Chapter

7

Advanced Castings

In this chapter, you will learn the following to World Class standards:

- **Converting a Fabricated Metal Design to a Casting**
- **Electrical Enclosure Casting Design in 2D**
- **Electrical Enclosure Casting Design in 3D**
- **Comparisons of the Two Designs**
- **More Designs**

Converting a Fabricated Metal Design to a Casting

Now that we know some of the basics about designing a casting, we can begin our first project utilizing that knowledge. In this assignment, we will reengineer an electrical enclosure that was originally made from fabricated aluminum and now make the box from cast aluminum. We can still make the cover plate and interior panel shown in Figure 7.1 from stamped aluminum, resulting in an economical solution for making these simple parts. Both the box and the gasket can be cast to save material and therefore reduce material and manufacturing cost. There are multiple ways to make the cast box and we will start with the easiest first.

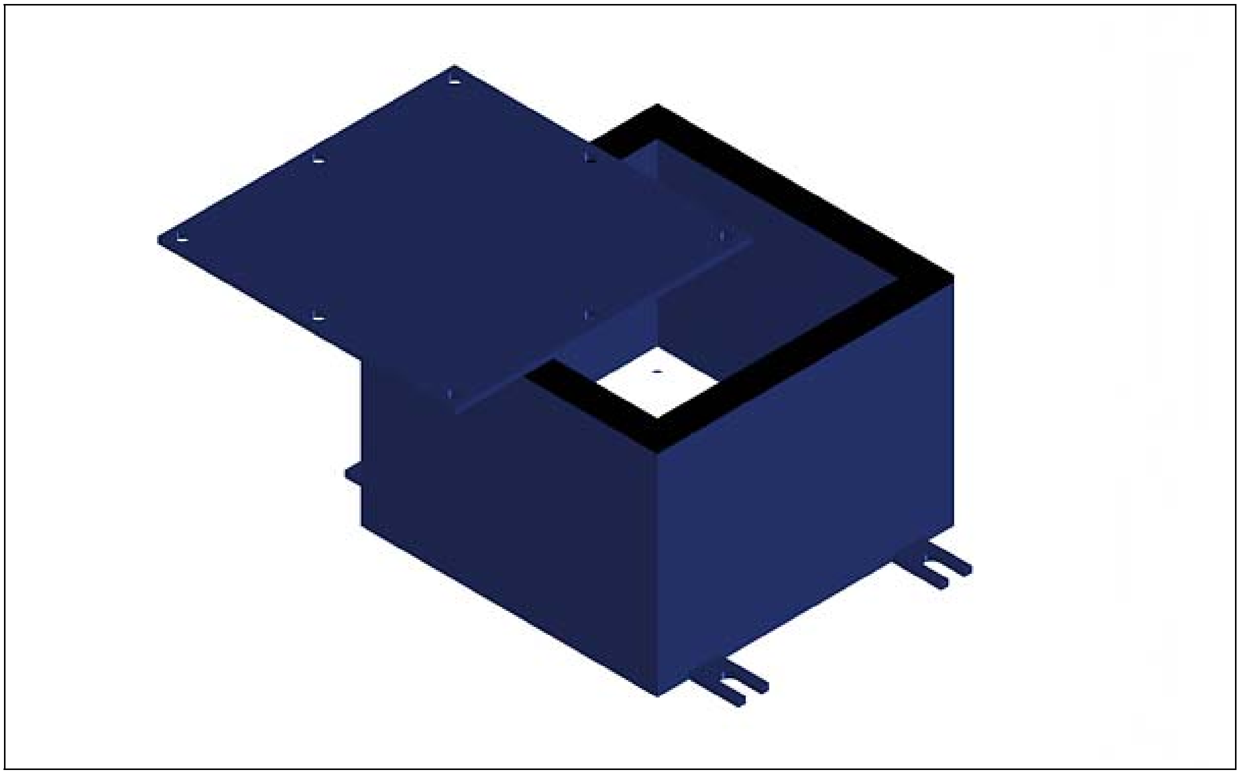

Figure 7.1 – Electrical Box

In Figure 7.2, the senior designer has given us the dimensions of the fabricated electrical enclosure. For many designers who are converting a design from metal fabrication to molding, they experience some dilemma on which dimensions are the most critical and which can be modified when changing the method of manufacturing. There is practically no possible way that the foundry can create the exact same box as the metal fabricator, because welded metal construction is entirely different from cast construction.

Engineers and technicians who use metal construction place many of the same characteristics in their design. Plates that are coming together tend to be at 90° angles with small bend radius or chamfers where welds are joining the sheets. Holes are straight sided and perpendicular to the sides. Edges are typically sharp and in many cases need to be deburred or broken to prevent injury to the consumer handling the part.

Designers that use cast construction will add draft to the walls of the enclosure so that the part can be removed from a die cast mold or the match plate can be removed from either the cope or the drag. On other features found in the cast design are rounded edges or fillets that are located between protrusions and the main body of the casting or in transitions between edges. Remember a generous rounded edge will allow the material to cool more evenly versus a sharp edge where the material will cool at a different rate than on the flatter surfaces. The casting's wall thickness can also vary depending upon the placement in the mold and if we use a core in the design.

