Basket Strainer Lid Cracking & Pressure Tap Analysis

Acrylic basket strainer lids often crack and have to be replaced. To address this issue, Fluidtrol Process Technologies, Inc. conducted a detailed study of acrylic basket strainer lids in an effort to develop a better design that would resist cracking. Finite element analysis of existing designs revealed that stress that leads to cracking is concentrated in two places: the top vent and the bolt holes and gasket interface. By moving or removing the vent and using larger washers, the conditions that lead to frequent lid cracking can be reduced by up to 50%.

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LID CRACKING

Reports of acrylic lids cracking are common across the industry. A detailed analysis was performed to identify steps to reduce cracking. While the lid material is thick enough to hold the pressure, stress concentration can create cracks that lead to lid failure. The acrylic lid was analyzed using a Finite Element Analysis tool to identify stress concentration areas and evaluate solutions. The table below lists the areas inspected and the expected improvements.

Stress Concentration Point	Possible Solutions	Results
Center Vent	Remove or relocate the vent	Reduce vent stress concentration up to 50%
	Use smaller vent	Did not reduce stress concentration
	Place stiffener across lid	Reduce vent stress concentration up to 33%
Bolt Hole & Gasket Interface	Use bigger washers	Reduce bolt hole stress concentration up to 15%
	Reduce bolt pre-load	Reduce bolt hole stress concentration up to 15%
	O-Ring Groove	Reduce bolt hole stress concentration up to 30% Increased gasket interface stress by 50%.

Lid Properties

An 8” SW style lid operating at 50 psi was used in the model. Bolt loads were calculated using the ASME B16.5 recommended bolt torque of 16 ft-lb and total bolt load of 10,161 lb. The acrylic modulus of elasticity (450,000 psi), Poisson ratio (0.35) and tensile strength (9,000 psi) were referenced from the Plexiglas G, cell-Cast Acrylic data sheets.

MODELING APPROACH

The stresses in the lid were calculated using Finite Element Analysis (FEA) software. Forces were applied at the bolt washers. The fluid pressure was applied on the bottom of the lid across the diameter of the gasket. The lid was supported with an effective gasket width of 0.2 inches.

