T-SEP: The Tube Contact Points

In developing the T-SEP Assembly™ (U.S. Patent No.: 9,732,884), Production Fastening Systems diligently considered the properties of all materials involved. Special attention was directed towards the non-metallic materials that would directly contact the tubing.

The two materials that make direct contact with the tubing are Acetron GP (Delta Bar) and Delrin 527 UV (Tube Spacers).

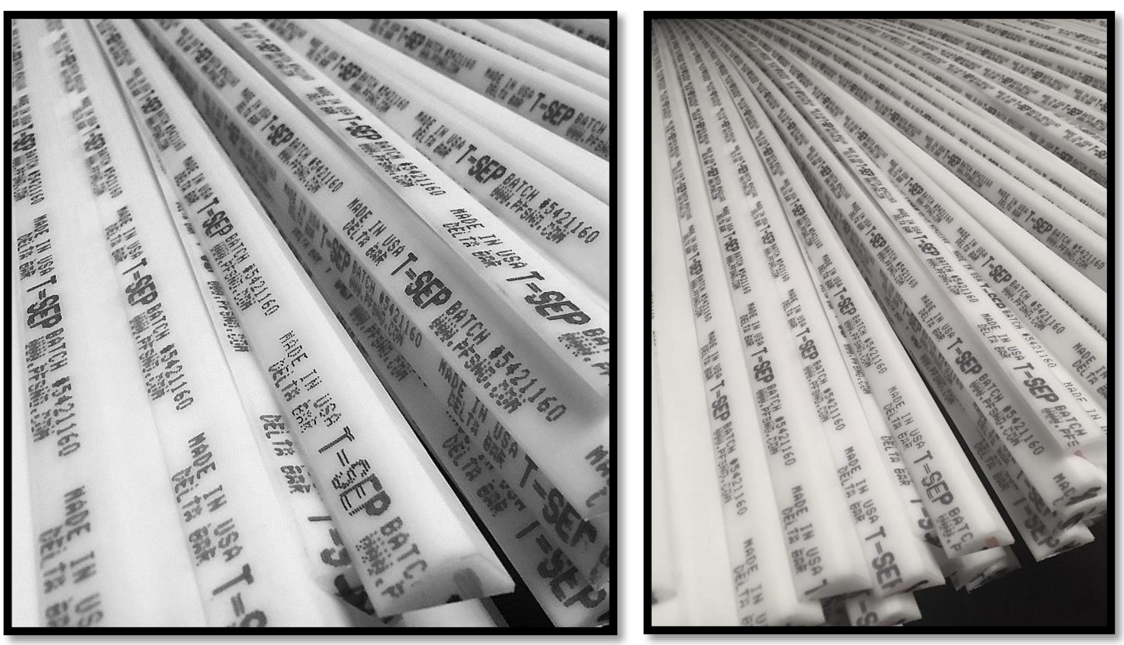
To best recognize the decision to use Delta Bar material, it is imperative to understand the principles of porosity and hygroscopicity.

Porosity: The impact of pores in plastics, meant to support weight and pressure in the offshore environment, is highly important. The existence of pores creates the opportunity for a structure to hold a gas or liquid.

Porous   Non Porous

Hygroscopicity: The existence of pores introduces characteristics of hydroscopicity or the ability to hold liquid. The ability to hold liquid is not ideal in offshore surroundings due to the nature of liquids in this environment. Salt spray and other chloride impurities can quickly compromise the integrity of acetals, especially those acetals under compressed force.

Delta Bar



The Purpose: Acetron GP was selected as the material for PFS Delta Bar because it represents the most durable and resilient fastening platform for pneumatic tubing. From Delta Bar's physical properties, to its chemical makeup, and geometry; PFS stands by Delta Bar as the industry standard for fastening pneumatic tubing. The purpose of Delta Bar is to clamp tubing in place. That being said, the material must have high compressive strength, no porosity

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or hygroscopic acceptance, resistance to high temperatures and be resilient to harsh environments. Acetron GP meets all of these marks.

