Rolls-Royce Nuclear Applications of Hot Isostatic Pressing (HIP)

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(Valves, Pumps, Piping, Vessel Mounting Systems, Manufacturing Support)

Scope (1)

- Introduction
- Method of Design/Process Justification
- Evolution of Experience:
  - Valve Seat Inserts
  - Thin-Walled Toroids
  - Thick-Walled Pressure Vessel
  - Large Bore Valves
  - Large Bore Pipework
  - Pump Bowl
- Summary

Introduction

June 2012

Rolls-Royce

Introduction (1)

- **Rolls-Royce has designed and supplied pressurised nuclear reactor plants for over 40 years.**
- **Components predominantly produced by forging.**
- **Rolls-Royce's HIP development work started just over 22 years ago –** *HIPed Valve Seat Inserts*.
- **Over the last 12 years we have been developing our HIP capability with thin- and thick-walled components.**

Introduction (2)

- **All our experience is with Stainless Steel, ie going back 42 years with the wrought form, and more recently with HIPing Types 316 and 304.**

- **Our HIPed, valve hard-facing experience has been with Stellite and Tristelle, both into SS and Monel bodies.**

Method of Design/Process Justification

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Method of Design/Process Justification (1)

- **Rolls-Royce produce the safety justifications for all component types for the UK Nuclear Submarine programme.**

- **Justifications - design analysis - provided to ASME III, predominantly Class 1 components.**

Method of Design/Process Justification (2)

- **Rolls-Royce have produced safety justifications and obtained UK Naval regulatory approval to fit and operate HIP components covering:**

  Valves,

  Thin-Walled Toroids,

  Thick-Walled Pressure Vessel,

  Large Bore Pipework,

  Currently developing the case for a Pump Bowl.

Method of Design/Process Justification (3)

- **The HIP justifications have been subjected to an *Independent Structural Safety Assessment* by the *UK Safety and Reliability Directorate (SRD)* as part of the UK regulatory approval, and agreement obtained.**

Method of Design/Process Justification (4)

- **A three step approach was taken to providing the necessary substantiation.**

- **Firstly, HIPing is a *standard* manufacturing technique supported by over 30 years of industrial experience, eg oil and gas industry.**

  'It is not a new manufacturing process.'

  An independent *review of the technology was commissioned which identified no concerns w.r.t applying the technology to safety critical applications.*

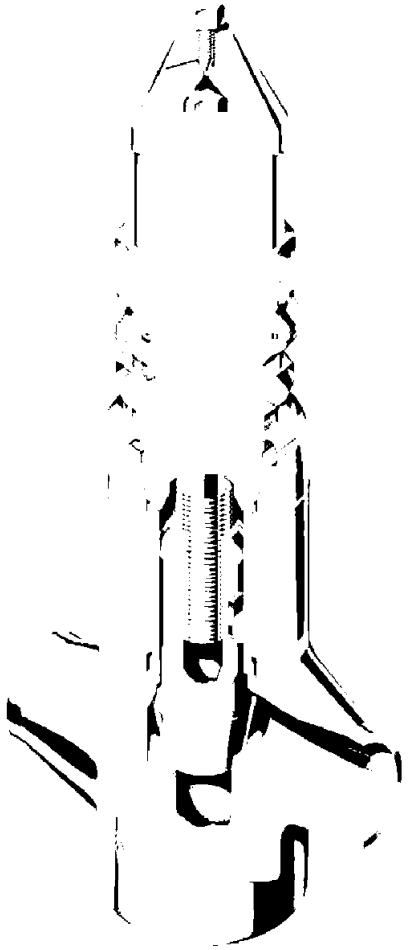
Method of Design/Process Justification (5)

- **Secondly, extensive comparative material testing was conducted to demonstrate equivalence to the wrought form.**

- **Thirdly, technology demonstrators of various components were manufactured and non-destructively and then destructively examined.**

