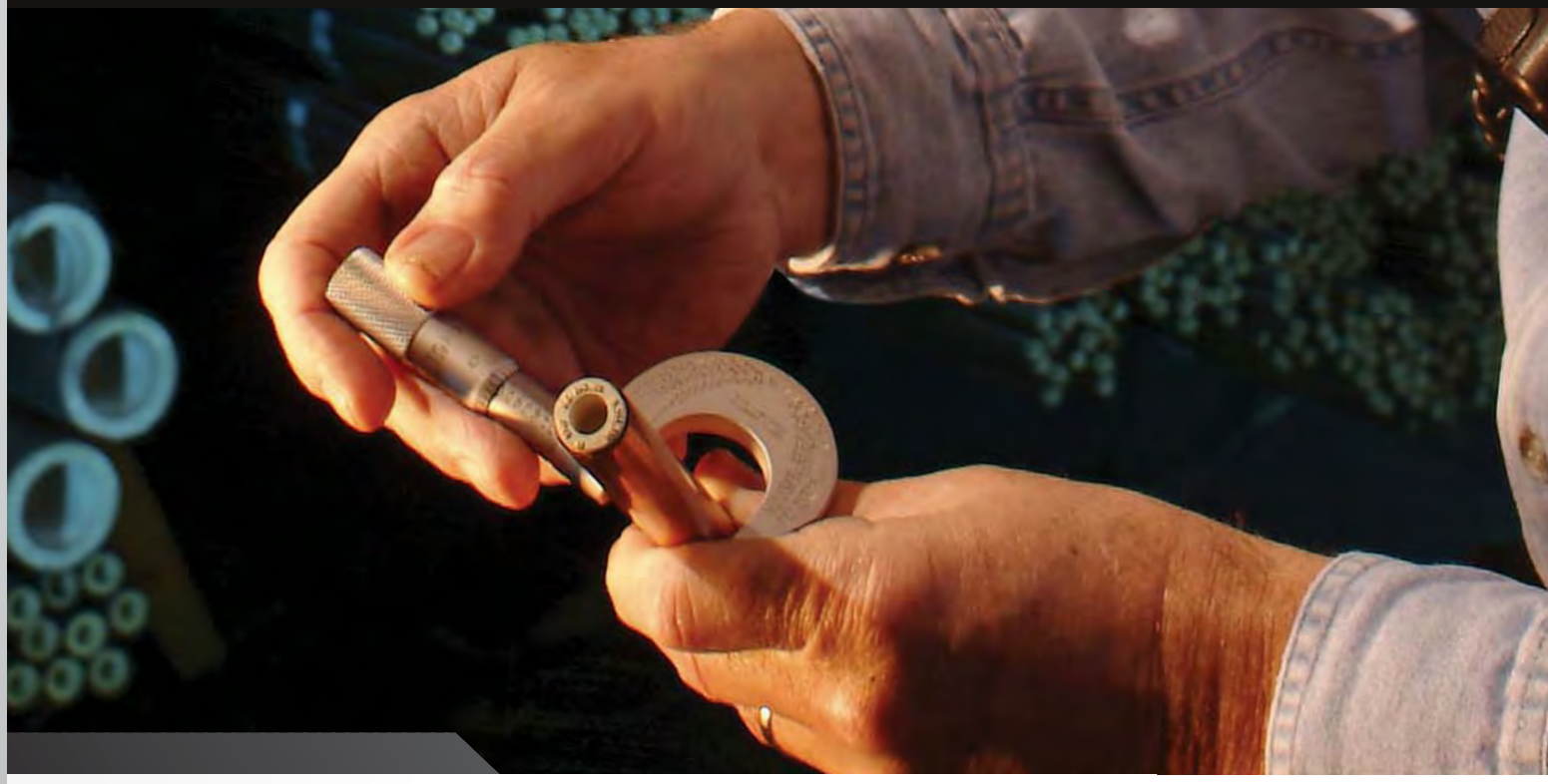
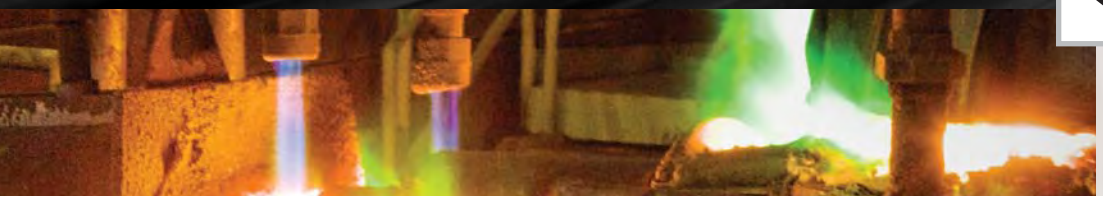


