Society of Plastics Engineers SPE Blow Molding Division

Annual Student Design Contest

Beekeeper Bee Box

Joyce O'Neal, Dylan Popies

Penn State Erie, The Behrend College

Due: 04/30/2026

This page is intentionally blank.

Table of Contents

Abstract

Beekeeping has been in practice for thousands of years and has been a sustainable process for the environment. Aspects like food supply, economy, and variety directly and indirectly depend on bee population; these are several provisions that beekeeping takes part in other than producing wild honey [1]. The blow molded beekeeper bee box will provide an alternative to the commonly used wood material to create a sustainable practice through beekeeping utilizing plastic. Through the utilization of high-density polyethylene (HDPE), the blow molded beekeeper bee box will prove ample integrity and performance. The beehouse perimeter that will be molded will serve as the foundation and surroundings of the beehive inside. This paper will emphasize the choices made regarding part design, material selection, molding method, tool and process requirements, and load calculations.

Introduction

The presence of bees in the environment has always been crucial, in which their role in the ecosystem is pollenating plants and crops. Their role has aided farmers and general food production for humans, in which bees support the overall yield of plant-based resources. Bee boxes are utilized for the benefit of bees to protect bee colonies and support eco-friendly farming [2]. Bee boxes provide a safe home for bees, especially with the rise of environmental pollution and urbanization; beekeepers can check on the health of bees as well due to potential environmental changes like so. Bee boxes are ideally placed near farms and crops to enforce the sustainable development of the environment by pollination of crops. Bee boxes are an ample way to control the volume of bees in an area, since overpopulation in natural hives is a problem that can hinder honey production. Bee boxes are much more structurally intact and have a service life longer than those of natural bee hives [2].

Figure 1: Traditional Wooden Bee Box & Honeycomb Frame

Bee boxes are primarily made with a wooden perimeter, with the intention of mimicking the environment bees are used to. The frames that contain the honeycomb system are also typically made of wood as well, but they must be able to be removed from the bee box. The focus of this particular design is to create the perimeter of the bee box that will be able to house the honeycomb frames. The major issue found with wood being used to construct bee boxes is that it is susceptible to moisture absorption from the environment and will rot overtime. Without proper maintenance, cracks or fractures in the wood can provide crevices for pests and pathogens to hide [4]. Plastic would prove to be an ample substitution for this issue, due to the non-porous surface quality, and the durability and fatigue resistance of the material.

Traditional wooden bee boxes are typically constructed from cedar or pine and are created in components to make up the perimeter. This is a long process to make all the required components and cuts that must be made, and a single extruded plastic box would prove more efficient. Bees enjoy the wood hives because of the texture of the wood; however, it is unchallenging to make a textured mold surface.

Bee boxes made from plastic are already available but are made in separate components to be assembled, with the parts primarily injection molded. The purpose of this design project is to create an alternative to that of a traditional wood bee box, through the use of blow molded plastic. The initial sketch is illustrated in figure 2, and the computer-aided design (CAD) model is depicted in figure 3.

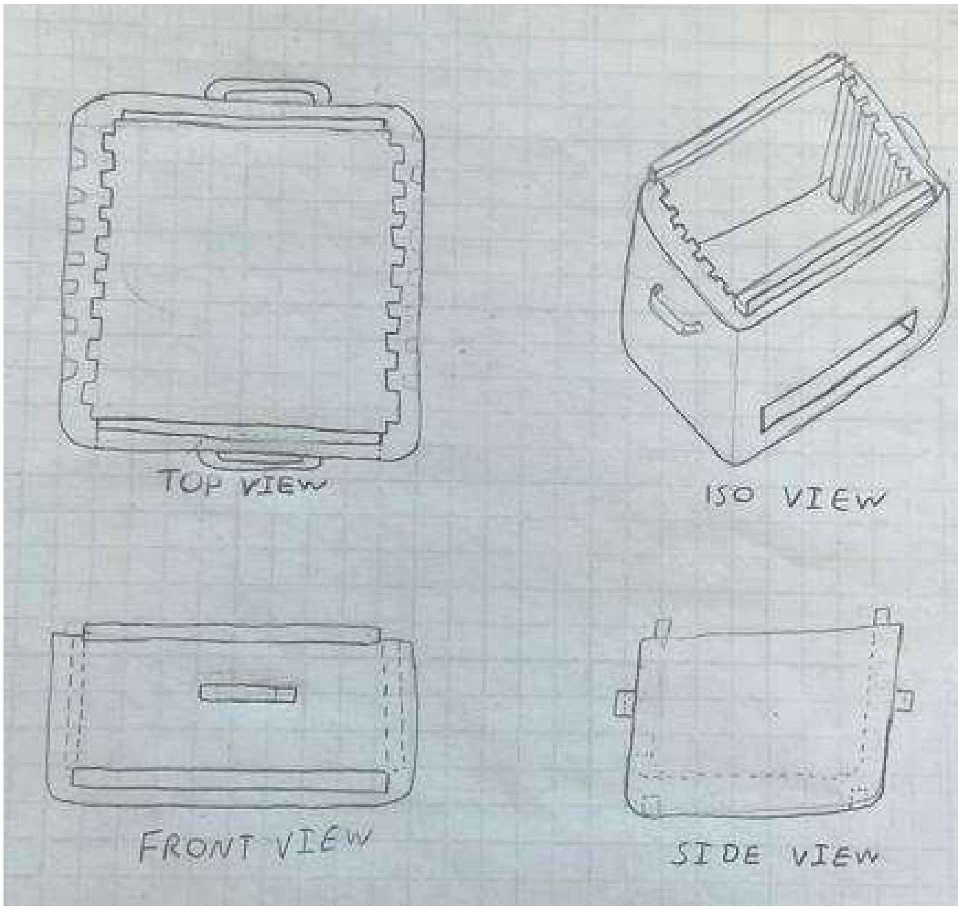


Figure 2: Preliminary Sketches of Bee Box

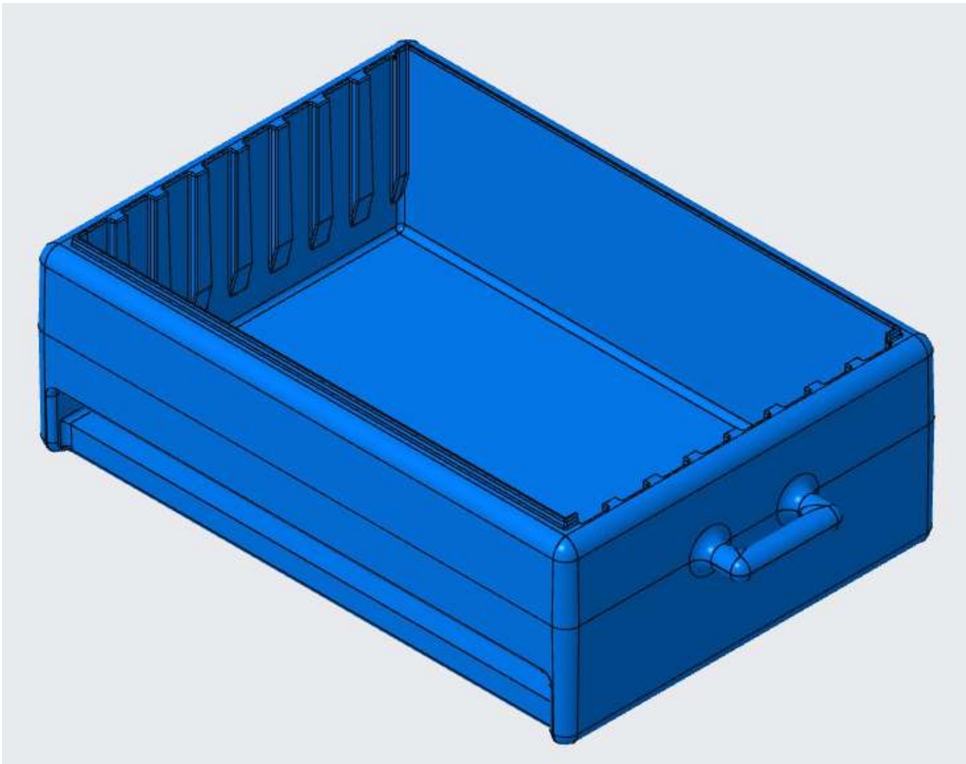


Figure 3: CAD Isometric View of Refined Bee Box Design

Blow Molding Application

The goal of this project is to prove the proposed design of the bee box can be blow molded and affirm that it will be a viable alternative to traditional wooden bee boxes and other plastic alternatives. The blow molded bee box will feature a hollow shell within the inside of the plastic walls, resulting in a reduction of material usage and production cost. This will create the capability to add insulating material such as dirt, sand, or foam due to the climate sensitivity of bees. Utilizing blow molding will yield a lightweight and easy to handle part while also meeting the structural requirements for a typical medium-sized bee box.

In comparison with injection molding, there is an absence of introducing air into the plastic part, in which the full volume of the part comprises plastic. This means more material will be used in the manufacturing process, and any potential material cost savings will be avoided; this includes the runner system as well. Blow molding is capable of manufacturing one whole lightweight part as opposed to multiple injection-molded parts without air; this will create ease of assembly. Rotational molding may also be an alternative up for debate due to the five-sided box archetype that the bee box exhibits, but this manufacturing method yields high cycle times and will not be able to utilize free volume within the plastic walls like blow molding [5].

Design Details

Dimensions

The design was based on the Langstroth standard for beehive boxes, with the outer width being approximately 14”, the length being 19 7/8 inches, and the medium depth of 6 5/8 inches. This medium box size is often considered the most versatile design. They are large enough to be used for brood chambers, but light enough to be used for honey storage. Brood chambers are a necessary component of beehive boxes for beekeepers, as this is the central nursery and the heart of a beehive. This is where the queen lays eggs and the colony is able to raise their young. With the mass production of this design, bees would be able to have ample room to produce honey as well as raise future generations of honeybees. The Langstroth stand for beehive boxes are important to ensure that bees have proper space to move, compatibility of materials, and functionality within a hive [7]. Most blow molded geometries, as well as wooden bee boxes, typically have a draft of 1-3° [10]. For this design, a draft of 1° was placed on the outside walls, split at the parting surface, to allow for easy release on both mold halves. The inside walls of the box also have a draft of 1°, but the hinge is at the bottom of the box, so that the part can easily eject.

Food Safe Compliance

Due to bee boxes producing most of the honey that will be sold worldwide for consumers to eat, the grade of material chosen must be food grade. Food grade plastic containers and packaging serve as the main protective system for preserving honey quality throughout the supply chain. These containers create a sealed and pressure resistant environment that prevents honey from absorbing moisture from the air, which is the leading cause of fermentation, while also protecting it from physical damage during long distance transport from remote production areas to urban markets [6].

Ultraviolet Resistance

The bee box shall be designed to withstand prolonged ultraviolet (UV) exposure while maintaining structural integrity and functional performance during outdoor use in a temperate climate such as Pennsylvania. The material shall resist UV-induced degradation, including cracking, embrittlement, and excessive warping, over a service life of at least 10 years if properly managed [8].

Force Applied

The typical weight of one medium sized box can withstand 60 lbs of force when made of wood [7]. With the incorporation of air and foamed material, the boxes will be substantially lighter, with increased durability. The density of HDPE is 0.0343 lb/in^3. Taking into account the volume of the bee boxes, the total weight per box is 4.69 lbs. A full frame of honeycomb weighs about 3.5 lbs [9]. There are eight frames, so the total combined weight inside of a full bee box would be 28lbs. The lid and drawers will be made of wood, which has a density of 0.02 lb/in^3. With the combination of eight frames of honey and one drawer in each box, a box being carried will have to withstand a force of 0.126 psi on the bottom face of the base. With a combination of two boxes full of honey, drawers, and the lid on top, the top supports on the bottom box will have to withstand 70. 56 lbs. See the appendix for calculations.

Material

Choosing the right material is an important factor when designing a part. For this design, the hope is to create a food safe and durable material for the exterior walls, and a foamed material inside that will help with insulation for the bees. The possible material candidates that will be considered when designing this bee box are High Density Polyethylene (HDPE), Polypropylene (PP), and Polyvinyl Chloride (PVC). The material to be foamed inside will be decided between Low Density Polyethylene (LDPE) and Polyurethane (PU).

Material Selection

Exterior Walls

Exterior Material Selection Matrix							
Properties	Weight (%)	HDPE		PP		PVC	
		Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score
Cost	15	5	45	4	60	3	45
UV Resistance	20	4	80	2	40	4	80
Regulatory Compliance	15	5	75	4	60	2	30
Density	5	4	20	5	25	2	10
Chemical Resistance	15	5	75	5	75	3	45
Thermal Resistance	15	3	45	4	60	2	30
Water Resistance	15	5	75	4	60	3	45
Total	100	-	415	-	380	-	285

Cost

The cost of material when designing a new part is necessary to consider. With the cost of wood rising, it is important to compare the cost savings of using a plastic alternative. As of 2026, the price per pound of HDPE is \$0.85/lb [11]. The price of PP is \$0.90/lb [11]. PVC is the most expensive option, with a price of \$0.96/lb [12]. With these prices of blow-molded grade materials in mind, HDPE ranks first, followed by PP and PVC.

