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Using Explosion Clad Metals to Extend the Life and Reduce the Cost of Heat Exchangers

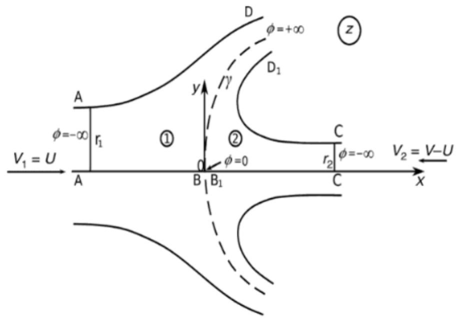
Heather Reuther Mroz, Technical Development Manager, NobelClad

Agenda

- The History of Explosion Cladding
- What is Explosion Cladding
- How to Ensure Clad Quality
- Examples of Clad Use in Heat Exchangers

The History of Explosion Cladding

- World War I: It was observed that bullets that were fired into armor plates became welded to the plates
- 1946: 1st Scientific Article published about Explosion Welding by Russian Mathematician, Mikhail Lavrentiev after phenomenon was also seen in World War II
- 1954: Lavrentiev developed the Jet Collision Phenomena Concept shown here



The History of Explosion Cladding

- 1959: DuPont De Nemours developed a commercially viable explosion welding (cladding) process to join two metals
- 1964: DuPont was granted US Patent 3,137,937 and trademarked it Detaclad. DuPont later sold rights.
- Process developed, commercialized and standardized in the 1960's and now classified in **EN 14610, EN ISO 4063** and American Welding Society (AWS) **WHC3.09**
- Today: Cladding has proven to be a highly reliable, robust process and its reliability has been demonstrated for 50+ years

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What is Explosion Clad

Combination of two or more metals in layers. Typically intended to serve a purpose one metal alone can not provide suitably or economically.

Cladding can:

- Corrosion resistance at lower cost
- Improved heat transfer characteristics,
- Acceptable strength or stiffness at reduced cost
- Improve electrical properties
- Improve abrasion or wear resistance

What is Explosion Clad

Ways to Clad:

- Extrusion
- Electroplating
- Chemical processes
- Weld Overlay
- Vacuum Cladding (also called *Vacuum Explosion Cladding*)
- Explosion Cladding also called *Explosion Welding or Atmospheric Cladding*
- Roll Bonding (cannot use for zirconium and some other metals)

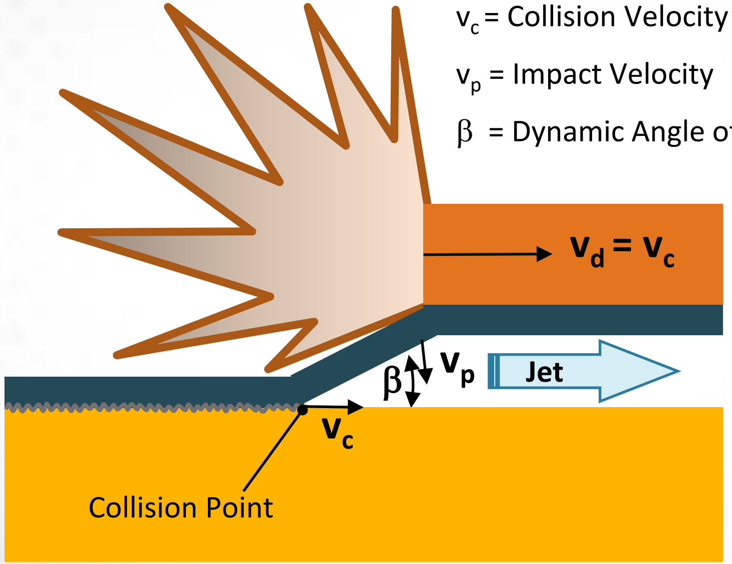
What is Explosion Clad

Explosion Clad is a solid-state welding process that uses precision explosions to bond two **dissimilar** or similar metals while retaining the mechanical, electrical and corrosion properties of both

Explosion cladding can join compatible and non-compatible metals with more than **300 metal combinations** possible.