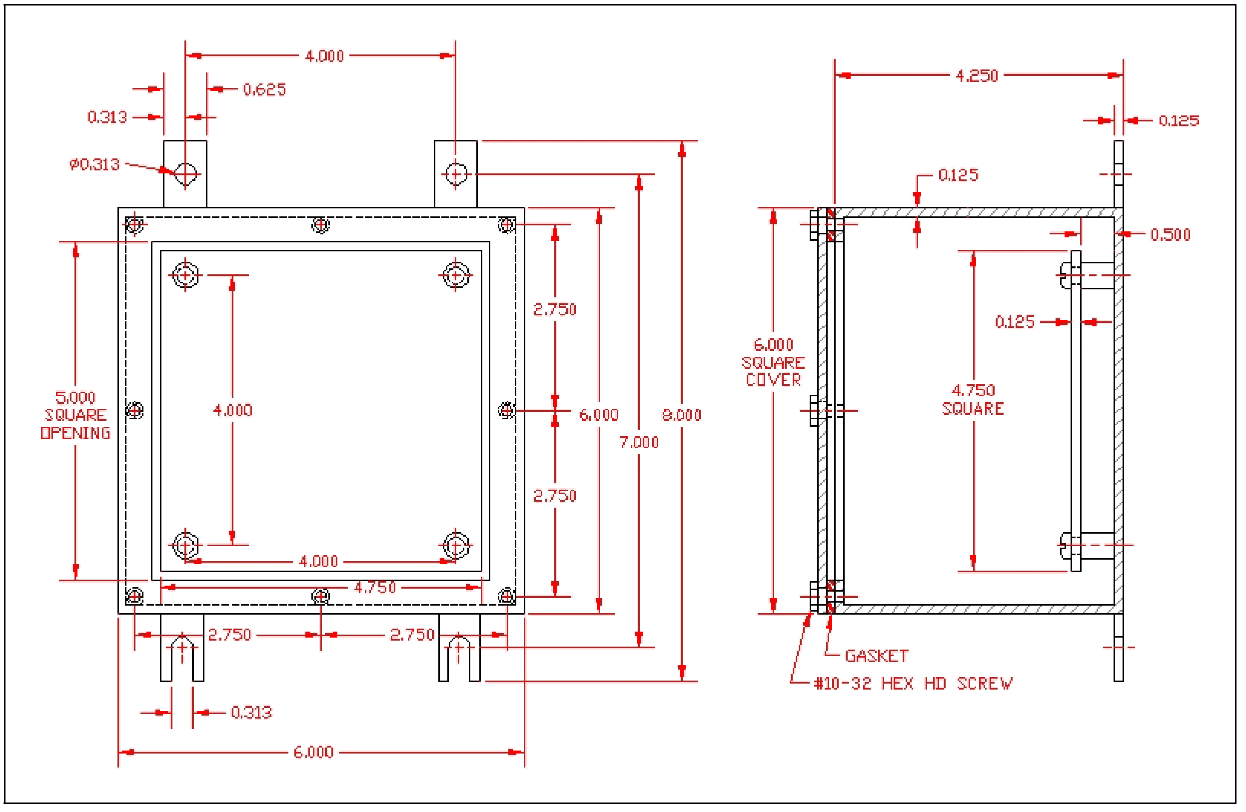

Figure 7.2 – Dimension of Existing Electrical Box

After receiving the project, we will have a discussion with the senior designer and determine which of these dimensions shown in Figure 7.2 are critical to the design of the electrical enclosure. After asking the question, the designer tells us that the mounting holes in our new design must match the existing product. The interior panel that holds electrical components must remain at 4.75 inches and have the same mounting dimensions. The depth of the box should remain the same, but for as the rest of the enclosure's dimensions, there are no exterior components that would interfere with a design and are mounted close to the fabricated box. The senior designer would like us to watch the wall thickness on the cast box that may make an electrician change their type of electrical connector coming into the box, but is willing to sacrifice wall thickness if the electrical box manufacturing cost is reduced to a small percentage of existing fabrication expenditure.

Electrical Enclosure Casting Design in 2D

There are really no steadfast rules that govern us when we convert a fabricated metal design to a casting other than cost and dimensional control. There are three common casting methods, which are sand castings, investment castings and die-castings. The tolerances we can hold on these three casting methods increase as the cost of the process increases. We can expect the foundry to be able to hold 1/16 of an inch on a sand casting while making the pattern for few hundred to a thousand dollars depending on the complexity of the design. Tolerances tighten with the investment casting method as well as the tooling cost. Most high production automotive or computer parts that we see are made in die cast molds where we can hold tolerances close to a few thousands of an inch and an inexpensive mold can cost over $10,000. The multiple thousands of dollars that we spend on a die cast mold will be offset by the thousands of parts made each day with this production method, so amortizing the cost of the mold into the price of manufacturing the part has little affect on the overall cost. In this chapter, we will design the cast electrical enclosure to be sand casted.

There are many different ways we can take the senior designers guidance and start to design our first practical casting, however in this design as in many we will look at the side view where the electrical enclosure or now our cast box will be pressed into the sand cast mold.

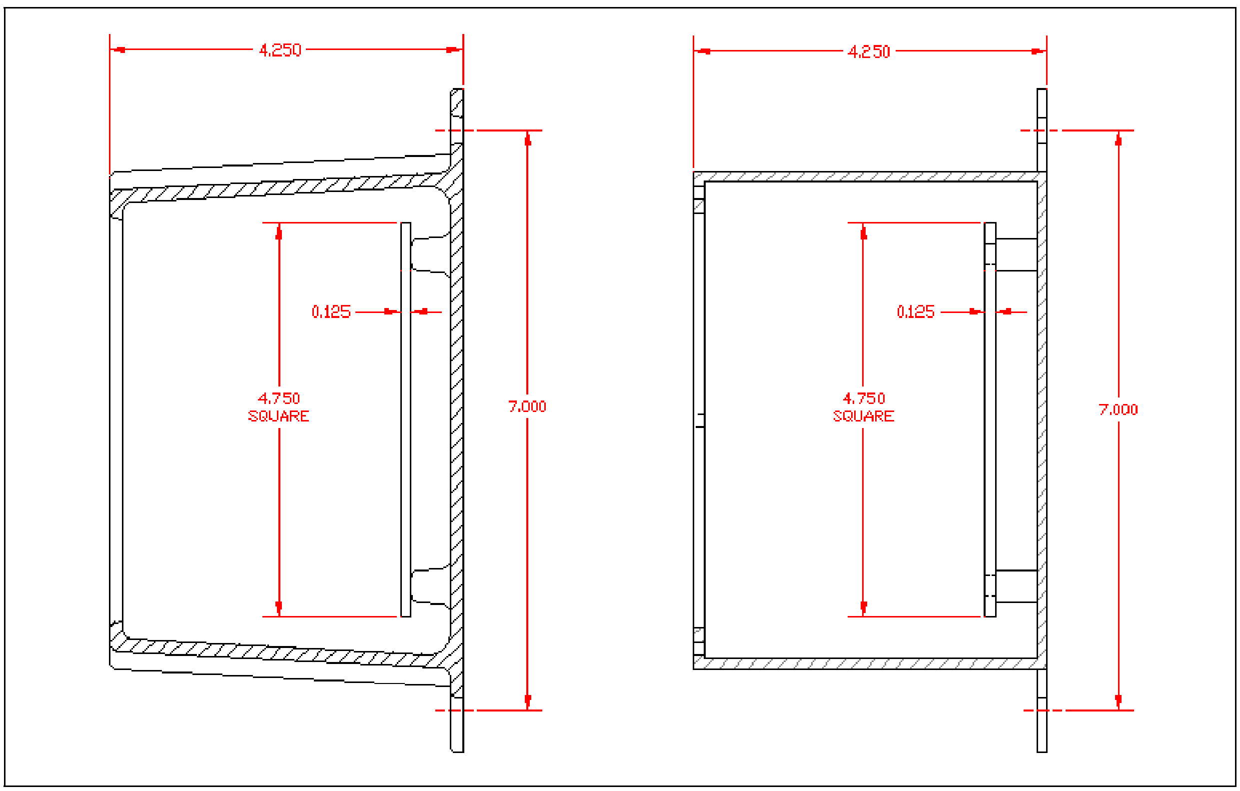

Figure 7.3 – Electrical Enclosure Casting Design 1

In Figure 7.3, we see the initial sketch that we made of the sand casting on the left side with the drawing of the fabricated metal box on the right side. We left the critical dimensions in the view for easy comparison. The parting line is on the extreme right side of the casting. We notice immediately that the walls on the side of the box have a draft angle of 3° and that the wall thickness is slightly larger than the fabricated box. In our design, we made the wall thickness 5/32 of an inch to compensate for the tolerance control in the sand casting method. In this design, we are using a core to create the interior of the cast electrical enclosure. The core will be rest on the bottom of the mold where the impression leaves a 5/32 of an inch rise for the opening of the box. The foundry worker will have to check the alignment of the core to guarantee even sides on the box. We made the box wall thickness slightly larger than the 1/8 thick sheet metal to account for any variance of wall thickness.

The core of the casting will have a draft angle that matches the slope of the box. By adding a core to the design of the casting, we do increase the level of difficulty in creating this casting, but having a thinner wall will reduce the weight of the cast part and therefore the product cost. A good quality control program at the foundry and with our own shipping and receiving department inspection team, we will watch for any cast electrical enclosures that do not meet dimensional control.

