PROJECT REPORT

Title: High Flex XLR Studio Cable.		
Date: 05/19/2017	Project Number: PDC2882, PDC2841	Report Number:
Author(s): Galen Gareis		Manager Approval:
Keywords: ICONOCLAST™, FLEX, MIC, STUDIO, XLR, IMPACT, CRUSH		
Lab Report Number(s): 177462, 177475		

Distribution: Subject File, ICONOCLAST™

BACKGROUND: The development of the ultra-low R, L and C ICONOCLAST™ home studio XLR cables exceeded design expectations and performance numbers reached. The patented use of true air tube dielectrics enabled electrical performance relative to size that is unattainable any other way.

The drawback to the pure performance ICONOCLAST™ design, is that the ultimate electrical performance does require a mechanical limitation in the cable's use that is wholly managed in the home audio space as performance is needed above all else, and in a more controlled and fixed installation.

The move to a STUDIO and professional market seems nearly impossible to reach the same size and electricals as the home market design. This paper covers the unique and high performance electrical XLR design that also meets, and exceeds electrical expectations for such a strong, flexible, crush and impact tolerant design.

BODY: The most difficult task was the design move from foamed Teflon with solid Teflon belting in the original design to a MUCH more ruggedized version for the studio market. The careful design of the AIR TUBE dielectric used for home use cables improve the cable's air tube physical performance (resist deformation and physical changes under use and to advise bend limits). Changing the process variables (bonding the outer tube to the inner filler) and materials (use a modified POE, Poly Olefin Elastomer) allowed a remarkably tough, flexible and crush resistant core structure. The POE's electrical characteristics were mitigated, as was the Teflon's in the home ICONOCLAST XLR), by putting AIR between the conductor and the solid dielectric materials. Where the dielectric materials were required to touch the wire the lowest dielectric material was kept in place, Teflon)

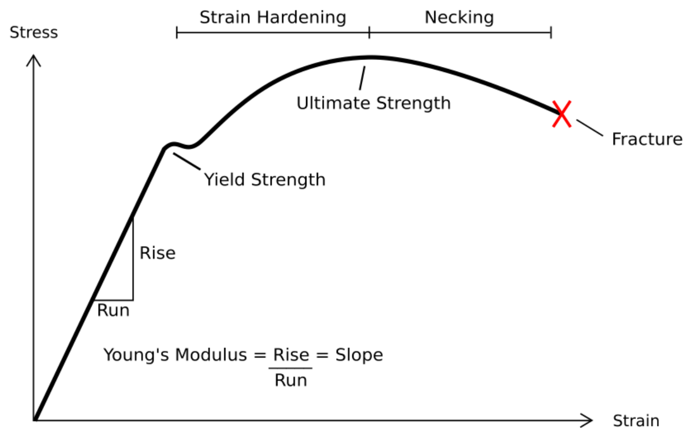
The selection of materials was important on two front; modulus of elasticity and dielectric properties. If either was deficient, the design will not work.

ELASTIC MODULUS – The modulus of elasticity (also known as the elastic modulus, the tensile modulus, or Young's modulus) is a number that measures an object or substance's resistance to being deformed elastically (i.e., non-permanently) when a force is applied to it. The material has to stretch or compress but with a high force (lower modulus) applied. This is called elastic deformation.

The chart below shows the graphical properties of plastic deformation. We need to work in the LINEAR region so the part will recover back to its original shape.

https://en.wikipedia.org/wiki/Deformation_(engineering)#Elastic_deformation – definition.
Linear elastic deformation is governed by Hooke's law, which states:
σ = E Where is the applied stress, E is a material constant called Young's modulus or elastic modulus, and ε is the resulting strain. This relationship only applies in the elastic range and indicates that the slope

of the stress vs. strain curve can be used to find Young's E). Engineers often use this calculation in tensile tests. The elastic range ends when the material reaches its yield strength. At this point plastic deformation begins.



