Gasifier Training Problem
Part 2: Gridding

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Training Objectives

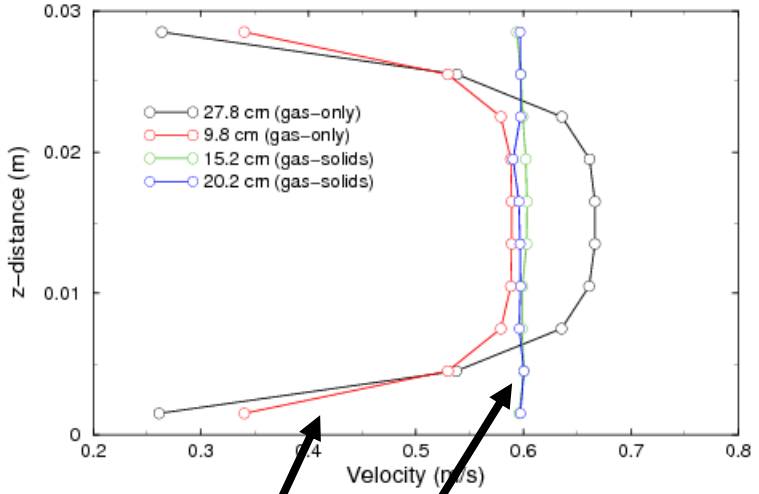
- Introduction to gridding concepts
- CAD requirements and construction
- Barracuda gridding exercise
    - Barracuda Grid Generator window
    - Running the grid generator
    - Using GMV to inspect the grid

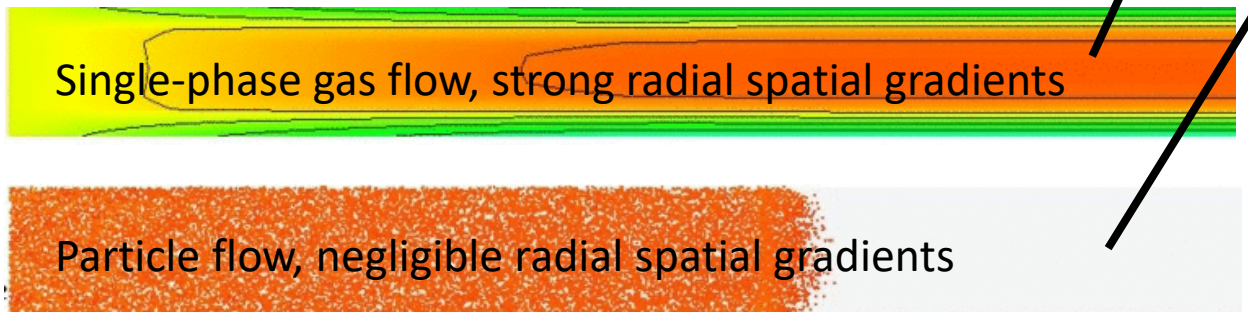
Why a Grid is Needed

- The grid defines the geometry of the simulation.
  - The walls of the vessel being modeled are defined by the outer surfaces of the grid.
  - A finer grid allows you to capture more geometric details.
  - A coarser grid allows for faster simulations.
- Spatial gradients depend on grid size
  - All fluid field properties are calculated on the grid. The grid defines your computational cells.
  - Particles are discrete, but their properties are interpolated to the grid for some calculations (inter-phase interpolation).
  - A finer grid allows you to capture more details of the fluid-particle flow field, such as small bubbles or jets.
  - A coarser grid allows for faster simulations.

How much grid do I need?

- Single-phase fluid flow (e.g. air flow) often requires a fine mesh to resolve near-wall spatial gradients
- The presence of particles, however, tends to break up radial spatial gradients. Thus, when modeling particle flows using a CPFD technology, the resultant computational grid is often much coarser than a corresponding grid for a single-phase, fluid calculation
- The appropriate grid size for a particular geometry will be discussed further as the Barracuda New User Training class progresses.





CAD Requirements

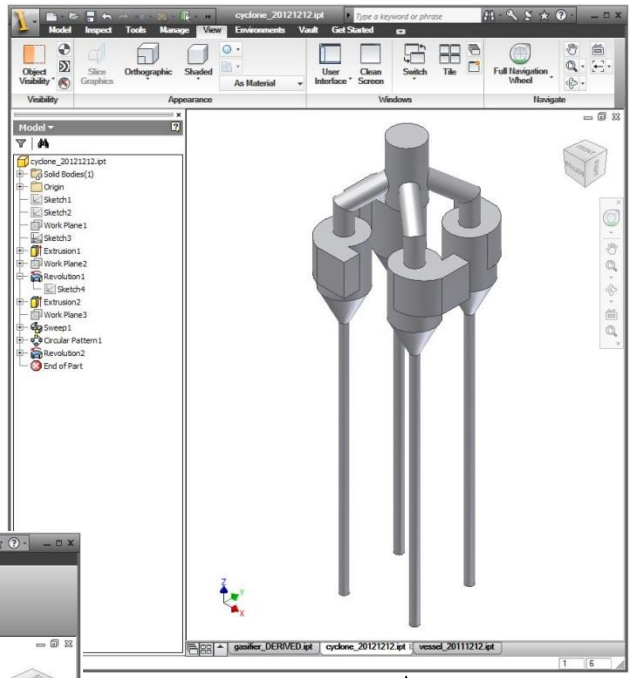
- For Barracuda simulations, we need a CAD model of the internal flow region.
  - Calculations are being performed on the fluid and particles flowing in the vessel, and we need to define the flow region.
- Many CAD designers will give you a thin-walled model of the vessel. But that is not what you want!
  - Imagine that you fill your vessel with water and then freeze it. What we want is a CAD model of the resulting ice.

Cyclones are "subtracted" from the model.

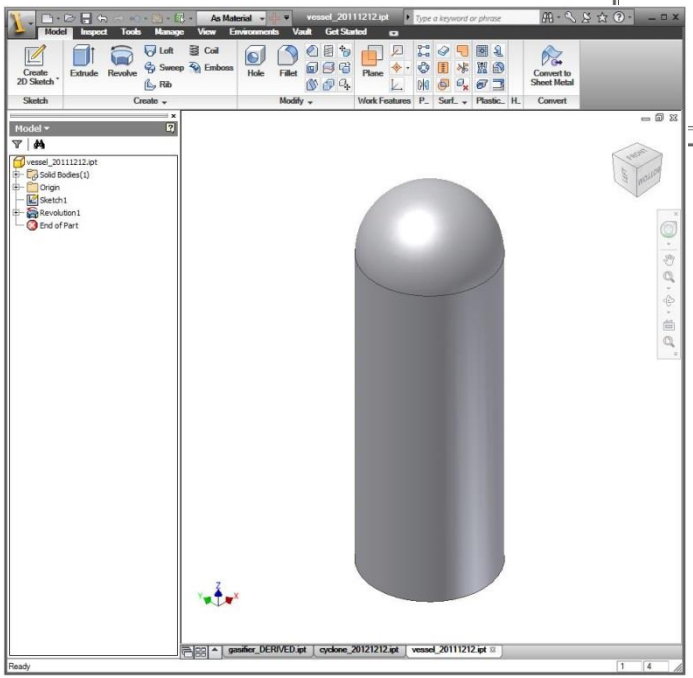
Internal flow region is solid in the CAD model.

CAD – Parts and Assemblies

- For CAD construction, we recommend using a parametric modeling system.
  - Using such a system makes changing the CAD much easier, and changing the CAD is often necessary when simulating several variations of a given system.
- The practice of using parts and assemblies is helpful for complex systems.
  - Basic components are built as “parts” which are then combined into an overall “assembly”.



