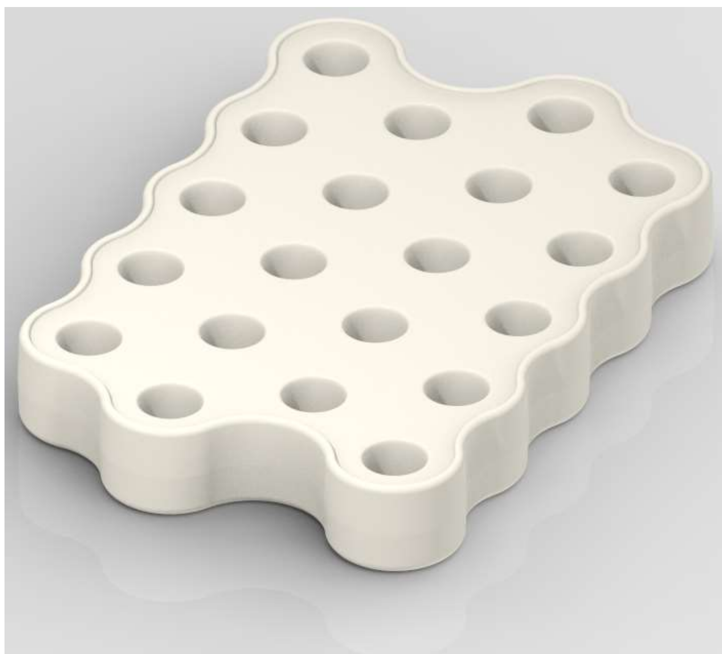
# Society of Plastics Engineers SPE Blow Molding Division

## Annual Student Design Contest

# AquaBloom – Floating Plant Bed




Drew Tracy – dat5607@psu.edu
Andrew Pfister – ajp7182@psu.edu
Kaitlyn Ezzone – kme5607@psu.edu


Due: 04/30/2025

# Table of Contents

## Abstract

Hydroponic agriculture offers a sustainable solution for food production by reducing water consumption, reutilizing the nutrient solutions, minimizing land use, and enabling cultivation in areas with poor soil quality[1]. To support this method of cultivation, a specialized floating plant bed, named AquaBloom, has been developed. AquaBloom is designed to provide a stable, durable, and environmentally compatible platform for hydroponic growth in both freshwater and saltwater environments. Manufactured from high density polyethylene (HDPE) via extrusion blow molding, AquaBloom's hollow structure ensures buoyancy while maintaining structural integrity. This paper will detail AquaBloom's design features, material selection rationale, manufacturing method, mold and process specifications, part cost analysis, buoyancy calculations, and maximum load-bearing capacity.

## Introduction

The floating bed or raft is used in hydroponic systems to hold plants above a nutrient rich water bath, for crop growth. The AquaBloom design aims to replace alternative materials and structures used in hydroponics which often waste space and have a negative environmental impact. As shown in Figure 1, the design holds 20 plants with holes for standard hydroponic plant pots having a 2.7" top diameter. All plants are evenly spaced, and the full plant beds can be integrated together for larger growth volumes. The holes go completely through the part to give roots access to water and nutrients. The holes are drafted for both the plant pots to rest on without falling through and to accommodate the blow molding process. In addition to draft angles, rounds have been added on all edges, again to accommodate the molding process.

*Figure 1: Isometric view of the AquaBloom raft.*

The AquaBloom was designed to replace alternative floating beds seen in industry and hobby settings. Research into hydroponics in both levels shows many 'home-made' versions, created from foamed polystyrene boards, tote lids, PVC pipes, and other plastic goods, shown in Figure 2. The company Beaver Plastics makes polystyrene boards specifically for growing lettuce in hydroponic tanks[2]. The major issue with these alternatives is their durability, longevity, and potential environmental impact. The polystyrene alternatives are prone to wear around the edges and algae buildup due to the heavily textured part surface. Algae buildup can impact the efficiency of the hydroponic system and offset the sensitive nutrient balance in these growth systems. Furthermore, if the polystyrene beads break off into the water it may contaminate or clog the hydroponic aeration systems. With increased focus on microplastic pollution and environmental sustainability, there is a growing demand for more durable and eco-friendly alternatives.

*Figure 2: Examples of 'home-made' hydroponic rafts used on various scales of farming. Top left shows a PVC fence being used[3], to the right is a Polyurethane foam insulation board with an aluminized polyester coating[4]. The bottom left shows a foam floor tile made of ethylene-vinyl acetate[5], to the right is an expanded polystyrene board covered in algae growth[6].*

In response to these challenges, the AquaBloom presents a solution that not only addresses the durability and environmental concerns of traditional materials but also aligns with the rising trend of hydroponics as a commercial agricultural method. The rise of hydroponics began in the 17th century when research on growing terrestrial plants without soil was published by Francis Bacon. The techniques discussed were continuously investigated and expanded on till the 20th century when further understanding of chemistry and plant physiology allowed for improvements in the technique. The term 'hydroponics' was coined by Dr. William F. Gericke of the University of California at Berkely in 1929, while he was working to perfect the mineral and chemical balances needed for efficient growth[7] . Since Gericke's work hydroponics has been expanded into large scale agriculture to become a 5-billion-dollar industry in 2023. The market is expected to grow by 12.4% annually from 2024 to 2030[8]. The AquaBloom will aim to capture this market growth by introducing a part that addresses the challenges mentioned.

## Application to the Process of Blow Molding

The challenges faced in the design of the hydroponic raft are particularly suited for the extrusion blow molding (EBM) process. The large, hollow, and buoyant part needed for the application will be easily molded via EBM. Moreover, the minimal structural requirements for the AquaBloom will allow for a thin wall thickness. Other considerations for the process are the rounded contours of the part, the 20 shutoffs across the face of the part, and the smooth surface finish. These requirements will be easily accomplished with the EBM process.

While the process used to make the AquaBloom may be more expensive than alternatives. The improved durability and functionality of the product should offset the cost difference. Alternative designs which use expanded polystyrene have a very low production and material cost, however, the product does not have the longevity of a blow molded part.

Other processes such as injection molding, thermoforming, and injection blow molding could be considered for the manufacturing of the AquaBloom. The major drawback of injection molding and thermoforming is that a secondary welding operation would need to be done to create a hollow body. Injection blow molding would also be inadequate because the preform would not be able to accommodate the hole shutoffs on the parting line.

## Design Details

### Specifications

There are several specification requirements that this product must meet to flourish in the hydroponics industry. Shown in Table 1 is the list of specifications that the AquaBloom must comply with.

*Table 1: AquaBloom Specifications*

| ***Specification*** | ***Explanation*** |
|---|---|
| 1. | Density must be less than 0.0361 $lb_m / in^3$. |
| 2. | Each bed must weigh less than 10 lb. |
| 3. | Must support at least 2x expected maximum plant weight. |
| 4. | Must pass the 96-hour OECD 203 test with "no abnormalities observed". |
| 5. | Must pass ASTM G155 Cycle 1 test for a minimum of 333 hours with no visual appearance change or loss of mechanical properties. |
| 6. | Must be chemically compatible in fresh and salt water (3.5% salinity) conditions. |
| 7. | Material must have an MFI between 0.2 and 0.8 g / 10 min. |

The first specification was established to ensure that the AquaBloom floats in water. Based on Archimedes' Principle, the average density of an object must be lower than the density of the fluid it's in if the object is to float[9]. 0.0361 $lb_m / in^3$ is the standard density of fresh water at an ambient temperature[10] and therefore the AquaBloom at its max plant capacity must be less dense to guarantee that it will naturally float.