In order to resist plastic deformation under tensile and compressive load simultaneously, a material with a high elastic modulus would be best. The material selected was DOW ENGAGE 8450

Mechanical	Nominal Value (English)	Nominal Value (SI)	Test Method
Tensile Modulus - 100% Secant [1] (Compression Molded)	1060 psi	7.30 MPa	ASTM D638
Tensile Strength [1] (Break, Compression Molded)	3250 psi	22.4 MPa	ASTM D638
Tensile Elongation [1]			ASTM D638
Break, Compression Molded	750 %	750 %	
Flexural Modulus			ASTM D790
1% Secant : Compression Molded	11100 psi	76.3 MPa	
2% Secant : Compression Molded	11000 psi	75.6 MPa	
Elastomers	**Nominal Value (English)**	**Nominal Value (SI)**	**Test Method**
Tear Strength [2]	515 lbf/in	90.2 kN/m	ASTM D624
Hardness	**Nominal Value (English)**	**Nominal Value (SI)**	**Test Method**
Durometer Hardness			ASTM D2240
Shore A, 1 sec, Compression Molded	90	90	
Shore D, 1 sec, Compression Molded	41	41	

The new part had to meet the same SIZE requirement for XLR compatibility as the TEFLON part, so material properties are extremely important. The PHOTOs below show the TEFLON part on the left and the DOW8450 part on the right.

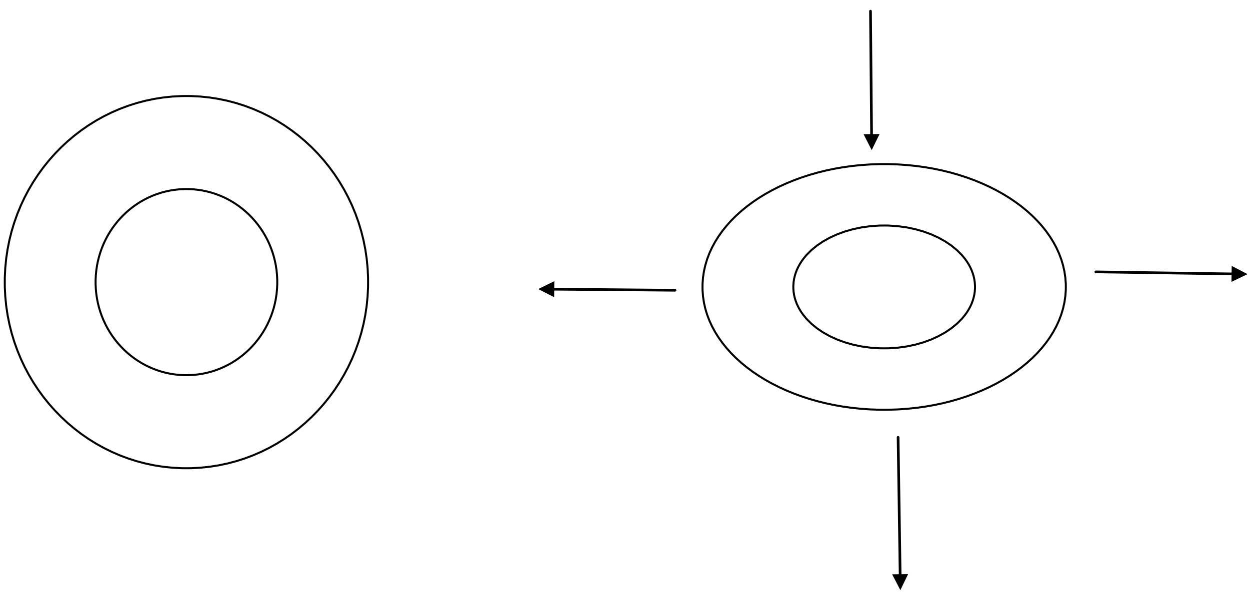
A very important design change other than the material was to BOND the outer POE material tube to the inner POE filler. This required a SOLID material to also enhance the YOUNG's modulus of the overall part. Bonding the two parts, the filler and tube, is much more critical than it seems for the intended application of this part. In order to meet crush and impact resistance with the part, it had to be bonded to SIMULTANEOUSLY be crushed and stretched concurrently.

When a tube is crushed, the sides will EXPAND in dimension. The inner filler X-design provides a high degree of tensile resistance to this elongation change, improving the parts deformation resistance. Once the force is removed, the part pulls back into its original shape. This is why a high 1060 PSI material is needed with a LARGE elongation percentage; 750%.

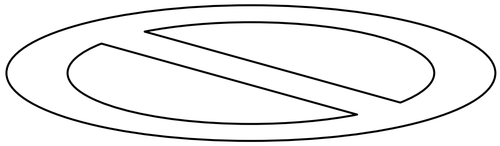
TEFLON PART - no interface bonds.

