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Commercial Dishwasher Design

New markets for rotational molding are being uncovered everyday as the versatility of the process continues to benefit manufacturers in ever more challenging applications. This is creating exciting new opportunities, which are typically developed by forward thinking designers and molders who are always pushing the boundaries of the process. An example of such a molding company is Solar Plastics, headed by President Chuck Carlsen which has successfully introduced the benefits of rotational molding to numerous companies in wide range of new markets. This dynamic business philosophy is the reason Solar Plastics has remained an industry leader.

Carlsen's peers recognize him as a progressive, market savvy individual who develops new opportunities by communicating design, processing expertise and cost competitiveness in slick presentations tailored to prospective customers. He frequently partners with outside design firms to introduce fresh ideas to companies who have been entrenched in the same production methods for decades. The synergy derived from innovative design concepts combined with proprietary technological capabilities enables Solar Plastics to penetrate untapped lucrative markets typically outside the mainstream of conventional rotational molders. The following case study provides an excellent example of how this marketing philosophy was applied to a revolutionary new design for a surprisingly conventional product, a commercial dishwasher.

Product Description

A few years ago I received a call from Chuck Carlsen engaging me to participate in the development of a rotationally molded commercial dishwasher as seen in Figure 1. Most commercial dishwashers are constructed from stainless steel. They are designed to be reliable and to withstand harsh environments, constant use, serious abuse, reliability and quick cycles of less than 2 minutes per run. Unlike consumer dishwashers, function overrides appearance. Efficient use of detergents, ease of cleaning and low water consumption are added requirements for a commercial dishwasher. These are some of the reasons stainless steel has been the unanimous choice of material for these products. However, despite their rugged design and construction, commercial dishwashers do experience chronic problems which require costly field maintenance repairs. Most premature failures are caused by the numerous parts and high labor content inherent in each unit as shown in Figure 2.

Design Objectives

The primary objective of the project was to design a dishwasher to reduce overall manufactured cost and improvements in appearance. Added functionality and improved reliability were also major goals for the project. Our first priority was to define the product requirements. These criteria were prioritized based on cost, risk and level of importance. This project was only developed to a concept level, which provided enough information to verify the feasibility of the design and associated costs. The remainder of this article will describe the design evolution during each phase of development.

Phase 1 – Information Gathering, Technical Feasibility Study & Product Specifications

The project was initiated with a research phase dedicated to accumulating and organizing information critical to the design of the product.

Figure 1

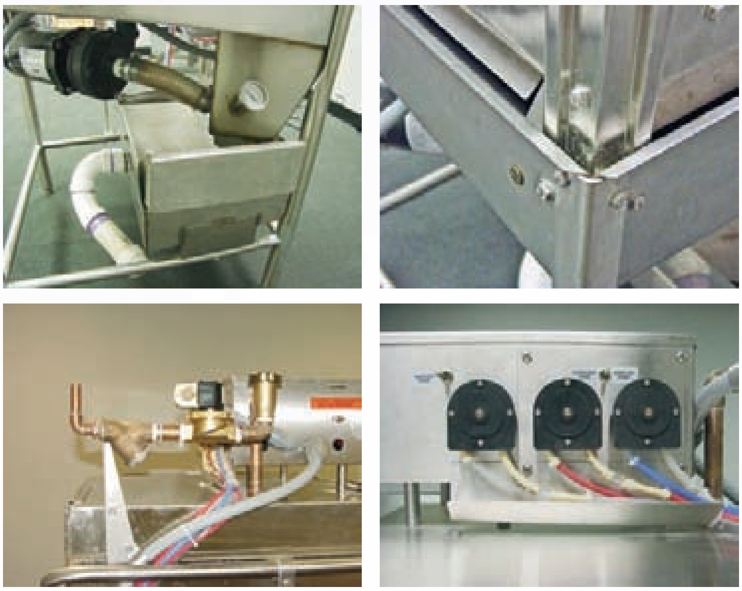

Figure 2

CAD Files, Documents and Drawings of All Purchased Parts

An assembly of all major components was modeled in a 3D CAD file which established a foundation for all subsequent design and development throughout the remainder of the project as shown in Figure 3 on page 20.

