NIST Technical Note 1889v2

CFAST – Consolidated Model of Fire Growth and Smoke Transport (Version 7)
Volume 2: User's Guide

Richard D. Peacock
Paul A. Reneke
Glenn P. Forney

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National Institute of
Standards and Technology
U.S. Department of Commerce

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U.S. Department of Commerce
Wilbur L. Ross, Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Undersecretary of Commerce for Standards and Technology

CFAST Developers

The Consolidated Model of Fire and Smoke Transport (CFAST) and Smokeview are the products of a collaborative effort led by the National Institute of Standards and Technology (NIST). Its developers and contributors are listed below.

Principal Developers of CFAST

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Glenn Forney, NIST
Paul Reneke, NIST
Kevin McGrattan, NIST
Walter Jones

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About the Developers

Richard Peacock is a chemical engineering in the Fire Research Division of NIST. He received a bachelor of science degree from the Clark School of Engineering of the University of Maryland in 1973. He joined the NIST staff in 1974 (then the National Bureau of Standards) and has worked on real-scale testing and the development and validation of fire models, most notably CFAST.

Glenn Forney is a computer scientist in the Fire Research Division of NIST. He received a bachelor of science degree in mathematics from Salisbury State College and a master of science and a doctorate in mathematics from Clemson University. He joined NIST in 1986 (then the National Bureau of Standards) and has since worked on developing tools that provide a better understanding of fire phenomena, most notably Smokeview, an advanced scientific software tool for visualizing Fire Dynamics Simulation data.

Paul Reneke is a computer scientist in the Fire Research Division of NIST. He received a bachelor of science degree in mathematical sciences from Clemson Univerity and a master of science degree in applied mathematics from The Johns Hopkins University. He joined NIST in 1990. He has worked on the development of user interfaces, graphics and improved numerics in fire models, notably CFAST. His research interests include sensitivity analysis and validation of fire models.

Kevin McGrattan is a mathematician in the Fire Research Division of NIST. He received a bachelor of science degree from the School of Engineering and Applied Science of Columbia University in 1987 and a doctorate at the Courant Institute of New York University in 1991. He joined the NIST staff in 1992 and has since worked on the development and validation of fire models, most notably the Fire Dynamics Simulator.

Walter Jones was a physicist at NIST (now retired). He received a bachelor of arts degree in physics from Oberlin College and a doctorate in physics from the University of Maryland. He was the original developer of the CFAST model. In addition to the development of fire models, he has worked on smart fire alarms and smoke control for naval vessels.

Disclaimer

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Intent and Use

The algorithms, procedures, and computer programs described in this report constitute a methodology for predicting some of the consequences resulting from a prescribed fire. They have been compiled from the best knowledge and understanding currently available, but have important limitations that must be understood and considered by the user. The program is intended for use by persons competent in the field of fire safety and with some familiarity with personal computers. It is intended as an aid in the fire safety decision-making process.

Abstract

CFAST is a two-zone fire model capable of predicting the environment in a multi-compartment structure subjected to a fire. It calculates the time-evolving distribution of smoke and gaseous combustion products as well as the temperature throughout a building during a user-prescribed fire. This report describes the use of the model, including installing and running the software, the computer platforms upon which it is supported and examples to verify correct installation.

Acknowledgments

Continuing support for CFAST is via internal funding at NIST. In addition, support is provided by other agencies of the U.S. Federal Government, most notably the Nuclear Regulatory Commission Office of Nuclear Regulatory Research and the U.S. Department of Energy. The U.S. NRC Office of Nuclear Regulatory Research has funded key validation experiments, the preparation of the CFAST manuals, and the continuing development of sub-models that are of importance in the area of nuclear power plant safety. Special thanks to Mark Salley and David Stroup for their efforts and support.

Support to refine the software development and quality assurance process for CFAST has been provided by the U.S. Department of Energy (DOE). The assistance of Subir Sen and Debra Sparkman in understanding DOE software quality assurance programs and the application of the process to CFAST is gratefully acknowledged. Thanks are also due to Allan Coutts, Washington Safety Management Solutions for his insight into the application of fire models to nuclear safety applications and detailed review of the CFAST document updates for DOE.

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Chapter 1

Getting Started

The Consolidated Model of Fire and Smoke Transport (CFAST) is documented by four publications, this user's guide, a technical reference guide [1] a verification and validation guide [2], and a configuration management guide [3]. The technical reference guide describes the underlying physical principles, provides a comparison with other models, and includes an evaluation of the model following the guidelines of ASTM E1355 [4]. The model verification and validation guide documents verification and validation efforts for the model. The configuration management guide documents the processes used during the development and validation of the model. This user's guide describes how to use the model and the input editor CEdit.

1.1 Installation

The installation of CFAST is made up of thre programs. The main program, CFAST, is written in Fortran and can be run as a stand alone command line application that reads input data from a text file. It has been compiled and run on a number of different operating systems but the version in the distribution was compiled to run under Windows. The input editor, CEdit, that is distributed with CFAST is designed to run on a Windows platform. Also the version of the visualization software, Smokeview, is compiled to run on Windows. All of the files associated with CFAST can be obtained at: `http://cfast.nist.gov`

The CFAST distribution consists of a self-extracting set-up program for Windows-based personal computers. After downloading the set-up program, double-clicking on the file's icon walks you through a series of steps for installation of the program. The most important part of the installation is the creation of a folder (`C:\Program Files\CFAST` by default) in which the CFAST executable files and supplemental data files are installed. Sample input files are found in the `Examples` folder.

CFAST input files are best created and run using a Windows-based input editor called CEdit. Sample input files are provided with the program for new users who are encouraged to first run the sample calculations before attempting to create an input file. To run the model, browse to the location of the CFAST sample input file (default location is in a folder called `Examples` in the installation folder) copy the file named `Users_Guide_Example.in` to a location of your choice and then double click on the copied file. This should open the file in the CFAST input editor, CEdit, as shown in Fig. 1.1. The simple test case can be run from the program window by clicking

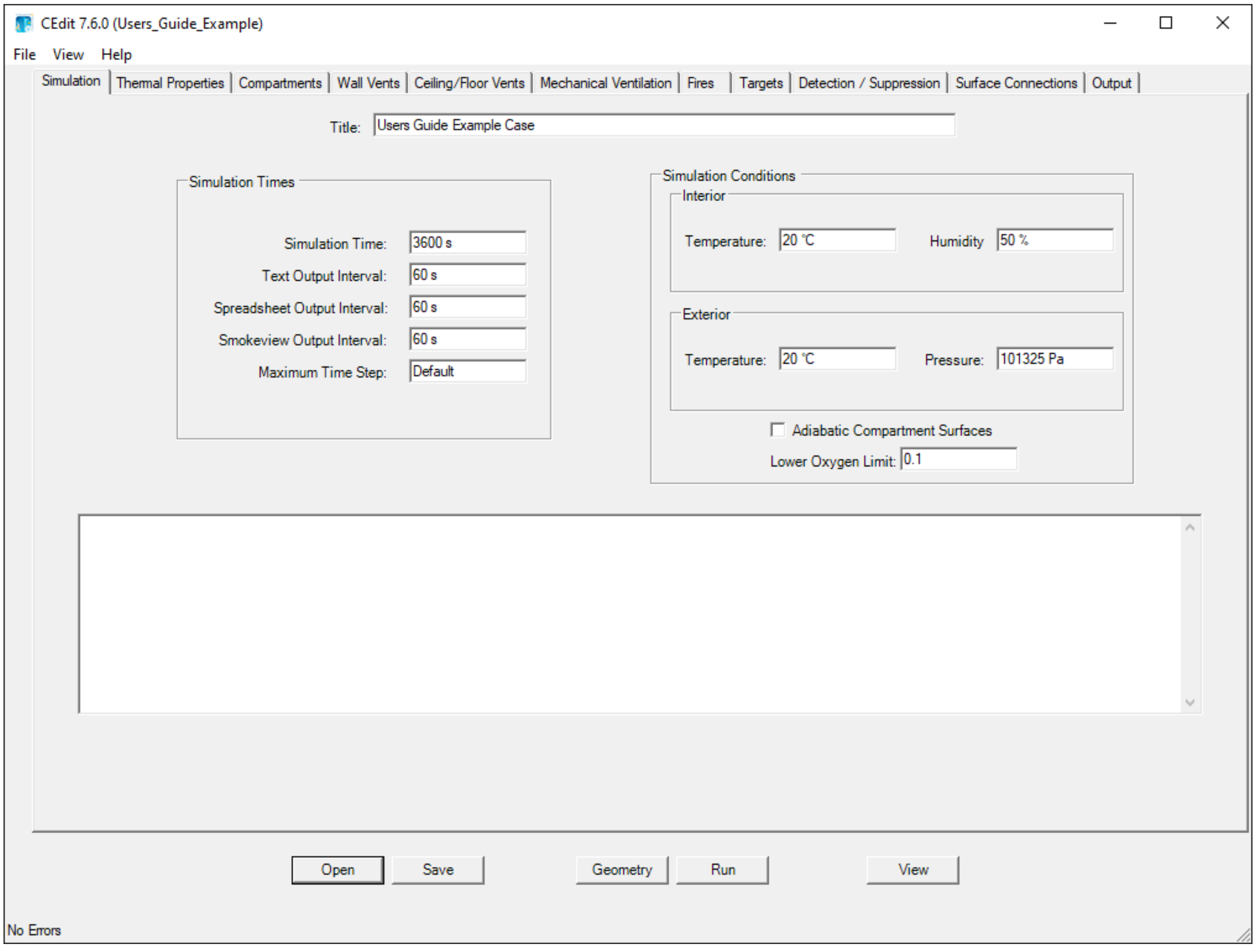


Figure 1.1: The Primary CFAST Input Page.

on the “Run” button. The case should finish in a few seconds. To verify that the installation has been done correctly, the output of the model should appear as shown in Fig. 1.2.

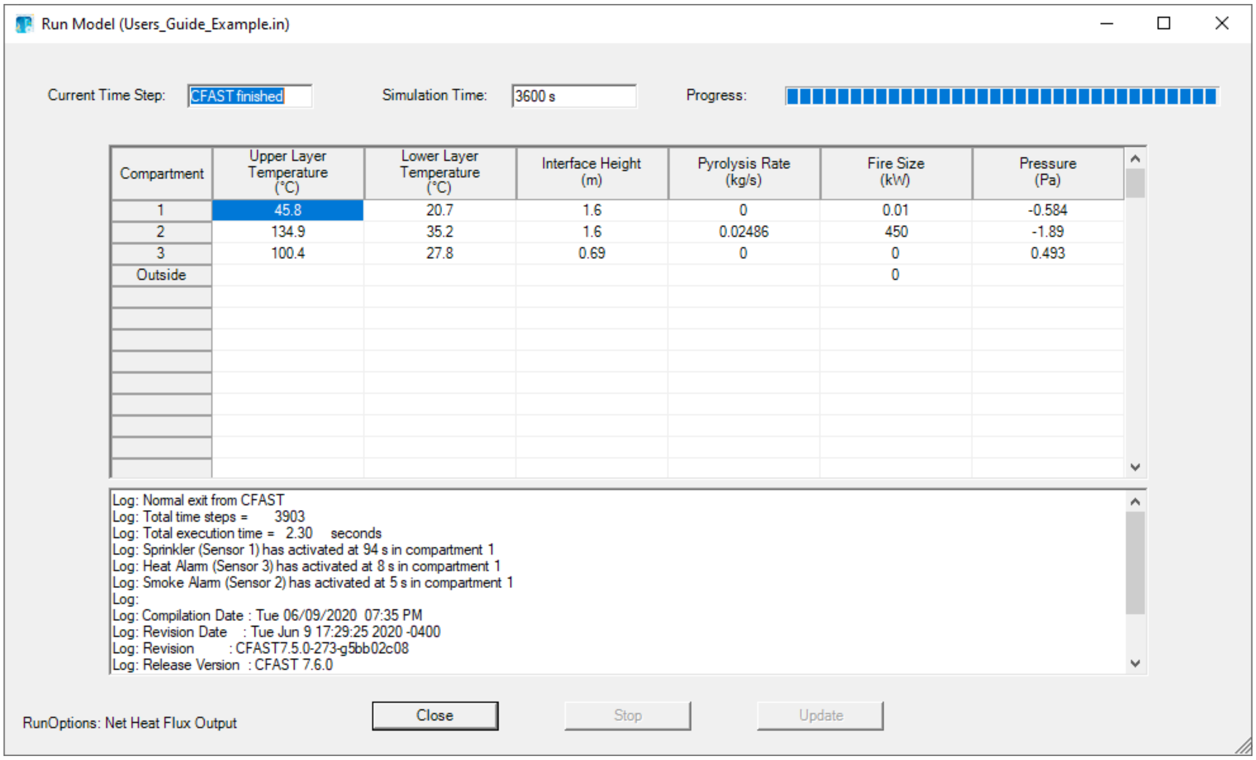


Figure 1.2: The Standard CFAST Output Screen.

1.2 Basic Features

The input parameters are organized via tabs near the top of the CEdit window, as shown in Fig. 1.1. The tabs are:

Simulation Environment includes simulation time, specification of model outputs, and ambient conditions. Also included on the page is a constantly updated list of errors, warnings, and messages about the input file specification or model simulation.

Thermal Properties defines the thermal conductivity, specific heat, density, thickness and emissivity values for all materials and fuel sources used in a simulation.

Compartments defines the size, construction characteristics, and position of the compartments in a simulation.

Wall Vents define doors and windows.

Ceiling/Floor Vents define holes in the ceiling/floor.

Mechanical Ventilation defines forced air ventilation.

Fires include user specification of the initial fire source and any additional burning objects in one or more of the compartments of the simulation.

Targets provide the ability to calculate the temperature and net heat flux to objects placed and oriented arbitrarily in the structure.

Detection / Suppression defines any heat or smoke alarms and sprinklers in the compartments of the simulation.

Surface Connections allows for more detailed description of the connections between compartments in the simulation to better simulate the transfer of heat from compartment to compartment in the simulation.

Visualizations allows specification of one or more 2-D and 3-D visualizations to be added to the simulation for viewing with Smokeview. Note that these can require significant additional computational time than a basic CFAST simulation without visualizations.

1.3 The View Menu

The View menu allows you to view or print the input data file, output file (if the simulation has been run and a text output file generated) and the log file of the simulation. If one of the items does not exist on the user's hard disk, the selection is grayed out.

Select Engineering Units allows you to select the units for input and output. By default, most outputs are in S.I. units, with temperature in Celsius.

1.4 The Help Menu

The Help menu accesses this user's guide, the CFAST web site, or an about dialog box that displays the user license and version of the program.

Chapter 2

Simulation Environment

The Environment page defines the initial conditions and simulation time for the CFAST input file.

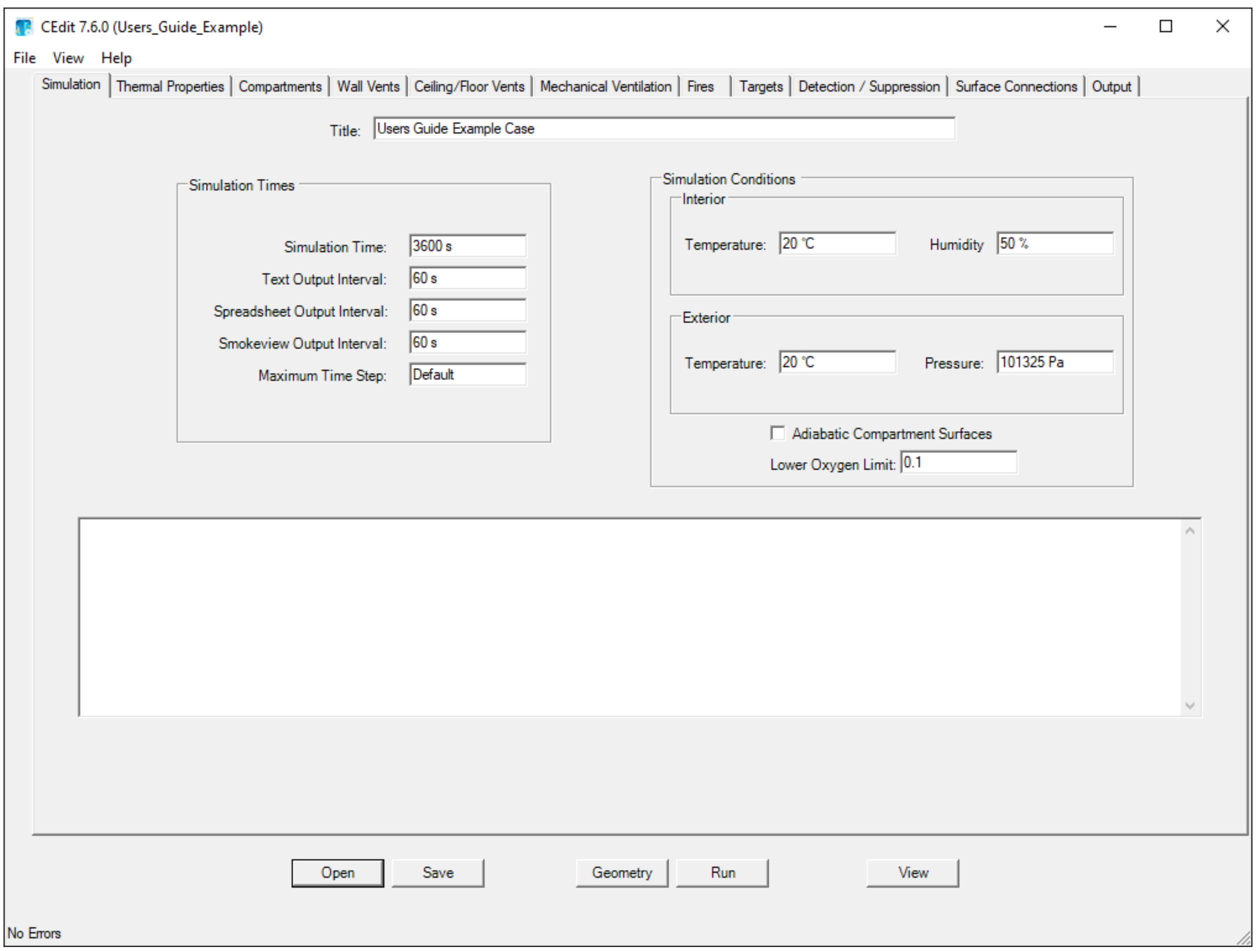


Figure 2.1: The CFAST Simulation Environment Tab.

2.1 Version and Title

Version The version of CFAST being used by the user. Version number can be found in the upper left corner in the CEdit user interface as shown in Fig. 1.1.

Title The first thing to do when setting up an input file is to give the simulation a title. The title is optional and may consist of letters, numbers, and/or symbols and may be up to 50 characters. All output files will be tagged with this character string.

2.2 Simulation Times

Simulation Time (default units: s, default value, 900 s): The length of time over which the simulation takes place. The maximum value for this input is 86400 s (1 day).

Text Output Interval (default units: s, default value, 60 s): The time interval between each printing of the output data. If equal to zero, no output values will appear.

Spreadsheet Output Interval (default units: s, default value, 15 s): CFAST can output the results of the simulation in a set of comma-delimited spreadsheet files. This parameter defines the time interval between these outputs. A value greater than zero must be used if the spreadsheet files are desired.

Smokeview Output Interval (default units: s, default value: 15 s): CFAST can output a subset of the results in a format compatible with the visualization program Smokeview. This input defines the time interval between outputs of the model results in a Smokeview-compatible format. A value greater than zero must be used if the Smokeview output is desired.

Maximum Time Step (default units: s, default value: 2 s): CFAST will automatically adjust the time interval for the solution of the differential equation set up or down so that the simulation is as efficient as possible within the pre-defined error tolerances. This parameter places a maximum value for the equation solver and can normally be left at the default value. In cases (which are hopefully rare) where the model fails to converge on a solution, this value can be reduced which often will allow the simulation to successfully complete.

2.3 Simulation Conditions

Ambient conditions define the environment at which the scenario begins. Initial pressures in a structure are calculated simply as a lapse rate (related to the height above sea level) based on the NOAA/NASA tables [5]. It is convenient to choose the base of a structure to be at zero height and then reference the height of the structure with respect to that height. The temperature and pressure must then be measured at that position. Another possible choice would be the pressure and temperature at sea level, with the structure elevations then given with respect to mean sea level. This is also acceptable, but somewhat more tedious in specifying the construction of a structure. Either of these choices works though, so long as they are consistent. Usually, the station elevation is set to zero and the pressure to ambient. The effect of changing these values is minor. Note that the equations implemented in the model are not designed to handle negative elevations and altitudes.

Temperature (default units: °C, default value: 20 °C): Initial ambient temperature inside the structure at the station elevation.

Humidity (default units % RH, default value: 50 %): The initial relative humidity in the system, only specified for the interior. This is converted to kilograms of water per cubic meter as an initial condition for both the interior and exterior of the structure.

Temperature (default units: °C, default value: 20 °C): Initial ambient temperature outside the structure at the station elevation.

Pressure (default units: Pa, default value: 101325 Pa): Initial values for ambient atmospheric pressure inside and outside the structure at the station elevation. The default value is standard atmospheric pressure at sea level.

2.4 Miscellaneous

Keywords associated to global parameters are organized in the miscellaneous namelist group.

Adiabatic Compartment Surfaces When this box is checked, all of the compartment surfaces are assumed to be perfect insulators and the materials section of the compartments tab becomes grayed out. This feature is useful when designing an experiment in which it is safe to assume that there is no heat transfer to the walls of the compartments.

Lower Oxygen Limit (default units: %, default value: 15 %): In the CFAST model, a limit is incorporated by limiting the burning rate as the oxygen level decreases until a "lower oxygen limit" (LOL) is reached. The lower oxygen limit is incorporated through a smooth decrease in the burning rate near the limit. Normally, this value would not be changed by the user.

Chapter 3

Thermal Properties

The thermophysical properites of materials used for compartment surfaces or targets are set in the Thermal Properties tab.

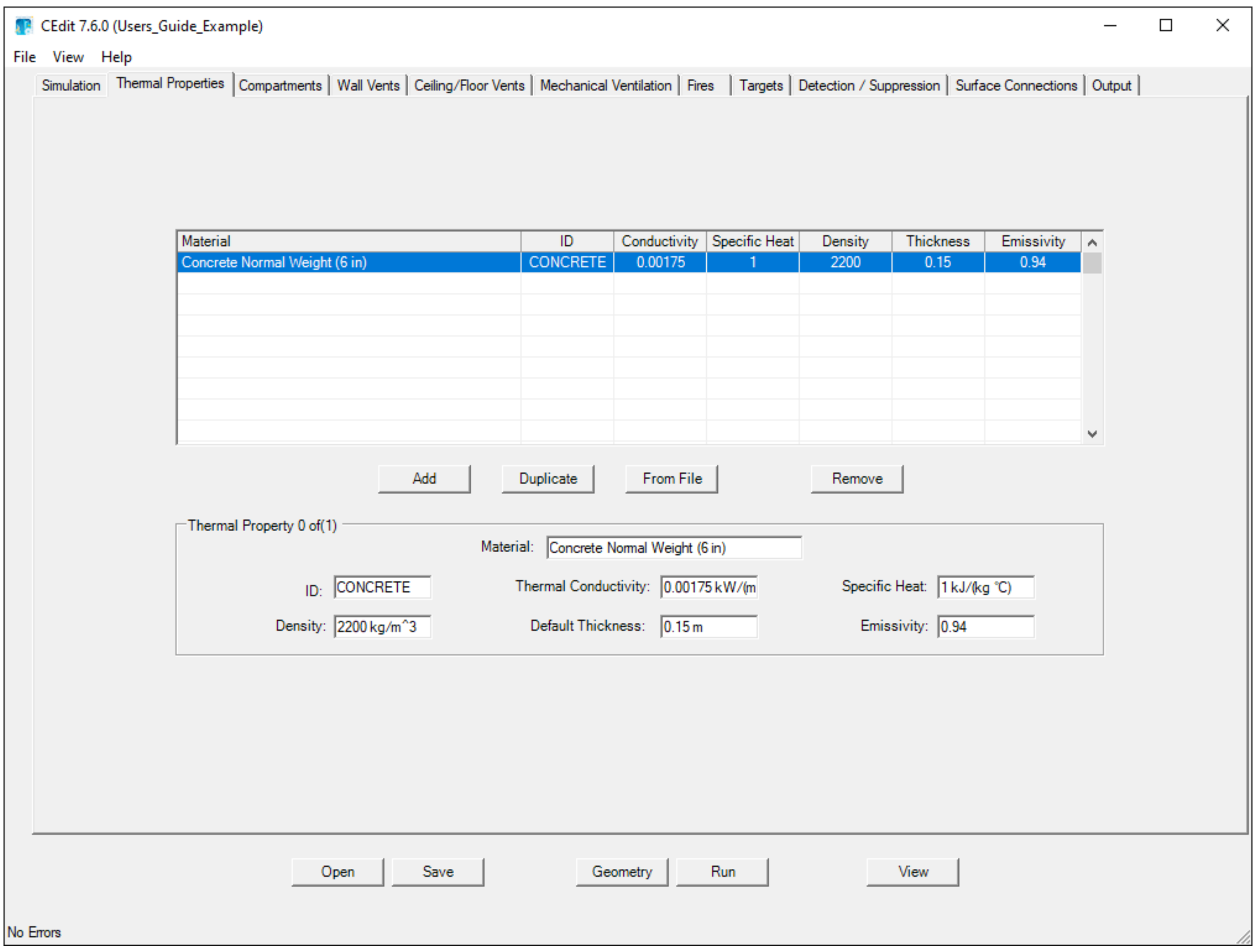


Figure 3.1: The CFAST Thermal Properties Tab.

