



Copper Piping & High Pressure Refrigerants

Wall Thickness is 'Part' of the Equation

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c  **US 700 PSI R410A**





Why Copper for Refrigeration?

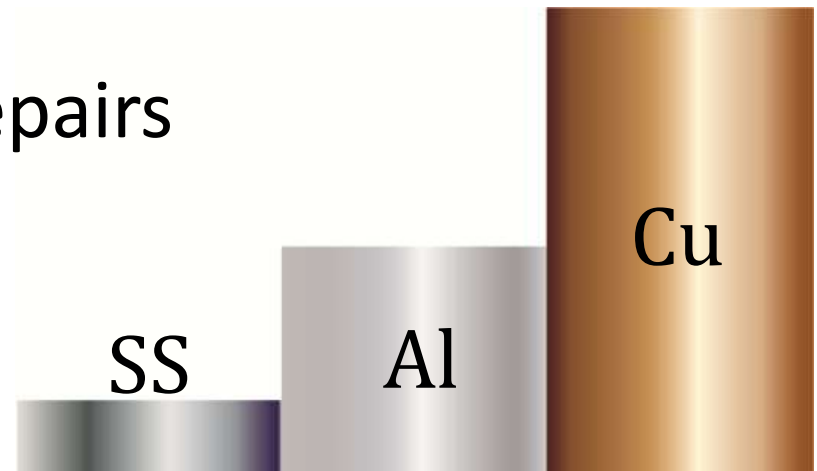
- Proven durability & reliability
- Workability in annealed state
- Corrosion resistance
- Anti-microbial properties





No Other Material Compares

- Superior heat transfer coefficient
 - Stainless Steel (SS).....25 W/mK
 - Aluminum (Al).....237 W/mK
 - Copper (Cu)398 W/mK
- Strong brazed joints
- Ability to make field repairs