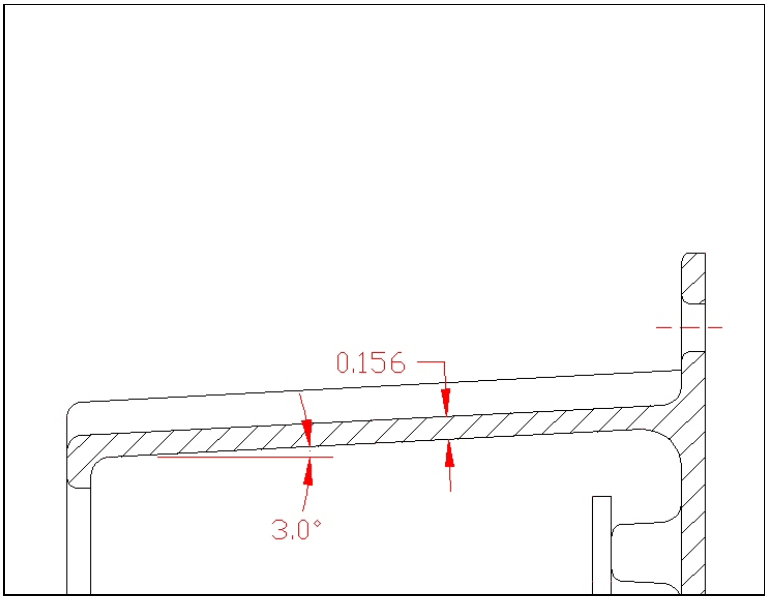

Figure 7.4 – Draft Angle and Wall Thickness

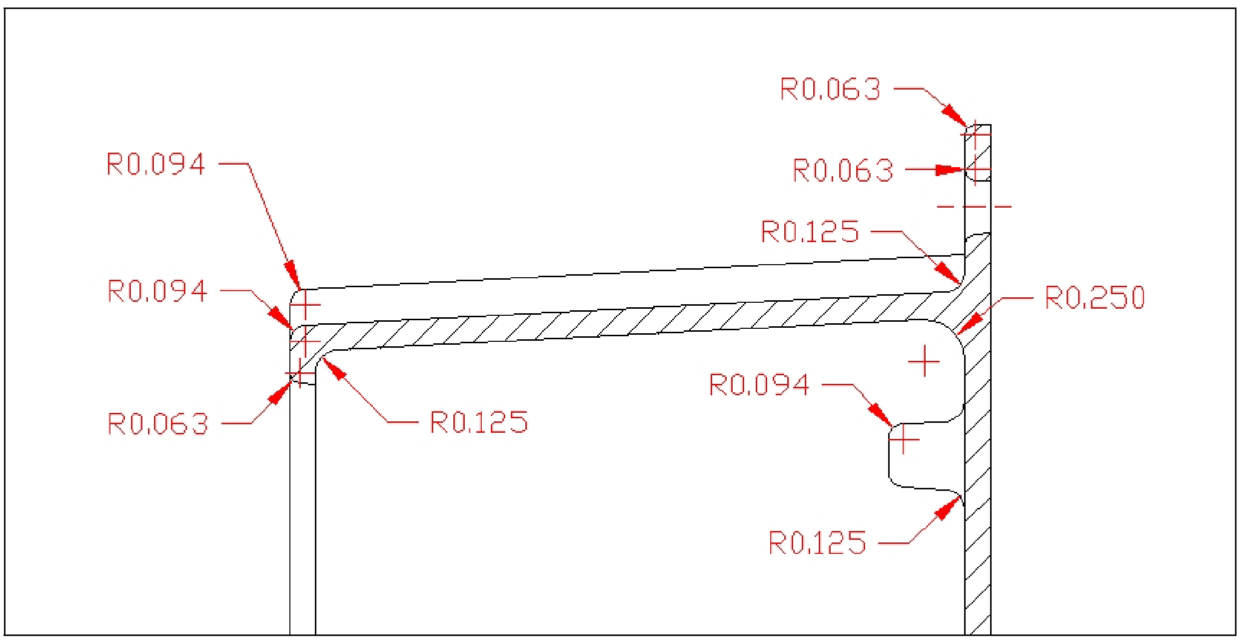

Figure 7.5 – Draft Angle and Wall Thickness

In Figure 7.5, we can see the many different fillets in the casting. At the beginning of the design process, we were initially targeting our fillets at 5/32 of an inch. However, using one fillet radius often does not lend itself to successful design considerations. For example, we will be adding a gasket between the box cover and the casted enclosure, so we have more surface area for the gasket by reducing the fillet size on the top of the cast enclosure. The four bosses on the inside of the casted enclosure have a 3/32 of an inch fillet, because the larger fillet would remove too much material for the interior panel to rest upon. As we can see, the fillets reflect how much material we can remove from casted intersections for assistance in cooling, while meeting design considerations for mating components. This side view has been a great attempt to solve an engineering problem, but looking at a three dimensions solid can solve other problems that we do not see presently in a 2D design.

The two dimensional drawing for a square box is easy to visualize, but many of us will have a hard time figuring out what the exterior detail will look like until the three dimensional solid model is made. One of the last details we added to the sketch was an increase in material where the eight mounting holes that will hold the top cover on the casted electrical enclosure. With a 3D model, we will see this detail clearly.

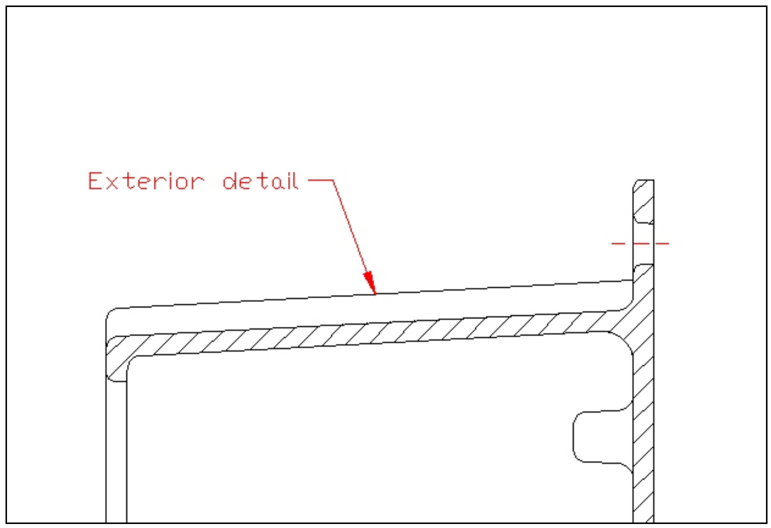

Figure 7.6 – Exterior Detail for Mounting Holes

Electrical Enclosure Casting Design in 3D

In AutoCAD, we are going to use the extrusion tool on the Modeling toolbar to obtain a casting with a 3° draft angle. In order to do this step, on the 2D drawing, we remove the fillets on the top of the casting and replace them with 0° intersections as we observe in Figure 7.7. The reason we do this in this computer aided design software is that we will replace the fillets after extruding the closed polyline into a solid.

In the left view of Figure 7.7, we see the orthographic projection of the top of the casted electrical enclosure and now we notice the 0.25 radius external detail where we will bolt the top cover onto the casted box. We will make the fillets between the 0.25 radius external details 5/32 of an inch. Remember that our electrical enclosure is square, so following the few dimensions that are provided, we can easily draw the top profile, turn the profile into a closed polyline and extrude the single entity. The box is 4.25 inches in depth, so we will extrude the box in the negative direction at -4.25 and with a negative taper of -3°.

In AutoCAD, a closed polyline profile drawn in the XY plane is extruded in the positive Z direction using the Extrude tool on the Modeling toolbar. A positive 3° taper in the Extrude function will cause solid to grow smaller, and a negative -3° taper allows the solid to grow larger. Since the majority of details that we need to control are in the front opening of the casted electrical enclosure, the most efficient method is to extrude the profile from this end.

