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INTRODUCTION

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

This program calculates heat transfer and pressure drop in cross flow over tube banks. The effects of the interaction between adjacent tubes are considered in the empirical equations used to analyze the problems. The program also supports finned tubes as well as several tube layouts including square, triangular, rotated square, and rotated triangular layout. Fin types supported includes rectangular, tapered, or spiral fins.

Additional Features

- Support for Reynolds number range from 0 to 2×10^6
- Allowance for the use of Corbels

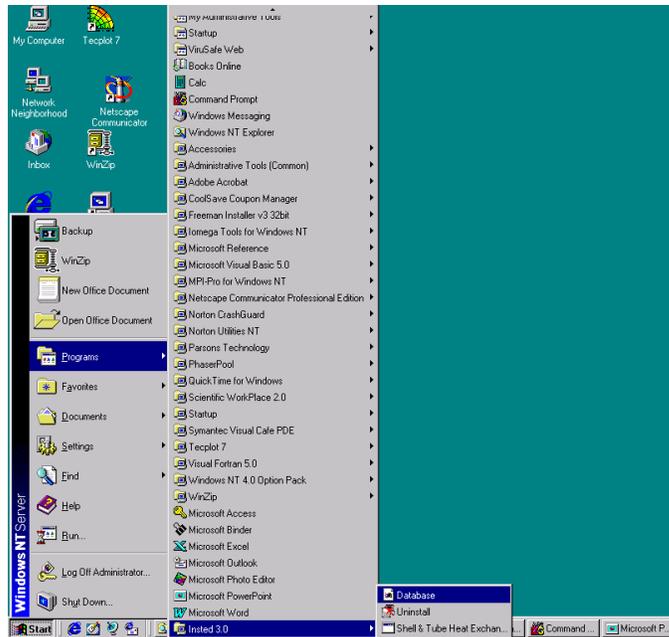
This section also includes a summary of the procedure for performing a sample analysis with the Tube Bank program.

RUNNING INSTED®/Tube Bank Program

Starting the Program

Follow this procedure to execute INSTED®/Tube Bank program:

1. Click on the Windows **Start** button.
2. Select **Program**
3. Select **INSTED 3.0**
4. Select the **Tube Bank Analysis** icon.



