HEAT EXCHANGER WORLD
CONFERENCE & EXPO
AMERICAS

# CORROSION RESISTANT MATERIALS AND FABRICATION

**Dennis Lamberth & Chuck Young – Tricor Metals**

TRICOR METALS

# Corrosion Resistant Alloys

- **Stainless Steel** – 304, 304L, 316, 316L
- **Super Austenitic SS** – 904L, Alloy 20, AL6XN, 254SMO
- **Duplex Stainless Steel** - 2205, 2507, 2101
- **Nickel Alloys** – Nickel 200, Monel 400, 625, C276, C2000, 825, B3, Alloy 59
- **Titanium** – Grade 2/2H, 7/7H, 9, 11, 12, 16/16H
- **Zirconium / Tantalum / Niobium**

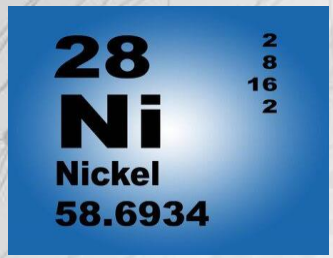
# Stainless Steel & Duplex SS

## 300” series Stainless Steel

- Iron – Chromium – Nickel alloys
- Intergranular Corrosion (welding & temperature related)
  - Use “L” grade to minimize (lower Carbon)
- Stress Corrosion Cracking possibility
- Used in nitric acid, phosphoric acid(@RT up to 85%), Sulfuric Acid (RT @80%), acetic acid, amines, urea and sulfurous acid

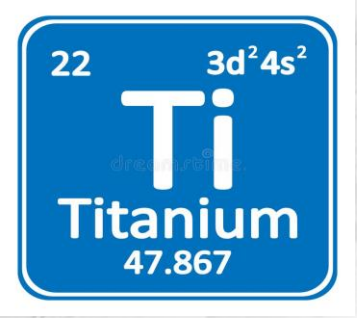
## Duplex Stainless Steel

- PREN # – Improved pitting and crevice-corrosion resistance in $Cl^-$
- Yield Strength about 2X SS
- Higher Stress Corrosion Cracking (SCC) resistance than SS
- At 100F use only under 15% Sulfuric or 3% HCl Acids
- Cautions on Welding – heat input, interpass temperature




# Nickel Alloys

- Range of Corrosion Resistance
- Wide variety of Alloys
- Alloys designed for specific corrosives
  - Acidic solutions - Alkali services
  - Chlorine, Marine,
  - Fertilizer manufacturing
  - variety of Chemical Processing




# Titanium Alloys

- Alloys for higher corrosion resistance - Pitting and crevice corrosion - Ti 12, Ti 7, Ti16

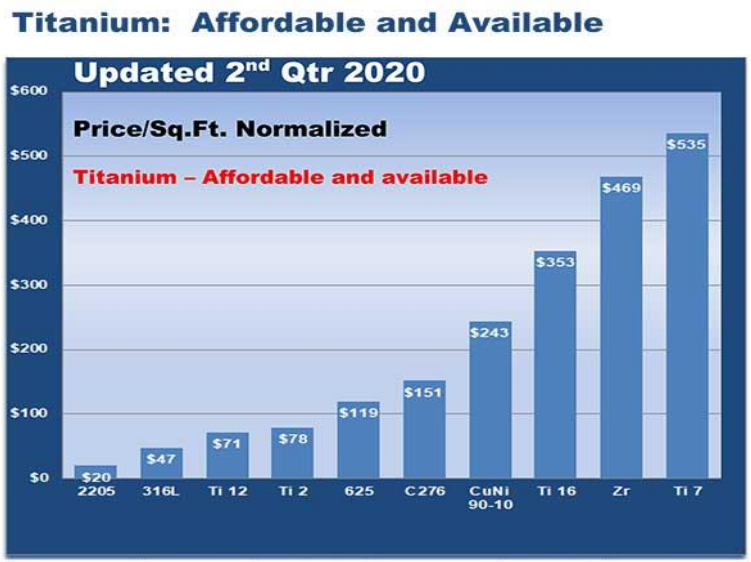
- Major CPI Applications
  - Chlorine (WET) & Bromine (WET) & Bleach & Seawater
  - Terepthalic Acid
  - Oxidizing Acids – nitric, chromic, perchloric
  - Low concentrations of Hydrochloric and Sulfuric Acids
  - Alkaline (ammonium hydroxide, sodium hydroxide, etc)
  - Organic Chemicals & Acids (adipic acid, benzene, acidic acid, formic acid)