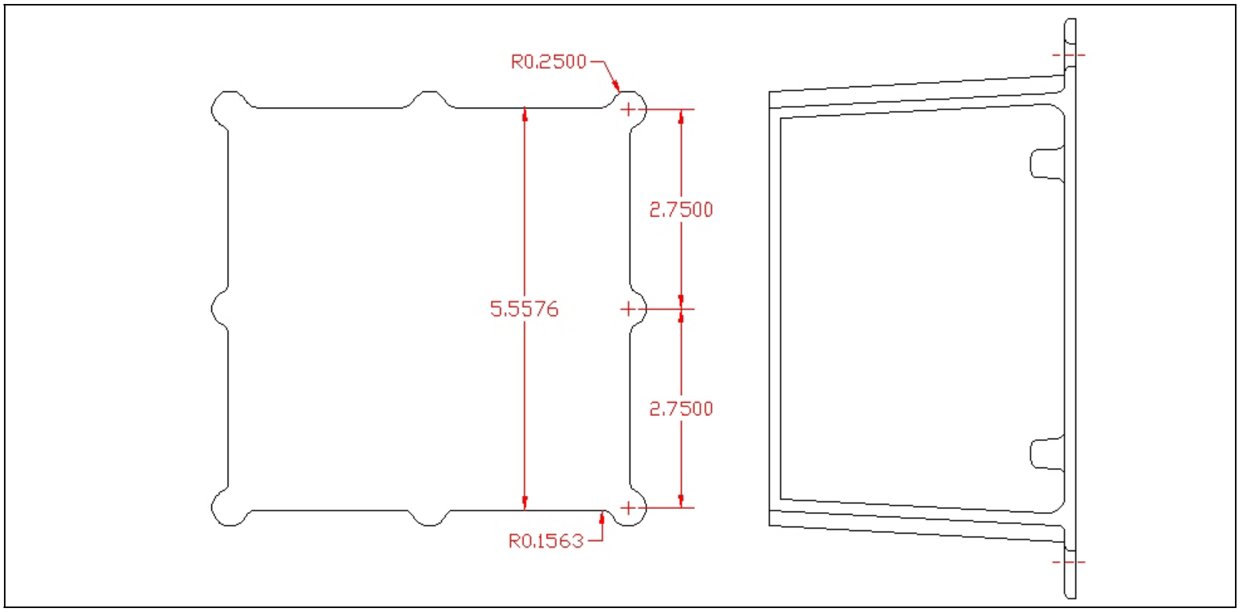

Figure 7.7 – Exterior Detail for Mounting Holes

In Figure 7.8, we see the shape that will now become the exterior sides of the casted box. The eight exterior details are now easy to see. We would not have to continue with this design if we quickly show the senior designer our idea and our idea is rejected. Many times, exterior details that we see in a product seem to give the manufactured goods character. For instance, in the roof of a station wagon or van, engineers will place bends in the sheet metal to add strength to the part giving the large section of metal strength to resist vibrations due to the wind going across the outside of the automobile when traveling. This shows us that function sometimes adds character to the appearance of a product.

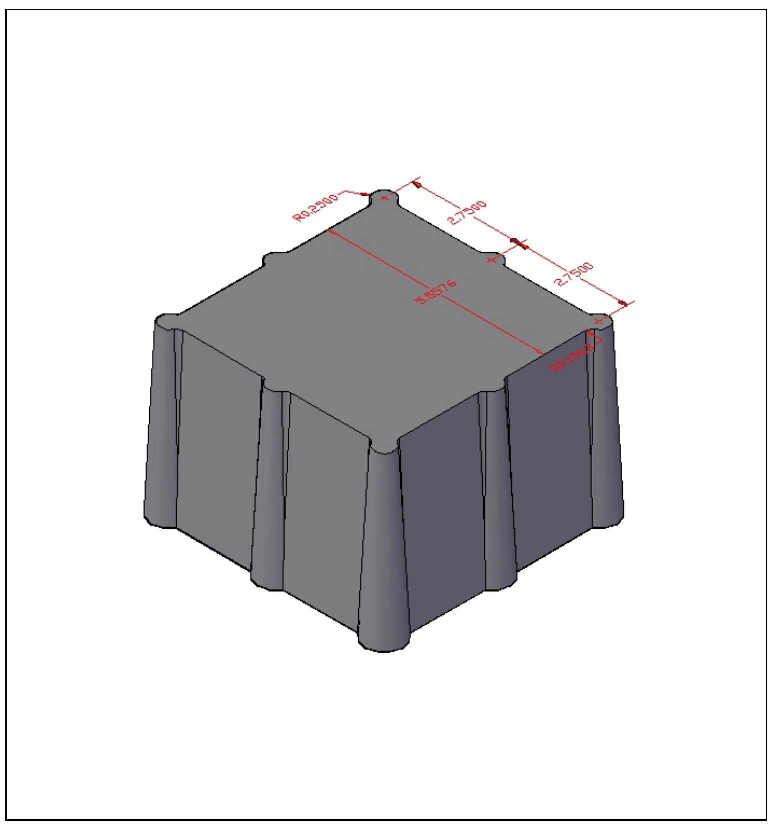

Figure 7.8 – Exterior Detail for Mounting Holes

So the senior designer likes our idea and now that the sides of the casted enclosure are in solid form, we need to place a rounded edge on the top side of the casting. Use the Fillet tool on the Modify toolbar and set the radius to 3/32 of an inch. Select the top edge of the casting has shown in Figure 7.9. When the prompt to chain the fillet appears, type “C” for chain and select the top edge again. The entire edge will highlight as shown in the figure and by continuing, the 3/32 fillet appears on the solid casting as shown in Figure 7.10.

