

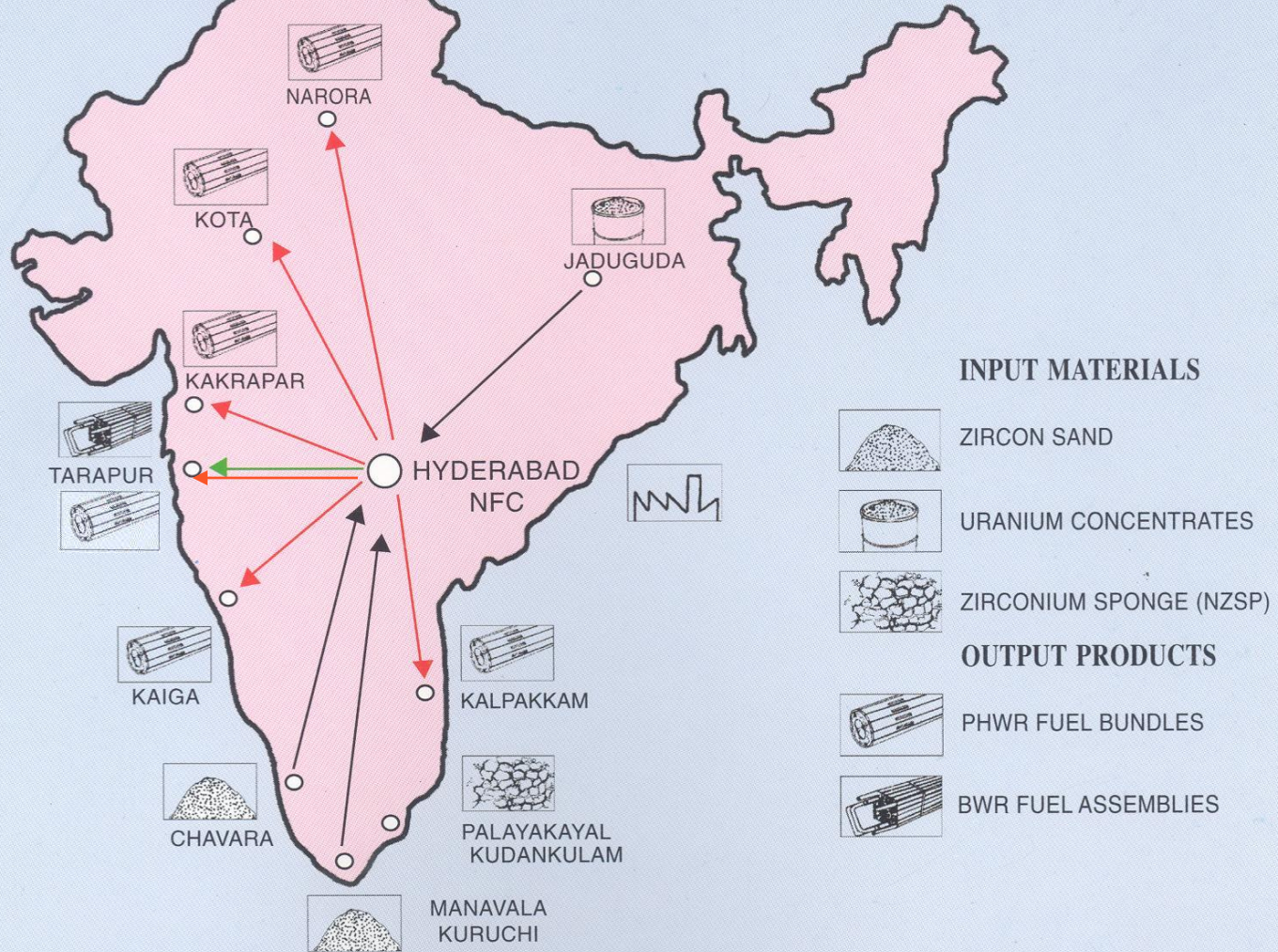


Fabrication of fuel and Zirconium products – NFC Capabilities

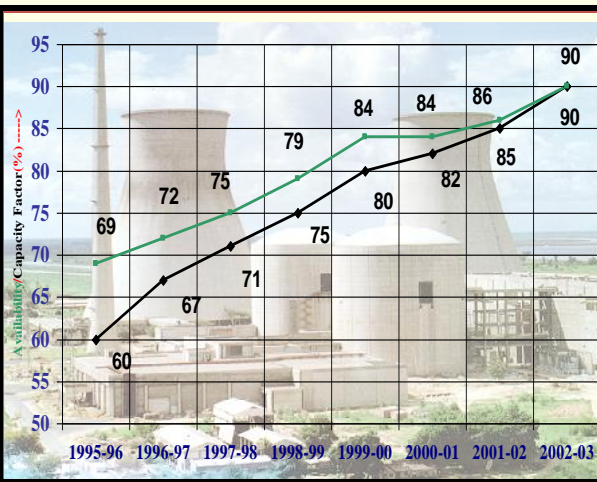
R.N. Jayaraj

**Chief Executive
Nuclear Fuel Complex
Department of Atomic Energy
Government of India
Hyderabad**

NUCLEAR FUEL COMPLEX INPUTS & OUTPUTS



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 \cong 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 \cong 350,000 Mwe**