Heat Transfer



Evolution of Refrigerants

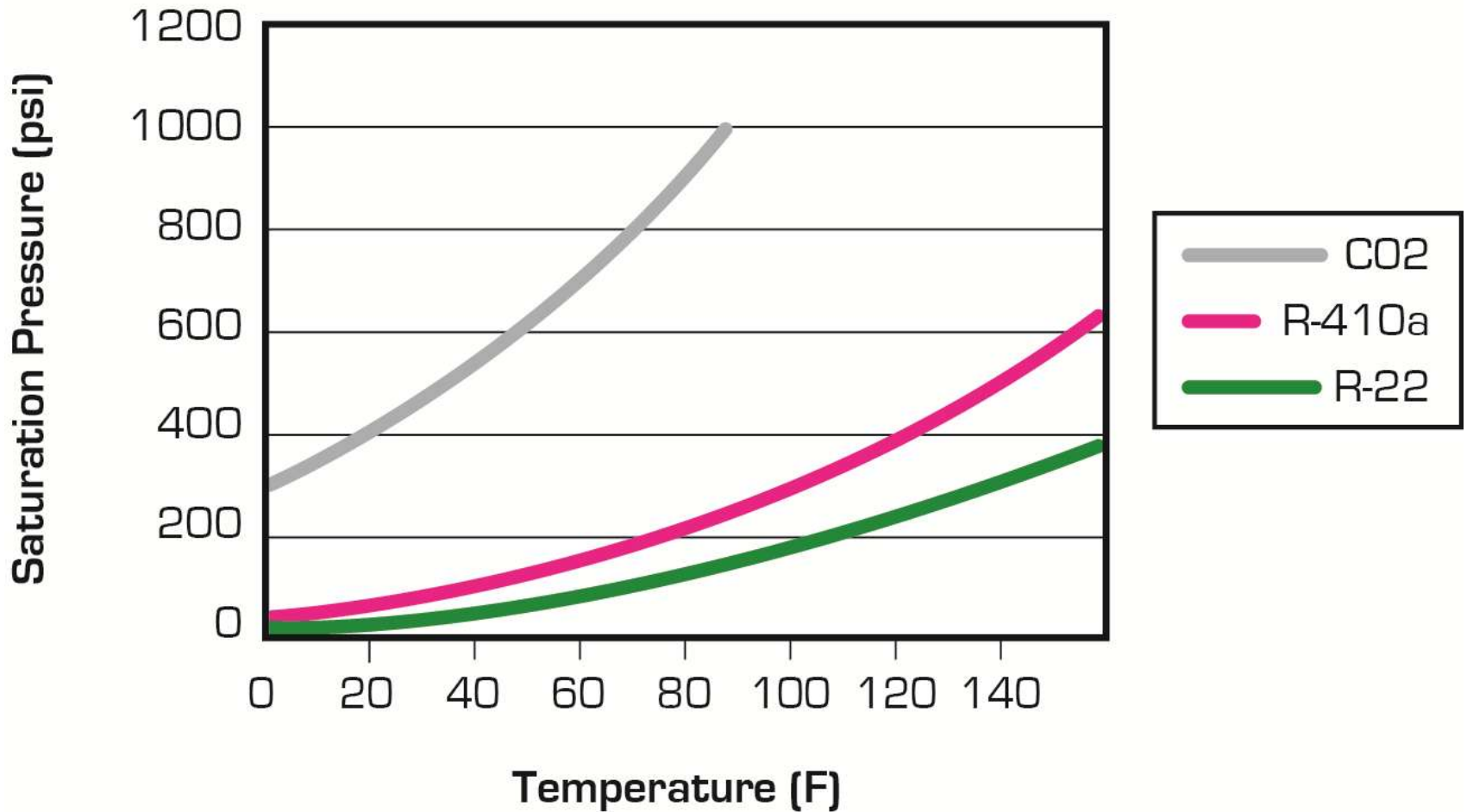


- Significant coordination with OEMs
- Pressures increased by over 50%

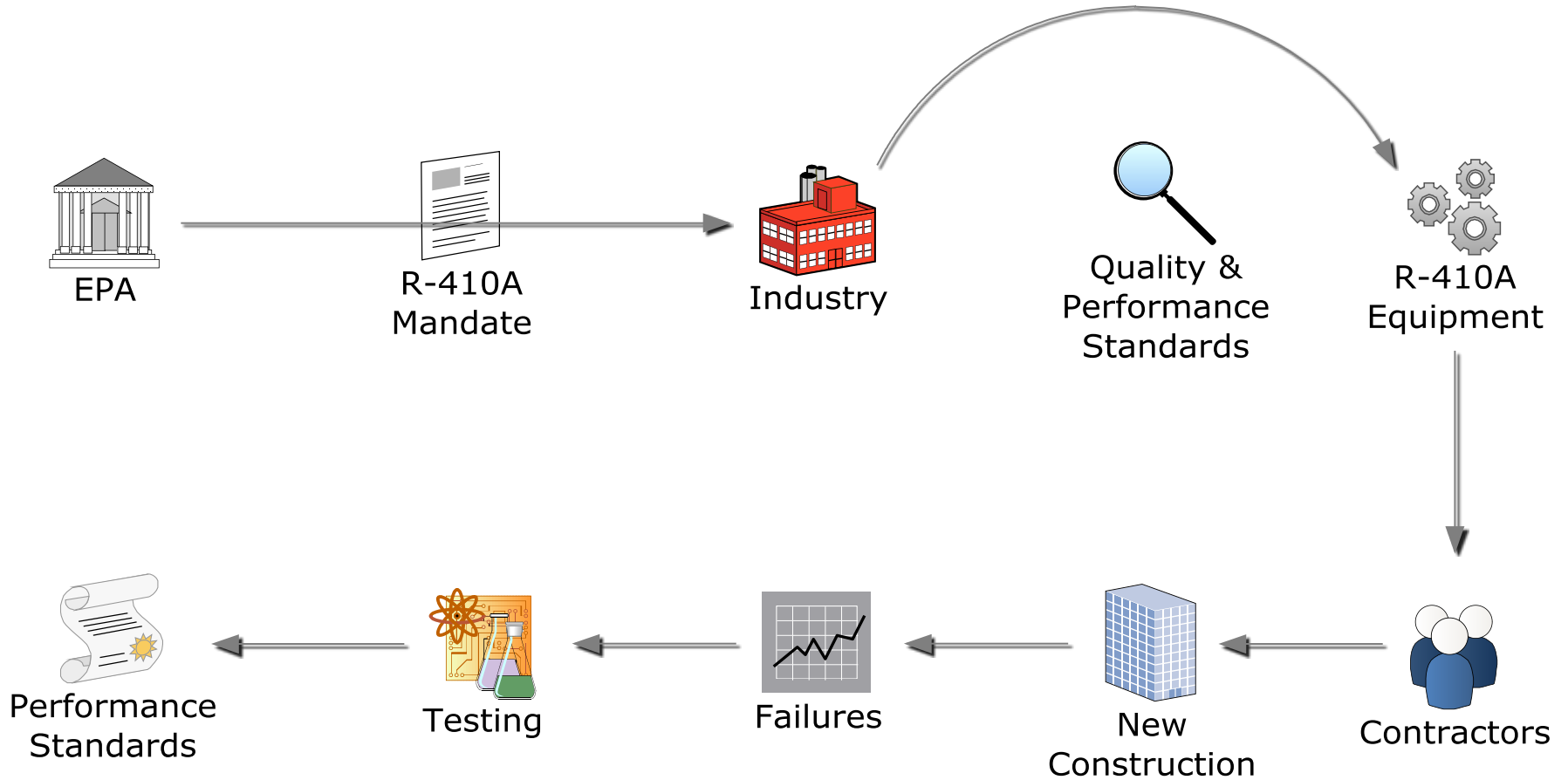


Evolution of Refrigerants

Saturation Pressure (psi)



Unintended Consequences





Pressure Formulas

- Are they absolute?
- What factors do they consider?

Current Pressure Formula

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

Where:

P = Burst

T = Wall Thickness

D = Outside Diameter

S = Tensile Strength



Consensus Standard Deficiencies

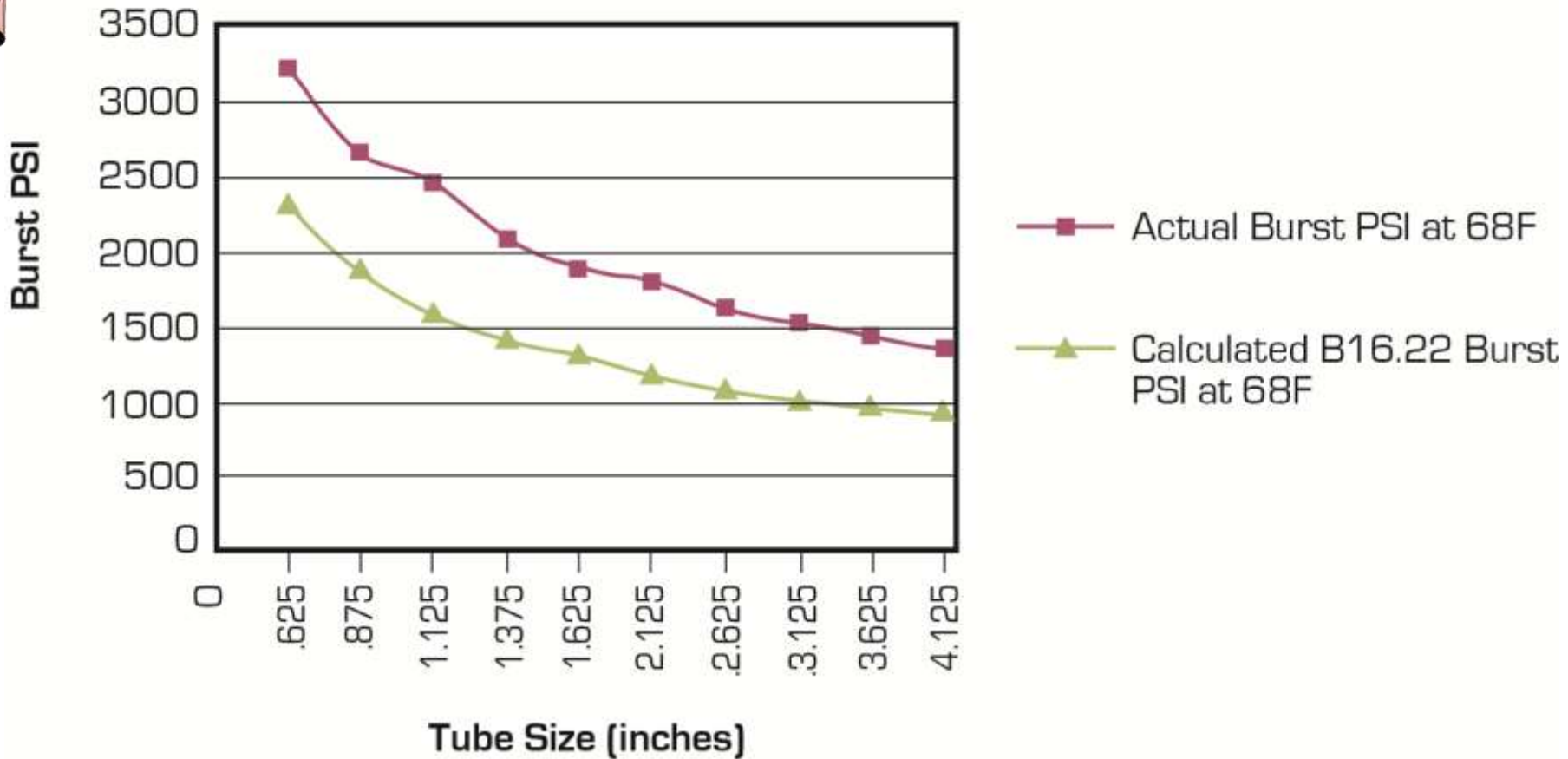
- ASME B16.22 - Wrought Copper Fittings
 - 5/8" at 150°F rated to 610psi
 - 1-1/8" at 150°F rated to 490psi
 - 2-1/8" at 150°F rated to 360psi
- DuPont Pressure-Temperature Guide*
 - R-410A at 150°F ~ 614psi
 - R-404A at 150°F ~ 457psi

* Document K-10909





Calculated Burst vs. Actual Burst



Hoop Strain Hardening

Annealed Copper system is subjected to high pressure

begin

1) Copper EXPANDS under pressure

2) Expansion creates STRAIN HARDENING


NO

4) Is the system now stable at this pressure?