The second specification was determined for ease of transportation, deployment, and scalability. Ensuring the AquaBloom is lightweight means the bed can be handled manually without special equipment. This will verify that everyone, including urban farmers, community gardeners, and small aquaponics operations have the ability to use our product.

The third specification is based on the typical factor of safety that is used for non-critical but performance-sensitive structures[11]. This specification is necessary to account for the increase in the plants' weight as they grow. Plants become heavier particularly with large root systems, water retention within the roots and stems, and with large fruiting plants like strawberries. In addition, the safety factor is designed to account for accumulated debris and uneven plant growth, which refers to one section of the bed being heavier than others.

The fourth specification protects AquaBloom's environmental credibility, prevents potential regulatory issues, and ensures that it remains an eco-conscious product. The OECD 203 is a standard acute toxicity test for fish[12]. Given that the AquaBloom is designed for direct contact with aquatic ecosystems such as lakes, ponds, or aquaponic tanks, it is crucial that its material does not leach harmful chemicals that could endanger aquatic life. Passing the OECD 203 test verifies that exposure to the material does not cause behavioral abnormalities, such as lethargy or erratic swimming, nor physiological harm, such as lesions or gill damage, in aquatic organisms[12]. In addition, this test ensures that there are no mortality occurrences due to the presence of AquaBloom[12].

The fifth specification takes into account the direct sunlight and moisture that the AquaBloom will be exposed to on a daily basis. ASTM G155 is an accelerated weathering test that simulates real-world outdoor conditions[13]. This ASTM provides a plethora of testing parameter options, so the AquaBloom material will be subjected to the following conditions to best simulate its intended environment:
The light source will be a xenon arc lamp with a daylight filter since it simulates the full spectrum of natural sunlight most accurately. The radiant exposure will be set it 0.35 $W/m^2$ at 340 nm which is the standard for outdoor plastics. The cycle is named Cycle 1; the common test used for outdoor polymer durability testing. This cycle will be 102 minutes of light at 63°C black panel temperature at 50% relative humidity, then 18 minutes of light plus water spray to simulate rain and moisture[13]. The plant growing season is expected to be around four months. 1,000 hours of ASTM G155 testing equates to roughly 1 year of outdoor Florida sunlight[13]. Therefore, the minimum testing time that the AquaBloom must withstand without any visual changes or reduction in mechanical properties is 333 hours which equates to about four months of Florida sunlight.

The sixth specification ensures the AquaBloom is compatible with saltwater conditions. Although many applications will be in freshwater environments like ponds, lakes, and tanks, some users may use the bed in coastal agriculture or saltwater-adjacent urban farms. The chemical compatibility will guarantee that the material does not degrade, weaken, or crack when exposed to salts.

The seventh specification ensures that the polymer resin has the necessary melt strength to endure the parison drop. The melt flow index (MFI) of a material used in a blow molding process must be between 0.2 and 0.8 g / 10 min[14,15]. A low MFI, such as what is needed for a blow molding process, indicates a higher molecular weight and is often associated with superior mechanical properties[14,15]. A low MFI can also be associated with a higher viscosity, and therefore a resistance to flow, which is desired for the blow molding process[14,15].

## Material Selection

A material selection process was conducted to identify the most suitable polymer for a floating hydroponic plant bed intended for long-term aquatic exposure. As shown in Table 2, seven key properties were evaluated: cost, OECD 203 aquatic toxicity performance, environmental stress cracking (ESCR) in salt water, ultraviolet (UV) resistance, water resistance, mechanical durability, and density. Each property was assigned a relative weighting factor based on its significance to the final application. The three materials assessed were high density polyethylene (HDPE), polypropylene (PP), and polyvinyl chloride (PVC) which are common materials used in the blow molding industry. Each material evaluated was based on a blow molding grade with an MFI between 0.2 and 0.8 using MatWeb, a material property data website[16–18].

*Table 2: Material selection matrix*

| **Material Selection Matrix** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | HDPE | | PP | | PVC | |
| *Properties* | *Weight (%)* | *Rank* | *Weighted Score* | *Rank* | *Weighted Score* | *Rank* | *Weighted Score* |
| Cost | 15 | 8 | 120 | 9 | 135 | 6 | 90 |
| OECD 203 test | 20 | 9 | 180 | 9 | 180 | 3 | 60 |
| ESCR in salt water | 10 | 9 | 90 | 8 | 80 | 6 | 60 |
| UV resistance | 10 | 8 | 80 | 6 | 60 | 5 | 50 |
| Water resistance | 10 | 10 | 100 | 9 | 90 | 10 | 100 |
| Durability | 15 | 8 | 120 | 7 | 105 | 9 | 135 |
| Density | 20 | 9 | 180 | 10 | 200 | 5 | 100 |
| *Results* | 100 | | 870 | | 850 | | 595 |

Cost was weighted at 15%  to balance performance with economic feasibility. PP achieved the highest ranking due to its relatively low cost and broad availability, followed closely by HDPE[19]. PVC ranked the lowest because it typically incurs higher material and processing costs[19].

Aquatic safety, measured by the potential to pass the OECD 203 toxicity test, was heavily weighted at 20% due to the AquaBloom's direct and continuous contact with aquatic ecosystems. HDPE and PP both received the highest scores based on their inertness and chemical stability in aquatic environments[19]. PVC was assigned a lower score due to concerns related to plasticizer migration and the potential to leach toxic vinyl chloride, which could negatively impact aquatic organisms[19].

Environmental stress crack resistance (ESCR) in salt water was weighted at 10% to reflect the need for long-term mechanical stability under mildly saline conditions. HDPE demonstrates excellent ESCR performance, making it highly suitable for saltwater applications[19]. PP also shows good ESCR resistance, although slightly less robust than HDPE[19]. PVC was warranted a lower ranking due to its relatively low resistance to stress cracking and its tendency toward embrittlement over time[19].

UV resistance was assigned a weight of 10% based on the requirement for extended exposure to high-intensity sunlight without material degradation. HDPE performs slightly better than PP under UV exposure, however both require stabilization additives for optimal performance[19]. PVC was ranked lower due to embrittlement risks when exposed to sunlight[19].

Water resistance was weighted at 10% and was uniformly high among all materials. HDPE, PP, and PVC all exhibit low water absorption rates, ensuring dimensional stability and structural integrity during prolonged exposure to water[19].

Durability was given a weight of 15%, assessing the ability to withstand mechanical stresses from impact and handling forces. PVC received the highest ranking due to its intrinsic toughness and rigidity[19]. HDPE and PP are impact resistant, but still less than PVC and therefore they received a slightly lower score[19].

Density was critically weighted at 20%, as buoyancy is a primary functional requirement of the AquaBloom. PP, with a density of about 0.032 lb / in$^3$, scored highest, followed closely by HDPE at approximately 0.0343 lb / in$^3$. Both PP and HDPE are inherently buoyant in freshwater and saltwater[17,18]. PVC has a density of roughly 0.045 lb / in$^3$ and therefore received the lowest rating, as it would not float without substantial structural modifications[16].

