

ISS Research Design Challenge: CELERE

Capillary Effects on Liquids Exploratory Research Experiments

<http://spaceflightsystems.grc.nasa.gov/CELERE/>



2016 Tutorial

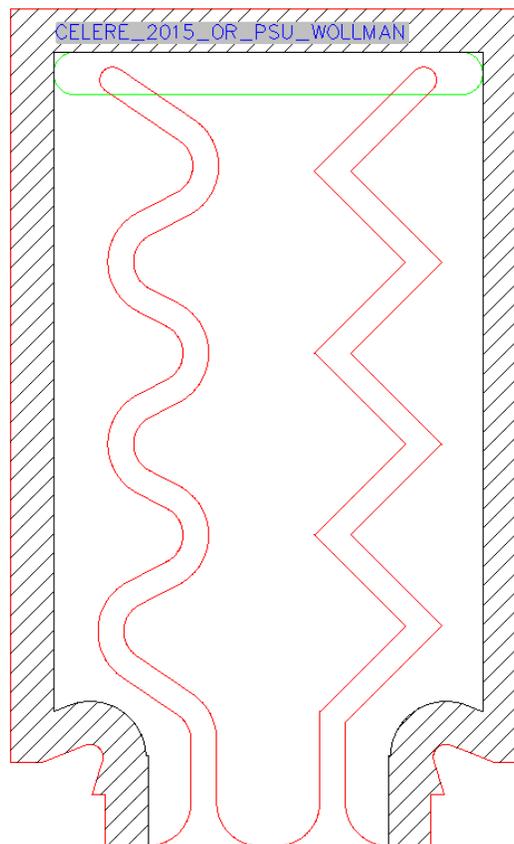
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and Dennis Stocker (NASA Glenn Research Center, Cleveland, Ohio)



The CELERE handbook is a separate document and can be downloaded from <http://spaceflightsystems.grc.nasa.gov/CELERE/Apply/>.

Capillary Rise in Zigzagging Channels

Through this tutorial, you will use Computer-Aided Design (CAD) to draw two zigzagging channels, one with round corners and one with sharp corners, as shown in the middle-layer figure below.



As a start:

1. Download *DraftSight 2015* for free from <https://www.3ds.com/products-services/draftsight-cad-software/free-download/> for Mac, Windows, etc. Earlier Windows versions can be downloaded (for example) from http://download.cnet.com/DraftSight/3000-18496_4-75445046.html.

- From <http://spaceflight systems.grc.nasa.gov/CELERE/Apply/>, download the CELERE_2016_TESTCELL_TEMPLATE.dwg, i.e., the drawing template for the test cell’s middle layer. Past participants should note that the template has been updated. Don’t use old templates for CELERE 2016!

While this tutorial uses many of the tools available in *DraftSight*, it is not an exhaustive instructional tool. For more guidance on *DraftSight*, download the user guide at:

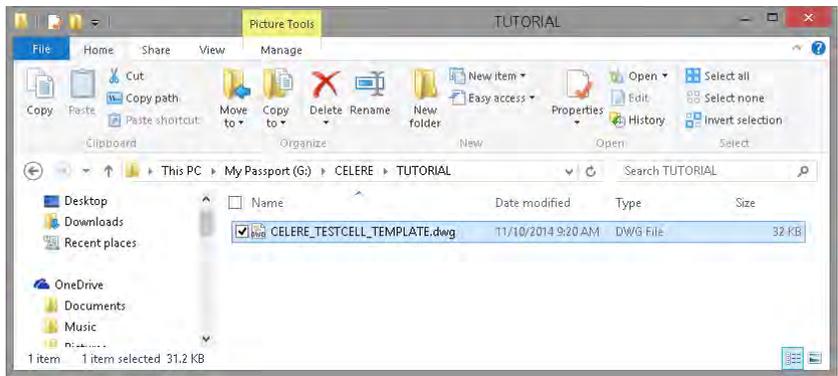
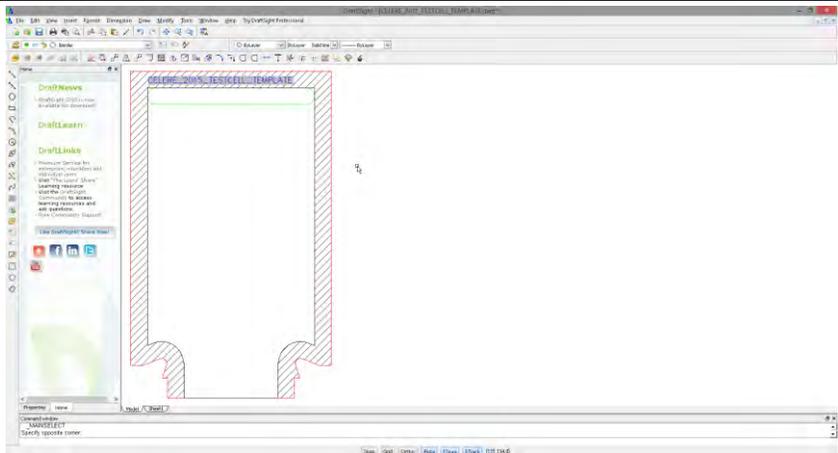
http://www.3ds.com/fileadmin/PRODUCTS/DRAFT_SIGHT/PDF/GETTING-STARTED-GUIDE.pdf

Another place for useful information on *DraftSight* is the program’s Help documentation. Launch *DraftSight* and press F1 or navigate to the Help menu from the main menu toolbar at the top of the screen.

The only significant changes in the tutorial from the 2015 version are the directions to (1) use the 2016 test cell template and (2) begin your file names with ‘CELERE_2016.’

It is strongly recommended that you go through all of this tutorial’s steps at least once, especially if you are not familiar with DraftSight!

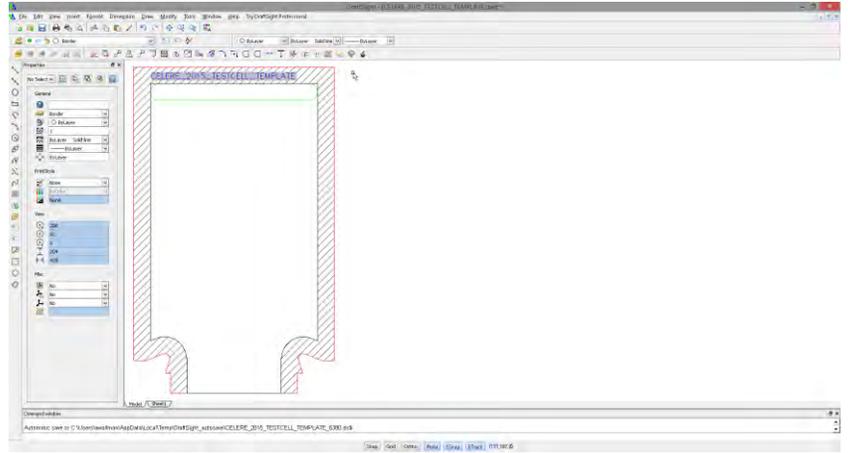
Note that product references do not indicate an endorsement on the part of NASA or the federal government.

Instructions & comments	Screen shots, images, and diagrams
<p>Launch DraftSight and open the drawing template, CELERE_2016_TESTCELL_TEMPLATE.dwg.</p> <p>Past participants should make sure to use the 2016 template because the test cell design has been revised.</p>	
<p>A screen similar to that on the right will be visible, but the background will be black.</p> <p>NOTE: The background in this tutorial has been changed to white to make it easier to read.</p> <p>Close the Home pane on the left side of screen to expose the Properties pane.</p>	

The template file, which provides the test cell outline including these main features:

- **Border (with diagonal pattern):** The channels that you design must fit within the border.
- **File name:** The file name appears at the top of the test channel so PSU can identify your middle layer and tell it apart from those of other teams.
- **Green slot:** The green slot is where the air will exit out the front and rear layers of the assembled test cell. The channels you design must extend into the green slot.

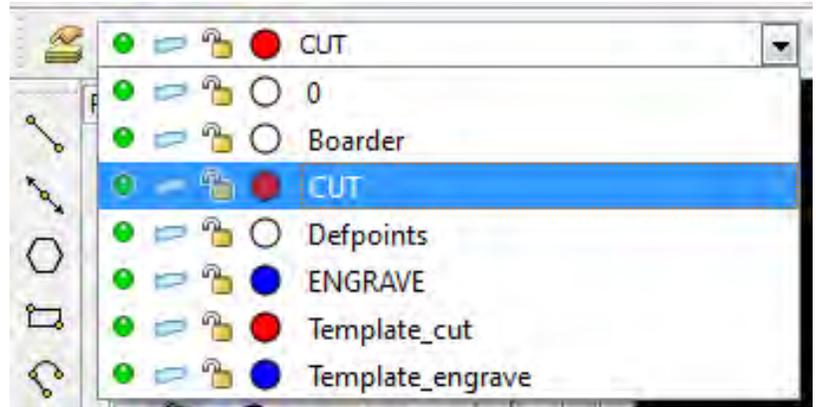
DO NOT ALTER THE TEST CELL OUTLINE BLOCK IN ANY WAY!



The template file includes several unique layers, where the most important layer is the CUT layer. Lines drawn on this layer will tell the laser cutter to cut through the acrylic.

Make sure your channel design is on the CUT layer. Items not on the cut layer will not be cut or printed at all. The other layers should not be used and are either DraftSight default layers or used by PSU.

DO NOT MODIFY THE LAYERS IN ANY WAY!



There are two tabs at the bottom of the template file. Make sure you are drawing on the 'Model' tab; 'Sheet1' should not be used.



RENAME THE DRAWING

Do not modify the provided CELERE template file. Instead re-save the file with a unique name and modify that copy. *The file name of your submitted drawing will be used to identify your part and help PSU keep track of all the experiments. Especially for that final drawing, use the following steps to format and name your new file.*

In the menu toolbar, navigate to:

File → Save As...

Save the template file as a new file using the following convention:

CELERE_2016_<StateInitials>_<OrgAbbrev>_<AdvisorLastName>_<ParticipantAbbrev>.dwg

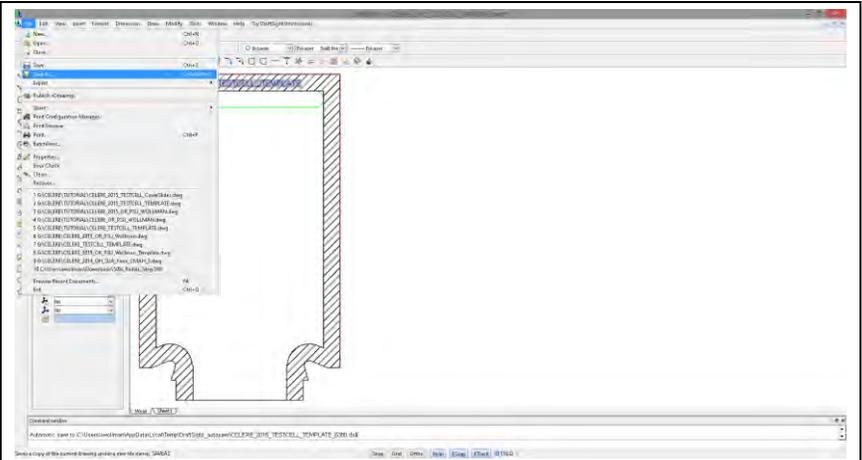
An example name:

CELERE_2016_OR_PSU_WOLLMAN_ABC.dwg

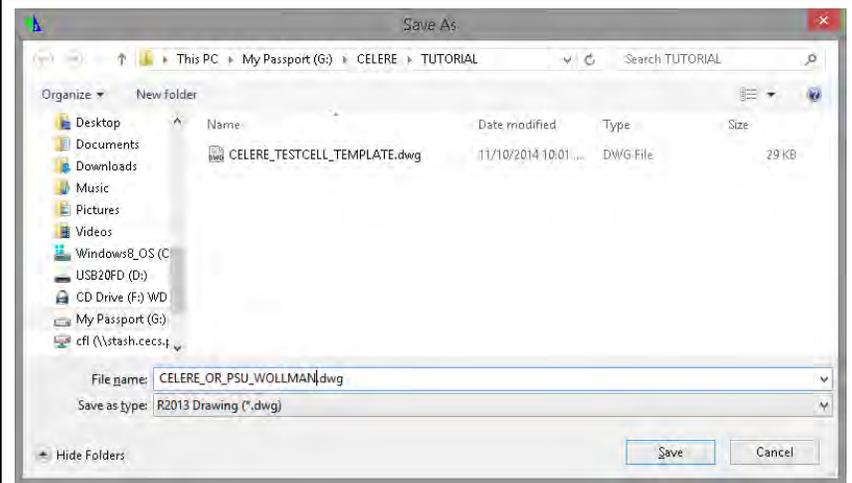
Field	Description
<StateInitials>	Use the two-letter mailing abbreviation for your state or territory, where they are listed below for reference. If you are from a DODEA school outside of the U.S. (including the listed territories) then use 'DOD' instead.
<OrgAbbrev>	An abbreviation for your team's organization, e.g., school, Scout troop, etc. For example: Franklin Middle School = FMS Helen Keller School for the Blind = HKSB Girl Scout Troop 123 = GST123 In the case of schools, please use the school name for the abbreviation rather than the name of a school club. If you are participating as an individual, please use an abbreviation for your school even if you aren't participating in CELERE as a school project. If you are home-schooled, you can use HOME.
<AdvisorLastName>	The last name of the team's adult advisor, e.g., teacher, Scout leader, etc., who serves as the team's principal contact with NASA.
<ParticipantAbbrev>	The end of the file name should be an abbreviation identifying your team or your initials if you are participating as an individual.

US State	Initial	US State	Initial	US State	Initial	US Territory	Initial
Alabama	AL	Louisiana	LA	Ohio	OH	American Samoa	AS
Alaska	AK	Maine	ME	Oklahoma	OK	District of Columbia	DC
Arizona	AZ	Maryland	MD	Oregon	OR	Guam	GU
Arkansas	AR	Massachusetts	MA	Pennsylvania	PA	Northern Mariana Islands	MP
California	CA	Michigan	MI	Rhode Island	RI	Puerto Rico	PR
Colorado	CO	Minnesota	MN	South Carolina	SC	U.S. Virgin Islands	VI
Connecticut	CT	Mississippi	MS	South Dakota	SD	DODEA Schools	DOD
Delaware	DE	Missouri	MO	Tennessee	TN		
Florida	FL	Montana	MT	Texas	TX		
Georgia	GA	Nebraska	NE	Utah	UT		
Hawaii	HI	Nevada	NV	Vermont	VT		
Idaho	ID	New Hampshire	NH	Virginia	VA		
Illinois	IL	New Jersey	NJ	Washington	WA		
Indiana	IN	New Mexico	NM	West Virginia	WV		
Iowa	IA	New York	NY	Wisconsin	WI		
Kansas	KS	North Carolina	NC	Wyoming	WY		
Kentucky	KY	North Dakota	ND				

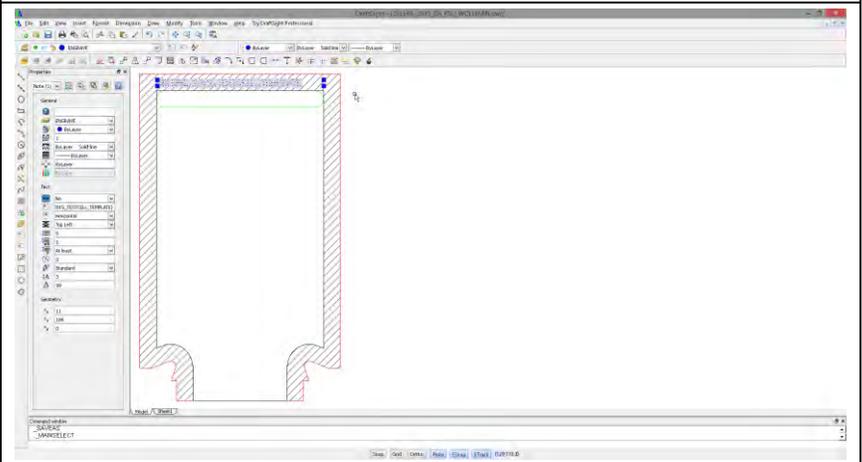
Under the top menu, File → Save As...



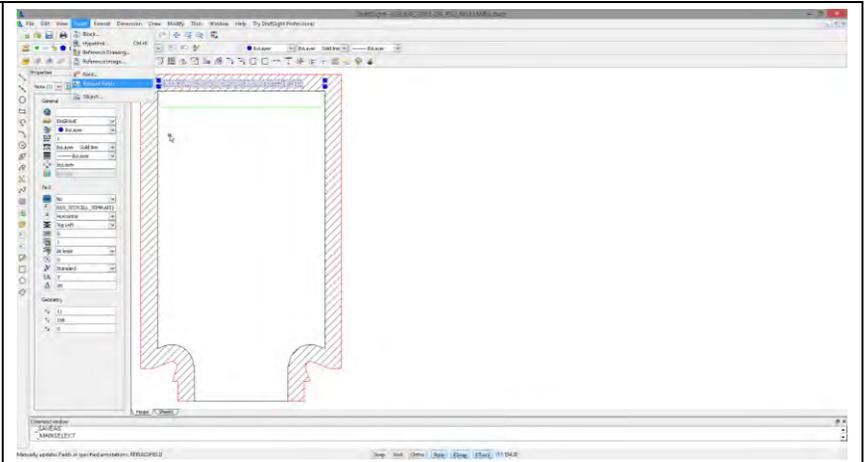
Rename the file per the instructions on the previous page.



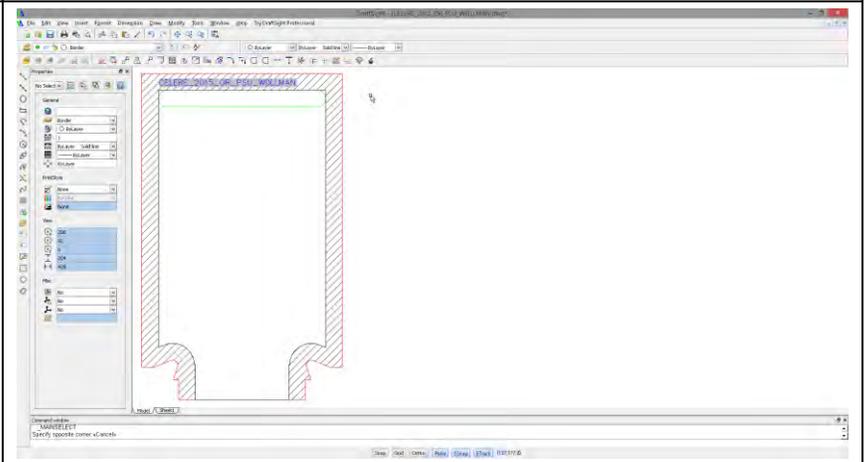
Select the text field at the top of the test cell by clicking on it.



Under the top menu, Insert → Rebuild Fields

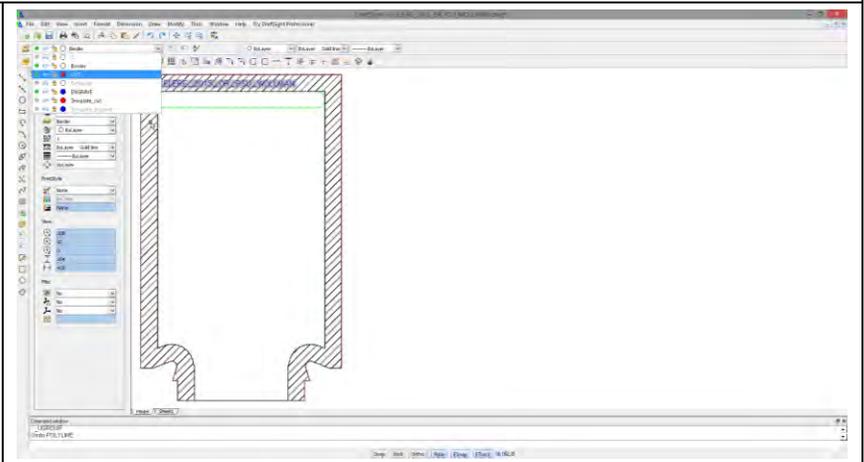


Now the text will read as the new file name.



