Release Notes:

Thermo-Calc Software Package and Databases

Version 2025a

Contents

Thermo-Calc Version 2025a Highlights

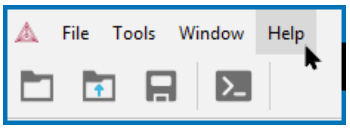
- ★ **Thermo-Calc:** New release highlights welcome window, new help, new licensing system; overlay plots of the same type onto each other, Scheil calculation solute trapping improvements.
- ★ **Noble Metal Alloys Model Library:** A new Model Library used with the TCNOBL3 database and including an *Optical Properties* Property Model. The model simulates the color, reflection, and transmission of light based on modeling the alloy microstructure and the resulting optical properties.
- ★ **Property Models (General):** Improvements to result quantity lists and hardness and strength quantities to generally make it easier to work with results.
- ★ **Additive Manufacturing Module:**
    - Export solidification speed and thermal gradient from a steady state simulation and overlay this to CET Model results. Includes a new 2D plot (*Thermal Gradient vs Solidification Rate*), which is also available in 3D and visualized using new axis variables (thermal gradient and solidification rate).
    - Export results to Exodus file types.
    - New options to work with visualizations tasks.
    - Absorptivity/resistivity uses Lorentz-Drude Model.
    - Steady-state simulations for aluminum alloys are improved.
- ★ **Precipitation Module (TC-PRISMA):** Import 2D PSD and convert to 3D, improved computation time for precipitation calculations using results from the AM Calculator, and a new method is available to split precipitate size distributions to identify statistics of individual populations.
- ★ **Process Metallurgy Module:** The Add-on Module is updated to align with the new elements included with the release of the metal oxides database, TCOX14.
- ★ **TC-Python and TC-Toolbox for MATLAB®:** New Noble Metal Alloys Model Library is available.
- ★ **Databases: New and Updated**
    - New versions of Thermo-Calc thermodynamic databases: steels and Fe-alloys (TCFE14), metal oxides (TCOX14), and molten salts (TCSALT2).
    - New version of the SGTE Solutions database (SSOL9).
    - Other updates to Thermo-Calc thermodynamic and mobility databases are for solders (TCSLD5.1), titanium (TCTI6.1), nickel (MOBNI6.1), and steel (MOBFE8.1).
- ★ **Thermophysical Properties:** The molten salts database (TCSALT2) now includes surface tension, viscosity, and molar volume. The metal oxides database (TCOX14) includes the electrical conductivity/resistivity model for solids in addition to the previously included ionic liquids model. In addition, thermal conductivity/resistivity is added to TCOX14.
- ★ **Elastic Properties**: The steels and Fe-alloys database (TCFE14) includes these and several updates are made to the titanium database (TCTI6.1).

Thermo-Calc

New Release Highlights Popup Window

When you first launch a new version of Thermo-Calc, there is now a summary popup window with all the highlights of the current release. The links take you to the website where you can read about the details in the blog and watch the release video. You can hide the pop up window at any time. If you later want to view the information go to **Help >> New in Thermo-Calc** *<release version>* (e.g. 2025a). Also see the Redesigned Help for other examples of how we are continuously improving your access to information.

The pop is always available from the Help menu. If you choose not to show the message again, or close the initial window, this is where you can open it at any time to view and link to the website content.



New Licensing System

Thermo-Calc Software is migrating to a new License Entitlement System starting with the 2025a release. The new license system greatly simplifies the licensing process and brings many advantages to our customers. Licenses will now be handled through a login, rather than downloading and storing license files on a computer.

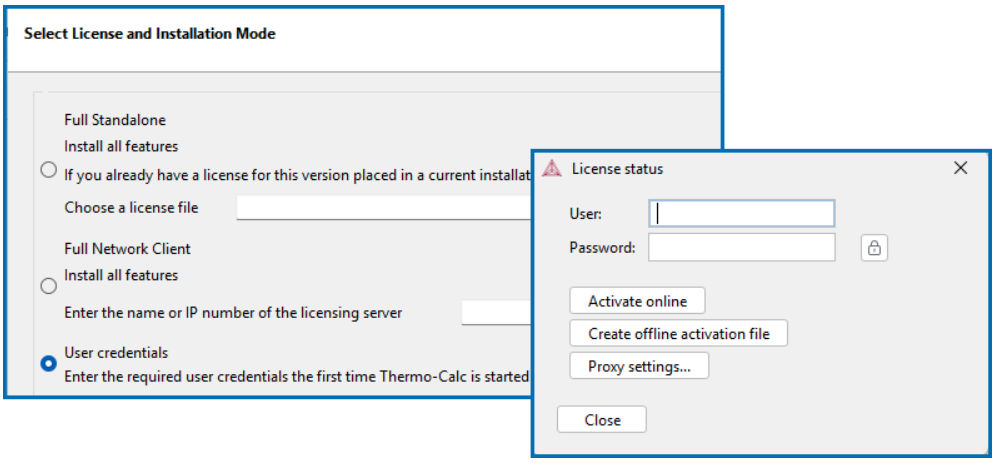
Benefits include:

- Users will no longer need to move license files around or send computer information to us via email (offline activation is still possible)
- Licenses are updated with the click of a button
- Licenses can easily be transferred to a new computer
- Less involvement from IT is required

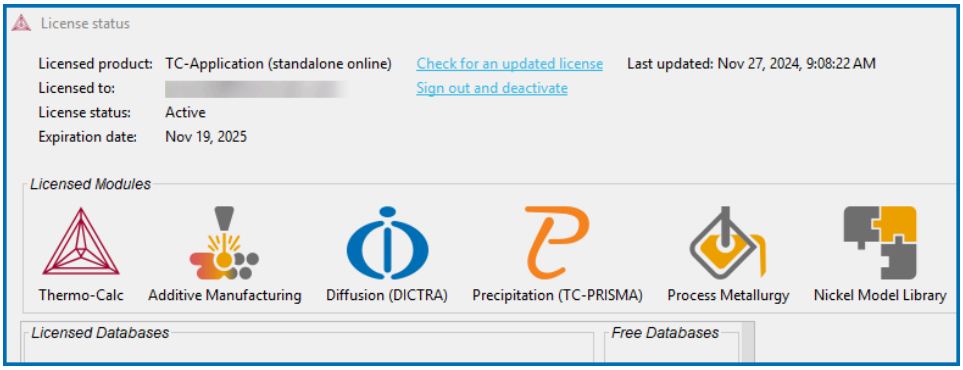
Due to this change, the 2025a release will be distributed gradually to users throughout January and February 2025. The primary contact for each account will receive an email with the new software download link and instructions on how to install the software and activate the license using the new user credentials.

Note: A small number of users will not be transferred to the new license system this release, but we aim to have everyone transitioned by the 2026a release.

The main change that new users will experience during installation is choosing **User credentials** from the Select License and Installation Mode window. Once selected, the installation continues as normal with no other information needed about licenses. Then when the new version of Thermo-Calc is opened, you are prompted with the **License status** window where you enter your **User name** and **Password** to **Activate online**. An option to **Create offline activation file** is also available for users who are in work environments where you perhaps do not have direct access to the Internet. Details about activating your license in both scenarios can be found in the help and Thermo-Calc Installation Guide.



*The installation **Select License and Installation Mode** window where you first select the **User credentials** option. The license is activated after Thermo-Calc is first opened and once you enter your credentials (received in an email) in the **License status** window and click **Activate online** or **Create offline activation file**. You can also add **Proxy settings** here.*



*An example of the License status window in Thermo-Calc once an online license is activated. As before, you can view this window at any time from the **Help > Show License Window** menu in both Graphical and Console Mode.*

There is a new Installation video available and all the guides are updated. There are additional steps to consider if you also have a license for TC-Python or TC-Toolbox for MATLAB® (also see the new examples TC-Python and TC-Toolbox (License Related)). Details are included in the Installation Guide and links to the new video and more can be found in the Release Overview Blog.

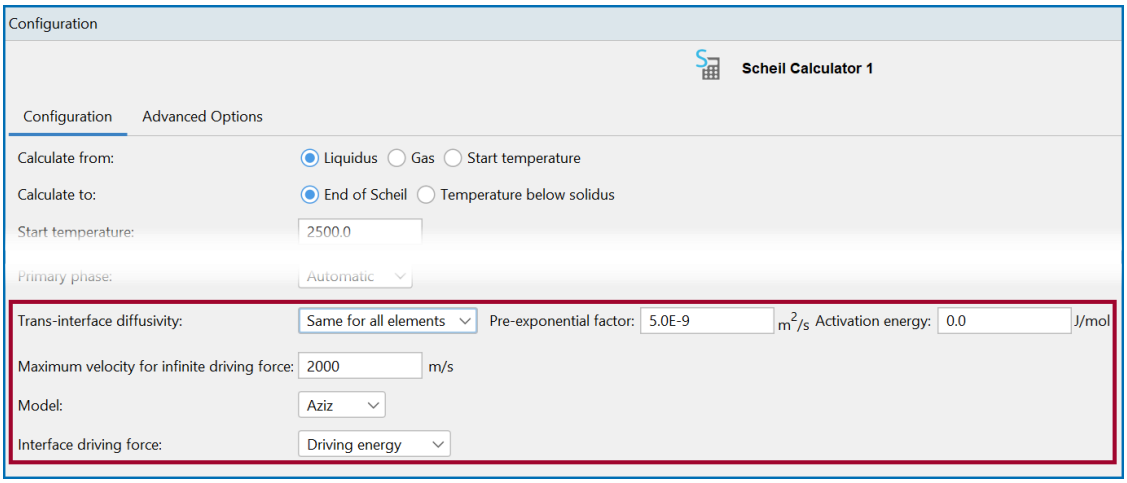
Scheil Improvements Including Updates to Solute Trapping Model

Solute Trapping Improvements

A new and improved Solute Trapping model for Scheil is available. It is more robust especially at high solidification velocity. Separate **Aziz** and **Hillert** models are available to choose from, and you can now choose how to define **Trans-interface diffusivity** and **Driving energy**.

The new settings are available on the **Scheil Calculator** in Graphical Mode and new parameters are also available with the SDKs (TC-Python and TC-Toolbox for MATLAB). No new prompts are included with Console Mode but the defaults for the solute trapping model are used for the solute trapping calculations.

Examples **T_13_Scheil_with_Solute_Trapping** (Graphical Mode) and **tcex57** (Console Mode) are updated to automatically use the new setting defaults.



There are new settings available on the Scheil Calculator to work with solute trapping and a new theory section in the help explaining the background of the model.

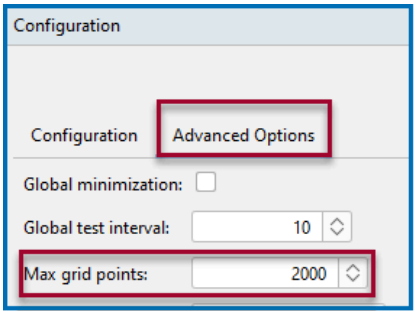
Solute Trapping Improvements in AM Module

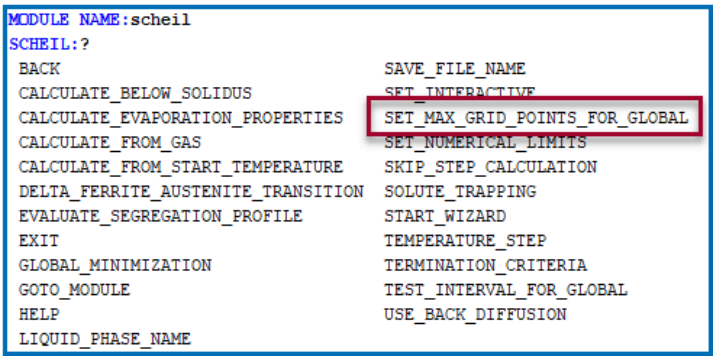
These improvements are also relevant to working with the Additive Manufacturing (AM Module), where a new example, **AM_11** uses it in combination with the aluminum database in a batch calculation. See Al Alloys: Improved Stability and Predictability for details.

Change Grid Size for Global Minimization

It is now possible to change the grid size for global minimization in Scheil calculations.

- In Graphical Mode there is a new setting called **Max grid points** on the **Advanced Options** tab for the Scheil Calculator.
- In Console Mode there is a new command called `SET_MAX_GRID_POINTS_FOR_GLOBAL` in the Scheil module.
- For the APIs (TC-Python and TC-Toolbox for MATLAB) use the command `set_global_minimization_max_grid_points`. This command existed even previously but did not affect the calculation.





Improvements and Bug Fixes (Thermo-Calc)

Graphical Mode

- Fixed a general bug where the labels (for decimal digits and number format) were missing from the **Add label** window.
- Table Renderer after a Scheil Calculator: The data is now displayed in the table when using “All phases” and other all markers where applicable.
- Fixed an issue with One Axis calculations that sometimes got unexpected spikes but the corresponding Console Mode step calculation did not.

Graphical Mode, Console Mode, and APIs (when Applicable)

- Fixed a bug where the automatic scaling did not scale as expected when a plotted axis had a small/zero range.
- Fixed a bug where repeated selection of a new system, for example in the same TC-Python session or in the same Console Mode window, could sometimes cause equilibrium calculations to not reach global minimum.
- Fixed a bug that prevented plotting quantities corresponding to phase composition sets that were created during an equilibrium one-axis (property diagram) calculation.
- Fixed a bug where on certain Linux desktops the help and other web links did not work. A solution was also implemented to open the web browser on KDE desktops.

Console Mode

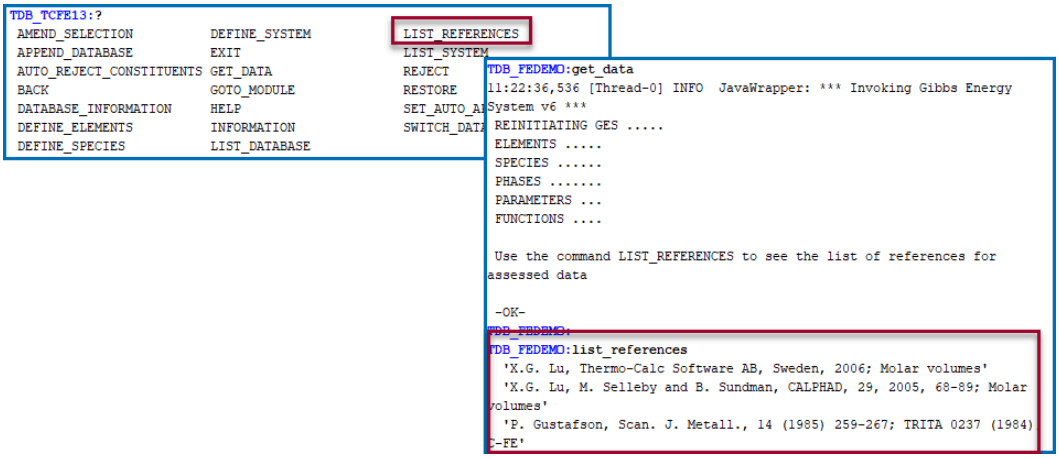
Calculation Related

- In the POLY module and when changing the status of all phases to “entered” with the command `CHANGE_STATUS`, it now only sets all those phases that are able to form to “entered” status. That is, any phase that was automatically suspended, because they can not form due to some of the components being suspended by the user, now correctly remains suspended when using the command to set all phases to “entered”.

