EZ-Tops World Wide, Inc

Dome Pressure Test

In collaboration with

Puget Sound Naval Shipyard STEM Outreach

&

Kitsap CREATE.org

August 2016

Contents

1.0 Background.

a. **Puget Sound Naval Shipyard (PSNS) in Bremerton**, Washington, is a large industrial organization established by the Navy in 1890 and currently employs over 15,000 craftsman, machinists, mechanics, engineers, managers, and Navy sailors and officers. Puget Sound Naval Shipyard's (PSNS) outreach program actively participates in various engineering and local community educational programs encompassing Science, Technology, Engineering, and Mathematics, (STEM). Local schools, colleges, enthusiasts groups, and military have expressed interest in underwater Remote Operational Vehicle (ROV) design with practical applications. To enhance the ROV effort and advanced build designs, two Domes were provided and shipped by EZ-Tops World Wide, Inc for testing at the request of Doyle Maleche, Kitsap CREATE.org founder and Lead investigator for PSNS outreach program.

b. **Kitsap Computers, Robotics, Electronics, Art & Technology Enthusiasts (CREATE).** Established in 2008, Kitsap CREATE, (formerly Kitsap Robotics) is an organization recognized by local and district schools, colleges, educators, and area businesses as a proven leader in technology and successful community outreach programs since. In November 2015, we became a state certified Non-Profit 501(c).3 and operate with a voluntary nine-member Board of Directors and structured leadership panel and management experts.

Kitsap County School districts, local colleges, hobbyists and parents, have demonstrated strong interests in Science, Technology, Engineering and Mathematics (STEM), with emphasis encompassing hands-on learning. Students did not have a resource outside of our education system to pursue this growing interest and most turned to the hobbyist community for continued support.

Kitsap CREATE bridged this gap by providing a consortium of professionals, engineers, military and Department of Defense employees, educators and hobbyists to collaborate with and mentor those who want to learn and expand their knowledge and proficiency, in Science Technology Engineering, Mathematics (STEM), Arts and Robotics. Through word-of-mouth, public and electronic media, the group's participants increased each month. New members were asked what they would like to take away from each meeting. This brought about new ideas and interests which expanded to art, mechanics, programming, gaming, and a *Maker*™ style model from which to accommodate a larger population and interests.

2.0 Pressure Chamber. Testing of the two 4" Domes was conducted using a manufactured and certified pressure chamber designed by Puget Sound Naval Shipyard (PSNS) in Bremerton, Washington. This pressure chamber was constructed using expended material, and manufactured by PSNS machinist students during their course of instruction in precision manufacturing. The pressure chamber conforms to exiting Navy approved standards and is capable of safe operating pressures up to 3,000psi. Figure 1 illustrates the construction and setup in conducting the dome pressure tests. The pressure vessel consists of a stainless steel cylinder milled from a solid 8 inch diameter stock ingot. A matching end flange with twelve K-monel fasteners provided full extreme pressure capability and integrity, and accommodates a calibrated pressure gage of up to 3,000psi. A hydrostatic pressure test system was employed to provide pressures up to 3,000 psi, however, only 1,800psi was required during this testing, or until dome compromise or failure