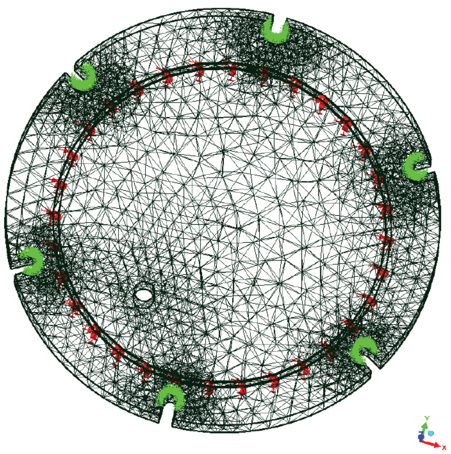
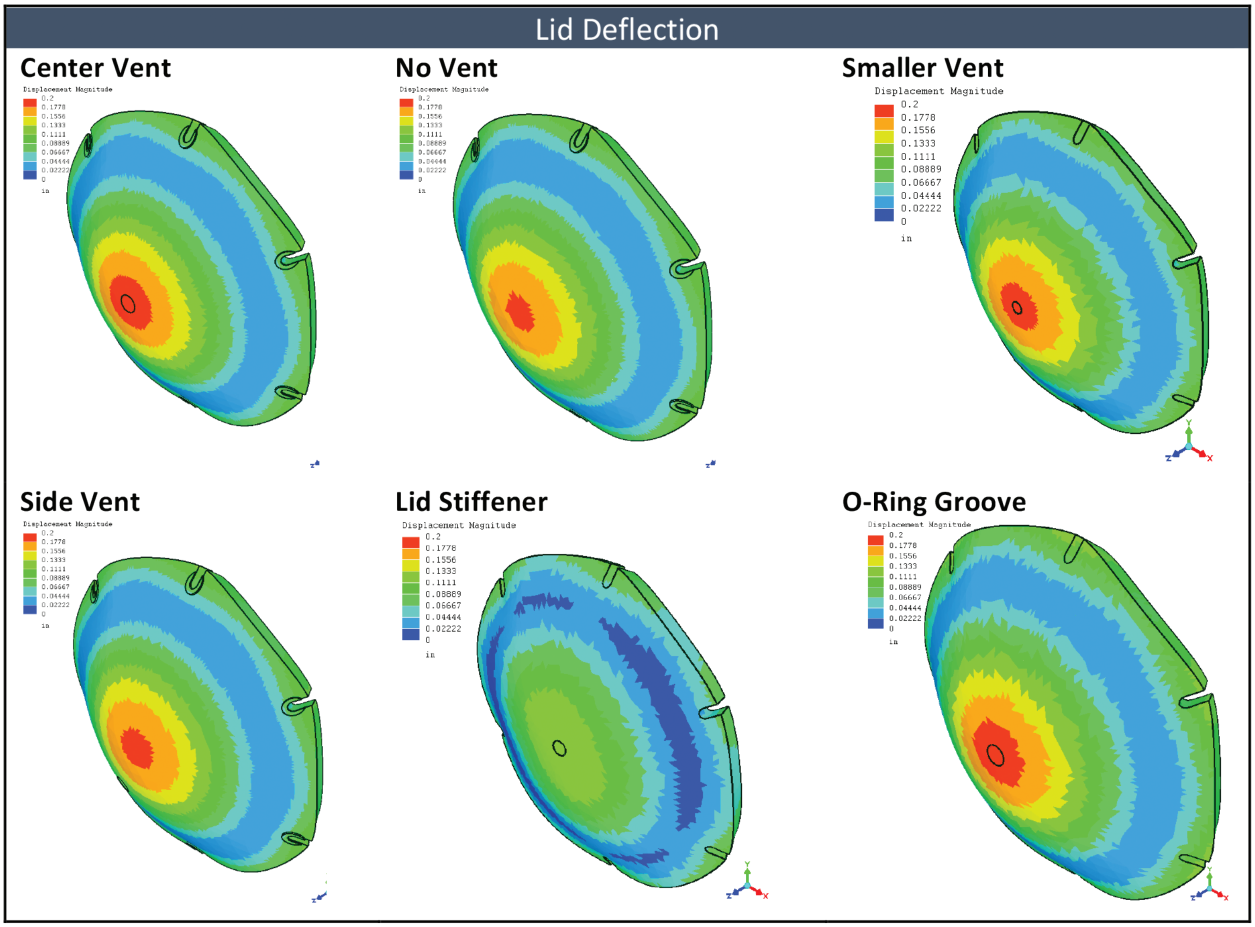


FIGURE 1.
The Finite Element Analysis (FEA) used a volumetric mesh with over 18,000 calculation nodes.

LID DEFLECTION

Deflection is a possible cause for lid fatigue and leakage. The bolts push down on the lid while the gasket and water pressure push the lid up. The color coded exaggerated map below indicates maximum deflection occurs at the center of the lid and is slightly worse with a center vent. At 50 psi, the top of the center vent lid may exceed 0.18 inch deflection. Using a lid stiffener can reduce the lid deflection by 50%.



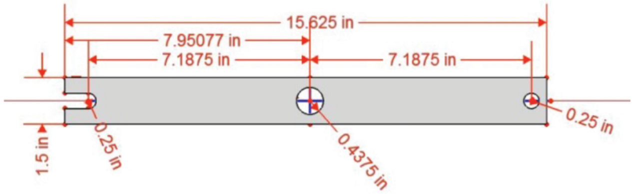
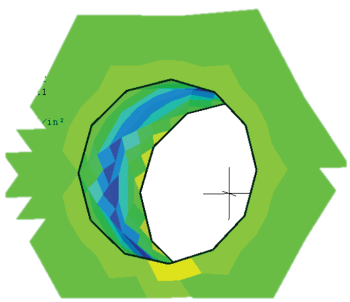
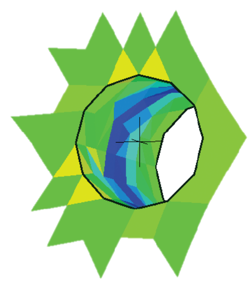


FIGURE 2.
The lid stiffener lid replaces washers for two I-Bolts. Its thickness does not require longer I-bolts.

