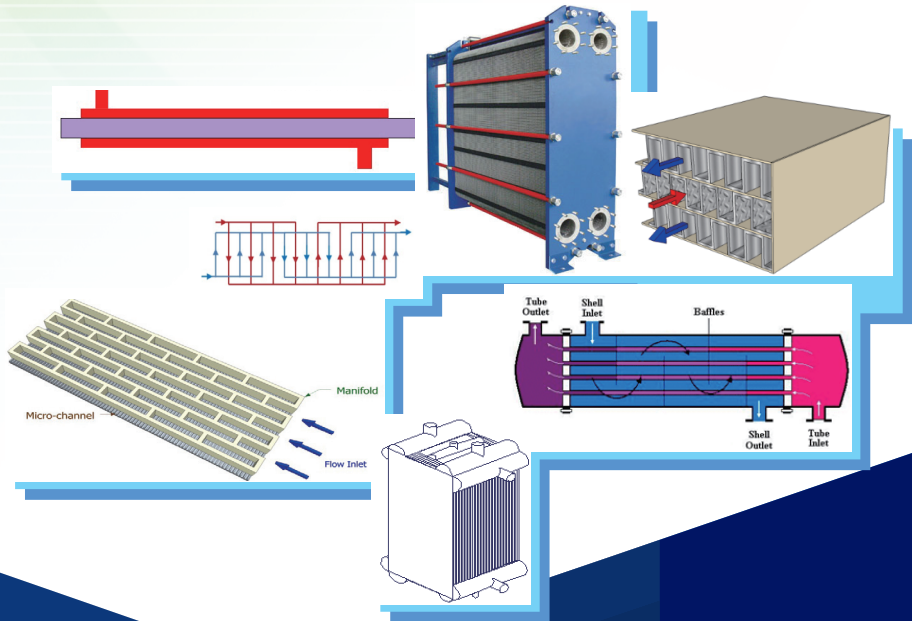


Pioneering engineering  
analysis software  
for next-generation engineers

# INSTED<sup>®</sup> Thermal Analysis Software

-Since 1993-



 ttc technologies

INSTED THERMAL ANALYSIS SOFTWARE  
Brochure

## INSTED Modules

### Heat Exchanger (HEX) Analysis Programs

- Plate-Fin Heat Exchanger
- Shell-and-Tubes Heat Exchanger
- Plate-Frame Heat Exchanger
- Concentric Tubes Heat Exchanger
- Manifolds-Microchannels
- 3D-Printed/Additively-Manufactured HEXs
- Smart Heat Exchangers

### Basic Thermal-Hydraulic Analysis Programs

- Series Piping Systems
- Heat Transfer from Fin and Fin Arrays
- Heat Conduction in Composite Solids
- Flow Over Tube Banks
- Internal Flow with Heat Transfer
- External Flow with Heat Transfer

### Two-Phase Models

- 37 Boiling & Condensation Models
- Modification for Enhanced Surfaces
- Incremental Method

### Engineering Tools

- Thermal-Hydraulic Database
- Advanced Math Calculation Tool
- Engineering Units Converter

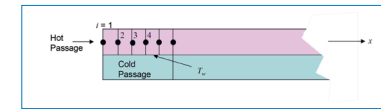
## Fast, Accurate, and Realistic Analysis

### Multiple HEX Design Tools

- Performance analysis (rating)
- Parameter analysis (multiple-rating)
- Preliminary design
- Sizing
- Optimization

### HEX Simulation Model

- Bulk ( $\epsilon$ -NTU)
- Discrete (differential equations)



### Advanced Optimization Algorithms

- Gradient method
- Adjoint-based method
- Genetic algorithm (GA)
- Advanced sensitivity analysis

### Customizable Data

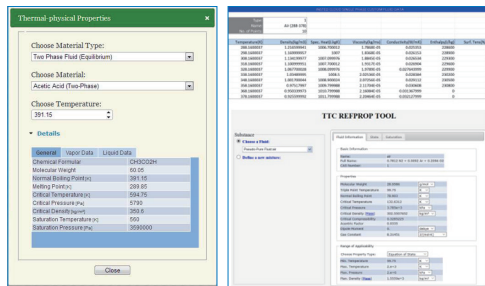
- Custom fluid properties
- Custom j/f data
- Custom fin geometry