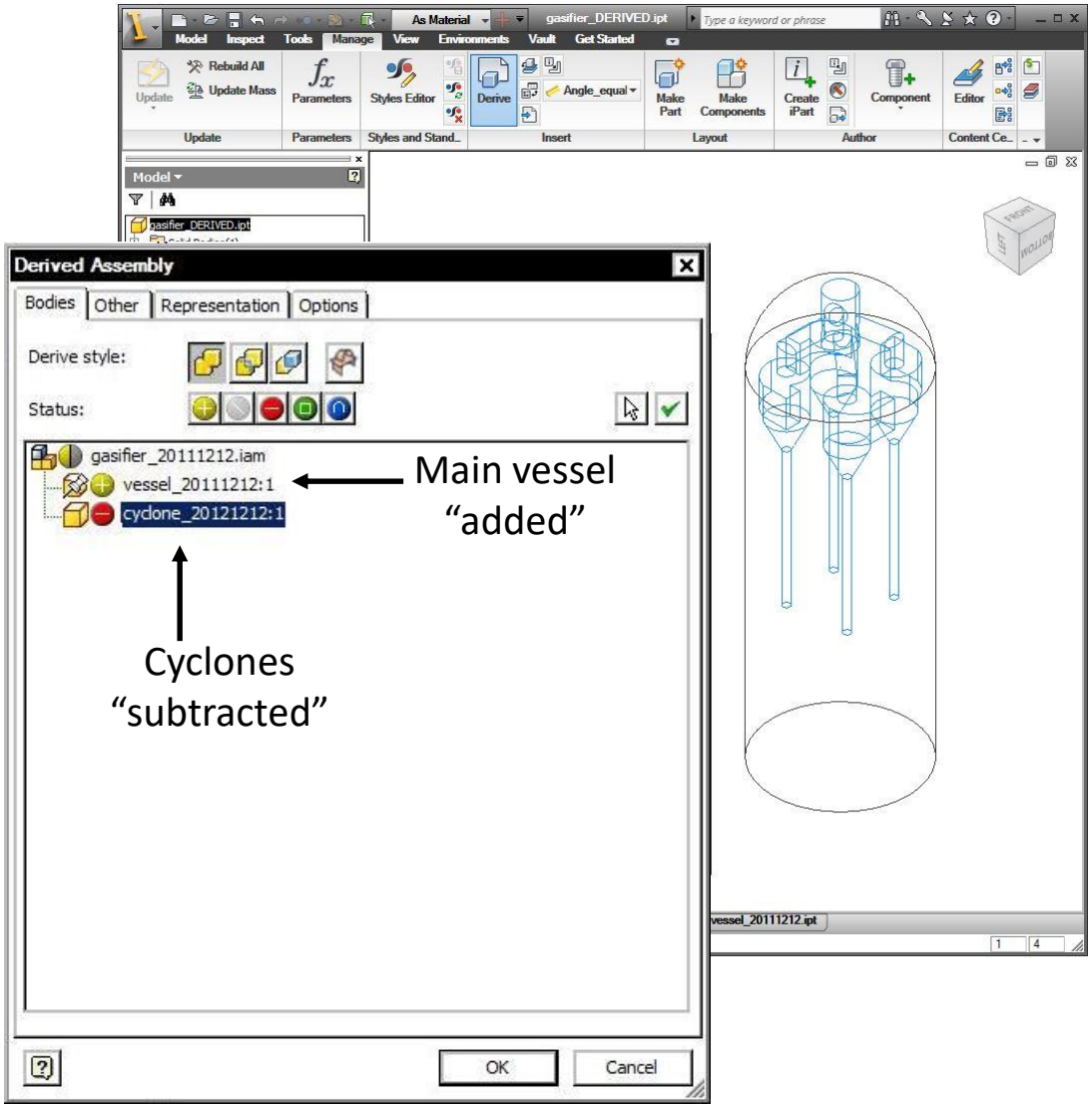
Cyclones part



Main vessel part

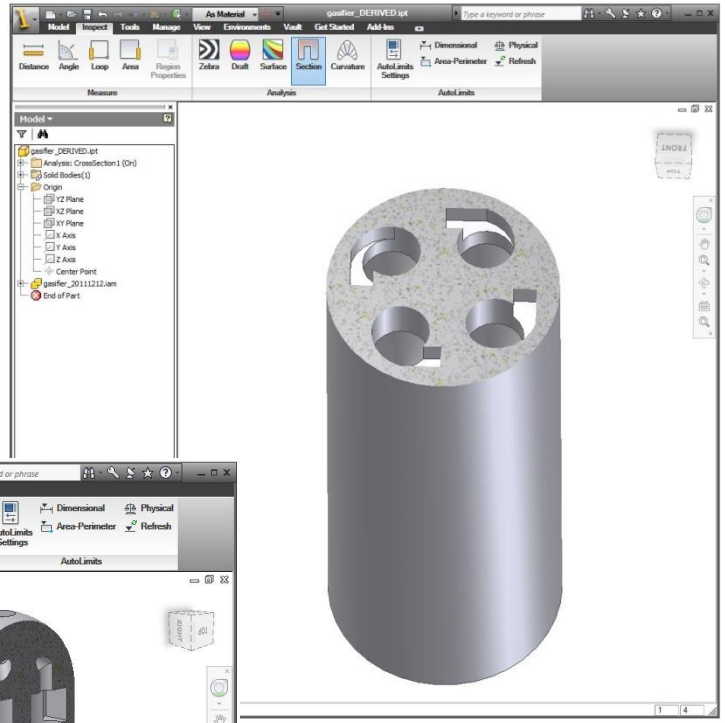
CAD – Subtracting Internals

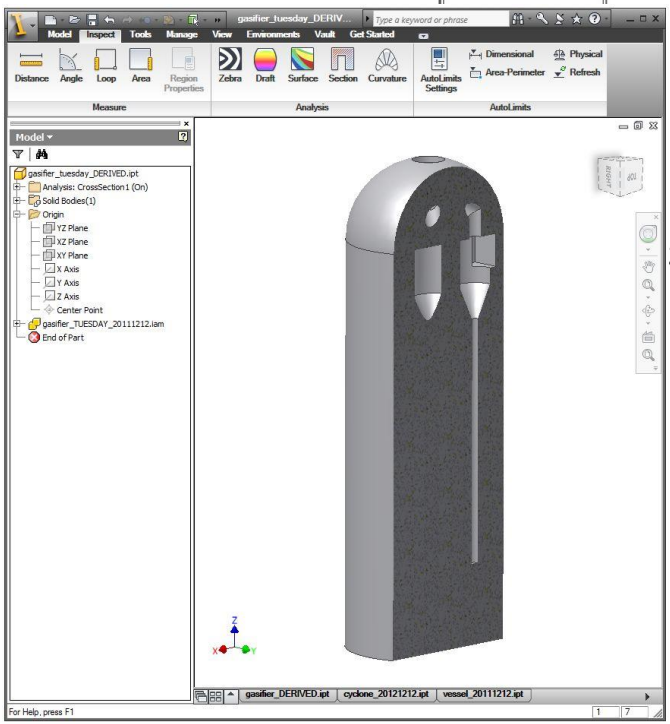
- The final geometry is defined by subtracting individual solid parts from the assembly.
    - The main vessel will typically be the only thing that you keep as a “solid”, and any internal geometry will be subtracted from it.
- In Autodesk Inventor, for example, one can use a “Derived Assembly” to select which parts are added and subtracted from the overall assembly.



CAD – Final Part

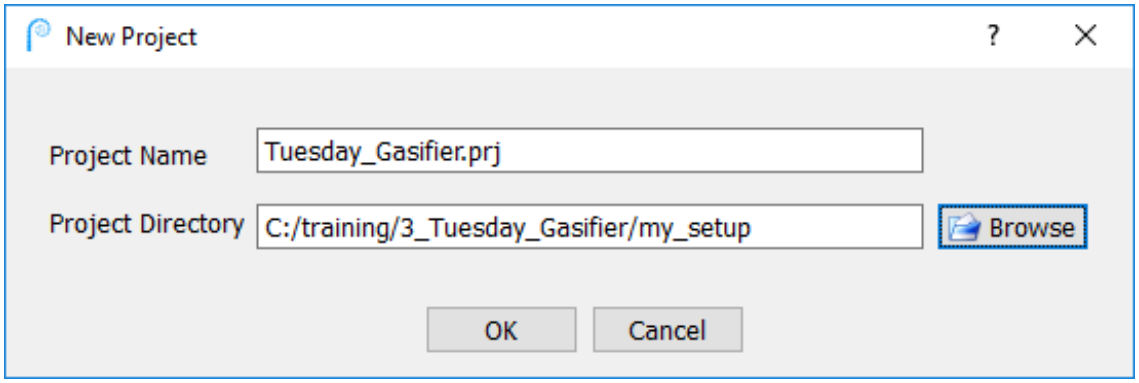
- The cutaway snapshots at right show that the final part is solid in all regions where fluid and particles can flow.
- Internal geometry, such as cyclones, are subtracted from the main vessel.
- Once the final part is complete, it needs to be exported in STL format for use in Barracuda. Both ASCII and binary STL formats are supported, but binary is preferred.





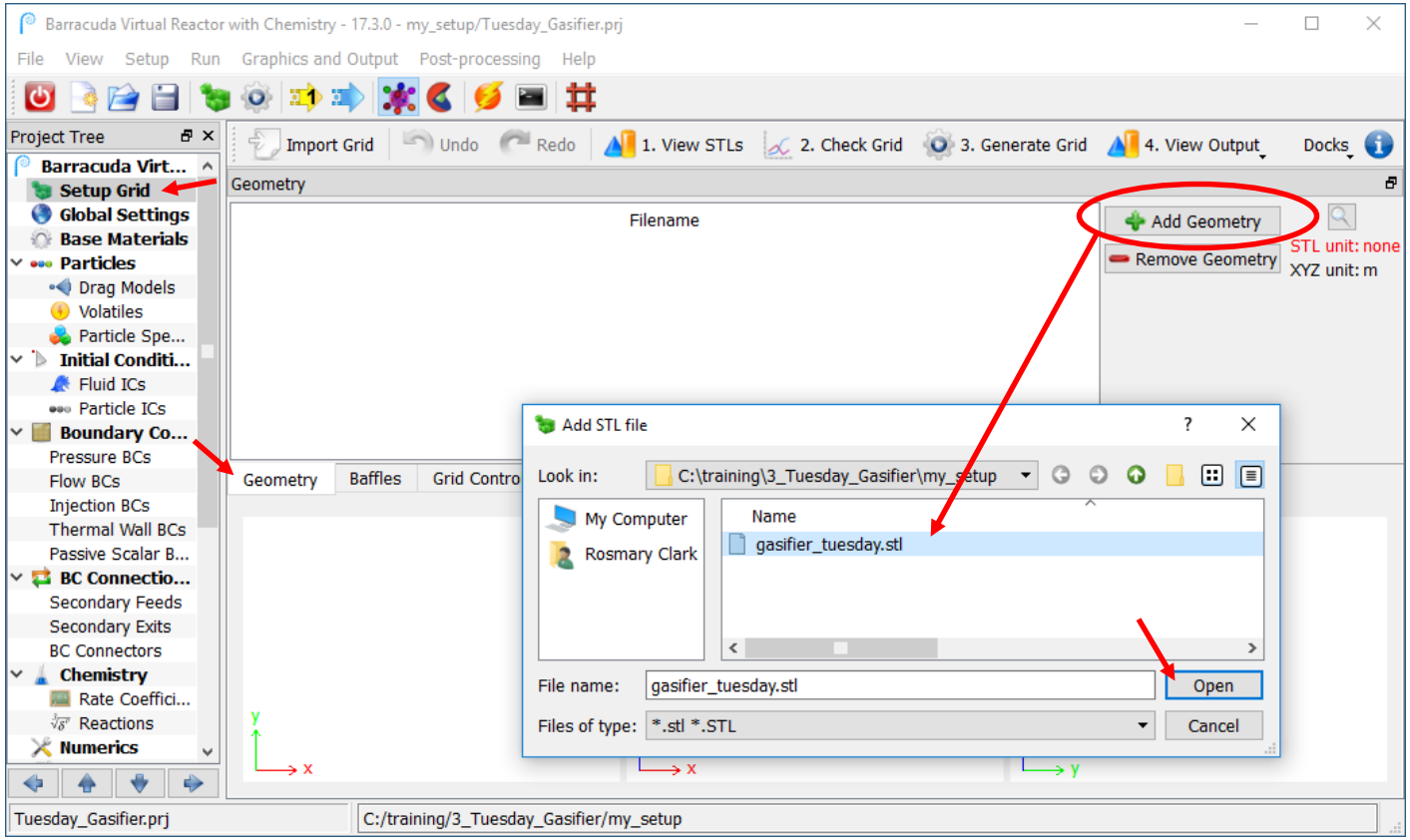
Create a New Barracuda Project

- Launch Barracuda, and create a new project file. Name the project: Tuesday_gasifier.prj
- Work in the directory:
  - Linux: /home/training/barracuda_training/3_Tuesday_Gasifier/my_setup/
  - Windows: C:\training\3_Tuesday_Gasifier\my_setup



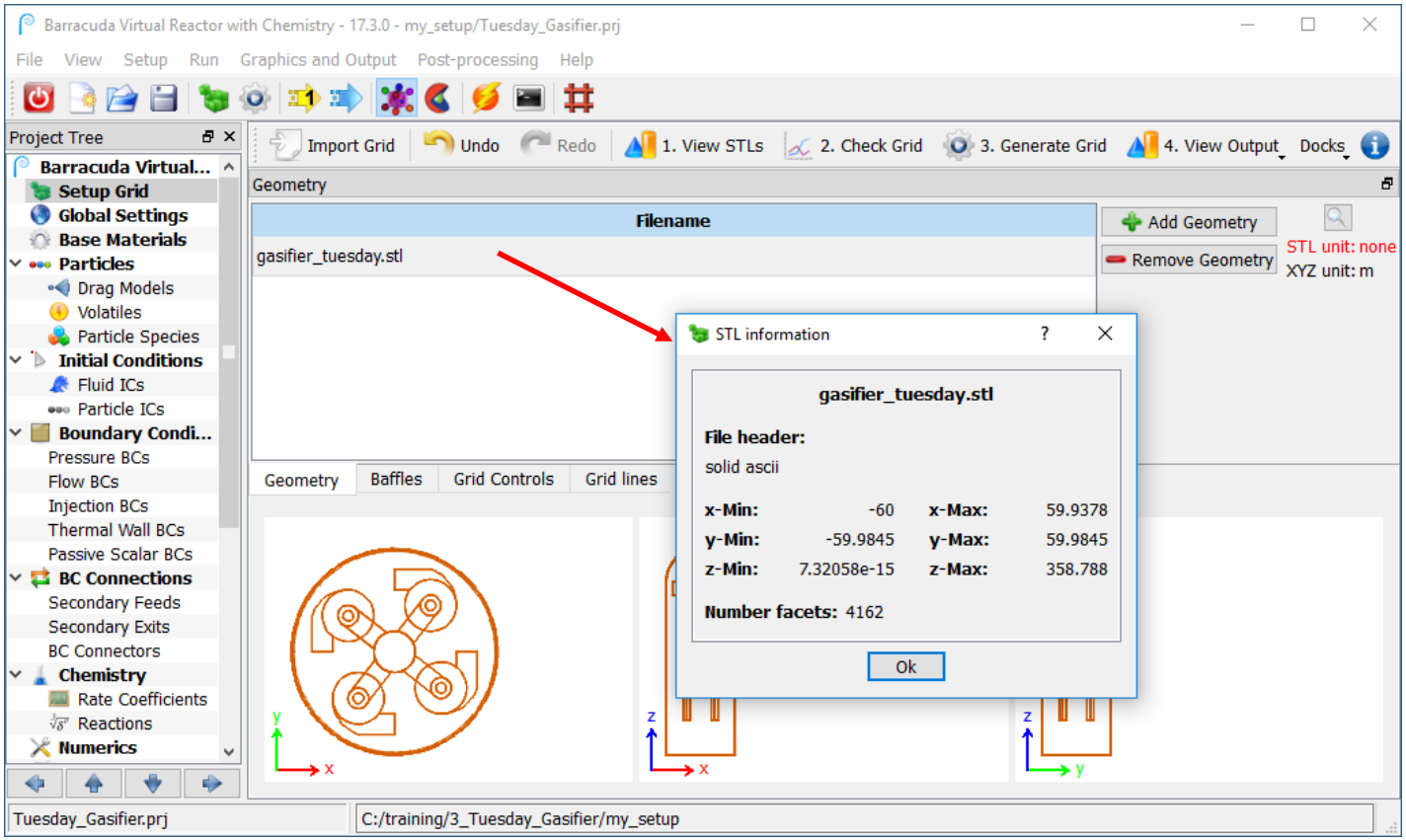
Add an STL File in the Grid Generator Window

- Select **Setup Grid** to enter the grid generator window.
- Click on the **Geometry** tab
- Select **Add Geometry** and use the file browser to select the STL file: **gasifier_tuesday.stl**
- Click **Open**
- It is possible to add multiple STL files to the list, but in this case we only need one file.



