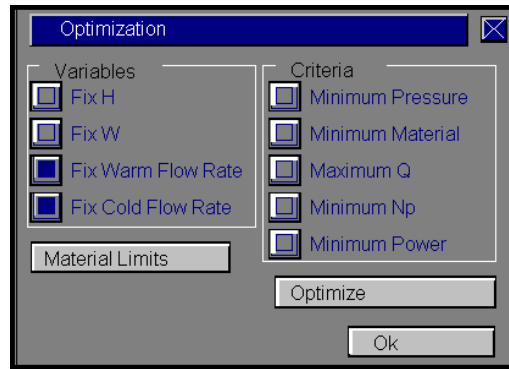
The variables to be kept fixed during the sizing/optimization iterations are selected from this dialog box. The time taken to complete these tasks depends on the number of free variables. For optimization tasks, the criteria are selected in this dialog box. The 'Material Limit' dialog box is also launched from the Sizing and Optimization dialog boxes, by pressing the 'Material Limits' button.

The Material Limits Dialog Box

This dialog box is a child dialog of the Sizing and Optimization dialog boxes.

You specify the allowable range for the flow rate, core dimensions, number of plates, and pressure loss in this dialog box. Sizing calculations will seek solutions that satisfy the constraints specified in this dialog box.
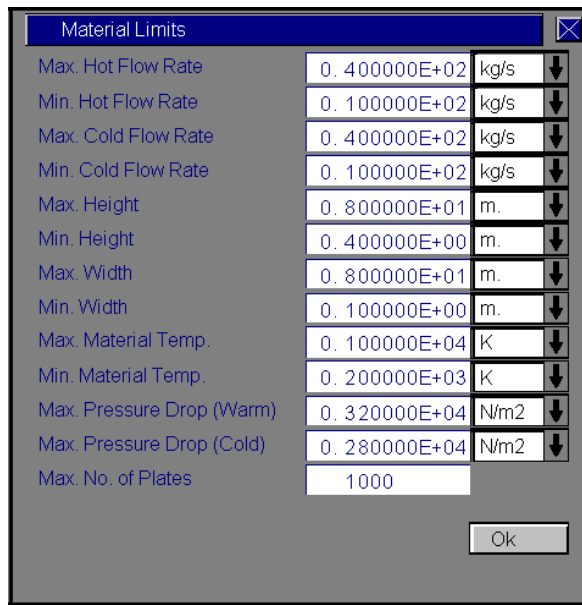
The Process Conditions Dialog Box

This dialog box consists of four sections as follows:

j/f Data Section

The first section deals with the method of computing *j* and *f*. INSTED supports many fin types such as rectangular, triangular, wavy, and trapezoidal fins with different profiles, including plain, serrated, and herringbone. However, fin types not supported by INSTED or fin types proprietary to a user, which are not public domain, may be described in INSTED. Therefore, you may either use your own custom j/f data or request INSTED to calculate them for you. The option to use a user-defined performance curve for calculating fin type or use INSTED's equations, is selected in this dialog box.

Click on the 'j, f Data from File' button in the 'Process Conditions' dialog box to instruct INSTED to use your (custom) j/f data. Note that you must have pregenerated the data before they can be available for use in the 'Process Conditions' dialog box. (You specify custom j/f data via the 'Edit j/f Data' dialog box, which can be accessed from the Main dialog box. This process is also described later in this manual.)

Choosing to use a custom *j/f* performance characteristic also means data input in the 'Fin Properties' dialog box will be ignored except for the input fields for plate-thickness and plate thermal conductivity.

Thermophysical Property Section

Fluid properties may be kept fixed during analysis or they may be allowed to vary with temperature. The fixed values could be specified in the 'Process Conditions' dialog box or obtained from INSTED/Database

To use the variable properties option, click the radio button and select the file containing the data for the fluid from the listbox that will appear. Note that the files in the listbox must have been pregenerated using INSTED/Database.