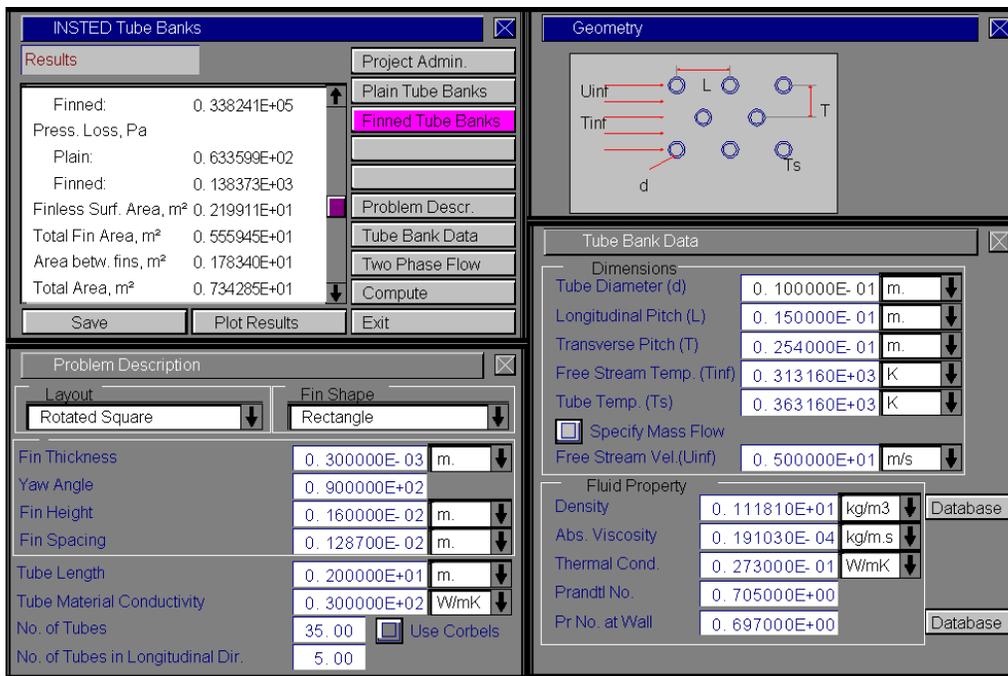
Tube Banks

The Restart File

The Tube Bank 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 as described later in this manual.

PROGRAM ORGANIZATION

The INSTED®/Tube Bank Program is organized into five dialog boxes: the Main, Project Administration, Problem Description, Geometry, and the Tube Bank Data 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.



Data Required for Analysis

The minimum data required for analysis is:

- Tube diameter
- Longitudinal pitch
- Transverse pitch
- Temperature of the incoming fluid stream
- Free stream velocity
- Free stream fluid properties including density, specific heat, thermal conductivity, and viscosity
- Tube length
- Tube material thermal conductivity
- Number of tubes
- Number of tubes in the longitudinal direction
- Indicator for using Corbels

Other Data

For finned tubes, the following additional data may be required

- Fin thickness
- Yaw angle (optional)
- Fin height
- Fin spacing

Results

- Total heat flow rate (plain/finned)
- Outlet temperature of the fluid stream
- Pressure loss (plain/finned)
- Heat transfer coefficient (plain/finned)
- Nusselt number (plain/finned)
- LMTD (Log Mean Temperature Difference)

- Total surface area (plain)
- Total area of fins
- Total area between fins
- Single fin efficiency
- Reynolds number of the flow
- Maximum velocity

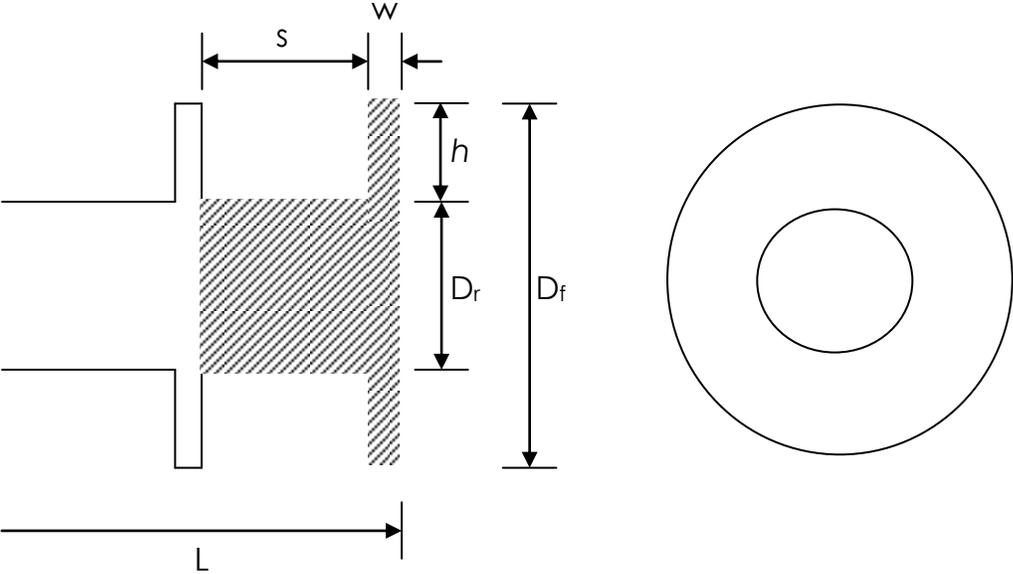
Layouts Supported by the Tube Banks Program

| Description | Layout Sketch |
|----------------------|---------------|
| In-line square pitch | |
| Rotated square pitch | |

| Description | Layout Sketch |
|--------------------------|---------------|
| Triangular pitch | |
| Rotated triangular pitch | |

Tube Banks

Input Requirements for Finned Tubes



Tube Banks

In the above figure, L is the tube length, s is the fin spacing, h is the fin height, w is the fin thickness, and D_r is the tube diameter. The diagram above represents the input requirements for rectangular fins on the tubes.