POE PART with interface bonds.

The pictures below illustrate the TUBES properties under compression. With no filler in the center, the tube will crush as easily as the material properties allow. To SIGNIFICANTY improve the crush values, an inner BONDED member is added across the lines of force.



The inner member resists the expansion of the part due to compressive loads. The above “POE PART” adds TWO cross members for the air channels and strands the cable with a helix lay so under compression there is always a cross member restricting the parts expansion under load.



In the above example, the cross member goes under TENSION when the tube is compressed. This HOLDS the tube's deformation in check, and more importantly, it has a MEMORY to what it was prior to crush, and the high elastic modulus pulls the part back into the original shape under normal compressive loads. The cable "heals" itself back to its original form. The core is tightly stranded to make sure there are always a cross member perpendicular to the load vector direction and / or TWO members largely perpendicular to the load vector.

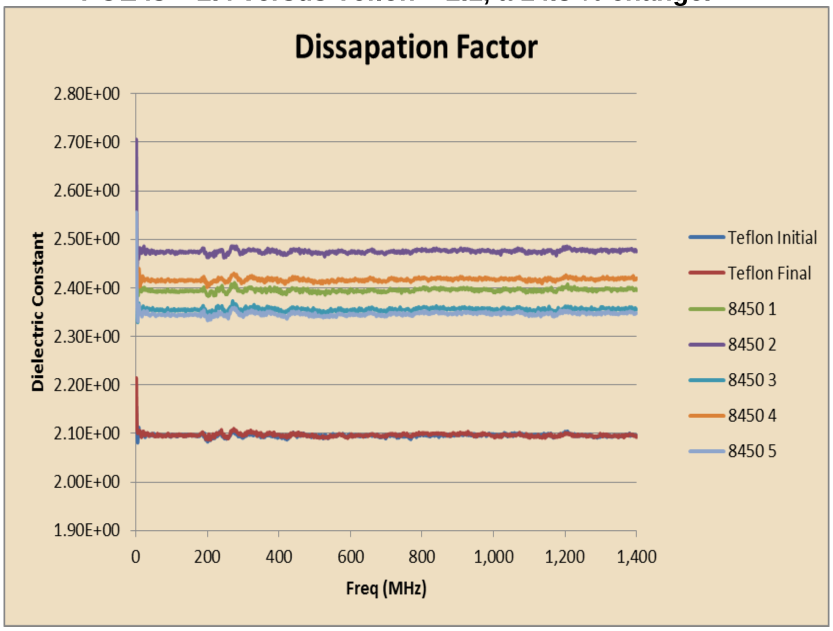
Part is tightly STRANDED to place X-web in ideal location for compression performance and recovery.

When a part is tightly bent, it is under COMPRSSION (inner surface) and TENSION (outer surface) This hybrid part is ideally made to resist this type of plastic deformation, and recovery.

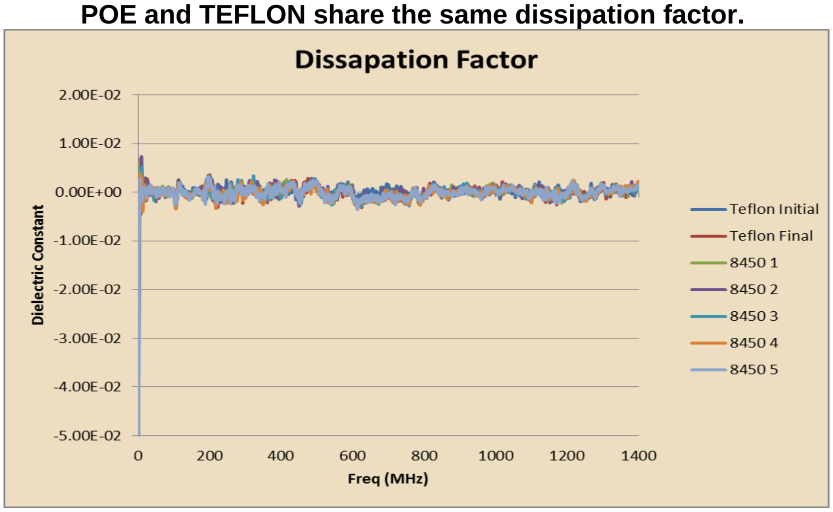
Since we had to use a SOLID material for ultimate Tensile / Elongation properties of the part the dielectric properties are going to be impacted to some degree. Is the erosion in electrical properties going to allow the overall high electrical standards that are also required of the finished part?