UV Resistance

Bee boxes are left outside year-round to ensure bees have proper access to their hive and queen. Absorbing sunlight year-round requires a material with excellent UV resistance that can compete with regular wooden boxes. HDPE is known for its high UV resistance, as it is commonly used for outdoor applications such as playground equipment and automotive parts. PVC also tends to have moderate to high UV resistance, as it is used for plastic decking and outdoor pipes. PP has the lowest UV resistance of the three, as its molecular structure absorbs UV radiation, triggering photooxidation that breaks down the polymer chains [13].

Regulatory Compliance

The material used for the bee box must be food grade, to ensure no chemicals or contaminants leech into the honey. HDPE is 100% food safe, as it is used for milk jugs and other food and drink containers. FDA-approved HDPE grades are often used for food applications because they provide a hygienic surface and safe contact [13]. PP is considered food safe for some grades, as it is also often used for food and drink packaging. For a bee box, an industrial grade PP would most likely be used due to its durability and fatigue resistance; however, this specific grade is not considered food safe. PVC is known for leaching chemicals like BPA and phthalates, which can negatively affect the health of both bees and humans. Food-safe PVC can be used, but it must be NSF-51 or FDA compliant [14].

Density

Knowing the density of a material is crucial for understanding the allowable load for an application. The density of maple wood is 0.675 g/cm3, which is significantly less than that of the three plastic material choices. It is important to choose a material that is dense enough to have proper rigidity and strength, but not so dense that it becomes too heavy for this application. PP has the lowest of 0.91 g/cm3, which is a sufficient density to be considered both lightweight and durable. HDPE has a density of 0.95 g/cm3, which gives the material excellent durability, but depending on the wall thickness, it could be considered too dense. PVC is the densest of the materials, with a value of 1.30 g/cm3, giving it the greatest rigidity, but the boxes will be significantly heavier [15].

Chemical Resistance

HDPE has excellent chemical resistance, especially acids, bases, solvents, and water. Ideal for chemical tanks, marine-grade components, and liners for industrial uses. In the case of the bee box, it will be susceptible to contact water and potentially cleaner if maintenance is performed on the bee box. Given that it is an outdoor environment, and beekeepers will likely perform routine maintenance of the bee box, the chemical resistance of HDPE will prove to be excellent. PP and PVC tend to have ample chemical resistance, but for this application, the best choice would be HDPE [13].

Thermal Resistance

HDPE possesses high thermal resistances, and many thermal properties that make it suitable for the environment during application. The service temperature window of HDPE can reach up to approximately 80°C for long term applications, which is well over typical environmental temperatures. The material retains mechanical properties through repeated thermal cycles, which would match the temperature changes outdoors. HDPE proves to be more thermally stable than most polyolefin counterparts, especially with added UV stabilizers [16]. PP has excellent thermal resistance, with a service temperature range of up to 82°C, making it better than HDPE without UV stabilizers [17]. PVC is the least thermal resistant, with a typical service range of up to 60°C [18].

Weather Resistance

Weather resistance is another key characteristic of HDPE resin. While it can tie back to moisture resistance, there are various environmental conditions to take consideration of: rain, prolonged sunlight, and excessive temperatures are all factors that can affect the performance of a component in the outside environment. HDPE, especially reinforced with UV stabilizers, can withstand all conditions and prove suitable for marine and agricultural applications [16]. PP is known for having acceptable weatherability. PVC has good impact strength and weatherproof attributes [19].

Interior Foam

Interior Foamed Material					
Properties	Weight (%)	LDPE		PU	
		Rank	Weighted Score	Rank	Weighted Score
Cost	15	5	75	3	45
Compressive Strength	25	4	100	1	25
Thermal Insulation	15	2	30	5	75
Durability	10	4	40	2	20
Density	15	5	75	3	45
Total	100	-	320	-	210

Cost

LDPE is one of the cheapest widely used plastics, making it an excellent choice to fill the volume inside the walls of the bee box. The price of LDPE in North America as of 2026 is \$0.63/lb. PU foam varies widely in cost depending on formulation and density and is generally more expensive due to chemical processing complexity. The cost of PU foam in North America as of 2026 is \$1.49/lb. [20]

Compressive Strength

LDPE is a tough, ductile solid that can withstand moderate loads before deforming. The range of compressive strength of expanded LDPE foam is 35 to 130 psi [21]. PU foam (especially low-density) collapses easily under compression and is not structural. The compressive strength range of PU foam is between 30 to 80 psi [22].

Thermal Insulation

Thermal insulation performance differs significantly between LDPE and PU foam due to their internal structures and resulting heat transfer mechanisms. LDPE has a continuous solid polymer structure, which allows heat to transfer relatively easily through molecular vibration and conduction. As a result, it has a relatively high thermal conductivity of about 0.33 W/m·K, meaning it provides only limited resistance to heat flow and therefore performs poorly as an insulator [23]. In contrast, PU foam has a cellular structure composed of numerous closed air pockets, which trap still air and greatly reduce heat transfer. Because air has very low thermal conductivity, these trapped cells interrupt conduction pathways and significantly slow the movement of heat through the material [24]. This gives PU foam a very low thermal conductivity of approximately 0.020–0.030 W/m·K, making it one of the most effective common insulating materials [25]. Overall, PU foam provides superior thermal insulation because its structure minimizes heat transfer, whereas LDPE’s solid polymer matrix allows heat to pass through more readily.

Durability

Although not directly exposed to the outside elements, the foam used must be a durable material for the needs of this application. It must withstand the elements, and the loads of being carried from location to location. LDPE foam is known for its closed-cell structure, which provides the material with excellent strength without excessive weight. This makes LDPE extremely durable maing it ideal for this application [26]. PU is a rigid foam that is able to withstand external impacts resulting from moisture or air movements [27].

Density

Foams of the same density can vary considerably in mechanical properties, depending on the foam production process. LDPE foam has a density of around 922 kg/m^3 and a Tm of 104C. LDPE is excellent for foaming with its high long chain branches. LDPE is considered the best for polyethylene foaming processes. The melt strength of LDPE is considered excellent because of the possession of long chain branches compared to linear PE [28]. Due to the capability of PU foaming variances, the range of density is 40 to 961 kg/m^3 [29].

Mold & Tooling Details

Mold Material

The choice of the molding material to utilize on the extrusion blow mold will have an influence on a variety of factors in production. Aluminum is the chosen material for this mold, as it is the primary material of choice among the blow molding industry. This is mainly due to the lessened cost when compared to that of standard steel and possesses greater heat dissipation when in contact with the molten plastic during molding [30]. Given that the bee box is a larger part and will call for higher tooling costs, aluminum would be the most viable mold material in this case.

Mold Features

The bee box mold possesses various mold features that allow it to be manufactured through extrusion blow molding. The pinch off or pinch line is a mold feature that will separate any excess flash from the parison as the mold closes and forms a part [31]. Pinch-off will be applied to the perimeter of the bee box as well as the insides of both box handles.

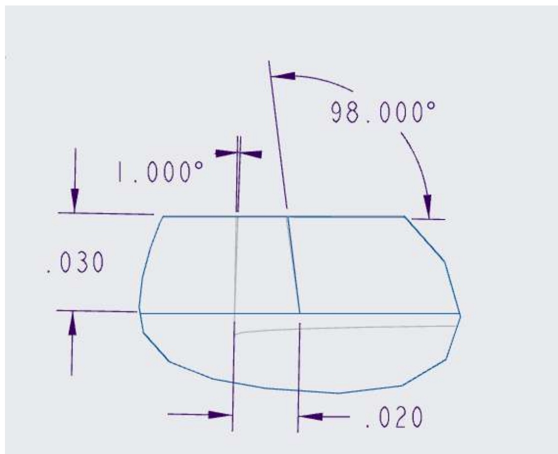


Figure 4: Detail Drawing of Mold Pinch-Off

The blow pin/needle location will establish the area where the air will be introduced to the resin jut after the parison becomes clamped by the mold [33]. Blow needles will be a viable option since it pierces the parison and does not leave an opening in the part. Three blow needles along the top sidewall of the component will be utilized in the manufacturing of the component.

Manufacturing Details

Process Methodology

There are various methods of blow molding that utilize air being introduced into the tool cavity. Due to the part shape being a five-sided container, the processing method considered for this application is extrusion blow molding. This process utilizes a die that extrudes a strand of plastic downwards known as the parison, in which it is then clamped inside a plastic mold. Air is then blown into the parison with a blow pin to expand the parison to the shape of the cavity and then cooled [34]. This process is very versatile with larger parts such as containers and tanks and multi-layer products.

Injection and injection stretch blow molding are both similar processes, mainly involving the use of remolded parts called preforms, in which hot air is introduced into the preform to take the shape of the cavity [34]. The difference between the two is that injection stretch blow molding utilizes a secondary step to stretch the parison vertically and horizontally to enhance mechanical properties; thin-walled parts are suitable for this variant. This process will be avoided with the manufacturing of the bee box mainly due to it catering mainly to bottles, in which preforms will not be needed. Both processes typically produce high volume and frequency, which would not be feasible with the large bee box given that production costs are typically higher with both variants of injection blow molding.

With the selection of extrusion blow molding as the processing method, the two main methodologies of this type of molding are continuous intermittent. Continuous molding involves the constant extrusion of the parison into the mold which then the mold clamps and air is introduced. Intermittent molding on the other hand involves a fixed amount of molten resin built up in what is known as an accumulator head [35]. The accumulator head will then push the plastic out sequentially in line with the goals of the user through parison programming. Parison programming allows the control of wall thickness and overall parison length for each molded part [36]. Intermittent molding is the ideal method of extrusion blow molding for the bee box. The cavity layout of the bee box will be C-shaped, which may cause issues if the parison is too long or too short regarding variable wall thickness. With an accumulator head, processing issues are less likely to happen due to the control over the parison that it allows for the processor.

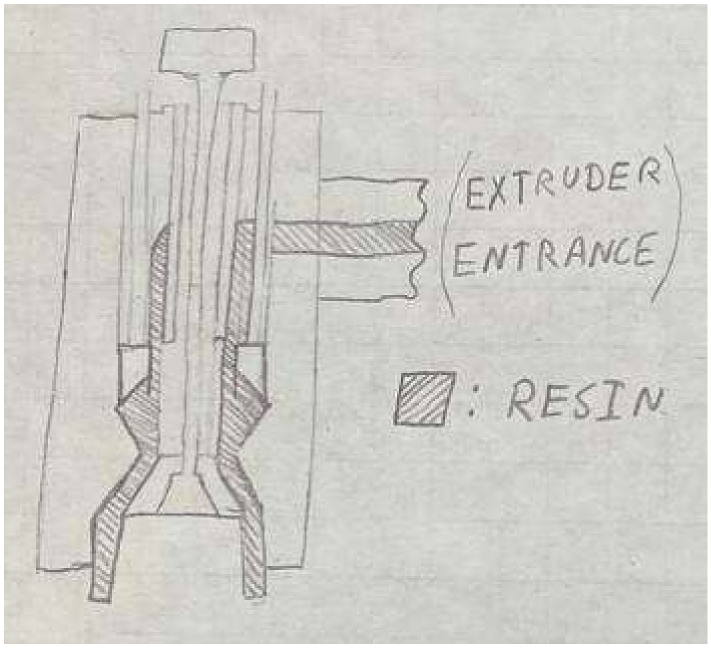


Figure 5: Sketch of Accumulator head with Diverging Die

Head Type

Several tooling considerations must be considered when designing a part that is to be extrusion blow molded. The head type for this part will either be converging or diverging; the most common options blow molding applications. The part to be molded is a wide five-sided container, which means that the parison needs to cover a significant area of the cavity initially before the air is introduced to minimize issues in air blowing. A diverging head die will be utilized in the manufacturing of the bee box. The methodology for diverging tool heads is to be able to blow mold larger parts; the machining being able to allow parisons up to 14” in diameter, as opposed to 6” with converging heads [37]. The use of diverging heads will also reduce the chance of a curtaining effect occurring in the parison, which is when sagging takes place during extrusion and creates variable wall thickness. The diverging path of the parison will allow it to cover the surface area of the cavity more efficiently than a converging tool head.