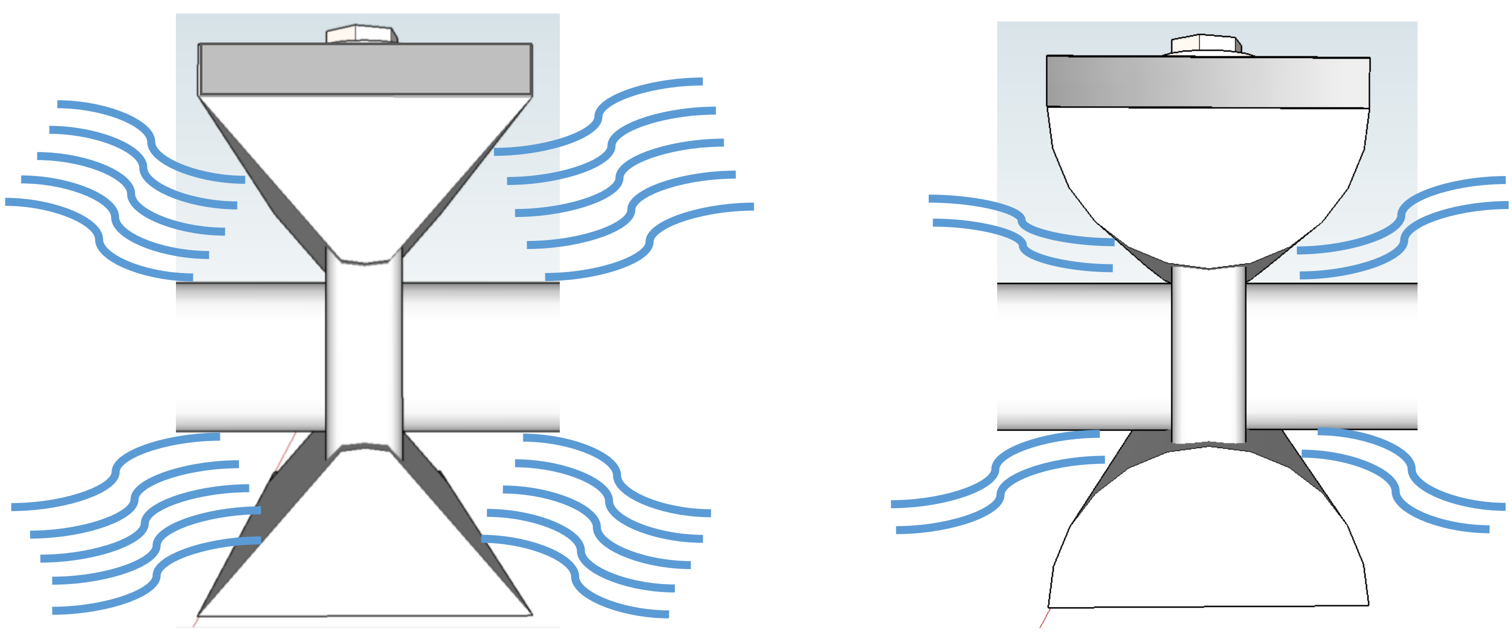
The Material: PFS Delta Bar is manufactured from Acetron GP, a high density copolymer acetal and the only porosity-free acetal product manufactured today. Acetron GP provides the performance and machinability of acetal without the center core porosity. The in-line manufacturing process and photometric quality procedure assures every rod is porosity-free and therefore non-hygroscopic.