3) STRAIN HARDENED copper is stronger



Hoop Strain Hardening



Annealed Copper system is subjected to high pressure

begin

1) Copper EXPANDS under pressure

2) Expansion creates STRAIN HARDENING

7X

System is now stable at higher pressure

end

YES

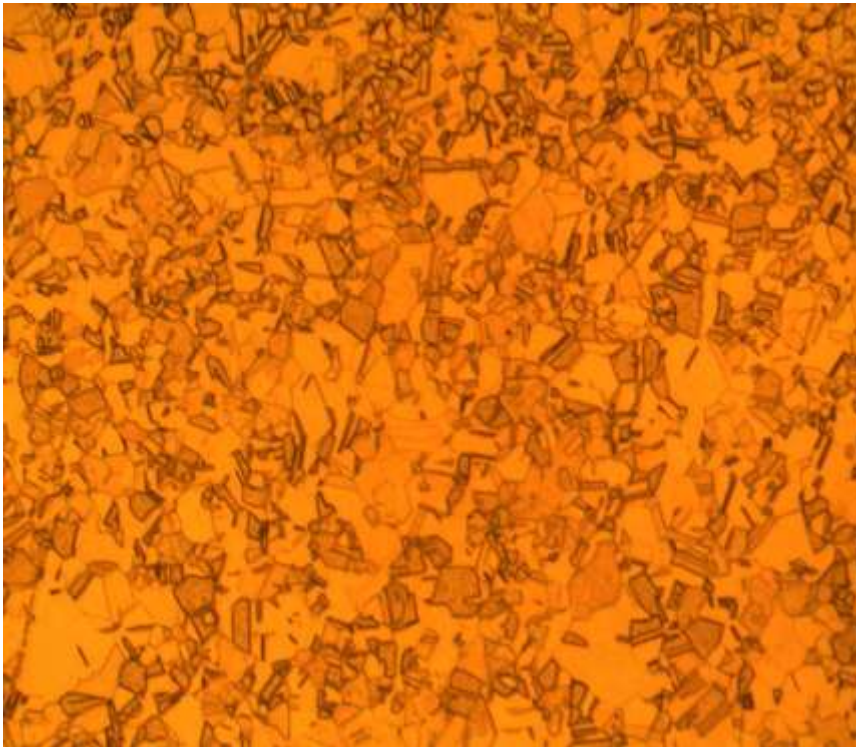
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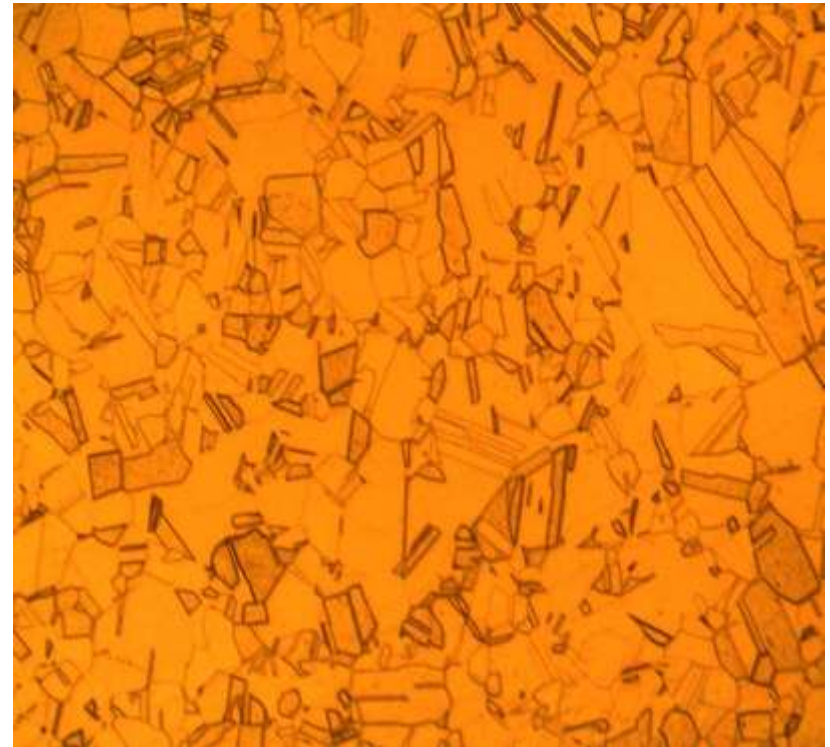
Grain Size Comparison

Two samples of C12200 copper under scanning tunneling microscope



100X Mag; Transverse Cross-Section; Potassium Dichromate Etch
1 5/8" Refrigeration Service Coil
0.055-mm Average Grain Size

Yield .2% Offset = 13,300 psi



100X Mag; Transverse Cross-Section; Potassium Dichromate Etch
1 3/8" Refrigeration Service Coil
0.070-mm Average Grain Size

Yield .2% Offset = 11000 psi



Strength Goes Beyond Wall Thickness

- Grain size
- Grain boundaries
- Process parameters
- Work hardening



Bottom Line:

Wall thickness is part of the equation to determine strength, yet it is only one part.



