

AN INNOVATIVE FAMILY OF FORMABLE TUBE PRODUCTS

FORMTUBE® CR

FORMTUBE® AL

FORMTUBE® SS

FORMTUBE® 800 / 1000 / 1200

FORMTUBE® QHS

NEXTUBE® 1200



FORMABLE TUBE PRODUCTS

FORMTUBE® CR – Product Description

Designed for improved formability at a lower cost for Pressure Tube and other high ductility applications. Cost-effective alternative for J356 standard applications.

TUBE MECHANICAL PROPERTIES (minimums)

Yield Strength	Tensile Strength	Elongation
172 MPa	276 MPa	35%

TUBE MECHANICAL PROPERTIES (typical)

Yield Strength	Tensile Strength	Elongation
235 MPa	310 MPa	46%

ADVANTAGES

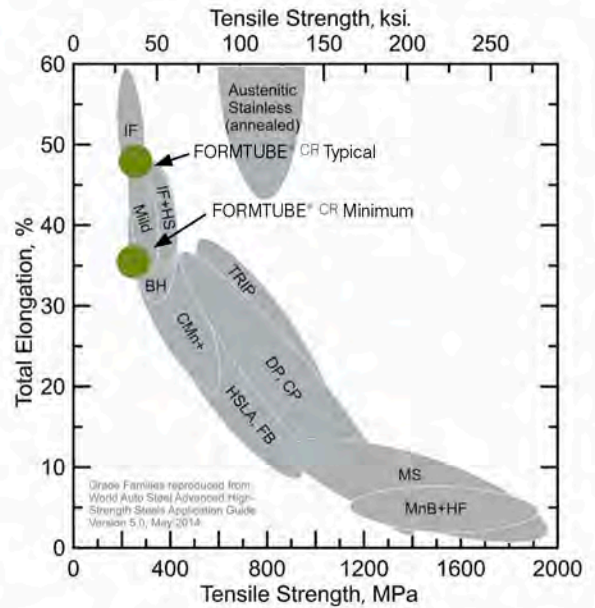
- Typical elongation of 46%
- Available as cold-rolled or aluminum-coated product
- Available in diameter-to-thickness (D/t) ratios up to 100:1
- Lower-cost alternative to annealed tube

APPLICATIONS

- Fuel filler neck
- Radiator tubes
- Fluid line tubing
- Vent tubes
- Exhaust tubes

SIZES

- 19 – 168 mm diameters
- 0.8 – 3.0 mm thickness



FORMABLE TUBE PRODUCTS

FORMTUBE® AL – Product Description

A highly-formable, aluminum-coated, carbon tubing available in extremely high D/t ratios, specifically designed for use in demanding exhaust applications that require tight 1XD bends. Proven to improve customer quality and reduce production costs. Meets ASTM A787.

TUBE MECHANICAL PROPERTIES (typical – 76 mm diameter)

