राष्ट्र की सेवा में परमाणु

एन एफ सी
NFC

ATOMS IN THE SERVICE OF THE NATION

नाभिकीय ईंधन सम्मिश्र
Nuclear Fuel Complex

हैदराबाद • Hyderabad

सुरिर्व़याँ
HIGHLIGHTS
2016 - 2017

Government of India
Department of Atomic Energy

NUCLEAR FUEL COMPLEX

Hyderabad - 500 062

QMS EMS OHSMS

Quality, Environment and Occupational Health & Safety Policy

- We manufacture and supply:
  - Fuel assemblies, core structural components and sub-assemblies for nuclear power reactors
  - Stainless steel & special alloy seamless tubes and high purity materials for high-tech applications in strategic industries
- We are committed to:
  - meet the quality requirements of customers
  - prevention of pollution
  - prevention of injury and ill health and
  - comply with the applicable statutory requirements
- We strive to continually improve Quality, Environmental and Occupational Health & Safety performance through technological & administrative measures and by enhancing awareness among employees.

(G. Kalyanakrishnan)
Chief Executive

HIGHLIGHTS सुरिर्वयाँ
2016- 2017

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MGMT. SYS. RvA C425 EMS

DNV ISO 9001:2008

NABCB QMS

DET NORSKE VERITAS 1864 OHSMS

Editorial Team

• MESSAGES •

शेखर बसु
Sekhar Basu

सत्यमेव जयते
Government of India

अध्यक्ष, परमाणु ऊर्जा आयोग
व
सचिव, परमाणु ऊर्जा विभाग
Chairman, Atomic Energy Commission
&
Secretary, Department of Atomic Energy

MESSAGE

NFC has always been a key-link to foster Indian Nuclear Power Programme. I am extremely delighted to note that NFC has once again achieved its highest ever annual production of 1512 tons PHWR fuel bundles during 2016-17 surpassing the previous year's production. I am glad to note that NFC has touched the milestone of 9th lakh fuel bundle and demonstrated its strength as a successful Company.

Though there was limited stock of imported fuel pellets on hand, NFC has sailed through the challenges by producing increased rate of UO2 powder/pellet through innovative process improvements. All NFC plants have exceeded their annual targets by which NFC, as a whole, could meet the deliverables for NPCIL and non-nuclear sectors.

It is praiseworthy to see NFC's efforts towards R&D activities too. NFC has been fulfilling its commitments towards strategic R&D programmes in collaboration with BARC, IGCAR, DRDO, ISRO, Midhani and RRCAT for products of nickel base super alloys, special titanium alloys, maraging steel, high purity niobium metal etc.

Nuclear business is a culture that needs to be nourished for a sustainable Power Programme. NFC is manifesting this culture through positive thinking. I am also pleased to note NFC's preparedness for increased fuel production in the coming years to fuel the series of forthcoming PHWR 700 reactors. NFC has already taken up many expansion projects including setting up of NFC-Kota for meeting these future challenges.

On this occasion, I compliment and congratulate NFC for its remarkable achievements and wish the Unit to reach greater heights.

(Sekhar Basu)

MESSAGES

जी. कल्याणकृष्णन
विशिष्ट वैज्ञानिक
अध्यक्ष एवं मुख्य कार्यपालक

सत्यमेव जयते
Government of India

नाभिकीय ईंधन सम्मिश्र
(अई.एस.ओ. 9001, अई.एस.ओ. 14001 &
ओ.हेच.एस.ए.एस. 18001 संगठन)
परमाणु ऊर्जा विभाग
भारत सरकार
हैदराबाद - 500 062.

G. KALYANAKRISHNAN
Distinguished Scientist
Chairman & Chief Executive

NUCLEAR FUEL COMPLEX
(an ISO 9001, ISO 14001 &
OHSAS 18001 organisation)
DEPARTMENT OF ATOMIC ENERGY
GOVERNMENT OF INDIA
HYDERABAD - 500 062.

MESSAGE

I am overwhelmed with the accomplishments of all the groups of NFC in 2016-17. The targets and the deliverables for PHWR fuel and other products have been exceeded. It is a matter of pride for NFC to achieve world record fuel production of 1512MT and also to touch the milestone of 9th lakh PHWR fuel bundle during the year. This achievement is a result of implementation of innovative process developments to phenomenally increase the production of UO_2 powder and sintered pellets, zirconium sponge, melting of zirconium alloys, manufacturing of fuel tubes and other components.

It is impressive to note the achievement of production value of Rs.125 crores through SS and job orders. R&D efforts in collaboration with BARC, IGCAR, RRCAT, DRDO, ISRO and Midhani have all resulted in development of new challenging materials like seamless tubes of Super-Ni, PT-7M, Titanium half alloys, stringent quality SS 304L, sheets of high purity Niobium metal among others this year.

I am happy to note that while excelling in production activities, NFC has implemented a higher order of safety culture across NFC and outsourced staff. I must acknowledge the efforts put in augmenting the infrastructure facilities under the XII plan projects and in exceeding the name plate capacities of the plants for meeting the future challenges.

The outstanding performance of NFC would not have been possible but for the support, commitment and dedicated services of each and every employee of NFC. On this occasion, I compliment all the NFCians and wish them greater success to take NFC forward.

(G. Kalyanakrishnan)

• NFC Board •

Shri G. Kalyanakrishnan
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BARC
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DCE (Fuels, FRF & ZC), NFC
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Member

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DCE (Z&SM), NFC
Member

Shri D. Pramanik
DCE (SSTP, Melting, Mktg., CED & NFC-K),
Member Secretary

Dr. Shaju K. Albert,
Head, MTD, MMG, IGCAR
Member

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Chairman

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DCE (Fuels, FRF & ZC)
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DCE (Str., ISO & FT)
Member Secretary