Exact Height and Specifications for Work Surfaces

Standard height ranges for the dish rack tables were also documented to set the optimum height and dimensions for the new dishwasher as shown in Figure 4 on page 20.

Codes and Industry Standards Including NSF

Codes and international standards specifically affecting the dishwasher were also documented.

Installation Procedure

The installation procedure was meticulously documented with videos, photographs and comments from installers. This information enabled us to design the optimum product configuration to minimize installation time.

Shipping and Handling

Shipping and handling of the dishwasher was documented to identify opportunities for improving packing, storage, inventory control, transportation and delivery.

Environments of Use

Photographs and floor plans of commercial kitchens were gathered to ensure that the new dishwasher design would be compliant with typical plumbing and special settings as shown in Figure 5 on page 20.

Product Use/ Human Factors

Videos recording the current dishwasher during the loading of various size plates, glasses and utensils were documented. Operation of doors, insertion and removal of dish racks as well as abuse were also recorded to optimize human factors design considerations.

Refurbishing

Our design team also documented the frequency and replacement cost associated for dishwasher components. This information was used to determine the break-even point for possibly higher costing components with improved reliability.

In addition to identifying overall product requirements, we also documented important engineering parameters affected by material and process selection. The differences between the traditionally used stainless steel and polyethylene required us to carefully examine many physical properties associated with the latter. A summary of those parameters is described below.

Temperature

Since the heat distortion temperature of polyethylene ranges from 135°F to 155°F, thermal tests were conducted to verify its performance in this application. The normal operating range for commercial washers ranged from 140°F to 170°F within a 90 second wash cycle. Solar Plastics agreed to conduct preliminary tests with rotationally molded door panels using a prototype mold. The test panels were used in place of the current stainless steel panels to verify performance as shown in Figure 6 on page 22.

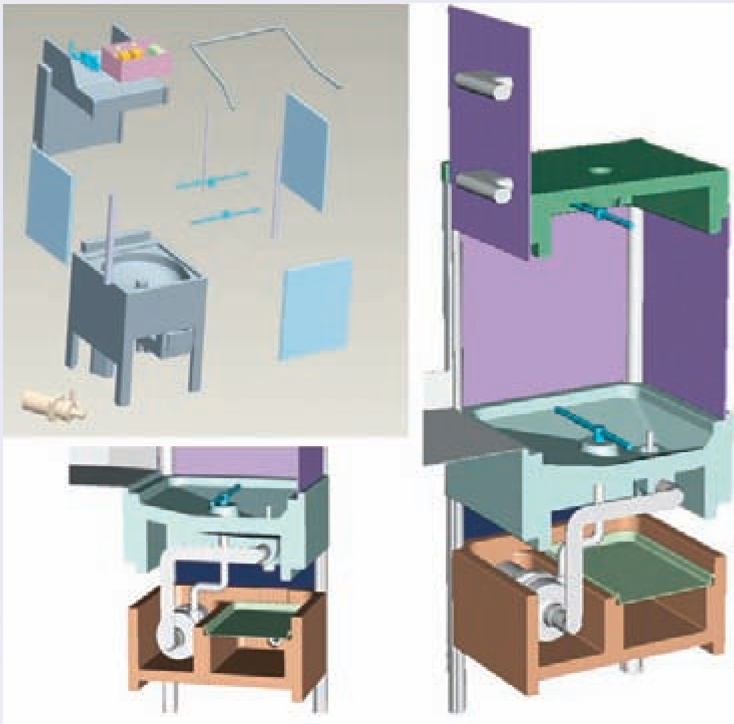

Figure 3

Figure 4

Figure 5

Creep

Long-term creep (permanent deformation under load) was also another critical physical property to examine. Since time, temperature and stress level affect creep rate, long time periods for testing were planned to attain accurate results. Areas of the washer subjected constant stress included the motor, door counter balance, washbasin and drain pan as shown in Figure 7 on page 22.