Yield Strength	Tensile Strength	Elongation
220 MPa	296 MPa	44%

ADVANTAGES

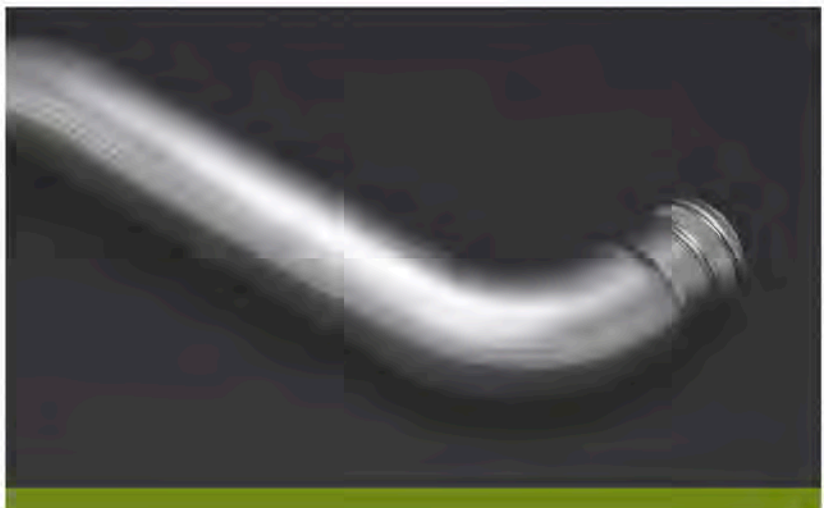
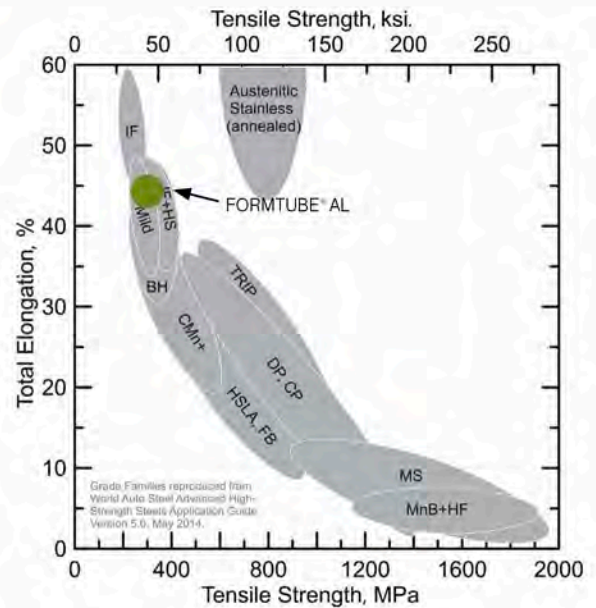
- High corrosion resistance in carbon tube
- Excellent heat reflectivity at temps less than 430 °C
- Material effective up to 680 °C
- Available in Diameter/t ratios up to 100:1

APPLICATIONS

- Automotive aftermarket exhaust tubular components
- OEM and aftermarket truck exhaust tubular components
- Coolant fluid transfer tubular components
- Heat Exchanger and HVAC tubular components

SIZES

- 19 – 168 mm diameters
- 0.8 – 3.0 mm thickness



FORMABLE TUBE PRODUCTS

FORMTUBE® SS – Product Description

Stainless steel tubing developed with superior formability. Available in 304L, 316L, 409, 436, 439, 441, 15 Cr-Cb™ and 18 Cr-Cb™. The 409 and 439 grades are available in aluminum coated versions.

TUBE MECHANICAL PROPERTIES (typical – 127 mm diameter)

Stainless	Yield Strength	Tensile Strength	Elongation
409	340 MPa	420 MPa	31%
439	370 MPa	475 MPa	29%
441	470 MPa	520 MPa	24%

ADVANTAGES

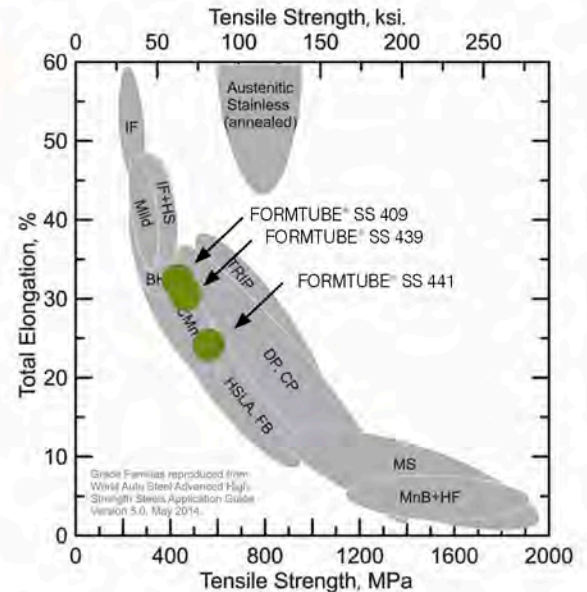
- Equiaxed grain structure improves forming and reduces customer scrap
- Uniform mechanical properties for repeated forming
- Minimal tube cold work allows maximum customer forming
- Aluminum-coated product available in 409 and 439 grades for increased corrosion resistance
- Available in D/t ratios up to 100:1

