
*TITANIUM 2006*

*23rd ITA Conference & Exposition*

*7 – 9 October 2007, Orlando FL*

# TITANIUM RESEARCH & DEVELOPMENT FOR NAVAL APPLICATIONS

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NAVSEA CARDEROCK Surface Warfare Center Division

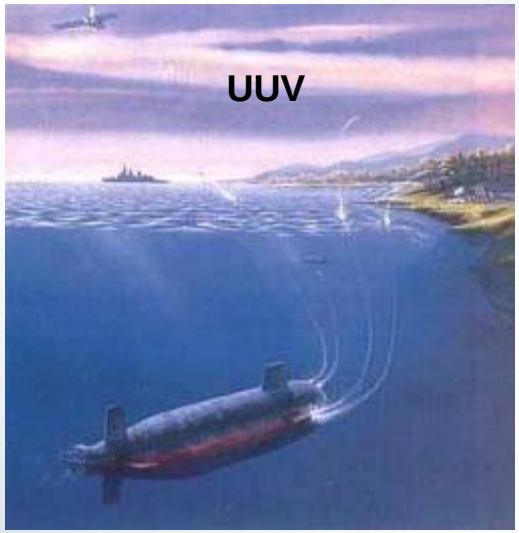
# Navy Platforms

**Reduced Surface Ship Signatures Required - RF, IR, Visible, Magnetic, Acoustic**

**DDG 1000**

**ASDS**

**Hardness Against Underwater Explosions (UNDEX), Air Blast, Ballistic and Fragment Penetration**




**Reduced Submarine and UUV Magnetic and Acoustic Signatures**

**Increased Speed & Improved Protection Systems**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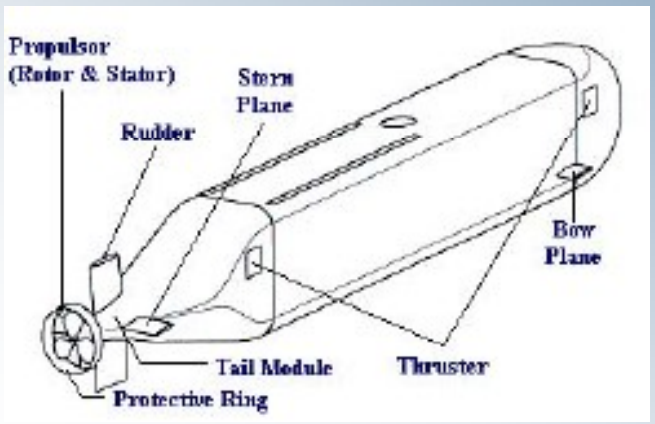
# Titanium Usage in USN Ships

| Ship Class | Total Weight of Titanium per Ship (lb) |
|---|---|
| CVN 68 | 16,500 |
| CG 47 | 20,800 |
| DDG 51 | 33,700 |
| SSN 688 | 31,375 |
| SSBN / SSGN | 31,375 |
| SSN 21 | 75,175 |
| SSN 774 | 31,375 |
| LPD 17 | 136,650 |

# ASDS Titanium Usage

- **High flow stress in tail**
  - Distortion of aluminum alloy
  - Replaced with Ti (?)
- **14 battery bottles**
  - 2 ft diameter x 5 ft long
  - Ti 6-4 ELI
- **Ti 5111 fasteners**




Advanced Seal Delivery System

# Ti-5111 for Naval Applications

## Ti-5111 Navy Service Application

- Extensive evaluation for Submarine Communications Mast Structure
- Mast is welded Ti-5111 structure – plate, bar, & forging
- Over 45 Masts deployed / first deployed in 2000

# Navy Titanium R&D Projects

- **Advanced Combatant Materials Program**
  - **Flow Formed Seamless CP Pipe**
  - **LCS Exhaust Gas Uptakes**
- **Unmanned Undersea Vehicle (UUV) Pressure Hulls**
  - **Investment Cast Ti-5111 & Ti CP-2LO**
  - Ti-5111 Forgings
- Metallic Material Advanced Development & Certification Program
  - Project on Ti 5111 Evaluation for Critical Applications
  - Certification of Ti-5111 Fasteners for Shock Applications
- Titanium Welding Fabrication R&D Projects
  - FSW, Flux-assisted Welding (Including FCAW), GMAW-PA
  - Laser Peening for Weld Fatigue Improvement
- Technical Support to Low-Cost Ti Program (DARPA)
  - Evaluation of Solid-State Ti Plate (Armstrong Process)
  - Ti Applications – Future Navy / Navy After Next
- ALVIN HOV Technical Support
  - New Pressure Hull (Ti-6Al-4V ELI Forgings)
- CVN 21 MANTECH Project (cancelled)