- ✓ <u>Compressive Strength:</u> Testing Method: D695 Value: 15,000 psi
- ✓ <u>Porosity:</u> Non-porous
- ✓ <u>Hygroscopicity:</u> Non-hygroscopic
- ✓ <u>Melting Point:</u> 335˚ F

The Geometry: In terms of preventing liquid corrosion, elevating tube runs off of flat surfaces is as paramount as separating them from one another. When fastened directly to a flat surface, the opportunity for long lasting contact with corrosive liquids rises. Delta Bar is extruded from 1" round bars and machined into 1/2" delta shaped rods. To avoid creating crevices above and/or beneath the tube runs, which could harbor corrosive materials and go unseen, PFS avoids notching the Delta Bar. Notched rods also present installation issues due to the lack of a temporary fastening resource. The signature PFS delta shape achieves three major goals:

1. **Strength:** The triangular shape provides the strongest geometry possible. When force is applied, it is evenly dispersed through all three sides.
2. **Impact:** The summit of the delta, where tubes will engage, is slightly rounded to lessen the impact point.
3. **Airflow:** Perhaps the most important aspect of this equation is maximizing airflow. Increased airflow prevents oxygen starvation, a process where stagnant air smothers its surroundings due to lack of airflow and often results in rapid corrosion and pitting of the tubing. In similar fastening applications, a half-round structure is utilized to clamp the tubing. Beyond being a weaker geometry, half-round structures also allows less airflow at the points of contact.

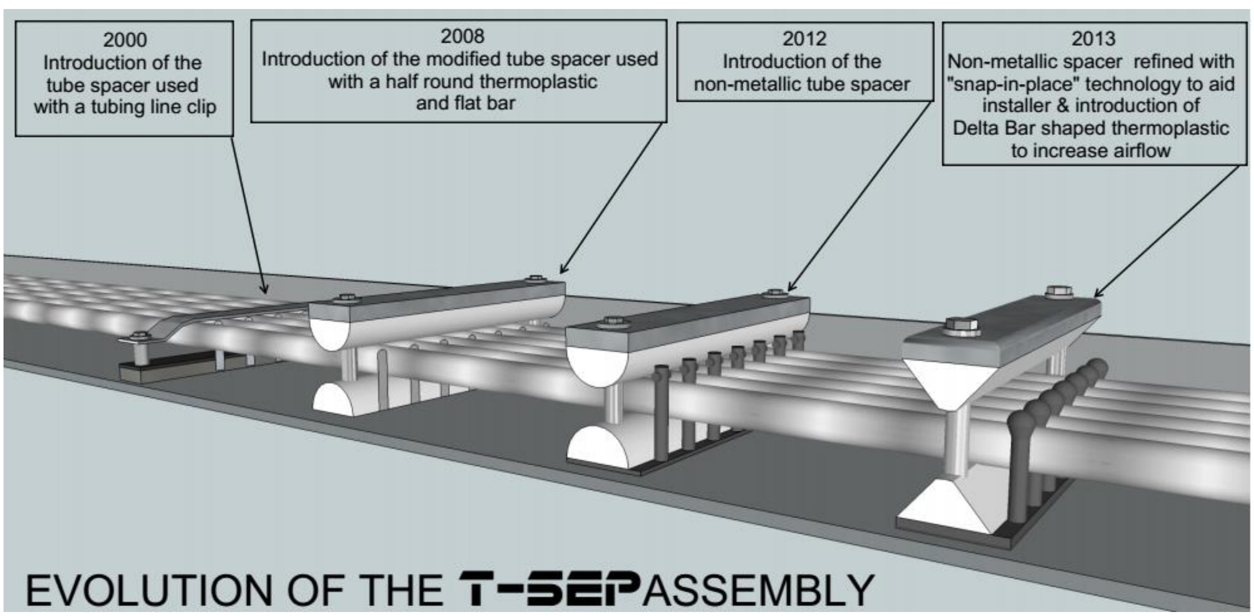
Airflow Comparative (Delta Shaped vs. Half-Round)



