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Naval Surface Warfare Center
Panama City, Florida 32407-7001

TECHNICAL MEMORANDUM
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SEPTEMBER 1992

MK 15 FULL FACE MASK INHALATION VALVE RETAINER TESTS

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ADMINISTRATIVE INFORMATION

These series of tests were sponsored by Naval Sea Systems Command (NAVSEA), SEA 06Z, for certification of the new MK 15 Mod O full face mask check valves. The testing was completed in March 1992, and the valves were certified for issuance in April 1992. The Coastal Systems Station, Dahlgren Division, project number was 54002. The NAVSEA funding document number was N0002492WX79115; the program manager at SEA 06Z was LCDR Frank Lauria.

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The MK 15 Mod 0 (MK 15) Underwater Breathing Apparatus (UBA) is a closed-circuit rebreather that recirculates the diver's respiratory gas, removing carbon dioxide from the breathing gas and adding oxygen when needed. Replacement valve assemblies for the full face mask were procured, and, because of material and design changes, destructive and nondestructive testing were performed to satisfy certification requirements prior to issuance to fleet users. The strength of the adhesive used in the assemblies was found by compressing the assembly until the adhesive failed. The adhesive strength was more than adequate for the intended use of the valve assemblies; saltwater soaks had no effect on adhesive strength. Remaining valve assemblies were then pressurized to three times the maximum in-use operating pressure. All assemblies remained intact.

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INTRODUCTION

BACKGROUND

The MK 15 Mod 0 (MK 15) Underwater Breathing Apparatus (UBA) is a closed-circuit rebreather that recirculates the diver's respiratory gas. Carbon dioxide is removed from the breathing gas and, when needed, oxygen is added to maintain a preset oxygen partial pressure, independent of depth. The MK 15 provides for bubble-free untethered operations to a maximum depth of 150 feet of seawater. Duration of the MK 15 at this depth is from 2 to 6 hours, depending on water temperature.

The MK 15 UBA may be used with a mouthpiece or with a full face mask. In the full face mask configuration, one-way check valves are installed between the manifold block of the mask and the breathing hoses. One-way valves ensure the correct path of the breathing gas from the diver to the UBA, where carbon dioxide is removed and oxygen added, and back to the diver. Originally, the one-way valve assemblies consisted of the Koegel, or cone-shaped valves, held in place in the face mask by the valve retainer, Figure 1.

Studies performed by the Navy Experimental Diving Unit in 1989 showed that the Koegel valves could leak, causing unacceptable carbon dioxide levels in the breathing gas.[1] This study also established the suitability of the mushroom-type, or flapper, one-way valves for use in the face mask, Figure 2. These flapper valves are the same as those used in other diving systems, i.e., MK 14 and MK 16. The retainers used to house the valves were designed and built by Biomarine, Inc., at that time the manufacturer of the MK 15 UBA. In early 1990, all Koegel valve assemblies used in the MK 15 full face mask were replaced with the Biomarine valve assemblies.

The polymeric material used for the Biomarine retainers was acrylonitrile-butadiene-styrene (ABS), though the specific type of ABS is unknown. Both inhalation and exhalation valve retainers were manufactured in two pieces, consisting of the cylindrical retainer body and the inside valve support or "spider". The engineering drawings for the valve retainers indicate the spiders were solvent bonded to the retainer bodies.

In 1991, requirements for additional flapper valve assemblies were received from fleet users. For cost considerations, the decision was made to design the valve retainers in-house, have the parts injection molded, assemble the valve assembly kits, and issue these to the fleet. The material chosen for the new retainers was Makroblend DP-4-1368, a polycarbonate/polyethylene terephthalate (PET) polyester blend. This material was chosen because it is more suitable for the injection molding process and because of its durability.

Using the injection molding process, it was possible to manufacture the exhalation valve retainer body and spider in one piece; however, the inhalation valve retainer had to be manufactured in two pieces (body and spider, Figure 3). As the properties of Makroblend do not lend themselves to solvent bonding, the spider of the inhalation valve was glued to the retainer body using a two-part urethane adhesive system, Lord Industries' Tyrite 7500 A and 7500 B system.

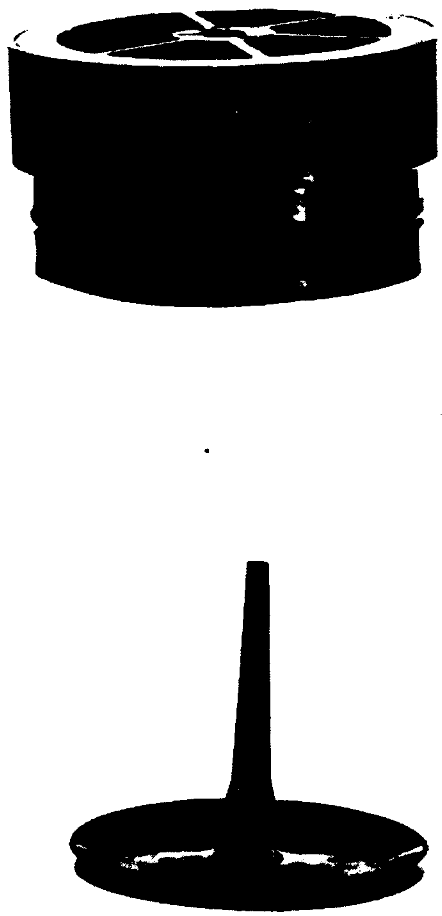
The materials and mode of production for the new retainers had changed from the previous Biomarine issue of the valve assemblies. In addition, an adhesive, instead of solvent bonding, was used to bond the spider of the inhalation valve retainer to the retainer body. Because of these configuration changes, the Supervisor of Diving, Naval Sea Systems Command, required the new assemblies pass destructive and nondestructive testing prior to issuance to the fleet.

