



Model created in COMSOL Multiphysics 6.4

# Steam Reformer Geometry

## *Introduction*

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Named selections in COMSOL Multiphysics collect geometric entities so that these can easily be reused for any number of model definitions, and are therefore a useful tool for an efficient simulation setup.

The types of selections that are available include the explicit selection features where you can collect individual geometry objects or geometric entities, for example boundaries and edges. You can also create coordinate-based selections to combine entities enclosed by the part of the geometry defined by the volume, area, or interval specified in the selection. You can set up both of these selection types either under the Definitions or the Geometry subnodes of a Component node in a model.

In addition to the selection features that you can add to the model tree, you can configure the features under a Geometry node (that is, the operations in the geometry sequence) to automatically create selections that contain the resulting entities from the operation. Geometry operations can also contribute to cumulative selections that are useful for more sophisticated designs where entirely different definitions of selections may be needed in different branches, which are controlled by If nodes of the geometry sequence.

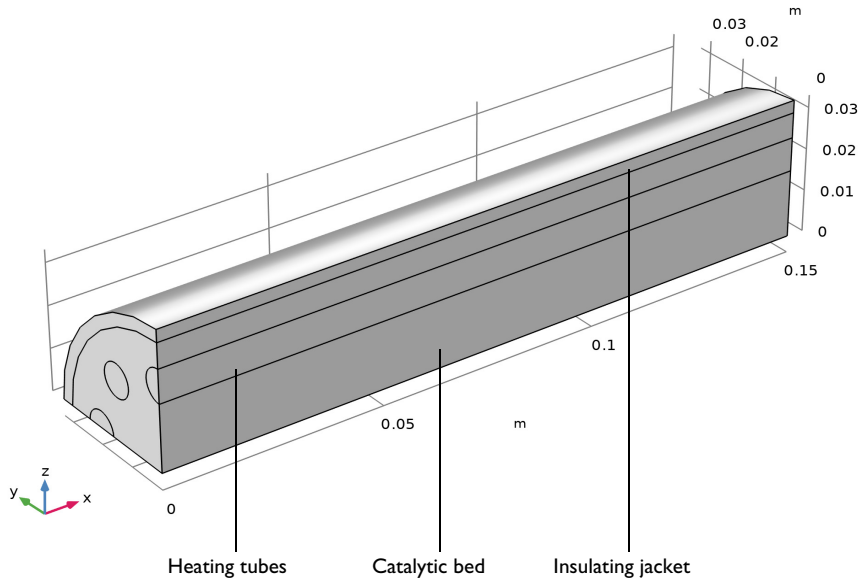
Other selection types include the selection of adjacent geometric entities and Boolean selections, including union, intersection, difference, and complement selections, which can be used to combine any previously defined selections and give you even more flexibility when setting up a model.

Selections that are added under the Definitions node can include geometric entities that exist on the finalized geometry on which you define the physics settings. You can use these selections, for example, for material and physics assignments, when creating a mesh or when creating views for results plots. Selections that you create inside the geometry sequence can, in addition, be used as input to feature nodes downstream of the selection in the sequence. Selections in the geometry sequence thus contain the objects and entities that exist at the current build state of the geometry. They are of help when you want to create robust, parameterized designs in cases when changing parameter values result in significant changes of the topology.

In this tutorial you will leverage selections for creating the parametric geometry for the analysis of a steam reformer and set up the selections needed for the physics definitions. The multiphysics analysis of the steam reformer is described in the model *Steam Reformer* found in the Chemical Reaction Engineering Module Application Library.

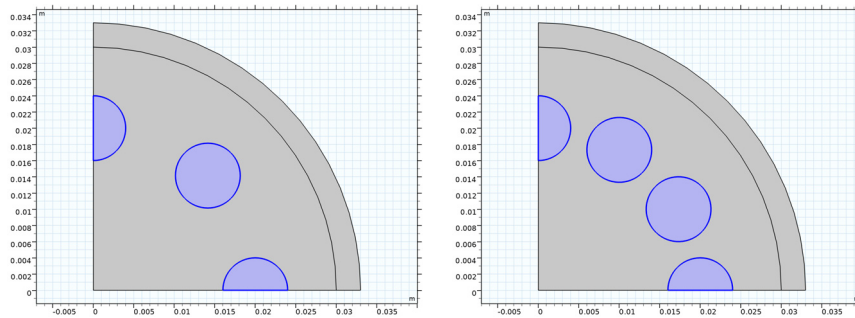
## Model Definition

The geometry that represents a quarter of the steam reformer is shown in [Figure 1](#). For each of the regions shown in the figure we will set up selections that contain the corresponding domains in the geometry. We will also define boundary selections for the inlets and outlets, symmetry boundaries, and the interfaces between the domains.



*Figure 1: Steam Reformer, quarter.*

To create the geometry, you start by drawing the cross section on a work plane; see [Figure 2](#), where the number of heating tubes is parameterized.



*Figure 2: The cross section of the steam reformer. The number of heating tubes can be changed by a parameter.*

After following this tutorial, you will be able to:

- Create Resulting object selections
- Use selections as input for geometry features
- Create Adjacent selections
- Combine selections with Boolean selections, such as
  - Intersection Selection
  - Difference Selection
- Set up a parameterized geometry where selections are automatically maintained when the topology is changing

This example describes only the process of creating the geometry sequence. For the physics setup, follow the instructions for the model *Steam Reformer* in the Chemical Reaction Engineering Module Application Library.

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**Application Library path:** COMSOL\_Multiphysics/Geometry\_Tutorials/  
steam\_reformer\_geometry


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### *Modeling Instructions*

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From the **File** menu, choose **New**.

## NEW

In the **New** window, click  **Blank Model**.

## GLOBAL DEFINITIONS

*Parameters 1*

- 1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.
- 2 In the **Settings** window for **Parameters**, locate the **Parameters** section.
- 3 In the table, enter the following settings:

Name	Expression	Value	Description
L	0.15[m]	0.15 m	Bed length
jr	33[mm]	0.033 m	Jacket radius
br	30[mm]	0.03 m	Bed radius
tr	4[mm]	0.004 m	Tube radius
nt	8	8	Number of tubes, must be a multiple of four
pt	20[mm]	0.02 m	Distance of tube center from origin



## ADD COMPONENT

In the **Home** toolbar, click  **Add Component** and choose **3D**.