# Zirconium

Zirconium is immune to SCC (Stress Corrosion Cracking) and has very good corrosion resistance in:

- Dry chlorine gas, bromine and iodine gas
- Hydrochloric acid - all concentrations up to boiling
- Nitric acid - all concentrations up to boiling
- Sulfuric acid up to 70% concentration at boiling
- Phosphoric acid up to 60% concentration at boiling
- Urea production
- Most organic acids (e.g. acetic, formic), all concentrations up to boiling temperature

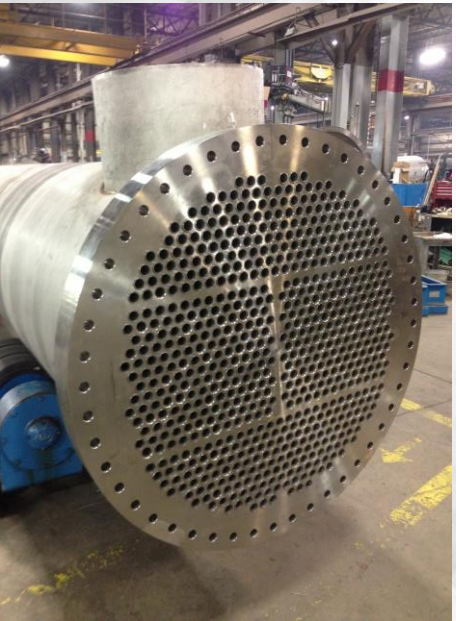
# Alloy Cost Comparison Chart




| Metal | Density (Lbs/In$^3$) | Yield Strength (PSI) | Price/LB | Price/Sq Ft | Price/Sq Ft Normalized |
|---|---|---|---|---|---|
| 2205 | 0.29 | 65,000 | $ 3.04 | $32 | $20 |
| 316L | 0.29 | 25,000 | $ 2.80 | $29 | $47 |
| Ti 12 | 0.163 | 50,000 | $ 15.07 | $88 | $71 |
| Ti 2 | 0.163 | 40,000 | $ 13.34 | $78 | $78 |
| 625 | 0.305 | 55,000 | $ 14.93 | $164 | $119 |
| C276 | 0.32 | 41,000 | $ 13.47 | $155 | $151 |
| CuNi 90-10 | 0.323 | 15,000 | $ 7.84 | $91 | $243 |
| Ti 16 | 0.163 | 40,000 | $ 60.09 | $353 | $353 |
| Zr | 0.234 | 30,000 | $ 41.73 | $352 | $469 |
| Ti 7 | 0.163 | 40,000 | $ 91.25 | $535 | $535 |

# Project Overview

- From Project Concept to Final Quality Product
  - Design Conditions
  - Mechanical Design
  - Thermal Design
  - Forming
  - Welding
  - Quality assurance / testing



# Design Conditions

- Accurately determine design conditions
  - Operating temperature & pressure – upset conditions too
  - Exact PPM of all components of process stream
    - Solids content
    - Other unique concerns (possible deposits)
  - Phase changes / composition changes
  - Process & service flow rates
  - Allowable pressure drops
- Determine proper metallurgy
- Do not “overdesign” in terms of pressure and temperature – Be realistic.