Tube Spacers

The Purpose: The PFS tube spacers are the backbone of the T-SEP Assembly. Because multiple tube runs are typically situated in parallel formation, constant contact has been a result of this fastening method. PFS was approached in 2000 with the task of separating tube runs with a minimal contact point fastening system. The idea of a physical spacer has been refined over time and is something PFS will continue to asses. The spacer began with stainless steel spacers and tubing line clamps in 2000 before adding half round rods in 2008, which lead to the introduction of non-metallic spacers in 2012 and now the current T-SEP assembly version.The spacer has continued to be refined for over a decade with one purpose in mind- to most efficiently separate tube runs from each other while keeping in root goals in focus:

1. **Minimal surface contact** at the points of fastening
2. Allow **maximum visual inspection** opportunity at the fastening and separation point
3. Be **environmentally resilient** against UV, salt/ chlorides and other fluids
4. Help **prevent oxygen starvation** by allowing significant air flow



PFS continued to expound on the efficiency of T-SEP through enhancements made to the tube spacer geometry.

The Material: The PFS tube spacer material is manufactured from Delrin 527UV. This medium viscosity black acetal homopolymer resin with UV stabilizers and thermal stability serves as an ideal option for separating pneumatic tubing. Because the spacer's #1 goal is to keep tubing aligned and separated, compression strength was less important than structural strength, shape memory, UV resistance, and flexibility. Delrin 527UV allows installers to install and remove tubing without serious risk of breaking spacer tines. This material has excellent shape memory and allows the spacers to flex back and forth while the installers conduct bends and positioning tasks common in the instrumentation installation process.

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The Geometry:

The tube spacer's geometric design is the result of years of research, recommendations and insights from engineers and installers. The base of the spacer is 1-3/16" wide to allow a flush platform for the 1" Delta Bar base to rest on while the 3/16" spacer tines protrude upward unimpeded. The cylindrical shape of the tines provides a round-on-round contact point with the tube in order to create the smallest interaction point possible and to maximum airflow space and inspectability. The 3/16" diameter thickness provides the necessary stability to complete an installation without fear of breaking off tines in the process. A ballard-shaped enlargement atop the spacer tines creates a snap-fit installation. This design asset, lauded by installers, allows installers to snap tubing in place for temporary hold until the top retainer is fastened with hardware provided with the assembly. The design also allows the installer(s) to necessitate less hands while performing the final fastening process. The spacer's strength will increase with each new tube when lodged between runs.

Flat Bar, Hardware, 3M double coated polyethylene foam tape

The remaining elements of the T-SEP Assembly do not make direct contact with the tubing and consist of the top flatbar, hardware and 3M double sided tape. The flat bar and hardware are all manufactured from stainless steel grade 316. 3M double coated polyethylene foam tape is utilized to temporarily attach the flat bar to the top retainer Delta Bar and to attach the tube spacer to the bottom retainer Delta Bar.

Putting T-SEP to the Test:

SWAAT and Thermal Exposure Testing

In July 2015, PFS subjected the T-SEP Assembly to a salt spray and thermal exposure test. The assembly consisted of (x8) 3/8" diameter tubes manufactured from super duplex 2507 tubing. The assembly was mounted to 6" wide X 6" long fiberglass channel tray using SS316 hardware for clamping. The salt water exposure test procedure, based on ASTM G85 Annex 3, can be used to test the relative resistance to corrosion of decorative chromium plating on steel and zinc based die castings, when exposed to an acetic acid salt spray climate at an elevated temperature.

Test specimens are placed in an enclosed chamber, and exposed to a changing climate that comprises of the following 2 part repeating cycle. 30 minutes exposure to a continuous indirect spray of acidified (pH 2.8 to 3.0) synthetic seawater solution, which falls-out on to the

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specimens at a rate of 1.0 to 2.0ml/80cm²/hour. This is followed by 90 minutes exposure to a high humidity climate of above 98%RH. The entire test cycle is at a constant chamber temperature of +49C which may be reduced to +24 to +35C for organically coated specimens). The number of cycles repeats 21 times. This test is also referred to as a SWAAT test.

