

PM/HIP Technology Current and Potential Applications

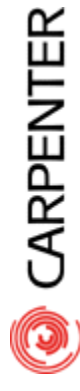


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June 25, 2007

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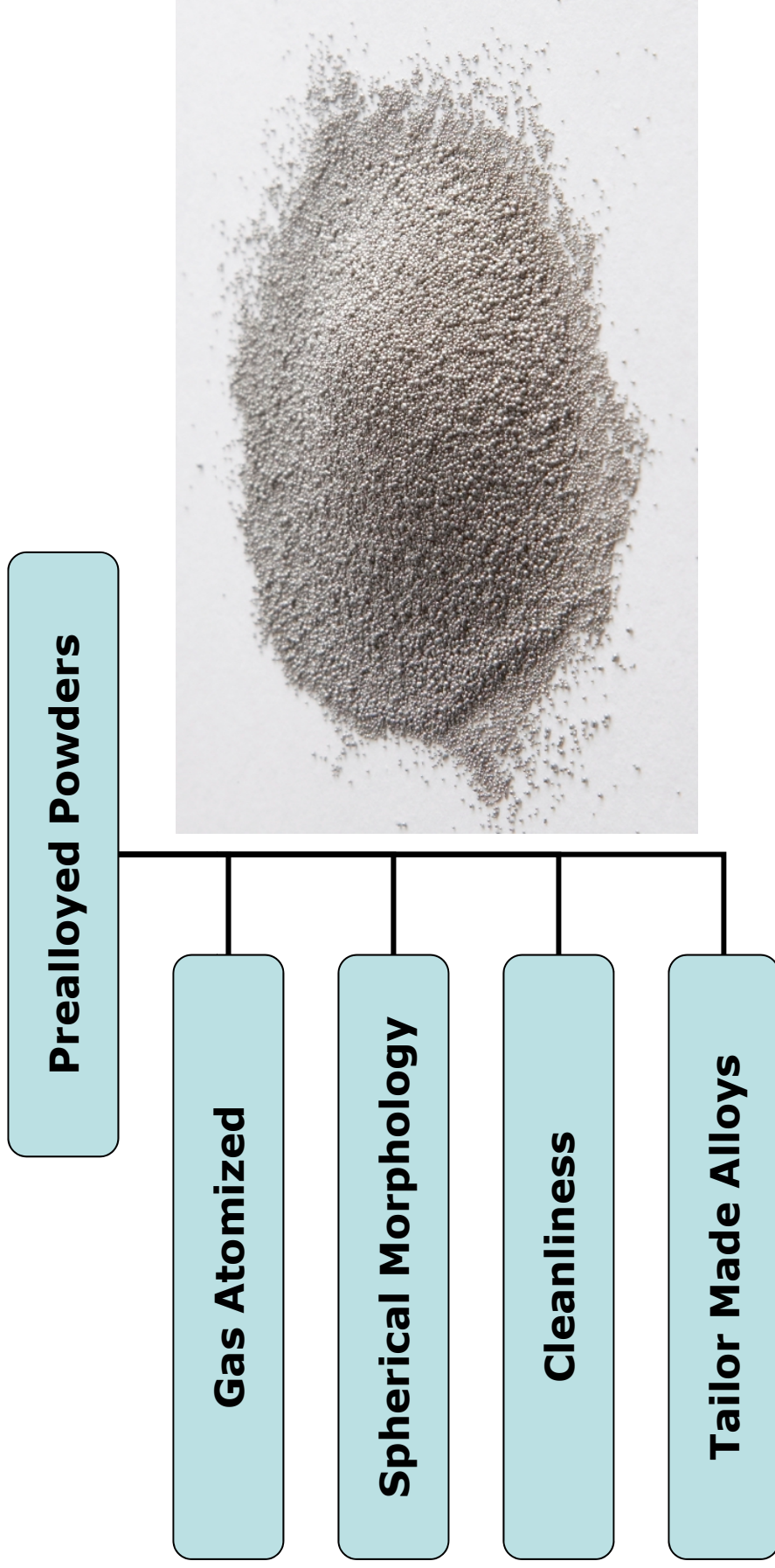
PM/HIP Technology - Market