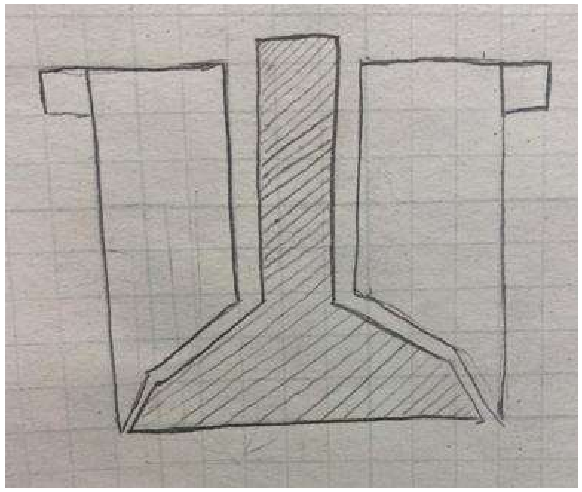


Figure 6: Sketch of Diverging Die Tooling

Machine Selection

In order to be able to manufacture the bee box, a suitable extrusion blow molding machine must be selected that can handle the mold and tooling dimensions and features. For a part with an approximate projected area of 310.211 in^2 and mold base dimensions of 40.875 in x 26 in x 18.875 in, the Bekum XBLOW 100 proved to be a suitable option. While the clamp force limit greatly exceeds what the bee box would need, the mold length threshold exceeds that of the XBLOW 50 maximum capability by 9.379”. In consideration of tonnage capability and allowable mold dimensions alone, the Bekum XBLOW 100 will prove to be suitable for the manufacturing of the bee box [38].

Secondary Processes

In the case of the bee box mold, secondary operations are required to manufacture the part completely at the opening near the base that will allow bees to enter the bee box and the entrance reducer drawer. During molding, the opening detail near the base of the bee box will create an undercut in the mold pull-direction, restricting the tooling from opening after a cycle. To create this feature, the molded part will not include the opening at the base and will be machined out in a CNC routing process. This process involves a computer-generated toolpath to remove material from a workpiece [39]. For the bee box, a fixture will need to be developed to ensure stable conditions for the part since it will be sitting 90° offset to the intended orientation sideways. The Z-axis travel window would have to exceed 14” due to the part width occupying that space. Trimming of the excess flash and pinch-off will be required for product quality at the hands of an operator as well.

Simulation Results

Finite Element Analysis (FEA) was utilized to simulate the structural response of the bee box in different load cases in ANSYS. This procedure is important to analyze the stability of the bee box in application-related scenarios. One such scenario was the act of carrying the bee box loaded with all eight hive racks and the top lid if applicable. A global mesh sizing of 0.5” was applied to the model, along with local face sizings of 0.3” to the top and bottom faces of the bee box base.

Figure 7: ANSYS Meshing Layout of Bee Box

First, a simulation was conducted to represent the loads applied to the bee box if an individual was carrying it by the two handles on the side of the part. The loads in this case are the calculated pressures from eight hive racks containing honey (≈ 3.5 lb) over the area of the box that will contain them; the area that the pressure is applied to is simplified. In the case that the box contains the wooden lid to cover the opening at the top, pressure was added to represent that load. The loads were set to last for twenty seconds on the bee box in which the deformation and von-mises stresses were obtained:

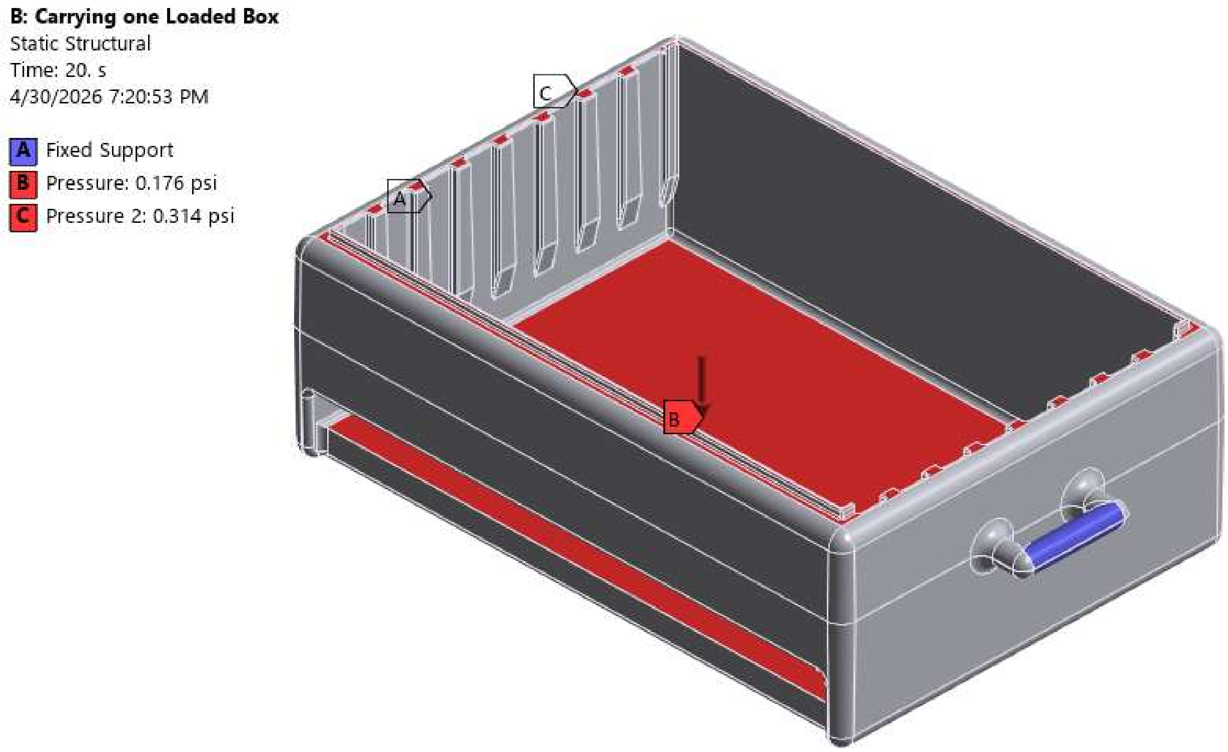


Figure 8: ANSYS Environment Plot of Bee Box Subject to Carrying Loads

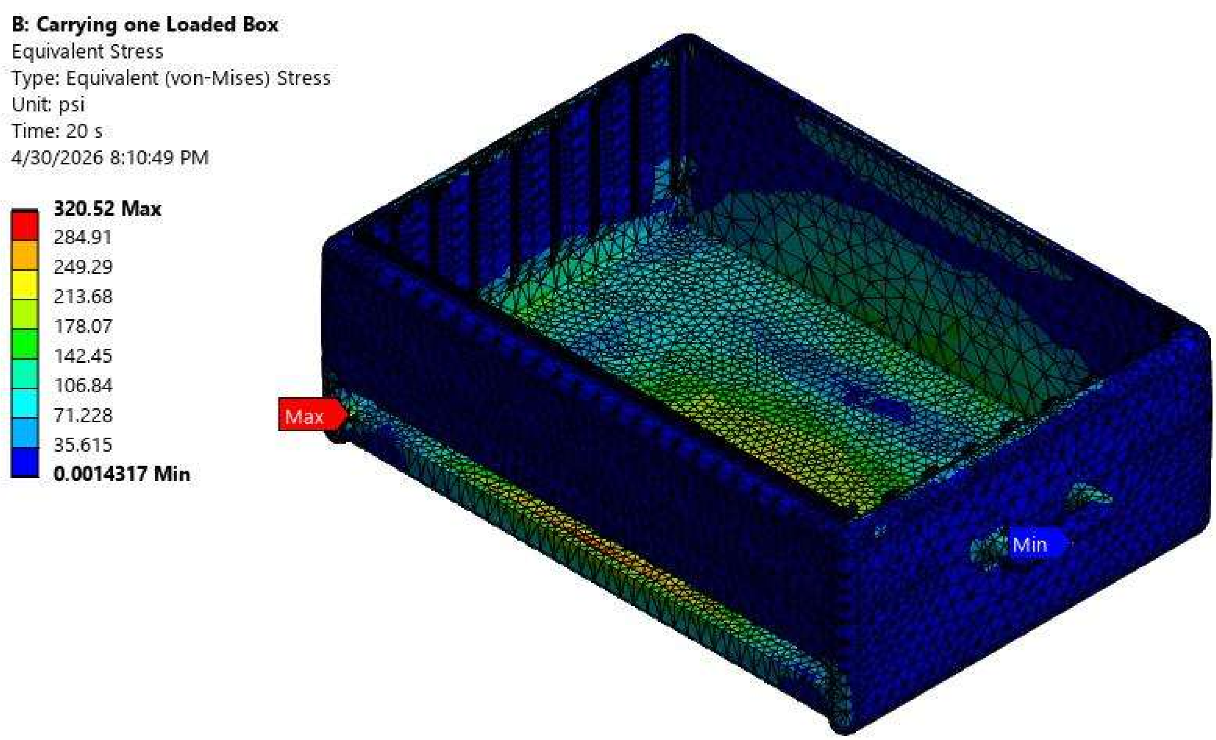


Figure 9: von-Mises Stresses of Bee Box Subject to Carrying Loads

In comparison to traditional wooden bee boxes, the designed plastic bee box will experience significant deformation when subject to the loads of eight full honeycomb frames. The primary contributor to the weight of the frames would be the honey build-up over time. Beekeepers may want to consider more frequent maintenance and harvesting of honey to ensure that the box does not deform excessively. Another solution would be to limit the number of frames placed in the box, especially if the hive becomes congested as the bee population grows. With less frequent need for maintenance, the trade-off would be less honey accumulation over time. Beekeepers typically take the honey racks out prior to carrying the box for maintenance, which would suggest different and variable load responses to the box in this scenario.

A second simulation was conducted to highlight the response of the bee box to stationary loading. In a full stack of three bee boxes, the bottom-most box will be subject to the loads of the two boxes, honey racks, and lid topper above it:

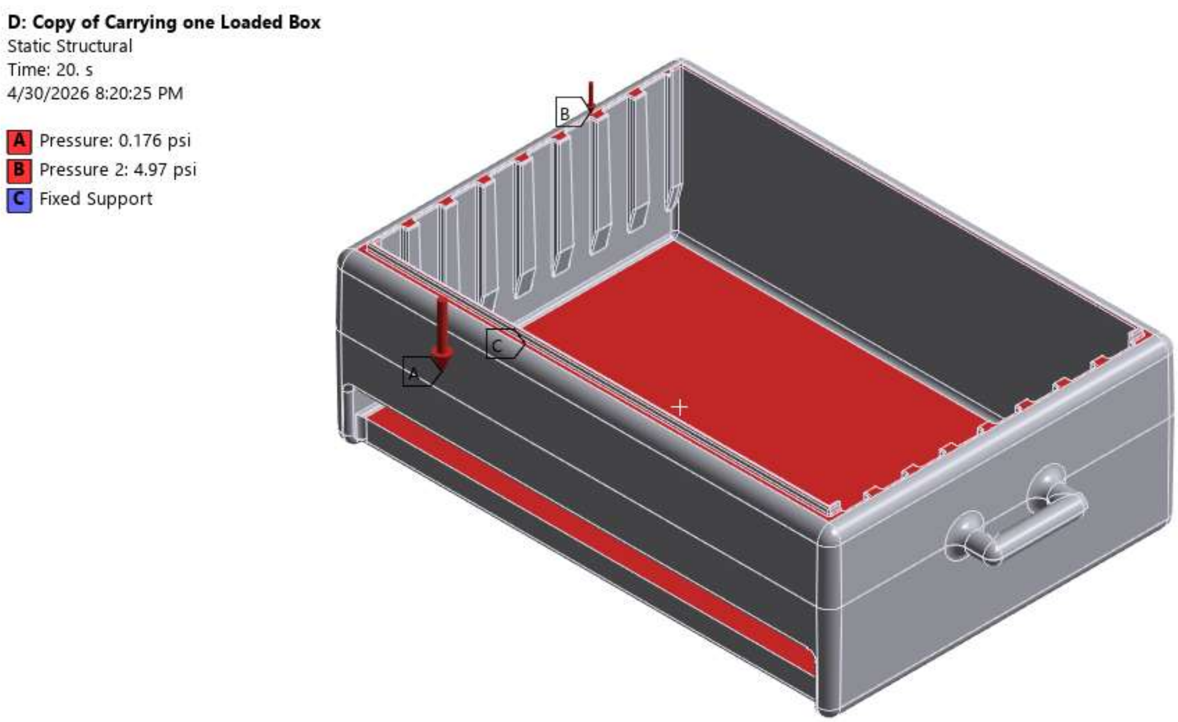


Figure 101: Environment Plot of Bee Box Subject to Static Loads

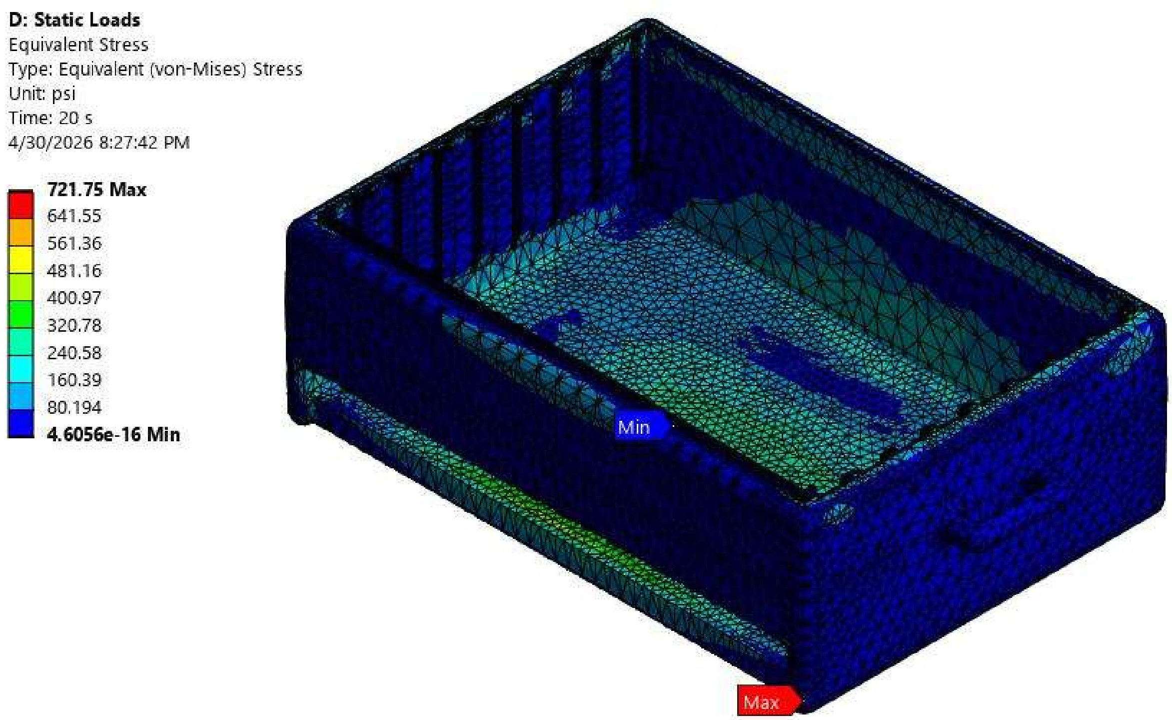


Figure 112: von-Mises Stresses of Bee Box Subject to Static Loads

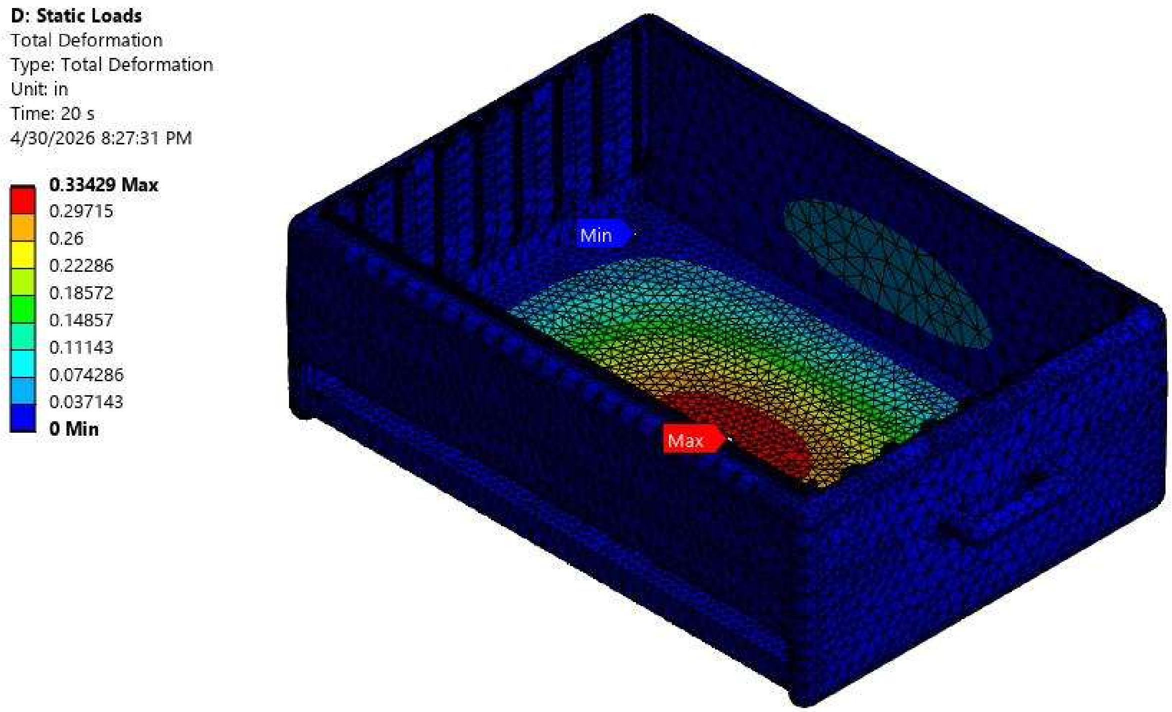


Figure 123: Total Deformation of Bee Box Subject to Static Loads

The stacked loads do not affect the structural appearance of the part, but the weight from the honey racks do. If the honey rack count nears the maximum capacity over a prolonged duration of application, it may be advised not to stack the boxes upon one another due to deformation taking place at the base. Assuming no changes mentioned after the first simulation are made, not stacking the boxes is suggested.

The idea of blow molding a beehive bee box is the crux of this report, and while the loading cases suggest instability in the bee box base, several remarks can be made about the design. This version of the bee box while also saving costs with material usage, can be a more accessible option for beginner beekeepers intending on low-volume honey production. The ease of assembly also creates convenience at the hands of the beekeeper. Overall, this design of a bee box comes with advantages and disadvantages but proves to be an optional alternative.

References

[1] Rutter, B.; Scott, E. *Bee Facts: 155 Amazing Facts about Bees and Beekeeping*. The Best Bees Company. https://bestbees.com/bee-facts/.

[2] *The Role of Bee Boxes in Sustainable Beekeeping | MULTI-SWEET GROUP*. MULTI-SWEET GROUP. https://www.multi-sweet.com/elementor-bee-boxes/.html (accessed 2026-04-25).

[3] *MayBee Hives Beeswax Coated 8 Frame 4 Layer Langstroth Beehive*. Maybee Hives. https://www.maybeehives.com/products/maybee-8-frame-4-layer-bee-hives-2-deep-2-super?srsltid=AfmBOoo-lOZNOE0sekELvjz0S-Mf6jQSU0X5In6Scz7kdbxRHu-Keef- (accessed 2026-04-25).

[4] HonestBee. *What are the pros and cons of plastic vs. wood beehives? A Guide to Choosing the Right Hive Material*. Honestbeeltd.com. https://honestbeeltd.com/faqs/what-are-the-pros-and-cons-of-plastic-vs-wood-beehives (accessed 2026-04-25).

[5] Group, G. *Rotational Molding Advantages and Disadvantages | Regency Plastics*. Gemini Group. https://geminigroup.net/rotational-molding-advantages-disadvantages/.

[6] HonestBee. *What Role Do Food-Grade Plastic Boxes and Packaging Play in the Transportation and Storage of Honey*. https://honestbeeltd.com/faqs/what-role-do-food-grade-plastic-boxes-and-packaging-play-in-the-transportation-and-storage-of-honey

[7] HonestBee. *What Are the Standardized Dimensions for Langstroth Beehive Boxes*. https://honestbeeltd.com/faqs/what-are-the-standardized-dimensions-for-langstroth-beehive-boxes

[8] Primal Bee. *Hive Maintenance—Cleaning, Repairs, Lifespan*. https://primalbee.com/tools/usage-guides/management-growth/hive-maintenance---cleaning-repairs-lifespan

[9] HonestBee. *How Much Honey Is in 1 Frame? A Beekeeper's Guide to Frame Sizes and Yields*. https://honestbeeltd.com/faqs/how-much-honey-is-in-1-frame#:~:text=in%201%20frame?-,A%20Beekeeper's%20Guide%20to%20Frame%20Sizes%20and%20Yields,(6%201/4%20inches)

[10] Custom-Pak. *Blow Molding Design Guide*. https://www.custom-pak.com/design/blow-molding-design-guide/

[11] The Plastics Exchange. https://www.theplasticsexchange.com/

[12] Business Analytiq. *PVC Price Index*. https://businessanalytiq.com/procurementanalytics/index/pvc-price-index/

[13] Welch Plastics. *HDPE: High-Density Polyethylene*. https://www.welchplastics.com/hdpe-high-density-polyethylene/

[14] ACME Plastics. *The Ultimate Guide to Food Grade and Food Safe Plastics*. https://www.acmeplastics.com/content/the-ultimate-guide-to-food-grade-and-food-safe-plastics/

[15] SpecialChem. *Density*. https://www.specialchem.com/plastics/guide/density

[16] Rapid Prototyping. *HDPE: Key Properties of HDPE (Density, Strength, Melting Point)*. https://www.rapid-protos.com/hdpe/#toc_Key_Properties_of_HDPE_Density_Strength_Melting_Point

[17] Palmetto Industries. *Is Polypropylene Heat Resistant?* https://www.palmetto-industries.com/is-polypropylene-heat-resistant/

[18] LESSO Pipe. *Temperature Limits for Rigid PVC Pipes*. https://en.lessopipe.com/industry-information/industry-news/what-are-the-temperature-limits-for-rigid-pvc-pipes.html

[19] British Plastics Federation. *PVC: Physical Properties*. https://www.bpf.co.uk/plastipedia/polymers/pvc.aspx#Physical%20Properties

[20] Business Analytiq. https://businessanalytiq.com/index/

[21] Foam By Mail. *Expanded Polyethylene Foam Sheet*. https://www.foambymail.com/expanded-polyethylene-foam-sheet.html?srsltid=AfmBOopM1YtuDTM6FOXgoOrOXKat479TG1HSN_58JGf4Kcm9Yqpnf5xl

[22] Superior PolyLift. *The Load-Bearing Strength of Polyurethane Foam Explained*. https://www.superiorpolylift.com/blog/the-load-bearing-strength-of-polyurethane-foam-explained/

[23] Engineering Database. *Thermal Conductivity of LDPE*. https://engdatabase.com/data/thermal-conductivity/ldpe

[24] U.S. Department of Energy. *Insulation Materials*. https://www.energy.gov/energysaver/insulation-materials#polyurethane

[25] Synthesia. *What Is the Thermal Conductivity of Polyurethane?* https://blog.synthesia.com/en/what-is-the-thermal-conductivity-of-polyurethane

[26] *LDPE Foam Durability Versus TPE Foam Flexibility Explained*. Samadfoam.com. https://www.samadfoam.com/insights/the-ultimate-showdown-ldpe-foams-durability-vs-tpe-foams-flexibility (accessed 2026-05-01).

[27] D*urability – Excellence in Insulation*. https://highperformanceinsulation.eu/home/insulating-with-pu/pu-a-premium-insulant/durability/.

[28] Muhammad Sohail Bashir; Qasim, M.; Bashir, H.; Wang, F. Polyethylene Foam. *ACS symposium series* **2023**, 183–204. https://doi.org/10.1021/bk-2023-1439.ch009.

[29] *Why Use Polyurethane Foam - High & Low Density Polyurethane Foam | General Plastics*. General Plastics. https://www.generalplastics.com/why-polyurethane.

[30] Lucy. *The Essential Guide to Blow Mold Tooling for Efficient Production - otivic.com*. otivic.com. https://otivic.com/blow-mold-tooling/ (accessed 2026-05-01).

[31] Blow Molding Design Guideline - Geminigroup.net. https://go.geminigroup.net/2023-Blow-Molding-Design-Guide?_gl=1.

[32] (1)Blow Molding. *ASM International eBooks* **1995**, 317–320. https://doi.org/10.31399/asm.hb.emde.a0003016.

[33] *Pin-Tip Blow Needle*. Dieco-Tech MFG. http://www.dieco-techmfg.com/pin-tip-blow-needle.html (accessed 2026-05-01).

[34] *What are the different types of blow molding?* EuP Egypt. https://www.eupegypt.com/blog/blow-molding-types/ (accessed 2026-05-01).

[35] *The Complete Guide to Plastic Blow Molding*. Plasticstoday.com. https://www.plasticstoday.com/blow-molding/the-complete-guide-to-plastic-blow-molding.