Stage - III

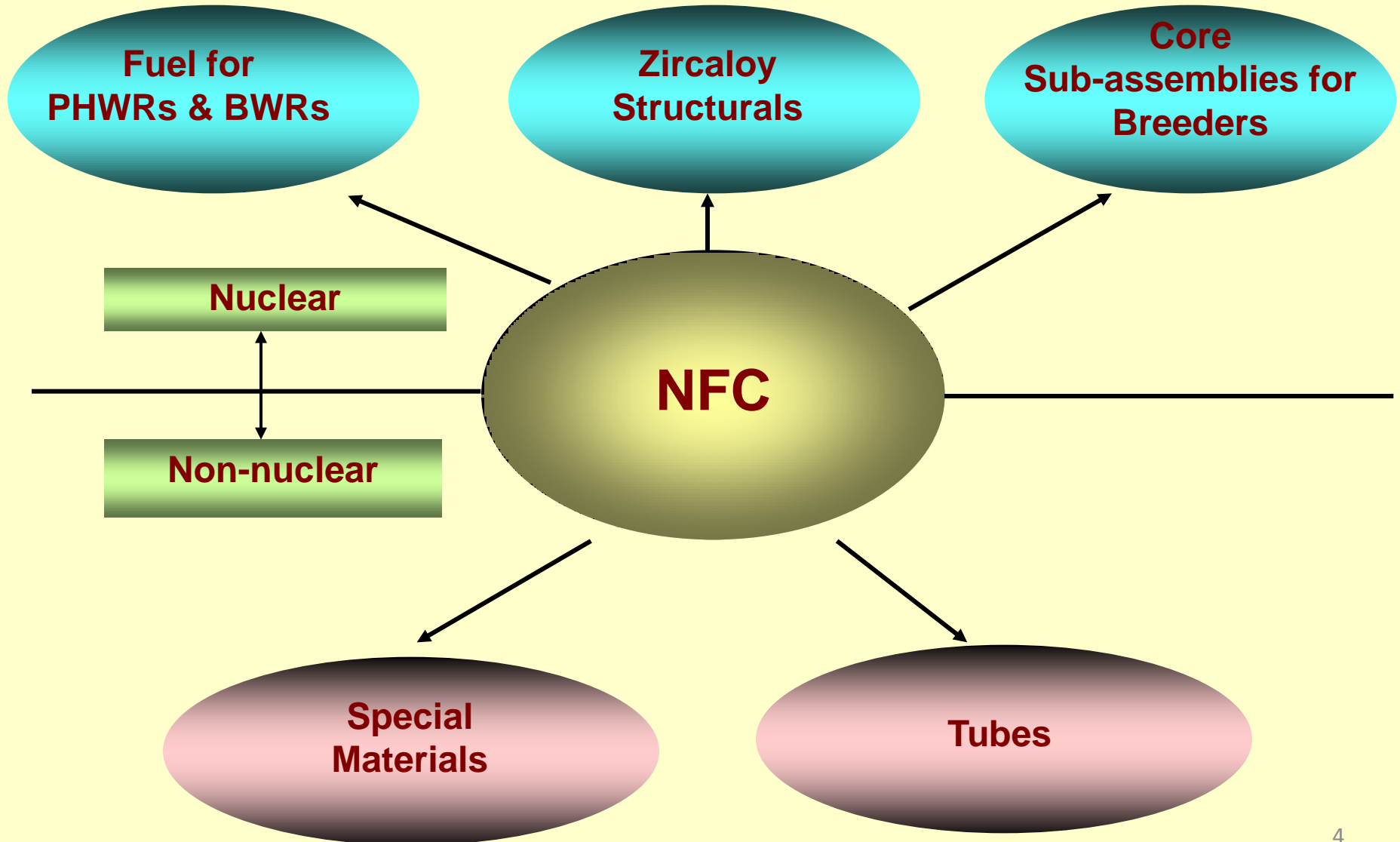
Thorium Based Reactors

- **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 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**

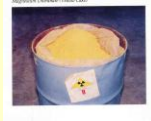
Imported

UF₆

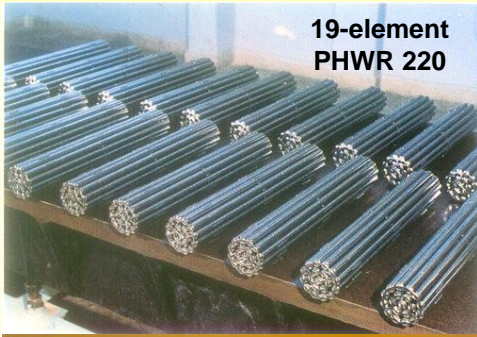
**Enriched UO₂
Powder**

**Enriched UO₂
Pellets**

**Fuel assemblies
for BWRs**



Manufacturing Activities at NFC



19-element
PHWR 220



37-element
PHWR 500

Zircaloy 4 clad Natural UO_2 Fuel Bundles for Pressurised Heavy Water Reactors (PHWR)



Stainless Steel (316/D-9) Hardwares for Fuel Assemblies & Core Components for FBTR & PFBR

- 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.
- DU / DDU – Direct Calcination – Reduction – Sintering – UO_2 Fuel Pellets – PHWR Fuel Bundles
- UF_6 – Pyrohydrolysis – Reduction – UO_2 Powder – UO_2 Pellets – BWR Fuel Assemblies.
- Manufacturing and supply of core sub-assemblies for Fast Reactors.



Zircaloy 2 clad 6x6 Enriched UO_2 Fuel Assemblies for Boiling Water Reactors (BWR) at Tarapur (TAPS 1&2)



Coolant & Calandria Tubes



Reactivity Mechanisms

BWR Fuel Assembly for Tarapur Atomic Power Stations-1&2



◆ ZIRCALOY AND OTHER COMPONENTS

FUEL TUBES	14.27 OD; 0.88 Wt; 3879 L	35 Nos.
	14.27 OD; 0.88 Wt; 469 L	8 Nos.
SPACER ASSEMBLY		7 Nos.
INCONEL AND SS COMPONENTS		114 Nos.
NUMBER OF WELDS		622 Nos.

◆ ENRICHED URANIUM OXIDE

NO OF ENRICHMENTS	3
PELLETS - 12.27 ϕ	9165 Nos.

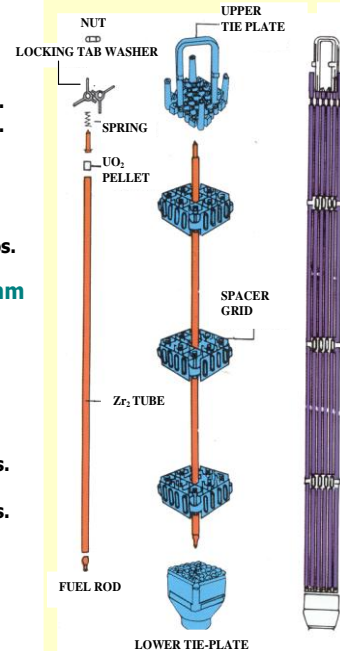
◆ LENGTH OF FUEL ASSEMBLY **4245 mm**

◆ WEIGHT OF FUEL PELLETS **160 Kg**

➤ ONE BWR CORE CONTAINS

* FUEL ASSEMBLIES	284 Nos.
- CONTAINED ENRICHED URANIUM OXIDE	45 Te
* REPLACEMENT FOR EACH OUTAGE	100 Nos.
- CONTAINED ENRICHED URANIUM OXIDE	16 Te

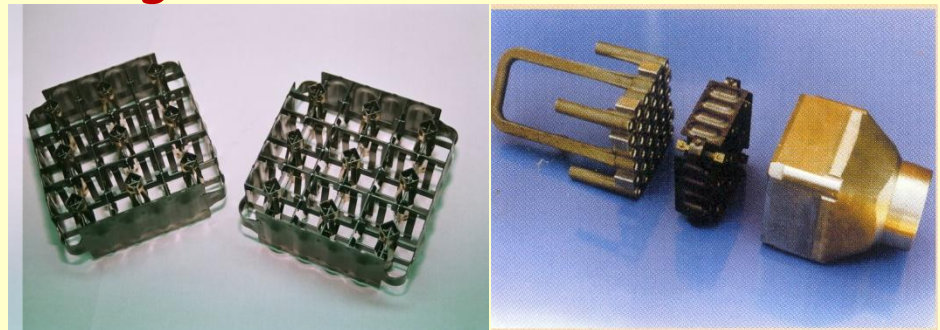
DIMENSIONS IN "mm"



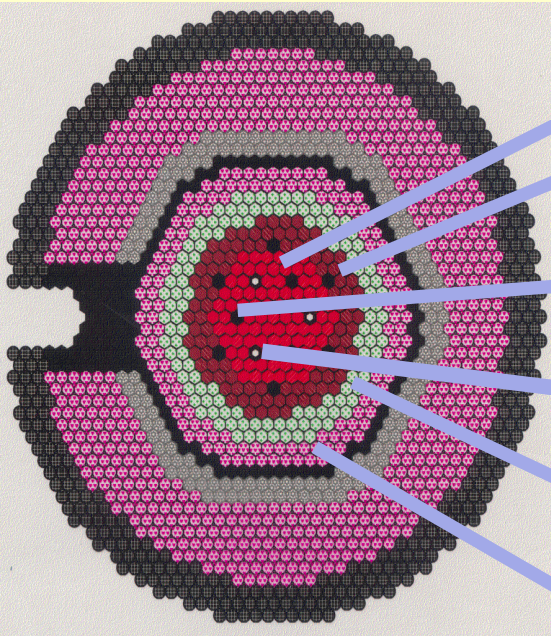
Indigenization

Improvements

- Fully annealed thick wall fuel sheath.
- Short and Chamfered Pellets
- Pre-Pressurization of Fuel Element



Second stage of India's Nuclear power Program



FUEL CLAD TUBES
(6.6 x 0.45 x 2555 mm)