The weighted scoring matrix resulted in HDPE achieving the highest total score of 870 points, slightly outperforming PP at 850 points. PVC lagged significantly behind at 595 points. Therefore, HDPE was determined to be the most appropriate material for this application, offering the optimal balance of material robustness, chemical safety, environmental durability, and buoyancy.

### Part Design

The AquaBloom was designed using Creo Parametric in U.S. customary inches. It was designed following standard guidelines for blow molded parts including, a hollow interior, no undercuts, and a minimum draft angle of 2°. The parts overall dimensions were determined with the goal of having 20 plants in 2.7” diameter plant pots, all spaced 6” apart. With those dimensions established the main body of the part was made with a contoured extrusion. The contour was added to reduce extra space between the plant beds if multiple are placed side by side. Holes were then added with a pattern feature and subsequent drafts and rounds were added for moldability, part function, and appearance. Finally, the model was shelled to create a hollow interior, with a wall thickness of 0.125”. The overall part has dimensions of 21.588” wide by 33.000” long, and 4.25” deep. A nominal wall thickness of 0.125” was selected to ensure the part was rigid and buoyant enough to support the weight of the plants, while maintaining moldability and low part cost. During design, the part was constantly reviewed and considered for manufacturing via blow molding. A major factor to consider is how wall thickness will vary across sections of the part where the parison will have to stretch further. Finally, a draft analysis was performed to ensure there were no undercuts or missing angles on surfaces, the analysis is shown in Appendix I.

## Mold and Tooling Details

### Parting Line

The mold parting line was created with a silhouette curve around the perimeter of the part and in each of the holes. The profile of the shut-off regions is shown in Figure 3. This form was used on all edges of the parting line with a depth of 0.1875” for the excess parison material. Moreover, each of the holes were created as separate inserts into the mold. Separate inserts will allow for greater cooling if they are made of a thermally conductive material such as beryllium copper and will make for easy maintenance or replacement as the parting surface wears over time. The parting line is also significant in that it defines the draft hinge for all regions of the part. As stated previously, a draft analysis of the part was performed to ensure that no undercuts were present. Additionally, the lack of texture on the mold means there is no need for draft more than 2°.

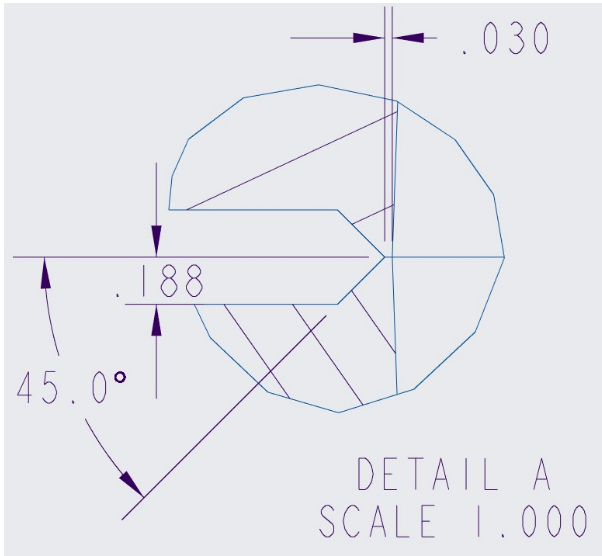



*Figure 3: Detailed view of the parting line with critical dimensions where the relief depth (~0.188") is determined by the wall thickness multiplied by a factor of 1.5. The full mold drawing can be found in Appendix H.*

In addition to the shut-off on the parting line, venting is also required to ensure the air in the mold has somewhere to go when the plastic expands. A standard vent profile will be used as shown in Figure 4, to be placed along the parting surface in deep regions. Venting may also be needed in the bottom of the cavities, in which case pin venting will be machined into the mold.

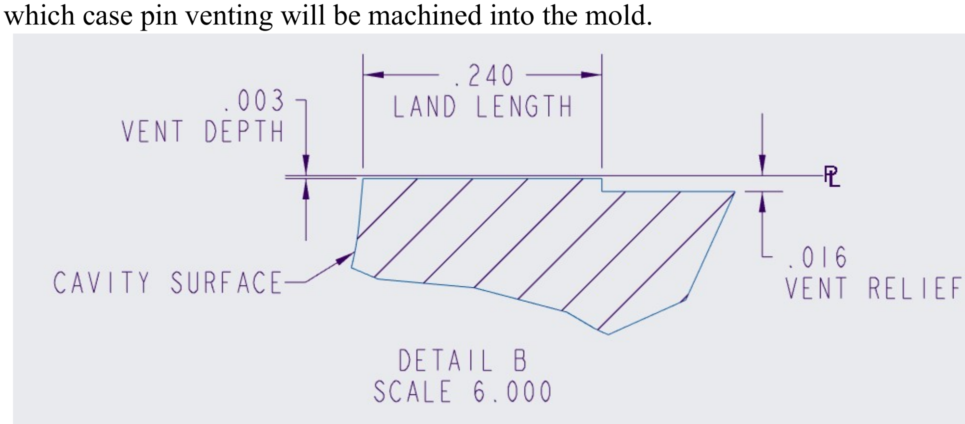



*Figure 4: Standard vent profile used along the parting line.*

## Additional Mold Details

Aluminum Alloy 2024 will be used to construct the mold. A sandblasting technique will be utilized to give the mold and thus the AquaBloom a matte finish. To inflate the parison, two blow needles just off the parting line will be used. They will be symmetrically placed about the length of the part to ensure even and consistent shape formation. Due to the abnormal geometry of the AquaBloom, the product will require assistance in ejection for removing the part from the mold. To consistently eject parts, ejector pins will be placed uniformly within the mold to ensure parts will leave the mold consistently.

# Manufacturing Details

## Process Selection

Extrusion blow molding and injection blow molding were the two processes that were considered for manufacturing this part. Due to the large and irregular geometry of the part, molding the part with an injection-molded preform is significantly less feasible in comparison to extrusion blow molding allowing for greater processability. The extrusion of a parison that is adjustable and allows irregular geometry to be molded gives a decisive advantage towards extrusion blow molding and makes it the most suitable process for making the AquaBloom.

## Machine Selection

To manufacture the AquaBloom via extrusion blow molding, The machine of choice for this operation was chosen to be the Bekum XBLOW 100. The XBLOW 100 was chosen primarily due having the 112-ton clamping force needed to keep the mold closed during processing, however the max mold dimensions of 59.1 in X 47.2 in X 11.8 in allows for a large range of part sizes to be moldable within processing[20]. The machine also has a sufficient daylight of 33.4 in, providing plenty of room to remove the AquaBloom from the mold[20]. Based on this information, the XBLOW 100 is going to be the optimal choice of machine for this product.

## Head Type

Due to the wide shape and non-round design of this part, a more specialized head type must be chosen for extruding the parison. Due to this restriction, an ovalized diverging die will be used to accommodate the wall thickness for the non-round design of the part, creating an extremely wide parison that can be used to fill the mold and allow air to flow unrestrictedly. Due to the size of the part, parison programming will also be used to modify the wall thickness of the parison as it is extruded, allowing for a more consistent thickness throughout the part and creating more reliable parts. In order to allow for parison programming to be implemented, a programmable die will be used so quick adjustments may be made to the parison in a consistent manner.

## Secondary Processes

To prepare the product for end use after demolding, secondary processes must be carried out. This is due to the mold design having numerous holes where the parison may flow. The flash between the holes must be trimmed from the part for it to function as intended. The flash will also need to be trimmed on the outside edges of the part to maintain an aesthetic appeal for the part. To trim the flash quickly and efficiently, the machine operator will be equipped with a knife for quick removal. Alternatively an automatic cutter may be implemented for high production rates.