Combinations of two or three metals may be achieved

What is Explosion Clad



KEY

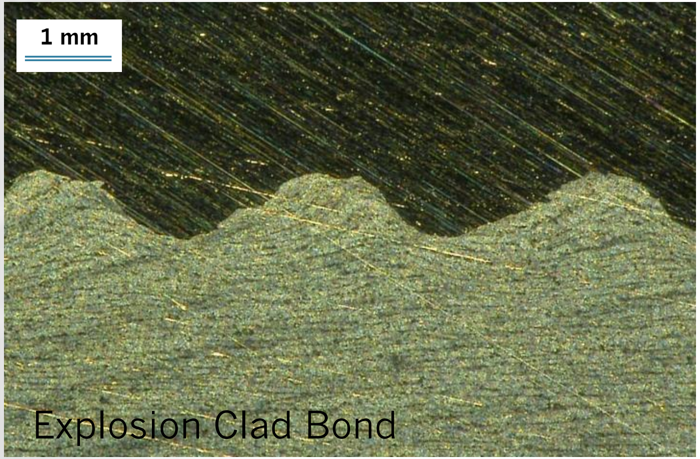
v_d = Detonation Velocity

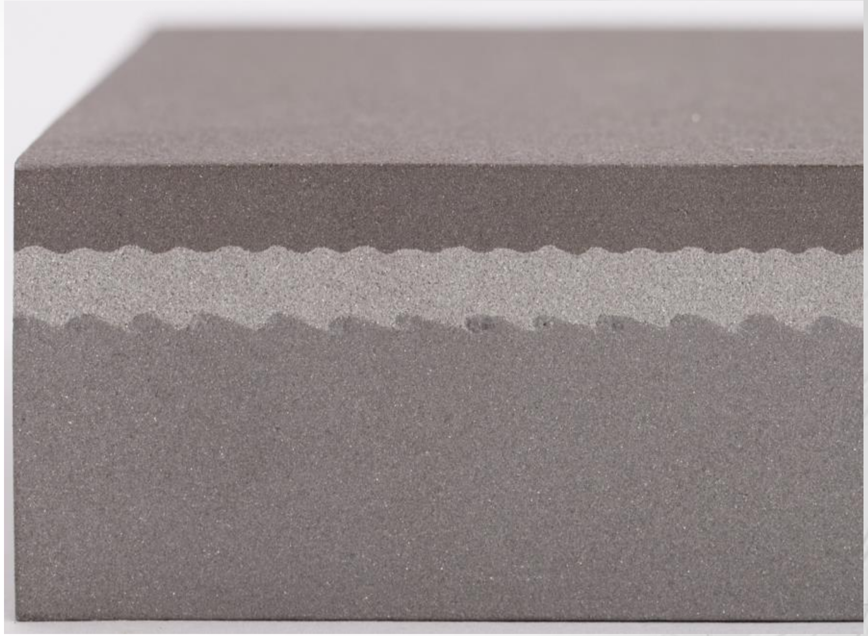
v_c = Collision Velocity

v_p = Impact Velocity

β = Dynamic Angle of Collision

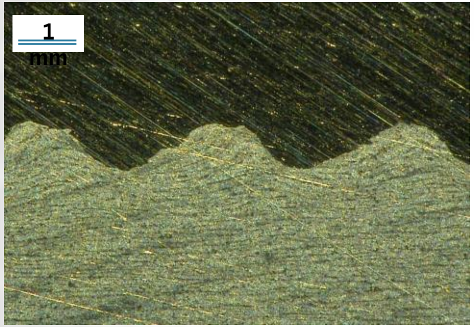
What is Explosion Clad



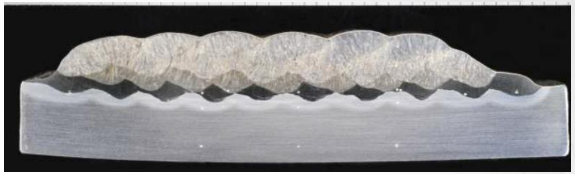


What is Explosion Clad?

Explosion Clad vs. Other Types of Cladding



Explosion Clad Bond



Weld Overlay Bond

Roll Bond

What is Explosion Clad?