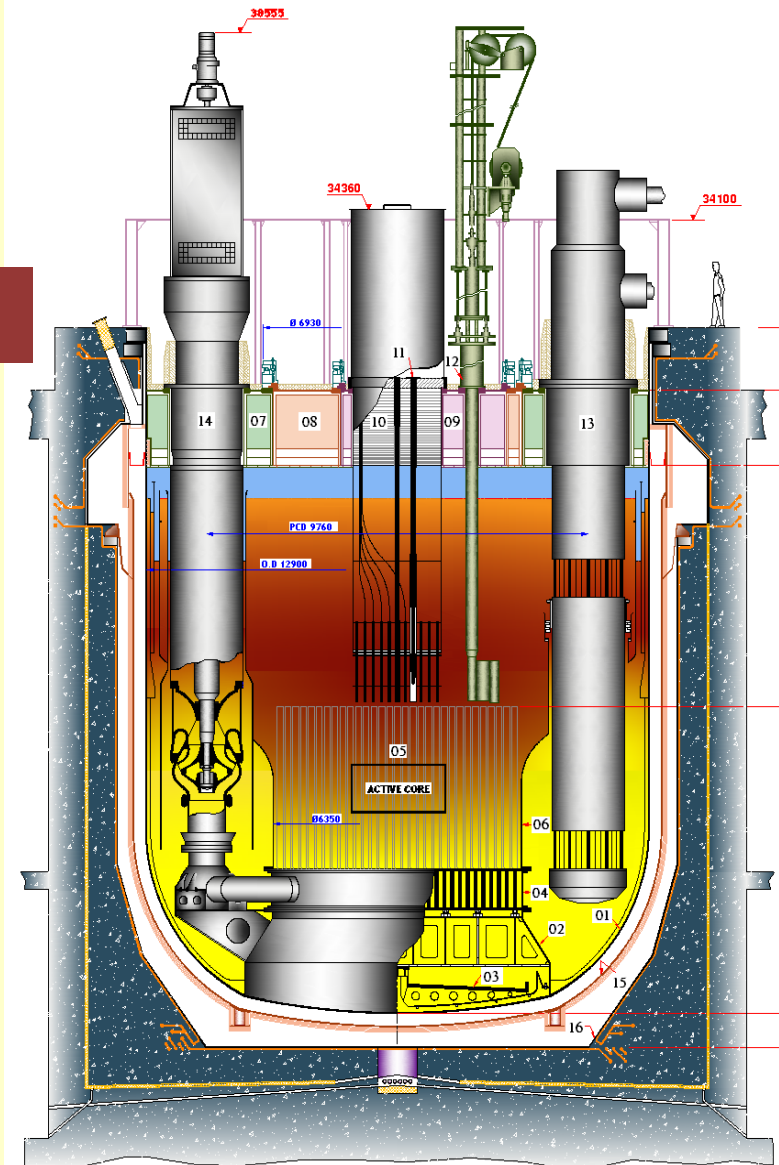
BLANKET CLAD TUBES
(14.33 x 0.56 x 2350 mm)

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)



TUBES FOR CORE STRUCTURALS

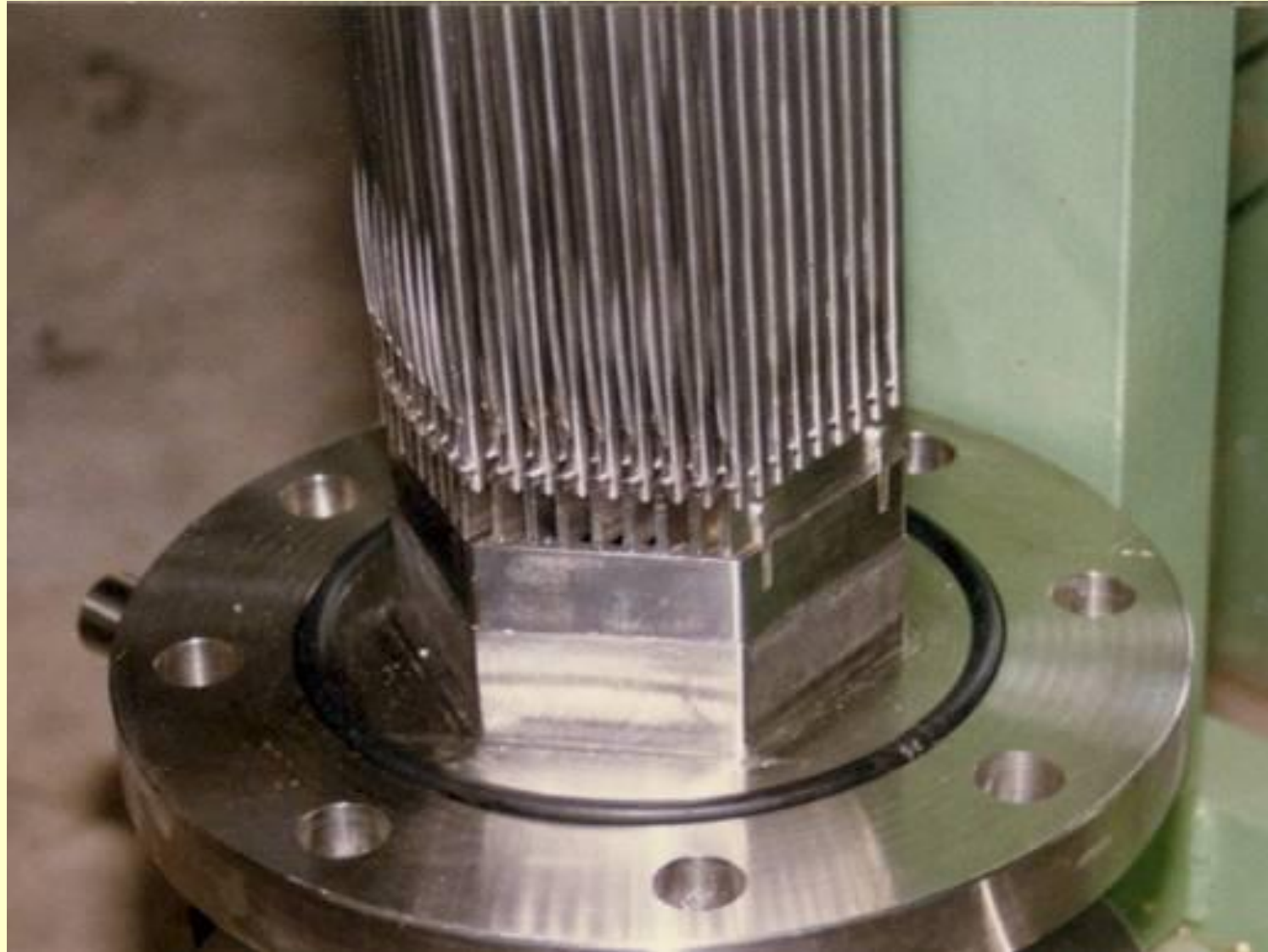


**9 Cr 1 Mo
Finished Tubes**



**D9 PFBR Fuel
Clad Tube**

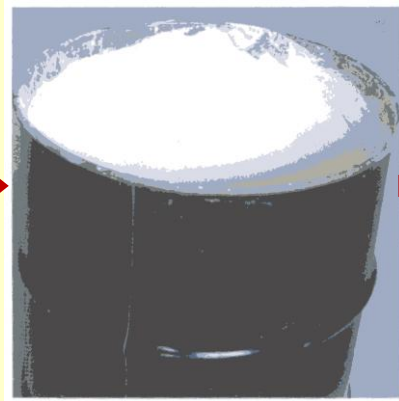
PFBR FUEL PIN GRID ASSEMBLY



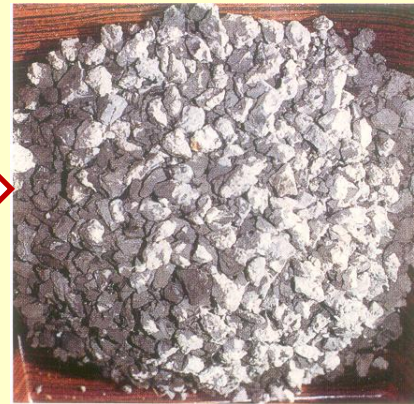
From Zircon Sand to Zirconium Alloy Ingots at NFC