Database Related

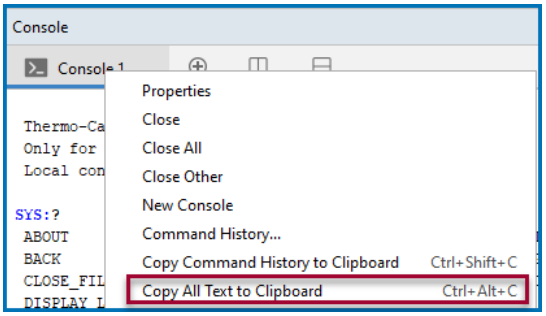
- It is no longer necessary to add a dummy reference first in a TDB file’s `ADD_REFERENCES` sections.

- A new command, `LIST_REFERENCES`, is available in the TDB module (Database Retrieval module). It is used to get a list of relevant literature references for the assessed data for the present system. This feature to list the references was previously included when you used the `GET_DATA` command. Now you can use this command after `GET_DATA` to list the references separately. You can also, for example, use the new shortcut (Ctrl+Alt+C) to copy the list of references to the clipboard.



General

- Fixed an issue that made it possible to display some properties of the disordered part of an order/disorder phase combination.
- A new keyboard shortcut is available to copy all text in a Console window so that it can be pasted into a relevant location for use. Right-click any tab and select **Copy All Text to Clipboard** from the menu. The shortcut for this command is to press <Ctrl+Alt+C> (Windows and Linux) or ⌥⌘C (macOS) on the keyboard.

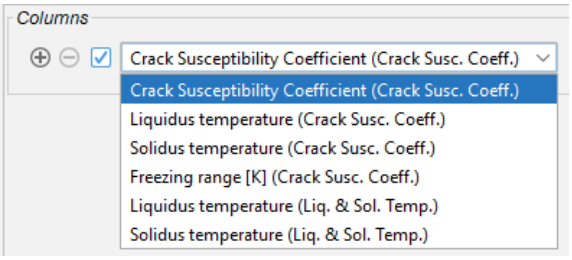


- For macOS, the keyboard shortcut listed on the menu for *Copy Command History to Keyboard* is corrected. It is now *Shift + Command + C*.
- Console formatting Error. Numbers below 1E-99 in magnitude were written without the **E,** e.g. 1.2-100. This bug was fixed in the compiler and now those values are set to 0.

General Property Models (Thermo-Calc)

Changes to Result Quantities Lists

Previously, when calculating with two or more Property Models that share names for one or more result quantities, for example *Liquidus temperature* in the *Crack Susceptibility Coefficient Model* and the *Liquidus and Solidus Temperature Model*, the results from the last executed model would overwrite the results from the former calculation. Furthermore, in the Table or Plot Renderers there would be no way to know from which model the quantity was calculated, since they were named the same. This is now changed, where each result quantity includes the abbreviated name of the model, in parentheses, as in the screenshot. The short name is added to all Property Model quantities, except for the *Equilibrium* model.



TC-Python important note: When using TC-Python it is still possible to use the unsuffixed quantity names when using the `get_value_of()` method, however, only suffixed quantities are listed when asking for available quantities.

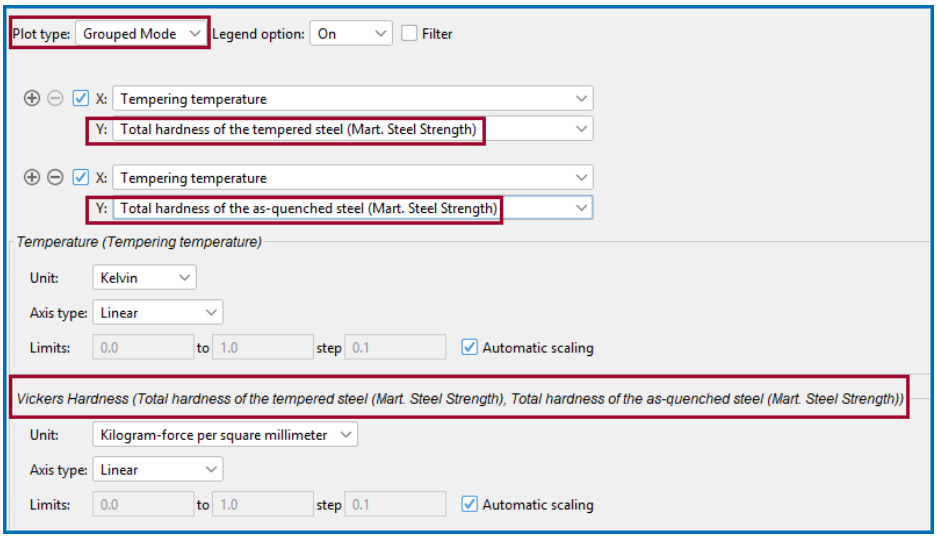
Hardness and Strength Quantity Changes and Improvements

Hardness and Strength Quantities Plotted on Separate Axes

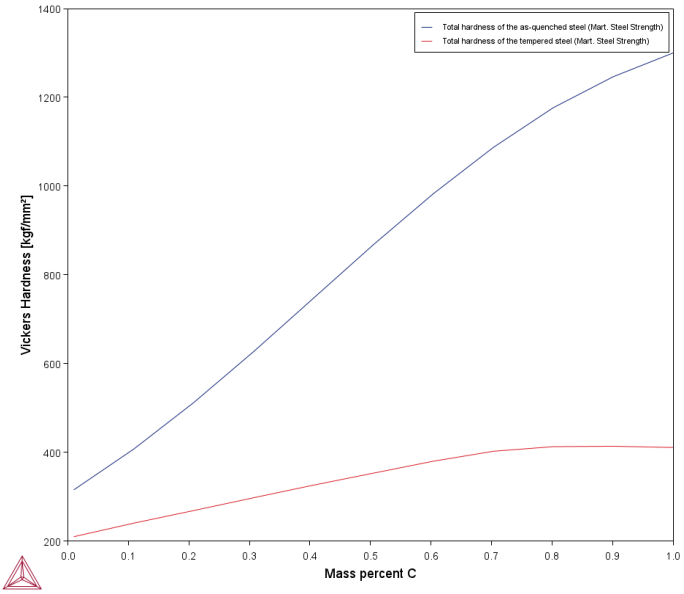
The *hardness* quantities used with some Property Models are now generally referred to as *Vickers hardness*. This change is seen on the **Configuration** window (when in Grouped Mode) and when two or more hardness quantities are plotted on the **Visualizations** window. Hardness continues to be available for use in parallel with the already existing *Strength* quantities; the change as of this release is that these quantities are plotted separately on the respective axes and no longer on a common axis.

All strength Property Models use the new Vickers hardness quantity. This is applicable to the following models:

- General Models: **Yield Strength**
- Steel Model Library: **Martensitic Steel Strength**
- Titanium Model Library: **Alloy Strength - Ti**

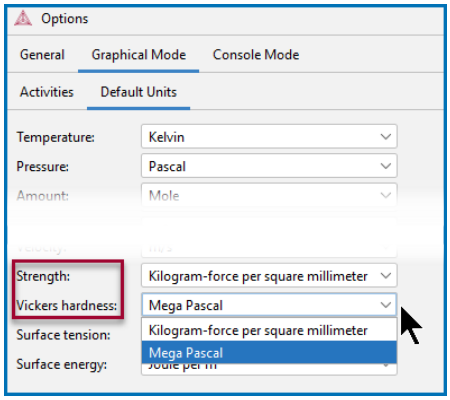


An example of choosing to plot two hardness quantities, which are then grouped together as Vickers Hardness on the Configuration window (when in Grouped Mode).



In the Visualizations window, and when plotting two or more hardness quantities, the respective axis (in this example the Y-axis) refers to Vickers hardness and the key lists the two individual hardness type quantities selected on the Configuration window. Another change (not shown here) is that hardness and strength are now plotted on separate axes when these quantities are selected on the Plot Renderer Configuration window.

Hardness Unit Renamed and Available to Set Global Defaults



In addition, the hardness unit *HV* is renamed to kgf/mm^2 (Kilogram-force per square millimeter) to better reflect the actual physical meaning of the hardness quantity. This unit is usable for both Vickers hardness and Strength quantities. These changes have no effect on the calculated values, it is only a name change.

You can now also set the Graphical Mode Global **Default Units** for **Vickers hardness** and **Strength** on the *Tools >> Options* menu.

Improvements and Bug Fixes (By Property Model)

Equilibrium

- For the Equilibrium Property Model, fixed an issue in 2024b prohibiting adding new columns to Table Renderers after clicking perform.

Scheil

- The result quantities in the **Scheil** Property Model have had their former suffix removed (i.e., Liquidus temperature**, Scheil**) in favour of the general solution described above in Changes to Result Quantities; it is now displayed as **Liquidus temperature (Scheil)**.
- A new result quantity, **Volumetric shrinkage (vol-%)** is added to the **Scheil** Property Model. This is found on the Plot or Table Renderer Configuration window.
- Fixed a bug where it was not possible to open a file with results when the Scheil Calculator did not have a result, and any other calculator had a result.

Coarsening

- Dynamic arguments, e.g., adding more than one phase in the **Coarsening** Property Model (or any other model that uses this functionality) by using the add button, broke between versions 2024a and 2024b. This is now fixed.

Interfacial Energy

- The detection of matrix and precipitate phases is improved and is expected to work for all cases. A global minimization step is also added as a last fall-back if global test and local only both fail. These two fixes together provide a much more reliable model for interfacial energy calculations.

Equilibrium with Freeze-in Temperature

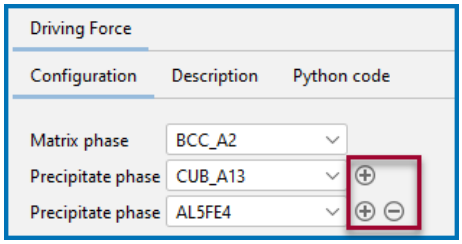
- **Equilibrium with Freeze-in Temperature** Property Model. The heat capacity was always calculated using freeze-in assumptions, also above the freeze-in temperature. This was not correct in cases where the option to calculate equilibrium above freeze-in temperature was used. This is now corrected.

Liquidus and Solidus Temperature

- The **Liquidus and Solidus Temperature** Property Model previously could not deal with liquid miscibility gaps. This has now been amended and the model can deal with any number of miscibility gaps for the selected liquid phase.
- It is now possible to set the solid fraction for the calculation of liquidus. Useful if there are small fractions of solids melting at a very high temperature.

Driving Force Model

- The **Driving Force** Property Model can now use dynamic arguments, i.e., adding more than one **Precipitate phase** to the calculation. This is also compatible with plotting using **Parallel coordinate** plots.



Bug Fixes and Improvements (General Property Models)

- On computers with an underscore (_) in its name, Property Models failed in Parallel calculation mode. This is fixed.
- Sometimes the bundled Python used for Property Models used packages in a Python installation that a user had installed. This bug is fixed that previously caused Property Models in Thermo-Calc to not work.
- **Event Log output improvements**: The functionality of the Property Model framework is expanded to allow for the *Warning* log type. Warnings are now marked as such and shown in yellow in the Event Log, just as for the other modules in the software. For example,

```
10:46:57,180 ERROR PropertyModelCalculator: tc-calculation-worker-1 - Nuh-uh!
10:46:57,187 INFO  PropertyModelCalculator: tc-calculation-worker-1 - Done
10:46:57,192 WARN  PropertyModelCalculator: tc-calculation-worker-1 - Yikes!
```

- Overlaying parallel plots from two different Property Model Calculators has been implemented.
- Temperature fields belonging to a property model would not have their input values converted to the correct unit if used as an axis in a one axis or multi-axis grid calculation. This has now been fixed and all temperatures are correctly converted to the unit chosen by the user.

Material Specific Property Model Libraries

New Noble Metal Alloys Model Library

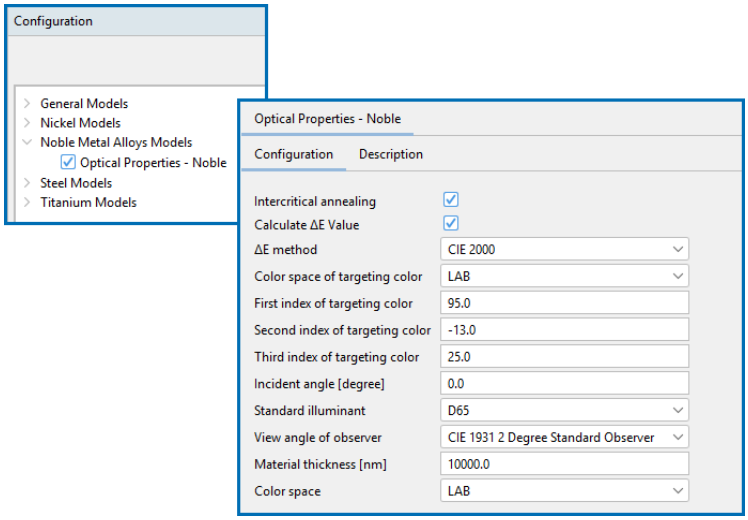
Visit the new Noble Metal Alloys page on the website.

Noble metal alloys are frequently developed for the purpose of achieving an attractive color. In particular, the system Au-Ag-Pt-Cu-Al is of interest. Al in particular has recently been of interest due to intermetallic phases with Au that produce a purple-tinted color. A new Property Model that predicts the apparent color of noble metal alloys is available - **Optical Properties - Noble** and it calculates dielectric function and/or the refractive properties of the phases as a function of composition and then appropriately averages these over the entire microstructure.

NOTE: To run calculations with the Noble Metal Alloys Models requires a valid maintenance license plus a license for the TCNOBL (version 3 and newer) database. Customers with an existing license for the TCNOBL3 database receive this new Property Model Library for free.