Streamline®

HIGH PERFORMANCE COPPER PRODUCTS

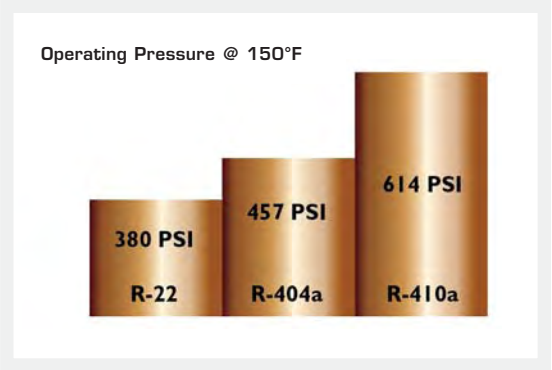
Mueller Industries has tested and validated its Streamline® copper tube and copper fittings for an operating pressure of 700PSI. The following information will give an insight on the testing and qualifications of Streamline® products.

A BRAND OF MUELLER INDUSTRIES



OVERVIEW:

As the industry rapidly changes and evolves with more efficient products, so must the standards, specifications and design equations for copper systems. The gradual phase-out of refrigerants harmful to the environment has ushered in newer, more efficient systems which operate at higher pressures. It is important not only to be cost effective but also to provide a safe environment for the public.



DESIGN FORMULAS: THEN AND NOW

Common equations used to calculate Operating & Burst Pressures:

Current ASME & ASTM equations for calculating operating & burst pressures for copper tube and fittings are primarily driven by an allowable stress based on a proportional limit (strain moves proportionally to the applied stress) and wall thickness of the tube or fitting.

Current Pressure Formula

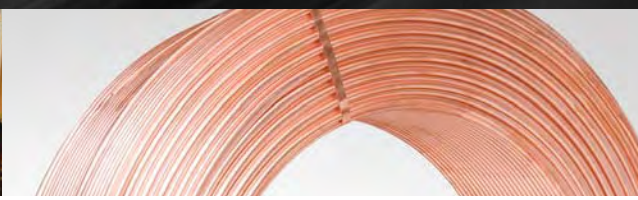
$$P = \frac{2TS}{D - 0.8T}$$

Where:
P = Burst Pressure
T = Wall Thickness
D = Outside Diameter
S = Tensile Strength

- The problem with using a proportional limit to designate an allowable stress for copper is that copper, unlike steel, does not have a proportional limit. Therefore any attempt to generate an allowable stress using some % offset is misleading and inaccurate.
- The problem with assuming wall thickness is directly proportional to the operating and burst pressure of a copper tube or fitting is that it totally ignores the grain size and grain cleanliness of the cast and hard drawn tube. In fact, the grain condition can have a greater impact on material strength than the wall thickness.
- Another problem with using an ill-defined allowable stress and a wall thickness as the strength drivers is that they do not account for the robust quality of strain hardening that copper possesses (as stress goes up copper strain hardens allowing for greater stress to be applied).
- A competent manufacturer of tube and fittings knows the processing characteristics and their impact on strength. Further a competent manufacturer can demonstrate through a program of laboratory and appropriate mathematical analysis, the actual operating and burst pressure.

80 Years of the Industry's Finest Products. And Counting.

Mueller Industries' Streamline® brand changed the piping world forever back in 1930 with the invention of the first solder joint copper fitting. That introduction launched Streamline into a position of leadership that we've maintained for over 80 years through continuous in-line product improvements, new product introductions, and a well-earned reputation for technological innovation, superior product quality, and customer service after the sale.