## GEOMETRY 1

Start by drawing the cross section of the geometry on a **Work Plane**.


*Work Plane 1 (wp1)*

- 1 In the **Geometry** toolbar, click  **Work Plane**.
- 2 In the **Settings** window for **Work Plane**, locate the **Plane Definition** section.
- 3 From the **Plane** list, choose **yz-plane**.
- 4 Click  **Go to Plane Geometry** on top of the **Settings** window for **Work Plane**.

*Work Plane 1 (wp1) > Plane Geometry*

In the **Sketch** toolbar, click  **Sketch** to leave Sketch mode and create the geometry by adding the primitive features from the **Work Plane** toolbar.

*Work Plane 1 (wp1) > Circle 1 (c1)*

- 1 In the **Work Plane** toolbar, click  **Circle**.
- 2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.


3 In the **Radius** text field, type jr.

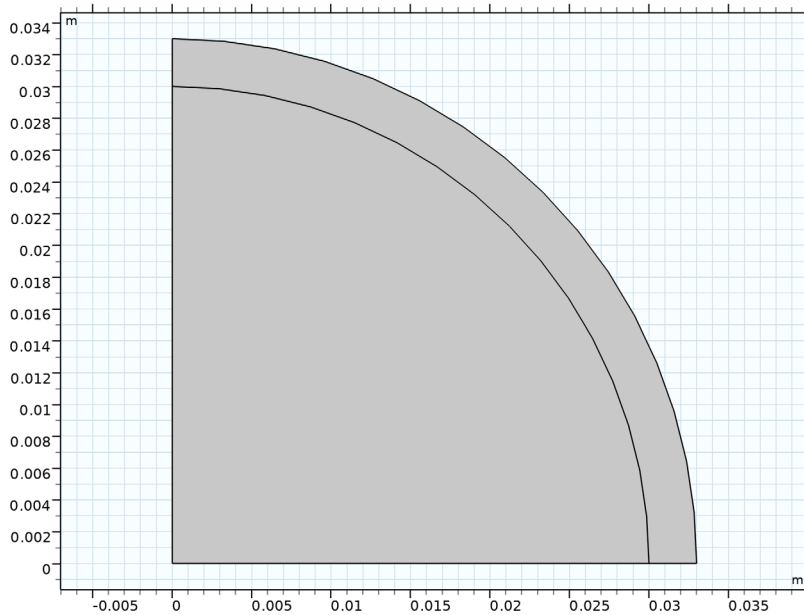
4 In the **Sector angle** text field, type 90.

5 Click to expand the **Layers** section. In the table, enter the following settings:

Layer name	Thickness (m)
Layer 1	jr-br

6 Click  **Build Selected**.

7 Click the  **Zoom Extents** button in the **Graphics** toolbar.



Add another circle to represent a heating tube.

*Work Plane 1 (wpl) > Plane Geometry*

In the **Work Plane** toolbar, click  **Circle**.

*Tubes Outlet*

1 In the **Settings** window for **Circle**, type Tubes Outlet in the **Label** text field.

2 Locate the **Size and Shape** section. In the **Radius** text field, type tr.

3 Locate the **Position** section. In the **yw** text field, type pt.

4 Locate the **Selections of Resulting Entities** section. Select the **Resulting objects selection** checkbox.

5 From the **Show in 3D** list, choose **All levels**.

Using this option, a selection with the name of the node will be available for subsequent geometry operations in the geometry sequence of the work plane and the 3D geometry sequence.

6 Click  **Build Selected**.

Now use the Rotate operation to create a circular array of heating tubes.

*Work Plane 1 (wp1) > Plane Geometry*

In the **Work Plane** toolbar, click  **Transforms** and choose **Rotate**.

*Work Plane 1 (wp1) > Rotate 1 (rot1)*

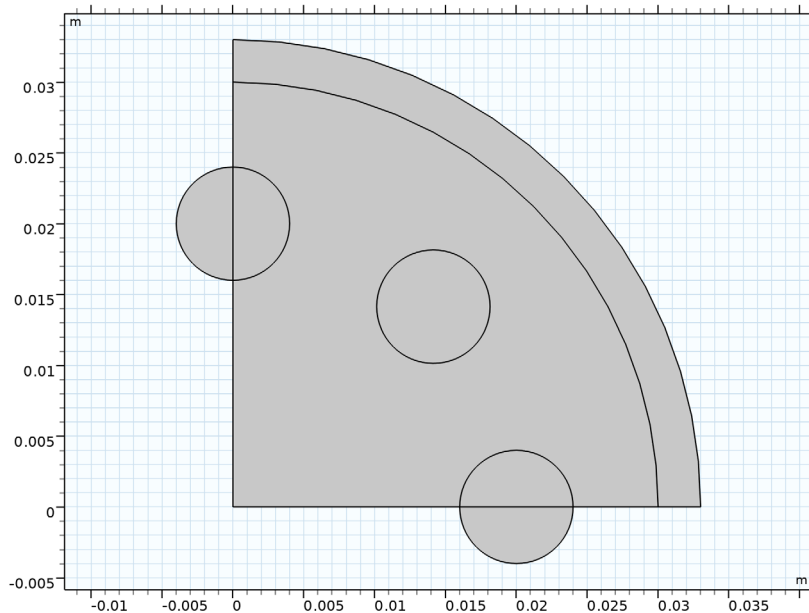
1 In the **Settings** window for **Rotate**, locate the **Input** section.

2 From the **Input objects** list, choose **Tubes Outlet**.



The range operator makes it easy to define the rotation. In this case, the angle between the heating tubes is  $360/nt$  [deg] and we want to generate one quarter of the geometry.

