Pevco TEC-6™ Carrier

A Design Case Study

By: Mark MacLean-Blevins

Overview:

As a designer and product development consultant, I am called upon to create and provide solutions to problems, both real and perceived, in many different functional arenas. More specifically, as a plastics design specialist, I am often called upon to provide solutions that will be produced in a plastic material or process. The following project case study is the story of one such solution.

My firm, MacLean-Blevins & Associates (M-B&A) was engaged by our client Pevco, a leader in pneumatic tube systems, to assist in the design and development of a new improved carrier assembly for use in pneumatic tube delivery systems; more specifically, for use in pneumatic tube systems made for healthcare institutions such as hospitals. This carrier is essentially a large scale version of the tube carrier used at most every drive-in bank teller window, except instead of shuttling deposits and cash, these larger scale carriers deliver pharmaceuticals, patient specimens for pathology, blood from the blood bank to the operating room, and other time critical and time sensitive medical supplies. Hence, the security of the payload is critical to patient care, and perhaps to sustaining life in emergency situations.

A primary specification for the new carrier was that it must be able to function in pre-existing tube system infrastructures and send/receive stations already installed throughout hospitals and healthcare institutions. A second primary specification defined that the new carrier needed to be superior to the existing available carrier assemblies from a user perspective. The carrier needed to be designed for easier handling and intuitive use by healthcare workers.

Working closely with our client, we sorted through several design alternatives and were able to creatively focus the best features of each down to a single best concept. This concept was then fully designed and developed into final form and validated through several iterations of prototypes, both visual and functional. We selected possible materials and our choices were reviewed by material suppliers and processors for application suitability for each part. Tooling estimates and piece part estimates were acquired from several sources. Estimates and tooling options were analyzed and reviewed with our client. After review and analysis of the options, and after some project negotiations with the top vendors, our client settled on a chosen vendor and the implementation phase of the project began. Initial and final tooling designs were reviewed prior to tool manufacture and the implementation timeline was agreed upon by each of the vendors. First trials, including tooling debug, processing debug, molded part debug, and assembly debug were performed by the selected molding and assembly vendor, with input, coordination, and review provided by M-B&A. The new carrier design is now in full production and has been accepted by our client's customer base with enthusiasm.

M-B&A Design Process:

- Research – study and understand the current state of the art and understand how users interact with the current art.

- Specify – prepare a clear and concise written specification to use as the guideline for the design effort and especially for testing and verification of the final part or assembly.
- Design – from the research, develop a design criterion to guide the design thinking and create as many functional solutions as possible for the given problem. Focus the ideas down, taking the best bits and features from each possible solution until one or two primary best concepts emerge. Develop the best concept into a final form design and review with the client for suitability, form and overall aesthetics.
- Select Processes and Materials – understanding the design criteria and the application, generate a short list of possible materials and processes for each part to be used – then evaluate each against the primary specifications and/or client goals for the final end product.
- Gather Consensus & Estimates – review the design of each part and the material/process selection for each part with potential tooling suppliers, potential molding service suppliers and potential material suppliers to gather feedback and preliminary estimates.
- Verify – prototypes are fabricated to allow looks-like and feels-like observations as well as functional testing and evaluation.
- Implement – data files and part specification drawings, including specifications for critical dimensions, critical draft locations, color and surface finish information, and other part or mold specific specifications are conveyed to the vendor(s).
- Coordinate – tooling layouts are reviewed from a part function and aesthetics perspective (location of gates, ejector pin marks, witness line, knit lines, etc.). First mold trials and first piece inspection reports are reviewed and remedial actions are implemented. Once in specification and functional, the part and associated tooling are released for production. Assist QA in preparing in-process checks to insure part dimensional control and functional reliability.

- Qualify – pilot lots are built and tested to verify design objectives.
- Final Review – review each part, process and material against the desired outcomes identifying any areas prime for future improvement or spin off products.