SUPERIOR MATERIAL

Proven Durability & Reliability

Copper piping systems have proven to be durable and reliable for over 80 years.

Workability In Annealed State

The workability of soft or annealed copper allows it to be run, without joints, through the building spaces where other materials would be difficult to use.

Corrosion Resistance

Corrosion resistance is valuable in critical cooling and refrigeration applications.

Anti-Microbial Properties

Engineers have begun to leverage the unique ability of copper to fight the growth of bacteria, mold, and mildew. The copper alloys used to make products made to ASTM B280 and ASME B16.22 are registered with the U.S. EPA as antimicrobial.

Broad working Temperature Range

Suitable for applications from -300°F to +400°F.

NOTHING ELSE COMPARES

Strong Brazed Joints

The process of joining copper in the field is easier, more efficient, and more reliable than with other materials.

Superior Heat Transfer Coefficient

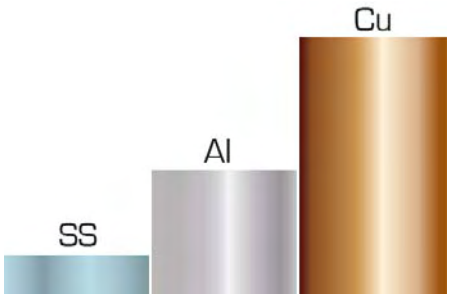
Stainless Steel *(SS)*	**25 W/mK**
Aluminum *(Al)*	**237 W/mK**
Copper *(Cu)*	**398 W/mK**

Ability To Make Field Repairs & Modifications

Welding stainless steel requires a high level of skill and is highly labor intensive. Aluminum has a low melting temperature, making it impractical to join or repair in the field.

Heat Transfer Comparison

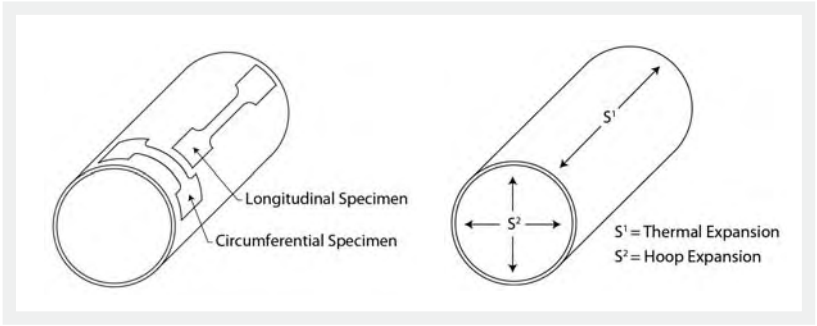
Stainless Steel and Aluminum vs. Copper



SUPERIOR SCIENCE

Copper Tube and Fittings The tensile test...a classic test of material strength. A flat piece of metal in the rough shape of a dog bone is pulled from opposing ends with sufficient force to deform the material. That measurable force applied to the material is the STRESS. The material's response to this stress is a measurable deformation, known as STRAIN.

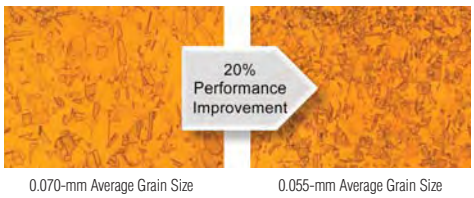
Hoop Strain Pulling on a dog bone in the longitudinal direction does not mimic the force applied by pressurization within a pipe. Internal pressure exerts its force to the entire circumference of the tube, which is known as hoop stress. The response of copper tubing to this stress is known as hoop strain.



Hoop Strain

DID YOU KNOW? The only time copper tube will fluctuate in length (S^1) is during expansion and contraction due to temperature. The only time copper tube will fluctuate in diameter (S^2) is during expansion due to pressure.

Work Hardening When copper stretches or strains (the deformation due to stress) the grain structure is reoriented and made stronger by work hardening. As more stress is applied, up to a point, copper simply gets stronger.