# Calculations

## Blow Ratio

Calculations of the parts blow ratio were performed in MathCAD and can be found in Appendix A. The blow ratio is used to approximate the stretching of the parison material into the cavity as it is inflated. The ratio is calculated by dividing the cavity surface area where the final part will lay, to the parison's area or the product of the parison diameter and part length. In the calculations the significant material information and part geometry is given at the top with the subsequent calculations. The parison diameter was determined to be 13.743" using the part width as a 'lay-flat' dimension to reference the circumference of the parison. The parison diameter was then compared to the cavity surface area to determine a blow ratio of 1.42. This ratio is smaller than typical blow ratios, however the unique shape of the part, specifically the shutoffs near the outside of the width require a large parison diameter. The blow ratio calculated is used to calculate the parison thickness needed to achieve the desired wall thickness and therefore the full volume of the parison and shot size.

## Part Cost

The calculation of part cost is in Appendix B, referencing values from the previous calculation of blow ratio, parison thickness, and shot size. A shot size of 257.213 $in^3$ was used with the HDPE's density of 0.0338 $lb/in^3$ and cost of \$0.60/lb. These values yielded a material cost of \$5.216/part which could be reduced by using regrind from the scrap in each part. In addition to the material cost, the tooling cost was estimated at \$32,468 based on the mold's dimensions and complexity[21]. The annual production was then calculated using an estimated cycle time of 75.5 seconds, to determine the tooling cost per part. The production rate was based on running one shift, five days a week with a 5% down time and 3% scrap rate. The part value was divided by the estimated annual production of 87,878 parts per year to yield a tooling cost of \$0.370/part. Finally, these values were added to result in a final part cost of \$5.586/part. This value is missing the machine and labor cost, which are unknown in this case.

Overall, the part cost of \$5.59 for the AquaBloom is comparable to the alternative products. An example was found to be \$24.00 per raft, made from expanded polystyrene[22]. By marketing the AquaBloom as a more durable, efficient, and eco-friendly product; the price could likely be increased further from \$24.00.

## FEA

To test the Aquabloom in relation to its specifications, simulations have been conducted using ANSYS workbench to represent the loading the part is expected to undergo. Due to the complex design of the part, simplifications have been made to the part to streamline the simulation process. Due to the thin wall thickness in proportion to the part, the model is represented using shell elements to simplify the meshing process. The part has been constrained by applying the 80 lbf loading throughout the contact regions the plants would make with the part, with a fixed support constrained at the bottom of the part where the AquaBloom would contact the ground as seen in Appendix D. The stresses observed during testing was localized primarily at the contact point between the AquaBloom and the ground, as observed in Appendix E. Using the surface area of the contact region to find the resultant pressure applied upon the part was used to validate Ansys results and determine if the information is usable. Based on the information provided, the stresses and deformation the AquaBloom will experience are well below the likelihood of failure occurring.

# References


(1) Rajaseger, G. Hydroponics: Current Trends in Sustainable Crop Production. *Bioinformation* **2023**, *19* (9). https://doi.org/10.6026/97320630019925.

(2) Beaver Plastics. *Beaver Plastics Lettuce Raft*. https://www.bpgrower.com/lettucerafts (accessed 2025-04-29).

(3) *The Aquaponic Source*. https://www.theaquaponicsource.com/wp-content/uploads/2018/07/File_003-scaled.jpeg (accessed 2025-04-29).

(4) *Hydroponic Lettuce Grow Raft*. https://i0.wp.com/phertzler.com/wp-content/uploads/2014/03/img_4199.jpg (accessed 2025-04-29).

(5) *River Hydroponics*. https://i.pinimg.com/736x/b7/b7/8d/b7b78d58eb13fb228f08ad8a29c63bed.jpg (accessed 2025-04-29).

(6) Foam Hydroponic Raft.

(7) Jeff Edwards. History of Hydroponics, Part I: The Beginnings of Water Culture. *Garden Culture Magazine*. March 24, 2016.

(8) *Hydroponics Market Size & Trends*; 2023. https://www.grandviewresearch.com/industry-analysis/hydroponics-market (accessed 2025-04-29).

(9) Loverude, M. E.; Kautz, C. H.; Heron, P. R. L. Helping Students Develop an Understanding of Archimedes' Principle. I. Research on Student Understanding. *Am J Phys* **2003**, *71* (11), 1178–1187. https://doi.org/10.1119/1.1607335.

(10) Water Science School. Water Density. **2018**.

(11) SafetyCulture. Factor of Safety Ratio for Safety in Design and Use. **2025**.

(12) OECD. *Section 2 Effects on Biotic Systems OECD GUIDELINE FOR TESTING OF CHEMICALS*; 2019. http://www.oecd.org/termsandconditions/.

(13) ASTM International. ASTM G155-21 Standard Practice for Operating Xenon Arc Lamp Apparatus for Exposure of Materials.

(14) Atlas Fibre. Understanding Melt Flow Index. **2024**.

(15) Asaclean. Understanding Melt Flow Rate (MFR) in Plastic Processing. **2025**.

(16) MatWeb. MaterialData_78521_PVC.

(17) MatWeb. MaterialData_78373_PP.

(18) MaterialData_22325_HDPE.

(19) Ibeh, C. C. *Thermoplastic Materials*; 2011. https://doi.org/10.1201/b13623.

(20) *Bekum Industrial Machines*. https://www.bekum.com/en/blow-moulding-machines/2-industrial-machines/ (accessed 2025-04-29).

(21) *CustomPart.Net - Mold Cost Estimator*. https://www.custompartnet.com/ (accessed 2025-04-29).

(22) *Floating Raft*. https://hortamericas.com/?srsltid=AfmBOoqSkPBaC6wYJjNe9faE-iKWothUlEOZ0ZoxswDsW1mpLF49QNlI (accessed 2025-04-29).

# Appendix

A. Blow Ratio Calculation: MathCAD calculation of the blow ratio for the AquaBloom using material properties, part, and mold geometry. The blow ratio is then used to determine the parison thickness and shot size.

<u>Material Information (HDPE):</u>

Material Cost, $C_{HDPE} := 0.60 \frac{¤}{lb}$

Density, $\rho_{HDPE} := 0.0338 \frac{lb}{in^3}$

<u>Part Geometry (from CAD):</u>

Overall Length, $L := 33.000\ in$

Overall Width, $W := 21.588\ in$

Overall Depth, $Z := 4.25\ in$

Nominal Wall Thickness, $t_{final} := 0.125\ in$

Part Volume of Material, $V_{part} := 249.454\ in^3$

Volume Displaced, $V_{disp} := 2067.33\ in^3$

<u>Cavity Geometry (from CAD):</u>

A-Side Surface Area, $A_{sA} := 980.388\ in^2$

B-Side Surface Area, $A_{sB} := 1042.93\ in^2$

==============================================

<u>Parison Gemetry:</u>

Parison Circumference, $C_p := W \cdot 2$

Parison Diameter, $d_p := \frac{C_p}{\pi} = 13.743\ in$

Blow Ratio, $BR := \frac{(A_{sA} + A_{sB})}{C_p \cdot L} = 1.42$

Parison Thickness, $t_p := t_{final} \cdot BR = 0.178\ in$

Parison Cross-section Area, $A_p := \frac{\pi}{4} \left(d_p^{\ 2} - (d_p - 2 \cdot t_p)^2\right) = 7.565\ in^2$

Parison Volume per Part, $V_p := A_p \cdot (L + 1\ in) = 257.213\ in^3$

B. Cost Estimate: Calculation of the AquaBloom cost per part using previously determined material shot volume and tooling cost estimates. The annual production rate could also be varied to reduce the tooling cost per part. Note,"¤" is a symbol for universal currency, here representing USD.