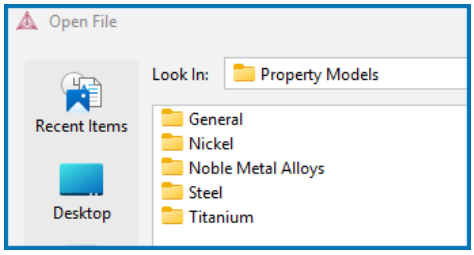
New Optical Properties - Noble Model and Example

Use the **Optical Properties - Noble** Model to simulate the color, reflection, and transmission of light, based on modeling the alloy microstructure and the resulting optical properties. The model is available from the new **Noble Metal Alloys Models** folder on the **Configuration** window for the **Property Model Calculator**.

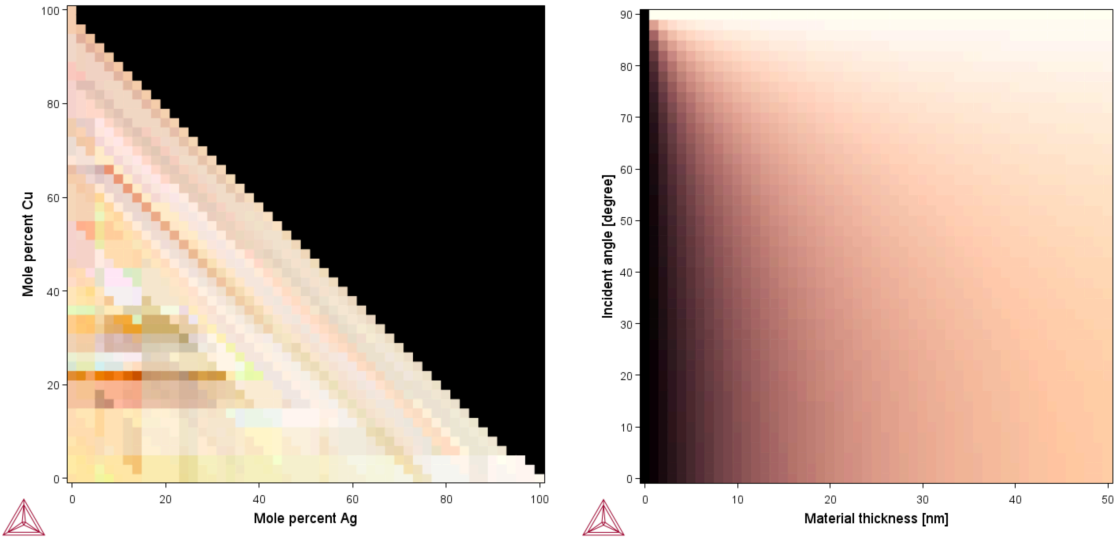


Several new settings are available and detailed information about these are included in the **Description** tab in Thermo-Calc and in the documentation.

A new example demonstrates three use cases for simulating color in the Ag-Au-Cu alloy system (1) screening the color of the alloy system (2) designing a green-gold alloy by adjusting Ag content, and (3) visualizing the impact of alloy thickness and light incident angle on color. More detail is included in the documentation.



The example **PM_Noble_01_Color_Prediction.tcu** is available from the **Property Models > Noble Metal Alloys** folder. Below are examples of the plots from this example.



Left: Color prediction for Ag-Au-Cu alloy. Right: Color of pure gold varies with different light incident angles and material thicknesses.

Steel Model Library

Martensitic Steel Strength

- Previously, when using the Martensitic Steel Strength model, BCC miscibility gaps would cause unrealistic behavior in the calculated strength and hardness after tempering, e.g., for high-Cr steels, especially at low tempering temperatures. This is fixed.
- The tempering model is re-parameterized to account for the new TCFE14 database. Furthermore, in 2024b, the parameterization would give much too high values for alloys containing Cu. This is also fixed with the re-parameterization.
- Previously, setting the tempering time to 0 (zero) would disable the tempering time correction. As this value coincides with the as-quenched condition, it is now changed to occur if a negative value is given.

Titanium Model Library

Martensite Temperatures - Ti

- Previously, when using the Annealing checkbox, the content of Ti would always be taken as the bulk content of the alloy, which caused apparent slopes in regions of composition where the composition of the BCC austenite phase was constant. The correct treatment is to take the Ti content from the BCC austenite phase, which is now corrected. This does not affect calculations where annealing is not selected.
- Previously, the model would give the stable phases calculated for an equilibrium at the selected temperature, even if the annealing check box was not selected. This is now corrected so that the stable phases are only shown if annealing is selected.

Additive Manufacturing Module

Visit the Additive Manufacturing Module on the website to access resources such as a Getting Started guide, webinar recordings, and much more.

Also see:

- AM Module Connected to Precipitation Calculator Improvements
- AM Module in TC-Python

Absorptivity/Resistivity Model Implemented

The absorptivity of a flat metal surface is a function of the alloy composition, temperature, the wavelength of the heat source, and the angle of incidence.

The absorptivity of a metallic powder is more complex. Most metallic powders are oxidized at the surface where a thin layer of oxide often increases absorptivity. Multiple reflections of the laser rays also increases the effective absorptivity, e.g. at surface roughness or between the particles within the powder layer. The additional complications of the metallic powder are neglected in this model, which focuses on an ideal flat surface of the liquid phase after the powder has melted. This simplification can be justified at steady-state conditions when a melt pool is established and most laser rays hit the liquid surface in the melt pool.

See the help for a new theory section about the absorptivity model. Also examples AM_06a and AM_06b are updated to align with the new functionality and features.

The absorptivity model takes the wavelength of the heat source as input together with a prefactor that can scale the calculated absorptivity up or down. The scaling can be required to calibrate the simulations against experiments. This model is derived from the Lorentz-Drude model, which relates the electric permittivity with the electric resistivity. The Lorentz-Drude model is used as a first approximation of the dielectric constants of an alloy. The model is then further calibrated against the available experimental information of dielectric constants, refraction index, and absorptivity of liquid metal.

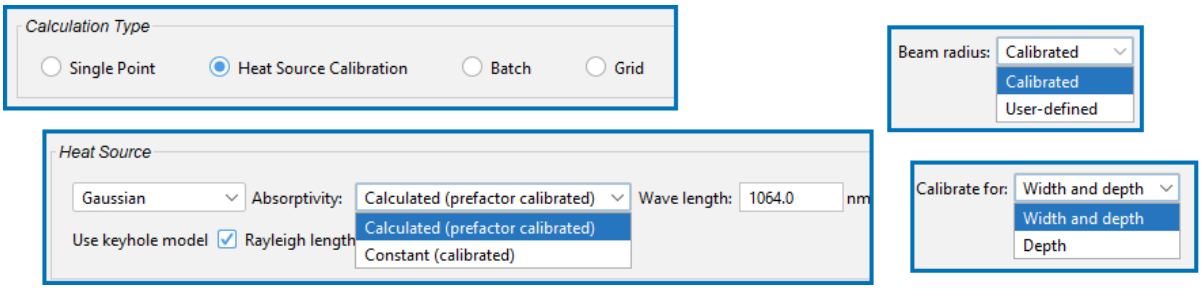
New Gaussian Heat Source Calibration Settings

For the **Gaussian** *Heat Source* Model and **Heat Source Calibration** *Calculation Type*, there are new settings available where you can use the temperature and angle dependent calculated absorptivity and calibrate the scaling prefactor to match the given experimental data. You can calculate the **Absorptivity** separately for each row in the **Experiment Data** table and choose to use:

- **Calculated (prefactor calibrated)** to use the calculated absorptivity and calibrate the prefactor. You also enter a **Wavelength** of the heat source (or use the default).
- **Constant (calibrated)** to calibrate the absolute value of absorptivity. This uses a constant value of absorptivity i.e. it is not dependent on temperature or incidence angle. Then you can calibrate that value to match the given experimental data.

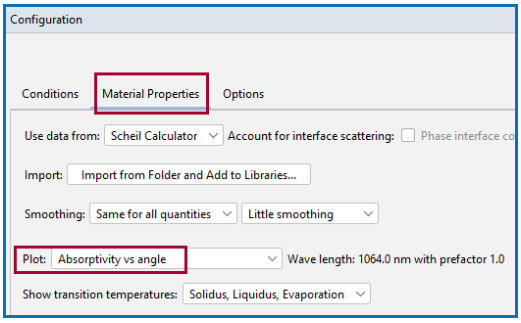
For both options you can also either calibrate the **Beam radius** along with the absorptivity or the prefactor (choose **Calibrated**), or use a fixed value and calibrate only the absorptivity (choose **User-defined**).

Another setting available is to calibrate for both the **Width and depth** of the melt pool from the experimental data or use only the **Depth** of the melt pool for the calibration. If you choose **Width and depth**, the *Experiment Data* values in the table require both the width and depth of the melt pool whereas if you only calibrate the depth then the data file needs to only include the information for the depth of the melt pool.



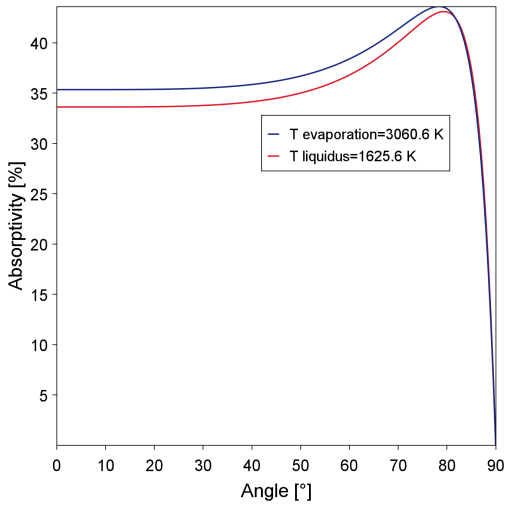
Materials Properties Tab Visualizations

The resulting absorptivity (given the wavelength and prefactor) can be visualized from the **Material Properties** tab on the AM Calculator **Configuration** window.



From the **Plot** list, select:

- **Absorptivity** to visualize the temperature dependent absorptivity for the liquid phase of the selected material.
- **Absorptivity vs angle** to visualize the angle dependent absorptivity at liquidus and the evaporation temperature.
- **Electric resistivity** to visualize it as a function of temperature. The electric resistivity is not directly used in the AM simulations, only indirectly through the absorptivity model that uses the electric resistivity when modeling the composition, temperature, and angle dependent absorptivity.



The calculated absorptivity as a function of angle of incidence for the alloy IN738LC. The red curve shows the absorptivity at the liquidus temperature and the blue curve the corresponding absorptivity at the evaporation temperature.

Overlay Similar 2D Plots from Any Calculator

In general, it is now possible to overlay plots from any Calculator with plots from any other Calculator, as shown in the next section.

2D plots are overlaid pair-wise which means if you add two or more AM Calculators as a predecessor in one Plot Renderer, similar 2D plots (such as Probe with Probe and Plot Over Line with Plot Over Line, etc.) are grouped and overlaid in one tab on the Visualizations window.

The most important use case is that you can overlay Probe plots from different Transient and Transient with heat source from Steady-state Calculators and Plot Over Line plots from all AM Calculators. Similarly, you can also overlay Meltpool vs energy density and Parity plot from different Batch, Grid, and Heat Source Calibration calculators.

Thermal Gradient and Solidification Rate Added and Can Be Overlayed Over CET Plots

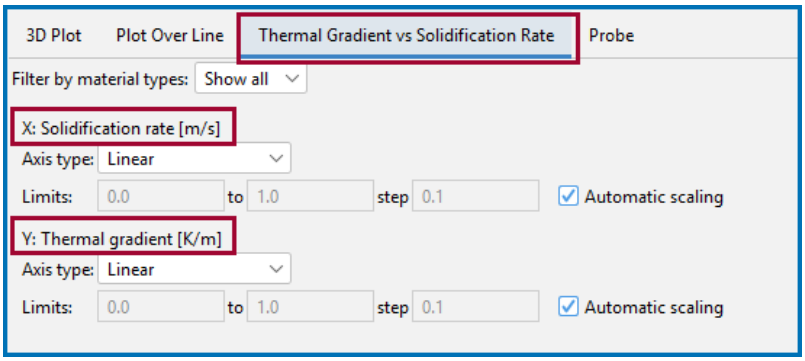
New Plot Options for Thermal Gradient vs Solidification Rate

A new 2D plot is available for the AM Module. The same variables are available to be plotted in 3D but it is handled differently.

There are two ways to plot *thermal gradient* vs. *solidification velocity* for both steady-state and transient simulations. In 2D as a scatterplot. In 3D you can plot this using two new axis variables - **thermal gradient** and **solidification velocity**. These plots are handled differently.

2D Plots

The 2D plot is available on the **Plot Renderer Configuration** and **Visualizations** windows as a tab of the same name, **Thermal Gradient vs Solidification Rate.** It plots **Thermal gradient [K/m**] on the Y-axis and **Solidification velocity [m/s]** on the X-axis. On the **Configuration** window, you can adjust the available settings and watch the dynamic changes to the plot on the **Visualizations** window.

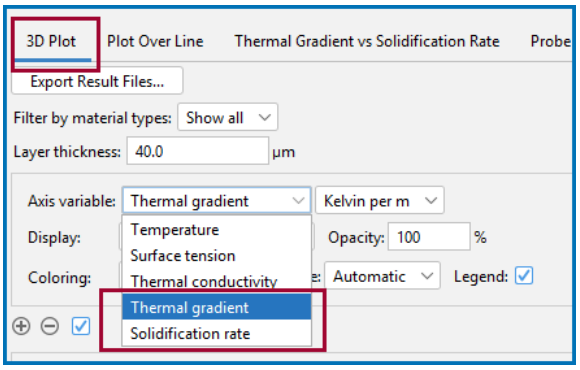


3D Plot

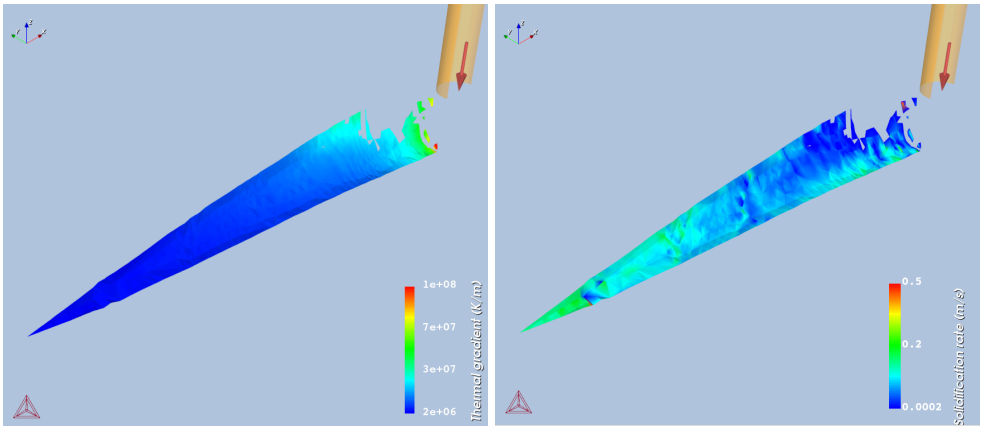
The 3D version of this plot is available via the **3D Plot** tab on the **Plot Renderer Configuration** window.