3.1 Adding Thermal Properties

CFAST and CEdit do not include predefined thermal properties for compartment materials. Thus, the user needs to define materials for use within a specific simulation. These may be from other simulations or input directly from reference sources or test results. Clicking the ‘Add’ button and assigning values to the following list of properties will create a set of thermal properties associated with a material used in a compartment or a target. The thermophysical properties are specified at one condition of temperature, humidity, etc. Only a single layer per boundary is allowed (some previous versions allowed up to three).

Material A descriptive name for the material.

ID A one-word (no more than 8 characters) **unique** identifier for the material. This identifier should not contain any spaces and is used in other CFAST inputs to identify the particular material referenced.

Conductivity (default units: kW/(m·°C) or kW/(m·K)): Thermal conductivity for the material.

Specific Heat (default units: kJ/(kg·°C) or kJ/(kg·K)): Specific heat for the material.

Density (default units: kg/m^3): Density for the material.

Thickness (default units: m): Thickness of the material. Note that if two materials with identical thermal properties but with different thicknesses are desired, two separate materials must be defined.

Emissivity (default units: none, default value: 0.9): Emissivity of the material surface. This is the fraction of radiation that is absorbed by the material.

3.2 Adding Thermal Properties From Another File

The ‘From File’ button allows you to insert thermal properties from existing CFAST input files to the current simulation.

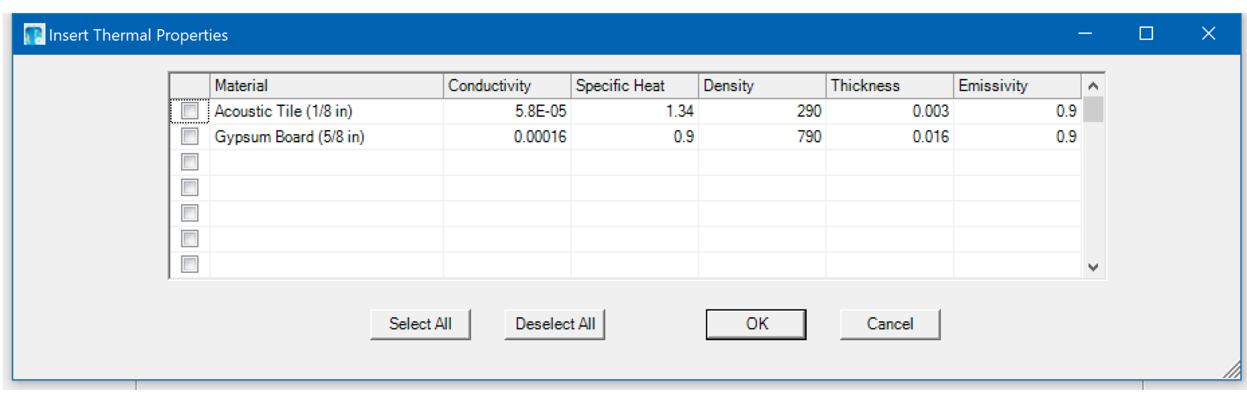


Figure 3.2: Inserting Thermal Properties in CFAST.

Chapter 4

Compartments

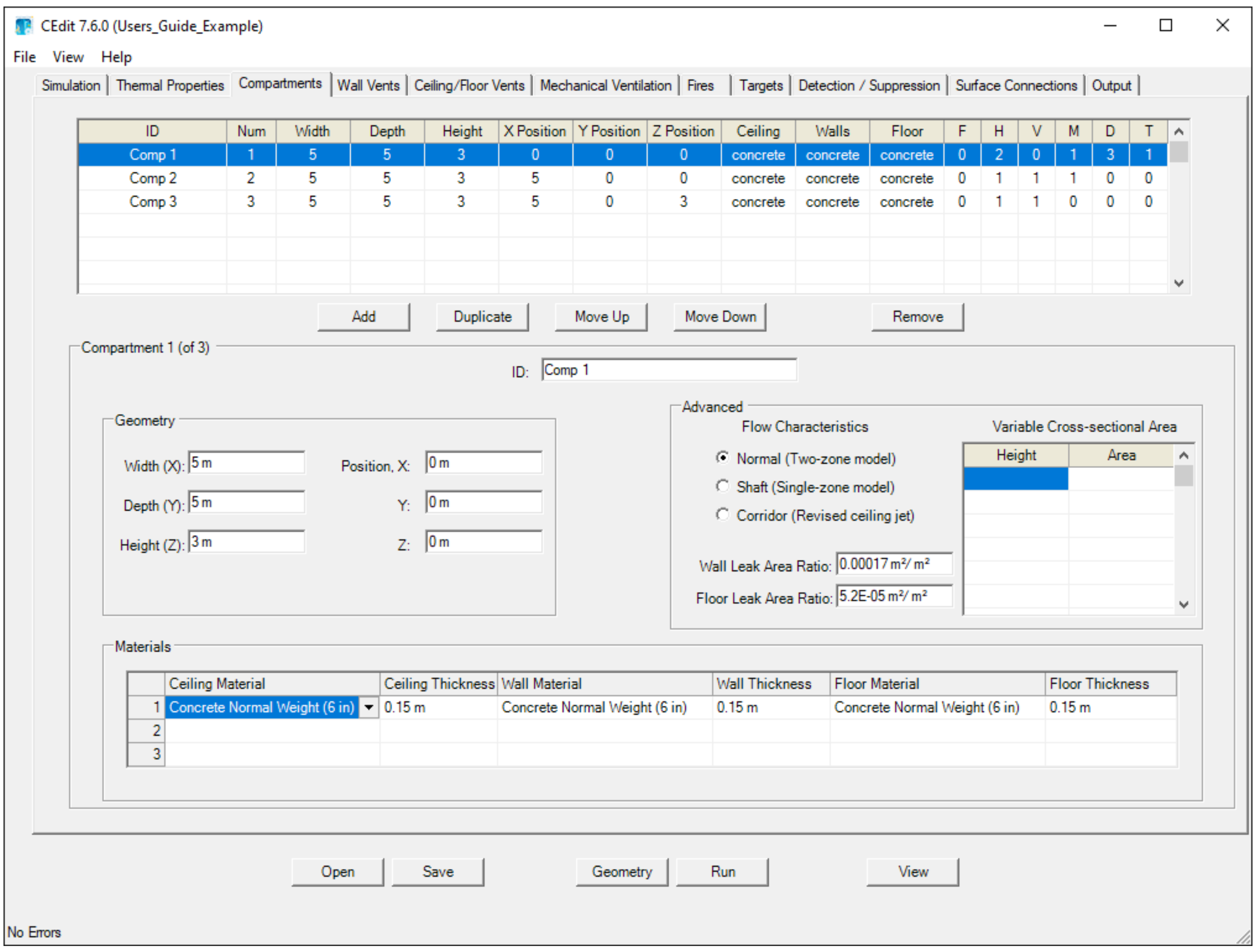
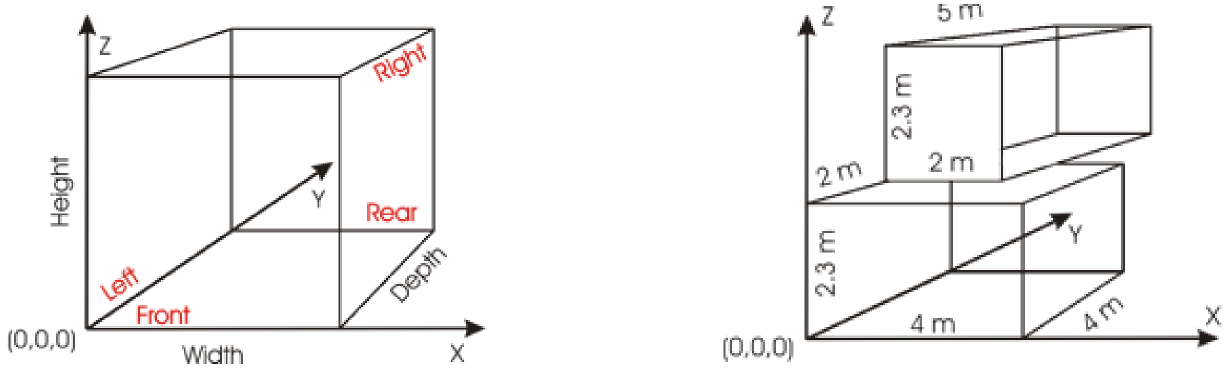


Figure 4.1: The CFAST Compartments Tab.

The Compartments page defines the size, position, materials of construction, and flow characteristics for the compartments in the simulation. Initially, only the simulation environment page and the ’Add’ button on the compartment geometry and thermal properties pages are enabled; all other pages are not available to the user for detailed inputs until a compartment has been added to the simulation.

In order to model a fire scenario, the size and position of each compartment relavent to the scenario must be specified. For a compartment, the width, depth, compartment height and height of the floor of the compartment provide this specification. The maximum number of compartments for version 7 is 100. The usual assumption is that compartments are rectangular parallelepipeds. However, the CFAST model can accommodate odd shapes as equivalent floor area parallelepipeds or with a cross-sectional area that varies with height.



Compartment Size Compartment Position

Figure 4.2: Compartment Orientation and Positioning in CFAST.

In CEdit the default size of a room has width of 3.6 m, depth of 2.4 m, and height of 2.4 m. There are defaults for absolute positioning (0,0,0). All surfaces, i.e., the ceiling, walls and floor, are turned off by default. The fully mixed (single zone) and corridor models are turned off by default.

Compartments in CFAST are most typically defined by a width, depth, and height. If desired, compartments can be prescribed by the cross-sectional area of the compartment as a function of height from floor to ceiling for other shapes. The absolute position of the compartment with respect to a single structure reference point can be defined to ease visualization or to allow exact placement of vents and surfaces relative to other compartments in a detailed calculation. This specification is important for positioning the compartments for visualization in Smokeview.

ID: Compartments are identified by a unique alphanumeric name. This may be as simple as a single character or number, or a description of the compartment.

4.1 Geometry

Width (default units m, default value 3.6 m) specifies the width of the compartment as measured on the X axis from the origin (0,0,0) of the compartment.

Depth (default units m, default value 2.4 m) specifies the depth of the compartment as measured on the Y axis from the origin (0,0,0) of the compartment.

Height (default units m, default value 2.4 m) specifies the height of the compartment as measured on the Z axis from the origin (0,0,0) of the compartment.

Position X (default units m, default value 0.0 m) specifies the absolute x coordinate of the lower, left, front corner of the room. All absolute positions for all compartments must be greater than or equal to zero, i.e., negative numbers are not allowed for these inputs. Important in positioning the compartments for visualization in Smokeview.

Position Y (default units m, default value 0.0 m) specifies the absolute y coordinate of the lower, left, front corner of the room. All absolute positions for all compartments must be greater than or equal to zero, i.e., negative numbers are not allowed for these inputs. Important in positioning the compartments for visualiz ation in Smokeview.

Position Z (default units m, default value 0.0 m) specifies the height of the floor of each compartment with respect to station elevation specified by the internal ambient conditions reference height parameter. The reference point must be the same for all elevations in the input data. For example, the two rooms in the sample to the right in Fig. 4.2 would be located at (0,0,0) and (0,2,2.3). All absolute positions for all compartments must be greater than or equal to zero, i.e., negative numbers are not allowed for these inputs.

4.2 Materials

To calculate heat loss through the ceiling, walls, and floor of a compartment, the properties of the bounding surfaces must be known. This includes the thermophysical properties of the surfaces and the arrangement of adjacent compartments if inter-compartment heat transfer is to be calculated. The bounding surfaces are the ceilings, walls and floors that define a compartment. These are referred to as thermophysical boundaries, since each participates in conduction, convection, and radiation as well as defining the compartments, unless these phenomena are explicitly turned off.

The thermophysical properties of the materials to be used to define the surfaces are defined in the Thermal Propertied tab described in section 3.1. The materials are then assigned to the ceiling, wall, and floor surfaces by use of the material ID

Ceiling Material (default value: Off): up to three materials from the thermal properties from the Materials tab can be used to define the layer(s) of the ceiling surface of the compartment. The innermost layer is specified first.

Ceiling Thickness (default units: m, default value: thickness of material specified on the Materials tab): thickness of each of the layers of the ceiling surface.

Wall Material (default value: Off): up to three materials from the thermal properties from the Materials tab can be used to define the layer(s) of the wall surface of the compartment. The innermost layer is specified first.

Wall Thickness (default units: m, default value: thickness of material specified on the Materials tab): thickness of each of the layers of the ceiling surface.

Floor Material (default value: Off): up to three materials from the thermal properties from the Materials tab can be used to define the layer(s) of the floor surface of the compartment. The innermost layer is specified first.

Floor Thickness (default units: m, default value: thickness of material specified on the Materials tab): thickness of each of the layers of the floor surface.

If the thermophysical properties of the enclosing surfaces are not included, CFAST will treat them as adiabatic (no heat transfer).

If a name is used which is not in the input file, the model should stop with an error message.

The back surfaces of compartments are assumed to be exposed to ambient conditions unless specifically specified (see the section on Surface Connections to specify heat transfer connections between compartments).

4.3 Modeling a Compartment as a Tall Shaft or Long Corridor

For tall compartments or those removed from the room of fire origin, the compartment may be modeled as a single, well-mixed zone rather than the default two-zone assumption. A single zone approximation is appropriate for smoke flow far from a fire source, where the two-zone layer stratification is less pronounced than in compartments near the fire or in situations where the stratification does not occur. Examples are elevators, shafts, complex stairwells, or compartments far from the fire.

By specifying the compartment as a corridor, the ceiling jet temperature is calculated with a different empirical correlation that results in a somewhat higher temperature near the ceiling. This will impact, for example, detectors, sprinkler, and targets near the ceiling in corridors.

Normal (Two-zone model) Conditions in the compartment are calculated with the normal two-zone approach. This is the default model used for a compartment.

Shaft (Single-zone model) Conditions in the compartment are calculated as a single well-mixed zone.

Corridor (Revised ceiling jet) Conditions in the compartment are calculated with the normal two-zone approach. Ceiling jet temperatures in the compartment are calculated with a revised empirical correlation specific to corridors.

4.4 Defining Variable Compartment Area

The Compartment Geometry page includes two additional entries that may be used for defining compartment properties for spaces which are not rectangular in area. Values for a chosen compartment are entered in a spreadsheet.

Height Value(s) (default units: m): Height off the floor of the compartment.

Area Value(s) (default units m^2): Cross-sectional area at the corresponding Height.

Once the total compartment volume is determined from the set of cross-sectional area and height inputs, an effective width and depth are calculated (maintaining the original user input for compartment height) so the compartment volume matches the actual total volume of the compartment. The aspect ratio (width/depth) is maintained.

Cross-sectional area values should be input in order by ascending height. If the first height value is not zero (i.e., at floor level), the cross-sectional area is assumed constant from the floor to the height specified in the first cross-sectional area value. Similarly, if the last height value is not at the ceiling height, the cross-sectional area is assumed constant from the height specified in the last cross-sectional area value to the ceiling. Between any two adjacent cross-sectional area data values in the input list, the area is assumed to be a pyramidal section (which by definition maintains the same width to depth aspect ratio for the compartment from floor to ceiling).

CFAST uses the variable cross-sectional area inputs to determine the layer height. The equations solved by CFAST determine the volume of the upper layer. For a normal rectangular room, this corresponds directly to a layer height. For a variable cross-sectional area compartment, a numerical integration of the area inputs beginning at the ceiling is used to determine the height at which the upper layer occupies the calculated volume of the upper layer.

4.5 Modeling Compartment Leakage

CFAST can automatically calculate leakage between one or more compartments and the outdoors. Leakage is specified for each desired compartment as a leakage area per unit wall area and/or per unit floor area.

Wall Leakage (default units: m^2/m^2): Leakage area ratio input as the leakage are per unit wall area.

Floor Leakage (default units: m^2/m^2): Leakage area ratio input as the leakage are per unit floor area.

For reference, the following table is taken from the *Handbook of Smoke Control Engineering* [6].

Table 4.1: Sample Flow Area of Walls and Floors of Commercial Buildings from the *Handbook of Smoke Control Engineering* [6], used with persmission

Construction Element	Leakage	Leakage Area (m^2/m^2) Leakage Area per Unit Wall Area
Exterior building walls (includes construction cracks and cracks around windows and doors)	Tight Average Loose Very Loose	5.0×10^{-5} 1.7×10^{-4} 3.5×10^{-4} 1.2×10^{-3}
Stairwell walls (includes construction cracks but not cracks around windows and doors)	Tight Average Loose	1.4×10^{-5} 1.1×10^{-4} 3.5×10^{-4}
Elevator shaft walls (includes construction cracks but not cracks around doors)	Tight Average Loose	1.8×10^{-4} 8.4×10^{-4} 1.8×10^{-3}

Construction Element	Leakage	Leakage Area (m^2/m^2) Leakage Area per Unit Floor Area
Floors (includes construction cracks and gaps around penetrations)	Tight Average Loose	6.6×10^{-6} 5.2×10^{-5} 1.7×10^{-4}

Chapter 5

Vents

5.1 Natural Ventilation

Natural ventilation can occur when two compartments are connected via open doorways or windows (**Wall Vents**); or when two compartments are connected via **Floor/Ceiling Vents**. If no vents are specified between two compartments, they are assumed to be isolated from each other.

5.1.1 Wall Vents

Wall vents are doors or windows that connect compartments that physically overlap in elevation, or that connect to the outside. Horizontal flow connections may also be used to account for leakage between compartments or to the outdoors.

ID The selected name must be unique (i.e., not the same as another vent in the same simulation).

First Compartment First of the two compartments connected by a door or window. All specifications of the vent are made relative to the floor of the first compartment.

Second Compartment Second of the two compartments connected by a door or window.

Sill (default units: m, default value: 0 m): Height of the bottom of the opening relative to the floor of the first compartment.

Soffit (default units: m, default value: 0 m): Height of the top of the opening relative to the floor of the first compartment.

Width (default units: m, default value: 0 m): The width of the opening.

Vent Offset (default units: m, default value: 0 m): For visualization only, the horizontal distance between the near edge of the vent and the origin of the axis defined by the selected face (below) in the first compartment.

Face The wall on which the vent is positioned. Choices are Front, Rear, Right, Left and are relative to the X-Z plane (Front and Rear faces are parallel to the X-axis; left and right are parallel to the Y-axis).

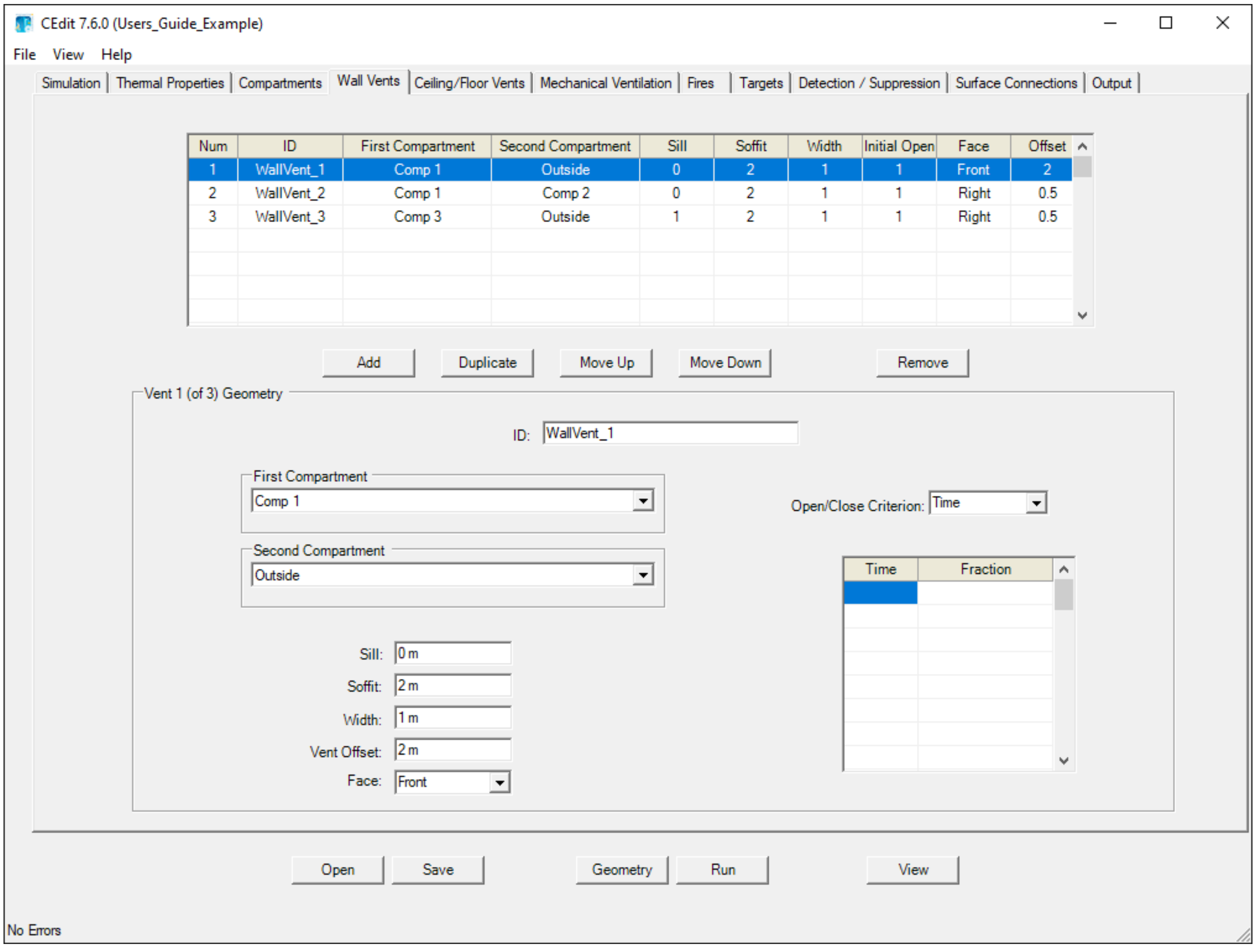


Figure 5.1: The CFAST Wall Vents Tab.

Vents in CFAST can be opened or closed at user-specified times or by a user-specified target's surface temperature or incident heat flux. For time-based opening changes, the inputs are a series of time points and associated opening fractions from 0 (fully closed) to 1 (fully open).

Time (default units: s, default values: 0 s): Time during the simulation at which to begin or end a change in the open fraction.

Fraction (default value: 1, fully open): Fraction between 0 and 1 of the vent width to indicate the vent is closed, partially-open, or fully-open as the associated time point.

For condition-based opening changes, the inputs specify an associated target, trigger value, and vent opening fractions before and after the trigger value has been reached.

Open/Close Criterion The time of ignition can be controlled by a user-specified time, or by a user-specified target's surface temperature or incident heat flux.

Set Point The critical value at which the vent opening change will occur. If it is less than or equal to zero, the default value of zero is taken.

Trigger Target User-specified target used to calculate surface temperature or incident heat flux to trigger a vent opening change. Target placement is specified by the user as part of the associated target definition.

Pre-Activation Fraction (default value: 1, fully open): Fraction between 0 and 1 of the vent width to indicate the vent is partially open at the start of the simulation.

Post-Activation Fraction (default value: 1, fully open): Opening fraction at the end of the simulation. The transition from the pre-activation fraction to the post-activation value is assumed to occur over one second beginning when the specified set point value is reached.

CFAST assumes a linear transition between time points. If the initial time specified for a time-changing opening fraction is non-zero, the vent is assumed to be open at the initial value of the open fraction from the beginning of the simulation up to and including the time associated with the initial value of the opening fraction. If the final value of the opening fraction is less than the total simulation time, the vent is assumed to be open at the final value of the opening fraction from and including the time associated with the final value of the opening fraction until the end of the simulation.