Environmental Stress Cracking

Environmental stress cracking or ESC is also a time dependent phenomenon which is affected by chemical concentration, temperature and stress. Susceptibility to ESC was determined with published data as well as testing of specific chemicals on samples of polyethylene.

Ultraviolet Light Stability

Since dishwashers are typically exposed to extensive amounts of UV light emitted from florescent lights as well as light passing through windows, UV stability was included as a material specification.

Flammability Rating

Flame retardants were also specified in the material properties to minimize fire risks.

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Rigidity

One of our foremost concerns was rigidity since the modulus of polyethylene is about .5% that of stainless steel. To offset this vast difference, we compensated with structural design features which optimized the design for polyethylene.

Impact Strength

Generous radii, avoidance of sharp notches and inclusion of contours were applied wherever possible to maximize impact strength.

Tolerances

Careful considerations for tolerances were conducted with Solar Plastics to assure that parts could reliably be molded within specifications. Critical parameters included flatness, part-to-part dimensions and twist.

Thermal Expansion

Differential thermal expansion was also investigated due to polyethylene's relatively high coefficient of thermal expansion. Thermal expansion would have contributed toward warpage and interference between closely toleranced parts causing binding.

During this first phase, our design team also investigated the preliminary economic feasibility of a rotationally molded commercial dishwasher based on a true overall product life cost accounting for the average NPV costs of the following:

Figure 6

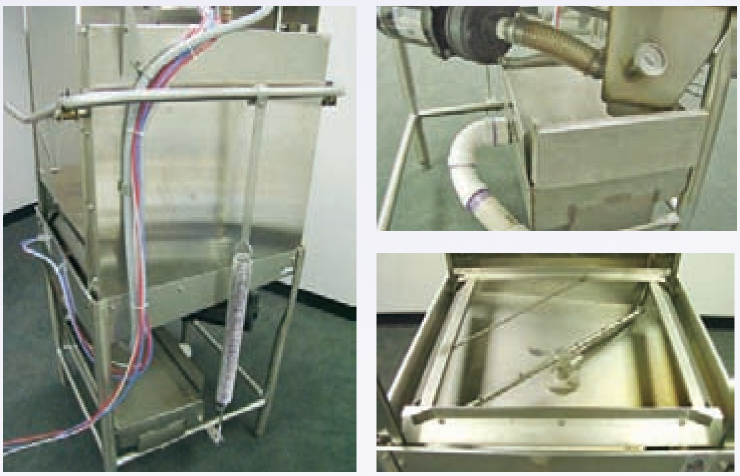

Figure 7

- Basic costs including materials and labor to assemble.
- Amortization of initial investment including development, testing and tooling. This cost will be a function of units manufactured in a given period of time based on NPV.
- Installation and removal costs.
- Shipping costs for initial installation and removal.
- Service and maintenance costs including parts and labor.
- Refurbishing costs.

This information was compiled in a product specification report which was referenced for the remainder of the design project.

Phase 2 – Concept Development

Phase 2 was dedicated to developing viable concepts for the dishwasher based on the specifications defined in Phase 1. This phase included the following tasks:

- Assembly of all major components of the dishwasher in a 3D CAD file which was used as the basis for the overall structural design.
- Alternative design possibilities and various based on alternative