Cladding Metals

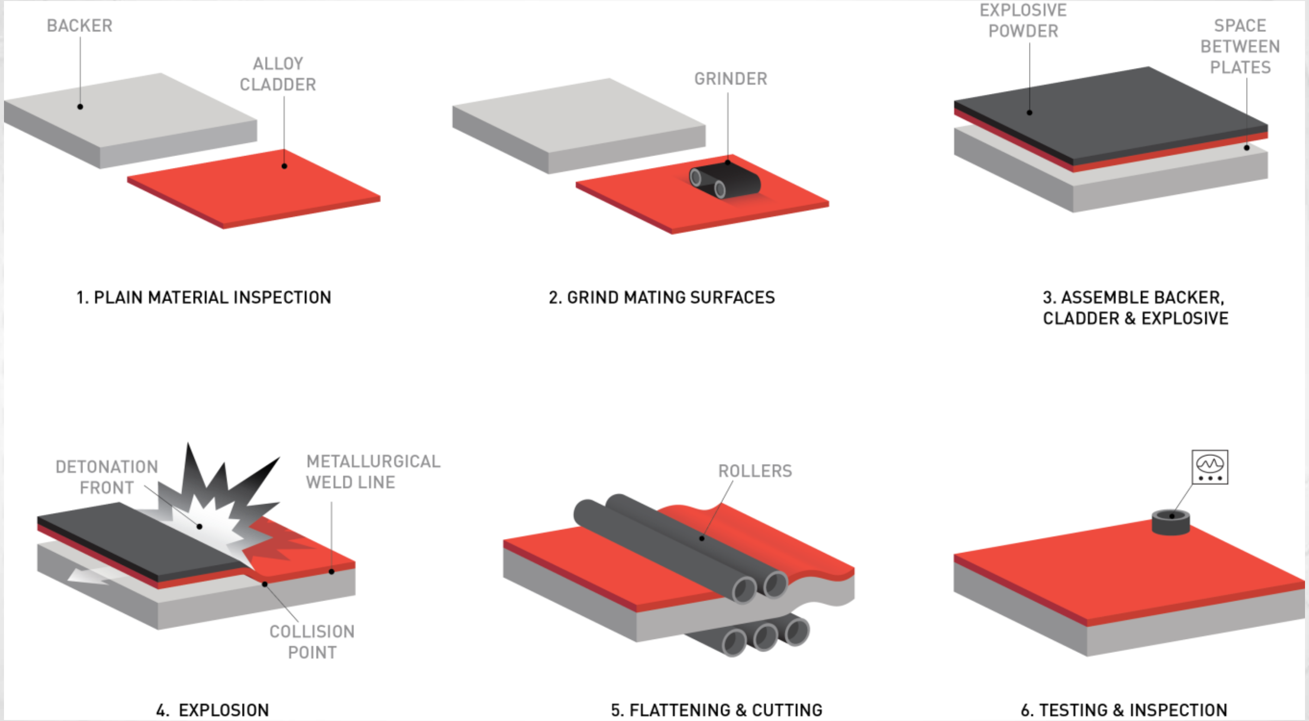
- Aluminum
- Copper Alloys
- Nickel Alloys
- Silver
- Stainless Steel
- Tantalum
- Titanium
- Zirconium

Base Metals

- Aluminum
- Alloy Steel Forgings and Plate
- Carbon Steel Forgings and Plate
- Stainless Steel Forgings and Plate

What is Explosion Clad?

How to Ensure Clad Quality?



How to Ensure Clad Quality

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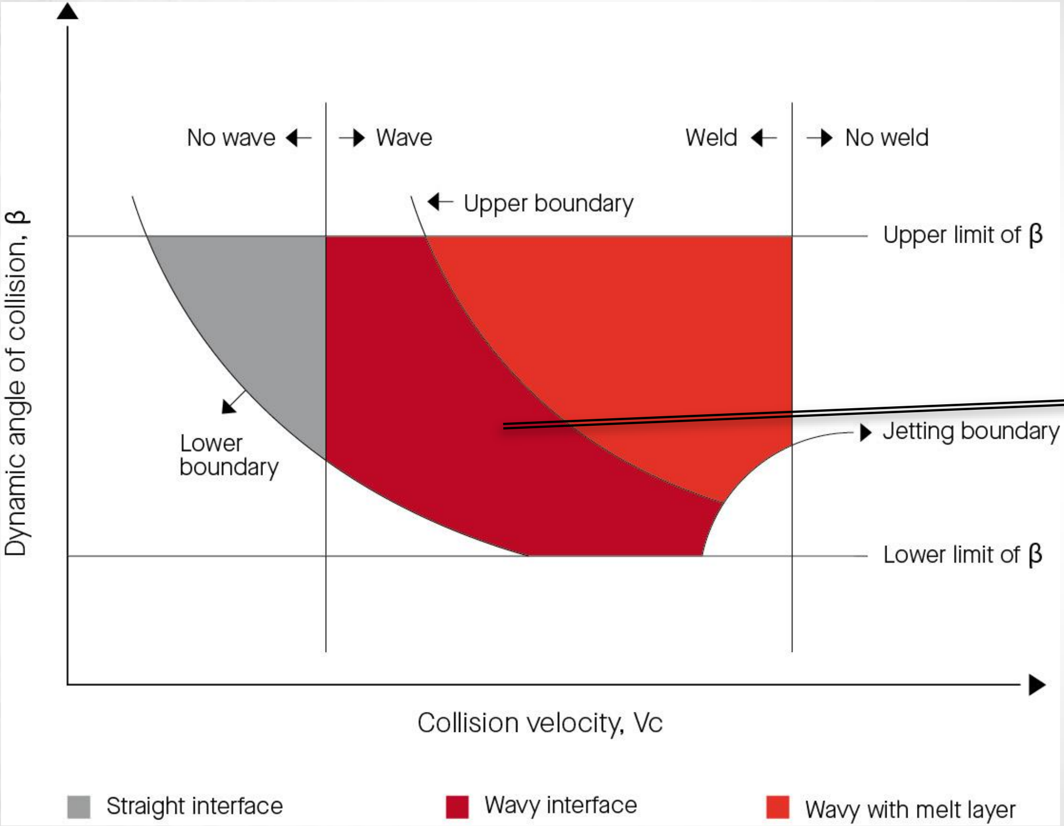