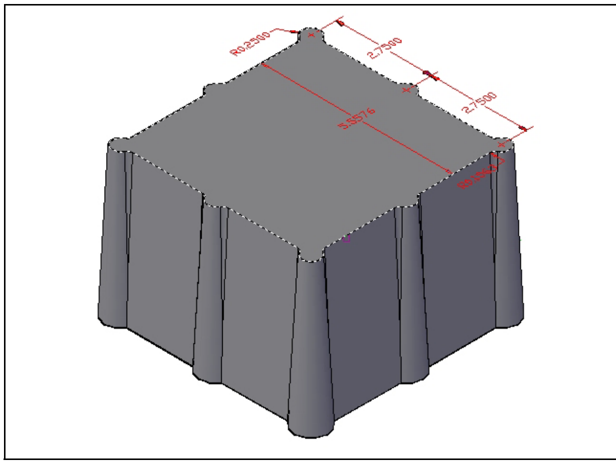

Figure 7.9 – Chain a 3/32 Radius Fillet

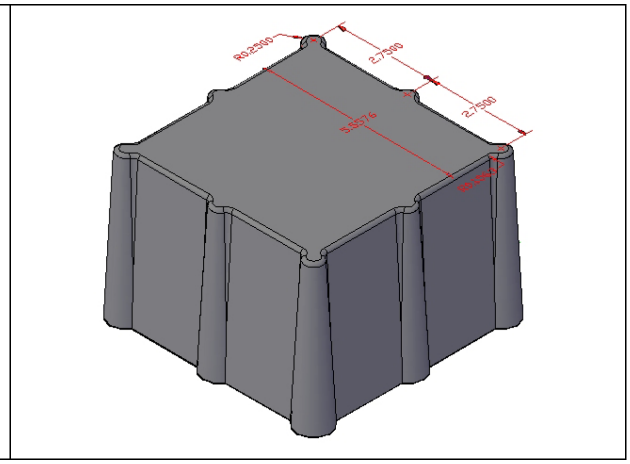

Figure 7.10 – Finished 3/32 Radius Fillet

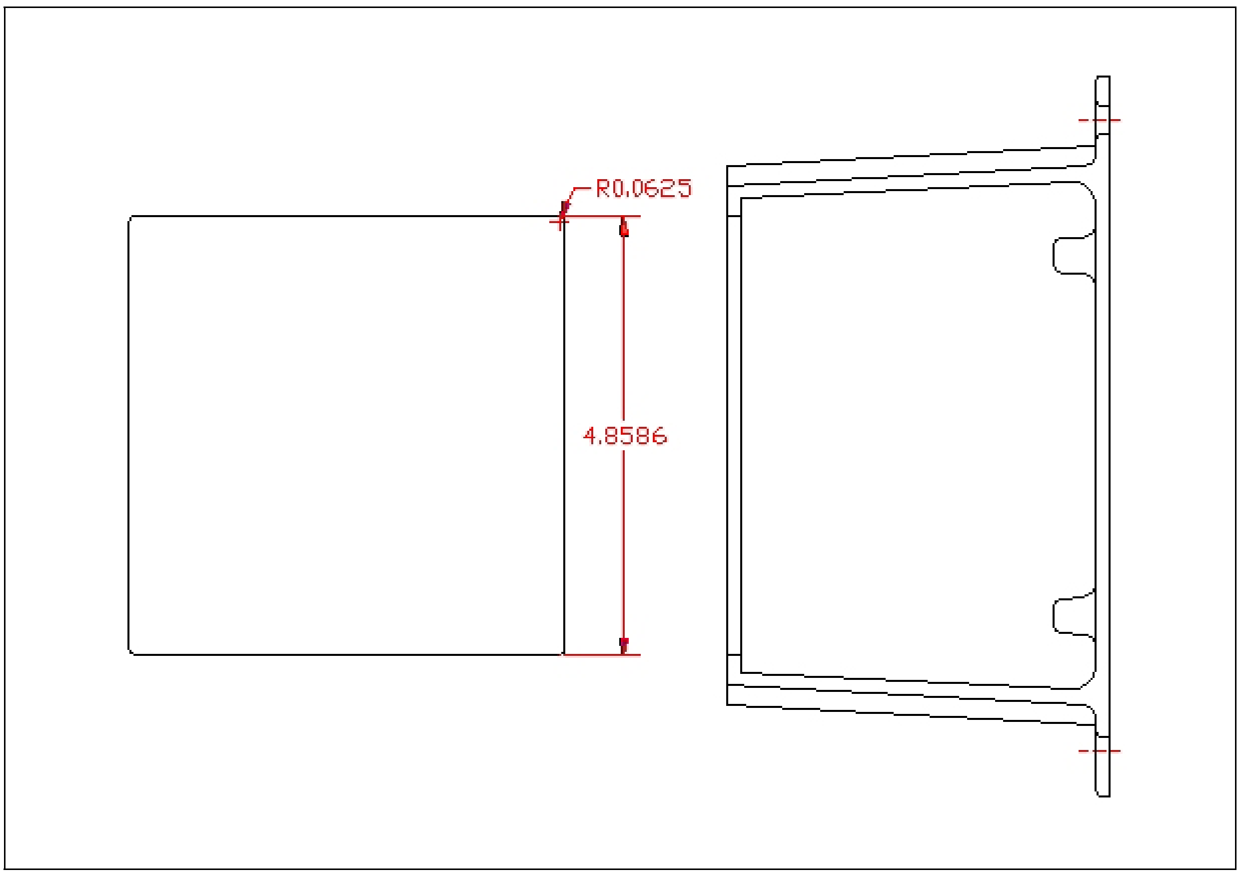

Figure 7.11 – Inserting the Cast Box Opening Detail

At the top of the casting, we will make a small detail that we will subtract from our first solid to make the opening of the casted box. In actuality, when the pattern is pressed into the mold, this detail is visible in the green sand, and the core will sit on this detail. After drawing the projected outline as shown in Figure 7.11, extrude the polyline with a negative 3° taper and a positive 5/32 height.

Once we move the extruded profile onto the top of the casted electrical enclosure, we subtract the detailed solid. Then we want to place a fillet on that interior lip with a radius of 1/16 of an inch. We will repeat the method of adding a chained fillet as we did previously. There is not a requirement to place a fillet at the interface where the core will sit. Once we subtract the volume for the core, we will see that a fillet in the area will is not functionable.