Set the Units of the STL File

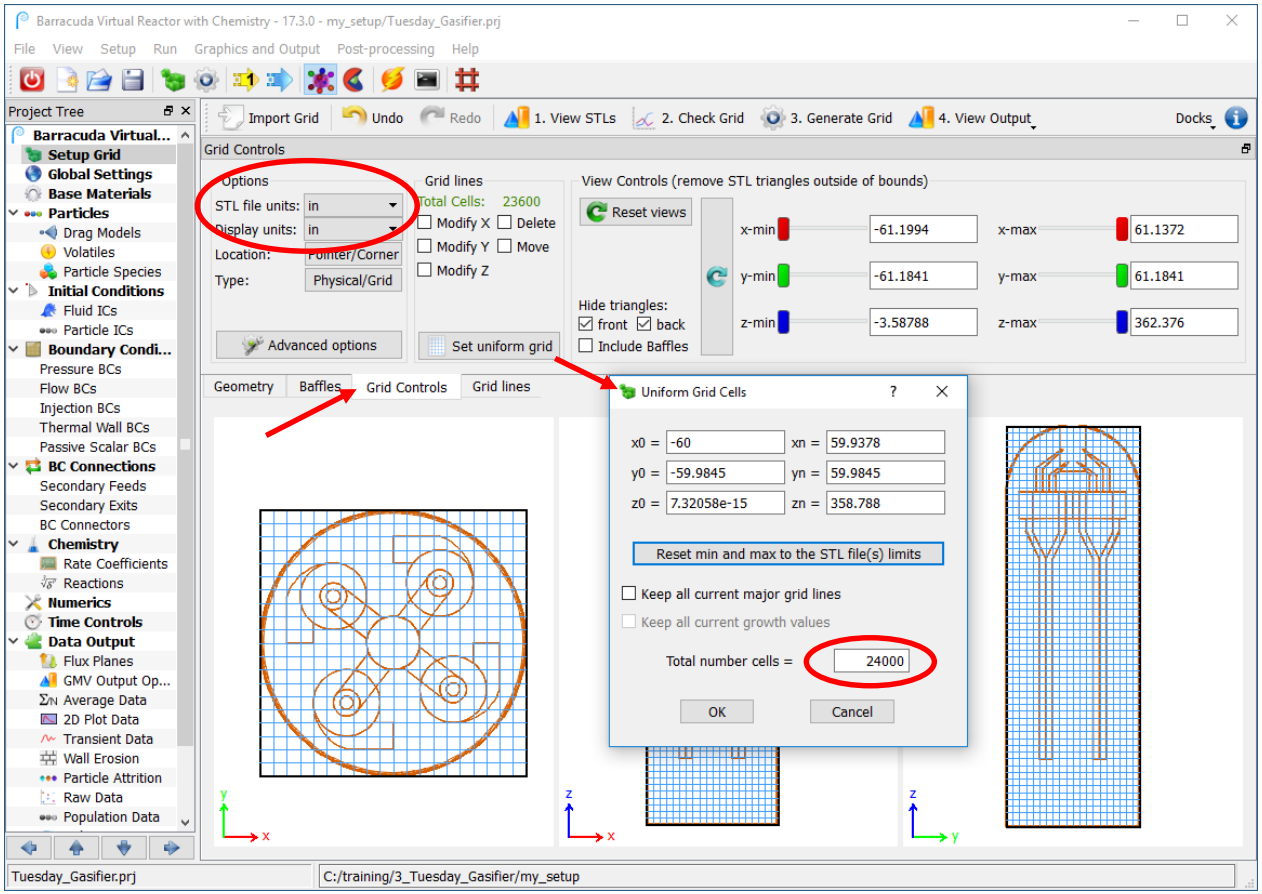
- STL files are unitless. You must tell Barracuda what the physical units of distance are. The units were set by the CAD designer when creating the model and exporting to STL. *It is recommended to check STL units carefully.*
- Double-click the file name of the STL in the **Geometry STL Files** list. This will raise the **STL Information** window.
- The gasifier we are modeling is 10 feet in diameter, but the STL file has x-Min and x-Max values of -60 and +60. So the STL has units of inches. Units are set in **Grid Controls** tab.



Start with a Uniform Grid

- In Barracuda, a uniform grid tends to work best. The strategy we will use for gridding this gasifier is: (1) start with a uniform grid, (2) use the **Split Cells** feature to capture important geometry.

- Click **Grid Controls** tab and first verify that **STL unit** and **xyz unit** are set to “in”. Then click on **Set uniform grid** and enter a value of “24000” cells.
- Click **OK**
- This results in a grid with 20 cells in the x- and y-directions, and 60 cells in the z-direction. The cells are all uniformly sized with side lengths of 6 inches.

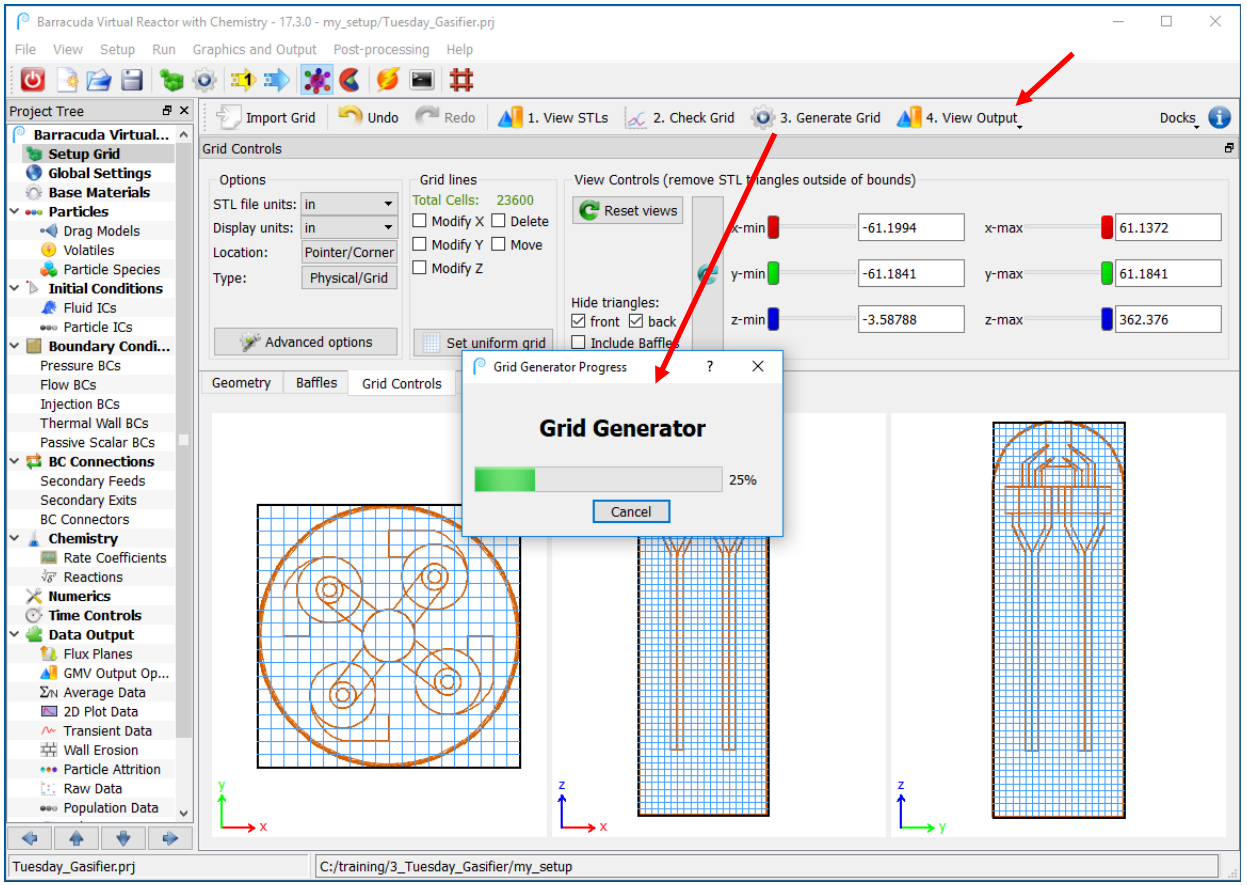


Generate the Grid

- We will need to split the uniform grid at some specific locations to properly capture the internal cyclones. However, it is instructive to generate the grid with the completely uniform cells to see what it looks like.

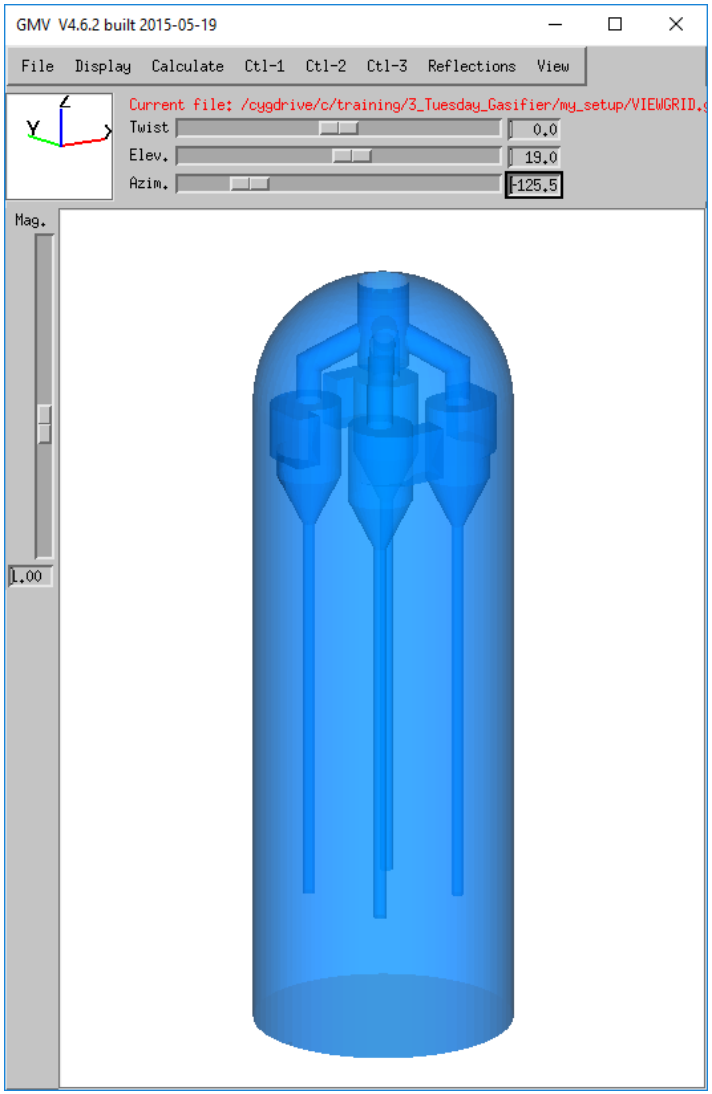
- Click **Generate Grid** and wait for the progress bar to reach 100%.

- When defining a grid, you need to decide if the resulting geometry is close enough to the STL file geometry. We will use several shortcuts under the **View Output** menu to make this decision.