# CP Titanium Piping Applications

- **Low Cost Titanium Piping**
  - **Rationale: Reduce Cost of Proven Titanium Application**
  - **Low Cost Powder Preform**
    - » **Hollow, Cylindrical Preform**
    - » **Navy Can Benefit from Government/Industry Low Cost Powder Initiatives**
    - » **Consolidation Process**
  - **Flowform Conversion**
    - » **Minimal Material Waste**
    - » **Proven Technology**

*Issue Limiting Increased Use:*

- *High material and fabrication costs*
- *Ti system estimated to saved $17M/ship if life cycle savings*

***USS SAN ANTONIO* (LPD 17)**

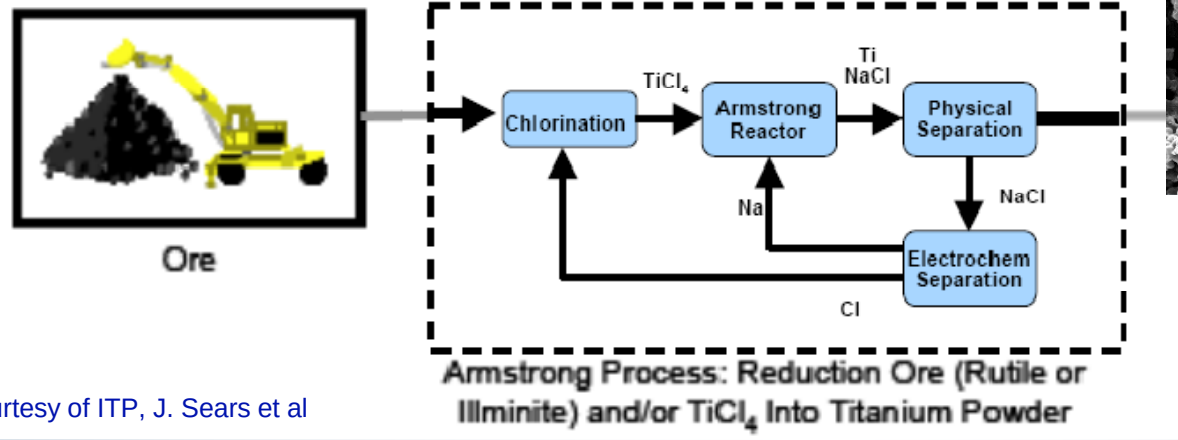
**Titanium Piping System Fabrication Facility**

# Overview CP Titanium Piping

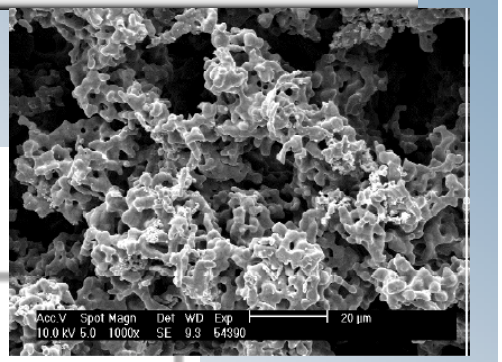
- **Rationale:**
  - Reduce Cost of Proven Titanium Application (Seawater Piping)
  - Navy Can Benefit from Government/Industry Low Cost Powder Initiatives
- **Goal:**
  - Develop titanium pipe conforming to ASTM B 861 (& B 338) from low-cost powder
- **Team: NSWCCD, ADMA, DFC, DuPont and CTC**
- **Approach:**
  - Hollow cylindrical preforms via powder metallurgy (PM) route
    - » CIP + Sintering of powder to hollow cylinders by ADMA
    - » Consolidation of CP Gr 2 powder to hollow cylinders via unique DuPont process (including CIP&HIP)
  - Conversion of preforms to pipe via flowforming by DFC

# CP Titanium Powder Processes

- **ITP Armstrong Process Powder**




Courtesy of ITP, J. Sears et al



- **ADMA's Hydride-Dehydride Powder**
- **DuPont-Honeywell's CP titanium powder via modified Hunter Process (?)**
- **DuPont-MER aims for even lower cost Ti under DARPA program**