Shri D. Pramanik
DCE (SSTP, Melting,
Mktg., CED & NFC-K)
Member

HIGHLIGHTS सुरिर्वयाँ
2016- 2017

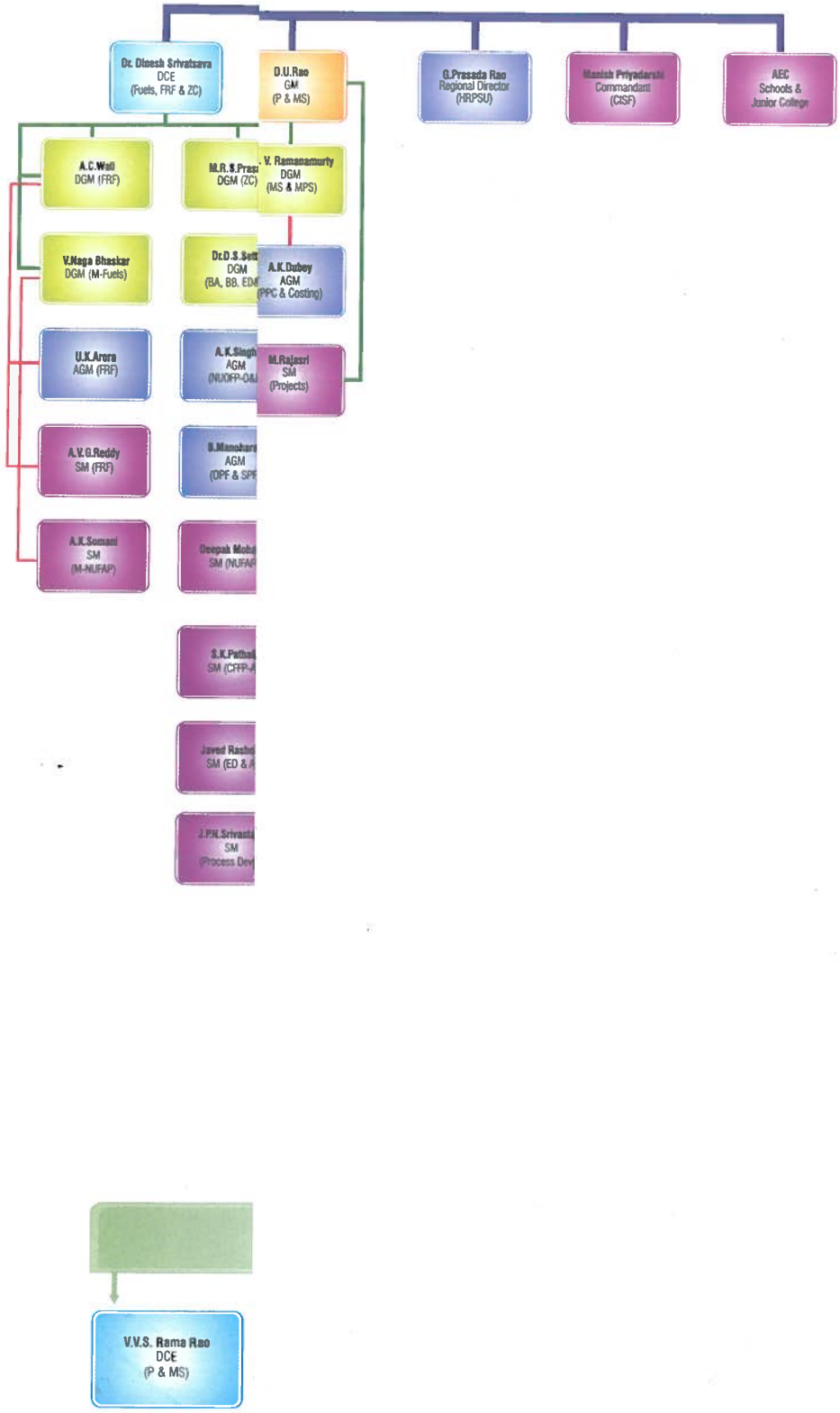
Major Events

Dr. Sekhar Basu, Chairman, AEC & Secretary, DAE receiving the Guard of Honour from CISF, NFC.

Shri G. Kalyanakrishnan, Chairman & CE, NFC handing over document on SuperNi-42 tubes & rods manufactured by NFC to Shri K.N.Vyas, Director, BARC.

Shri G. Kalyanakrishnan,Chairman & CE, NFC and Senior Executives welcoming Smt. Vandita Sharma, IAS, Member for Finance, AEC.

As on 21.0


Dr. Dinesh Srivatsava
DCE
(Fuels, FRF & ZC)
D.U.Rao
GM
(P & MS)
G.Prasada Rao
Regional Director
(HRPSU)
Manish Priyadarshi
Commandant
(CISF)
AEC
Schools &
Junior College
A.C.Wali
DGM (FRF)
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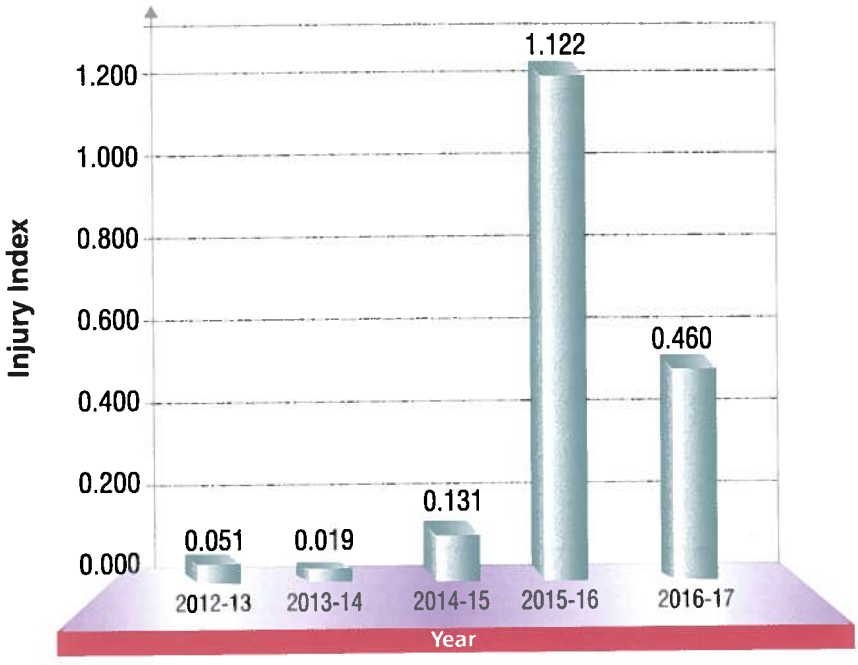
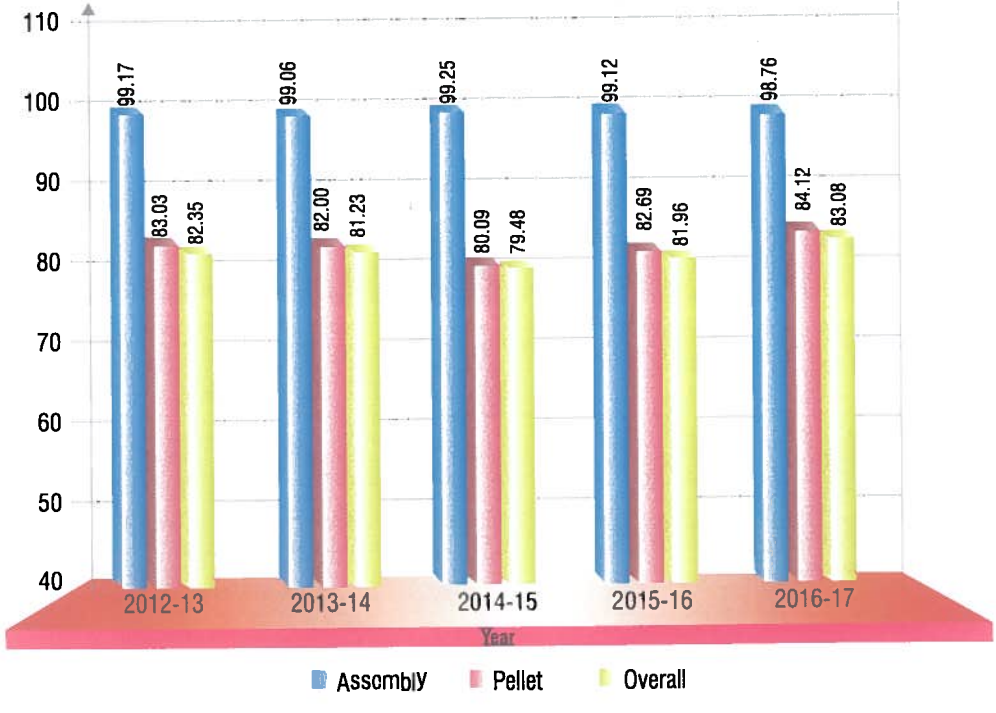
DGM
(MS & MPS)
V.Naga Bhaskar
DGM (M-Fuels)
A.K.Dubey
AGM
(PPC & Costing)
U.K.Arora
AGM (FRF)
M.Rajasri
SM
(Projects)
A.V.G.Reddy
SM (FRF)
A.K.Somani
SM
(M-NUFAP)
V.V.S. Rama Rao
DCE
(P & MS)