Part Cost Calculation:

Tooling Cost, $TC := 32486$ ¤

Estimated Cycle Time, $t_{cycle} := 75.5\ sec$

Parts per Year, $Q := \dfrac{7200000\ sec}{75.5\ sec} \cdot 0.95 \cdot 0.97 = 87878$

Tooling Cost per Part, $C_t := \dfrac{TC}{Q} = 0.370$ ¤

Shot Volume, $V_{shot} := V_p = 257.213\ in^3$

Shot Weight, $W_{shot} := V_p \cdot \rho_{HDPE} = 8.694\ lb$

Material Cost per Part, $C_{shot} := C_{HDPE} \cdot W_{shot} = 5.216$ ¤

Total Part Cost, $C_{total} := C_{shot} + C_t = 5.586$ ¤

C. Structural Hand Calculation: Calculations made to validate the structural simulations conducted within Ansys.

Expected plant weight, $W_{plant} := 2\ lbf$

Simulated plant weight, $W_{sim} := W_{plant} \cdot 2 = 4\ lbf$

Total Load, $F := W_{sim} \cdot 20 = 80\ lbf$

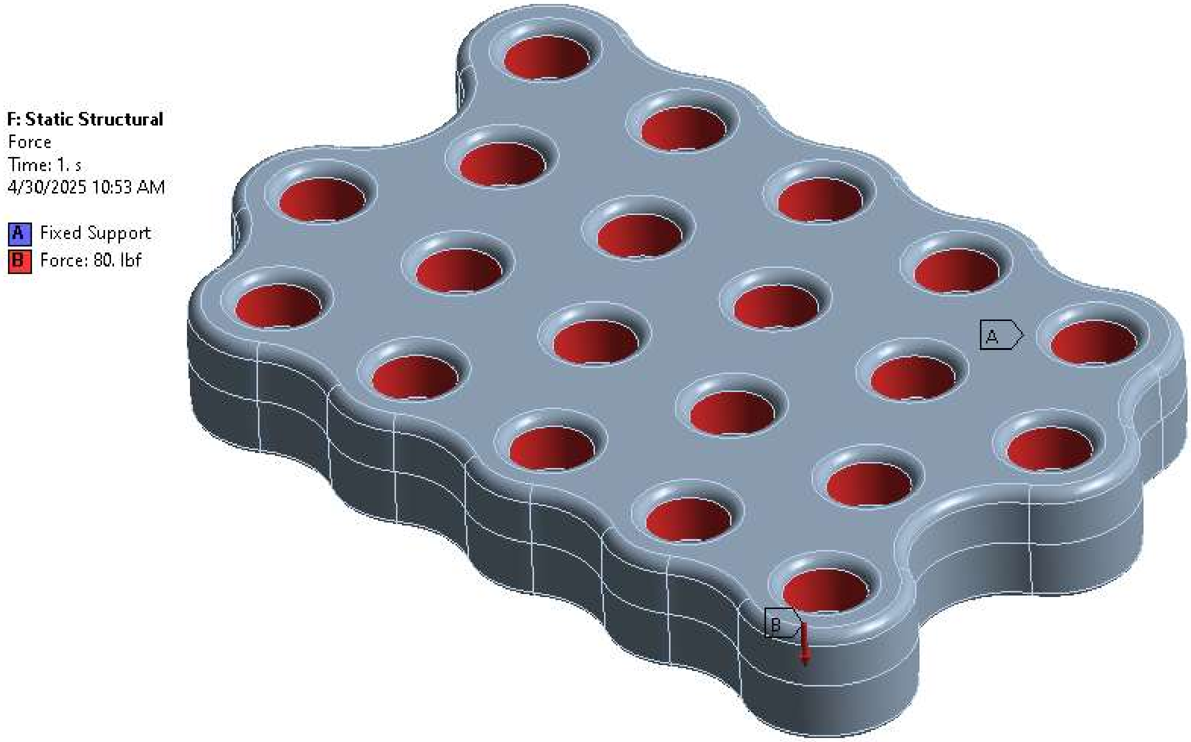
Contact area between part & ground, $A_C := 3.069\ in^2$

Resultant normal stress, $\sigma_R := \dfrac{F}{A_C} = 26.07\ psi$

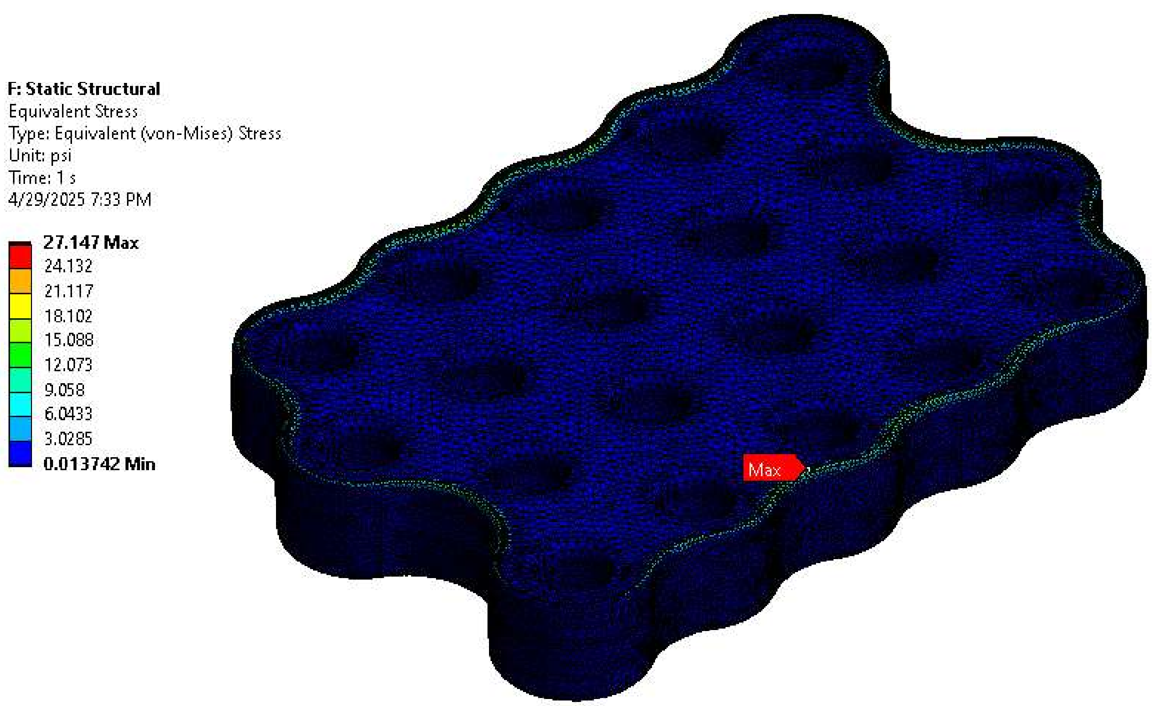
Maximum equivalent stress, $\sigma_{ansys} := 27.15\ psi$