Starting a New Project

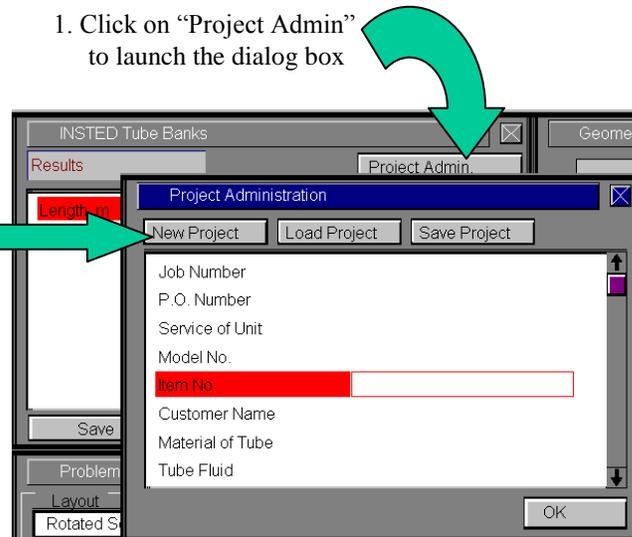
To start a new project:

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.

Note that the Project Administration dialog is modal and needs to be closed before analysis can continue.

1. Click on “Project Admin” to launch the dialog box

2. Click “New Project” to start a new project

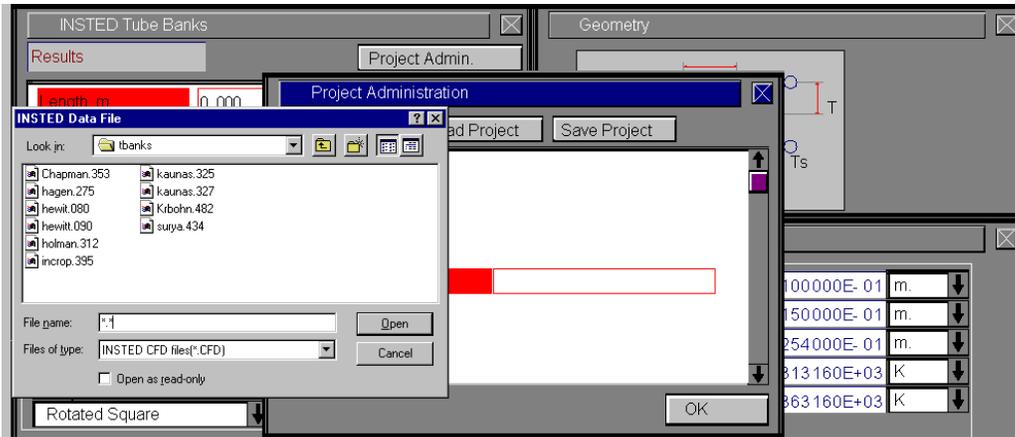


Loading an Old Project

To load an old project:

1. Click the “Project Admin.” button on the Main dialog box
 2. Click on the “Load Project” button
- ⇒ An operating system ‘File Load’ dialog box appears
3. Go to the ‘samples’ subdirectory
 4. Type “*.*” in the file name text box

5. Press the Enter key.
6. Select the file you wish to open by locating it on the Windows file open dialog. This dialog box is shown below.



Saving a New Project

To save a new project:

1. Click on the “Project Admin.” button on the Main dialog box
 2. Click on the “Save Project” button
- ⇒ A Windows ‘File Save’ dialog box will appear
3. Select the path where 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 functions of the dialog boxes in INSTED®/Tube Bank program.