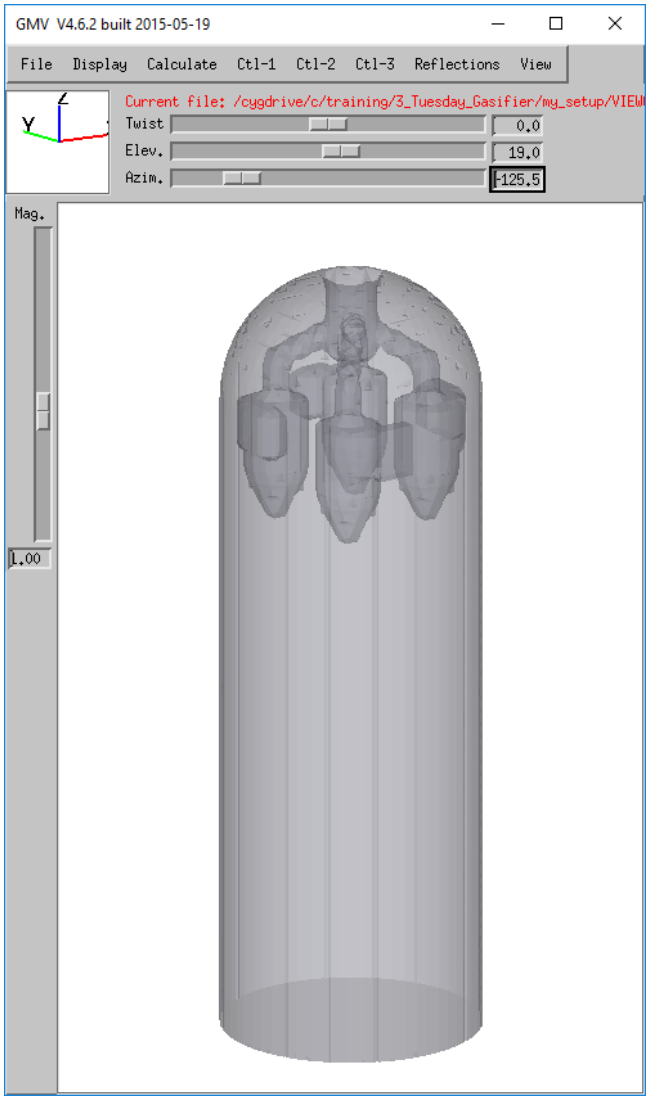
View the Original STL Geometry

- To view the original STL geometry, use the shortcut **View Output, View CAD**.
- This provides a view of the STL before any cells have been created by the grid generator.



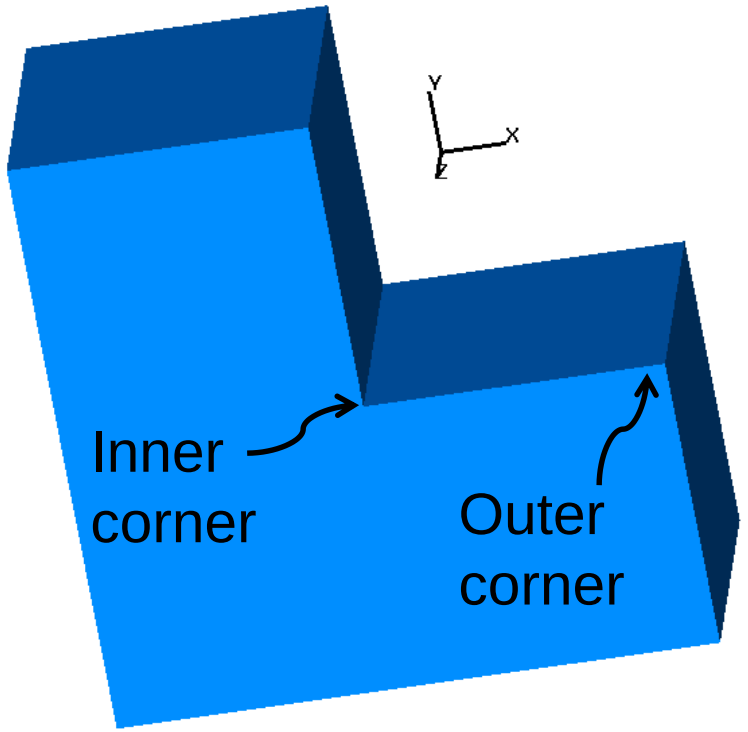
View the Gridded Geometry

- To view the results of applying a uniform grid to the gasifier STL, use the Barracuda shortcut **View Output, View Transparent Model**.
- GMV will open with an transparent view of the computational cells created by the grid.
- Comparing this view with that of the original STL file shows that our completely uniform grid did not capture the cyclone diplegs.
- Also, the cyclone inlet horns, which will be used as boundary condition cells, need to be better resolved.
- With these points in mind, we will return to the grid generator window in Barracuda and modify the grid to better capture the geometry.



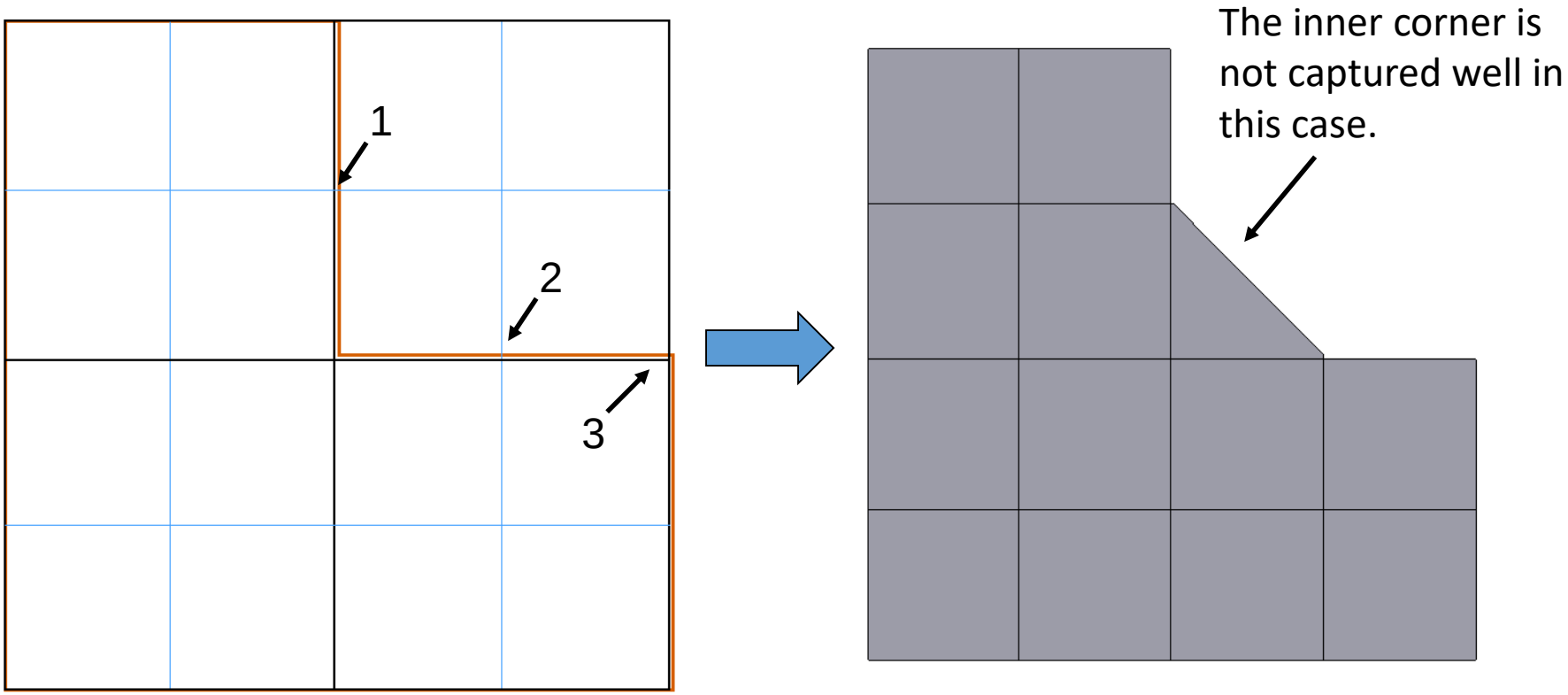
Grid Generator Methodology Example 1: L-Shaped Geometry

- The grid generator works by finding intersections of your defined grid lines with the STL geometry. It then "connects the dots" in 3-dimensional space to create the computational cells.
- Consider the L-shaped geometry shown at right. This is a simple geometry, and it can be used to help us understand how the grid generator works. We will focus on the two corners indicated.
- Three grid variations are shown next:
  - Grid lines placed just inside the solid geometry.
  - Grid lines placed just outside the solid geometry.
  - Grid lines placed specifically to capture both corners well.



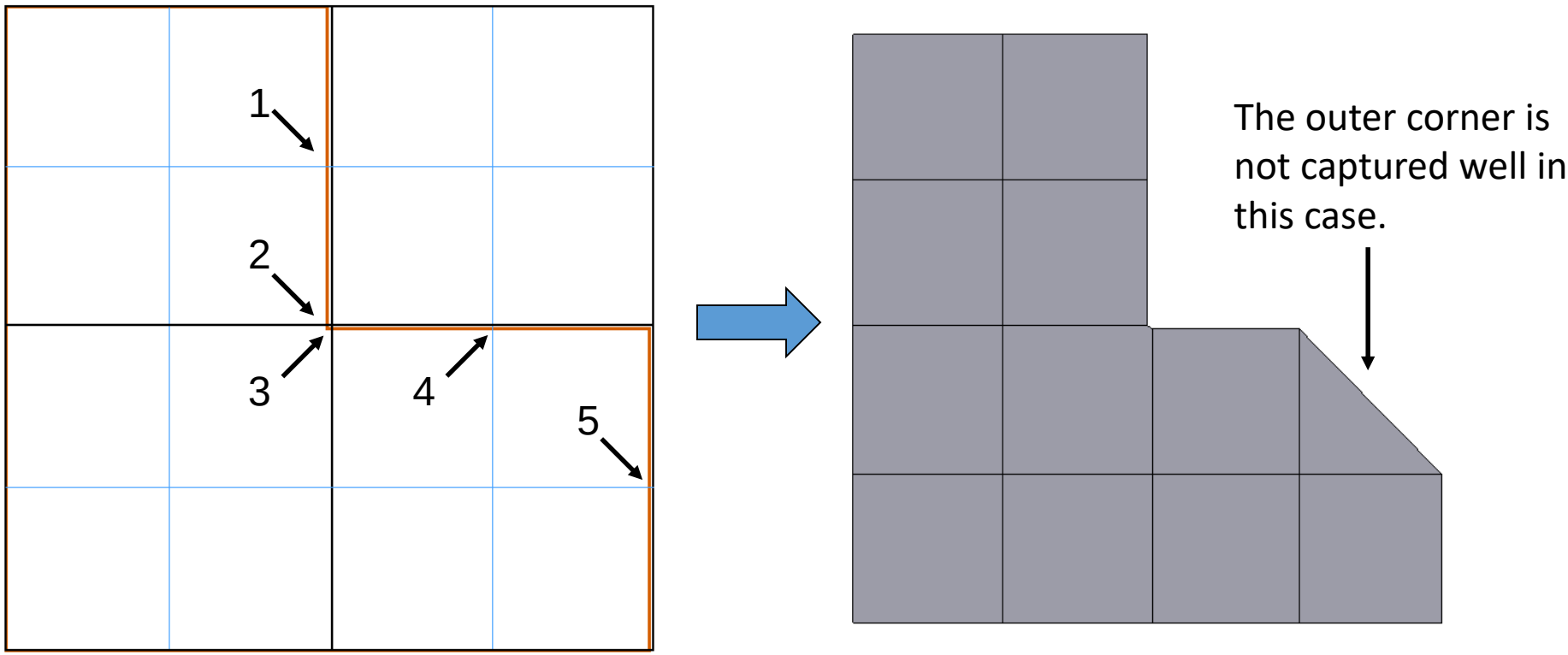
Grid Generator Methodology
Grid Lines Just Inside Geometry

- The grid generator searches for intersections of the grid lines (blue and black lines) with the STL edges (orange lines).
- The intersections found in the case of grid lines placed just inside the solid geometry are shown below.



