Fabrication of fuel and Zirconium products – NFC Capabilities

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NUCLEAR FUEL COMPLEX
INPUTS & OUTPUTS

INPUT MATERIALS
- ZIRCON SAND
- URANIUM CONCENTRATES
- ZIRCONIUM SPONGE (NZSP)

OUTPUT PRODUCTS
- PHWR FUEL BUNDLES
- BWR FUEL ASSEMBLIES
Indian Three Stage Nuclear Power Program

Stage – I  PHWRs

• 17- Operating
• 1 - Under construction
• Several others planned
• Scaling to 700 MWe
• Gestation period being reduced
• POWER POTENTIAL ≈ 10,000 MWe

LWRs

• 2 BWRs Operating
• 2 VVERs under construction

Stage - II  Fast Breeder Reactors

• 40 MWth FBTR - Operating since 1985
  Technology Objectives realised
• 500 MWe PFBR - Under Construction
• POWER POTENTIAL ≈ 350,000 Mwe

Stage - III  Thorium Based Reactors

• 30 kWth KAMINI - Operating
• 300 MWe AHWR - Under Development

POWER POTENTIAL IS VERY LARGE

Availability of ADS can enable early introduction of Thorium on a large scale
NFC Activities

Fuel for PHWRs & BWRs
Zircaloy Structuralss
Core Sub-assemblies for Breeders

Nuclear
Non-nuclear

Special Materials
Tubes
Fuel Fabrication Activities at Nuclear Fuel Complex

UCIL
- MDU
  - Natural UO₂ Powder
  - Natural UO₂ Pellets
  - Fuel Bundles for PHWRs

IREL
- Zircon Sand
  - Zirconium Oxide
  - Zirconium Sponge
  - Zr Alloying
  - Fuel Tubes & Components

Imported
- UF₆
  - Enriched UO₂ Powder
  - Enriched UO₂ Pellets
  - Fuel assemblies for BWRs
Manufacturing Activities at NFC

- **Zircon** – Nuclear Grade ZrO$_2$ – Reactor Grade Zirconium Sponge – Zirc –2, Zirc –4, Zr-2.5% Nb, etc.
- **MDU** – Nuclear and Sinterable Grade UO$_2$ powder – Sintered UO$_2$ fuel pellets – PHWR Fuel Bundles.
- Manufacturing and supply of core sub-assemblies for Fast Reactors.

- Stainless Steel (316/D-9) Hardwares for Fuel Assemblies & Core Components for FBTR & PFBR
- Coolant & Calandria Tubes
- Reactivity Mechanisms

Zircaloy 2 clad 6x6 Enriched UO$_2$ Fuel Assemblies for Boiling Water Reactors (BWR) at Tarapur (TAPS 1&2)
BWR Fuel Assembly for Tarapur Atomic Power Stations-1&2

- Fully annealed thick wall fuel sheath.
- Short and Chamfered Pellets
- Pre-Pressurization of Fuel Element
Second stage of India’s Nuclear power Program

TUBES FOR CORE STRUCTURALS

FUEL CLAD TUBES
(6.6 x 0.45 x 2555 mm)

BLANKET CLAD TUBES
(14.33 x 0.56 x 2350 mm)

CSR CLAD TUBES
(22.4 x 1 x 1260 mm)

DSR CLAD TUBES
(21.4 x 0.7 x 1110 mm)

REFLECTOR CLAD TUBES
(44 x 1 x 3325 mm)

IBC CLAD TUBES
(44 x 1 x 3325 mm)
9 Cr 1 Mo
Finished Tubes
D9 PFBR Fuel Clad Tube
PFBR FUEL PIN GRID ASSEMBLY
From Zircon Sand to Zirconium Alloy Ingots at NFC

1. Zircon Sand
2. Hf-free ZrO$_2$ Powder
3. Nuclear Grade Zr Sponge
4. Vacuum Arc Melting Furnace using Consumable Electrode
5. Electron Beam Welding of Briquettes to form Consumable Electrode
6. EB Welded Electrode
7. Lock Valve
8. Copper Mould
9. Compaction of Zr Sponge + alloying elements Briquettes
10. Zirconium Alloy Ingot
   Max. size: 350 mm dia x 2 m height
Major Activities of Zirconium Alloy Fabrication Plant at NFC

- Hot Extrusion of Zirconium Alloy Billets
- Pilot Hole Expansion Press
- Pilger Mill for Production of Zirconium Alloy Fuel Tubes
- Array of Zirconium Alloy Fuel Tubes
- Hot Rolling of Zirconium Alloy Sheets
- Cold Swaging of Zirconium Alloy Bar
Fabrication of Seamless Pressure Tubes and Calandria Tubes through Pilgering Route

Welded tubes: Non-homogeneous microstructure (3 distinct zones)

Seamless Tube: Homogeneous Equiaxed Microstructure

Zr-2.5%Nb Pressure Tubes

Zircaloy 4 Calandria Tubes
Manufacture of Hexcans & Square Channels through Pilgering Route

DIFFICULTIES ENCOUNTERED DURING FABRICATION

- Formation of twist
- Formation of bow
Reactivity Control Mechanism Assemblies

CLASSIFICATION OF 540 MWe PHWR REACTIVITY DEVICES

1) Flux Monitoring
   a) Vertical Flux Units – 26 Nos.
   b) Horizontal Flux Units – 7 Nos.