Safety Performance

Injury Index 2012-13 to 2016-17



PHWR Fuel recovery



ISO 9001:2008

OHSMS

NABCB
QMS

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HIGHLIGHTS
2016- 2017

राष्ट्र की सेवा में परमाणु
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NFC
ATOMS IN THE SERVICE OF THE NATION

FUEL

Fuel sub-assembly

Integrated Spacer cum bearing pad welding machine

Uranium di-oxide pellets

37 element fuel bundle

Automatic density measurement unit

Fuel

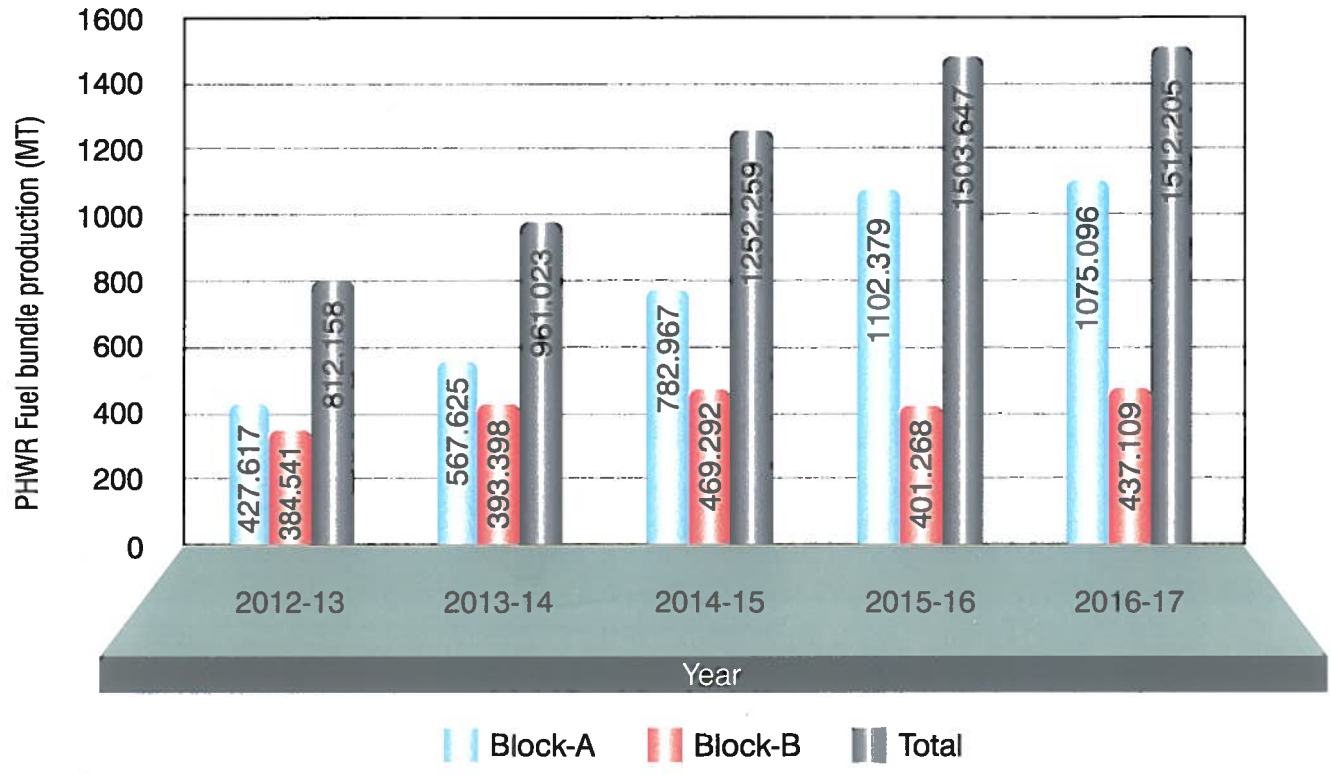
Fuel Group of NFC manufactures and supplies 19/37 element Natural Uranium Fuel bundles for all the Pressurized Heavy Water Reactors (PHWRs), Enriched Uranium Fuel Assemblies of 6 x 6 type for the two Boiling Water Reactors (BWRs) at Tarapur, Reactor Core Sub-assemblies for the Fast Breeder Test Reactor (FBTR) and the 500MWe Prototype Fast Breeder Reactor (PFBR) which is under construction. In addition, Fuel group is given the mandate for fabrication of AHWR fuel clusters and is actively involved in establishing re processed Uranium plant and core sub-assemblies plant in Fast Reactor Fuel Cycle Facility (FRFCF).

PHWR Fuel

Powder manufacturing plant (UOP), Pellet manufacturing plant (CFFP-P) and Fuel Assembly fabrication plant (CFFP-A) constitute Block-A facilities and contribute for manufacturing 19 element PHWR fuel bundles for safeguarded reactors as per the separation plan. Imported Natural Uranium in the form of Uranium Ore Concentrate (UOC) or Uranium di-oxide pellets is converted into fuel bundles. Similarly NUOFP-O, NUOFP-P and NUFAP produce powder, pellets and assemblies respectively for manufacturing 19 and 37 element fuel bundles for out of safeguarded reactors from MDU/SU supplied by M/s UCIL.

In the year 2016-17, NFC has achieved world's highest production of 1512 MT of PHWR fuel. This has been yet another milestone year and NFC has emerged as the world leader in PHWR fuel fabrication for the third consecutive year.

