CarbCalc II
Carbon Diffusion Model for Atmosphere Furnaces

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1 Introduction

1.1 Welcome to SuperSystems

Super Systems Inc.

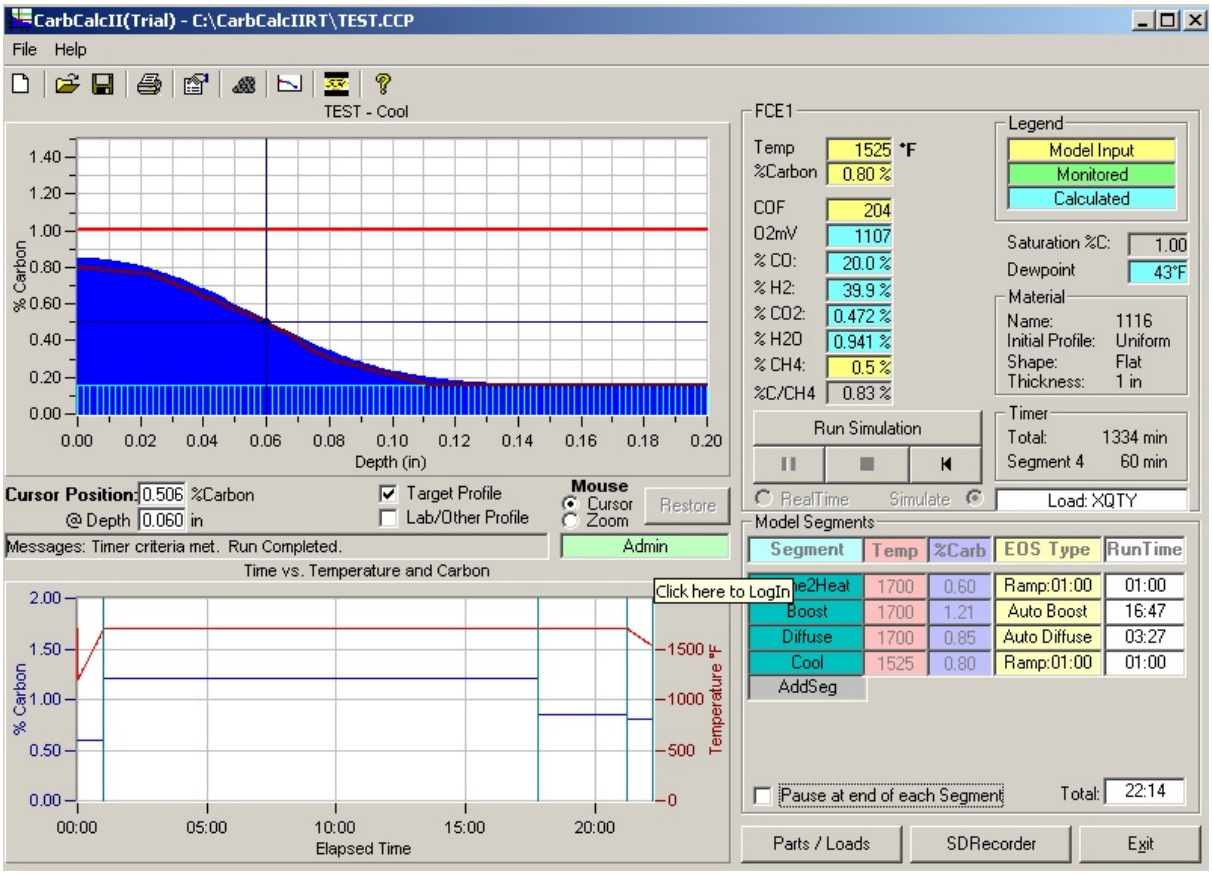
Super Systems Introduces
CarbCalcII
with
Load Tracking and RealTime Control

DISCLAIMER

CARBCALCII is a software program to be used by the Heat Treater. Super Systems Inc. is not responsible or liable for any product, process, or damage or injury incurred as a result of using CARBCALCII. Super Systems Inc. makes no representations or warranties with respect to the contents hereof and specifically disclaims any implied warranties or merchantability or fitness for any particular purpose.

1.2 CarbCalcII Introduction

CarbCalcII is a Carbon Diffusion Model for use with Batch Furnace Gas Carburizing.



Gas Carburizing is a case-hardening process in which carbon is dissolved in the surface layers of a low-carbon steel part at a temperature sufficient to render the steel austenitic, followed by quenching and tempering to form a martensitic microstructure. The resulting gradient in carbon content below the surface of the part causes a gradient in hardness, producing a strong, wear-resistant surface layer on a material, usually low-carbon steel, which is readily fabricated into parts. In gas carburizing the source of carbon is a carbon-rich furnace atmosphere produced either from gaseous hydrocarbons, for example, methane (CH4), propane (C3H3), and butane (C4H10), or from vaporized hydrocarbon liquids.

Carbon Sources

Low-carbon steel parts exposed to carbon-rich atmospheres will carburize at temperatures of 850°C (1560°F) and above. If the carbon source is so rich that the solubility limit of carbon in austenite is reached at the surface of the steel some carbides may form at the surface. At these "above saturation" atmospheres soot will deposit on surfaces within the furnace, including the parts. The goal of modern gas carburizing practice is to control the carbon content of furnace atmospheres such that: The final carbon concentration at the surface of the parts is below the solubility limit in austenite and Sooting of the furnace atmosphere is minimized. Endothermic gas (Endogas) is a blend of carbon monoxide, hydrogen, and nitrogen (with smaller amounts of carbon dioxide water vapor, and methane) produced by reacting a hydrocarbon gas such as natural, gas (primarily methane), propane or butane with air. A

carrier gas similar in composition to Endogas may be produced from methane can be formed from a nitrogen-methanol blend.

Carburizing Process Variables
The gas carburizing process depends on the control of three principal variables:
- Temperature
- Time
- Atmosphere composition.

Other variables that affect the amount of carbon transferred to parts include the degree of atmosphere circulation and the alloy content of the parts.

Temperature. The maximum rate at which carbon can be added to steel is limited by the rate of diffusion of carbon in austenite. This diffusion rate increases greatly with increasing temperature; the rate of carbon addition at 925°C (1700°F) is about 40% greater than at 870°C (1600°F). The temperature most commonly used for carburizing is 925°C (1700°F). This temperature permits a reasonably rapid carburizing rate without excessively rapid deterioration of furnace equipment. The carburizing temperature is sometimes raised to 955°C (1750°F) or 980°C (1800°F) to shorten the time of carburizing for parts requiring deep cases. Conversely, shallow case carburizing is frequently done at lower temperatures because case depth can be controlled more accurately with the slower rate of carburizing obtained at lower temperatures. For best results, the workload should be heated to the carburizing temperature in a near-neutral furnace atmosphere. In batch furnaces, parts can be heated in Endogas until they reach the furnace temperature; then carburizing can commence with the addition of the enriching gas.

Time. The effect of time and temperature on the Carbon vs Depth profile shows that the carburizing time decreases with increasing carburizing temperature. In addition to the time at the carburizing temperature, several hours may be required to bring large work pieces or heavy loads of smaller parts to operating temperature. For a work piece quenched directly from the carburizing furnace, the cycle may be lengthened further by allowing time for the work piece to cool from the carburizing temperature to about 843°C (1550°F) prior to quenching. Similarly, additional diffusion and interchange of carbon with the atmosphere will occur during cooling prior to quenching.

Carbon Potential. The carbon potential of the furnace atmosphere must be greater than the carbon potential at the surface of the work piece in order for carburizing to occur. It is the difference in carbon potential that provides the driving force for carbon transfer into the parts.

Carbon Diffusion. The combined effects of time, temperature, and carbon concentration on the diffusion of carbon in austenite can be expressed by Fick's laws of diffusion.

Alloy Effects. The various alloying elements found in carburizing steels have an influence on the activity of carbon dissolved in austenite.
- **Chromium** tends to decrease the activity of carbon
- **Nickel** tends to raise the activity of carbon

The primary effect of alloys on the diffusion of carbon is their effect on the driving force at the surface reaction.

The CarbCalcII Model
CARBCALCII is a carbon difussion model for simulation and analysis of gas carburizing process for low-alloy steels. The interactions of the gas carburizing process cannot be modeled by simple one-dimensional analysis. In order to accurately predict how a low-alloy steel will react in a controlled atmosphere process, many factors must be taken into account, including:
- Alloy steel composition
- Equilibrium and non-equilibrium gas composition
- Temperature
- Atmosphere agitation
- Surface radius of curvature, concave or convex

- Initial carbon profile

CARBCALCII takes as many factors as possible into account for the accurate prediction of (1) transfer of carbon between gas and steel surface, and (2) diffusion of carbon within the steel.

Possible uses for CARBCALCII include:

- Computer-aided design of heat treatment processes
- Optimization of existing cycles
- "What if" analysis when a change in an existing process or material is contemplated
- Reconstruction of the effects that an out-of-control process may have had on a load
- Education of personnel in the intricacies of atmosphere processing
- Real-Time control with an on-line process

CARBCALCII can pay for itself quickly because process development experiments can be carried out quickly on the computer instead of weeks in a furnace. When a trial is finally made in the furnace, the results will be reasonably close to those predicted by the software.

CARBCALCII has thee main operating modes:

1. Simulation
2. RealTime Control
3. Monitor/Replay

The object in all cases is to accurately predict the diffusion gradient that carbon establishes in a given material from a given set of processing parameters.

SIMULATION allows construction of a diffusion gradient from complex a set of processing parameters. For example, in a batch integral quench furnace, one might be interested in the following sequence:

- Come to Heat
- Boost Carburize
- Diffuse Carburize
- Equalize for Quench
- Brief Exposure to Vestibule Atmosphere

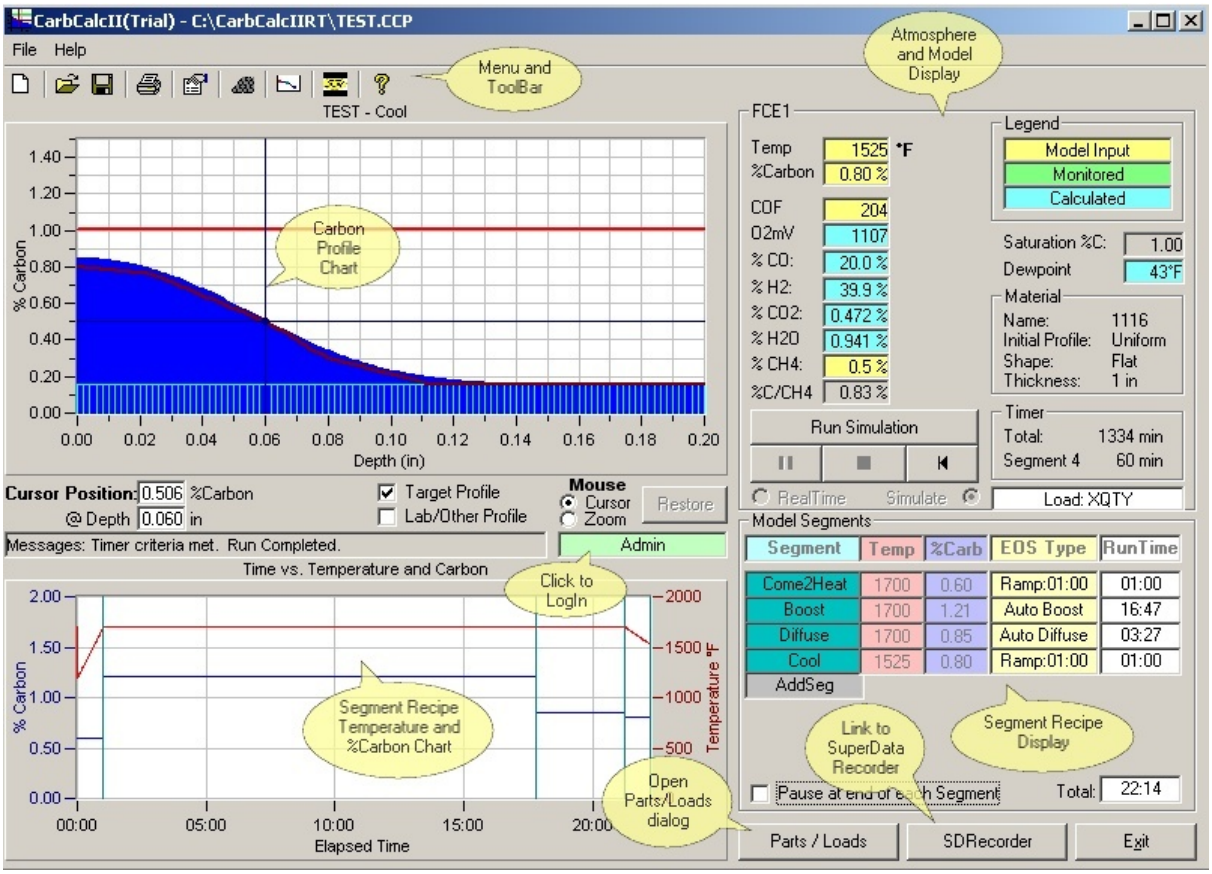
REALTIME CONTROL - CarbCalcII is able to connect to "dumb controllers" via SuperData communications. In this mode, CarbCalcII becomes the "Recipe Programmer" and sends setpoints to the Temperature and Carbon Controllers.

MONITOR/REPLAY is used to view the Carbon Profile for load cycles previously run or currently running and logged in SuperData. This mode can be integrated with BatchMaster furnace control systems.

2 CarbCalcII

2.1 Overview

The Main Screen.



- **Menu and ToolBar:** Provides access to Files, Printer and Model settings.
- **Furnace Atmosphere Display:** Displays Temperature, %Carbon and Gas values. Also displays material information and timers.
- **Recipe Segment Display:** Displays the Recipe segments in the current model, (Max 8 segments).
- **Recipe Temperature and Carbon Chart:** Displays theTemperature and Carbon vs Time. Also displays segment markers.
- **Carbon Profile Chart:** Displays Initial Carbon, Carbon Diffusion profile, Target profile and Saturation Carbon line.

2.2 Typical Uses

In **Simulation mode**, CabcalcII is used to develop Batch Carburizing Segment recipes.

- Up to 8 segments may be modeled.
- For each segment, define the Segment Name, Temperature, Carbon and End-Of-Segment (EOS) type.
- EOS types are:
  1. Timed - ends after a specified time.
  2. Match Surface Carbon - ends when Surface Carbon matches the Target Surface Carbon.
  3. Match Carbon at a specified depth - ends when Diffused Carbon matches Carbon at a specified depth.
  4. Auto Boost - ends when the amount of excess carbon near the surface exceeds the deficient carbon at depth.
  5. Auto Diffuse - ends when the deviation between the diffused profile and the target profile is minimized (curve matching).
- Model Temperature units may be displayed in Celsius of Fahrenheit and Measurement units in inches or mm.
- Probe Factors may use either the CO Factor or the Process Factor (typical to Marathon Instruments) .
- The Type of Material may be selected from a Material Database.
- The Initial Carbon Profile is based on the material selected and is assumed to be uniform.
- The Initial Carbon Profile may be customized based on 10 points - useful for modeling "Rework" recipes.
- The Target Profile (up to 10 points) may be specified or you can request a recommended profile based on Surface Carbon, Carbon at Effective Case Depth and Carbon at total Case Depth.
- After starting the simulation, it may be paused at any time. You can also set it to "AutoPause" at the end of each segment.

In **RealTime Control mode**, CarbCalcII is connected to a Carbon Controller and a Temperature Controller and is used to Control a running Batch Furnace Carb Cycle.

- A simple Load Entry system is used
- The Segment display represents the Carb Cycle Recipe.
- The Time vs Temperature and Carbon chart displays both the Setpoints and Actual values for Temperature and Carbon.
- The Carbon Profile is based on actual data from the instruments.
- Instrument communication data sources are easily configured from within the application and saved in a "Furnace" file.