3 Locate the **Rotation** section. In the **Angle** text field, type  $-\text{range}(0, 360/nt, 360/4)$ .

4 Click  **Build Selected**.






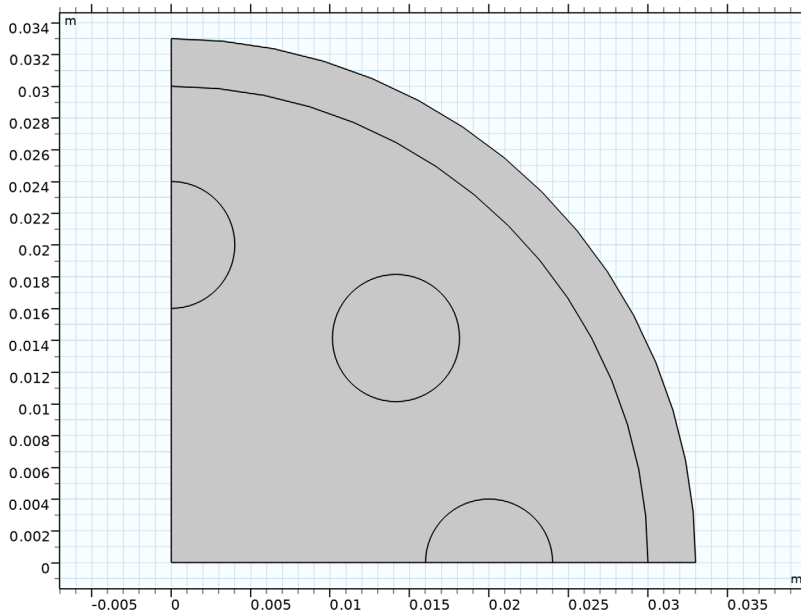
*Work Plane 1 (wp1) > Union 1 (uni1)*

- 1 In the **Work Plane** toolbar, click  **Booleans and Partitions** and choose **Union**.
- 2 In the **Settings** window for **Union**, locate the **Union** section.
- 3 From the **Input objects** list, choose **Tubes Outlet**.
- 4 Click  **Build Selected**.

The **Compose** Boolean operation provides an easy way of combining the geometry objects created so far. An alternative is to use the **Union** and **Intersection** Boolean operations.

*Work Plane 1 (wp1) > Compose 1 (col)*


- 1 In the **Work Plane** toolbar, click  **Booleans and Partitions** and choose **Compose**.
- 2 Click the  **Select All** button in the **Graphics** toolbar.
- 3 In the **Settings** window for **Compose**, locate the **Compose** section.
- 4 In the **Set formula** text field, type  $c1+c1*uni1$ .
- 5 Click  **Build Selected**.

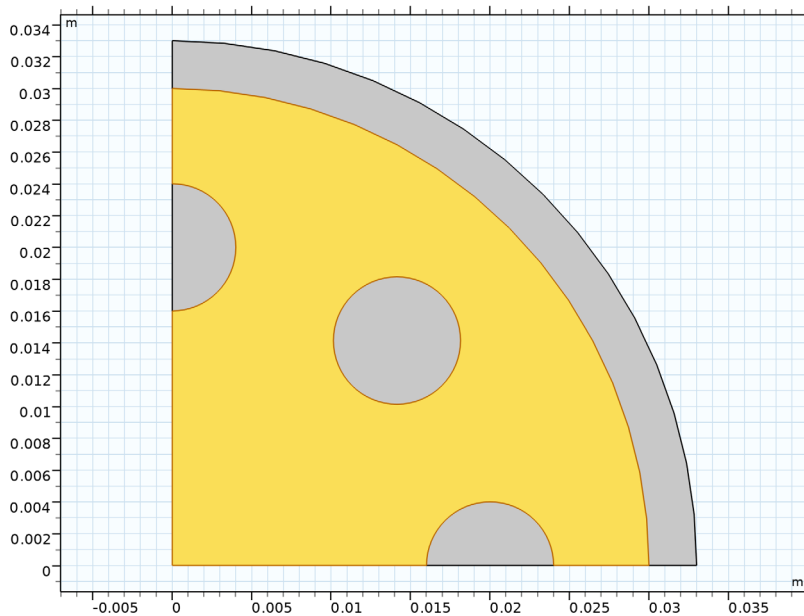


Next, define a selection for the bed inlet. This is the face (domain in the work plane) that is adjacent to the heating tubes.

*Bed Inlet*

- 1 In the **Work Plane** toolbar, click  **Selections** and choose **Adjacent Selection**.

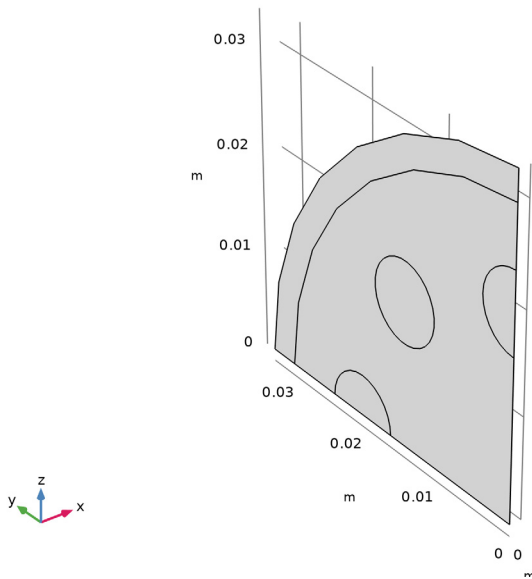
- 2 In the **Settings** window for **Adjacent Selection**, type **Bed Inlet** in the **Label** text field.
- 3 Locate the **Input Entities** section. Click **+ Add**.
- 4 In the **Add** dialog, select **Tubes Outlet** in the **Input selections** list.
- 5 Click **OK**.
- 6 In the **Settings** window for **Adjacent Selection**, locate the **Output Entities** section.
- 7 From the **Geometric entity level** list, choose **Adjacent domains**.
- 8 Click  **Build Selected**.



*Work Plane 1 (wp1)*


- 1 In the **Model Builder** window, under **Component 1 (comp1) > Geometry 1** click **Work Plane 1 (wp1)**.
- 2 In the **Settings** window for **Work Plane**, locate the **Unite Objects** section.
- 3 Clear the **Unite objects** checkbox.
- 4 Locate the **Selections of Resulting Entities** section. Find the **Selections from plane geometry** subsection. Select the **Show in physics** checkbox, to make the selections from the work plane available for the physics setup.

