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**

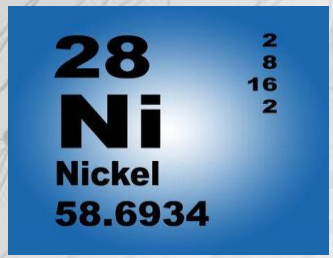
Stainless Steel & Duplex SS

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

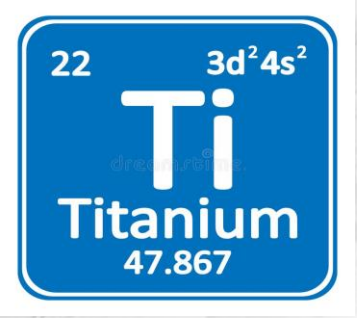
Duplex Stainless Steel

- 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

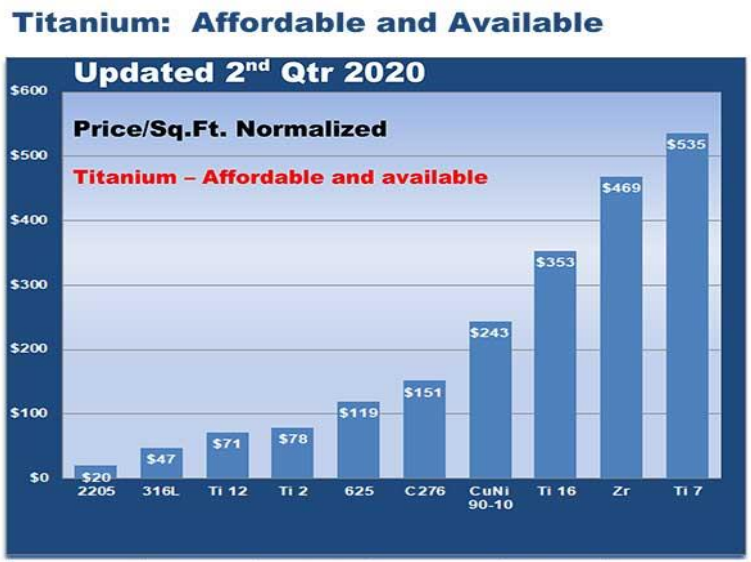
- Major CPI Applications
  - Chlorine (WET) & Bromine (WET) & Bleach & Seawater
  - Terepthalic Acid
  - Oxidizing Acids – nitric, chromic, perchloric
  - Low concentrations of Hydrochloric and Sulfuric Acids
  - Alkaline (ammonium hydroxide, sodium hydroxide, etc)
  - Organic Chemicals & Acids (adipic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

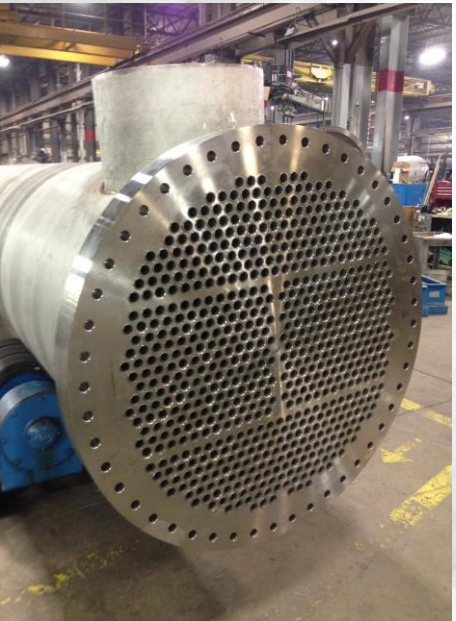
Alloy Cost Comparison Chart



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	ρV^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*

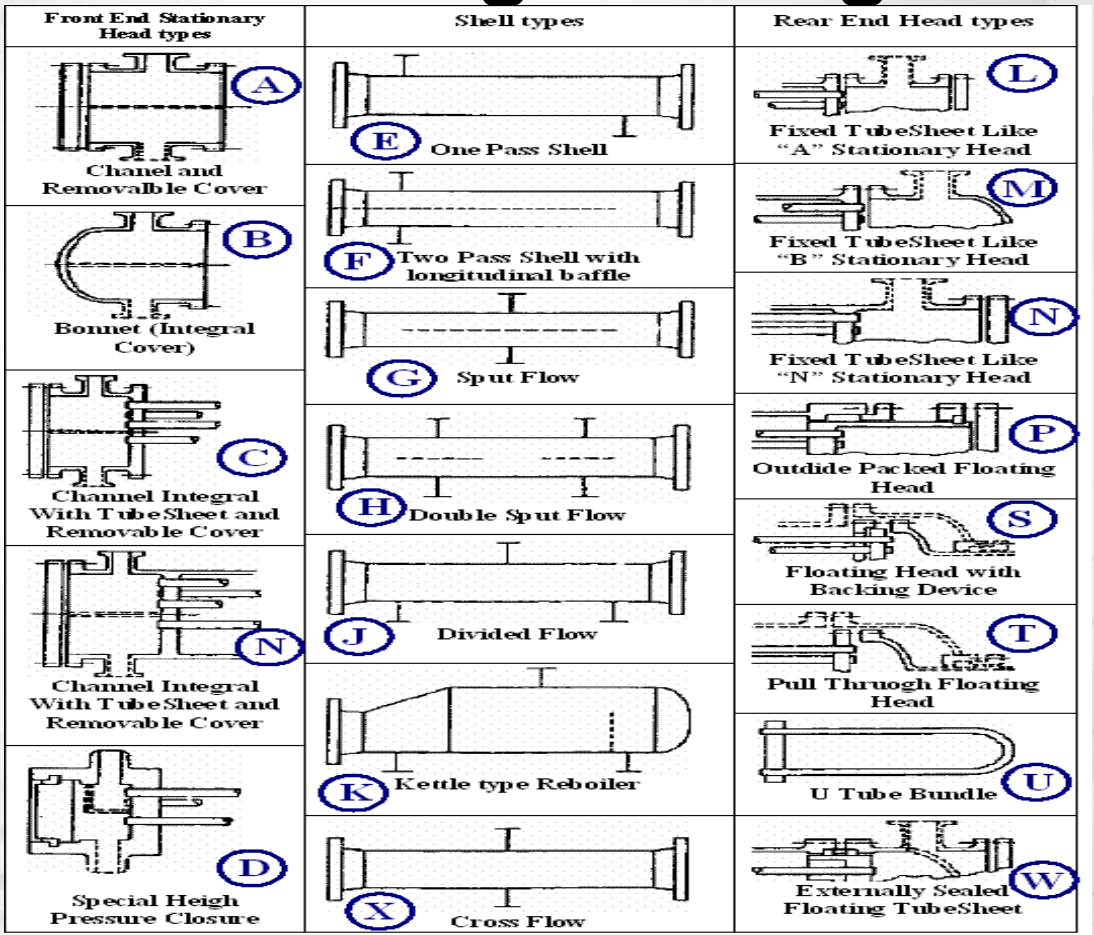
Shell & Tube Heat Exchangers

- 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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