Passage Geometry Section

The number of passes and the number of passages are specified in this section, as are the number of partitions and the flow lengths. For parallel flows, the flow width is also specified in this section.

Multi-passing and partitioning are used to increase the heat transfer coefficients of plate-fins. The sketch below depicts passes and partitions as they relate to the input quantities in INSTED.

| Process Conditions		
	Warm	Cold
j,f Data from File		
INSTED Calculates j,f Data		
Use Variable Properties		
Use Fixed Properties		
	Database	Database	Units
Density	0.5400000	4.8600001	kg/m3
Spec. Heat	1060.0000000	1060.0000000	J/kgK
Abs. Visc	0.0000320	0.0000320	kg/m.s
Therm. Cond.	0.0500000	0.0500000	W/mK
No. of Passages	150	150	
No. of Passes	1	1	
Bar Thickness	0.000000E+00	0.000000E+00	m.
Partitions	1	1	
Flow Length	0.9000E+00	0.1800E+01	m
Inlet Temp.	733.1599731	573.1599731	K
Flow Rate	25.3999996	25.0000000	kg/s
Fouling Res.	0.000000E+00	0.000000E+00	m2K/W

Inlet Conditions Section

Inlet conditions are specified in this dialog box. This includes the inlet temperature and inlet quality for two-phase flows. The fouling resistance of the fluid along the flow passages may also be specified in this section.

(a) Two partitions in core   (b) Two-pass flow in core
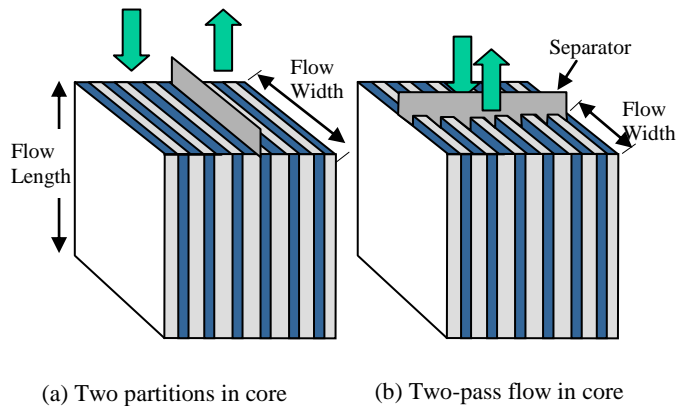
The Fin Properties Dialog Box

This dialog box contains a description of the fins, including their physical dimension, shape, type, and material properties. The plate thickness and thermal conductivity should also be specified in this dialog box.

The following data may also be specified: the fin shape and profile, fin thickness, height, pitch, and thermal conductivity. The plate material thermal conductivity may be obtained from the INSTED/Database program, if installed.
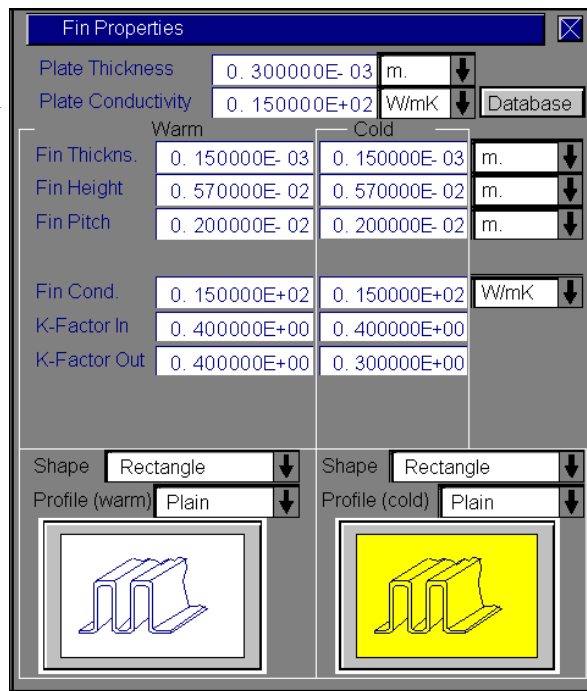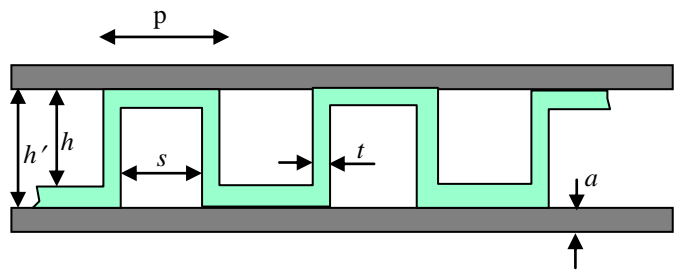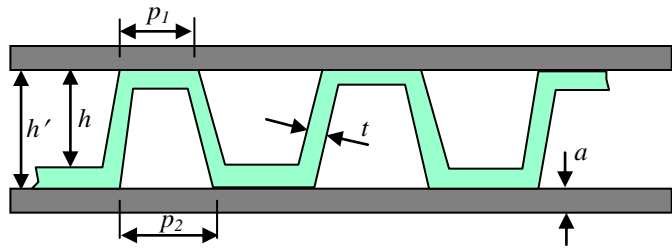
INSTED Fin Types and Profiles

