The Application of Titanium in Direct Seawater Cooled LNG Plants
LNG: A Growth Market

(LNG growth 1980 – 2004 CAGR 7%)

(LNG growth 2005 – 2010 CAGR 13%)

Global Expansion

- 78 liquefaction trains in service today
- Over 60 new trains in proposal, FEED or EPC
- **Titanium** plays a critical role if seawater is utilized
- 250 tons of titanium for typical Plant
LNG and Seawater Cooling

- 50% of trains
- Advantages
  - Energy Efficient
  - Stable temperature
- Common Concerns
  - Reliability
  - Thermal Effluent
Reliability & Material Selection

- 1st generation plants use Cu-Ni
- Case History: Bontang, Indonesia
- Survey of all LNG plants
- Summary of lessons Learned

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Case History: Bontang LNG

- MR Compressor Coolers
  - 1979 -- 90/10 Cu-Ni tubes
  - Failure rate: 7% / year
- Under deposit corrosion
- Unplanned down-time!
  - Average of one outage per year
  - Lost production cost $$

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Titanium Retrofit Solution

- 1992 - present
- Titanium Fine-Fin tubes / RodBaffle Exchanger type
- No corrosion or erosion in 15 years
- Increased capacity

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Summary of Lessons Learned

- Avoid copper alloys / specify titanium
- Maintain SW flow rate $> 2 \text{ M/S}$
- Design for SW exit temperature $< 40 \text{ C}$
- Provide continuous cleaning SW strainers & continuous chlorination
- Design piping to eliminate low velocity pockets
Titanium Adds Value

- Cost of unplanned down time of typical LNG train is $500,000.00 /day
- Added cost of titanium vs. Cu-Ni Propane condenser = 5 million USD
- LNG plant cost is 2 billion USD
- Material selection is insurance
New LNG Projects Specify Titanium

- Oman, Qatar, Norway, Yemen, U.A.E.
- New heat exchanger technologies applied
- Over 500 tons of titanium supplied in 2006

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Titanium Helifin Exchanger, Snovit LNG
Propane Condenser, Yemen LNG

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Compressor Cooler, Gasco NGL train 4

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Titanium Fine-Fin Tube bundles
Titanium Fine-Fin Tubing

- 2.5 times increase in surface area
- Less material required
- Hydrocarbon gas cooling / condensing shell-side
- Seawater tube-side

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Material Selection and Market Factors

- Is there a titanium shortage?
- Is the current price level impacting material selection or project approvals?
- Competing materials
  - Super-ferritic stainless (Sea-Cure, 29-4C)
  - 6 Mo Stainless
  - Super-Duplex stainless 2507
  - Copper Nickel
Conclusion

- LNG is the fastest growing sector of the energy market.
- Seawater cooling improves LNG plant efficiency.
- Titanium reduces the risk of unplanned downtime and has become the standard for seawater service.
- Technologies such as Fine-Fin tubing and anti-vibration baffle structures have improved the performance of titanium heat exchangers.