Major HIP Applications

- Densification
 - Aerospace, Orthopedics, IGT, Automotive
- *Compaction of P/M Billets & Preforms*
 - HSS, Cutting Tools, Aero-Engines, Sputtering Targets
 - PM Near Net Shape and HIP Clad Components
 - Chemical, Oil and Gas Drilling
 - Post Densification of Carbides, Cermets & Ceramics
 - Plungers, Textile Guides, Bearings
 - Wear Components, Bearings

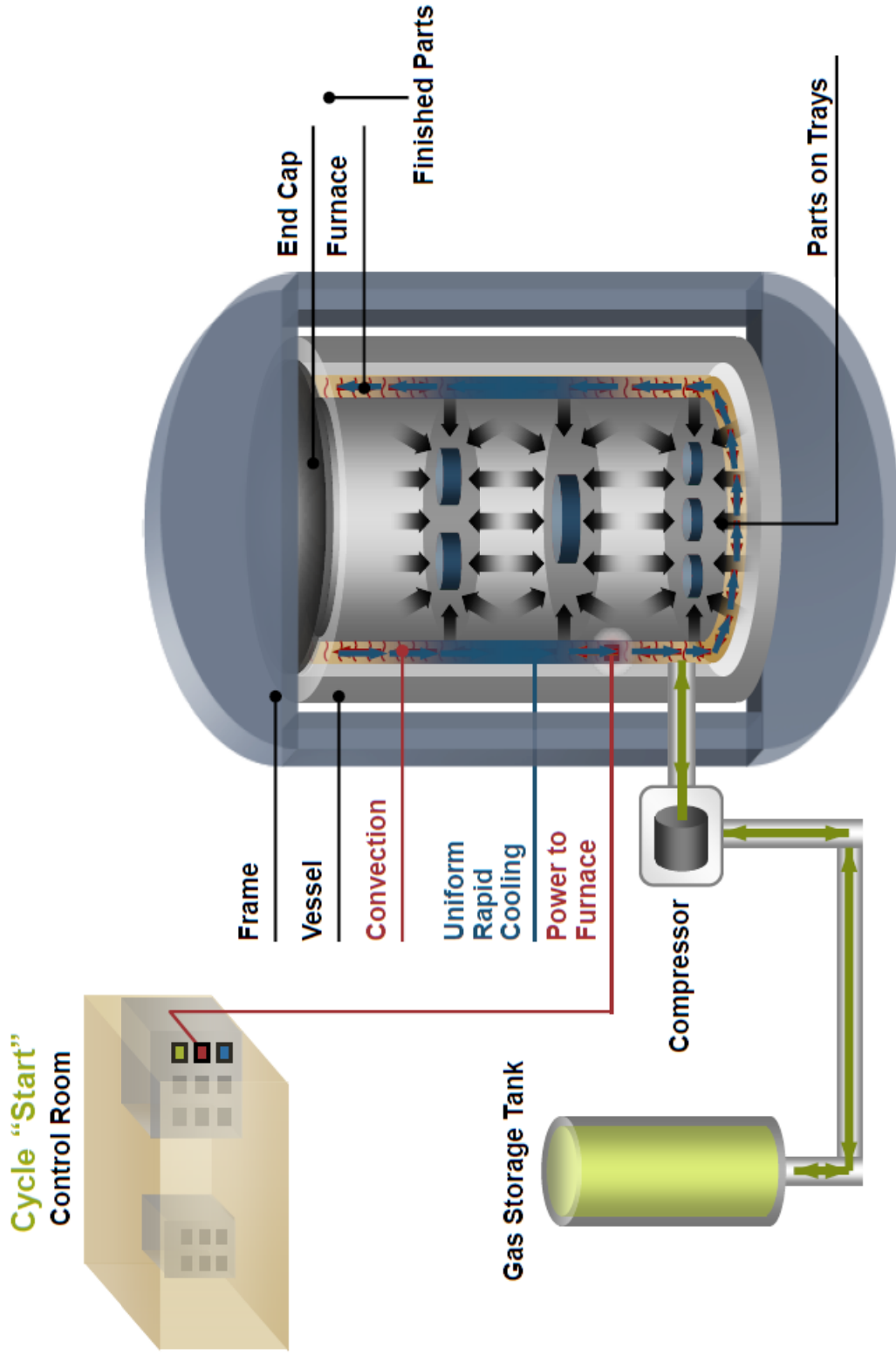
PM/HIP Technology - Prerequisite