After connecting two AM Calculators to one Plot Renderer, you can then choose **Thermal gradient** and **Solidification rate** as axis variables then continue to define your 3D Plot as you want with the other settings.

It is important that you click **Perform for this to update the plots in the **Visualizations** window.



On the **Visualizations** window, the plot is then available on two (or more) **3D Plot** tabs.



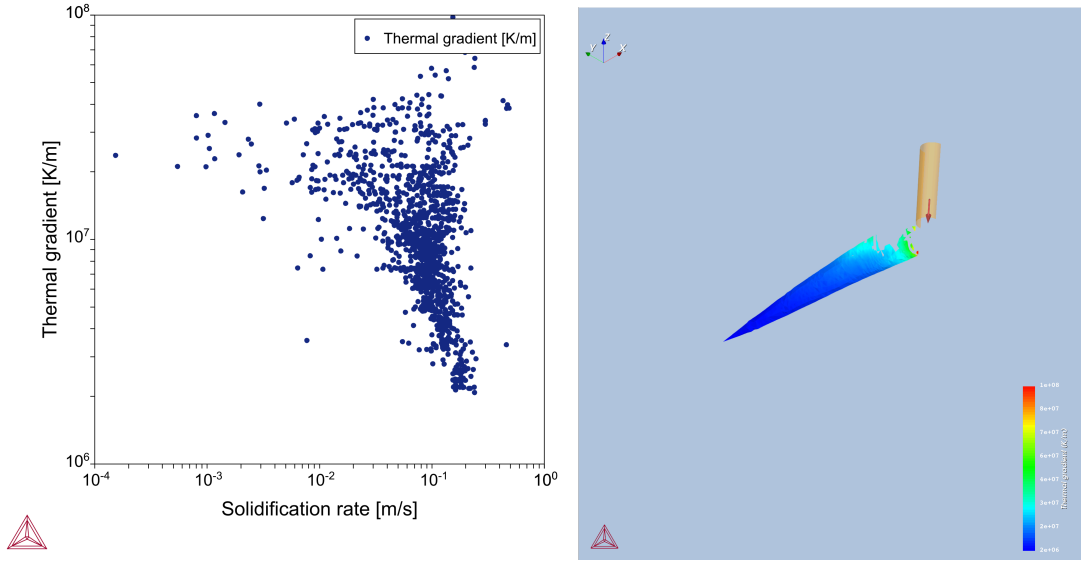
From example AM_10, this is how it is visualized. Left is thermal gradient, right is solidification rate.

Examples of the AM Calculator and CET Property Model

Two new installed examples are available.

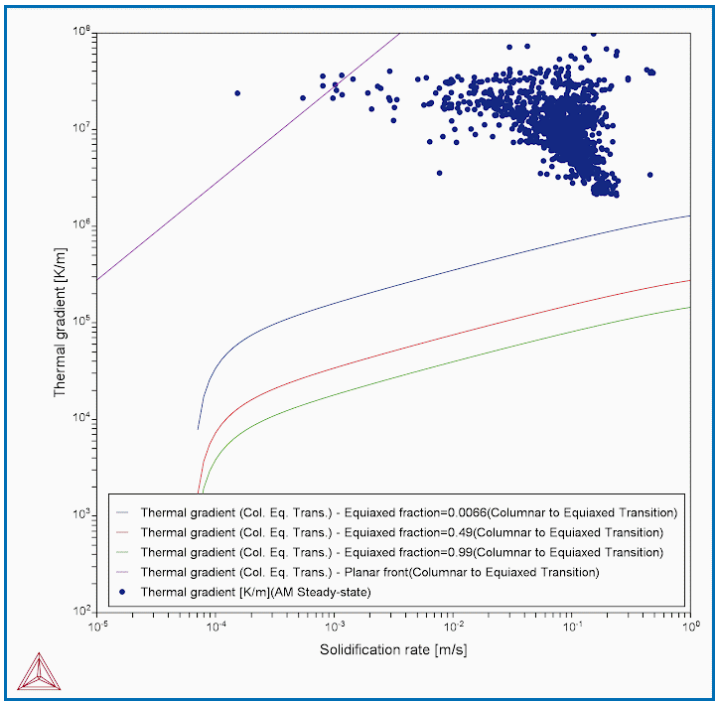
- *Graphical Mode*: **AM_10_Columnar_to_Equiaxed_Transition_IN718.tcu**
  - Requires licenses for AM Module and TCNI12 and MOBNI6 databases.
- *TC-Python*: **pyex_AM_08_CET_IN718.py**
  - Requires a license for TC-Python.

The AM Module adds the ability to plot thermal gradients and solidification rates for both steady-state and transient simulations. These can be plotted in 2D as a scatter plot or in 3D.



Left shows 2D plot of thermal gradient vs solidification rate for IN718. Right shows a 3D plot of thermal gradient for the same alloy.

The 2D plot can then be overlaid over CET (Columnar to Equiaxed Transition) plots from the General Model Library, allowing users to evaluate whether the solidified microstructure corresponds to columnar or equiaxed, given the solidification conditions in the melt pool.



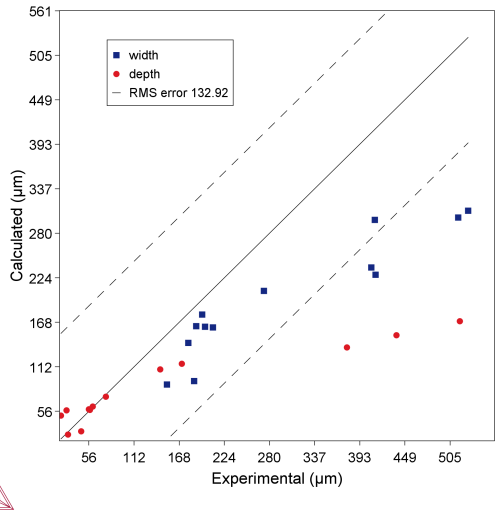
The plot shows thermal gradient vs solidification for IN718. The lines show the equiaxed fraction from the CET Model and the points show the solidification conditions at the melt pool calculated with the AM Module. As can be seen, nearly all the points (those below the purple line) exist in a fully columnar region.

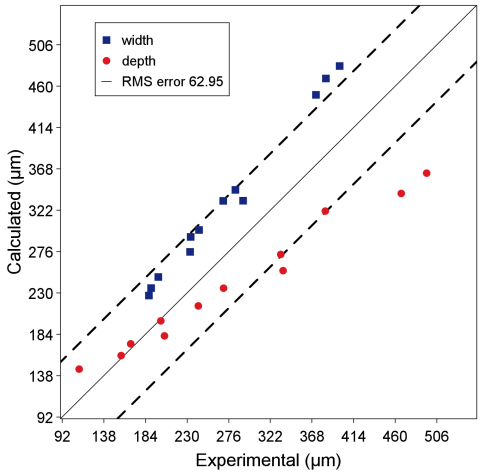
Improved Stability and Predictability for Al Alloys

Simulations for aluminum alloys are improved in the Additive Manufacturing Module. Aluminum alloys have several challenges that make accurate simulations especially challenging, particularly in these areas:

- Thermal conductivity was overestimated for alloys with large amount of secondary phases due to the effect of microstructure
- Al-alloys have low viscosity, so when they have high flow rates you get turbulent flows
- Absorptivity is not constant for Al

Due to these challenges, AM simulations for aluminum alloys often failed or provided inaccurate results in previous versions of the software. Therefore, work has been done to address these issues and make Al simulations more stable and accurate, namely three additions in the software.

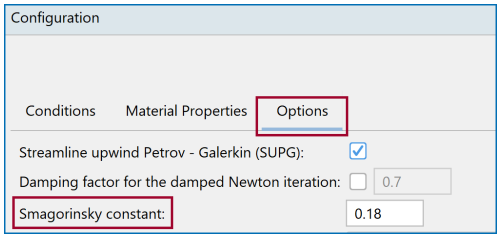




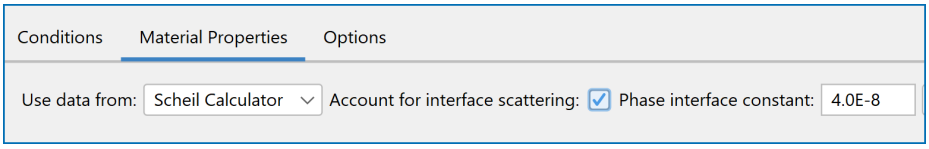
Left: Al10SiMg - abs. 20% simulated in 2024b showing disagreement between experimental and simulated results; right: from Example AM_11_Batch_Al10SiMg in 2025a showing good agreement after the improvements

First, the absorptivity modeling that was discussed in Absorptivity/Resistivity Model Implemented.

Second, in the AM Calculator Options tab, the **Smagorinsky constant** can now be set by the user, whereas it was hardcoded before. This allows the simulation to better account for turbulent flows.



And finally, a new setting has been added to the Scheil calculator that allows for interface scattering to be applied after Scheil. This improves the predictability of as-cast and as-printed conductivity for all alloys with large amounts of secondary phases, not just aluminum alloys. This new setting has been added to the main Scheil calculator as well, not just the one related to the AM Module.



New Example

A new example is available from the **Graphical Mode > Additive Manufacturing** folder to demonstrate these improvements: **AM_11_Batch_Al10SiMg.tcu**.

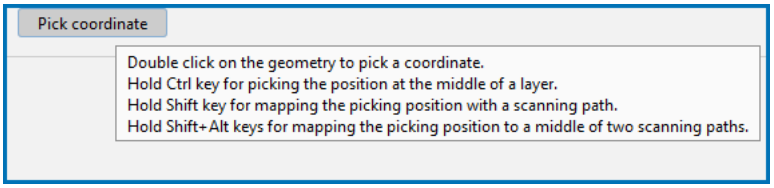
General AM Module Changes and Improvements

New Options to Work with Visualizations Tasks

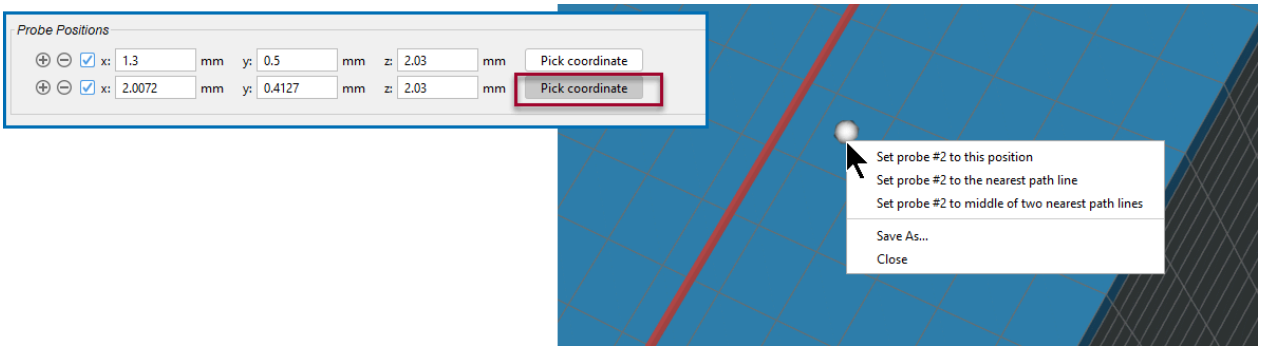
When working with the AM Calculator and its associated Plot Renderer, there are new options available to work with various tasks in the Visualizations window. The options related to saving an image of the geometry or a 3D plot, setting probe positions, or deleting markers, are available either as tooltips or from menus when you right-click in the Visualizations window. More details are available in the help content.

Setting the Probe Position and Saving an Image of the Geometry

When you are setting up the probe position for an AM Calculator (on the Configuration window) and picking the coordinate on the geometry (on the Visualizations window) there are tooltips to guide you with the actions you can do to set the location on the **Visualizations** window. Hover over the **Pick coordinate** button on the AM Calculator **Configuration** window to view these options to place the probe.



Then when placing the probe (i.e. picking the coordinates on the geometry on the Visualizations window), you can right-click the probe point to set the probe coordinate more quickly. You can also save a snapshot image (in png, jpg, or gif format) when you select **Save As**.

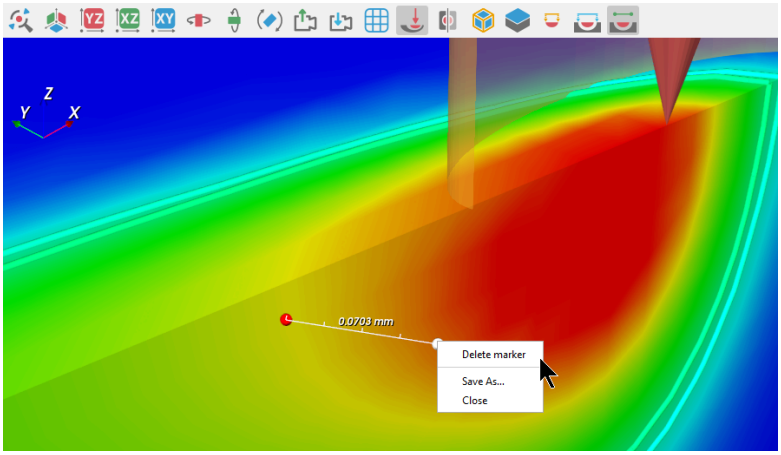


Deleting Markers and Saving an Image of the 3D Plot

When working with a 3D Plot (with a Plot Renderer successor to an AM Calculator), you can add markers to measure between two points on the heat source, for example.

The new menu available enables you to delete markers that are added to the plot as needed. You can also hover over the **Show Manual Ruler** button on the toolbar to view various tooltips (which were there before).