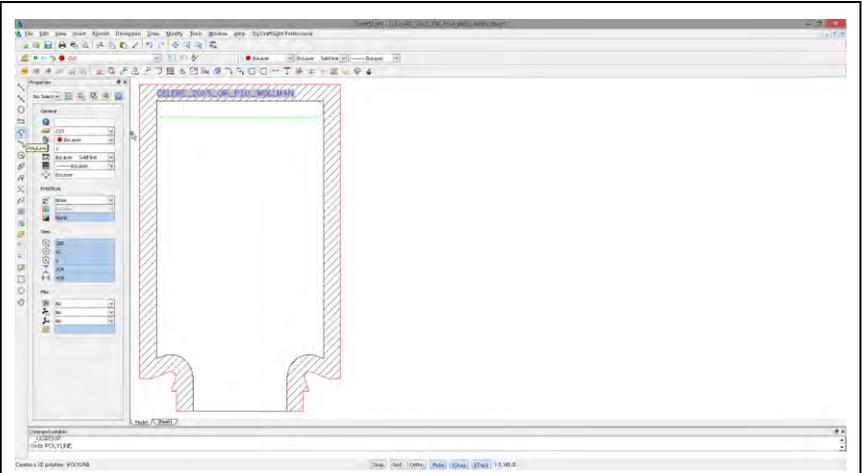
DRAW A ZIGZAG IN THE CUT LAYER

Use the layers pull-down menu (in the upper left) to select the CUT layer.



Click on the POLYLINE icon  (on the left menu) to enter the POLYLINE command.

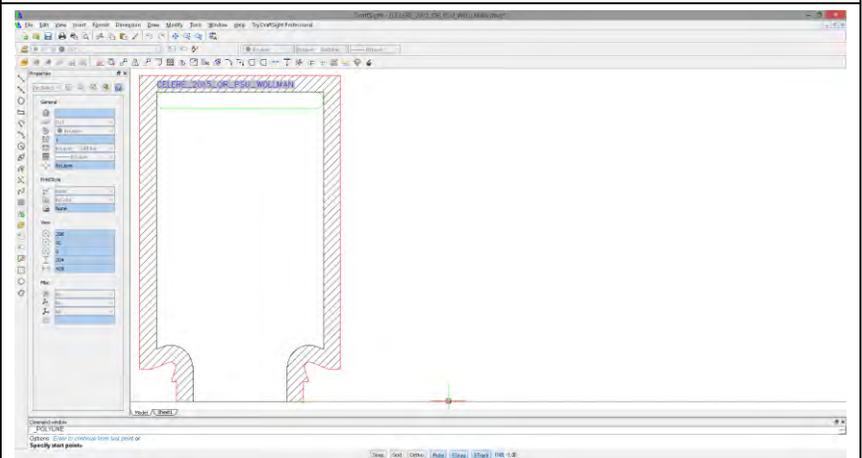
A 'polyline' is a group of connected straight and arced lines. For this example, we will use a 'polyline' to outline the borders of the capillary channels of the test cell.



If you are going to free sketch the channel, do so within the borders of the test cell margins. Since this example problem uses predefined geometry we'll work off to the right of the test cell.

Off to the right of the Test Cell outline, select the first point of the POLYLINE.

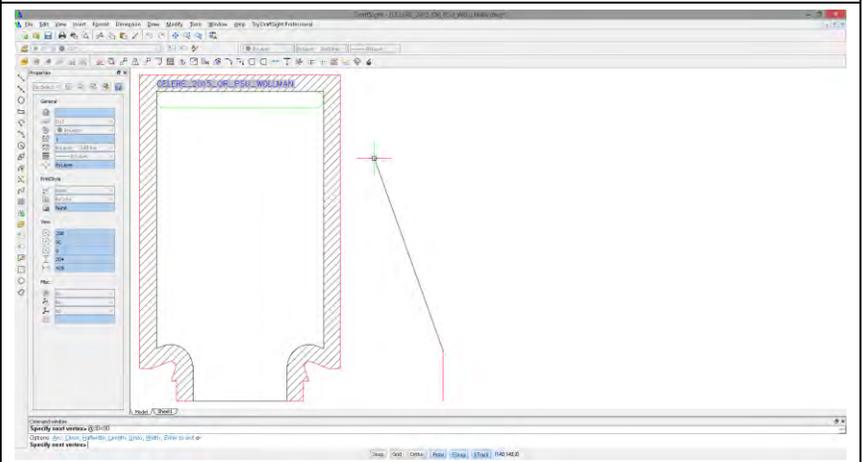
Left click to specify the start point.



You can identify the location of a line end point by typing in relative coordinates. To draw a line 30 mm long at a 90 degree angle off of horizontal (vertical) ...

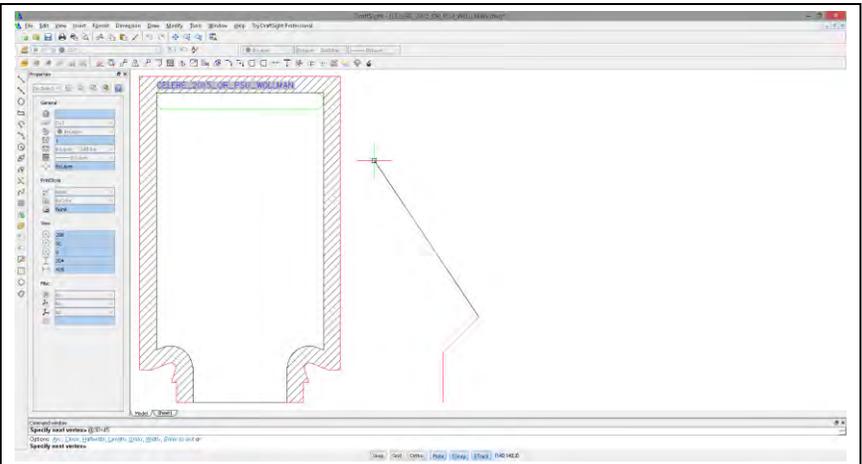
Type: @30<90 <space>

The <space> executes the command.



To draw a line that is 30 mm long at 45 degrees off horizontal ...

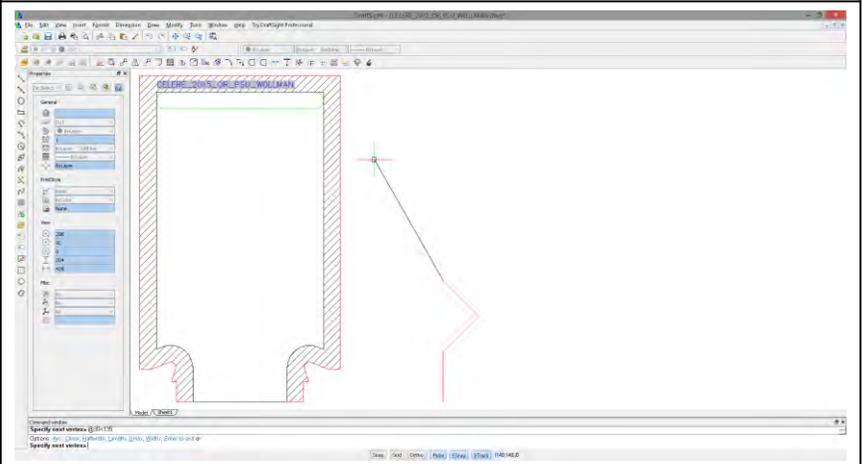
Type: @30<45 <space>



Type: @30<135 <space>

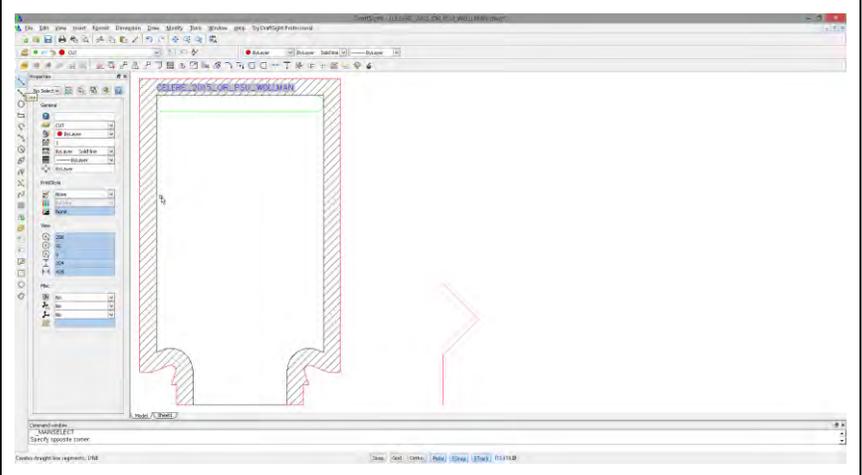
The polyline is done.
Press esc to exit the POLYLINE command.

Save the drawing using Ctrl+S or the Save icon:



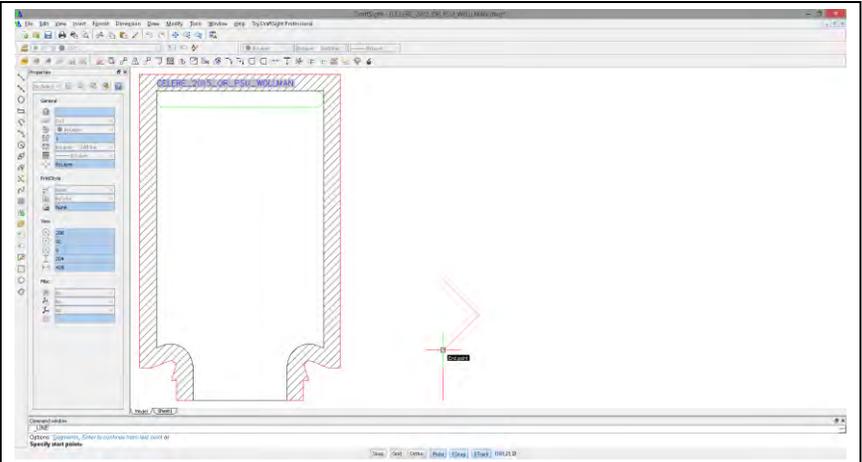
DUPLICATE THE ZIGZAG TO MAKE A ZIGZAGGING LINE

Click on the LINE icon  (on the left menu) to enter the LINE command.

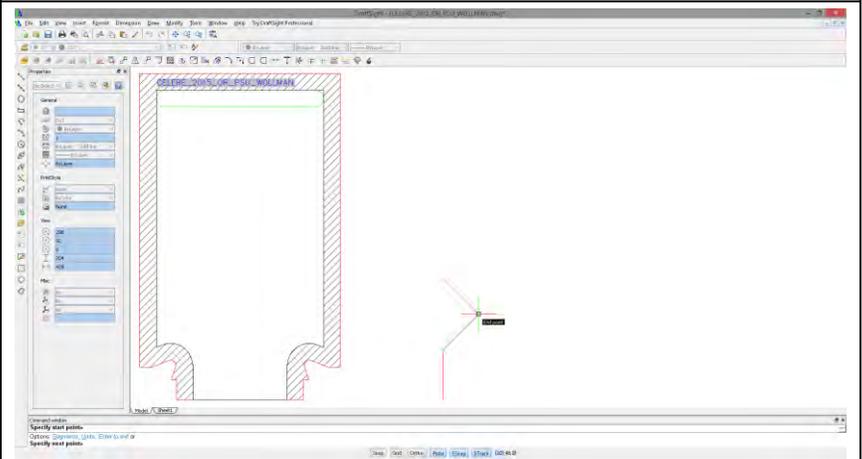


Trace the bent section of the polyline as a guide.

Left click on the end point shown to specify the starting point of the zigzag.

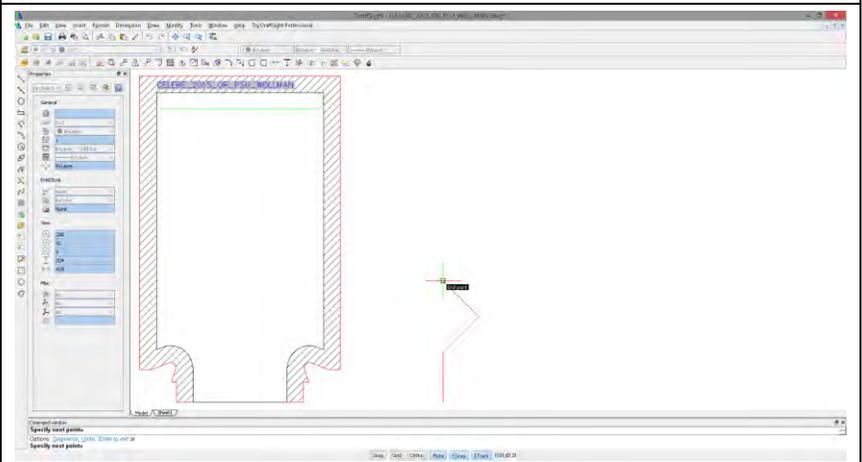


Left click on the end point shown to specify the middle point of the zigzag.



Left click on the end point shown to specify last point of the zigzag.

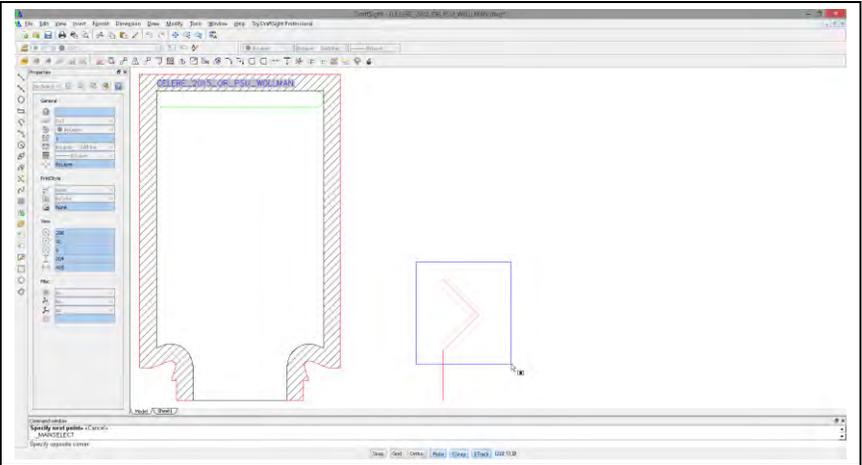
The line is finished.
Press esc to exit line command.



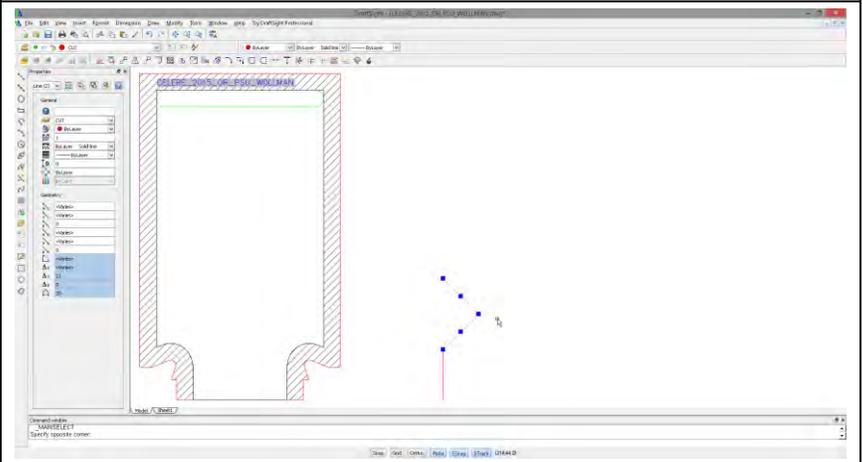
Select the two lines you just drew using the encompassing selection option. Left click somewhere up and left from the lines and move your mouse down and to the right.

The selection box is blue. All objects that are fully encompassed in the box will be selected.

Left click when only the bend of the poly line is inside the box as shown.



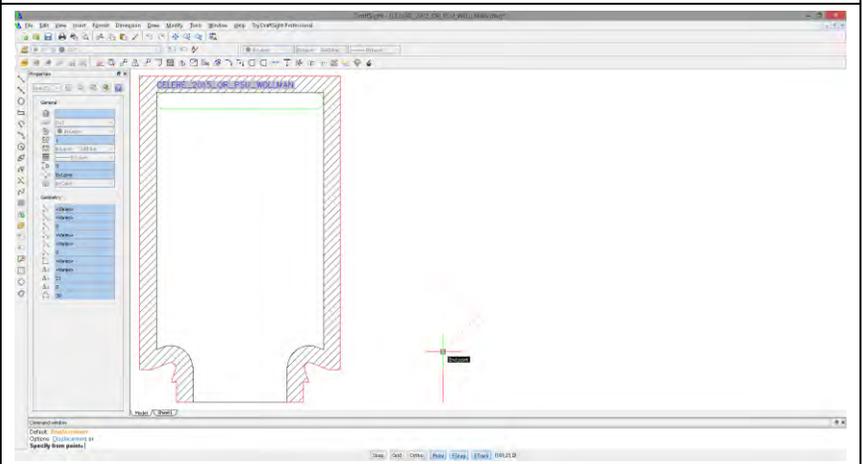
Notice that only the lines are selected. The polyline was not.



To move the selected lines, enter the MOVE command by doing the following.

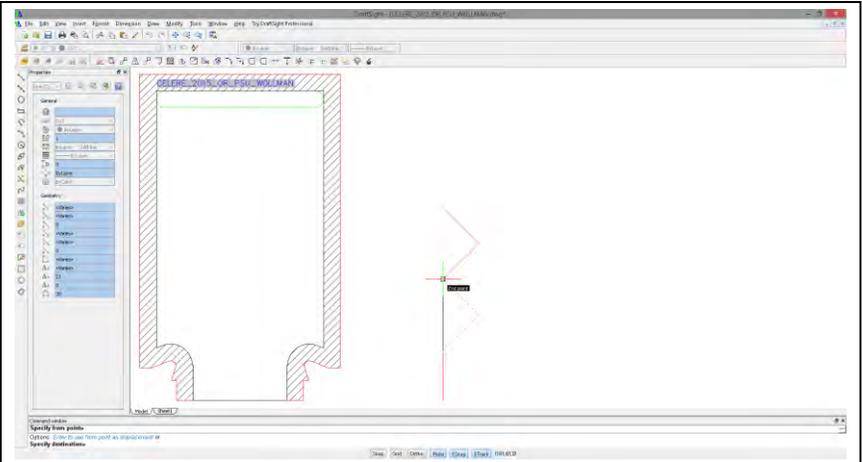
Type: m <space>

Left click on the end point shown (the bottom of the zigzag) to specify the 'from' point.



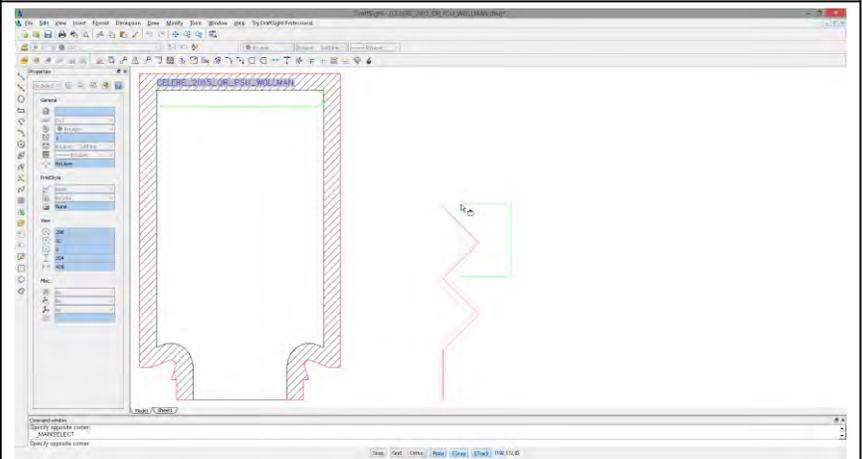
Move the cursor up to the end point shown (the top of the zigzag) and left click to specify the destination.

The MOVE is finished.



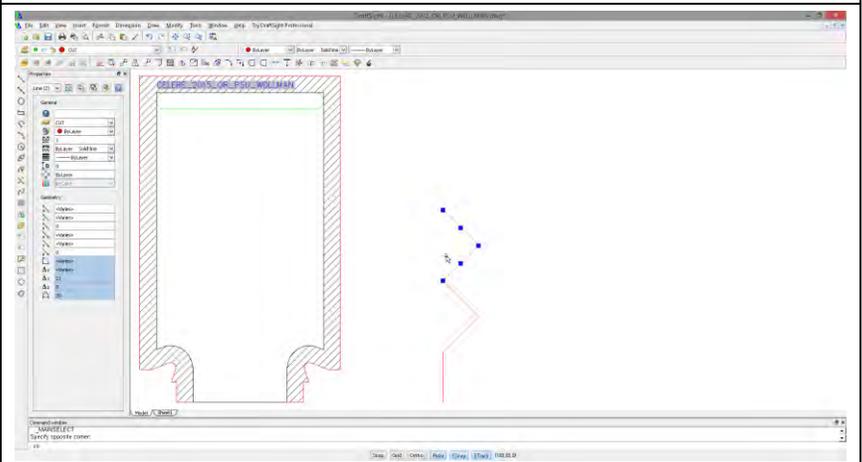
Select top two lines using the intersection selection tool.