5.1.2 Ceiling/Floor Vents

Examples of these openings are scuddles in a ship, or a hole in the roof of a residence. Connections can exist between compartments or between a compartment and the outdoors. Combined buoyancy and pressure-driven flow through a vertical flow vent is possible when the connected spaces adjacent to the vent are filled with gases of different density in an unstable configuration, with the density of the top space greater than that of the bottom space. With a moderate cross-vent pressure difference, the instability leads to a bi-directional flow between the two spaces. For relatively large cross-vent pressure difference the flow through the vent is unidirectional.

ID The selected name must be unique (i.e., not the same as another vent in the same simulation).

Top Compartment Compartment where the vent is in the floor

Bottom Compartment The adjacent compartment where the vent is in the ceiling.

Cross-sectional Area (default units: m^2, default value: 0 m^2)

Shape The shape factor changes the calculation of the effective diameter of the vent and flow coefficients for flow through the vent.

Vent Offset (default units: m, default value: 0 m): For visualization only, the horizontal distances between the center of the vent and the origin of the X and Y axes in the upper compartment. See figure 4.2 for axis position conventions in CFAST.

Vents in CFAST can be opened or closed at user-specified times or by a user-specified target's surface temperature or incident heat flux. For time-based opening changes, the inputs are a series of time points and associated opening fractions from 0 (fully closed) to 1 (fully open).

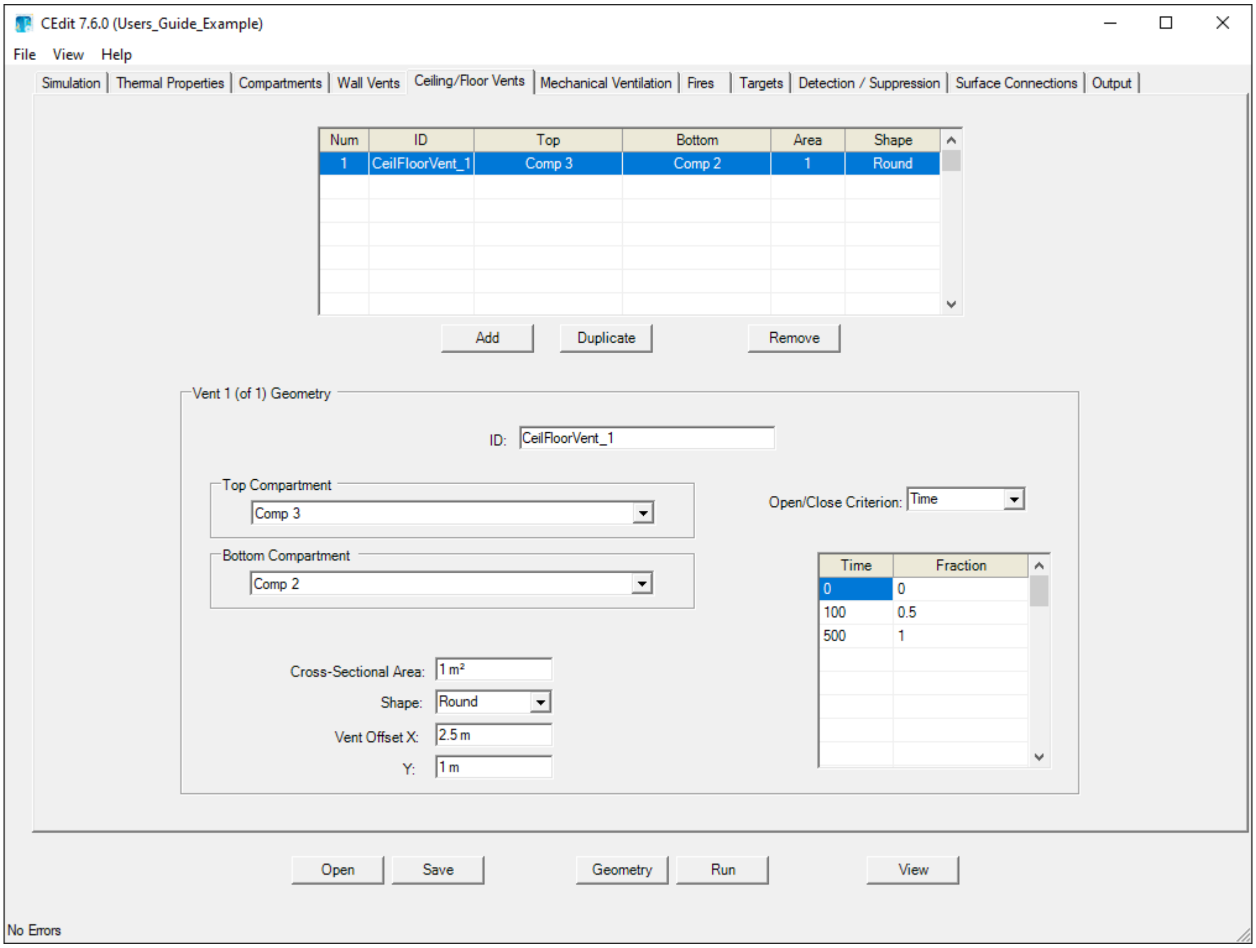


Figure 5.2: The CFAST Ceiling/Floor Vents Tab.

Time (default units: s, default value: 0 s): Time during the simulation at which to begin or end a change in the open fraction.

Fraction (default value: 1, fully open): Fraction between 0 and 1 of the vent width to indicate the vent is closed, partially-open, or fully-open as the associated time point.

For condition-based opening changes, the inputs specify an associated target, trigger value, and vent opening fractions before and after the trigger value has been reached.

Open/Close Criterion The time of ignition can be controlled by a user-specified time, or by a user-specified target's surface temperature or incident heat flux.

Set Point The critical value at which the vent opening change will occur. If it is less than or equal to zero, the default value of zero is taken.

Trigger Target User-specified target used to calculate surface temperature or incident heat flux to trigger a vent opening change. Target placement is specified by the user as part of the associated target definition.

Pre-Activation Fraction (default value: 1, fully open): Fraction between 0 and 1 of the vent width to indicate the vent is partially open at the start of the simulation.

Post-Activation Fraction (default value: 1, fully open): Opening fraction at the end of the simulation. The transition from the pre-activation fraction to the post-activation fraction is assumed to occur over one second beginning when the specified set point value is reached.

CFAST assumes a linear transition between time points. If the initial time specified for a time-changing opening fraction is non-zero, the vent is assumed to be open at the initial value of the open fraction from the beginning of the simulation up to and including the time associated with the initial value of the opening fraction. If the final value of the opening fraction is less than the total simulation time, the vent is assumed to be open at the final value of the opening fraction from and including the time associated with the final value of the opening fraction until the end of the simulation.

CFAST allows only a single ceiling/floor connection between any pair of compartments included in a simulation because the empirical correlation governing the flow was developed using only a single opening between connected compartments.

Vertical connections can only be created between compartments that could be physically stacked based on specified floor and ceiling elevations for the compartments. Some overlap between the absolute floor height of one compartment and the absolute ceiling height of another compartment is allowed. However, whether the compartments are stacked or overlap somewhat, the ceiling/floor absolute elevations must be within 0.01 m of each other. The check is not done when the connection is to the outside.

5.2 Mechanical Ventilation

Fan-duct systems are commonly used in buildings for heating, ventilation, air conditioning, pressurization, and exhaust. Generally, systems that maintain comfortable conditions have either one or two fans. Residences often have a system with a single fan. Further information about these systems is presented in Klote and Milke [7] and the *Handbook of Smoke Control Engineering* [6].

CFAST models mechanical ventilation in terms of user-specified volume flows at various points in the compartment. The model does not include duct work or fan curves, and thus mechanical ventilation connections are simply described by the connections to the two compartments and a fan whose throughput is a constant volumetric flow up to a user-specified pressure drop across the fan, dropping to zero at high backwards pressure on the fan.

5.2.1 Connections to Compartments

ID The selected name must be unique (i.e., not the same as another mechanical ventilation system in the same simulation).

First Compartment The compartment from which the fan flow originates.

Second Compartment The compartment to which the fan flow terminates.

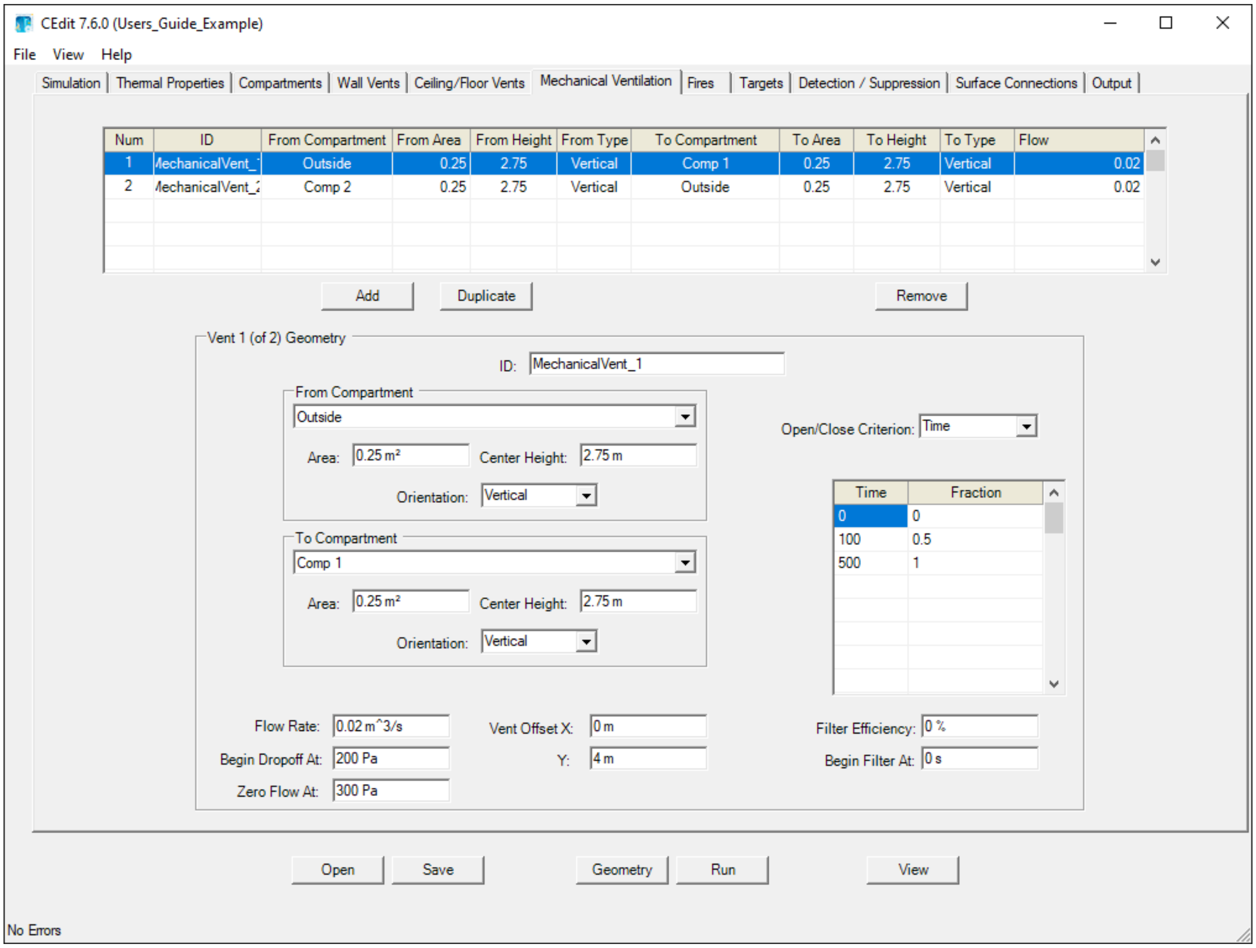


Figure 5.3: The CFAST Mechanical Vents Tab.

Area (default units: m^2, default value: 0 m^2): Cross-sectional area of the opening.

Center Height (default units: m, default value: 0 m): Height of the midpoint of the duct opening above the floor.

Orientation (default vertical) A horizontal diffuser implies vertical flow through the ceiling or floor of the compartment. A vertical diffuser implies horizontal flow through a wall of the compartment.

Vent Offset (default units: m, Default value: 0 m): For visualization only, the horizontal distances between the center of the vent and the origin of the X and Y axes in the first compartment. See figure 4.2 for axis position conventions in CFAST.

Vents in CFAST can be opened or closed at user-specified times or by a user-specified target's surface temperature or incident heat flux. For time-based opening changes, the inputs are a series of time points and associated opening fractions from 0 (fully closed) to 1 (fully open).

Time (default units: s, default values: 0 s): Time during the simulation at which to begin or end a change in the open fraction.

Fraction (default value: 1, fully open): Fraction between 0 and 1 of the vent width to indicate the vent is closed, partially-open, or fully-open as the associated time point.

CFAST assumes a linear transition between time points. If the initial time specified for a time-changing opening fraction is non-zero, the vent is assumed to be open at the initial value of the open fraction from the beginning of the simulation up to and including the time associated with the initial value of the opening fraction. If the final value of the opening fraction is less than the total simulation time, the vent is assumed to be open at the final value of the opening fraction from and including the time associated with the final value of the opening fraction until the end of the simulation.

For condition-based opening changes, the inputs specify an associated target, trigger value, and vent opening fractions before and after the trigger value has been reached.

Open/Close Criterion The time of ignition can be controlled by a user-specified time, or by a user-specified target's surface temperature or incident heat flux.

Set Point The critical value at which the vent opening change will occur. If it is less than or equal to zero, the default value of zero is taken.

Trigger Target User-specified target used to calculate surface temperature or incident heat flux to trigger a vent opening change. Target is placement is specified by the user as part of the associated target definition.

Pre-Activation Fraction (default value: 1, fully open): Fraction between 0 and 1 of the vent width to indicate the vent is partially open at the start of the simulation.

Post-Activation Fraction (default value: 1, fully open): Opening fraction at the end of the simulation. The transition from the pre-activation fraction to the post-activation fraction is assumed to occur over one second beginning when the specified set point value is reached.

5.2.2 Fans

CFAST does not include provisions for reverse flow through a fan, or a fan curve. Rather, you may specify a pressure above which the flow linearly decreases to zero.

Flow Rate (default units: m^3/s, default value: 0 m^3/s): Constant flow rate of the fan.

Begin Drop Off Pressure (default units: Pa, default value: 200 Pa): Above this pressure, the flow begins a drop-off to zero. A hyperbolic tangent function is used to ensure a smooth transition from full flow at the "Begin Drop Off Pressure" to zero flow at the "Zero Flow Pressure".

Zero Flow Pressure (default units: Pa, default value: 300 Pa): The pressure above which the flow is zero.

5.2.3 Filtering

For mechanical vents, there are two species that can be filtered out of the gas flow: soot and the user-defined trace species. Filters are applied only to fan openings. The fan must have been defined before the filter can be applied. Initially filtering is off.

Filter Efficiency (default units: %, default value: 0%): Flow through mechanical vents may include filtering that removes a user-specified portion of soot and trace species mass from the flow through the vent. By default, there is no filtering applied; that is, all of the soot and trace species mass in the vent flow is passed through the vent. Within the user interface, this is specified as a filter efficiency of 0 %. If desired, you may specify the fraction of the soot and trace species mass to be removed as a percentage.

Begin Filtering At Time (default units: s, default value: 0 s): Time during the simulation at which the mechanical vent filtering begins.

If the simulation includes mechanical ventilation filtering, care should be taken in choosing trace species production rates to insure the production rate is small compared to the total pyrolysis rate since the filtering removes mass from the system. This will better allow appropriate conservation of mass in the solution of the system of differential equation. For large production rates of trace species, scaling factors can be used (e.g., divide by 1000) for the trace species production rate to reduce the relative magnitude compared to the pyrolysis rate. For analysis, the resulting trace species in compartments and filters can be converted back to original units multiplying by the scaling factor used.

Chapter 6

Fires

A fire in CFAST is specified via a time-dependent heat release rate (HRR). The specified heat of combustion is used to calculate the mass loss rate of fuel, from which the production rate of combustion products can be calculated using specified product yields. The heat release and the corresponding product generation rates go to zero when the lower oxygen limit is reached, and are replaced by the appropriate production rate of unburned fuel gas which is transported from zone to zone until there is sufficient oxygen and a high enough temperature to support combustion.

The model can simulate multiple fires in one or more compartments. These fires are treated as totally separate entities, with no interaction of the plumes. These fires can be ignited at a prescribed time, or when a corresponding target (see Chapter 7.1) reaches a specified temperature or heat flux.

The combustion model is defined by the following one-step reaction:

$$\begin{aligned} \mathrm{C}_{n_\mathrm{C}}\mathrm{H}_{n_\mathrm{H}}\mathrm{O}_{n_\mathrm{O}}\mathrm{N}_{n_\mathrm{N}}\mathrm{Cl}_{n_\mathrm{Cl}} \quad &+ \quad \nu_{\mathrm{O_2}}\,\mathrm{O_2} \rightarrow \\ \nu_{\mathrm{CO_2}}\,\mathrm{CO_2} \quad &+ \quad \nu_{\mathrm{H_2O}}\,\mathrm{H_2O} + \nu_{\mathrm{CO}}\,\mathrm{CO} + \nu_{\mathrm{S}}\,\mathrm{Soot} + \nu_{\mathrm{HCl}}\mathrm{HCl} + \nu_{\mathrm{HCN}}\mathrm{HCN} \end{aligned} \tag{6.1}$$

It is assumed that all the nitrogen and chlorine in the fuel are converted to HCN and HCl.

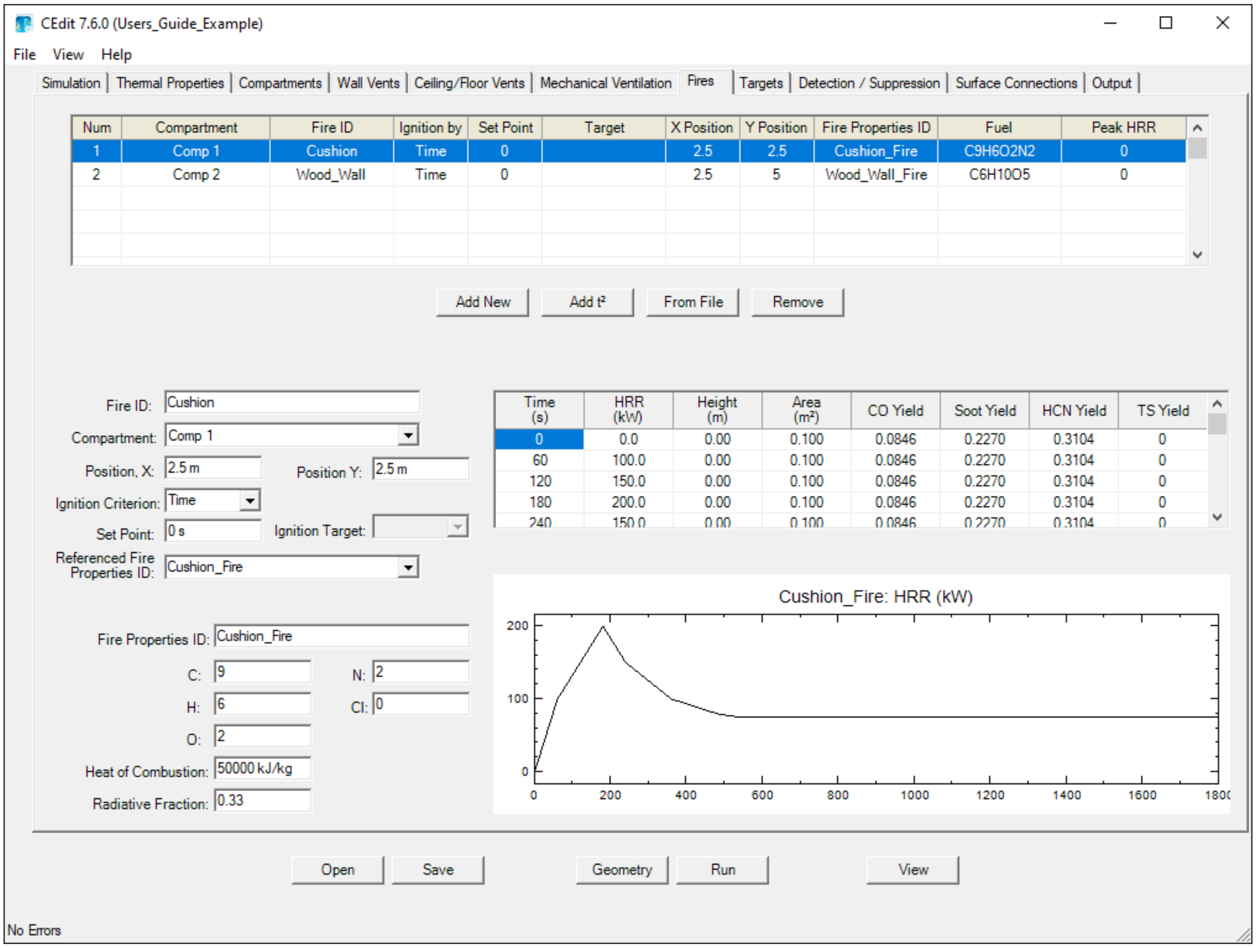


Figure 6.1: The CFAST Fires Tab.

6.1 Adding Fires

Fires in CFAST are defined in two parts: a "Fire Definition" that specifies the fuel composition, heat release rate, and species yields for the fire, and a "Fire Instance" that specifies the placement of a defined fire within a compartment in the simulation. A single fire definition may be associated with more than one fire instance in a simulation if desired.

For a new fire , click on the **Add New** button or **Add t^2** buttons within the fire definition block of inputs. The latter is useful because it has predefined quadratic growth rate options that are commonly used in fire analyses. See Section 6.3 for details. For each fire instance, specify the following properties:

Fire ID The selected name must be unique (i.e., not the same as another fire instance in the same simulation).

Compartment Name of the compartment where the fire occurs.

Position X, Y (default units: m, default value: compartment center): Position of the center of the base of the fire relative to the front left corner of the compartment.

Ignition Criterion The time of ignition can be controlled by a user-specified time, or by a user-specified target's surface temperature or incident heat flux.

Set Point The critical value at which ignition will occur. If it is less than or equal to zero, the default value of zero is taken.

Ignition Target User-specified target used to calculate surface temperature or incident heat flux to ignite fire. Target is typically placed at the base of the fire to be ignited.

Referenced Fire the name of the associated fire definition for this fire instance can be selected from a list of fire definitions. A fire definition must exist before it can be selected.

Each instance of a fire can be unique fires with different chemical composition and time-dependent fire properties. Alternatively, two or more fires can reference the same set of fire properties. The following parameters define the composition and burning properties of the fire.

Fire Properties ID The selected name must be unique (i.e., not the same as another fire definition in the same simulation). IDs for fire definitions can be the same as ones for fire instances.

C, H, O, N, Cl The number of each atom in the fuel molecule. Burning fuels in CFAST are assumed to be hydrocarbon fuels that contain at least carbon and hydrogen and optionally oxygen, nitrogen, and chlorine. All of the specified nitrogen and chlorine is assumed to completely react to form HCN and HCl.

Heat of Combustion (default units: kJ/kg, default value: 50000 kJ/kg): The energy released per unit mass of fuel consumed.

Radiative Fraction (default units: none, default value: 0.35): The fraction of the combustion energy that is emitted in the form of thermal radiation. Values for various fuels are suggested by Beyler [8].

6.2 Time-Dependent Properties

Following is a list of fire properties that can be specified as a function of time. The properties are linearly interpolated between specified points. If the simulation time is longer than the total duration of the fire, the final values specified for the fire are continued until the end of the simulation. Normal copy (Ctrl-C), cut (Ctrl-X), and paste (Ctrl-V) keyboard shortcuts work for data editing. In addition, Alt-Insert will insert a complete row above the currently-selected row in the spreadsheet and Alt-Delete will delete the current row in the spreadsheet.

Time (default units: s, default values: none): Time from ignition.

HRR (default units: kW, default values: none): Heat release rate of the fire.

Height (default units: m, default values: 0 m): Height of the base of the fire.

Area (default units: m^2, default values: calculated from heat release rate such that the fire Froude number is unity[1]): Area of the base of the fire. The plume correlations used in CFAST generally regard the base to be circular. Do not set this value to zero because it is used in the various plume correlations.

CO Yield (default units: kg/kg, default value: 0 kg/kg): Mass of CO produced per unit mass of fuel consumed.

Soot Yield (default units: kg/kg, default value: 0 kg/kg): Mass of soot produced per unit mass of fuel consumed.