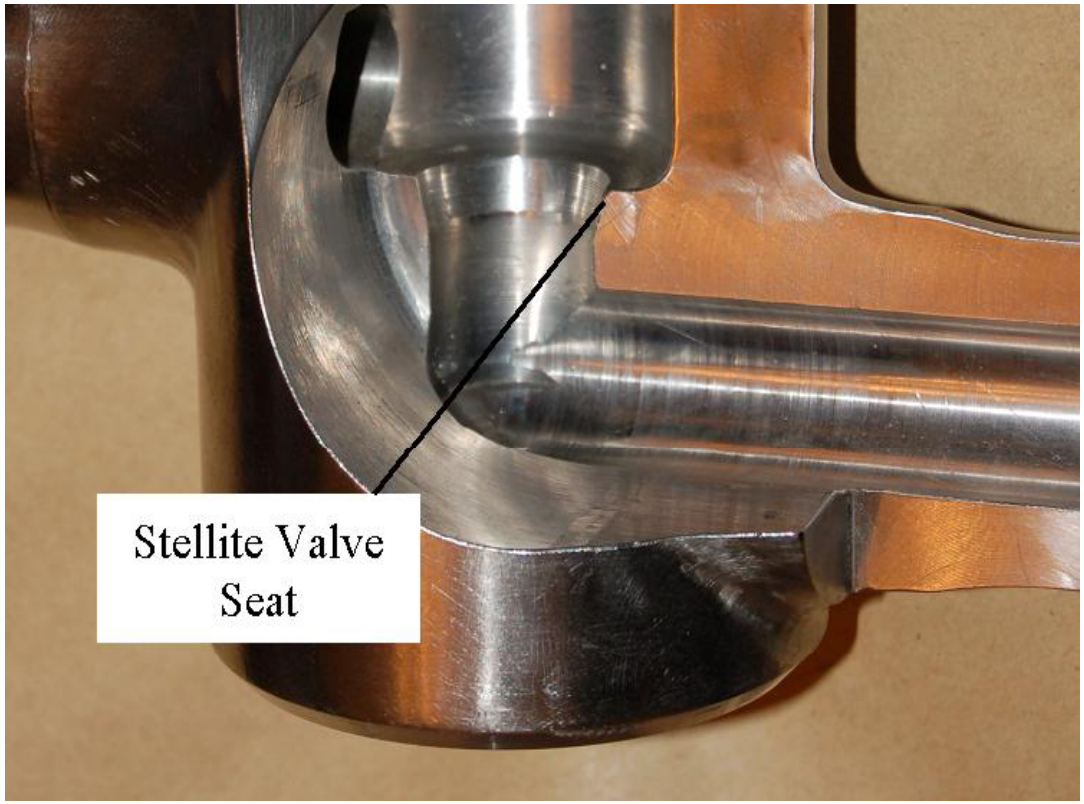
Evolution of Experience

Valve Seat Inserts



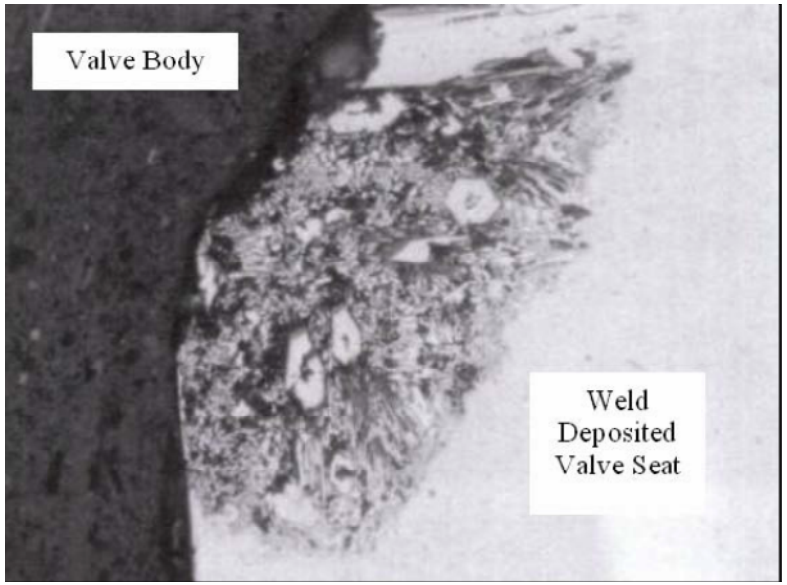
Presentation to the NRC – June 2012