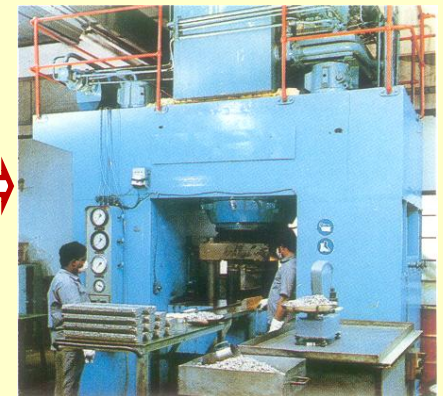
Zircon Sand



Hf-free ZrO_2 Powder



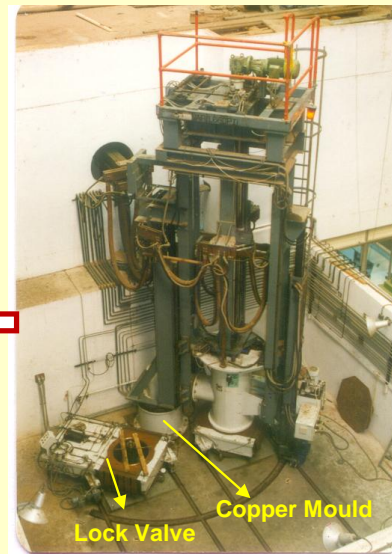
Nuclear Grade Zr Sponge



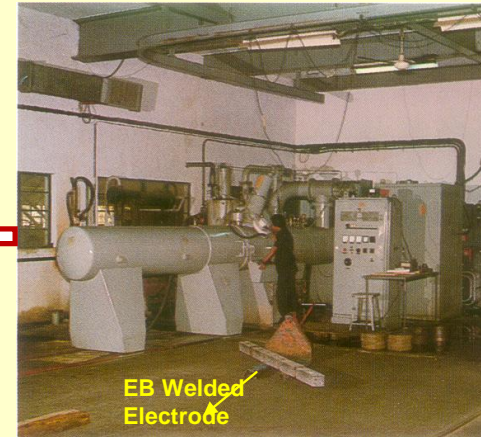
Compaction of Zr Sponge + alloying elements Briquettes



Zirconium Alloy Ingot
Max. size: 350 mm dia x 2 m height



Vacuum Arc Melting Furnace
using Consumable Electrode



Electron Beam Welding of Briquettes
to form Consumable Electrode

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



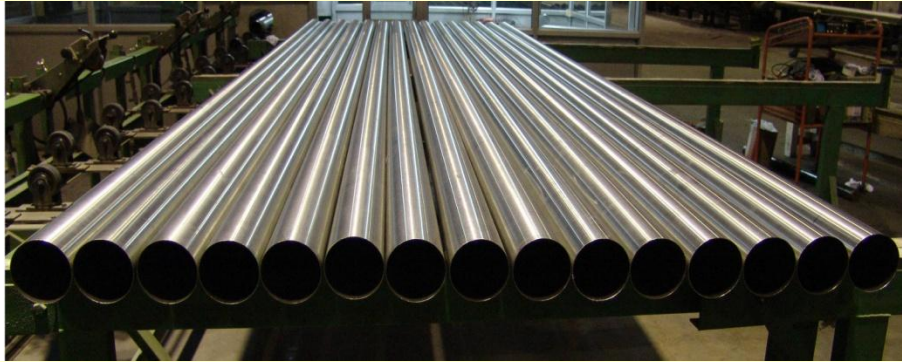
Hot Rolling of Zirconium Alloy Sheets



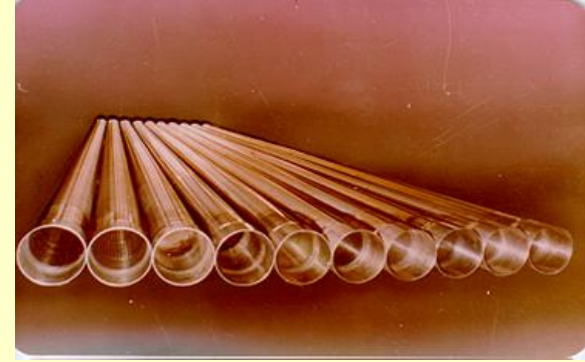
Cold Swaging of Zirconium Alloy Bar



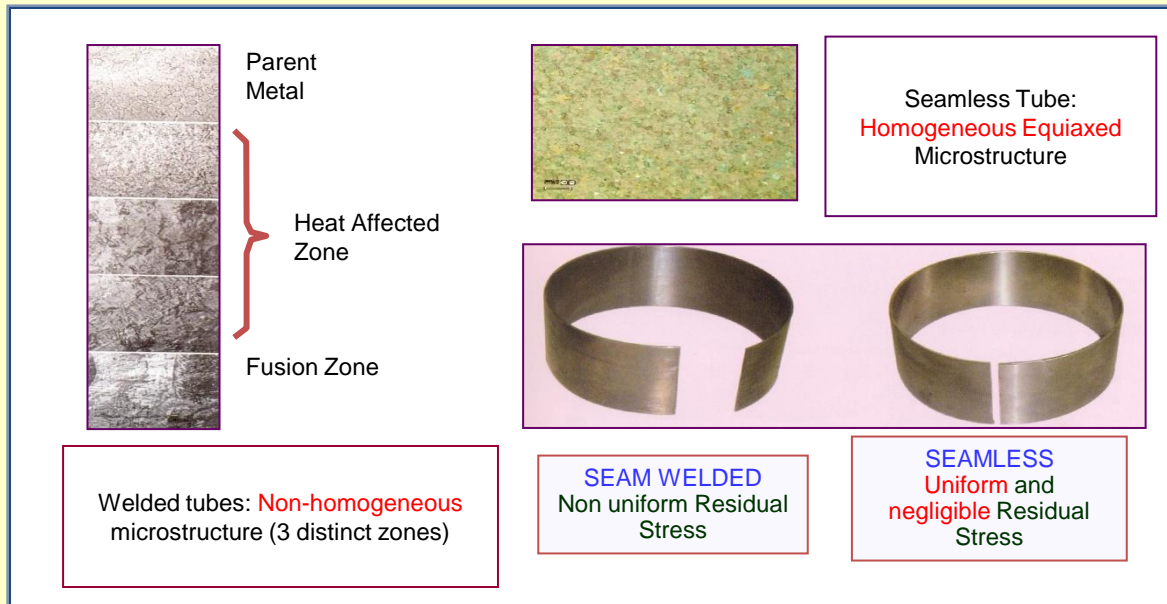
Fabrication of Seamless Pressure Tubes and Calandria Tubes through Pilgering Route