5 Click  **Build Selected**.

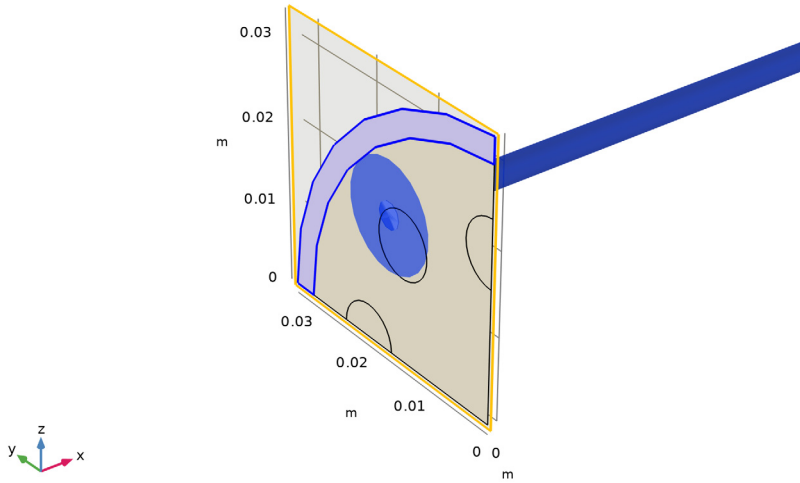


Extrude the faces from the work plane. The label of the feature node becomes the name of the output selection when you use the **Resulting object selection** option for the operation.

#### *Jacket*

- 1 In the **Geometry** toolbar, click  **Extrude**.
- 2 In the **Settings** window for **Extrude**, type **Jacket** in the **Label** text field.
- 3 Locate the **General** section. From the **Extrude from** list, choose **Faces** This is the outer layer of the cross section.
- 4 On the object **wp1**, select **Boundary 3** only.

5 From the **Input object handling** list, choose **Keep**.



6 Locate the **Distances** section. In the table, enter the following settings:

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**Distances (m)**

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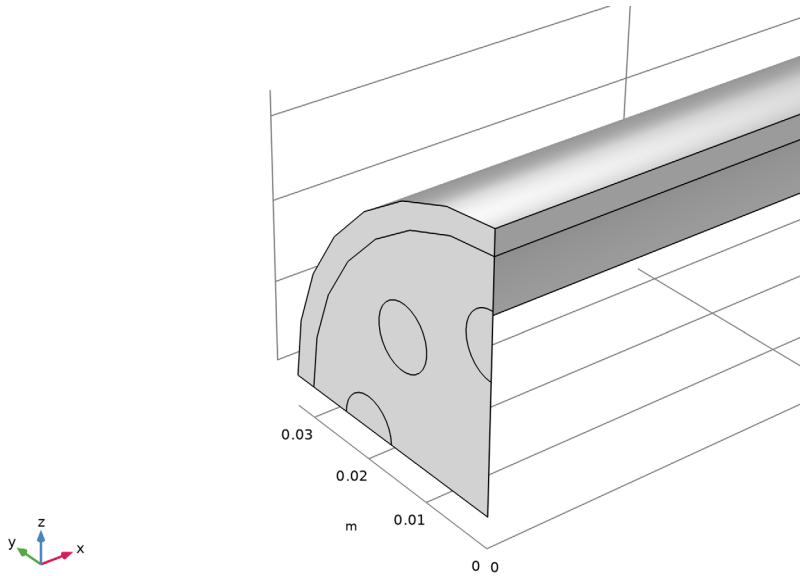
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7 Locate the **Selections of Resulting Entities** section. Select the **Resulting objects selection** checkbox.

8 From the **Show in physics** list, choose **All levels**.

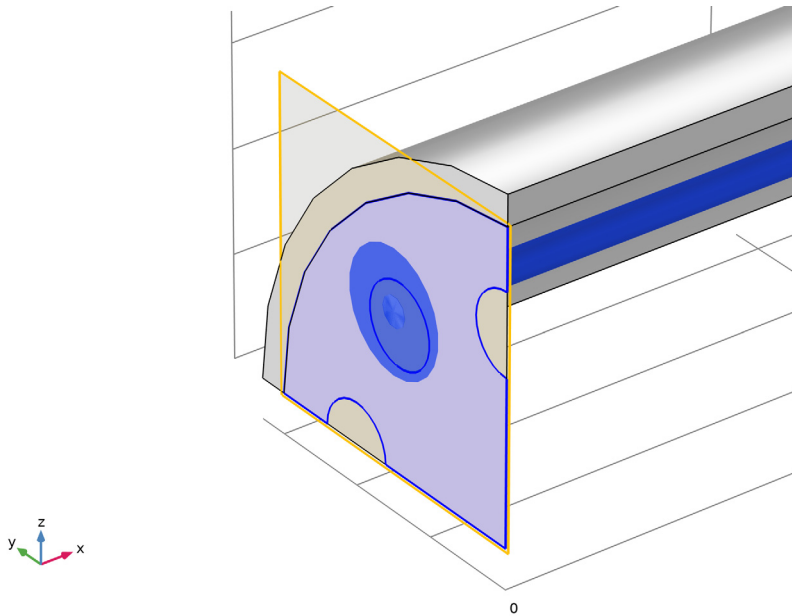
9 Click  **Build Selected**.



### *Catalytic Bed*

- 1 In the **Geometry** toolbar, click  **Extrude**.
- 2 In the **Settings** window for **Extrude**, type **Catalytic Bed** in the **Label** text field.
- 3 Locate the **General** section. From the **Extrude from** list, choose **Faces**.
- 4 From the **Input faces** list, choose **Bed Inlet (Work Plane 1)**.

