INSTED J/F Equation Interpreter Syntax Reference

Ver. 1.0

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Introduction

The new INSTED Release (INSTED Version 9.2) allows you to provide your own custom data for the Colburn factor j and Fanning friction factor f by simply typing the analytical expressions for j and f directly on the keyboard of your computer during an INSTED session. INSTED can interpret (parse) the typed expressions and evaluate the j and f values inside the INSTED solver at runtime. This manual gives you the details of the syntax for the mathematical expressions and operators that the INSTED equation interpreter supports. The manual starts with the basic arithmetic operators supported. Then the concept of pre-defined variables will be introduced. The list of supported intrinsic functions is also given. Lastly, relational operations to support discontinuous equations will be presented.

Limitations of the INSTED Equation Interpreter

The limitations of the current INSTED equation interpreter are itemized below:

- Only real scalar numbers are supported. Complex numbers or matrices are not supported.
- All real number are treated as double precision in order to reduce truncation errors during analysis.
- The equation string must be a single line string. Multi-line strings are not supported.
- There is currently no limit on the length on the equation string.
- White spaces will be ignored.

Basic Arithmetic Operators

The following arithmetic operators are supported:

Operators	Explanation
+	Addition
-	Subtraction / Unary Subtraction
*****	Multiplication
/	Division
%	Modulus
^	Power

Scientific Notation

Scientific notation is supported. For example, -2.5×10^5 can be written as

$$-2.5e5 \quad or \quad -2.5E5 \quad or \quad -2.5E+5 \quad or \quad -2.5E+05, \text{etc.}$$

Math Constants

The following math constants are supported

Constants	Syntax
π constant	$pi \quad or \quad PI$
Euler's constant	$e \quad or \quad E$

Intrinsic Functions

The following intrinsic functions are supported:

Intrinsic Functions	Syntax			Note
Absolute value	$\mathrm{abs}(x)$	or	$ABS(x)$	
Power function	$\mathrm{pow}(x,y)$	or	$POW(x,y)$	
Exponential function	$\exp(x)$	or	$EXP(x)$	
Square root function	$\mathrm{sqrt}(x)$	or	$SQRT(x)$	
Sign function	$\mathrm{sign}(x)$	or	$SIGN(x)$	
Natural logarithm	$\log(x)$	or	$LOG(x)$	
Common logarithm (base 10)	$\log 10(x)$	or	$LOG10(x)$	
Sine function	$\sin(x)$	or	$SIN(x)$	x in radian
Cosine function	$\cos(x)$	or	$COS(x)$	x in radian
Tangent function	$\tan(x)$	or	$TAN(x)$	x in radian
Inverse sine function	$\mathrm{asin}(x)$	or	$ASIN(x)$	return value in radian
Inverse cosine function	$\mathrm{acos}(x)$	or	$ACOS(x)$	return value in radian
Inverse tangent function	$\mathrm{atan}(x)$	or	$ATAN(x)$	return value in radian
Hyperbolic sine function	$\sinh(x)$	or	$SINH(x)$	x in radian
Hyperbolic cosine function	$\cosh(x)$	or	$COSH(x)$	x in radian
Hyperbolic tangent function	$\tanh(x)$	or	$TANH(x)$	x in radian
Inverse hyperbolic sine function	$\mathrm{asinh}(x)$	or	$ASINH(x)$	return value in radian
Inverse hyperbolic cosine function	$\mathrm{acosh}(x)$	or	$ACOSH(x)$	return value in radian
Inverse hyperbolic tangent function	$\mathrm{atanh}(x)$	or	$ATANH(x)$	return value in radian

Pre-Defined Variables

The j/f correlations are usually functions of heat exchanger geometry and/or flow and heat transfer variables such as Reynolds number, Prandtl number, fin height, fin pitch, etc. In the INSTED equation interpreter, these variables are predefined in the form “$[i]$”, where “i” is an integer. For example, in the Plate-Fin module, “[1]” represents Reynolds number and “[2]” represents Prandtl number. The complete list of pre-defined variables in the Plate-Fin module is presented in the table below:

Variable	Meaning	Note	Unit
[0]	Friction factor (f)	Some j correlations use f as one of arguments	-
[1]	Reynolds number (Re)	Single phase only	-
[2]	Prandtl number (Pr)	Single phase only	-
[3]	Hydraulic diameter (D_h)		$[m]$
[4]	Mass flux (G)		$[kg/(s \cdot m^2)]$
[5]	Plate spacing (b)		$[m]$
[6]	Fin pitch (p)		$[m]$
[7]	Fin height (h)	rectangular fin, $h = b - t$	$[m]$
[8]	Fin width (s)	rectangular fin, $s = p - t$	$[m]$
[9]	Fin thickness (t)		$[m]$
[10]	Top fin width (s_1)	trapezoidal fin only, $s_1 = p_1 - t$	$[m]$
[11]	Bottom fin width (s_2)	trapezoidal fin only, $s_2 = p_2 - t$	$[m]$
[12]	Fin profile offset pitch (l)	offset-strip fin only	$[m]$
[13]	Fin profile wavelength (λ)	wavy/herringbone fin only	$[m]$
[14]	Fin profile wave amplitude (a)	wavy/herringbone fin only	$[m]$
[15]	Fluid density (ρ)	single phase only	$[kg/m^3]$
[16]	Fluid specific heat (c_p)	single phase only	$[J/(kg \cdot K)]$
[17]	Fluid viscosity (μ)	single phase only	$[kg/(m \cdot s)]$
[18]	Fluid thermal conductivity (k)	single phase only	$[W/(m \cdot K)]$
[19]	Saturation fluid temperature (T_{sat})	two-phase only	$[K]$
[20]	Plate temperature (T_w)	two-phase only	$[K]$
[21]	Saturation fluid pressure (P_{sat})	two-phase only	$[Pa]$
[22]	Liquid phase fluid density (ρ_l)	two-phase only	$[kg/m^3]$
[23]	Liquid phase fluid specific heat ($c_{p,l}$)	two-phase only	$[J/(kg \cdot K)]$
[24]	Liquid phase fluid viscosity (μ_l)	two-phase only	$[kg/(m \cdot s)]$
[25]	Liquid phase fluid thermal conductivity (k_l)	two-phase only	$[W/(m \cdot K)]$
[26]	Gas phase fluid density (ρ_g)	two-phase only	$[kg/m^3]$
[27]	Gas phase fluid specific heat ($c_{p,g}$)	two-phase only	$[J/(kg \cdot K)]$
[28]	Gas phase fluid viscosity (μ_g)	two-phase only	$[kg/(m \cdot s)]$
[29]	Gas phase fluid thermal conductivity (k_g)	two-phase only	$[W/(m \cdot K)]$
[30]	Surface tension (σ)	two-phase only	$[N/m]$
[31]	Critical pressure (p_{crit})	two-phase only	$[Pa]$
[32]	Heat of vaporization (h_{lg})	two-phase only	$[J/kg]$
[33]	Local quality (x)	two-phase only	-
[34]	Boiling number (Bo)	two-phase only	-
[35]	Martinelli parameter (X_{tt})	two-phase only	-

Conditional Expressions

In INSTED, conditional expressions are in the form:

$$(logic\ condition)\ ?\ a : b$$

If the $logic\ condition$ is true, the conditional expression returns the value of a, else, the condition expression returns the value of b.

For example: The following expression

$$(\sin(PI/4) > 0.5)\ ?\ -1 : 0.5$$

will return value of -1.

Boolean Operators

The following Boolean operators are supported

Boolean Constants	Syntax
True	$true$ or $TRUE$
False	$false$ or $FALSE$

Relational Operators

The following relational operators are supported:

Comparators	Explanation
>	larger than
>=	larger than or equal to
<	smaller than
<=	smaller than or equal to
==	equal to
!=	not equal to

Logical Operators

The following logical operators are supported:

Logical Relations	Explanation
&&	logic AND
||	logic OR
!	logic NOT

For example, the following expression

$$!\,(\sin(PI/4) > 0.5 \,||\, \cos(0) \;== 1)\,?-1{:}\,0.5$$

will return 0.5.

More Examples

1. Dittus-Boelter correlation for j:

$$Nu \ = \ j \cdot Re \cdot \mathrm{Pr}^{1/3} = 0.023 \cdot Re^{0.8} \cdot Pr^{0.4}$$

In INSTED, the following expression can be typed on the keyboard for j:

j =
```
0.023*[1]^0.8*[2]^0.4/[1]/([2]^(1.0/3.0))
```

2. The correlations by Manglik and Bergles (1995) for j and f (offset-strip fin):

$$j \ = \ 0.6522 Re^{-0.5403} \alpha^{-0.1541} \delta^{0.1499} \gamma^{-0.0678} \times (1 + 5.269 \times 10^{-5} Re^{1.34} \alpha^{0.504} \delta^{0.456} \gamma^{-1.055})^{0.1}$$

$$f \ = \ 9.6243 Re^{-0.7422} \alpha^{-0.1856} \delta^{0.3053} \gamma^{-0.2659} \times (1 + 7.699 \times 10^{-8} Re^{4.429} \alpha^{0.92} \delta^{3.767} \gamma^{0.236})^{0.1}$$

where

$$\alpha \ = \frac{s}{h}, \ \ \delta \ = \frac{t}{l}, \ \ \gamma \ = \ t/s$$

In INSTED, the following expressions can be typed on the keyboard for the above correlations for j and f:

j =
```
0.6522*[1]^(-0.5403)*([8]/[7])^(-0.1541)*
([9]/[12])^0.1499*([9]/[8])^(-0.0678)*(1.0+5.269e-5*
[1]^1.34*([8]/[7])^0.504*([9]/[12])^0.456*
([9]/[8])^(-1.055))^0.1
```

f =
```
9.6243*[1]^(-0.7422)*([8]/[7])^(-0.1856)*
([9]/[12])^0.3053*([9]/[8])^(-0.2659)*(1.0+7.699e-8*
[1]^4.429*([8]/[7])^0.92*([9]/[12])^3.767*
([9]/[8])^0.236)^0.1
```

3. Discontinuous function example:

$$f = \begin{cases} \dfrac{16}{Re} & \text{when } Re < 2100 & \text{fully developed laminar flow} \\ 0.0054 + 2.3 \times 10^{-8} Re^{1.5} & \text{when } 2100 \leq Re \leq 4000 & \text{transition flow (Bhatti \& Shah)} \\ 0.0791 Re^{-0.25} & \text{when } 4000 < Re < 10^5 & \text{fully developed turbulent flow (Blasius)} \end{cases}$$

In INSTED, the following can be typed on the keyboard for f:

f =
```
([1] < 2100) ? (16 / [1]) : (([1] > 4000) ? (0.079 *
[1]^-0.25) : (0.0054 + 2.3e-8 * [1]^1.5))
```

Reference

Manglik, R. M. and Bergles, A. E. "Heat Transfer and Pressure Drop Correlations for the Rectangular Offset-Strip-Fin Comact Heat Exchangers," Experimental Thermal and Fluid Science, Vol. 10, 1995, pp. 171-180