In **Monitor/Replay mode**, CarbCalcII is used to reproduce a cycle based on a Furnace Load and the data logged by the SuperSystems communications datalogger. This mode is useful in analyzing a comparing a cycle profile with the actual Profile from Lab results.· Display is similar to RealTime mode but the data source is from the historical logged data.

- Model runs at high speed similar to simulation mode.
- Model may be paused, stopped or restarted at any time.
- Target profile may be used to compare actual Lab measured profile for comparison with the model results.
- Analysis may be helpful in "Tuning" the recipe to achieve more precise results.

2.3 Menu and Toolbar

- **Menu Items**
  - **File** - Provides standard file open, save and close routines for CarbCalcII Model Files.
  - **Help** - Opens Help file and About box.

- **ToolBar Items**


New Model - Opens the default New Model


Open Model - displays the File Open dialog for CarbCalcII Model Files


Save Model - saves the current model.·


Print - prints the Carbon Profile report. (report depends on model mode and settings - see Reports in this help file)


Model and Furnace Settings - Opens the Model and Furnace settings dialog.


Material - Opens the Material selection dialog.

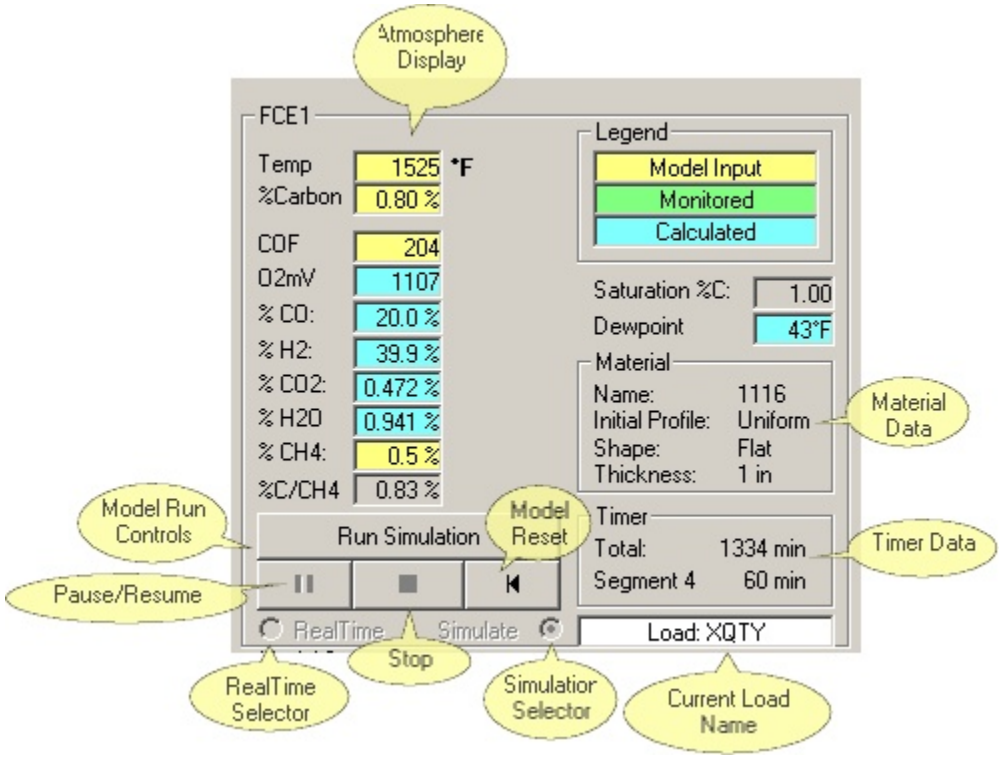

Carbon Profiles - Opens the Carbon Profiles dialog.


SuperCalc - Opens the SuperCalc program.


Help - Opens this help file.

2.4 Displays

2.4.1 Atmosphere Display Area



- **Atmosphere**

All atmosphere values are displayed. Model Inputs (yellow background) are "given" or "assumed" values. Monitored values (green background) are used only in the RealTime and Replay modes. Calculated values (blue background) are calculated based on Model Inputs and the assumption that the atmosphere is in equilibrium.

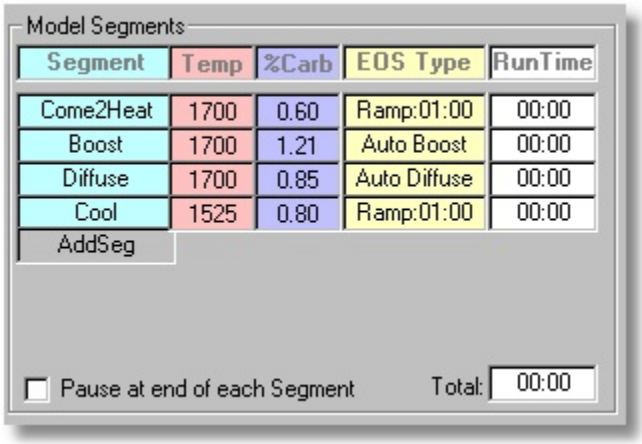
In simulation mode, the inputs will always be Temperature, %Carbon, Probe Factor and CH4. In Realtime and Replay modes the model inputs are selectable. In these modes, data that is available but not selected as a model input may be monitored - in this case, a monitored value will be displayed next to the model value.

- **Temperature** - units may be in Fahrenheit or Celsius.
- **%Carbon** - Carbon Potential (based on water-gas equations)
- **PF or COF** - Process Factor or CO Factor (depends on type of controller)
- **O2mV** - Oxygen Probe millivolts
- **%CO** - %Carbon Monoxide in the furnace atmosphere
- **%H2** - %Hydrogen Monoxide in the furnace atmosphere
- **%CO2** - %Carbon Dioxide in the furnace atmosphere
- **%H2O** - %Water in the furnace atmosphere
- **%CH4** - %Hydrocarbon in the furnace atmosphere
- **%C/CH4** - Efective%Carbon with CH4 taken into consideration

- **Saturation Carbon** - the level at witch free carbon (soot) precipitates in the atmosphere. Primarily dependent on Temperature. When designing recipes, a good rule of thumb is to keep the %C setpoint below about 90% of the Saturation Carbon.

- **Dewpoint** - displays the calculated Dewpoint for the given atmosphere.
- **Material** - displays the material selected, may be changed by opening the material dialog with the material toolbar icon.
- **Timers** -Displays the Total elapsed time and segment elapsed time in minutes.
- **Model Run Controls** - Used to start, stop, pause and reset the simulation.

2.4.2 Model Segment Display Area



A **Model Recipe** may have up to 8 Segments.

- **Segment** - the name given to the segment (defaults to Seg1, Seg2, etc). When the simulation is paused or stopped, you may click on the segment name to open the segment properties dialog and edit the segment.
- **Temp** - The temperature for the segment. You may edit the temperature for segments that have not yet executed.
- **%Carb** - The %Carbon for the segment. You may edit the %Carbon for segments that have not yet executed.
- **EOS Type** - The End-Of-Segment type determines how the segment terminates. There are 6 types available:
  1. **Timed Soak** - ends after a given time is reached.
  2. **Timed Ramp** - ramps temperature ends after a given time is reached.
  3. **Surface** - ends when the Carbon profile "matches" a specified Surface Carbon.
  4. **Depth** - ends when the Carbon profile "matches" a specified carbon at a specified depth.
  5. **AutoBoost** - ends when the "excess" carbon is sufficient to satisfy the "deficient" carbon. "Excess" carbon is the carbon above the "target" profile and "deficient" carbon is carbon below the target profile.
  6. **AutoDiffuse** - ends when the Carbon Profile matches the Target Profile ("best fit") .
- **RunTime** - displays the segment time in days, hours and minutes (D:HH:MM).

- **Pause Checkbox** - (simulation and replay only) check this box to make the simulation pause at the end of each segment.
- **Total Timer** - displays the total time in days, hours and minutes (D:HH:MM).
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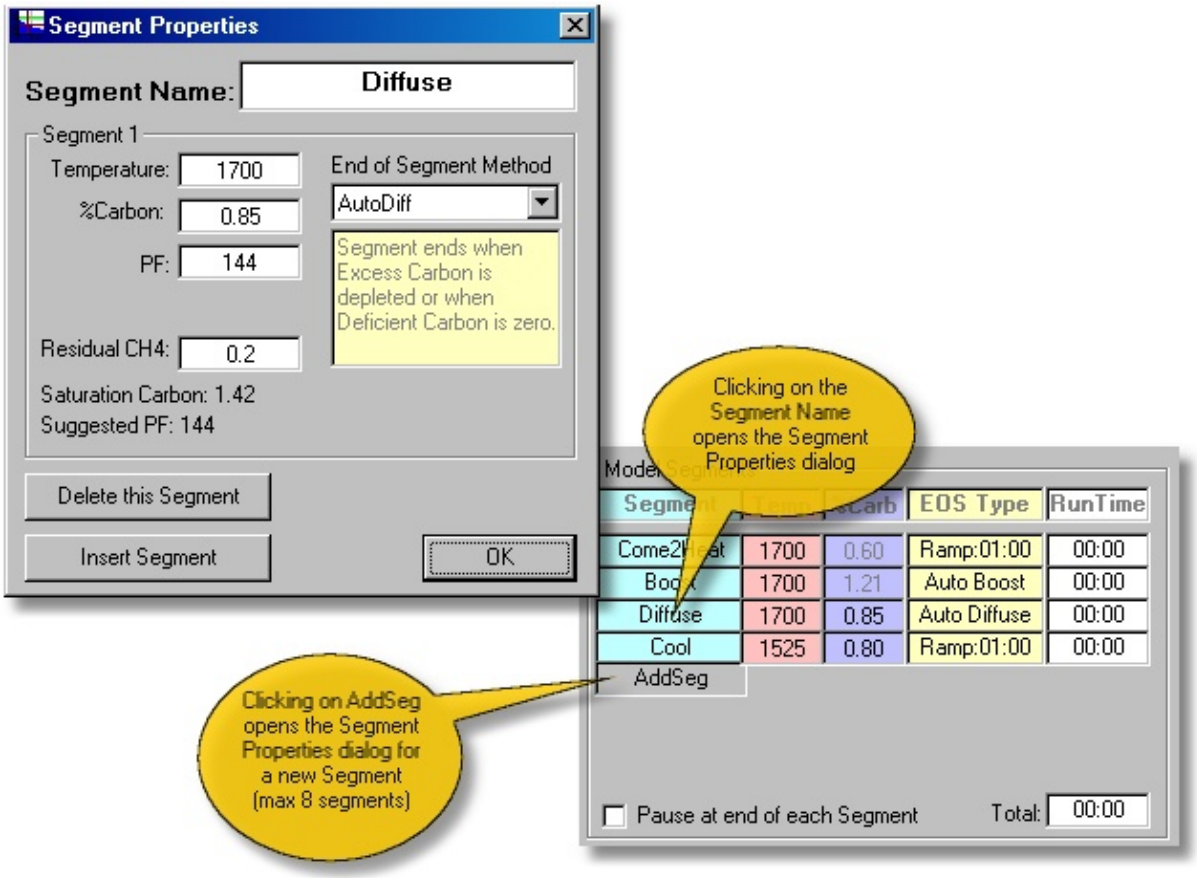
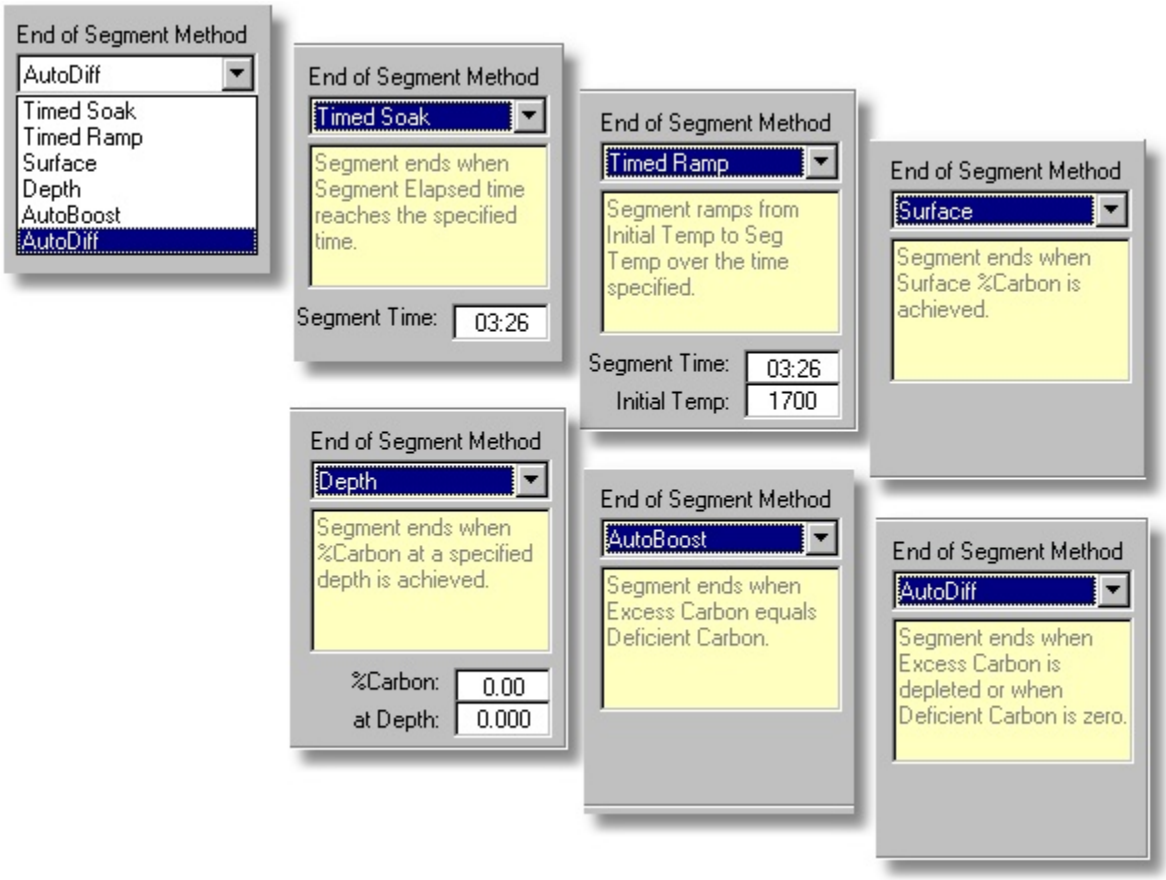
- **Note:** The Model Segment Display Area is always used in Simulation and Realtime Control Modes. It is not normally not displayed during Monitor and Replay modes.

