CLAYTON CORPORATION'S INNOVATION

IN THE AEROSOL ONE COMPONENT POLYURETHANE VALVE MARKET - BY RIC BERGER

The new Soft Touch Valve follows in the footsteps of a long tradition of innovative aerosol valve technology developed by Clayton Corporation for the aerosol one component moisture cure polyurethane foam market (OCF). The Soft Touch Valve, which is being introduced by Clayton Corporation in 2017, is the next in the line of aerosol valves designed to solve the latest challenges in the OCF market, the history of which is summarized below.

THE EARLY PROBLEMS AND THE CLAYTON SOLUTION

Clayton's contributions in the OCF valve market have been significant beginning in the early days of the OCF industry. The original attempts to dispense OCF were made through standard spring valves; however, those attempts were unsuccessful as the spring valve clogged (clogged valves described valves that would never open on the first try, or, would not open again after the first use). Early efforts to solve clogging in spring valves were attempted by inventors Peter M. Holleran (US Patent 4,667,855) and Frank Scotti (US Patent 4,429,814). In Scotti's patent he states, "This premature setting and clogging of the dispensing mechanism is believed to be due to the interaction of air and the thermosetting polymer in quite narrow valve passageways associated with the dispensing valve." These inventors' attempts at solving the clogging issue in a spring valves didn't solve the problem and accordingly they were never commercially successful.

The beginning of Clayton's involvement in the OCF market as explained to me was that through a chance meeting between Clayton and the initial fillers of OCF the fillers learned of Clayton's large diameter stem rubber valve technology. These valves were being used for dispensing viscous and foaming products such as whipped cream and aerosol cheese. When Clayton's valve was tested with polyurethane foam not only did the product dispensed properly initially it also dispensed again after 1st use. The clogging issue was solved and the OCF industry began utilizing the rubber valve technology.

When I began working for Clayton in 1989, it was quite common in the US market for a can of OCF to be returned to the store due to the user's inability to dispense product. There were multiple reasons for this problem, including improper mixing of the materials during production and loss of propellant however, the major reason was the valve would not toggle, it was stuck. We discovered the cause of the valve sticking by cutting opening the cans and finding that the foam had glued the valve shut from inside of the can. While this was a problem in the US market, fillers in Europe were not experiencing stuck valves.

When Dr. Joe Lott, Floyd French, Clyde Smothers and I began investigating the problem of stuck valves, the first question we asked was; Why in the US and not in Europe? We identified a couple of major differences between the US and European market:

1. The US market was, and still is, mainly a market where "do-it-yourselfers" (DIY users) purchase the product from hardware stores. When homeowners feel a cold draft in their house, they go to the hardware store and purchase a can of foam to block the hole. In Europe, the normal users at this time were professionals who used it regularly in construction.

2. In the US market the product sold in the DIY market was manufactured using hydrocarbon as a propellant while in the much smaller US professional market the product contained hydroflourocarbon propellants. In Europe, the product was filled using hydroflourocarbon propellants. The reason for the use of hydroflourocarbon propellants in the US professional market and in Europe was the desire to stay away from any flammability issues. DIY users in the US market were comfortable using flammable products in the home, such as hairsprays and other consumer products. This familiarity with flammable aerosols along with the fact that they would be using a small amount of foam at any given allowed US OCF fillers to use a flammable propellant. It was different on a construction site where multiple cans were used at a time.

The Clayton team theorized that in order for the valve to glue shut, the prepolymer in the can had to be in contact with the valve for extended periods of time. Lab testing proved out the theory that valve sticking occurred when the product was stored improperly (on its side or upside down). OCF cures by moisture and when a can is upside down or on its side, moisture migrating through the valve's rubber seal causes the prepolymer to cure, gluing the valve shut. We knew the can stayed upright in production but were not sure how it was stored in the hardware stores. As a result, we continued our investigation into the problem by checking can storage conditions in the hardware stores. What we found was that even though product on display was normally stored right side up, any remaining product in the carton was commonly stored on its side on the top shelf. As a result Clayton embarked on a program of educating proper storage which provide some relief but did not solve the issue.

DIY users typically purchase one or two cans at a time, if one didn't work they just took the defective can back to the hardware store where they received a replacement. The hardware stores would either return the defective cans back to the filler for credit or the store was provided a monthly allowance to cover defective cans. While this was a nuisance, it didn't have a major financial impact on the US OCF fillers.