The Main Dialog Box

This dialog box contains ten buttons. The functions of the buttons are described below:

Project Admin

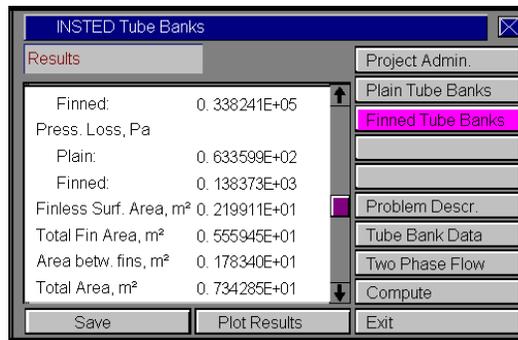
This button opens the Project Administration dialog box, which performs administrative functions, including loading and saving the session data.

Plain Tube Banks

Press the “Plain Tube Banks” button to perform calculations on tube banks without fins.

Finned Tube Banks

Press the “Finned Tube Banks” button to perform calculations on finned tube banks.



Problem Description

This button opens the ‘Problem Description’ dialog box, which contains a description of the tube layout, length and number of tubes and receives input about the fin geometry for finned tube analysis.

Tube Bank Data

This button opens up the 'Tube Bank Data' dialog box, which contains the input data for the tube geometry, material and the thermophysical properties of the fluid.

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 not be successful and the missing input is indicated, via a (warning) message box.

To Save

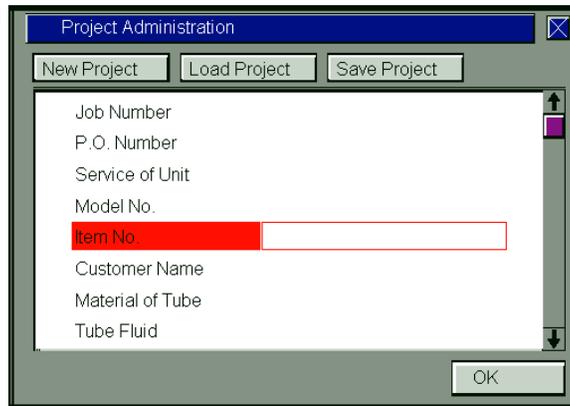
Click on the "Save" button, which is conveniently situated on the Main dialog box. To safeguard work done in the session, it is advisable to intermittently perform a save operation. Note that an error occurs if no project has been loaded and previously saved using the "Save Project" button in the 'Project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

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 functions of the 'Project Administration' dialog box have been covered in previous sections, including loading an existing project, saving a new project, and starting a new project.

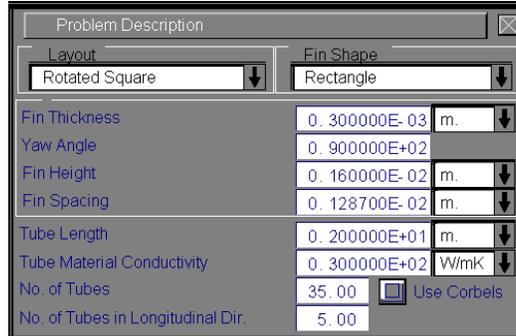


Tube Banks

The Project Administration dialog box 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 is 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 description of the problem. The layout of the tubes is described in this dialog box. Supported layouts include square, rotated square, triangular, and rotated triangular layouts.



The length of the tubes, number of tubes and the thermal conductivity of the tubes are also entered in this dialog box. INSTED supports the use of Corbels. An indicator for the use Corbels should be turned on in this dialog box.

For finned tubes, the following input data are required – the fin shape, thickness, height, spacing and the yaw angle. Supported fin shapes includes rectangular, tapered, and spiral.

Tube Bank Data Dialog Box

This dialog box contains input fields for the geometry of the tube layout, including the tube diameter and the longitudinal and transverse pitch. The free stream temperature is specified here, as well as the tube surface temperature and the mass flow rate or free stream velocity.