VENT HOLE STRESS CONCENTRATION

The vent hole in the lid allows for easy purging of air buildup in the strainer. This is a popular feature for maintenance crews. Unfortunately, the vent creates a stress concentration point. As shown in the figure below, the center vent has high stress concentration points near the edges of the hole. The following page has a table that quantifies the maximum stress concentration of various options.

Stress Concentration at Center Vent		
Configuration	**½” Plug Center Vent**	**3/8” Plug Center Vent**
Both sizes have stress concentration exceeding 6,667 psi		

The stress concentration figures are color coded to represent the Von Mises stress. The Von Mises stress is a combination of stress from all six stress dimensions represented in a single picture. Red indicates yielding. Yellow indicates near yielding. Dark blue indicates little stress.

Four options were considered to reduce the vent stress. Each option was evaluated based on the maximum stress expected. The maximum stress is a better indicator of when a part begins to crack.

Some of the options evaluated offered better results. Removing or strategically relocating the vent can reduce the maximum stress by 50%. The lid stiffener reduced the maximum stress by 33%. Using a smaller vent did not significantly reduce the stress and may increase the possibility of over torqueing. It is suggested to remove or relocate the vent. The use of a lid stiffener can be used to further reduce stress.

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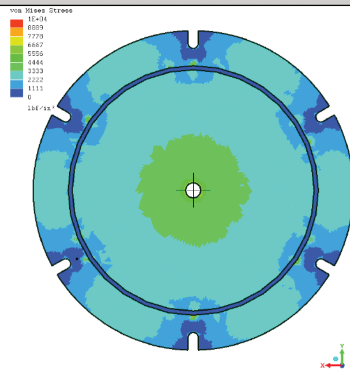
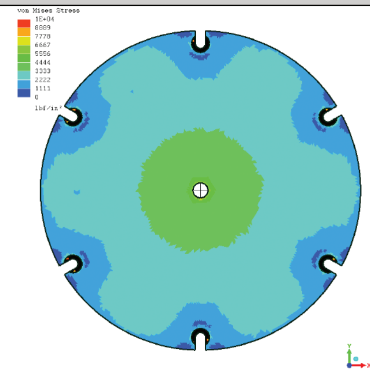
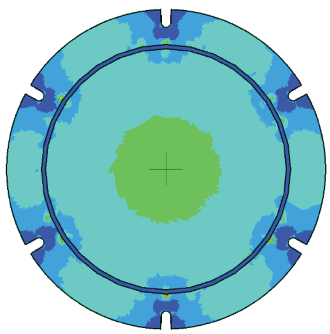
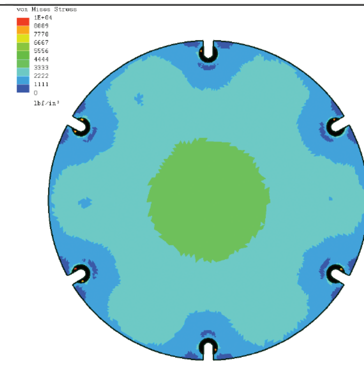
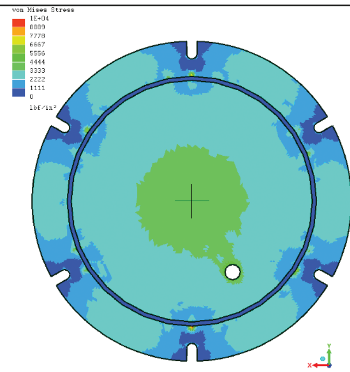
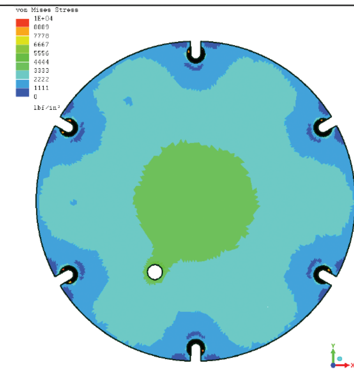
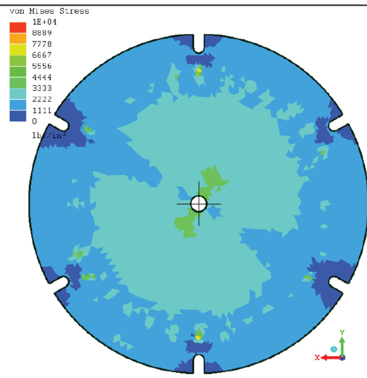
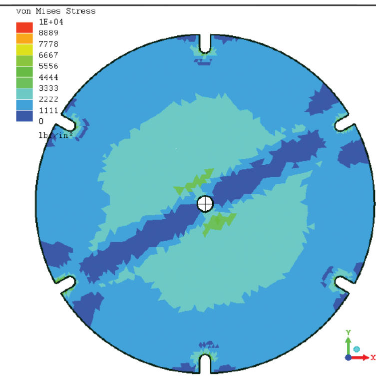
Stress Concentration at Vent