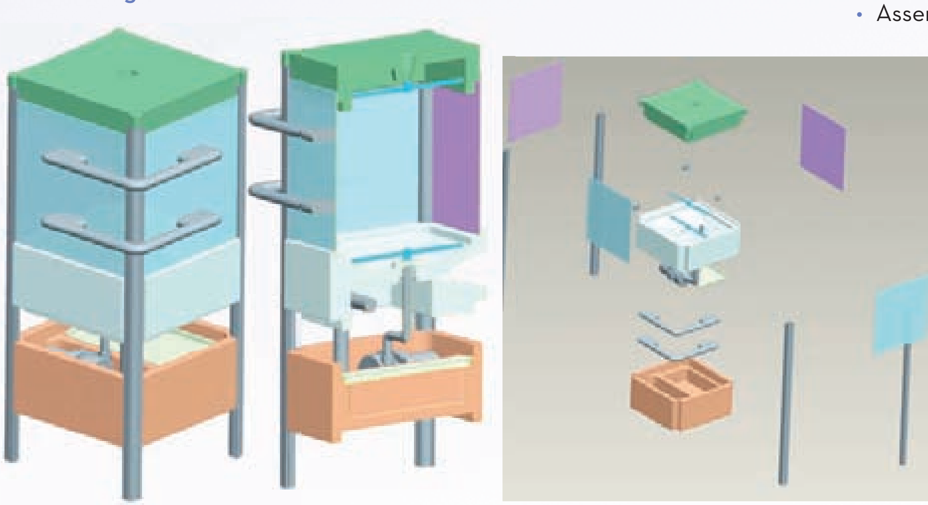

Figure 8

manufacturing methods were explored.

- Evaluation of each concept based on overall design, product specifications, investments, costs and risks.
- Development of a viable design and prototype to verify the concept.

Our design team developed numerous design options based on a wide range of ideas, combination of materials and processing methods. In addition to satisfying the practical product requirements, we were also searching for a design that could provide our client with a new image which reinforced their well-established brand identity. Product branding is conveyed with a readily identifiable overall appearance as well as details pertaining to surface contours, handles, graphics and colors.

Below are a few examples of the many concepts developed for the rotationally molded dishwasher and a brief description of each.

The concept illustrated in Figure 8 on page 22 depicts an evolutionary design based on the original sheet metal dishwasher. It consisted of four extruded aluminum corner posts which were bolted to three rotationally molded sections, a lower support platform, a middle washbasin and a top roof. The four walls surrounding the wash chamber would be fabricated in either stainless steel or plastic sheet. Internal plumbing was to be integrated within the rotationally molded walls whenever possible.