Also new on the 3D Plot in the Visualizations window is that you can save a snapshot of the plot by right-clicking anywhere and then select **Save As** from the menu. You can save to png, jpg, or gif format.



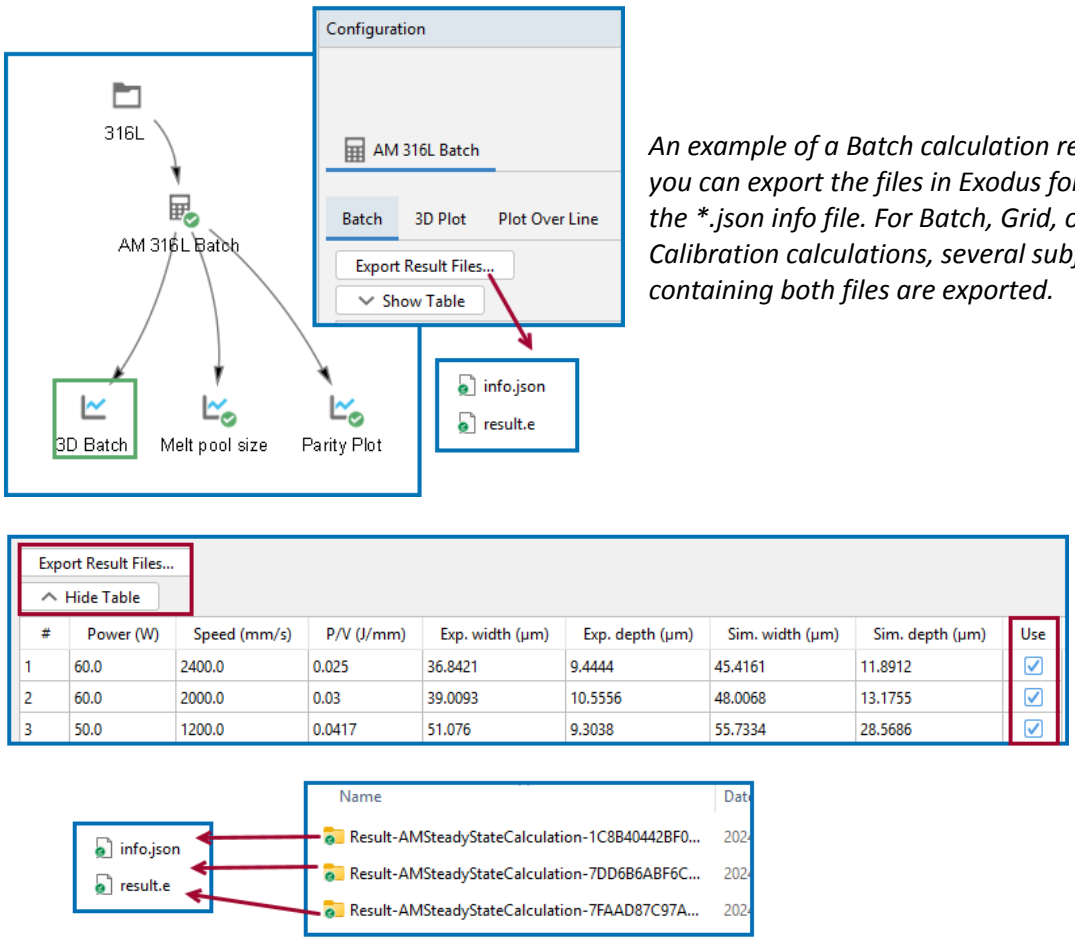
*Example of the submenu on an AM Plot Renderer 3D Plot. You can right-click in the plot area to either save a snapshot of the plot at the given zoom level (select **Save As**), or when working with markers you can right-click to **Delete marker** when you are using the **Show Manual Ruler** button to measure between two points.*

Export Results to the Exodus File Format

It is now possible to export results from the Additive Manufacturing Module in the Exodus file format. The Exodus file format is used with finite element analysis programs. Once exported, you can retrieve the files and use them to further process and analyze simulation results.

The result files are available after running simulations and are exported to a folder location and name of your choice. The new **Export Result Files** button is available on the **Plot Renderer Configuration** window on the **3D Plot**, **Batch**, **Grid**, and **Heat Source Calibration** tabs. The individual exported files are generally named `info.json` and `result.e`. The json info file contains the settings and results from each data point. You can open the json info file in a text reader (i.e. Notepad) to review it before using the Exodus file in the external software.

When exporting from the **Grid**, **Batch**, and **Heat Source Calibration** tabs, the results are saved in separate subfolders, each containing the `.json` and `.e` files. When there are multiple subfolders the number of folders exported is the same as the number of rows of data selected to be used. If the **Use** checkbox is not selected, the result folder (and files) for that data point is not exported.



An example of a Batch calculation result where you can export the files in Exodus format (.e) plus the *.json info file. For Batch, Grid, or Heat Source Calibration calculations, several subfolders containing both files are exported.*

When exporting from Batch, Grid, or Heat Source Calibration calculations, individual folders each contain the files and only those rows with the Use checkbox selected on the Plot Renderer Configuration window are exported.

Improvements and Bug Fixes

Heat Source Calibration Related

- Fixed an issue in 2024b where an exception was thrown in the **Heat Source Calibration** results when the parameters' interpolation function was changed from 2D cubic to any other function.
- For a **Heat Source Calibration**, and when a parameter had a 2D cubic function selected, the extrapolation for the “b” parameter and also all other parameters with constant extrapolation having no 2D cubic option was not correct. This is fixed.
- Fixed a bug where user heat sources should not be shown in the Heat Source list when **Heat Source Calibration** is selected.
- Gaussian heat source calibration table result has sometimes disabled rows for existing results.
- Fixed a bug where the wrong configuration was shown when a Transient file is opened which is run after **Heat Source Calibration** was selected.

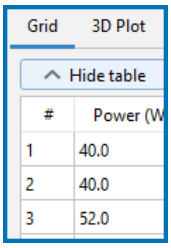
- When a Plot Renderer is added to an AM Calculator with **Heat Source Calibration**, the minimum and maximum values for P/v in the table are applied to the below and above inputs. If the table is changed, these values are updated. However, if the user changes below/above values, they will not be updated anymore.

Keyhole Model Related

- Improved the stabilization of the keyhole model, and corrected the melt pool shape. This is important, for example, for high energy cases.

Grid or Batch Calculation Related

- In **Grid** calculations, the keyhole model did not previously work when *Users heat sources* file was chosen, even when the *Use keyhole model* checkbox was selected. This is now fixed.
- For **Grid** calculations and **Printability map** plots in 2024b, the ***grid point #*** calculation result listed in the Event Log did not match correctly to the **#** column in the table that is on the Plot Renderer Configuration window. This is fixed.



- Fixed a bug related to **Grid** and **Batch** calculations. Previously a particular sequence of events resulted in heat source parameters not being updated: (1) If the non-single steady-state was selected, then (2) non-steady state was selected, and then (3) a user heat source was selected, the inputs for heat source parameters were not updated. This is fixed.

Plot Related

- Smoothing levels did not load correctly in 2024b when *Per quantity* was selected as the *Smoothing type*.
- The coordinates for the 2D Plot Over Line in a **Transient with heat source from Steady-state** and its **Steady-state** model are now synchronized. This means if one switches between these computational models, the resulting 2D Plot Over Line coordinates show the same result.
- Fixed an issue that related to when the powder layer thickness was changed on the AM Calculator and the corresponding input was not updated in the Plot Renderer as expected.
- Fixed a bug where an error occurred after running **Batch** or **Heat Source Calibration** calculations using imported table data.
- Fixed a caching bug that happened when using a different selection for smoothing levels for a material, i.e. previously, the results were being used from the cache in error when a calculation was rerun.

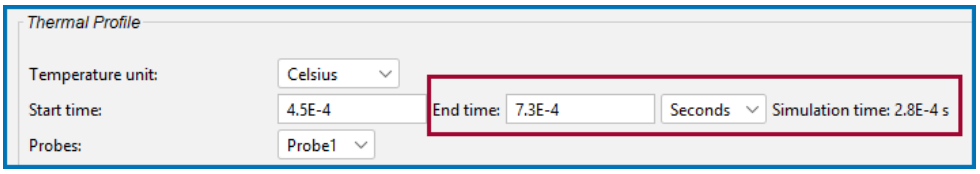
Probe Related

- Fixed an error that intermittently occurred after opening a project file that had probes enabled.
- Fixed a bug related to probes being used with the Add-on Diffusion (DICTRA) and Precipitation (TC-PRISMA) Modules. Previously, the initial temperature (at time 0 s) conversion was incorrect for these probe values.

- Fixed an issue when working with AM Calculator and probes in the Precipitation Module (TC-PRISMA). Previously, the Thermal Profile plot was shown in the Plot Renderer after the Precipitation Calculator when it was clicked on the plot.
- Fixed a bug related to pausing/resuming calculations when working with the AM Calculator and Precipitation Calculator probe calculation. Previously, when a Precipitation Calculator calculation was paused the thermal profile (time/temperature) table rows were locked, but new rows could be added, and there was difficulty resuming the calculation. Now when the Calculator activity is not valid when paused, the Continue button becomes disabled until whatever error is in the configuration is fixed by the user.

Diffusion or Precipitation Calculator Related

- The default smallest allowed dt in Diffusion Calculator (under options) is reduced to 1e-9 for when it is connected to AM Calculator.
- Fixed a bug related to when the Precipitation Calculator is added to an AM Calculator. Now the Thermal Profile table is updated correctly after there are AM Calculator changes.
- Fixed a bug where the Diffusion Calculator could not previously be connected to an AM Calculator unless the AM Calculator had a result.
- When a file without result is opened , and the thermal profile table has a lower number of rows than the probe data, after performing AM, only that row is updated with probe data, and on the second perform, all probe data is added.
- Previously, when a table was edited for either the Diffusion or Precipitation Calculator, and the AM Calculator is reperformed (but without changing any AM Calculator input), the table was overwritten with probe data. This is fixed so that the table is updated when the AM Calculator configuration is changed and re-performed or when the result from a previous calculation is found.
- Previously, if a file with a Precipitation Calculator was added to an AM Calculator, and AM had results, but the Precipitation Calculator did not have results, the table for the Precipitation Calculator was shown to be empty. This is fixed.
- The settings for a Diffusion Calculator or Precipitation Calculator connected to an AM Calculator was changed so that on the Diffusion or Precipitation Calculator you can enter an End time (instead of previously it said Simulation time). Now Simulation time is shown as text. The simulation time is added to time for the Plot Renderer.



An example of the Diffusion Calculator where End time can be entered (instead of previously it was simulation time) and the Simulation time is displayed only as text.

Precipitation Module (TC-PRISMA)

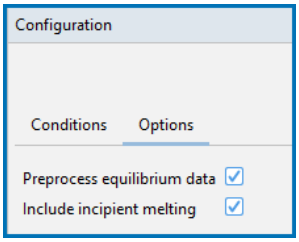
Visit the Precipitation Module (TC-PRISMA) on the website to access resources such as training videos, publications, application examples, and much more.

AM Module Connected to Precipitation Calculator Improvements

Also see some of the bugs that are fixed and listed in the AM Module section: In Probe Related and Diffusion or Precipitation Calculator Related.

New Options Improve Calculation Time for Precipitation-related Simulations

There are two new checkboxes available on the **Precipitation Calculator Configuration** window **Options** tab: **Preprocess equilibrium data** and **Include incipient melting**. Selecting one or both of these options can improve the computation time when using the Precipitation Calculator with the AM Calculator. Applications that benefit when using these options include welding, additive manufacturing (AM), and continuous cooling. The calculation speeds are improved based on the following:



- For the equilibrium data, this calculates the required phase equilibrium properties as a function of temperature for stable and metastable conditions.
- For incipient melting, which can be used in combination with the property diagram data preprocessing, it approximates the melting temperature of precipitate phases. The precipitates are removed upon exceeding this temperature.

Preprocess Equilibrium Data

When the **Preprocess equilibrium data** checkbox is selected, the stable and metastable property diagram equilibrium phase data for all simulated precipitate phases is preprocessed. This avoids repeating global equilibrium calculations, and speeds up computational time. It also allows for an improved description of precipitate kinetics under severe dissolution conditions. This can occur when temperatures are too high, where the phase is no longer detected in equilibrium calculations, or if the matrix is depleted of precipitate forming species, and the precipitate phase is lost when calculating the driving force.

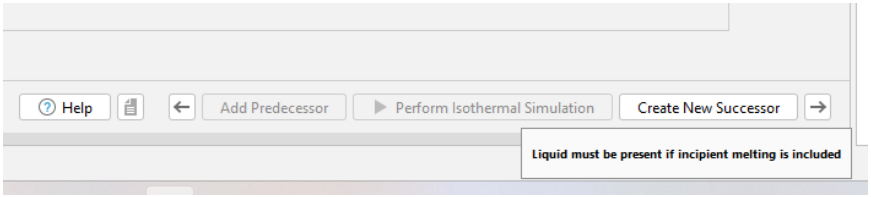
This feature is used primarily for non-isothermal simulations. For isothermal simulations it can be used when there is difficulty losing precipitate phases during the calculation. In this case, it alters the predicted dissolution kinetics in certain conditions where the precipitation phase is lost and then it also speeds up these calculations.

Incipient Melting

The **Include incipient melting** checkbox is available when the **Preprocess equilibrium data** checkbox is selected.

Incipient melting is a phenomenon where, due to rapid heating rates, a solid-state precipitate is in solution at temperatures where it would normally dissolve. It liquidates rather than dissolves into the matrix. Being able to include (or exclude) the incipient melting is relevant to simulations involving welding and AM. Including incipient melting in AM calculations is useful to avoid excessive computation time modeling the dissolution of precipitates which would melt. The precipitates are assumed to melt instantaneously upon reaching their incipient melting temperature. The precipitates are removed from the system in the simulation.

To use the **Include incipient melting** checkbox requires that the thermodynamic database (i.e. TCFE, TCNI, and so on) includes the liquid phase. If the liquid phase is not included, then the **Perform** button is not available (it is grayed out with a message explaining why) until either a liquid phase is included or this checkbox is deselected.