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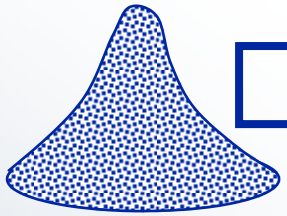
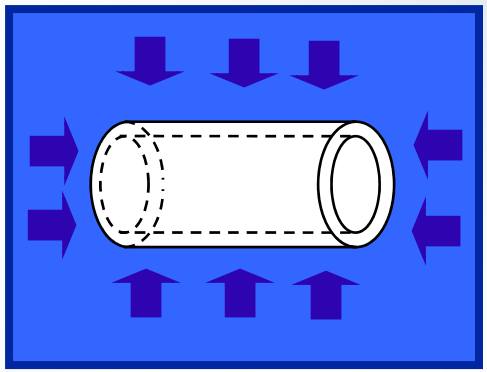
# CP Titanium Pipe Processing



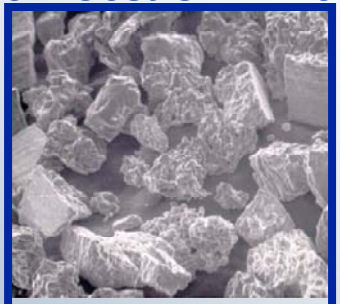
Low Cost CP Ti Powder



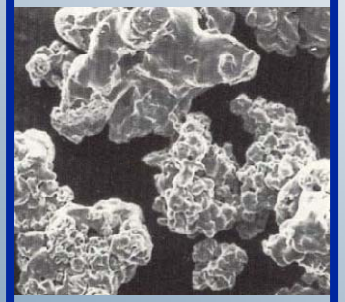
Cold Isostatic Pressing

Vacuum Sintering

Preform



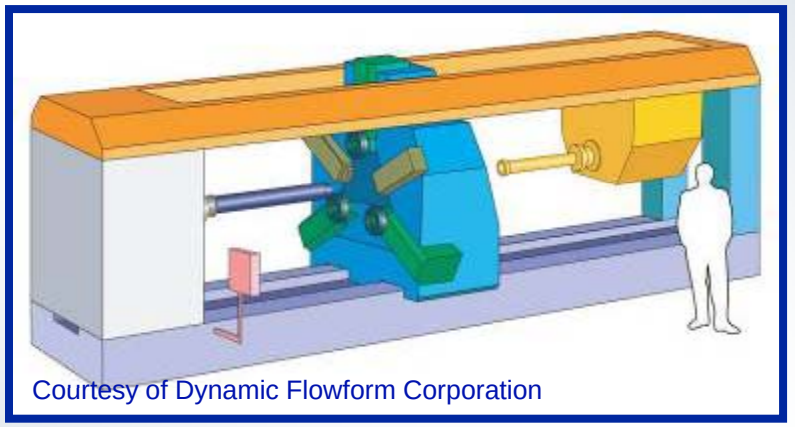
HDH Powder



Sponge Fines

Courtesy of Sam Froes

Flowformed Pipes

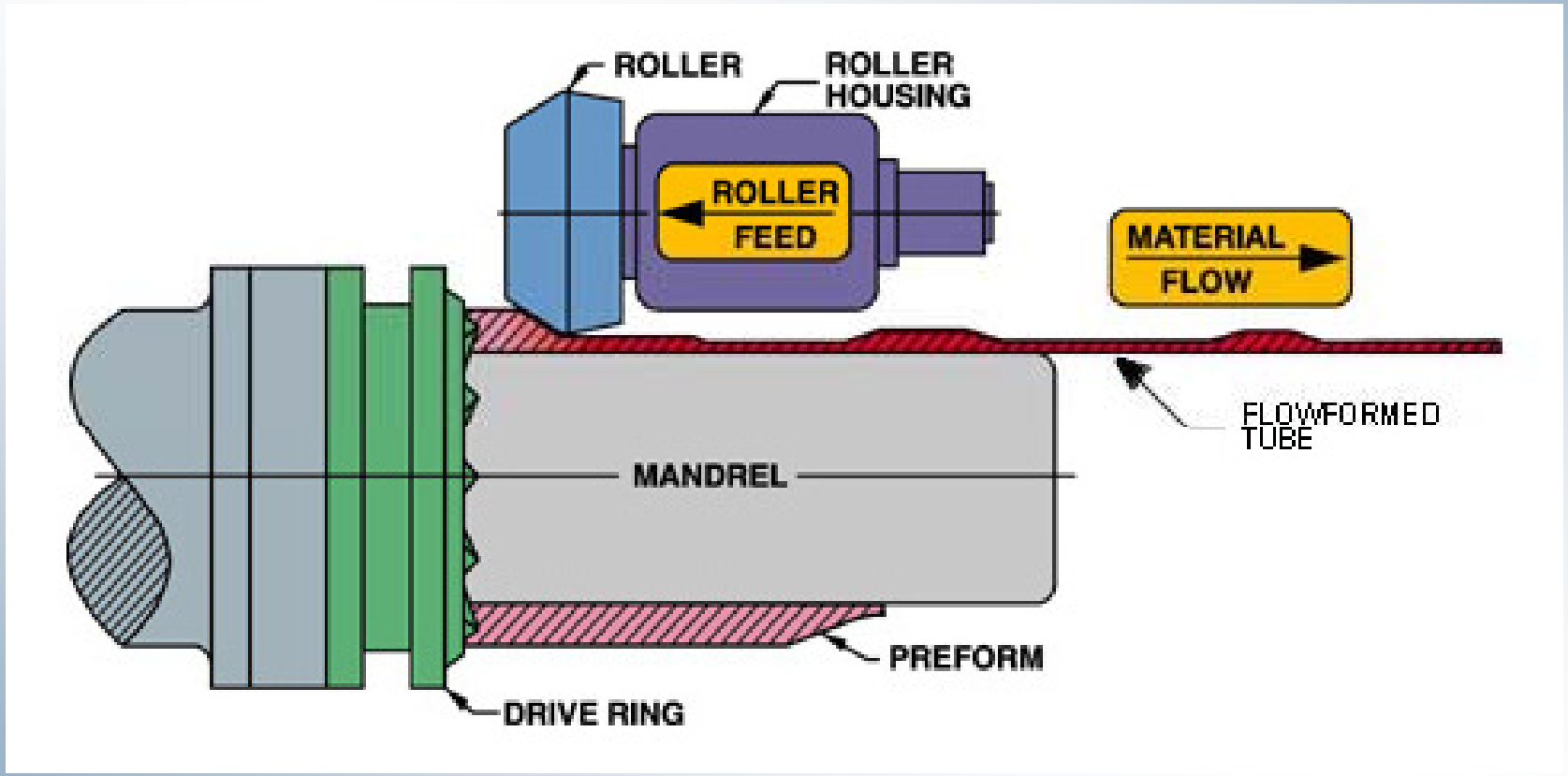


Courtesy of Dynamic Flowform Corporation