VALVE RETAINER

KOEGEL VALVE

FIGURE 1. KOEGEL VALVE AND RETAINER

VALVE RETAINER



MUSHROOM VALVE

FIGURE 2. MUSHROOM VALVE AND RETAINER

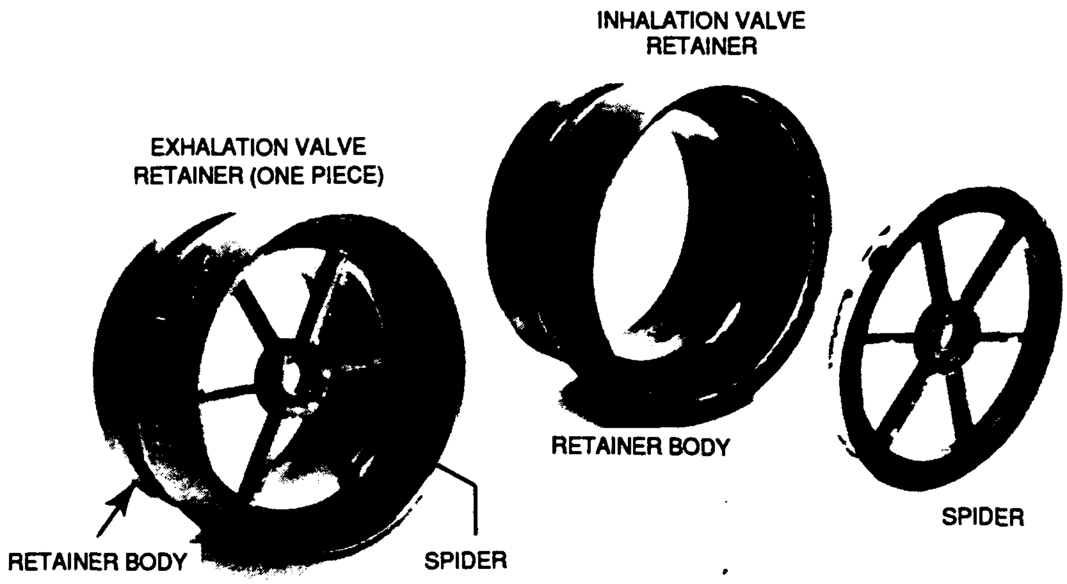


FIGURE 3. NEW EXHALATION AND INHALATION VALVE RETAINERS

OBJECTIVE

The objective of these tests was two-fold. The first part entailed destructive testing of the inhalation valve retainers to determine the failure point of the adhesive under a variety of conditions. In use, the valve assemblies can be subjected to three extreme cases:

- o storage in a clean dry environment
- o exposure to salt water at temperatures as low as 40°F
- o exposure to warm salt water (70°F and above), as well as the diver's exhaled breath (approximately 95°F).

Three sets of samples were tested. Each set was subjected to conditions simulating each of the cases above. The **control set** was subjected to no outside influences prior to testing (simulating storage). The **cold salt-water immersed set** was soaked in a 40°F salt-water bath (simulating the lower end of the in-use temperature range), and the **warm salt-water immersed set** was soaked in a 95°F salt-water bath (simulating the upper end of the in-use temperature range, as well as the temperature of the diver's exhaled breath). Samples were immersed in the salt-water baths for 48 hours.

The second part of the testing consisted of nondestructively pressurizing the complete valve assembly to ensure that the spider remained intact on the retainer body. The valve assembly was pressurized to two to three times (2X - 3X) its maximum in-use operating pressure. This procedure was proposed as a way to qualify the remaining assemblies for distribution.

An additional test was performed. One Biomarine inhalation valve retainer was destroyed to determine the failure point of the solvent bonding. This retainer was subjected to no outside influences prior to testing (control). The failure of this sample was to be compared against the failure of the new valve assemblies.

Details of the test plan are included in Appendix A.

DESTRUCTIVE TESTS

PROCEDURES AND RESULTS

Equipment Required

Inhalation valve retainer samples
Female testing jig (Figure 4)
Male testing jig 1.5-inch diameter (Figure 4)
Instron Tensile Testing Machine and supporting recorders
Biomarine inhalation valve retainer

Procedures

Setup. As a preliminary step, a computer-generated model of the inhalation retainer was produced using the Algor™ Finite Element Analysis software. Mechanical properties of both the plastic and the adhesive used for the retainer were taken from the manufacturer's literature and were input into the model. The model was then subjected to a 5-pound force, and then a 10-pound force, directed along the circumference of the adhesive bond line between the spider and the retainer body. This loading simulated the proposed destructive testing method. The results of the loading on the model are shown in Appendix B. Stress calculations reported in Appendix B are *von Mises* stresses,

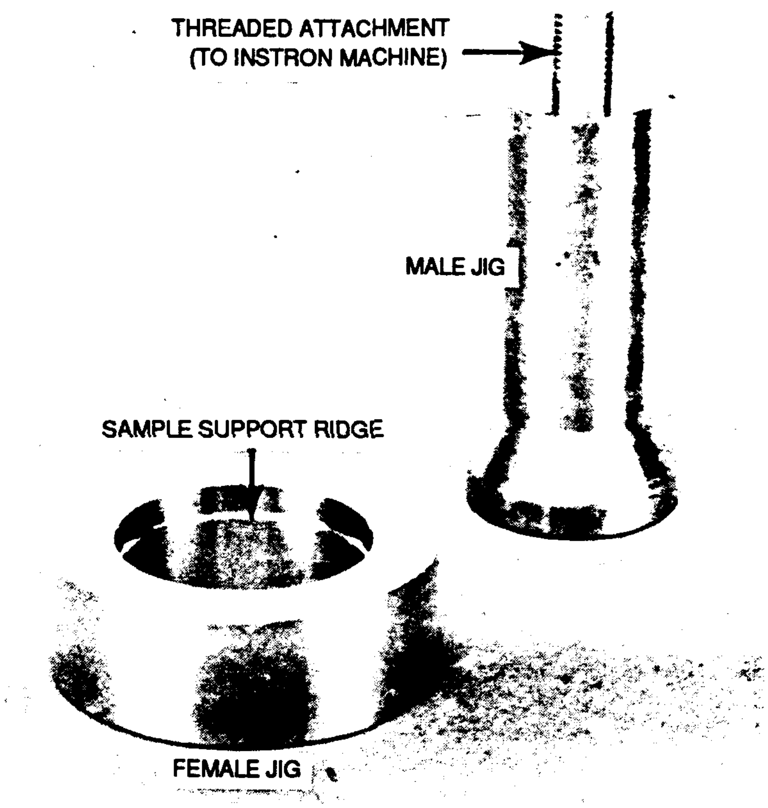


FIGURE 4. FEMALE AND MALE TESTING JIGS

which encompass both shear and tensile stresses in the model. Observations made based on these stress estimates indicated that the adhesive would fail at circumferential loads of between 60 and 80 pounds (lbs).

For destructive testing, all the inhalation valve retainers used for test samples were cut apart approximately 5/16" from the spider end, thereby eliminating the inside undercut (Figure 5). This aided in designing the male testing jig and helped in the testing itself. The sample fit into the female testing jig as shown in Figure 6, and seated on a ridge so that no part of the spider was supported.

The male testing jig was threaded and locked into the upper grippers of the Instron Tensile Testing Machine. The female jig with the test sample installed was positioned on the lower platform of the testing machine, directly under the male jig. The male jig was lowered and centered on the sample so that all force applied was directed along the circumference of the spider (Figure 7). The sample was preloaded with 2 lbs.

The testing machine was set using a 5000-pound load cell. The machine was controlled to apply a compressive load to the sample. The load rate was regulated at 5 pounds per minute (lbs/min). Based on the preliminary failure calculations discussed above, the machine was set to stop at 60 lbs, in an effort to avoid damage to the machine once failure occurred.

During the first run on a sample from the control set, the sample withstood the maximum load of 60 lbs without failure. This sample was then unloaded. The maximum load was adjusted to 100 lbs, as failure was expected between 60 and 80 lbs. The sample was subjected to this load and, again, failure did not occur at the maximum load. The maximum load was then set to 200 lbs. The initial load rate of 5 lbs/min was revised to 20 lbs/min to decrease the amount of time to the end of the run. The sample failed at 187 lbs.