APPLICATIONS

- Automotive, truck and ATV/UTV exhaust tubes
- OEM Hot and cold end exhaust system tubular components
- Coolant fluid transfer tubular components
- Heat Exchanger and HVAC tubular components

SIZES

- 32 – 168 mm diameters
- 0.8 – 3.0 mm thickness



FORMABLE TUBE PRODUCTS

FORMTUBE® 800 / 1000 / 1200 and NEXTUBE® 1200 Product Description

Available in 600 / 800 / 1000 and 1200 MPa Tensile Strength Grades - both bare and galvanized coated versions. Multiple Multi-Phase Steel versions (including a Gen 3 option) allows flexible application for maximum finished part strength performance. Offered with the highest D:t ratios in the industry for superior design application. Excellent for lightweighting.

TUBE MECHANICAL PROPERTIES (typical - raw tube)

AHSS	Yield Strength	Tensile Strength	Elongation
DP 800	620 MPa	810 MPa	17%
DP 1000	730 MPa	1020 MPa	12%
MP 1000	870 MPa	1030 MPa	8%
DP 1200	1000 MPa	1270 MPa	8%
NEXMET® 1200	1050 MPa	1260 MPa	11%

Note: Typical bake hardening effect on Yield Strength - 7% increase

TUBE MECHANICAL PROPERTIES (typical - bake hardened tube)

AHSS	Yield Strength	Tensile Strength	Elongation
DP 800	680 MPa	810 MPa	12%
DP 1000	860 MPa	1060 MPa	10%
MP 1000	1000 MPa	1040 MPa	6%
DP 1200	1120 MPa	1265 MPa	7%
NEXMET® 1200	1120 MPa	1290 MPa	9%

Note: Final tube strength/elongation design dependent

ADVANTAGES

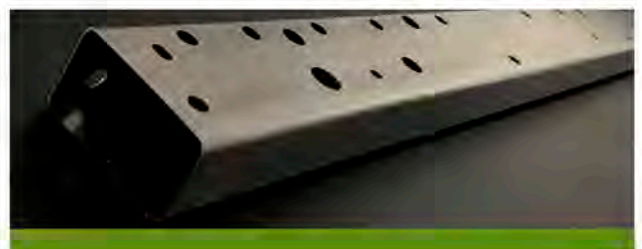
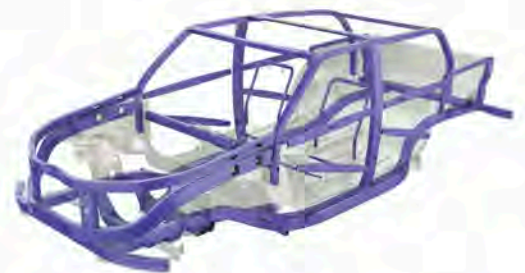
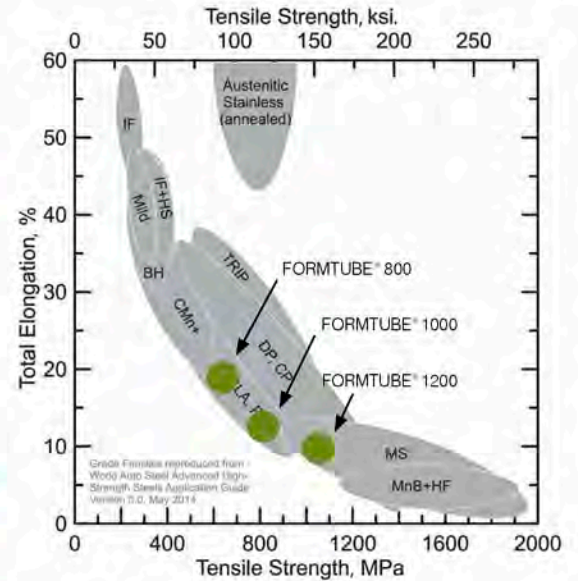
- High available D:t ratios - up to 100:1
- Smooth OD and ID cutting for efficient forming
- Lightweight alternative to current mild carbon or HSLA grades