Material samples were taken, along with the TFELON reference and measured for dielectric properties. The tables below show the excellent measured electricals relative to TEFLON. We should see minimal electrical impacts in the Audio frequency range with the exception of CAPCITANCE which is directly tied to the dielectric material. But, the use of AIR TUBES mitigates the changes of capacitance.

POE is ~ 2.4 versus Teflon ~ 2.1, a 14.3 % change.



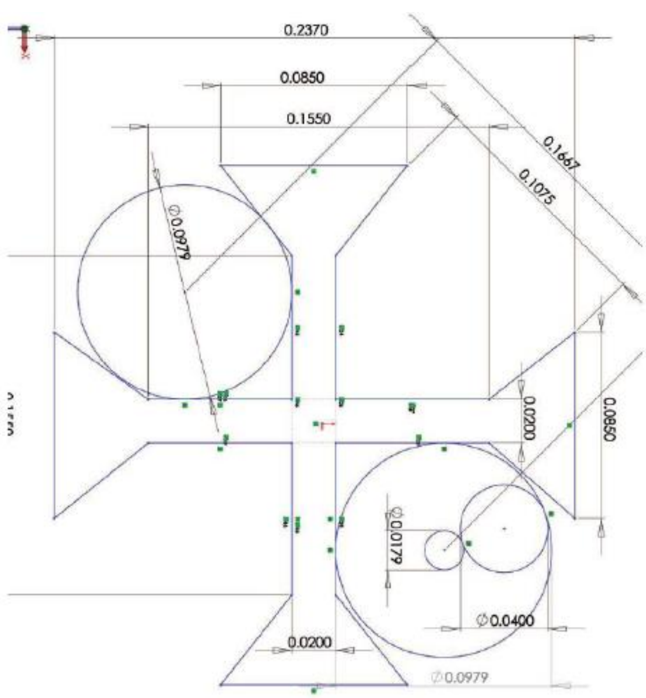
POE and TEFLON share the same dissipation factor.



The capacitive effect is logarithmic so the farther the material is from the reference metallic member the lower the capacitive effects. Twice the distance is one-fourth the effect. We have AIR inside the part, which is the best dielectric there is. Where material does contact the wire, we use a TEFLON thread to mitigate the capacitive effect of the wire, to thread, to outer POE material tube.

Where the magnetic fields are strongest, near the wire surface, we need AIR and or minimal dielectric influences (use TEFLON thread). The outer influences decrease significantly with distance. If a surface in infinitely away from the conductors, the electromagnetic effects are zero. The use of AIR as a dielectric (constant = 1) allows “infinity” to be reached much sooner than if higher dielectric constant materials are used between ground plane (conductor to inner braid surface). The task is how to do this and allow extreme durability and flex, while meeting superb measured electricals. The careful positioning of material is necessary.

AIR spaced CONDUCTORS with FEP TEFLON THREAD SPACERS.



The overall GROUP delay is the superposition of ALL the material between the conductor and outer braid. The use of AIR keeps the VP and capacitance changes in control per measurements below on a braided core.

Capacitance @ 1 kHz per ELP 423, Agilent E4980 Precision LCR Meter, Belden 4TP Cap/Ind Test Fixture
Cap @ 1 kHz Spec est: 8.0 +/- 2.0 pF/ft nom   60485Y – 8.95 pF/ft

Inductance @ 1 kHz per ELP 424, Agilent E4980 Precision LCR Meter, Belden 4TP Cap/Ind Test Fixture
Inductance Spec: NA (uH/ft)   60485Y – 0.15 uH/ft

Velocity of Propagation (VOP) per ELP 392, HP8751A Network Analyzer, HP VEE Instrument Control Software with Velocity of Propagation program and a GPIB card installed.
VOP Spec est: 87 +/- 1 %   60485Y – 84.7%