As all of the control samples were expected to fail at approximately the same load, the maximum load was set to 200 lbs for testing on the second sample. Again, the sample withstood the maximum load, was unloaded, the maximum load set higher (250 lbs), and the sample reloaded. Failure occurred at 240 lbs. The trend continued through the third sample. Maximum load on this piece was ultimately set to 500 lbs, which remained the maximum load setting for tests on all of the new valve retainer samples. During testing of the Biomarine retainer, the sample withstood the maximum load of 500 lbs; maximum load was reset to 1000 lbs, with failure occurring at a load of 780 lbs.

Samples. There were four sets of samples tested: control set (5 pieces), cold salt-water immersed set (3 pieces), warm salt-water immersed set (3 pieces), and original Biomarine set (1 piece). The destructive testing for all samples was performed in the manner described above.

The cold salt-water immersed samples were soaked in a 5% by weight solution of sodium chloride and water, which simulates the chemistry of the ocean environment. The temperature of the salt-water solution was held constant at 40°F (the lower end of the valve assembly in-use temperature range). Samples remained fully immersed for 48 hours, allowing adequate time for the samples to attain temperature equilibrium. The test pieces were not rinsed with clean water, nor were they allowed to dry prior to destructive testing.

The warm salt-water immersed samples were also soaked in a 5% by weight solution of sodium chloride and water. The temperature of this solution was held constant at 95°F (the upper end of the valve assembly in-use temperature range, as well as the temperature of the diver's exhaled breath). Samples remained fully immersed for 48 hours, allowing adequate time for the samples to attain temperature equilibrium. Again, the test pieces were not rinsed with clean water, nor were they allowed to dry prior to destructive testing.

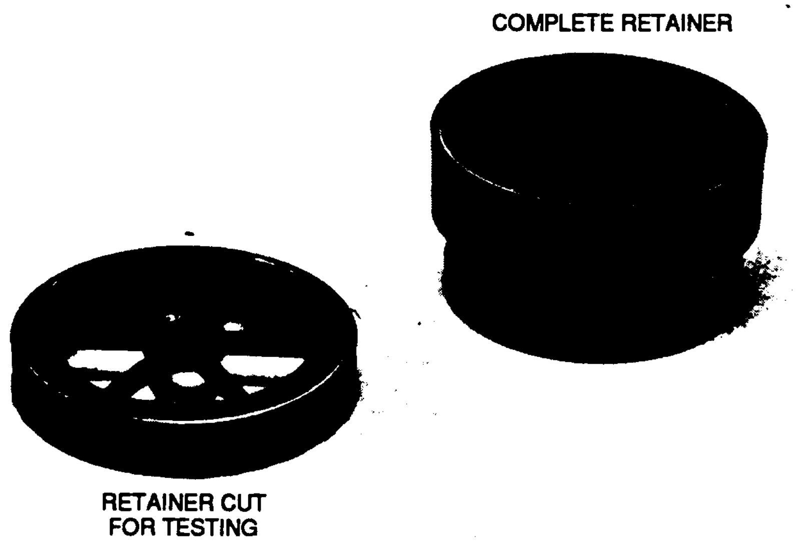


FIGURE 5. RETAINER CUT TO FACILITATE TESTING

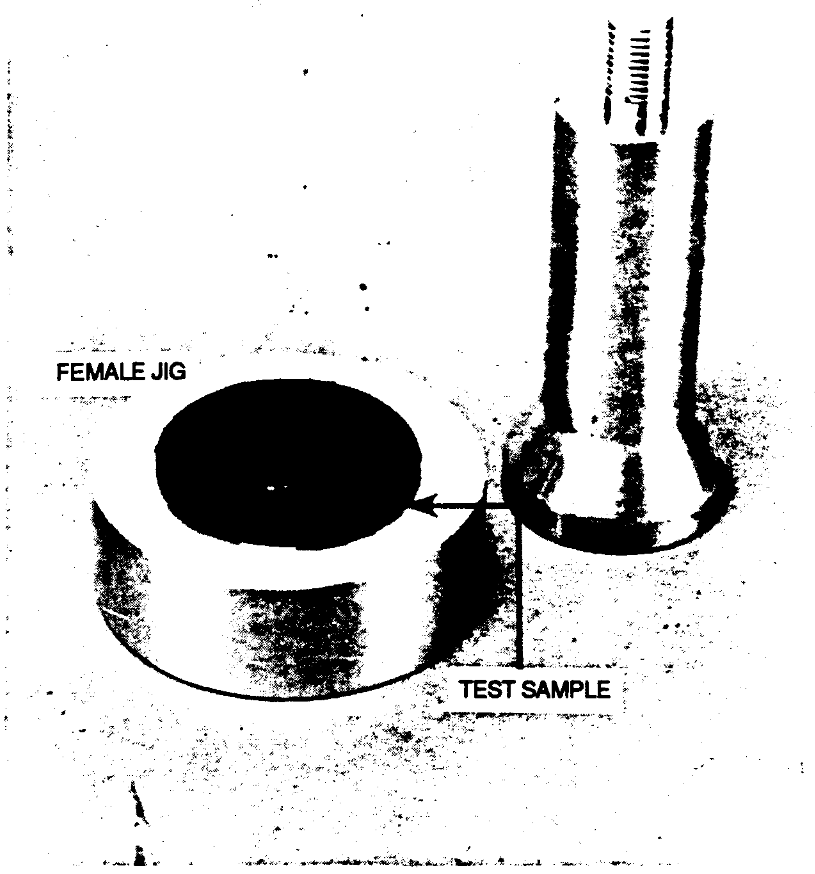


FIGURE 6. TEST SAMPLE FIT INTO FEMALE JIG

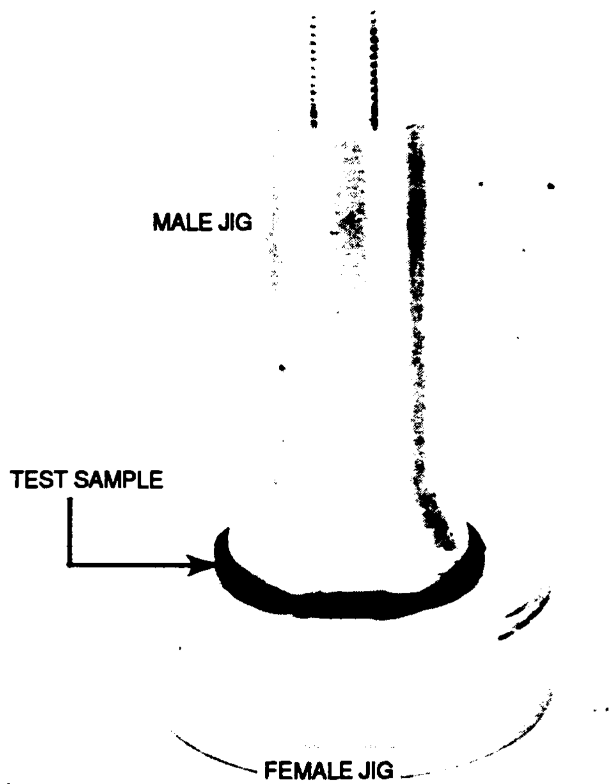


FIGURE 7. MALE TESTING JIG IN PLACE

Results

Testing Results. For each sample test, the Instron testing machine generated a graph showing force applied vs. total deflection of the spider. The results of the tests are outlined in Table 1. Recorded values were taken directly from the generated graphs. Explanations of the column headings are:

Piece = sample number
Max Load = maximum load to which Instron machine was set to stop (lbs)
Load Rate = rate at which load was applied (lbs/min)
Displacement = displacement of spider, measured at (a) end of run to maximum load, or (b) failure (in.)
Init. Deformation = load at which inelastic deformation first occurred (lbs)
Failure = load at failure of sample (lbs)

Unfortunately, for test pieces 1-6, the graphs generated from the testing machine were destroyed before the initial deformation values could be recorded.

Results of Visual Inspection. A visual inspection of each failed piece was also performed. In all cases of the new valve retainer samples, failure occurred at the adhesive bond line between the spider and retainer body. In no case did failure of the plastic occur. There was little evidence that the adhesive actually sheared apart; failure occurred because the adhesive separated from the plastic bonded surface. The Biomarine retainer failed when the plastic fractured (see Discussion).

Visual inspection of the cold salt-water immersed set showed adhesive failures in much the same manner as the control set; however, inspection of the warm salt-water immersed set showed that the adhesive had become more ductile, or pliable.

Discussion

Computer Model. A word should be mentioned here on the discrepancies between the Algor™ computer model results and results of actual destructive testing. In developing the computer model, a very conservative approach was taken, outlined below:

1. As stated previously, data used to develop the adhesive bondline for the model were taken from the adhesive manufacturer's literature. These data are the minimum advertised properties; that is, over the range of testing, these values were found to be the minimums.

2. The adhesive bondline in the model reflected only bonding between the perimeter of the spider and the wall of the retainer; in actuality, the adhesive also bonds the spider against a small counterbore surface that acts as a support (refer to Figure 8A).

3. The model was subjected to a uniform pressure loading across the entire area of the spider, whereas forces applied to the actual test sample were directed along the circumference of the spider only.

By taking this approach, the model was intended to reflect the "worst case" conditions of the test pieces.

TABLE 1

DESTRUCTIVE TESTING RESULTS

Piece	Max load (lbs)	Load rate (lbs/min)	Displacement (in.)	Init Deformation 0% offset (lbs)	Failure (lbs)
CONTROL SET					
1	60	5	0.010	N/A	+
	100	5	0.010	N/A	+
	200	20	0.020	*	187
2	200	20	0.020	N/A	+
	250	20	0.025	*	240
3	250	20	0.025	N/A	+
	500	20	0.035	*	225
4	500	20	0.025	*	320
5	500	20	0.030	*	210
BIOMARINE RETAINER					
6	500	20	0.015	N/A	+
	1000	40	0.025	*	780
COLD SALT-WATER SET					
7	500	20	0.040	300	320
8	500	20	0.035	320	325
9	500	20	0.035	205	215
WARM SALT-WATER SET					
10	500	20	0.040	170	235
11	500	20	0.035	130	155
12	500	20	0.037	285	335

*These graphs were destroyed before these values could be determined.

+Sample was loaded to maximum load without failure, then unloaded.
Sample was reloaded to next higher recorded maximum load until failure.