As I mentioned, at the time, stuck valves were not a problem in Europe. It was believed that the lack of complaints was associated with the fact that the product was used by professionals who understood how to store the product. In the late 1990's European OCF fillers were required through regulations to stop using hydroflourocarbon propellants. At that time the market for OCF switched to hydrocarbon propellants after which time European fillers began to receive stuck valve complaints. When the professionals in Europe had problems, they didn't return one can like in the DIY market, they returned their entire shipment. This could amount to pallets of product being return to European OCF fillers at a time. Stuck valves quickly became a very expensive problem for the industry.

It was when Europe started experiencing stuck valves that Clayton realized hydrocarbon propellants where a link to stuck valves along with improper storage. To address the stuck valve problem, Clayton introduced its patented 900 Series PU foam valves to the market in 2004. This was the first rubber valve based technology to resist sticking for a period longer than the shelf life of the product. This technology allowed Clayton to offer the first and still only written warranty against sticking.

AN EVOLVING MARKET CREATES NEW PROBLEMS

The OCF industry has continued to evolve and new OCF formulas have been developed to; 1) act as adhesives, 2) work in colder and less humid conditions, 3) increase the amount of expansion (providing more volume of foam or yield, mega foams), 4) work as fire barriers, 5) cure faster and 6) incorporate alternate raw materials to reduce cost. In addition to the changing formulas and materials since 2004 the market has experienced new regulations and environmental concerns with respect to the product. These new formulas increased the OCF market but along with new regulations created new problems for the industry.

Another influence on the market also occurred; users have been changing their preferred method of applying the foam. They have been moving from using mainly products that are dispensed with an adapter and straw to products dispensed through a dispensing gun. As the demand for dispensing guns grew, so did the number of suppliers providing them. The increased number of dispensing gun suppliers compounded the fact that there are no standards for the fitment of the valve, gun collar and dispensing gun together.

As a leader and innovator in the PU Foam Valve market Clayton continually monitors changes in the OCF market. Market monitoring and analysis resulted in Clayton developing a list of new problems that required improvement to valves used on OCF. The problems identified are:

1. **Uncontrollable Foam Dispensing and Hard to Toggle Valves**
   In straw foam applications, two issues occur relating to the dispensing of foam; 1) Burst of foam(puffing) when the valve first opens causing voids to be overfilled which results in added time trimming excess foam and 2) the force required to toggle the valve is too hard resulting in hand fatigue.

2. **Valves may Leaking when a can of OCF is Attached to Dispensing Guns**
   When OCF gun foam cans are screwed onto the dispensing gun, foam would begin to leak at the interface. Fillers control the valve and gun collar they put on the can but they can't guarantee the end user will use an approved dispensing gun. As such, they may not know the conditions their product will encounter when attached to the end user's dispensing gun.

3. **Excessive Propellant Permeation**
   Clayton learned that OCF formulators were including a higher percentage of propellant in the can. In addition, they began using higher levels of DME in propellant mix. These changes increase the rate at which propellant permeates through the valve. High propellant permeation rates manifested itself into a couple of issues; 1) reduced product function over time and 2) hazard and flammability concerns in shipping when port authorities found hydrocarbon in the air of sealed containers.

4. **Spontaneous Foam Leaking**
   Months after cans of OCF have been produced OCF fillers receive complaints that cans have leaked a small amount of foam through the valve.

5. **Skin Formation in the Can Preventing Product Dispensing**
   OCF fillers receive complaints that cans of OCF do not dispense. When

returned cans are opened, they find a skin has formed on the surface of the prepolymer which blocks the product from coming out.

With changes the chemicals used and the amount of product filled in the OCF can came a new phenomenon, skinning. Skinning is when a hardened skin forms on top of the prepolymer in the can. When the surface of the prepolymer completely hardens over, the hardened skin prevents the product from being dispensed. While certain chemicals were found to play a major part in the problem, the valve was also being looked at as the major path through which moisture is able to enter into the can.

DIAGNOSIS OF THE NEW OCF PROBLEMS

With the list of problems in hand, Clayton's R&D team embarked on a project of innovation designed to develop the next generation of OCF valve technology. The development engineers were instructed to solve the new problems while at the same time, not reducing the valve's current performance in any area.