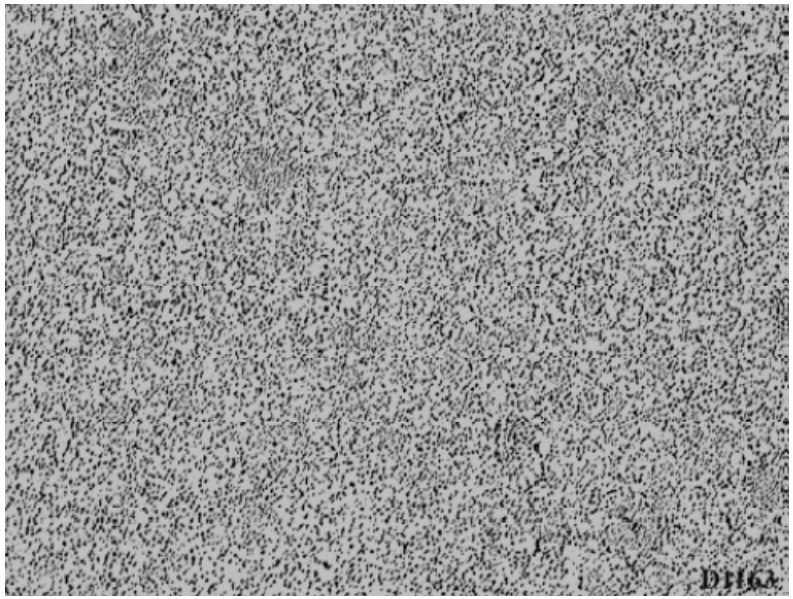
Valve Seat Inserts (1)



1800 Manufactured
500 In-Service
Longest time 18 years
No in-service problems

Valve Seat Inserts (2)