Configuration Max stress	Bottom View Stress	Top View Stress
Base Case Center Vent Center Point Stress 6,667 psi		
No Vent Center Point Stress 3,333 psi 50% reduction		
Offset Vent Center Point Stress 3,333 psi 50% reduction		
Lid Stiffener Center Point Stress 4,444 psi 33% reduction		

BOLT HOLE & GASKET INTERFACE STRESS CONCENTRATION

The bolt hole and gasket interface are a source of stress concentration. The bolts are compressing and flexing the lid over the gasket interface. Bolt loading is required to seat the gasket and maintain the seal of a pressurized vessel. The figure below shows stress in the lid with only the bolt load applied. Stress concentrates between the bolt holes and the gasket. The following table below compares effectiveness of possible solutions.

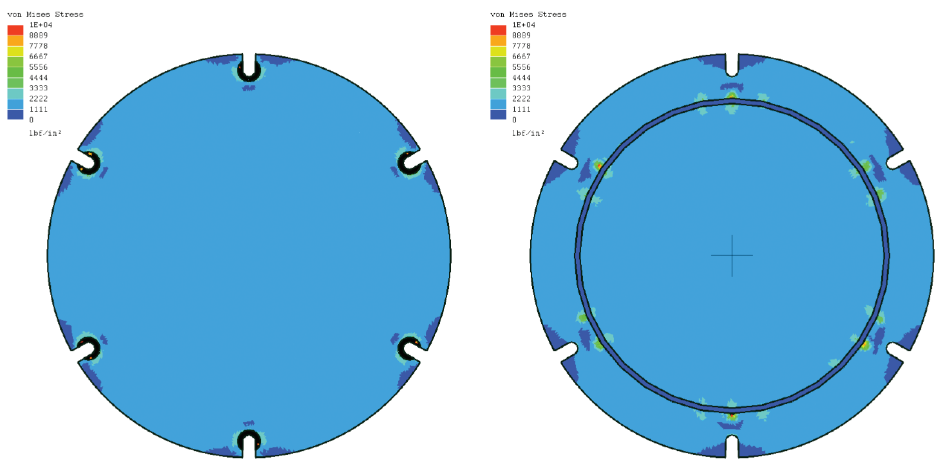
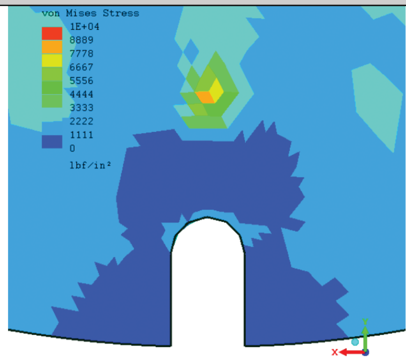
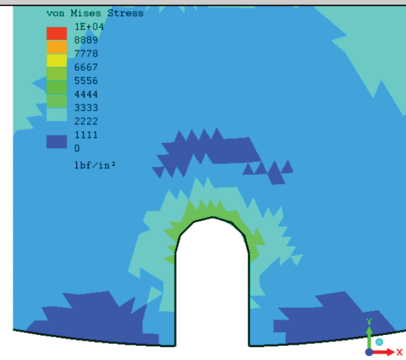