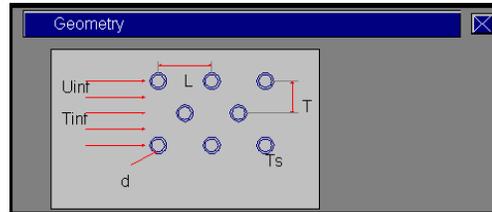
The screenshot shows the 'Tube Bank Data' dialog box with the following fields and values:

| Dimensions | | | |
|--|--------------|--------|------------|
| Tube Diameter (d) | 0.100000E-01 | m | ↓ |
| Longitudinal Pitch (L) | 0.150000E-01 | m | ↓ |
| Transverse Pitch (T) | 0.254000E-01 | m | ↓ |
| Free Stream Temp. (Tinf) | 0.313160E+03 | K | ↓ |
| Tube Temp. (Ts) | 0.363160E+03 | K | ↓ |
| <input type="checkbox"/> Specify Mass Flow | | | |
| Free Stream Vel.(Uinf) | 0.500000E+01 | m/s | ↓ |
| Fluid Property | | | |
| Density | 0.111810E+01 | kg/m3 | ↓ Database |
| Abs. Viscosity | 0.191030E-04 | kg/m.s | ↓ |
| Thermal Cond. | 0.273000E-01 | W/mK | ↓ |
| Prandtl No. | 0.705000E+00 | | |
| Pr No. at Wall | 0.697000E+00 | | Database |

The thermophysical properties of the fluid can also be specified directly in this dialog box or obtained from the Database program.

Geometry Dialog Box

This dialog box contains a sketch of the tube bank layout. The longitudinal (L) and transverse (T) pitches are shown in the sketch. Also labeled are the surface temperature, T_s , tube outer diameter, d , free stream velocity, U_{inf} , and the free stream temperature, T_{inf} . Clicking on the labels will transfer you to the input fields for the variable corresponding to the label.



RUNNING A SAMPLE PROBLEM

This section illustrates the use of the INSTED/Tube Bank program. A sample problem best illustrates the procedure.

Problem Statement

Air conditioning systems often use “cooling coils” to reduce the temperature of air for human comfort. A “coil” consists of a bank of tubes placed in an air-conditioning duct such that the air flows normal to the tubes while a cooling medium (chilled water or refrigerant) flows through the tubes. The tubes in this case consists of a staggered array of tubes with a diameter of 1.59 cm. There are four rows of tubes with a longitudinal spacing of 3 cm. Chilled water flowing through the tubes maintains the tube surface temperature at 5°C. Atmospheric-pressure air is incident on the bank with freestream velocity 5 m/s and temperature 30°C.

- (a) Estimate the surface heat transfer coefficient
- (b) Find the pressure drop of the air across the tube banks.

Source

Alan J. Chapman, 1987. “Fundamentals of Heat Transfer”. Macmillan Publishing Co., NY, Page 353.

Comments

- Use online unit conversion in INSTED to convert from °C to K.
- A staggered tube layout is used.
- Use thermophysical properties given in the source ($\rho = 1.20503 \text{ kg/m}^3$, $\mu = 0.17918 \times 10^{-4} \text{ Ns/m}^2$, $k = 0.02545 \text{ W/mK}$, $\text{Pr} = 0.714$, $\text{Pr}_{\text{wall}} = 0.717$).

Name of Data

The input data for the present sample problem are contained in the file
\insted30\tbanks\samples\Chapman.353.

Instructions for running a sample file

Sample files for INSTED/Tube Bank program are located in the installation drive.
To run the sample file 'Chapman.353', follow these procedures:

1. From the 'Project Admin' dialog, click on the "Load Project" button
2. Locate the directory \insted30\tbanks\samples\ on the installation drive
3. Type " *.* " in the filename position and press Enter
→ A list of the files present in the directory is displayed
4. Select the file 'Chapman.353' and click on the 'Ok' button
5. Click "Compute" on the Main dialog to calculate the results