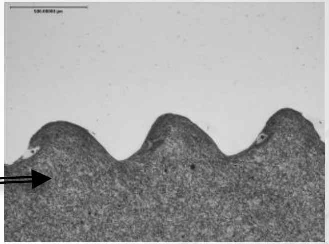

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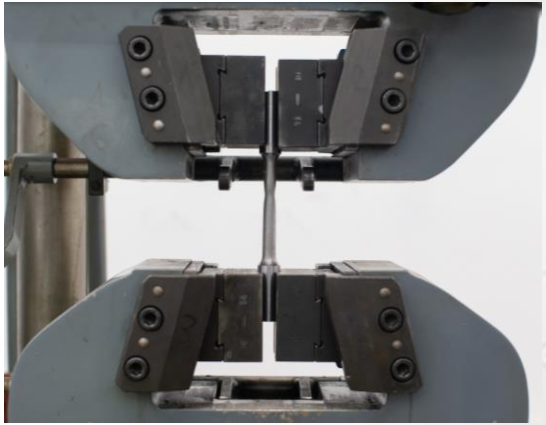
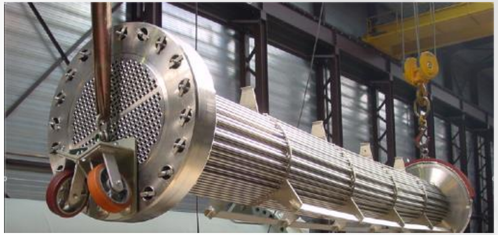


How to Ensure Clad Quality

Evaluate the Clad Supplier

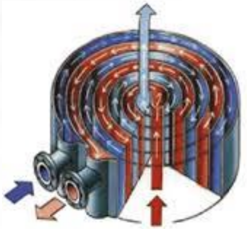
- Today's Global Procurement methods frequently underestimate the significance of a Quality Culture on the Project Success Equation
- The presence of an effective Quality System is critical and must be verifiable
- Building a Quality Culture takes time and dedication
- Quality audits must address a vendor's Quality System and their true Quality Culture
- Proven experience of producing a defect-free, high quality product with on-time is critical
- Quality Systems must be ISO 9001-2008 Certified manufactured in accordance with internationally recognized design codes including ASME, PED, industry, and customer-specific requirements.

Explosion Clad Metals in Heat Exchangers



Shell and Tube

- Tube Sheets
- Shell
- Water Boxes
- Heads



Spiral

- Channels
- Face
- Nozzle

All Welded Plate/Plate and Shell

- Covers
- Nozzles

Direct Contact

- Clad straight pipe

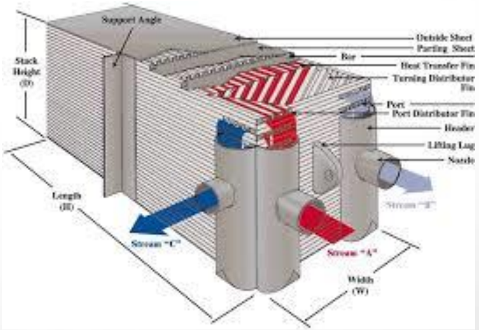
Explosion Clad Metals in Heat Exchangers