PHWR Fuel bundle production performance

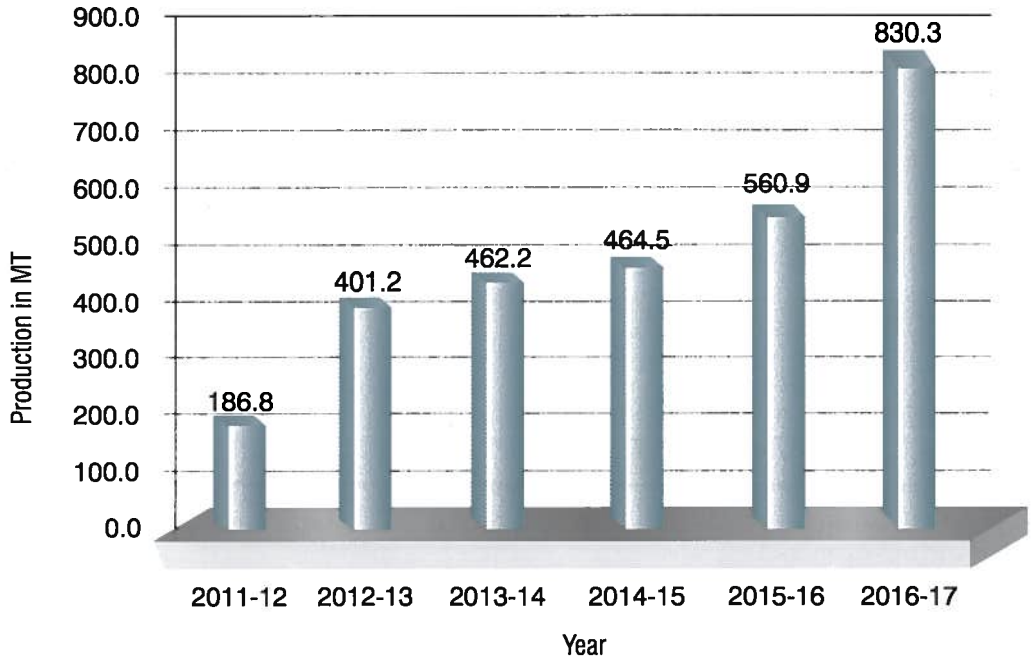


This achievement has a special significance as the major production was through the conversion of UOC powder in to pellets and is a result of many unprecedented innovations and process modifications. Plant-wise key innovations and process modifications carried out in the Fuels Group are mentioned below.

Uranium Oxide Plant (UOP)

UOP has achieved production of 830.3 MT UO_2 powder against target of 650 MT. The plant has achieved highest monthly production of 120.9 MT in the month of March'17. Production for the Q4 of FY 2016-17 is 310.6 MT which is an all time highest quarterly production with 94.2% plant recovery.

Production Performance of UOP



The following developmental activities were carried out in the plant for achieving the highest ever production:

a) Increase in UOC dissolution capacity

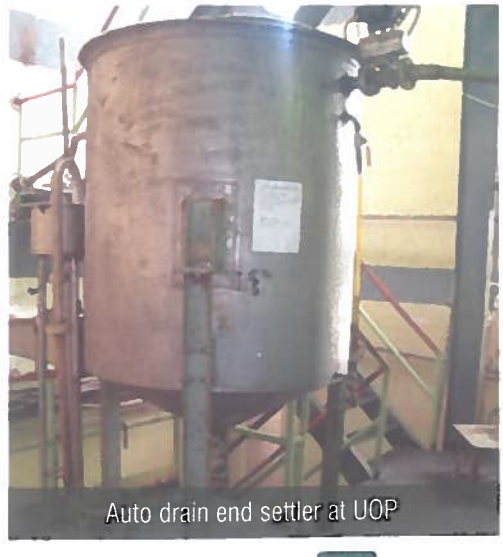
In the dissolution process, the control on temperature is very essential for safe and smooth operation. A cold water loop has been introduced in the dissolution process for controlling the temperature. This has enabled incremental acid flow from 50 lph to 500 lph thereby reducing the batch time from 24 hrs to 16 hrs and increasing the batch size from 2.3 to 2.7 MTe. This modification has resulted in increasing the capacity in dissolution stage from earlier 2.5 MTe/day to 5 MTe/day.

b) Design, fabrication and installation of steam coil in feed tanks

The increase in uranium concentration and free acidity of uranyl nitrate feed accelerated the crystallization of uranyl nitrate and impacted the extraction efficiency & operation. To overcome crystallization of U feed, a system with steam coil has designed, fabricated and successfully installed in uranyl nitrate feed tanks. The feed temperature is now controlled at 40°C to prevent crystallization. This system is fully automated and maintains the required temperature of the feed.

c) Modification in slurry extraction

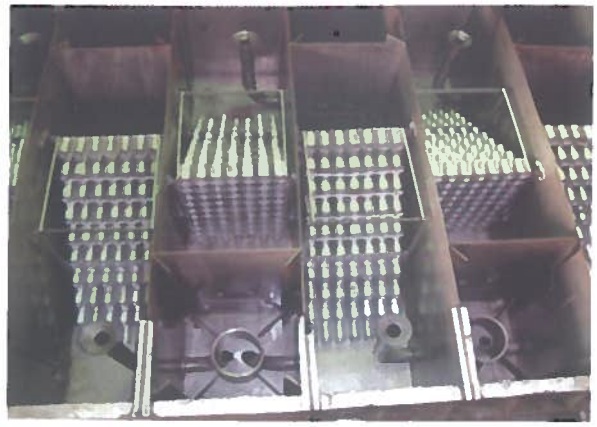
Uranyl nitrate feed concentration was increased from 300 lph to 400 lph. The feed concentration was also increased from 330 gUpl to 450 gUpl. The feed entry to the slurry extractor has been modified from 1st stage to 3rd stage and the reflux entry has been modified from 2nd stage to 5th stage. Solvent entry has been introduced in 6th and 7th stages. Furthermore, a new auto drain end settler has also been designed and installed. The zero settler capacity has been doubled to 2 kL. In addition to these, the hydrostatic head at the solvent entry point has been increased. These modifications have resulted in increase in solvent extraction capacity from 100 kg/hr to 180 kg/hr.


Auto drain end settler at UOP

d) Design, development, fabrication and installation of coalescer units

In the uranium purification process, the step of stripping is more crucial as compared to the extraction step due to the difficulties in coalescence of organic and aqueous phases. In the conventional mixer-settler design, "back mixing" is a limiting factor which decreases the efficiency of the stripping process. For the first time in the world, a unique concept of coalescer has

been designed for addressing the problem of back mixing. The innovative coalescer unit was designed and 17 nos. of such coalesce units have been fabricated in-house by ED&A. Introduction of the coalesce units in each Innovative Coalescer in Stripping Section chamber of mixer settler I & II have achieved laminar flow even at increased throughput thereby preventing back-mixing and increasing the stripping capacity in solvent extraction. Further, the throughput of aqueous and organic streams have also increased by 2.4 and 2 times respectively with 100% separation of organic and aqueous phase by effective channelizing the fluid flow in laminar manner and eliminating cross flow. This has in turn enhanced the production capacity by nearly 2.5 times in the same equipment.