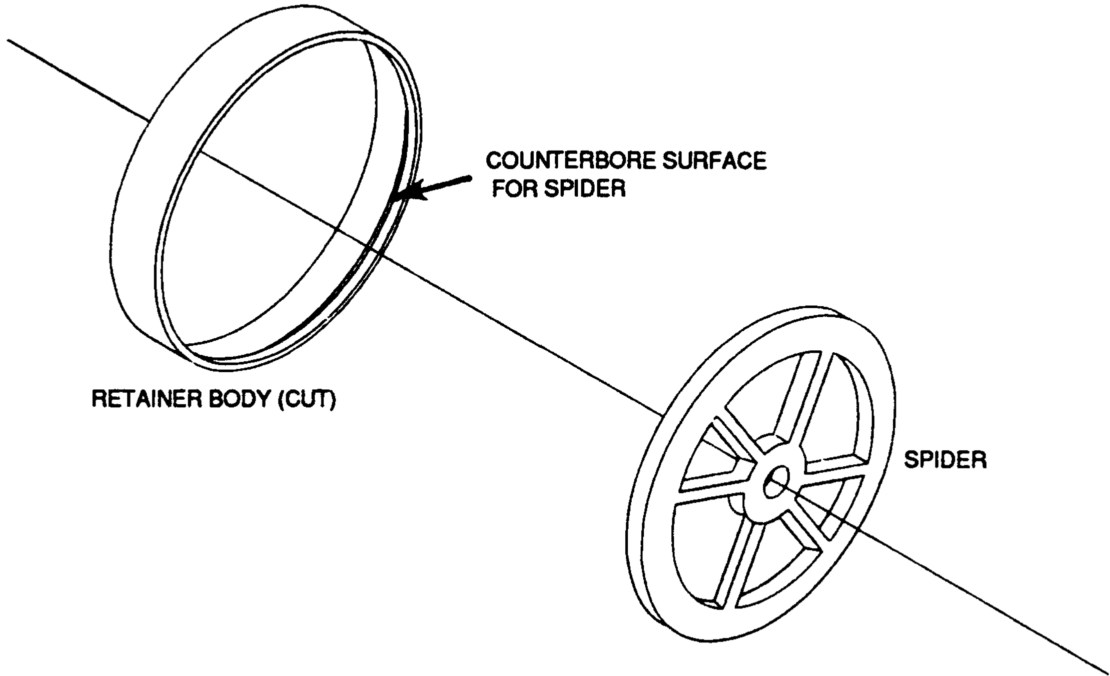


FIGURE 8A. NEW INHALATION VALVE RETAINER

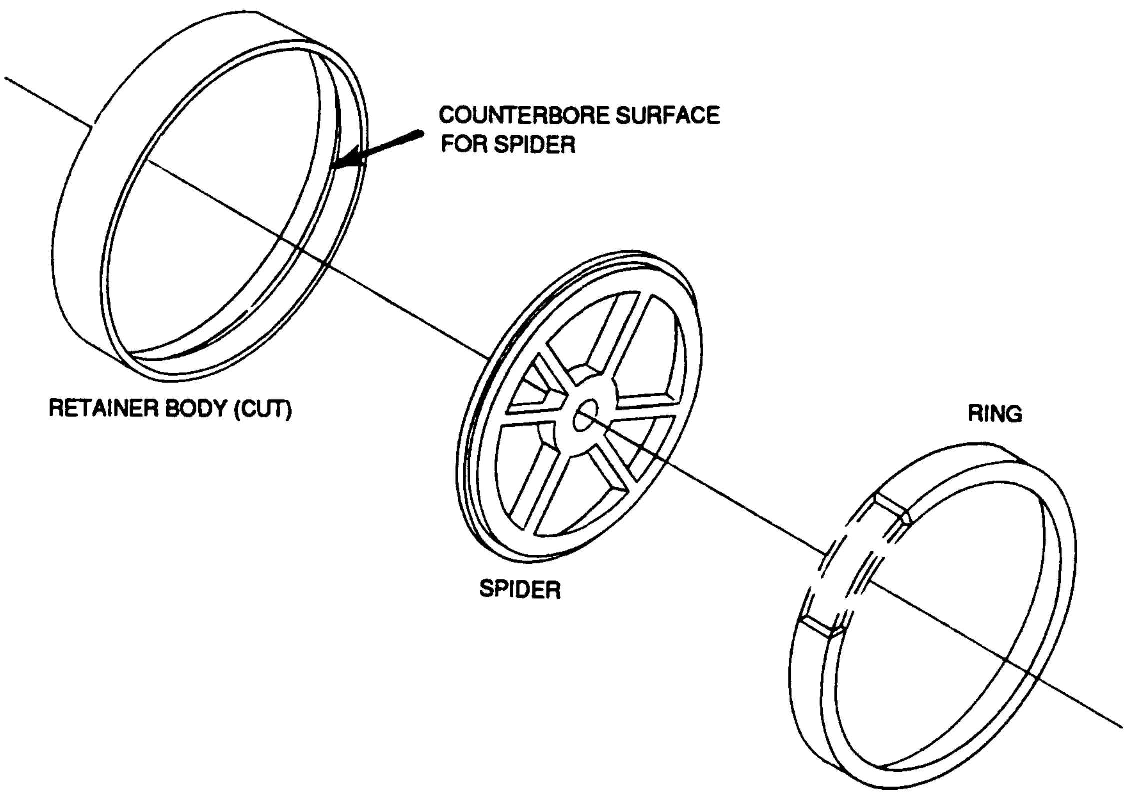


FIGURE 8B. BIOMARINE INHALATION VALVE RETAINER

Discussion of Test Results. While there is a wide range of loads over which failure occurs, the inhalation retainer can sustain a circumferential force of at least 150 pounds before the adhesive fails. The range of loads is most likely due to inconsistencies in the adhesive bonding process, i.e., thickness of the adhesive applied, possible trapped air bubbles in the adhesive, improper preparation of the bonding surface, cleanness of the bond area, etc.

Another factor to consider is the inadvertent cyclic loading of the test pieces (specifically the adhesive bond line) as seen in Cases 1, 2, and 3. Especially interesting is Case 3, which held to 250 pounds, was unloaded, then failed at 225 pounds. This behavior is most likely due to exceeding the elastic deformation limit of the adhesive.

No great discrepancies in the load at failure of the adhesive were seen related to the cold or warm salt-water soaks; however, at warm water temperatures, the adhesive appears to become more ductile.

The smallest load at which failure of the new retainers occurred was 155 pounds. The area of the bonded section was calculated to be 0.47 square inches (in.^{2}), indicating a shear stress of 329.8 pounds per square inch (psi) in the adhesive at failure.

Lord Industries, supplier of the Tyrite 7500 adhesive system, has performed shear strength tests using their adhesive with a variety of base stocks. While no tests were conducted on the Makroblend DP-4-1368 plastic, tests were performed on other reinforced injection molded plastics produced by Mobay Corporation, producer of Makroblend. Samples consisted of two 1-inch by 4-inch plastic specimens bonded together with 1/2-inch overlap. Samples were then subjected to tensile loading. Results showed that the samples failed by "stock break" (the plastic fractured), at a load of 420 lbs, representing a shear stress of 840 psi along the bonded area. The strongest of the new valve retainer samples failed at 335 lbs, representing a shear stress of 712.7 psi in the bonded area.

If the total surface area of the spider is considered a solid, simulating the spider with the valve in place, this total area is 1.96 in.^{2}. Calculating the pressure as the force applied divided by total area, the total pressure needed to cause failure is AT LEAST 79.1 psi. Studies previously performed at the Navy Experimental Diving Unit, among others, show the maximum pressure that can be exerted from the lungs is only 2 psi. In the event of exhalation valve failure, and if the diver exhaled as hard as he could, the inhalation valve would see a back pressure of 2 psi. However, during normal use, with the exhalation valve functional, the back pressure seen by the inhalation valve is only 0.3 psi for a diver at a depth of 198 feet of seawater performing moderate to heavy work.

Failure comparison to the Biomarine valve. The Biomarine inhalation valve retainer failed at 780 pounds, more than twice the force required to break the strongest new retainer. Closer inspection of this failed piece revealed that the two retainers were assembled differently. The new retainer (Figure 8A) consists of a 0.095-inch thick, 1.58-inch outside diameter (OD) spider that fits into the retainer body and seats on a very small ridge. The bonding area consists of the entire circumference of the spider, plus a small bonding area between the ridge and spider, nominally 0.471 in.^{2}.

The Biomarine retainer was built in a more complex process that resulted in three pieces (Figure 8B). The spider consists of a 1.487-inch OD, 0.10-inch total thickness piece; however, 0.054 inches from the top of the spider, the diameter was shaved to 1.400 inches, creating a "small" piece atop a "larger" piece. This spider was then bonded inside a piece with a 1.585-inch OD and a 1.400-inch ID (ring). The ring has a lip around it that is 0.049 inches wide and 0.198 inches long. In effect, the ring seats on the larger diameter of the spider, with the lip of the ring surrounding the spider and extending 0.098 inches beyond the thickness of the spider. The lip part of the ring was then bonded into the retainer.

The assembly of the Biomarine exhalation valve retainer showed that the spiders of both the exhalation and inhalation retainers are interchangeable. The spider of the exhalation retainer fits exactly within the retainer body; however, the spider is too small to fit in its allotted space in the inhalation retainer. The conclusion can be drawn that the "ring" used in the inhalation retainer was designed to compensate for the difference in diameters between the spider and the retainer body.

The effective area of bonding of the spider and ring is nominally 0.980 $in.^2$, approximately twice the bonding area of the new configuration. The test loading performed on the Biomarine piece pushed against the ring instead of the spider.

NONDESTRUCTIVE TESTS

PROCEDURES AND RESULTS

Equipment Required

Inhalation valve assembly
Pressure test jig and plug
Compressed gas source with pressure gauge

Procedures

Setup. The pressure test jig was made of three PVC parts (Figure 9). Part one was equipped with an adapter that connected to a compressed gas source. The valve assembly was held in this part. The inside diameter of this part was such to allow a snug fit on the o-ring of the retainer. Part two was hollowed and machined to fit on top of the retainer. A lip inside this part held the retainer in place but supported no part of the spider. Both parts were threaded around the outside. Part three was a ring, which was threaded onto parts one and two, to ensure a good connection between the two.