Piping

- Explosion Clad Pipe for aggressive media (limited materials)

Fluid Transition Joints (machined from clad plate)

- Aluminum to steel or stainless provide high performance without galvanic corrosion and easy customer connections.
- Microchannel, industrial refrigeration connections
- Cryogenic Transitions



Things to consider when comparing **explosion clad** vs **solid construction**

- Thickness of the backer metal
- Cladding Material
- Overall size
- Pressure & temperature

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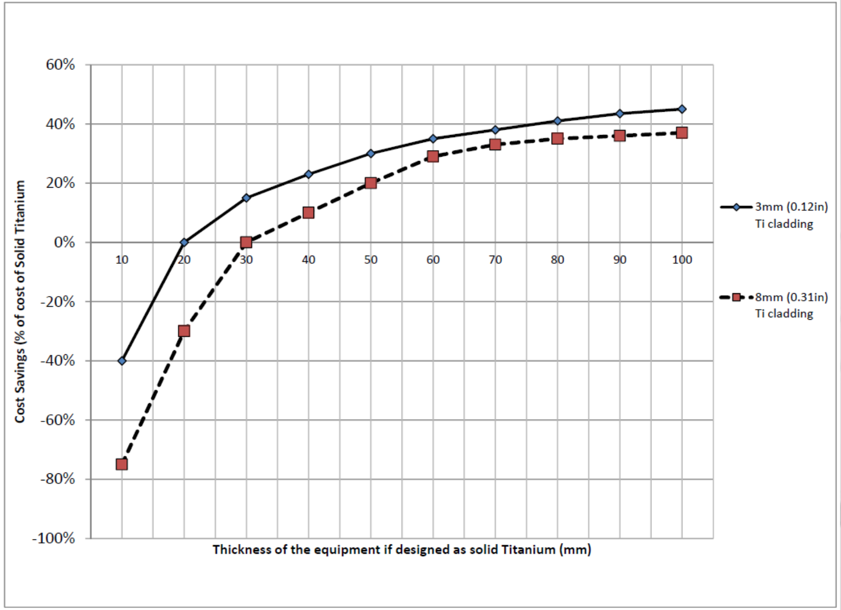
Economics of Ti clad vs. solid Ti equipment is most favorable for **wall thickness >20mm***

Economics of clad Ti clad vs. solid Ti heat exchanger tubesheets is most favorable for **wall thickness >35mm***

For **equipment with thinner walls**, Ti clad construction may offer lower cost for other reasons

- To enhance equipment reliability – fewer welds
- To reduce welding and inspection time/costs
- For ease of welding on external attachments
- For jacketed vessels – weld to carbon steel, not Zr
- For field erected vessels



*Depending on the current market price of titanium and titanium alloys

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Feed Effluent Heat Exchangers in the Diesel Hydrotreating

- High temperature/high pressure application with a high risk of hydrogen induced cracking (HIC) of carbon steel. A crack could result in the collapse of the metallic structure and, in the worst case, pose the risk of explosion.

Solution:

- Stainless steel tubes
- Head, Tube Sheets and Shell – Carbon Steel (Chrome Moly) explosion clad with Stainless Steel (347)

Advantage: Corrosion Resistance of stainless steel with strength of carbon steel

Alternative: Solid Stainless Steel (thick) shell is several times the cost of clad carbon steel.

Cooling with Seawater in LNG Refining

Shell and Tube Heat Exchangers, cooled with seawater, have a stable temperature range and are the most cost effective and safe way to cool.

Solution:

- Titanium Tubes
- Steel Shell
- Titanium Clad Tube Sheets

Advantage: Corrosion Resistance of Titanium with strength of carbon steel

Alternative: Solid Titanium tube sheets adds capital cost to project

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Heat Exchangers for Nitric Acid Cooler Condenser (50-60% concentration)

Solution:

- Zirconium tubes with additional baffle support
- Zirconium clad stainless steel tube sheets
- Stainless steel shell with expansion element

Advantage: Zirconium clad is much less expensive and makes this solution commercially viable

Alternative: Solid Zirconium ZR702

Bimetallic Transition Joints for Industrial Refrigeration (Refrigerated Warehouse)

Solution:

- Bimetallic AL to SS or AL to Steel fluid transitions join aluminum heat transfer coils to steel piping
- Advantage: Two permanently joined metals allow for easy field connections and high pressures
- Alternative: Dielectric union or gasketed flange