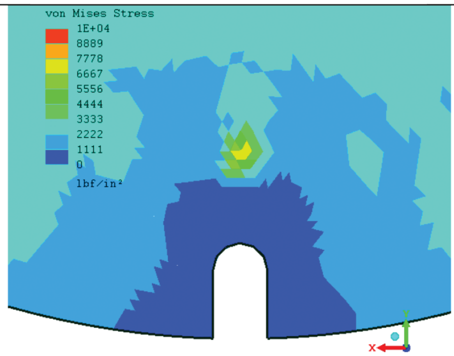
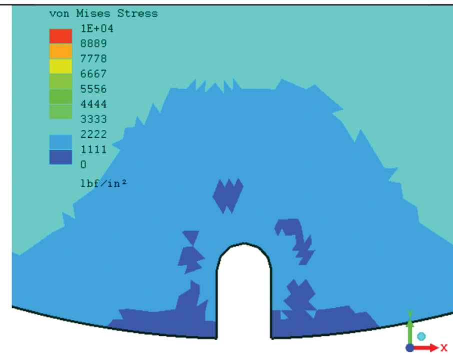
FIGURE 3.
The Von Mises stress for the lid with no pressure and loaded gasket has light stress concentration between the gasket and bolt holes.

Three options were considered to reduce the bolt hole stress. Using an oversized washer reduced stress concentration by 15%. Reducing the bolt loading by 10% reduced stress concentration by 15%. The bolt loading can be reduced by using a gasket that requires less force to make a tight seal, such as an O-ring over flat gasket. Another option to reduce the required bolt load is to reduce the distance between the gasket and bolts. Cutting an O-ring groove into the lid had mixed results. A stress concentration point near the bolt holes improved, but a ring of stress formed where the groove was cut.

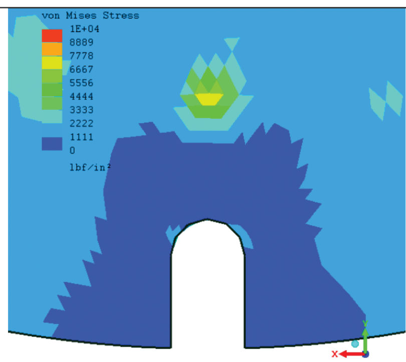
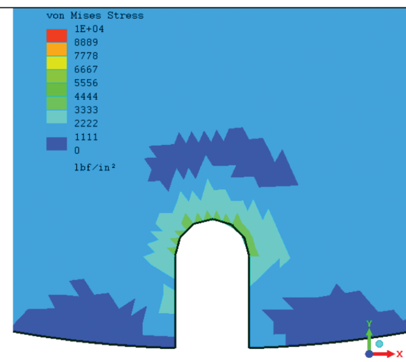
<table>
<tr><th colspan="3">Stress Concentration at Bolt Hole and Gasket Seat</th></tr>
<tr><th>Configuration
Max Stress</th><th>Bottom View</th><th>Top View</th></tr>
<tr><td>Reg. Washer
0.85” OD

Bolt Hole Stress
7,778 psi</td><td></td><td></td></tr>
<tr><td>Large Washer
1.25” OD

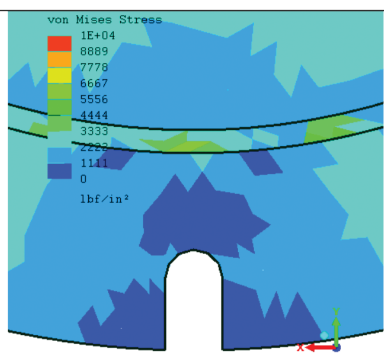
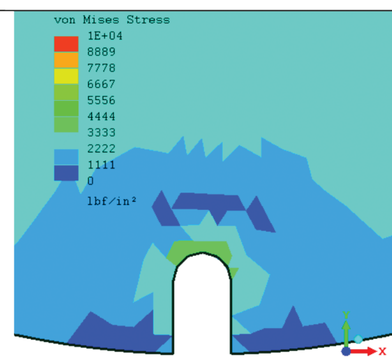
Bolt Hole Stress
6,667 psi