For this particular design case study, we will focus on the design related portions of the process including research, design and materials.

Initial Research:

Looking at the two primary specifications required by our client, our first action was to perform a thorough review of the current state of the art. In studying the then current carrier assemblies, several things were apparent; the current carrier was robust and easy to manufacture, however its design did not provide the user-centric features desired. Additionally, reviewing end of life carriers taught us some of the failure modes encountered with these devices. Our second action was to study actual hospital personnel using these carriers for everyday tasks, observing the way the nurses and technicians held the carriers, the way they interacted when removing or inserting the payload, and the way they worked with the carriers when retrieving them or sending them from the send/receive stations. Through these user studies we learned that the client's desire for a more user-friendly carrier was indeed a needed innovation for these medical grade carriers.

The first primary specification mandated that the carrier fit and fly (yes, fly … carriers can move at velocities exceeding 15 MPH) within existing tube system infrastructure. Current tube system infrastructure is built around 6 inch diameter steel tubing with a 48 inch minimum bend radius for the system. However, there are some systems which actually use a 36 inch minimum bend radii elbows within the system. A carrier designed to fly in a 48 inch radii elbow will actually rub the inside of the tube when flying through a 36 inch radii elbow. Based on these facts, our design criteria specified that the new carrier would fly in a 36 inch minimum

bend radii system to avoid any potential interference in any existing tube system infrastructure. Additionally, the location of the carrier pneumatic seals relative to the end of the carrier were determined to be critical to the ability of the carrier to be launched from the send/receive station. The pneumatic seal must be positioned within the inlet of the tube system when the vacuum is applied, for proper lift and launch of the carrier, especially with a heavy payload (say a 2 liter IV bag).

The second primary specification required by our client called for the new carrier design to be superior from a user perspective; the carrier should be easier to hold and intuitive to use. Again, in reviewing the state of the art carriers several items were noted. First, the current art carrier was basically cylindrical through the mid-section; actually at a diameter of 5.36 inches it was difficult for all but the largest handed person to grasp without using two hands. Second, the latch mechanisms were easy to use but they were not intuitive and there was no easy indication to recognize if they were fully latched or not. During our user studies, we noted many operators talking or otherwise looking elsewhere while closing and latching the carriers, with absolutely no second look to insure the carriers were indeed latched prior to inserting the carrier in the station to send. This is an important observation because an unlatched carrier flying in a tube system will often become stuck or broken within the system, causing unwanted system downtime and perhaps degradation of the payload (the efficacy of many pharmaceuticals can be time dependent, as can the patient samples sent for pathological evaluation). Another possible risk is leakage, If the carrier is not latched properly the carrier housing seal will not be fully compressed, resulting in a potential leak condition should the payload contents leak. Further, the current art latch mechanisms were known to break within the tube system, sending small bits and pieces through the system which can cause damage to expensive blower units.

Figure 1 – CAD Renderings of our Design

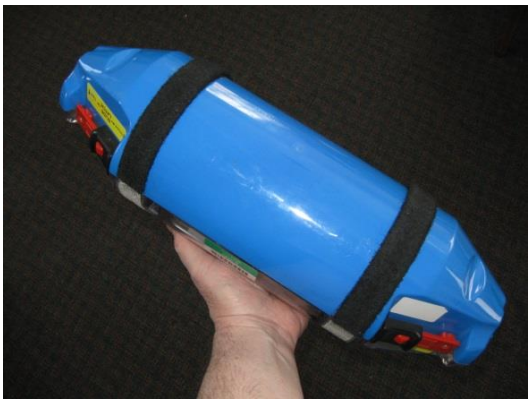
Design:

We began the design effort by identifying desired design criteria based upon the research described above. Idea and concept generation followed, looking at all of the possible ways to open and close a carrier, all of the different ways to latch and unlatch a carrier, all of the ways to assist a user in holding and using a carrier, and so on. Through several iterative design reviews with our client, we were able to take the best ideas generated and focus them down into a best concept for development.