2.4.3 Segment Properties Dialog

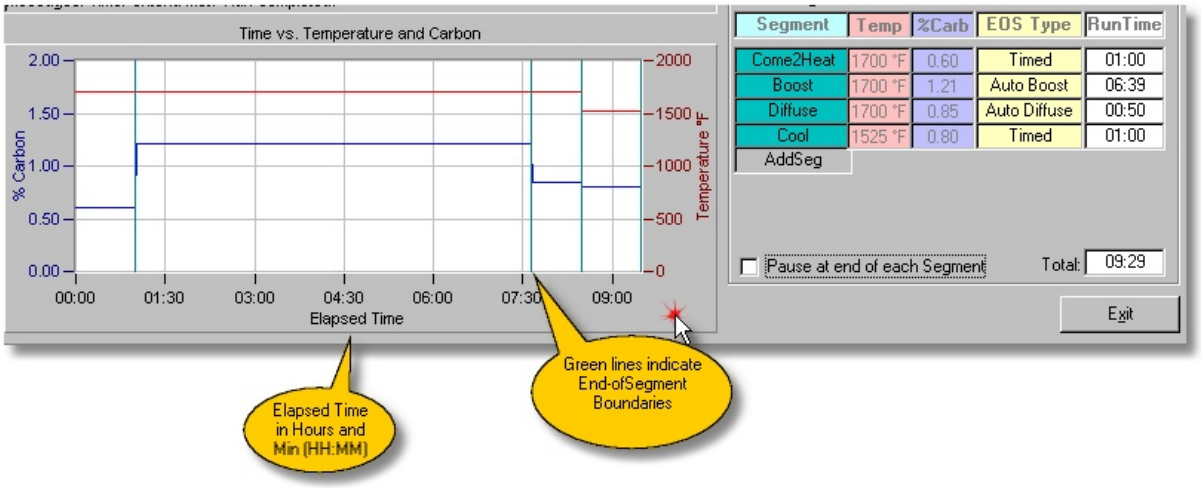


- **Segment Name** - Enter or Edit the Segment Name.
- **Temperature** - Enter or Edit the Segment Temperature
- **%Carbon** - Enter or Edit the Segment %Carbon.
- **Probe Factor** (PF or COF) - Enter or Edit the Probe Factor. Note: for new segments this will default to the Suggested PF and may be edited.
- **Residual CH4** - Enter or Edit the CH4 (normally 0.0 to 5.0 depending on your furnace).
- **Saturation Carbon** - displays saturation carbon level, %Carbon should be set to a value less than this amount.
- **Suggested Probe Factor** (PF or COF) - Theoretical value of the Probe Factor based on Material selected.
- **End of Segment Method** - select the End of Segment type and supply required data as indicated below.



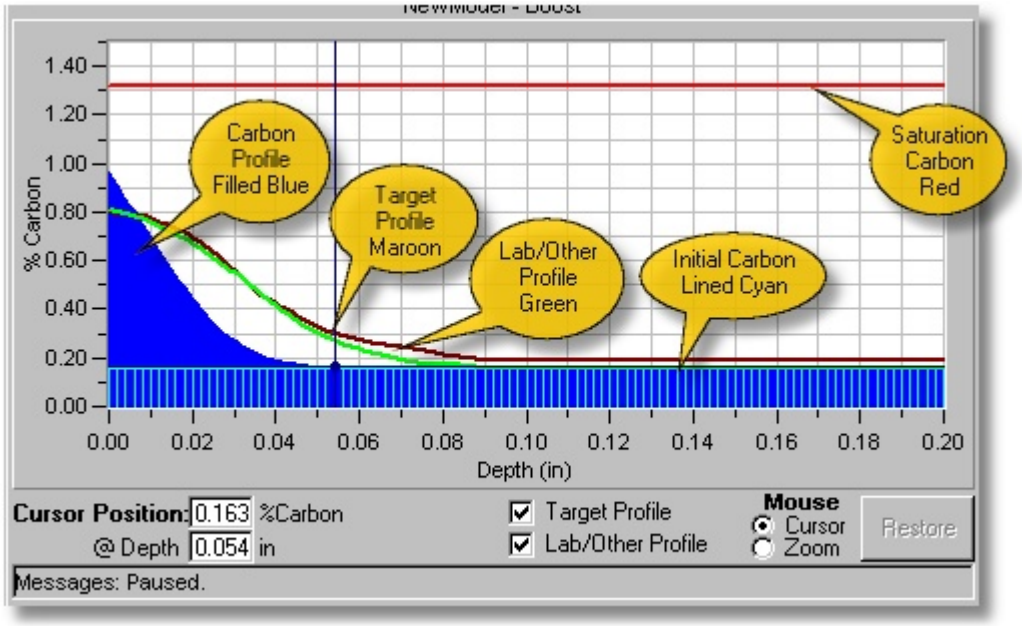
- **Delete Button** - clicking on this button will delete this segment from the model.
- **Insert Button** - clicking this button inserts the segment as a new segment.
- **OK Button** - exits the dialog and saves changes to the segment.

2.4.4 Temperature and Carbon Chart



In **Simulation mode**, the Temperature and Carbon Chart displays a profile of the recipe as it is executed.
In **RealTime** and **Replay modes**, the Actual monitored values of the Temperature and Carbon process variables and setpoints are displayed and times are displayed as actual clock times rather than elapsed times.

2.4.5 Carbon Profile Chart



The Carbon Profile Chart displays %Carbon (Y axis) vs Depth (X axis).

- **Title** - In Simulation mode, displays "Model Name - Segment Name"
  In RealTime and Replay Modes, displays Load Name and Model Name.
- **Y Axis** - %Carbon
- **X Axis** - Depth (in inches or mm depending on model settings)
- **Cursor Position** - displays the %Carbon at Depth corresponding to the cursor crosshair position.
- **Target Profile** - check to display the target profile.
- **Lab/Other Profile** - check to display the Lab or other imported profile.
- **Mouse Mode** - places mouse in either cursor or zoom mode (default is cursor).
- **Restore Button** - used to restore the chart after using the zoom mode.
- **Message box** - message display.
- **Carbon Profile** - primary display (filled Blue) Carbon vs Depth
- **Initial Carbon Profile** - Uniform or Custom Initial Carbon Profile (Lined Cyan)
- **Target Profile** - Maroon line indicating the "spec" or Target Profile
- **Lab/Other Profile** - Green line indicating the imported Lab or other imported Profile.
- **Saturation Carbon** - Red Line indicating the "saturation" carbon for the given furnace temperature.

2.5 Users and Security

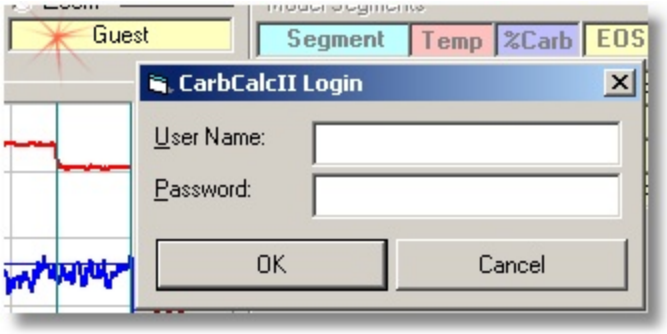
2.5.1 Login

Previous versions of CarbCalcII did not require Login or passwords. This version may be used to control furnace cycles in a production environment and therefore requires some protection. For each authorized user a User Name, Password and Access Level are maintained. When a user successfully logs in, he is granted access to program features depending on Access Level, Run Mode and Run Status.

A Login remains valid until 1) User Logs out or 2) In RealTime Control with program running Login is valid for 15 minutes.

There are 6 Access Levels (0 through 5):

- Level 0 - Guest
  - access to simulation modes
  - cannot save or create models, parts, or loads
  - Note: This is the default User Level
- Level 1 - Basic Operator
  - Access level 0 plus
  - can start and stop realtime loads
- Level 2 - Advanced Operator
  - Access level 1 plus
  - can save and create loads, parts and models
- Level 3 - Supervisor
  - Access Level 2 plus
  - can add and edit Material in the Material database
  - Note: This is the default User Level for BatchMaster Integration
- Level 4 - Advanced Supervisor
  - Access level 3 plus
- Level 5 - Administrator
  - Access level 4 plus
  - Manage User accounts
  - Unrestricted access to all features



To Login, click on the User Name Display/Login button. The Login dialog will open as shown above.

- Enter User Name (not case sensitive)
- Enter Password (this is case sensitive)
- Click Enter
  - Successful Login - User name will be displayed in the User Name Display with a green background.
  - Unsuccessful login - message and Guest will be displayed as user name.
- Click Cancel to logout (reverts to Guest)

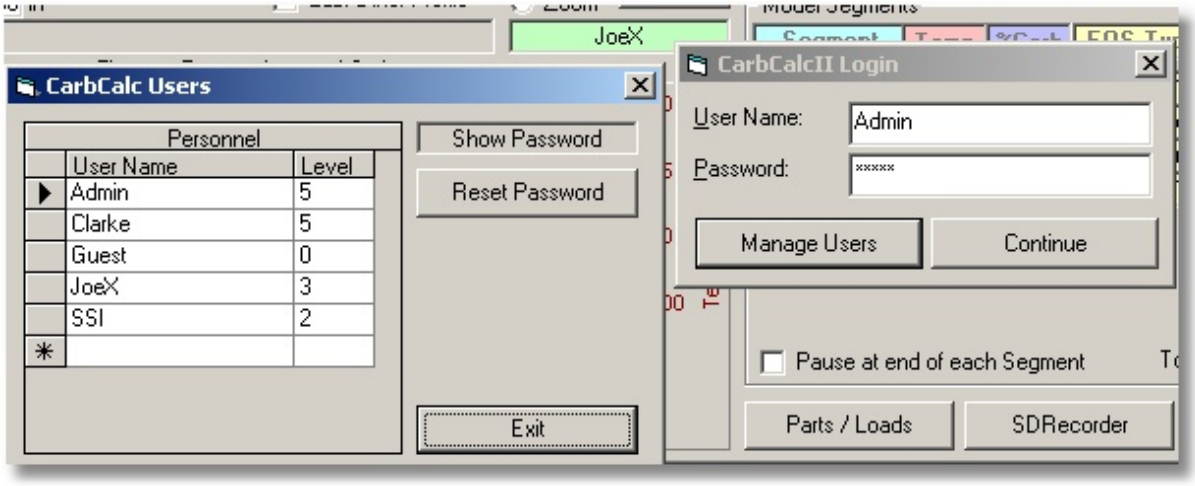
Password restrictions:

- Password cannot be blank
- Password must be 3 or more characters or numbers
- Password cannot be the same as user name (indicates reset)

Setting or changing a password. Only the Administrator can "reset" your password. When it is reset, the password is set to the User Name. When you logon, you will be prompted to enter a new password. If you forget your password, the Administrator can access it.

2.5.2 Manage Users

Only the Administrator (Access Level 5) can access the User's screen.



When you login as Administrator, the buttons at the bottom of the login dialog will change to "Manage Users" and "Continue". Click continue to complete the login normally. Click "Manage Users" to show the Users Dialog.

- Personnel Grid - Use the grid to Add, Edit or Delete Users.
- Show Password - click and hold to display password for selected user.
- Reset Password - click to reset the selected user's password. When reset, the password becomes the User Name and must be changed on next login.

2.6 Parts and Loads

2.6.1 Loads

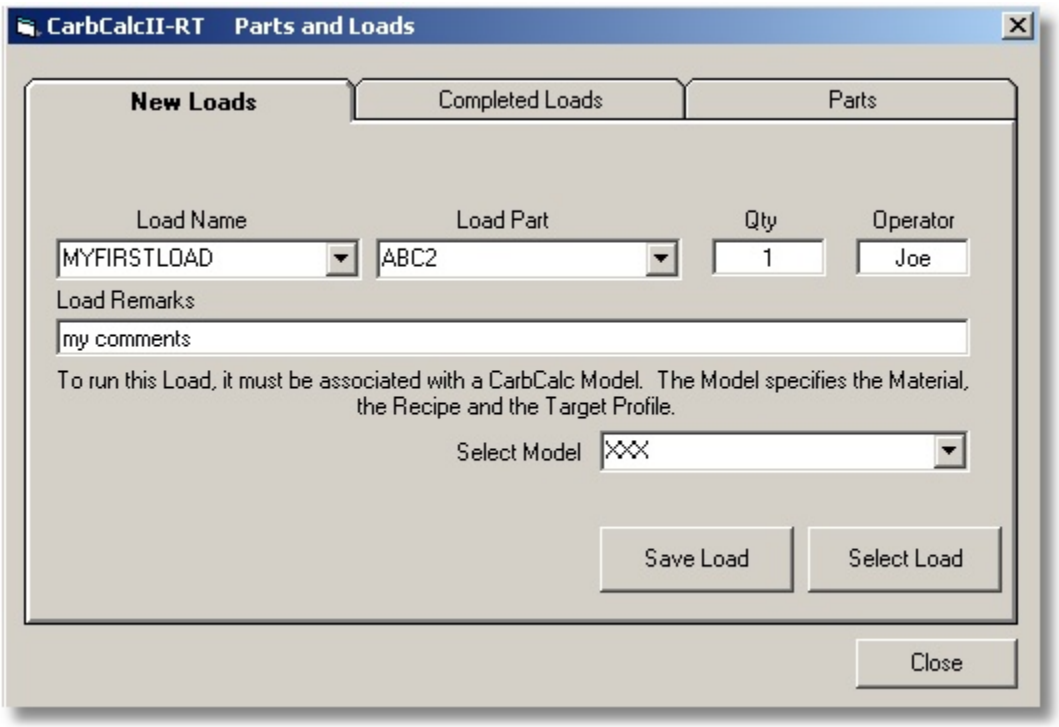
CarbCalcII comes with a Part and Load database. The user interface with the database varies depending on the operating mode,

- CarbCalcII in Control Mode - Loads and Parts integrated with Load Entry System.
- CarbCalcII in Monitor Mode - Loadfs and Parts for display and replay of data.
- CarbCalcII integrated with BatchMaster - BatchMaster Load database used for display and replay of data.

2.6.2 Control Mode

The Parts and Loads dialog contains 3 tabs: New Loads, Completed Loads and Parts.

New Loads - This tab is used to build loads and add them to the Loads database. It is also used to select a load to run.
(Note: Yous must be logged in with access level 2 or higher to use this screen)

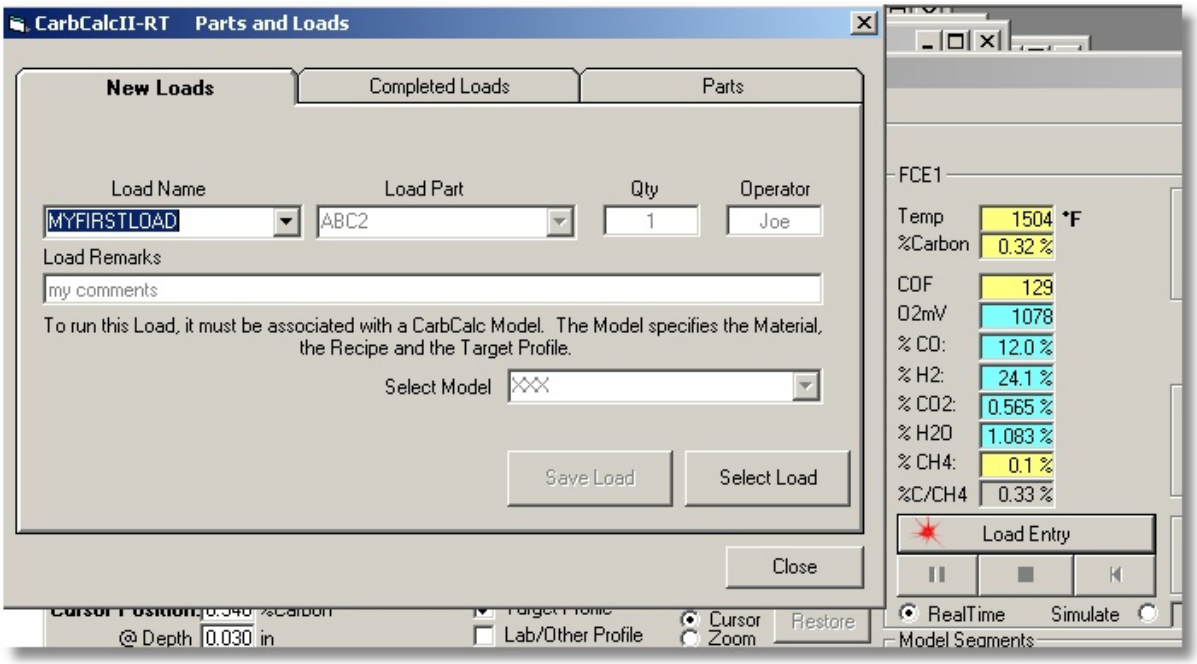


- **Load Name** - A unique name to identify the Load. You may use the drop list to select an existing load or type in a new name for a new load. The drop list will only display loads that have not been completed.
- **Load Part** - Select a part for the load (when a part is selected, the Model will change to the model associated with that part.
- **Qty** - enter the quantity of parts in this load.
- **Operator** - (optional) enter an identifier for the operator
- **Load Remarks** - Optional remarks
- **Model** - Select the model to use for this load (model is selected when you select a part, but may be changed using the droplist)

- **Save Load** - Click to save the Load in the database (does not select the load for execution)
- **Select Load** - Click to select the load for execution (also saves the load to the database)

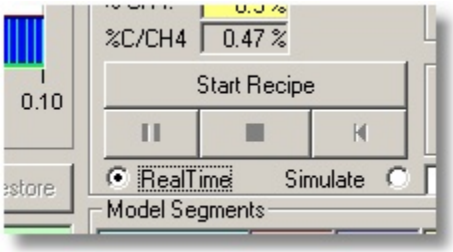
2.6.2.1 Entering a Load

In the Control Mode, you may enter a new load and either "Save" it for later use or "Select" it for current operations.