Proprietary Processes



- Controlled *Grain Size*
- High *Grain Density*
- Cleanliness of *Grain Boundaries*





Proprietary Processes

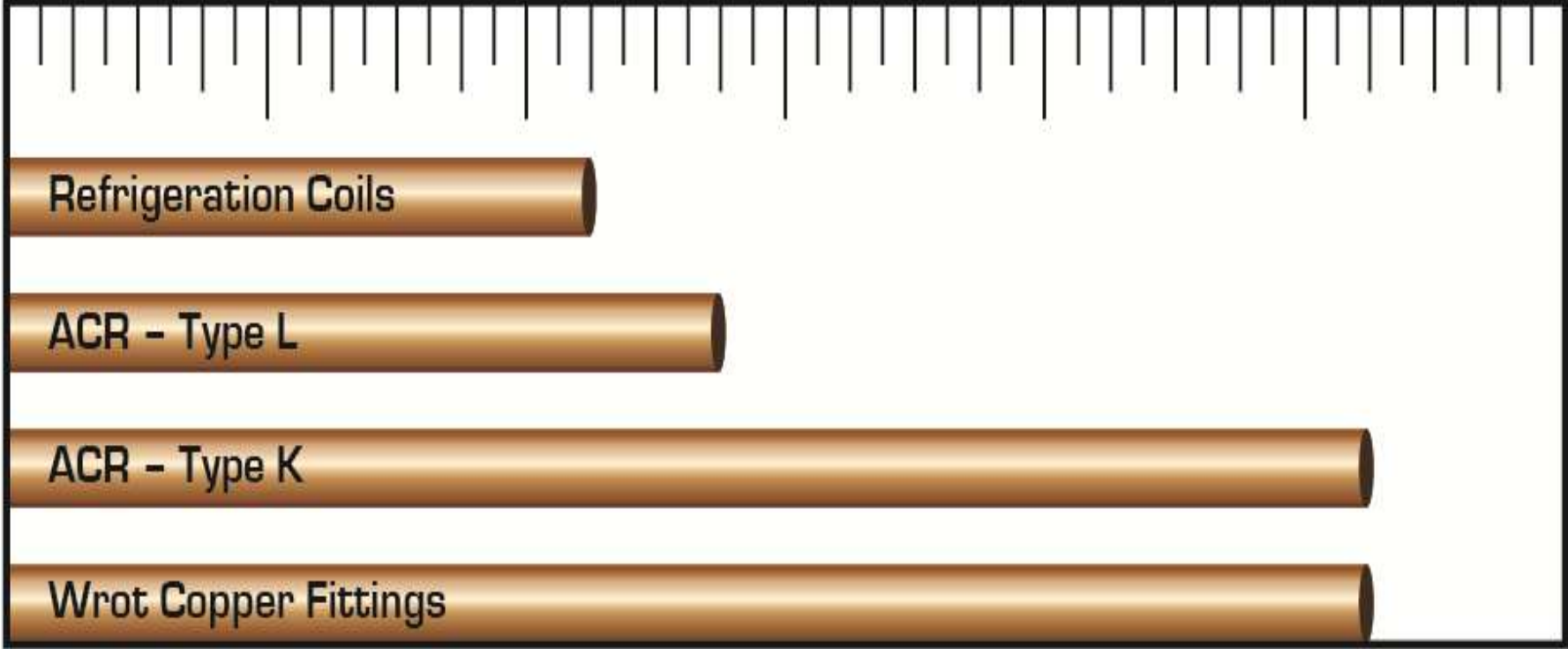
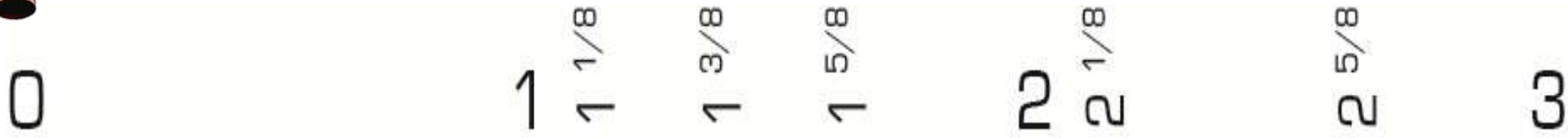


- Patented *Extrusion Process*
- Precision *Cascade Drawing*
- Predictable *Work Hardening*