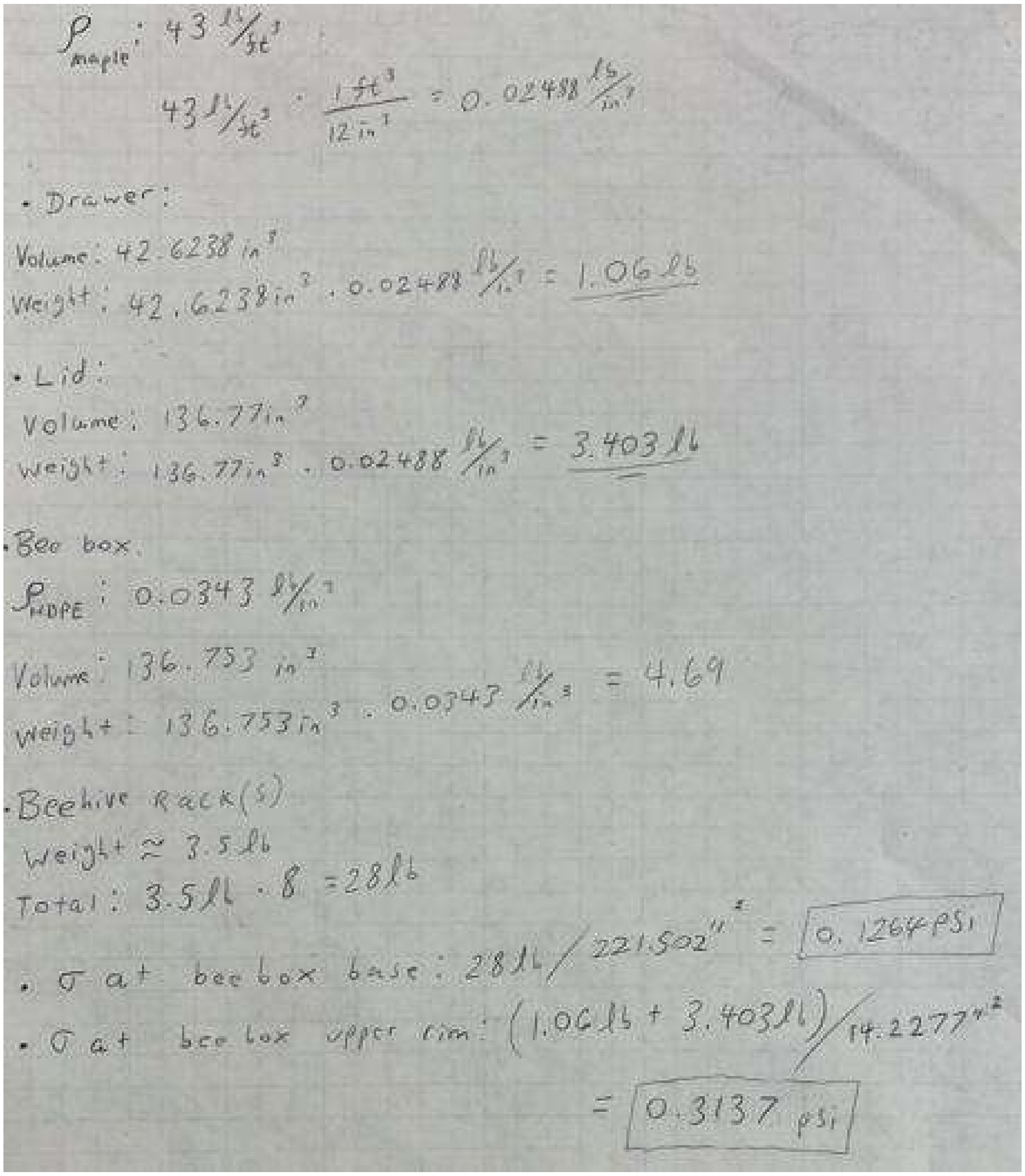
[36] modinatheme. *What is Accumulator Type Blow Molding Machine - Kingplas*. Kingplas Machinery Co., Ltd. https://www.kingplasmc.com/accumulator-type-blow-molding-machine/ (accessed 2026-05-01).

[37] *Know Your Head Tooling Requirements*. www.ptonline.com. https://www.ptonline.com/columns/know-your-head-tooling-requirements.

[38] *XBLOW 50 - 100 EN*. Bekum.com. https://www.bekum.com/en/product/xblow-50-100-en/ (accessed 2026-05-01).

[39] *CNC Routing Explained: Machines, Process, and How It Works*. Jlccnc.com. https://jlccnc.com/blog/what-is-cnc-routing.

Appendix



ρ_{maple}: $43\ lb/ft^3$

$43\ lb/ft^3 \cdot \frac{1\ ft^3}{12\ in^3} = 0.02488\ lb/in^3$

• Drawer:

Volume: $42.6238\ in^3$

Weight: $42.6238\ in^3 \cdot 0.02488\ lb/in^3 = \underline{1.06\ lb}$

• Lid:

Volume: $136.77\ in^3$

Weight: $136.77\ in^3 \cdot 0.02488\ lb/in^3 = \underline{3.403\ lb}$

• Bee box.

ρ_{HDPE}: $0.0343\ lb/in^3$

Volume: $136.753\ in^3$

Weight: $136.753\ in^3 \cdot 0.0343\ lb/in^3 = 4.69$

• Beehive Rack(s)

Weight $\approx 3.5\ lb$

Total: $3.5\ lb \cdot 8 = 28\ lb$

• σ at bee box base: $28\ lb / 221.502''^2 = \boxed{0.1264\ psi}$

• σ at bee box upper rim: $(1.06\ lb + 3.403\ lb) / 14.2277''^2$

$= \boxed{0.3137\ psi}$

Figure 14: Hand Calculations of Stress Applied to Handles Under Carrying Loads

Drawer:

weight: $0.02488\ lb/in^3 \cdot 39.7057\ in^3 = 0.9879\ lb$

$0.9879\ lb \cdot 2 = \underline{1.9758\ lb}$

Lid:

weight: $\underline{3.403\ lb}$

Box: $4.69\ lb \cdot 2 = \underline{9.38\ lb}$

Bee Hive Racks: $3.5\ lb \cdot 8 = 28\ lb \cdot 2 = \underline{56\ lb}$

Total weight: $1.9758\ lb + 3.403\ lb + 9.38\ lb + 56\ lb = \boxed{70.7588\ lb}$

σ on upper rim of bottom box due to stacking:

$$70.7588\ lb / 14.2277''^2 = \boxed{4.97\ psi}$$

Figure 135: Hand Calculations of Stresses on Bee Box Subject to Static Loads

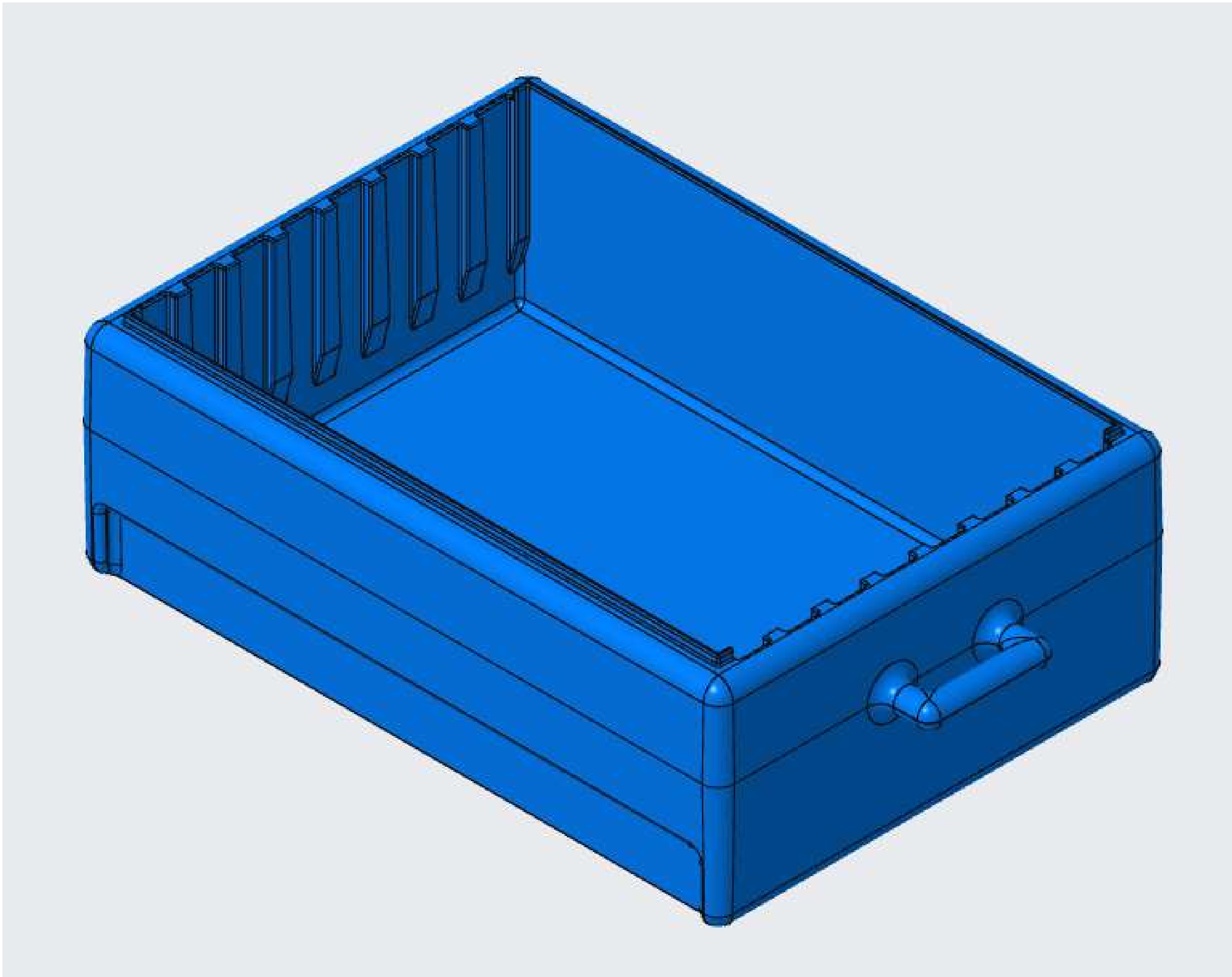


Figure 146: Bee Box CAD Geometry Without Cutout

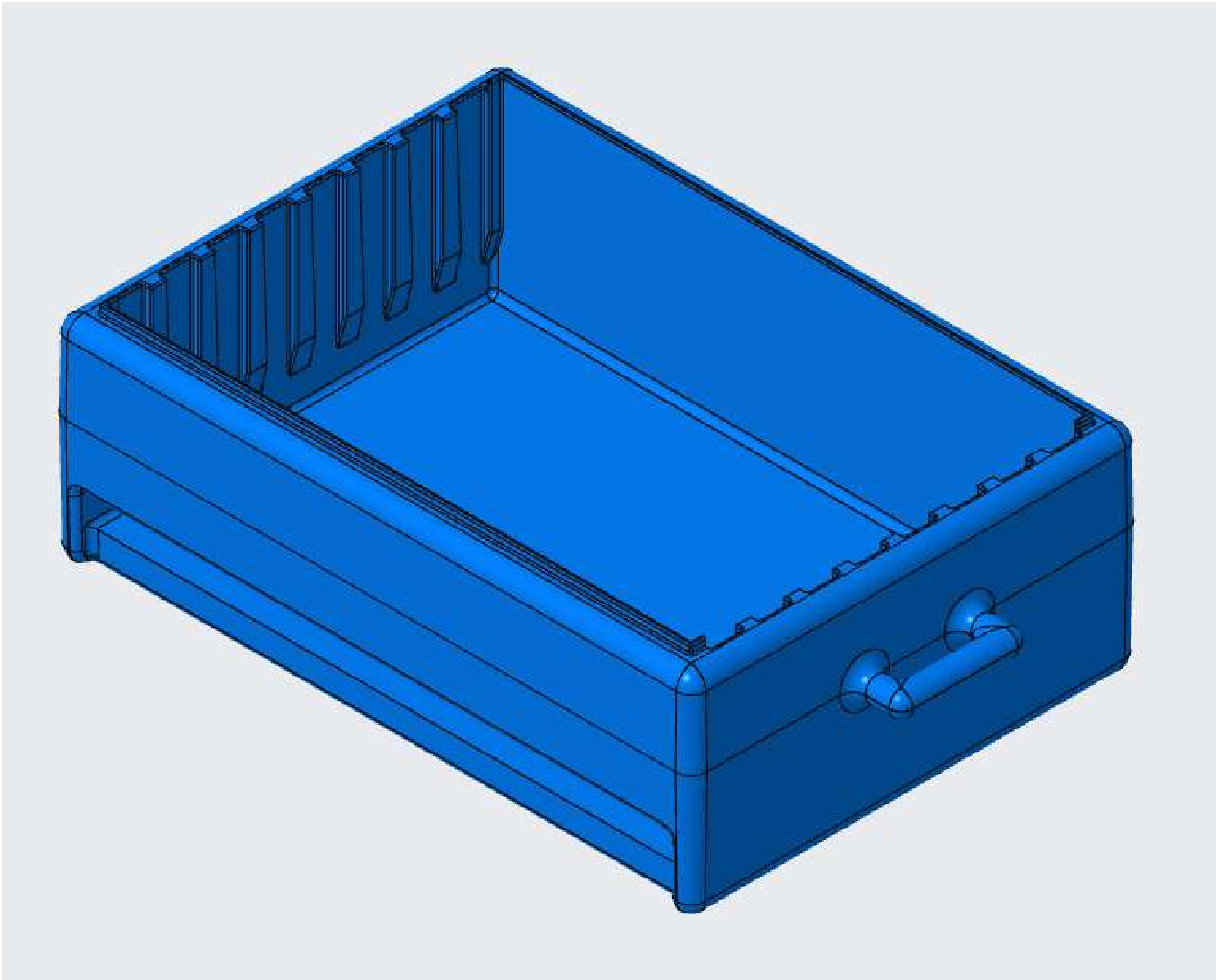


Figure 17: Bee Box Geometry Without Cutout

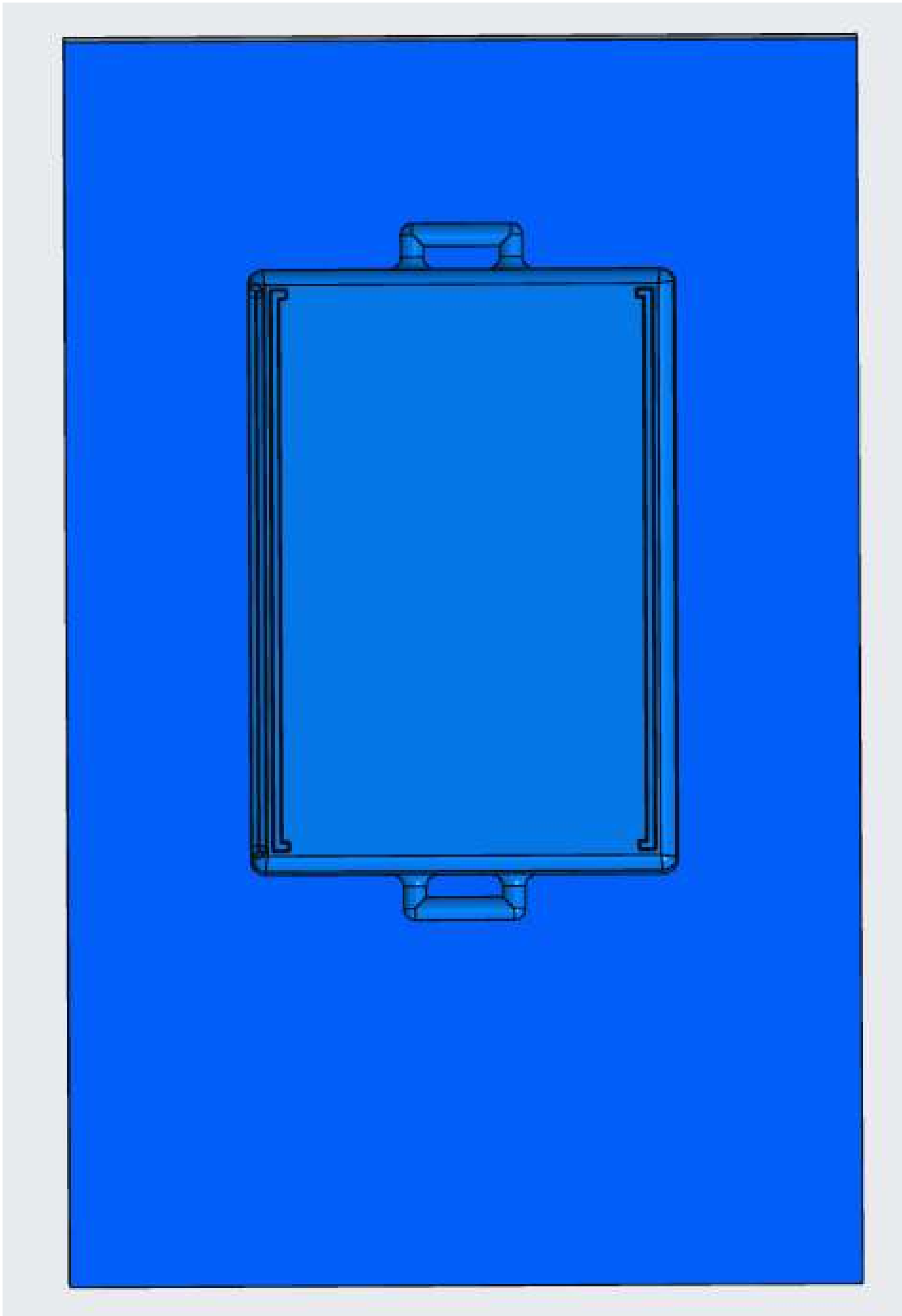