Steps to Enter and execute a Load in Realtime Control Mode

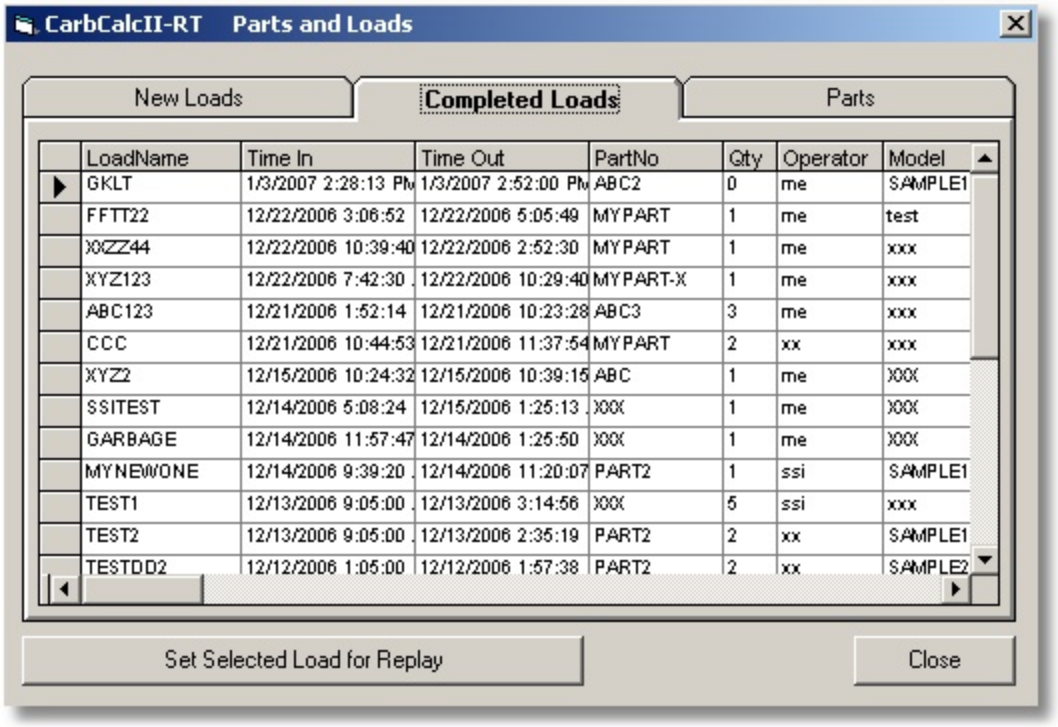
1. Select Realtime Mode (the run button changes to 'Load Entry")
2. Click on "Load Entry" to open the New Loads dialog
3. Select a Load and click on the Select Load button



4. The button changes from "Load Entry" to Start Recipe.
5. At this point you should verify the recipe, profile, material etc. You may switch to "Simulation" and make simulation runs before starting the recipe in RealTime control.
6. Make sure the furnace is physically loaded.
7. Start the recipe. When the recipe is running, the computer is sending setpoints to the Carbon and Temperature controllers. Ath this point, CarbCalcII and the CarbCalc computer are dedicated to controlling the recipe. If you attempt to stop CarbCalcII you will get a warning message.

2.6.2.2 Load History in Control Mode

The Completed Loads Tab may be used to select loads for "Replay". Note: This tab is not available when a load is active in control mode.

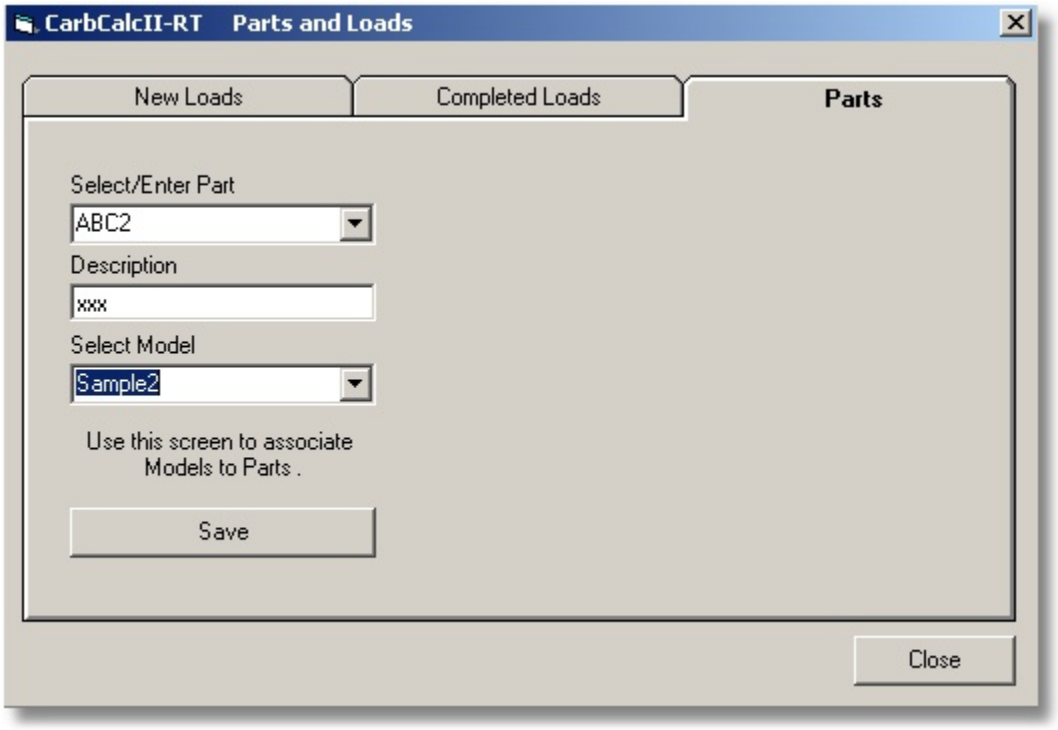


The Completed Load Tab is displays a grid of loads, most recently completed on top.
The "Time In" is stamped when the "Start Recipe" button is pressed and the "Time Out" is stamped when the load is completed ("unloaded"). These times may be edited on this screen with the appropriate access level. With appropriate access level, Loads may be edited, added or deleted from the database using the grid view.

To replay a load, select the load with the arrow indicator and click on the "Set Selected Load" button.

2.6.2.3 Parts in Control Mode

The Parts Tab is used to associate parts with models.



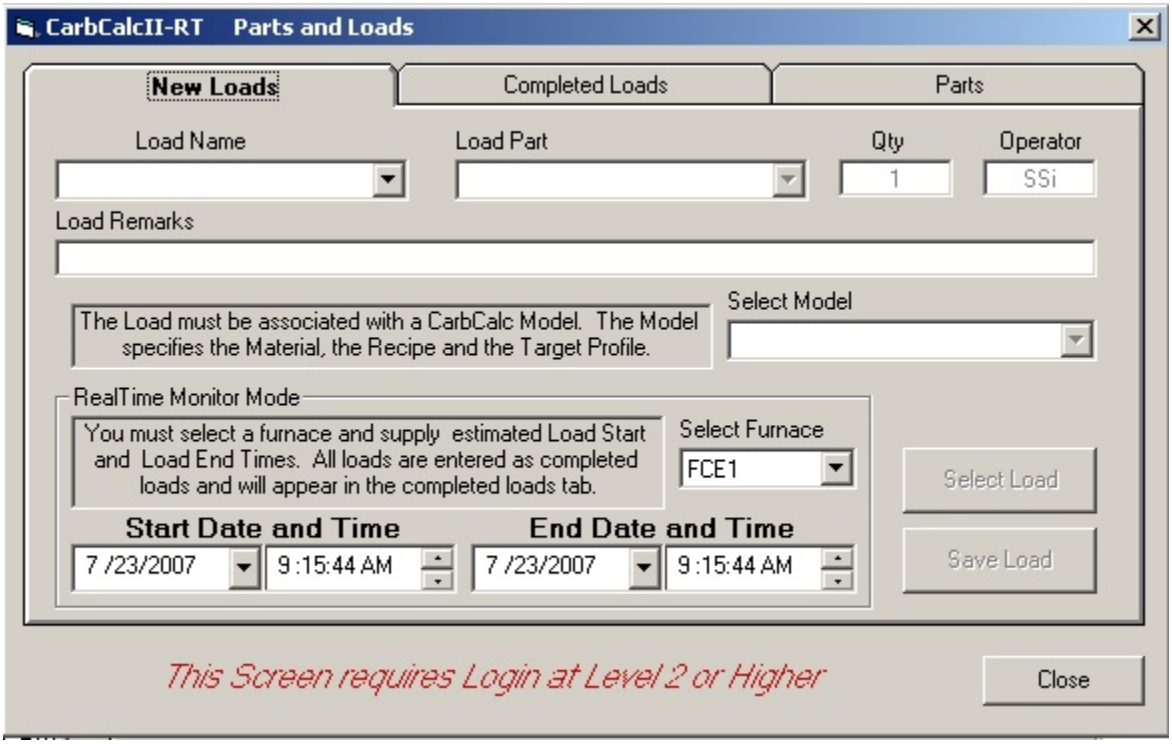
- **Select/Enter Part** - Select an existing part or enter a new part name.
- **Description** - enter/edit a part description.
- **Select Model** - Select the model to use when loading this part.
- **Save** - save changes

Note: A Model is a set containing the "Material", "Target Profile" and "Recipe". Models are normally developed using CarbCalcII in the Simulation Mode.

2.6.3 Monitor Mode

The Parts and Loads dialog contains 3 tabs: New Loads, Completed Loads and Parts. In the Monitor Mode, there is no control of the process. However, Loads may be manually added to the loads database and replayed using SuperData's logged process data.

New Loads - This tab is used to create loads and add them to the Loads database.
(Note: Yous must be logged in with access level 2 or higher to use this screen)



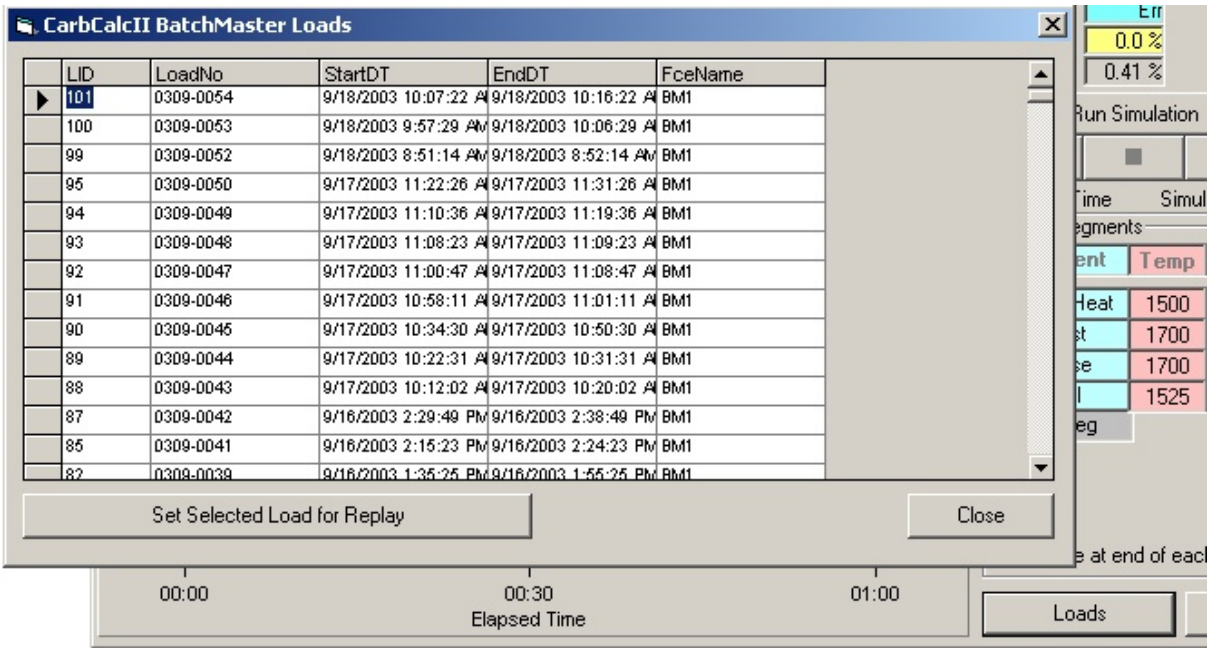
- **Load Name** - A unique name to identify the Load.
- **Load Part** - Select a part for the load (when a part is selected, the Model will change to the model associated with that part.
- **Qty** - enter the quantity of parts in this load.
- **Operator** - (optional) enter an identifier for the operator
- **Load Remarks** - Optional remarks
- **Model** - Select the model to use for this load (model is selected when you select a part, but may be changed using the droplist)
- **Select Furnace** - Select the furnace that ran this load (CarbCalcII must know where to get the logged process data).
- **Start Date and Time** - Enter the estimated Load Start date and time (may be edited later)
- **End Date and Time** - Enter the estimated load end date and time (may be edited later). (Note: End date and time initializes to the start date and time)

- **Save Load** - Click to save the Load in the database (does not select the load for replay)
- **Select Load** - Click to select the load for replay (also saves the load to the database)

In the Monitor Mode, the **Completed Loads** and **Parts** Tabs operate the same as in the Control Mode.