Contact Information

NobelClad, A DMC Company
11800 Ridge Parkway, Suite 300
Broomfield, Colorado 80021
USA

W www.nobelclad.com
E info@nobelclad.com
T +1 303.665.5700
F +1 303.604.1897

Heather Mroz
Technical Development Manager
E hmroz@nobelclad.com
M +1 720.498.9428

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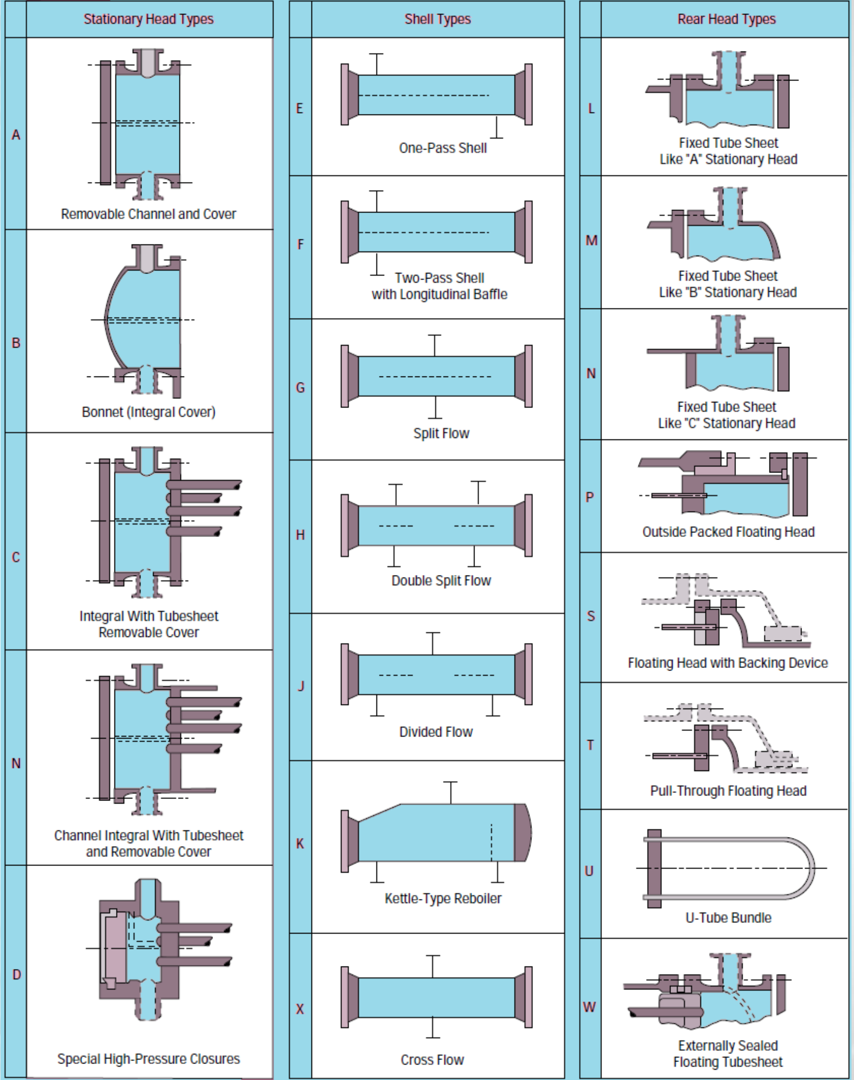
Using Explosion Clad - Heather Mroz, NobelClad


Stationary Head Types
A
Removable Channel and Cover
B
Bonnet (Integral Cover)
C
Integral With Tubesheet Removable Cover
N
Channel Integral With Tubesheet and Removable Cover
D
Special High-Pressure Closures
Shell Types
E
One-Pass Shell
F
Two-Pass Shell with Longitudinal Baffle
G
Split Flow
H
Double Split Flow
J
Divided Flow
K
Kettle-Type Reboiler
X
Cross Flow
Rear Head Types
L
Fixed Tube Sheet Like "A" Stationary Head
M
Fixed Tube Sheet Like "B" Stationary Head
N
Fixed Tube Sheet Like "C" Stationary Head
P
Outside Packed Floating Head
S
Floating Head with Backing Device
T
Pull-Through Floating Head
U
U-Tube Bundle
W
Externally Sealed Floating Tubesheet