- Rectangular
- Triangular
- Wavy
- Trapezoidal

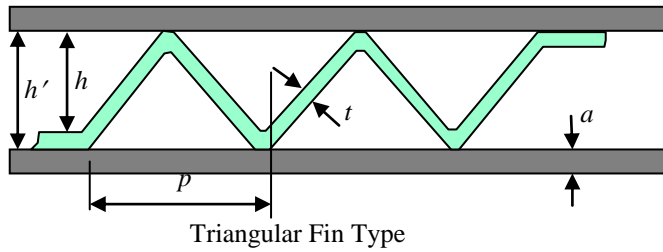All fin types support the plain, serrated, or herringbone profiles.

The figure below shows INSTED fin types.

Rectangular Fin Type

Trapezoidal Fin Type

Triangular Fin Type

In INSTED, h' is the input fin height.

Edit j/f Dialog Box

This dialog box is provided for user-defined j/f characteristics. Both j and f values are entered as a function of Reynolds number.
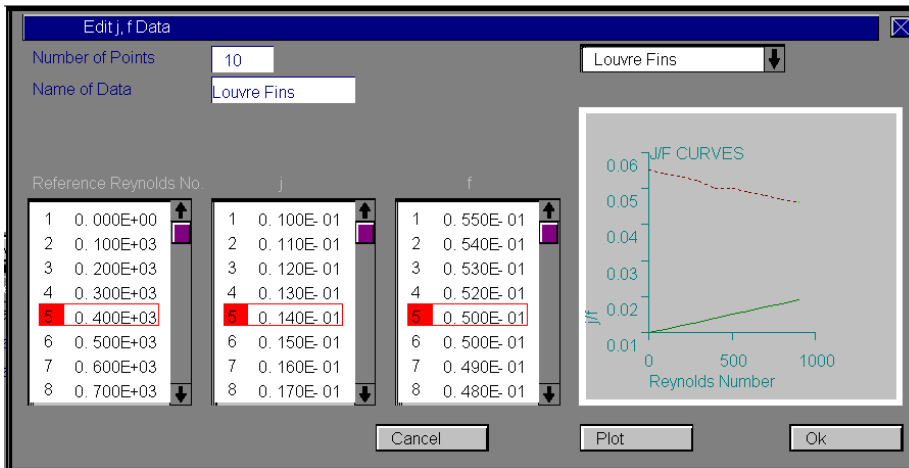
Enter the number of data points first and then the name you wish to use to describe your input. Pressing the "Cancel" button will close the dialog box without saving the input while pressing the "Ok" button will save the input and exit the dialog box.