# Other Considerations

- **Physical design decisions**
  - Space limitations / piping hookups in place
  - Materials of Construction (Possible Coupon Testing)
  - Maintain corrosive process to tubeside for cost reduction
  - Maintenance & cleaning considerations
  - U-tube / kettle / reboiler design – TEMA designs
  - Single or double fixed (& welded) tubesheets
  - Maintain corrosive process to tubeside for cost reduction

# Thermal Design

- Performed by a heat transfer expert
- Data sheet filled out by plant engineer
- Materials of construction

# Mechanical Design

- Using ASME guidelines for chosen materials of construction
  - Design allowable stress at operating temperature
  - Maximum operating temperatures
  - Possible upset conditions
- This allows the designer to calculate material thickness
  - Tubes
  - Shell
  - Tubesheets

# Specification Data Sheet

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Client | COMPANY NAME | | | Location | CITY or PLANT | | | Page 1 of 1 | | | | | |
| 2 | Process Unit | Line 1 | | | Item No. | HE-4356273-A | | | Document No. | | | | | |
| 3 | Job No. | | | | *Fabricator* | TRICOR METALS | | | | | | | | |
| 4 | Service of Unit | *Cooling of process waste water* | | | | | | | | | | *No. of Units* | *1* | |
| 5 | Size | | *TEMA Type (Hor/~~Vert~~)* | | | | | *Connected in* | | *Parallel* | | | *Series* | |
| 6 | Surface/Unit (Eff.) | | *ft²* | *Shells/Unit* | | | | *Surface/Shell (Eff.)* | | | | | | *ft²* |
| 7 | **PERFORMANCE OF ONE UNIT (Optional)** | | | | | | | | | | | | | |
| 8 | Fluid Allocation | | | | *(Inlet)* | *SHELL SIDE* | *(Outlet)* | | *(Inlet)* | *TUBE SIDE* | *(Outlet)* | | | |
| 9 | Fluid Name | | | | | *COOLING FLUID* | | | | *PROCESS FLUID* | | | | |
| 10 | Fluid Quantity, Total | | | *lb/hr* | | *100000* | | | | *140000* | | | | |
| 11 | | Vapor (MW) | | *lb/hr* | | | | | | | | | | |
| 12 | | Liquid | | *lb/hr* | | | | | | | | | | |
| 13 | | Steam | | *lb/hr* | | | | | | | | | | |
| 14 | | Water | | *lb/hr* | | | | | | | | | | |
| 15 | | Noncondensable (MW) | | *lb/hr* | | | | | | | | | | |
| 16 | Temperature | | | *°F* | | *75* | | *85.0* | | *120.0* | | *108.0* | | |
| 17 | Density (Vapor/Liquid) | | | *lb/ft³* | | | | | | | | | | |
| 18 | Viscosity (Vapor/Liquid) | | | *cP* | | | | | | | | | | |
| 19 | Specific Heat (Vapor/Liquid) | | | *Btu/lb °F* | | | | | | | | | | |
| 20 | Thermal Conductivity (Vapor/Liquid) | | | *Btu/hr ft °F* | | | | | | | | | | |
| 21 | Latent Heat | | | *Btu/lb @ °F* | | *@* | | | | *@* | | | | |
| 22 | Inlet Pressure | | | *psia/psig* | | *50 psig* | | | | *75 psig* | | | | |
| 23 | Velocity | | | *ft/s* | | | | | | | | | | |
| 24 | Pressure Drop (Allowable/Calculated) | | | *psi* | | *5.* | | | | *5.* | | | | |
| 25 | Fouling Resistance | | | *hr ft² °F/Btu* | | *0.0010* | | | | *0.0015* | | | | |
| 26 | Avg. Film Coefficient | | | *Btu/hr ft² °F* | | | | | | | | | | |
| 27 | Heat Exchanged | | | | | *Btu/hr* | *MTD (Corrected)* | | *(Weighted)* | | | | | *°F* |
| 28 | Transfer Rate (Required/Fouled/Clean) | | | | | | | | | | | | | *Btu/hr ft² °F* |
| 29 | $\rho V^2$ - lb/ft-s$^2$ : | Inlet Nozzle | | | *Bundle Entrance* | | | *Bundle Exit* | | | | | | |