New Example for Using Probes in the AM Module

A new example is available from the **Graphical Mode > Additive Manufacturing** folder to demonstrate these improvements: **AM_12_AM_Probe_to_Precipitation.tcu.**

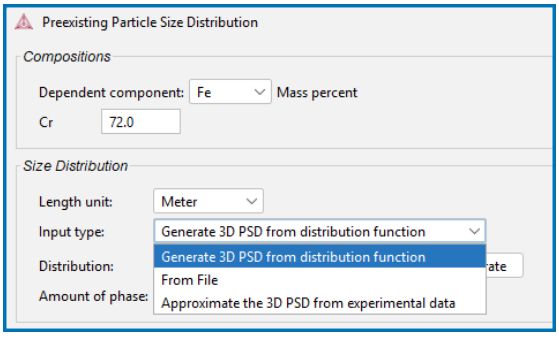
Import 2D PSD and Convert to 3D

The Precipitation Module (TC-PRISMA) adds the ability to convert two-dimension (2D) distribution to three-dimensional (3D) distribution. This allows users to upload experimental 2D particle size distribution data into the program, convert it to 3D distribution data and compare that to simulated results.

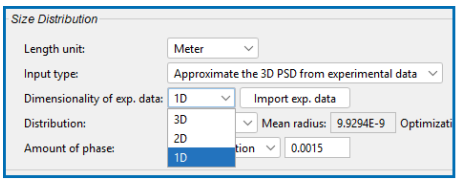
The converse ability, to convert 3D distribution to 2D distribution, was added to the software in Thermo-Calc 2024a. Graphical mode example P_10 is updated to demonstrate the new and existing conversion options.

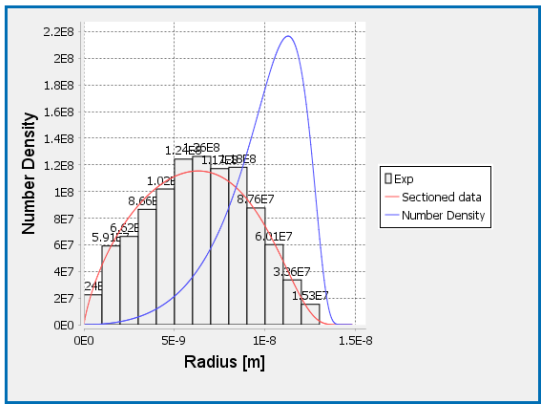
The improvement includes a new setting available on the Preexisting Particle Size Distribution window, **Input type**. Choose **Generate 3D PSD from distribution function**, **From File**, or **Approximate the 3D PSD from experimental data**. Use each type of preview to locate errors with the calibration, which can help choose the best distribution function for a given dataset.

- **Generate 3D PSD from distribution function:** Allows the generation of the size distribution from a list of probability distribution functions.
- **From File:** Allows you load the initial size distribution from a file.
- **Approximate the 3D PSD from experimental data:** Allows you to calibrate a continuous probability distribution function to an experimentally measured size distribution, and account for stereological considerations.



When **Approximate the 3D PSD from experimental data** is chosen, there is an additional option (**Dimensionality of exp. data**) to choose the dimension (**1D**, **2D**, or **3D**) and then import experimental data. For 3D data, there are two datasets shown- the experimental data and the 3D model data. For 2D and 1D data, the sectioned model data is also shown and compared with the experimental data.





From the updated example P_10, M7C3 phase uses 1D dimensionality and imports experimental data.

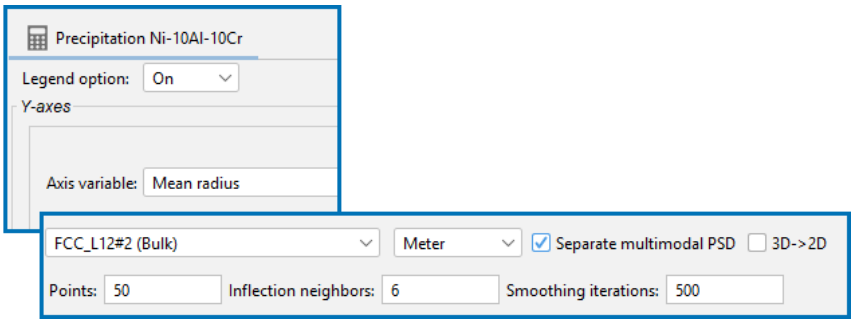
New Method for Splitting Multi-modal Distributions

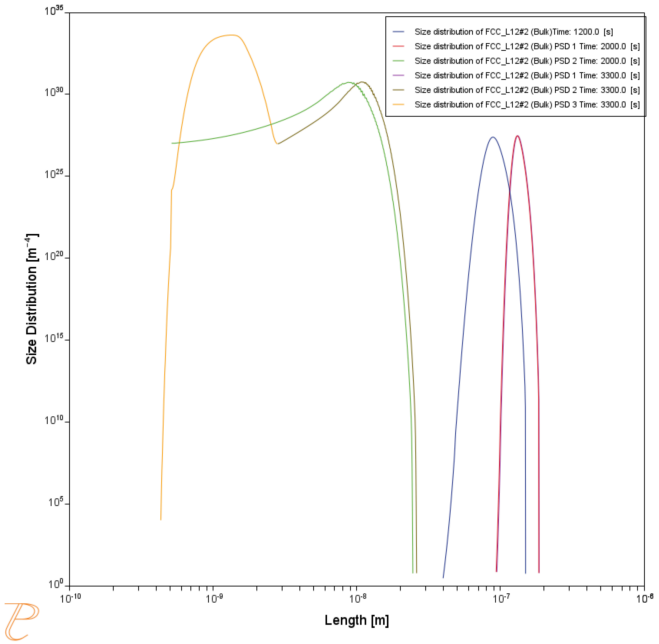
Also see Precipitation Module in TC-Python and TC-Toolbox for more information.

A new method is implemented in the Precipitation Module (TC-PRISMA) to split precipitate size distributions to identify statistics of individual populations. You can both section and split several post processing quantities. Example P_06 is updated to demonstrate this improvement that simplifies the process and makes it more robust to identify individual populations.

In Graphical Mode for a Plot Renderer associated with a Precipitation Calculator:

- There are two new settings available: **Inflection neighbors** and **Smoothing iterations**.
- The previous settings **Excess Kurtosis**, **Minimum separation limit** (Valley depth ratio), and **Minimum peak,** are removed as options as of this release.





Example P_06 is updated to include the new settings. In this plot from the example, the results show the predicted size distributions of precipitates at different times during the quench for the Ni-10Al-10Cr alloy. The individual particle populations are distinguished using the "Separate multimodal PSD" option showing the formation of a tri-modal dispersion.

Improvements and Bug Fixes

- Fixed a bug where the composition unit was not visible for multiple initial particle size distributions.
- Previously, when changing nucleation sites, the number of nucleation sites is updated even if the setting *Calculate from matrix settings* is disabled. The fix gives the user a sensible value to start working with.
- When changing the model from calculating the evolution of the grain size distribution to a static approximation of the grain size, the previously set initial grain size is used as the default value for the grain diameter.
- Fixed a bug where incorrect grain size and aspect ratio were used to calculate nucleation sites when changing the type of nucleation site and/or toggling the option to model grain growth.
- The grain size is now set as a diameter if grain growth is not modeled. When modeling grain growth, the grain radius distribution is modeled. The use of radius and diameter is clarified in the text.
- Fixed a meshing bug that created minor noise with multi-modal dispersions.
- Fixed a bug impacting the initial shape of existing particle and grain size distributions.

Diffusion Module (DICTRA)

Visit the DIffusion Module (DICTRA) on the website to access resources such as a tutorial, training videos, publications, application examples, and much more.

AM Module Connected to Diffusion Calculator

Also see some of the bugs that are fixed and listed in the AM Module section: In Probe Related and Diffusion or Precipitation Calculator Related.

Improvements and Bug Fixes

Both Console and Graphical Mode

- Fixed an issue with the mass balance that could happen with classic DICTRA if there was an inactive stoichiometric phase to the right of a solution phase.
- Fixed an issue that could result in one or more phases missing in DICTRA plots.

Graphical Mode and SDKs

- Improved the stability of phases allowed to form (“inactive” phases) next to a region. This is also for the APIs (TC-Python and TC-Toolbox).

Console Mode Only

- There is a new command `REINITIATE_MODULE`, for the DICTRA module, which resets the state to what it was when you first entered the workspace.

```
SYS:goto dictra
 NO TIME STEP DEFINED
DIC>?
 ADD_STOP_CRITERION            LIST_PROFILES
 ADVANCED_HOMOGENIZATION_OPTIO LIST_REGION
 AMEND_CELL_DISTRIBUTION       LIST_TIMESTEPS
 AMEND_MOBILITY_DATA           MACRO_FILE_OPEN
 BACK                          PARA_EQUILIBRIUM_MODEL
 CHECK_DIFFUSION_MATRIX        POLY_COMMAND
 COARSENING_MODEL              POST_PROCESSOR
 CREATE_NEW_CELL               READ_WORKSPACES
 DEBUGGING                     REINITIATE_MODULE
 DELETE_REGION                 REMOVE_STOP_CRITERION
```

- A new prompt option called `LOOKUP_TABLE_TEMPERATU`, is added to the `SET_CONDITION` command. This enables you to read a file with time-temperature pairs. This fixes a previous issue where non-isothermal simulations in DICTRA with heat treatments generated from the Additive Manufacturing Module failed.
- Added validation for composition profile function
- The command `CHECK_DIFFUSION_MATRIX` now gives correct values and displays the units.

Process Metallurgy Module

Updated to Use New TCOX14

- Added Li and Ba that are now available in TCOX14.

Improvements and Bug Fixes

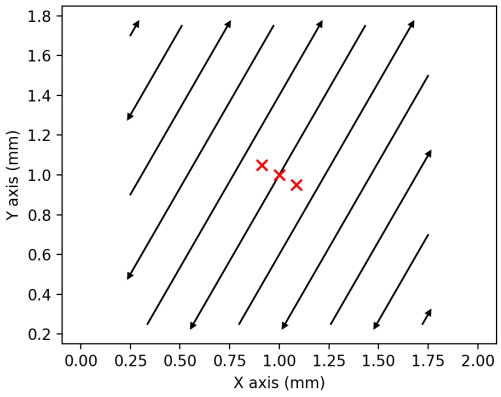
- Corrected the element to component conversion for those species: NAB+4, NAAL+4, KAL+4, K2MG+4.

TC-Python API and TC-Toolbox for MATLAB®

AM Module in TC-Python

New Example For Laser Strategy and Probe Position

A new example **pyex_AM_07_Laser_Strategy_Probe_Position.py** is added demonstrating how to visualize and assess the laser strategy, and use this information to guide probe placement. There is now a `ScanningPath` class which stores the information about the laser scanning path for each layer. The example plots the laser strategy with a figure created for each layer. A line-scan of probes is created that is positioned on a laser as it passes the closest to the center. It starts and ends at the midpoint with the neighboring laser passes. The location of the probes are shown on the plots.



Bug Fixes

- Fixed an issue in TC-Python where more than 9 probes did not work correctly.
- Clarified the use of the TC-Python Scheil method in the documentation related to `calculate_from_start_temperature()`
- Interface scattering setting is added when creating a material library from a Scheil result.

Precipitation Module in TC-Python and TC-Toolbox

Splitting Multi-modal Distributions

A new method (`get_split_mean_radius`) for splitting precipitate size distributions to identify statistics of individual populations is implemented in the SDKs, TC-Python and TC-Toolbox for MATLAB. You can both section and split several post processing quantities. The TC-Python example pyex_P_08 is updated to include the new functionality for splitting and sectioning the precipitation predictions.

See New Method for Splitting Multi-modal Distributions for details.

New Noble Metal Alloys Model Library in TC-Python and TC-Toolbox

For details about the new product, see Noble Metal Alloys Property Model Library.

New Python Packages in Bundled Python Interpreter

The Python packages tmm and color-science are now included in the bundled Python interpreter. These packages are used with the new Optical Properties Property Model.

Improvements and Bug Fixes

- Improved the stability of phases allowed to form ("inactive" phases) next to a region. This is for both the APIs (TC-Python and TC-Toolbox) and the Diffusion Calculator in Graphical Mode.
- Added user-input solute trapping parameters in TC-Python. This is for both the APIs (TC-Python and TC-Toolbox) and the Scheil Calculator in Graphical Mode.

Databases

All the thermodynamic and kinetic databases have dedicated web pages where new and updated Technical Information and Example Collections are available in addition to links to examples, publications, webinars, and many other resources can be found.

New Thermodynamic and Kinetic Databases

TCS Steel and Fe-alloys Database (TCFE14)

New Elastic Properties

In 2024b, elastic properties were added to the TCS Ti/TiAl-based Alloys Database (TCTI6). TCFE14 is the next database to include these properties.

- Elastic constants (C11, C12, C13, C33, and C44) are added for FCC_A1, BCC_A2 and HCP_A3 phases. The elastic constants description can be used to derive the elastic moduli (bulk modulus, shear modulus, and Young's modulus) for a single-phase microstructure.
- Unary systems assessed:
  - FCC_A1, BCC_A2, HCP_A3: Al, Ca, Ce, Co, Cr, Cu, Fe, Mg, Mn, Mo, Nb, Ni, P, Ru, S, Si, Sn, Ta, Ti, V, W, Y, Zn, Zr
- Binary systems assessed:
  - Fe-X (X = Al, Co, Cr, Mg, Mn, Mo, Nb, Ni, Si, Ti, V, W)
  - Mo-X (X = Nb, Sn, Ta, Ti, W, Zr)
  - Nb-X (X = Sn, Ta, Ti, V, W, Zr)
  - Sn-X (X = Ta, Ti, Zr)
  - Ta-X (X = Ti, W, Zr)
  - Ti-X (X = Al, Cr, V, W, Y, Zr)
  - W-X (X = Cr, V, Zr)
  - Cr-Ni

New Systems and Phases

- 18 new ternary systems (total of 335)
- 4 new quaternary systems (total of 84)
- 30 new phases (total of 465)

Improved Solubility

- BN in liquid and solid Fe: B-N, Fe-B, Fe-B-N
- Mg in cast irons: C-Fe-Mg, C-Fe-Mg-Si
- Si in CEMENTITE_D011 phase: C-Fe-Si
- Sn in CORUNDUM phase: O-Sn, Fe-O-Sn

Improved Systems

- S systems
  - S-X (X= Ce, Co, Cr, Fe, Ni, Ru, Ti, V)
  - Fe-S-X (X=Ce, Cr, Mo, Ni, Ta, Ti, V, Zn)
  - Cr-Fe-Ni-S
- Ti systems
  - Ti-X (X=Al, Fe, Si)
  - Fe-Ti-X (X= Al, Cr, Nb, Ni, Si, V)

Improved $\alpha/\gamma/\sigma$ Equilibria

- Fe-Ni-V, Cr-Ni-V, Cr-Fe-Ni-V
- Mo-V, Fe-Mo-V

Improved Descriptions

- Cubic carbides: C-Nb, C-X-Y (X-Y= Cr-Ti, Cr-V, Fe-Ti, Mo-Nb, Mo-Ti, Mo-V, Nb-Ti, Nb-V, Ti-V)
- TiN inclusions in steel melts: Cr-Fe-Ni-Ti-N
- Ni3X (X=Mo,Ti) precipitates in maraging steels: Mo-Ni, Mo-Nb-Ni, Mo-Ni-Ti, Nb-Ni-Ti

Improved Thermophysical Properties

- Thermal conductivity for cemented carbide systems improved

TCS Metal Oxide Solutions Database (TCOX14)

New Elements and Phases

- Two new elements: Barium (Ba) and Lithium (Li) (for a total of 34 elements.
  - Ba is for glass ceramics, cathode, and potential applications in metallurgy. The BaO-containing systems are important for the glass industry, in particular for TV panel glasses and glasses used for nuclear waste disposal.
  - Li is for glass ceramics, metallurgical processes, semiconductor, electrode industry, and recovering lithium from Li-ion battery recycling slags. Note that low temperature phases relevant for cathode or anode battery development are not included in TCOX.
- 138 new phases (744 phases in total).