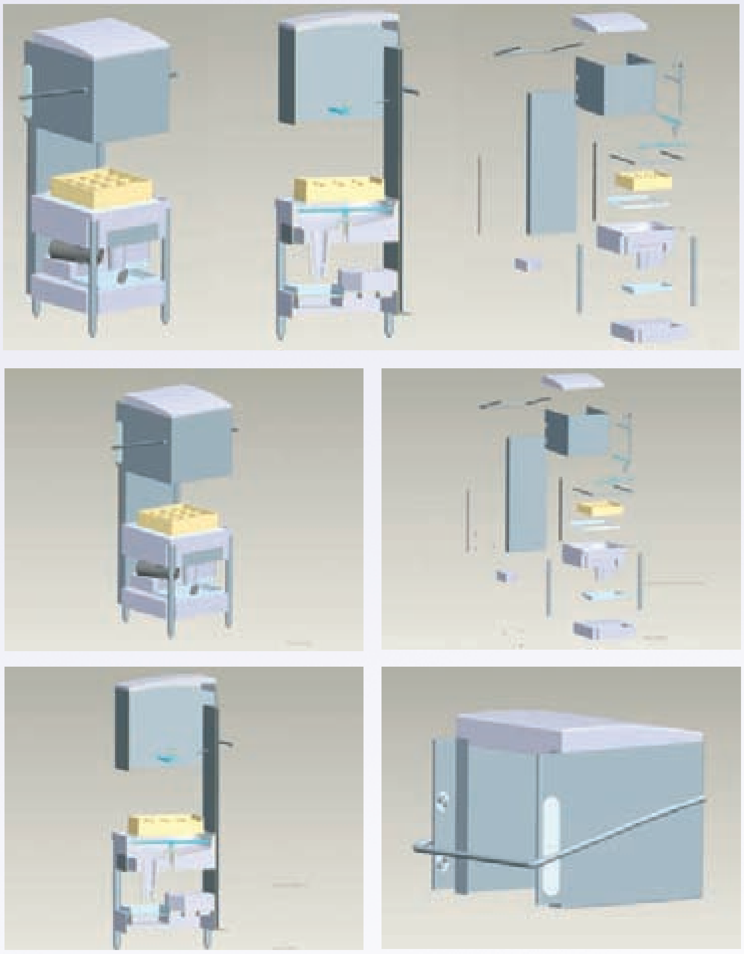

Figure 9

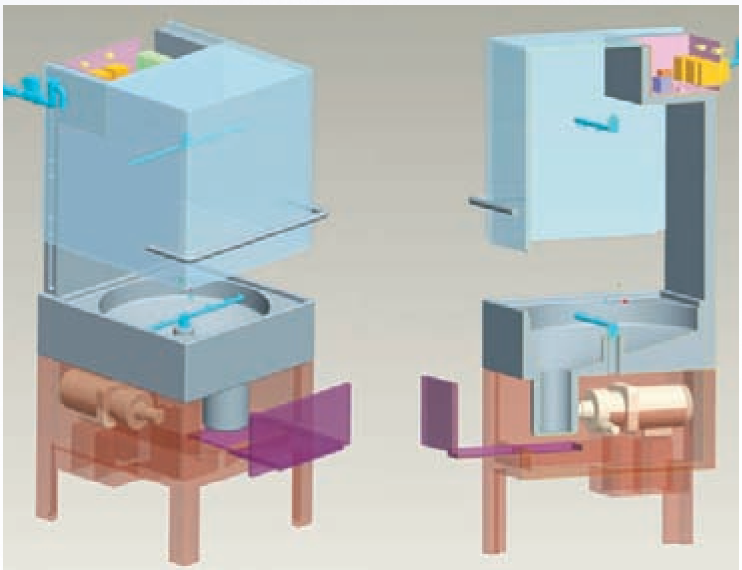

Figure 10

An alternative design shown in Figure 9 illustrates a concept based on a different principle of operation for the 3-sided sliding doors. Instead of moving three separate panels in precisely aligned tracks like the current stainless steel washer, this design proposed a single folded 3-sided stainless steel chamber. The one-piece chamber would be capped with an injection molded top cover and would include a set of rollers at the rear. The rollers would run in a pair of tracks within the rear stainless steel sheet metal wall. A rotationally molded washbasin and lower support platform consolidated numerous parts for the two most complicated assemblies of the dishwasher. Tubular legs and miscellaneous hardware completed the remainder of the assembly.

Figure 10 represented a design based on a greater consolidation of parts. It included a one-piece rotationally molded lower platform with integral legs, an upper wash basin/rear wall component and a one-piece, 3-walled sliding chamber door which would track along the rear wall. This concept was a major departure from the current sheet metal design with a minimum number of parts. Although the design was a bit too ambitious for rotational molding, it did provide many good ideas for the next iteration.

Figure 11 on page 24 represented a concept based on the culmination of all the work and preceding evolutionary improvements. This design maintained a balance of minimizing the number of parts with technological limitations of rotational molding. The rear wall was designed as a one-piece rotationally molded structure which would include a track for the sliding one-piece door assembly as well as providing rear legs. A one-piece multifunctional wash basin/lower platform included features for supporting the motor as well as many other components, including the front legs. The sliding one-piece door was designed for rotational molding. Thermal testing of the prototype verified this application to be viable.

This summary of concepts was selected from the countless design iterations to convey the thought process and development which took place during this project. A final design was ultimately derived and is detailed in the next phase.