2.6.4 BatchMaster Mode

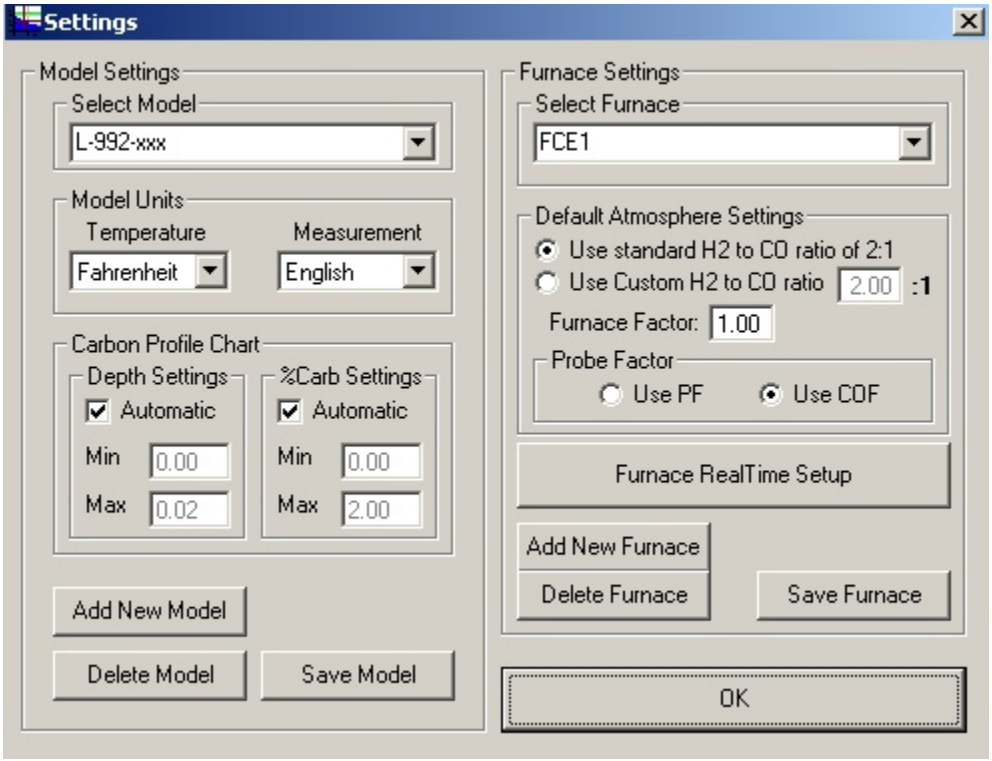
The **BatchMaster Integration** mode is a special case of CarbCalcII's Monitor Mode. In the BatchMaster Mode, the Loads database is provided and maintained by an external application (normally AFC-Holcroft's BatchMaster system). In the BatchMaster Mode, CarbCalcII provides simulation for modelling and Load Replay for monitoring cycles. Since the external application provides the load information, parts, times, etc. the "**New Loads**" and "**Parts**" tabs are not provided. Only the " **Completed Loads**" tab is provided in the BatcfhMaster" mode.



See the "Configuration" section for setting up the BatchMaster Integration mode.

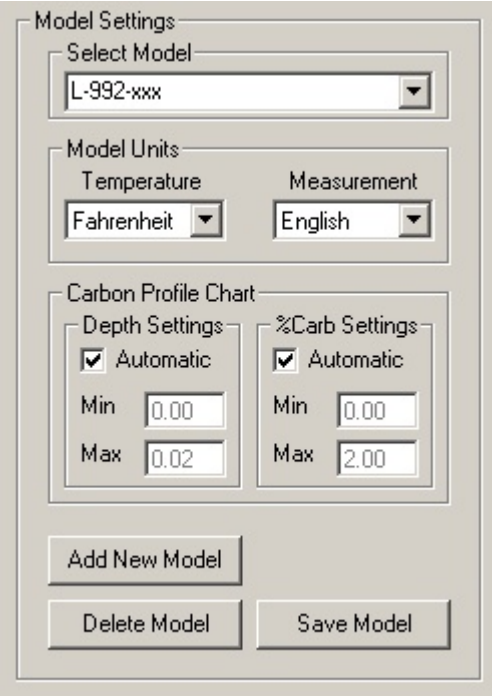
2.7 Model and Furnace Settings

2.7.1 Settings Overview



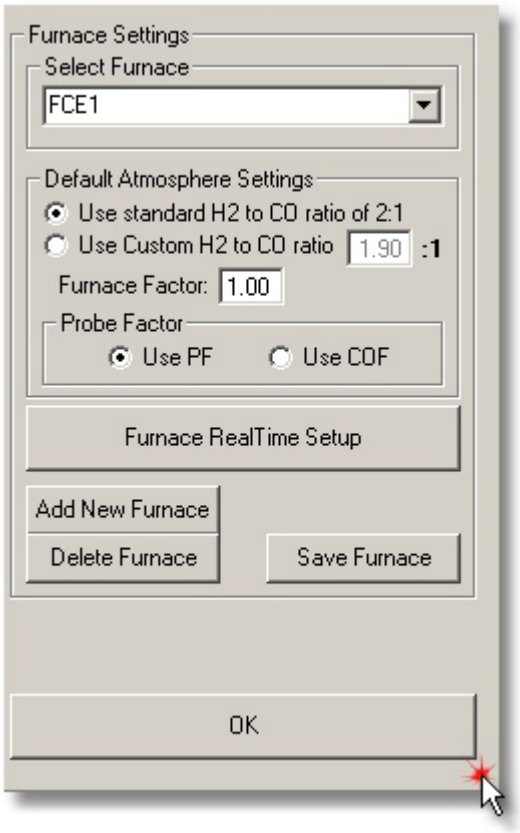
- The **Settings dialog** is used to select the Model and the Furnace.
- The **model** contains the "recipe segments", the material, the target profile, etc.
- The **Furnace** contains data specific to a furnace.
- Any model may be used with any furnace.

2.7.2 Model Settings



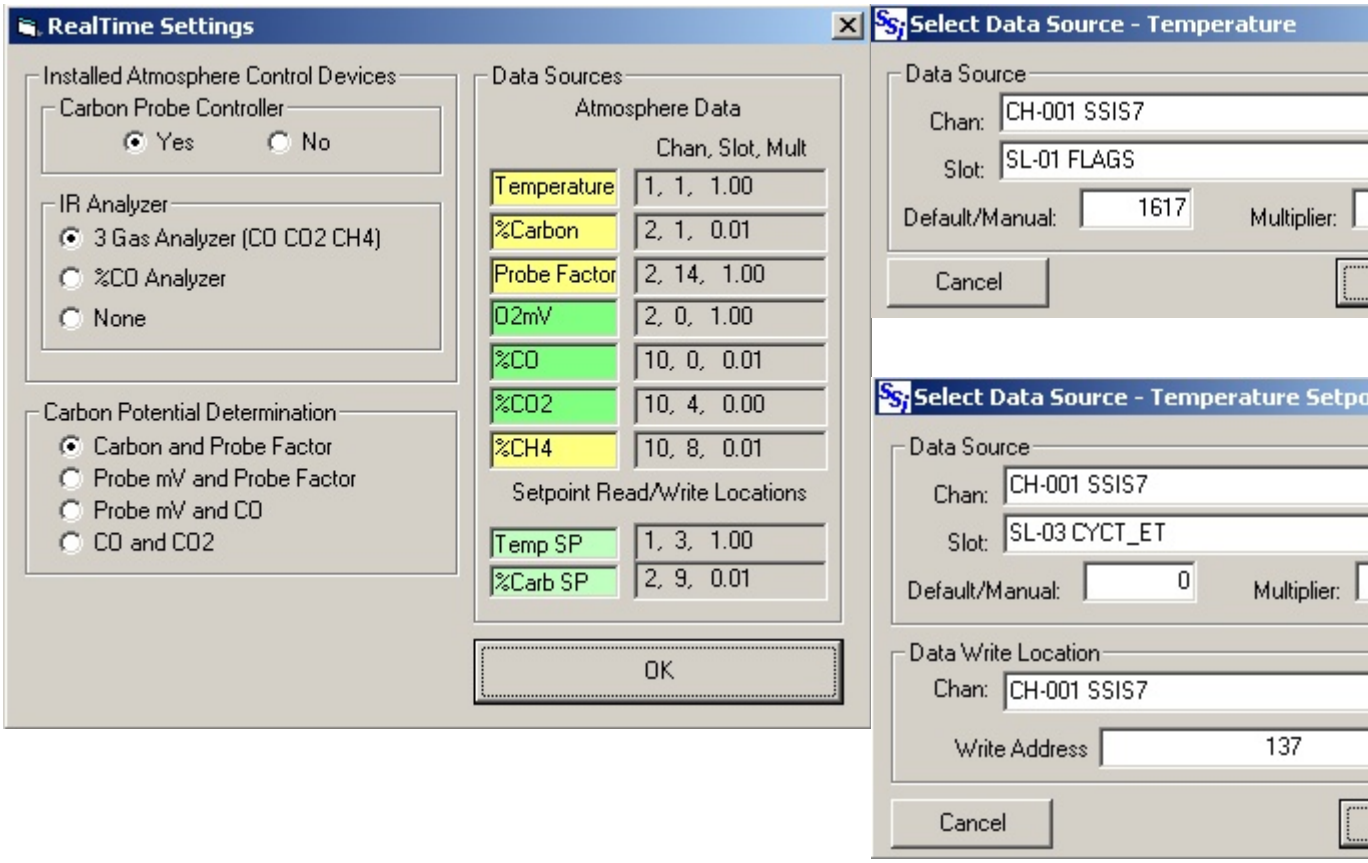
- **Select Mode**l - use this dropdown to select the desired model.
- **Model Units** ·Temperature - select Celsius or Fahrenheit
- **Measurement** - select English or Metric
- **Carbon Profile Chart**
  - **X Axis** setting (Depth Axis) - Auto is recommended.
  - **Y Axis** setting (Carbon Axis) - Auto is recommended.
- **Add New Model** - Clicking this button will prompt you to enter a name for the new model, the model will be saved with the current model settings. The settings may be subsequently changed and saved as desired.
- **Delete Mode**l - clicking this button will delete the current model.
- **Save Model** - will save the current model and all changes that may have been made since the model was last saved.

2.7.3 Furnace Settings



- **Select Furnace** - use this dropdown to select the desired furnace.
- **Default Atmosphere Settings**
  - Set Use Standard H2 to CO ratio 2:1
  - or Specify Custom H2 to CO ratio
  - Specify a Furnace Factor (range 0.0 to 2.5 with normal value of 1.0)
  - **Probe Factor**
    - **PF** - used by Marathon Instruments
    - or **COF** - used by most instruments
- **Furnace RealTime Setup** - Clicking this button opens the RealTime setup dialog for the selected furnace.
- **Add New Furnace** - Clicking this button will prompt you to enter a name for the new Furnace, the furnace will be saved with the current furnace settings. The settings may be subsequently changed and saved as desired.
- **Delete Furnace** - clicking this button will delete the current furnace.
- **Save Furnace** - will save the current furnace and all changes that may have been made since the furnace was last saved.

2.7.4 Furnace RealTime Setup



- **Furnace RealTime Settings** - The realtime settings are required for the realtime control and monitor/replay modes, they are not required for simulation mode. The realtime settings describe what information is available from the furnace instrumentation and where it can be accessed from SuperData. The realtime modes require SuperData communications and datalog system.
- **Installed Atmosphere control**
  - **Carbon Probe Controller** - select yes or no.
  - **IR Analyze**r - select type installed or none.
- **Carbon Potential Determination** - Select data values to be used as model inputs.·Note: Temperature and %CH4 are always assumed to be model inputs.
  - **Carbon and Probe Factor** - Uses Carbon and Probe Factor as model inputs.
  - **Probe Millivolts and Probe Factor** - Uses Probe millivolts and Probe Factor as model inputs.
  - **Probe Millivolts and %CO** - Uses Probe Millivolts and %CO as model inputs (requires IR Analyzer).
  - **%CO and %CO2** - Uses %CO and %CO2 as model inputs (requires IR Analyzer).
- **Data Sources** - Displays the data source (SuperData channel and slot) for the models data values.
  - **Data Name** - name of the data value, Clicking on the Data Name opens the Data Source Dialog.
  - **Background color**
    - Yellow - model input
    - Green - monitored but not used as model input
    - Blue - calculated value
    - Red - not used
  - **Data Source** - displays the Channel, Slot and Multiplier location for the data value.

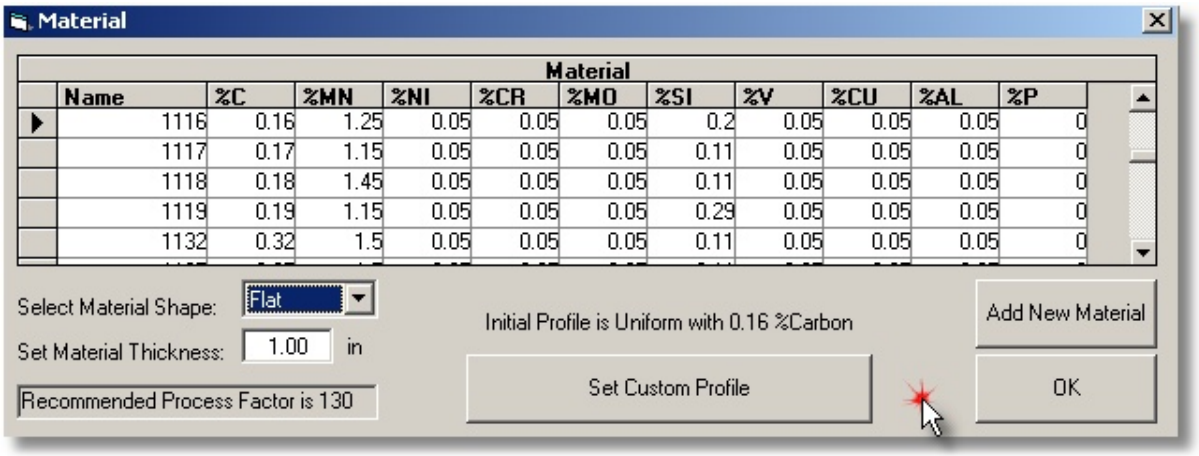
- **Select Data Source Dialog** - the dialog is opened when you click on the Data Name. The dialog is

used to specify the data source values.

- **Chan**. - select the SuperData channel from the dropdown.
- **Slot**. - select the SuperData slot from the dropdown.
- **Default/Manual** - enter a default value - this value is used in the model when communications is lost, the value is also used as a manual input value when the data is not available and the channel is set to "(None)".
- **Multiplier** - SuperData data is always stored as integer with implied decimal points. e.g. 1.05 %C would be stored as 105, For this reason, it is necessary to provide a multiplier to retrieve the correct value. In the case of %Carbon, the multiplier is 0.01.
- **OK Button** - saves the changes for the current furnace (you must save the furnace settings to make these changes permanent)
- **Cancel Button** - ignores any changes and exits the dialog.
-
- **Note:** When in Control mode, you will also be prompted to supply the Setpoint Write Locations.

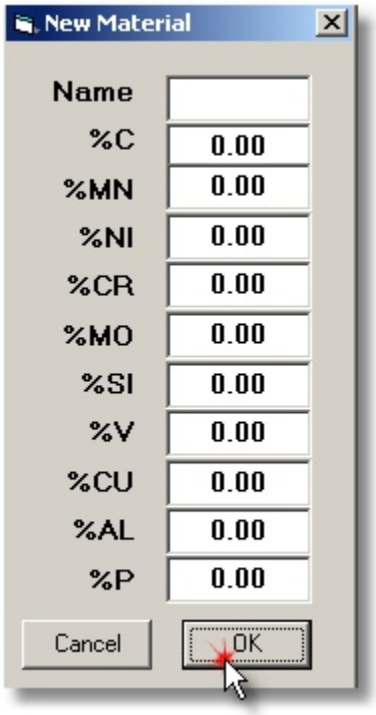
2.8 Material Selection

2.8.1 Material Dtabase



The **Material database** dialog allows selection of most standard material for the given model. Additional material may be added to the database. The Probe Factor calculated by the model takes into account the composition of the steel. The %Carbon in the steel is used to set the initial Carbon Profile for the model (uniform).