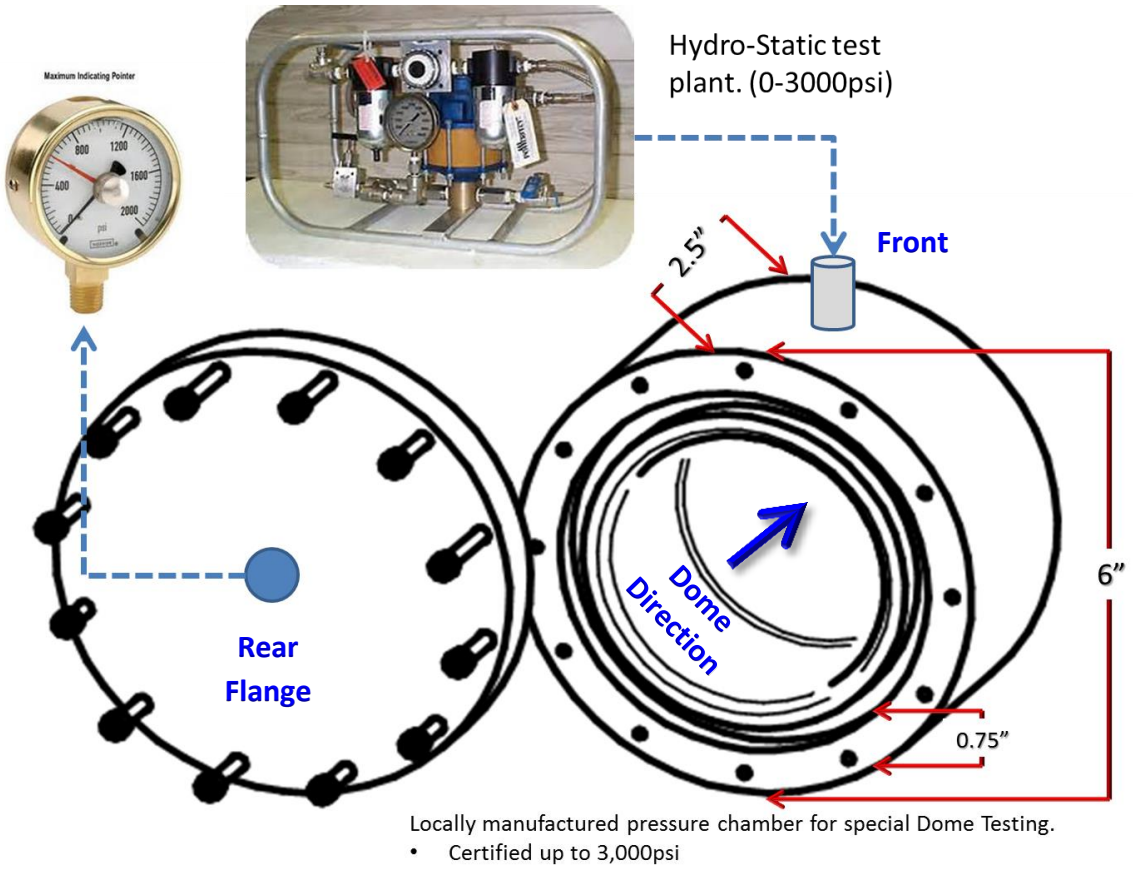

Figure 1. Manufactured Dome Test Chamber

3.0 Testing. Dome tests were conducted by the engineering and machinist students using similar methods and strict compliance required by the Navy. Test results varied based on material type.

These tests 'assumes':

- EZ-Tops' manufacturing processes incorporates consistent manufacturing standards and/or Quality Assurance (QA) processes associated with each mold and material type
- Material type is of consistent attribute and characteristic
- One-time test of each component (Dome) resulting in a single metric vice average or multiple tests of the same type. Non-repeating evaluation.
- Testing (pressure) began at atmospheric and increased by 20 psi and observed for 3 minutes until failure or compromise.
- Dome integrity was maintained at pressure (psi)/depth for 3 minutes while monitoring for water compromise.
- Ambient/water temperature is within 37˚ to 78˚ Fahrenheit

3.1 **Test 1: Lexan Dome:**

Dimensions: 4" diameter, 0.25 " thick, 2" Dome

Initial Observation: Some stress fractures or deformation (scarring) is noted around the inner circumference edge.

Failure: 800 psi (~1900 feet). Figure 2 Inversion. Testing continued until 1,800 psi to evaluate failure, however, the inversion point rested against the rear flange. It is surmised that pressure integrity would sustain due to the Lexan acting as a 'gasket' pressure boundary. Full failure was not tested beyond 1,800 psi.

Failure Type: Inversion. Due to the resilient characteristics of Lexan, the dome inverted and maintained integrity.