This best concept stayed with a split on-axis carrier opening action, similar to the current art carriers. This opening action was intuitive and understood by the users and allowed a carrier housing part design that could perhaps use the same part for both halves of the housing. The pneumatic seals were designed and placed exactly in the correct position to provide the seal required for lift/launch from the station. In the mid-section of the housing, between the pneumatic seals, we shaped the housing surfaces to be slightly concave allowing the carrier to fly within the smaller 36 inch radii elbows as mentioned above. In addition, depressions to allow a grab surface were designed into this surface. The combination of the concave outer surface and the grip depressions provide the ergonomic geometry to allow a single-handed grab of the carrier by a smaller handed user. Three depressions per side were used and the depressions were shaped to allow a straight open/shut mold operation with plenty of draft on both

the core side and the cavity side. Features to provide a sealed payload compartment were designed into the carrier halves, a bead on one half and a groove to receive an elastomeric seal on the other.

Figure 2 – Carrier Comparisons



Old art Carrier Assembly

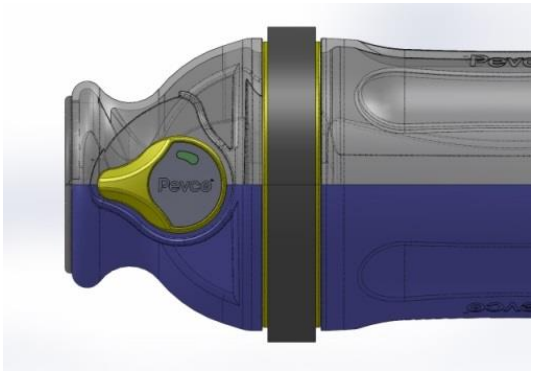
New TEC-6™ Carrier

The carrier housing ends were designed to be a graspable surface and to function as a base when the carrier is stood on end. This is a radical departure from the current art, in as much as the current art typically shows the ends as a streamlined bullet tip – something to convey an aerodynamic look and feel. The reality is, however, that extremely little air actually flows past the device when it is traveling through the tube system; rather, the carrier works as a plug to be pushed or pulled by the pressure difference existing on either end of the carrier within the tube system. Hence, we elected to use the carrier ends for an ergonomic grip and for a stable base when the unit is stood on end.

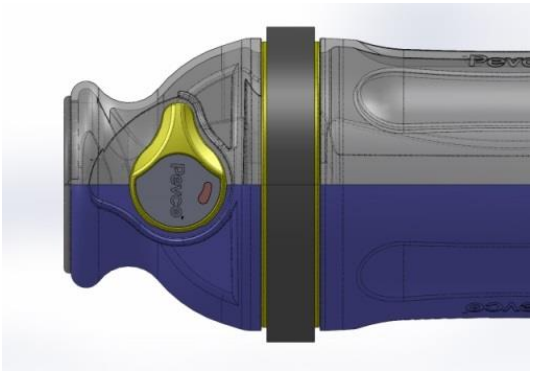
It was desired to provide a new, more intuitive latching system, possibly with some feedback to the user indicating the carrier was suitably latched and ready to send through the tube system. Our design took the form of a rotary latch on each end of the carrier, operable by the user's thumbs when the carrier was held by the end grab feature at either end of the carrier. This rotary latch mechanism was recessed into the carrier below the normal surface profile as a means of protecting the latch during flight within the tube system. The latch

rotated 90 degrees on a boss, molded into the carrier housing, with a corresponding latch strike also molded into the carrier housing (at the opposite end). A single screw fastener captured the latch to securely retain it to the carrier housing and a polycarbonate graphic overlay was placed over the latch face to hide the screw. The latch design incorporated a lever handle extension from the circular portion of the latch. This lever extension was shaped for easy thumb actuation in both rotary directions and the lever acts as a visual indication of the latch condition. When the lever extension is in line with the carrier axis, the unit is latched and ready to send; alternatively, when the lever is perpendicular to the carrier axis the unit is unlatched and not ready to send. A spring loaded detent feature was added to the design to provide some tactile feedback at each end of the rotary latch stroke. In addition, a visible color indicator was incorporated within rotary latch design; showing a green indication if the unit is latched and ready to send and a red indication if the unit is unlatched and not ready to send.