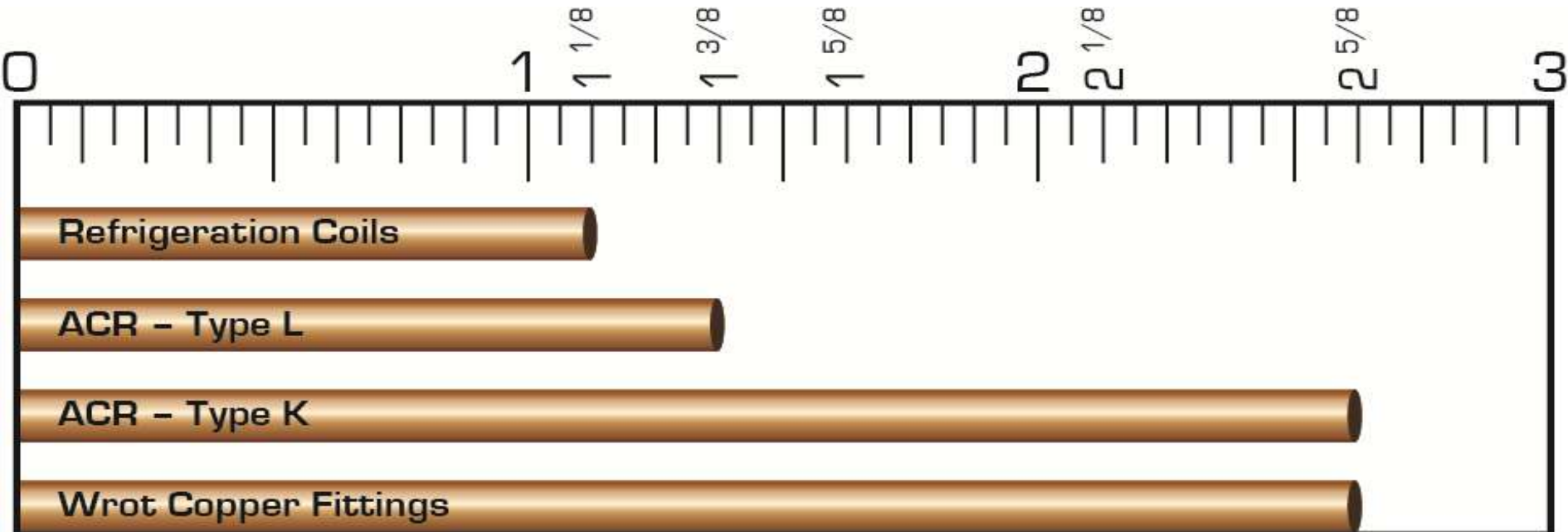
UL Recognized Copper 700psi Ratings





Leveraging the Potential

- Consider Type M copper (plumbing) tube for low pressure, secondary cooling loops
- Use standard ACR tubing up to 1-3/8"
- Request Nitrogenized ACR - Type K for the most demanding applications





Why 700psi as the high pressure target?

- Covers all common synthetic refrigerants
 - R-410A
 - R-404A
 - R-22
- Covers subcritical CO₂
- Compatible with other key system components





Components...700psi



WP700PSIG
(4827kPa)



M
Q2
700 PSI
TYPE I



M
Q2
700 PSI
TYPE I



Other Products...700psi





Competitive Landscape

- Fittings with wall thickness below B16.22 & Line Sets with thinner walls
 - Not tested to the same standards as MLI
 - Risky with R-410A & CO₂
- Fittings with wall thickness above B16.22
 - Not tested to the same standards as MLI
 - So what is the value proposition?

Wall thickness is 'part' of the equation



Alternative Material Considerations

- Long-term joint integrity concerns
- Precision required to braze other metals to copper components
- Welded Together \neq Permanently Sealed
- Repair-ability over service life

Industry Applications

- Copper systems are field proven with R-410A and CO₂ (subcritical)
- Only Streamline™ Copper Tube & Fittings are UL Recognized to 700psi operating
- Mueller Industries is leading the industry to update standards at ASTM & ASME
- Consult with your manufacturer or supplier for their pressure ratings



QUESTIONS ?



Visit us on the web at:

StreamlineCopperQuality.com

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