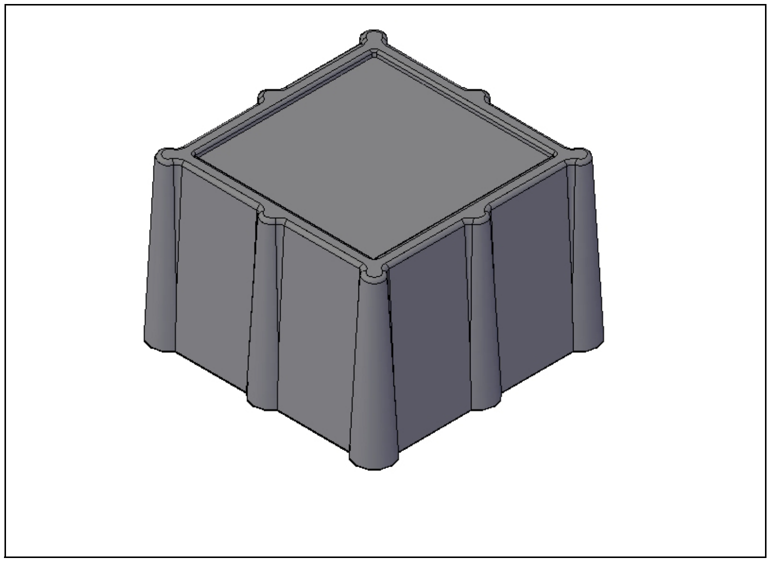

Figure 7.12 – The Cast Box with Opening Detail

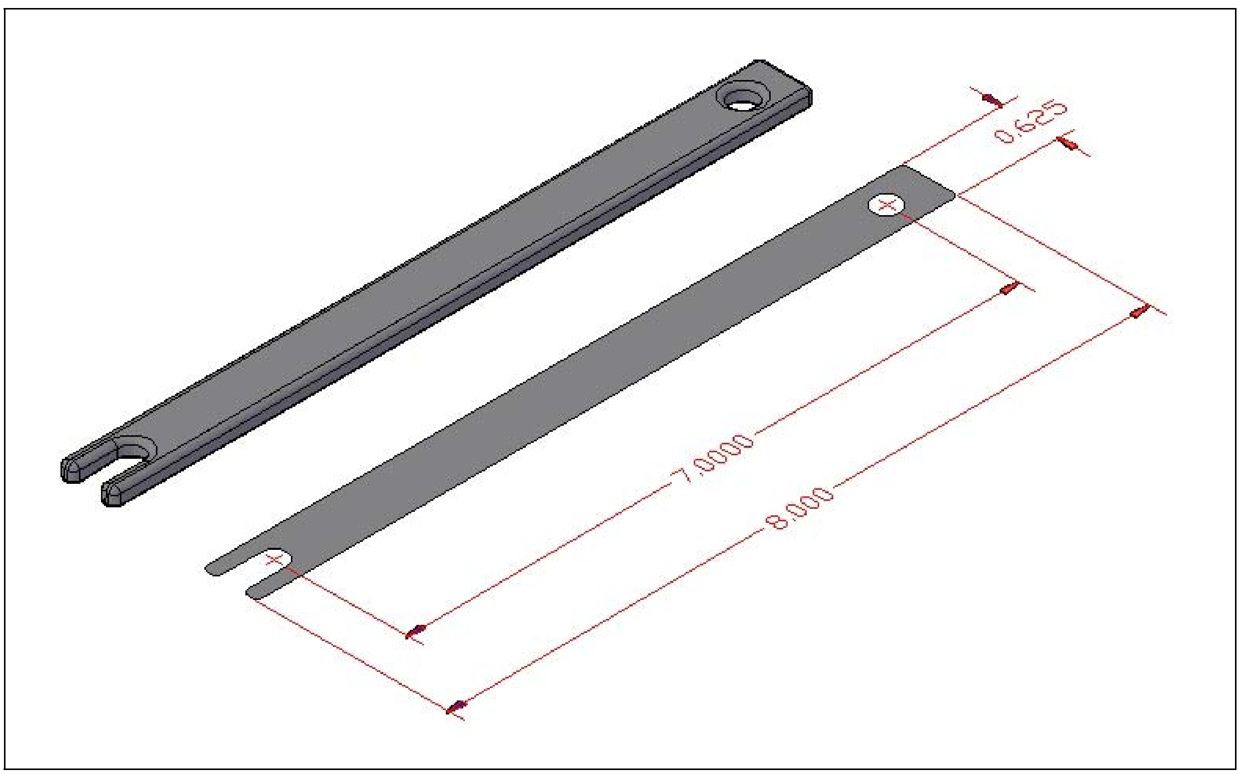

Figure 7.13 – The Cast Box with Opening Detail

The last details for us to place on the exterior of the casted enclosure are the mounting feet, which attach the box to a wall or assembly. At the lower right of Figure 7.13, we see the detail of the profile which we will extrude and on the upper left we already have a three dimensional solid of the mounting feet. We actually took the dimensions from Figure 7.2 and extruded a profile with a negative -0.15625 depth and with a negative -3° taper.

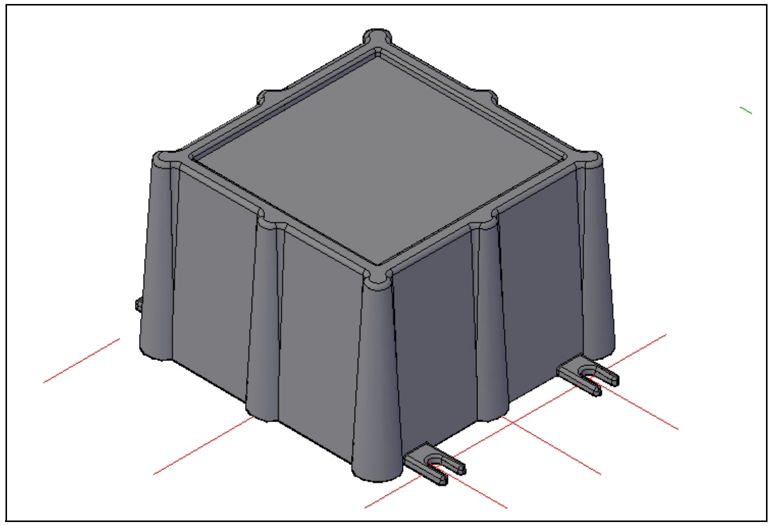

Figure 7.14 – The Cast Box with Opening Detail

After creating the solid mounting feet, we move them to the casted enclosure, and place them by using a few construction lines that identify the mounting locations, which are 2.000 inches from center on the horizontal and 3.500 inches from center on the vertical. We can easily see these dimensions on the sketch provided by the senior designer (See Figure 7.2). After placing the mounting pads in the correct position, we union all three solids together. A small fillet can be chained on the three sides of the interface with the box.

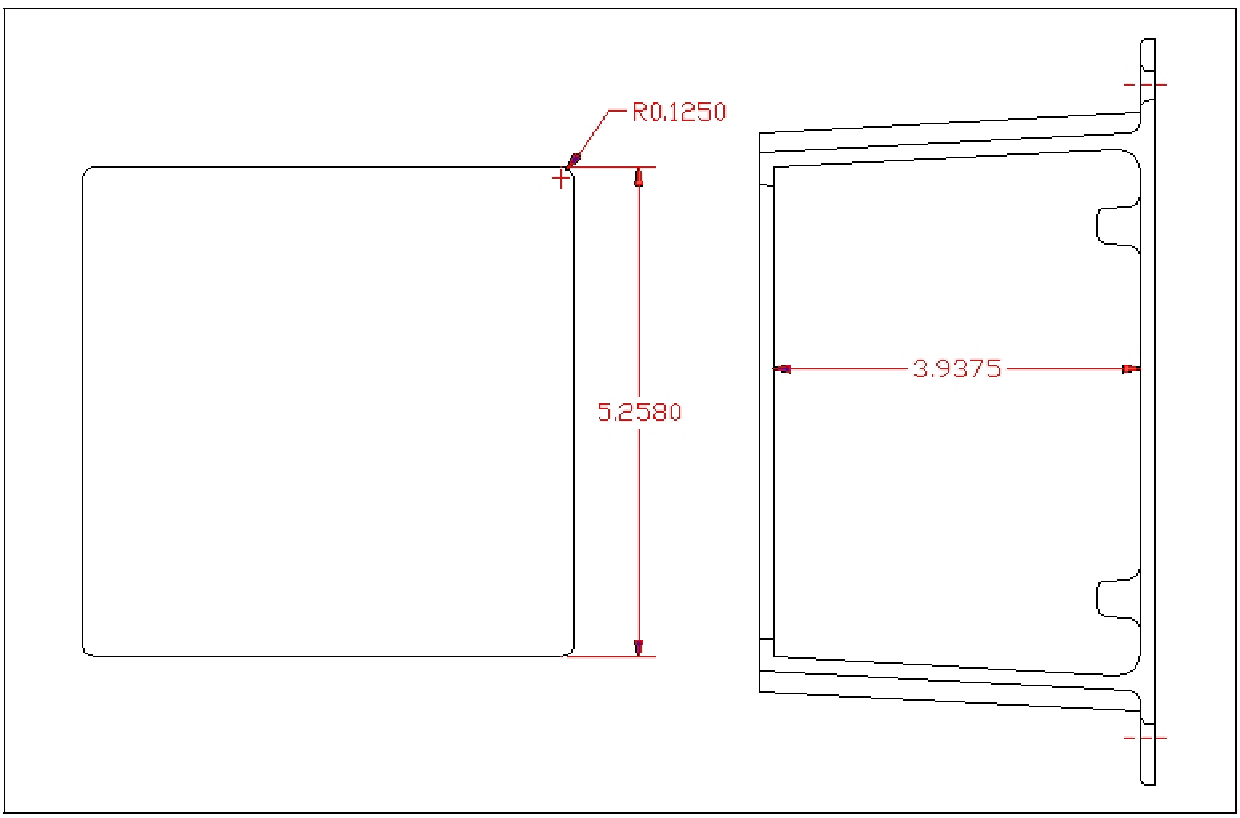

Figure 7.15 – The Cast Box with Opening Detail

Now that we have completed the last details of the exterior of the cast box, the next step in the process is to design the core of the casting. In Figure 7.15, the top profile of the core, which is a closed polyline is shown and on the left side of the image.