Left click to the lower right of the second zigzag and move the cursor up and to the left. *The green dashed selection box will select any object it intersects.*

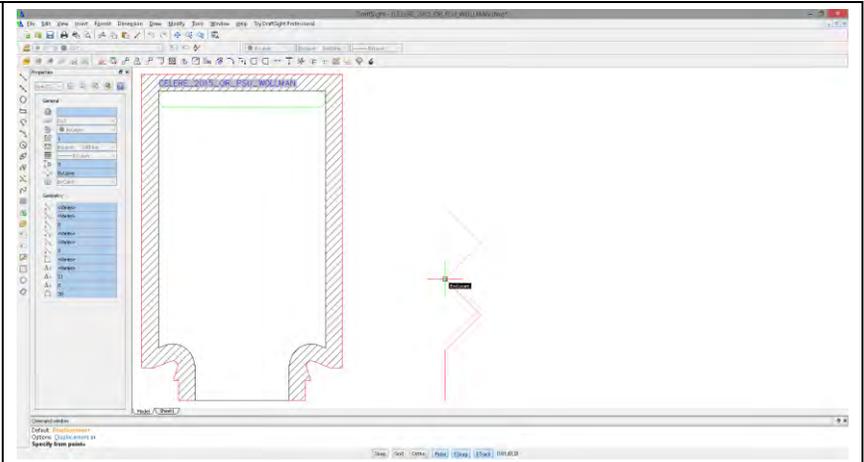


Once the top two lines are selected, we want to copy them using the COPY command.

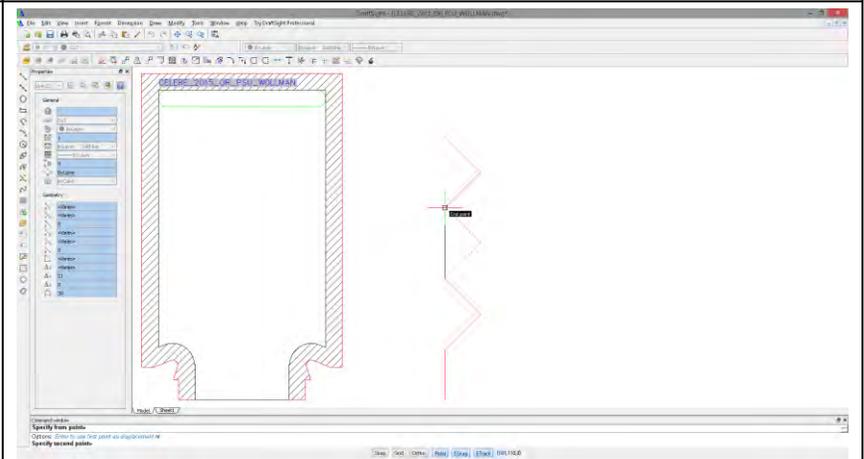
To enter the COPY command ...
Type: co <space>



Left click on the lower end point (of the second zigzag) as shown to specify the 'from' point.

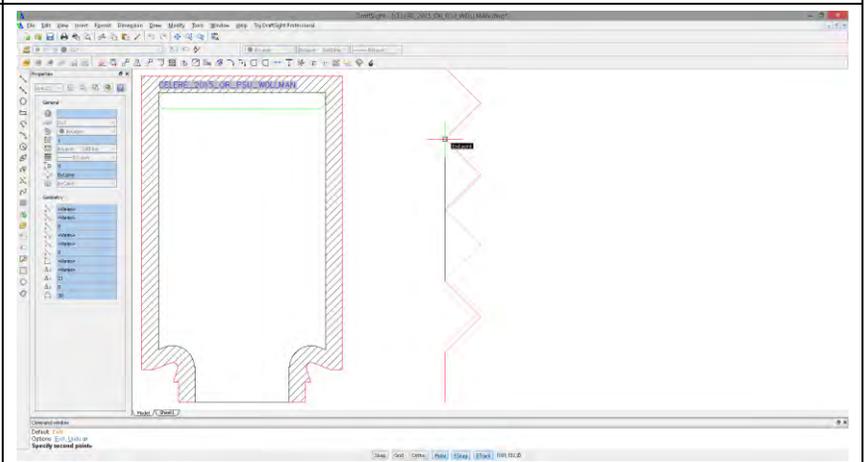


Move the cursor and left click on the top end point (of the second zigzag) as shown to specify the destination.



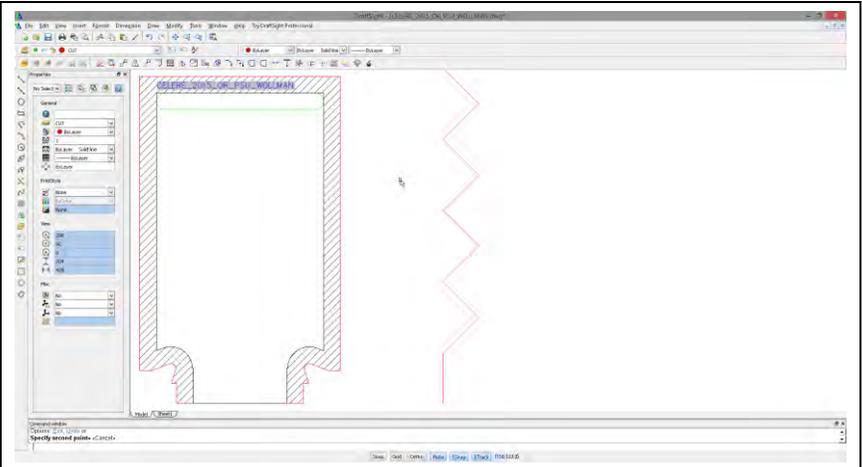
The COPY command does not end automatically.

Left click on the new top end point as shown to specify the start point of another zigzag.

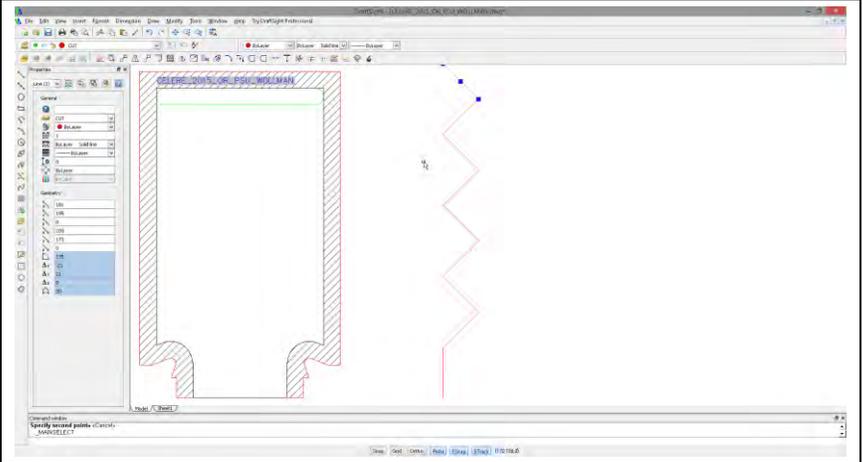


We are done with the COPY command.
Press escape.

Save the drawing using Ctrl+S or the Save icon:

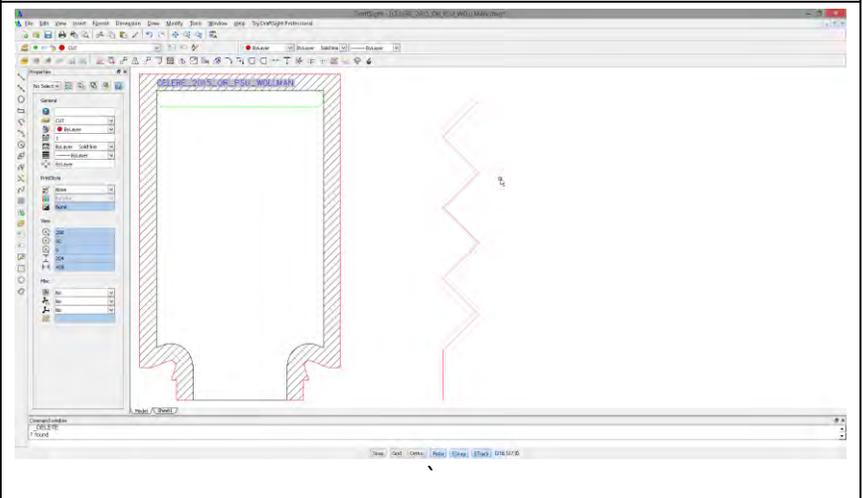


Left click on the top line to select it. Press the delete key to delete it.



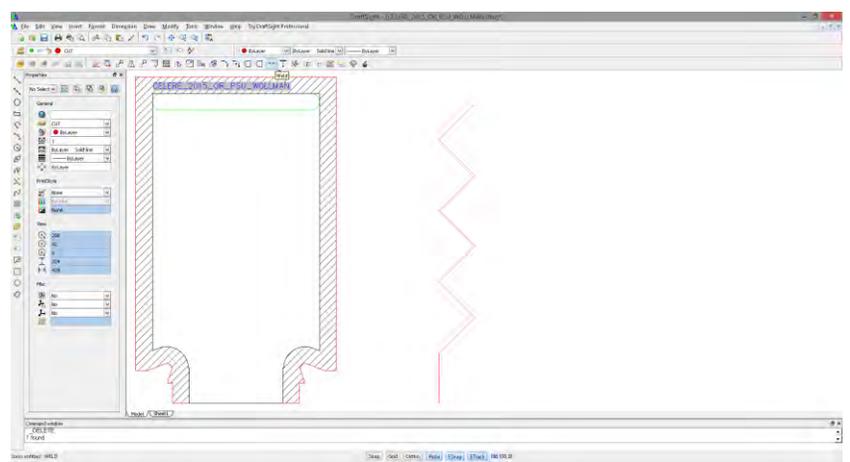
The deletion is done.

Your channel should look like the one to the right.

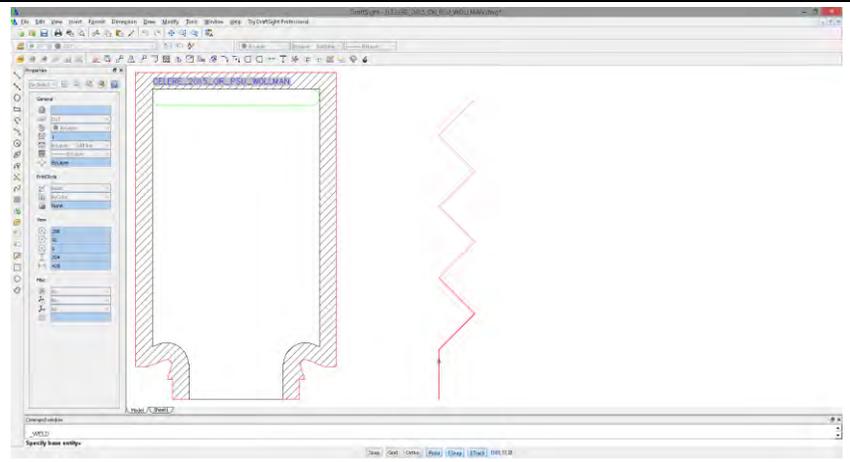


WELD THE ZIGZAGGING LINE SEGMENTS TOGETHER

To weld the lines and the polyline together ...
Under the top menu, Modify → click on the weld icon  to enter the WELD command.

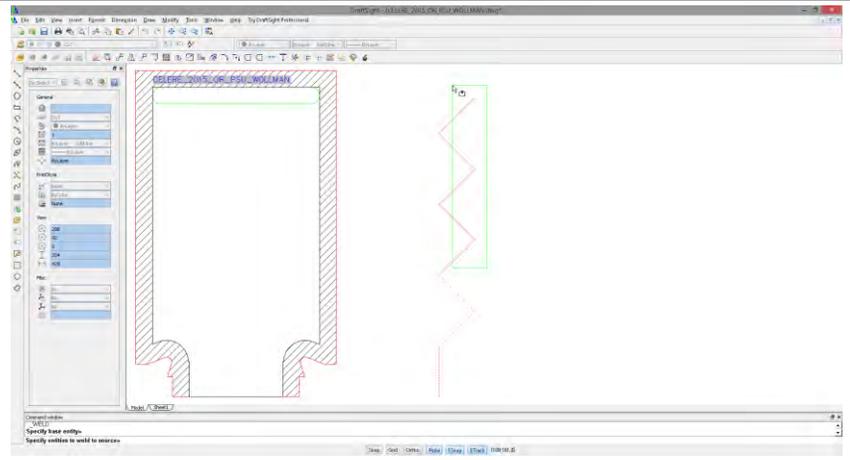


Left click the polyline on the bottom to select the bottom of the zigzagging line.

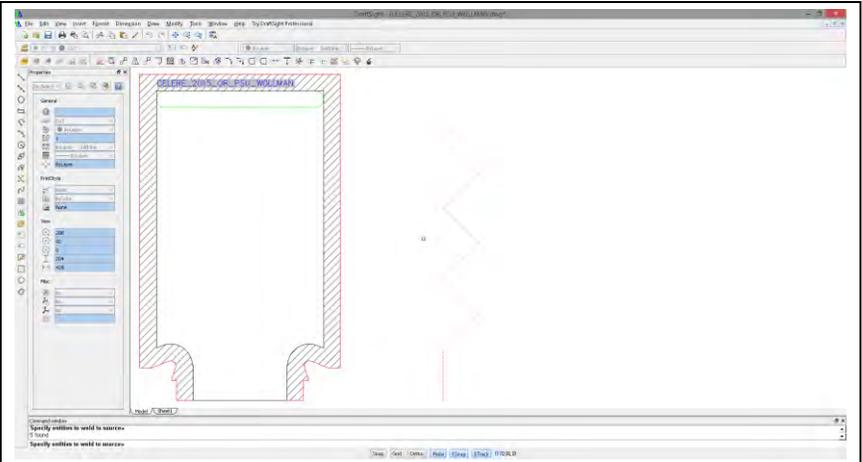


Select the other lines to add to the polyline.

To the right the intersection selection method is used.

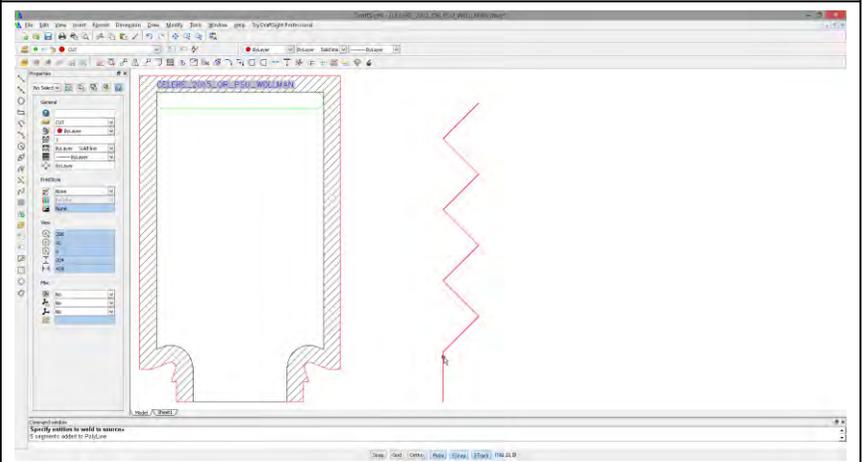


The selected lines turn to a dashed line.
 Press <space> to finish executing the weld command.



Hover the mouse cursor over the poly line to check if the welding worked. *You should see the entire zigzagging polyline bold in highlight.*

Save the drawing using Ctrl+S or the Save icon:



DUPLICATE THE ZIGZAGGING LINE ... IN A MIRRORED ORIENTATION

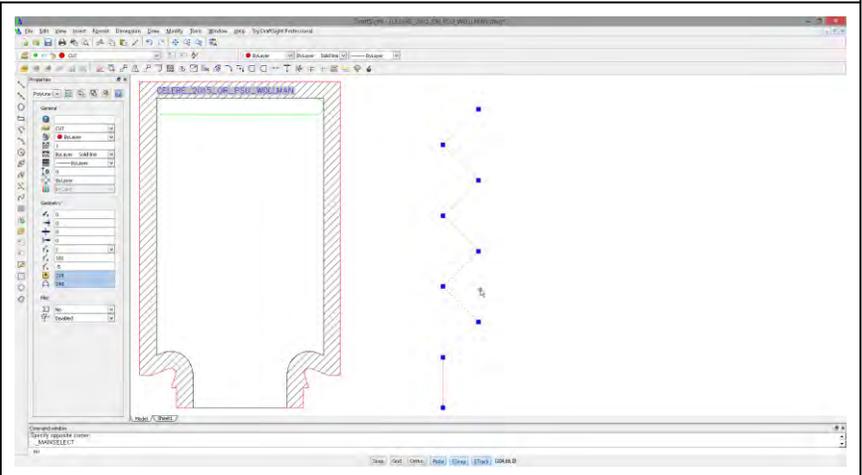
We want to mirror the poly line about the vertical axis.

To mirror the polyline enter the MIRROR command...

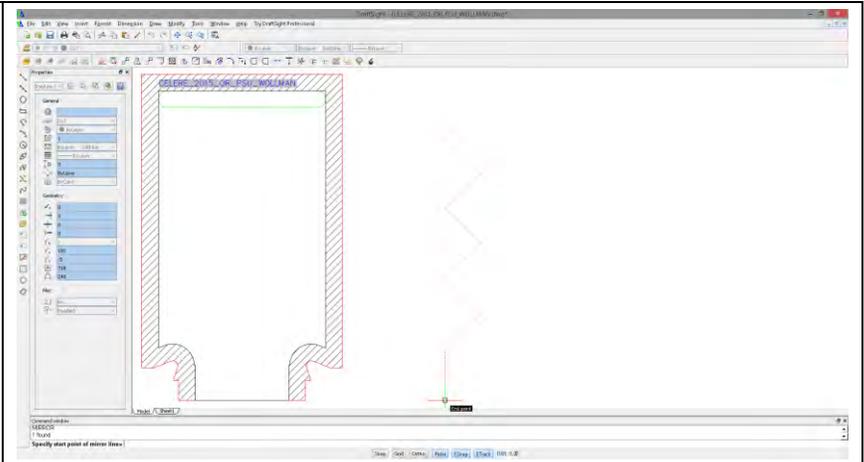
Type: mi <space>

Alternately, you can ...

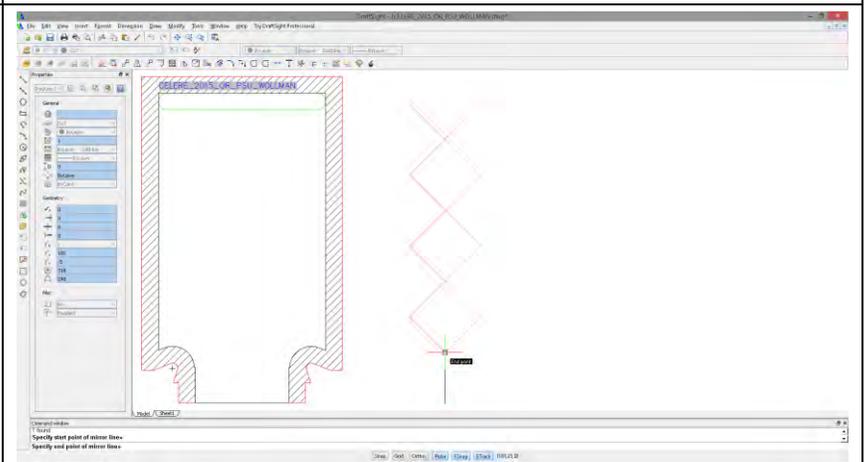
Under the top menu, Modify → click on the MIRROR icon  .



Left click on the end point of the polyline as shown (at the bottom of the zigzagging line) to specify start point of mirror line.