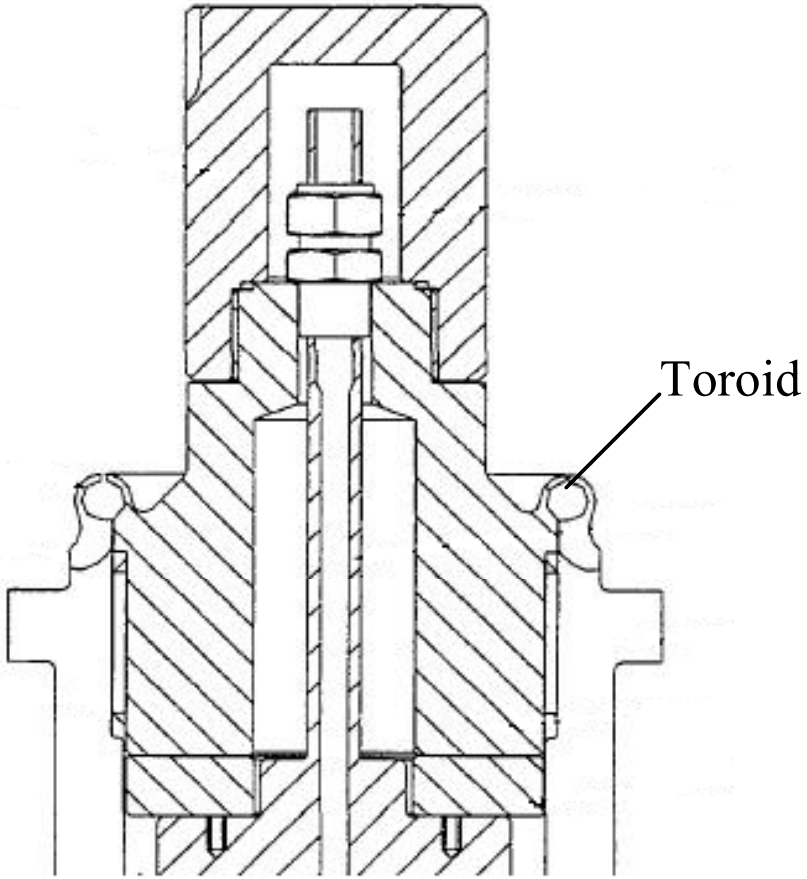




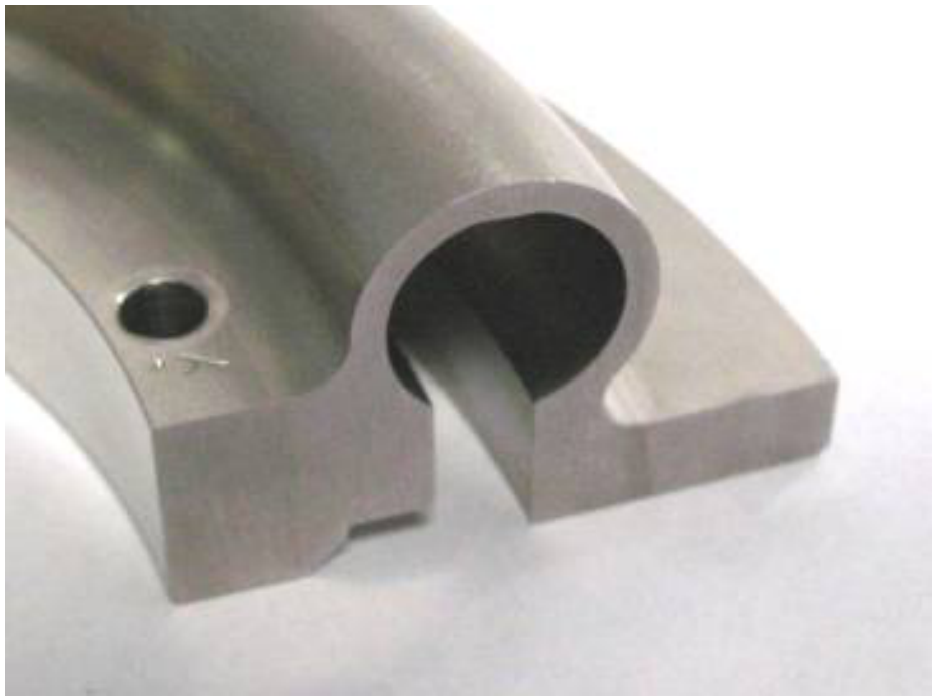
Evolution of Experience

Thin-Walled Toroids

Thin-Walled Toroids (1)



Thin-Walled Toroids (2)