Added Thermophysical Properties for the New Elements

- For both Ba and Li: Molar volume, viscosity, surface tension, electrical conductivity/resistivity and thermal conductivity/resistivity are included for the new elements.

Added Thermal Conductivity/Resistivity and Electrical Conductivity/Resistivity

- Thermal conductivity/resistivity is included for the ionic liquids and solids.
- Electrical conductivity/resistivity is included for the solids. ELCD/ELRS of ionic liquids already included with TCOX13.

New Systems

- 41 new binary systems are assessed: Ba-B, Ba-Ca, Ba-F, Ba-Fe, Ba-Gd, Ba-La, Ba-Li, Ba-Mg, Ba-Mn, Ba-Mo, Ba-Ni, Ba-O, Ba-Ti, Ba-V, Ba-Y, Ba-Yb, Li-Al, Li-Ca, Li-Co, Li-Cr, Li-Cu, Li-F, Li-Fe, Li-Gd, Li-Hf, Li-K, Li-La, Li-Mg, Li-Mn, Li-Mo, Li-N, Li-Na, Li-Nb, Li-Ni, Li-O, Li-S, Li-Ti, Li-V, Li-W, Li-Y, Li-Yb, Li-Zr.
- 49 new ternary systems are assessed: Al-Ba-O, B-Ba-O, Ba-C-O, Ba-Ca-O, Ba-Cr-O, Ba-F-O, Ba-Fe-O, Ba-Gd-O, Ba-Hf-O, Ba-La-O, Ba-Li-O, Ba-Mg-O, Ba-N-O, Ba-Ni-O, Ba-O-P, Ba-O-Si, Ba-O-Ti, Ba-O-Y, Ba-O-Yb, Ba-O-Zr, Al-Li-O, B-Li-O, C-Li-O, Ca-Li-O, Co-Li-O, Cr-Li-O, Cu-Li-O, F-Li-O, Fe-Li-O, Li-Mg-O, Li-Mn-O, Li-N-O, Li-O-P, Li-O-Si, Li-O-Ti, Li-O-Y, Li-O-Zr, Ba-Ca-F, Ba-F-K, Ba-F-Li, Ba-F-Mg, Ba-F-Na, Ba-F-Zr, Ca-F-Li, F-K-Li, F-Li-Mg, F-Li-Na, F-Li-Zr, Al-Li-Mg.
- 48 new quaternary systems are assessed: Al-B-Ba-O, Al-Ba-Ca-O, Al-Ba-Mg-O, Al-Ba-O-Si, Al-Ca-Li-O, Al-Fe-Li-O, Al-Li-Mg-O, Al-Li-Na-O, Al-Li-O-Si, B-Ba-Ca-O, B-Ba-F-O, B-Ba-K-O, B-Ba-Li-O, B-Ba-Na-O, B-Ba-O-Si, B-Li-Na-O, B-Li-O-Si, Ba-C-Li-O, Ba-C-Na-O, Ba-Ca-Fe-O, Ba-Ca-N-O, Ba-Ca-O-P, Ba-Ca-O-Si, Ba-Ca-O-Y, Ba-Cr-F-O, Ba-Fe-O-P, Ba-Fe-O-Si, Ba-K-N-O, Ba-K-O-Si, Ba-Li-N-O, Ba-Li-O-Si, Ba-Mg-O-Si, Ba-Na-O-Si, Ba-O-Si-Ti, Ba-O-Y-Zr, C-F-Li-O, C-K-Li-O, C-Li-N-O, C-Li-Na-O, Ca-Li-N-O, Ca-Li-O-Si, F-K-Li-Na, F-Li-N-O, K-Li-N-O, Li-Mg-N-O, Li-Mg-O-Si, Li-N-Na-O, Li-Na-O-Si.
- 1 new higher order system is assessed: Ba-Ca-Mg-O-Si.

TCS Molten Salts Database (TCSALT2)

New Element and Phases

- One new element: Lithium (Li) (for a total of 12 elements).
- 23 new phases (177 phases in total).

Systems

- 21 new pseudo-binary systems are assessed: $AlCl_3$-LiCl, $CaCl_2$-LiCl, KCl-LiCl, LiCl-$MgCl_2$, LiCl-NaCl, LiCl-$SrCl_2$, LiCl-$ZnCl_2$, AlF_3-LiF, CaF_2-LiF, KF-LiF, LiF-MgF_2, LiF-NaF, LiF-SrF_2, LiF-ZnF_2, Al_2O_3-Li_2O, CaO-Li_2O, K_2O-Li_2O, Li_2O-MgO, Li_2O-Na_2O, Li_2O-SiO_2, Li_2O-ZnO.
- 24 new pseudo-ternary systems are assessed: $AlCl_3$-KCl-LiCl, $CaCl_2$-KCl-LiCl, $CaCl_2$-LiCl-NaCl, $CaCl_2$-LiCl-$SrCl_2$, KCl-LiCl-$MgCl_2$, KCl-LiCl-NaCl, KCl-LiCl-$SrCl_2$, KCl-LiCl-$ZnCl_2$, LiCl-NaCl-$SrCl_2$, AlF_3-CaF2-LiF, AlF_3-KF-LiF, AlF_3-LiF-NaF, CaF_2-KF-LiF, CaF_2-LiF-MgF_2, CaF_2-LiF-NaF, CaF_2-LiF-SrF_2, KF-LiF-MgF_2, KF-LiF-NaF, LiF-MgF_2-NaF, LiF-MgF_2-SrF_2, Al_2O_3-Li_2O-Na_2O, CaO-Li_2O-SiO_2, Li_2O-MgO-SiO_2, Li_2O-Na2O-SiO_2.
- 8 new mixed systems are assessed: $AlCl_3$-AlF_3-LiCl-LiF, $CaCl_2$-CaF_2-LiCl-LiF, KCl-KF-LiCl-LiF, Li_2O-LiCl, Li_2O-LiF, LiCl-LiF, LiCl-LiF-NaCl-NaF, LiCl-LiF-$SrCl_2$-SrF_2.

Thermophysical Properties Added

- Surface tension and viscosity of the ionic liquids.
- Molar volume of the ionic liquids and solids.

SGTE Solutions Database (SSOL9)

In this release there are now 1053 assessed systems (879 binary, 154 ternary, and 20 higher-order systems) and 2352 phases.

Binary Systems

- Updated 19 binary systems: Ag-Te, As-Ga, Al-Sr, Al-Ta, Be-Si, Ca-Mg, Ca-Pb, Co-Cu, Co-Sn, Co-Ti, Ga-Hg, Ga-Mg, Mg-Sn, Pb-Sn, Si-Te, Si-Sr, Si-Y, Au-Pr (removed), Mn-Ni (reinstated).
- For some problematic binary systems e.g. with inverse liquid miscibility gap, additional information of maximum recommended temperature of calculation is included in the corresponding reference. This information (i.e. lists of references) are available as follows:
    - Console Mode: After the GET command.
    - Graphical Mode: After performing the System Definer activity it is either listed in the Event Log or available on the Data Sources tab.
- Added 96 new binary systems: Ag-As, Ag-P, Ag-S, Ag-Sm, Ag-Yb, Al-Am, Al-H, Al-K, Al-Na, Al-Tl, As-Te, As-U, As-Zn, Au-Dy, Au-Gd, Au-Lu, Au-Th, Au-Yb, B-Er, B-La, B-Lu, B-Pr, B-Ta, B-Tm, B-Zn, Ba-Fe, Ba-Ga, Ba-Ge, Ba-Yb, Be-C, Bi-Cr, Bi-Rh, C-Dy, C-Y, Ca-Ce, Ca-Fe, Ca-Ni, Ce-Pr, Ce-Pt, Ce-Te, Co-La, Co-Mg, Co-Nd, Co-Te, Co-Th, Cr-Re, Cr-U, Cs-Mo, Cu-Dy, Cu-Pu, Cu-Ta, Cu-U, Dy-Si, Dy-Zn, Er-Lu, Er-Zn, Eu-Ga, Fe-Ho, Fe-Lu, Fe-Pu, Fe-Rh, Fe-Th, Fe-Tm, Ga-Te, Gd-Sm, Gd-Ti, Gd-Tl, Ge-Lu, H-Mg, H-Na, H-Nb, Hf-Ru, Hg-Te, Ho-Ni, Ho-Sb, Ho-Zn, In-Ir, In-Na, In-Sr, Ir-Ti, K-Sb, K-Te, K-V, La-Mn, La-Mo, La-Nd, La-Pb, La-Pr, Li-Te, Nb-Re, Pb-Se, Re-Ta, S-Sn, Se-Sn, Sn-Te, and Sr-Te.

Ternary Systems

- Added 10 new ternary system: Ag-Sn-Te, Al-Si-Sr, As-Ga-Zn, Be-C-Si, C-Dy-Si, C-Si-Y, Ca-Ce-Mg, Ca-Mg-Sn, Ga-Hg-Mg, and Pb-Se-Sn.
- Fe-Mn-Ni reinstated.

Unary Systems

- Update of basic element data to be consistent with Unary 5.1, except that ORTHORHOMBIC_S renamed as ORTHORHOMBIC_A16.
- B solid solution now named as BETA_RHOMBO_B105.

GAS Phase

- Te gas species (Te and Te2) updated.
- Added gas species for Ga, As, and Si.

Other Updates

- G(BCT_A5,PD;0) fixed.
- G(DHCP,BI;0) fixed.
- Eu and Pu removed from HCP_A3 (no unary, not appearing in any system).
- G(FCC_A1,PR:VA;0) updated.
- G(HCP_ZN,HG:VA;0) added.
- Ca removed from LAVES_C14 as it is not appearing in any system.
- G(M4N,CR:VA;0) fixed.
- G(MU_PHASE,MN:MN:MN;0) fixed. MN removed from SL 2 and 3. Not required.
- G(RHOMBOHEDRAL_A7,ND;0) fixed.
- G(RHOMB_C19,MN) fixed.

Updated Thermodynamic and Kinetic Databases

TCS Solder Alloy Solutions Database (TCSLD5.0 to TCSLD5.1)

- Improved phase description of HCP_A3 and EPSILON_HCP in Ag-Sb-Zn, Ag-Sn-Zn, Al-Cu-Zn, and Cu-Si-Zn systems
- Added the Ag-Cu-Zn system

TCS Ti/TiAl-based Alloys Database (TCTI6.0 to TCTI6.1)

This update is related to adjustments to the new elastic properties.

Unary Systems

- Reassessed elastic constant model parameters to ensure that the calculated results at high temperatures align more closely with physically expected behavior.
    - FCC_A1: Ni
    - BCC_A2: Fe, Mo, Nb, Ta, Ti, V, W, Zr
    - HCP_A3: Co, Ti, Zr
- Reassessed elastic constant model parameters for metastable systems that enhance model consistency and improve composition profiles for both titanium-containing and non-titanium binary systems.
    - FCC_A1: Co, Cr
    - BCC_A2: Al
    - HCP_A3: Cr, Mo, Nb, V
- Fixed rounding error that affected the calculated accuracy of a few systems.

Binary Systems

Reassessed binary interaction parameters affected by the adjustments made to unary elastic constant model parameters.

- BCC_A2:
    - Ti-X (X = Al, Cr, Mo, Nb, Sn, Ta, V, W, Zr)
    - Mo-X (X = Nb, Sn, Ta, W, Zr)
    - Nb-X (X = Al, Sn, Ta, V, W, Zr)
    - Sn-X (X = Ta, Zr)
    - W-X (X = Cr, Ta, V, Zr)
    - Zr-X (X = Ta, V)
- HCP_A3: Ti-X (X = Al, Cr, Mo, Nb, Sn, V, Zr)

TCS Ni-alloys Mobility Database (MOBNI6.0 to MOBNI6.1)

- Reassessment of FCC_L12 in Ni-Ta system.

TCS Steels/Fe-Alloys Mobility Database (MOBFE8.0 to MOBFE8.1)

- Reassessment of FCC_L12 in Ni-Ta system

Thermophysical and Elastic Properties

Important thermophysical and elastic properties are progressively being added to the databases over time as shown in this summary of the additions.