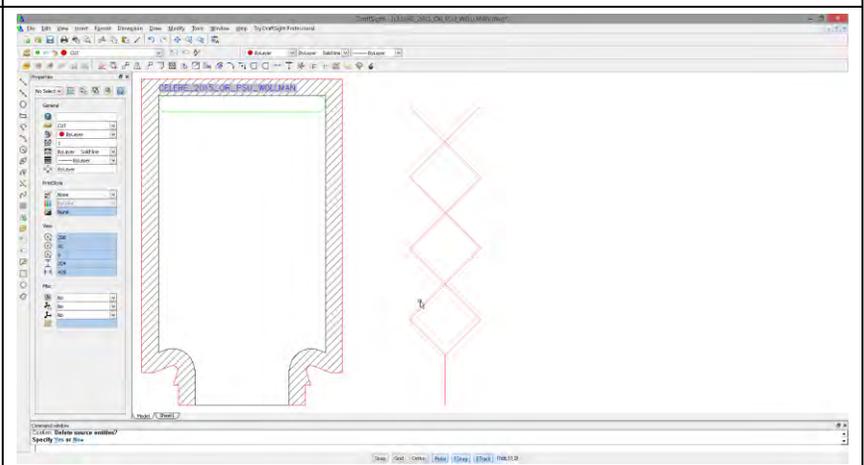


Left click on the end point of the polyline as shown (at the top of the vertical segment) to specify the end point of mirror line.

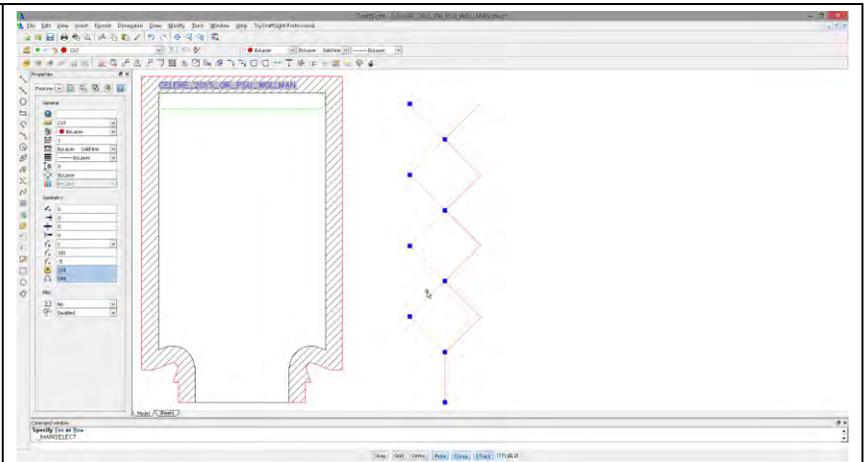


The command window prompts you to Confirm: Delete source entities? The default is no.

Press <space> to finish MIRROR.



To move the new polyline, left click the new polyline to select it.



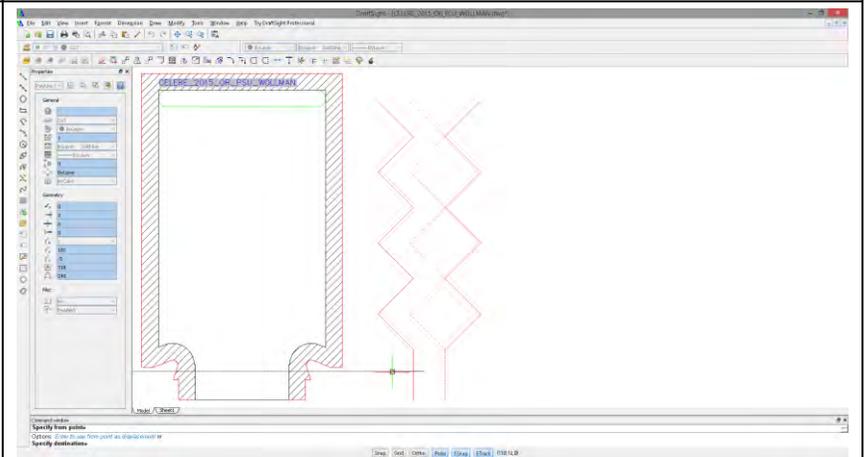
To enter the MOVE command ...

Type: m <space>

Left click anywhere in the window to select the 'from' point.

Move the mouse to the left of the 'from' point and make sure you see the horizontal guide lines.

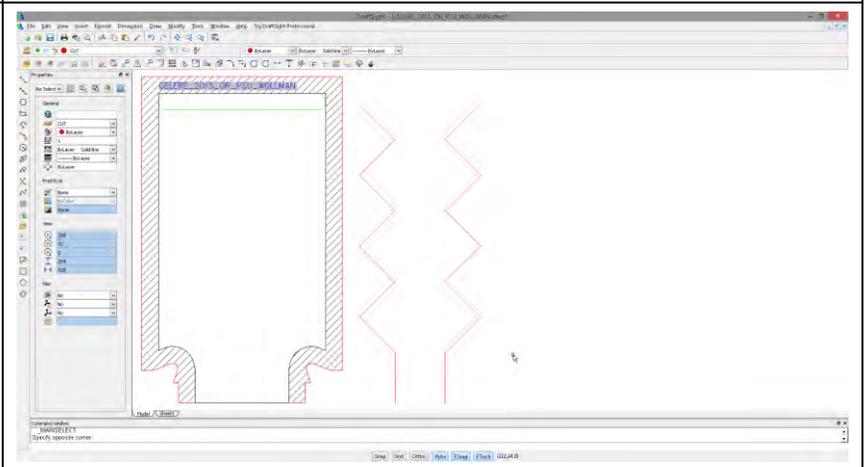
Type: 30 <space>



The move is done. Make sure the new polyline is a little away from the test cell outline.

If it is too close as it is in the screen shot to the right, select both polylines and move them together away from the test cell outline.

Save the drawing using Ctrl+S or the Save icon:

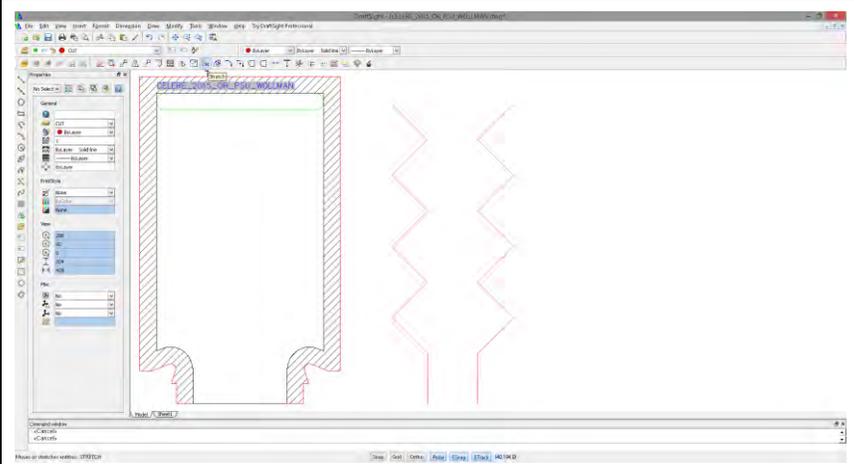


HORIZONTALLY STRETCH THE ZIGZAGS IN THE LEFT LINE

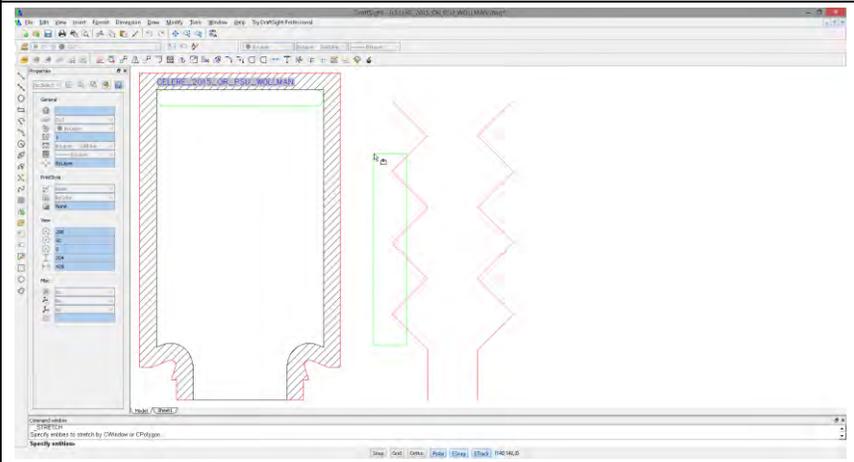
This tutorial includes two significant differences between the channels even though the channels in CELERE test cells should ideally have just one difference. The presence of curved vs. sharp corners in the zigzags is the most obvious, but the left channel is also stretched such that the zigzags in the two channels are at different angles. However, as a result of the stretching, the horizontal span of the zigzags is similar when the left channel's corners are curved. To be clear, if the left channel was not stretched, the horizontal span would be much shorter with the curved corners. This is an example where it is sometimes not possible to have a single difference between two channels, which is why the design requirement is **ideally** one difference between channels and why the design hint MOOD is **Mainly Only One Difference**.

To stretch the polylines, ...

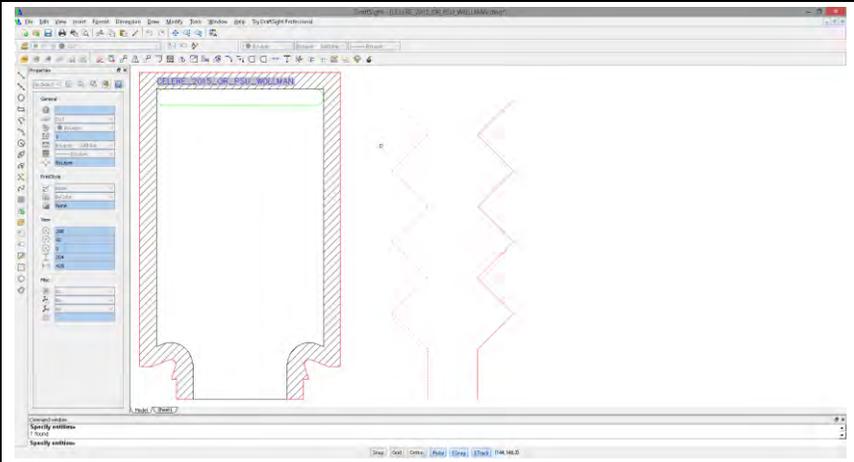
Under the top menu, Modify → click on the STRETCH icon .



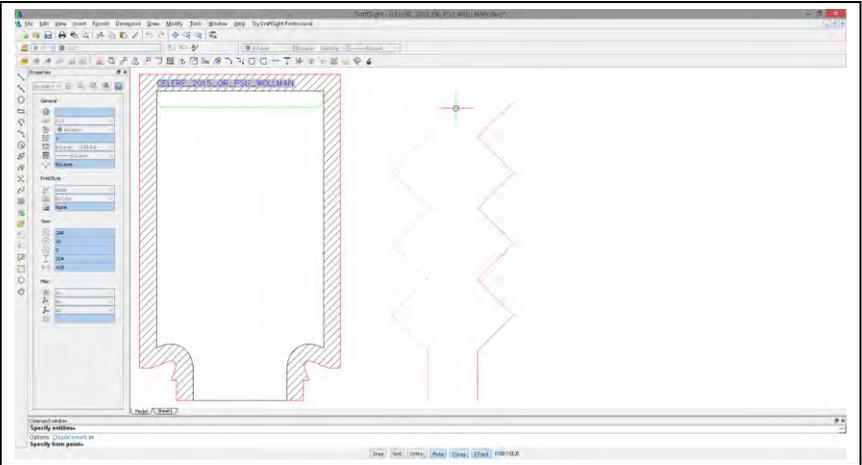
Use the intersection selection method to select the left three points of the left hand polyline.



Press <space> to indicate that all entities have been selected and execute the command.

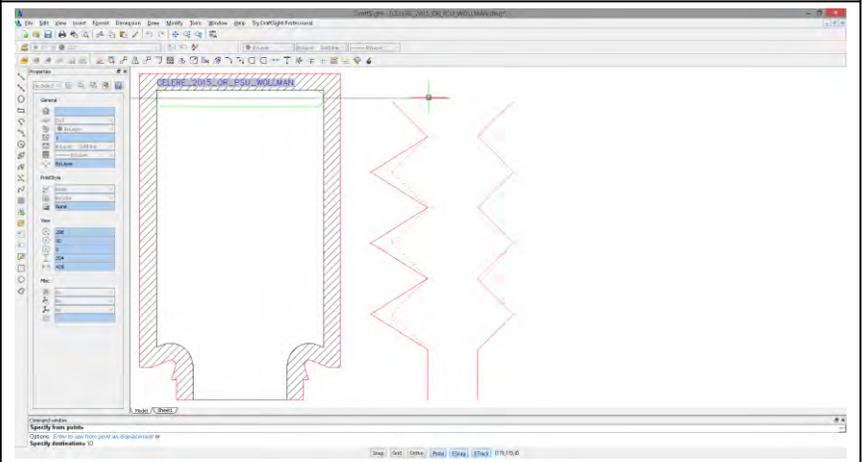


Somewhere in the workspace left click to select the 'from' point.

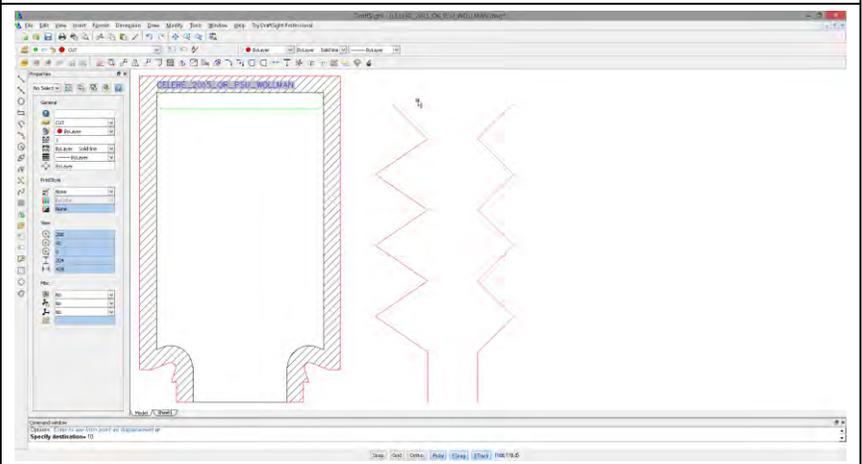


Move the mouse cursor horizontally to the left. Make sure the horizontal guide curve is activated.

Type: 10 <space>

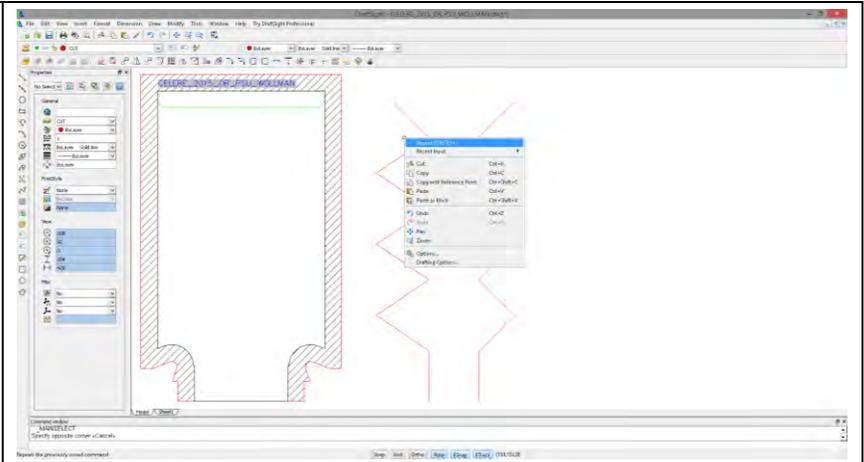


The stretch is done and the STRETCH command is automatically exited.



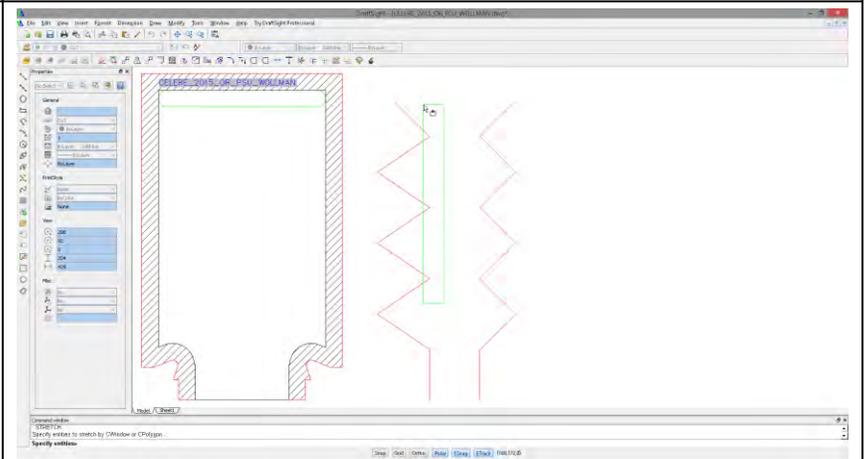
To stretch the other side, repeat the STRETCH command.

Right click on the workspace and select 'Repeat STRETCH' from the pop up menu.



Use the intersection selection method to select the right three points of the left hand polyline.

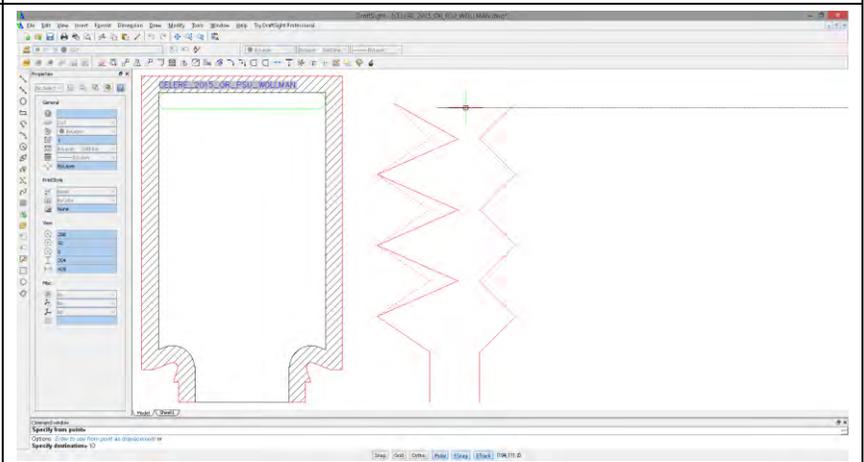
Press <space> to indicate that all entities have been selected and execute the command.



Somewhere in the workspace left click to select the 'from' point.

Move the mouse cursor horizontally to the right. Make sure the horizontal guide curve is activated.

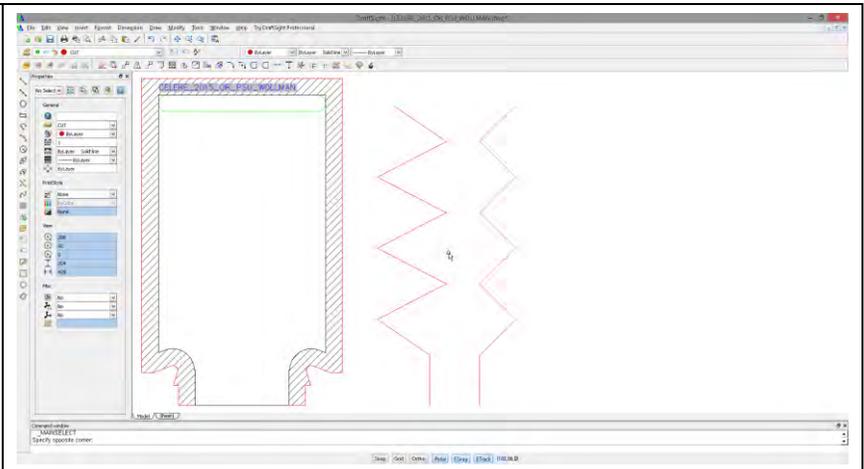
Type: 10 <space>



The *STRETCH* command exits.

We are done stretching.

Save the drawing using Ctrl+S or the Save icon:



MAKE THE CORNERS CURVED (INSTEAD OF SHARP) IN THE LEFT LINE

To fillet the polyline, ...

Under the top menu, Modify → click on the

FILLET icon .