Metal Powders for Hipping



PM/HIP Technology - Process

HIP Cycle



PM/HIP Technology - Process

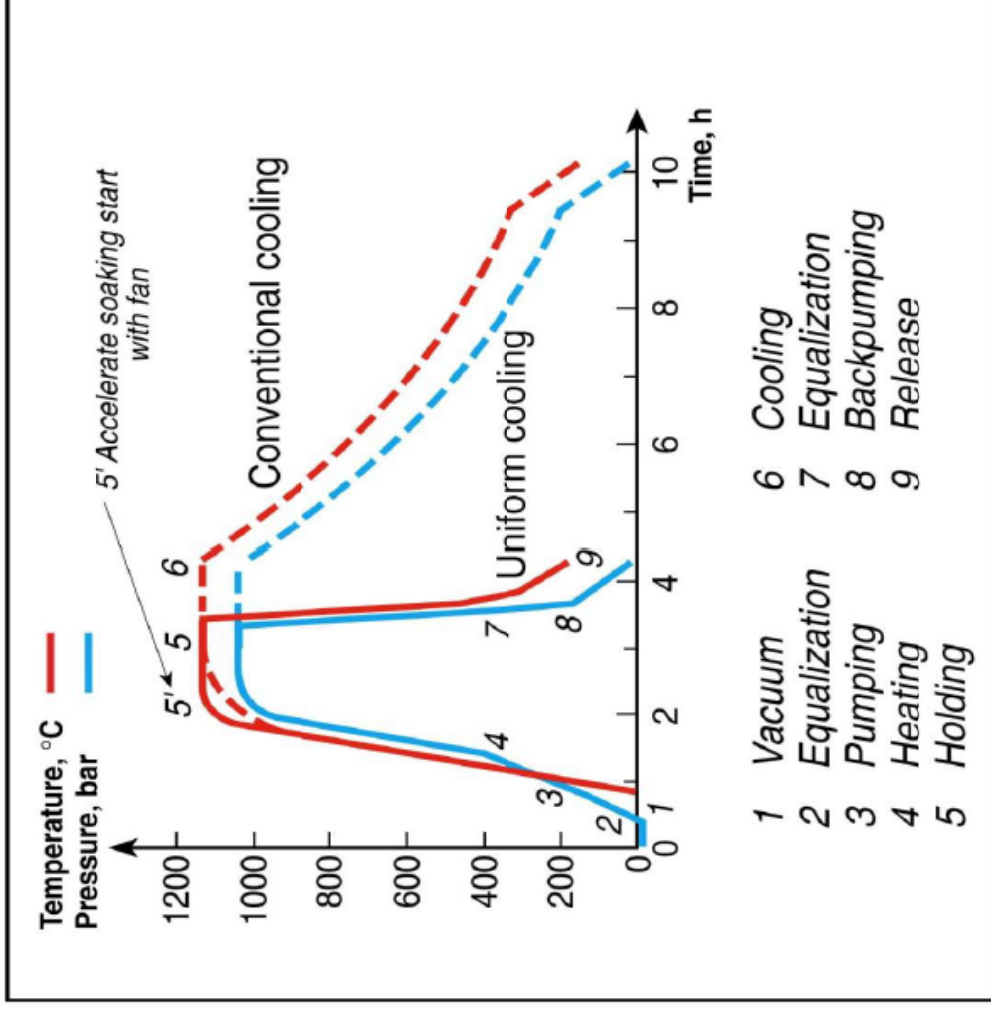
Physical effects of HIP Cycle

- Increases the specific heat of the surrounding gas
 - Increases the heat transfer between the gas and any surfaces
- α of $> > 1000 \text{ W/m}^2\text{C}$ ($> 50 \text{ Btu/s.ft}^2\text{F}$) can be achieved
- Exceeds the yield stress
 - Accelerates creep and diffusion by orders of magnitude