5 Click the  **Zoom to Selection** button for **Input faces**.



6 From the **Input object handling** list, choose **Keep**.


7 Locate the **Distances** section. In the table, enter the following settings:

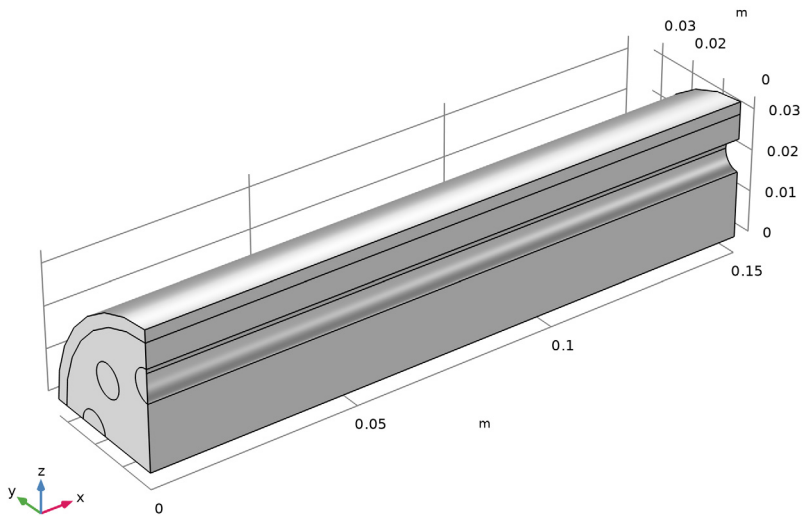
<b>Distances (m)</b>
L

8 Locate the **Selections of Resulting Entities** section. Select the **Resulting objects selection** checkbox.


9 From the **Show in physics** list, choose **All levels**.

10 Click  **Build Selected**.

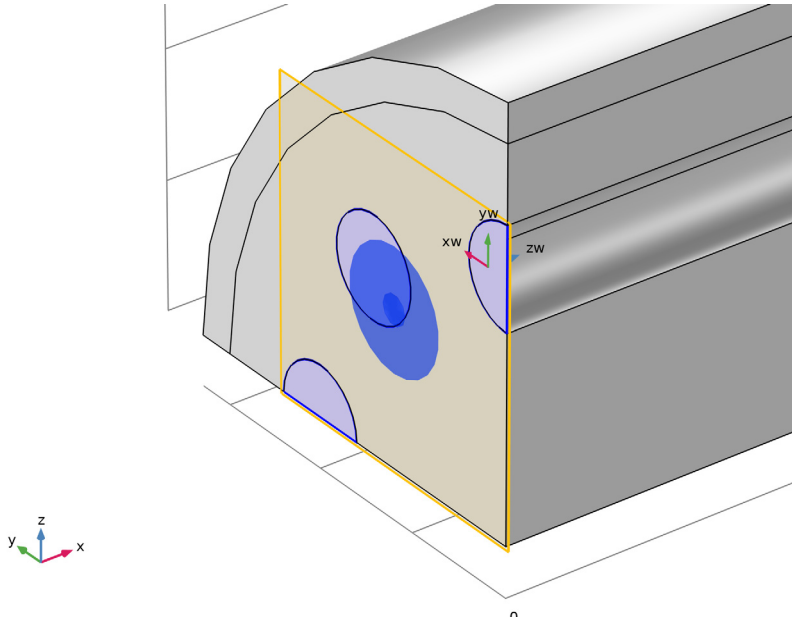
11 Click the  **Zoom Extents** button in the **Graphics** toolbar.



### *Heating Tubes*

- 1 In the **Geometry** toolbar, click  **Extrude**.
- 2 In the **Settings** window for **Extrude**, type Heating Tubes in the **Label** text field.
- 3 Locate the **General** section. From the **Extrude from** list, choose **Faces**.
- 4 From the **Input faces** list, choose **Tubes Outlet (Work Plane I)**.

5 Click the  **Zoom to Selection** button for **Input faces**.



6 From the **Input object handling** list, choose **Keep**.


7 Locate the **Distances** section. In the table, enter the following settings:

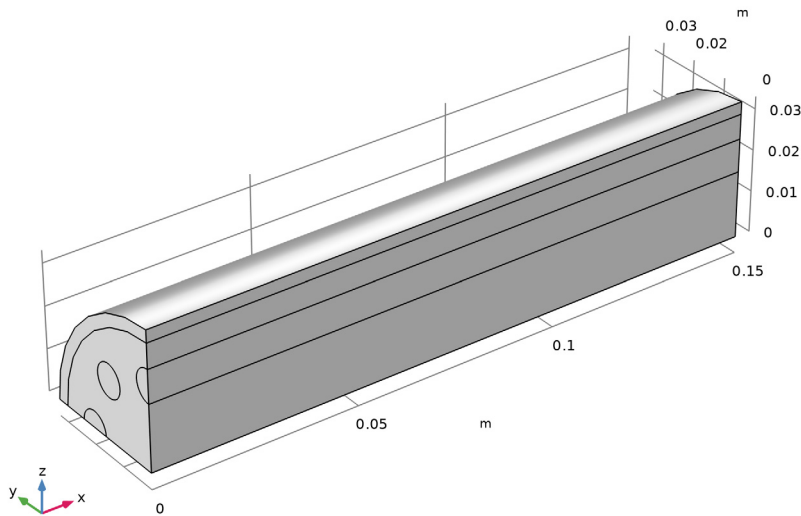
<b>Distances (m)</b>
L

8 Locate the **Selections of Resulting Entities** section. Select the **Resulting objects selection** checkbox.



9 From the **Show in physics** list, choose **All levels**.

10 Click  **Build Selected**.

II Click the  **Zoom Extents** button in the **Graphics** toolbar.



### *Form Union (fin)*

- 1 In the **Model Builder** window, click **Form Union (fin)**.
- 2 In the **Settings** window for **Form Union/Assembly**, click  **Build Selected**.
- 3 Click the  **Wireframe Rendering** button in the **Graphics** toolbar, to get a better overview of the interior entities.

The geometry of the steam reformer is now complete. In the following we will generate the remaining selections for the simulation setup using selection operations. The technique of defining selections illustrated in this tutorial is especially useful for more complex geometries where manually selecting many geometric entities can be inefficient. This technique can also provide a robust way of creating selections when running geometric parametric sweeps that change the topology, for example when exploring the effect on the results of the number of heating tubes in this geometry.



Activate the **Selection List** window for easy access to the selections already defined in the model.

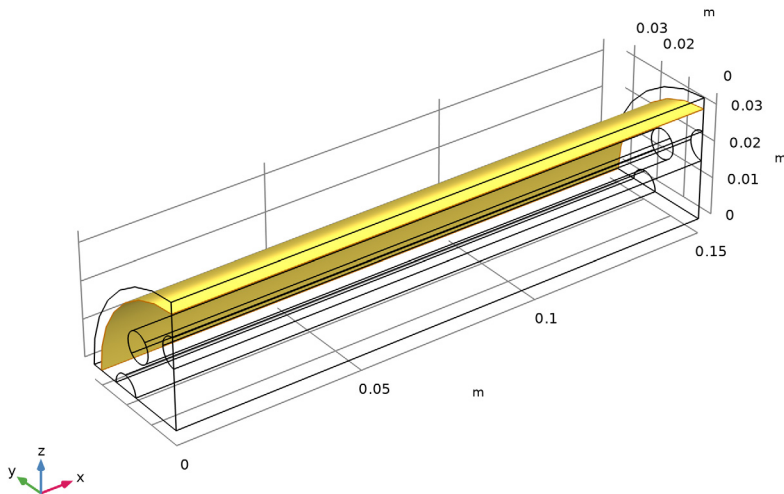
### **SELECTION LIST**

In the **Geometry** toolbar, click  **Selection List** to open the **Selection List** window.