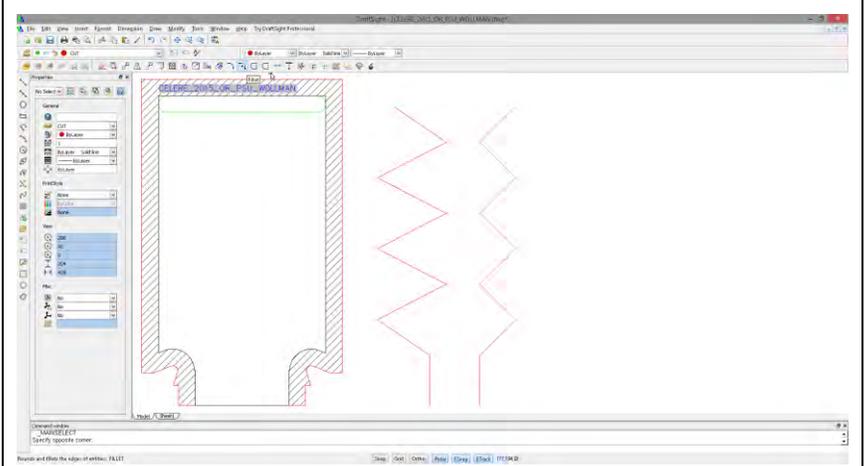
To change the default radius size, ...

Type:

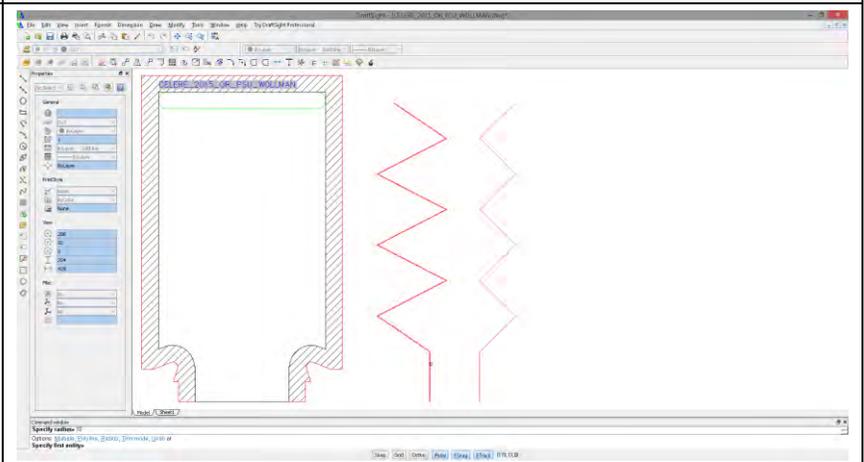
R <space>

12 <space>

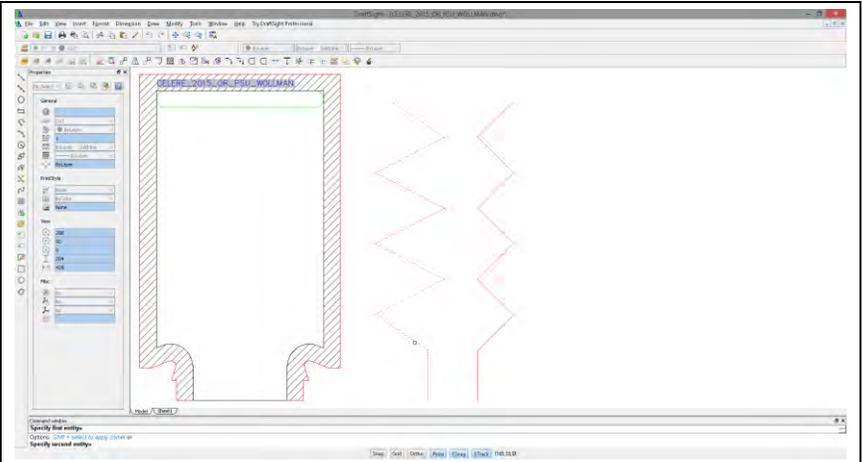
Note: The *FILLET* command is still activated.



Left click on the vertical line segment of the polyline on the left to select it.

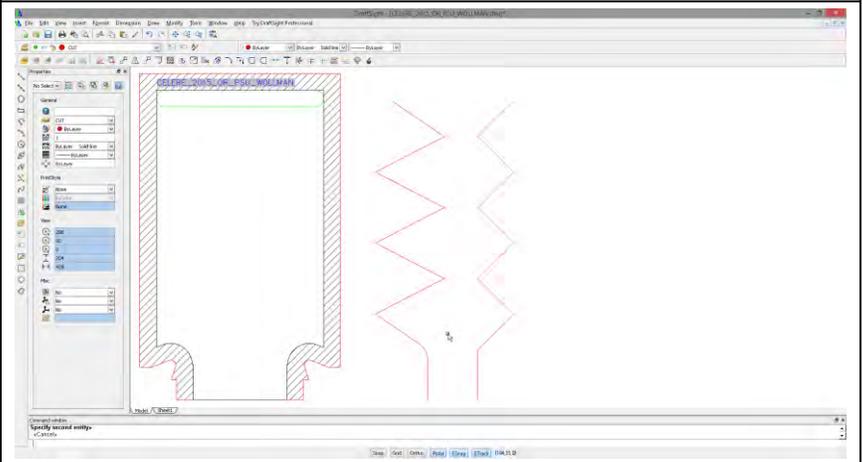


Left click on the first line above the vertical line.



This creates a filleted corner between these two line segments.

The FILLET command is still active.
Press escape to end the command.



The space bar can be used to repeat the last command. Repeat the FILLET command.

To change the fillet size,

Type:
R <space>
10 <space>

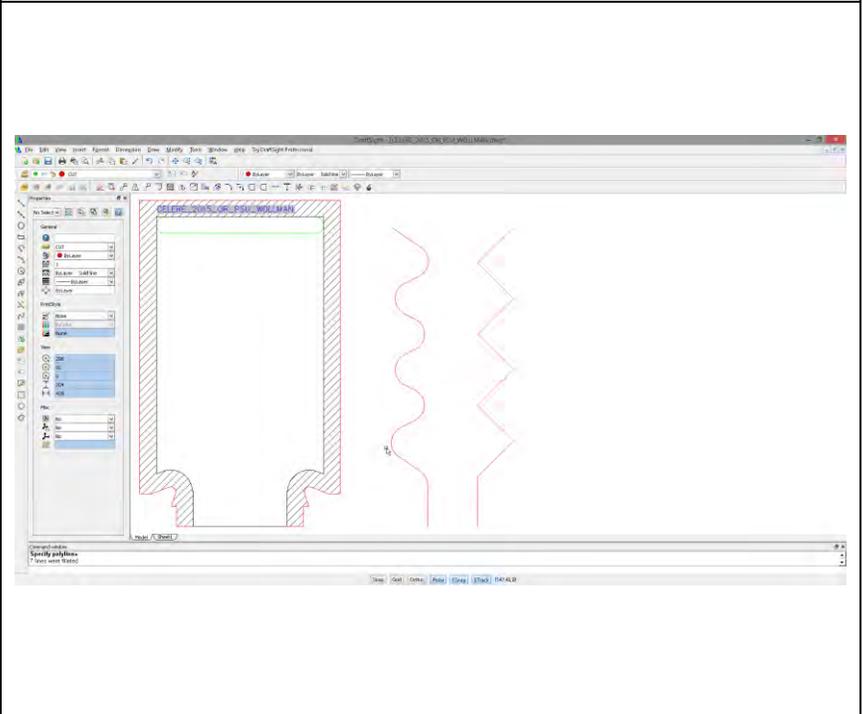
To fillet all the sharp corners of a polyline, ...

Type:
P <space>

Left click on the left hand polyline to select it for filleting.

The filleting task is done.

Save the drawing using Ctrl+S or the Save icon:

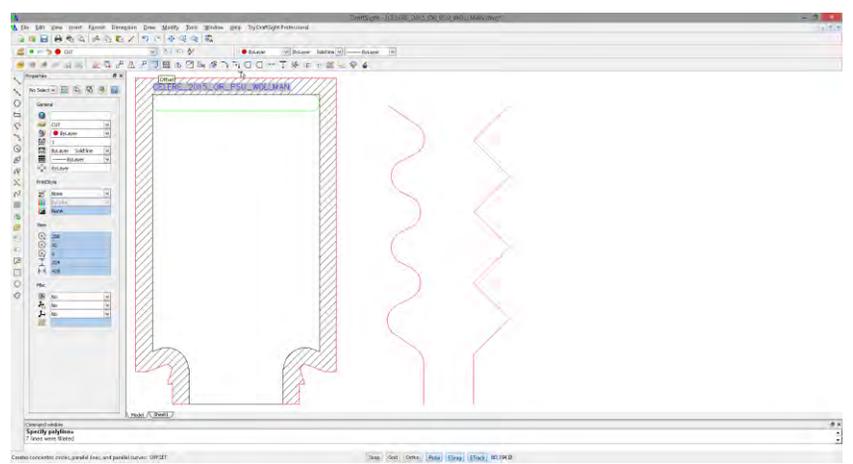


CHANGE THE ZIGZAGGING LINES INTO CHANNELS

We have drawn the center line of the channel.

To offset the center line to form the channel walls, ...

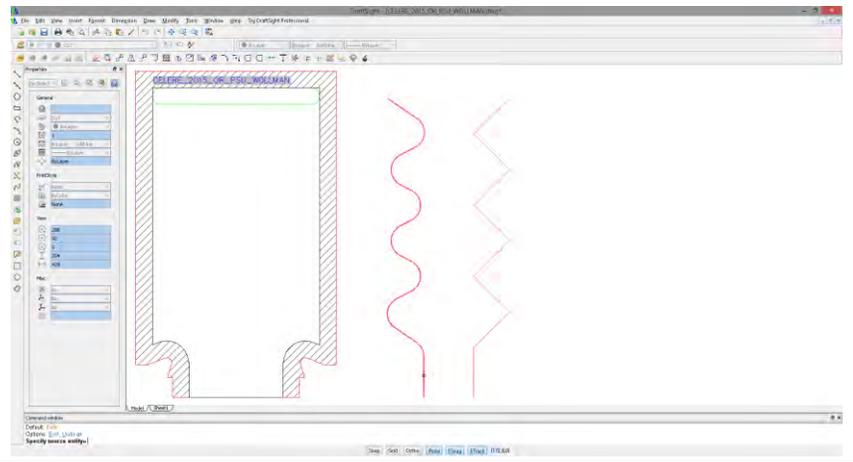
Under the top menu, Modify → click the OFFSET icon .



In the command window, specify off set distance of 3 mm.

Type: 3 <space>

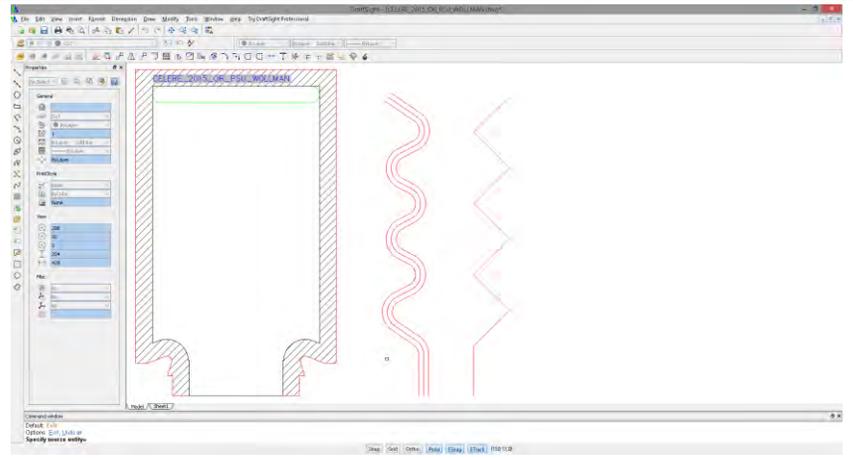
Left click on the left hand polyline to specify the source entity, i.e., the feature to be offset.



The command window will prompt you to specify the side for the destination, i.e., offset.

Type: B <space>

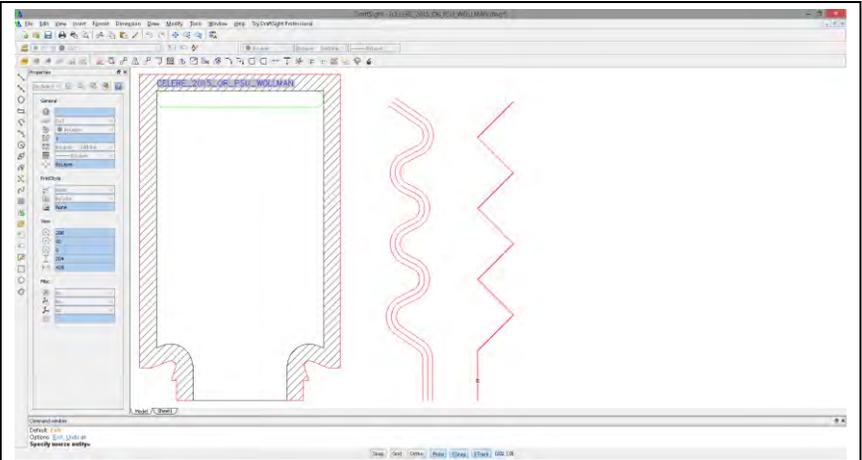
This tells the program to offset the line 3mm in both directions.



The OFFSET command is still active.

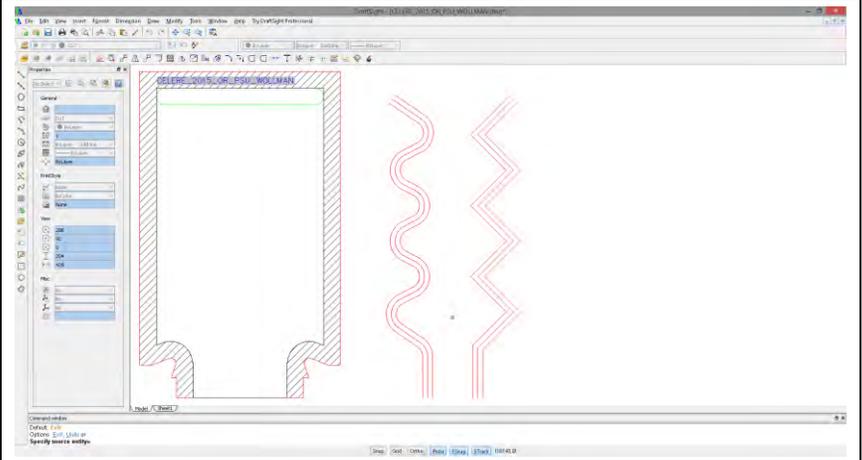
Select the right hand polyline.

Type: B <space>



The offset task is done.

Save the drawing using Ctrl+S or the Save icon:

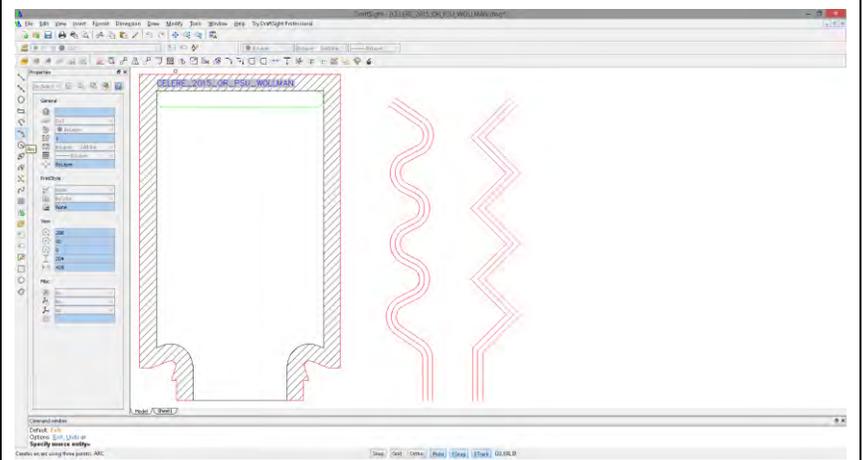


CLOSE THE CHANNEL TOPS

A common mistake is to skip this step, which in this example would yield 4 narrow channels that are the width of the laser cut.

To draw an arc to cap the two channels, ...

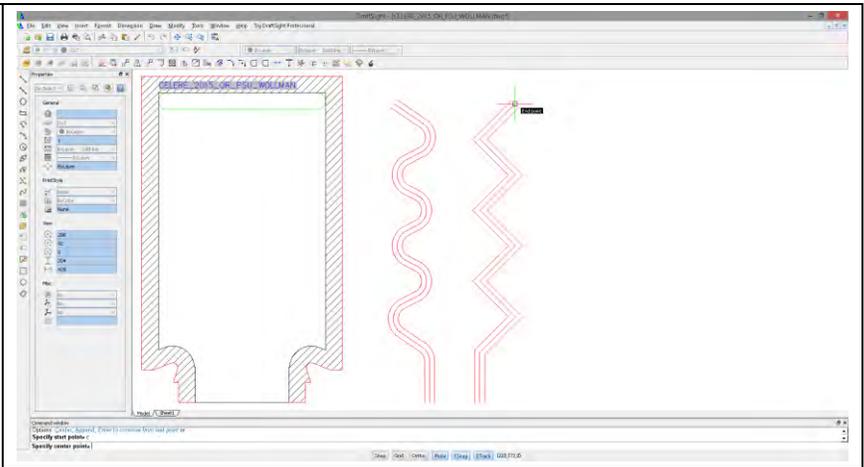
On the left menu, click on arc icon  to start the ARC command.



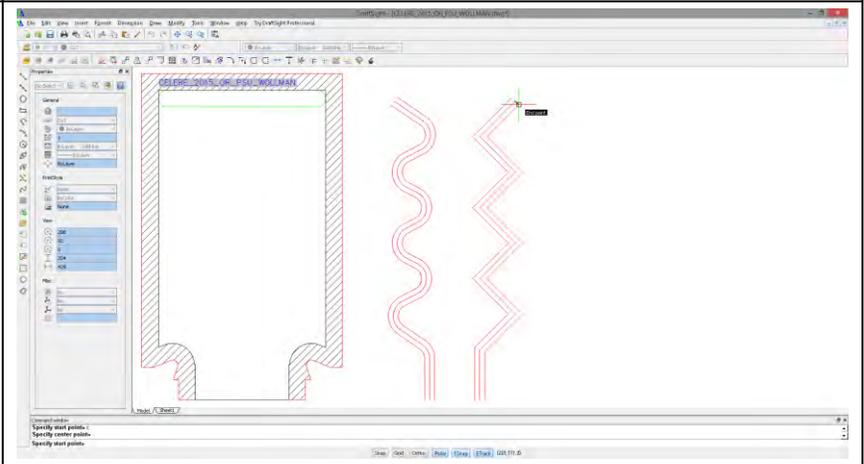
To draw an arc by specifying its center and then two end points, ...

Type: C <space>

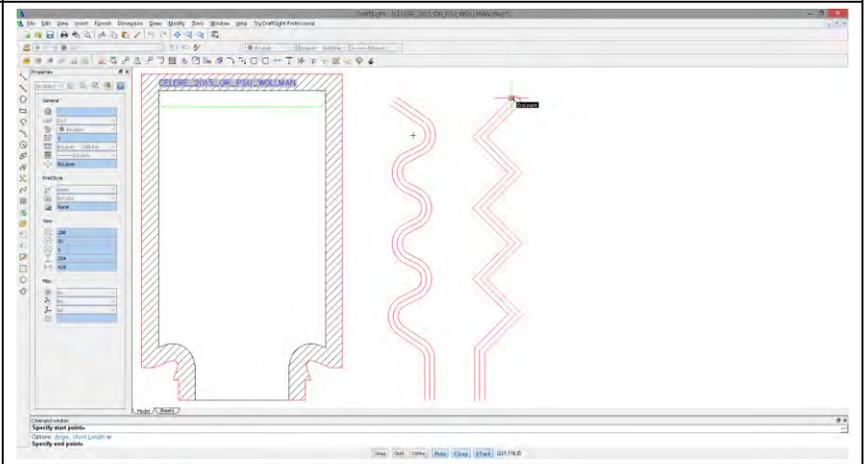
Left click on the end point shown on the right, i.e., the top of the right channel's center line.



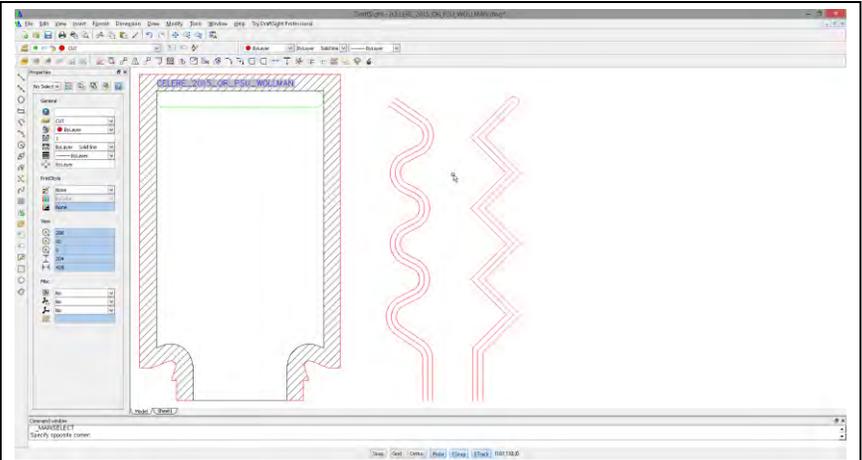
Left click on the end point shown on the right, i.e., the top of the right channel's right wall.