Flowforming

# Flowforming

- **Reverse Flowforming for pipe making**




Courtesy of Dynamic Flowform Corporation

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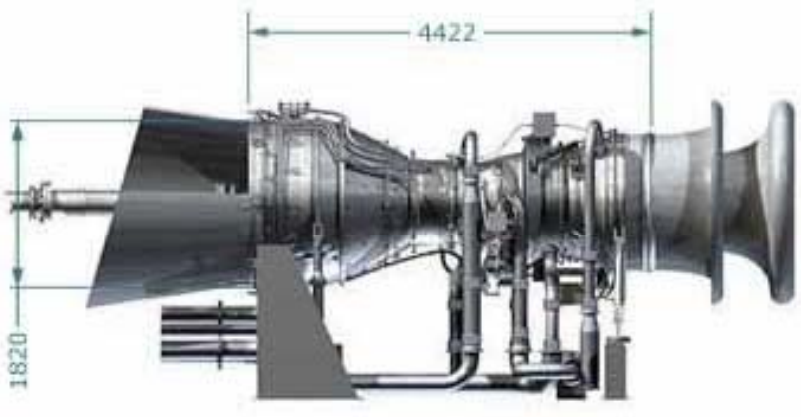
# Flowforming Facility @ DFC


Courtesy of Dynamic Flowform Corporation

# LCS Titanium Uptakes Overview

- Objective: Perform feasibility analysis to determine whether titanium alloys are viable materials to meet the design and performance requirements of the current LCS gas turbines uptakes.