After drawing the polyline profile with four 0.125-inch fillets, we will extrude the core with a negative -3° taper and at a negative -3.9375 depth. The core is visible in Figure 7.16, where we see a 1/8 of an inch fillet chained along the top of the core and a 1/4 of an inch fillet chained along the bottom of the core.

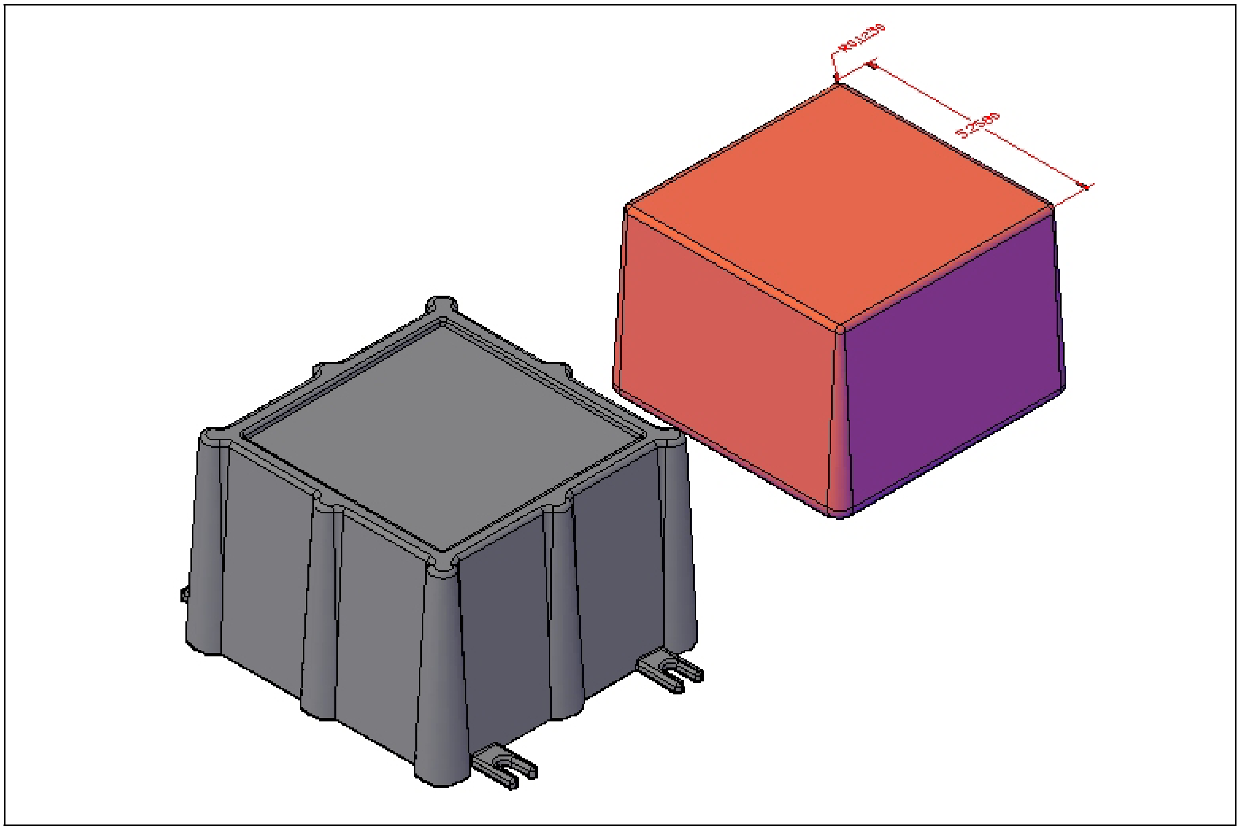

Figure 7.16 – The Cast Box with Opening Detail

The finishing details in the core of the casting are the four bosses that hold the interior panel at assembly. The boss is 3/8 of an inch in diameter and is 0.5 inch in depth. There is a 3° taper on the boss where the feature will grow, as it gets closer to the back of the enclosure. The top fillet is 3/32 of an inch and the fillet at the base of the boss measures at a radius of 1/8 of an inch. We will actually draw a single three-dimensional boss and array the single solid using a pattern of two columns and two rows that are 4 inches apart.

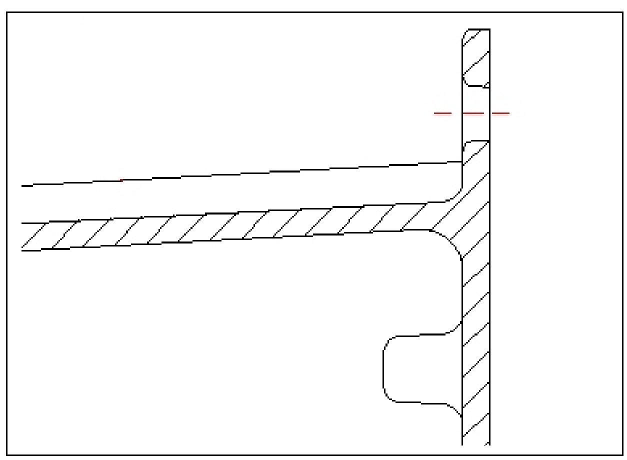

Figure 7.17 – Detail of the Boss

In Figure 7.18, we subtract the four bosses from that core. At the foundry, this is exactly the way the part will be assembled. The exterior detail of the pattern will be mounted to a match plate that will be pressed into the mold. The cores will be prepared separately and placed into impressions made by the match plate in the green sand. As we said before, the technician working at the foundry will accurately place the core into the hollowed out portion of the sand, taking care to perfectly center the core.