JACKETED TEST of PD2882
Capacitance @ 1 kHz per ELP 423, Agilent E4980 Precision LCR Meter, Belden 4TP Cap/Ind Test Fixture
Cap @ 1 kHz Spec: 10.5 pF/ft max   PDC2882 – 10.1026 pF/ft
Inductance @ 1 kHz per ELP 424, Agilent E4980 Precision LCR Meter, Belden 4TP Cap/Ind Test Fixture
Inductance Spec: NA (uH/ft)   PDC2882 – 0.1542 uH/ft
Velocity of Propagation (VOP) per ELP 392, HP8751A Network Analyzer, HP VEE Instrument Control Software with Velocity of Propagation program and a GPIB card installed.
VOP Spec: NA (%)   PDC2882 – 83.4%

The above tested numbers are excellent compared to the CONTROL all FEP design. The estimate capacitance is negligible with nearly the same group VP;

SUPER FLEX MIC CABLE	ICONOCLAST™	LLDPE DESIGN
8.95 -10.5 pF/foot (PIN 2 -3)	5.5 pF/foot	9.44 pF/foot (PIN 2 -3)
0.15 – 0.154 uH/foot	0.15uH/foot	0.153 uH/foot
83.4 - 85%4 nominal VP	87%	84.2%
Dia. 0.350"	Dia. 0.325"	Dia.0.350"

A cable can be crush resistant and impact resistance but STILL be too inflexible for the intended use. This is called the BENDING MOMENT. Or, the amount of force to bend the cable ninety degrees around a specified reference mandrel when comparing cable types. This cable is EXTREMELY flexible and bends ninety degree under its own weight (illustration).

FLEX UNDER STATIC WEIGHT TEST

SUMMARY: The PDC2882 initial design trial has been extraordinarily successful at meeting electrical and physical design parameters. The design actually well exceeds expectations using the DOW ENGAGE 8450 material properties.

The PDC2841 LLDPE design met similar electricals, but fell far short on physicals.

We can run a full extrude jacket with paper tape separator to improve cosmetics (perfectly round) and enhance crush even more.

CONCLUSION: The DOW 8450 material design is the best electrical and physical XLR cable design for heavy duty studio application with extremely high audio standard properties for sound quality. The DOW 8450 inner core member should provide industry leading sound quality with the best durability possible. The cable's self-healing tensile modulus properties insure a higher degree of user abuse than any air core cable made today;

- Best dielectric near the wire is NO dielectric.
- We use AIR tubes, and tubes are usually STIFF by design.
    - 25 AWG signal wire insure high flexibility with a tight stranding lay.
- A special physical and electrical material was sought after and found for this design.
- Our BONDED perimeter air TUBE core solves the CRUSH and recovery issue.
- Air tubes are now an ADVANTAGE in a flex application.
- The target electricals were to be as near the all Teflon ICONOCLAST version as possible.
- We met that goal and with FAR, FAR superior physicals;
    - **Capacitance @ 1 kHz** per ELP 423, Agilent E4980 Precision LCR Meter, Belden 4TP Cap/Ind Test Fixture
    - **Cap @ 1 kHz Spec: 10.5 pF/ft max** **PDC2882 – 10.1026 pF/ft**
    - **Inductance @ 1 kHz** per ELP 42C, Agilent E4980 Precision LCR Meter, Belden 4TP Cap/Ind Test Fixture
    - **Inductance Spec: NA (uH/ft)** **PDC2882 – 0.1542 uH/ft**
    - **Velocity of Propagation** (VOP) per ELP 392, HP8751A Network Analyzer, HP VEE Instrument Control Software with Velocity of Propagation program and a GPIB card installed.
    - **VOP Spec: NA (%)** **PDC2882 – 83.4%**
- Fits Standard XLR with a 0.350" outer dimension.
- Cable exhibits standard XLR benefits of reduced external noise with passive CMRR design.
- Air dielectric insures the best possible conductor interface.
- Smaller signal wire insure better signal coherence (more even current distribution with respect to frequency)
- Star quad design double-up the CMA are to act like a larger wire for longer distances.
- CMRR keeps ingress noise low, even magnetic origin, with a tight strand lay (even exposure to external noise).
- 90% BC braid lowers EMI / RFI noise BEFORE it encounters CMRR on the four signal wires.
    - Wire should be purely resistive fore time coherence at audio but it isn't;
        - Low capacitance keeps reactive first order filter roll-off values well away from the audio band.
        - Low inductance improves reactive current related variables to a minimal reactance.