## GEOMETRY I

### *Bed/Jacket*

- 1 In the **Geometry** toolbar, click  **Selections** and choose **Intersection Selection**.
- 2 In the **Settings** window for **Intersection Selection**, type Bed/Jacket in the **Label** text field.
- 3 Locate the **Geometric Entity Level** section. From the **Level** list, choose **Boundary**.
- 4 Locate the **Input Entities** section. Click  **Add**.
- 5 In the **Add** dialog, in the **Selections to intersect** list, choose **Jacket** and **Catalytic Bed**.
- 6 Click **OK**.



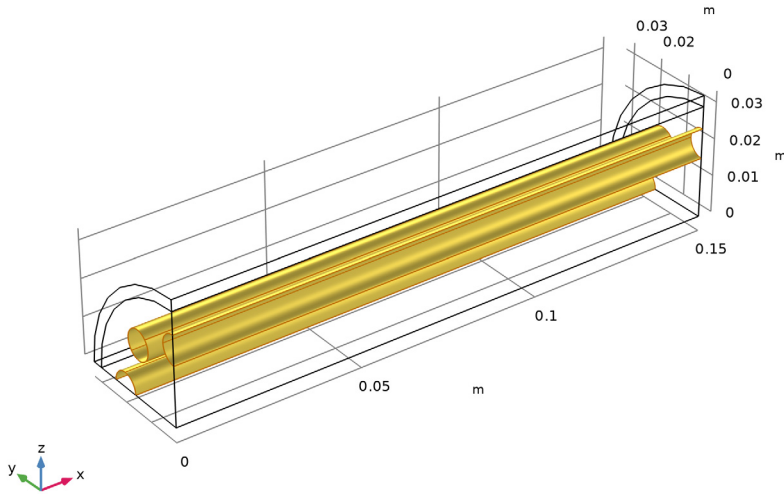
## SELECTION LIST

Go to the **Selection List** window.

### *Tubes/Bed*


- 1 In the **Boundary selections** tree, select **Catalytic Bed** and **Heating Tubes**.
- 2 Right-click on the selected entities. From the **Create Selection** menu, choose **Intersection Selection**.
- 3 Right-click **Create Selection** and choose **Intersection Selection**.

- 4 In the **Create Selection** dialog, type Tubes/Bed in the **Selection name** text field.
- 5 Click **OK**.

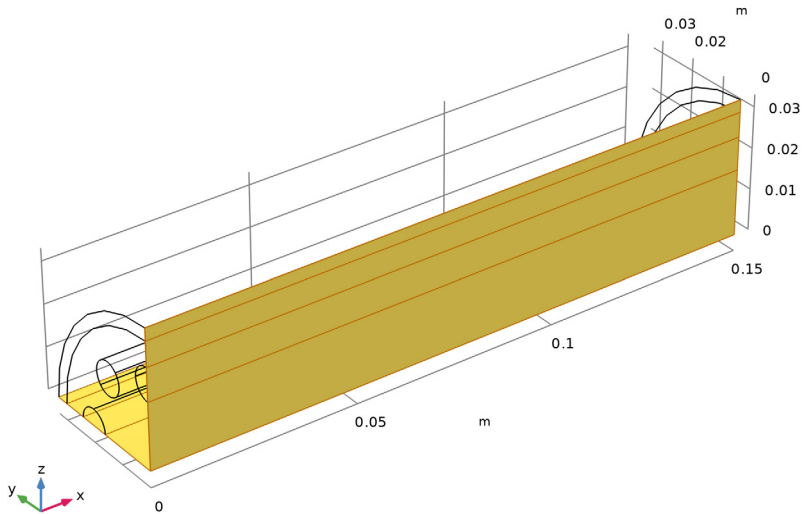


## GEOMETRY I

### *Cylinder Selection 1 (cylsel1)*

- 1 In the **Geometry** toolbar, click  **Selections** and choose **Cylinder Selection**.
- 2 In the **Settings** window for **Cylinder Selection**, locate the **Geometric Entity Level** section.
- 3 From the **Level** list, choose **Boundary**.
- 4 Locate the **Size and Shape** section. In the **Outer radius** text field, type `inf`.
- 5 In the **Start angle** text field, type 180.
- 6 In the **End angle** text field, type 90.
- 7 Locate the **Axis** section. From the **Axis type** list, choose **x-axis**.
- 8 Locate the **Output Entities** section. From the **Include entity if** list, choose **Entity inside cylinder**.

- 9 Locate the **Resulting Selection** section. From the **Show in physics** list, choose **Off**.



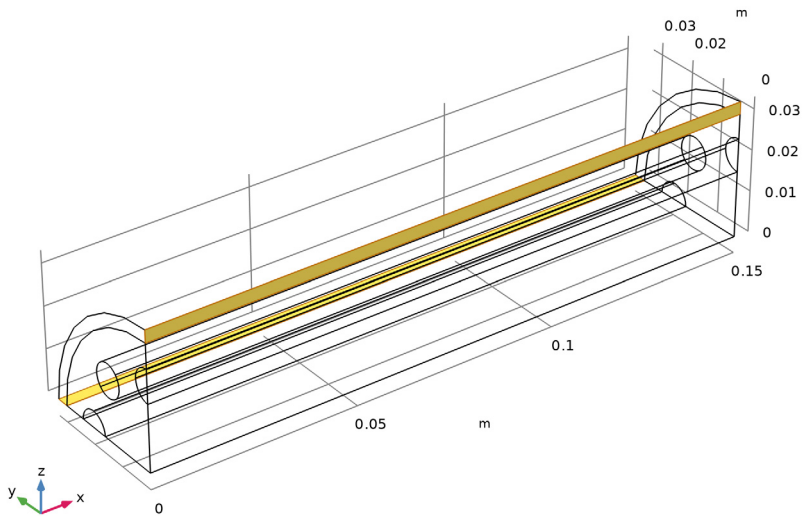
### SELECTION LIST

Go to the **Selection List** window.