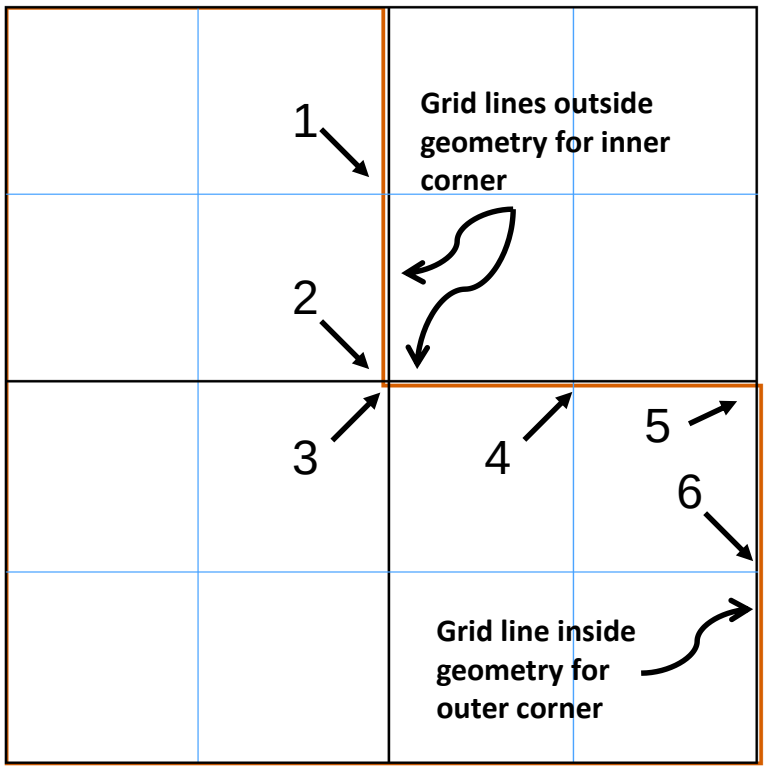
Grid Generator Methodology
Grid Lines Just Outside Geometry

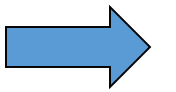
- Moving the grid lines so they are just outside the geometry at both corners of interest changes the results. Now, the inner corner is captured well, but the outer corner is not.

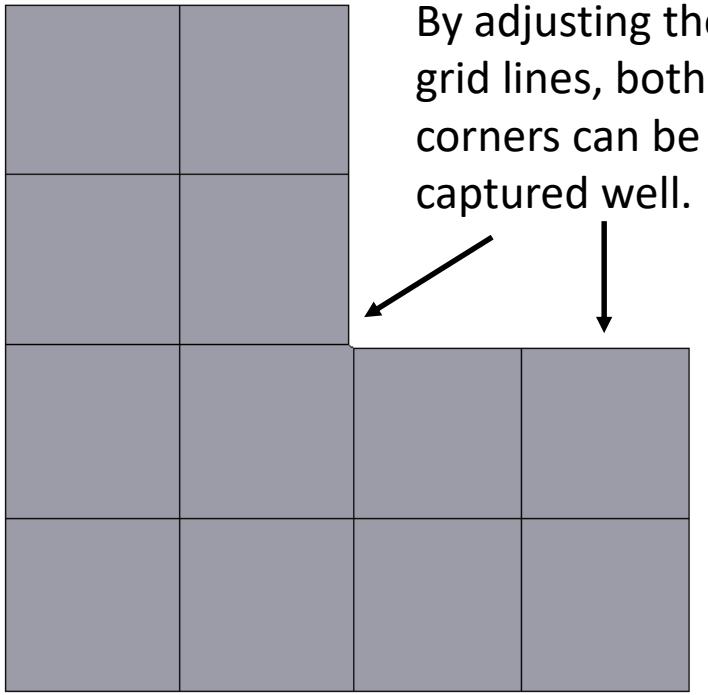


Grid Generator Methodology
Capturing Both Corners Well

- In most cases, you can capture both inner at outer corners simultaneously by placing grid lines in the correct locations (i.e. either inside or outside the geometry). The images below show how to define a grid that captures the L-shaped geometry well at both corners.

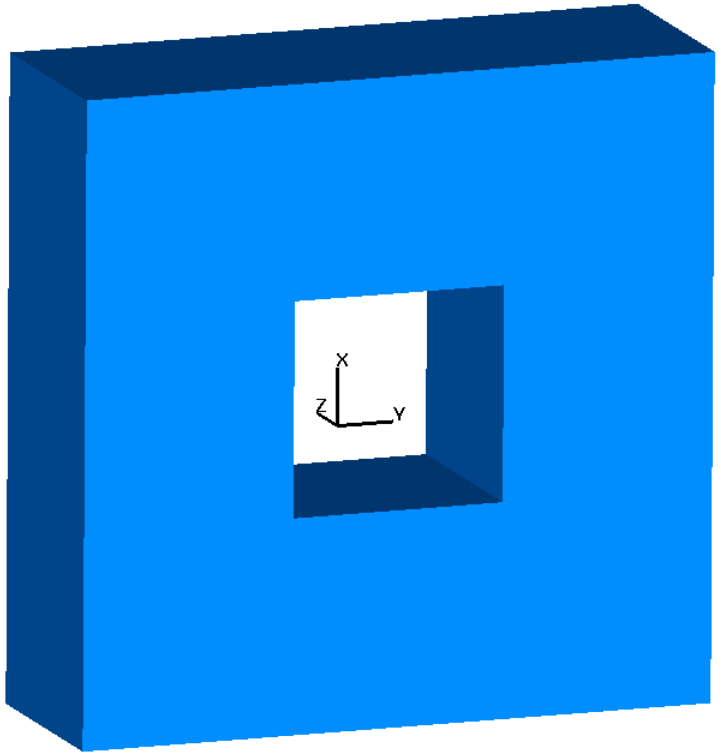






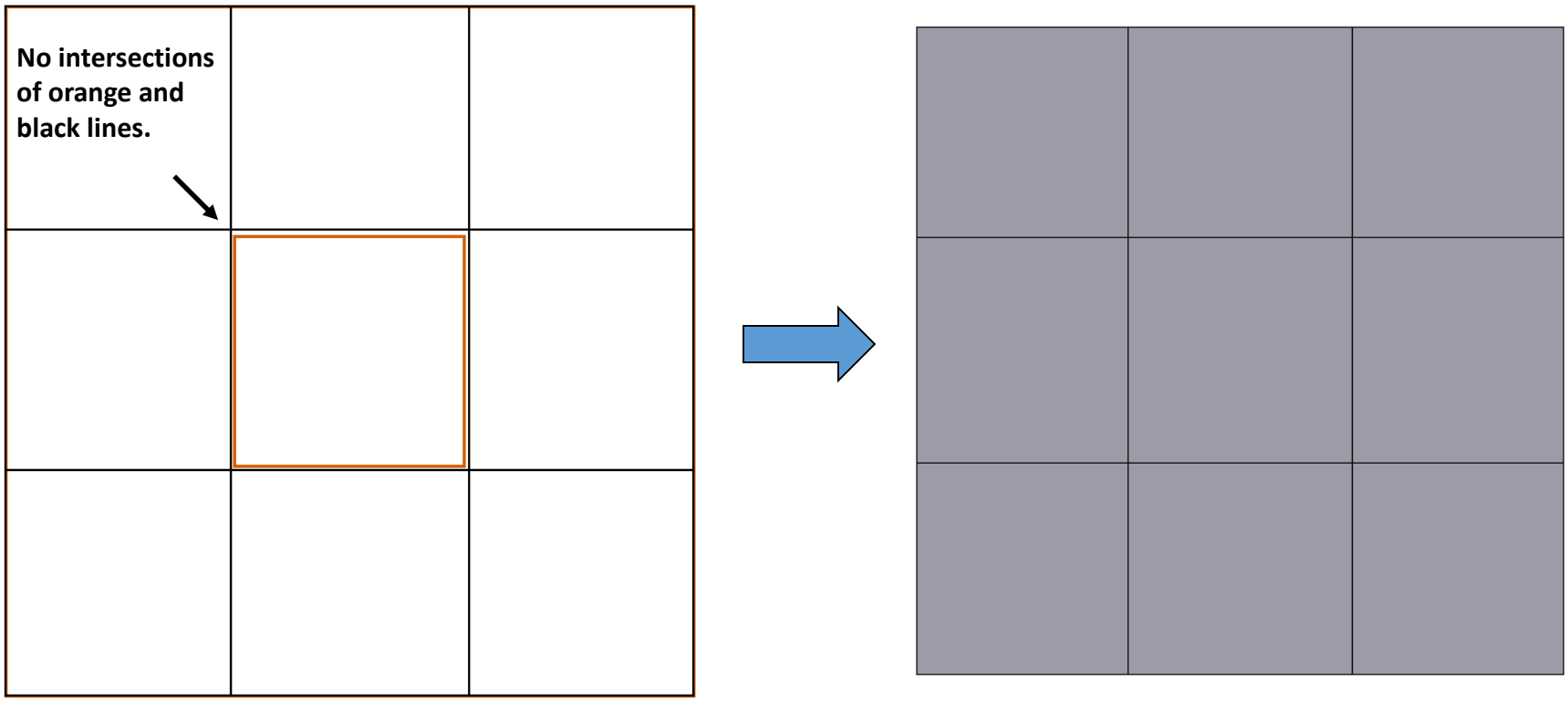
Grid Generator Methodology Example 2: Block with Hole

- A common situation when gridding geometries in Barracuda is that you need to capture “holes”, usually internal structures such as cyclones or spargers that were subtracted from the vessel during CAD creation.
- Consider the square block shown at right, which has a square hole removed from the center.
- Three grid variations are shown next:
  - Grid lines placed just inside the solid geometry (outside the hole).
  - Grid lines placed just outside the solid geometry (inside the hole).
  - Grid lines placed in a “cross shape” across the hole.



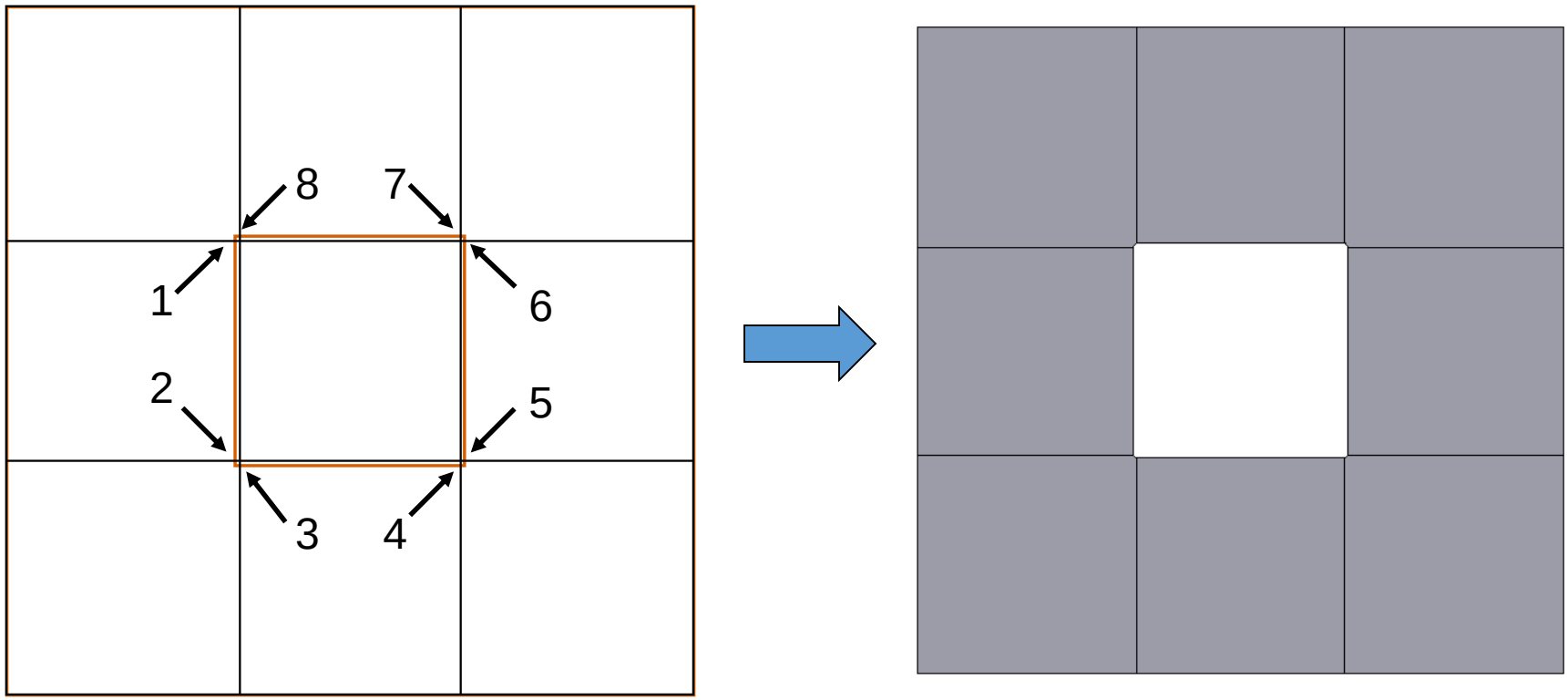
Grid Generator Methodology
Grid Lines Just Inside Geometry

- If all grid lines lie inside the solid geometry (i.e. none cross the edges of the hole), then the hole will not be captured by the grid.
- Since no grid lines intersected the edge of the hole, the resulting grid is completely solid.