A solid plug made of Delrin stock 0.80 inches high with a diameter of 1.243 inches was made to fit inside the valve assembly, to help seal the valve against the spider. This plug was inserted into the retainer, then the retainer was installed in the testing jig as described above.

The jig was connected to the compressed gas source. For these tests, oil-free nitrogen was used. A 0-30 psi gauge was used to measure pressure applied. Pressure was regulated to 5 psi, equivalent to a 9.8-pound force distributed over the area of the spider.

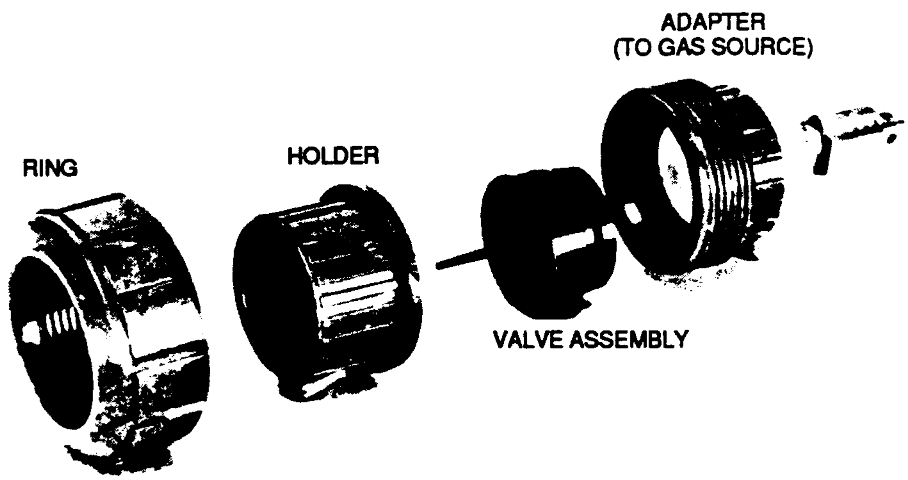


FIGURE 9. PRESSURE TEST APPARATUS (WITHOUT PLUG)

Samples. Prior to the pressure check on the inhalation valve assemblies, each valve retainer was tested by manually depressing the middle of the spider from inside the retainer. By this pre-test, 18 of 213 retainers were found with faulty adhesive seals, i.e., the spider pushed through. Incidentally, the force applied was sufficient to break the inner ring of two spiders without adhesive failure. All remaining assemblies (193 total) were pressure tested.

Results

Testing Results. In each case, some leakage occurred around the valve, but the compressed gas source was regulated so that a steady 5-psi pressure on the assembly was maintained.

Discussion

Discussion of Test Results. All the inhalation valves that were pressure tested passed. The process of manually pushing on the spider to detect failure was a way to weed out those retainers that may cause problems. Attempting this procedure with the remaining valve retainers will most likely cause the center of the spider to break before the adhesive fails. While this is a very subjective test, it does raise the question of how much force on the center of the spider is enough to ensure bonding integrity. It also verifies the need to revise the pre-dive and post-dive procedures for the full face mask so that the "thumb" test is replaced with a more quantitative test, should testing of this form be required during pre- and post-dive.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Studies previously performed show the maximum pressure seen by the valve assemblies in operational use would be 2 psi, with a more realistic pressure being 0.3 psi. These numbers translate to an effective force on the valve of 0.6 to 3.9 lbs. As seen by the destructive tests performed, the inhalation valve retainer can withstand an effective pressure of 79.1 psi or a force of 155 lbs before failure of the adhesive bond. As seen in the nondestructive testing, all valve assemblies remained intact while subjected to a 5-psi pressure.

Testing has shown that the adhesive bond of the inhalation valve retainer is sufficient for the intended use of the valve assemblies. Warm and cold salt water have no effect on the strength of the adhesive. Weakly bonded retainers have already been removed from the lot, and the remaining 193 retainers pressure tested, all of which passed.

RECOMMENDATIONS

It is recommended that these valve sets be distributed to fleet users as soon as possible.

In light of the high failure rate of the adhesive bondline in the retainers, two recommendations are made concerning any future procurements of these pieces:

1. Should the pieces be procured as in this case, more stringent gluing procedures should be developed and followed, as well as better quality control and assurance.

2. If a different design approach is preferred, the pieces be developed and materials used that would more easily lend themselves to solvent bonding or ultrasonic welding.

REFERENCES

1. LT J. T. Hermann and HM1 S. B. Wakefield, *Evaluation of Koegel Valves Used with MK 15 Mod 0 UBA Full Face Mask*, NEDU TM 89-04, Navy Experimental Diving Unit, April 1989.

CSS TM 607-92

APPENDIX A

TEST PLAN FOR MK 15 FULL FACE MASK INHALATION VALVES

WITH REVISIONS

By: Theresa Barth, Coastal Systems Station, Code N2530

Date: Original 9 March 1992
Rev 1 17 March 1992

TEST PLAN FOR MK 15 FULL FACE MASK INHALATION VALVES -- REV 1

3.2.3. Pressure Check (Revised)

3.2.3.1. Sample size = 100% Inspection

3.2.3.2. Place Delrin plug inside retainer. Assemble retainer into testing jig.

3.2.3.3. Attach assembly to compressed gas source.

3.2.3.4. Pressurize assembly to 5 psi. Observe retainer to ensure spider remains in valve assembly. Close gas flow and bleed pressure. Remove valve assembly from testing jig.

3.2.3.5. Record the following data:
Test pressure
Results of visual check

3.2.3.6. Repeat for remaining retainers.

TEST PLAN FOR MK 15 FULL FACE MASK INHALATION VALVES

1.0 DISCUSSION

In early 1990, the Koegel valve assemblies used in the MK 15 Full Face Mask were replaced with the mushroom type valve assemblies. The valves themselves are the same as those used in other diving systems, i.e. MK 14 and MK 16. The retainers used to hold the valves in place were designed and built by Biomarine, Inc, at that time the manufacturer of the MK 15. Valve assembly retrofit kits were distributed to users of the MK 15 in January 1990, with all masks retrofitted by April 1990.

In 1991, requirements for additional retrofit valve assemblies were received from fleet users. For several reasons, the decision was made to design the valve retainers in-house, have the parts injection molded, assemble the retrofit kits, and issue these to the fleet. Because the material and mode of production had changed from the previous issue of valve assemblies, and because an adhesive was used to bond the "spider" of the inhalation valve retainer to the retainer body, NAVSEA has requested destructive and nondestructive testing be performed on the new valve retainers prior to issuance to the fleet.