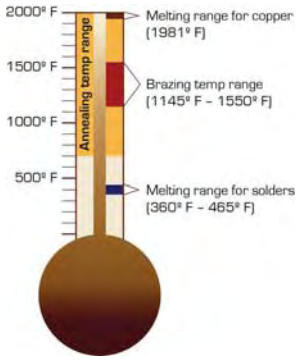


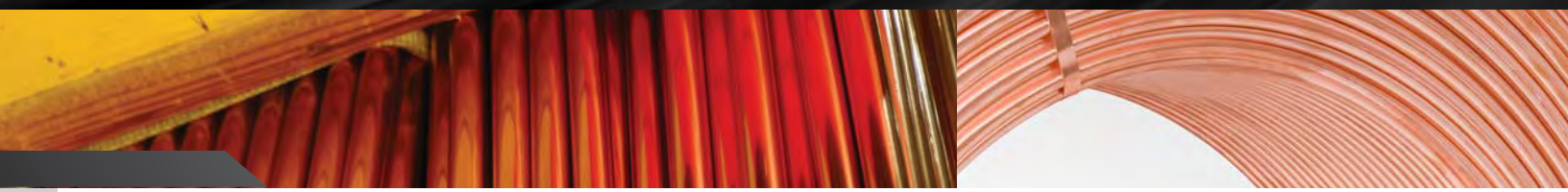
What Your Eyes Can't See: A smaller, tighter grain structure can result in greatly improved performance. In these (copper tube) samples, viewed at 100x magnification, the one on the right outperforms by over 20%.

Annealed Copper

Copper begins to anneal at 700°F and becomes "softer" with increasing time and temperature. Since the HVAC/R industry joins copper by brazing pieces together between 1,150°F to 1,550°F, all HVAC/R systems are considered to be annealed.

Annealed Temperatures





SUPERIOR PROCESSES

Only Mueller Industries' Streamline® copper products are made in the USA with the proprietary technologies of DuraGrain™ and TrueCenter.™ These industry leading processes provide for more consistent and higher performing copper products and are a few of the many reasons Streamline® copper products are better than the rest.

High Grain Density Copper for Superior Metallurgy

DuraGrain™ is Mueller Industries' proprietary copper, which is carefully refined in our own furnaces to achieve a denser, stronger grain structure with 99.9% copper purity. Whether refined from virgin copper cathode or carefully screened, post-consumer recycled copper, we use advanced metallurgical and spectrum analysis protocols to produce the highest-quality copper in the industry. The more uniform and durable properties of Mueller's DuraGrain™ copper contribute significantly to the superior performance of Streamline copper tube, line sets and fittings.

DURAGRAIN™

- Raw copper is refined to a purity of 99.9%
- Advanced metallurgy results in an optimum grain structure
- Continuous testing for quality and consistency
- Made in the U.S.A.

Precision Extrusion for Consistently Uniform Walls

TrueCenter™ is Mueller Industries' patented, laser-directed precision extrusion process. Developed by Mueller Industries to extrude copper tube with exceptionally uniform wall thickness, TrueCenter™ ensures that Streamline copper tube, line sets and fittings are highly concentric – so each finished product has consistently strong walls without thin/weak spots that could result in a field failure.

TRUE CENTER™

- Patented laser-guided system
- Promotes uniform wall thickness
- Assures uniform grain consistency
- Made in the U.S.A.

ENGINEERED TESTING FOR VALIDATION

Each test served a specific purpose but it is the collective result that provides the ultimate confidence in the strength of copper. Streamline® Nitrogenized ACR tube and copper fittings were used for all assemblies.

Hoop Strain Test proved expansion predictability when Streamline copper tube and fittings are exposed to increasing pressures and temperatures.

1ST TEST ASSEMBLY AT 69°F

- Pressurized to 635psi for 10 minutes
- Measure change in diameter & length
- Repeat at 800 psi, 1000 psi, and 1500psi

2ND TEST ASSEMBLY AT 180°F

3RD TEST ASSEMBLY AT 250°F

RESULTS: All measurable strain was in hoop.