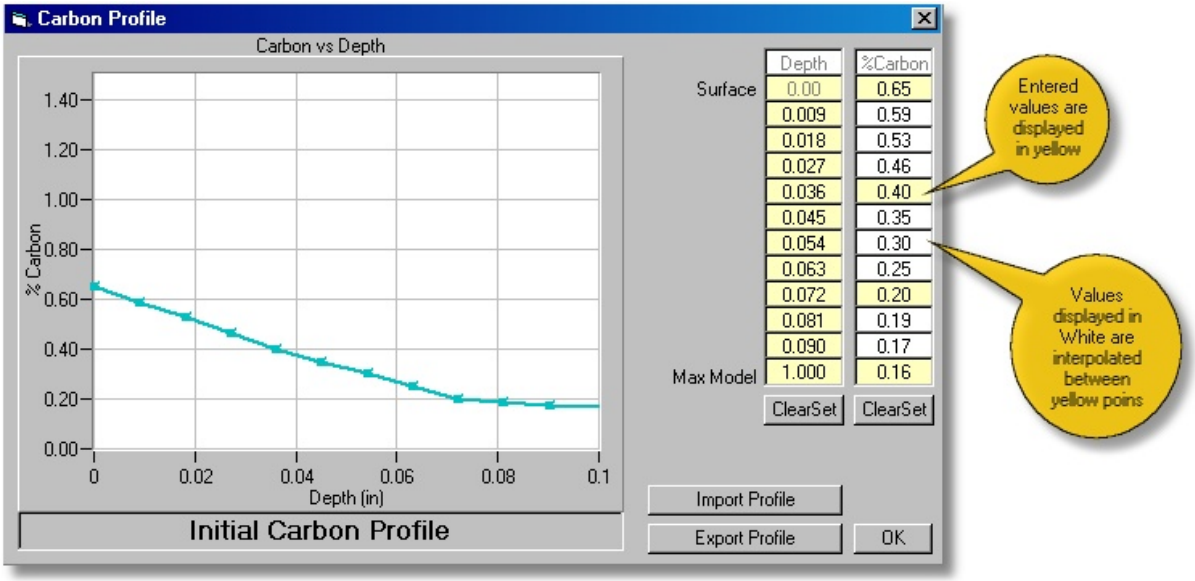
- **Material grid** - Use the row selector to select the desired steel.
- **Material Shape** - select from Flat, Concave or Convex (not implemented - Flat is always used) .
- **Material Thickness** - enter value, (max value for the model is 1.0 inch or 25.4 mm)
- **Set Custom Profile** - clicking this button opens the Custom Profile dialog. The custom profile is normally used for modeling re-work where the Initial Carbon Profile is no longer uniform as in new steel.
- **Add New Material** - clicking this button opens the "Add New Material" dialog.
- **OK Button** - applies changes to the current model and closes the material dialog.



The Add New Material dialog permits adding material to the database. You must specify a material name and composition.

2.8.2 Initial Carbon Profile

The Initial Carbon Profile is assumed to be uniform based on the %Carbon in the steel. This is the normal case for new product. In special circumstances, e.g. product to be re-worked, the Initial Carbon Profile may be substantially different.



- **Chart Area** - displays the initial %Carbon vs Depth.
- **Depth and %Carbon Columns** - Values in yellow background have been entered, values between

entered values are interpolated and displayed with a white background. Surface and Max Model depth values are fixed.

- **Clear Set** - this button clears the yellow background for the Depth and %Carbon values respectively.
- **Import Profile** - permits importing (from a .tsv or .csv file) a carbon profile to be used as the initial carbon.
- **Export Profile** - permits exporting the initial carbon profile to an excell compatible .tsv or .csv file.
- **OK** - accepts changes and applies them to the current model. Note changes are not saved with the model, the next time the model is loaded it will revert to uniform carbon for the selected material.

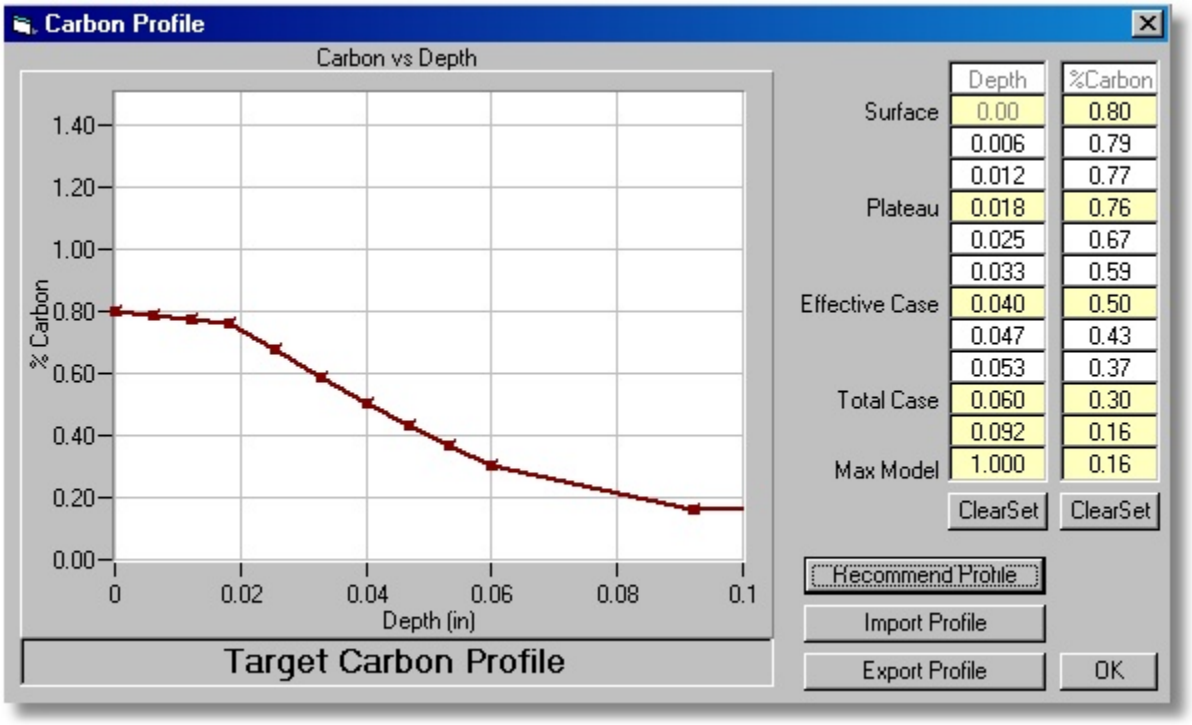
2.9 Target Profile

2.9.1 Specifying a Target Profile

The Target Profile is normally the specified goal for the simulation. The Target Profile is used to calculate excess and deficient Carbon during the "Auto Boost" segment and is used for curve matching in the "Auto Diffuse" segment.

Note: The Boost Diffuse Carbon cycle normally results in a profile that is "S" shaped. The principal points in describing the curve are:

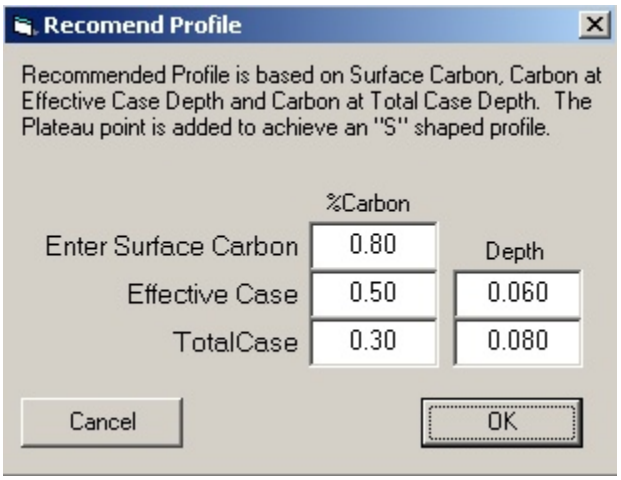
- Surface - surface %Carbon
- Plateau - %Carbon at half of the effective case depth to produce an "s" shape curve.
- Effective Case - Depth/Carbon for the effective case depth.
- Total Case - Depth/Carbon for the total case depth (Carbon defaults to the %Carbon in the material).
- Max Model - Always 1 inch (25.4 mm) with carbon the same as the material initial carbon.



- **Chart Area** - displays the Target Profile as %Carbon vs Depth.
- **Depth and %Carbon Columns** - Values in yellow background have been entered, values between entered values are interpolated and displayed with a white background. Surface and Max Model depth values are fixed.
- **Clear Set** - this button clears the yellow background for the %Carbon values.
- **Import Profile** - permits importing (from a .tsv or .csv file) a carbon profile to be used as the Target Profile.
- **Export Profile** - permits exporting the Target carbon profile to an excell compatible .tsv or .csv file.
- **Recommend Profile** - opens the "Recommend Profile" Dialog.
- **OK** - accepts changes and applies them to the current model.

2.9.2 Recommended Profile

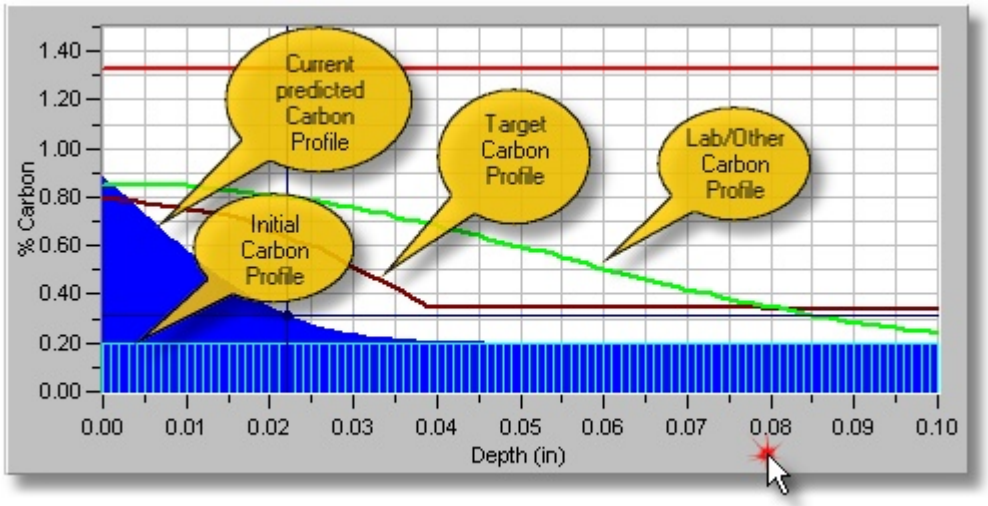
The Recommended Profile dialog permits easy entry of the target profile based on Surface Carbon,Carbon at the Effective Case Depth and Carbon at Total Case Depth.



- Edit Carbon and Depth values as desired
- Cancel - ignores any changes and closes the dialog.
- OK - Applies changes and closed the dialog.

2.10 Carbobn Profiles

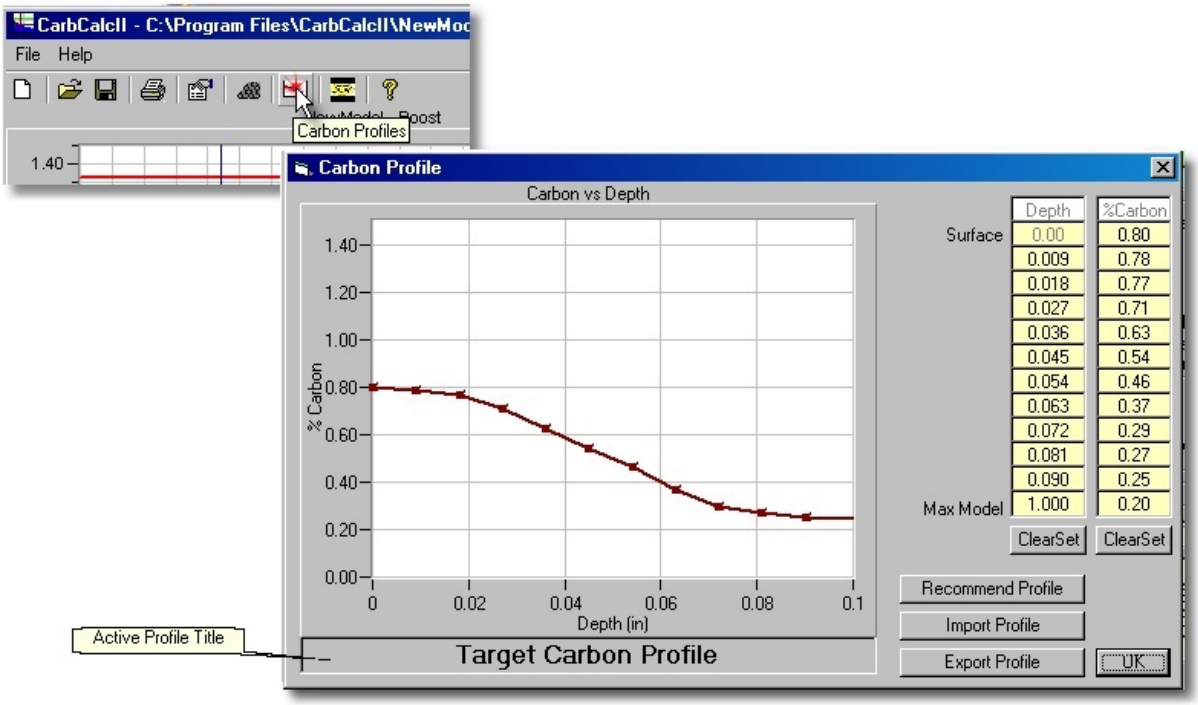
2.10.1 Carbobn Profile Dialog



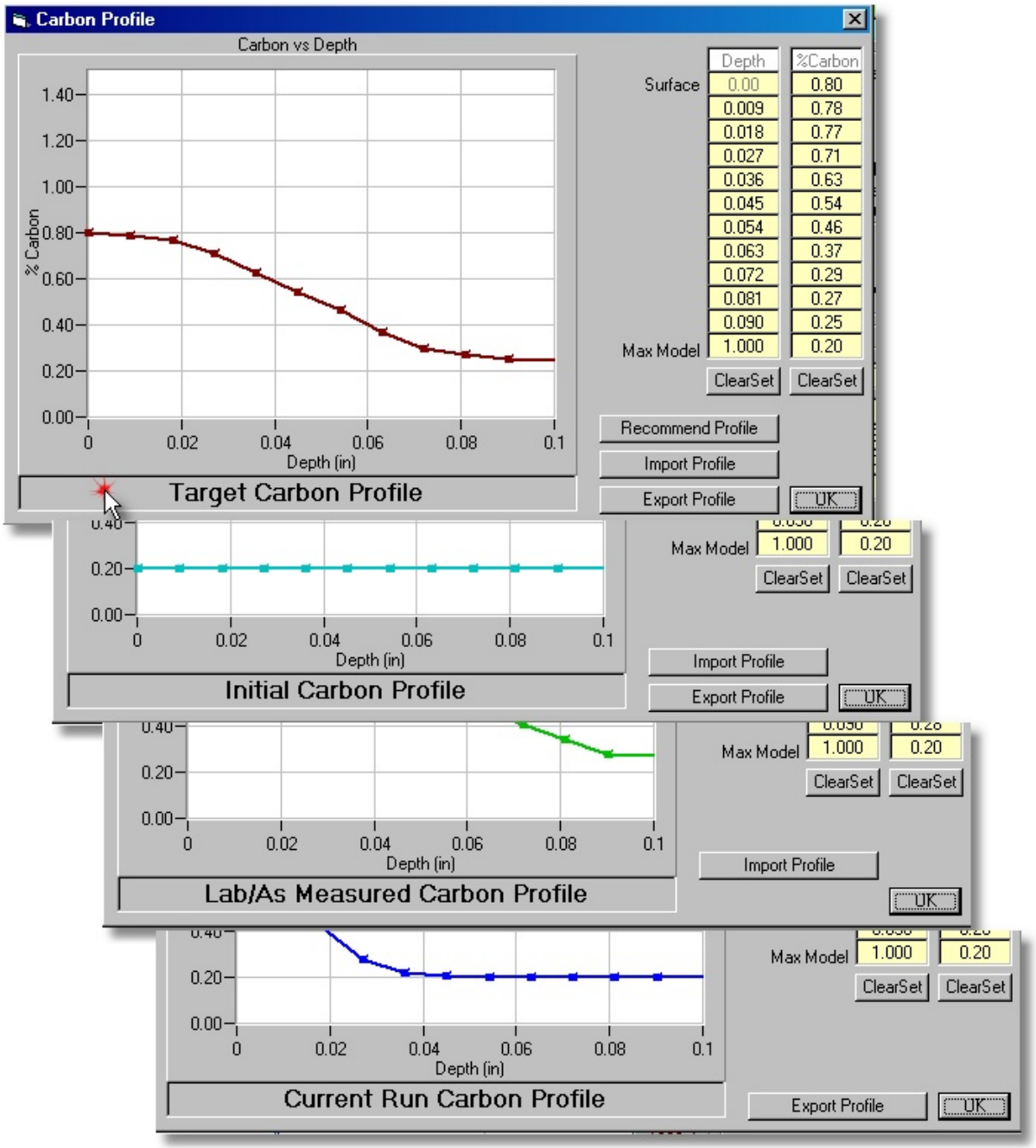
There may be up to 4 simultaneously displayed on CarbCalcII's Carbon profile chart:

- Current Predicted Carbon - The model's current predicted carbon profile
- Initial Carbon - The material's initial carbon profile
- Target Carbon - The target or specification carbon profile
- Lab/Other Carbon - An imported Carbon profile, may be from lab data or other source.