Figure 18: Bee Box Mold (A-Side) Normal View

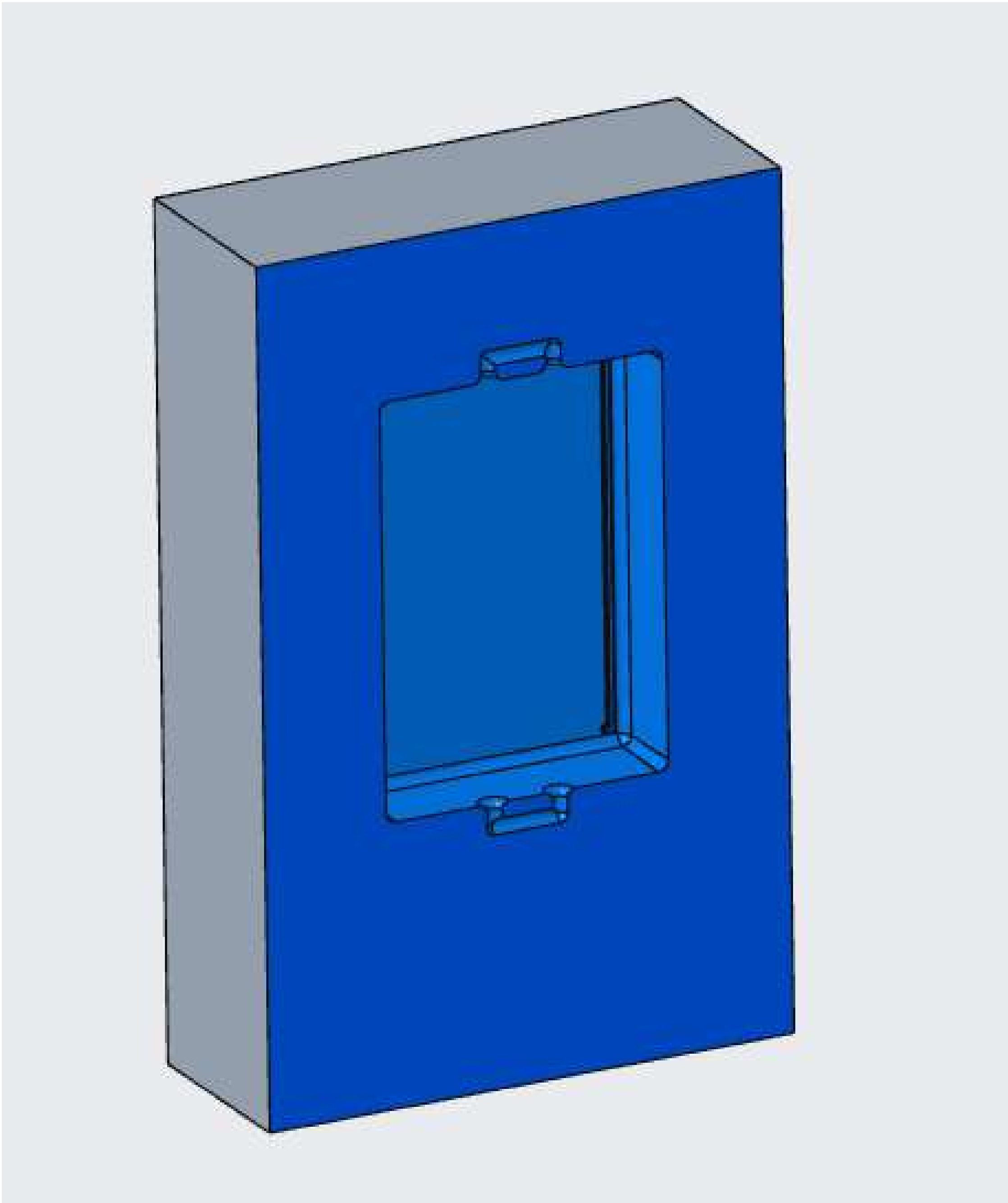


Figure 19: Bee Box Mold (A-Side) Isometric View

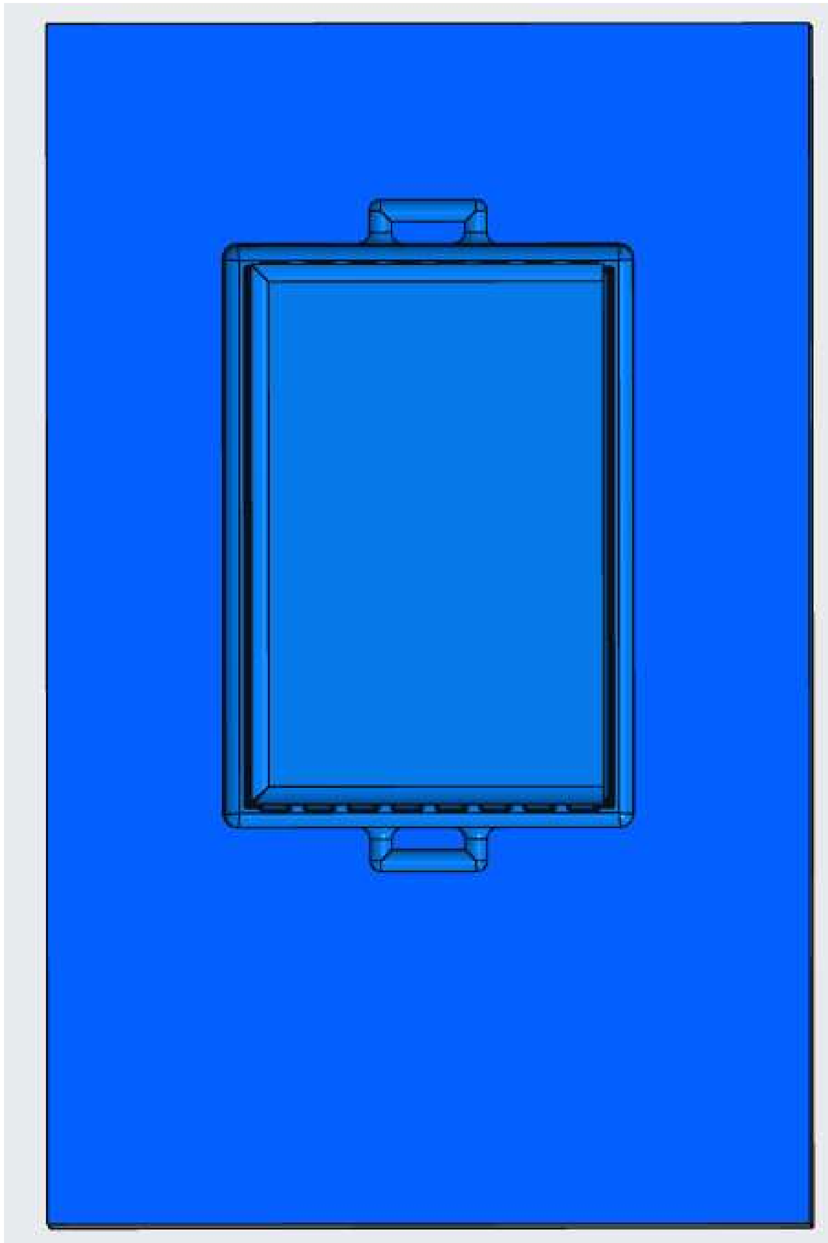


Figure 19: Bee Box Mold (B-Side) Normal View

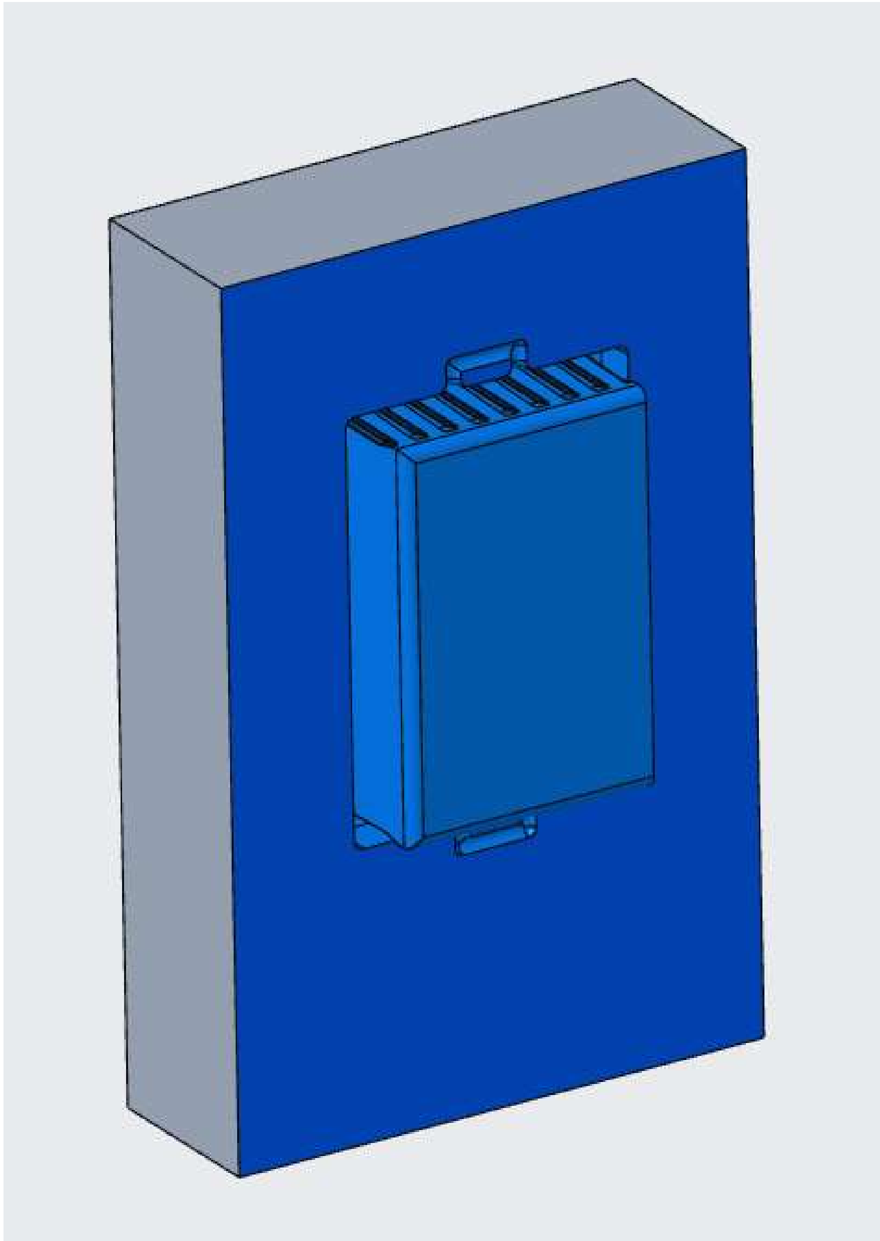
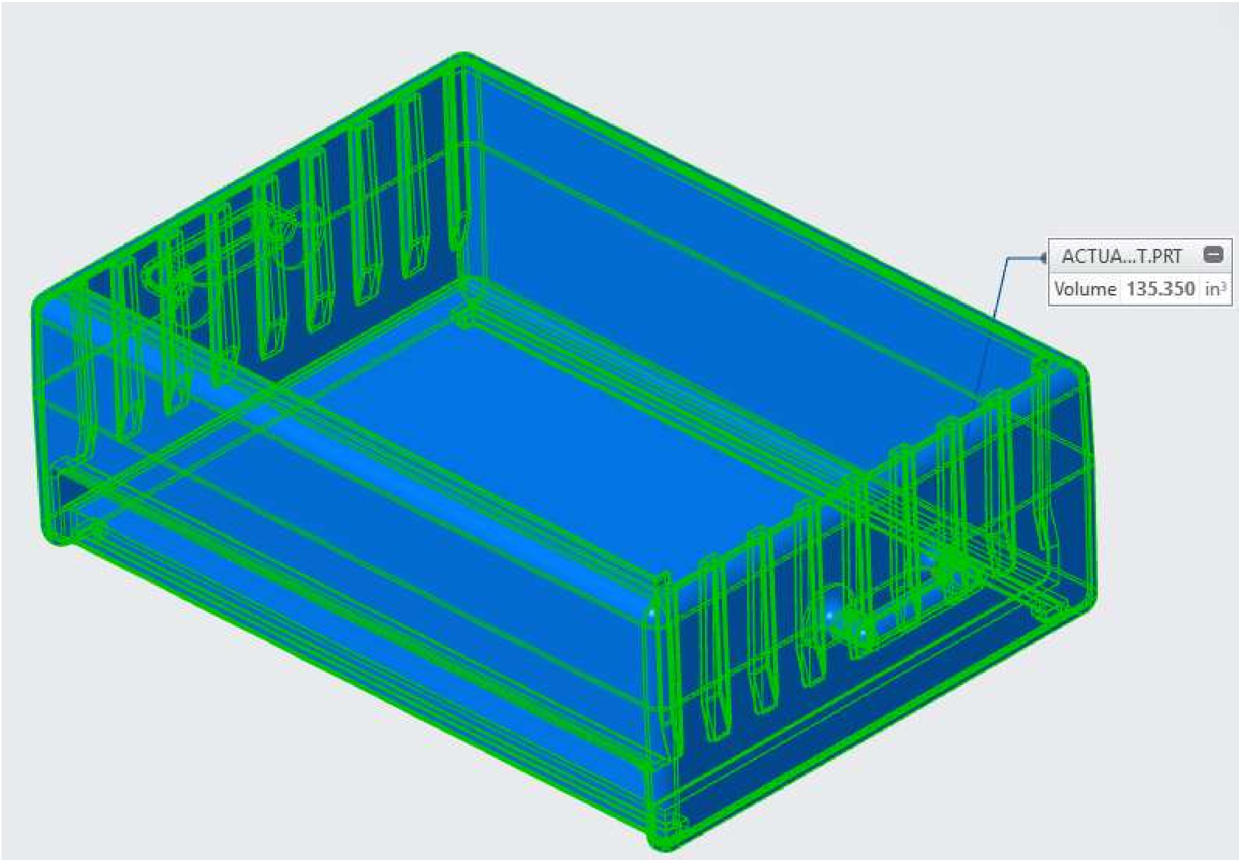