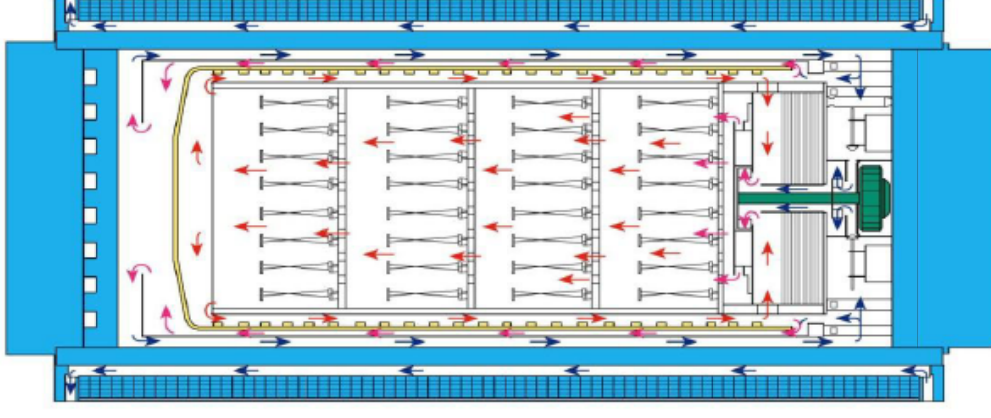
PM/HIP Technology - Process

Uniform Rapid Cooling

HIP Cycle: Conventional Cooling versus URC



HIP Furnace with URC



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PM/HIP Technology - Process

Superior Material Properties

- Any number of temperature steps can easily be included to a cycle.
- Pressure can change the equilibrium lines and kinetics in CCT and TTT diagrams.

Seeking out the influence of pressure at different temperatures gives the metallurgist an entirely new tool to create new materials.

- A new field of materials
- science is opened up for exploration



PM/HIP Technology – Controlled Cooling

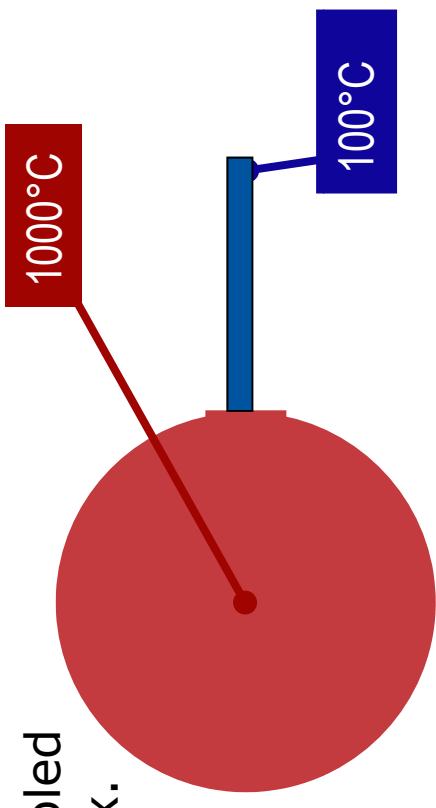
Superior Dimensional Control

- ΔT is lower compared to other methods of cooling
 - Thin and thick cross sections will be closer in temperature
- Lower thermal stresses
 - less warping
 - less cracking
 - less residual stresses
- More accurate tolerances

PM/HIP Technology – Shape Control

Stress Calculations

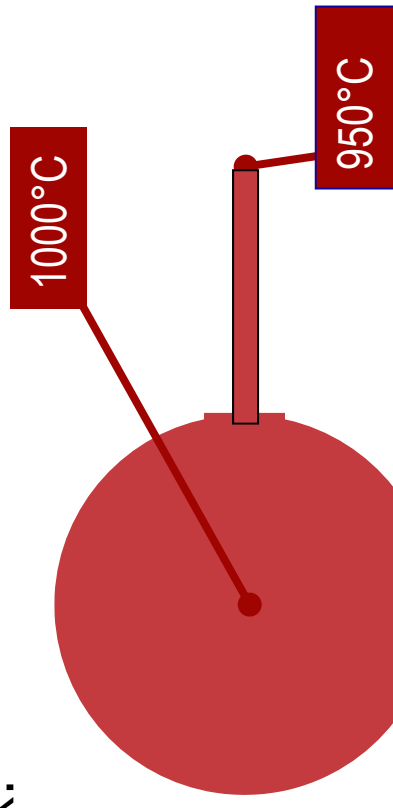
As the center of the air-cooled part has cooled to 1000°C, the temperatures will be approx. distributed like this:



The stress in the thin section will be:

3240 MPa (470 Ksi)

As the center of the HIP-cooled part* has cooled to 1000°C, the temperatures will be approx. distributed like this:



The stress in the thin section will be approximately:

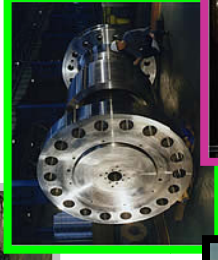
180 MPa (– 150 ≈ **30 MPa** (4 Ksi))

*** Uniform Rapid Cooling**

PM/HIP Technology

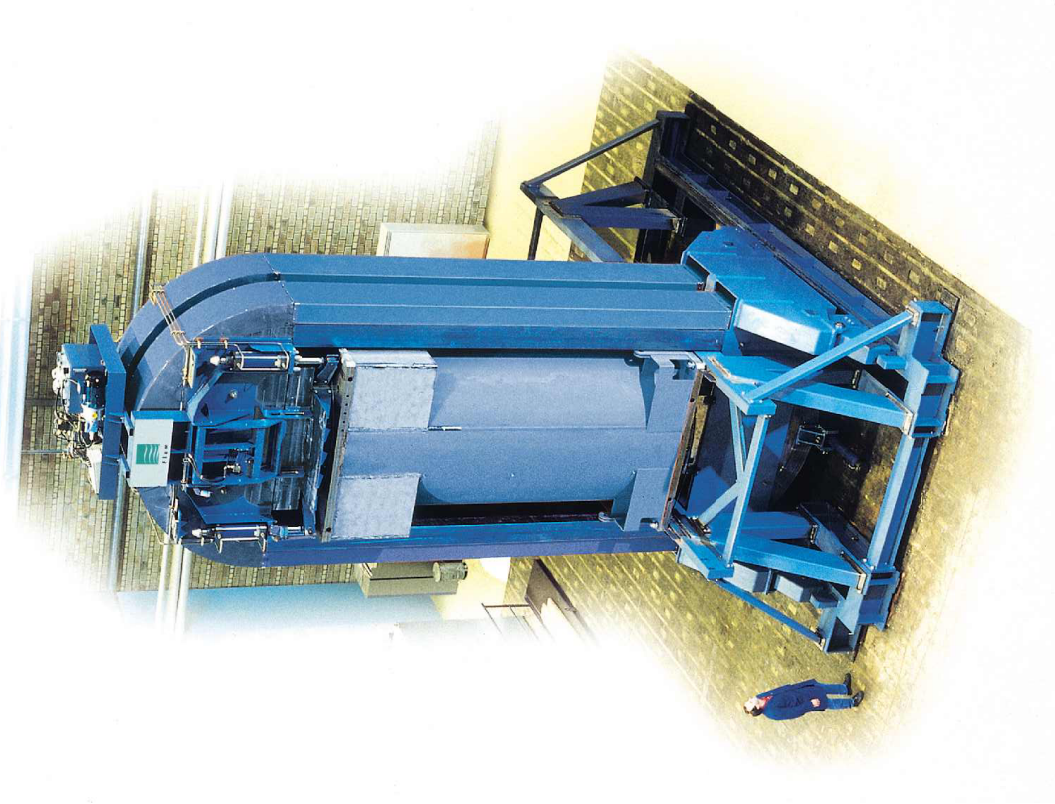
Benefits

- PM/HIP opens new markets**
- Cuts end customer lead time / cost**
- Increases quality (full density)**
- Improves efficiency (less machining)**
- “Green” processing (material savings)**
- New markets**



PM/HIP Technology - Equipment

Large HIP systems are now in production around the world



Commercial PM HIP Capacity

Large-HIP Units in World

<u>Company</u>	<u>Size</u>	<u>Country</u>
Kinzaku Giken	81"Øx164" Long	Japan
Bodycote	71"Øx130" Long	Sweden
	58"Øx146" Long	Sweden
	(3) 66"Øx100" Long	USA
	(2) 49"Øx 98" Long	UK
ATI	51"Øx118" Long	USA
Howmet	59"Øx 80" Long	USA
	42"Øx 97" Long	USA
Kittyhawk	47"Øx 79" Long	USA
Avure(TeraHIP)	124"Øx197" Long	Proposed