The thermal exposure procedure test was based on DS EN 60068-2-52. This procedure can be used to test the relative resistance to corrosion of components or equipment, when exposed to a changing climate of a salt spray mist, followed by a high humidity at an elevated temperature.

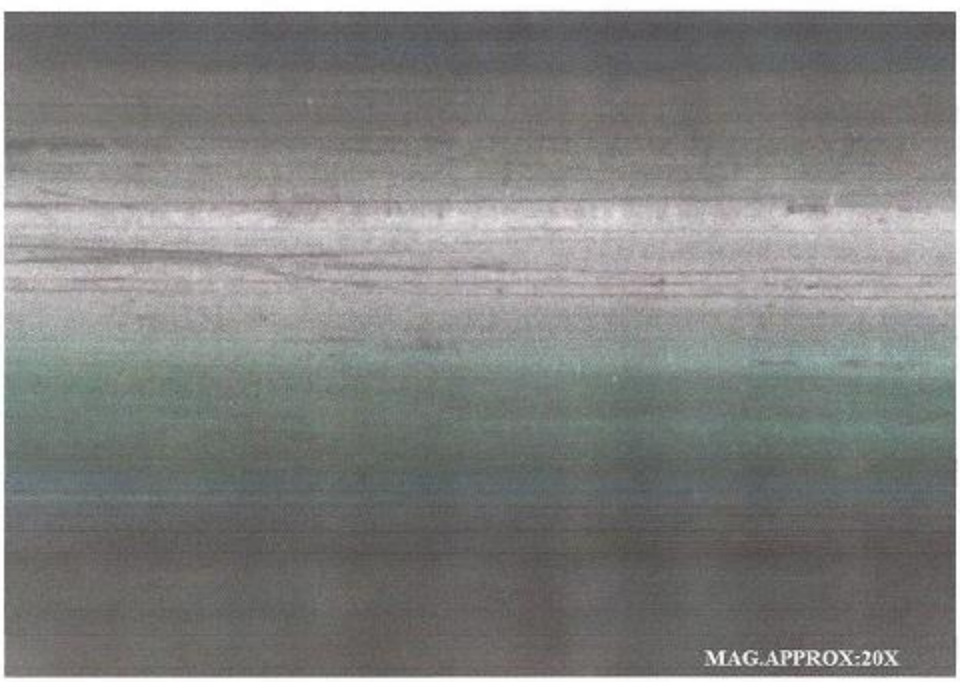
Test specimens are placed in an enclosed chamber, (a separate salt mist chamber and controlled humidity chamber are generally used), and exposed to a changing climate that comprises of the following 2 part repeating cycle: 2.0 hours exposure to a continuous indirect spray of neutral (pH 6.5 to 7.2) salt water solution, which falls-out on to the specimens at a rate of 1.0 to 2.0ml/80cm²/hour, in a chamber temperature of +15 to +35C. This is followed by 5 days exposure to a high humidity climate of 93%RH, in a chamber temperature of +40C. The number of cycle repeats is variable depending on the test severity. One storage period of three days at 21C - 25C at 45% - 55%RH is also required.
After testing was completed, the tubes were observed for corrosion attack and a macrograph X20 was performed.

Results:
Parts exhibited isolated red rust on the assembly nuts and washers, however, **no attack was observed on the tubes.**

"ASTM G85 Annex A3 – Seawater Acidified Test, Cyclic"