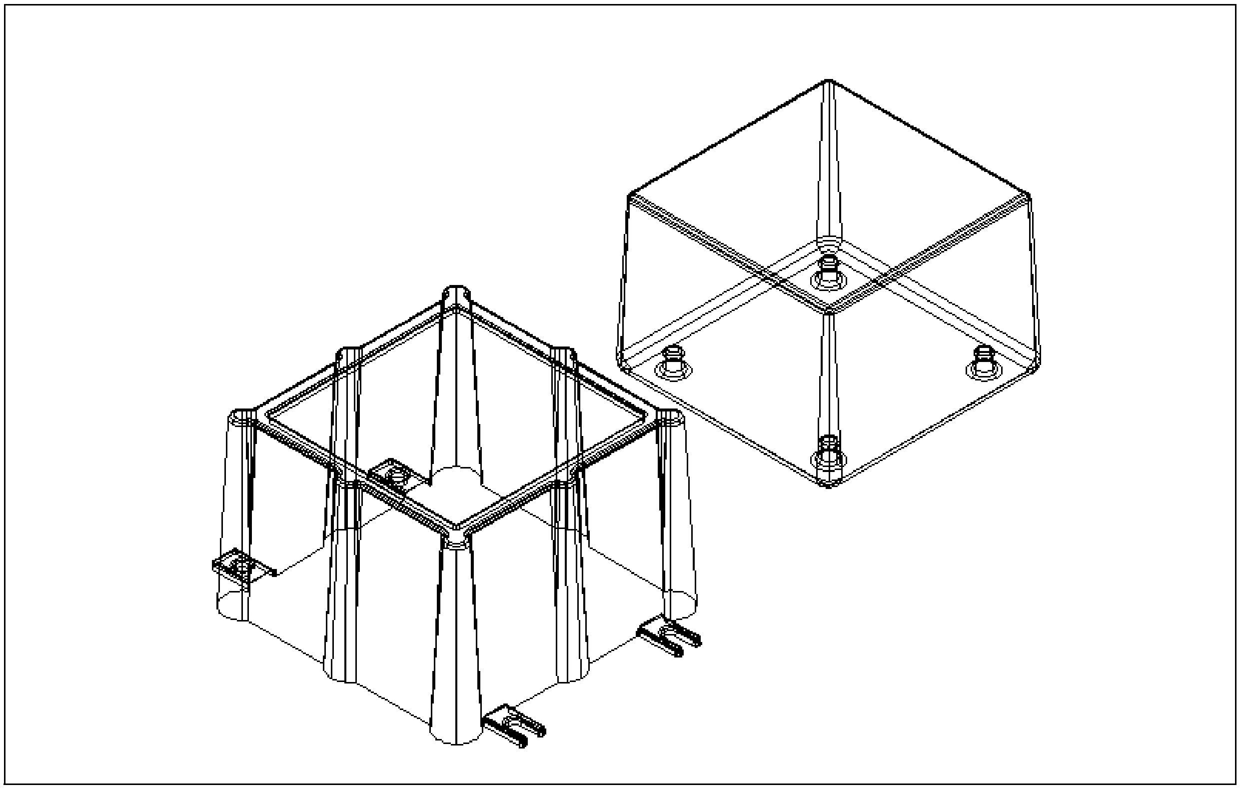

Figure 7.18 – The Cast Box with Opening Detail

Now that the design is finished, place the core into the solid casting and subtract the core from the exterior three-dimensional solid. The completed electrical enclosure is shown in Figure 7.19 without the interior panel, the gasket and the front cover. This design will require a new gasket and front cover design.

Comparison of the Two Designs

We can use the Mass Properties tool to compare both designs. The volume of aluminum in the fabricated box is 18.07 cubic inches. The volume of aluminum in the casted box is 26.72 cubic inches.

The cost of sheet aluminum rolled in the mill is three to four times that of cast aluminum, so we expect the material price of the cast enclosure to save around $1.00 to $2.00 per box. The price of welding at least 16 to 20 inches of 1/8 inch aluminum is extremely expensive, and the labor to weld the box would be totally eliminated, saving another few dollars for each enclosure. So we expect to largely reduce our material and labor cost with this design

The box cover, the gasket in the interior panel will remain essentially the same weight and manufacturing cost. The interior panel from the fabricated assembly will mount in the casted enclosure. As with the previous design, we will still need to drill and tap twelve holes into the casted enclosure, four tapped and drilled holes for the interior panel and eight tapped and drilled holes for the top cover.

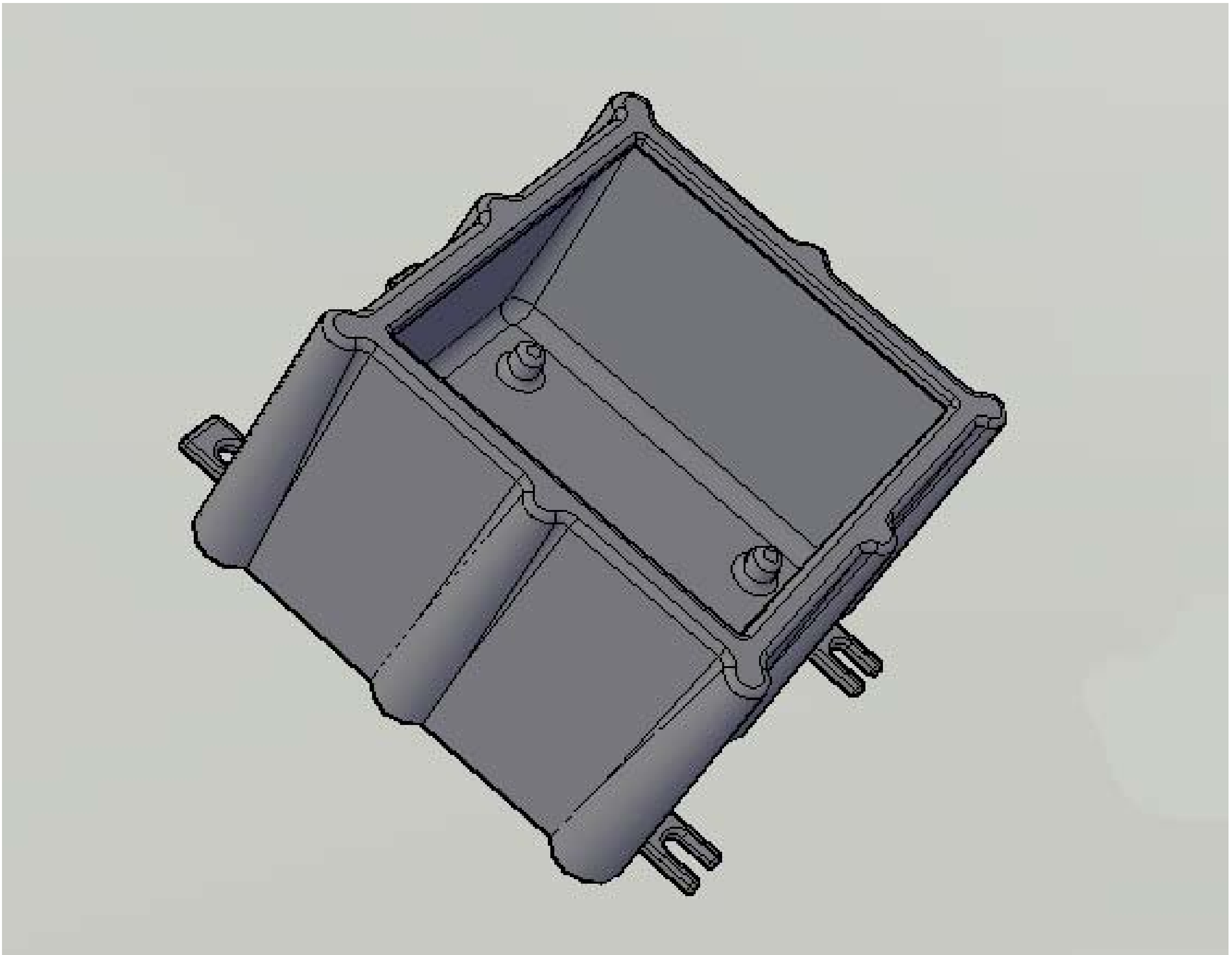

Figure 7.19 – The Finished Cast Box

The wall thickness of the casting is essentially the same as the fabricated box, so the electrical technicians can use the same feed through connectors.

More Designs

What if the senior designer decides that this design is the ugliest product to come across their desk in years or that we did not save enough money in our design presentation. We need to expect that type of review when ever we show a new design. There is even a possibility that our design will not meet a production test which was not fully outlined at the beginning of the project.

First of all, the project is not going away and we only have spent two hours or less on this design and have already discovered that we can save a multitude of money not fabricating the original design. We need to continue to learn more about casting techniques and the manufacturing costs of different processes. Only by presenting multiple ideas to the senior designer and having the confidence to suggest that one or more will provide both the answers to the customer's or manufacturer's problem and please everyone.

If the senior designer like your design, create a part drawing from the three dimensional model, dimension orthographic views, note that drawing and release it to build your prototypes for test.

One last point is that prior to the release of three-dimensional design software, solving a casting problem like the one shown in this chapter in less than a couple of hours would have been impossible.

*** World Class CAD Challenge 08-16 * - Close this drawing file. Create a New file design another casting that will replace a 6 x 6 x 4 electrical enclosure, dimension, and place the border and notes in less than 120 minutes. Continue this drill two more times, each occasion completing the drawing under 120 minutes to maintain your World Class ranking.**