APPLICATIONS

- Any structural application - including auto, truck, or power sports
- Lightweighting and/or crash management
- C-STAR® (Cliffs Steel Tubes As Reinforcement) assemblies

SIZES

- 19 – 168 mm diameter
- 0.9 – 2.5 mm thickness
- Round, conventional or complex shape



FORMABLE TUBE PRODUCTS

FORMTUBE® QHS – Product Description

Available in 1500 MPa and 2000 MPa Tensile Quench Hardenable Steel (QHS) grades. Designed specifically for tubular hot-forming, heat-treating and C-STAR® applications.

TUBE MECHANICAL PROPERTIES (typical – before Heat-Treating)

	Yield Strength	Tensile Strength	Elongation
QHS 1500	440 MPa	550 MPa	23%
*QHS 2000	470 MPa	660 MPa	22%

TUBE MECHANICAL PROPERTIES (typical – after Heat-Treating)

	Yield Strength	Tensile Strength	Elongation
QHS 1500	1100 MPa	1550 MPa	6%
*QHS 2000	1500 MPa	1900 MPa	5%

* QHS 2000 product under development

ADVANTAGES

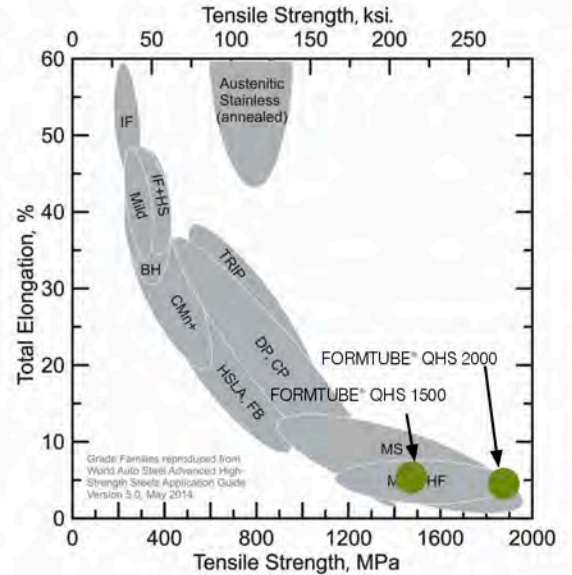
- Bare or Aluminum-coated product available
- Available in round or complex custom shapes
- Smooth cut ID and OD surface for precise mandrel bending
- Available in D/t ratios up to 100:1

APPLICATIONS

- Hot-formed structural components
- Impact beams, roof rails and pillars
- C-STAR® (Cliffs Steel Tubes As Reinforcement) assemblies

SIZES

- 19 – 168 mm diameters
- 1.0 – 3.5 mm thickness



* Note: Properties after hot-treating



TUBULAR COMPONENTS CAPABILITIES

Tube Mill Production

Tube Mills

- 11 Tube Mills
- 220K tons capacity (5 day)

Diameters

- 19.0 – 168.3 mm -> Carbon
- 31.8 – 168.3 mm -> Stainless

Wall Thickness

- 0.8 – 4.8 mm -> Carbon
- 0.8 – 2.8 mm -> Stainless

Cold Saw Cutting

Diameters

- 25.4 – 101.6 mm
- 1.00 – 4.00 inches

Lengths

- 25 – 2032 mm
- 1 – 80 inches

Wall Thickness

- 0.8 mm – unlimited
- 0.031 inches – unlimited

Laser Cutting

Diameters

- 19.0 – 152.4 mm
- 0.75 – 6.00 inches

Lengths

- 13 – 3050 mm
- 1/2 – 120 inches

Wall Thickness

- 0.8 mm – 4.8 mm
- 0.031 inches – 0.187 inches

Conventional Stainless Steel Grades

- All 200 Series
- All 300 Series
- All 400 Series
- Bare or Aluminum Coated

Conventional Carbon Steel Grades

- HR, CR, or HRPO
- Ultra Low Carbon through 1026
- HSLA 45 through 80
- Zinc Coated
- Aluminum Coated