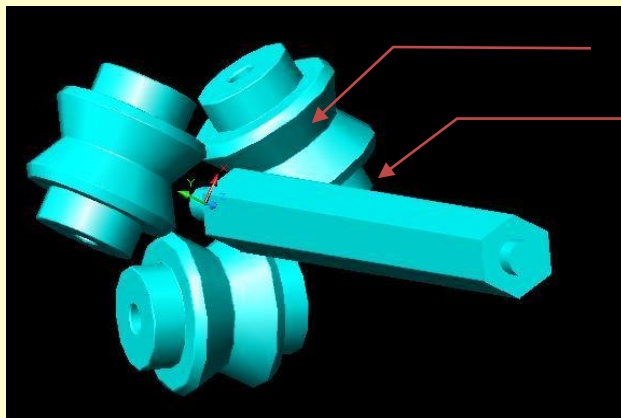
Zr-2.5%Nb Pressure Tubes



Zircaloy 4 Calandria Tubes



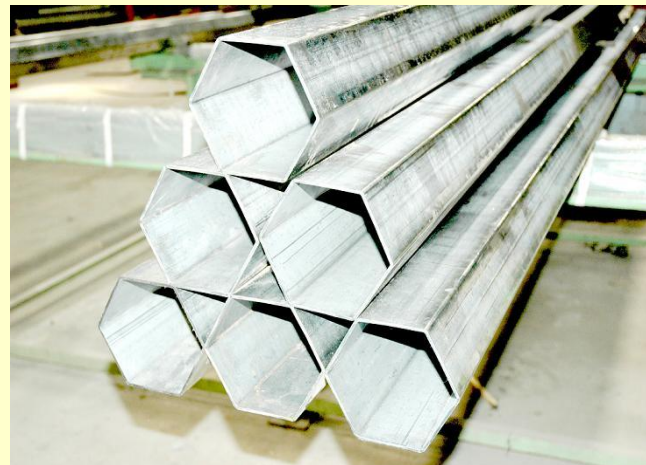
Manufacture of Hexcans & Square Channels through Pilgering Route



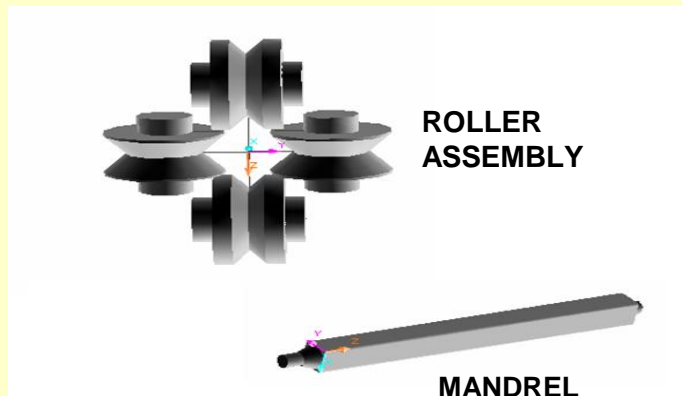
ROLLER

MANDREL

Roller Scheme for Hexagonal Tube Pilgering



PILGERED HEXCAN



ROLLER
ASSEMBLY

MANDREL

ROLLER SCHEME FOR PILGERING OF SQUARE SECTIONS



FINISHED SQUARE CHANNEL

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.

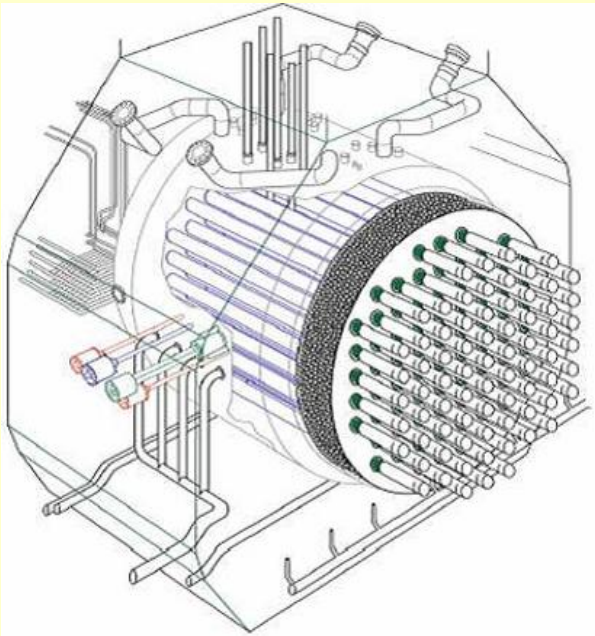
2) Regulation & Control

- 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.

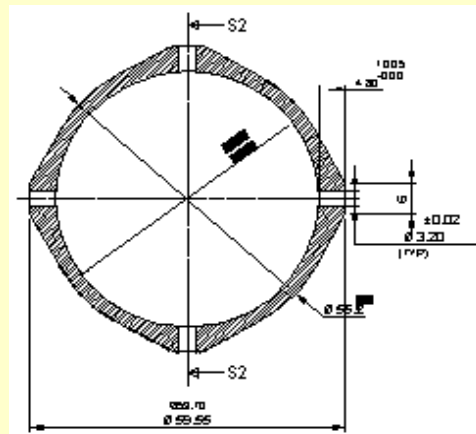
TOTAL NO. OF ASSEMBLIES : 94



TYPICAL VIEW OF 540 MWe PHWR CORE



3-COMPARTMENT LIQUID ZONE CONTROL UNIT OF 13 METER LENGTH



CROSS SECTION OF LIQUID POISON INJECTION UNIT



HORIZONTAL FLUX UNIT ASSEMBLY OF 13 METER LENGTH

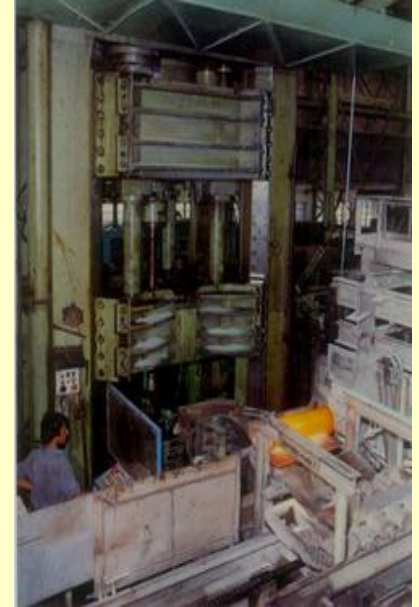
Cobalt Absorber Assemblies for PHWRs



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

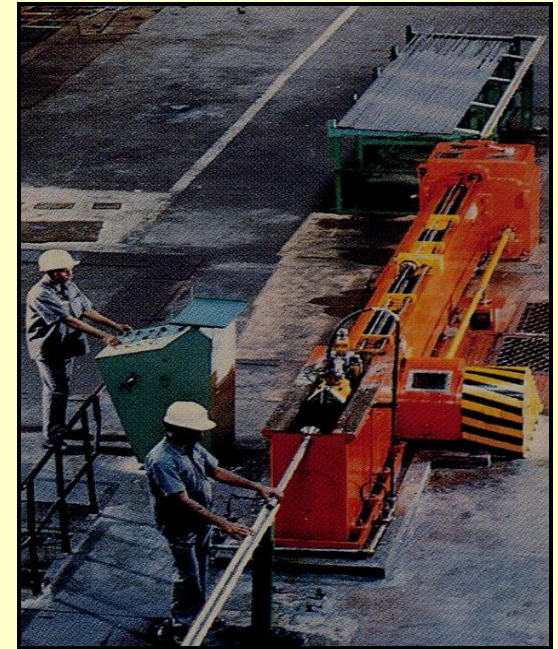




2 Roll Pilger Mill

– 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)**



3 Roller Pilger Mill



Triple Tube Draw Bench

Heat treatment facilities

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



Tube finishing facilities

- Cross roller tube straightners
- Belt grinding stations
- Cutting and deburring stations
- Pickling and degreasing facilities



High Vacuum Annealing Furnace

(1000 °C., 10⁻⁵ torr)