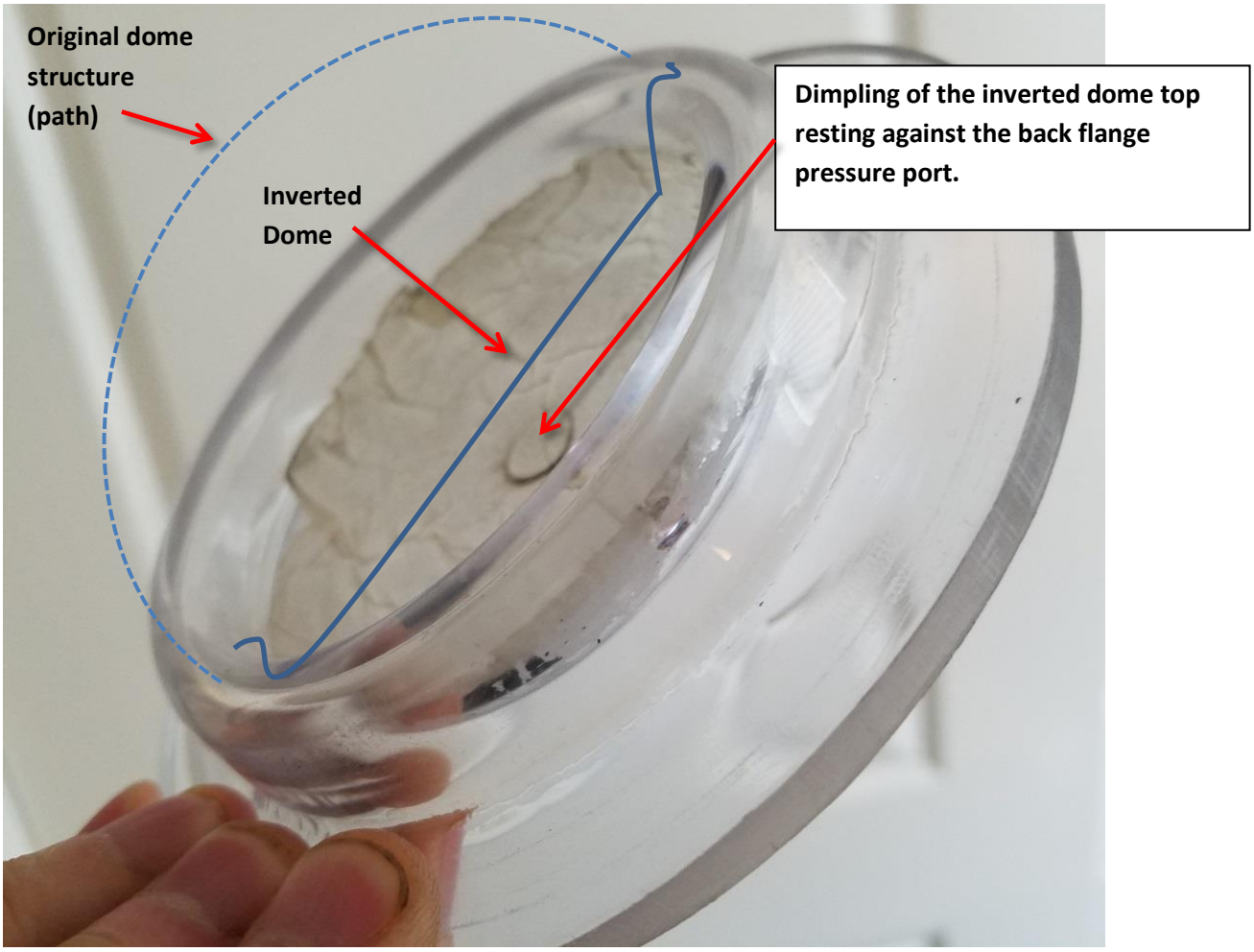

Figure 2. Lexan Dome Inversion

Potential cause: N/A

3.2 **Test 2: Plexiglas Dome:**

Dimensions: 4" diameter, 0.25 " thick, 2" Dome

Initial Observation: Some stress fractures or deformation (scarring) is noted around the inner circumference edge.

Failure: 600 psi (~1200 feet).

Failure Type: Stress fracture of the material around the bend radius.