Figure 3 – Latch Conditions



Latched – Ready to Send



Unlatched – NOT Ready to Send

Within the carrier ends, removable snap-in inserts were created to provide a resilient bumper surface for the carrier. These end bumpers were specified to be resilient enough to take the landing impact when the carrier arrives at a send/receive station, while remaining resistant to picking up dirt and dust when the carrier is stood on end. The end bumper inserts also allow the end use facility a means for color coding their carrier inventory; for example, the facility may

choose to use red inserts for the blood bank carriers, blue inserts for the pharmacy, green inserts for the pathology lab, etc. As with all design efforts, some are good and some are, well ….. not so good; this particular innovation proved to be a bad idea. The removable end bumpers proved to be a nuisance to the institutions, as many were removed by bored workers and lost or discarded. Hence, the new carrier assembly is currently under renovation to remove the end bumper features and the associated details on the housing parts.

The carrier hinge elements were designed to become the removable mounting surface for the pneumatic seals, sometimes called wear-bands or glide-bands. These glide-bands provide a low-friction cushion around the perimeter of the carrier to allow it to move within the tube system. In addition, these pneumatic seals or glide-bands act to seal the carrier within the tube, allowing the system controlled pressure differentials to motivate the carrier through tube system. The hinge assemblies provide an easy means for the secure attachment of the glide-bands and provide an easy means for rapid removal and replacement of these glide-bands. This new method for maintaining and replacing the glide-bands will result in increased efficiency (less down time) for the end-use healthcare facility.

Finally, an elastomeric seal element was designed to provide a water tight seal for the payload compartment. Transportation of patient fluids for pathological lab analysis is a common use for the carriers and a leak of any such fluid would contaminate the entire tube system, hence a properly sealed compartment is required. For this element we started with a foamed polyurethane cord, cut to length and bonded to from a large O-ring like seal. However, qualification testing showed that the foam cord was taking a compression set and failing after some limited use. Our design then turned to materials that might not suffer the compression set failure observed. We selected a custom extrusion of a low durometer proprietary silicone formulation. This low durometer formulation combined with a novel extruded profile geometry,

provided by the manufacturer, gave us the desired seal without the compression set problems encountered earlier.

Materials and Processes:

Previous carriers had been injection molded of polycarbonate resin for durability and clarity. During conceptual idea generation we looked at other materials and other processes including blow molding and thermoforming. We elected to stay with injection molding for economic and aesthetic reasons. The carrier housing halves on our design were specified to be injection molded from Tritan™*, a copolyester polymer from Eastman. The copolyester provides superior toughness, excellent clarity, both primary requirements for the parts. In addition, the copolyester carriers can be cleaned with common hospital sanitizers, unlike the polycarbonate carriers which required non-solvent based cleaners. The choice of the Tritan™* material provides one additional benefit that the current polycarbonate carriers do not, a BPA-free solution. Hospital staff members that use the carrier dozens of times per hour will no longer be subject to potential BPA exposure.