Percent Difference, $\sigma_{PD} := \dfrac{2 \cdot \left|\sigma_R - \sigma_{ansys}\right|}{\sigma_R + \sigma_{ansys}} = 4.07\%$

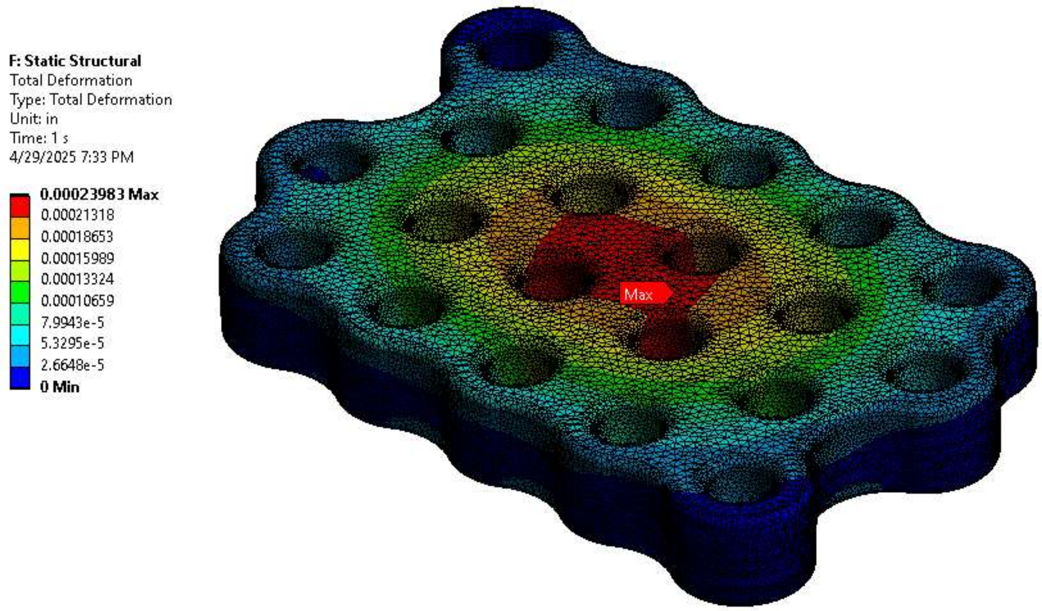
D. Constraint plot representing the boundary conditions the part underwent during simulation, highlighting the applied force and the fixed support on the part.




E. Equivalent Stress plot of the AquaBloom during double the expected loading, highlighting the max stress occurring at the point of contact between the product and the fixed support.



F. Total Deformation Plot of the AquaBloom during double the expected loading, indicating the product meets the specification's requirements.




G. Buoyancy verification calculations

Buoyancy Calculation:

*Gravity Constant*, $g := 386 \, \frac{in}{s^2}$

*Density of Water*, $\rho_{H2O} := 0.0338 \, \frac{lbm}{in^3}$

Buoyant Force, $F_B := \frac{\rho_{H2O}}{g} \cdot g \cdot V_{disp} = 69.876 \, lb$

Part Weight, $W_{part} := \rho_{HDPE} \cdot V_{part} = 8.432 \, lb$

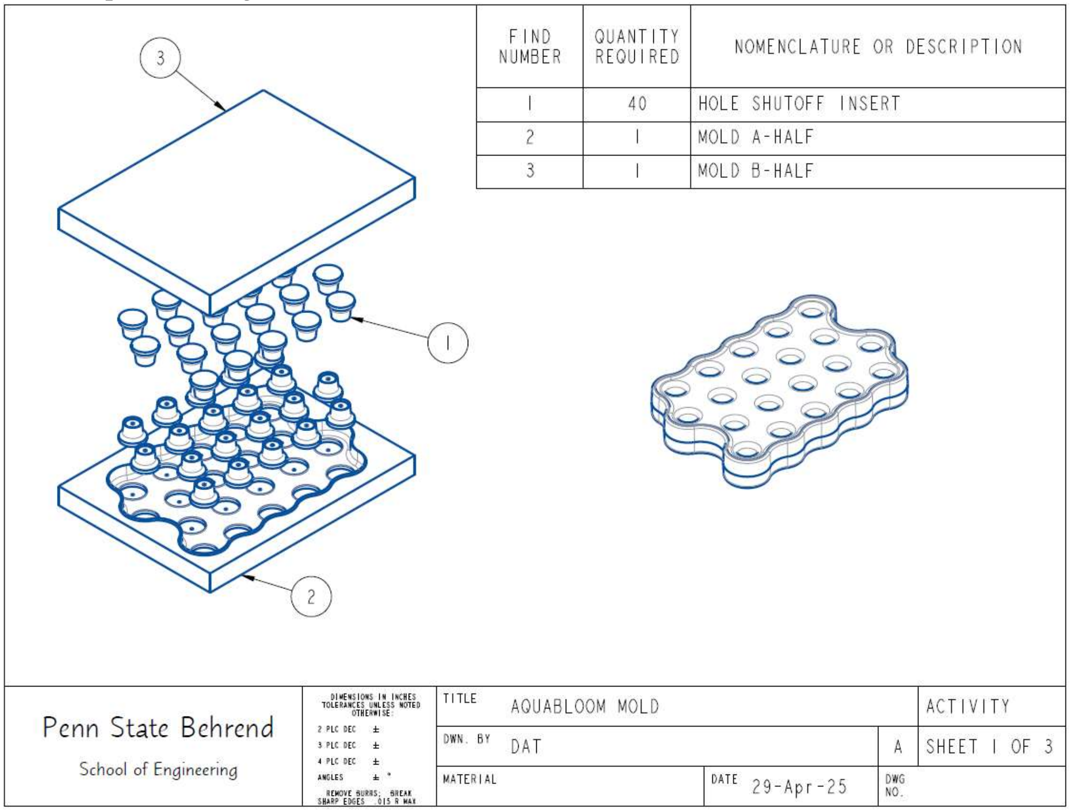
Loading Force, $F_{load} := 20 \cdot 2 \, lb = 40 \, lb$