HCN Yield (default units: kg/kg, default value: 0 kg/kg): Mass of hydrogen cyanide produced per unit mass of fuel consumed.

TS Yield (default units: kg/kg, default value: 0 kg/kg): Mass of user-defined trace species per unit mass of fuel consumed. The trace species is transported along with the other products of combustion, but is assumed not to take part in the combustion reaction and is assumed not to be a significant source of overall mass for the system mass balance. This implies that the production rate of trace species specified should be small.

6.3 Special Topic: t-Squared Fires

Use the 'Add t^2' button to create a new fire with a heat release rate that grows as a function of the time squared [9]:

$$\dot{Q}(t) = \dot{Q}_{\mathrm{peak}} \left(\frac{t}{t_{\mathrm{peak}}} \right)^2 \tag{6.2}$$

Fire Growth Rate A set of specific t-squared fires labeled slow, medium, fast, or ultra-fast such that the fire reaches 1054 kW (1000 BTU/s) in 600 s, 300 s, 150 s, and 75 s. A custom selection allows you to define any growth or decay rate desired.

Time to Peak (default units: s, default value: 300 s): The time for the fire to reach the peak HRR.

Peak HRR (default units: kW, default value: 1054 kW): The peak heat release rate of the t-squared fire.

Steady Burning Period (default units: s, default value: 300 s): Duration of time that the fire continues burning at the rate specified by the peak HRR.

Decay Time (default units: s, default value, 300 s): Duration of time for the fire to decay back to a zero value. Decay follows the inverse of the t-squared growth rate.

[1] The Fire Froude Number, $\dot{Q}^*$, is defined as $\dot{Q}^* = \frac{\dot{Q}}{\rho_\infty c_p T_\infty \sqrt{gD}D^2}$. It is essentially the ratio of the fuel gas exit velocity and the buoyancy-induced plume velocity. Jet fires are characterized by large Froude numbers. Typical accidental fires have a Froude number near unity.

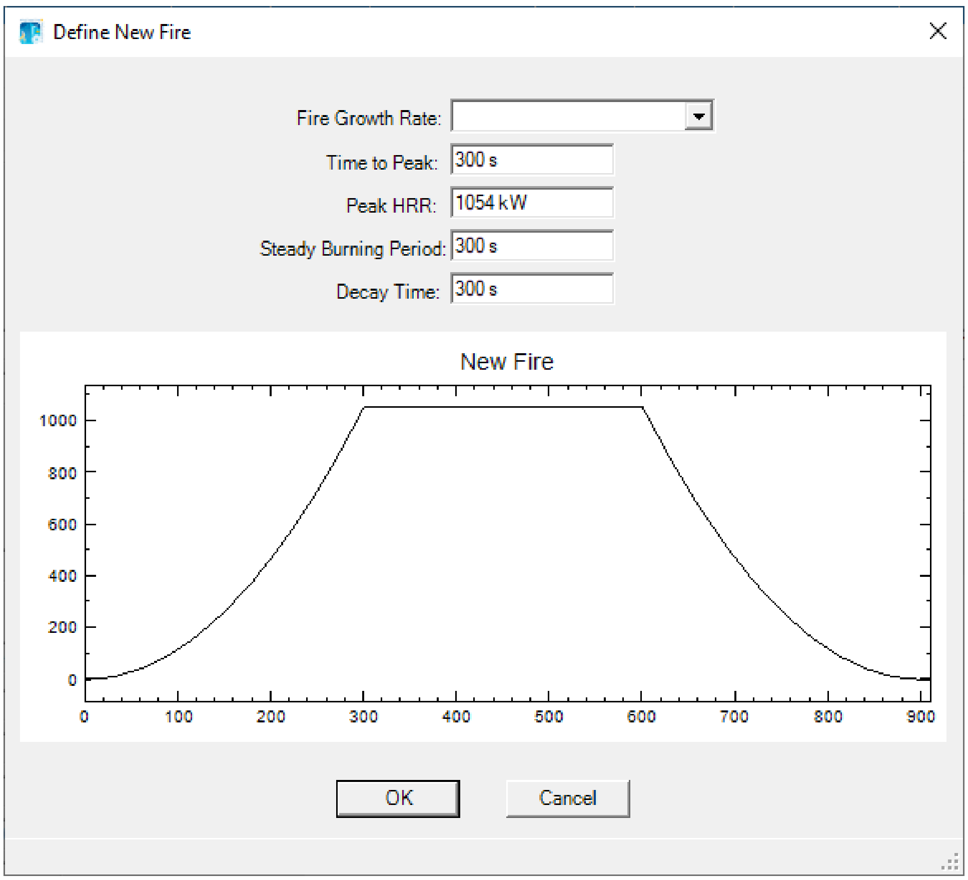


Figure 6.2: Inserting T-squared Fires in CFAST.

Chapter 7

Measurement and Fire Protection Devices

7.1 Targets

A target is any object in the simulation that can heat up via radiative and convective heat transfer. The heat conduction into the target is performed via a one-dimensional calculation in either cartesian or cylindrical coordinates.

ID The selected name must be unique (i.e., not the same as another target in the same simulation).

Compartment The compartment in which the target is located.

Target Type Specify Plate, or Cylindrical. For plate targets, CFAST solves a partial differential equation in cartesian coordinates, and for cylindrical targets, a partial differential equation in cylindrical coordinates.

Width (X) (default units: m): Distance from the left wall of the target compartment.

Depth (Y) (default units: m): Distance from the front wall of the target compartment.

Height (Z) (default units: m): Height of the target above the floor.

Normal Vector (X,Y,Z) : specifies a vector of unit length perpendicular to the exposed surface of the target. For example, the vector (-1,0,0) indicates that the target is facing the left wall. The vector (0,0,1) is facing the ceiling.

Material What the target is made of. Any existing material in the list of thermal properties may be used here. There can be only one material per target.

Internal Temperature (default units: none, default value: 0.5): For each target, CFAST calculates the internal temperature at a number of node points within the target. By default, the reported internal temperature (in the printed and spreadsheet output) is the temperature at the center of the target, e.g., equidistant from the front and back faces of the target. This input allows the user to override this default position. The input represents the position as a fraction of the thickness from the front surface to the back surface of the material.

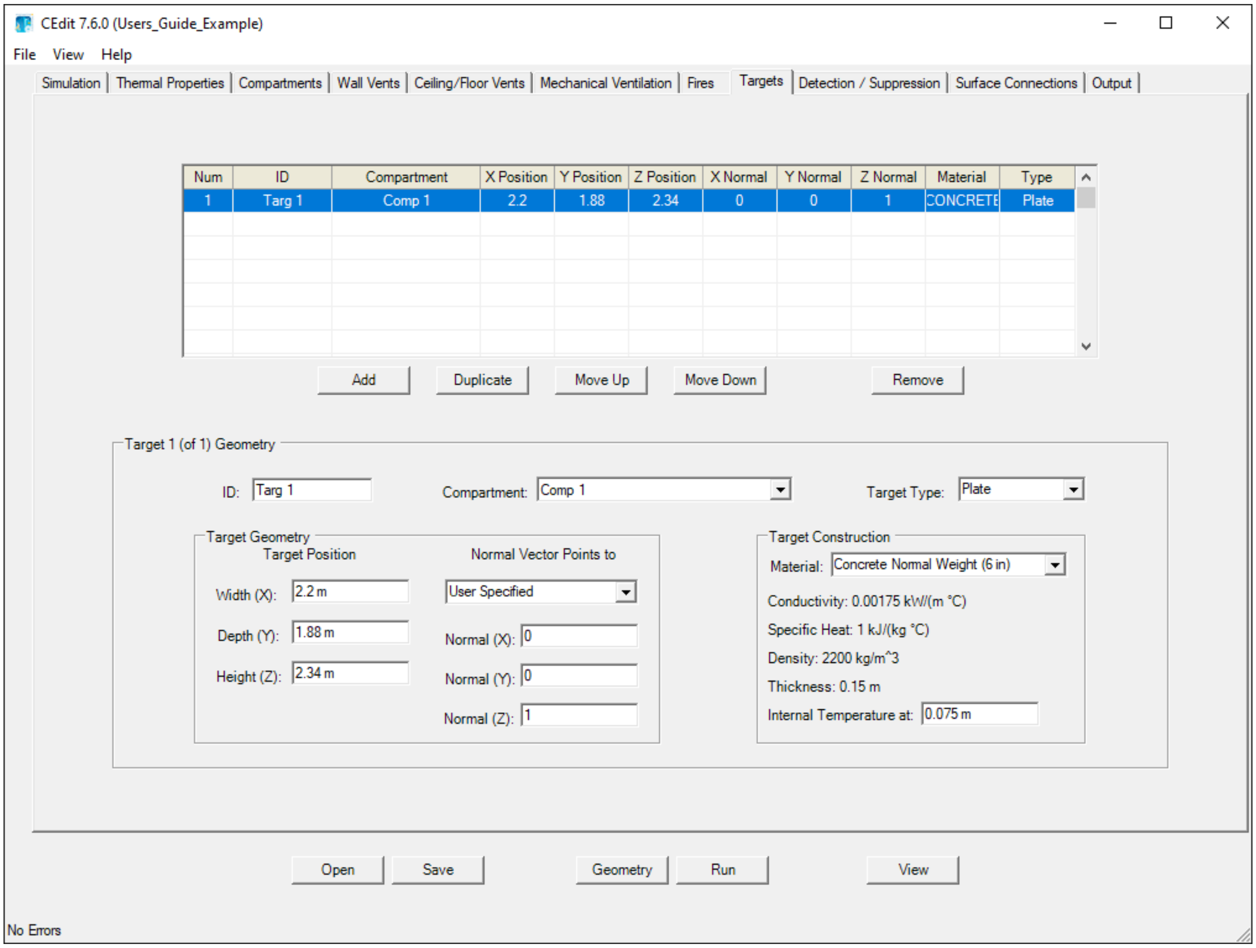


Figure 7.1: The CFAST Targets Tab.

If the target is only needed to report the local gas temperature, which may include the plume or ceiling jet, then you may specify arbitrary properties and normal vector. The output spreadsheet file includes the local gas temperature in addition to the target temperature.

The normal vectors in the x, y, and z directions from a target at $[x, y, z]$ to a location $[x_L, y_L, z_L]$ are:

$$x_N = \frac{x_L - x}{\sqrt{(x_L - x)^2 + (y_L - y)^2 + (z_L - z)^2}} \tag{7.1}$$

$$y_N = \frac{y_L - y}{\sqrt{(x_L - x)^2 + (y_L - y)^2 + (z_L - z)^2}} \tag{7.2}$$

$$z_N = \frac{z_L - z}{\sqrt{(x_L - x)^2 + (y_L - y)^2 + (z_L - z)^2}} \tag{7.3}$$

7.2 Sprinklers and Detectors

Sprinklers and detectors are both considered detection devices by the CFAST model and are handled using the same inputs. Detection is based upon heat transfer to the detector. Fire suppression by a user-specified water spray begins once the associated detection device is activated.

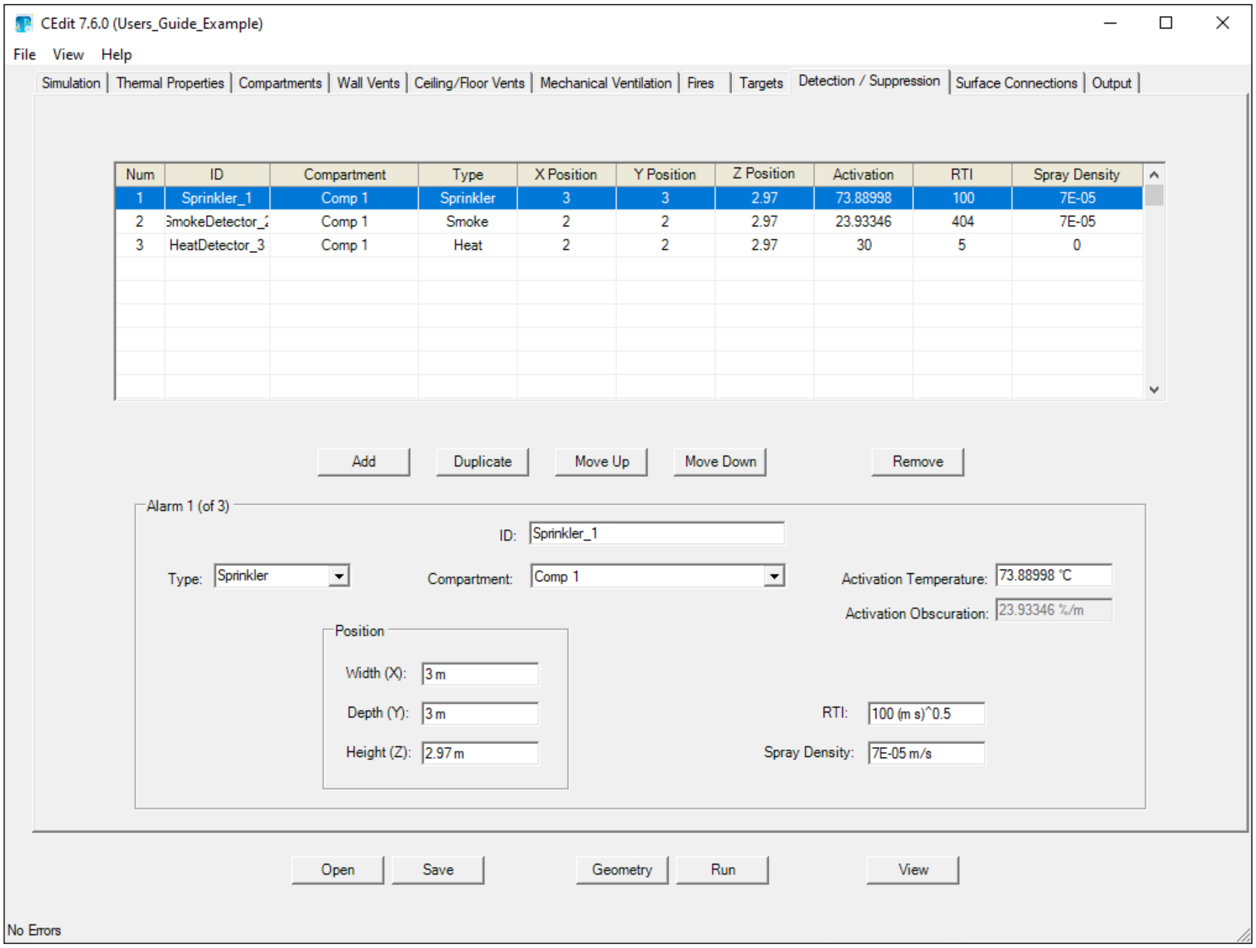


Figure 7.2: The CFAST Detection/Suppression Tab.

ID The selected name must be unique (i.e., not the same as another sprinkler or detector in the same simulation).

Type type of detector, select smoke detector, heat detector, or sprinkler.

Compartment the compartment in which the detector or sprinkler is located.

Activation Temperature (default units: °C, default value: dependent on type): the temperature at or above which the detector link activates.

Activation Obscuration (default units: %/m, default value: 23.93 %/m (8 %/ft)): the obscuration at or above which the detector link activates.

Width (X) Position (default units: m, default value: none): position of the object as a distance from the left wall of the compartment (X direction).

Depth (Y) Position (default units: m, default value: none): position of the detector or sprinkler as a distance from the front wall of the compartment (Y direction).

Height (Z) Position (default units: m, default value: none): position of the object as a distance from the floor of the compartment (Z direction).

RTI (default units: $(\mathrm{m}\cdot\mathrm{s})^{1/2}$, default value: none): the Response Time Index (RTI) for the sprinkler or detection device.

Spray Density (default units: m/s, default value: none): the amount of water dispersed by a sprinkler. The units for spray density are length/time, derived by dividing the volumetric flow rate by the spray area. The suppression calculation is based upon an experimental correlation by Evans [10].

Care should be taken when specifying detectors to activate based on smoke obscuration since the only calculation included in CFAST is a simple two-zone calculation of soot concentration that does not include the impact of an initial ceiling layer as is done for temperature-based calculations. Often, the activation of smoke alarms is simulated with a temperature-based criterion (in CFAST as a heat alarm), typically in the range of 5 °C to 10 °C above ambient. Davis and Notarianni studied the activation of heat and smoke alarms in small and large compartments [11]. They conclude that a temperature rise of approximately 5 °C corresponded to activation of ionization alarms for a range of fire sources and ceiling heights. The Nuclear Regulatory Commission includes a default value of 10 °C with an RTI value of 5 $(\mathrm{m}\cdot\mathrm{s})^{1/2}$ in NUREG-1805 [12].

Several cautions should be observed when using estimates of sprinkler suppression within the model: 1) The first sprinkler activated controls the effect of the sprinkler on the heat release rate of the fire. Subsequent sprinklers which may activate have no additional effect on the fire simulation. 2) The fire suppression algorithm assumes the effect of the sprinkler is solely to reduce the heat release rate of the fire. Any effects of the sprinkler spray on gas temperatures or mixing within the compartment are ignored. 3) The sprinkler always reduces the heat release rate of the fire. The ability of a fire to overwhelm an under-designed sprinkler is not modeled. 4) Since the dynamics of the sprinkler and direct effects of the spray on gas temperatures and velocities are not modeled, calculated times of activation of secondary sprinklers and / or detectors after the first sprinkler is activated should not be modeled since the impact of the first sprinkler on the activation of additional sprinklers is not included in the CFAST model.

Chapter 8

Surface Connections

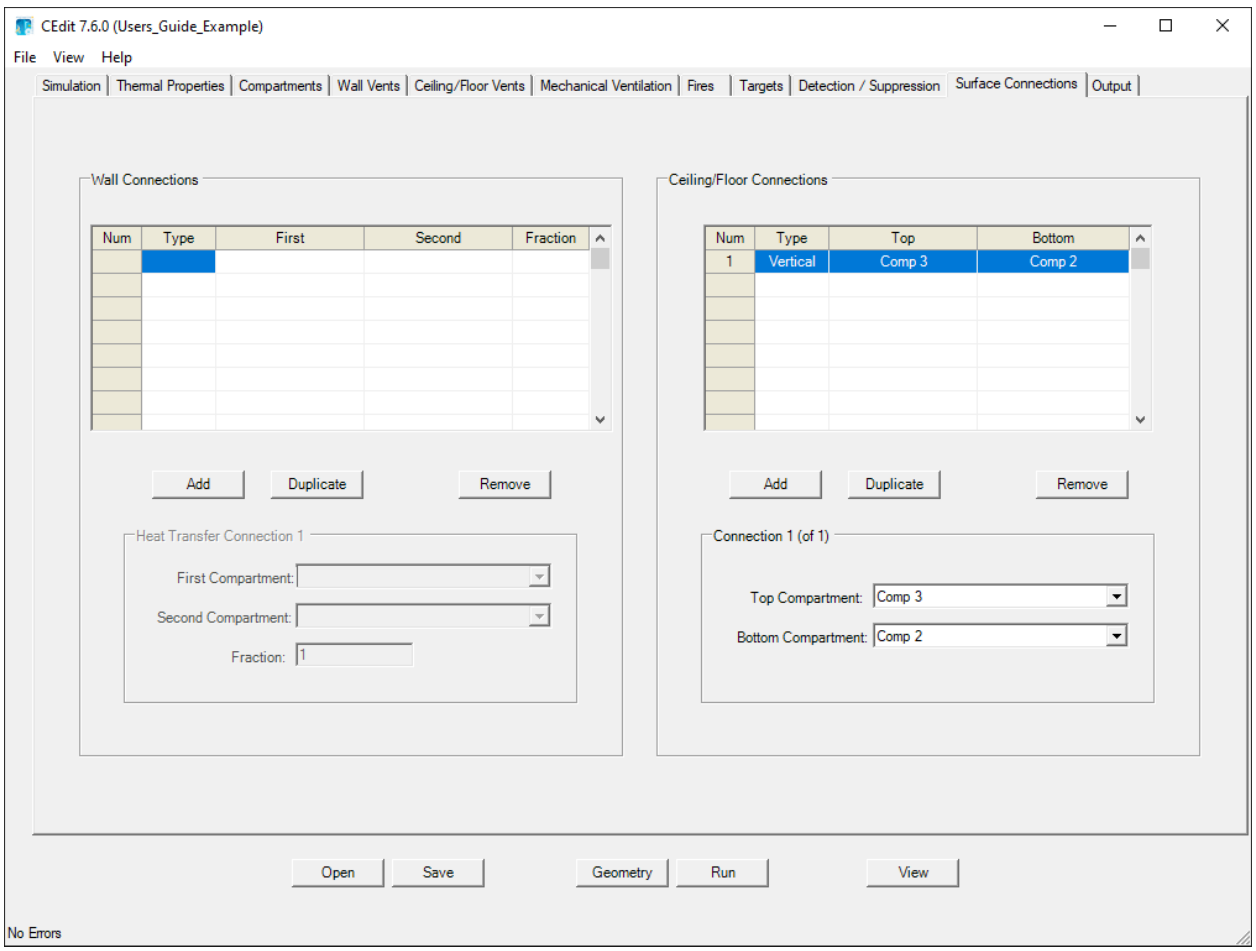


Figure 8.1: The CFAST Surface Connections Tab.

The Surface Connections page allows the user to define heat transfer between compartments in a simulation. Energy can be transferred from compartment to compartment through solid boundaries (walls, ceilings and floors) by means of conduction. The heat transfer between connected compartments is modeled by setting the boundary condition for the outside surface of a compartment to the temperature of the outside surface of the connected compartment. As before, temperatures are determined by the solver so that the heat flux striking the wall surface (both interior and exterior) is consistent with the temperature gradient at that surface.

First Compartment First of the compartments whose walls are connected for horizontal heat transfer.

Second Compartment Second of the compartments whose walls are connected for horizontal heat transfer.

Fraction Specifies the fraction of the vertical surface areas of the compartments which are connected. The fraction specifies the fraction of the vertical surface area of the first compartment that connects the first and second compartment pair.

Top Compartment The top or first of the two compartments to be connected by a vertical heat transfer connection. The connection is through the floor of this compartment.

Bottom Compartment The bottom or second of the two compartments to be connected by a vertical heat transfer connection. The connection is through the ceiling of this compartment.

Consider two compartments that share a single wall. Both compartments are 1 m x 1 m x 1 m in size. The resulting horizontal heat transfer connections would be 0.25 for both compartments since they share 1 m^2 of a total wall surface of 4 m^2. If the compartments are of different size, then the fraction would be different for the two directions. For example, if compartment 1 is 1 m x 1 m x 1 m and compartment 2 is 2 m x 2 m x 2 m, then the connection from 1>2 is 0.25 and the connection from 2>1 is 0.125.

For horizontal heat transfer, you must include a connection for each compartment. For example, for a connection between compartment 1 and compartment 2, you must include a connection from 1 to 2 AND a connection from 2 to 1. For consistency, the fraction for each compartment needs to specify equal areas in the two compartments. Fractions for connections should add to unity. An error is generated if the fractions for a compartment add to greater than unity. If the fractions for a compartment add to less than unity, the remaining surface area will be assigned to be connected to the outdoors.

Chapter 9

Visualization

Calculated results from a CFAST simulation can be visualized using Smokeview [13]. This allows the user to see the compartment geometry and connections or view the results of the simulation visually. In addition to a simplified view of the layer temperatures and vent flows, more detailed estimates of gas temperature, gas velocity, vent flow velocity, target temperature, and detector status can be visualized.