Phase 3-Design Refinement Preliminary Prototype and Cost Analysis

The last concept developed in the previous phase was further refined in Phase 3. Tasks completed during this design phase paid closer attention to details pertaining to appearance, shipping, graphics, color, handle design and function. A partial functional prototype was also constructed to validate the design for a counterbalanced door mechanism based on a one-piece rotationally molded door. Refined cost estimates for tooling and parts were summarized based on CAD files of the completed assembly. A comparative cost of the newly proposed design and the current washer

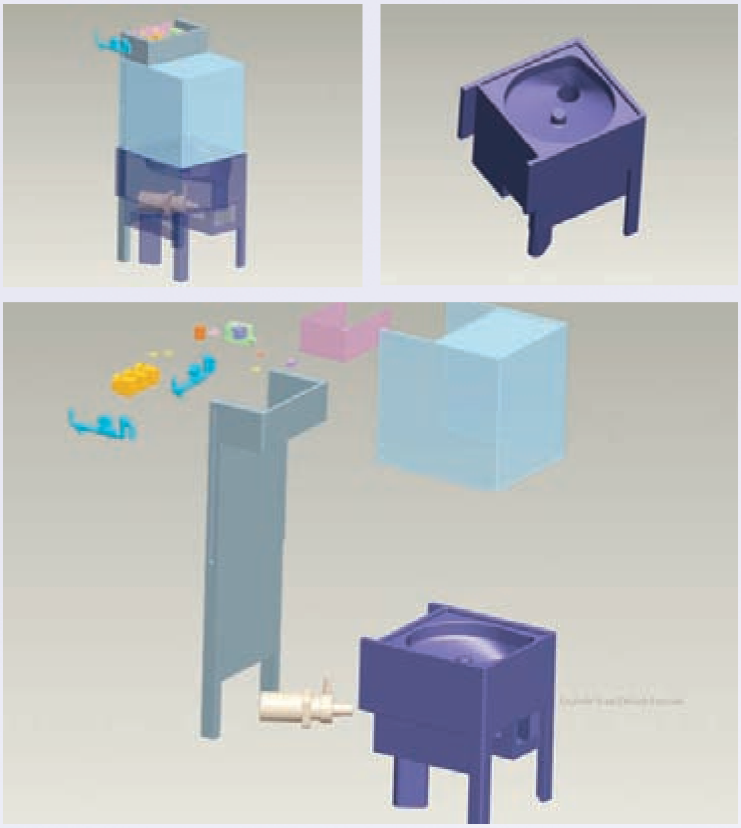

Figure 11

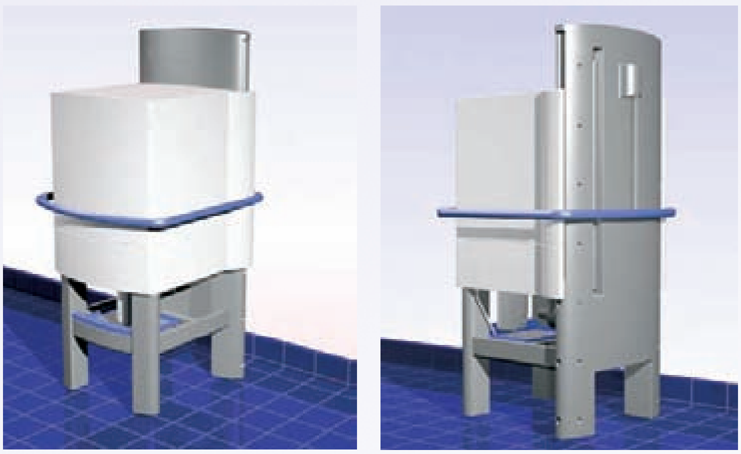

Figure 12

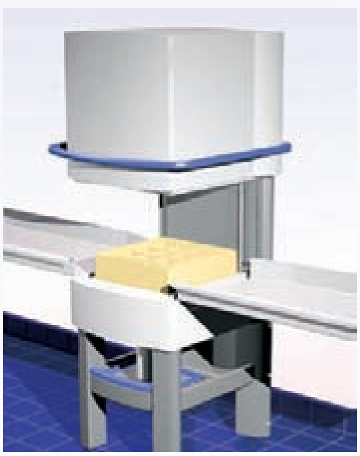

Figure 13

Figure 14

was finally consolidated in a detailed spreadsheet.