Innovative Coalescer in Stripping Section

e) Re-extraction in MS – I & II

The capacity of the re-extraction cycle in MS-I and MS-II has been increased to 2.3 MT/day from 1.2 MT/day and 0.6 MT/day respectively through the introduction of mechanical coalescer units, introduction of temperature controlled stripping at 40°C and increasing the hydrostatic head at LS and UNPS exit points. Additionally, in MS-II, the reflux of aqueous entry has been introduced at 3rd stage instead of 6th place and the gravity flow of DM water has been replaced with pumping.

f) Modification in batch precipitation

The capacity of the batch precipitation process has been improved from 2.3 MT/day to 4.2 MT/day by increasing the ammonia flow rate from 50 kg/hr to 100 kg/hr. This has helped in the production of more active AU powder, reducing the median particle size by 2-3 μm. The jar settled volume increased from 60 cc to 80 cc. The batch size also increased from 550 to 700 kg.

g) Turbo dryer modification

All the 76 heating elements in the turbo dryer have been replaced with new elements. In addition to this, 12 nos. of new heating elements have been added which has increased the capacity from 152 kW to 176 kW. The thermal insulation of the dryer surface has helped in an increase of 10°C by reducing the heat losses. With this, the capacity increased from 2.3 MT/day to 4.2 MT/day.

h) Modifications in ADU bunkers

The existing ADU bunkers which can accommodate around 650 kg powder have been modified to enhance its capacity to 850 kg. This has helped in the increase of batch size in precipitation and has reduced the number of bunker changes in reduction and calcination furnaces which in turn has helped reducing manpower and material handling operations. Further, for the first time the level sensing concept in powder handling bunkers is introduced and installed in these bunkers which has prevented the filling of chute resulting in elimination of the problem of choking in the discharge of turbo dryer. These bunkers have been tested and are being used in regular production line.

Modified Bunker

i) Modification in Calcination Furnace

The introduction of specially designed cascaders and lifters into the furnace internal cage increased the heat transfer area. The change in the furnace internals reduced the calcination temperature from 735°C to 695°C to prevent partial sintering and for increasing seal life. These modifications have increased the calcination capacity from 3.2 MT/day to 5.6 MT/day.

j) Introduction of LM guide rails

Alignment of inlet port of UO_2 bunker on castor wheeled trolley with discharging bellow of the furnace is a very tedious and time consuming. Linear motion (LM) guided rails have been fixed in the discharge pit of two furnaces for the movement of UO_2 powder bunkers, each weighing approximately 1100 kgs. This LM guides based track system has resulted in smooth and trouble-free alignment and has helped in reduction of human fatigue ultimately leading to increased productivity.

k) Re-optimization of Reduction Parameters

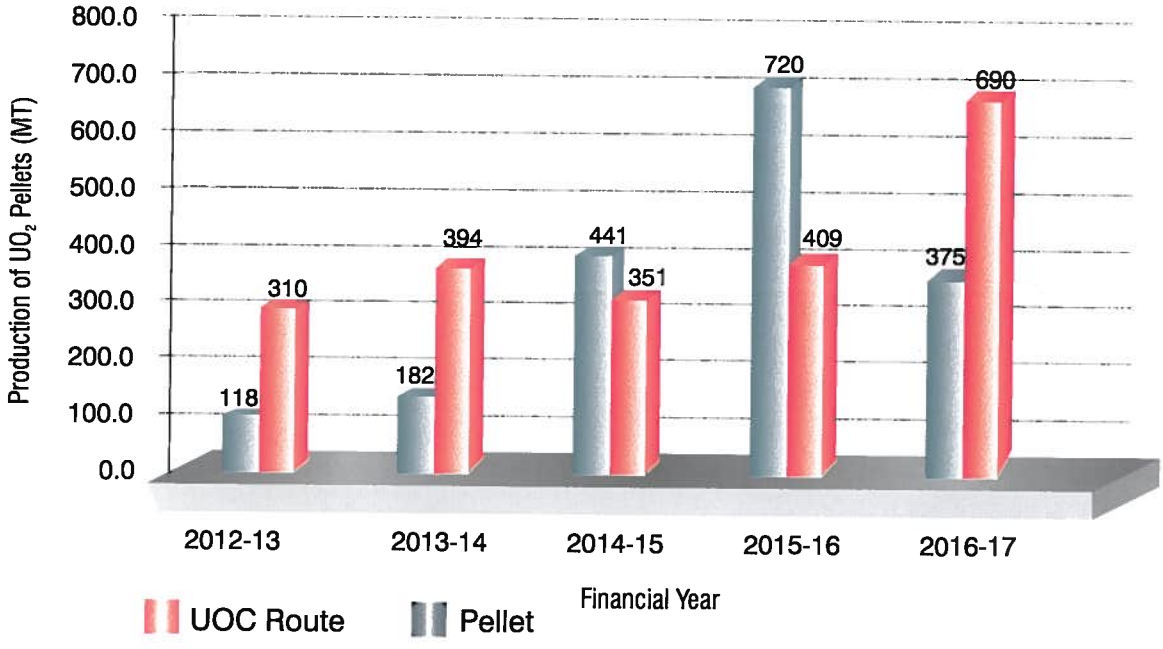
The cracked ammonia gas flow rate has been re-optimized from 9 m^3/hr to 11m^3/hr. The feed rate was also increased from 80 kg/hr to 120 kg/hr. The improvement in the calcination process has helped in lowering the temperature in the reduction step from 580°C to 550°C. These modifications have helped in increasing the capacity from 3.2 MT/day to 5.6 MT/day.

l) Stabilization parameter optimization

The feed rate of the stabilization process has been increased from 120 kg/hr to 200 kg/hr. Consequently, the gas flow rate has been re-optimized from 5.4 m^3/hr to 7 m^3/hr. The cooling water flow rate has also been controlled for attaining better chemisorption. These modifications have resulted in improving the capacity from 2.3 to 4.2 MT/day.

Ceramic Fuel Fabrication Plant – Pelletizing (CFFP - P)

CFFP (P) has achieved over 1065 MT of UO2 pellets loading into fuel tubes which constituted more than 70% of total PHWR fuel production at NFC for this year. Out of 1065 MT, about 690 MT of finished fuel pellets were produced through UOC route which is the highest ever fuel pellet production at CFFP (P).