240 Manufactured
140 In-Service
Longest time 6 years
No in-service problems

Evolution of Experience

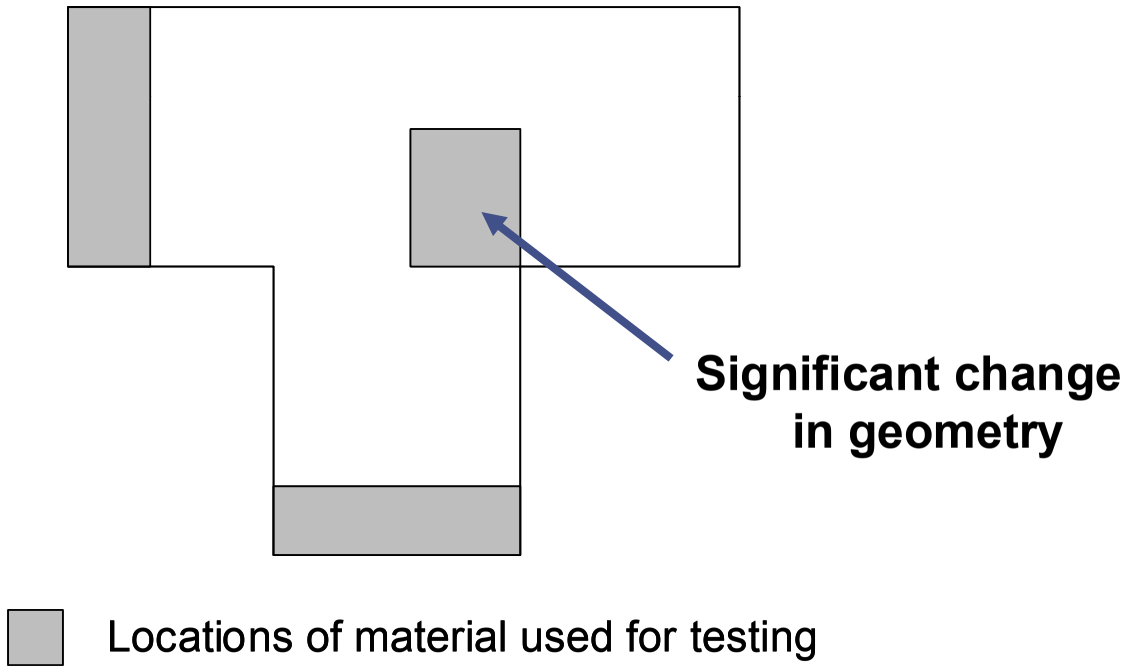
Thick-Walled Component

Thick-Walled Component (1)

14 Manufactured
New Build

Thick-Walled Component (2)

- **Test pieces were taken from locations throughout the bulk material.**



Evolution of Experience

Large-Bore Valves

Large-Bore Valves (1)

One Technology Demonstrator – Destructively Examined.
Targeted for New Build

Large-Bore Valves (2)

Evolution of Experience

Large Bore Pipework

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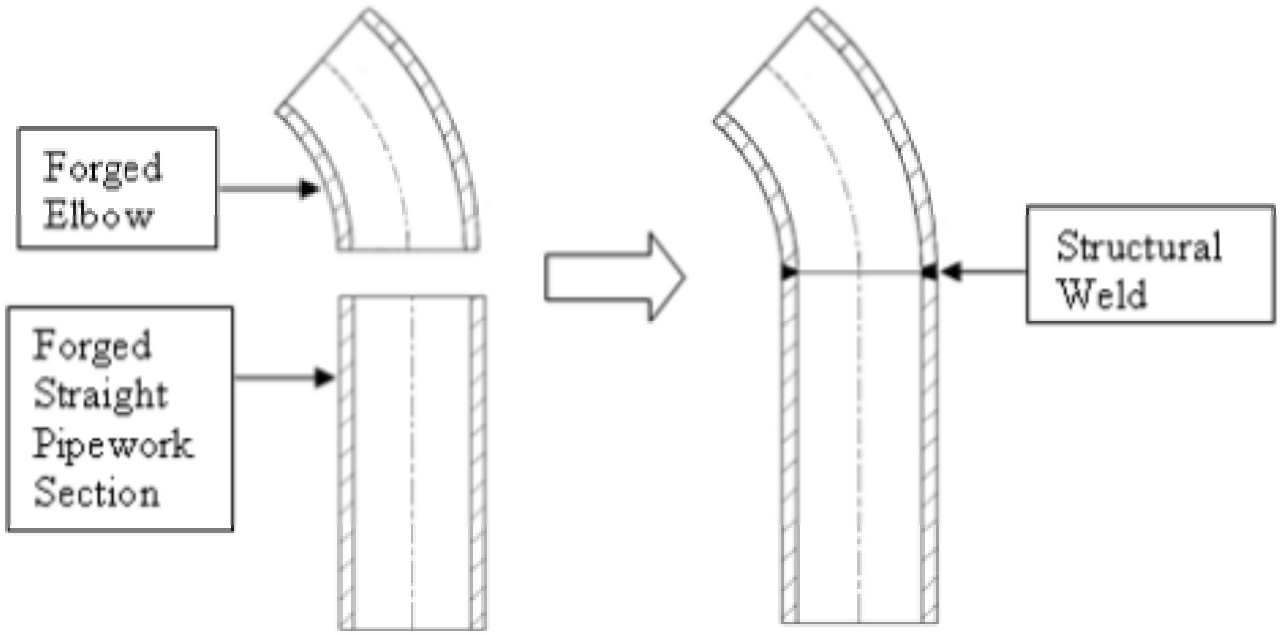
Large-Bore Pipework (1)