Review of the Final Design Concept

The final design proposal shown in Figure 12 was derived from a combination of ideas developed in the previous concepts. Major sections of the dishwasher were designed for rotational molding with the exception of a tubular metal handle wrapping around the sliding chamber door. Colors and graphics were specified to comply with corporate standards for enhanced product branding. Clean lines, smooth surfaces and minimal crevices yielded a dishwasher which could easily be sanitized. Rotational molding eliminated all of the sharp edges, brackets, hardware and springs in the previous stainless washer.

Access to the inner chamber was easily attained with the one-piece rotationally molded door which could conveniently be lifted as illustrated in Figure 13. Standard stainless steel work surfaces could easily be assembled in right angle or straight configurations in relation to the dishwasher providing maximum versatility for any commercial kitchen as shown in Figure 14.

Troughs for routing tie wrapped bundles of wires and tubing were integrated into the molded parts. These arteries provided a convenient means of distributing, protecting and isolating delicate electrical cables. The vertical trough in the rear wall provided a channel for electrical wires and tubing to be guided down the rear of the unit to the underside of the tub.

Parts were consolidated with molded in features which provided support for the motor, solenoids, containers and control box components as shown in Figure 15. Fewer parts equated to faster assembly, lower production costs and higher reliability.

The blue handle wrapping around the sliding one-piece door also provided additional rigidity and dimensional stability by limiting flexing. The counter weight sliding within the rear wall was attached to the handle.

Lap joints were molded into the door panels and washbasin to contain water as shown in Figure 16. Additional parts consolidation was achieved by integrating a roller assembly into each side of the chamber door/hood. Specification of roller bearings on either side of the door assembly friction while accommodating a wide tolerance range as shown in Figure 17. Since this design was a significant departure from the original sheet metal dishwasher, a prototype was fabricated to verify its viability.

A special prototype design was developed specifically to test the roller system. The pictures in Figure 18 illustrate CAD files for the simple low cost prototype