#### *Jacket Symmetry*

- 1 In the **Boundary selections** tree, select **Cylinder Selection 1** and **Jacket**.
- 2 Right-click on the selected entities. From the menu, choose **Intersection Selection**.
- 3 Right-click **Create Selection** and choose **Intersection Selection**.
- 4 In the **Create Selection** dialog, type **Jacket Symmetry** in the **Selection name** text field.

5 Click **OK**.

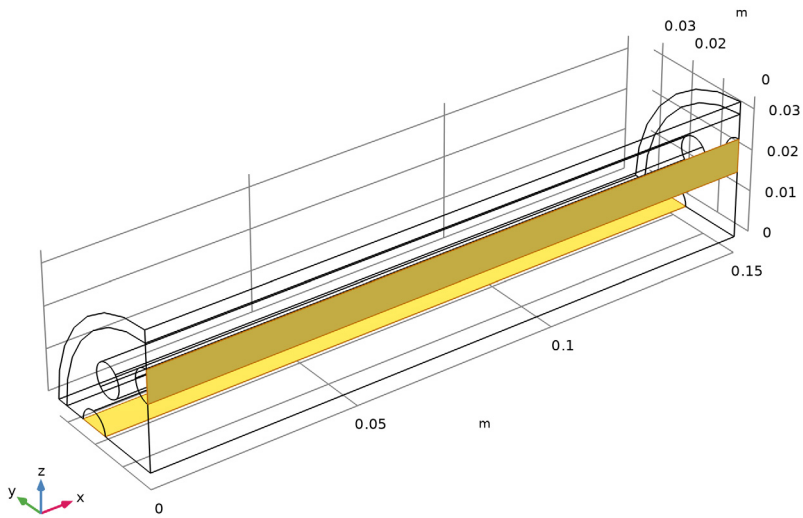


6 Go to the **Selection List** window.

#### *Tubes Symmetry*

- 1 In the **Boundary selections** tree, select **Cylinder Selection 1** and **Heating Tubes**.
- 2 Right-click on the selected entities. From the menu, choose **Intersection Selection**.
- 3 Right-click **Create Selection** and choose **Intersection Selection**.
- 4 In the **Create Selection** dialog, type **Tubes Symmetry** in the **Selection name** text field.

5 Click **OK**.

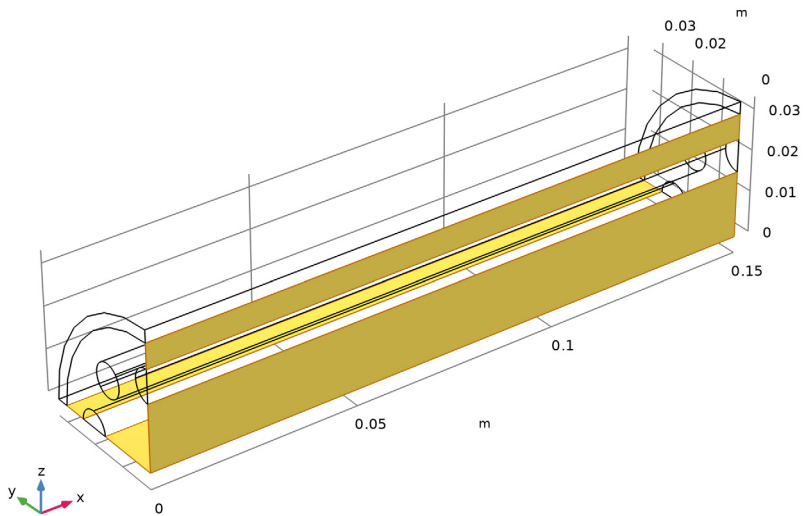


6 Go to the **Selection List** window.

#### *Bed Symmetry*


- 1 In the **Boundary selections** tree, select **Catalytic Bed** and **Cylinder Selection 1**.
- 2 Right-click on the selected entities. From the menu, choose **Intersection Selection**.
- 3 Right-click **Create Selection** and choose **Intersection Selection**.
- 4 In the **Create Selection** dialog, type **Bed Symmetry** in the **Selection name** text field.

5 Click **OK**.

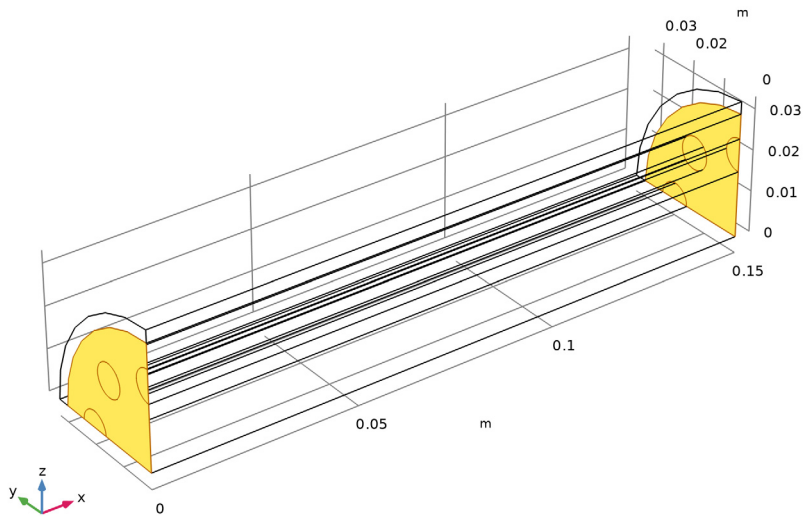


## GEOMETRY I


### *Inlets and Outlets*

- 1 In the **Geometry** toolbar, click  **Selections** and choose **Difference Selection**.
- 2 In the **Settings** window for **Difference Selection**, type **Inlets** and **Outlets** in the **Label** text field.
- 3 Locate the **Geometric Entity Level** section. From the **Level** list, choose **Boundary**.
- 4 Locate the **Input Entities** section. Click the **+ Add** button for **Selections to add**.
- 5 In the **Add** dialog, in the **Selections to add** list, choose **Catalytic Bed** and **Heating Tubes**.
- 6 Click **OK**.
- 7 In the **Settings** window for **Difference Selection**, locate the **Input Entities** section.
- 8 Click the **+ Add** button for **Selections to subtract**.
- 9 In the **Add** dialog, in the **Selections to subtract** list, choose **Bed/Jacket**, **Tubes/Bed**, **Tubes Symmetry**, and **Bed Symmetry**.