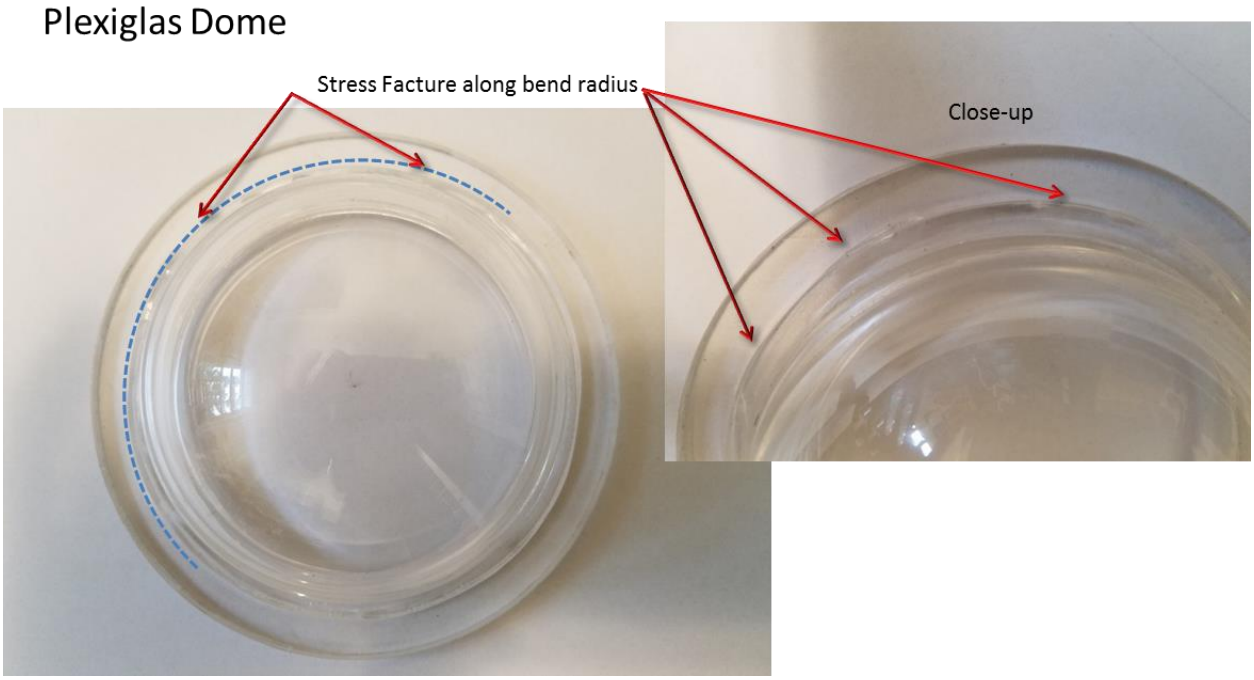

Figure 3. Plexiglas Stress Fracture

Potential cause: It appears that the failure occurred around the internal bend radius at the base and leading edge of the dome due to the scarring which induced weak points during manufacturing process. Dome compression caused stress points as the result of the outer flange maintaining a static state from the o-ring and chamber retaining ring. The outer dome flange was unable to follow or compensate with the upper dome movement or deformation during compression.

Actions/Fix:

Allow the Chamber flange to maintain adequate seal using less fastener torque. As Depth increases, sea pressure will proportionally provide a better seal method against the internal Dome flange o-ring against the chamber body.

4.0 Conclusion:

Dome results and metrics will be consistent if aligned with standards in the manufacturing process. Quality Control (QA) processes must be utilized to ensure compliance with test results stated in this report.

Based on single metric failure results, EZ-Tops' Domes are capable of sustaining a safe operating depth for the following Dome Type:

Lexan: 1200 feet (~600psi)

Plexiglas: 800 feet (~400psi)

Additional stress analysis over multiple manufacturing lot series of EZ-Tops Domes, may provide a more accurate and constant depth rating.

5.0 Recommendation: EZ-Tops' Domes are manufactured for various purposes as stated on their website http://eztopsworldwide.com/.

The STEM program along with Engineering disciplines should consider incorporation of EZ-Tops' Dome for underwater Remote Operational Vehicles (ROV) design. Kitsap CREATE and PSNS STEM Outreach will recommend and advocate EZ-Tops cost effective products for this purpose.