15% Reduction</td><td></td><td></td></tr>
<tr><td>Reduced Bolt
Load by 10%

Bolt Hole Stress
6,667 psi

15% Reduction</td><td></td><td></td></tr>
<tr><td>O-Ring Groove

Bolt Hole Stress
5,556 psi

30% Reduction of bolt hole stress but introduced ring of stress</td><td></td><td></td></tr>
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PRESSURE TAPS

Pressure taps on the outlet side of the basket strainer present a few issues. Issues include cracking, leaking, and confusing readings. The following discussion addresses these issues.

CRACKED PRESSURE TAPS

Pressure taps on the PVC/FRP strainer are standard PVC fittings. A ¼" PVC tap will have female National Standard Tapered Threads (NPT). When inserting the brass fitting of a pressure gage, the joint is easily cracked if threaded too far. The threads are tapered, which means the male threads act as wedge into the female fitting. Threading too far will exceed the stress limits of the fittings. Because PVC is much weaker than metallic fittings, threading a metal fitting in too far is very likely to crack the pressure tap.

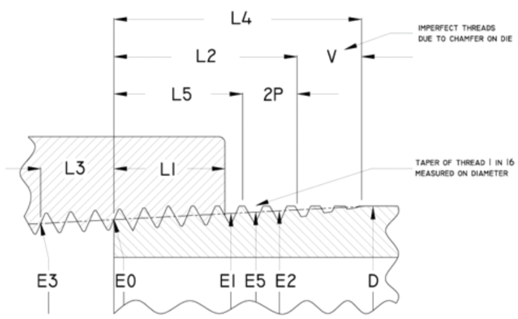


FIGURE 4.
National Standard Pipe Thread. Notice there is a 1.6° taper. Once the threads have been inserted to L1 the male threads will begin to deform the female fitting. To avoid damage to the female fitting, the male fitting should be made from a weaker material.

The rule of thumb for threading PVC fittings is hand tight plus 1–2 turns. Unfortunately, hand tight is ambiguous. The smaller the fitting the less torque is required for finger tight. Additionally, the use of lubricants will further skew one's ability to determine hand tight. The following table lists the NPT standards for thread engagement. Notice the two turn rule overstresses smaller PVC fittings. It is better to stop at hand tight and use larger fittings that are less sensitive to over torqueing.

National Standard Taper Pipe Threads on PVC Fittings

Nominal Size	Thread Per Inch	Thread Engagement (inch)	Turns Past Hand Tight	% Stress Limit
1/4	18	0.200	2	128%
1/2	14	0.320	2	121%
3/4	14	0.339	2	107%
1	11.5	0.400	2	105%
1¼	11.5	0.420	2	94%

LEAKING PRESSURE TAPS

Lasco Fittings, Inc., PVC fitting manufacturer, recommends using a non-lubricating, non-hardening sealant instead of Teflon tape. Teflon tape is its worst enemy. Applied incorrectly, it will crack threads causing small leaks. Users typically respond with more torque or more tape. Both actions increase the likelihood of splitting. Additionally, tapes and hardening pastes permit a leak path to develop when a joint is backed off, mechanically flexed, or expand with rising temperatures. Loctite makes a non-hardening compound that is forced by water pressure into potential points of leakage, thereby performing a true sealing function. It is currently used in the pool industry.

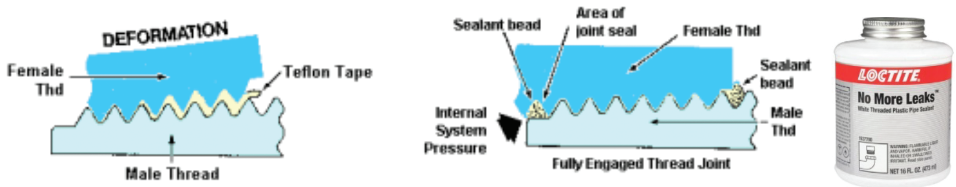
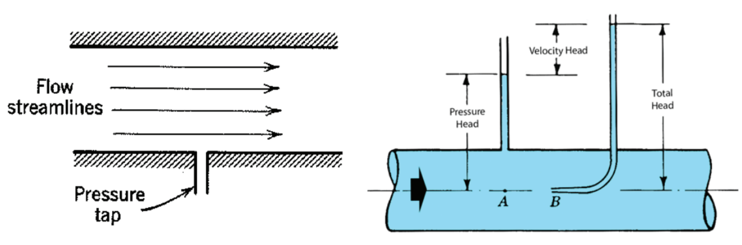