BS EN 60068-2-52 Environmental Testing Part 2 Tests - Test Kb: Salt Mist, Cyclic

PHOTOMACROGRAPH



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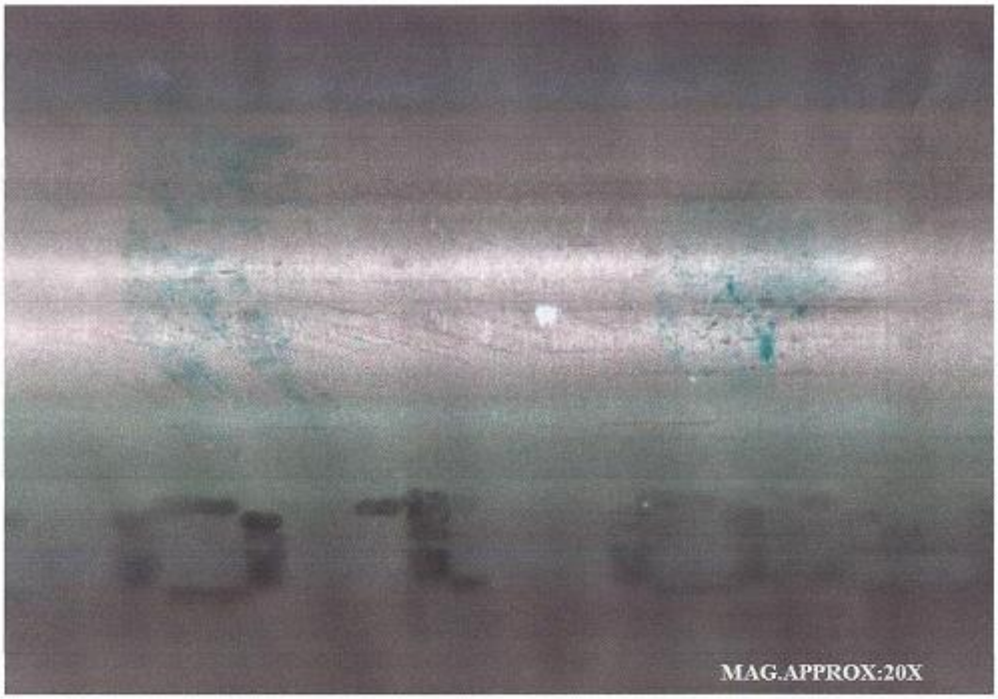
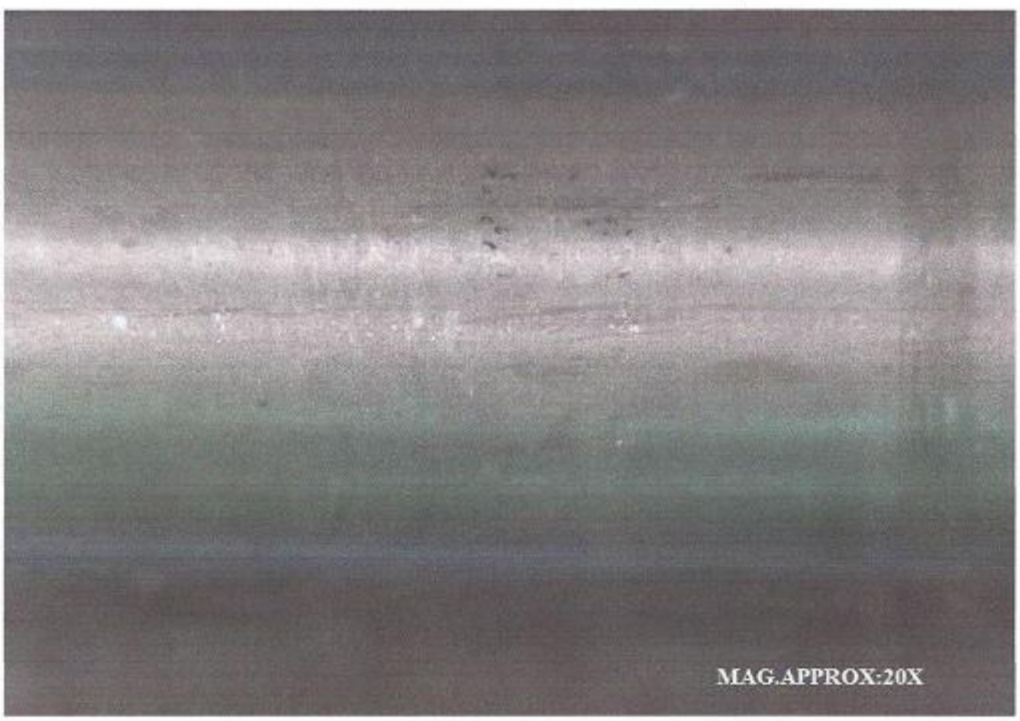
The above photograph shows the contact point of the Bottom Tube Alignment Section to the Duplex Tubing
See #1 on Exploded View Image Below