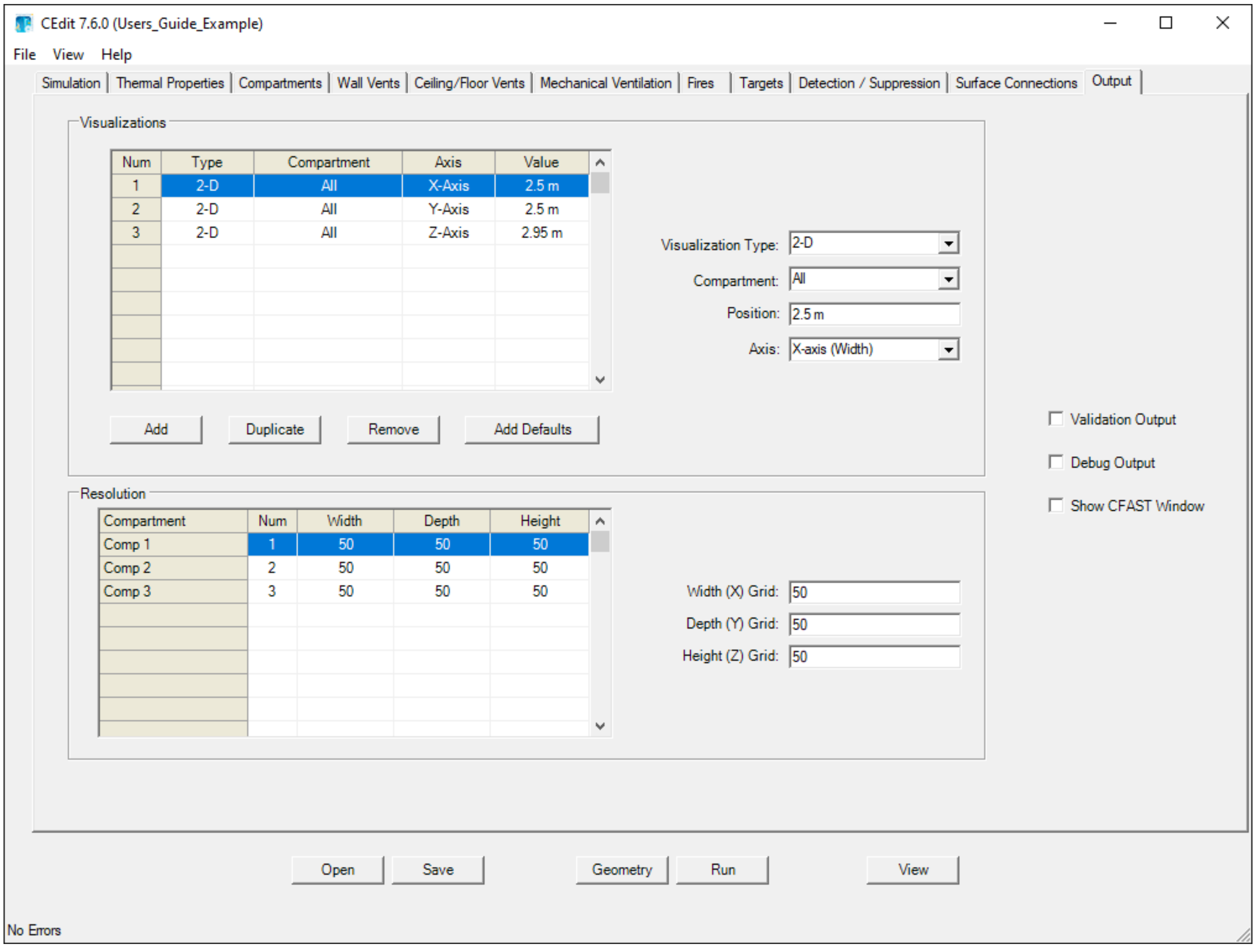


Figure 9.1: The CFAST Visualizations Tab.

9.1 Adding Visualizations

Visualization Type (default value: 2-D): The type of visualization to be included. Choose from 2-D (a single plane slice of temperature at the position and axis specified), 3-D (a set of three animated slices whose position can be moved along its respective axis, or Isosurface (a fixed 3-D surface where the gas temperature is equal to the value specified. See the Smokeview documentation [13] for details on the use of Smokeview.

Compartment (default value: All): Visualizations can be placed in a single compartment or at the same position and axis in all compartments.

Value (default units: m, default value: 0 m): Position along the specified axes where the slice is placed measured from the compartment origin for the selected axis (0,0,0 is the bottom left corner of the compartment. See page 12).

Axis (default value: X-axis (Width)): Axis perpendicular to the specified slice. The slice is place perpendicular to the selected axis (the Y-Z plane for the X-Axis; the X-Z plane for the Y-Axis, and the X-Y plane for the Z-Axis)

Temperature (default units °C, default value: none): Specified gas temperature for the selected isosurface.

Use the Add Defaults button to add a default set of visualizations for the current simulation. A slice file entry is created at the center of each compartment in the x (width) and y (depth) directions along with one near the ceiling in the z direction. A 3-D slice file entry is created for each compartment as well.

9.2 Visualization Resolution

By default, slice files are generated with a grid of 50 data points in each direction for each compartment specified. If desired, the grid spacing can be adjusted up or down individually by compartment. Specifying a larger number of data points can *dramatically* slow program execution since the gas temperature and velocity are evaluated at each grid location every time a Smokeview output is specified. The default value should be appropriate for most simulations.

Width (X) Grid (default unites: n/a, default value: 50): slices included along the X axis for each compartment are uniformly divided into the specified number of data points.

Width (Y) Grid (default unites: n/a, default value: 50): slices included along the Y axis for each compartment are uniformly divided into the specified number of data points.

Width (Z) Grid (default unites: n/a, default value: 50): slices included along the Z axis for each compartment are divided into the specified number of data points.

Sample visualizations are included below.

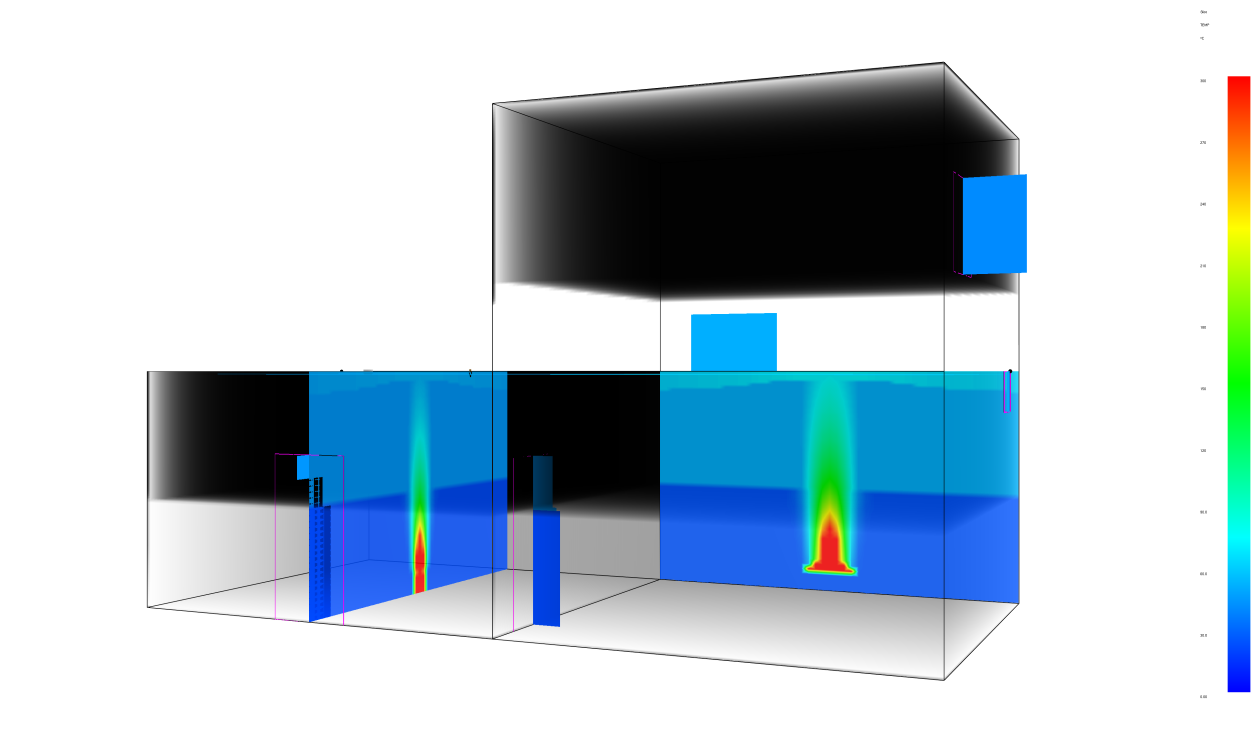


Figure 9.2: example Smokeview Visualization for a Three Compartment Test Case with Two Fires (`User_Guide_Example.in`)

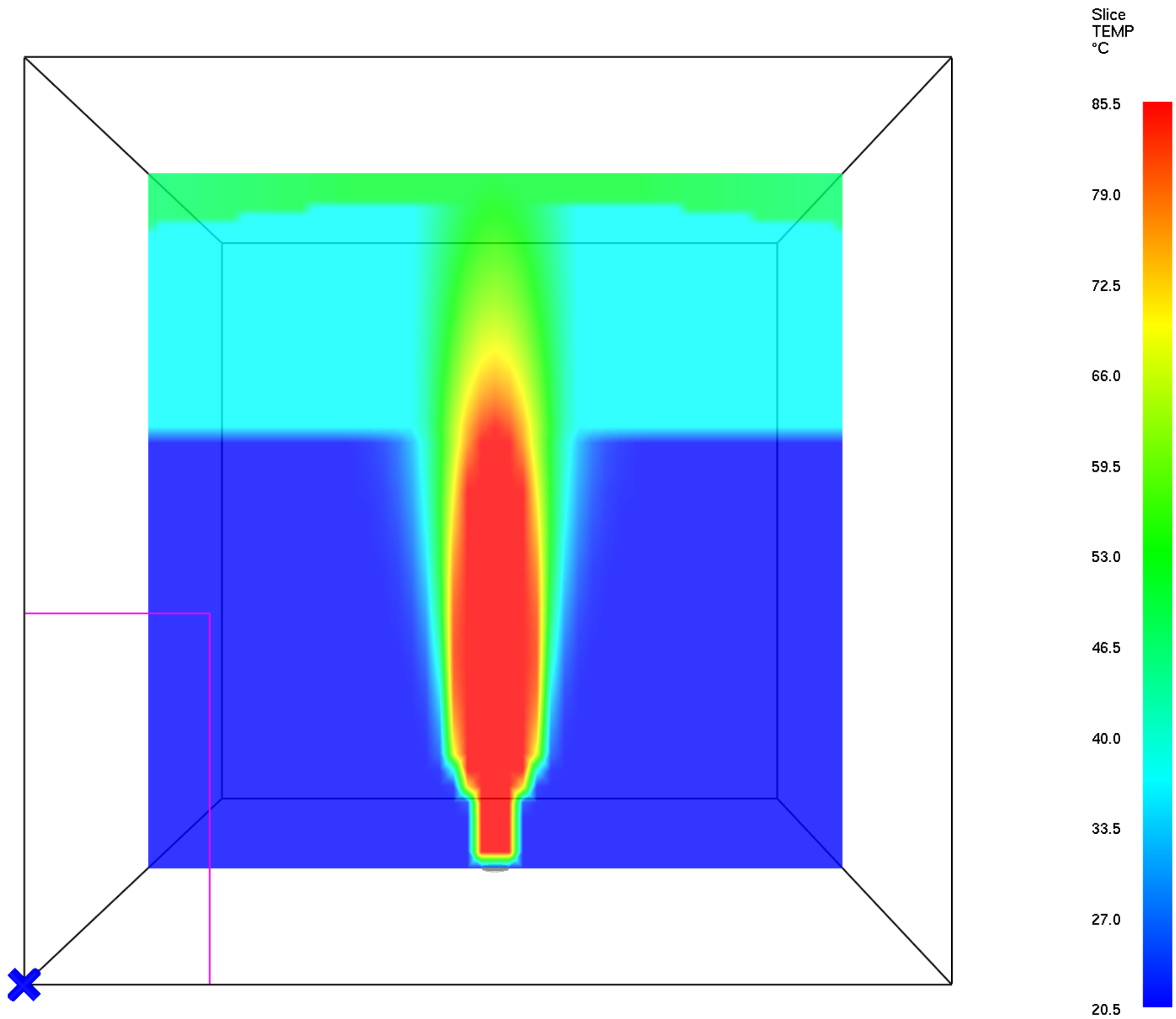


Figure 9.3: Smokeview Visualization of Gas Temperature with a Single Fire

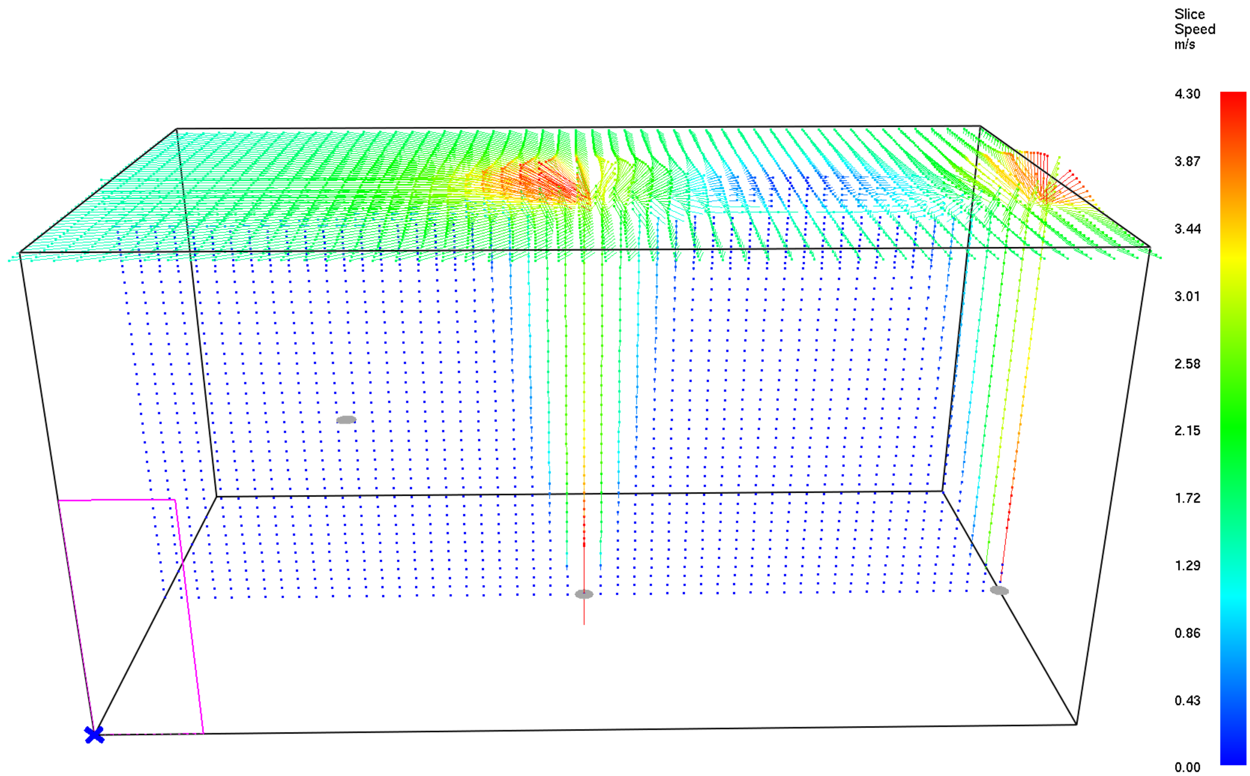


Figure 9.4: Smokeview Visualization of Gas Velocity with Two Fires

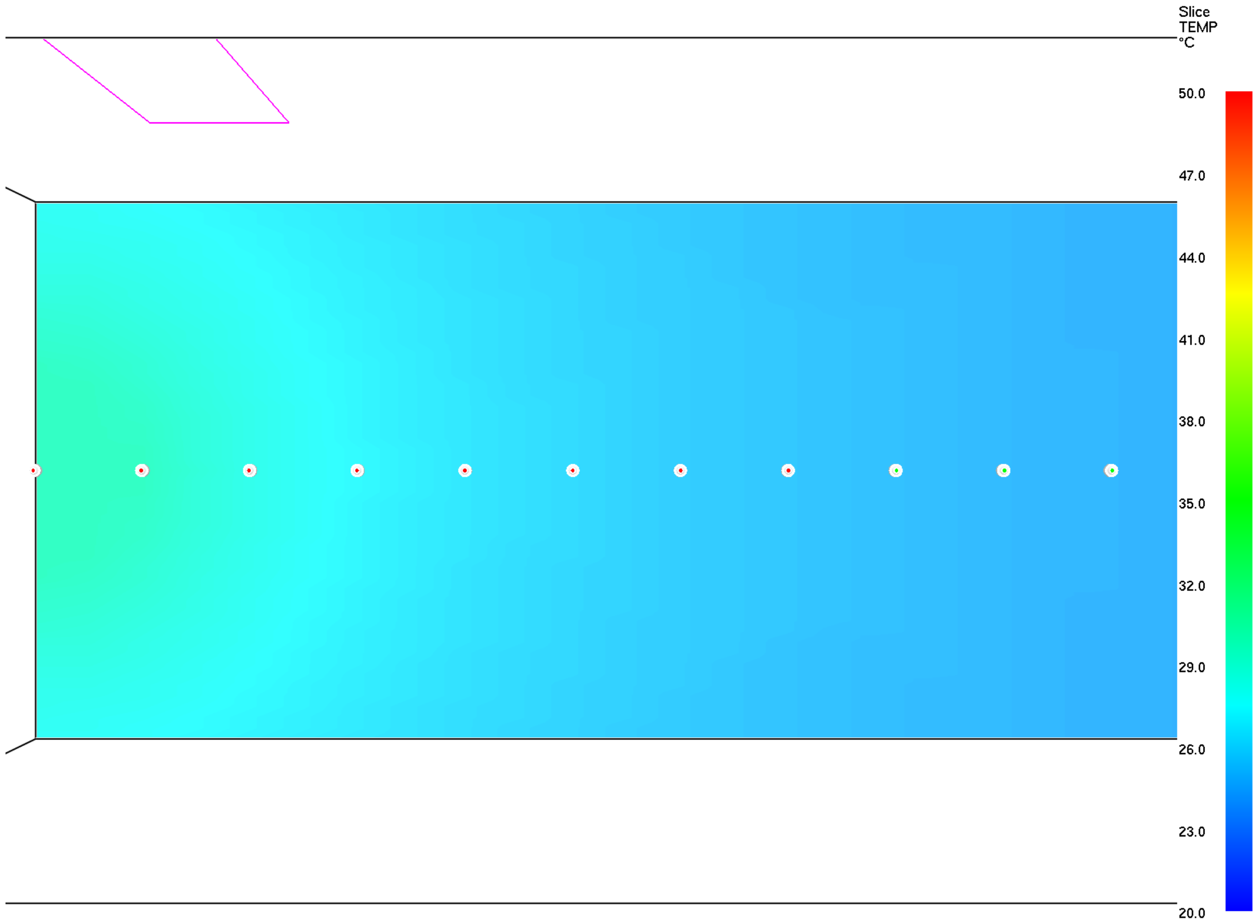


Figure 9.5: Smokeview Visualization of Detector Activation in a Corridor

9.3 Output Options

By default, CFAST generates a set of output files that includes a formatted readable output and a set of spreadsheet files. Options are available to modify the output files. The default output should be appropriate for most simulations.

CFAST Validation Output If checked, this item directs the CFAST model to output abbreviated headings for spreadsheet columns that are better for automated processing of the data.

Debug Output If checked, CFAST will create a detailed output spreadsheet that contains values of all the solution variables at each successful solution time step. This file is typically only of use to model developers diagnosing a problem with the model.

Show CFAST Window If checked, this item allows the user to see the windows command prompt that is used to execute the CFAST model when the Model Simulation, CFAST menu item is used. By default, this is not checked. Normally, this can be left unchecked. For troubleshooting, this can be selected to see additional details of the calculation as it progresses.

Chapter 10

Output from CFAST

The output of CFAST includes the temperatures of the upper and lower gas layers within each compartment, the ceiling/wall/floor temperatures within each compartment, the visible smoke and gas species concentrations within each layer, target temperatures and sprinkler activation time. The amount of information can be very large, especially for complex geometries and long simulations.

10.1 Compact Output

The default output to the console is called the compact form, and shows the basic information about a scenario, including layer temperatures and the size of fires. Default text output provides a simple overview for the user to make sure the case runs as expected.

```
****************************
* Time =   3600.0 seconds. *
****************************

Compartment    Upper     Lower      Inter.      Upper              Upper      Lower       Pressure
               Temp.     Temp       Height      Vol                Absor      Absorb
               (C)       (C)        (m)         (m^3)              (1/m)      (1/m)       (Pa)
----------------------------------------------------------------------------------------------------
Comp 1         48.52      20.89      1.542       36.    ( 49%)  0.172      9.306E-02   -0.570
Comp 2         138.4      36.39      1.586       35.    ( 47%)  0.171      9.338E-02    -1.86
Comp 3         103.7      27.50      1.000       50.    ( 67%)  0.161      0.104        0.983
```

The first column contains the compartment ID. On each row with its compartment number from left to right is the upper layer temperature, lower layer temperature, the height of the interface between the two layers, the total pyrolysis rate, and finally the total fire size. The only value given for the outside is the total heat release rate of fires venting to the outside.

10.2 Detailed Outputs

The following sections describe each of the outputs from the model. Each section refers to a specific part of the print out and appears in the order the output appears. A description of each option follows. When running CFAST from within CEdit an output file is automatically generated based on the input file name. For example, running the example file `Users_Guide_Example.in` generates an output file named `Users_Guide_Example.out`. All the detailed outputs described in the following sections are included in the output file.

10.2.1 Output for Initialization

This prints the initial conditions to the output before the actual run starts. This merely mimics the inputs specified by the user in the input data file The initial conditions break down into seven sections. Each is described below with the section name. The following explanation uses the output from the case `Users_Guide_Example.in` which is included in the distribution.

Overview

The overview gives a general description of the case. The output is fairly self explanatory. "Doors, ..." is the total number of horizontal natural flow vent connections or wall vents in all compartments of the simulation. "Ceil. Vents, ..." gives the total number of vertical natural flow vent connections or ceiling/floor vents in all compartments of the simulation. The last header on the line "MV Connections" has the total number mechanical flow connections to all compartments in the simulation. Times in these outputs are the times discused in section 2.2. All times are in s.

```
CFAST

Release Version  : CFAST 7.3.1
Revision         : CFAST7.3.1-0-g6b9b32bb
Revision Date    : Mon Apr 8 12:38:20 2019 -0400
Compilation Date : Thu 04/18/2019  12:05 PM

Data file: C:\Users\rpeacoc\firemodels\cfast\Utilities\for_bundle\Bin\Data\Users_Guide_Example.in
Title: Users Guide Example Case


OVERVIEW


Compartments    Doors, ...    Ceil. Vents, ...    MV Connects
-------------------------------------------------------------
   3              3              1                     2

Simulation     Output         Smokeview      Spreadsheet
Time           Interval       Interval       Interval
   (s)            (s)            (s)            (s)
--------------------------------------------------------
   3600.00         60.00          60.00          60.00
```

Ambient Conditions

This section, like the overview section, needs little elaboration. It gives the starting atmospheric conditions for the simulation both for outside and inside the structure. Temperatures are in °C and pressure in Pa.

```
AMBIENT CONDITIONS

Interior       Interior       Exterior       Exterior
Temperature    Pressure       Temperature    Pressure
  (C)            (Pa)           (C)            (Pa)
-----------------------------------------------------
    20.          101325.          20.          101325.
```

Compartments

The compartments section gives a summary of the geometry for the simulation. A simple table summarizes the geometry with compartments running down the page in order specified. The various dimensions for each compartment are on the row with its compartment number and name. Two columns need explanation. The second to last column "Ceiling Height" gives the height of the ceiling relative to the base height which is 0. Similarly the "Floor Height" refers to the height of the floor above the base height.

COMPARTMENTS

Compartment	Name	Width (m)	Depth (m)	Height (m)	Floor Height (m)	Ceiling Height (m)	Shaft	Hall
1	Comp 1	5.00	5.00	3.00	0.00	3.00		
2	Comp 2	5.00	5.00	3.00	0.00	3.00		
3	Comp 3	5.00	5.00	3.00	3.00	6.00		

All the information in this table comes from the compartments tab discused in section 4.1

Wall Vents

This is the first table in the vent connections section. Each row in the table characterizes one vent. The first two columns contain the two compartments connected by the vent. The third column gives the vent number. Column four is the width of the vent. The next two columns report the sill and soffit height for the vent relative to the floor of the first compartment. The seventh and eighth columns have a second listing of the sill and soffit height, this time relative to the base height.

VENT CONNECTIONS

Wall Vents (Doors, Windows, ...)

From Compartment	To Compartment	Vent Number	Width (m)	Sill Height (m)	Soffit Height (m)	Open/Close Type (m)	Trigger Value (C/W/m^2)	Target	Initial Time (s)	Initial Fraction	Final Time (s)	Final Fraction
Comp 1	Outside	1	1.00	0.00	2.00	Time			0.00	1.00	0.00	1.00
Comp 1	Comp 2	2	1.00	0.00	2.00	Time			0.00	1.00	0.00	1.00
Comp 3	Outside	3	1.00	1.00	2.00	Time			0.00	1.00	0.00	1.00

From compartment, to compartment, vent number, width, sill height, and soffit height all come directly from the wall vent tab discussed in section 5.1.1. Vent opening and closing information can be specified by time, by an associated time / fraction history or by an associated target to trigger a change in the vent opening by temperature or heat flux are all set in the same tab.