Commercial HIP Capacity

Japanese Giga HIP Unit



PM/HIP Technology – Examples

Potential PM Power Plant Components

- **Steam generators**
- **Reactor vessel heads**
- **Tanks and supports**



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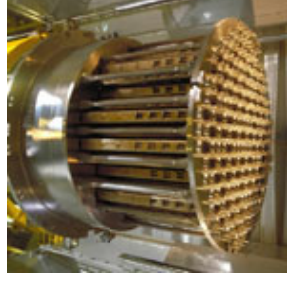
PM/HIP Technology – Examples

Potential PM Power Plant Components

- **Reactor coolant pumps**



- **Reactor vessels**

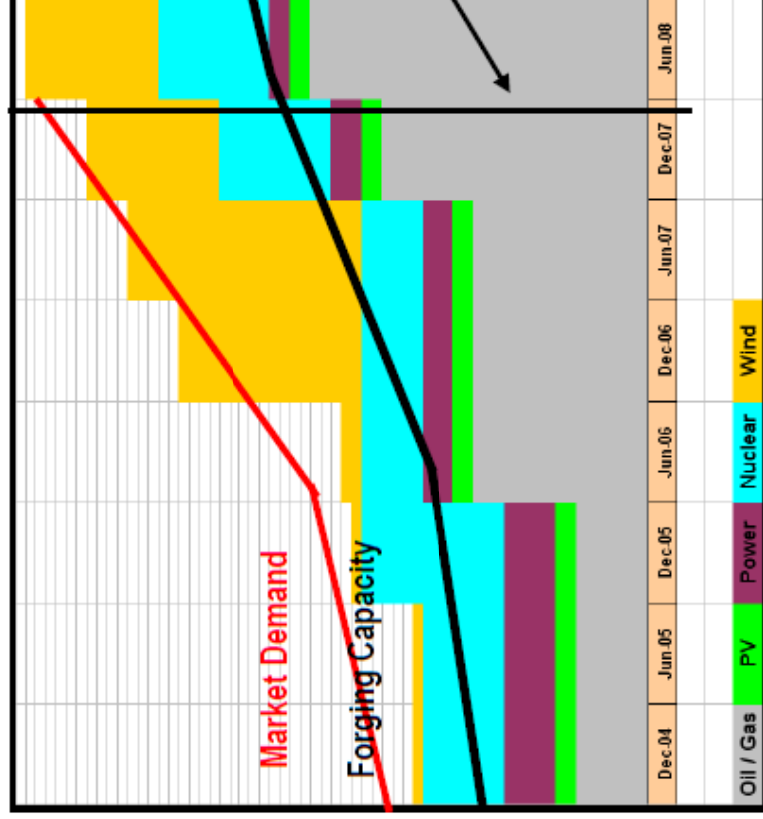
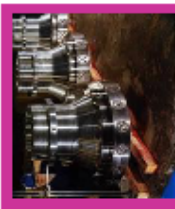
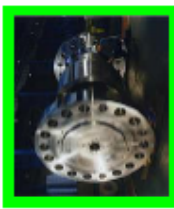


- **Pressurizers**



PM/HIP Technology - Logistics

Forging Capacity vs Market Demand



PM/HIP Technology – Size Limitation

Forged Part Candidates – To Large



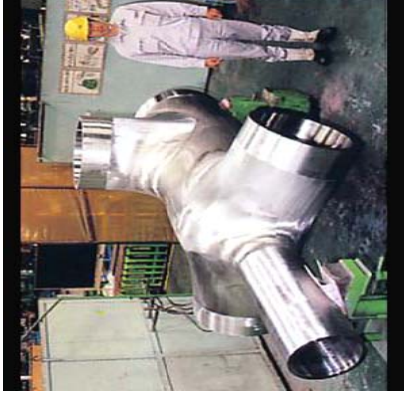
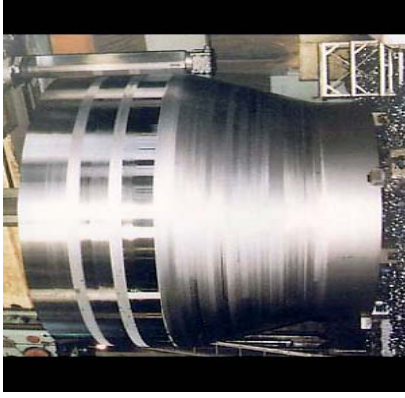
RPV	
Core Region Shell	
Dimension :	294"OD 156" Tall
Weight:	127ton
Material:	ASME SA508, CL.3EQ.