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# Specification Data Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 30 | **CONSTRUCTION PER SHELL** | | | | | | | |
| 31 | Tube No. | | OD | | in | **NOZZLES - No. Size & Rating (Optional)** | | |
| 32 | Thickness | | in/BWG (Min./Avg.) | | | | **SHELL SIDE** | **TUBE SIDE** |
| 33 | Pitch | | in | | | Inlet | **6"** | *4"* |
| 34 | Length | **200** | in Type | | | Outlet | **6"** | *4"* |
| 35 | Tube-Tubesheet Joint | | | | | Intermediate | | |
| 36 | Shell Diameter (ID/OD) | | | | in | Vent | **3/4"** | *3/4"* |
| 37 | Cross Baffle Type | | | | | Drain | **3/4"** | *3/4"* |
| 38 | Spacing: c/c | | in | No. of Crosspasses | | | | |
| 39 | % Cut (Dia./Area) | | | | | | | |
| 40 | Tube Support | | | Design Pressure | psig | | **150** | **150** |
| 41 | Long Baffle Seal Type | | | Design Temp(Max/MDMT) °F | | | **400 / 0** | **400 / 0** |
| 42 | By-Pass Seal Type | | | No. of Passes per Shell | | | | |
| 43 | Impingement Protection (Y/N) | | | Corrosion Allowance | in | | **1/16"** | **None** |
| 44 | **MATERIALS OF CONSTRUCTION (Optional)** | | | | | | | |
| 45 | Tubes | *Titanium all process wetted areas* | | | | Gaskets | | |
| 46 | Shell | *316L Stainless Steel* | | | | Shell Side | | |
| 47 | Shell Cover | | | | | Tube Side | | |
| 48 | Channel or Bonnet | | | | | Floating Head | | |
| 49 | Channel Cover | | | | | Spare Sets Req'd | | |
| 50 | Floating Head Cover/Bolts | | | | | Test Ring Req'd (Y/N) | | |
| 51 | Tubesheets | | | | | Insulation: Shell | | |
| 52 | Baffles & Support Plates | | | | | Channel Inlet/Exit | | |
| 53 | Expansion Joint Type | | *None* | | | Expansion Joint Material | | |
| 54 | Code Requirements | **ASME Sect. VIII** | | | | Calc. MAWP (Y/N) | **Y** | ***TEMA Class B*** |
| 55 | REMARKS: | 1) Process water contains up to 5 % dissolved NaCl | | | | | | |
| 56 | | | | | | | | |
| 57 | | | | | | | | |
| 58 | | | | | | | | |
| 59 | Originator/Check: | | *Approved:* | | | *Issue Date:* | *Issue No.* | *A* |