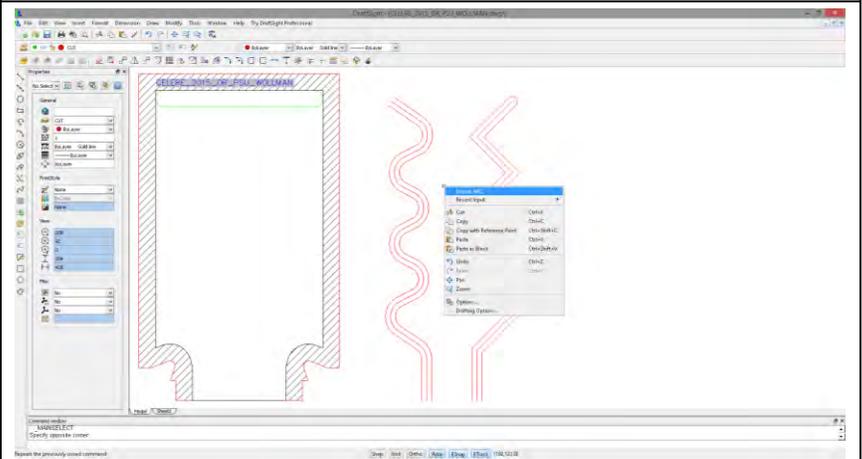
Left click on the end point shown on the right, i.e., the top of the right channel's left wall.



The arc is completed on the right channel.



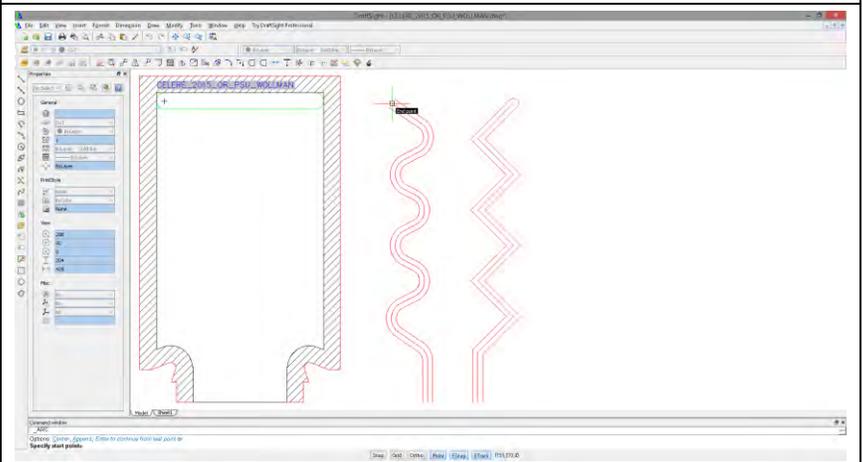
Right click on the workspace and select 'Repeat ARC' from the pop up menu.



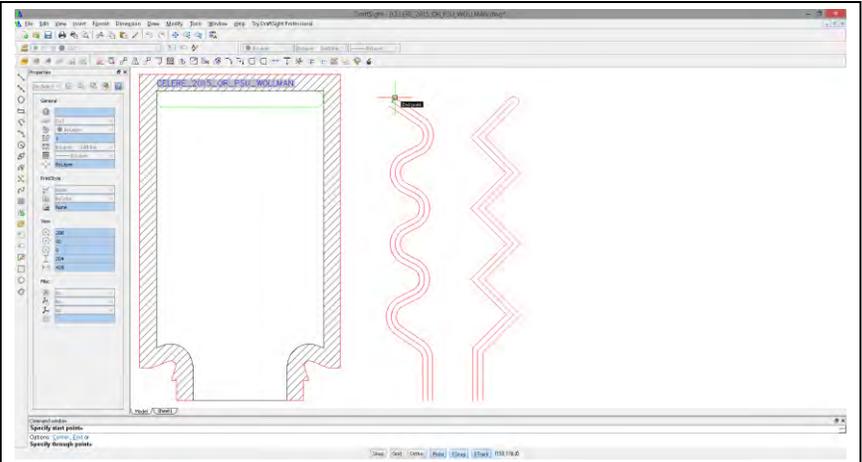
To draw an arc by specifying its center and then two end points, ...

Type: C <space>

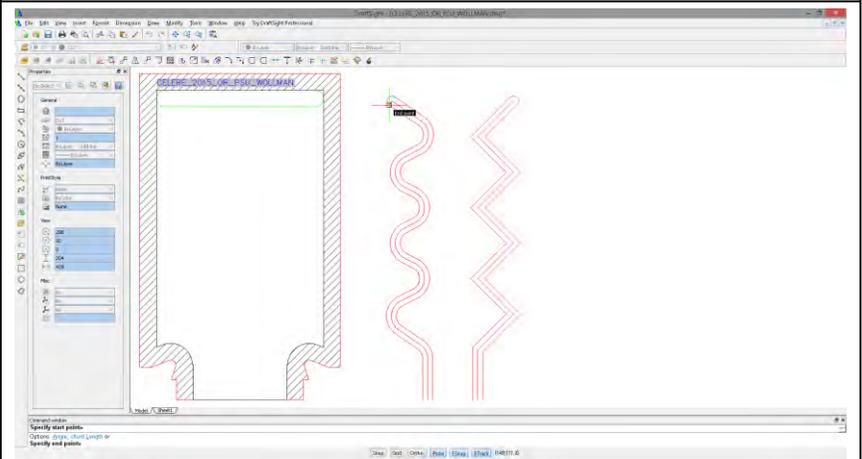
Left click on the end point shown on the right, i.e., the top of the left channel's center line.



Left click on the end point shown on the right, i.e., the top of the left channel's right wall.

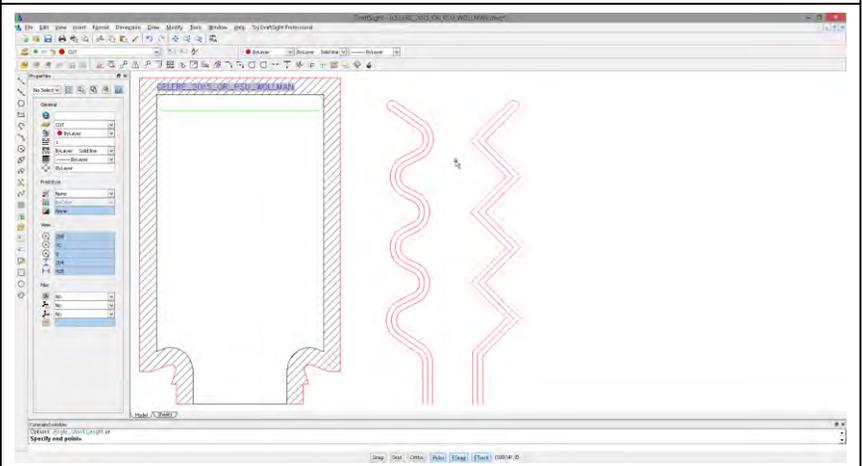


Left click on the end point shown on the right, i.e., the top of the left channel's left wall.



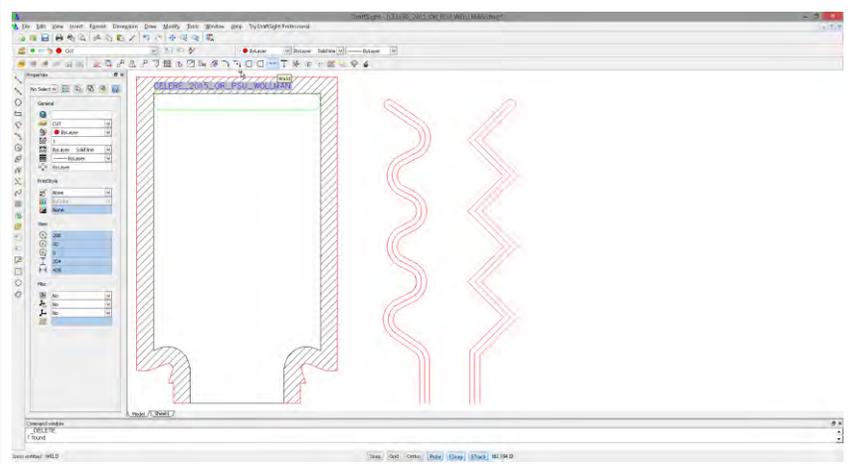
The task of closing the top of the channels with arc is complete.

Save the drawing using Ctrl+S or the Save icon:

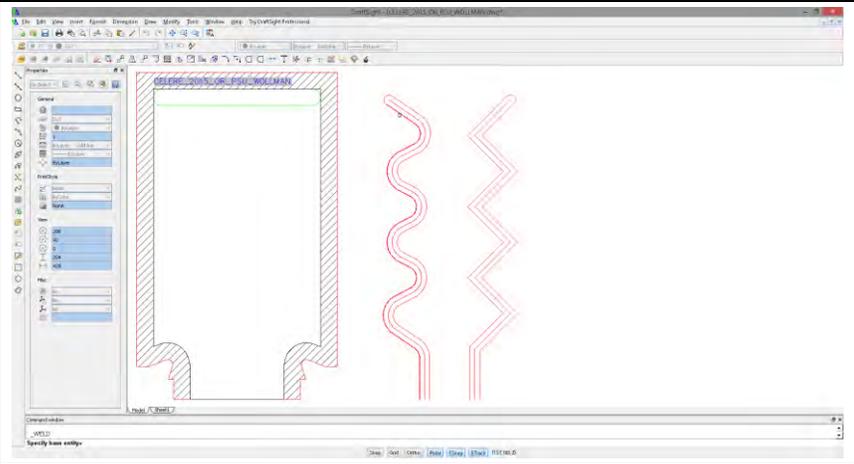


WELD TOGETHER THE LEFT, TOP, AND RIGHT PARTS OF EACH CHANNEL

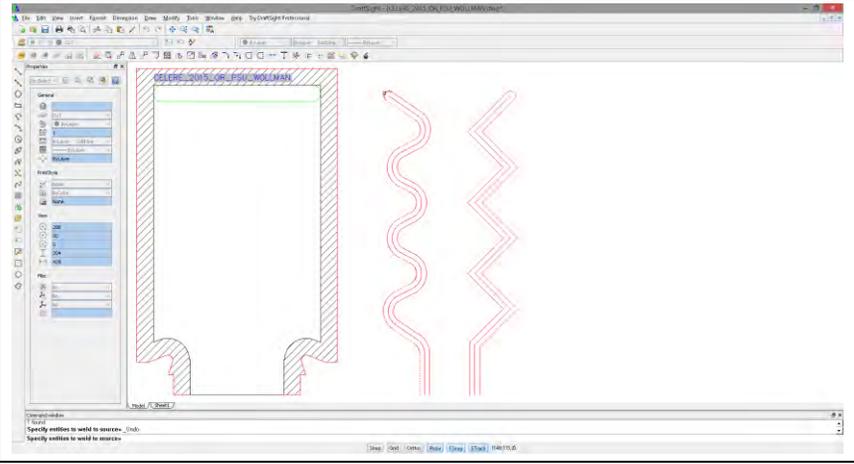
To weld the left, top, and right parts of each channel (i.e., the polylines and arc) together, Under the top menu, Modify → click on the weld icon  to enter the WELD command.



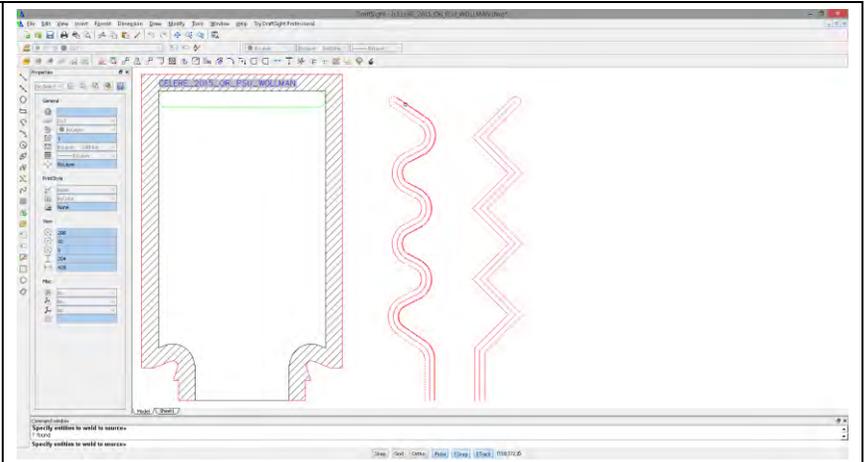
Left click the left wall (i.e., polyline) of the left channel.



Left click the left channel's top (i.e., arc).

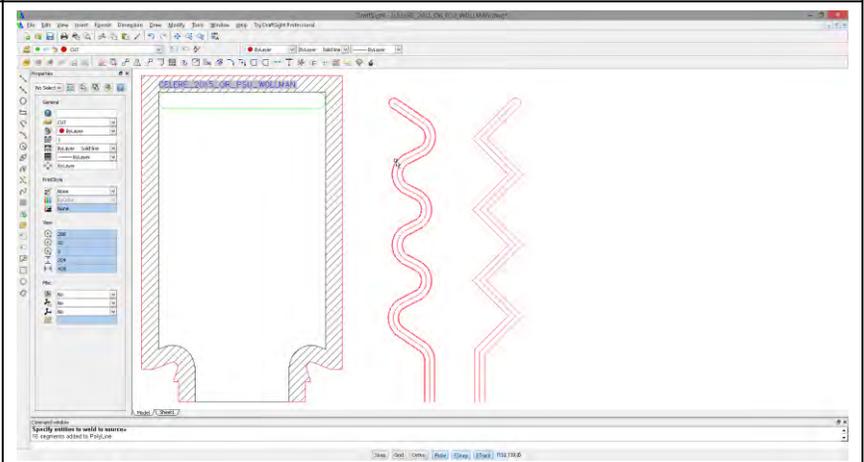


Left click the right wall (i.e., polyline) of the left channel.



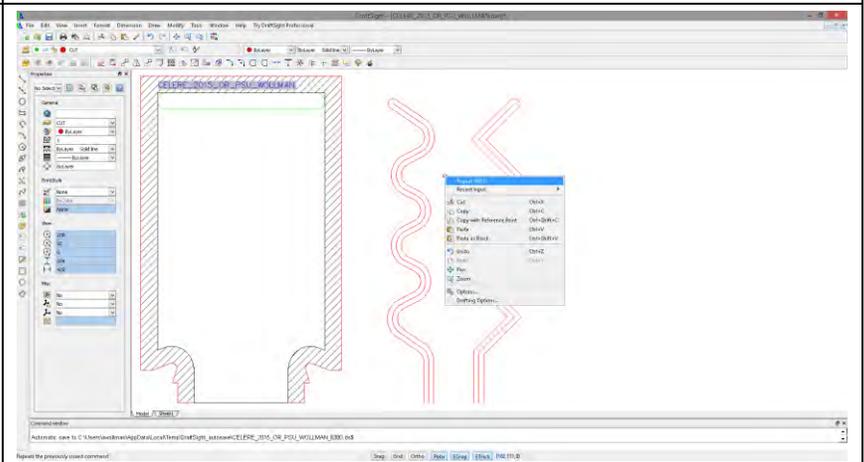
Press <space> to execute the command.
The left hand channel is welded together.

Hovering the mouse cursor over the channel shows that the three channel components are welded together and should be bold as shown on the right.

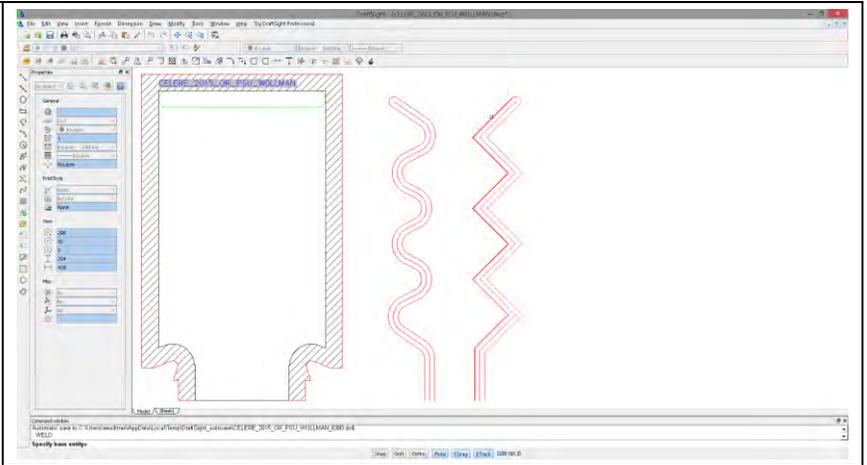


Save the drawing using Ctrl+S or the Save icon:

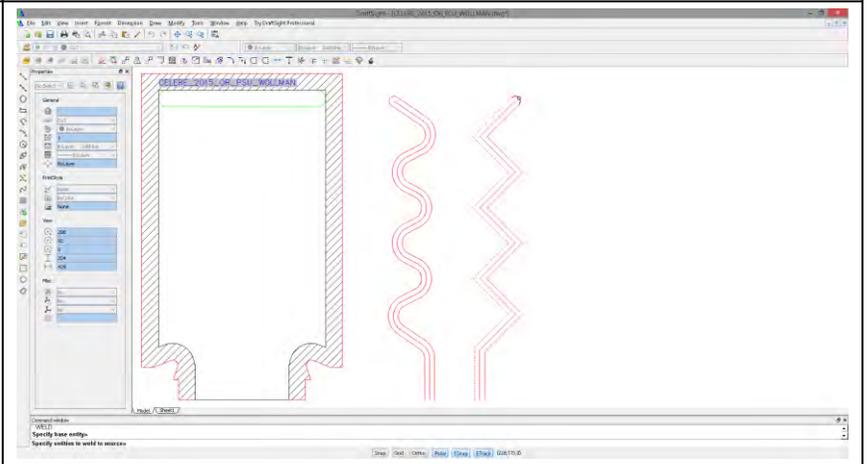

To weld the left, top, and right parts of the right channel (i.e., the polylines and arc) together,
Right click on the workspace and select 'Repeat ARC' from the pop up menu.



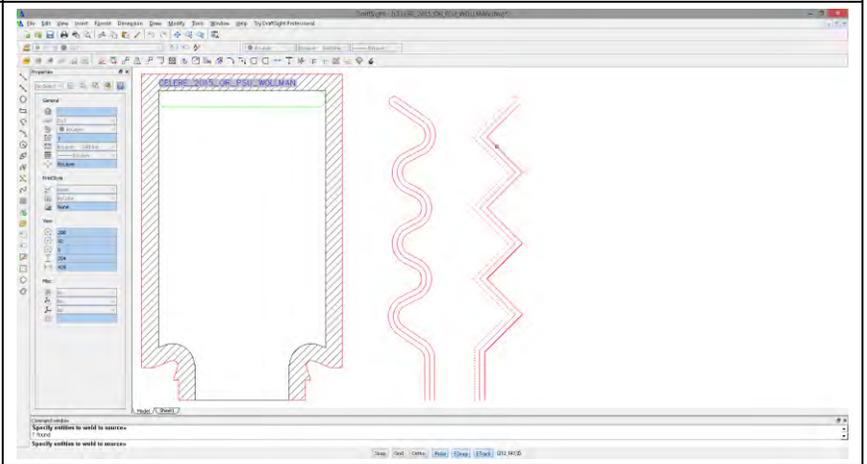
Left click the left wall (i.e., polyline) of the right channel.



Left click the right channel's top (i.e., arc).