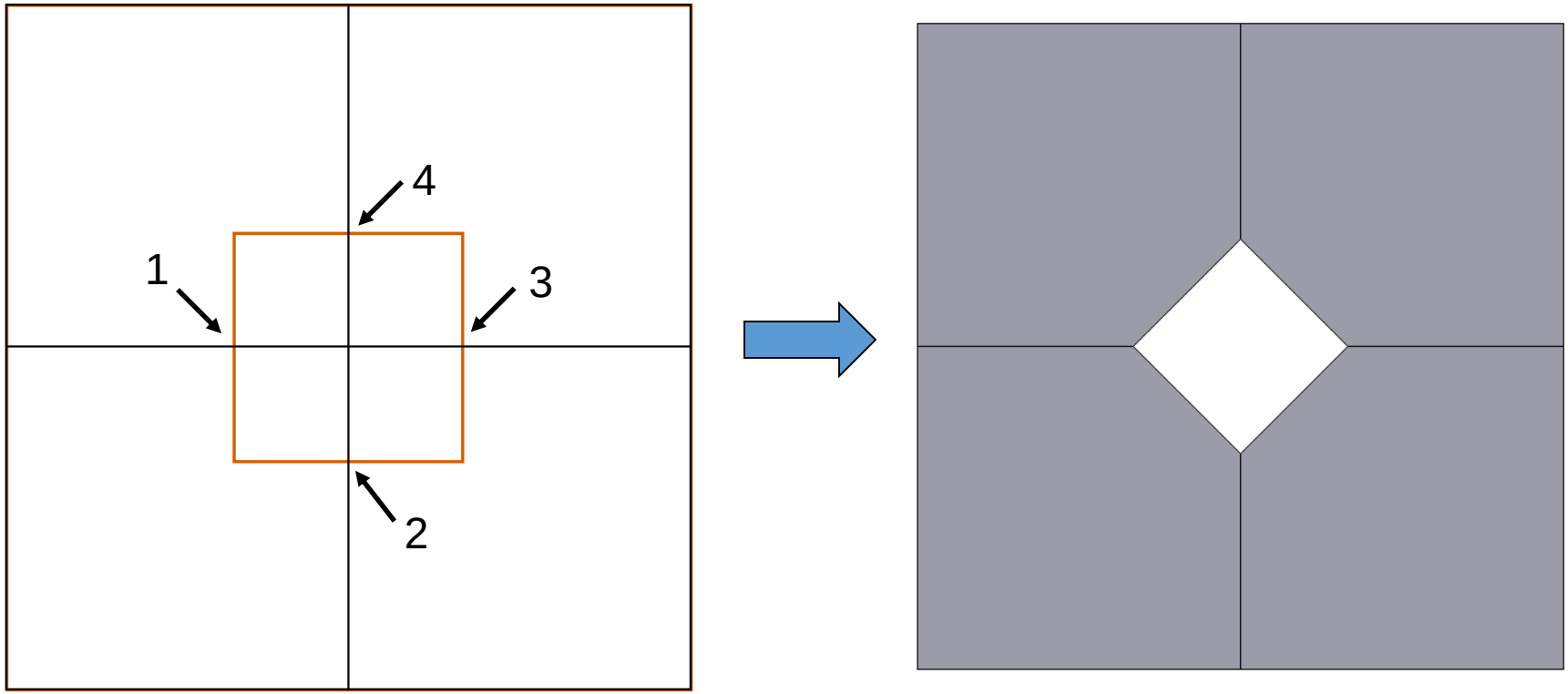
Grid Generator Methodology
Grid Lines Just Outside Geometry

- Since the grid lines are all just outside the geometry (i.e. just inside the hole), there are many intersections between grid lines and STL edges.
- The resulting grid captures the hole very well.



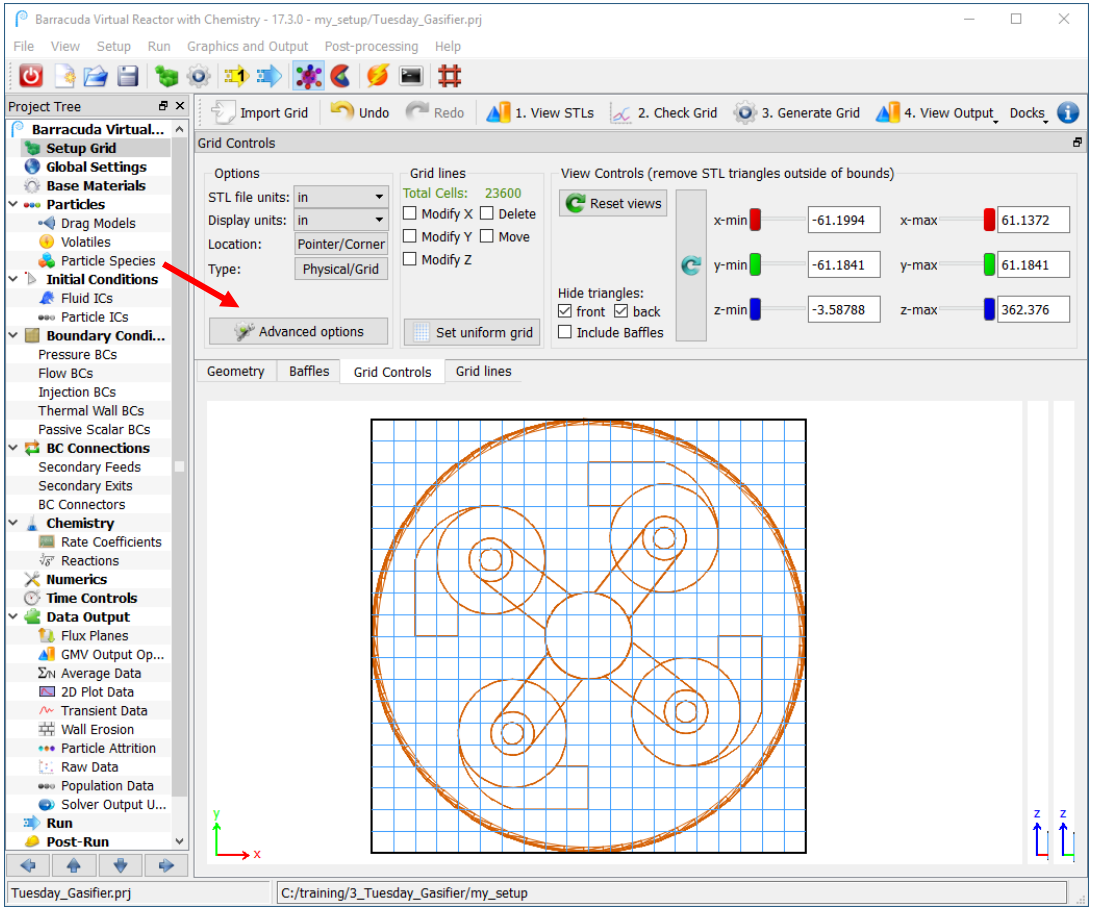
Grid Generator Methodology
Cross Shaped Grid Lines

- In some cases, a geometric feature is so small you can only intersect it with one grid line in each direction, such as the “cross shape” grid lines below.
- The resulting grid has a hole, but it is “diamond” shaped rather than the original square shape. This is because the grid only intersects the STL at four points.



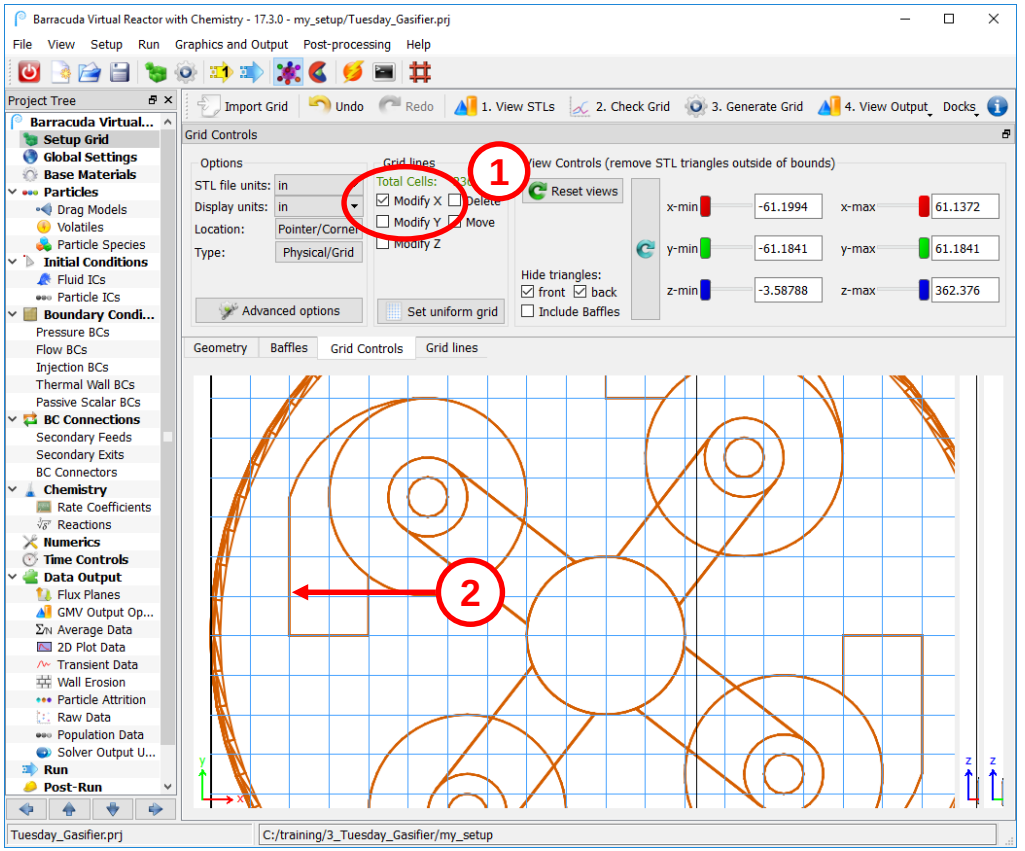
Set View Properties to Make Gridding Easier

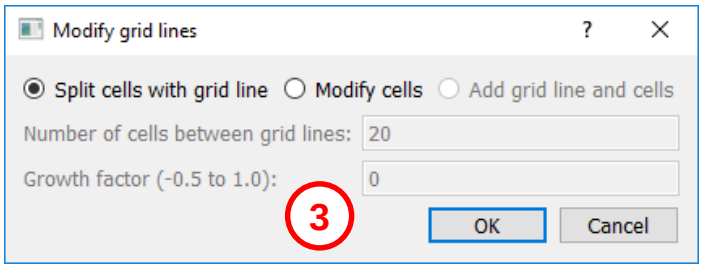
- When modifying the grid, it is helpful to have as clear a view as possible of the geometry that you want to capture. Using the following settings can help:
  - Maximize the Barracuda window so you have a large view of the grid lines
  - Increase the STL line widths by clicking **Advanced Options**, and increasing the value of Pixel width for STL lines (try 2 or 3).