Advanced High Strength Steels

- All MP & DP 600 to 1200
- All TRIP 600 to 700
- Quench Hardened Steels:
 - Bare or Aluminum Coated

3rd Gen Advanced High Strength Steels

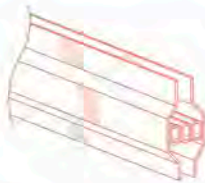
- NEXMET®1200
 - Bare or Zinc Coated
- NITRONIC® 30 Tensitized
 - Austenitic Stainless

C-STAR[®] PROTECTION

CLIFFS STEEL TUBES AS REINFORCEMENT – C-STAR PROTECTION – IS AN INNOVATIVE VEHICLE STRUCTURE STEEL SOLUTION

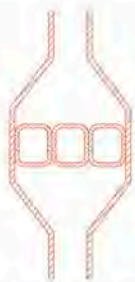
C-STAR PROTECTION FEATURES:

- Cost-efficiency and sustainability
- Scalability to meet different performance requirements
- Manufacturability
- Less product design space requirement

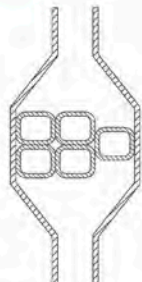


WHAT DO YOU WANT PROTECTING YOUR FAMILY, VEHICLE AND VEHICLE BATTERY?

Modern vehicles use a variety of structural components to protect both passengers and internal mechanical and electrical systems. In the event of a collision, you want the structural components to absorb energy and/or deform in a controlled and predictable way. Cliffs' Steel Tubes As Reinforcement – C-STAR[®] protection – used in combination with structural components, contributes to the ability for structural components to absorb energy and/or deform in a more controlled and predictable way.



Front cross-section of 3-tube stacked reinforced panel



Front cross-section of 5-tube stacked reinforced panel



Front view of C-STAR[®] steel design tested sample



Front view of comparative extruded aluminum design

For example, a C-STAR[®] structure may be used in electric, hybrid, or ICE vehicles as reinforcements in rocker panels to protect passengers and/or batteries from a side-impact collision. C-STAR[®] protection may also be used to protect motors, engines, electrical components, passenger compartments, storage compartments, and any area in a vehicle where this design is implemented. The specifics of the design can be varied to meet your performance criteria, such as by varying wall thickness, shape, configurations, orientation of the tubes, and/or steel grades. Suitable alternative applications may include reinforcement of, or functioning as, A-pillars, B-pillars, C-pillars, D-pillars, bumpers, roof bows, roof rails, cross members, window rails, and more.

In summary, C-STAR[®] protection is a configurable and scalable Advanced High-Strength Steel (AHSS) steel tube system used for occupant or battery protection, or protection in any other area in any type of vehicle. By varying design attributes as described above, C-STAR[®] Protection offers unlimited options to meet your performance criteria. Two distinct examples of C-STAR[®] Protection are shown on the upcoming pages, including the recently developed C-STAR[®] ONE design.

C-STAR® PROTECTION

Various C-STAR® Protection designs have been manufactured and compared in a three-point bending test against current production components that are made using extruded aluminum. In this first example, a C-STAR® Protection design utilizing three stacked rectangular tubes is compared to an existing aluminum design, simulating a side-impact collision. The involved application is a rocker reinforcement.