	Re	j	f	
1	300.0	0.014	0.057	✖
2	400.0	0.0117656	0.0495644	✖
3	500.0	0.0098982	0.0397575	✖
4	600.0	0.0085648	0.0322262	✖
5	800.0	0.0067295	0.0253199	✖
6	1000.0	0.005616	0.0202061	✖
7	1500.0	0.0043949	0.0145536	✖
8	2000.0	0.004023	0.0124148	✖
9	3000.0	0.0037122	0.0105362	✖
10	4000.0	0.0035233	0.0097063	✖
11	5000.0	0.0033574	0.0092686	✖
12	6000.0	0.0032642	0.0088961	✖
13	8000.0	0.0030609	0.0084082	✖

## Integrated Analysis Environment

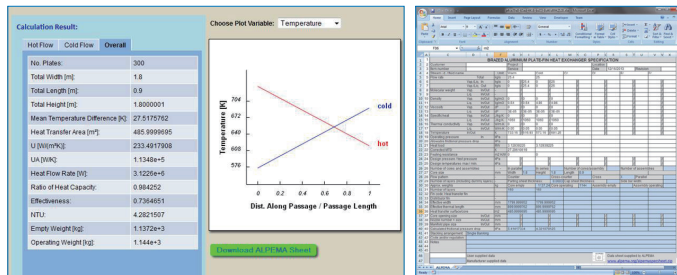
### Integrated Thermophysical Properties Database

- INSTED solid/fluid database
- NIST's REFPROP
- User-defined fluid properties



### Result Plotting & Export

- Line plots along flow passage
- Exporting data to Excel file

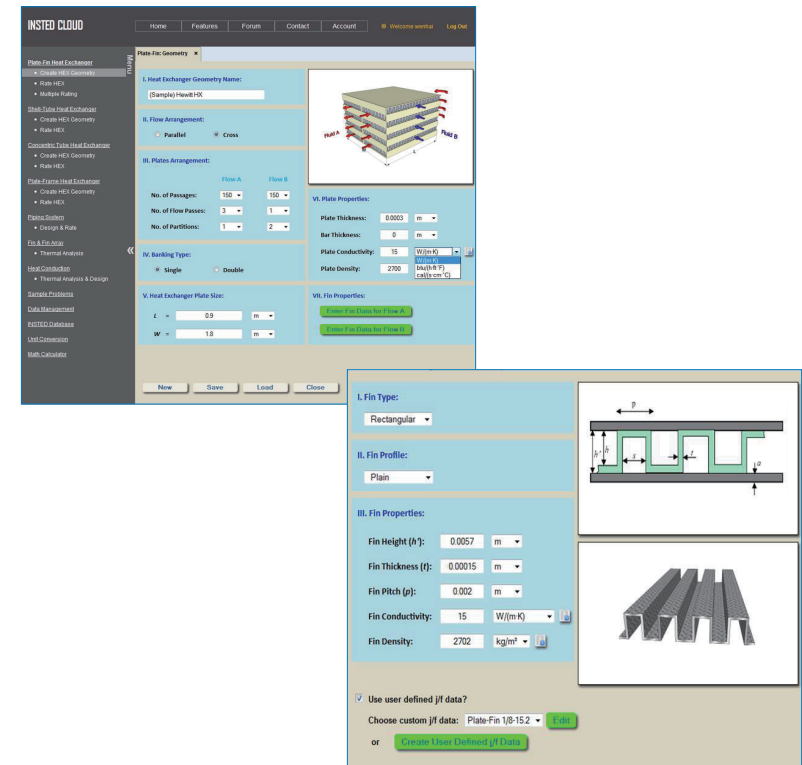


### Unit Preference Setup      Unit Conversion On-the-Fly

## Easy-to-Use Interface

### Cloud Version vs Desktop Version

Cloud Version	Desktop Version
Access data in INSTED anywhere, anytime	Protect your data by running INSTED on your computer



# Plate-Fin Heat Exchanger

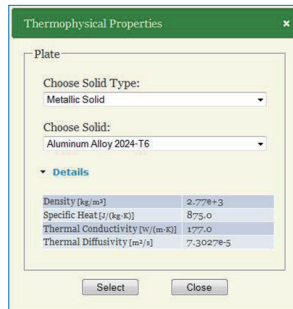
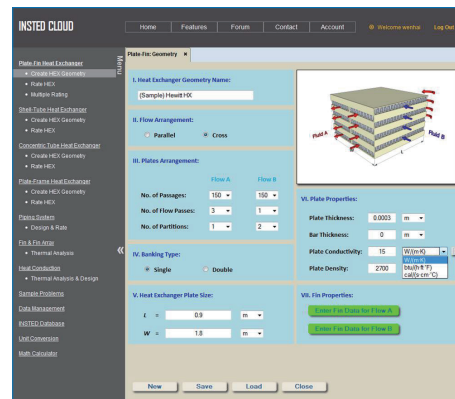
## Features:

- Performance Analysis
- Parametric Rating Calculations
- Sizing & Optimization
- Custom j/f Data Input for Fins
- Kays & London Data for Fins
- User-Defined Fin Geometry Data

## I. HEX Geometry

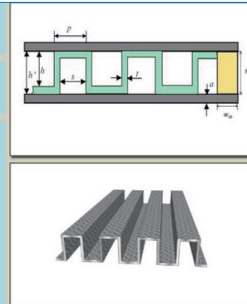
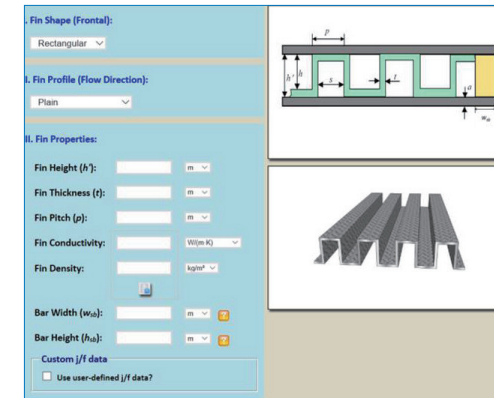
### Different plate/flow arrangements

- Parallel or cross-flow
- Multiple flow passes
- Multiple partitions
- Single- or double-banking



# Plate-Fin Heat Exchanger

## II. Fin Geometry



### Fin types

- Rectangular
- Trapezoidal
- Triangle
- Wavy
- User-defined

### Fin profiles

- Plain
- Herringbone
- Offset-strip
- User-defined

## Kays & London fin data

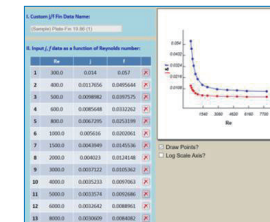
Kays & London fin data

Use fin data from Kays & London?

Choose a Kays & London Fin: plain plate-fin: 2.0

Name	Value	Fin Area / Total Area	Value
Heat Exchanger Type	plain plate-fin	Base Width of Fin [ m ]	0.013589
Fin Shape (frontal)	trapezoidal	Top Width of Fin [ m ]	0.01016
Fin Spacing (flow direction)	plain	Fin Length (parallel to flow direction) [ m ]	0
Fin Pitch (flow direction)	plain	Gap Space (perpendicular to flow direction) [ m ]	0
Fin Pitch (per meter)	78.74	Reverse Placement	0
Plate Spacing [ m ]	0.01905	Number of Splitters	0
Hydraulic Diameter [ m ]	0.014453	Splitter Ratio	0
Fin Thickness [ m ]	8.13e-4	Splitter Thickness [ m ]	0
Total Heat Transfer Area / Volume Between Plates [ 1/m ]	249.672		

## Custom j/f data



# Plate-Fin Heat Transfer

## Multiple Rating

Parameter	Value
Inlet Temperature [°C]	515.1599791
Cold Inlet Temperature [°C]	306.1514219
Pressure Loss [Pa]	242.922119
Inlet Quality	0
Mass Flow Rate [kg/s]	0.99916
Mass Flux [kg/m²]	4.7897005
Flow Velocity [m/s]	6.4138319
Fouling Resistance [m²/K]	0
Equivalent Diameter [m]	0.001897
Reynolds Number	376.651987
Heat Coefficient [W/m²K]	79.793533
Effectiveness [0-1]	1.0758e4
Column Factor	0.9129919
Grid Factor	0.0264979
Fin Efficiency %	0.8024977
Flow Length [m]	0.3
Flow Width [m]	0.0002
Prandtl No.	291.5329235
Specific Heat [kJ/kg K]	1.022e+3
Heat Capacity [kJ/K]	915.8752027

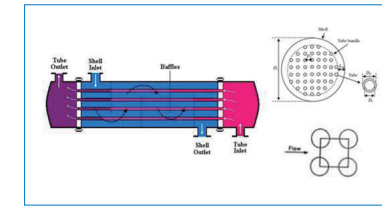
## Optimization

Realization	Pressure Loss [Pa]	Heat Transfer Area [m²]	Weight	Cost
1	0.61488076	1.84817766	25.4	25.4
2	0.4088	1.6009	25.4	25.4
3	0.62394099	1.60447768	25.4	25.4
4	0.89879719	1.89901428	25.4	25.4
5	0.80696303	1.94818353	25.4	25.4