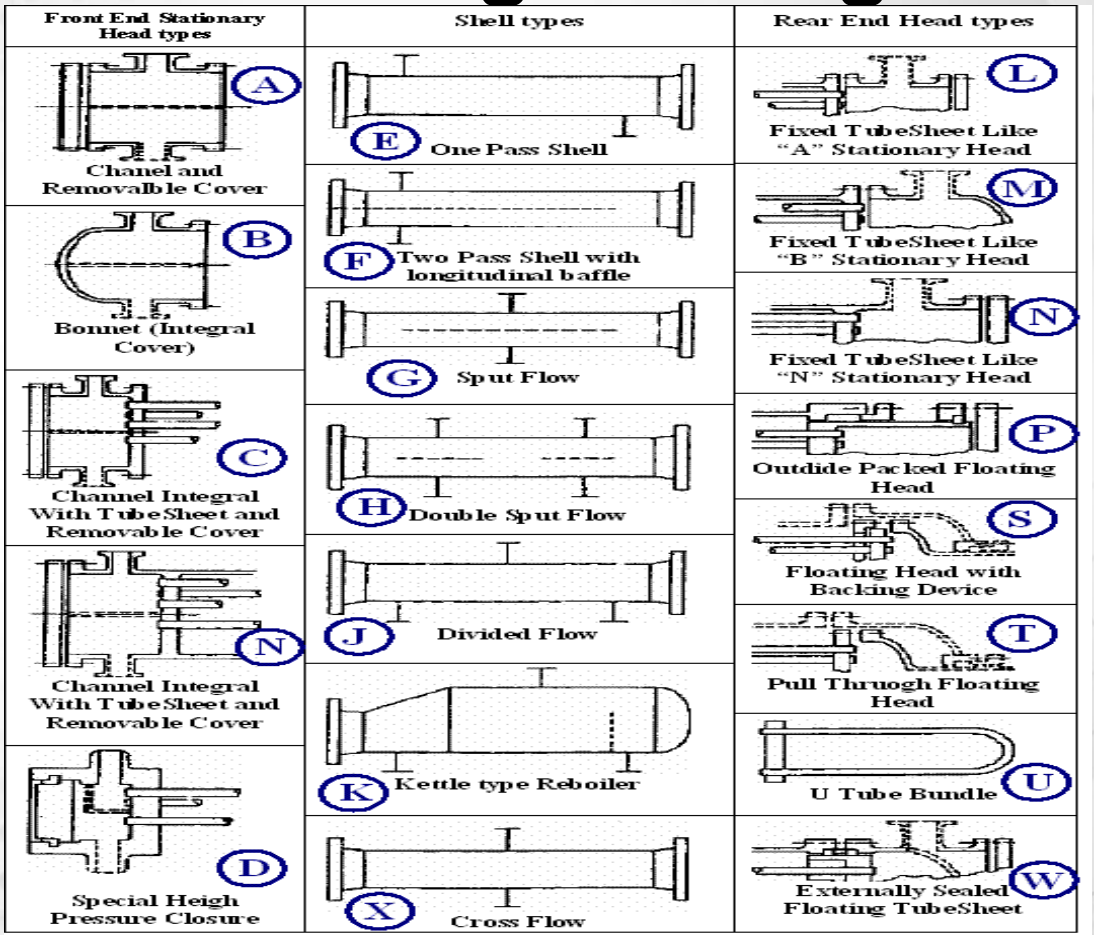
# Shell & Tube Heat Exchangers

- Extremely flexible and robust
- Wide design  capability
- Shell and Tube sides can be different materials
- Some designs can be dismantled for ease of cleaning
- May not be economical for very small applications where custom engineering is required

# TEMA Types

- TEMA designations use a three letter code
  - Inlet bonnet
  - Shell type
  - Outlet bonnet
  - Example: BEM

# TEMA Exchanger Designations

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# Titanium U-tube Bundle

# Zirconium BKU Heat Exchanger

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# Plate & Frame Exchangers

- High heat transfer surface area
- Compact and lower cost than shell and tube
- Flexible (easy to add or subtract plates)
- Temperature & Pressure Limited
- Does not work well with solids

# Rules of Procurement

- Know what you are buying
- Know your Fabricator
- Don’t over design
- Define Quality Requirements
- Define Delivery Requirements
- Lowest price isn’t always lowest cost

# Tricor Experience

- Over 28 years in operation
- Management with over 45 years in specialty metals business
- Many welders with over 10 years' experience
- Tricor welder school training – Welding Engineer on staff
- Metallurgist and 2 PE's on staff
- Engineering, Quality Control and Sales with over 35 years' individual experience

# THANK YOU FOR LISTENING

## Tricor Metals

***Cost Effective Corrosion Solutions***
***Through Design & Engineering***


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