Rolls Royce MT30

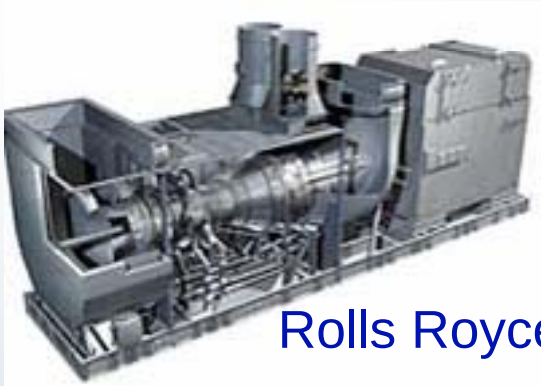
- Goal: Achieve weight savings, approach a cost-neutral solution
- Current LCS uptake design employs nickel-based Inconel 625
- Evaluate as high temperature replacement

# LCS Titanium Uptake Feasibility

## Tensile Yield Strength

| | IN 625 | Ti1100 | IN 625 | Ti1100 |
|---|---|---|---|---|
| Temp (F) | YS (ksi) | | YS (ksi)/Density(lb/in3) | |
| 75 | 69.5 | 134 | 227.9 | 822.1 |
| 1200 | 106 | 81 | 347.5 | 496.9 |
| 1400 | 79 | 77 | 259.0 | 472.4 |

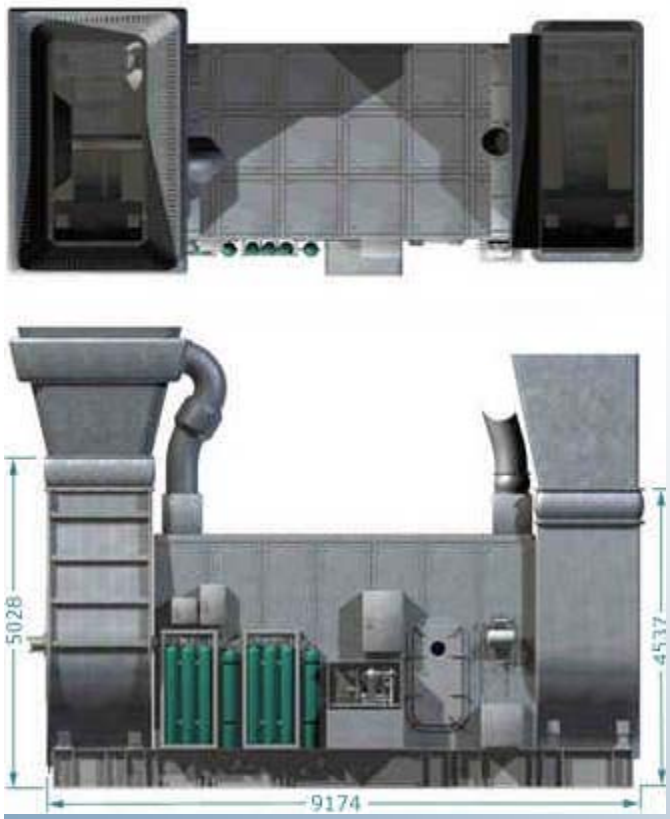
Freedom (LCS1)



Rolls Royce MT30

# LCS Titanium Uptake Feasibility

Rolls Royce MT30




- Level of substitution
  - Inner sheath
  - L-Bracket framing
  - Outer sheath
- Critical design criteria
  - Design shock load during operation
  - High-temperature creep resistance
  - Thermal fatigue
  - Corrosion resistance
  - Substitution compatibility with present materials (YS, % elongation, manufacturability, etc.)
- Investigate up to 3 candidate materials
  - Ti-1100, Ti-21S, Other?
- Determine weight savings (based on 1:1 substitution)
- Perform FEA on best candidate material

# Cast Titanium & Ti-5111 Alloy

*Unmanned Undersea Vehicles (UUV)*

Near net-shape pressure hull castings

Hull Inserts, Penetrations

**Trial Casting**
**Ti CP-2LO UUV Hull Section**

**Trial Casting**

**Ti-5111 UUV Hull Section**

*High-Speed Ships (LCS)*

Castings (Waterjet components - impellers, pump casings, ducts)

# SUMMARY

- Titanium is an optimum material for seawater service
- It has been successfully used in the Navy for decades and continues to be used primarily in auxiliary systems
- Increased use and large structural applications are limited by high material & fabrication costs
- Although initial cost may be offset by reduced life cycle and end of life value, ***ship acquisition cost rules***
- Opportunities exist for titanium to increased payload, range, stability, and operating cycles