2.0 OBJECTIVE

The objective of these tests is two-fold. The first part entails destructive testing of the inhalation valve retainers to determine the failure point of the adhesive. Tests will be conducted under three conditions: control, cold salt-water immersion, and warm salt-water immersion. The second part consists of nondestructively testing the valve assembly to twice its normal operating pressure. This method is proposed as a way to qualify the remaining valves for distribution to fleet users.

One additional tests will also be performed. One set of previously issued valve assemblies will be destroyed to determine the failure point of that bonding used. This failure will be compared against the failure of the new valve assemblies.

3.0 PROCEDURES

3.1 DESTRUCTIVE TESTS:

3.1.1. Equipment Required:

Inhalation valve retainers
Female testing jig
Male testing jig 1.5" diameter
Instron Tensile Testing Machine and supporting recorders
Previously issued inhalation valve retainer

3.1.2. Control

3.1.2.1. Sample size = 3.

3.1.2.2. For destructive testing, retainer is cut approximately 5/16" from the spider end, thereby eliminating the inside undercut. This aided in designing the male testing jig.

3.1.2.3. Install inhalation valve retainer into female testing jig. Valve will seat so that no part of the spider is supported.

3.1.2.4. Position 1.5" male testing jig into retainer. Jig is designed so that all force is directed along the circumference of the spider (no force along the spokes).

3.1.2.5. Install testing configuration into Instron Tensile Testing machine, ensuring proper alignment.

3.1.2.6. Apply a force of 5 lbs per minute until adhesive fails.

3.1.2.7. Visually inspect retainer parts to determine mode of adhesive failure, i.e., adhesive should remain on entire surface of both parts.

3.1.2.8. Record following data:
Load rate
Displacement
Force at which initial deformation occurs
Force at failure
Results of visual inspection

3.1.2.9. Repeat for two additional samples.

3.1.3 Deleted

3.1.4. Deleted

3.1.5. Cold Salt Water Immersion

3.1.5.1. Sample size = 3.

3.1.5.2. For destructive testing, retainer is cut approximately 5/16" from the spider end, thereby eliminating the inside undercut. This aided in designing the male testing jig.

3.1.5.3. Soak retainers 48 hours in salt water solution with following specifications:

5% Sodium chloride by weight
pH level 6.5-7.2
temperature 40°F

3.1.5.4. Upon completion of soaking, remove and immediately test retainers in accordance with 3.1.2.3. - 3.1.2.9.

3.1.6. Hot Salt Water Immersion

3.1.6.1. Sample size = 3.

3.1.6.2. For destructive testing, retainer is cut approximately 5/16" from the spider end, thereby eliminating the inside undercut. This aided in designing the male testing jig.

3.1.6.3. Soak retainers 48 hours in salt water solution with following specifications:

5% Sodium chloride by weight
pH level 6.2-7.0
temperature 95°F

3.1.6.4. Upon completion of soaking, remove and immediately test retainers in accordance with 3.1.2.3. - 3.1.2.9.

3.1.7. Previously Issued Retainer Test

3.1.7.1. Sample size = 1.

3.1.7.2. For destructive testing, retainer is cut approximately 5/16" from the spider end, thereby eliminating the inside undercut. This aided in designing the male testing jig.

3.1.7.3. Install inhalation valve retainer into female testing jig. Valve will seat so that no part of the spider is supported.

3.1.7.4. Position 1.5" male testing jig into retainer. Jig is designed so that all force is directed along the circumference of the spider (no force along the spokes).

3.1.7.5. Install testing configuration into Instron Tensile Testing machine, ensuring proper alignment.

3.1.7.6. Apply a force of 5 lbs per minute until adhesive fails.

3.1.7.7. Record following data:
Force at which initial deformation occurs
Force at failure

3.2 NONDESTRUCTIVE TESTS

3.2.1 Equipment Required:

Inhalation valve assembly
Pressure test jig
Compressed gas source with pressure gauge
Pail of water

3.2.2. Deleted

3.2.3. Pressure Check

3.2.3.1. Sample size = 100% Inspection

3.2.3.2. Assemble retainer into testing piece. Attach brace to spider end of valve retainer.

3.2.3.3. Attach assembly to compressed gas source.

3.2.3.4. Pressurize assembly to 5 psi. Submerge assembly in water. Check for any leaks around adhesive bond.

3.2.3.5. Record the following data:
Test pressure
Results of visual check

3.2.3.6. Repeat for remaining retainers.

3.2.4 Deleted

CSS TM 607-92

APPENDIX B

FINITE ELEMENT ANALYSIS
OF
INHALATION VALVE RETAINER

By: Brian Stout, Mechanical Engineer, Coastal Systems Station, Code N2530

Date: 20 March 1992

20 March 1992

MEMORANDUM

From: Brian Stout, Code 2520
To: Theresa Barth, Code 2530

Subj: FINITE ELEMENT ANALYSIS OF INHALATION NONRETURN VALVE RETAINER

encl: (1) 5 pound force exerted on perimeter of retainer's face
(2) 10 pound force exerted on perimeter of retainer's face