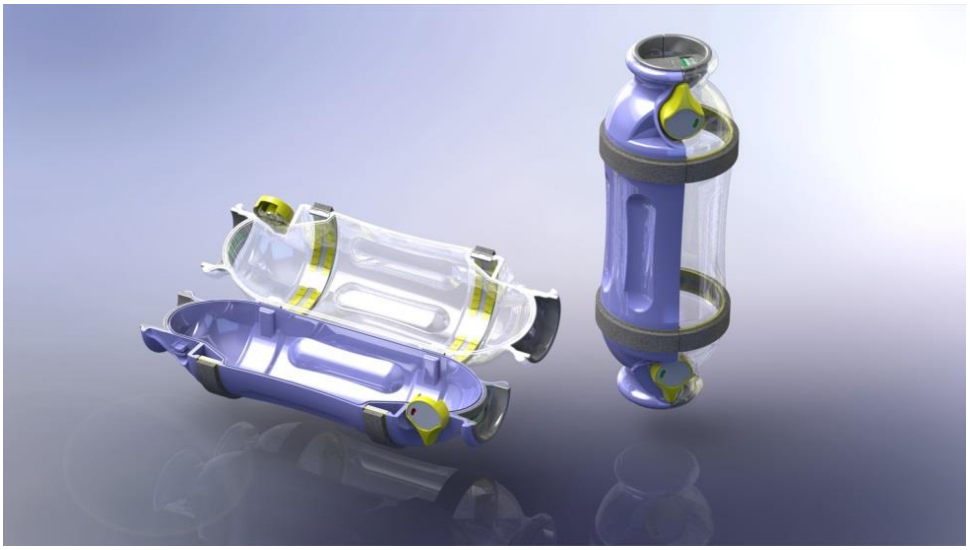
The latch mechanisms were injection molded from a super tough nylon resin providing a durable impact resistant part with a different surface hardness from the Tritan™* on which bearing surface the latch turns. For the detent feature a stainless steel compression spring was topped with an acetal resin injection molded nose piece. The acetal resin provided a durable and hard surface, with a low coefficient of friction, to snap into and out of the recess molded into the inner surface of the super tough nylon latch part.

The hinge assembly is fabricated from steel sheet, tempered for stiffness and durability, and then plated for corrosion resistance.

Design Verification:

Prototypes, developed from SLA materials and from machined CNC solid polycarbonate parts, were sourced and used for design verification, including ergonomic considerations and functional flight testing in the pneumatic tube system. During this functional testing we learned that the geometry of our carrier end grab feature needed to change slightly to assist the entry into the send/receive station. It turns out that the carriers are received into the station in a vertical orientation, come to a full stop, and then are released to slide into a horizontal resting position. This gravity slide movement was impeded by our larger end grab feature. Re-sizing our feature to reduce the grab diameter by less than 1/4 inch was all that was needed to insure proper operation in the send/receive stations.

Figure 4 – TEC-6 Final Product Rendering



Results:

The carrier design has been fully implemented into production and is shipping to institutions both nationally and around the globe. The parts are molded, fully assembled, tested and packaged under one roof and the product is 100% made in the USA. The carrier was a finalist in the SPI International Plastic Design Competition and was demonstrated on the show floor at NPE 2012 in

Orlando. The IPDC entry was covered by *Canadian Plastics* magazine, June 2012 issue, pages 12 & 13. In addition, the carrier was included in a feature article by Jon Evans (page 14) in the October 2013 issue of SPE's *Plastic Engineering* magazine. Two US patents have issued to protect the innovations created and implemented for this carrier.

References:

- http://pevco.com/products_tec-6.html
- http://www.eastman.com/Company/News_Center/2012/Pages/Pevco_Selects_Eastman_Tritan_Copolyester_for_Durable_TEC_6_Pneumatic_Tube_Carrier.aspx
- http://www.eastman.com/Literature_Center/S/Success61.pdf

* Tritan™ is a trademark of Eastman Chemical Company
TEC-6 is a trademark of Pevco Systems International, Inc.

About the author: Mark MacLean-Blevins, founder of M-B&A, is an independent product design consultant in practice since 1993 with forty patents issued for innovations developed as a result of his creative work. Mark and Kim MacLean-Blevins and their family of eight children (four still at home) live and work in Westminster, Maryland.
Visit www.maclean-blevins.com to learn more.

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