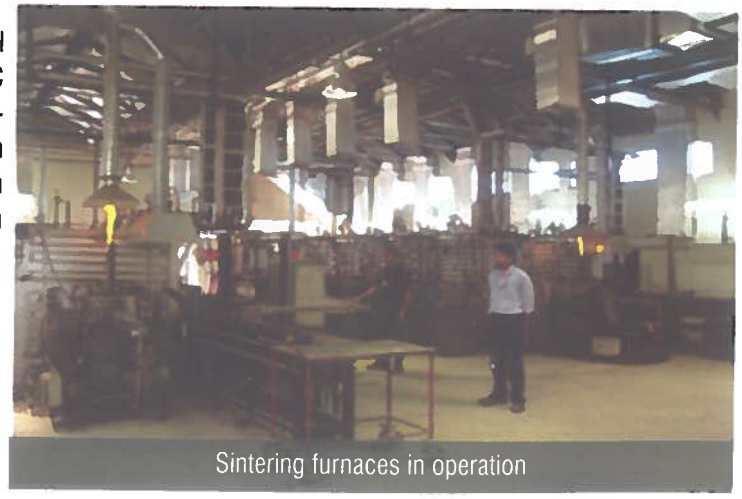


Production Performance of CFFP (P) during last 5 years

The key modifications carried out in the plant during this year are given below:

a) Accelerated sintering

Five furnaces were operated at 1 hr. pushing interval during 2016-17 thereby producing 711MT of QC cleared UO2 pellets as compared to 202 MT in 2015-16. In SF-3 sintering furnace, regular molybdenum charge carriers have been completely replaced by high capacity molybdenum charge carriers which contributed to 236 MT of production.



Sintering furnaces in operation

b) Shifting of two high capacity high temperature sintering furnaces

In view of the enhanced production requirement in Block - A fuel plants, the UOP well shed area was identified for capacity expansion of CFFP (P) and 2 nos. of high capacity high temperature sintering furnaces were shifted from Block-B. In order to save the time involved in the re-alignment of insulation bricks and other commissioning works, the two furnaces, each weighing nearly 20 MT were shifted in 'as is' condition with intact insulation bricks and heating elements using an innovative and specially designed lifting structure. This structure was fabricated completely in-house at ED&A and D&W. These furnaces were then successfully re-installed and re-commissioned with the close co-ordinated efforts from multiple agencies of NFC in a record time of about 3 months. About 153 MT of QC cleared sintered UO_2 fuel pellets have been produced from these two furnaces from July'16.

High Capacity Sintering Furnaces with Lifting Structure

c) Installation of high capacity 3D blending unit

A new high capacity 3D blender was commissioned successfully replacing the old horizontal roller system for uniform mixing of granulated UO_2 powder and organic lubricant powder before final compaction as pellets. This development has reduced the blending time by 50% and has improved the homogeneity of binder in the granules thereby improving quality and maintaining uniform consistency.

3D Blending System

d) Introduction of poly-chord conveyors

The UO_2material is abrasive in nature and results in wear and tear in the pellet conveyor system during grinding operation. In view of this, the existing "flat belt" conveyors have been replaced with "poly-chord" conveyors in centreless grinding machine which has resulted in enhanced belt life and ease of maintenance with lesser down time.

e) Introduction of weight lifting system

In order to know the net UO_2 pellets within the PHWR fuel tubes during pellet loading operation, a new automatic system was developed in-house and integrated with existing manual fuel tube loading station. This has enabled easy and error-free weight measurement of all the 19 elements in a single instance. This has resulted in elimination of tedious weighing operation, reduced operator fatigue and the entire process time has been reduced due to less number of operational steps.

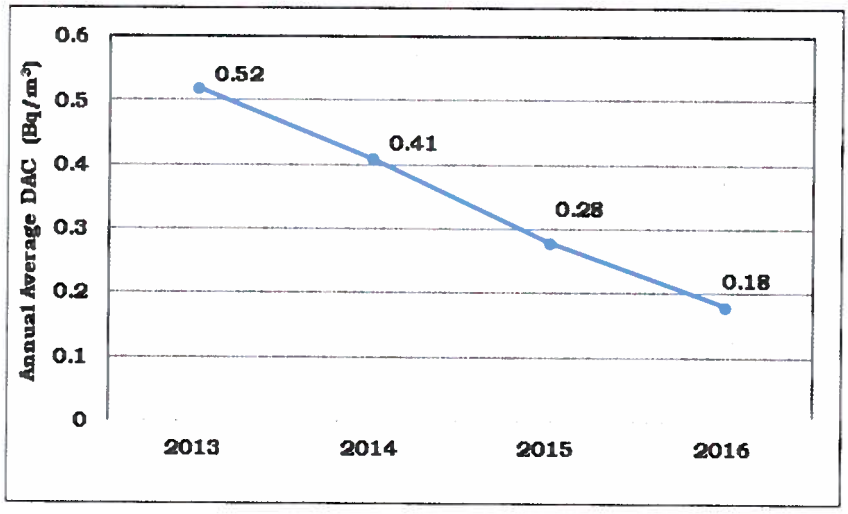
f) Automatic pellet unloading system

An Automatic Pellet Unloading System for unloading of sintered UO_2 pellets from Molybdenum charge carriers(boats)onto SS rod trays and followed by automatic arrangement of these SS trays into trolleys has been developed, installed and successfully commissioned. This integrated system has replaced all the manual operations involved in unloading of UO_2 pellets.

Manual Unloading

Automated Pellet Unloading System

g) State-of-the-art containment systems were installed on the centreless grinding machines resulting in substantial decrease in the average air activity. Over the past 4 years, the average air-borne activity has been reduced by nearly 3 times.



Annual average air activity in centreless grinding area

Ceramic Fuel Fabrication Plant – Assembly (CFFP –A)

CFFP-A has achieved an annual production of 1075 Te during this year with improved recovery of 99.27%. The plant crossed 1000 Te annual production for the second consecutive year.

The plant has safely and securely stored the entire finished QC and QS cleared bundles in designated sheds. The current stock pile of 19-element QS cleared bundles is sufficient to cater to the fuel requirements for all safeguarded PHWRs for about five years. All IAEA safeguard inspections including SNI and PIV have been successfully completed with lowest MUF than the permissible value. During PIV, fuel bundles equivalent to nearly 2210 Te have been successfully inspected by IAEA. In this year, nearly 22.33 lakh spacer pads and 16.75 lakh bearing pads have been welded on to nearly 8.84 lakh fuel tubes. IAEA appreciated the NUMAC procedure followed at NFC.