Property	Database and Release Version
Elastic Moduli	• TCTI6 as of 2024b (bulk, shear, and Young's modulus) • TCTI6.1 Updates in 2025a • **New!** TCFE14 as of 2025a
Elastic Constants (Cij)	• TCTI6 as of 2024b (C11, C12, C13, C33, and C44) • TCTI6.1 Updates in 2025a • **New!** TCFE14 as of 2025a
Viscosity of Liquid	• TCHEA4 and TCFE10 as of 2020a • TCAL7, TCNI10 and TCOX10* as of 2020b • TCTI3 and TCMG6 as of 2021a • TCCU4 and TCSLD4 as of 2021b • TCZR1 and TCPMAG1 as of 2022a • TCNOBL3 as of 2023b • TCMO1 and TCNB1 as of 2024b • **New! TCSALT2* as of 2025a** *viscosity of ionic liquids
Surface Tension of Liquid	• TCAL7 and TCNI10 as of 2020b • TCTI3, TCMG6 and TCFE11 as of 2021a • TCHEA5, TCOX11*, TCCU4, TCSLD4 as of 2021b • TCZR1 and TCPMAG1 as of 2022a • TCNOBL3 as of 2023b • TCMO1 and TCNB1 as of 2024b • **New! TCSALT2* as of 2025a** *surface tension of oxide slag/molten salt *There are also changes to the surface tension model as of 2023b, which are rolled out to databases as new releases occur. See Reminder: New Model for Surface Tension.*
Electrical Conductivity/Resistivity and Thermal Conductivity/Resistivity	• TCAL7 as of 2020b • TCMG6 as of 2021a • TCHEA5, TCNI11 and updates for TCAL8 and TCMG6.1 as of 2021b • TCFE12 and TCTI4 as of 2022a • TCNOBL3 and TCCU6 as of 2023b • TCOX13 as of 2024a (electrical conductivity/resistivity for ionic liquids) • TCSLD5, TCMO1, and TCNB1 as of 2024b • **New!** TCOX14 as of 2025a (thermal conductivity/resistivity of the ionic liquids and solids; electrical conductivity/resistivity is now included for the solids)

Property	Database and Release Version
Molar Volume	Molar volume has been included with many databases for some time. Below lists more recent additions: ● TCTI2 as of 2019a ● TCOX10 as of 2020b ● TCMG6 as of 2021a ● TCZR1 and TCPMAG1 as of 2022a ● TCUHTM2 as of 2024b ● **New! TCSALT2 as of 2025a**

Reminder: New Model for Surface Tension

Starting with Thermo-Calc 2023b, there is now the possibility to choose a model for surface tension. If the phase in the database has one or more XI parameters, the Modified Guggenheim is used. Otherwise the surface tension is calculated as the Redlich-Kister expansion of the SIGM parameter.

Depreciation of the XI Parameter Over Time for the Databases

This change to how surface tension is handled in the databases is also related to new and updated databases, both in this release as well as past and future releases. As new versions of the other databases are updated, this parameter will continue to be deprecated. Summary of the changes starting with 2023b. New databases (i.e. recently released such as TCMO1 and TCNB1 already use the new model).

Software Version	Database Version Where the Change Is Implemented
2025a	No new databases updated to the new model in this release.
2024b	● TCSLD5
2024a	● TCMG7, TCAL9, TCHEA7 ● TCOX13 - only the surface tension of metallic liquid is changed
2023b	● Note that the parameter, XI, is already not used in the TCOX database (all versions). See 2024a above for the TCOX13 change. ● TCFE13, TCNI12.1, TCTI5.1, TCNOBL3, TCPMAG2, and TCCU6.

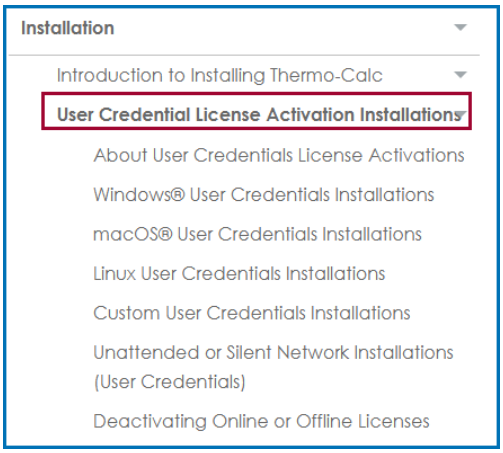
Installation

See New Licensing System for general information about this new tool. The Installation Guide has also undergone an overhaul to describe using the new user credentials license activation.

For TC-Python and TC-Toolbox for MATLAB, new examples are included to show how to manage licenses that are activated with user credentials. See TC-Python and TC-Toolbox (License Related).

Updated Installation Guides

With the implementation of the new license system, the installation guides are extensively overhauled. In the help the information is found in the **Installation > User Credential License Activation** section.



The Guides are also available as usual on the website and from the **Help > Manuals Folder** after installation.

Thermo-Calc Changes and Fixes

The details are described in the *Thermo-Calc Installation Guide*, available from various places including our website.

- Previously when on the Installation Wizard's Components setup window, *Additive Manufacturing* was available in error as an option to install or uninstall separately as a component. This is now removed as a separate component and will always be installed together (bundled) with Thermo-Calc.
- The database directory size needed on disk is significantly reduced by about 1.38 GM or 64% from previous versions of the software.
- In 2024b, TQ-Interface examples for macOS were included in error in Windows installations. This is fixed.
- For macOS, a bug was fixed where previously using the update option for a new version of the software (i.e. an update between versions of Thermo-Calc) did not work if the update tries to be done by an admin user that differed from the root user.

Reminder for TDB Editor Installations to Update the Plugin

For anyone who installed the TDB Editor (released with 2021a), you will need to update the plugin for this after installing a new version of Thermo-Calc. When Thermo-Calc is updated to a new version, VSCode should be updated too with the VSIX extension of the new release. This then includes the latest bug fixes and any other changes or improvements.

If VSCode is not updated with a new VSIX extension, it will continue to work as before with the language server of a previous release, as long as this release is not uninstalled. If the release is uninstalled, the VSIX extension (and thus the TDB Editor) will cease to work.

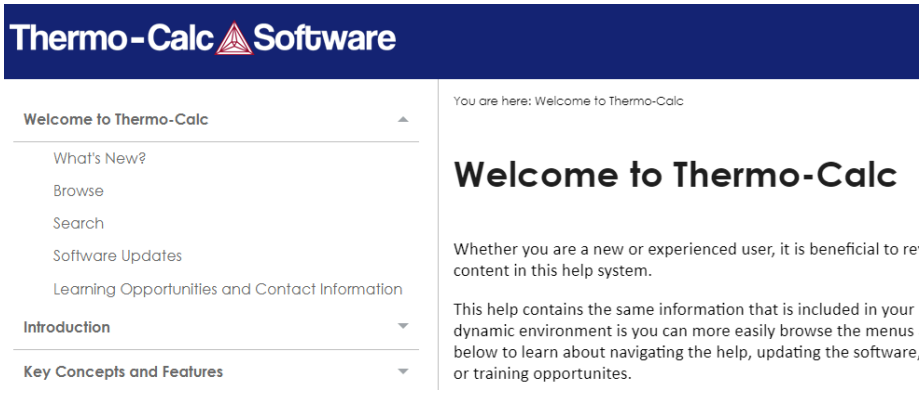
This installation is done after Thermo-Calc is installed. Search the help (press F1 in Thermo-Calc) for *Installing VSCode and the TDB Editor*.

Documentation

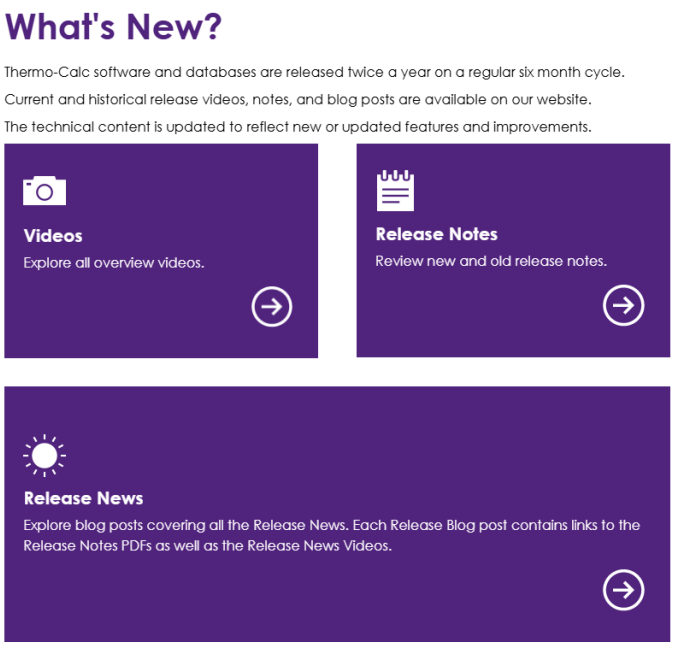
In Thermo-Calc, press F1 to search the online help.

Redesigned Help

There is a new look and feel for the online help as well as a reorganization of the content to make it easier to navigate the many features, Add-on Modules, and Databases.

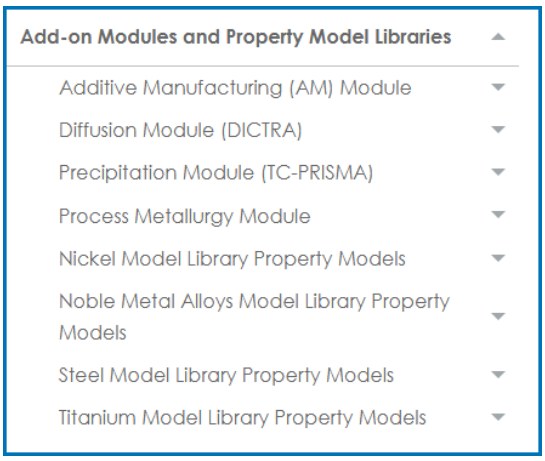


Top down menu changed to left-side menu with a lot of reorganization of content

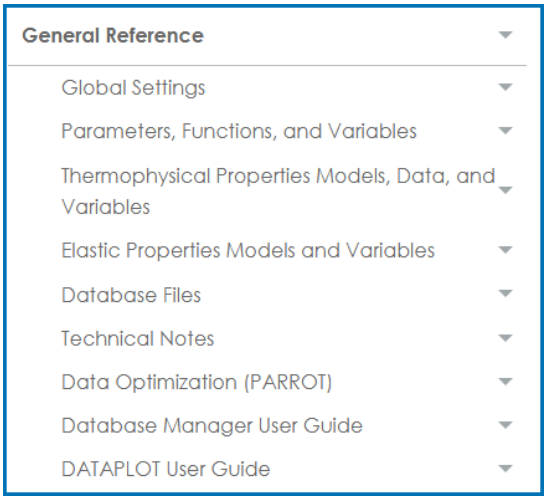


A new **What's New** section is similar to the New Release Highlights Popup Window in that it provides links to videos, release news, and release notes.

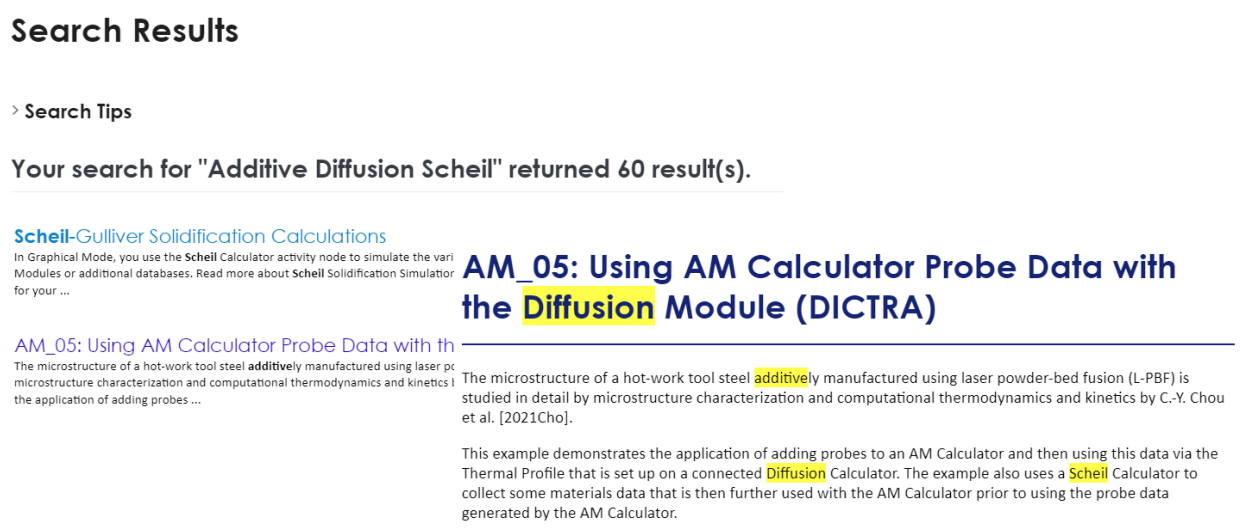
Add-on Modules and Property Model Libraries content is moved into their own sections. The big change is that the Diffusion Module and Precipitation Module information is now accessed from the side menu and not from a top down menu. All the Material Specific Property Model Libraries are in this section as well as the Additive Manufacturing (AM) Module and Process Metallurgy Module.



Lots of additional reorganization is the result of this new side menu, where a lot of content related to Console Mode is moved to the **General Reference** section, for example Data Optimization (PARROT), Database Manager User Guide, and DATAPLOT User Guide.



The **Search** functionality is also improved. Highlights are added when you search and land on a topic, certain other design features added including a list of search tips and expanded Search topic with more details.



New Examples

There are several new examples described elsewhere in this document and listed here for convenience.

Additive Manufacturing

- AM_10_Columnar_to_Equiaxed_Transition_IN718.tcu
- AM_11_Batch_Al10SiMg.tcu
- AM_12_AM_Probe_to_Precipitation.tcu

TC-Python (AM Module)

- pyex_AM_07_Laser_Strategy_Probe_Position.py (see above for FEM-887)
- pyex_AM_08_CET_IN718.py similar to the Graphical example AM_10

TC-Python and TC-Toolbox (License Related)

These examples show how to manage licenses that are activated with user credentials in TC-Python or TC-Toolbox. They are accessed from the **Miscellaneous** folder.

- pyex_M_04_license.py
- matex_M_04_license.m

Noble Metal Alloys Model Library

- PM_Noble_01_Color_Prediction.tcu

Updated Examples

Thermo-Calc

- Thermo-Calc Graphical Mode T_05 example. Removed the DIAMOND_FCC_A4 from the calculation of the metastable Fe-C phase diagram.
- Thermo-Calc Console Mode tcex32 updated to use TCOX12, tcex10 updated to use TCOX13 (as it will be very different from earlier versions).

Additive Manufacturing Module

- AM_06a and AM_06b updated with new absorptivity settings and adjustments

Diffusion Module (DICTRA)

- DICTRA Console Mode exb2, exc2, and exe1 all now use the MFEDEMO database instead of MOBFE4 (which required a license)
- Fixed DICTRA Console Mode example exc2, which was previously not working in 2024b.

Process Metallurgy Module

- PMET_07 updated to use TCOX13

Precipitation Module (TC-PRISMA)

- P_06 is updated to include the new functionality for splitting and sectioning precipitation predictions

TC-Python (Precipitation Module (TC-PRISMA))

- The TC-Python example pyex_P_08_Precipitation_Ni_Al_Cr_NonIsothermal.py is updated to include the new functionality for splitting and sectioning precipitation predictions.

Platform Roadmap and System Requirements

For information about platforms being phased out visit our Roadmap for Platform Support.

For information about disk space requirements for installation and calculations, review the System Requirements page on our website.