Cyclic Fatigue Test verified the strength of Streamline copper tube and fittings for over 250,000 cycles; along with testing the superior work hardening capabilities of the copper assemblies.

700 PSI @ 68°F AND 180°F WITH 4-SECOND CYCLES

RESULTS: Tube diameter change is always higher than fittings.

Temperature has minimal impact. Grain structure has significant impact.

Calculated Burst vs. Actual Burst demonstrated that Streamline copper tube and fittings significantly outperform current standards and design equations, allowing select Streamline products be rated to 700 PSI.

STANDARD ACR TUBE TAKEN TO FAILURE (BURST) AT 68°F

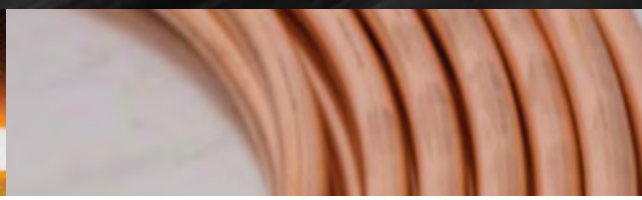
RESULTS: Actual burst pressure for tube and fittings significantly out-performed current ASME formulas used to calculate burst pressures.

Thermal Cycling: Life Acceleration Test confirmed the reliability of Streamline copper tube and fittings when utilized in an R-410a refrigeration system under accelerated, long-term conditions.

TYPICAL R-410a HEAT PUMP UTILIZED WITH AN ASSEMBLY PLACED IN CONTINUOUS LOOP FORCED TO 180°F

RESULTS: The assembly ran for over 25,000 cycles.