RUNNING A SAMPLE FILE

This section is designed to illustrate the use of INSTED/Plate-Fin program to compute single-phase problems with thermophysical properties obtained at a single, representative temperature. The INSTED book of test problems contains more details on the test problems used to validate the calculations in INSTED. Therefore, the present section of the manual serves to illustrate the use of the INSTED/Plate-Fin program.

Problem Statement

A cross flow plate-fin heat exchanger is designed for the gas turbine cycle illustrated in the table below. It uses heat form the turbine exhaust gases at 460°C to preheat air leaving the compressor at 300°C. The flow rates of gas and air are respectively, 25.0 and 25.4 kg/s, and the dimensions of the heat exchanger are as shown in the table. What are the temperatures of air and gas leaving the heat exchanger and what are the corresponding pressure drops for the two streams?

	Warm Stream	**Cold Stream**
Density (kg/m^3)	0.54	4.86
Specific heat (J/kgK)	1060	1060
Viscosity (kg/ms)	0.000032	0.000032
Fluid thermal conductivity (W/mK)	0.05	0.05
Flow Length (m)	0.9	1.8
Number of passages/passes	150/1	150/1
Plate thickness (m)	0.0003	0.0003
Plate thermal conductivity (W/mK)	150	150
Fin type	Plain Rectangle	Plain Rectangle
Fin pitch (m)	0.002	0.002
Fin height (m)	0.0057	0.0057
Fin thickness (m)	0.00015	0.00015
Fin thermal conductivity (W/mK)	Same as for plate	Same as for plate

Source

Hewitt, G. F., Shires, G. L., Bott, T. R. Process Heat Transfer, CRC Press. 1998. Pages 321-323.

Comments

- In INSTED, choose the "Performance Analysis" task.
- The gas is the hot fluid while air is the cold fluid in the 'Process Condition' dialog box.
- Enter the thermophysical properties for both the hot and cold fluids as given above in the 'Process Condition' dialog box.
- Enter the fin properties including the pitch, height, thickness and fin type in the 'Fin Properties' dialog box.

Name of Data File

The input data for this sample problem are contained in the file 'hewitt.315' which can be found in the 'samples' sub-directory of INSTED/Plate-Fin.

Instructions for running a sample file

To run the sample file 'hewitt.315', follow these procedures:

1. From the Project Admin dialog, click on the "Load Project" button.
2. Locate the directory \insted30\plate\samples\ on the installation drive.
3. Type " *.* " in the filename position and press Enter
   →   The list of the files in the directory is displayed.
4. Select the file 'hewitt.315' and click the 'Ok' button.
5. Click "Compute" on the Main dialog and wait for computation to end.
6. Click "Temperature Plot" on the Main dialog box to view the result of the calculations for temperature
7. Click "ALPEMA Sheet" to view the results on the ALPEMA sheet.
8. On the top left corner of the screen, select File/Print, to print the ALPEMA sheet.
9. Click any point on the ALPEMA sheet to exit the sheet and return to the program.

Further Instructions for Using User-Defined j/f Characteristics

1. Click the "Edit j, f Data" button on the Main dialog box.
⇒ The 'Edit j, f Data' dialog box appears.
2. Select the data you wish to edit from the listbox on the top left hand corner.
3. Enter the number of points which this data will have in the textbox – "Number of Points"
4. Enter the name of data in the textbox – "Name of Data". This name will be adopted in the listbox after you save your changes.
5. Enter the Reynolds numbers and the corresponding j and f data in their respective editboxes.
6. Click the "Plot" button at the bottom of the dialog box to view the data you have entered. (The j, f plot is also presented anytime you select a new data.)
7. Click on "Ok" to save your changes and "Cancel" to exit the dialog box.

Limitations

The current version of the INSTED/Plate-Fin program has the following limitations:

- Sizing or Optimization is not done for two-phase plate-fins or problems with multi-passes.
- The saturation temperature for a two-phase analysis is assumed fix and does not vary along the flow passages.
- Steady state conditions are supported.