Use Modify x and y to Split Cells

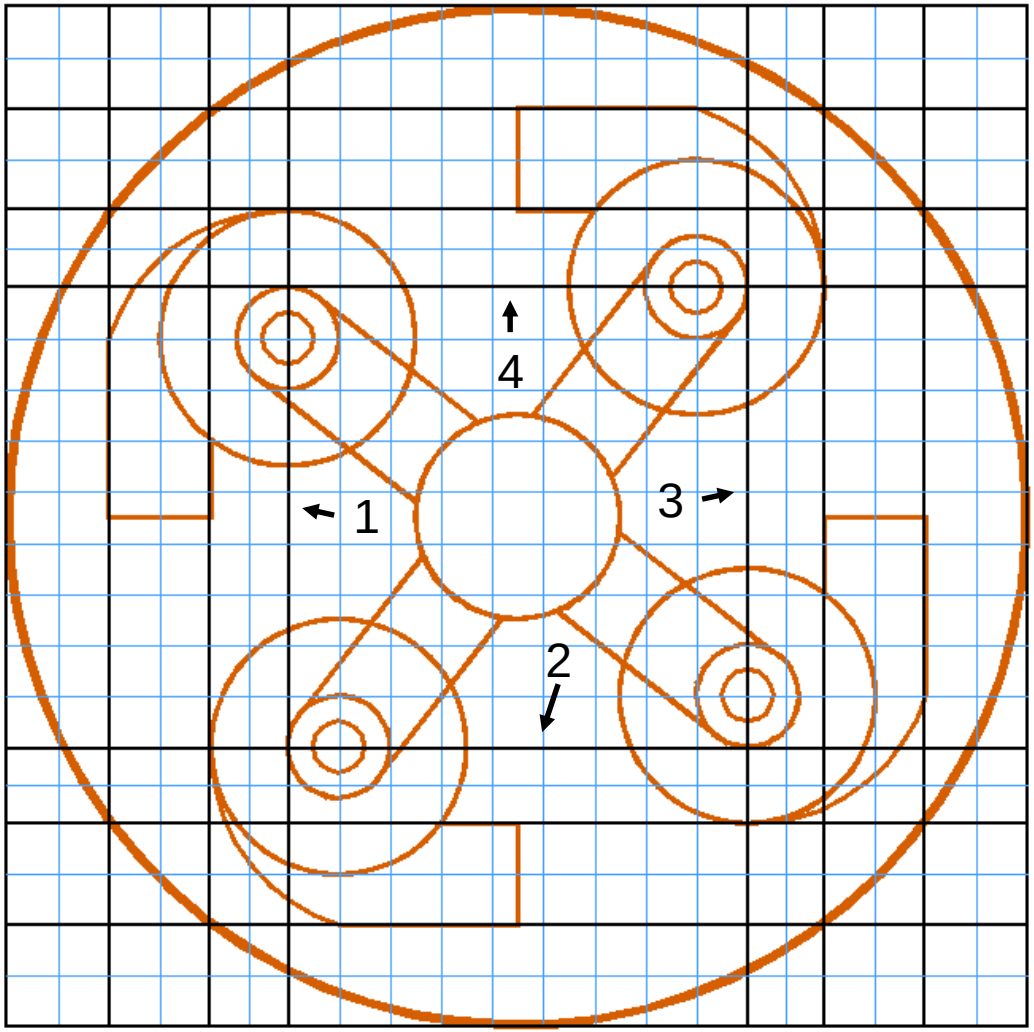
- We will use the method of “splitting cells” to modify the grid. The goal is to keep the overall grid as uniform as possible, while still capturing the important geometry of the gasifier.
- Based on the grid generator methodology shown for the simple L-shaped geometry, split the grid at strategic locations to capture the internal cyclones.
- Start with a top (x-y) view of the reactor. Use **Modify x**, then click just inside one of the cyclone horns. When you click, a pop-up will appear to ask how you want to modify the grid. Choose **Split cells** and click **OK**.
- Repeat this process to outline all 4 cyclone inlet horns.





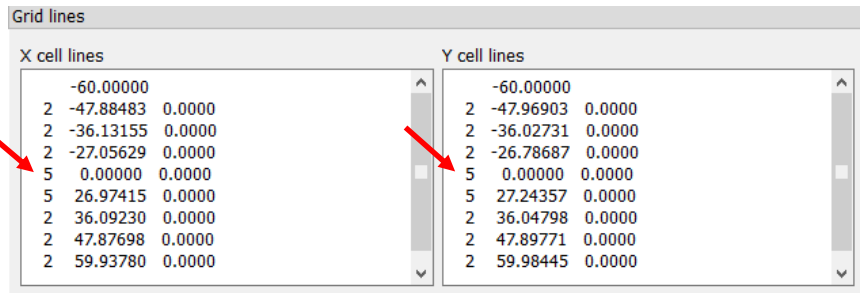
Capture Cyclone Diplegs

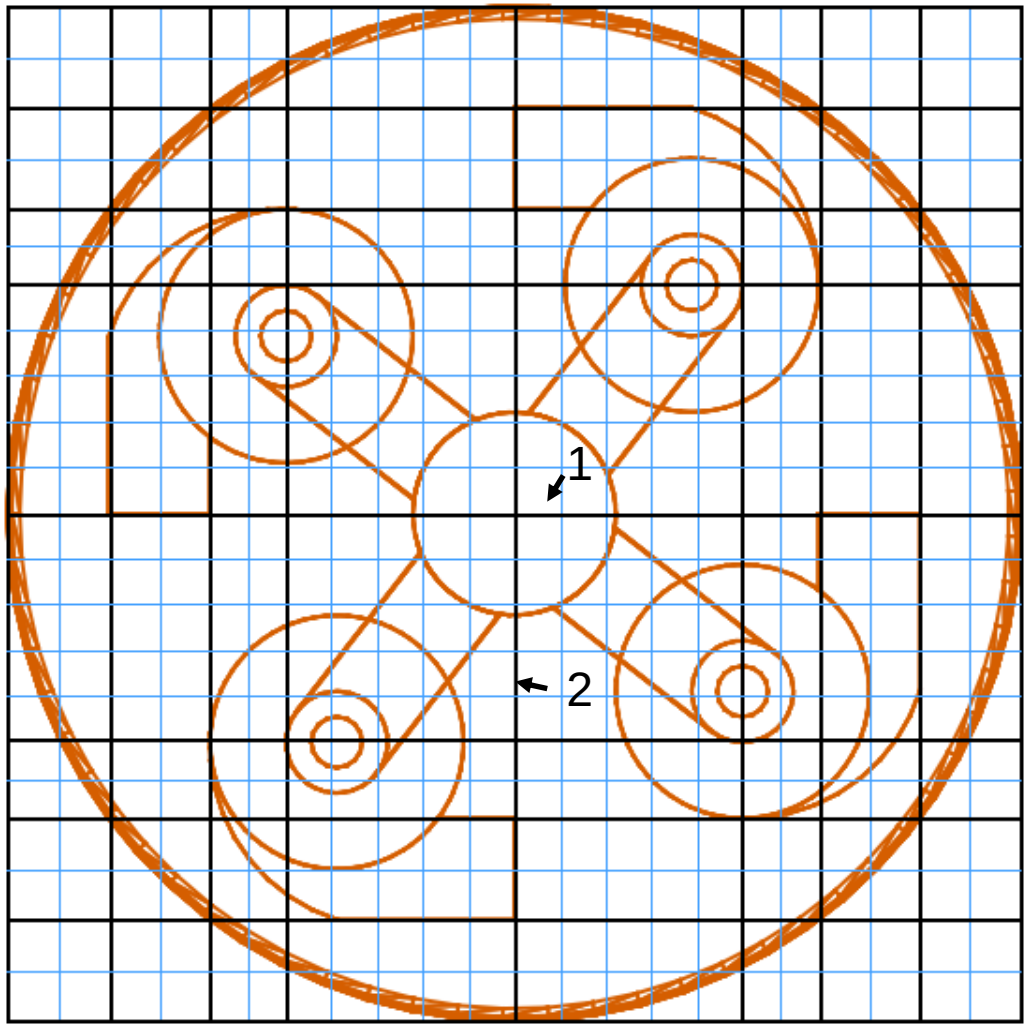
- The cyclone diplegs are almost the same diameter as a typical cell size for this simulation.
- You could capture them with either four grid lines (top, bottom, left, and right), or with two grid lines intersecting in the middle.
- Because of the offset between each dipleg (none of them are exactly horizontally or vertically aligned), using the “cross” method, as discussed on slide 23, is easier in this case.



Capture Cyclone Inlet Horn Faces

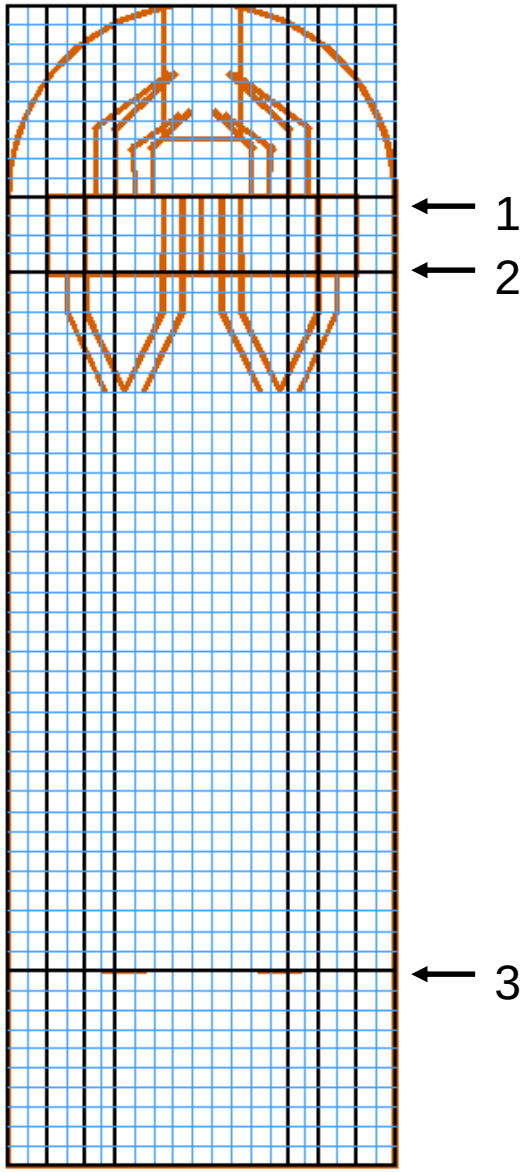
- A pressure BC will be applied to each inlet horn face during project setup, and a full cell is best for this procedure.
- In order to capture a full cell right on the face of the inlet horn, a grid line can be placed at x=0 and y=0.
- To ensure that the lines are placed exactly at the axes, use the **Grid Lines** tab. Change the X-cell lines and Y-cell lines number that is closest to zero to 0. Also check to make sure there is an equal number of cells on either side of the x=0 and y=0 major grid lines.