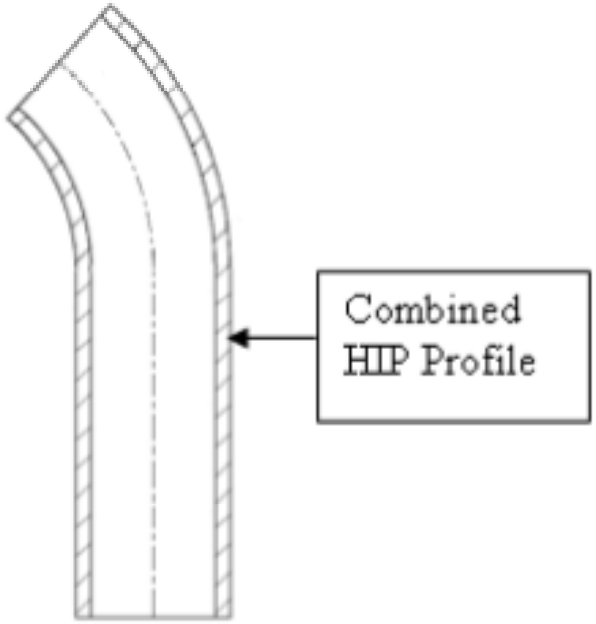
- **Objective**
  - **Eliminate straight-to-elbow welds to provide:**
    - **Structural integrity improvements.**
    - **Reduced build costs - elimination of welding and NDE**

Method of Manufacture Pre-HIP (2)



HIP Method of Manufacture HIP (3)

- **Elbow and straight sections HIPed as an integral section.**



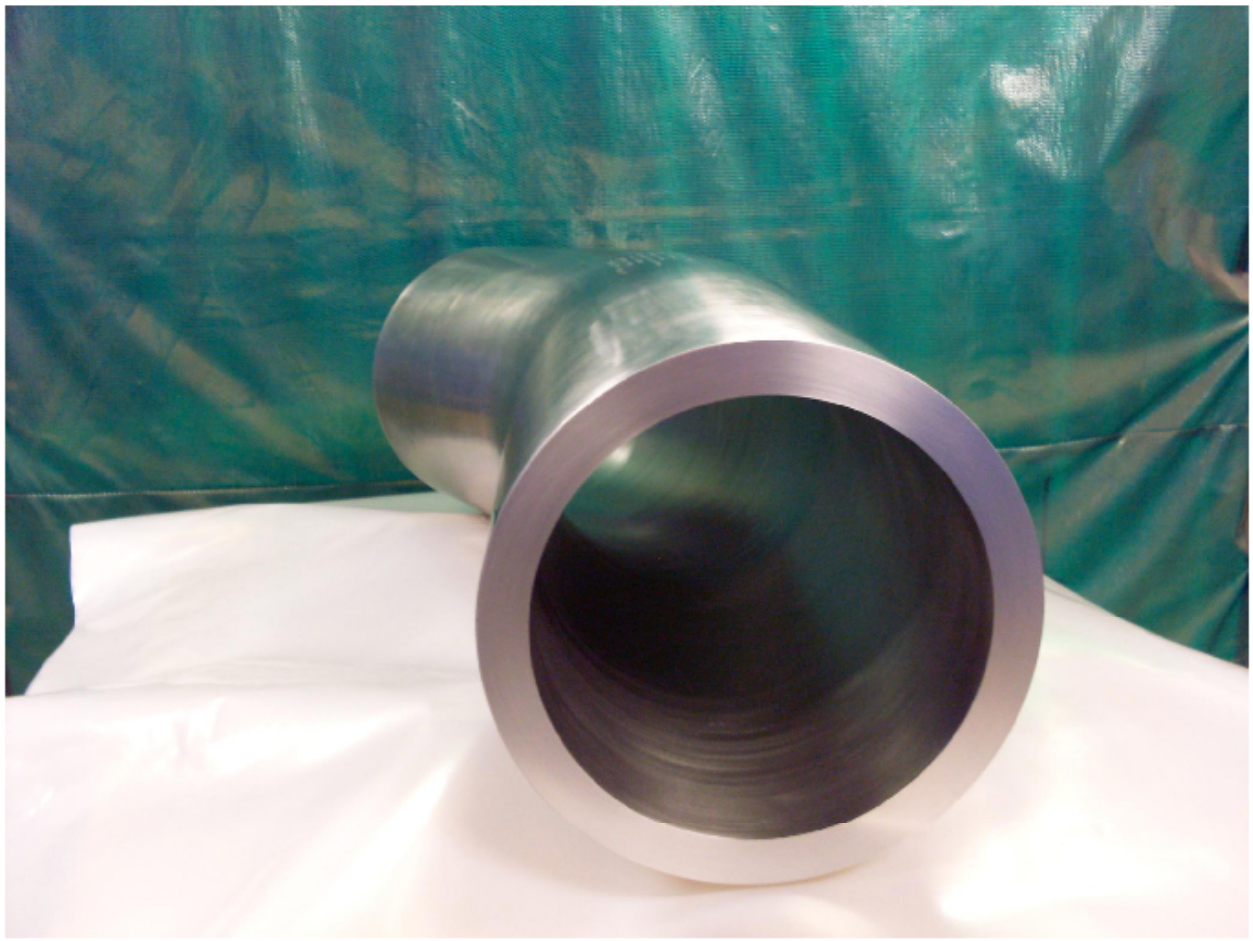
HIP Method of Manufacture HIP (4)