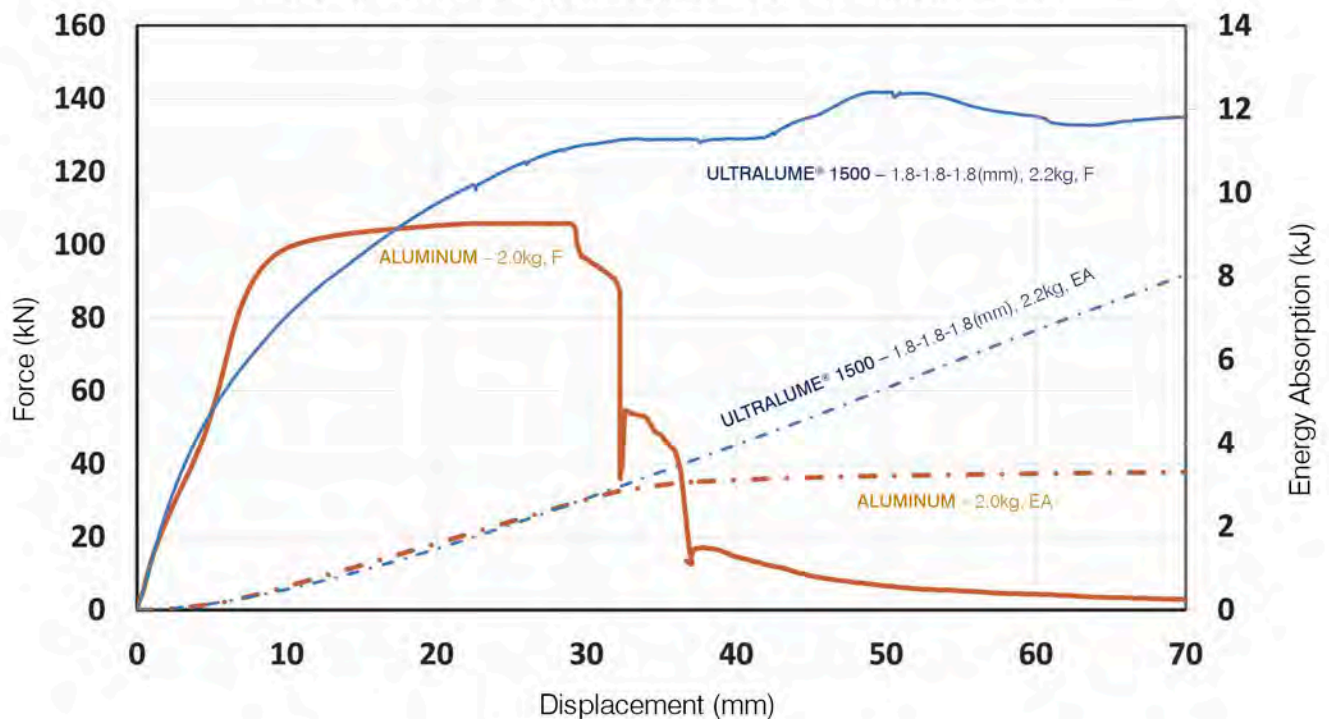


These photos were taken after completion of the test that generated the data shown below.

As shown below, in a three-point bending test, 1.8 mm ULTRALUME®1500 C-STAR® outperforms the baseline 6000 series extruded aluminum at peak force by 33%, with 10% higher mass. For energy absorption, C-STAR® matches the aluminum up to 33 mm when the aluminum collapses, and outperforms aluminum by 50% at 50mm displacement.

Offering superior performance at mass parity to aluminum, C-STAR® protection is the choice

Force (F) and Energy Absorption (EA) vs. Displacement

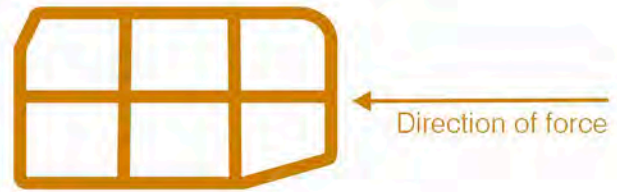


INTRODUCING C-STAR® ONE PROTECTION

C-STAR® ONE, a second-generation C-STAR® design, is a recent development from Cleveland-Cliffs' Advanced Engineering team that consists of a single specially shaped tube (patent pending). This avoids the need to weld tubes together and simplifies manufacturing while providing excellent protection. This application is also a rocker reinforcement. The cross-sectional images below show the unique design of C-STAR® ONE and the competing aluminum design.