# Shell & Tubes Heat Exchanger

## Features

- Performance Analysis
- Parametric Rating Calculations
- Preliminary Design
- Two-Phase



## Types of Shells

- Generic
- TEMA-E
- TEMA-J
- TEMA-K
- TEMA-X

## Types of Tube Bundles

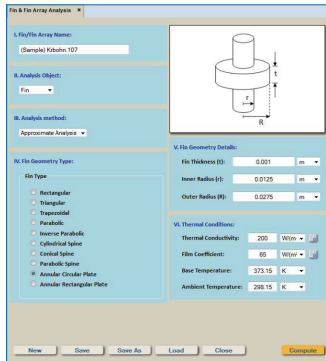
- Square
- Rotated Square
- Triangle
- Rotated Triangle

Rate a shell-and-tubes heat exchanger by providing flow conditions

## Shell-Side Film Coefficients Calculation Methods:

- Kern's Integral
- Bell-Delaware
- Stream Analysis

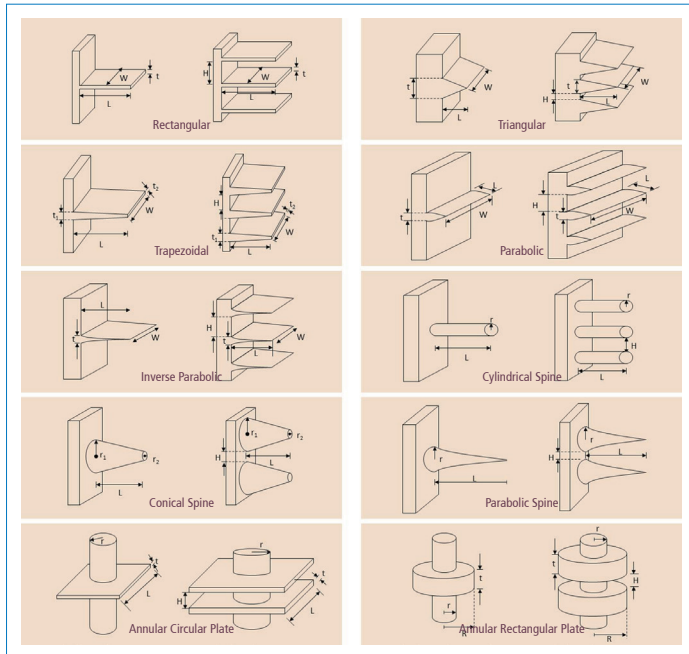
## Fin/Fin Array Analysis



### Features

- Single Fin and Fin Arrays.
- Calculation of Heat Flow Rate, Finned area, Fin Resistance, Single Fin Efficiency, Finned Surface Efficiency

### Supported Fins & Fin Arrays



## Microsoft Excel Output of Results

Design #	Description (for example, flow arrangement, multipassing, single/two phase flow etc.)	HX Problem Statement										
		Performance Requirement			Operating Conditions - Hot			Operating Conditions - Cold				
		Q	$\Delta p$ -hot	$\Delta p$ -cold	Fluid Type	Flow Rate	$T_{in}$	$P_{in}$	Fluid Type	Flow Rate	$T_{in}$	$P_{in}$
[kW]	[kPa]	[kPa]	[-]	[lb/s]	[°F]	[psi]	[-]	[lb/s]	[°F]	[psi]		
1	Cross-flow, single banking					55.997	860	0		55.116	572.02	0

HX Problem Statement						HX Size, Weight and Performance- Output					
HX Core Design Input						HX Core Dimensions					
t-sp	t-ep	w-sb-hot	h-sb-hot	w-sb-cold	h-sb-cold	P-L	P-W	L-NF/S	Np-h	Np-c	W
[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[-]	[-]	[lb]
0.012	0.012	0	0.224	0	0.224	35.43	70.9	70.9	150	150	2510

HX Size, Weight and Performance- Output								
Hot Side								
Type	N-Fin or Channel	H (Plate Spacing)	t-fin	l or $\lambda$	2a	dh	Ac	A
[-]	[1/in]	[in]	[in]	[in]	[in]	[in]	[in <sup>2</sup> ]	[in <sup>2</sup> ]
rectangular/plain	12.7	0.224	0.006			0.109	2148	376650

HX Size, Weight and Performance- Output								
Cold Side								
Type	N-Fin or Channel	H (Plate Spacing)	t	l or $\lambda$	2a	dh	Ac	A
[-]	[1/in]	[in]	[in]	[in]	[in]	[in]	[in <sup>2</sup> ]	[in <sup>2</sup> ]
rectangular/plain	12.7	0.224	0.006			0.109	1074	376650

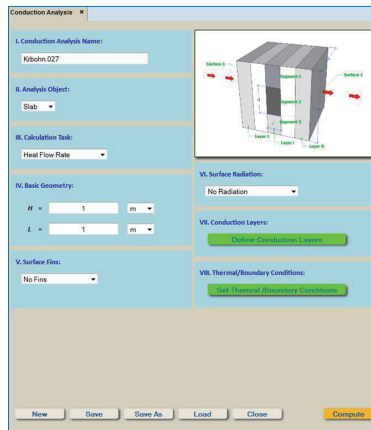
HX Size, Weight and Performance- Output										
Cold Side										
$T_{out}$	$T_{mean}$	$\Delta p$	$\alpha \Delta P$	$P_{mean}$	$\mu_{mean}$	$C_{p-mean}$	$K_{p-mean}$	Re	Pr	Nu
[°F]	[°F]	[psi]	[kPa]	[lb/ft <sup>2</sup> ]	[lb/(ft*s)]	[Btu/(lb*°F)]	[btu/(h*ft*°F)]	[-]	[-]	[-]
784.1	621.5	0.627		0.3034	0.0000215	0.253	0.029	3128	0.678	11.55

HX Size, Weight and Performance- Output								
Cold Side			Overall HX Core Performance					
$\eta hA$	P	EB	$C^*$	$\epsilon$	Q	NTU	UA	COP
[btu/(h*°F)]	[Btu/h]	[%]	[-]	[-]	[Btu/h]	[-]	[btu/(h*°F)]	[-]
542442.6	75844		0.984	0.736	10654794.2	4.282	215110.8	9.05088

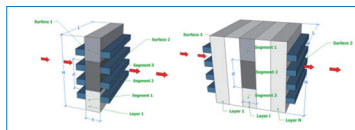
## Heat Conduction Analysis

### Features

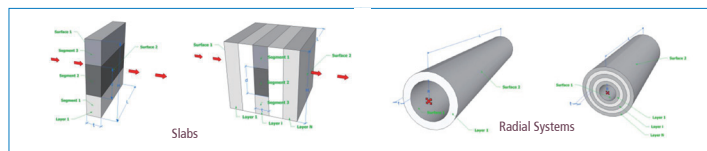
- Calculation of Total Heat Flow Rate, Thermal Resistance, Net Temperature Difference, Critical Radius (for Radial Walls only), and Thickness of a Layer



### Support for finned surfaces



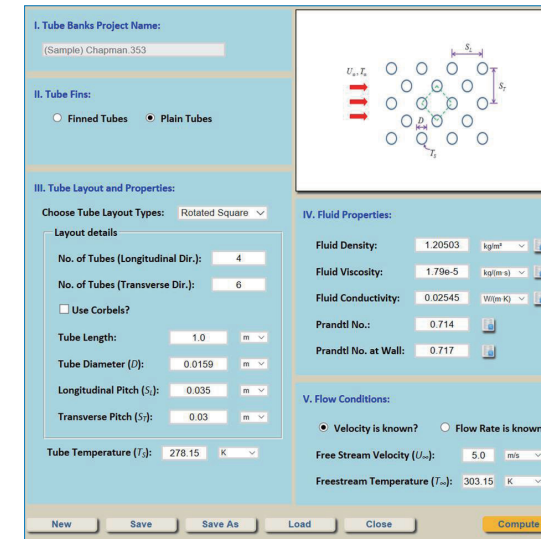
### Support for the following systems



## Tube Banks

### Features

- Plain Tubes or Finned Tubes
- Calculation of Pressure Drop, Reynolds Number, Heat Transfer Rates for Tube Banks



Calculation Result:		
Maximum Velocity:	10.638298035	m/s
Reynolds No.:	11387.125976563	
Prandtl No. Ratio:	0.995815873	
Nusselt No. (plain):	85.541069031	
No. of Tubes:	24	
Heat Transfer Coefficient (plain):	136.919509888	W/(m² K)
Outlet Temperature:	299.687255859	K
LMTD:	-23.225631714	K
Heat Transfer Rate (plain):	-3812.3359375	W
Pressure Loss (plain):	93.94808197	Pa

## INSTED Database

**Thermophysical Properties Database:**

**Fluid Properties**  
Single phase fluid, two phase fluid at equilibrium state

**Solid Properties**  
Metallic/non-metallic solid, building material, insulation material

**Thermal Analysis Database:**

**Pipe Schedules**  
Access pipe dimensions

**Tube Counts**  
Tube count data for Shell and Tube heat exchanger systems

**Minor Loss K-Factor**  
K-factors associated with the flow pressure losses for piping system

**Moody Charts**  
Calculates friction factors for pipe flow.

**Suggested Velocities**  
Economic flow velocity range for pipes

**Sample Film Coefficient**  
Contains ballpark values of the heat transfer coefficients

**Fouling Factors**  
The resistances to heat flow due to the surface residues

**Absolute Roughness**  
Average absolute roughness data for various commercial pipes

**Radiation Properties**  
Contains the normal emissivity for various surfaces

**NIST REFPROP**  
NIST refrigerant properties (License validation required)

## INSTED Database

### Features

- Includes the Following Data and More;
  - Thermophysical properties of fluids and solids
  - Pipe schedules
  - Suggested velocities for the flow 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
- Database is Integrated Throughout INSTED
- A standalone Version of the Database tool is also Available on Apple Store and Google Play

The screenshots show the 'Thermal-physical Properties' dialog box in three different states:

- Left Screenshot:** Material Type: Two Phase Fluid (Equilibrium), Material: Acetic Acid (Two-Phase), Temperature: 391.15. A table of properties is visible, including Molecular Weight (60.05), Normal Boiling Point (391.15), Melting Point (298.15), Critical Temperature (594.75), Critical Pressure (37.60), Critical Density (496.6), Saturation Temperature (356.0), and Saturation Pressure (3590000).
- Middle Screenshot:** Material Type: Single Phase Fluid at Atmospheric Pressure, Material: Al, Temperature: 100. Shows a table of properties for Aluminum.
- Right Screenshot:** Material Type: Metallic Solid, Material: Aluminum Alloy 195. Shows a table of properties for Aluminum Alloy 195, including Density (2700), Specific Heat (900), Thermal Conductivity (168), and Thermal Diffusivity (6.89e-5).



## INSTED Database

The INSTED Database software interface includes several key modules:

- Tube Counts:** A dialog box for selecting tube specifications.
  - Choose Group: 3/4 in. OD (TUBE), 1 in. SQUARE PITCH
  - Choose Shell Inner Diameter: 10 in.
  - Choose Number of Tube Passes: 2
  - Details:**
    - Tube Arrange Type: square
    - Tube Pitch [in]: 1.0
    - No. of Tube Passes: 2
    - No. of Tubes: 52
- Pipe Dimensions:** A dialog box for selecting pipe material and size.
  - Select Pipe Material: Wrought Steel / Wrought Iron
  - 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 [m²]: 0.8643188
- Moody Chart:** A dialog box for calculating friction factors.
  - Reynolds Number: 500.0
  - Pipe Diameter: 0.2 m
  - Absolute Roughness: 0.01 m
  - Buttons: Calculate, Close
- TTC REFPROP TOOL:** A detailed property calculator.
  - Substance: CH3CH3
  - Fluid Information:
    - Species: CH3CH3
    - Molar Mass: 0.030070 kg/mol
    - SMILES: C
  - Properties:
    - Molecular Weight: 30.068
    - Normal Boiling Point: 184.52 K
    - Critical Temperature: 305.5 K
    - Critical Pressure: 4.913 Pa
    - Critical Density: 212 kg/m³
    - Saturation Temperature: 285 K
    - Saturation Pressure: 3,155.5 Pa

## Mobile App for Thermal-Hydraulic Database

Android Version



The mobile app interface for Fluid Thermophysical Properties includes:

- Fluid Thermophysical Properties:**
  - SELECT FLUID TYPE: Two-Phase Fluid (Equilibrium)
  - SELECT FLUID: Ethane
  - SET TEMPERATURE [ K ]: 285
  - Button: Get Fluid Properties
- Fluid Properties Table:**

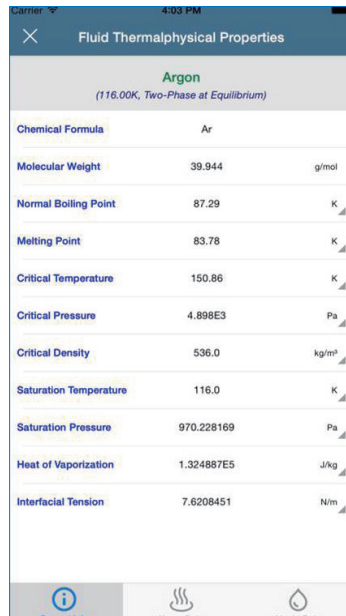
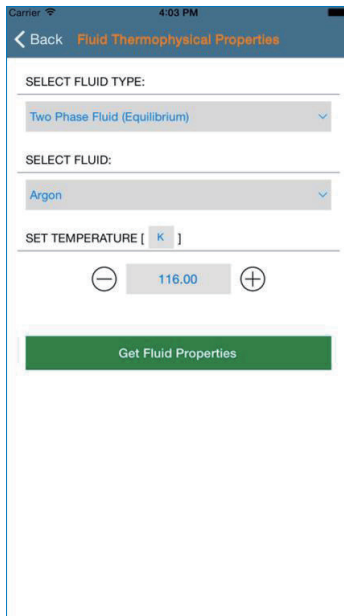
GENERAL INFO	VAPOR DATA	LIQUID DATA
Chemical Formula	CH3CH3	
Molecular Weight	30.068	[g/mol]
Normal Boiling Point	184.52	K
Melting Point	89.88	K
Critical Temperature	305.5	K
Critical Pressure	4,913	Pa
Critical Density	212	kg/m³
Saturation Temperature	285	K
Saturation Pressure	3,155.5	Pa

Say 'Thermal-Hydraulic Database' at Google Play

Google Play to launch app

## Mobile App for Thermal-Hydraulic Database

iOS Version

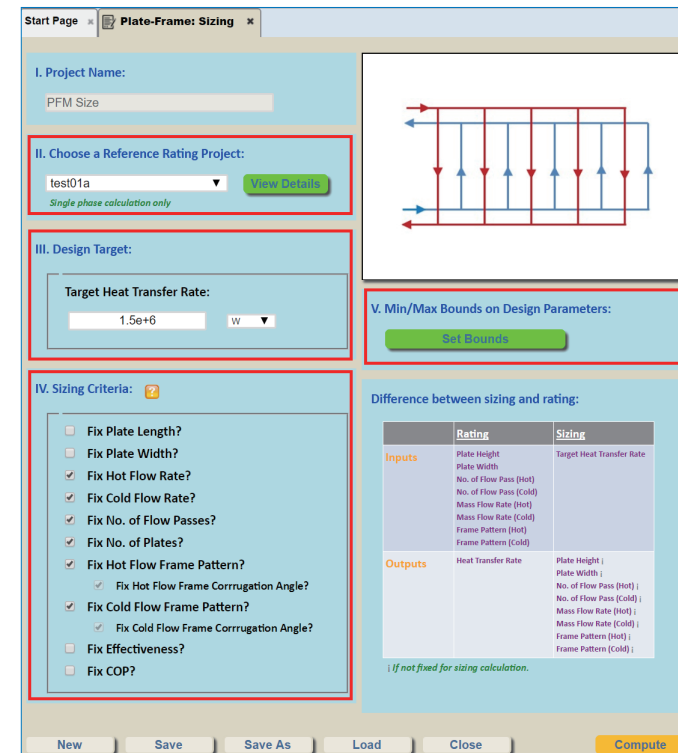


Ask Siri for 'Thermal-Hydraulic Database'

## PLATE – FRAME MODULE

Features

- Performance Analysis
- Parametric Rating Calculations
- Sizing & Optimization
- Custom j/f Data Input for Fins
- User-Defined Fin Geometry Data



## MANIFOLDS-MICROCHANNELS

Start Page x Plate-Frame: Geometry x Plate-Frame: Pla

**Plate Pattern Type:**

Manifold-Microchannel ▼

Manifold Height ( $h_{mnd}$ ) =  m ▼

Manifold Width ( $w_{mnd}$ ) =  m ▼

Manifold Thickness ( $t_{mnd}$ ) =  m ▼

Manifold Offset Length ( $l_{mnd}$ ) =  m ▼

Micro-channel Height ( $h_{ch}$ ) =  m ▼

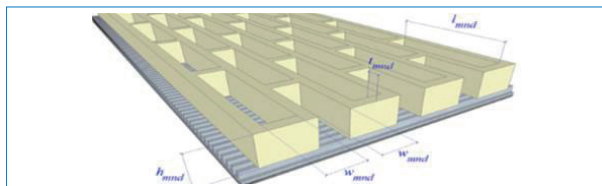
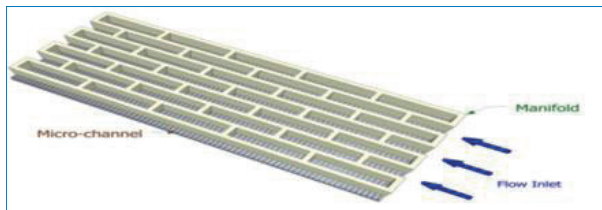
Micro-channel Width ( $w_{mnd}$ ) =  m ▼

Micro-channel Thickness ( $t_{mnd}$ ) =  m ▼

Manifold Conductivity =  W/(r) ▼

Manifold Density =  kg/m<sup>3</sup> ▼

Use user defined j/f data?



## Two-Phase Models

20 Condensation Models

17 Boiling Models

Please choose two-phase calculation models:

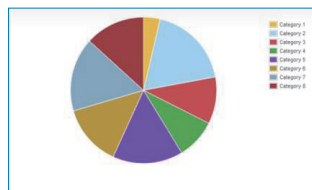
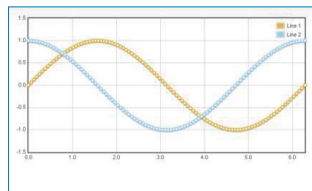
**Two-Phase Heat Transfer Models**

<p><b>Condensation Models for Hot Flow:</b></p> <ul style="list-style-type: none"> <li><input checked="" type="radio"/> Fujii</li> <li><input type="radio"/> Carpenter-Colburn</li> <li><input type="radio"/> Kosky-Staub</li> <li><input type="radio"/> Shah</li> <li><input type="radio"/> Haraguchi</li> <li><input type="radio"/> Akers</li> <li><input type="radio"/> Traviss</li> <li><input type="radio"/> Cavallini &amp; Zecchin</li> <li><input type="radio"/> Moser</li> <li><input type="radio"/> Dobson</li> <li><input type="radio"/> Azer</li> <li><input type="radio"/> Jaster-Kosky</li> <li><input type="radio"/> Tang</li> <li><input type="radio"/> Thome-El Hajal-Cavallini</li> <li><input type="radio"/> Cavallini</li> <li><input type="radio"/> Cavallini (#2)</li> <li><input type="radio"/> Shah (#2)</li> <li><input type="radio"/> Webb</li> <li><input type="radio"/> Yu-Koyama</li> <li><input type="radio"/> Palen</li> </ul>	<p><b>Boiling Models for Cold Flow:</b></p> <ul style="list-style-type: none"> <li><input checked="" type="radio"/> Chen</li> <li><input type="radio"/> Kandlicker</li> <li><input type="radio"/> Gugnor and Winterton</li> <li><input type="radio"/> Shah</li> <li><input type="radio"/> Gugnor &amp; Winterton (#2)</li> <li><input type="radio"/> Chen (#2)</li> <li><input type="radio"/> Rohsenow</li> <li><input type="radio"/> Tran-Wambsganss</li> <li><input type="radio"/> Liu &amp; Winterton</li> <li><input type="radio"/> Steiner-Taborek</li> <li><input type="radio"/> Tran</li> <li><input type="radio"/> Lazarek-Black</li> <li><input type="radio"/> Kew-Cornell</li> <li><input type="radio"/> Warrier</li> <li><input type="radio"/> Yu</li> <li><input type="radio"/> Cooper</li> <li><input type="radio"/> Fujii</li> </ul>
---	--

**Two-Phase Pressure Loss Models**

<p><b>Frictional Pressure Loss Models for Hot Flow:</b></p> <ul style="list-style-type: none"> <li><input checked="" type="radio"/> Friedel</li> <li><input type="radio"/> Lockhart-Martinelli</li> <li><input type="radio"/> Chisholm</li> <li><input type="radio"/> Wambsganss</li> </ul>	<p><b>Frictional Pressure Loss Models for Cold Flow:</b></p> <ul style="list-style-type: none"> <li><input checked="" type="radio"/> Friedel</li> <li><input type="radio"/> Lockhart-Martinelli</li> <li><input type="radio"/> Chisholm</li> <li><input type="radio"/> Wambsganss</li> </ul>
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## TTC Engineering Tools



## Sample TTC's Customers



U.S. AIR FORCE



GE Power Systems



Lockhart Industries



Ametek Hughes-Treitler



Assembly Ingenieros (Spain)



Champ Products



Korea Institute of Energy Research



U.S. Dept. of Defense



SUNY Buffalo



UTC



Virginia Tech



University of Cincinnati

Pioneering engineering  
analysis software  
for next-generation engineers

INSTED<sup>®</sup>  
Thermal Analysis Software



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Suite 206B  
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Centereach, New York 11720, USA

Email: [Info@ttctech.com](mailto:Info@ttctech.com) Website: [www.ttctech.com](http://www.ttctech.com) Phone: +1 631 285 7127 X 310

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