50 Manufactured
New Build

HIP Method of Manufacture HIP (5)

HIP Method of Manufacture HIP (6)

HIP Method of Manufacture HIP (7)

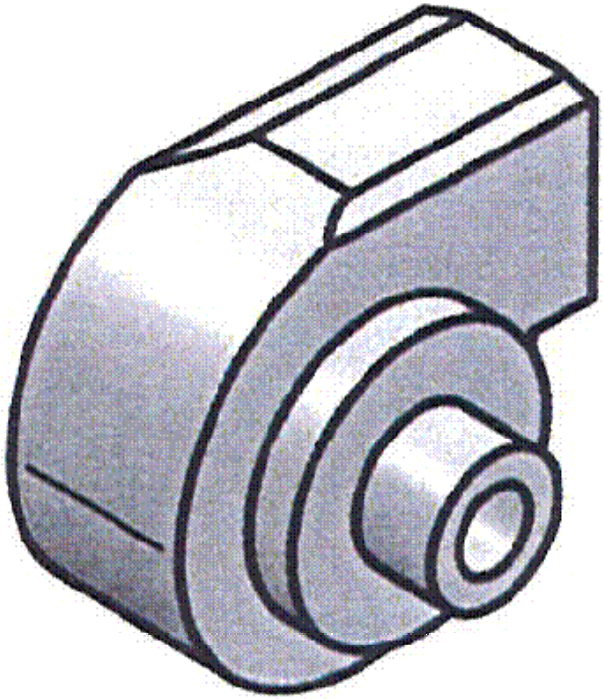


Evolution of Experience

Pump Bowl

Pump Bowl (1)

- **Elimination of last remaining casting – for New Build.**
- **Significant difficulties with achieving the necessary material quality with castings – suction leg – weld repairs.**
- **At the limit of HIP vessel size.**
- **Test loop bowl currently in manufacture.**



Summary

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Summary (1)

- **Technical benefits have been achieved such as:**
  - **Improved microstructure and mechanical properties**
  - **More searching NDE**
  - **Improved corrosion resistance**
  - **Smaller defect sizes**

Summary (2)

- **Programme benefits:**

  Overall programme cost and lead-time reductions.

  Provision of viable manufacturing routes – material quality assurance.

Acknowledgements

- Rolls-Royce would like to thank the NRC for the opportunity to present our applications of HIP.