The first step of the process was to understand the cause and effect of the new problems on the valve. In other words, how were the valve's materials and design related to the specific problems? Through trial and error, lots of sweat and a little blood (cutting cans open can be a hazard) Clayton learned about the relationships between the valve's design and materials with respect to each of the new problems. Clayton's testing and analysis discovered the following about each problem:

1. **Uncontrollable Foam Dispensing and Hard to Toggle Valves**
   By measuring the valve's actuation force, as it moves from a closed to open position, Clayton learned that at the instant the valve opens, there is a drop in force. With the user applying a constant to increasing pressure on the dispensing adapter, the valve jumps open further at the instant the valve opens due to this drop in force. This results in a large/unexpected burst of foam to be dispensed before the user can make adjustments and gain control of how fast the foam comes out. This same test also allowed Clayton to measure the toggle force associated with opening the valve.

2. **Valves may Leaking when a can of OCF is Attached to Dispensing Guns**
   By evaluating cans of gun foam that leaked after being attached to a dispensing gun, Clayton learned two things, 1) the valve was being opened further than the valve's design allowed and 2) that in some cases the dimensions of the dispensing gun's receiving basket were such that it pinched the rubber seal of the valve tearing it in such a way that the stem and seal would be pushed back into the can. When this happens, the fit between the valve's rubber seal and metal mounting cup is destroyed resulting in product leaking.

3. **Excess Propellant Permeation**
   Clayton understood that different materials, which could be used to manufacture the rubber seal, provide different permeation rates. The problem is selecting a material that is; 1) resistant to hydrocarbon propellants, 2) resistant to effects from MDI and the other chemicals used in OCF formulas, 3) resistant to water moisture permeations and 4) work well at a wide range of temperatures.

   In this study not only did Clayton's design engineers incorporate different materials, they also worked with different shapes for the rubber seal. From testing different shapes it was learned that shape also played a part in the permeation rate.

4. **Spontaneous Foam Leaking**
   Whenever Clayton receives an OCF valve complaint, one step in our evaluation procedure is to cross section the rubber seal. If a can of OCF has been stored upside down, you will find in the cross section of the seal a hard shinny line. This line is where the prepolymer has migrated into the rubber from inside the can and met up with moisture permeating in from outside the can. What is interesting in the samples exhibiting a small leakage of foam is that when the seal is cross sectioned, the hard shinny line only shows up on one side of the cross section.

   With this information in hand, Clayton developed a test which entailed storing OCF cans on their side in a manner which submerged only half of the valve in the prepolymer. The other half of the valve is exposed to propellant. With this test Clayton was able to evaluate a valve's resistance to uneven swelling. As known, the different chemicals and propellants in OCF cause different swell rates in the rubber seal. The rubber seal's uneven swelling as a result of not being fully submerged in the prepolymer results in the valve tilting and opening slightly.

5. **Skin Formation in Can Preventing Product Dispensing**
   Since moisture is the curing agent for OCF, understanding the rate at which moisture permeates through a valve may help OCF manufacturers understand the skin formation phenomena. As such, Clayton has developed a new test to evaluate the amount of moisture that permeates through the valve.

CLAYTON DEVELOPS THE NEXT GENERATION PU VALVE TECHNOLOGY

Having a good understanding of the problems being faced in the OCF market and new ways to test new designs and materials, Clayton developed its new patented Soft Touch Valves, for both straw and gun foam applications. Lab test and initial field trials have shown:

1. **Soft Touch Valve has no Burst of Foam and is up to 77% easier to Toggle**
   The new Soft Touch Valve has vir-

tually no change in the force at the instant the valve opens unlike a competitor's valve (See Figure 1). This allows the user of a can of OCF with the Soft Touch Valve to maintain control of the amount of product dispensed allowing them to dispense a uniform bead of foam. In addition, by reducing the toggle force by up to 77% it is easier for the user to complete larger jobs.

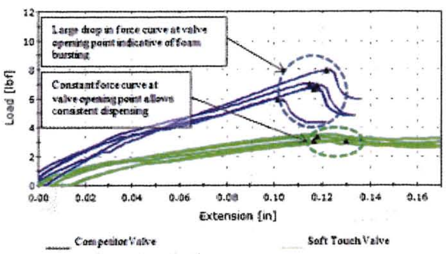


Figure 1 - Force Curve for OCF Valve Opening

2. Soft Touch Valve is More Resistant to Variations in Dispensing Guns

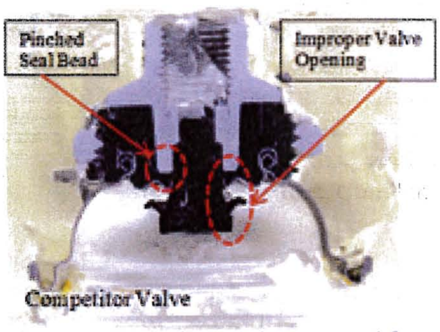


Figure 3 – Competitor's Valve Damaged from Improperly Dimensioned Dispensing Gun Basket

Unlike as shown with a competitor's gun valve (see Figure 3) when an improperly dimensioned dispensing gun basket is used with the new patented Soft Touch Valve design you can see that there is added space between the gun basket and rubber seal thus preventing the gun basket from pinching and damaging the portion of the valve's rubber seal (bead) that locks it into the valve's metal mounting cup (see Figure 4). You will also notice in the figures that improperly dimensioned basket can improperly open the valve. Thus the new Soft Touch Valve prevents the rubber seal from becoming damaged preventing foam leakage.