Net Force, $F_{net} := F_B - W_{part} - F_{load} = 21.444 \, lb$

Submerged, $d_s := \frac{W_{part} + F_{load}}{F_B} \cdot Z = 2.946 \, in$

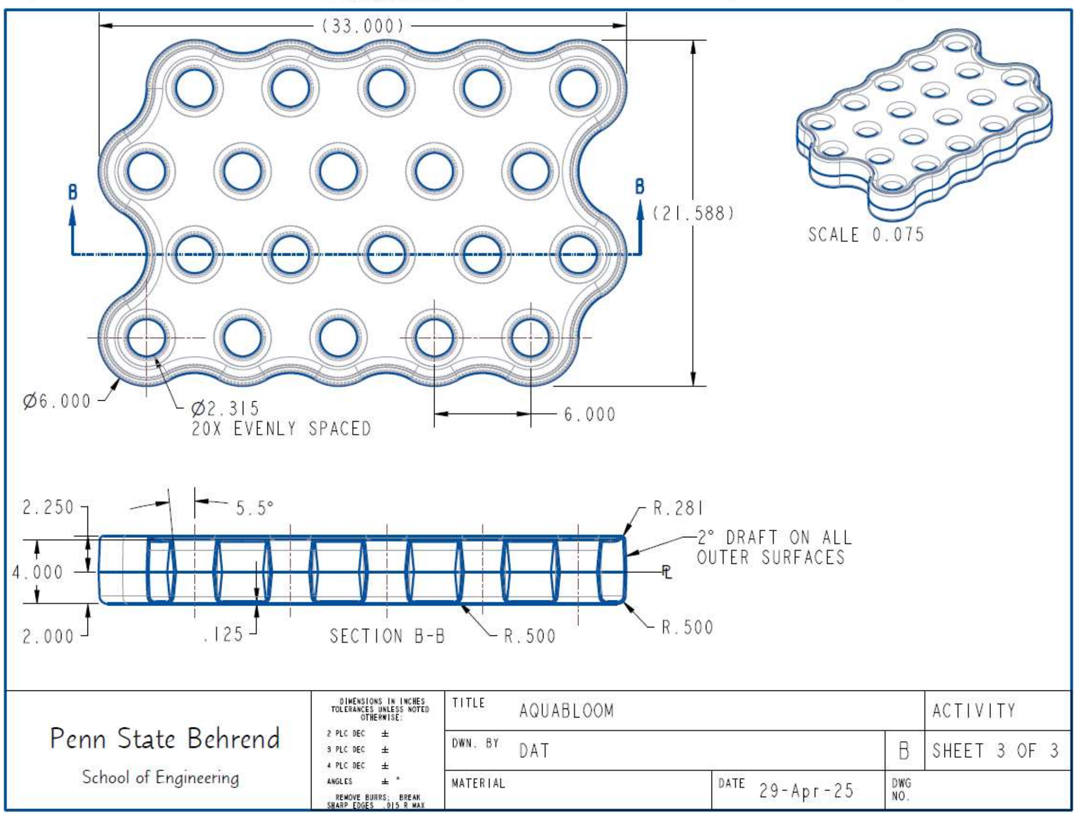
Floating, $d_f := Z - d_s = 1.304 \, in$

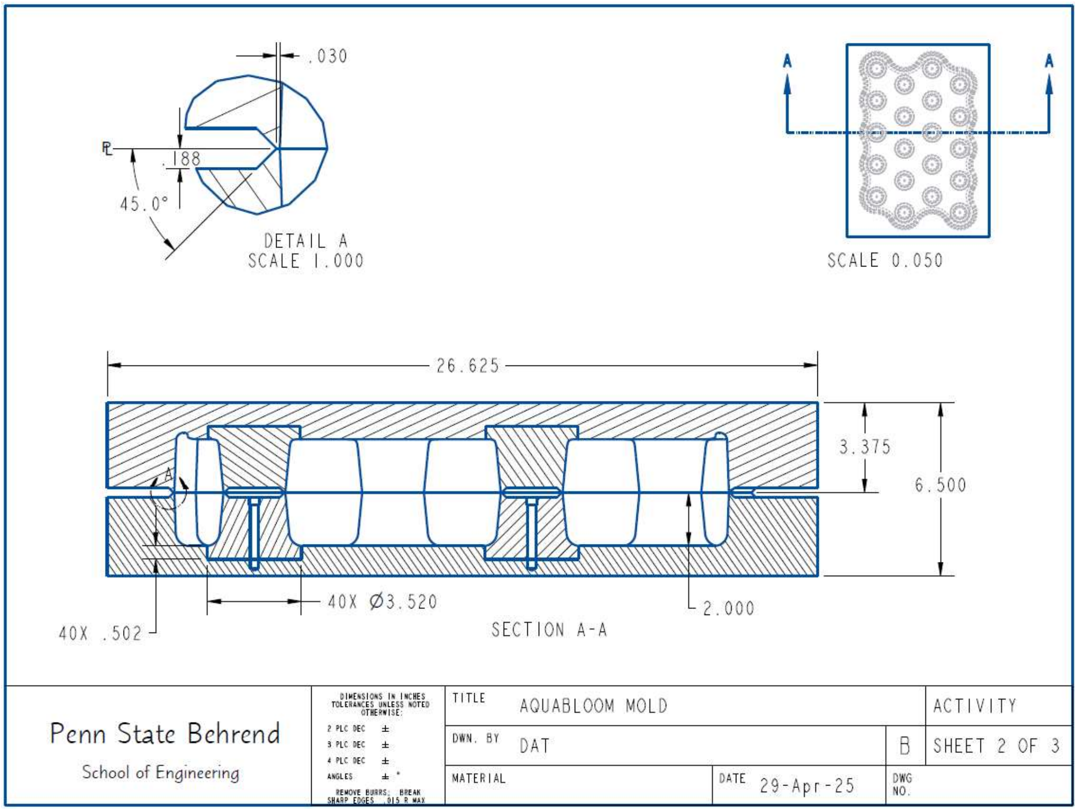
H. Mold and part drawings



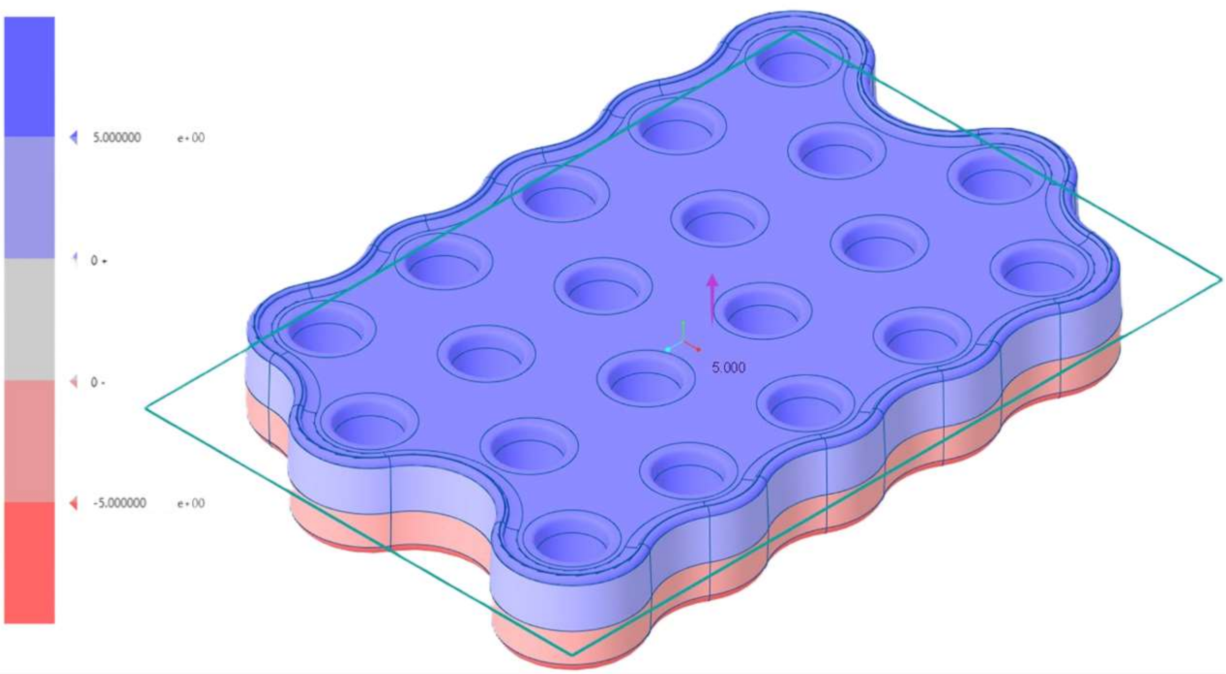
| FIND NUMBER | QUANTITY REQUIRED | NOMENCLATURE OR DESCRIPTION |
|---|---|---|
| 1 | 40 | HOLE SHUTOFF INSERT |
| 2 | 1 | MOLD A-HALF |
| 3 | 1 | MOLD B-HALF |