Figure 19: Bee Box Mold (B-Side) Isometric View



Firgure 20 : Volume of Bee Box

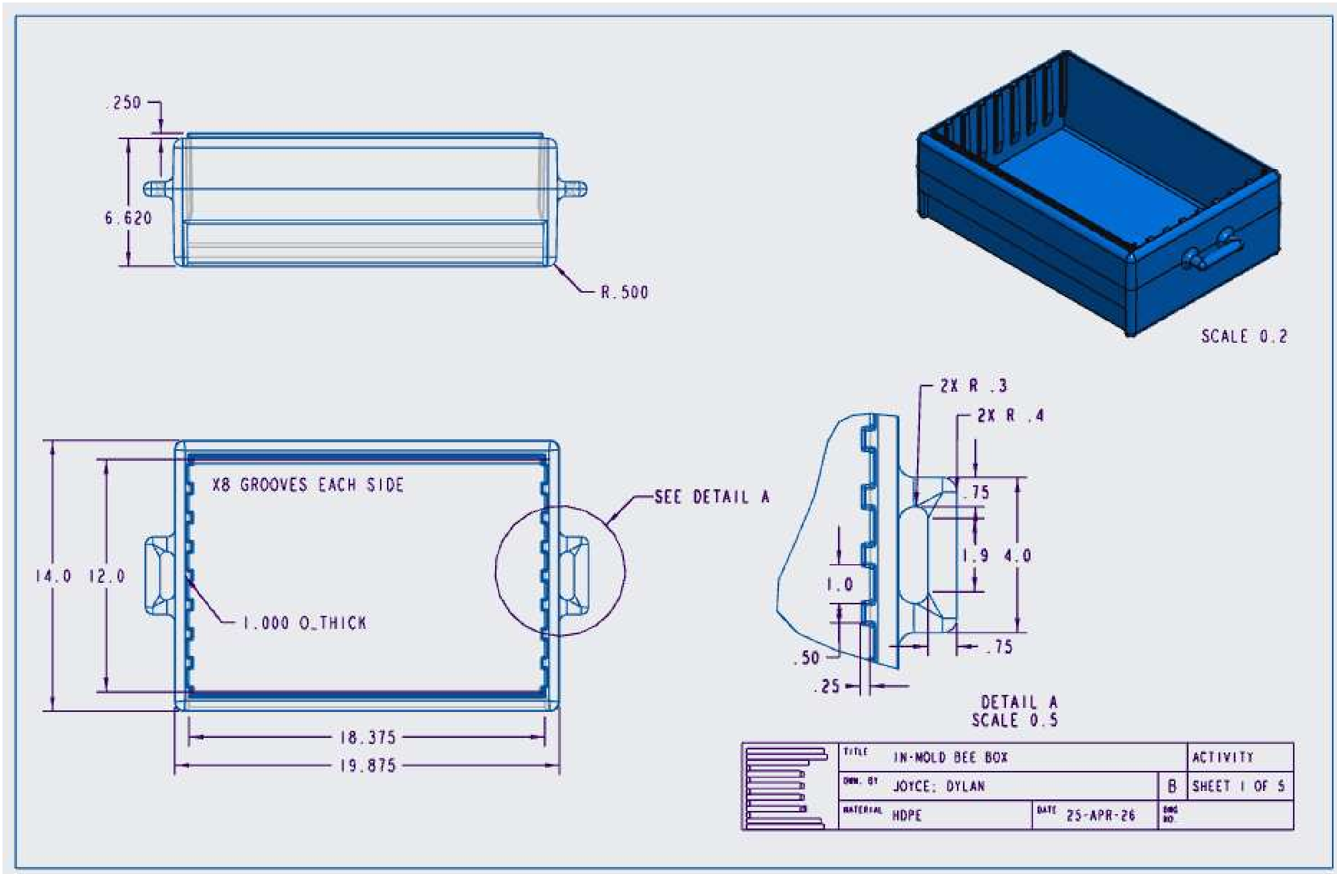


Figure 21: Dimensioned Drawing of In-Mold Bee Box

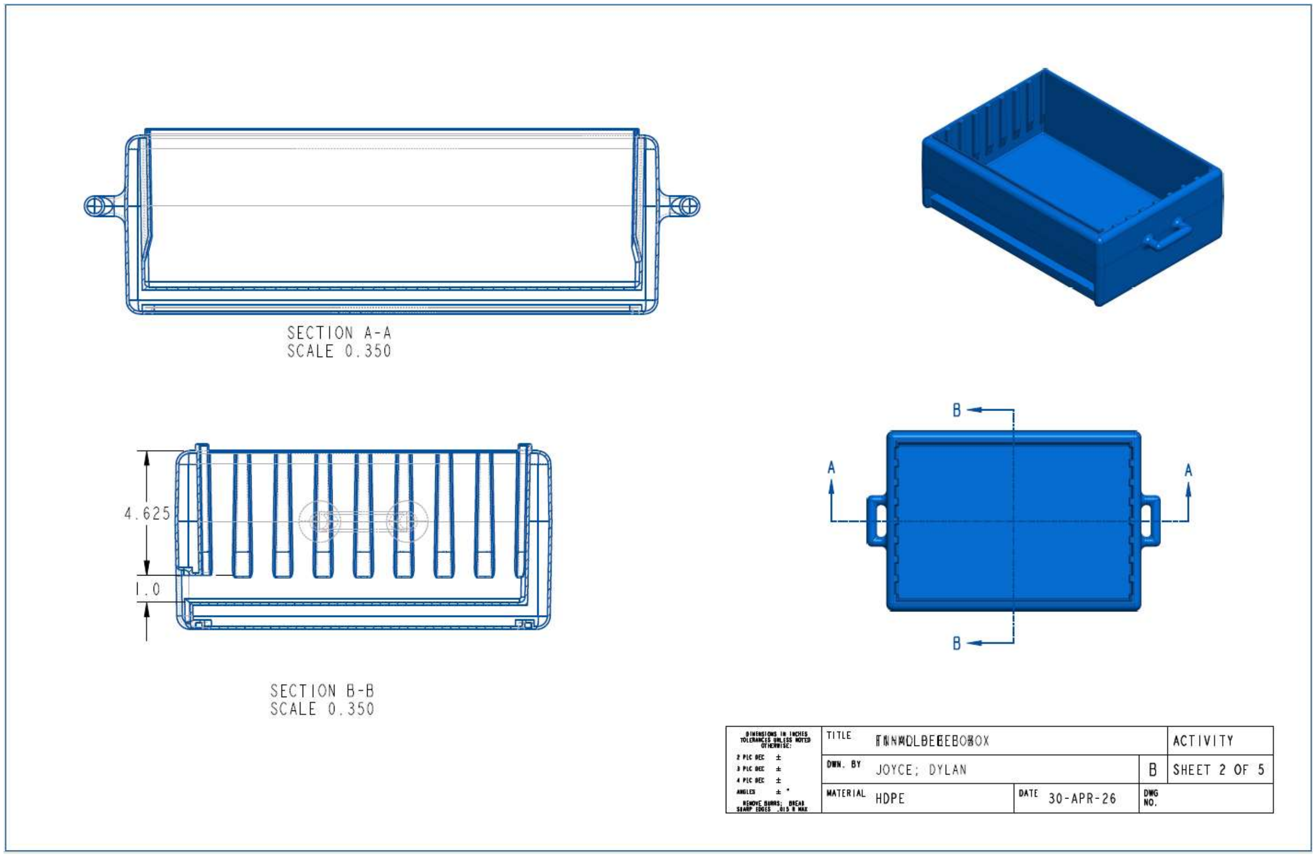


Figure 22: Dimensioned Drawing of Post Assembly Bee Box

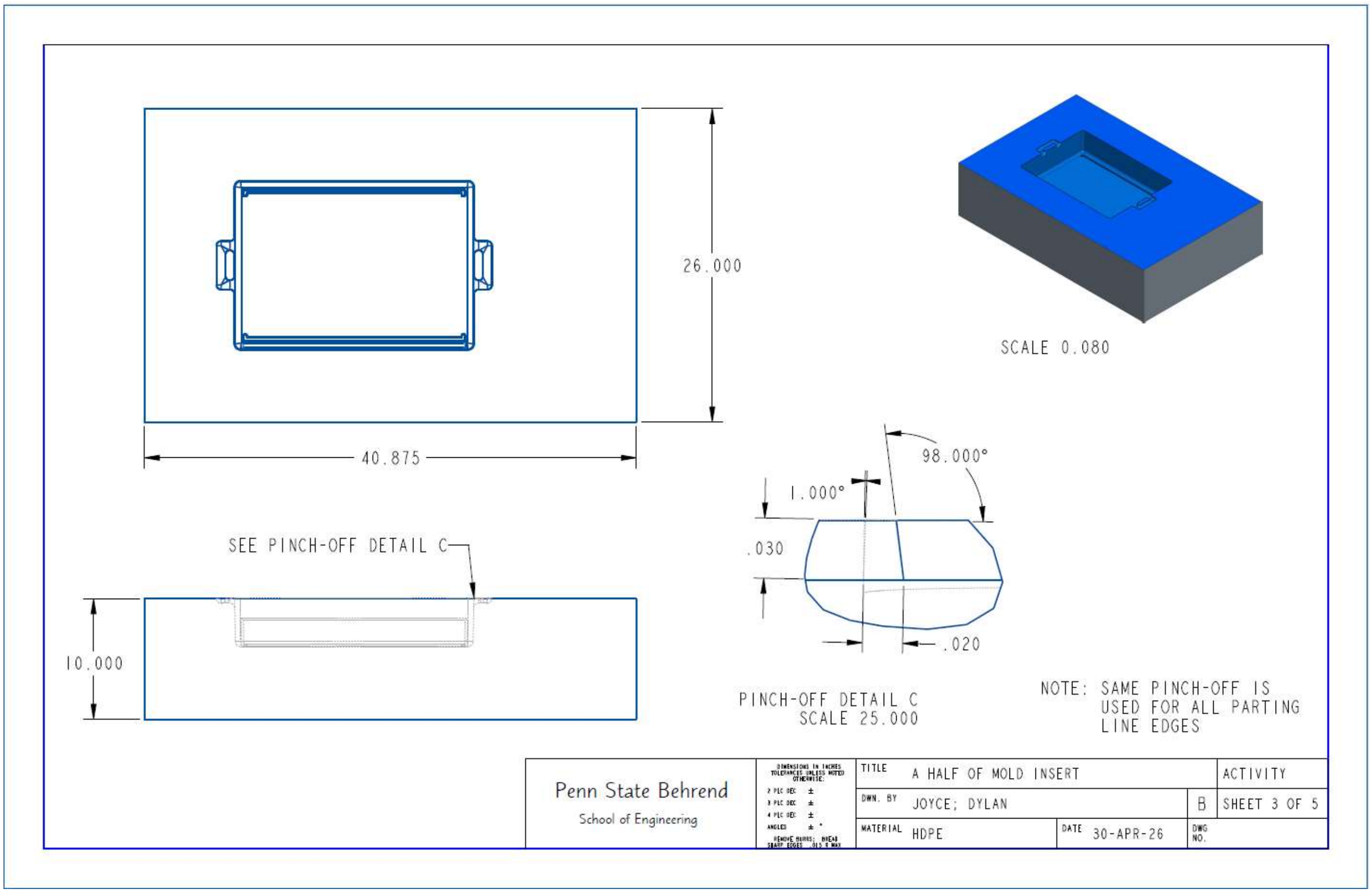


Figure 23: Dimensioned Drawing of A-Side of Mold Insert

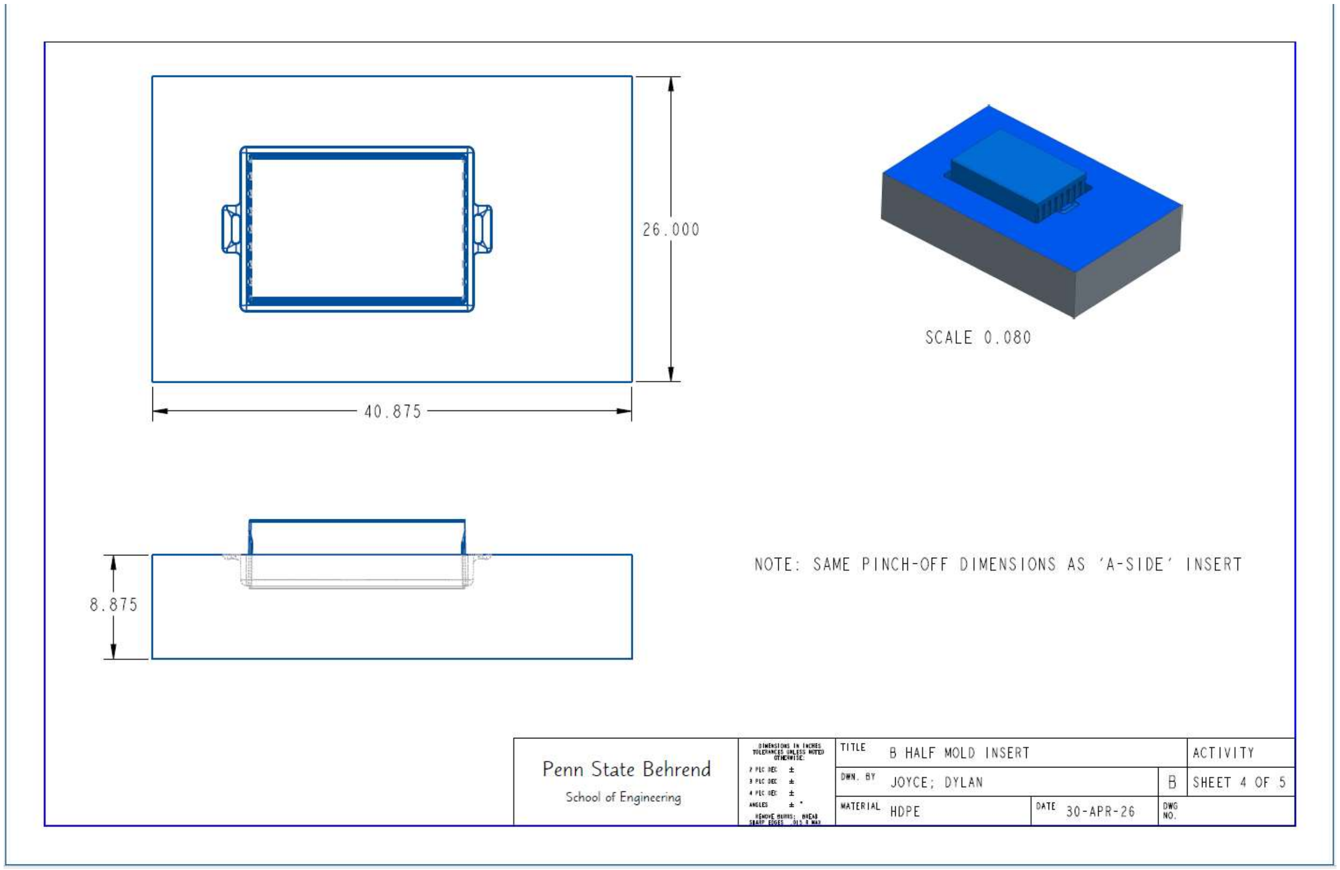


Figure 24: Dimensioned Drawing of B-Side of Mold Insert

SABIC® HDPE ICP4907S

High Density Polyethylene

Saudi Basic Industries Corporation (SABIC)

Message:

SABIC® HDPE ICP4907S is part of SABIC's high density polyethylene Industrial Container Product portfolio.
SABIC® HDPE ICP4907S is typically used for state of the art blow moulding UN certified Intermediate Bulk Containers and Heating Oil Tanks, up to 1000 liters and more. This UV-stabilised and food approved grade combines good processing performance with good stress crack resistance, stiffness and impact performance.
This product is not intended for and must not be used in any pharmaceutical/medical applications.

General Information			
Additive	UV Stabilizer		
Features	Food Contact Acceptable Good Crack Resistance Good Impact Resistance Good Processability Good Stiffness Good UV Resistance High Density		
Uses	Industrial Containers Non-specific Food Applications Tanks		
Processing Method	Blow Molding		
Physical	**Nominal Value**	**Unit**	**Test Method**
Density	0.949	g/cm³	ISO 1183
Melt Mass-Flow Rate (MFR) (190°C/21.6 kg)	7.0	g/10 min	ISO 1133
Environmental Stress-Cracking Resistance (10% Igepal CO-630, Compression Molded, F50)	800	hr	ASTM D1693B
Hardness	**Nominal Value**	**Unit**	**Test Method**
Shore Hardness (Shore D, Compression Molded)	60		ISO 868
Mechanical	**Nominal Value**	**Unit**	**Test Method**
Tensile Modulus (2.00 mm, Compression Molded)	950	MPa	ISO 527-2/1BA/50
Tensile Stress			ISO 527-2/1BA/50
Yield, 2.00 mm, Compression Molded	23.0	MPa	
Break, 2.00 mm, Compression Molded	34.0	MPa	
Tensile Strain (Break, 2.00 mm, Compression Molded)	> 1000	%	ISO 527-2/1BA/50

Flexural Modulus (2.00 mm, Compression Molded)	1000	MPa	ISO 178
Flexural Stress (2.00 mm, Compression Molded)	24.0	MPa	ISO 178
ESCR (Strain Hardening) - Gp	30.0	MPa	Internal Method
Enthalpy Change	192	J/g	ISO 11357-3
Impact	**Nominal Value**	**Unit**	**Test Method**
Notched Izod Impact Strength (-30°C, Compression Molded)	17	kJ/m²	ISO 180/A
Thermal	**Nominal Value**	**Unit**	**Test Method**
Heat Deflection Temperature (0.45 MPa, Unannealed)	77.0	°C	ISO 75-2/B
Vicat Softening Temperature	126	°C	ISO 306/A
Melting Temperature (DSC)	131	°C	ISO 11357-3

Figures 25 & 26: HDPE Material Data Sheet

SABIC® LDPE HP0722NDF

LOW DENSITY POLYETHYLENE FOR FOAMING

DESCRIPTION

SABIC® LDPE HP0722NDF is a grade typically used in foam applications. It is without slip and anti-block additives. This grades is ideally suitable for foaming processes using both physical and chemical blowing agents.

TYPICAL APPLICATIONS

SABIC® LDPE HP0722NDF can be typically used for all types of foam, produced with chemical blowing agents or physical gases, X-linked and non X-linked. Due to its excellent characteristic; the main applications are:
- Packaging
- Construction
- Automotive
- Footwear, Sports & Leisure

Contact SABIC for detailed information about this resin and its applications.

This product is not intended for and must not be used in any pharmaceutical/medical applications.

TYPICAL PROPERTY VALUES

Revision 20201103

PROPERTIES	TYPICAL VALUES	UNITS	TEST METHODS
POLYMER PROPERTIES (1)			
Melt Flow Rate (MFR)			
at 190°C and 2.16kg	0.75	g/10 min	ASTM D1238
Density			
at 23°C	922	kg/m³	ASTM D1505
THERMAL PROPERTIES			
Crystallization Temperature	95	°C	ISO 11357-3
Avg. Heat of Fusion	146	J/g	ISO 11357-3
Melting Point	112	°C	SABIC method
Vicat Softening Point	95	°C	ASTM D1525

(1) Typical values; not to be construed as specification limits.

PACKAGING

Polyethylene resins (in pelletized or powder form) should be stored in such a way that it prevents exposure to direct sunlight and/or heat, as this may lead to quality deterioration. The storage location should also be dry, dust free and the ambient temperature should not exceed 50 °C. Not complying with these precautionary measures can lead to a degradation of the product which can result in color changes, bad smell and inadequate product performance. It is also advisable to process polyethylene resins (in pelletized or powder form) within 6 months after delivery, this because also excessive aging of polyethylene can lead to a deterioration in quality.

CHARACTERISTICS

SABIC® LDPE HP0722NDF is a grade typically used in foam applications. It is without slip and anti-block additives. It demonstrates the following main properties: • Good processability • High consistency • Excellent foamability • Dimensional stability

CHEMISTRY THAT MATTERS™

Figure 27: LDPE Foam Material Data Sheet