In addition to the production activity, the following developmental activities were carried out in this year:

a) Modification of ISBU

As a part of continual improvement, various modifications have been carried out in the appendage welding section like,

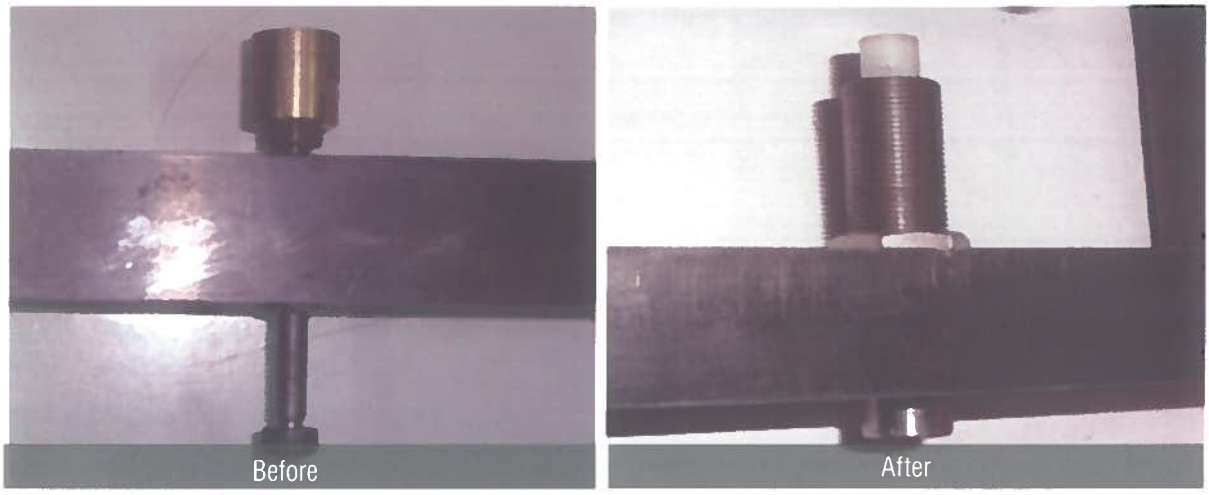
i. Increase of welded tube output collection bin to twice its capacity of ISBU-11. This has further been extended to all the other ISBUs. This modification has helped in reduced material handling operations resulting in reduced operator fatigue.

Before
Capacity: 60 Tubes

After
Capacity: More than 120 Tubes

Modifications in ISBUs

ii. Modifications in Appendage pick-up system of all ISBUs to eliminate any probability of middle bearing pad (1.01 mm thick) going into end bearing pad (1.29 mm thick) slot. The modified appendage picking system has the advantages like less vibration, less noise, cushioning, fine adjustment etc.



Modification of appendage picking system

b) To meet the increased production requirement, around 28 lakh endplates and end caps have been cleaned and taken for welding. About 131 lakh appendages (including spacer and bearing pads) have been pickled and supplied to both the PHWR assembly manufacturing pants.

c) In end cap and end plate washing section, highly carcinogenic TCE has been replaced by a biodegradable cleaner, LPS. New baskets have been designed for automated degreasing and washing of end caps and end plates in linear degreasing unit. The modified baskets have provision for accommodating multiple baskets with smaller sub-lots.

End Caps Washing Basket
*Lot size reduced to less than 700 Nos.
*6 buckets in one basket.
*Suitable for Linear degreasing unit.

End Plate Washing Basket
*30 rods for endplates washing
*Suitable for Linear degreasing unit.

Modified Endcap and Endplate Washing Basket

d) Introduction of PHWR fuel element weighing system

In order to ensure the correct pellet stack in the individual fuel elements, an online PHWR fuel element weighing systems on two double head turning machines (DUAP machines) have been introduced. This system can identify elements with lower weight and thereby detecting less pellet stack length. Through this system, nearly 7,20,000 individual elements were weighed in this financial year which has eliminated low weight fuel elements going into bundle stage and also improving overall recovery and product reliability.

e) Modification in End cap welding machines

Safety Features of all End Cap Welding Units have been further enhanced by introducing safety guards and incorporating additional safety interlocks through PLC.

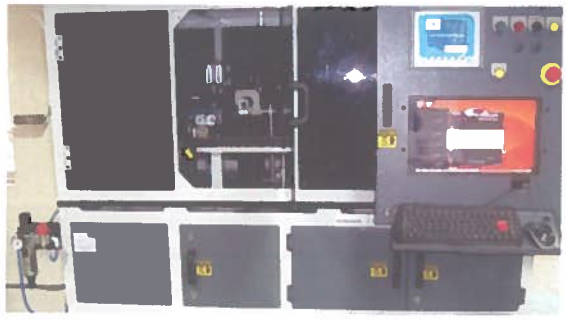
f) Shifting of vacuum baking furnace

An old baking oven existing at CFFP-A has been dismantled and shifted to Block-B. The unit has been re-commissioned at NUFAP and gave significant contribution in baking graphite coated tubes.

g) Introduction of vision based end cap inspection system

State-of-the-art vision based Automatic End caps inspection system has been developed, manufactured and commissioned. This system is capable of inspecting all major dimensional details and identifying surface defects.

Modified end cap welding machine



Vision based automatic end cap inspection system

Natural Uranium Oxide Fabrication Plant – Oxide (NUOFP-O)

With a production of 535 MT of UO2 powder achieved during April 2016 to March2017, the plant was able to meet the targeted fuel production for the OSG reactors in spite of inconsistent raw material supply from UCIL. The ammonia supply to fuel plants has been carried out uninterruptedly from centralized supply system of NUOFP (O) which has helped to cater to the high production targets in a safe manner. This has eliminated tedious and hazardous manual handling of ammonia tonners. The plant had processed different raw materials such as MDU, HTUP and SDU with improved overall powder to pellet recoveries. Apart from the regular production activities, the following developmental activities were taken up.

a) Treatment of uranyl nitrate raffinate (UNR) by second cycle of solvent extraction

Uranyl Nitrate Raffinate (UNR) treatment by second cycle of solvent extraction has been re-established with UNR generated from Magnesium Di-uranate(MDU) raw material source. The parameters were fine tuned to operate 5 nos. of cross-flow stages instead of earlier 6 nos. of stages. This resulted in reduction in consumption of treated solvent and subsequently reduced load on solvent treatment, generation of wash solution reduced by about 15%. By this route the plant successfully produced 50MT UO_2which resulted in avoiding generation of 38MT of UNRC.

b) Installation and commissioning of filtration system

The Ammonium Nitrate (AN) filtrate containing fine ADU particles is treated with Ferric chloride and allowed to settle in settling tanks. After settling is completed, the sludge containing ADU, ferric chloride and ammonium nitrate is transferred to sludge tank and then recycled to dissolution section. This system has been introduced for reducing both the volume of the effluent and also the uranium content in the AN solution which will be disposed by sale. A modification has been carried out to completely separate the clear ammonium nitrate supernatant and ADU particulate matter along with ferric chloride. This is carried out by filtering the sludge in a rectangular filter under vacuum. The resultant clear ammonium nitrate solution is sent to effluent storage tanks & the residual cake containing 'Uranium' is recycled to dissolution for recovery of 'U'. A dedicated filtration system has been installed and commissioned for the above purposes. This has improved the quality of final effluent being sold to recognised vendors and elimination of ammonium nitrate sludge generation for recycling.

Natural Uranium Oxide Plant – Pelletizing (NUOFP-P)

The plant has achieved total production of 446 MT out of which 270 MT is for 19 element and 175 MT is of 37 element fuel during this year. Highest ever quarterly production of 153.53 MT was achieved in Q-4 of 2016-17 with highest ever over all powder to pellet recovery of 82.3% during the year. Various developments and modifications were carried out to reduce the airborne activity which has resulted in decrease of annual average airborne activity from 0.23 Bq/m^3 in 2015-16 to less than 0.20 Bq/m^3 in this year.