C-STAR® ONE Design

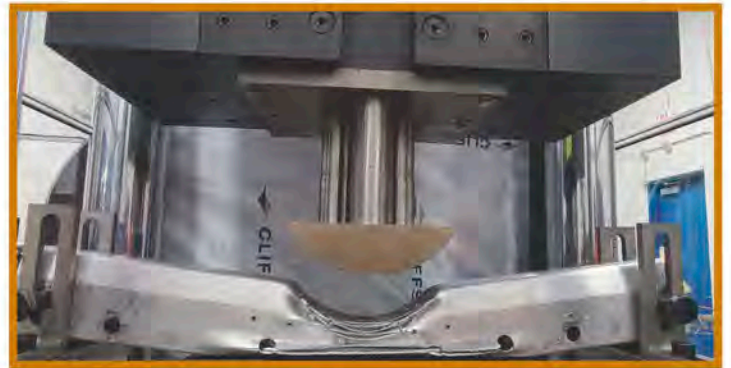


Competing Aluminum Design

In this example, the C-STAR® ONE design was made using 3.2 mm ULTRALUME® 1500 and is compared to another existing aluminum production design in a customized three-point bending test.



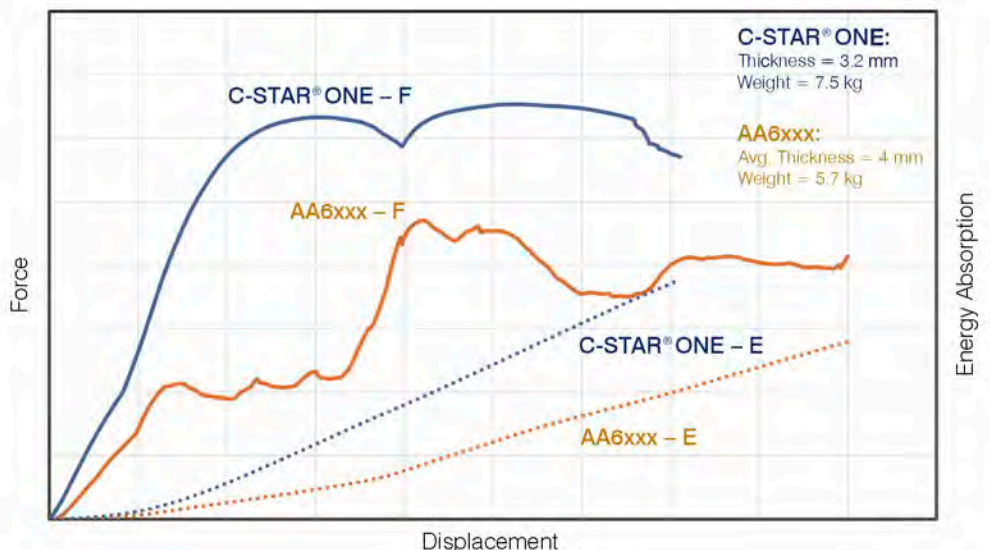
Testing the C-STAR® ONE design



Testing the Aluminum design

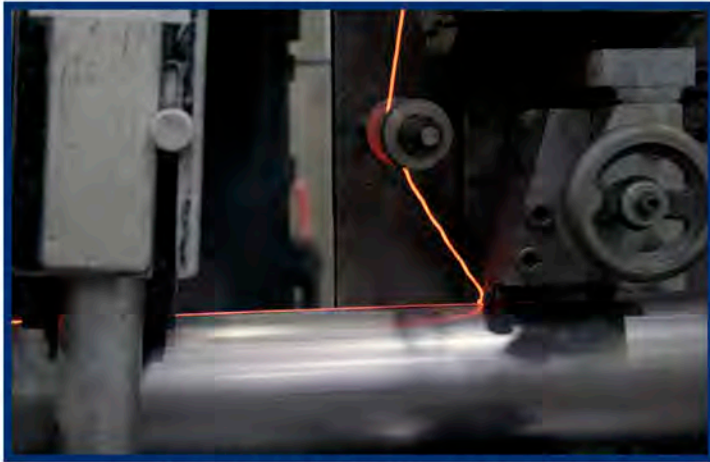
As shown by the chart to the right, the C-STAR® ONE design made from 3.2 mm ULTRALUME® 1500 outperforms the baseline 6000 series extruded aluminum:

- In resistance force by 30% ~ 180%.
- In energy absorption by 135% ~ 150%.