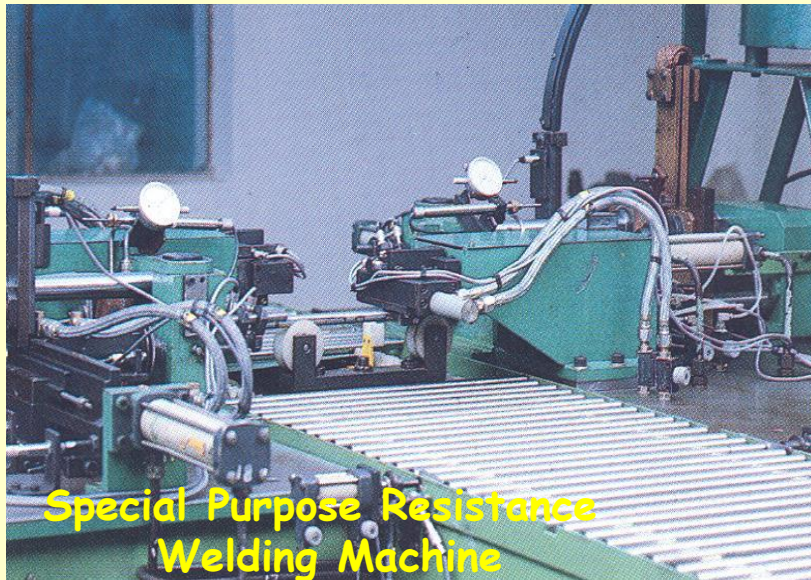
Indigenous Capability to Manufacture Process Equipment



High Temperature Sintering Furnace



Calcination / Reduction Furnaces



**Special Purpose Resistance
Welding Machine**



**Integrate Spacer / Bearing Pad
Welding Machine**

**Bearing Pad Welding Machine for
PHWR Fuel Elements**



End Plate Welding Machine

**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

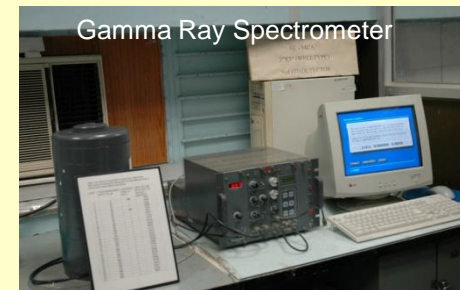


Quality Control Activities

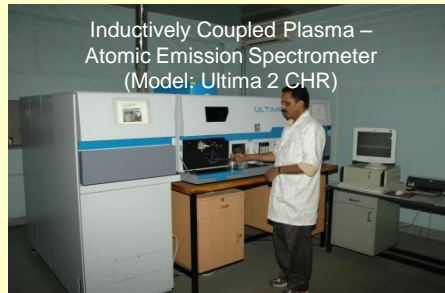
Analytical Laboratory



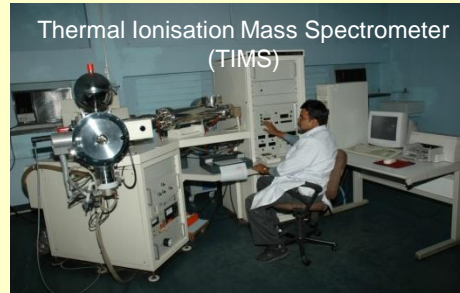
Atomic Absorption Spectrophotometer



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



23 m long 9Cr-1Mo tubes under testing



Automated Eddy Current Testing Unit

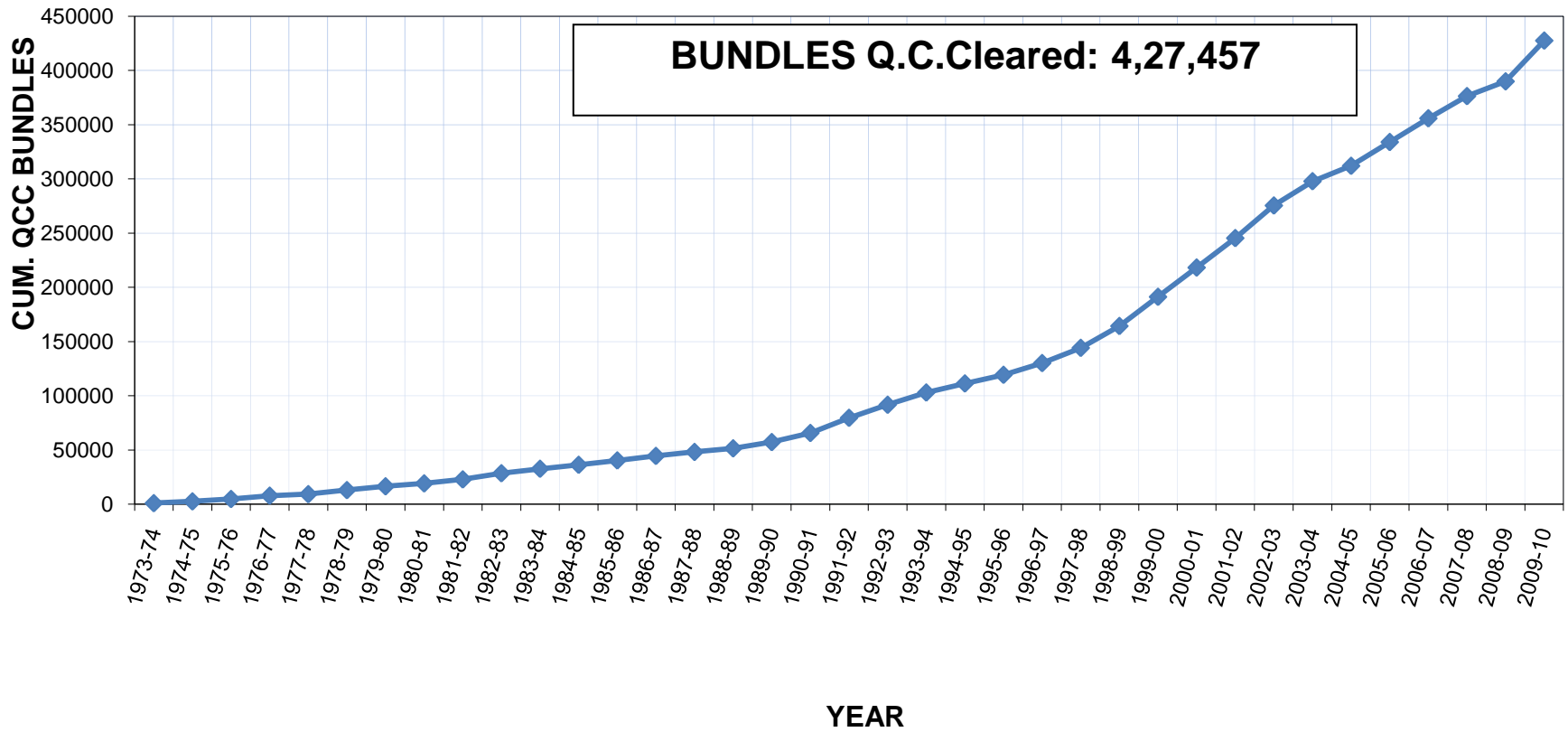


Types of PHWR Bundles Manufactured at NFC

- **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



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 Incaloy 800 steam generator tubings

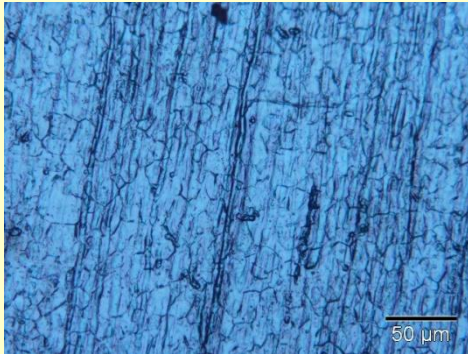
- Optimized Conditions for Extrusion, pilgering U-bending and shot-peening