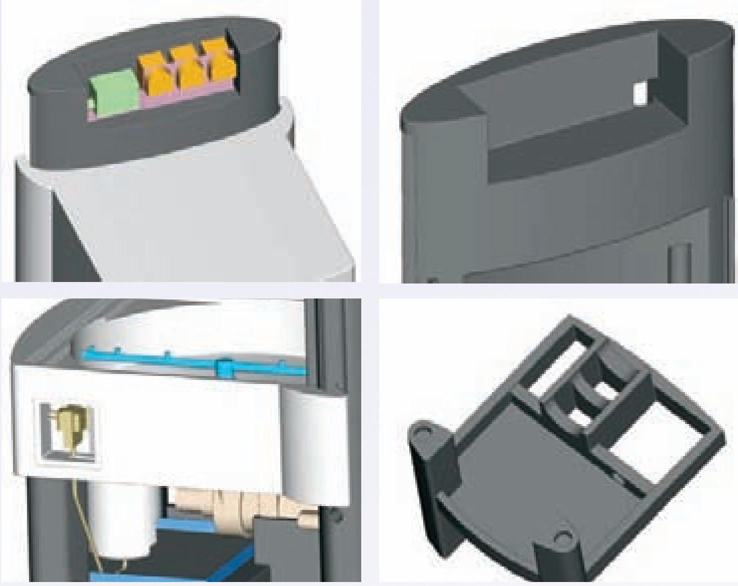

Figure 15

Figure 16

Figure 17

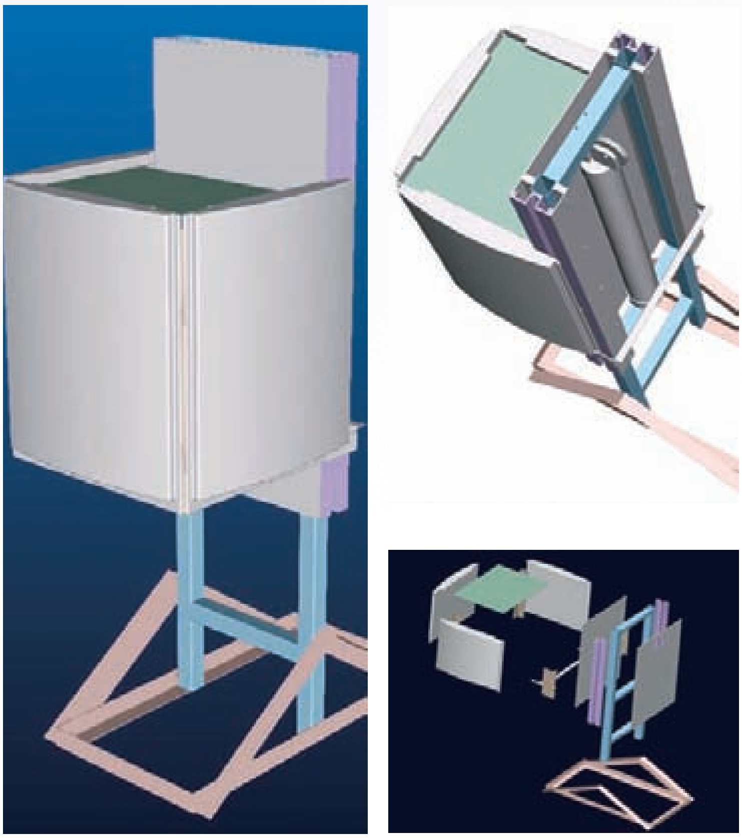

Figure 18

developed to quickly and easily evaluate the design. This prototype was constructed to determine maximum tolerance allowances for the roller system as well as its overall performance. Prototype costs and complexity were minimized limiting the design to a welded frame and fabricated plastic rear wall which simulated the rotationally molded part. The actual prototype shown in Figure 19 on page 26 was tested and verified to function as expected, thus establishing the necessary confidence in the proposed concept.

Final Cost Analysis and Part Count

At the conclusion of this project, our client was presented with a comprehensive presentation which included an analysis of the final concept based on the following information:

- **Review Tooling Budget. Part Cost, Lead Times:** An analysis of projected sales versus tooling budget, amortization and number of parts was completed for final design.
- **Review Servicing Requirements:** Design details pertaining to each sub-assembly were reviewed based on ease of access during field service. This information influenced how parts are designed, manufactured and assembled.
- **Review Manufacturing and Assembly Issues:** Parameters pertaining to assembly steps, preferences, testing

procedures and overall production methods were reviewed for specific sub assemblies.

Conclusion and Final Decision

After reviewing the comparative costs and trade-offs between the existing sheet metal versus the proposed rotationally molded design, our client decided to remain with the former. This decision was based on a number of reasons. One major factor that entered into the decision making process was China. Management compared the costs of manufacturing the rotationally molded unit domestically versus manufacturing the sheet metal unit in China. Another factor that influenced the final decision was the costing methods used to evaluate the comparative costs. Unfortunately, the cost analysis was based on a bill of materials cost, burdened with an arbitrary labor and overhead cost. These factors imposed a significant disadvantage to the rotationally molded washer. In addition to cost, marketing had reservations about the perception of a plastic dishwasher into a market that was so heavily accustomed to stainless steel. Unlike the consumer market, commercial institutions are very traditional and slow to accepting change.

It is the author's opinion that the final design satisfied all of the original design objectives, especially lowering cost. Unfortunately, the cost analysis did not account for many of the typically overlooked costs such as reliability, labor, shipping, assembly and service. In addition, the question of customer acceptance for a plastic commercial dishwasher was not adequately addressed. Stainless steel details could have been added to the proposed design to lower the barrier of potential customer resistance to new materials. Since this design project demonstrated so many positive benefits of rotational molding for a very demanding application, it may provide an inspiration for others to find new markets for this versatile process.

Figure 19