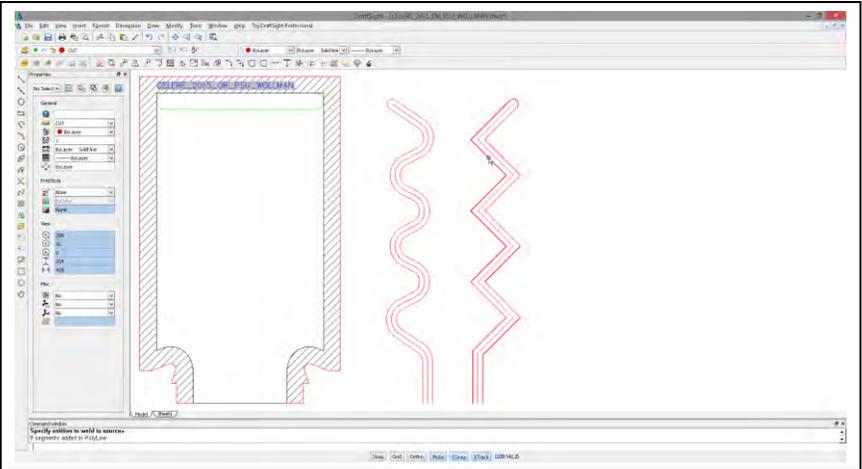


Left click the right wall (i.e., polyline) of the left channel.



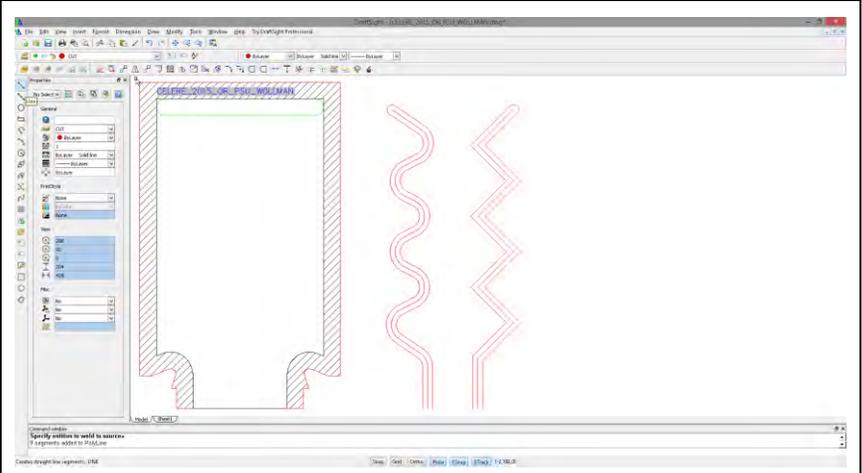
Type: <space>
to confirm that the right channel welding is done.

Save the drawing using Ctrl+S or the Save icon:

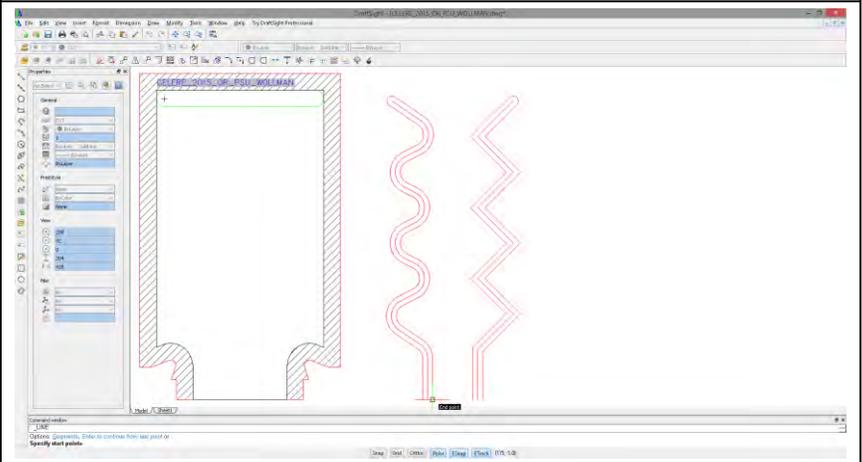


CREATE THE BASE OF THE TEST CELL'S MIDDLE LAYER

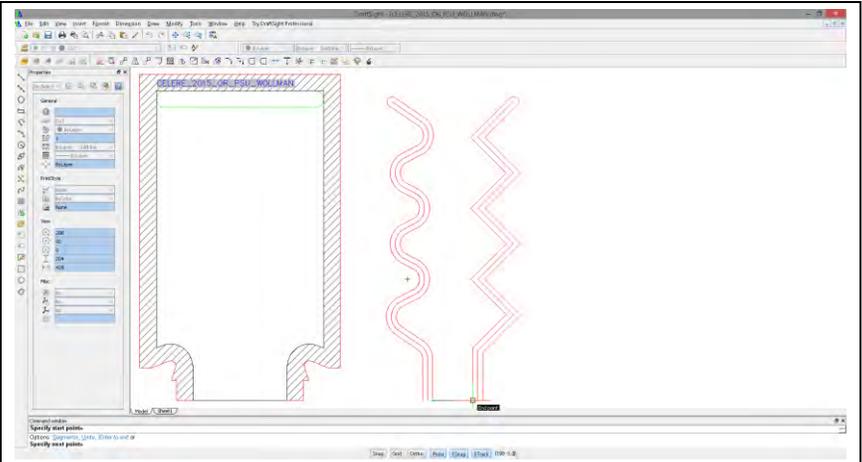
On the left menu, click on the LINE icon  to enter the LINE command.



Left click the end point shown (i.e., the bottom of the left channel's right wall) to specify the start point.

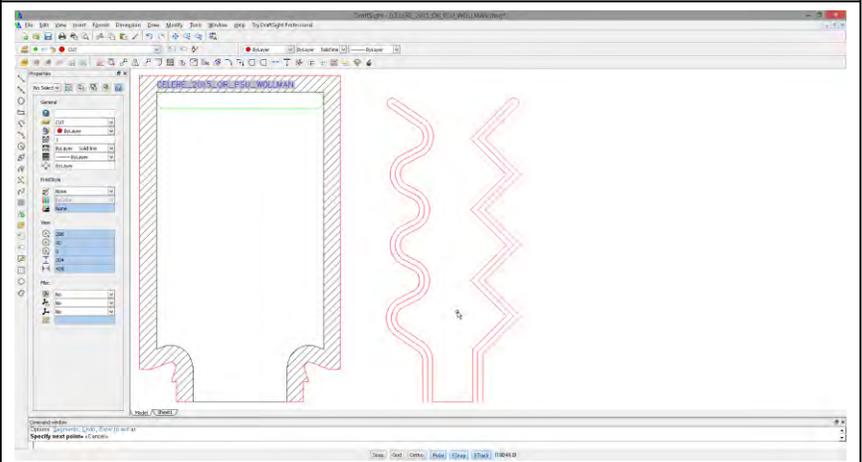


Left click the end point shown (i.e., the bottom of the right channel's left wall) to specify the next point.



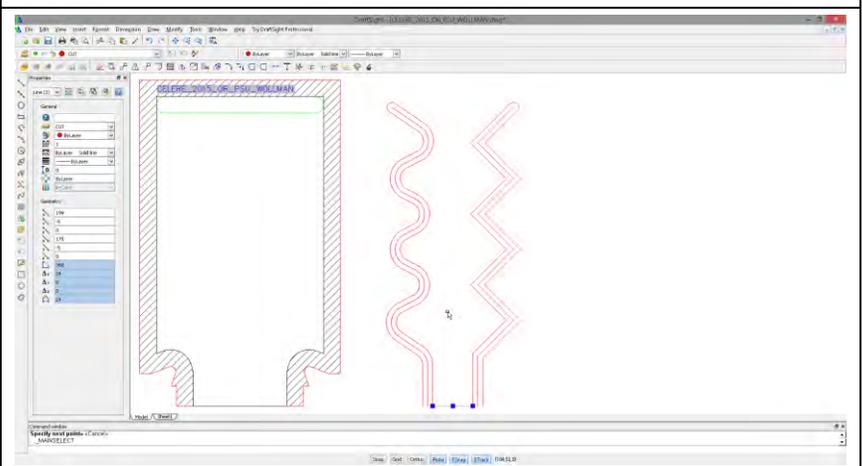
Exit the LINE command by pushing escape.

Save the drawing using Ctrl+S or the Save icon:

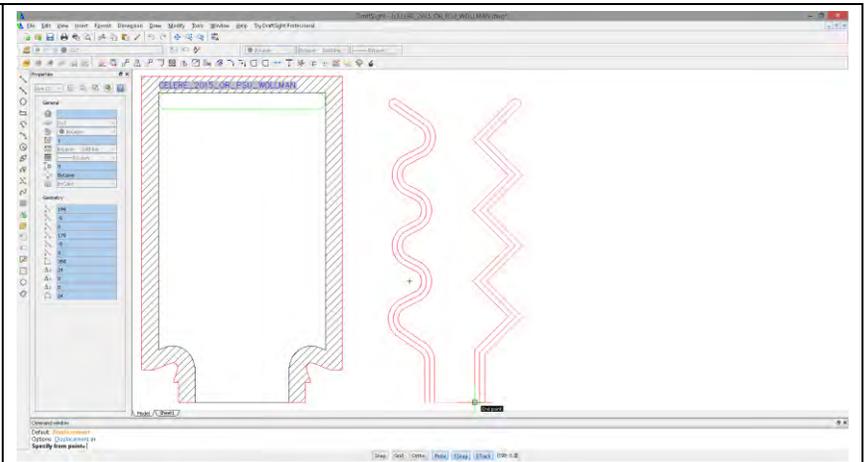


To copy the line we just drew, ...
Left click on the line to select it.

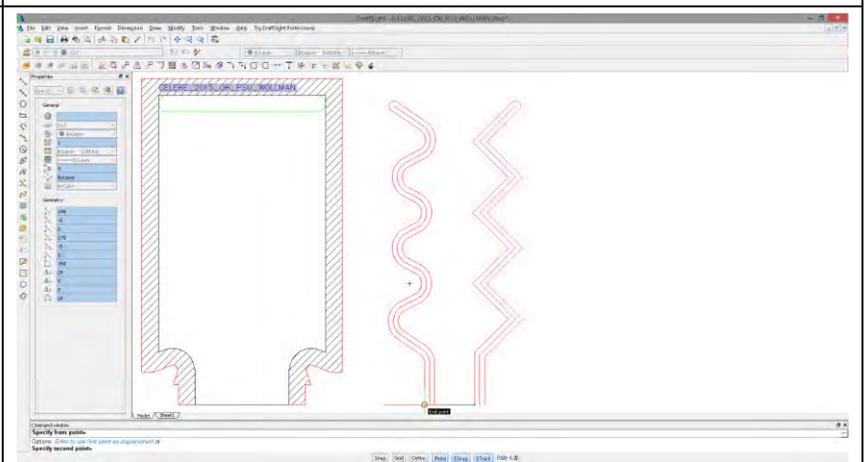
Type: co <space>



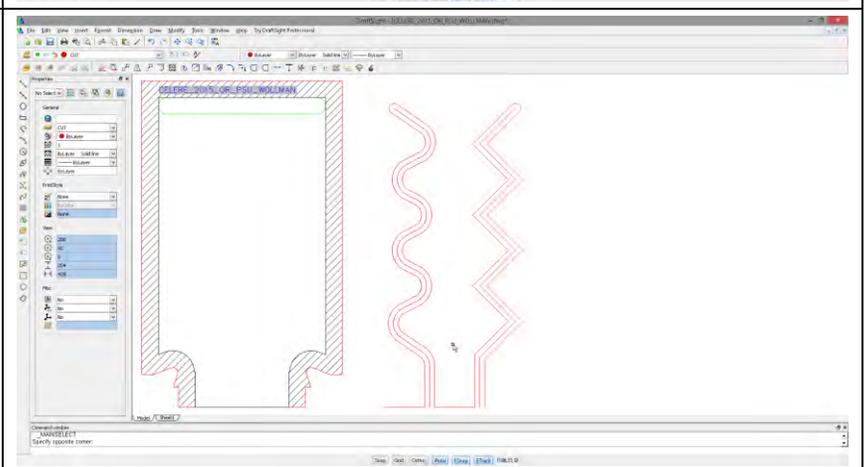
Click on the right end point of the line as shown. *This specifies the 'from' point.*



Select the end point as shown (i.e., the bottom of the left channel's left wall) as the destination for the copy.

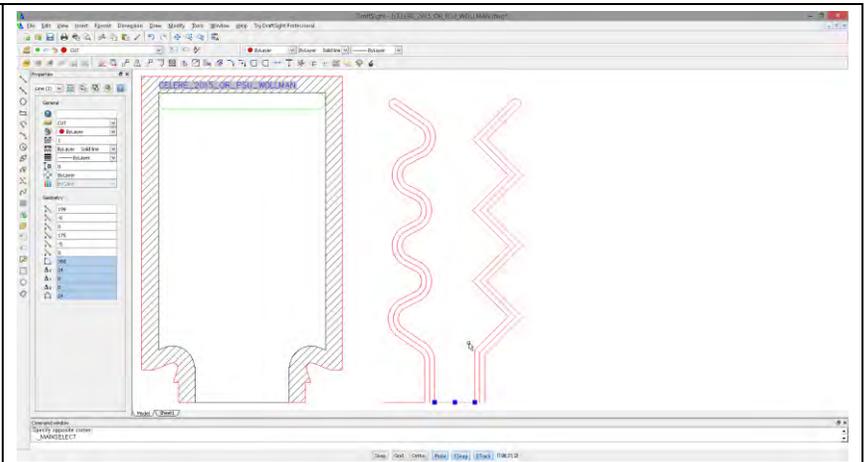


The copying of the line to the left is complete. Press escape to exit the COPY command.

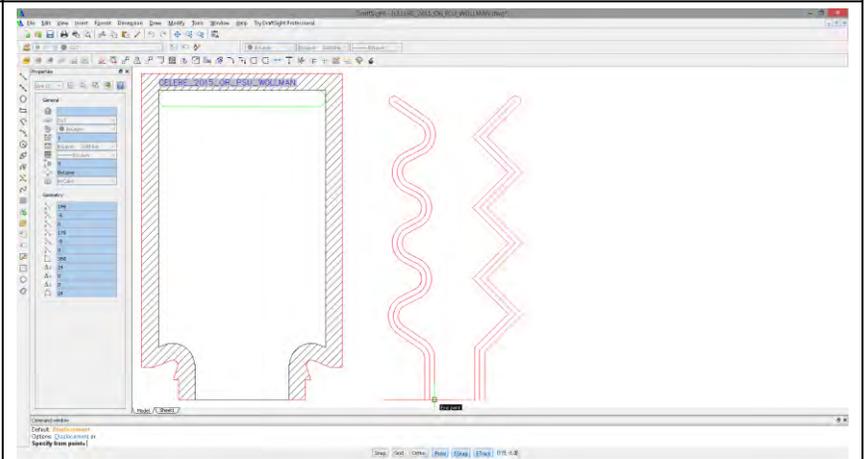


Select center line again. *We are going to copy it using a different 'from' point.*

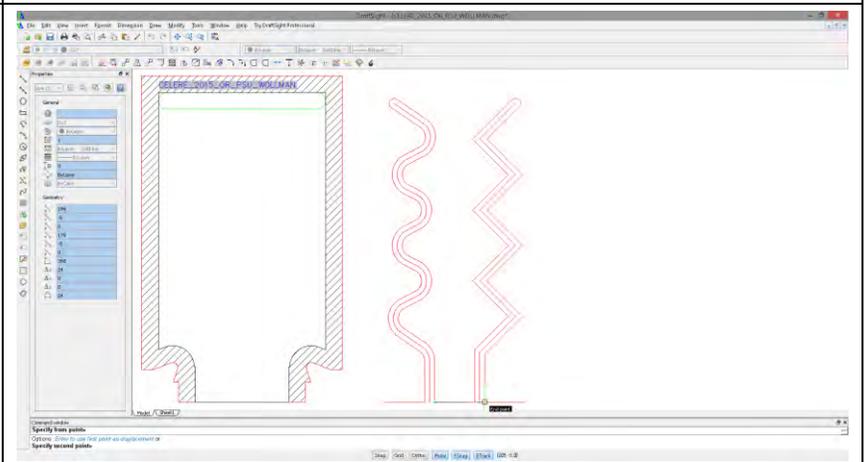
Type: co <space>



This time select the left end point of the line as shown (i.e., at the bottom of the right wall of the left channel).

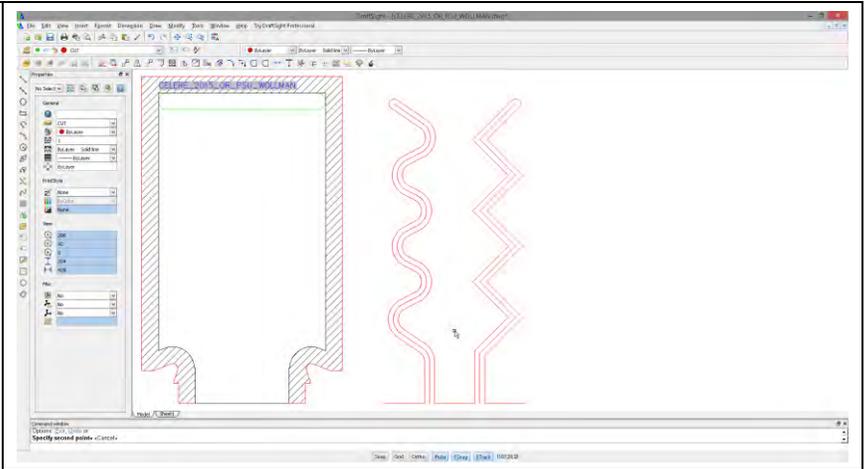


Select the end point as shown (i.e., the bottom of the right channel's right wall) as the destination for the copy.



The copying of the line to the right is complete.

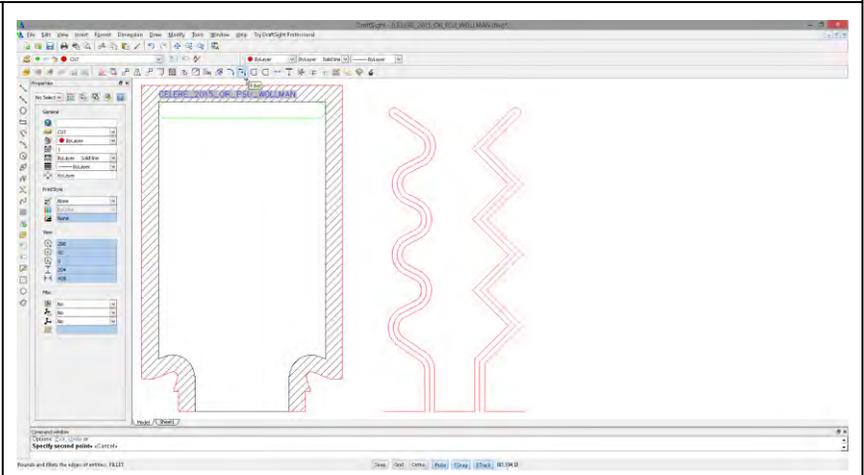
Save the drawing using Ctrl+S or the Save icon:



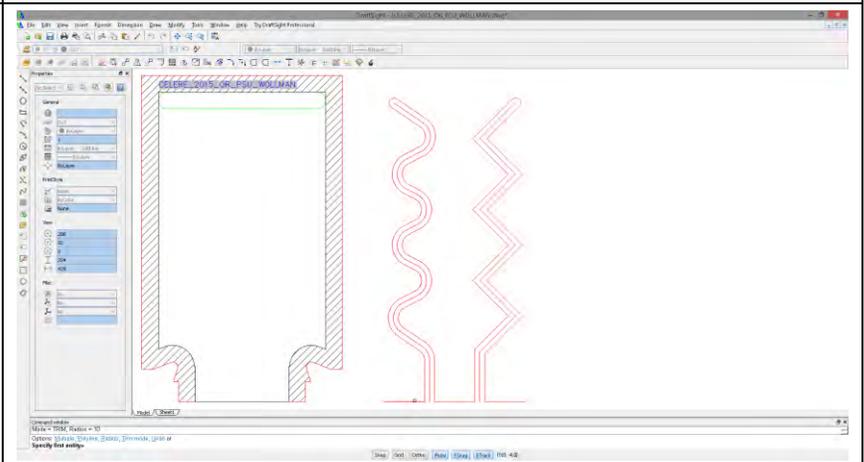
CREATE CURVED INLET SECTIONS FOR THE CHANNELS

To fillet the base of the channel walls, ...
Under the top menu, Modify → click on the
FILLET icon .