Ceiling and Floor Vents

The first column is the upper compartment. The upper compartment is the compartment where the vent opens into the floor. The second column is the lower compartment where the vent is in the ceiling. Each vent connection between compartment pairs is also identified by a vent number index beginning with 1. The fourth column describes the shape of the vent, which can be either round or square. The fifth column gives the area of the vent. Vent opening and closing information can be specified by time, by an associated time / fraction history or by an associated target to trigger a change in the vent opening by temperature or heat flux.

Ceiling and Floor Vents

Top Compartment	Bottom Compartment	Vent Number	Shape	Area (m^2)	Open/Close Type	Trigger Value (C/W/m^2)	Target	Initial Time (s)	Initial Fraction	Final Time (s)	Final Fraction
Comp 3	Comp 2	1	Round	1.00	RAMP # 1						

Top compartment, bottom compartment, shape, and area come from the Ceiling/Floor Vent tab discuussed in section 5.1.2. Relative height is the height of the vent above the floor of the bottom compartment and absolute height is the height of the vent above the base elevation. Vent opening and closing information can be specified by time, by an associated time / fraction history or by an associated target to trigger a change in the vent opening by temperature or heat flux are all set in the same tab.

Mechanical Flow Connections

This section lists all connections to compartments and fans that connect between compartments. The table lists, in order, the compartments connected by the fan, a numeric index assigned to the fan beginning with 1. A fan actually draws air from the first or "from" compartment and pushes it to the second or "to" compartment. The fourth column is the cross-sectional area of the duct connection to the chosen compartment. Vent opening and closing information can be specified by time, by an associated time / fraction history or by an associated target to trigger a change in the vent opening by temperature or heat flux.

Mechanical Vents (Fans)

From Compartment	To Compartment	Fan Number	Area (m^2)	Flowrate (m^3/s)	Open/Close Type	Trigger Value (C/W/m^2)	Target	Initial Time (s)	Initial Fraction	Final Time (s)	Final Fraction
Outside	Comp 1	1	0.02	0.25	RAMP # 2						
Comp 2	Outside	2	0.02	0.25	RAMP # 3						

From compartment, to compartment, fan number, area, and flowrate are all set in the Mechanical Ventilation tab discussed in sections 5.2.1 and 5.2.2. Vent opening and closing information can be specified by time, by an associated time / fraction history or by an associated target to trigger a change in the vent opening by temperature or heat flux are all set in the same tab.

Ventilation Opening Time Specifications

Opening and closing of vents in CFAST can be specified by a series of times and opening fractions for a specified vent. By default, all vents are open at the beginning of a simulation and remain open throughout the simulation. On the tab for each type of ventilation a time / fraction history can be associated with the vent. These time / fraction histories are called Vent Ramps and have their own tables.

VENT RAMPS

Type	From Compartment	To Compartment	Vent Number		(s)	(s)	(s)
V	Comp 3	Comp 2	1	Time	0	100	500
				Fraction	0.00	0.50	1.00
M		Comp 1	1	Time	0	100	500
				Fraction	0.00	0.50	1.00
M	Comp 2	Outside	2	Time	0	100	500
				Fraction	0.00	0.50	1.00

Thermal Properties

The thermal properties section is broken into two parts. The first part is a table that lists the material for each surface of each compartment. The compartments appear as rows down the page in order of specification. From left to right next to the compartment name comes the material for the ceiling, wall and floor. The second table lists the properties of each material used in the simulation. For each listing of a material, the name is followed by the conductivity, specific heat, density, thickness and emissivity. In addition to materials for compartment surfaces, any thermal properties specified for targets are also listed (this may include thermal properties for gaseous materials specified as fire sources in a simulation.)

```
THERMAL PROPERTIES

Compartment     Ceiling       Wall          Floor
-----------------------------------------------
Comp 1        CONCRETE     CONCRETE     CONCRETE
Comp 2        CONCRETE     CONCRETE     CONCRETE
Comp 3        CONCRETE     CONCRETE     CONCRETE


Name     Conductivity       Specific Heat      Density        Thickness     Emissivity
-------------------------------------------------------------------------------------
CONCRETE      1.75              1.000E+03         2.200E+03       0.150            0.940
DEFAULT      0.120               900.              800.          1.200E-02         0.900
```

Material choices of the ceiling, walls, and floors is discussed in section 4.2. Setting thermal-physical properties is done in the Thermal Properites tad discussed in section 3.1. Units for thermal properties are standard S.I. units. For thermal conductivity, kW/(m·K); for specific heat, kJ/(kg·K); for density, kg/m^3; for thickness, m; emissivity is dimensionless.

Fires

The fire section lists all the information about all fires that might exist. All the information for each fire is listed separately. Each fire listing has the same form. First is the name of the fire followed by a list of general information. Listed left to right is the compartment the fire is in, the type of fire, the initial x (width), y (depth), z (height) position of the fire, the relative humidity, the lower oxygen limit, and finally the radiative fraction for the fire.

A table of time history curves for the fire follows. The table contains all the time history curves for the fire. Each row on the table is a specific time given in the left most column. The rest of the columns give the values at that particular time. The column headers indicate each input quantity and correspond to specific keywords in the fire definition. The headings are defined as follows: 'Mdot' is pyrolysis rate; 'Hcomb' is the heat of combustion; 'Qdot' is the heat release rate; 'Zoffset' is height of the fire above the base z-position; 'Soot' is the fraction of the fuel mass converted to soot during combustion; 'CO' is the fraction of the fuel mass converted to carbon monoxide during combustion; 'HCN' is the fraction of the fuel mass converted to hydrogen cyanide during combustion; 'HCl' is the fraction of the fuel mass converted to hydrogen chloride during combustion; and 'TS' is the fraction of fuel mass converted to trace species during combustion.

```
FIRES


Name: Cushion   Referenced as object #  1 Normal fire

Compartment     Fire Type       Time to Flaming       Position (x,y,z)       Relative    Lower O2     Radiative
                                                                             Humidity    Limit        Fraction
----------------------------------------------------------------------------------------------------------------
Comp 1         Constrained            0.0            2.50    2.50    0.00      50.0        10.00         0.33
```

Chemical formula of the fuel

Carbon	Hydrogen	Oxygen	Nitrogen	Chlorine
9.000	6.000	2.000	2.000	0.000

Time (s)	Mdot (kg/s)	Hcomb (J/kg)	Qdot (W)	Zoffset (m)	Soot (kg/kg)	CO (kg/kg)	HCN (kg/kg)	HCl (kg/kg)	TS (kg/kg)
0.	0.0	5.00E+07	0.0	0.0	0.23	8.46E−02	0.31	0.0	0.0
60.	2.00E−03	5.00E+07	1.00E+05	0.0	0.23	8.46E−02	0.31	0.0	0.0
120.	3.00E−03	5.00E+07	1.50E+05	0.0	0.23	8.46E−02	0.31	0.0	0.0
180.	4.00E−03	5.00E+07	2.00E+05	0.0	0.23	8.46E−02	0.31	0.0	0.0
240.	3.00E−03	5.00E+07	1.50E+05	0.0	0.23	8.46E−02	0.31	0.0	0.0
300.	2.50E−03	5.00E+07	1.25E+05	0.0	0.23	8.46E−02	0.31	0.0	0.0
360.	2.00E−03	5.00E+07	1.00E+05	0.0	0.23	8.46E−02	0.31	0.0	0.0
420.	1.80E−03	5.00E+07	9.00E+04	0.0	0.23	8.46E−02	0.31	0.0	0.0
480.	1.60E−03	5.00E+07	8.00E+04	0.0	0.23	8.46E−02	0.31	0.0	0.0
540.	1.50E−03	5.00E+07	7.50E+04	0.0	0.23	8.46E−02	0.31	0.0	0.0
1800.	1.50E−03	5.00E+07	7.50E+04	0.0	0.23	8.46E−02	0.31	0.0	0.0

All of the inputs for all fires come from the fire specifications set in the Fires tab discussed in section 6.1. Units for most values are included in the output. Fire position is in m, relative humidity is in %, lower oxygen limit is in volume %, and pyrolysis temperature is in K.

Targets

The entry for targets shows the orientation of additional targets specified in the data file. Targets explicitly specified in the data file are listed first in the order they are included in the data file. The compartment number, position of the target within the compartment, direction of the front face of the target object expressed as a normal unit vector to the surface, and object material.

TARGETS

Target		Compartment	Position (x, y, z)			Direction (x, y, z)			Material
1	Targ 1	Comp 1	2.20	1.88	2.34	0.00	0.00	1.00	CONCRETE

All of the inputs for targets come from the Targets tab discussed in chapter 7. Direction is specified as a unit vector as described in the section on target input. Units for position and direction are all in m.

Detectors and Sprinklers

The entry for each detector or sprinkler shows the compartment and position of the device and its activation characteristics. For smoke detectors, activation is based on the smoke obscuration at the position of the detector; for heat detectors and sprinkler, the temperature of the detector.

DETECTORS/ALARMS/SPRINKLERS

Target	Compartment	Type	Position (x, y, z) (m)	(m)	(m)	Activation Obscuration (%/m)	Flaming Obscuration (%/m)	Smoldering Obscuration (%/m)	Temperature (C)	RTI (m s)^1/2	Spray Density (mm/s)
1	Comp 1	SPRINK	3.00	3.00	2.97				73.89	100.00	7.00E−02
2	Comp 1	SMOKE	2.00	2.00	2.97	23.93					
3	Comp 1	HEAT	2.00	2.00	2.97				30.00	5.00	

All of the inputs for detectors and sprinklers come from the Detector / Surpression tab discussed in section 7.2. Units for position are all in m.

10.2.2 Output for Main Variables

The normal print out is the first information printed at each time interval. This information includes the layer temperatures, interface height, volume of the upper layer, layer absorption coefficients, and compartment pressure (relative to ambient).

Time = 3600.0 seconds.

Compartment	Upper Temp. (C)	Lower Temp (C)	Inter. Height (m)	Upper Vol (m^3)		Upper Absor (m^-1)	Lower Absorb (m^-1)	Pressure (Pa)
Comp 1	78.70	23.01	1.404	40.	(53%)	0.235	0.100	-0.430
Comp 2	176.5	44.97	1.495	38.	(50%)	0.240	9.153E-02	-1.49
Comp 3	104.3	27.58	1.248	44.	(58%)	0.241	9.556E-02	-0.336

The second table of the normal print out has information about the fires. In essence it is two tables joined. The first part lists information by fire. It lists fires in the order they are specified in the input file down the page. The fires are listed in the second column followed by the plume flow rate, the pyrolysis rate, the fire size, and flame height. The next three columns are then skipped. The next column with information is the amount of heat given off by each fire convectively, followed by the amount of heat given off radiantly. The last two columns give the total mass pyrolyzed and the amount of trace species produced. The second part starts after all the fires have been individually listed. It gives the totals for all fires in each compartment. The first column has the compartment name. The compartments are listed down the page in order specified. The third to fifth columns are the same as the first part except the values are totals for the compartment and not just for one fire. The sixth column has the total heat release rate that occurs in the upper layer. The next column has the same total in the lower layer. The eighth column has the total size of vent fires in the compartment.

FIRES

Compartment	Fire	Ign	Plume Flow (kg/s)	Pyrol Rate (kg/s)	Fire Size (W)	Flame Height (m)	Fire in Upper (W)	Fire in Lower (W)	Vent Fire (W)	Convec. (W)	Radiat. (W)	Pyrolysate kg)	Trace (kg)
	Cushion	Y	1.802E-04	1.503E-07	7.51	0.00				5.04	2.48	1.06	0.00
	Wood_Wall	Y	1.57	2.486E-02	4.500E+05	0.382				3.015E+05	1.485E+05	44.8	0.00
Comp 1			1.802E-04	1.503E-07	7.51		0.00	7.51	0.00				
Comp 2			1.57	2.486E-02	4.500E+05		0.00	4.500E+05	0.00				

Flame height is calculated from the work of Heskestad [14]. The average flame height is defined as the distance from the fuel source to the top of the visible flame where the intermittency is 0.5. A flame intermittency of 0.5 means that the visible flame is above the mean 50 % of the time and below the mean 50 % of the time.

10.2.3 Output for Wall Surfaces, Targets, and Detectors/Sprinklers

The printed output provides two tables displaying information about wall surface or target temperatures and fluxes, and heat detectors or sprinklers. The left most column specifies the compartment name; followed by four columns providing the temperatures of the bounding surfaces of the compartment in contact with the ceiling, upper wall surface (in contact with the upper layer gases), lower wall surface (in contact with the lower layer gases), and floor, in that order. Next comes information about targets in the compartment, with each target listed on a separate line. Information in the columns includes the surface temperature of the target, net heat flux to the target, and the percentage of that net flux that is due to radiation from the fire, radiation from compartment surfaces, radiation from the gas layers, and convection from the gas surrounding the target. CFAST includes one target in the center of the floor for all compartments. Information on additional targets specified by the user in the input data file are also included, in the order specified in the input file.

For smoke detectors, heat detectors, and sprinklers, the temperature of the device, its current state (activated or not), and the nearby gas temperature and velocity are included.

SURFACES AND TARGETS

Compartment	Ceiling Temp. (C)	Up wall Temp. (C)	Low wall Temp. (C)	Floor Temp. (C)	Target	Gas Temp. (C)	Surface Temp. (C)	Interior Temp. (C)	Incident Flux (W/m^2)	Net Flux (W/m^2)	Gas FED	Heat FED
Comp 1	25.7	24.5	21.4	22.0								
					Targ 1	48.5	24.5	22.2	451.	190.	94.9	0.134
Comp 2	129.	51.8	76.4	46.9								
Comp 3	33.8	33.7	22.7	23.1								

DETECTORS/ALARMS/SPRINKLERS

Number	Compartment	Type	Sensor Temp (C)	Smoke Temp (C)	Vel (m/s)	Obs (1/m)	Activated
1	Comp 1	SPRINK	4.706E+01	4.852E+01	1.194E-01		YES
2	Comp 1	SMOKE		4.852E+01	1.194E-01	7.875E-01	YES
3	Comp 1	HEAT	4.850E+01	4.852E+01			YES

In all cases, the flux to/from a target is net radiation or net convection. That is, it is the incoming minus the outgoing. So while a target or object is heating, the flux will be positive, and once it starts to cool, the flux will be negative. Values for radiation from fires (fire rad.), radiation from surfaces (surface rad.), radiation from the gas layers (gas rad.), and convection from surfaces (convect) are expressed as the net flux to target (flux to target). Positive values indicate heat gains by the target and negative values indicate heat losses.

10.2.4 Output for Gas Species

The output has two tables displaying information about the amounts of species in each layer. The species information follows the normal print out. The first table gives species volume % for the upper layers of all the compartments and the second reports the same for the lower layers of all the compartments. Again the compartments are listed down the page and the information across the page. The species are each given in one of several different terms. Below each header are the units for the given value. Most of the headers are simply the chemical formula for the species being tracked (Elemental nitrogen, oxygen, carbon dioxide, carbon monoxide, hydrogen cyanide, hydrochloric acid, and water). However, several are not obvious. "TUHC" is the total unburned hydrocarbons or the pyrolyzed fuel that hasn't burned yet. "OD" is the optical density, which is a measure of the amount of smoke. "OD S" and "OD F" and the optical density resulting from only smoldering and flaming smoke production, respectively. "TS" is trace species.

UPPER LAYER SPECIES

Compartment	N2 (%)	O2 (%)	CO2 (%)	CO (%)	HCN (%)	HCL (%)	TUHC (%)	H2O (%)	OD (1/m)	OD_F (1/m)	OD_S (1/m)	TS kg
Comp 1	77.3	19.1	1.29	8.077E-03	2.025E-04	0.00	0.00	2.27	0.788	0.788	0.00	0.00
Comp 2	77.0	18.6	1.71	1.061E-02	2.008E-05	0.00	0.00	2.63	0.808	0.808	0.00	0.00
Comp 3	77.0	18.7	1.64	1.018E-02	2.190E-05	0.00	0.00	2.57	0.847	0.847	0.00	0.00

The report by species are % by volume. Optical depth per meter is a measure of the visibility in the smoke. Trace species (TS) is the total mass of the trace species that is present in the layer in kilograms. It is an absolute measure and not percent or density.

10.2.5 Output for Vent Flows

Information about vent flow is obtained in this section. It includes information detailing mass flow through horizontal, vertical, and mechanical vents. There are two forms for the vent flow. The first is flow through the vents as kg/s. The second gives the total mass which has flowed through the vent(s) and the relative mass of trace species divided by the total mass of trace species produced up to the current time.

The section for vent flow is titled “FLOW THROUGH VENTS (kg/s).” Because flow is always given in positive values, each vent is listed twice, once for flow going from compartment A to compartment B (labelled as “Flow relative to ‘from”’) and a second time for flow from B to A (labelled as “Flow relative to ‘To”’. As the example below shows, the first column specifies the vent, including the type of vent (an “H” in this column stands for horizontal flow, such as through a doorway or window; a “V” here would mean vertical flow, such as through an opening in the ceiling, and an “M” stands for a mechanical ventilation connection) and the compartment from which the flow comes. The second column lists the name of the compartment. Up to six additional columns detail the flow at this vent. Flow into and out of the compartment through the vent in the upper and lower layers are included.

A second table shows total (mass) flow through vents. At present this is confined to mechanical ventilation (It applies only to vents which can be filtered, in this case mechanical ventilation). The last column is obtained by summing the outflow/inflow for each vent and then dividing that sum by the total trace species produced by all fires. For details on this value, see the section on output listing for fires.

FLOW THROUGH VENTS (kg/s)

			Flow relative to 'From'				Flow Relative to 'To'			
			Upper Layer		Lower Layer		Upper Layer		Lower Layer	
Vent	From/Bottom	To/Top	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
H 1	Comp 1	Outside	0.5279E-03		0.1480E+01					0.1480E+01
H 2	Comp 1	Comp 2	0.1093E+00	0.1051E+00		0.1508E+01	0.3196E-03	0.1093E+00	0.1613E+01	
H 3	Comp 3	Outside		0.1516E+01		0.3120E-03	0.1517E+01			
V 1	Comp 2	Comp 3		0.1461E+01		0.5241E-01	0.1514E+01			
M 1	Outside	Comp 1				0.2391E-01	0.2391E-01			
M 2	Comp 2	Outside		0.1703E-01					0.1703E-01	

TOTAL MASS FLOW THROUGH MECHANICAL VENTS (kg)

To	Through	Upper Layer		Lower Layer		Trace Species	
Compartment	Vent	Inflow	Outflow	Inflow	Outflow	Vented	Filtered
Outside	Comp 1				0.8190E+02		
Comp 2	Outside		0.6667E+02		0.2223E-01		

10.3 Spreadsheet Output

CFAST generates a number of output files in a plain text spreadsheet format. These files capture a snap shot of the modeling data at an instant of time. This instance is on the Simulation tab discussed in section 2.2. *However*, there are events which can occur in between these reporting periods. Examples are the ignition of objects and the activation of detectors or sprinklers. These are *not* reported in these output files.

Several spreadsheet files are generated with each CFAST simulation:

1. **project_compartments.csv** contains layer temperature and height, species concentrations, and fire-related outputs.
2. **project_devices.csv** contains outputs for targets and detectors (detailed target info with -V option)
3. **project_masses.csv** contains mass of species in compartment layers and total trace species masses (detailed unburned fuel info with -V flag)
4. **project_vents.csv** contains vent flows (additional flow details with -V option)
5. **project_walls.csv** contains compartment surface temperatures

10.3.1 Primary Output Variables (project_compartments.csv)

There are three sets of information in this file. The first includes compartment information such as layer temperature. This is output by compartment and there are entries for each compartment plus a column that indicates the current simulation time:

Time (s)

Upper Layer Temperature (°C)

Lower Layer Temperature (°C)

Layer Height (m)

Upper Layer Volume (m^3): total volume of the upper layer. This is just the floor area times the difference between the ceiling height and the layer height.

Pressure (Pa): pressure at compartment floor relative to the outside at the absolute height of the floor.

N2 Upper/Lower Layer (mol %): nitrogen concentration in the upper (or lower) layer in the current compartment

O2 Upper/Lower Layer (mol %): oxygen concentration in the upper (or lower) layer in the current compartment

CO2 Upper/Lower Layer (mol %): carbon dioxide concentration in the upper (or lower) layer in the current compartment

CO Upper/Lower Layer (mol %): carbon monoxide concentration in the upper (or lower) layer in the current compartment (multiply by 10 000 to convert to ppm)

HCN Upper/Lower Layer (mol %): HCN concentration in the upper (or lower) layer in the current compartment (multiply by 10 000 to convert to ppm)

HCL Upper/Lower Layer (mol %): HCl concentration in the upper (or lower) layer in the current compartment (multiply by 10 000 to convert to ppm)

H2O Upper/Lower Layer (mol %): water vapor concentration in the upper (or lower) layer in the current compartment

Optical Density Upper/Lower Layer (m^{-1}): optical density in the upper (or lower) layer in the current compartment

Optical Density Upper/Lower Layer (m^{-1}): optical density from flaming-generated smoke in the upper (or lower) layer in the current compartment

Optical Density Upper/Lower Layer (m^{-1}): optical density from smoldering-generated smoke in the upper (or lower) layer in the current compartment

Trace Species Upper/Lower Layer (kg): total mass of trace species in the upper (or lower) layer in the current compartment

HRR Door Jet Fires (W): total heat release rate of all door jet fires *adding* heat to this compartment.

The second set of information is for fires. This information is displayed for each fire:

Ignition : indicates whether the fire has ignited. entry is zero if the fire has not yet ignited and one if it has ignited.

Plume Entrainment Rate (kg/s): current mass entrained from the lower layer into the plume for this fire.

Pyrolysis Rate (kg/s): current rate of mass loss for this fire.

HRR Expected (W): current heat release rate input for this fire. This is the HRR input by the user before it is adjusted for available oxygen or sprinkler activation.

HRR Actual (W): current total heat release rate for this fire. This is just the sum of the heat release rate for the lower layer and upper layer for this fire. It may be lower than the user input if the fire is constrained by available oxygen or if a sprinkler has activated in the compartment.

HRR Convective actual (W): current rate of heat release by convection for this fire. The remainder is released by radiation to the surroundings.

HRR Lower Actual (W): current heat release rate for burning in the lower layer for this fire.

HRR Upper Actual (W): current heat release rate for burning in the upper layer for this fire.

Flame Height (m): current calculated flame height for this fire.

Total Pyrolysate Released (kg): total mass released by the fire up to the current time.

Total Trace Species Released (kg): total mass of trace species released by the fire up to the current time.

The last set of information is for door jet fires. This information is displayed for each compartment and for the outside:

HRR Door Jet Fires (W): current total heat release rate for door jet fires in this compartment.

10.3.2 Target Temperature and Heat Flux (project_devices.csv)

This file provides information on target temperatures and flux, and reports on the current state of detectors and sprinklers (as a sub-set of detectors). The output is in two sections, one for target temperature and heat flux, and one for detector/sprinkler temperature and activation. The first set of columns pertain to the targets. The second set of columns pertain to the user-defined targets included in the simulation.

Target Surrounding Gas Temperature (°C): gas temperature nearby the current target

Target Surface Temperature (°C): temperature of the surface of the current target

Target Internal Temperature (°C): interior temperature of the current target

Target Incident Flux (kW/m2): total heat flux striking the front surface of the current target

Target Net Flux (kW/m2): total net heat flux to the front surface of the current target

Target Gas FED : fractional effective dose due to toxic gases at the current target location

Target Gas FED Increment : incremental fractional effective dose due to toxic gases at the current target location

Target Heat FED : fractional effective dose due to convective heat at the current target location

Target Heat FED Increment : incremental fractional effective dose due to convective heat at the current target location

Target Obscuration (m^{-1}): optical density at the current target location

Target Convective Flux (kW/m^2): convective heat flux to the front surface of the current target (validation output only)

Target Radiative Flux (kW/m^2): total net radiative heat flux to the front surface of the current target (validation output only)

Target Fire Radiative Flux (kW/m^2): radiative heat flux from fires to the front surface of the current target (validation output only)

Target Surface Radiative Flux (kW/m^2): radiative heat flux from compartment surfaces to the front surface of the current target (validation output only)

Target Gas Radiative Flux (kW/m^2): radiative heat flux from the upper and lower gas layers to the front surface of the current target (validation output only)

Target Radiative Loss Flux (kW/m^2): radiative heat flux from the current target to surroundings at the calculated temperature of the target (validation output only)

Target Total Gauge Flux (kW/m2): total net heat flux to the front surface of the current target assuming the target radiative losses are at ambient temperature (validation output only)

Target Radiative Gauge Flux (kW/m^2): total net radiative heat flux to the front surface of the current target assuming the target radiative losses are at ambient temperature (validation output only)

Target Radiative Loss Gauge Flux (kW/m^2): radiative heat flux from the current target to surroundings assuming the target radiative losses are at ambient temperature (validation output only)

The second set of columns pertain to the detector/sprinkler output.