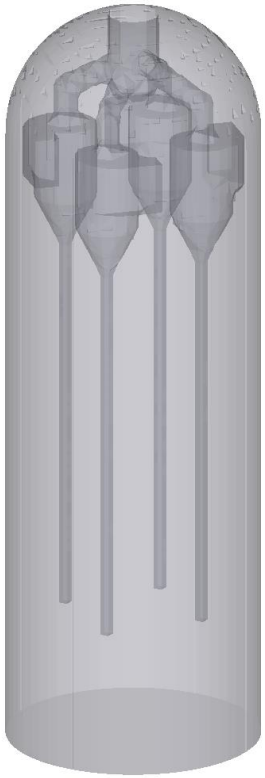
Use Modify z to Split Cells

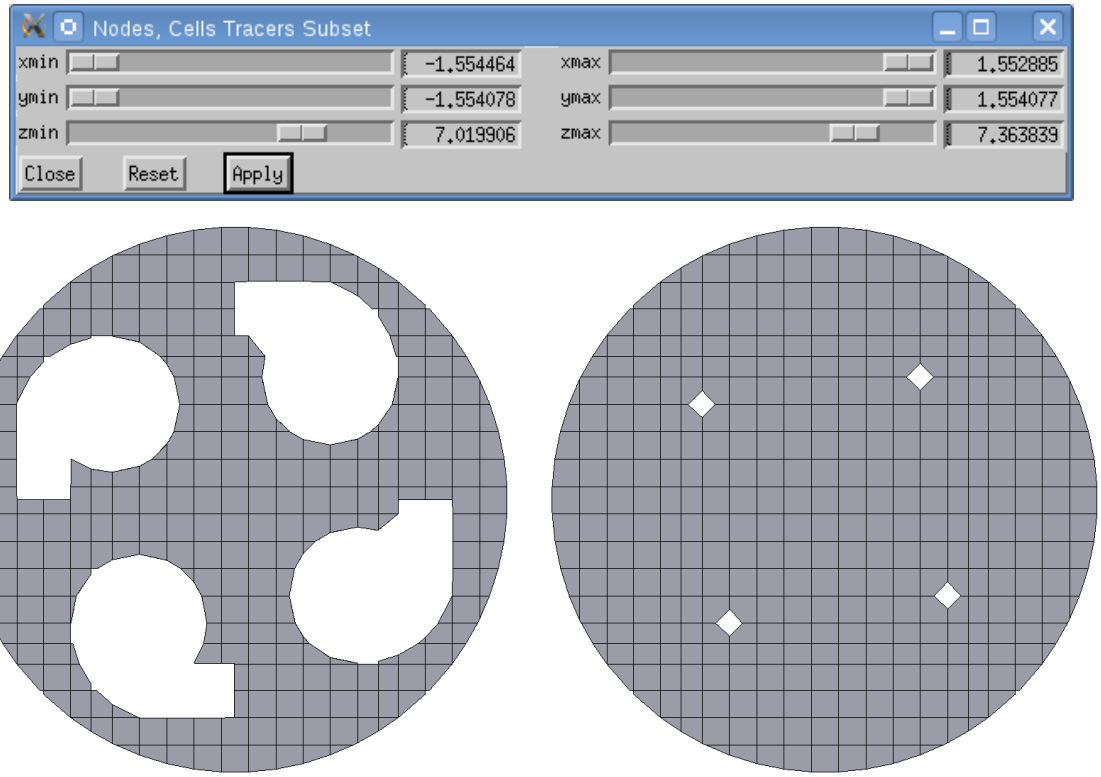
- In the vertical direction, we need to define grid lines in specific locations:
  - The top and bottom surfaces of the cyclone inlet horns.
  - The bottom surface of the cyclone diplegs.
- In the x-z view pane, use **Modify z** to split the grid at the appropriate locations.



Generate the Grid

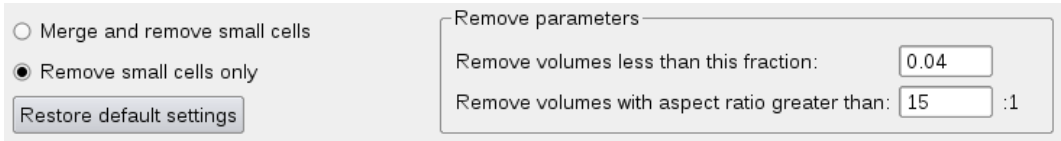
- Click **Generate Grid**, and view the transparent model to see if the geometry was successfully captured.
- Also, use **View Grid**, then apply subset limits in GMV to verify that the cyclone inlet horns and cyclone diplegs were captured.



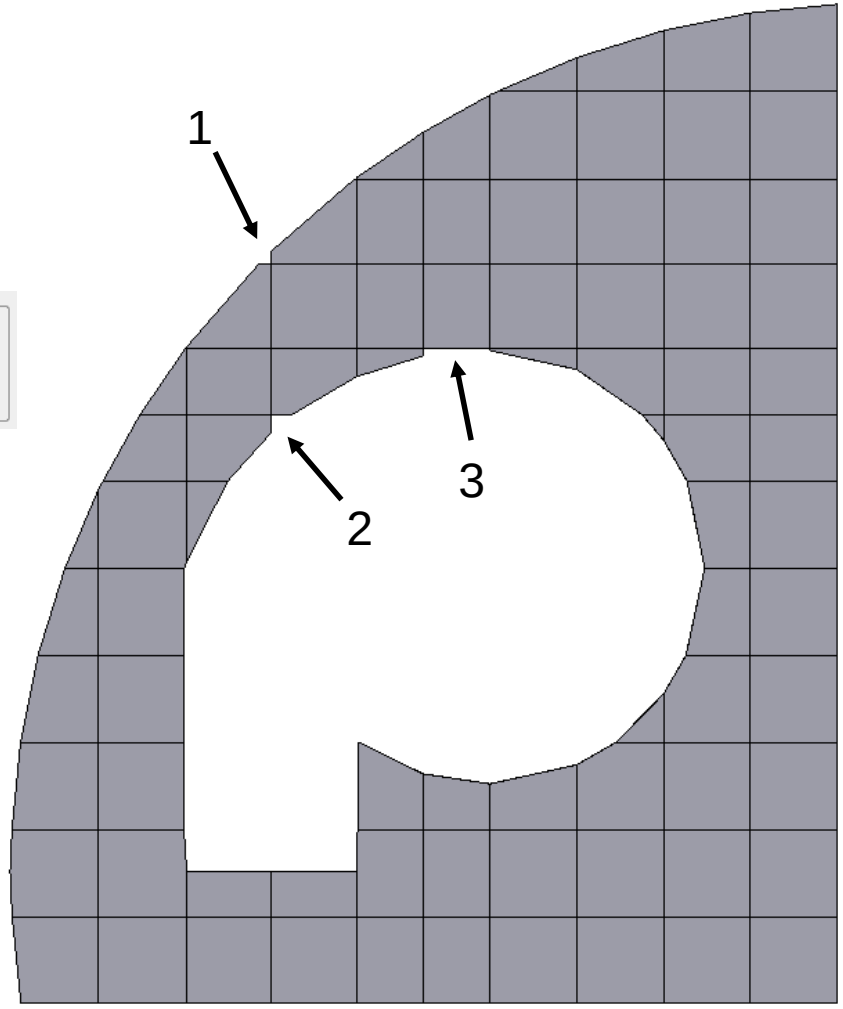


Cell Removal Criteria

- Notice that there are some areas of the gridded geometry that are not as smooth as the original CAD.
- Barracuda has certain criteria for removing cells from the grid. To see the default removal criteria, click **Advanced Options** in the grid generator window.

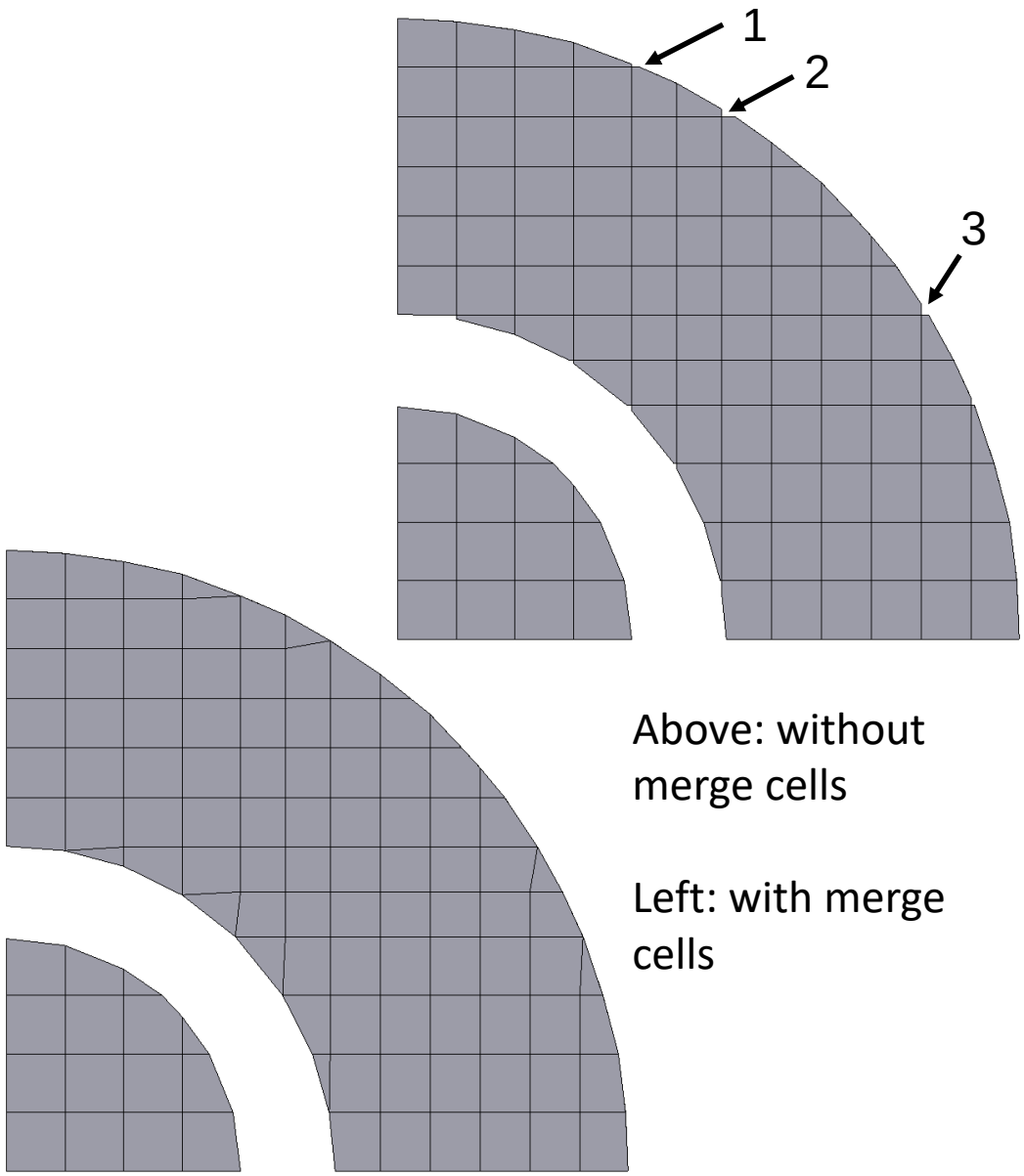


- Removing small cells helps to ensure numerical stability, so it is not recommended that you change the default values. Keeping smaller cells from being removed to make the geometry "look nicer" will not necessarily produce better simulation results. In fact, it could make the simulation run much worse.



When to Use Merge Cells

- In some cases, the types of corners produced by cell removal can be detrimental to the physical calculations of particle flow.
- When simulating the rotational flow of particles within a cyclone, for instance, particles would hit such corners and their momentum would be lost.
- In such cases, using **Merge and Remove** within the **Advanced Options** can help. Cells are “merged” rather than removed by moving their nodes away from their normal Cartesian locations. The missing cell is thus avoided by creating cells that are not perfectly Cartesian in shape.
- In general, the merge option should be used only when necessary.



Above: without merge cells

Left: with merge cells

Grid Review with Instructor

- Review your grid with the instructor.
- Discuss any questions you have regarding the grid generation process used in Barracuda.
- Once you are satisfied with the grid, move on to the project setup assignment.