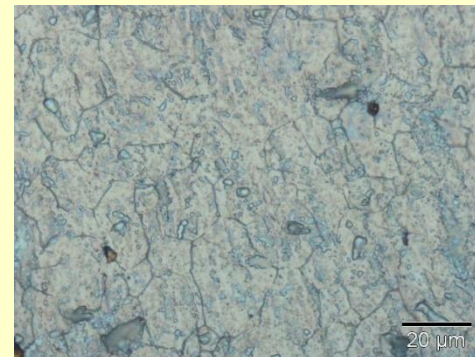
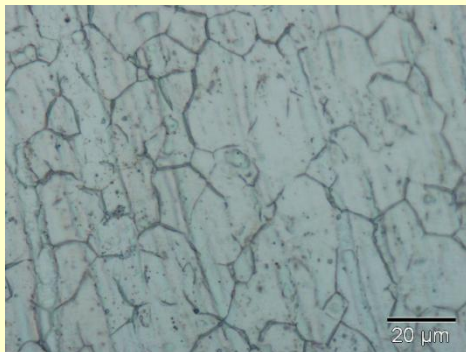
Superfer 800 blanks



Glass Bead shot peened U bend Tube

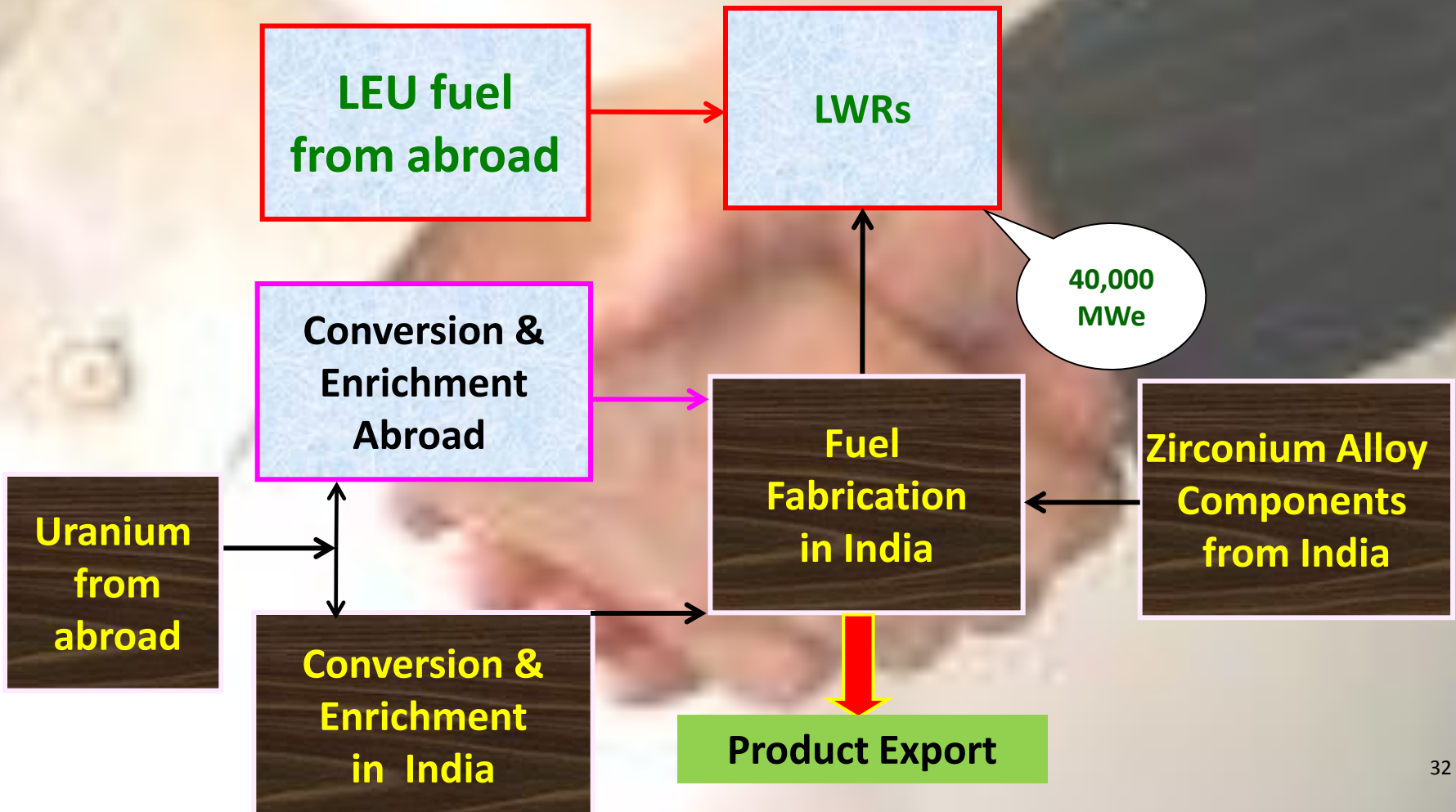


Optical microstructure of 19.0 mm dia X 1.1 mm WT UNS 8800 tube sample (longitudinal section) at 400 X magnification showing fine grain size and flow lines

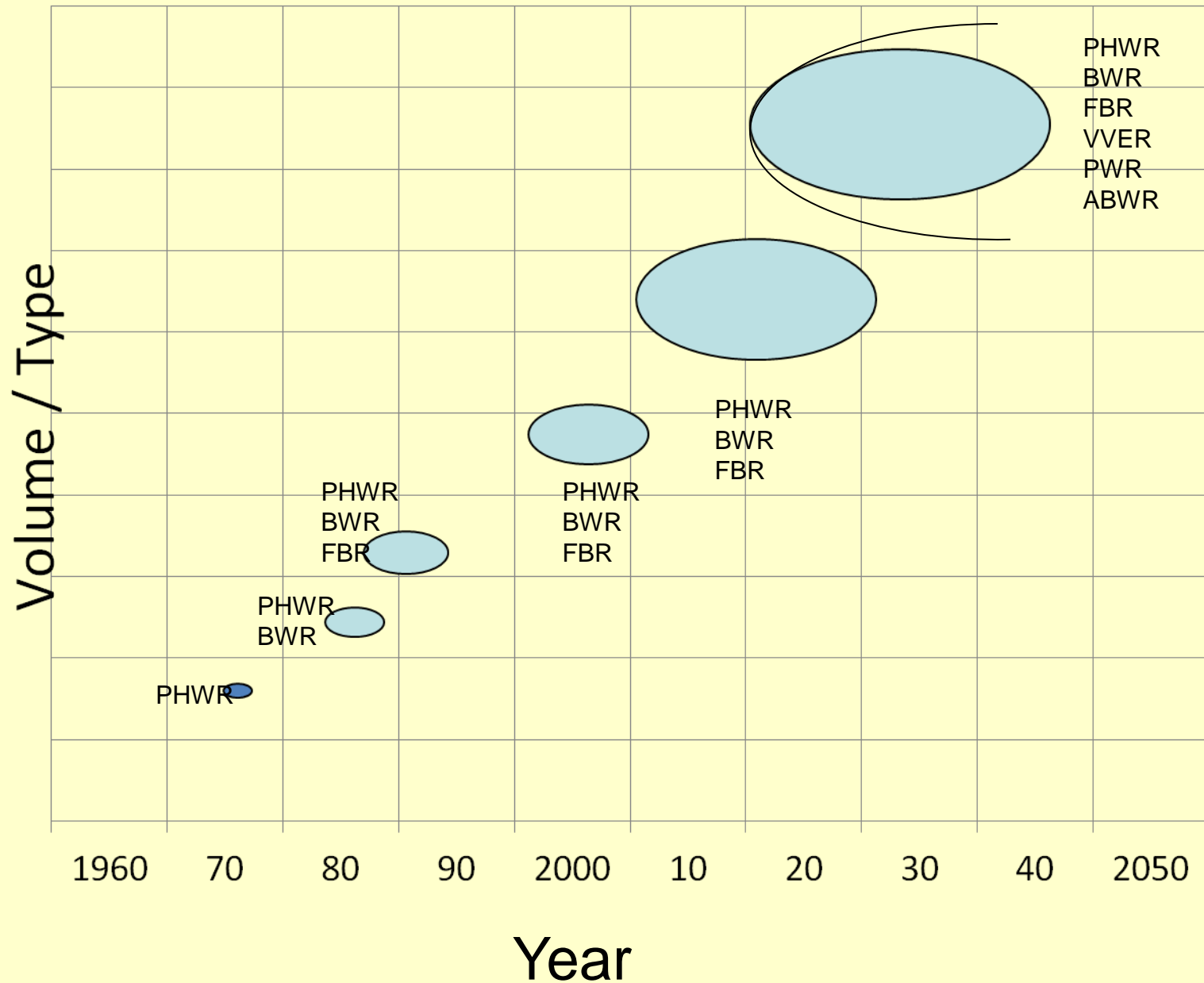


Optical microstructure of 19.0 mm dia X 1.1 mm WT UNS 8800 tube sample at 1000 X magnification a) longitudinal section b) Transverse section