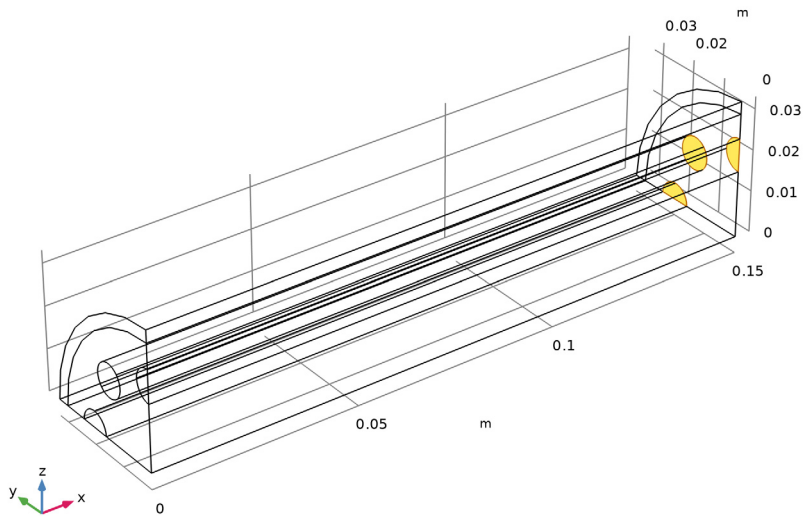
10 Click **OK**.




#### *Tubes Inlet*

- 1 In the **Geometry** toolbar, click  **Selections** and choose **Difference Selection**.
- 2 In the **Settings** window for **Difference Selection**, type Tubes Inlet in the **Label** text field.
- 3 Locate the **Geometric Entity Level** section. From the **Level** list, choose **Boundary**.
- 4 Locate the **Input Entities** section. Click the **+ Add** button for **Selections to add**.
- 5 In the **Add** dialog, select **Inlets and Outlets** in the **Selections to add** list.
- 6 Click **OK**.
- 7 In the **Settings** window for **Difference Selection**, locate the **Input Entities** section.
- 8 Click the **+ Add** button for **Selections to subtract**.
- 9 In the **Add** dialog, in the **Selections to subtract** list, choose **Tubes Outlet (Work Plane I)** and **Catalytic Bed**.

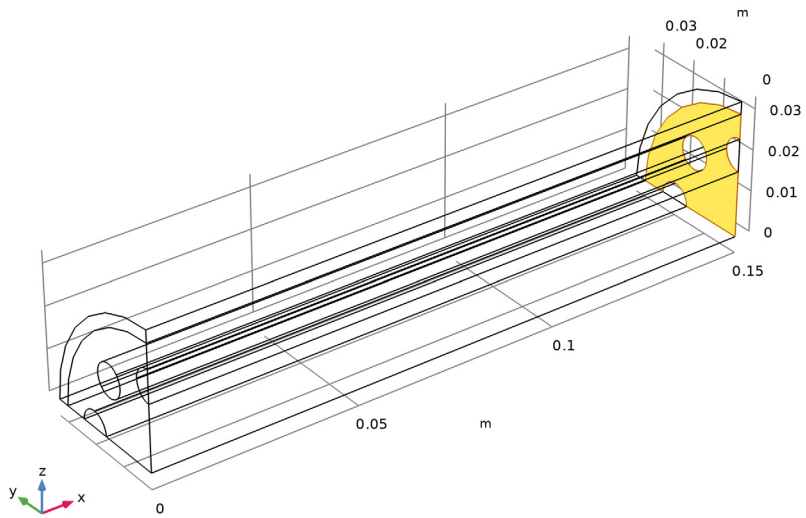
10 Click **OK**.



#### *Bed Outlet*

- 1 In the **Geometry** toolbar, click  **Selections** and choose **Difference Selection**.
- 2 In the **Settings** window for **Difference Selection**, type **Bed Outlet** in the **Label** text field.
- 3 Locate the **Geometric Entity Level** section. From the **Level** list, choose **Boundary**.
- 4 Locate the **Input Entities** section. Click the **+ Add** button for **Selections to add**.
- 5 In the **Add** dialog, select **Inlets and Outlets** in the **Selections to add** list.
- 6 Click **OK**.
- 7 In the **Settings** window for **Difference Selection**, locate the **Input Entities** section.
- 8 Click the **+ Add** button for **Selections to subtract**.
- 9 In the **Add** dialog, in the **Selections to subtract** list, choose **Bed Inlet (Work Plane 1)** and **Heating Tubes**.

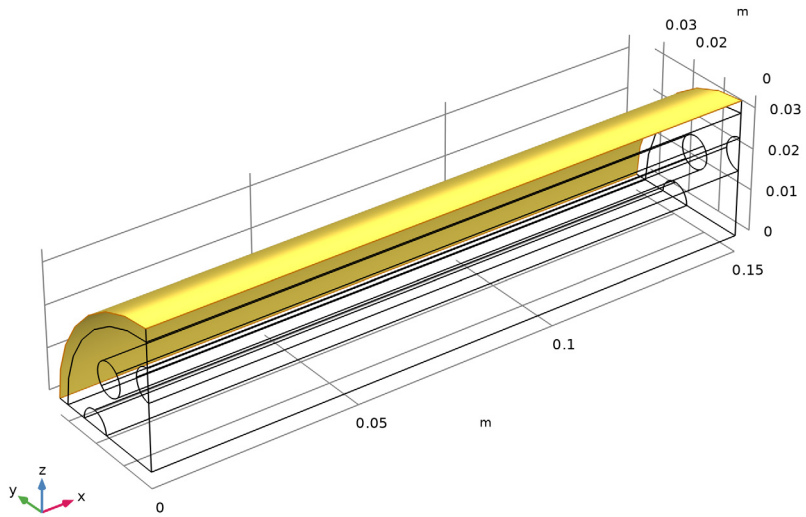
10 Click **OK**.



*Jacket/Ambient*

- 1 On the object **fin**, select Boundary 12 only. This is the outer cylindrical face.
- 2 Right-click in the **Graphics** window and select **Explicit Selection** from the context menu.

- 3 In the **Settings** window for **Explicit Selection**, type Jacket/Ambient in the **Label** text field.



- 4 Click  **Build Selected**.

- 5 In the **Geometry** toolbar, click  **Selection List** to close the **Selection List** window.