2) Regulation & Control
   a) Liquid Zone Control System – 6 Nos.
   b) Adjuster Rods – 17 Nos.
   c) Control Rods – 4 Nos.

3) Shutdown
   a) Shut-off Rods – 28 Nos.
   b) Liquid Poison Injection System – 6 Nos.

TOTAL NO. OF ASSEMBLIES : 94
Cobalt Absorber Assemblies for PHWRs
MANUFACTURING FACILITIES AT NFC
Tube Manufacturing facilities at NFC

• NFC produces seamless tubes using a combination of hot working and cold working operations.

• Hot working facilities
  – 1200 T Vertical Piercing/Expansion press
  – 3780 T Horizontal hot Extrusion press
Cold working facilities

- 2 Roll Pilger mills (17 – 150mm OD)
- 3 Roller Pilger mills (4 – 30mm OD)
- 3/4 Roller Universal Pilger mill (Square, Hexagonal and circular cross sections up to 160mm OD)
- Triple Tube Draw bench (up to 40mm OD)
Heat treatment facilities

- LPG fired annealing furnace (1000kg/hr)
- Bright annealing furnace (250kg/hr)

Tube finishing facilities

- Cross roller tube straighteners
- Belt grinding stations
- Cutting and deburring stations
- Pickling and degreasing facilities
Indigenous Capability to Manufacture Process Equipment
High Temperature Sintering Furnace

Calcination / Reduction Furnaces

Special Purpose Resistance Welding Machine

Integrate Spacer / Bearing Pad Welding Machine
End Plate Welding Machine

Bearing Pad Welding Machine for PHWR Fuel Elements

Vacuum Baking Furnace for Graphite coating of PHWR Fuel Tubes
Robotic end plate welding machine

- Conceptualized, procured and successfully qualified for production of 19 and 37 element PHWR fuel bundles
- Robot integrated welding stations with other work stations.
- The productivity has increased by 50%
- Provision for integrating another end plate welding machine
Quality Control Activities

Analytical Laboratory

Atomic Absorption Spectrophotometer
Gamma Ray Spectrometer
Inductively Coupled Plasma – Atomic Emission Spectrometer (Model: Ultima 2 CHR)
Thermal Ionisation Mass Spectrometer (TIMS)

Non-Destructive Testing Facilities

Automated Ultrasonic Testing Unit
Automated Eddy Current Testing Unit
23 m long 9Cr-1Mo tubes under testing
Types of PHWR Bundles Manufactured at NFC

- 19-element wire-wrap Bundle
- 19-element split spacer Bundle
- 22-element split spacer Bundle
- 37-element split spacer Bundle
- 19-element Thoria Bundles
- 19-element RU Bundles
- 37-element RU Bundles
- 19-element SEU Bundles
Cumulative Production of PHWR Fuel Bundles at NFC

BUNDLES Q.C. Cleared: 4,27,457
Product Range

• Sizes:
  – OD: 4.7 mm to 250 mm
  – WT: 0.45 to 50 mm
  – Length: Up to 24 m

• Shape:
  – Square cross section.
  – Circular cross section.
  – Hexagonal cross section.
  – Combination of all the above.

• Materials:
  – All grades of SS-Austenitic, ferritic, martensitic & duplex, Zirconium and Titanium alloys, super alloys-Nickel base, Iron base, defence grades etc.

• Specifications:
  – ASTM A 312, 213, 269, 789 etc with additional customer requirements for other than Titanium alloys.
  – AMS specification for Titanium alloys.
9Cr-1Mo Steam Generator Tubes

• SG one of the Most critical components of PFBR.

• Shell and tube type counter current flow heat exchanger with liquid sodium on shell side and water on the tube side.

• Even a very small leak of high pressure water/steam into the sodium can start a violent sodium water reaction which calls for high degree of integrity

• Each tube is of 23 m long, 17.2mm Dia and 2.3mm WT and is having a bend to accommodate differential thermal expansion between the tubes and shell

• The material of construction is modified 9 Cr-1Mo (Gr 91).

• Total quantity = 4950 Nos for 9 Steam Generators with each having 550 tubes
Manufacture of Incoloy 800 steam generator tubings

- Optimized Conditions for Extrusion, pilgering U-bending and shot-peening

Superfer 800 blanks

Glass Bead shot peened U bend Tube

Optical microstructure of 19.0 mm dia X 1.1 mm WT UNS 8800 tube sample (longitudinal section) at 400 X magnification showing fine grain size and flow lines

Optical microstructure of 19.0 mm dia X 1.1 mm WT UNS 8800 tube sample at 1000 X magnification a) longitudinal section b) Transverse section
Localization of Fuel Fabrication Facilities for LWRs in India

LEU fuel from abroad

Conversion & Enrichment Abroad

Conversion & Enrichment in India

Fuel Fabrication in India

Product Export

Zirconium Alloy Components from India

40,000 MWe

Uranium from abroad

LWRs
Co-operation in the areas of Zirconium materials and components

- Zirconium concentrate
- Electrolytic Zirconium Powder
- Zirconium Sponge
Fuels for LWRs

PWR

VVER

BWR
NFC - an ISO Certified Organization
THANK YOU