Localization of Fuel Fabrication Facilities for LWRs in India



Fuel & Core Sub-assembly activities - a Vision

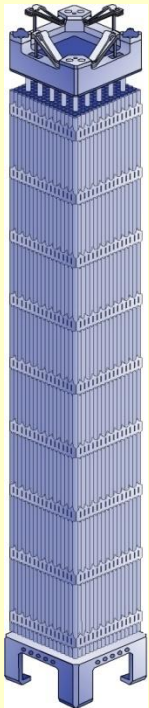


Co-operation in the areas of Zirconium materials and components

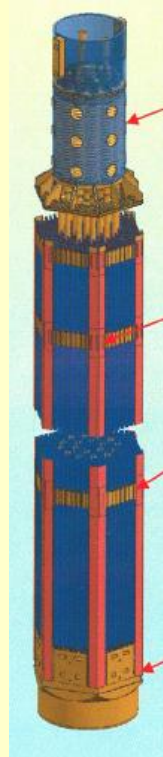
- Zirconium concentrate
- Electrolytic Zirconium Powder
- Zirconium Sponge

Fuels for LWRs

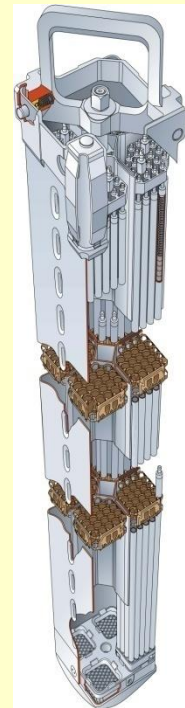
PWR



VVER



BWR



NFC - an ISO Certified Organization



DET NORSKE VERITAS
MANAGEMENT SYSTEM CERTIFICATE

Certificate No. 1504-2007-AQ-IND-NACB

*This is to certify that
the Quality Management System
of*

NUCLEAR FUEL COMPLEX
Department of Atomic Energy
Government of India

at
Hyderabad - 500 062, Andhra Pradesh, INDIA

has been found to conform to the Quality Management System Standard:
ISO 9001:2000

This Certificate is valid concerning all activities related to:

Manufacturing and supply of high quality natural, recycled and enriched uranium dioxide fuel assemblies, reactor-grade zirconium sponge and zirconium alloy components for fuel assemblies and core structural for water cooled nuclear power reactors; stainless steel cladding tubes, fuel sub-assembly components, blanket and other core sub-assemblies for sodium cooled fast reactors; stainless steel and special alloy seamless tubes and high purity advanced materials for strategic industries like atomic energy, electronics, defence and space.


Original Certification date:
2004-01-23

Place and date:
Chennai, 2007-03-28

This Certificate is valid until:
2010-01-23

Compliance to the Standard in respect to the indicated scope is verified by the DNV approved registered Team Leader:

Seeenivasa Rao Nellutla
Lead Auditor



for the Accredited Unit:
DNV CERTIFICATION SERVICES,
REGION INDIA

Krishnakumar N.R.
Management Representative

Lack of fulfillment of conditions as set out in the Appendix may render this Certificate invalid.

DNV AS CERTIFICATION SERVICES, EMERSON CHAMBERS, 10, C.S.T. ROAD, VIJAYNAGAR, KALINA, SANTAGIRY (E), MUMBAI - 400 098



DET NORSKE VERITAS
MANAGEMENT SYSTEM CERTIFICATE

Certificate No. 00058-2005-AE-MDR-RVA

*This is to certify that
the Environmental Management System
of*

NUCLEAR FUEL COMPLEX
Department of Atomic Energy
Government of India

at
Hyderabad - 500 062, Andhra Pradesh, INDIA

has been found to conform to the Environmental Management System Standard:
ISO 14001:2004

This Certificate is valid concerning all activities related to:

Manufacturing and supply of high quality natural, depleted, recycled and enriched uranium dioxide fuel assemblies, thorium oxide pellets and assemblies, reactor-grade zirconium sponge and zirconium alloy components for fuel assemblies and core structural for water cooled nuclear power reactors; stainless steel cladding tubes, fuel sub-assembly components, blanket and other core sub-assemblies for sodium cooled fast reactors; stainless steel and special alloy seamless tubes and high purity advanced materials for strategic industries like atomic energy, electronics, defence and space.

Original Certification date:
2005-12-30

Place and date:
Chennai, 2005-12-31

This Certificate is valid until:
2008-12-30

Compliance to the Standard in respect to the indicated scope is verified by the DNV approved registered Team Leader:

G. Venugopal
Lead Auditor



for the Accredited Unit:
DNV CERTIFICATION B.V.,
THE NETHERLANDS

Krishnakumar N.R.
Management Representative

Lack of fulfillment of conditions as set out in the Appendix may render this Certificate invalid.

DNV 80111.2

DNV CERTIFICATION B.V. Haashtstraat 7, 3079 DC Rotterdam, The Netherlands, TEL:INT.+31 10 2022 688, FAX:+31 10 4796 768



DET NORSKE VERITAS
MANAGEMENT SYSTEM CERTIFICATE

Certificate No. 00023-2005-AHSO-MDR

*This is to certify that
the Occupational Health and Safety Management System
of*

NUCLEAR FUEL COMPLEX
Department of Atomic Energy
Government of India

at
Hyderabad - 500 062, Andhra Pradesh, INDIA

has been found to conform to the Occupational Health and Safety Management System Standard:
OHSAS 18001:1999

This Certificate is valid for the following product or service range:

Manufacturing and supply of high quality natural, depleted, recycled and enriched uranium dioxide fuel assemblies, thorium oxide pellets and assemblies, reactor-grade zirconium sponge and zirconium alloy components for fuel assemblies and core structural for water cooled nuclear power reactors; stainless steel cladding tubes, fuel sub-assembly components, blanket and other core sub-assemblies for sodium cooled fast reactors; stainless steel and special alloy seamless tubes and high purity advanced materials for strategic industries like atomic energy, electronics, defence and space.

Original Certification date:
2005-12-30

Place and date:
Chennai, 2005-12-31

This Certificate is valid until:
2008-12-30

Compliance to the Standard in respect to the indicated scope is verified by the DNV approved registered Team Leader:

G. Venugopal
Lead Auditor



for the Accredited Unit:
DNV CERTIFICATION SERVICES,
REGION INDIA

Krishnakumar N.R.
Country Manager
Region India, Sri Lanka, Bangladesh & Nepal

Lack of fulfillment of conditions as set out in the Appendix may render this Certificate invalid.

DNV 80111.1

DNV CERTIFICATION SERVICES, 203, SAVITHI SADAN I, 11, PREET VIHAR COMMUNITY CENTRE, NEW DELHI 110 092

THANK YOU