3. Soft Touch Valve Reduces Propellant Permeation

The Soft Touch Valve reduces propellant permeation by approximately 66% (see Figure 5). With more propellant remaining in the can, container shipments are safer, reduces hydrocarbon gas is reduced in storage areas and the product's characteristics over the shelf life of the can are better maintained.

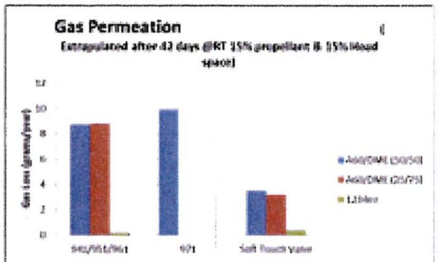


Figure 5 - Gas Permeation Results Clayton's 900 Series Valves vs. New Soft Touch Valve

4. Soft Touch Valve Stops Spontaneous Foam Leaking

While current valves on the market

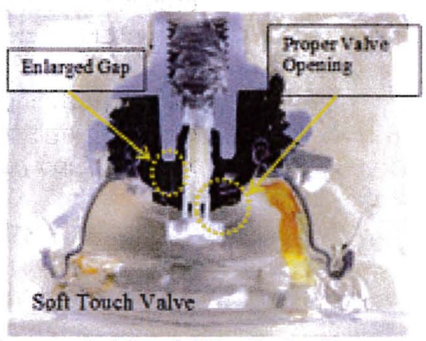
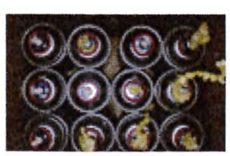


Figure 4 – Soft Touch Valve Resists Damage from Improperly Dimensioned Dispensing Gun Basket

will start leaking in as little as 3 to 6 weeks (see Figure 6) when the valve is half submerged in prepolymer and half exposed to propellant the Soft Touch Valve shows no signs of leaking after 1 year (see Figure 7).



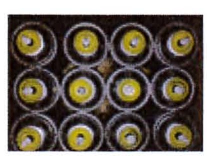


Figure 6 - Current market

Figure 7 - Soft Touch Valve valves leak beginning not leaking after 1-year at 3 weeks

5. Soft Touch Valve Impedes the Start of Skin Formation

Lab testing has shown that it takes twice as long for skin formation to begin in cans using the Soft Touch Valve versus currently market OCF valves. There appears to be a correlation between moisture vapor permeation and skinning results because valve in Figure 8 that have higher moisture vapor permeation skin quicker.

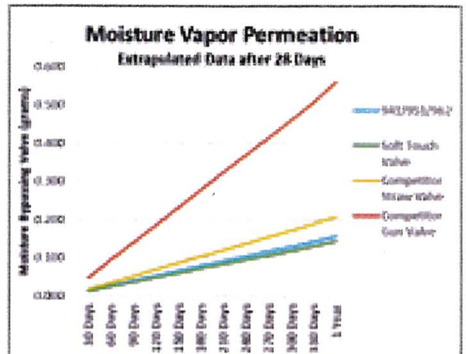


Figure 8 Moisture Vapor Permeation Test

As mentioned, it was also a requirement that when developing the new valve, the current features of Clayton's PU valve must be maintained at their current level or improved. In the case of the Soft Touch Valve for PU foam:

1. The valve is a drop in for production. It will run through the same feeding and gassing equipment at the OCF filler.

2. Even though the toggle force was reduced, there is no change in the vertical force required to open the valve. The result is no change in the gassing operation in production.

3. Fits with current gun collars and dispensing adapters

4. Includes the same patented technology as Clayton's 900 Series Valves and as such is provided with the only written industry warranty against sticking.

Clayton has been a continuing part of the history relating to aerosol one component moisture cure polyurethane foam. As history has shown, this industry continues to evolve. While we believe that the new Soft Touch Valve solves issues of today, Clayton is already working on tomorrow's innovations.