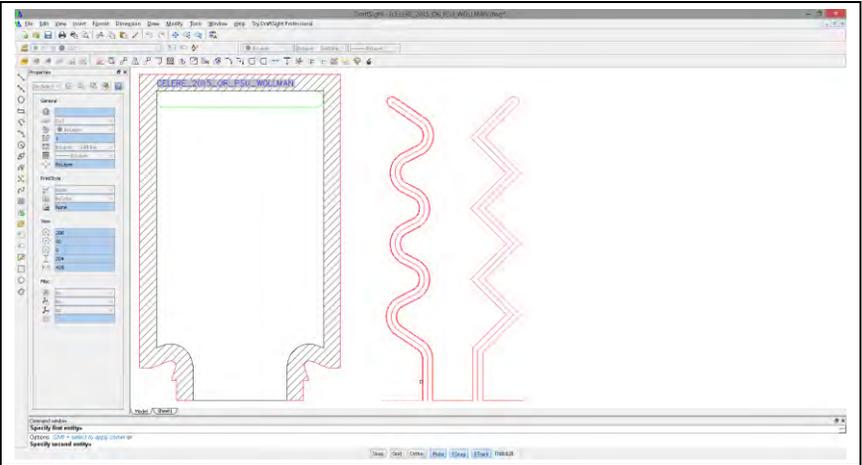
To change the default radius size, ...
Type:
R <space>
10 <space>



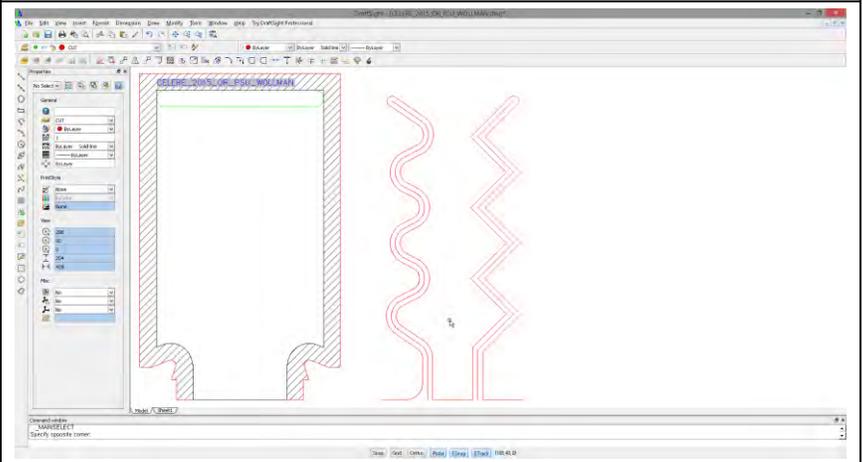
Select the horizontal line on the left to specify
the first item.



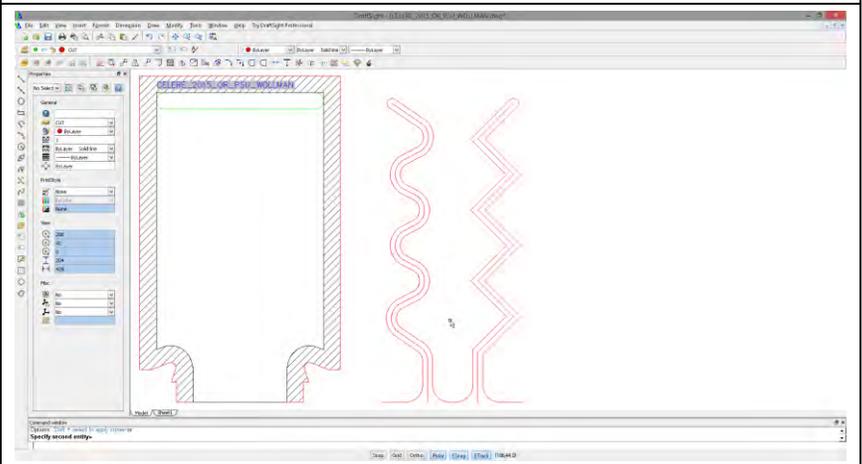
Select the left channel to specify the second item.



The left channel's left corner now has a fillet.



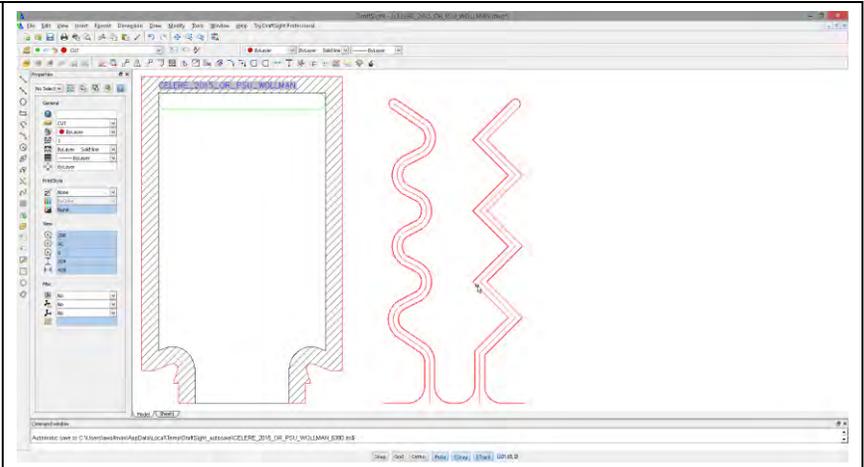
Repeat the same process for the other three corners at the entrance to the channels.



The fillet task is complete. Note how the line is now completely connected.

Hover mouse over the channel outline to verify the entire outline is highlighted.

Save the drawing using Ctrl+S or the Save icon:

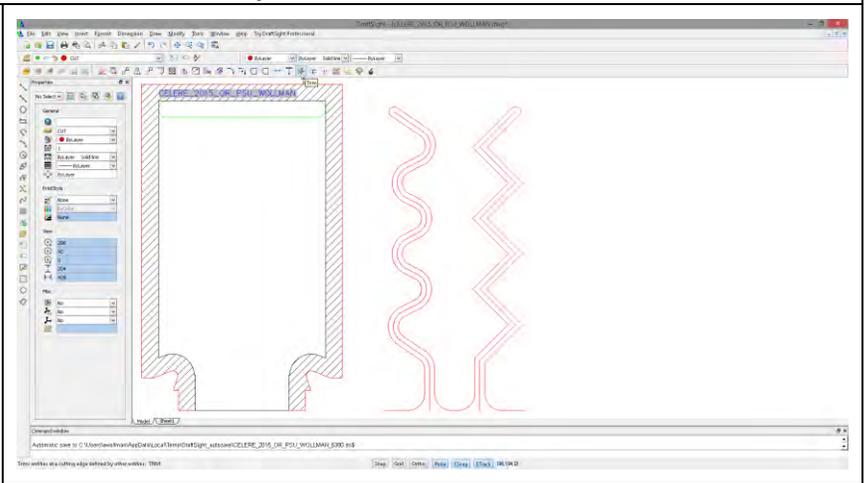


TRIM THE LINE AT THE BOTTOM (I.E., TEST CELL BASE)

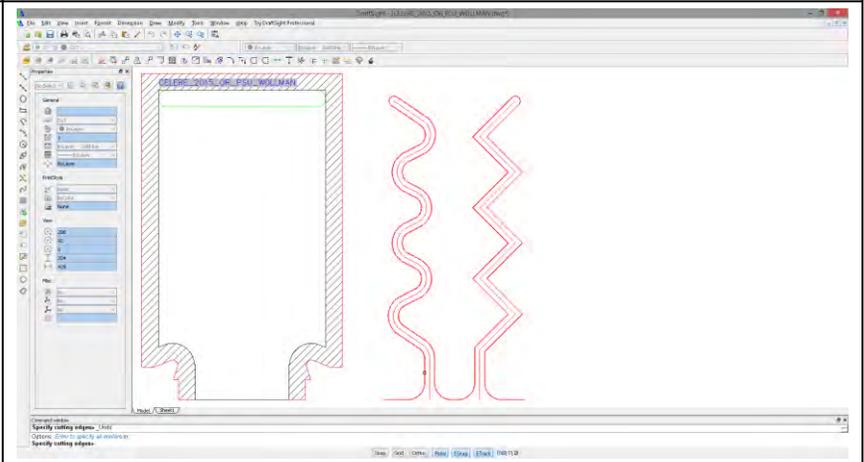
To trim (i.e., eliminate) line segments that we don't need or want, ...

Under the top menu, Modify → click on the

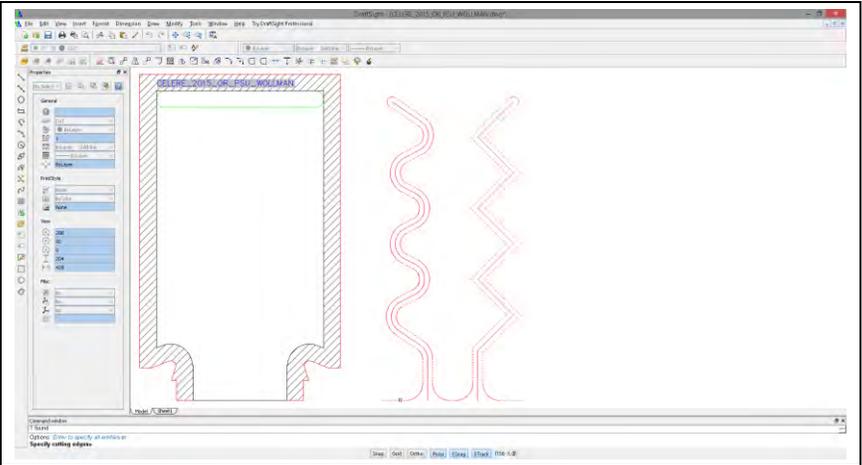
TRIM icon  to start the TRIM command.



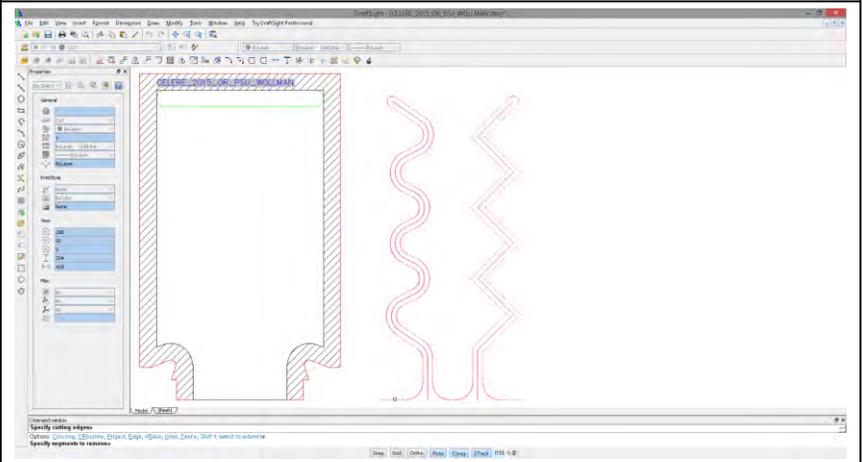
Select the polyline (i.e., channels) to specify that item that needs trimming.



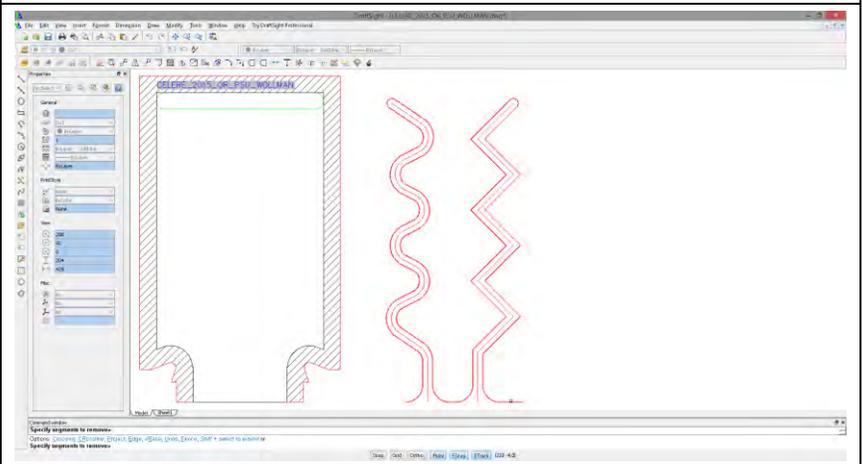
Type <space> to confirm the selection.



Select the left hand horizontal line as shown for trimming.

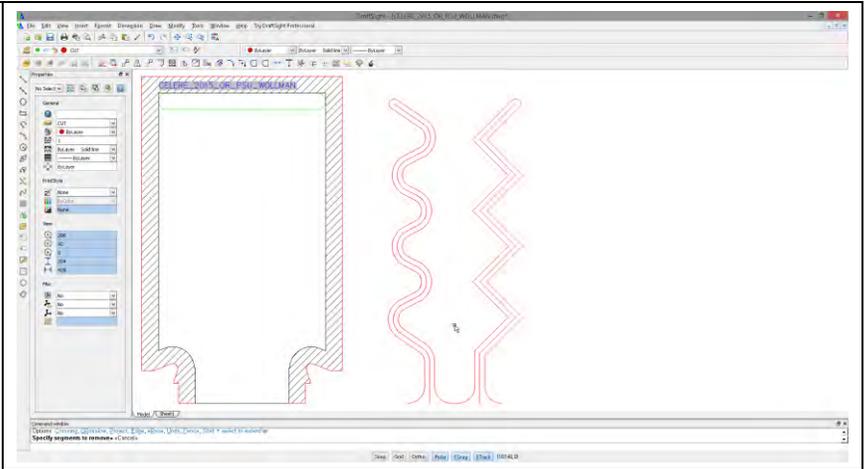


Select the right hand horizontal line as shown for trimming.



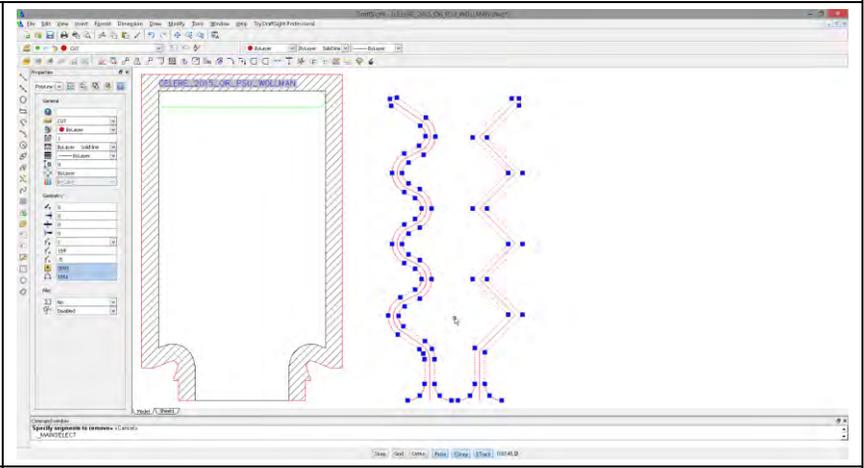
The trimming is complete. Press escape to exit the TRIM command.

Save the drawing using Ctrl+S or the Save icon:



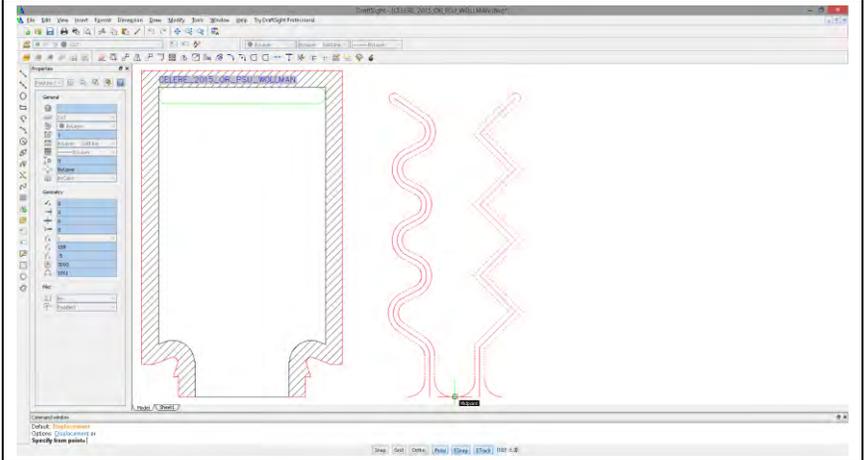
MOVE THE CHANNELS INTO THE TEST CELL

Select the channel polyline.



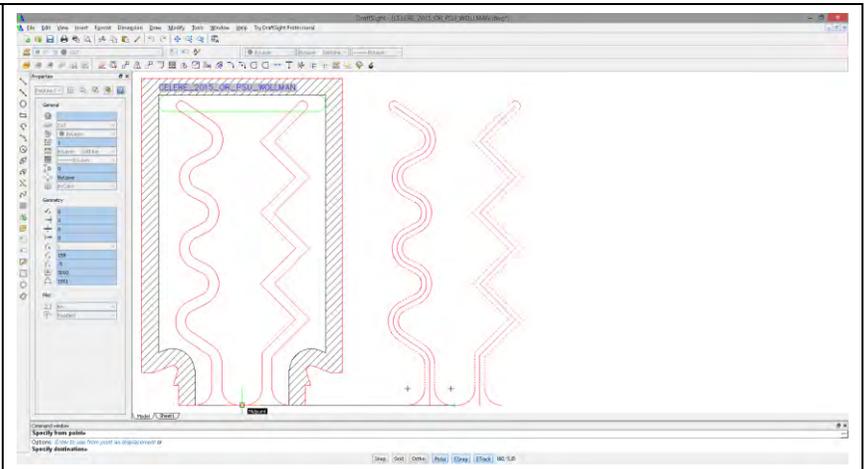
Type: m <space>

Select the midpoint of the horizontal line to specify the 'from' point.



Specify the destination by selecting the midpoint of the test cell bottom.

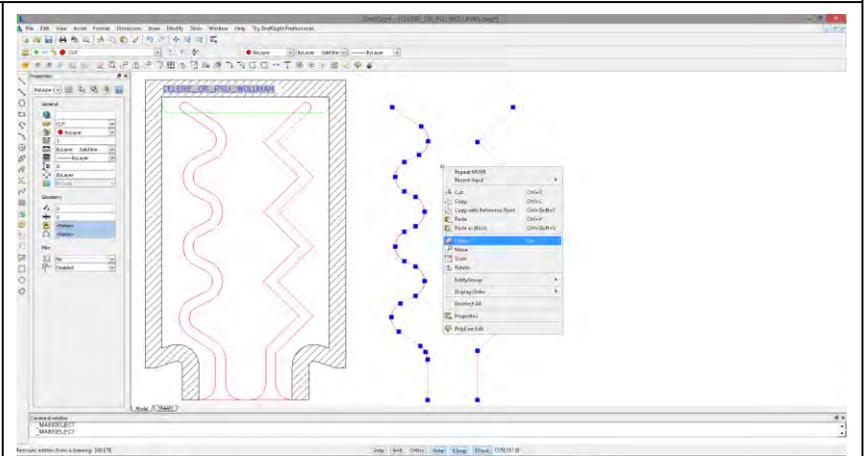
Save the drawing using Ctrl+S or the Save icon:



FINISH THE DRAWING

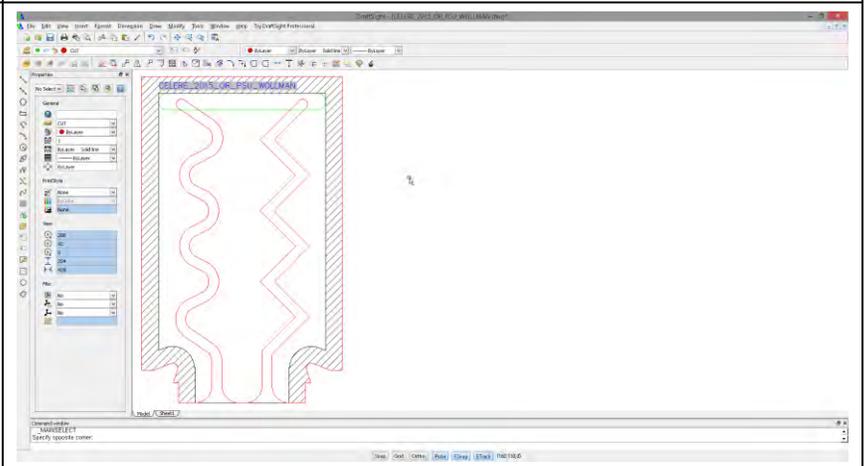
To clean up the drawing, ...

Select the remaining channel center lines (i.e., to the right of the test cell), right click on the workspace, and select 'Delete' from the pop up window.



The drawing is done.

Save the drawing using Ctrl+S or the Save icon:



Questions

As a start, please review the CELERE information available on the web at:

<http://spaceflightsystems.grc.nasa.gov/CELERE/>

www.facebook.com/NASA.celere

For more information, please e-mail celere@lists.nasa.gov.