Sensor Temperature (°C): temperature of the current detector / sprinkler

Sensor Activation (none): indicator of activation of the current detector / sprinkler; takes a value of zero if the sensor has not activated and one if it has

Sensor Surrounding Gas Temperature (°C): gas temperature nearby the current detector / sprinkler. This is the ceiling jet temperature at the device location if the device is in the ceiling jet or the appropriate gas layer temperature if the device is lower in the compartment

Sensor Surrounding Gas Velocity (m/s): gas velocity nearby the current detector / sprinkler. This is the velocity of the ceiling jet at the device location if the device is in the ceiling jet or a default value of 0.1 m/s if the device is lower in the compartment

Sensor Obscuration (m^{-1}): optical density at the current sensor location

10.3.3 Layer Masses (project_masses.csv

Time (s)

N2 Upper/Lower Layer (kg): total nitrogen mass in the upper (or lower) layer in the current compartment

O2 Upper/Lower Layer (kg): total oxygen mass in the upper (or lower) layer in the current compartment

CO2 Upper/Lower Layer (kg): total carbon dioxide mass in the upper (or lower) layer in the current compartment

CO Upper/Lower Layer (kg): total carbon monoxide mass in the upper (or lower) layer in the current compartment (multiply by 10 000 to convert to ppm)

HCN Upper/Lower Layer (kg): total HCN mass in the upper (or lower) layer in the current compartment (multiply by 10 000 to convert to ppm)

HCL Upper/Lower Layer (kg): total HCl mass in the upper (or lower) layer in the current compartment (multiply by 10 000 to convert to ppm)

H2O Upper/Lower Layer (kg): total water vapor mass in the upper (or lower) layer in the current compartment

Optical Density Upper/Lower Layer (kg): total soot mass in the upper (or lower) layer in the current compartment

Optical Density Upper/Lower Layer (kg): total soot mass from flaming-generated smoke in the upper (or lower) layer in the current compartment

Optical Density Upper/Lower Layer (kg): total soot mass from smoldering-generated smoke in the upper (or lower) layer in the current compartment

Trace Species Upper/Lower Layer (kg): total mass of trace species in the upper (or lower) layer in the current compartment

10.3.4 Vent Flow (project_vents.csv)

The entries in this file pertain to the flow vents such as windows/doors, ceiling/floor vents, mechanical vents, and compartment leakage.

Time (s)

Net Inflow (kg/s): net mass flow into the current compartment through the current horizontal flow (door/windows) vent connected to the current compartment.

Opening Fraction : fraction the vent is open. Zero indicated a fully-closed vent; one indicates a fully-opened vent.

Trace Species Flow kg: total mass of trace species through this vent up to the current time (mechanical vents only).

Trace Species Flow kg: total mass of trace species removed by a specified filter in this vent up to the current time (for mechanical vents only).

Net Inflow (kg/s): net mass flow into the current compartment via wall and floor leakage (for each compartment that includes leakage).

10.3.5 Compartment Surface Temperature(project_walls.csv)

This file provides information on compartment surface temperatures

Time (s)

Ceiling Temperature (°C): temperature of the ceiling surface in the current compartment

Upper Wall Temperature (°C): temperature of the wall surface adjacent to the upper layer in the current compartment

Lower Wall Temperature (°C): temperature of the wall surface adjacent to the lower layer in the current compartment

Floor Temperature (°C): temperature of the floor surface in the current compartment

10.4 Error Messages

In some (hopefully rare) cases, a simulation will fail to complete. In those cases, an error message provides guidance to the user on possible reasons for the failure. The message will contain an error number which provides a reference to additional information from the table below. Most often, these errors result from improper information in the input data files. During initialization of the program for a simulation, CFAST may stop with an error message if the simulation cannot be initialized due to a missing or incorrect file specification. The error codes are as follows:

100 program called with no arguments (no input file)

101 internal error in fire input; code for a free burning fire should not be reachable

102 project file does not exist

103 total file name length including path is more than 256 characters

104 one of the output files is not accessible (for example, if a CFAST case with this name is already running)

105 error writing to an output file (openoutputfiles)

106 a system fault has occurred. Applies to all open/close pairs once the model is running

107 incompatible options

108 not currently used

109 cannot find/open a file

110 error in handling the status input/output

Error codes from 1 to 99 are from the routine which parses the input and will be reported in the .log file. The first set indicates a command with the wrong number of arguments. These errors indicate an error in a particular input command as follows:

1 TIMES command

2 TAMB command

3 EAMB command

4 LIMO2 command

5 THERMAL or FIRE commands

7 MAINF command

8 COMPA command

10 HVENT command

11 EVENT command

12 MVENT command

23 VVENT command

24 WIND command

25 INTER command

26 MVOPN command

28 MVDCT command

29 MVFAN command

32 OBJECT command

34 CJET and DETEC command

35 STPMAX command

37 VHEAT command

39 ONEZ command

41 TARGE command

46 HALL command

47 ROOMA command

51 ROOMH command

55 DTCHE command

56 SETP command

58 HHEAT command

65 HEATF command

The second set of errors related to parsing the input indicate specific errors with a command as follows:

9, compa Compartment out of range

26, inter Not a defined compartment

27, mvopn Specified node number too large for this system

30, mvfan Fan curve has incorrect specification

31, mvfan Exceeded allowed number of fans

33, object Object must be assigned to an existing compartment

35, detect Invalid DETECTOR specification

36, detect A referenced compartment is not yet defined

38, vheat VHEAT has specified a non-existent compartment

42, target Too many targets are being defined

43, target The compartment specified by TARGET does not exist

44, target Invalid TARGET solution method specified

45, target Invalid equation type specified in TARGET

49, rooma Compartment specified by ROOMA does not exist

52, roomh Compartment specified by ROOMH is not defined

53, roomh ROOMH error on data line

54, roomh Data on the ROOMA (or H) line must be positive

57, setp Trying to reset the SETP parameters

61, hheat HHEAT specification error in compartment pairs

62, hheat Error in fraction for HHEAT

63, object Fire type out of range

64, object The fire must be assigned to an existing compartment

66, heatf The heat source must be assigned to an existing compartment

67, mvent Compartment has not been defined

68, mvent Exceed one of the array bounds, ierror=68 (external), 69 (internal) and 70 (fan)

71, event Undefined vent type

72, inter Specification for interface height is outside of allowable range

73, inter Compartments must be defined in pairs

74, setp The requested “SETP” command does not exists

75, setp Incorrect file reference

76, setp Cannot read the parameter file

77, setp Unsupported parameter

Errors 400 and above are failures while the model is running. 610 through 685 are failures in the numerical routines; these are rarely seen, but typically result from an internal error in the model.

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Appendix A

Scenario and Software Limits

CFAST is intended for use with a wide variety of fire scenarios. A number of limits to the inputs in the software implementation of the model are noted below.

Maximum simulation time in seconds	86400
Maximum number of compartments	100
Maximum number of horizontal flow (door/window) vent connections that can be included in a single test case	2500
Maximum number of vertical flow (ceiling/floor) vent connections which can be included in a single test case	2500
Maximum total number of connections between compartments and mechanical ventilation systems which can be included in a single test case	2500
Maximum number of fans that can be included in a single test cases	1250
Maximum number of fires which can be included in a single test case	2500
Maximum number of data points for a single fire definition	199
Maximum number of data points in a variable cross-sectional area definition for a single compartment	199
Maximum number of material thermal property definitions which can be included in a single thermal database file	2500
Maximum number of targets which can be included in a single test case. In addition, the CFAST model includes a target on the floor of each compartment in the simulation and one for each object fire in simulation.	2500
Maximum number of detectors/sprinklers which can be included in a single test case.	2500

Appendix B

CFAST Text-based Input File

The operation of CFAST is based on a single ASCII[1] text file containing parameters organized into *namelist*[2] groups. The input file provides CFAST with all of the necessary information to describe the scenario. The graphical user interface, CEdit, writes this file. This appendix details all the parameters, which are organized into groups that roughly coincide with the tabs in the graphical user interface.

B.1 Naming the Input File

The input file is saved with a name such as `job_name.in`, where `job_name` is any character string that helps to identify the simulation. All of the output files associated with the calculation will then have this common prefix name.

There should be no blank spaces in the job name. Instead use the underscore character to represent a space.

Be aware that CFAST will simply over-write the output files of a given case if its assigned name is the same. This is convenient when developing an input file because you save on disk space. Just be careful not to overwrite a calculation that you want to keep.

B.2 Namelist Formatting

Parameters are specified within the input file by using *namelist* formatted records. Each namelist record begins with the ampersand character, `&`, followed immediately by the name of the namelist group, then a comma-delimited list of the input parameters, and finally a forward slash, `/`. For example, the line

```
&TIME  SIMULATION = 3600., PRINT = 50., SMOKEVIEW = 50., SPREADSHEET = 50. /
```

sets various values of parameters contained in the `TIME` namelist group. The meanings of these various parameters is explained in this guide. The namelist records can span multiple lines in the

[1]ASCII – American Standard Code for Information Interchange. There are 256 characters that make up the standard ASCII text.

[2]A *namelist* is a Fortran input record.

input file, but just be sure to end the record with a slash or else the data will not be understood. Do not add anything to a namelist line other than the parameters and values appropriate for that group. Otherwise, CFAST will stop immediately upon execution.

Parameters within a namelist record can be separated by either commas, spaces, or line breaks. It is recommended that you use commas or line breaks, and never use tab stops because they are not explicitly defined in the namelist data structure. CFAST and CEdit expect the first character of the file to be an ampersand, `&`, and by convention the first namelist is the `HEAD` namelist but any namelist can be the first. Comments and notes can be written into the file between namelists so long as nothing comes before the ampersand except a space and nothing comes between the ampersand and the slash except appropriate parameters corresponding to that particular namelist group. However, it is important to note that any comments in an input file that is opened by CEdit and saved will be lost.

The parameters in the input file can be integers, reals, character strings, or logical parameters. A logical parameter is either `.TRUE.` or `.FALSE.` – the periods are a Fortran convention. Character strings that are listed in this User's Guide must be copied exactly as written – the code is case sensitive and underscores *do* matter. The maximum length of most character input parameters is 60.

Most of the input parameters are simply real or integer scalars, like `PRINT = 50.`, but sometimes the inputs can be arrays.

Note that character strings can be enclosed either by single or double quotation marks, however CEdit only recognizes the single quotation mark. Be careful not to create the input file by pasting text from something other than a simple text editor, in which case the punctuation marks may not transfer properly into the text file. Some text file encodings may not work on all systems. If file reading errors occur and no typographical errors can be found in the input file, try saving the input file using a different encoding. For example, the text file editor Notepad works fine on a Windows PC, but a file edited in Notepad may not work on Linux or Mac OS X because of the difference in line endings between Windows and Unix/Linux operating systems. The editor Wordpad typically works better, but try a simple case first.

B.3 Input File Structure

In general, the namelist records can be entered in any order in the input file, but it is a good idea to organize them in some systematic way. Typically, general information is listed near the top of the input file, and detailed information, like obstructions, devices, and so on, are listed below. CFAST scans the entire input file each time it processes a particular namelist group. With some text editors, it has been noticed that the last line of the file is often not read by CFAST because of the presence of an "end of file" character. To ensure that CFAST reads the entire input file, add

```
&TAIL /
```

as the last line at the end of the input file. This completes the file from `&HEAD` to `&TAIL`. CFAST does not even look for this last line. It just forces the "end of file" character past relevant input.

The general structure of an input file is shown below, with many lines of the original input file[3]

[3]The actual input file, Users_Guide_Example.in, is part of the CFAST software distribution

removed for clarity.

```
&HEAD VERSION = 7300, TITLE = 'Users Guide Example Case' /
!! Scenario Configuration
&TIME SIMULATION = 3600 PRINT = 50 SMOKEVIEW = 50 SPREADSHEET = 50 /
&INIT PRESSURE = 101325 RELATIVE_HUMIDITY = 50 INTERIOR_TEMPERATURE = 20 EXTERIOR_TEMPERATURE = 20 /
&MISC  LOWER_OXYGEN_LIMIT = 0.1 /
!! Material Properties
&MATL ID = 'CONCRETE' MATERIAL = 'Concrete, Normal Weight (6 in)',
      CONDUCTIVITY = 1.75 DENSITY = 2200 SPECIFIC_HEAT = 1, THICKNESS = 0.15 EMISSIVITY = 0.94 /
!! Comparments
&COMP ID = 'Comp 1'
      DEPTH = 5 HEIGHT = 3 WIDTH = 5 CEILING_MATL_ID = 'CONCRETE' WALL_MATL_ID = 'CONCRETE' FLOOR_MATL_ID = 'CONCRETE'
      ORIGIN = 0, 0, 0 GRID = 50, 50, 50 /
!! Devices
&DEVC ID = 'HeatDetector_3' COMP_ID = 'Comp 1' LOCATION = 2, 2, 2.97 TYPE = 'HEAT_DETECTOR' SETPOINT = 30, RTI = 5 /
!! Wall Vents
&VENT TYPE = 'WALL' ID = 'WallVent_1' COMP_IDS = 'Comp 1' 'OUTSIDE'  TOP = 2, BOTTOM = 0, WIDTH = 1
      FACE = 'FRONT' OFFSET = 2 /
!! Fires
&FIRE ID = 'Wood_Wall' COMP_ID = 'Comp 2', FIRE_ID = 'Wood_Wall_Fire'  LOCATION = 2.5, 5 /
&CHEM ID = 'Wood_Wall_Fire' CARBON = 6 CHLORINE = 0 HYDROGEN = 10 NITROGEN = 0 OXYGEN = 5 HEAT_OF_COMBUSTION = 18100
     RADIATIVE_FRACTION = 0.33 /
&TABL ID = 'Wood_Wall_Fire' LABELS = 'TIME', 'HRR' , 'HEIGHT' , 'AREA' , 'CO_YIELD' , 'SOOT_YIELD' , 'HCN_YIELD' , 'HCL_YIELD' ,
      'TRACE_YIELD' /
&TABL ID = 'Wood_Wall_Fire', DATA = 0, 0, 0, 0.05, 0.006171682, 0.015, 0, 0, 0 /
&TABL ID = 'Wood_Wall_Fire', DATA = 8000, 1000, 3, 9, 0.006171682, 0.015, 0, 0, 0 /
!! Surface Connections
&CONN TYPE = 'FLOOR' COMP_ID = 'Comp 3' COMP_IDS = 'Comp 2' /
!! Visualizations
&SLCF DOMAIN = '2-D'  POSITION = 2.5, PLANE = 'X' /
&TAIL /
```

It is recommended that when looking at a new scenario, first select a pre-written input file that resembles the case, make the necessary changes, then run the case to determine if the geometry is set up correctly. It is best to start off with a relatively simple file that captures the main features of the problem without getting tied down with too much detail that might mask a fundamental flaw in the calculation. As you learn how to write input files, you will continually run and re-run your case as you add in complexity.

Table B.1 provides a quick reference to all the namelist parameters and where you can find the reference to where it is introduced in the document and the table containing all of the keywords for each group.

Examples of each of the inputs are included in the sections that follow. All examples are taken from the sample input file `Users_Guide_Example.in` included with the CFAST distribution. Following are some general rules about the CFAST input file:

- The `HEAD` input identifies the version of CFAST for which the input file was created and is typically the first line in the input file. Use `&TAIL` as the last line at the end of the input file. This completes the file from `&HEAD` to `&TAIL`. CFAST does not even look for this last line. It just forces the “end of file” character past relevant input.

- Many of the listed keywords are mutually exclusive. Repeated entry of some keywords can cause the program to either fail or run in an unpredictable manner.

- Use of some keywords triggers the code to operate in a certain mode/condition. For example, specifying `ADIABATIC` to be `.TRUE.` triggers the code to treat all compartment surfaces to be perfectly insulated.

- Multiple inputs are required whenever the keyword is in plural form — keywords ending with an **s**. For example, the keyword parameter, `TEMPERATURES`, within the namelist group, `INIT`, requires two temperature values (in this case, one for exterior ambient temperature and one for

Table B.1: CFAST Input File Keywords

Group Name	Namelist Group Description	Reference Section	Parameter Table
COMP	Compartments	4.1	B.7
CHEM	Fire Chemistry	6.1	B.12
CONN	Surface Connections	8	B.15
DEVC	Devices	7	B.14
DIAG	Diagnostics		B.18
FIRE	Fires Placement	6.2	B.11
HEAD	Input File Header	2.1	B.2
INIT	Initial Conditions	2.3	B.4
ISOF	Isosurface File Outputs	9.1	B.16
MATL	Material Properties	3.1	B.6
MISC	Miscellaneous	2.4	B.5
SLCF	Slice File Outputs	9.1	B.17
TAIL	End of Input File Indicator		
TABL	Table of Time-Based Inputs	B.8	B.13
TIME	Simulation Time	2.2	B.3
VENT	Vents	5.1.1	B.8

interior ambient temperature). In the case of missing inputs, an error message will be generated to assist users in troubleshooting any errors.

- Default values to inputs are assigned to some of the keywords to facilitate the set up of an input file. For instance, Table B.5 shows that the LOWER_OXYGEN_LIMIT has a default value of 0.15. This value is taken from the SFPE handbook [15] and implies that the burning rate will be reduced when the oxygen level is below 15 %. Users should review the applicability of any default values for their simulation.

B.4 Simulation Environment, Namelist Groups HEAD, TIME, INIT, and MISC

Table B.2: For more information see Section 2.1.

HEAD (Header Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
VERSION	Integer	Section 2.1		
TITLE	Character	Section 2.1		

Table B.3: For more information see Section 2.2.

TIME (Time Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
PRINT	Integer	Section 2.2	s	60
SIMULATION	Integer	Section 2.2	s	3600
SMOKEVIEW	Integer	Section 2.2	s	15
SPREADSHEET	Integer	Section 2.2	s	15

Table B.4: For more information see Section 2.3.

INIT (Initial Conditions)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
PRESSURE	Real	Section 2.3	Pa	101325
RELATIVE_HUMIDITY	Real	Section 2.3	%	50
INTERIOR_TEMPERATURE	Real	Section 2.3	°C	20
EXTERIOR_TEMPERATURE	Real	Section 2.3	°C	20

Table B.5: For more information see Section 2.4.

MISC (Miscellaneous Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
ADIABATIC	Logical	Section 2.4		.FALSE.
LOWER_OXYGEN_LIMIT	Real	Section 2.4		0.15
MAX_TIME_STEP	Real	Section 2.4	s	1
OVERWRITE	Logical	Section 2.4		.TRUE.
SPECIFIC_EXTINCTION	Real Doublet	Section 2.4		8700,4400

Examples:

```
&HEAD  VERSION = 7300, TITLE = 'Users Guide Example Case' /
```

```
&TIME  SIMULATION = 3600., PRINT = 50., SMOKEVIEW = 50., SPREADSHEET = 50. /
&INIT  INTERIOR_TEMPERATURE = 20., EXTERIOR_TEMPERATURE = 20. /
&MISC  LOWER_OXYGEN_LIMIT = 0.10 /
```

B.5 Thermal Properties, Namelist Group MATL

Table B.6: For more information see Section 3.1.

MATL (Material Properties)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
CONDUCTIVITY*[a]	Real	Section 3.1	kW/(m·K)	
DENSITY*	Real	Section 3.1	kg/m^3	
EMISSIVITY	Real	Section 3.1		0.9
ID*	Character	Section 3.1		
MATERIAL*	Character	Section 3.1		
SPECIFIC_HEAT*	Real	Section 3.1	kJ/(kg·K)	
THICKNESS*[b]	Real	Section 3.1	m	

[a]* indicates a required input for each MATL input included in the input file.

[b]THICKNESS provides a default value for the material. It can be overridden for a specific compartment surface. For targets, the default value is used.

Example:

```
&MATL ID = 'CONCRETE', MATERIAL = 'Light weight concrete',
      CONDUCTIVITY = 1.75, SPECIFIC_HEAT = 1.,
      DENSITY = 2200., EMISSIVITY = 0.94, THICKNESS = 0.15 /
```

B.6 Compartments, Namelist Group COMP

Table B.7: For more information see Section 4.1.

COMP (Compartment Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
CEILING_MATL_ID[a]	Character Triplet	Section 4.2		
CEILING_THICKNESS[b]	Real Triplet	Section 4.2		
CROSS_SECT_AREAS [c]	Real Array	Section 4.4		
CROSS_SECT_HEIGHTS	Real Array	Section 4.4		
DEPTH*[d]	Real	Section 4.1	m	
FLOOR_MATL_ID	Character Triplet	Section 4.2		
FLOOR_THICKNESS	Real Triplet	Section 4.2		
GRID	Integer Triplet	Section 9.2		50,50,50
HALL	Logical	Section 4.3		.FALSE.
HEIGHT*	Real	Section 4.1	m	
ID*	Character	Section 4.1		
LEAK_AREA	Real Doublet	Section 4.1	m^2/m^2	
ORIGIN	Real Triplet	Section 4.1	m	0,0,0
SHAFT	Logical	Section 4.3		.FALSE.
TYPE	Character	Section 4.1		
WALL_MATL_ID	Character Triplet	Section 4.2		
WALL_THICKNESS	Real Triplet	Section 4.2		
WIDTH*	Real	Section 4.1	m	

[a]If included, from 1 to 3 material ids can each be input for the ceiling, floor, and walls.

[b]If included, from 1 to 3 material thicknesses can each be input for the ceiling, floor, and walls. If a zero value is input, the default thickness for the material is used.

[c]For compartments where the cross-sectional area varies with height, the inputs, CROSS_SECT_AREAS and CROSS_SECT_HEIGHTS can be used.

[d]* indicates a required input for each COMP input included in the input file. At least one COMP input must be included in an input file.

Example:

```
&COMP ID = 'Comp 1'
      DEPTH = 6.1 HEIGHT = 2.4 WIDTH = 3.7
      CEILING_MATL_ID = 'FiberCem' CEILING_THICKNESS = 0.025
      WALL_MATL_ID = 'FiberCem', 'Gypsum', 'Concrete'
      WALL_THICKNESS = 0.013, 0.03, 0.61
      FLOOR_MATL_ID = 'FiberCem', 'Gypsum', 'Concrete'
      FLOOR_THICKNESS = 0.013, 0.03, 0.61
      ORIGIN = 0, 0, 0 GRID = 50, 50, 50 LEAK_AREA_RATIO = 0, 0.0005 /
```

B.7 Vents, Namelist Group VENT

B.7.1 Wall Vents, TYPE='WALL'

Table B.8: For more information see Section 5.1.1.

VENT, TYPE='WALL' (Wall Vent Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
BOTTOM[a] *	Real	Section 5.1.1	m	
COMP_IDS*	Character Doublet	Section 5.1.1		
CRITERION[b]	Selection List	Section 5.1.1		
DEVC_ID	Character	Section 5.1.1		
F[c]	Real Array	Section 5.1.1		
FACE[d]	Selection List	Section 5.1.1		
ID*	Character	Section 5.1.1		
OFFSET	Real	Section 5.1.1	m	0
PRE_FRACTION[e]	Real	Section 5.1.1	m	1
POST_FRACTION	Real	Section 5.1.1	m	1
SETPOINT	Real	Section 5.1.1	s | °C | kW/m^2	
T	Real Array	Section 5.1.1		
TYPE[f] *	Selection List	Section B.7		
TOP*	Real	Section 5.1.1	m	
WIDTH*	Real	Section 5.1.1	m	

[a]* indicates a required input for each wall VENT input included in the input file.

[b]Input for CRITERION must be FLUX, TEMPERATURE, or TIME. An associated SETPOINT is required. For FLUX or TEMPERATURE, an associated ignition target must be specified by DEVC_ID.

[c]Specifies the fraction of vent width for wall vents as a function of time and is only applicable when CRITERION is set to TIME. Must also include T.

[d]Input for FACE must be RIGHT, FRONT, LEFT, or REAR. Both FACE and OFFSET positioning refer to the first compartment specified (COMP_IDS(1)).

[e]PRE_FRACTION and POST_FRACTION specify the vent fraction before and after the SETPOINT is reached when CRITERION is either TEMPERATURE or FLUX. They cannot be used with F and T.

[f]Input for TYPE must be WALL to specify a wall vent.

Wall vents (TYPE='WALL') are defined by BOTTOM, TOP, and WIDTH. Location of the vent for visualization is defined by FACE, and OFFSET.