All tube and fitting expansion stabilized after 20 cycles

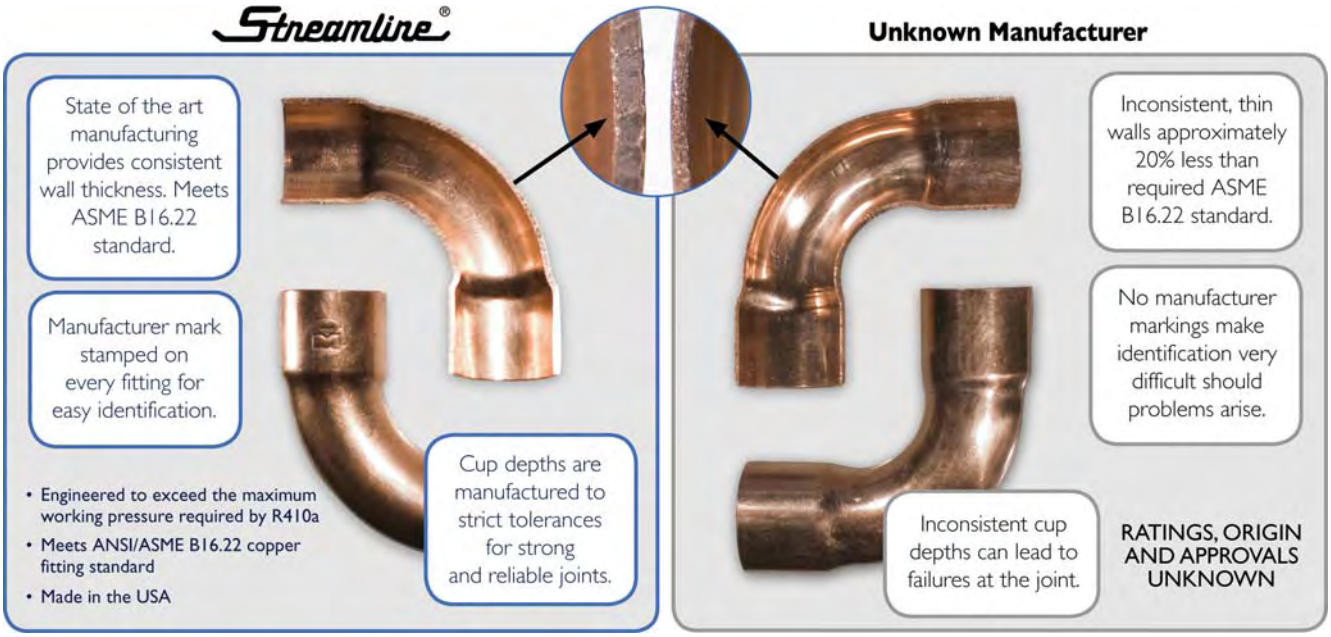


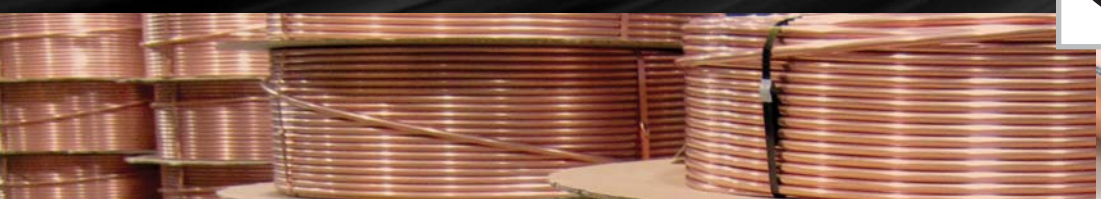
ANOTHER REFRIGERATION INDUSTRY FIRST: UL RECOGNIZED COPPER TUBE AND FITTINGS

Mueller Streamline Co. is now able to offer the first refrigeration copper tube and fittings UL Recognized to 700PSI in select sizes. In order to provide the highest level of assurance to our customers that these products continue to meet the higher pressure demands of these modern refrigerants, we have taken the additional step of implementing third-party verification – through Underwriters Laboratories (UL) – of the extensive testing procedures. The testing and third-party certification validates performance of these products up to operating pressures of 700psi at 250°F.

c UL us 700 PSI R410A

STREAMLINE COPPER FITTINGS VS. OTHERS





PUT THE SUPERIOR QUALITY OF STREAMLINE® TO WORK FOR YOU

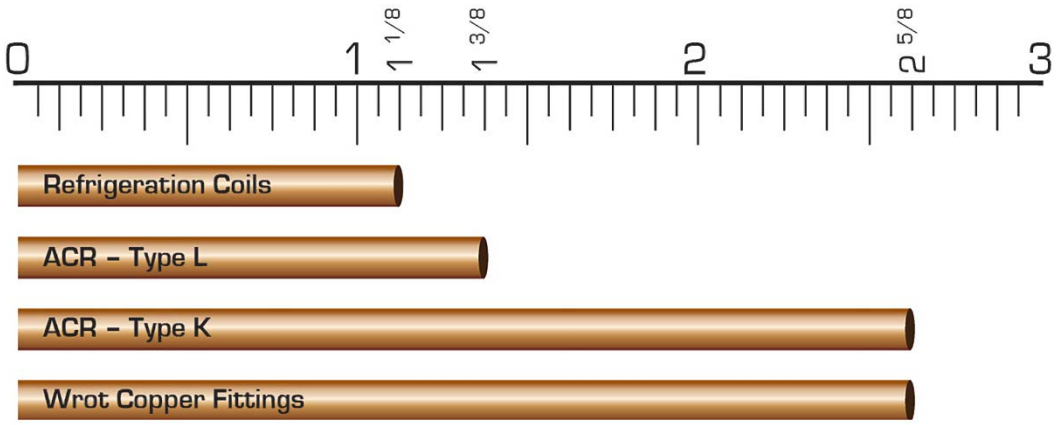
Low Pressure Applications Streamline® copper tubing is available with a thinner wall, known as Type M, which is commonly used in plumbing systems. While unsuitable for refrigerant-bearing applications, Type M tube is a good choice for low pressure, secondary cooling loops.

High Pressure Applications You don't need heavier walls…you need higher quality. Some manufacturers would lead you to believe that heavy-wall copper tube and fittings are required for R-410a and subcritical CO2 systems. With their products, this may be true. However, with Streamline® copper tube and fittings, the products that have been used and trusted for over 75 years are still suitable. Per the chart below, the industry standard Streamline ACR tube (Type L) is UL Recognized to 700psi through 1-3/8".