RPV	
Bottom Petal	
Dimension:	300" OD 64" Tall
Weight:	80ton
Material:	ASME SA508, CL.3EQ

RPV	
Integrated Type Closure Head	
Dimension :	158" OD 67" Tall
Weight:	38ton
Material:	ASME SA508, CL.3EQ

PM/HIP Technology – Examples

Forged Part Candidates



Steam Generator	
Cone Shell – To Large	
Dimension:	189" OD 130" Tall
Weight:	44ton
Material:	ASME SA508, CL.3EQ.

Piping	
Cross With Nozzle - Ok	
Dimension:	60" x96"
Weight:	2ton
Material:	SUS F 316L(N)

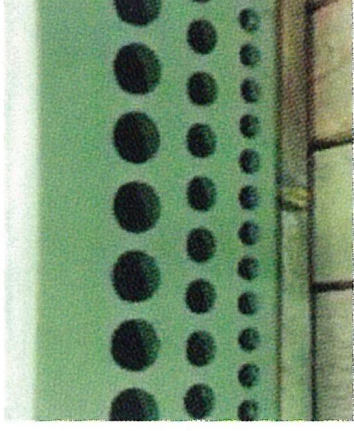
PM/HIP Technology – Current Applications



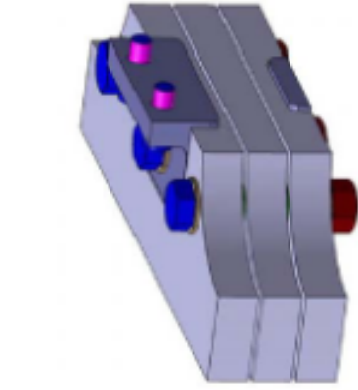
CERN End Cover



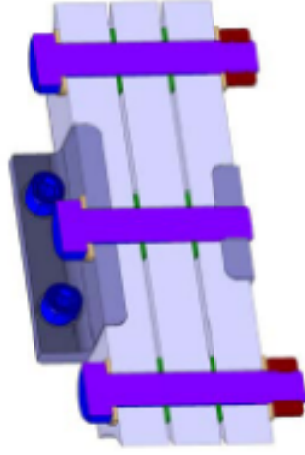
**Suction Roll Shell
for Paper Machine**



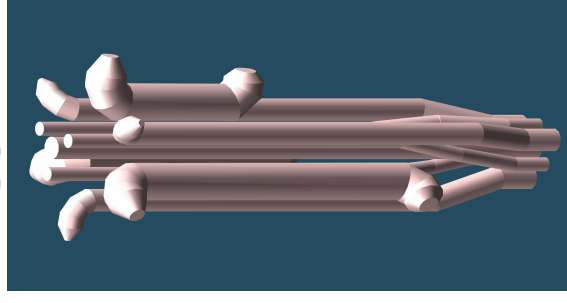
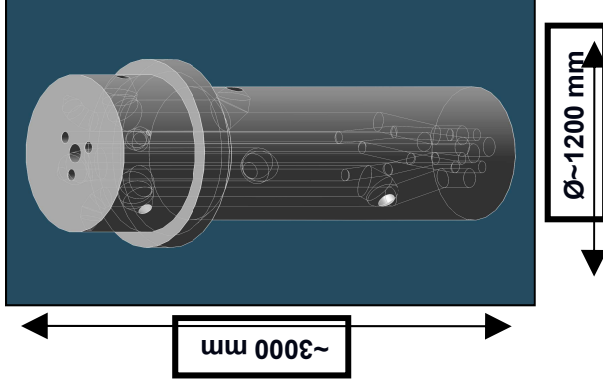
ITER Part Prototype



Pre-assembled Block for ITER



Swivel for Offshore Application



PM/HIP Technology

Summary

By combining the possibilities of metal powders, pressure and temperature control PM/HIP technology can offer many advantages

- **Lower scattering of properties**
- **Better ductility**
- **Better fatigue properties**
- **Repeatability**
- **Heat treatment steps can be included**
- **New, better and unique materials can be created**
- **Savings in logistics**