Example:

```
&VENT TYPE = 'WALL', ID = 'HVENT 1', COMP_IDS = 'Comp 1', 'OUTSIDE',
      WIDTH = 1., TOP = 2., BOTTOM = 0.,
      OFFSET = 2., FACE = 'FRONT' /
```

B.7.2 Ceiling / Floor Vents, TYPE='CEILING' or TYPE='FLOOR'

Table B.9: For more information see Section 5.1.1.

VENT, TYPE='CEILING' or TYPE='FLOOR' (Ceiling/Floor Vent Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
AREA[a] *	Real	Section 5.1.2	m^2	
COMP_IDS*	Character Doublet	Section 5.1.1		
CRITERION[b]	Selection List	Section 5.1.1		
DEVC_ID	Character	Section 5.1.1		
F[c]	Real Array	Section 5.1.1		
ID*	Character	Section 5.1.1		
OFFSETS	Real Doublet	Section 5.1.1	m	0,0
PRE_FRACTION[d]	Real	Section 5.1.1	m	1
POST_FRACTION	Real	Section 5.1.1	m	1
SHAPE*[e]	Selection List	Section 5.1.2		
T	Real Array	Section 5.1.1		
TYPE[f] *	Selection List	Section B.7		

[a] * indicates a required input for each ceiling/floor VENT input included in the input file.

[b] Input for CRITERION must be FLUX, TEMPERATURE, or TIME. An associated SETPOINT is required. For FLUX or TEMPERATURE, an associated ignition target must be specified by DEVC_ID.

[c] Specifies the fraction of vent width for wall vents as a function of time and is only applicable when CRITERION is set to TIME. Must also include T.

[d] PRE_FRACTION and POST_FRACTION specify the vent fraction before and after the SETPOINT is reached when CRITERION is either TEMPERATURE or FLUX. They cannot be used with F and T.

[e] Input for SHAPE must be ROUND or SQUARE.

[f] Input for TYPE must be CEILING or FLOOR for ceiling and floor vents. These may be used interchangeably. The order of COMP_IDS specifies the location of the vent with COMP_IDS(1) specifying the top compartment and COMP_IDS(2) specifying the bottom compartment.

Ceiling and floor vents (TYPE='CEILING' or TYPE='FLOOR') are defined by AREA and SHAPE. Location of the vent for visualization is defined by OFFSETS as the distance from the compartment origin in the X (width) and Y (depth) direction. It is visualized on the floor of COMP_IDS(1).

Example:

```
&VENT TYPE = 'CEILING', ID = 'VVENT 1', COMP_IDS = 'Comp 3', 'Comp 2',
      AREA = 1., SHAPE = 'ROUND', CRITERION= 'TIME',
      T = 0., 100., 500.,
      F = 0., 0.5, 1. /
```

B.7.3 Mechanical Vents, TYPE='MECHANICAL'

Table B.10: For more information see Section 5.1.1.

VENT, TYPE='MECHANICAL' (Mechanical Vent Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
AREAS[a] *	Real Doublet	Section 5.2.1	m^2	
COMP_IDS*	Character Doublet	Section 5.1.1		
CRITERION[b]	Selection List	Section 5.1.1		
CUTOFFS	Real Doublet	Section 5.2.2	Pa	200.,300.
DEVC_ID	Character	Section 5.1.1		
F[c]	Real Array	Section 5.1.1		
FILTER_TIME	Real	Section 5.1.1	s	0
FILTER_EFFICIENCY	Real	Section 5.1.1	% removed	0.0
FLOW*	Real	Section 5.2.2	m^3/s	
HEIGHTS*	Real Doublet	Section 5.2.1	m	
ID*	Character	Section 5.1.1		
OFFSETS	Real Doublet	Section 5.1.1	m	0.,0.
ORIENTATIONS[d]	Selection List Doublet	Section 5.1.1		VERTICAL,VERTICAL
PRE_FRACTION[e]	Real	Section 5.1.1	m	1
POST_FRACTION	Real	Section 5.1.1	m	1
SETPOINT	Real	Section 5.1.1	s | °C | kW/m^2	
T	Real Array	Section 5.1.1		
TYPE[f] *	Selection List	Section B.7		

[a] * indicates a required input for each mechanical VENT input included in the input file.

[b] Input for CRITERION must be FLUX, TEMPERATURE, or TIME. An associated SETPOINT is required. For FLUX or TEMPERATURE, an associated ignition target must be specified by DEVC_ID.

[c] Specifies the fraction of vent width for wall vents as a function of time and is only applicable when CRITERION is set to TIME. Must also include T.

[d] Input for ORIENTATION must be HORIZONTAL or VERTICAL

[e] PRE_FRACTION and POST_FRACTION specify the vent fraction before and after the SETPOINT is reached when CRITERION is either TEMPERATURE or FLUX. They cannot be used with F and T.

[f] Input for TYPE must be MECHANICAL for mechanical vents.

Mechanical vents TYPE='MECHANICAL' are defined by AREAS, CUTOFFS, FLOW, and HEIGHTS. Location of the vent for visualization is defined by ORIENTATION and OFFSETS as the distance from the compartment origin in the X (width) and Y (depth) direction and by HEIGHTS(1) in the z direction.

Example:

```
&VENT TYPE = 'MECHANICAL', ID = 'MVENT_1',
      COMP_IDS = 'OUTSIDE', 'Comp 1', AREAS = 0.25, 0.25,
      HEIGHTS = 2.75, 2.75, FLOW = 0.02,
```

```
CUTOFFS = 200., 300., ORIENTATION='VERTICAL', OFFSETS = 0., 4. /
```

B.8 Fires, Namelist Groups FIRE, CHEM, and TABL

Table B.11: For more information see Section 6.1.

FIRE (Individual Instance of a Fire Object)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
COMP_ID[a] *	Character	Section 6.1		
DEVC_ID	Character	Section 6.1		
FIRE_ID*	Character	Section 6.1		
ID*	Character	Section 6.1		
IGNITION_CRITERION[b]	Selection List	Section 6.1		TIME
LOCATION*	Real Pair	Section 6.1	m	
SETPOINT	Real	Section 6.1	s | °C | kW/m^2	0 s

[a]* indicates a required input for each FIRE input included in the input file.
[b]for IGNITION_CRITERION inputs must beTIME,TEMPERTURE, or FLUX

Table B.12: For more information see Section 6.1.

CHEM (Fire Chemistry Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
CARBON	Real	Section 6.1		1
CHLORINE	Real	Section 6.1		0
FLAMING_TRANSITION_TIME	Real	Section 6.1		0
HEAT_OF_COMBUSTION	Real	Section 6.1	kJ/kg	50000
HYDROGEN	Real	Section 6.1		4
ID[a] *	Character	Section 6.1		
NITROGEN	Real	Section 6.1		0
OXYGEN	Real	Section 6.1		0
RADIATIVE_FRACTION	Real	Section 6.1		0.35

[a]* indicates a required input for each CHEM input included in the input file.

Table B.13: For more information see Section 6.1.

TABL (Time-Based Fire Chemistry Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
LABELS	Character Array	Section 6.1		
ID[a] *	Character	Section 6.1		
DATA	Real Array	Section 6.1		

[a]* indicates a required input for each TABL input included in the input file.

Example:

```
&FIRE ID = 'Wood_Wall'
 COMP_ID = 'Comp 2', FIRE_ID = 'Wood_Wall_Fire'
 LOCATION = 2.5, 5 /
&CHEM ID = 'Wood_Wall_Fire'
 CARBON = 6, CHLORINE = 0, HYDROGEN = 10, NITROGEN = 0, OXYGEN = 5
 HEAT_OF_COMBUSTION = 18100,  RADIATIVE_FRACTION = 0.33 /
&TABL ID = 'Wood_Wall_Fire', LABELS = 'TIME', 'HRR', 'HEIGHT', 'AREA',
   'CO_YIELD', 'SOOT_YIELD' /
&TABL ID = 'Wood_Wall_Fire', DATA =    0,      0,     0,        0.05,
   0.00617,    0.015 /
&TABL ID = 'Wood_Wall_Fire', DATA =    8000,   1000,  3,        9,
   0.00617,    0.015 /
```

B.9 Devices, Namelist Group DEVC

Table B.14: For more information see Section 7.

DEVC (Device Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
ADIABATIC_TARGET[a]	Logical	Section 7		.FALSE.
CONVECTION_COEFFICENTS	Real Doublet	Section 7	kW/(m^2·K)	0, 0
COMP_ID*[b]	Character	Section 7		
SURFACE_ORIENTATION	Selection List	Section 7	see footnote[c]	
SURFACE_TEMPERATURE	Real	Section 7		
ID*	Character	Section 7		
DEPTH_UNITS	Character	Section 7	none or m	FRACTION
LOCATION*	Real Triplet	Section 7	m	
MATL_ID	Character	Section 7		
NORMAL	Real Triplet	Section 7		0,0,1
RTI	Real	Section 7.2	$\sqrt{\text{m} \cdot \text{s}}$	130
SETPOINT	Real	Section 7	°C or %/m	see footnote[d]
SETPOINTS	Real Doublet	Section 7	%/m	see footnote[e]
SPRAY_DENSITY	Real	Section 7.2	m/s	
TEMPERATURE_DEPTH	Real	Section 7		0.5
THICKNESS	Real	Section 7		material thickness
TYPE*	Selection List	Section 7		

[a] If included, inputs for CONVECTION_COEFFICENTS are required.

[b] * indicates a required input for each DEVC input included in the input file. Additional inputs may be required depending on the type of device.

[c] Indicates where the front surface of the target is facing. Allowable input are CEILING, FLOOR, FRONT WALL, BACK WALL, LEFT WALL, RIGHT WALL to indicate one of the compartment surfaces or a FIRE_ID for a fire contained within the compartment. With a FIRE_ID, the normal vector is calculated from a vector pointing towards a point 1/3 of the flame height above the base of the fire at the peak heat release rate of the fire.

[d] For smoke detectors, the input is obscuration with a default value of 23.93 %/m (8 %/ft); for heat detectors, temperature with a default value of 57 °C (135 °F); and for sprinklers, temperature with a default value of 74 °C (165 °F).

[e] For smoke detectors, the input is obscuration with a default value of 23.93 %/m (8 %/ft) for both smoldering and flaming smoke.

PLATE and CYLINDER targets are defined by COMP_ID, TYPE, ID, LOCATION, TEMPERATURE_DEPTH, DEPTH_UNITSand NORMAL.

A sprinkler is defined by COMP_ID, TYPE, ID, LOCATION, RTI, SETPOINT, and SPRAY_DENSITY.

A smoke detector is defined by COMP_ID, TYPE, ID, LOCATION, and SETPOINT or SETPOINTS. The latter tracks smoulder smoke and flaming smoke separately.

A heat detector is defined by COMP_ID, TYPE, ID, LOCATION, RTI, and SETPOINT.

Examples:

```
&DEVC ID = 'Targ 1', COMP_ID = 'Comp 1', TYPE = 'PLATE',
      LOCATION = 2.2, 1.88, 2.34., NORMAL = 0., 0., 1.,
      MATL_ID = 'CONCRETE', TEMPERATURE_DEPTH = 0.1, DEPTH_UNITS = 'M' /

&DEVC ID = 'Sprinkler 1', COMP_ID = 'Comp 1',
      TYPE = 'SPRINKLER',
      LOCATION = 3., 3., 2.97,
      SETPOINT = 73.8889, RTI = 100., SPRAY_DENSITY = 7.E-5 /

&DEVC ID = 'Adiabatic Targ', COMP_ID = 'Comp 1', TYPE = 'PLATE',
      LOCATION = 2.2, 1.88, 2.34., NORMAL = 0., 0., 1.,
      MATL_ID = 'CONCRETE',
      ADIABATIC_TARGET = 'TRUE', CONVECTION_COEFFICIENTS = 3.E-3, 5.E-3 /
```

B.10 Compartment Connections, Namelist Group CONN

Table B.15: For more information see Section 8.

CONN (Connection Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
COMP_ID*[a]	Character	Section 8		
COMP_IDS*	Character Array	Section 8		
F	Real Array	Section 8		
TYPE* [b]	Selection List	Section 8		

[a]* indicates a required input for each CONN input included in the input file.
[b]Input for TYPE must be CEILING, FLOOR, or WALL

Example:

```
&CONN TYPE = 'FLOOR', COMP_ID = 'Comp 3', COMP_IDS = 'Comp 2' /
```

B.11 Visualization, Namelist Groups ISOF, SLCF

B.11.1 ISOF (Isosurface Parameters)

Table B.16: For more information see Section 9.1.

ISOF (Isosurface Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
COMP_ID*[a]	Character	Section 9.1		
VALUE*	Real	Section 9.1	°C	

[a]* indicates a required input for each ISOF input included in the input file.

Example:

```
&ISOF COMP_ID = 'COMP_1', VALUE = 100. /
```

B.11.2 SLCF (Slice File Parameters)

Table B.17: For more information see Section 9.1.

SLCF (Slice File Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
COMP_ID[a] *	Character	Section 9.1		
DOMAIN*[b]	Selection List	Section 9.1		
PLANE	Selection List	Section 9.1		
POSITION	Real	Section 9.1		

[a]* indicates a required input for each SLCF input included in the input file. All inputs are required for a 2-D domain slice file.

[b]DOMAIN must be 2-D or 3-D. If 2-D, PLANE specifies the orientation of the slice in the X, Y, or Z direction and POSITION specifies the offset from the origin of the specified plane.

Example:

```
&SLCF  DOMAIN = '2-D', PLANE = 'X', POSITION = 2.5 /
```

B.12 DIAG (Diagnostic Parameters)

These inputs are for internal diagnostic purposes used to test and verify specific model functions. They are included in this appendix for completeness but are never used in typical CFAST scenarios.

Table B.18

DIAG (Diagnostic Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
ADIABATIC_TARGET_VERIFICATION[a b]	Selection List			OFF
CEILING_JET_SUB_MODEL[a]	Selection List			ON
CONDUCTION_SUB_MODEL[a]	Selection List			ON
CONVECTION_SUB_MODEL[a]	Selection List			ON
DASSL_DEBUG_PRINT[a]	Selection List			OFF
DEBUG_PRINT[a]	Selection List			OFF
DOOR_JET_FIRE_SUB_MODEL[a]	Selection List			ON
ENTRAINMENT_SUB_MODEL [a]	Selection List			ON
F[c]	Real Array		°C	
FIRE_SUB_MODEL[a]	Selection List			ON
GAS_TEMPERATURE[d]	Real		°C	
GAS_ABSORPTION_SUB_MODEL[e]	Selection List			CALCULATED
HORIZONTAL_FLOW_SUB_MODEL[a]	Selection List			ON
KEYBOARD_INPUT[a]	Selection List			ON
LAYER_MIXING_SUB_MODEL[a]	Selection List			ON
MECHANICAL_FLOW_SUB_MODEL[a]	Selection List			ON
OXYGEN_TRACKING[a]	Selection List			OFF
PARTIAL_PRESSURE_CO[d]	Real		Pa	
PARTIAL_PRESSURE_H2O[d]	Real		Pa	
RADIATIVE_INCIDIENT_FLUX	Real		kW/m^2	0
RADIATION_SUB_MODEL[a]	Selection List			ON
RADSOLVER[f]	Selection List			DEFAULT
RESIDUAL_DEBUG_PRINT[a]	Selection List			OFF
STEADY_STATE_INTIAL_CONDITIONS[a]	Selection List			OFF
T[c]	Real Array		s	
VERTICAL_FLOW_SUB_MODEL[a]	Selection List			ON

[a]If included, must be either ON or OFF
[b]If ON, RADIATIVE_INCIDIENT_FLUX is required.
[c]If included, both F and T are required.
[d]If included, GAS_TEMPERATURE, PARTIAL_PRESSURE_H2O, and PARTIAL_PRESSURE_CO are all required.
[e]GAS_ABSORPTION, if included, must be either CALCULATED or CONSTANT
[f]RADSOLVER, if included, must be either DEFAULT or RADNET.

B.13 Custom Output and Post-run Calculations

CFAST has the ability to calculate user-specified summary statistics at the end of a model run. These are intended for large sets of similar runs where the user wants to perform comparative analyses on the results of hundreds or thousands of calculations. Although not supported for detailed input in CEdit, they can be added to a file and preserved when read and write in CEdit.

Table B.19

DUMP (Output and Post-Run Calculation Parameters)				
Parameter	**Type**	**Reference**	**Units**	**Default Value**
ID	Character			
FILE_TYPE [a]	Selection List			
TYPE [b]	Selection List			
CRITERIA	Real			
FIRST_DEVICE	Character			
FIRST_MEASUREMENT	Character			
SECOND_DEVICE	Character			
SECOND_MEASUREMENT	Character			

[a] FILE_TYPE must be one of the CFAST spreadsheet outputs: NORMAL, FLOW, MASS, SPECIES, or WALL.
[b] TYPE must be TRIGGER_GREATER, TRIGGER_LESSER, MINIMUM, MAXIMUM, INTEGRATE, or CHECK_TOTAL_HRR

Example:

```
&DUMP ID = 'Total Time Completed'
     FILE_TYPE = 'DEVICES'  TYPE = 'MAXIMUM'
     FIRST_DEVICE = 'Time'  FIRST_MEASUREMENT = 'Simulation Time' /
&DUMP ID = 'Fire Room Ion Detector'
     FILE_TYPE = 'DEVICES'  TYPE = 'TRIGGER_GREATER'  CRITERIA = 1
     FIRST_DEVICE = 'Time'  FIRST_MEASUREMENT = 'Simulation Time'
     SECOND_DEVICE = 'Ionization Detector Room 1'  SECOND_MEASUREMENT =
        'Sensor Activation' /
```

Appendix C

CFAST Spreadsheet Outputs

At the user's option, CFAST outputs simulation results to one or more comma-delimited spreadsheets for further analysis by the user. The following table details all the possible outputs categorized by the physical object that is being represented in the model (here termed measurement 'devices') and one or more measurements associated with that device.

Table C.1

DUMP (Spreadsheet Outputs)			
Device	**Measurement**	**Notes**	**Default Spreadsheet**
Compartments	Upper Layer Temperature	Device is identified by user-specified compartment ID	_compartments.csv
	Lower Layer Temperature		
	Layer Height		
	Upper Layer Volume		
	Lower Layer Volume		
	Pressure		
	Ceiling Temperature		
	Upper Wall Temperature		
	Lower Wall Temperature		
	Floor Temperature		
	CO2 Upper Layer		
	CO2 Lower Layer		
	CO Upper Layer		
	CO Lower Layer		
	HCN Upper Layer		
	HCN Lower Layer		
	HCL Upper Layer		
	HCL Lower Layer		
	Unburned Fuel Upper Layer		
	Unburned Fuel Lower Layer		
	H2O Upper Layer		
	H2O Lower Layer		
	Optical Density Upper Layer		
	Optical Density Lower Layer		
	OD from Flaming Upper Layer		

Table C.1: Continued

DUMP (Spreadsheet Outputs)			
	OD from Flaming Lower Layer		
	OD from Smoldering Upper Layer		
	OD from Smoldering Lower Layer		
	CO2 Upper Layer Mass		
	CO2 Lower Layer Mass		
	CO Upper Layer Mass		
	CO Lower Layer Mass		
	HCN Upper Layer Mass		
	HCN Lower Layer Mass		
	HCL Upper Layer Mass		
	HCL Lower Layer Mass		
	Unburned Fuel Upper Layer Mass		
	Unburned Fuel Lower Layer Mass		
	H2O Upper Layer Mass		
	H2O Lower Layer Mass		
	Soot Upper Layer Mass		
	Soot Lower Layer Mass		
	Soot from Flaming Upper Layer Mass		
	Soot from Flaming Lower Layer Mass		
	Soot from Smoldering Upper Layer Mass		
	Soot from Smoldering Lower Layer Mass		
	Potential Total Heat Upper Layer	-V option only	
	Potential Total Heat Lower Layer	-V option only	
	Potential CO2 Upper Layer Mass	-V option only	
	Potential CO2 Lower Layer Mass	-V option only	
	Potential CO Upper Layer Mass	-V option only	
	Potential CO Lower Layer Mass	-V option only	
	Potential Total Heat Upper Layer	-V option only	

Table C.1: Continued

DUMP (Spreadsheet Outputs)			
	Potential Total Heat Lower Layer	-V option only	
	Potential HCN Upper Layer Mass	-V option only	
	Potential HCN Lower Layer Mass	-V option only	
	Potential HCL Upper Layer Mass	-V option only	
	Potential HCL Lower Layer Mass	-V option only	
	Potential H2O Upper Layer Mass	-V option only	
	Potential H2O Lower Layer Mass	-V option only	
	Potential Soot Upper Layer Mass	-V option only	
	Potential Soot Lower Layer Mass	-V option only	
	Potential Soot from Flaming Upper Layer Mass	-V option only	
	Potential Soot from Flaming Lower Layer Mass	-V option only	
	Potential Soot from Smoldering Upper Layer Mass	-V option only	
	Potential Soot from Smoldering Lower Layer Mass	-V option only	

Table C.1: Continued

DUMP (Spreadsheet Outputs)			
Vents	Net Inflow		_vents
	Total Inflow Upper		
	Total Inflow Lower		
	Total Outflow Upper		
	Total Outflow Lower		
	Opening Fraction		
	Trace Species Flow		
	Trace Species Filtered		

Table C.1: Continued

DUMP (Spreadsheet Outputs)			
Fires	Ignition	Device is identified by user-specified fire ID	_fires
	Plume Entrainment Rate		
	Pyrolysis Rate		
	HRR Expected		
	HRR Actual		
	HRR Convective Actual		
	HRR Upper Actual		
	HRR Lower Actual		
	Flame Height		
	HRR Door Jet Fires		
	Total Pyrolysate Released		
	Total Trace Species Released		

Table C.1: Continued

DUMP (Spreadsheet Outputs)			
Targets	Target Surrounding Gas Temperature	Device is identified by user-specified target ID	_devices
	Target Surface Temperature		
	Target Internal Temperature		
	Target Incident Flux		
	Back Target Incident Flux		
	Target Net Flux		
	Back Target Net Flux		
	Target Gas FED		
	Target Gas FED Increment		
	Target Heat FED		
	Target Heat FED Increment		
	Target Obscuration		
	Target Radiative Flux	-V option only	
	Back Target Radiative Flux	-V option only	
	Target Convective Flux	-V option only	
	Back Target Convective Flux	-V option only	
	Target Radiative Fire Flux	-V option only	
	Back Target Radiative Fire Flux	-V option only	
	Target Surface Radiative Flux	-V option only	
	Back Target Surface Radiative Flux	-V option only	
	Target Gas Radiative Flux	-V option only	
	Back Gas Target Radiative Flux	-V option only	
	Target Radiative Loss Flux	-V option only	
	Back Target Radiative Loss Flux	-V option only	
	Target Total Gauge Flux	-V option only	
	Back Target Total Gauge Flux	-V option only	
	Target Radiative Gauge Flux	-V option only	

Table C.1: Continued

DUMP (Spreadsheet Outputs)			
	Back Target Radiative Gauge Flux	-V option only	
	Target Convective Gauge Flux	-V option only	
	Back Target Convective Gauge Flux	-V option only	
	Target Radiative Loss Gauge Flux	-V option only	
	Back Target Radiative Loss Gauge Flux	-V option only	
Detectors	Sensor Surrounding Gas Temperature	Device is identified by user-specified detector ID	_devices
	Sensor Surrounding Gas Velocity		
	Sensor Obscuration		
	Sensor Temperature		
	Sensor Activation		

Appendix D

Running CFAST from a Command Prompt

The model CFAST can also be run from a Windows command prompt. CFAST can be run from any folder, and refer to a data file in any other folder.

```
[drive1:\][folder1\]cfast [drive2:\][folder2\]project
```

The project name will have extensions appended as needed (see below). For example, to run a test case when the CFAST executable is located in c:\firemodels\cfast7 and the input data file is located in c:\data, the following command could be used:

```
c:\firemodels\cfast7\cfast c:\data\testfire0   <<< note that the extension is
    optional.
```

One or more command line options can follow the name of the file to be run as follows:

- -k - no interactive keyboard access
- -i - initialization only
- -c - compact output
- -f - full output (c and f are exclusive). Note the interaction of the f and c option. The default for the console output is -c. The default for the file output is /f. This default action can be overwritten by explicitly including the /f or /c option.
- -n - net heat flux option
- -s - limit spreadsheet output to the files specified: C for _compartments.csv, D for _devices.csv, M for _masses.csv, V for _vents.csv, and W for _walls.csv. Default is -S:CDMVW for output of all spreadsheet files.
- -v - validation output (outputs a modified set of spreadsheet files with different column headers designed to facilitate automated analysis of the output)