Clicking on the Carbon Profiles toolbar icon opens the Carbon Profile dialogue with the Target Profile active.



Clicking on the Active Profile Title box will switch the dialog to the next profile.



- **Chart Area** - displays the Active Profile as %Carbon vs Depth.
- **Depth and %Carbon Columns** - Values in yellow background have been "set", values between entered values are interpolated and displayed with a white background. Surface and Max Model depth values are fixed.
- **Clear Set** - this button clears the yellow background for the Depth or %Carbon values respectively.
- **Import Profile** - permits importing (from a .tsv or .csv file) a carbon profile to be used as the selected Active Profile (Target, Initial or Lab).
- **Export Profile** - permits exporting the Active carbon profile to an excell compatible .tsv or .csv file.
- **Recommend Profile** - opens the "Recommend Profile" Dialog (Target Profile only).

- **OK** - accepts changes and applies them to the current model.

2.11 SuperCalc

2.11.1 The SuperCalc Application

SuperCalc is an SSi Utility that aids in determining Carbon and Dewpoint based on Oxygen Probe or 3Gas IR analyzer. This utility is included with CarbCalcII and is also available on the web at SuperSystems.com

2.12 Simulation Mode

2.12.1 Typical Uses

The Simulation mode provides a method for developing Carb Cycle recipes for Batch Furnaces. Typical uses include:

- ·Developing recipes for new product.
- ·Developing re-work recipes.
- ·Modifying existing recipes to potentially shorten furnace time.

In the Simulation mode, model inputs are always Temperature, %Carbon, Probe Factor and %CH4.

The Simulation Mode features various methods to model the End of Segment.

- Timed segments
- Match Surface Carbon
- Match Carbon at a specified depth
- Auto Boost
- Auto Diffuse

Typical Steps in developing a Boost-Diffuse Carburizing Recipe

1. Select the Furnace
2. Select the Material
3. Generate a Target Profile (Use recommended profile and modify as desired)
4. Generate recipe segments
   - Usually 4 segments will be adequate (Come2Heat, Boost, Diffuse, Equalize)
   - Come2Heat - Soak for specified time
   - Boost - Use "AutoBoost" to end segment. %Carb should be just less than saturation for the given temperature.
   - Diffuse - Use "AutoDiff" to end segment. %Carb should be at or slightly above the Target Profile Surface Carbon.
   - Equalize/Cool - Timed Soak
5. Run Simulation and evaluate results.
6. Modify model (steps 2,3 and 4 above) and repeat simulation.
7. When satisfied with simulation results, make a product test run,
8. Compare test run lab results with simulation results (may use "Lab Profile" to aid in comparison).
9. May be necessary to adjust the "Furnace Factor" to correct for differences in Lab Profile and Simulation Profile.

Note 1: When developing a "re-work" recipe, you will need to modify the "Initial Profile", all other steps remain the same.

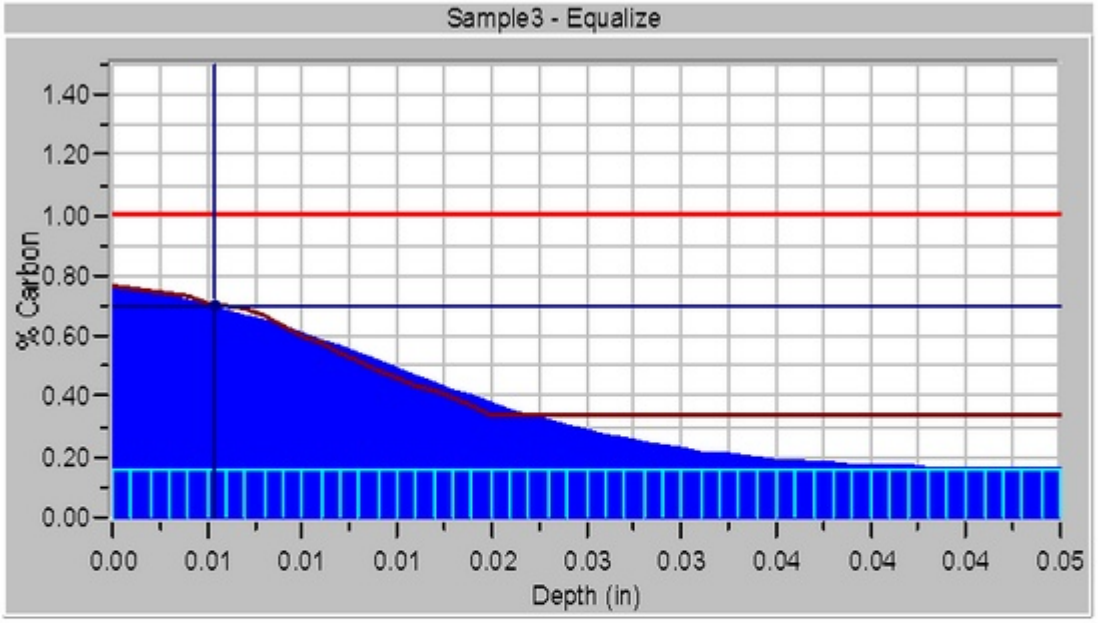
Note 2: When modifying an existing recipe, replace the 4 segment cysle in step 4 with your existing recipe.

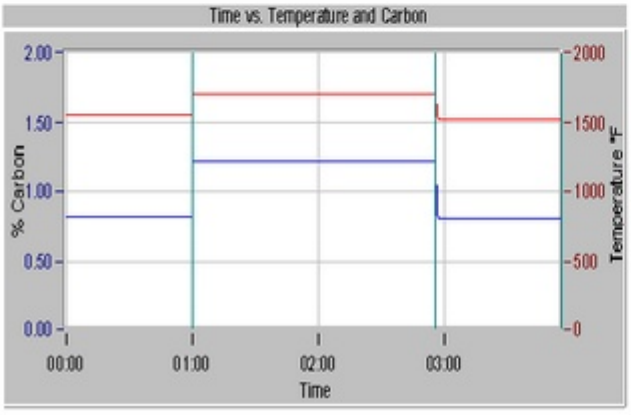
2.12.2 Report

In the simulation mode, clicking on the print icon will print the following report. The report is a snapshot of the current model status and can be printed at any time during the simulation.

7/6/2005 2:49:32 PM
Model Name: Sample3
Furnace Name: FCE1
Run Mode: Simulation

Material
Name: 1116
Initial Profile: Uniform
Shape: Flat
Thickness: 1 in





Model Segments

Segment	Temp	%Carb	EOS Type	RunTime
Come2Heat	1551	0.82	Timed:01:00	01:00
Boost	1700	1.21	Auto Boost	01:56
Diffuse	1700	0.85	Auto Diffuse	00:00
Equalize	1525	0.80	Timed:01:00	01:00
AddSeg				

Total: 03:56

2.13 RealTime Control Mode

2.13.1 Typical Uses

In the RealTime Control Mode, a Carb Cycle may be controlled via SuperData Communications. Typical uses include:
Controlling a Carbon Cycle Recipe and monitoring the Carbon Profile in RealTime

In the RealTime mode, Model inputs include Temperature and %CH4 and either Probe Data or IR Analyzer Data for Carbon Potential determination.

2.13.2 Report

In the RealTime Control mode, clicking on the print icon will print the following report. The report is a snapshot of the current model status and can be printed at any time during the run.

1/4/2007 11:53:17 AM

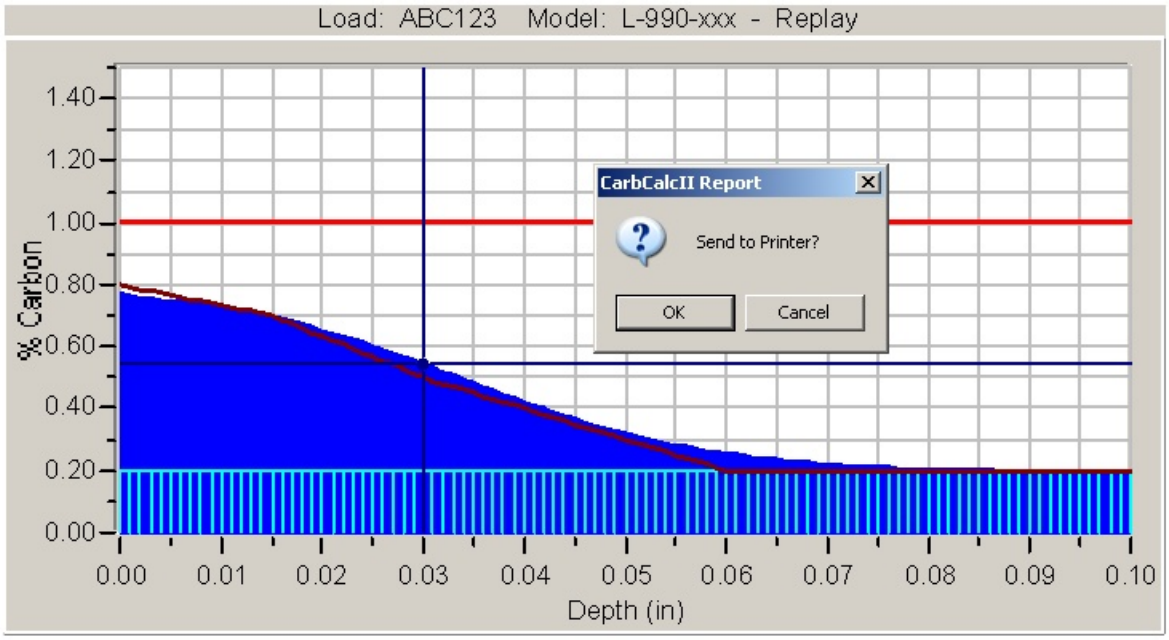
Model Name: L-990-xxx

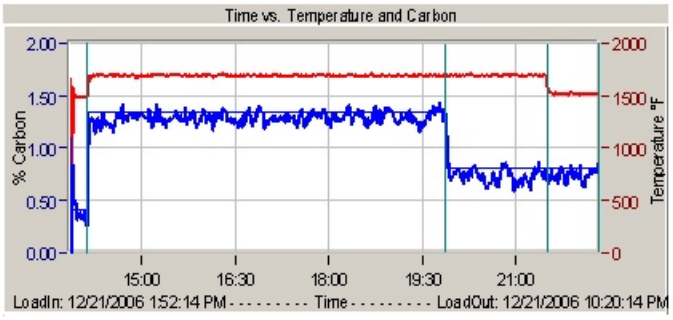
Furnace Name: FCE1

Run Mode: Replay. Start: 12/21/2006 1:52:14 PM End: 12/21/2006 10:20:14 PM

Material

Name:	8720
Initial Profile:	Uniform
Shape:	Flat
Thickness:	1 in





Model Segments

Segment	Temp	%Carb	EOS Type	RunTime
Come2Heat	1500	0.40	Soak:00:15	00:15
Boost	1700	1.35	Auto Boost	05:45
Diffuse	1700	0.80	Auto Diffuse	01:37
Cool	1525	0.80	Soak:00:30	00:50
AddSeg				

Total: 08:28

2.14 Replay Monitor Mode

2.14.1 Typical Uses

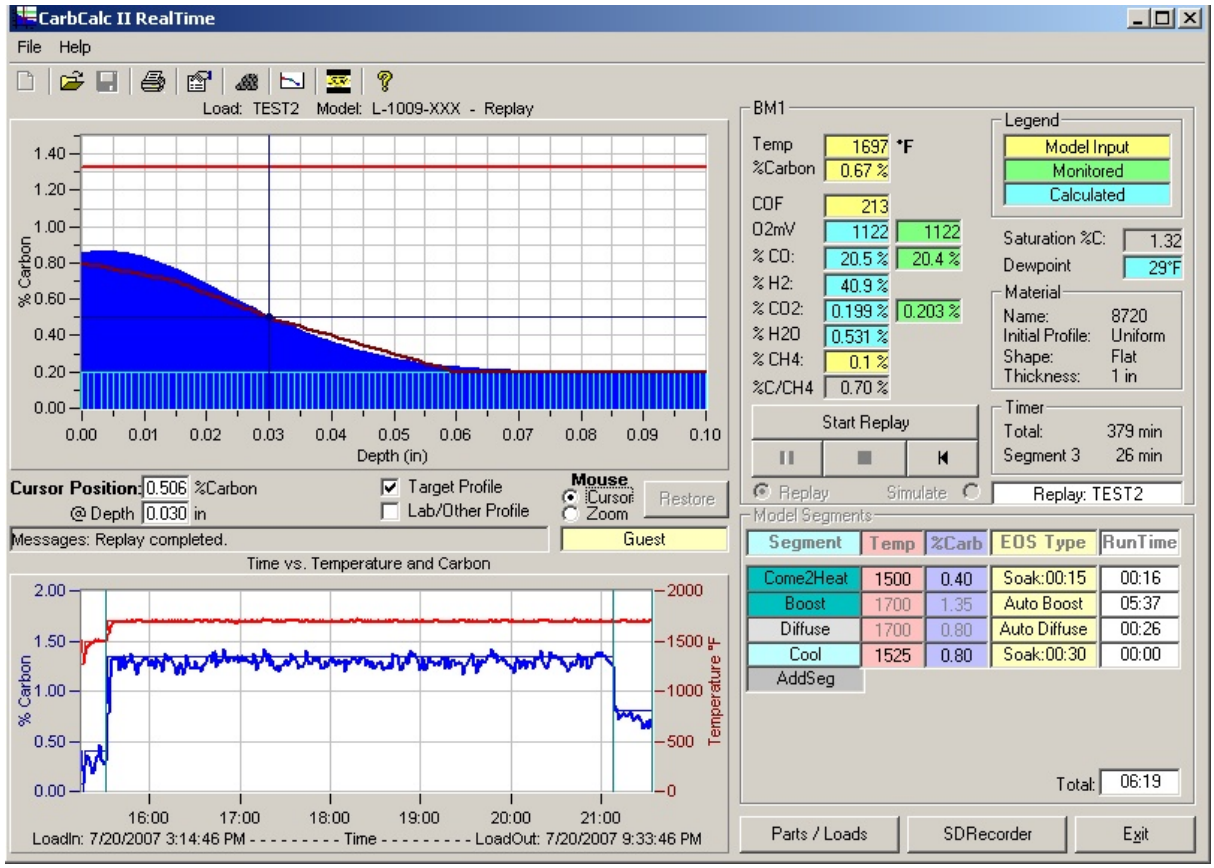
The Replay/Monitor mode may be used to review potential probelms with a load and as an aid in determining what may have gone wrong. The Replay/Monitor mode may be used in conjunction with the RealTime control Mode or with Superdata Datalog and a manually maintained Loads Database, or with BatchMaster Integration using an external Loads database.