Streamline® wrot copper fittings are formed from our own tube, providing quality control throughout the process. The thickness of these fittings is highly correlated to ACR tube (Type L). The process of shaping this tube into fittings imparts additional work hardening on the copper. As a result, fittings of similar wall are consistently stronger than the tube they are made from. Wrot copper fittings manufactured by Mueller Streamline Co are rated to 700psi through 2-5/8".

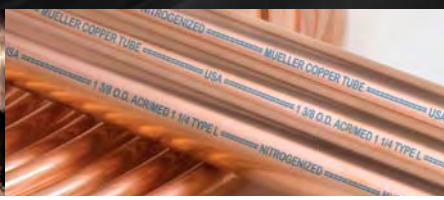
High Demand Applications For especially demanding applications where larger tube diameters are required, the solution is simple. Streamline® ACR – Type K is a heavy wall copper tube that goes through a five-step cleaning process before being nitrogen charged and plugged. This product is available with limited lead-time and is rated to 700psi through 2-5/8" OD.

STREAMLINE COPPER 700 PSI RATING



700 PSI Rating at Operational Temperature of 250°F.





STREAMLINE PRODUCTS

Streamline® Wrot Copper Pressure Fittings

All Streamline® fittings are formed to exacting tolerances using blanks we make ourselves from our own manufactured copper tube. From our DuraGrain™ copper, to our TrueCenter™ precision-extrusion process, to our sophisticated push-form manufacturing processes, to our smart-vision inspection systems – and right down to the piece by piece hand inspections – we take every step possible to ensure that each Streamline fitting will exceed your expectations.

- Made from DuraGrain™ Copper – a Mueller Industries Exclusive
- Formed from Precision Extruded Streamline® Copper Tube
- Made to ASME Standard B16.22
- NSF Certified
- UL Recognized 700 PSI Rating (select sizes)
- Manufactured in the U.S.A.

Streamline® Copper Tube

Our Streamline® brand has set the standard of excellence for over 80 years. We take pride in maintaining our leadership position as the best manufacturer of quality copper tube in the world, and we work hard through research, development and testing to guarantee that the Streamline copper tube you buy will always be the highest quality obtainable.

- Engineered and Tested for R-410A and CO2
- Made from DuraGrain™ Copper – a Mueller Industries Exclusive
- Precision Extruded using TrueCenter™ Laser Technology – a Mueller Industries Exclusive
- Made to ASTM Standard B-88, B-306, B-280, B-819
- NSF Certified
- UL Recognized 700 PSI Rating (Refrigeration Tube in select sizes)
- Manufactured in the U.S.A.

Streamline® Line Sets and Mini Splits

We leverage our 80 years of experience and expertise in copper tube manufacturing in every line set we make. From standard liquid lines and suction lines to unique insulation applications and packaging, every line set meets rigorous standards for quality and consistency, so our customers can be confident they're using the best line set on the market.

- UL Recognized at 700 PSI MWP
- R410A Engineered & Tested
- Insulation meets ASTM C-534 & UL 25-50 Fire & Smoke Rating
- Integrated production processes eliminate kinking and work-hardening associated with other line sets
- Manufactured in the U.S.A.

Streamline Refrigeration Valves & Protection Devices

Mueller Streamline® is a leader in the design and manufacturing of HVAC/R valves and protection devices – including filter driers, sight glasses, and strainers. These products are trusted and respected worldwide for providing optimum system performance and enhanced serviceability. Incorporating many proprietary technologies and the latest industry innovations and performance features, Streamline® HVAC/R valves are compatible with the newest refrigerants and oils – and deliver flawless operation over a wide range of operating temperatures.

- UL/cUL Recognized, CE Certified, and RoHS Compliant
- Compatible with all CFC, HCFC and HFC refrigerants and oils
- Working pressure ratings up to 700 psig (48 bar)

Streamline®

QUALITY COPPER PRODUCTS FOR TODAY'S NEEDS

8285 Tournament Drive, Suite 150 • Memphis, TN 38125 • www.muellerindustries.com
1-800-846-9750 • www.streamlinecopperquality.com

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