PHOTOMACROGRAPH



The above photograph shows the contact point of the Top Retainer Section to the Duplex Tubing
See #2 on Exploded View Image Below

PHOTOMACROGRAPH



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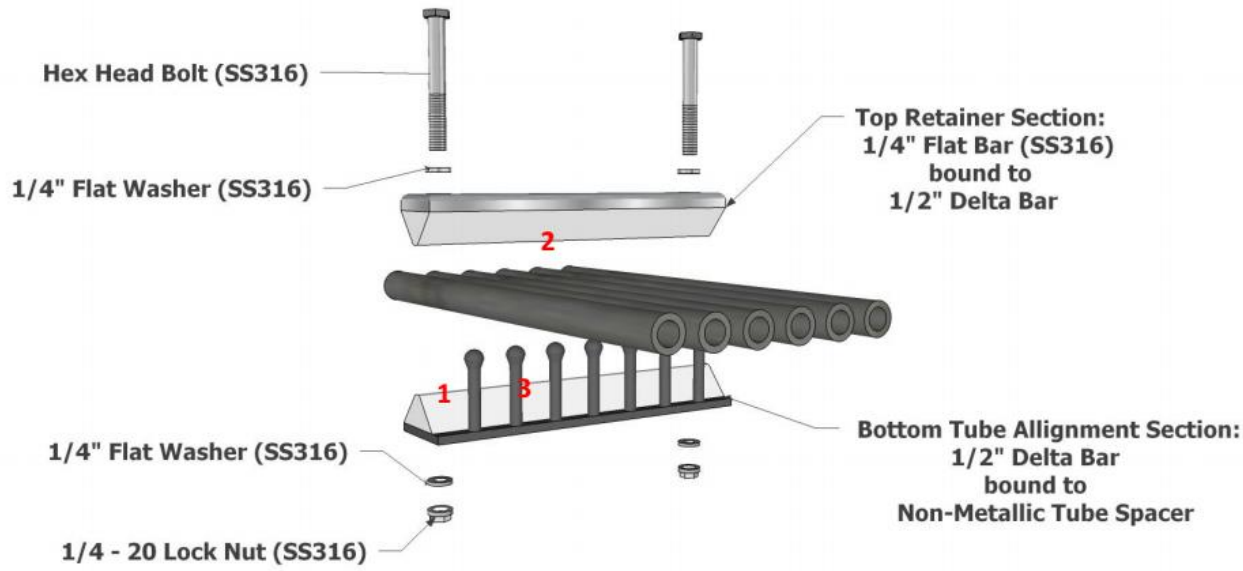
The above photograph shows the contact point of the Tube Spacer to the Duplex Tubing
See #3 on Exploded View Image Below



Exploded View

Recap

1. Round-on-round positioning for minimal surface contact.
2. Allows 360° visual inspection of tubing.
3. Offers a complete and stable platform mounted to channel, ladder tray or PFS Slotted T-Bar tube support.
4. Environmentally resilient against UV light, salts/chlorides and other fluids.
5. Helps prevent oxygen starvation by allowing significant air flow throughout the assembly.
6. Helps prevent dirt and chloride accumulation on the tube surface due to three dimensional positioning of horizontal and vertical separators.
7. Employs snap fit technology to assist in stabilizing tubes during installation.
8. NO crevice or notches exists where corrosive materials will accumulate unseen thereby initiating crevice corrosion.

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