C-STAR® PROTECTION IS FULLY COMMERCIALIZED

C-STAR® Protection tubes in production at Tubular Components



FORMTUBE® 1000 C-STAR® Tube Production



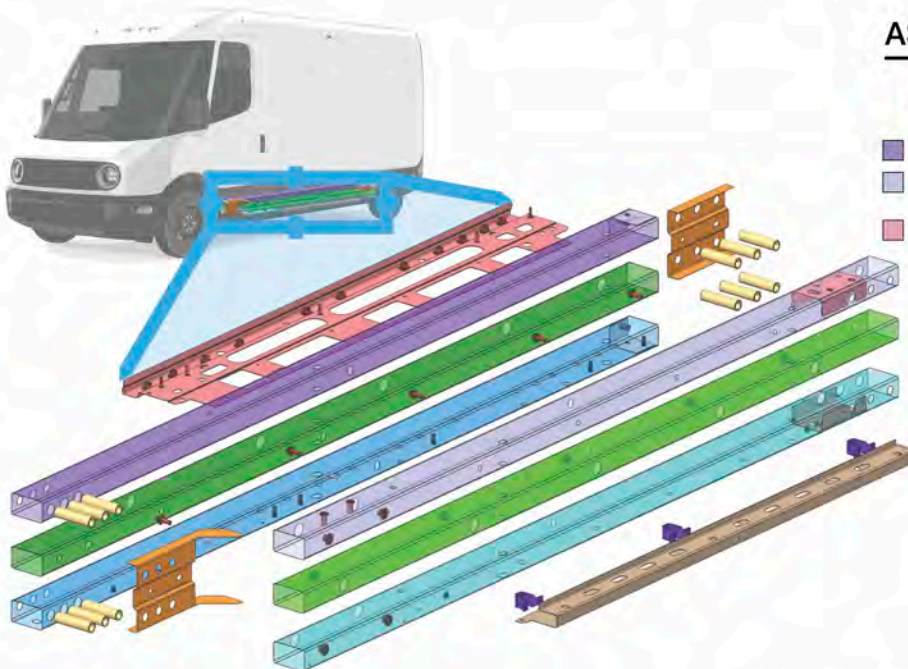
FORMTUBE® 1000 C-STAR® Laser Cutting



CLIFFS

Midrail Assembly Constructed with Cleveland-Cliffs Steel

OUTPERFORMS ALUMINUM EXTRUSION DESIGN IN CAE, SIDE POLE, NVH AND AXIAL CRUSH TESTING



ASSEMBLY CONTENT

-   **2** Roll Form Products
-    **6** Discrete Tubes
-    **9** Stampings
-  **12** CF Sleeves
-  **47** Fasteners
- 55ft.** Adhesive
- 69ft.** Laser Coach Welding
- 170** Laser Staple Welds
- E-Coat/P-Coat

CLIFFS MATERIAL USED

- Cleveland-Cliffs Steel: CR-590Y-980T-DP
- Cleveland-Cliffs Steel: CR-420Y-480T-LA

CLIFFS PROCESSES USED

- Cleveland-Cliffs Tubular Components: FORMTUBE® 1000 / Laser Processing
- Cleveland-Cliffs Tooling & Stamping: Stampings
- Cleveland-Cliffs Tooling & Stamping: Laser Weld/Assembly

TUBULAR COMPONENTS



About Cleveland-Cliffs Inc.

Cleveland-Cliffs is a leading North America-based steel producer with focus on value-added sheet products, particularly for the automotive industry. The Company is vertically integrated from mined raw materials, direct reduced iron, and ferrous scrap to primary steelmaking and downstream finishing, stamping, tooling, and tubing. The Company serves a diverse range of markets due to its comprehensive offering of flat-rolled steel products and is the largest supplier of steel to the automotive industry in North America. The Company is headquartered in Cleveland, Ohio with mining, steel and downstream manufacturing operations located across the United States and in Canada. For more information, visit www.clevelandcliffs.com.