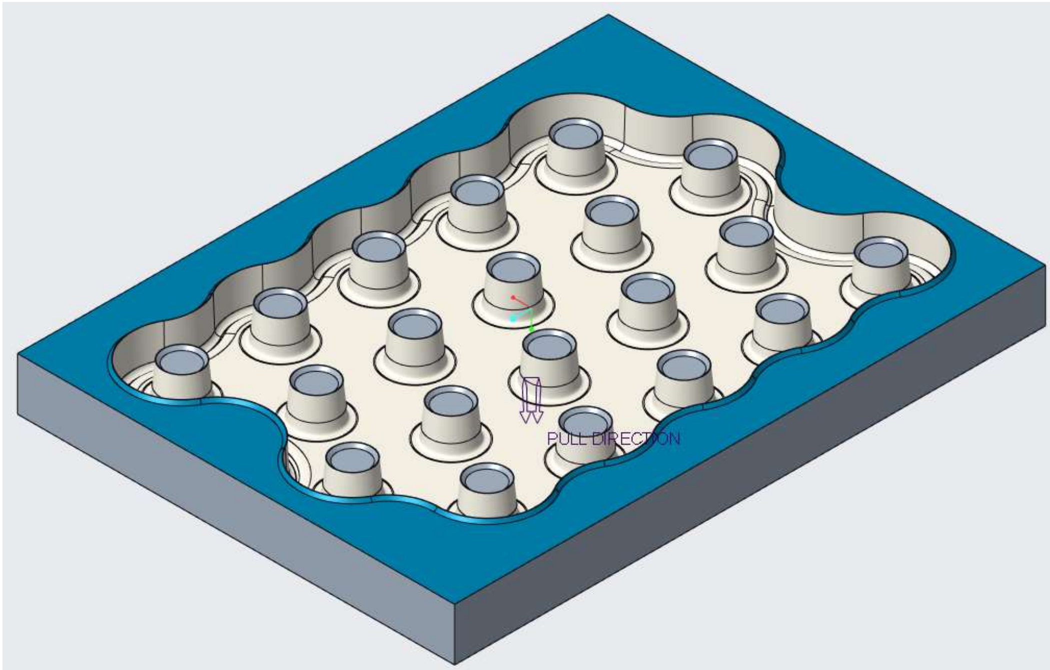


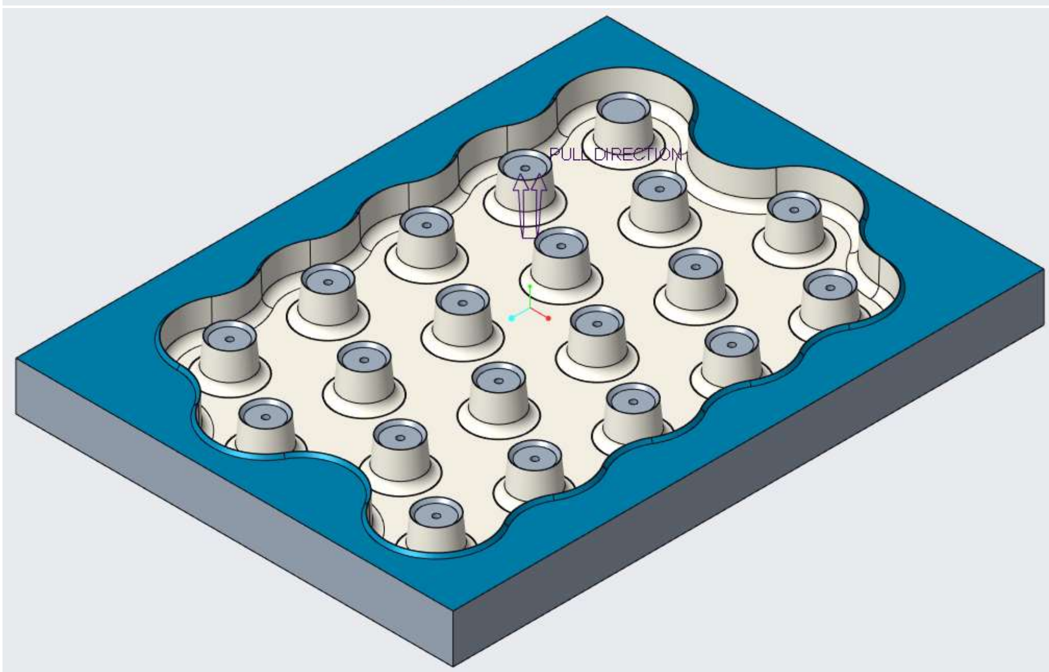



I. HydroBloom Draft Analysis



J. Mold A and B half from CAD.



K. High Density Polypropylene Material Datasheet

## Aclo Accucomp Polyethylene HD0200L High Density

**Categories:** Polymer; Thermoplastic; Polyethylene (PE); High Density (HDPE); High Density Polyethylene (HDPE), Injection Molded

**Material Notes:**

**Vendors:** No vendors are listed for this material. Please click here if you are a supplier and would like information on how to add your listing to this material.

| Physical Properties | Metric | English | Comments |
|---|---|---|---|
| Density | 0.950 g/cc | 0.0343 lb/in³ | ASTM D792 |
| Linear Mold Shrinkage | 0.026 cm/cm | 0.026 in/in | MD; ASTM D955 |
| Melt Flow | 0.50 g/10 min | 0.50 g/10 min | ASTM D1238 |

| Mechanical Properties | Metric | English | Comments |
|---|---|---|---|
| Hardness, Rockwell R | 33 | 33 | ASTM D785 |
| Tensile Strength at Break | 15.0 MPa | 2180 psi | ASTM D638 |
| Tensile Strength, Yield | 26.0 MPa | 3770 psi | ASTM D638 |
| Elongation at Break | 350 % | 350 % | ASTM D638 |
| Elongation at Yield | 44 % | 44 % | ASTM D638 |
| Tensile Modulus | 0.9501 GPa | 137.8 ksi | ASTM D638 |
| Flexural Strength | 21.0 MPa | 3050 psi | ASTM D790 |
| Flexural Modulus | 0.800 GPa | 116 ksi | ASTM D790 |
| Izod Impact, Notched | NB | NB | ASTM D256 |

| Thermal Properties | Metric | English | Comments |
|---|---|---|---|
| Deflection Temperature at 0.46 MPa (66 psi) | 62.2 °C | 144 °F | ASTM D648 |
| Deflection Temperature at 1.8 MPa (264 psi) | 42.8 °C | 109 °F | |

Some of the values displayed above may have been converted from their original units and/or rounded in order to display the information in a consistent format. Users requiring more precise data for scientific or engineering calculations can click on the property value to see the original value as well as raw conversions to equivalent units. We advise that you only use the original value or one of its raw conversions in your calculations to minimize rounding error. We also ask that you refer to MatWeb's terms of use regarding this information. Click here to view all the property values for this datasheet as they were originally entered into MatWeb.