Following are some developmental works completed or under progress:

a) Development of pellet feeding system for centreless grinder

A new pellet feeding system has been developed in which sintered pellets stacked on molybdenum sheets are directly dumped in a vibratory bowl in which randomly arranged pellets are oriented horizontally through vibration and are fed into the charging conveyor of centreless grinder. This development has eliminated multiple discharges in sintering and centreless grinding areas leading to increased productivity, reduced manual effort and radiation exposure to the plant personnel.

Pellet feeding system for centreless grinder

b) Procurement and commissioning of ammonia cracker with advanced features

In addition to the existing, a new 50 NM^3 capacity ammonia cracker unit with special features has been procured and commissioned at NUOFP(P) to meet the cracked ammonia requirement of sintering and reduction furnaces. The cracker unit has two "U" tube retorts in place of cylindrical retorts to maintain leak tightness by accommodating the thermal stresses generated. A new molecular sieve purifier unit is also introduced in the ammonia cracker unit for the first time to ensure cracking efficiency up to 99.999% and dew point below -70°C

c) Dedicated primary ventilation system for roll compaction area

Installation and commissioning of a dedicated primary exhaust blower system for Roll compactors has been carried out for reducing the airborne activity levels in pre-compaction area. Earlier roll press area primary ventilation was provided by final compaction area blowers. Installation of new dedicated blowers for pre compaction area has helped in making ventilation more effective in final compaction area. It has also reduced the load on pre and HEPA filters of final compaction area.

d) Modification of powder transfer ports

New leak tight transfer ports were designed and implemented for transfer of virgin UO_2 powder from UO_2 container to roll press hopper and fines screw conveyor to UO_2 container. This has resulted in reduction of average air borne activity level below 0.2 Bq/m^3 from 0.25 Bq/m^3.

e) Roll press area layout modification and erection of new roll compactor

New roll compactor in NUOFP-P The layout of Roll compaction area of NUOFP (P) has been modified to accommodate newly procured Roll compactor used for pre-compaction of virgin UO_2 powder. A new double door entry passage and access path for forklift has been constructed. False roofing, ventilation ducts have been rerouted to meet the space and ventilation requirements of the compactor. The Roll compactor has been safely unloaded and erected at site. It has advanced safety and maintenance features like fail safe ball screw based powder container lifting system, leak tight granule transfer bellows, easily removable sub-assemblies etc.

New roll compactor in NUOFP-P

Natural Uranium Fabrication Assembly Plant (NUFAP)

NUFAP has achieved an annual production of PHWR fuel assemblies of 437.10 MT. The plant has also achieved highest ever annual production of 11.04 lakhs tubes and highest ever monthly production of 1.60 lakhs tubes at appendage welding section. In addition to the regular production activities, following developmental activities were taken up in the plant and successfully completed.

a) Design, development and qualification of modified end cap weld design has been carried out to achieve a smooth &notch free weld profile with good fusion characteristics & sound weld quality. The proposal is submitted to NPCIL for approval.

b) **Installation and re-commissioning of vacuum baking furnace shifted from CFFP-A**

A vacuum baking furnace from CFFP-A was shifted to NUFAP and was successfully installed and commissioned as vacuum baking oven –3. This baking oven has immensely helped as a standby in tube baking operation during crucial period of March 2017.

Re-commissioned vacuum baking furnace at NUFAP

c) Installation of Rapiscan unit

Installation and commissioning of RAPISCAN X-Ray machine have been carried out successfully for identifying PHWR fuel elements with less stack length. In this system, the fuel elements are scanned by X-ray after end cap welding to check for any less stack length.

Rapiscan system in NUFAP

Enriched Fuel Fabrication Plant

EFFP has produced 105 nos. of BWR Fuel assemblies against the target of 100 nos. by February 2017 with average top plug welding recovery of around 98% and contributed the manpower to other fuel fabrication plants for PHWR fuel production of 1512 Te. The key activities of EFFP-A are mentioned below,

a) Successfully dispatched 104 nos. of fuel assemblies for the outage requirement of TAPS 1 & 2.

b) Carried out de-canning of around 27,000 nos. of rejected PHWR fuel elements and recovered more than 21.7 MT of UO2 pellets for inspection and subsequent loading into fresh fuel tubes.

Fast Reactor Facility (FRF) of NFC is engaged in the following activities:

1) Manufacturing of core sub-assemblies (SA) for 13 MWe Fast Breeder Test Reactor (FBTR).
2) Manufacturing of first core sub-assemblies for 500 MWe Prototype Fast Breeder Reactor (PFBR).
3) Setting up of two production plants viz., RUP and CSP, under Fast Reactor Fuel Cycle Facility (FRFCF) project being set up at Kalpakkam

FRF has contributed significantly in the above areas as follows:

1) Manufacture of FBTR SA required for annual replacement & Irradiation experiments :

- 8 nos of FBTR Fuel SA fabrication involving fuel pins (MK-I) assembly and final fabrication has been completed at FBTR, IGCAR, Kalpakkam and supplied to IGCAR.
- 4 nos of Carrier SA fabrication involving precision components machining viz. Lock housing, upper hexagonal sheath, Middle hex blocks etc., assembly and welding was completed and supplied to IGCAR.
- Mark-I Fuel Pin components supply to RMD, BARC: 1448 nos of SS 316M clad tubes were machined and supplied.
- D9 Hexagonal tubes (Outer type): Button forming, Button milling and chrome plating operations were carried out on the 105 No's of D9 Hexagonal tubes (Outer type) manufactured and supplied by STP, NFC. These will be used for various types of FBTR SA to be manufactured with new & improved grade clad & wrapper tubes by switching over from the present grades of SS316 materials.

2) Manufacture of PFBR SA required for Initial Core & 2nd Core:

1st Core Requirements

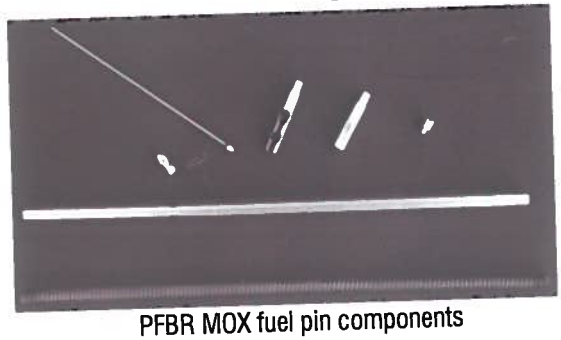
- Diluent Subassemblies : 8 nos of these Special SA fabrication involving Natural UO_2 pellets loaded Diluent pins fabrication, lower part and upper part assembly, hexcan to lower part welding, inspection & testing has been carried out establishing all the operations for the first time successfully.
- Final Assembly Activity consisting of major operations like Fuel pins assembly, Hexcan welding, Bead grinding, