SinapsPlus®
Fin Prebuilt Model

User Documentation
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1.0 Introduction

This document explains the use of the prebuilt Sinaps*Plus*® model of a constant area fin. The software and other supporting documentation are freely distributed and are available separately. To run this model, you must:

1. Install Sinaps*Plus* Version 4.6 or later for your machine (PC, Sun, or HP).
2. Install the fin prebuilt package in the location where Sinaps*Plus* was installed, per the instructions in the generic prebuilt document (available separately).

A basic understanding of SINDA/FLUINT and Sinaps*Plus* is necessary to utilize this model. Tutorials, training notes, and on-line users manuals for SINDA/FLUINT and Sinaps*Plus* are available separately, as are generic descriptions of prebuilt models and their usage. These documents (along with Sinaps*Plus* and the prebuilt package) may be accessed via C&R's web page (http://www.crtech.com). Please contact Cindy Beer at (303) 567-4514 (cindy@crtech.com) for more information, or for copies of these documents and software for those lacking Internet access.

1.1 Prebuilt Models using SINDA/FLUINT and Sinaps*Plus*

This paper documents one of a series of prebuilt models ("prebuilts") offered by Cullimore and Ring Technologies (C&R) that provide useful analysis tools to the heat transfer and fluid flow engineering community. Prebuilt models are built using SINDA/FLUINT general-purpose thermal/fluid modeling software and Sinaps*Plus*, its graphical user interface.

Prebuilts may be used without a license to run either SINDA/FLUINT or Sinaps*Plus, nor do they need the Fortran compiler normally required to execute SINDA/FLUINT.* The user of the prebuilt model will be able to change input parameters (dimensions, thermophysical properties, boundary conditions), and generate new results. Using the parametric study option, the user will be able to evaluate fin performance over a range of user-specified parameters. As explained in separately available documentation on prebuilt models, unlicensed users cannot make changes to the thermal/fluid network itself, nor to the user logic.

1.2 About This Prebuilt

This model performs a steady-state analysis of a generic constant area fin. Unlike most textbook solutions for extended surfaces which only include convective heat transfer, this prebuilt model includes simultaneous convective and radiative heat transfer to the environment. This prebuilt model was validated with several steady-state analytical solutions.[*]

This model was generated in Sinaps*Plus* (SINDA Application Programming System), a graphical SINDA/FLUINT pre- and postprocessing system. This prebuilt can be used as a design tool to easily evaluate specific system and design requirements for any constant area fin. The user can quickly perform various parametric sizing analyses through the use of pre-defined registers.

Future updates to this fin model will include transient analyses and variable areas.

1.3 Introduction to Fin Heat Transfer

Fins or extended surfaces are used to increase heat transfer in a variety of applications. This increase in heat transfer occurs because there is a substantial increase in heat transfer area. Some common applications of fin heat transfer are: automobile radiators, compact heat exchangers, evaporators, condensers and electronic heat sinks. While many fin heat transfer applications are associated with the heat rejection process, fins may also be used to improve the heat acquisition process.

The heat transfer associated with an extended surface is shown schematically for a single fin in Figure 1. Here, heat flows from the root or base of the fin, to its tip. Along the length of the fin, heat is transferred with the environment by both convection and radiation thereby producing a temperature gradient along its length. Heat transfer with the environment may also occur through the tip area of the fin. The important parameters affecting this heat transfer process are the thermal conductivity of the fin, the cross-sectional area of the fin, the surface emissivity, the convective heat transfer coefficient, the length of the fin, the base temperature, and the temperature of the surroundings.

2.0 Purpose, Capabilities, and Limitations

2.1 Purpose

The primary purpose of this prebuilt is to allow a user to perform a parametric analysis of a simple constant area fin over a range of user-specified parameters. Output maybe in the form of plots of temperature gradients in the fin, or plots of fin efficiencies or temperatures at various locations along the length of fin versus various user-specified input parameters, or coloring of the node network diagram by temperature or heat rate. For example, the user will be able to see how the performance of a fin changes as a function of environmental temperature, system dimensions, or material properties.

[*] Keller, J.R., and Vogel, M.R.,"Validation of the SINDA/FLUINT Thermal Analyzer Code Using Several Analytical Solution," SAE Paper number 961452, 1996.

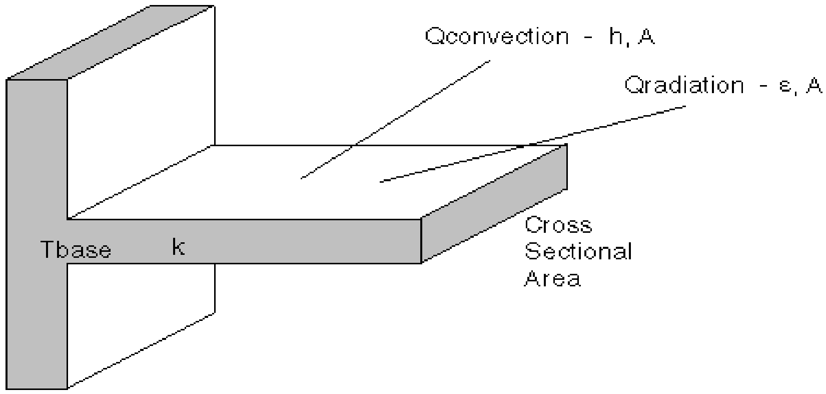

FIGURE 1. Schematic of a Constant Area Fin

Another purpose of this prebuilt is to demonstrate simple modeling in SINDA/FLUINT using Sinaps*Plus*. It can also be used by licensed users as a starting point for generating more complex models of fins.

2.2 Modeling Assumptions and Limitations

The assumptions for the fin model are:

1. The model can use either metric (m, W, K) or English (ft, BTU/hr, R) units.
2. The fin has constant thermophysical properties along its length (conductivity, specific heat, emissivity, density).
3. The cross sectional area is constant along its length.
4. The convective heat transfer coefficient is constant along its length.
5. While real fin applications have sets of fins, only one fin will be considered. This approach neglects fin to fin heat transfer.
6. There are separate sinks for both radiation heat transfer and convective heat transfer. There are many situations where separate sink occurs, such a fin at night radiating to the cold sky and being warmed by the night air.
7. The fin tip may be active (open to the environment) or inactive (insulated, or representing an adiabat by symmetry if a half-fin is being modeled).
8. Only steady-state conditions are considered: *specific heat and density inputs are currently ignored*.

The following parameters can be changed by the user:

1. The dimension of the fin (length, width, diameter, and thickness).
2. The material properties (conductivity, specific heat, emissivity, density).
3. The convective heat transfer coefficient.
4. The temperature boundary conditions.
5. The fin tip may be active or inactive.
6. Heat transfer from the edges may be turned on (open to the environment) or off (infinite fin, or adiabatic due to insulation)

3.0 Fin Model Description

3.1 User Defined Registers

Although other inputs may be changed throughout the model, like most prebuilts, the fin model is designed to use Registers as a “control panel” for making global changes to key model parameters. Registers are accessed from the left menu of the “model control” tab in the “model control” window. These registers are used throughout the model in network definitions, logic blocks, and in the calculation of other registers. The values can easily be modified by the user to tailor the analysis to a specific design or application. The registers also provide a convenient mechanism to perform parametric analyses without excessive need for user logic. The register values can be modified within the program, and then update the parameters which used the registers in their definition.

Table 1 summarizes the registers along with their default values. A more complete discussion of these variables can be found in Appendix A on page 10.

Table 1: Register Summary - Fin Model

Register Name	Initial Value	Units	Description	Change Notes
LENGTH	0.1 m	m or ft	Fin length from base to tip	must be positive
WIDTH	0.1 m	m or ft	Width of the fin	Used in the calculation of the cross-sectional area. Set to 0 for circular fins.
THICK	0.001m	m or ft	Thickness of the fin	Used in the calculation of the cross-sectional area.
DIAMETER	0.0 m	m or ft	Diameter of a circular fin	For non-circular fins set to 0.
CONDUCT	10 W/m-K	W/m-K Btu/hr - ft-R	Thermal conductivity of the fin material	Avoid choosing extremely large values (>500) or extremely low values (<0.01).
SPHEAT	1.0 J/kg - K	J/kg - K Btu/ lb_m - F	Specific heat of the fin material	Not used in this release of the prebuilt fin. For transient simulations
DENSITY	1.0 kg/m^3	kg/m^3 lb_m/ft^3	Density of the fin material	Not used in this release of the prebuilt fin. For transient simulations
EMISS	0.25	-	Emissivity of the fin surface	Must be between 0.0 and 1.0. To turn off radiation, set to near zero.
TBASE	300 K	K or R	Base temperature of the fin	Must be positive
TAMB	270 K	K or R	Convection temperature sink	Must be positive
TRAD	200 K	K or R	Radiation temperature sink	Must be positive
HCOEFF	1.0 W/m^2-K	W/m^2-K Btu/hr - ft^2-R	Convective heat transfer coefficient	Must be positive. Set to zero to turn of convective heat transfer.
SB	sbconsi	W/m^4-K Btu/hr - ft^4-R	Stefan-Boltzmann constant	Set to either sbconsi (SI) or sbcon (English). These are built-in Sinaps*Plus* register values.
ITERATE	10000	-	Maximum number of iterations	Avoid values too small

Table 1: Register Summary - Fin Model

Register Name	Initial Value	Units	Description	Change Notes
NUMNODE	25	-	Number of nodes representing the fin	This value can only be changed by a licensed user.
TIPACT	1.0	-	Sets heat transfer from tip	Set to one for tip heat transfer. Set to zero for no tip heat transfer.
THKACT	1.0	-	Sets heat transfer from edges	Set to one for edge heat transfer. Set to zero for no edge heat transfer.
PSTUDY	2	-	Puts model in the parametric study phase	See Section 4.2 for list of parameters
PMAX	100.0	-	Maximum value for the parametric study	Must be positive.
PMIN	10.0	-	Minimum value for the parametric study.	Must be less than PMAX and must be positive.
PNUM	9	-	Number of divisions for parametric study	Must be greater than one.
FINEFF	1.0		Storage location for fin efficiency, the value is calculated internally.	The user may postprocess this register to plot fin efficiency for the various parametrics.
QFIN	Defined Function	W Btu/hr	Total heat rejected by the fin. Calculated internally.	
PERIM	User Defined	m or ft	Perimeter around the fin	Maybe be overridden with a value or different expression
CSAREA	User Defined	m^2 or ft^2	Cross sectional area of the fin	Maybe be overridden with a value or different expression
GC	Defined Function	W/K Btu/hr-R	Program defined conduction conductor	See section 3.2 for definition
GR	Defined Function	W/K Btu/hr-R	Program defined radiation conductor	See section 3.2 for definition
GH	Defined Function	W/K Btu/hr-R	Program defined convection conductor	See section 3.2 for definition
GR2	Defined Function	W/K Btu/hr-R	Program defined radiation conductor for tip heat transfer	See section 3.2 for definition
GH2	Defined Function	W/K Btu/hr-R	Program defined convection conductor for tip heat transfer	See section 3.2 for definition
CN	Defined Function	J/K Btu/R	Program defined capacitance	See section 3.2 for definition

A more complete discussion of these variables can be found in Appendix A. Internal logic in the SINDA/FLUINT model is employed to ensure than the user does not input unrealistic values.

3.2 The Fin Model

The thermal submodel EXTENDED represents the fin material and the radiative and convective heat transfer to their respected environmental sinks. A summary of the node descriptions is provided in Table 2. Table 3

Table 2: EXTENDED Node Summary

NODE ID	TYPE	Description	Definition
10000	HEATER	Sets Base Temperature	
9999	BOUNDARY	Convection Sink Temperature	
9998	BOUNDARY	Radiative Sink Temperature	
1 - 25	DIFFUSION	Fin	Density*Specific Heat*Volume

summarizes the definitions and descriptions for the various conductors in the EXTENDED submodel. While the user has the ability to modify the parameters in these equations, it is not recommended that the user modify these standard text book definitions.

Table 3: EXTENDED Conductor Summary

Conductor ID	Type	Definition	Description
100 - 125	L	GH = HCOEFF*PERIM*(LENGTH/NUMNODE)	Convective heat transfer to the ambient temperature sink
200 - 225	R	GR = EMISS*SB*PERIM*(LENGTH/NUMNODE)	Radiation conductors to the radiation sink
300 - 325	L	GC = CONDUCT*(LENGTH/NUMNODE)	Conduction along the length of the fin
9998	R	GR2 = EMISS*SB*CSAREA*TIPACT	Radiation heat transfer from the tip
9999	L	GH2 = HCOEFF*CSAREA*TIPACT	Convection heat transfer from the tip

4.0 Running SINDA/FLUINT

The executable for the prebuilt fin model allows the user to perform steady state analyses for either a single condition or for a parametric study.

4.1 Generating New Results

To run this executable, change the desired calculator registers, or network inputs, and then select Run SINDA/FLUINT from the “model control” tab in the “model control” window, then Preprocess and Run-->Rerun Existing Executable.” **Unlicensed users: do not use the Clean-up option nor any other options within this submenu structure.**

Upon completion of a run, the user should find that the model has generated four files. The file EXTENDED.OUT file is the standard SINDA/FLUINT output file. The user should check file to ensure that there were no errors during the execution of the program. The file, EXTENDED.ECH, is an input check of the registers. The file EXTENDED.DAT contains the heat rejection by the fin and its fin efficiency. If the parametric study option has been selected, these results will be printed at each variable change. Finally, the model writes out the save file EXTENDED.SAV, which is used for processing.

4.2 Running Parametric Studies

A parametric study is invoked when the user sets the variable, PSTUDY, to a value from 1 to 12. The parameters that PSTUDY affects are listed below.

This variable invokes the parametric study feature of the prebuilt model. When PSTUDY is set to zero, the model will use the standard inputs. When the variable is set to one or higher, the parametric option is invoked and one variable can be altered. A list of the variables changed for different values of PSTUDY are listed below.

1 - length of the fin (LENGTH)

2 - thermal conductivity of the fin (CONDUCT)

3 - specific heat (SPHEAT) - reserved for future options

4 - density (DENSITY) - reserved for future options

5 - emissivity (EMISS)

6 - the base (root) temperature (TBASE)

7 - the ambient environment temperature (TAMB)

8 - the radiation environment temperature (TRAD)

9 - the convective heat transfer coefficient (HCOEFF)

10- the width of the fin (WIDTH)

11- the thickness of the fin (THICK)

12- the diameter of the fin, for round fins (DIAMETER)

The cross sectional area and perimeter are not included in this parametric study portion of this prebuilt model, since these terms are interrelated and a relationship describing each is needed. This would require that the internal SINDA logic be modified each time a new relationship was used, which the unlicensed user can not do.

The SINDA routine PSWEEP is used for the parametric analysis. PSWEEP performs a series of steady state solutions varying the PSTUDY variable between the values of PMIN and PMAX across PNUM increments.

5.0 Postprocessing

Once a run has been made and completed successfully, Sinaps*Plus* can be used to postprocess data in a variety of graphical methods. The user can postprocess the network based on temperature, capacitance, conductance etc. To begin postprocessing, the user should go to the submodel Extended network diagram, and choose the desired SAVE file (Save File Info under PostProcessing) as explained in Appendix B and the tutorial (available at **www.crtech.com**). Appendix B contains the portion of the Sinaps*Plus* manual which describes postprocessing. Some examples of postprocessing are presented in this section.

Figure 2 depicts postprocessing of the EXTENDED submodel nodes for the initial conditions listed in Table 1 (This is a single steady-state run). A color scale is added to the network and the nodes are displayed in color based on temperature. These color results clearly show the expected temperature decrease along the length of the fin.

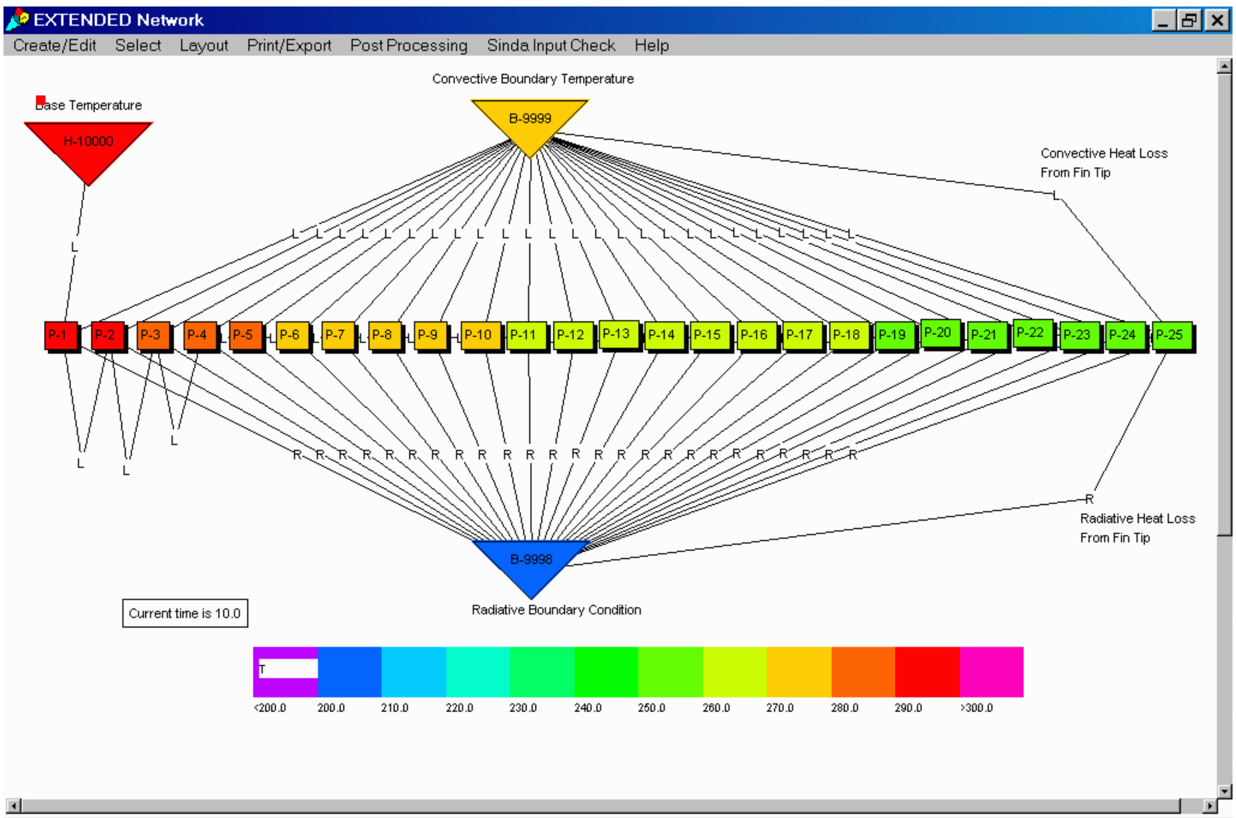

FIGURE 2. Predicted Nodal Temperatures.

In addition to coloring the nodes to evaluate the results, the results may also be plotted on X-Y plots or Bar Plots. Figure 3 shows the nodal temperatures along the length of the fin for various values of thermal conductivity. This figure was generated by setting PSTUDY to 2 (parametric study of fin conductivity), PMAX to 10 and PMIN to 5, while the rest of the variable were held to the initial register values. These results show that as the conductivity of the fin's material increases, the temperature along the length approaches the root tempera-

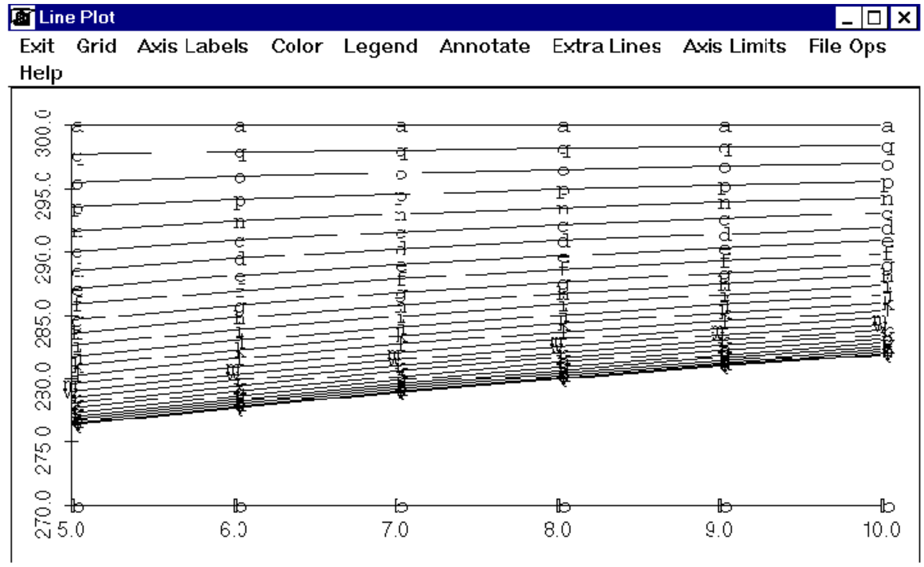

FIGURE 3. Predicted Nodal Temperature for Various Conductivities.

ture. This occurs because the thermal resistance decreases, which in turn allows more heat to be conducted down the length of the fin.

The fin efficiency is calculated in logic and stored as register FINEFF. The user may plot the fin efficiency for a parametric by selecting Registers from the model Control Panel. From the pull down menu select Post Processing --> Save File Info. A window will pop up prompting you to locate the save file. Unlicensed users cannot change the name of the save file so simply select Exit-->Save and Exit. The select Post Processing-->XY Plot for the menu. A window will pop up listing all defined registers. Find “FINEFF” and highlight it. Then select Exit-->Save and Exit. A window will then appear waiting for you to place it with the curser. After you place the window a plot will appear in the window. This plot depicts the fin efficiency as a function of save file record. In the pull down menu of the plot window select Axis Control-->X-axis Points-->Register and a window will appear listing all the register names. Select Conduct representing the thermal conductivity of the fin. Select “OK” to exit the register list. The plot now depicts fin efficiency as a function of thermal conductivity. This plot can then be enhanced as shown in Figure 4 by the user by adding axes tables, colorization, or other parameters. See the Sinaps*Plus* user manual for future details on plotting.

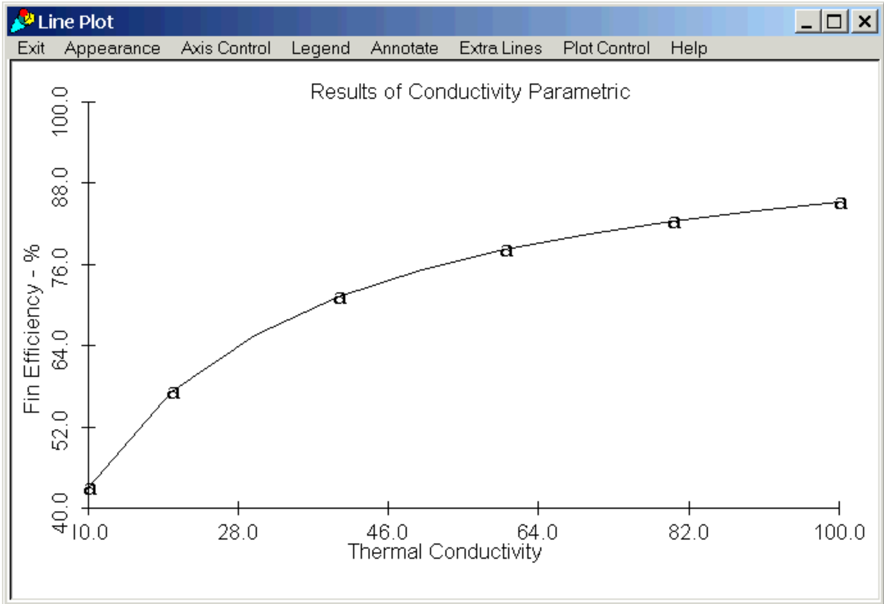

FIGURE 4. Parametric Plotting

6.0 Usage Cautions

The user should be aware of the following before running this prebuilt model.

1. When the fin conductivity is high and its length short, more iterations are required to resolve the small variations in temperature along the length of the fin. Reducing the fin thickness or conductivity, or increasing the emissivity or the heat transfer coefficient may overcome this problem.
2. There may be instances when the numeric solution is not converged. When this occurs the user will find the message “Solution Not Converged” in the output file. The user can try several of the following techniques to obtain a converged solution: increase the number of iterations (ITERATE), increase the heat transfer coefficient (HCOEFF), increase the emissivity (EMISS), decrease the thickness (THICK), and/or decrease the conductivity (CONDUCT). In some cases, all that is required is to only slightly change these value, as little as 2%.
3. The model should be run using realistic values for the thermophysical properties, the convective heat transfer coefficient, and the emissivity. If realistic conditions are not used, the model may not converge. For example, the conductivity should be no greater than 400 W/m-k (Copper), the convective heat transfer coefficient should be greater than 0.5 W/m2-K (Minimum Natural Heat Transfer Coefficient), and the emissivity should be greater than 0.03 (A Highly Polished Metal).
4. When the convective heat transfer coefficient is set to zero, the emissivity should be set a moderately large value (0.30 or greater). This ensures that the model will converge for most situations.

7.0 For More Information

For questions about this or other prebuilt models or about the use or availability of SINDA/FLUINT and Sinaps*Plus*, contact:

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If you have access to the internet, you may contact us via e-mail at info@crtech.com. Also our web site is available at www.crtech.com. This site contains demonstration versions, training materials, newsletters, manuals, and other announcements.

8.0 Appendix A - Detailed Description of the Variables

Below is a listing of all the calculator register values.

length

This term is the length of the fin from its base to its tip. This term is important in determining the conduction along the length of the fin and the convective and radiative exchange with the ambient environment.

This value must be positive.

If using the English system this value should be in feet, whereas if using the SI system this value should be in meters. The user must also change “sb” (named calculator register) if a radiation environment is active.

width

This is the width or depth of the fin when the fin has a rectangular cross section. This term should be set to zero for circular fins.

In the SI system, the width is in meters, while in the English system, the width is in feet. The user must also change “sb” (named calculator register) if a radiation environment is active.

This value must be positive.

If the csarea and perim expressions have been overridden, this value may become irrelevant.

thick

This is the thickness of a rectangular fin when the fin has a rectangular cross section. For circular fins this term has no meaning and is irrelevant.

In the SI system, the width is in meters, while in the English system, the width is in feet. The user must also change “sb” (named calculator register) if a radiation environment is active.

This value must be positive.

If the csarea and perim expressions have been overridden, this value may become irrelevant.

diameter

If a circular fin is used this is the diameter of the fin when the fin has a circular cross section. For non-circular fin this must be set to zero.

In the SI system, the diameter is in meters, while in the English system, the diameter is in feet.

Conduct

The variable, conduct, is used to describe the thermal conductivity of the fin. In the English system the term should have units of Btu/hr-ft-F. In the SI system, this term should have units of W/m-K.

This value must be positive.

Some suggested values of conductivity are listed below.

Copper (pure)	393 W/m-K	227 BTU/hr-ft-F
Aluminum (pure)	221 W/m-K	128 BTU/hr-ft-F
Steel (typical)	36 W/m-K	20.8 BTU/hr-ft-F

spheat

This term represents the specific heat of the fin material. Its units should be Btu/lb-F in the English system, while it in the SI system its units should be J/kg-K. This term is used in the calculation of transient phenomenon.

This value must be positive.

Suggested values of specific heat:

Copper (pure)	383 J/kg-K	0.165 BTU/lb-F
Aluminum (pure)	896 J/kg-K	0.385 BTU/lb-F
Steel (typical)	486 J/kg-K	0.209 BTU/lb-F

This value is not currently used. It is reserved for future options.

density

The variable, density, represents the density of the fin material. This term is used with the specific heat in the calculation of transient phenomenon. Units for density are either lb/ft3 (English) or Kg/m3 (metric).

This value must be positive.

Suggested values of density:

Copper (pure)	8900 kg/m3	556 lb/ft3
Aluminum (pure)	2740 kg/m3	171 lb/ft3
Steel (typical)	7830 kg/m3	489 lb/ft3

This value is not currently used. It is reserved for future options.

emiss

This is the emissivity of the fin. This is a unitless term. Emissivity should be between 0.0 and 1.0. By setting the emissivity to zero, radiative heat transfer is turned off.

Suggested values of emissivity are listed below.

Copper	0.10 (polished)
Aluminum	0.05 (polished)
Steel	0.20 (polished)

Tbase

This term represents the base or root temperature of the fin. This temperature can be either in Rankin (English) or Kelvin (Metric).

This value must be positive.

Tamb

This is the temperature of the ambient environment for convective heat transfer. This temperature can be either is Rankin (English) or Kelvin (Metric).

This value must be positive.

Trad

This is the temperature of the ambient environment for convective heat transfer. This temperature can be either is Rankin (English) or Kelvin (Metric).

This value must be positive.

hcoeff

This variable describes the convective heat transfer coefficient for the fin. It is assumed constant the entire length of the fin. It units are Btu/hr-ft2-R (English) or W/m2-K (metric).

This value must be nonnegative.

To turn off convection to the environment set hcoeff to zero.

sb

This is the Stefan-Boltzmann constant and it is used for radiative heat transfer. In the English system its value is 1.712E-9 Btu/hr-ft2-R4 and in the metric system it is 5.67E-8 w/m2-K4. These values are stored as built-in Sinaps*Plus* registers: “sbcon” and “sbconsi”, respectively. Set “sb” to “sbcon” when using English units and to “sbconsi” when using metric units.

If the emissivity has been zeroed, the value of this constant is irrelevant.

iterate

This is the maximum number of iterations that the code will perform before giving up on a steady state solution. This term sets NLOOPS in the SINDA/FLUINT Model.

numnodes

This is the number of segments into which the fin is subdivided.

THIS VALUE SHOULD NOT BE CHANGED BY THE UNLICENSED USER. It is supplied for the convenience of licensed users. Changing facilitates the task of changing the fin resolution, but the user must still add/delete nodes and conductors in the diagram window.

tipact

This factor controls whether or not the fin tip is exposed to the radiation and/or convection environment. It is set to 1.0 initially, meaning the tip is active. To turn off heat transfer at the tip (adiabatic, perhaps by symmetry) set this value to zero.

thkact

This factor controls whether or not the fin edge is exposed to the radiation and/or convection environment. It is set to 1.0 initially, meaning the edge is active. To turn off heat transfer at the edge (adiabatic, perhaps by symmetry) set this value to zero.

pstudy

This integer variable invokes the parametric study feature of the prebuilt model. When pstudy is set to set to zero, the model will use the standard inputs. When the variable is set to one through twelve the parametric option is invoked and one variable can be altered.

pmax

This is the maximum value to be used in the parametric study.

pmin

This is the minimum value to be used in the parametric study.

pnum

This is the number of steps to be used in the parametric study. Must be an integer.

fineff

Storage location for fin efficiency, the value is calculated internally and should not be changed by the user. The user may postprocess this register to plot fin efficiency for the various parametrics.

qfin

Total heat rejected by the fin. This term is calculated internally and should not be changed by the user.

Units: Watt or BTU/HR

csarea

The variable, csarea, is the constant, cross-sectional area of the fin. This term is currently set to calculate the cross sectional area for either a circular or rectangular fin. It is recommended the user not alter the formula.

This value is important in determining the conduction along the length of the fin. For a rectangular fin, this area is its thickness multiplied by its width (the initial expression). For a circular fin, the cross sectional area is PI multiplied by the radius squared (“pi” is a built-in Sinaps*Plus* register).

This value must be positive.

If using the English system this value should be in feet, whereas if using the SI system this value should be in meters. The user must also change “sb” (named calculator register) to the appropriate units system, if a radiation environment is active.

perim

Perim is the perimeter of the fin. This term is currently set to calculate the perimeter for either a circular or rectangular fin. It is recommended the user not alter the formula.

This parameter is important in determining the convective and radiative heat transfer from the surface of the fin. For a rectangular fin the perimeter is twice the thickness plus twice the width (the initial expression). If only one side of the fin is active, set perim equal to the width. For a circular fin, the perimeter is diameter multiplied by PI (“pi” is a built-in Sinaps*Plus* register).

This value must be positive.

If using the English system this value should be in feet, whereas if using the SI system this value should be in meters. The user must also change “sb” (named calculator register) to the appropriate units system if a radiation environment is active.

9.0 Appendix B - Selected Post Processing Sections from the Sinaps*Plus* Manual

After SINDA/FLUINT has been executed, the results that it produces can be visualized using the Sinaps*Plus* post-processing features. Perusing SAVE files and manipulating display options is the domain of the **post processing** option of the main menu. Once **post processing** is chosen the user is led into a menu tree where various options maybe utilized. This section is generic for all Sinaps*Plus* usage, not just for this pre-built.

9.1 Save Files

This section describes the selection and usage of save files that are produced by SINDA/FLUINT.

Selecting the Save File

Before any postprocessing can be performed, a save file must be specified. When the user picks save file info from the post processing menu a data form will appear. At the top of the form, the user chooses the source machine from the available machine types (SUN, HP, PC). Use the *select* button to select the type of machine which produced the save file (e.g., if SINDA/FLUINT was run on a SUN and that was where the save file was created - select SUN).

In the middle of the form is a field in which the user enters the name of the save file, including possible subdirectory information. If the user is unsure of the name or location of the save file, the button near the bottom of the form, Find Save File, may be used to invoke a file selector window.

If SINDA/FLUINT has been rerun without changing the save file name, then the user must so indicate to Sinaps*Plus* via the reopen button. Otherwise, the save file from the previous postprocessing session will still be used.

9.2 Color

The color options provide a means to color nodes, lumps, conductors, paths and ties by data values that are found on a SINDA save file, or that can be calculated using those values. The user has control over the color scaling, and is able to step through or *animate* the save file and monitor changes propagating through the network.

9.2.1 Setting a Time

Before any color displays maybe created, the user must first specify the desired time or record in the save file that contains the data. This is accomplished by selecting the Set Starting Time/Record option in the Post Processing pull down. When this option is selected, a scrolling list of records will be displayed. Pressing and releasing the *select* mouse button over a highlighted time/record will select that time. When colorization is later performed, a boxed comment will appear that lists the current time being postprocessed.

9.2.2 The Color Bar

When a set of objects are colored, a color bar will appear. The characteristics of this color bar may be set before or after it is displayed. The user has control over whether or not the bar is autoscaling, and if not, what the minimum and maximum values should be. There are toggles for a vertical or horizontal bar and toggles for color or grey scale. The user may also control the number of colors that are used by the bar. For certain directional values such as heat rates, flow rates, delta pressures, and delta temperatures, the user can signal that only the absolute value of requested data is to be displayed via the abs. value button.

Note: *The displayed scale numbers represent the edges and not the centers of each data range*. When autoscaling is off, values out of range are colored or shaded according to the ends of each bar (roughly, purple and pink), which were chosen to catch the user’s attention.

The data for new option is used to set the characteristics of the next color bar to be created. The edit old option allows the use to select a color bar and then edit the characteristics of that bar, although simply double-clicking the color bar is a faster means of modifying an existing color bar. The network will then be recolored to reflect the changes in the color bar. Color bars may also be resized with the resize option, whereby the user indicated the desired dimensions (and location) via an areal drag.

The reset option is used to remove all color bars from the graph, and the remove option can be used to delete them individually. Color bars may also be selected and moved like any other icon, using either the menu bar or the <shift> *select* keys. (The latter provides a convenient means of bringing the color bar over to a particular colored icon in order to compare colors.)

Up to three color bars may be displayed simultaneously: one for nodes/lumps, one for conductors/paths, and a third one in FLUINT models for ties.

9.2.3 Selecting Objects to Color, and Values by Which to Color

Object selection for post processing is performed by the same methods used elsewhere in Sinaps*Plus*. Furthermore, operations not applicable to certain selected items will be ignored by those items (e.g., coloration of nodes will not affect any inadvertently selected conductors, etc.). The user will then be shown a select menu to obtain the parameter to be read (T, C, TL etc.), and the network will be colored. As with other post processing options, many values are derived (e.g., delta temperature or pressures) and have no standard representation in SINDA/FLUINT.

After selecting the items and the operations for the first time, a box will appear under the cursor for placement. This box describes the current time being postprocessed. Next, a color bar will appear for placement, and the selected network items will be colored as requested.

9.2.4 Stepping Through a Save File

Once one or more groups of objects have been colored, the user may step through the save file. This is accomplished with the next time, current time, previous time and animate options under the Color/Thickness Control menu. If multiple groups of objects have been colored (e.g., nodes and conductors), stepping through the save file will update all of them. (This option also updates any thicken-by-value operations that have been requested, as will be described below in Section 9.3.)

There are two options for updating the display that are controlled by editing the color bars. If autoscaling is on, then stepping through a save file will update the scaling numbers of the color bar. If autoscaling is turned off, the colors will change on the nodes/lump and conductors/paths etc. As guidance, note that the color bar default of *autoscaling is usually undesirable when stepping through or animating results*. Otherwise, the scale changes while the color of the selected icons remains roughly invariant. On the other hand, when using fixed scaling the user must apply foresight in selecting the scale limits to avoid ranges that are too limited.

The animate option will bring up a data form that allows the user to specify how many steps to take through the save file and whether Sinaps*Plus* should wait for a mouse click between steps or step continuously. The user also has control over whether the steps are forward or backward through the file and if save file records should be skipped between the steps. The user may step by time or by record number.

9.3 Thickness

Conductors, paths and ties may be thickened by value. This operation is analogous to the previously described color operations, except that the objects are thickened instead of (and perhaps in addition to) being colored. The user is encouraged to explore this option, since thickening often results in presentations that are more intuitively understood than colorization.

Objects may be both colored and thickened independently. For example, conductors may be simultaneously colored by conductance and thickened by heat rate, while nodes are colored by temperature. This usage visually provides the same information as does QMAP.

When a group of objects are thickened a thickness scale will appear that will follow the cursor until dropped in its final location. The numbers on the thickness scales represent edges, rather than centers of each range. Caution should be used when interpreting data if negative values are present, since the thickness scale is one dimensional. An **abs. value** option is available if helpful in such circumstances.

The thickness scale are editable in a manner analogous to that of color bars, and they contain analogous suboptions whose descriptions will not be repeated here. Analogous to the number of colors in a color scale, the user may select the number of lines in a thickness scale. The user should note that turning off autoscaling for thickness scales can sometimes result in exceptionally thick lines, and that for this reason an upper limit (approximately one inch) is placed on the maximum possible thickness for any tie, path, or conductor.

9.4 Plotting

Sinaps*Plus* provides a number of different plotting options, including X-Y plots, bar plots and polar plots. Any information found on the SINDA save file may be displayed with these options.

9.4.1 X-Y Plots

Several types of X-Y plots may be created: plots of variables versus time (or save file points or snapshots, in the case of sets of parametric steady-state), plots of variables versus icon position, plots of variable verses loop count and plots of variable verses registers. In the first case, the user need not first specify the starting time since the entire save file will be plotted by default.

As with colorization options, once a group of objects is selected, a query form will appear to determine which information to plot. This selection form will be appropriate to the type of object selected (e.g., nodes will query for T, Q and C, conductors for G).

Sinaps*Plus* will then produce an independent X-Y plot window which the user may place and size like any other Sinaps*Plus* window. (Resizing the window automatically resizes the plot.) Once the plot is created, a number of options exist within the plot window.

The various plot options that will be described below allow the user to toggle a grid, color the lines, add or edit labels for the X and Y axes, save the plot (to be accessed later from the edit old plot option), and print.

9.4.1.1 Legends

Legends may be turned on or off, moved and edited. When the legend is turned on or moved, it will follow the cursor until the *select* button is pressed (like placing a node). The on/move/refresh option brings up a new legend, and allows its placement. The old legend will remain until the new one is placed, at which time the old legend will be erased. Legends may also be turned off (the default state).

If edit is chosen, a text editing window will appear that contains the legend text. Once saved, the new legend will appear for placement.

9.4.1.2 Annotations and Extra Lines

Annotations (comments) are added in a manner analogous to that used to create comments in a network diagram. If annotate is chosen a window will appear to obtain the annotation text. Once this text is accepted, the text will appear on the plot and will follow the cursor until the *select* button is pressed.

The extra lines choice will cause a select cursor to appear. Place the cursor over the start point of the line and press the *select* button. A line will then appear that will follow the cursor until the *select* button is pressed again.

Legend annotation and extra line positions are window dependent. If you resize the window it is likely that these items will no longer be in the appropriate position.

Note that the usual mode of select-then-operate is not available for editing plots. The user must first select the operation from the pull-down menu bar, or from the pop-up *operate* menu, and a select cursor will appear to prompt the user to choose the desired element (e.g., annotation, extra line, etc.)

9.4.1.3 Appearance (Grids and Coloring Lines)

If desired, a grid can be toggled on or off. This grid follows the resolution of the axes, which can be customized separately (Section 9.4.1.4).

If more than one value is plotted and it becomes difficult to distinguish between lines, the user may choose to color the data lines. When this option is chosen, the program assigns a distinct color to each line. An internal list of approximately 8 distinct colors is used, and plotting more than that number of data values in one plot will result in at least two lines sharing the same color.

9.4.1.4 Axis Limits and Expressions

The axis limits may be changed so that all or part of a set of curves is visible. If axis limits is chosen a data form will appear to obtain the new minimum, maximum and step size for each axis. Only data points falling within the chosen range will be shown, potentially truncating some lines.

In addition to scaling specifications, an expression may be applied as a filter for the data being plotted along each axis. In other words, mathematical operations can be specified that operate on the data being plotted in order to change units for display purposes, etc. This expression may be consist of any equation that is recognized by the Sinaps*Plus* calculator but should include the name of the axis (X or Y). For example to change the X axis from hours to seconds enter “x*3600.0” or to change the Y axis from degrees F to degrees C enter “(y-32.0)/1.8”.

These expressions do not apply to the range limits (in the upper part of the form), since those values are based on the raw data. The original data (i.e., that contained on the save file) was produced in units of hours, but the plot shows units of seconds along the x axis. Thus, the axis limits in the top part of the form are defined in terms of hours, but the expression in the bottom field converts the display units to seconds.

The “X Axis Points” option in the Axis Control pull down menu allows the user to select which parameter is to be plotted on the X axis.

9.4.1.5 Plot Control

Under the Plot Control pull-down are several options which can greatly enhance the presentation of the SINDA/FLUINT predictions and the control the appearance and usefulness of plots. These features allow the plotting of results from different submodels and from different save files in addition to manipulating plot items and plotting from multiple submodels. It is important to note that a plot must first be created before the plot control features can be invoked.

9.4.1.6 File Ops: Saving, Printing, and Exporting Data

Plots may be saved independently of models and images via the File Ops --> Save Plot option. The resulting machine-independent binary file may be used for archival purposes, or can be read into any model desktop. Although the plot can then be changed and edited, the underlying data upon which the plot is based will remain unchanged as later post processing operations are performed, including save file changes. (To access new data, a new plot must be created.) The purpose of this option is to enable users to exchange plots, to prepare and save report graphics independently of other model changes.

A print option also exists under File Ops, which operates analogously to the network diagram print option. As part of the print option the user will be prompted for a plot title. In addition the user will have a choice of portrait or landscape modes as well as control over the plot scaling.

An important option under File Ops is Save Points, which allows the user to export files containing ASCII tables of the data underlying the plot. These tables can then be imported into third party plotting software or spreadsheets.

9.4.1.7 Plotting vs. Location

In addition to X-Y plotting by time, Sinaps*Plus* provides for plotting vs. *icon* location. To plot by location, select group of nodes or lumps are chosen and then choose a data value (temperature etc.) to plot. A plot of temperature versus the location of the nodes and lumps in the diagram will be produced.

Since there is no actual geometry in Sinaps*Plus, the location displayed is the relative screen location of the object in units of pixels*. However, if the user has evenly spaced the icons, then the Sinaps*Plus* depiction may be used to represent a spatial relationship. The axis scaling expressions (Section 9.4.1.4) can then be used to convert to real dimensions. The legend lists the screen locations to aid in the development of the rescale expression.

For example, if 10 nodes were known to represent 33.4 feet of a rod, and the legend in the plot showed the x axis limit to be 1032 pixels, then the following expression can be used to convert the display diagram from pixels to feet: "x*33.4/1032."

The reader should note that certain gradient information is also accessible by coloring and/or thickening paths, ties, and conductors by delta temperature or delta pressure.

9.5 Bar Plots

These plotting options work in the same manner as X-Y plots; refer to the prior subsection for a description. One of the few differences is that bar plots have a slightly different axis limits form since there is only one axis (the "y" or independent variable axis) that may be scaled.

Bar plots also provide a unique and very useful node/lump balance option that is similar to the SINDA/FLUINT NODMAP and LMPMAP routines. This type of plot may only be performed on a single node or lump. A bar plot can be produced that shows the energy into and out of the node on a per conductor/path basis. For lumps, the user has a choice of mass flowrate, energy flowrate, tie conductance or tie heat rate as the plotting criteria. The legend in such plots contains further details about the node or lump in question.

Lump balance plotting can only be performed if the save file record was created using the 'ALL' option in the SAVE or RESAVE argument. Otherwise, Sinaps*Plus* will report an error reading the save file since all required information could not be found in that file. Also, all relevant network elements (nodes, conductors, etc.) should be depicted within Sinaps*Plus*, and should not be contained within INCLUDE files. Otherwise, misleading plots may be produced.

Since SAVE files produced by SINDA/FLUINT Version 2.6 and earlier contain no information regarding which subset of submodels are currently active (i.e., named on the current BUILD statement), Sinaps*Plus* considers all submodels to be active at all times under such circumstances. For node and lump balance plots where the BUILD or BUILDF configuration changes, this may cause spurious heat and mass flows to appear to elements in other models that are not currently active. Heat flows for active paths and conductors will be correct, but the net term may be in error. This difficulty does not exist when using SINDA/FLUINT Version 3.0 and later.

9.6 Text Output

In addition to plots and colorization and thickening, the user may request ASCII text output for requested post processing operations. This option allows the user to request data for the current time, or for all times. When invoked, a pop-up text edit window will appear containing the requested data. This option is supplemented by the **Text** option feature found under bar, and X-Y plots.

9.7 Submodel Initialization

Initialize Submodel operates analogously to the model-level option. However, in this option the save file already selected for postprocessing will be used for the initialization, which will be confined to the current submodel only. The user must use the set starting time/record option to determine which data is to be read.

Warning: Using this option will destroy any expressions (including calculator register references) entered into data fields. SIV options and other similar time- and temperature-varying options that are calculated at run time are not affected by this operation. **Initialize Submodel should not be used by unlicensed users**.