FIGURE 5.
Lasco recommends using a non-lubricating sealant applied before and after threads to avoid wedging or over torqueing. Teflon tape is often misused to lubricate PVC fittings, allowing users to over torque and deform fittings. Loctite makes a sealant designed for this application.

PRESSURE ACCURACY

The pressure tap location, penetration, and size affect the accuracy of the static pressure reading. Piezometer pressure taps should be parallel to the flow streamlines; otherwise, they will begin to measure dynamic pressure (force of moving fluid). The tap should be flush with the walls of the pipe and two pipe diameters away from any fittings. The size of the pressure tap is a balance between maintenance and accuracy. Smaller taps are less likely to create a hydraulic that skews readings; whereas, a larger tap is less likely to become plugged. The tap should also be free of burs, rounding the edges eliminates burs. The following figure lists the recommended tap parameters.



Nominal Size	Maximum diameter of tap	Radius of rounding	Distance from Fitting
4	1/2	1/32	8
6	1/2	1/32	12
8	1/2	1/16	16
10	1/2	1/16	20
12	1/2	1/16	24
14	1/2	1/16	28
16	3/4	1/16	32

FIGURE 6.
Piezometer pressure taps measure static pressure when applied correctly. The tap should be perpendicula to the flow lines for static pressure measurement. The B tap measures total pressure because it senses the velocity head, dynamic pressure. A wall tap drilled at an angle will measure a portion of the dynamic pressure and skew static pressure readings. The table list rules to assist with tap placement.

Basket Strainer Lid Cracking & Pressure Tap Analysis

Installing pressure taps on or near a reducer will measure dynamic head. A greater velocity will produce a larger error. An inclusion on the upstream side of the tap can create a hydraulic and negative pressure. An inclusion on the downstream side can create positive pressure. The figures below illustrate how dynamic pressure changes drastically for reducing strainers. Pressure taps used to identify a plugged basket should be placed on the strainer housing to avoid dynamic pressure issues.

Potential Error due to Dynamic Pressure at Outlet for 8" Reducer (psi)

Inlet Velocity (ft/sec)	Reducer Outlet Diameter 4	5	6	7	8
2	0.22	0.09	0.04	0.02	0.01
3	0.50	0.20	0.10	0.05	0.03
4	0.89	0.36	0.18	0.09	0.06
5	1.39	0.57	0.27	0.15	0.09
6	2.00	0.82	0.40	0.21	0.13
7	2.72	1.12	0.54	0.29	0.17

FIGURE 7.
Dynamic pressure can skew static readings. An 8″ inlet shown above with a 7 ft/s inlet velocity will have 2.72 psi dynamic pressure exiting a 4″ outlet. Incorrect tap positioning can create up to a 2.72 psi error, which is significant for low-pressure systems.

FIGURE 8.
SW Strainer and a RSW strainer pressure gradient simulation using Computational Fluid Dynamics (CFD) software. Notice the reducer is the major source of pressure drop because of the increased velocity. Pressure taps will give inaccurate readings when installed within 2 pipe diameters of pipe fittings.

RECOMMENDATIONS

Several options were presented to reduce stress on the lid. It is advised to use larger washers and either relocate or remove the vent. A lid stiffener will help if installation teams do not mind the extra hardware.

It is advised to reconsider pressure taps. The accuracy of static pressure readings is questionable near reducers and strainers even if perfectly installed. Relocation to the basket housing can provide a differential pressure across the filter media. All threaded PVC ports should be sealed with a non-lubricating, non-hardening sealant instead of tape. Larger taps and changing torqueing procedures should help reduce fitting cracking.