Replay Monitor in conjunction with the RealTime Control Mode.

The Replay mode is similar to the RealTime Control Mode. When a Carb Cycle is run in Control Mode, the following data is saved:

- Load Information - in the CCLoads Database
- Model as run - an "as run" model file is saved under the name "L-xxx-model.ccp" (where xxx=load id number and model=model name)
- Logged Process data - SuperData Communications historically logged data.

Using this data, the Cycle can be selected from the CCLoads database and may be replayed.



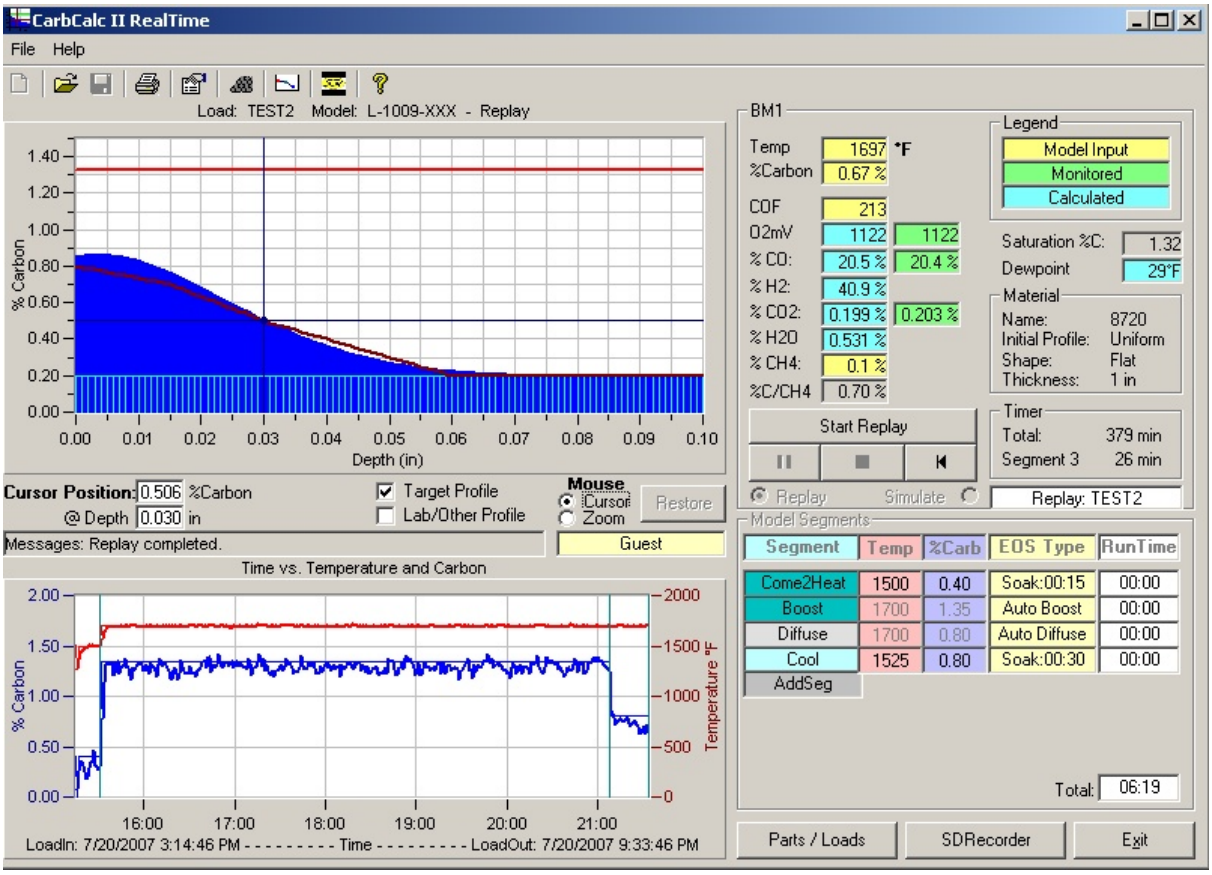
Replay Monitor With SuperData and a Manual Database.

This method is used when the Control Mode is not used. This method requires that the RealTime Data Sources be configured for each furnace supported. This method also requires that a Load be

manually entered using the Load Entry Screen. Load Entry must include a Load Start and Load End time.

- Load Information - manually entered in the CCLoads Database
- Model as run - after the first replay, an "as run" model file is saved under the name "L-xxx-model.ccp" (where xxx=load id number and model=model name)
- Logged Process data - SuperData Communications historically logged data.

Using this data, the Cycle can be selected from the CCLoads database and may be replayed. During replay, the recipe will be displayed, but only the total time (not segment times) will be displayed. This is becaause the actual recipe used in the control instrument is unknown to CarbCalcII; only the logged data and start/ent times are known.



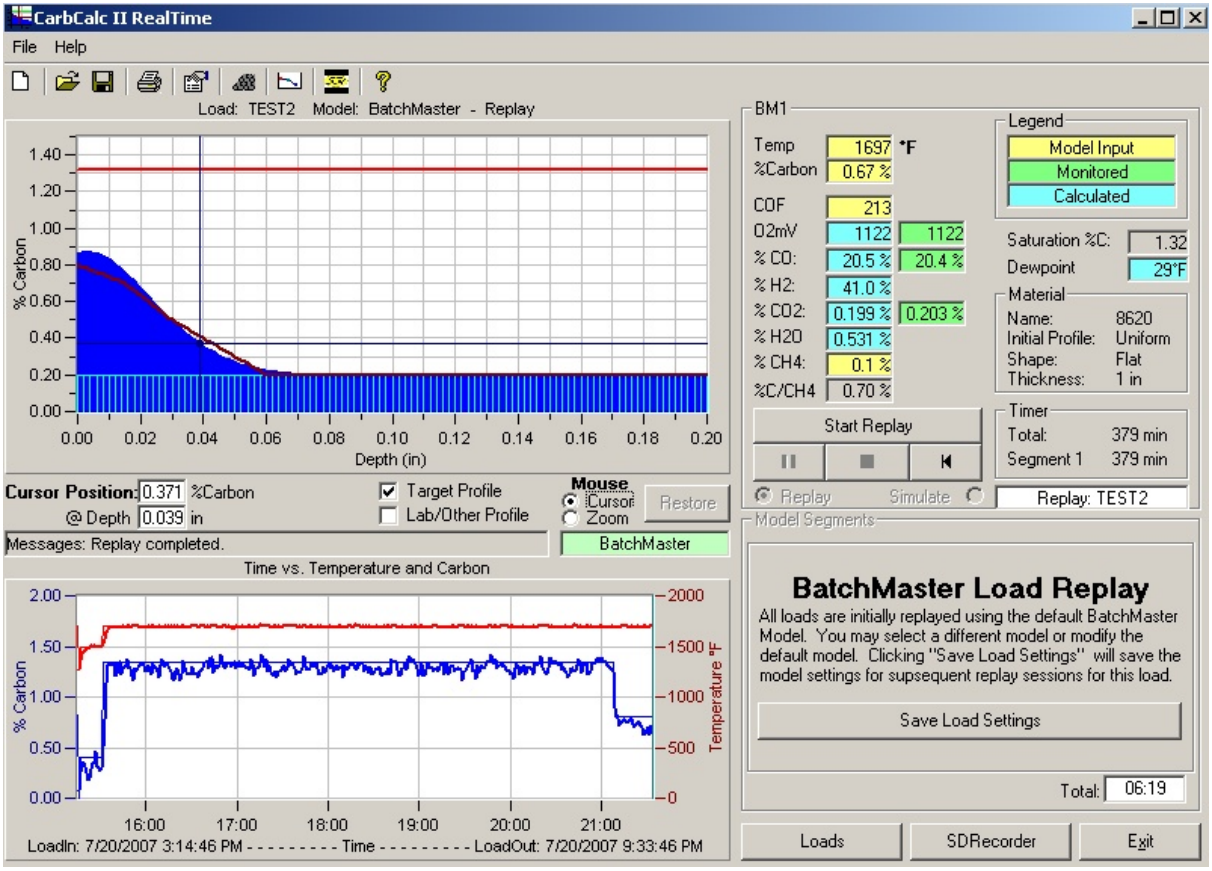
Replay Monitor With BatchMaster Integration and an External Database.

This method is used when an external Load Entry system and Database are used (e.g with BatchMaster or other Load Tracking systems). This method requires that the RealTime Data Sources be configured for each furnace supported. This method also requires that the External Database must be available through an ODBC DSN and that the carbcalc.ini file be configured for Load Database access (see configuration section).

- Load Information - obrtained from an external Load Tracking Database
- Model as run - initial replay uses default settings, saving the load settings saves an "as-run" model file for the load the name "BML-xxx-model.ccp" (where xxx=load id number and model=model name)

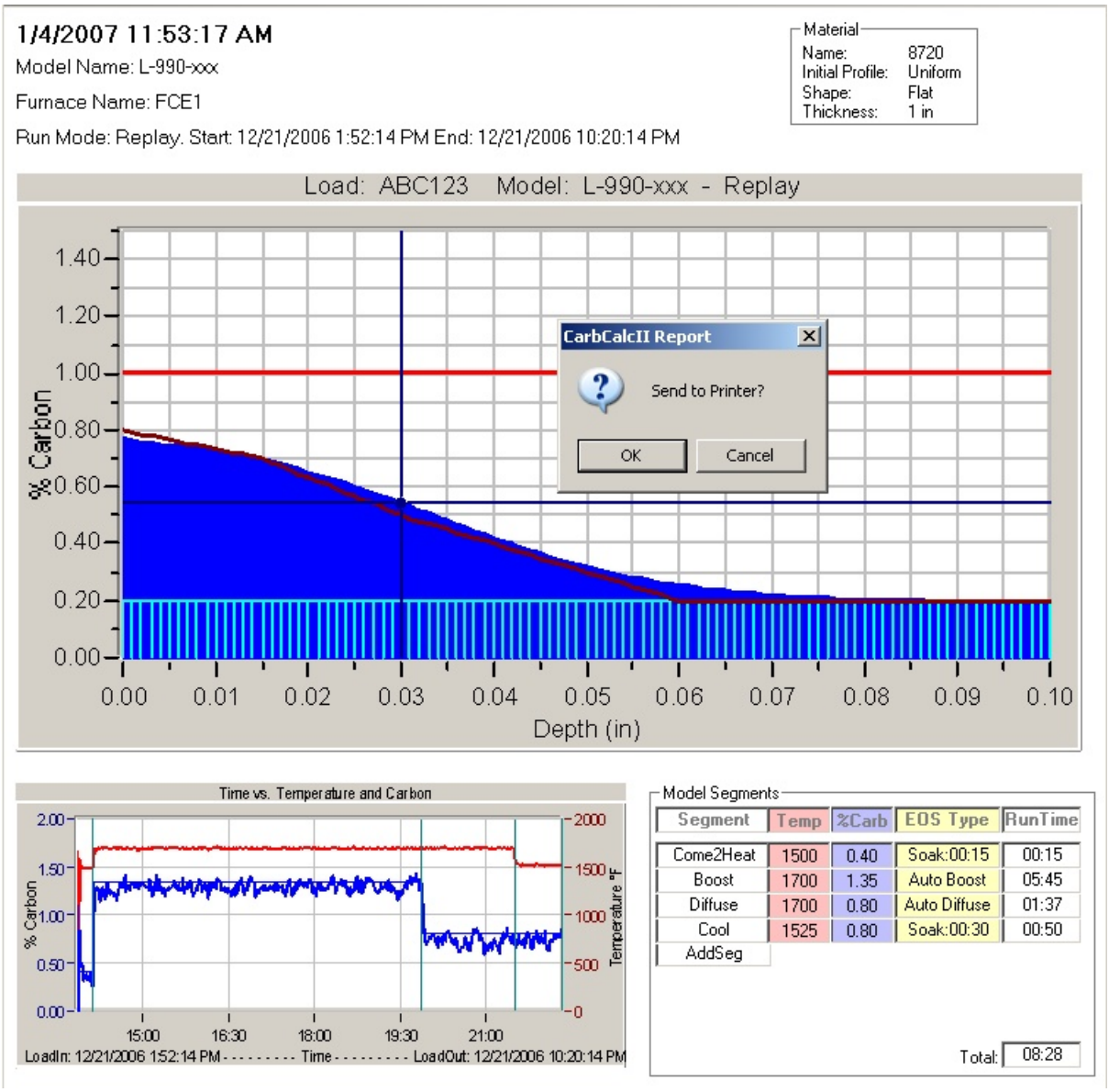
- Logged Process data - SuperData Communications historically logged data.

Using this data, the Cycle can selected from the CCLoads database and may be replayed. During replay, the recipe will not be displayed; only the total time will be displayed. This is becaause the actual recipe used in the control instrument is unknown to CarbCalcII; only the logged data and start/ent times are known.



2.14.2 Report

n the Replay mode, clicking on the print icon will print the following report. The report is a snapshot of the current model status and can be printed at any time during the replay.



3 CarbCalcII Configuration

CarbCalcII is supplied in a fully functional 30 day "Trial" version. To continue using CarbCalcII beyond the 30 day time limit, it must be registered and purchased from Super Systems Inc. Instructions for registering ar contained in the Help/About screen.

CarbCalcII will require some configuration at time of installation.

CarbCalc **Simulation** mode
- No configuration required

CarbCalc **RealTime Control, Replay and Monitoring** modes
- Communications Data Sources must be configured for each furnace. (part of furnace settings)

CarbCalc.ini file : This file will be located in the same directory that contains CarbCalcII.exe (the application directory). This file is used to configure some operating modes, and database locations and external database structure.

The **General** section

- TID = xxxx (where xxxx = a 4 digit TrialID number. Do not remove this number, you may lose your registration.)
- RTMONITOR=x (where x=0 or 1. When set to 1, puts CarbCalc in a Replay/Monitor mode using CCLoads Database)
- BMIntegration=x (where x=0 or 1. When set to 1, puts CarbCalc in a BatchMaster Monitor mode using and external Database)

The **Databases** section

- Material=<name>.mdb (where <name> is the name of the material access database (default **carbcalc.mdb** if not specified)
- CCLoads=<name>.mdb (where <name> is the name of the CarbCalc Load access database (default **CCLoads.mdb** if not specified)

Note: the database names may be filename only (assumes file is in the application directory) or full path and filename.

The **BMLoads** section (only required when BMIntegration=1, ignored otherwise)

- DSN=<name> (where <name> is the ODBC DSN)
- T_LOAD=<name> (where <name> is the table name for the table containing the load information)
- F_ID=<name> (where <name> is the field name for the numeric field containing the load ID)
- F_LNAME=<name> (where <name> is the field name for the character field containing the load Name)
- F_FCE=<name> (where <name> is the field name for the character field containing the Furnace Name)
- F_TIMEIN=<name> (where <name> is the field name for the datetime field containing the Load Start time)
- F_TIMEOUT=<name> (where <name> is the field name for the datetime field containing the Load End time)
- F_LINFO=<name> (where <name> is the field name for a character field containing additional Load Information)
- F_COMMENTS=<name> (where <name> is the field name for a character field containing additional LoadComments)

Sample Carbcalc.ini file

```
[General]
*trial ID
TID= 9638
RTMONITOR=0
BMIntegration=1

[DataBases]
Material=carbcalc.mdb
CCLoads=C:\ssi\data\CCLoads.mdb

[BMLoads]
DSN=BM1
T_LOAD=Loads
```

F_ID=LID
F_LNAME=LoadNo
F_FCE=FceName
F_TIMEIN=StartDT
F_TIMEOUT=EndDT
F_LINFO=Recipe
F_COMMENTS=Part