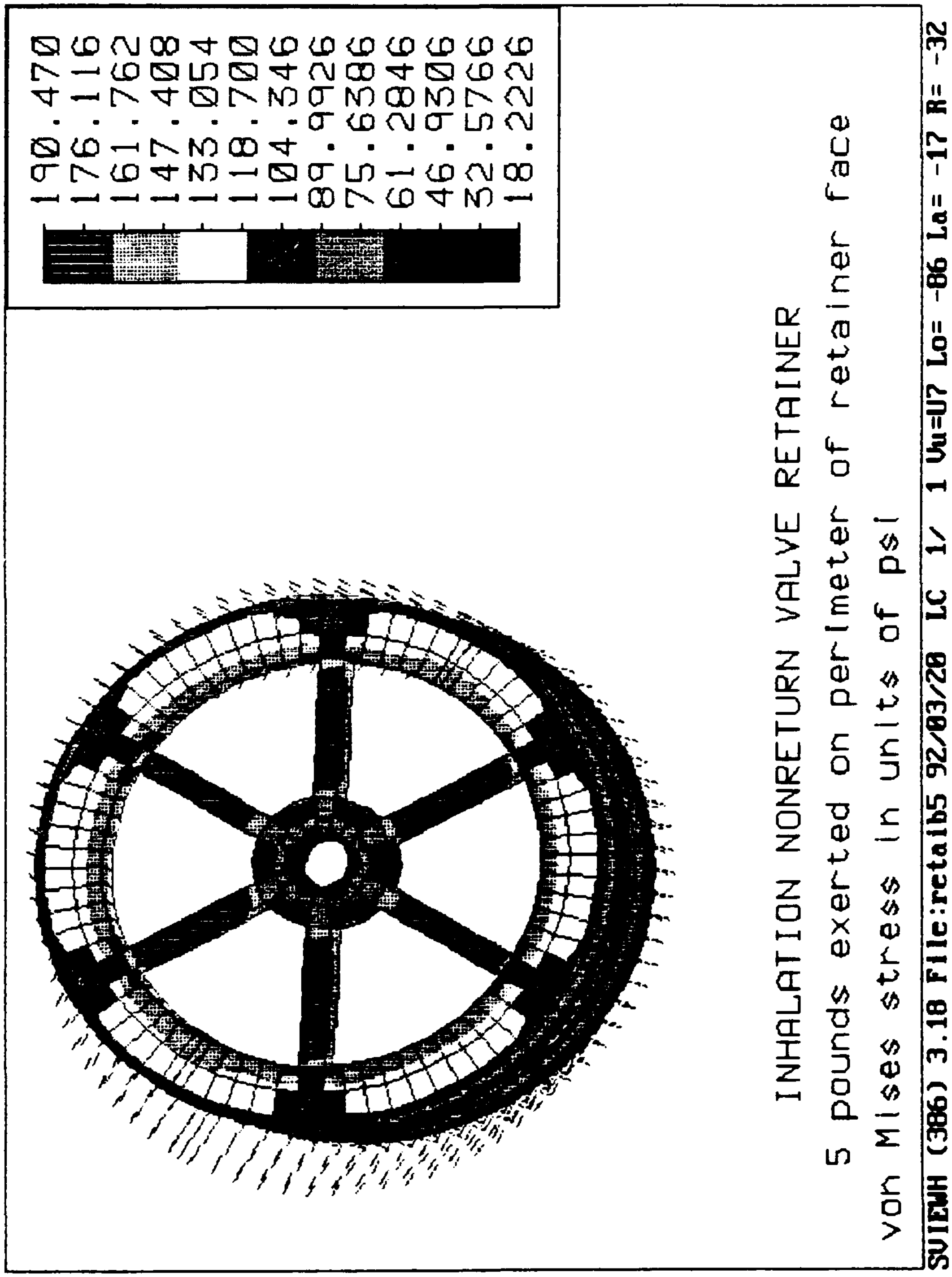
1. As requested, I conducted an analysis to determine the stresses created in the retainer when it was exposed to static loads.

2. The area of interest exists at the retainer face/ glue interface. With a 10 pound load exerted on the edge of the retainer face, the stress at the interface is approximately 150 psi. Under the same conditions, a 5 pound load resulted in 75 psi stress at the interface.

3. The property values used in the analysis of the retainer are given below:

	plastic	glue
Density (psi)	0.0466	0.0469
Poisson's ratio	0.3	0.1
Young's modulus (psi)	380000	100000

Brian Stout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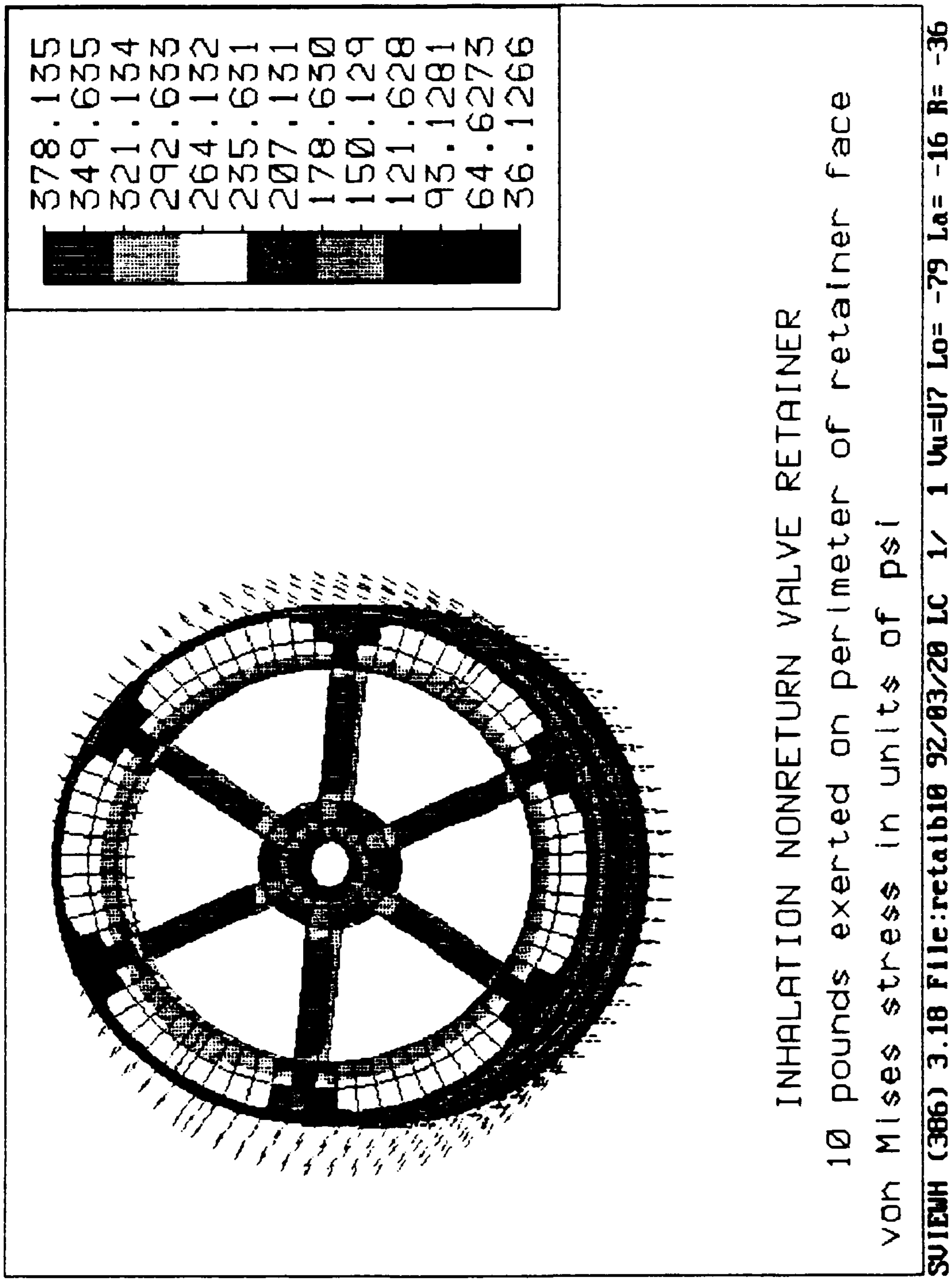
32.5766
18.2226
INHALATION NONRETURN VALVE RETAINER
5 pounds exerted on perimeter of retainer face
von Mises stress in units of psi
SVIEWH (386) 3.18 File:retaib5 92/03/20 LC 1/ 1 Vu=U7 Lo= -86 La= -17 R= -32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INHALATION NONRETURN VALVE RETAINER
10 pounds exerted on perimeter of retainer face
von Mises stress in units of psi
SUIEWH (386) 3.18 File:retalb10 92/03/20 LC 1/ 1 Vu=U7 Lo= -79 La= -16 R= -36

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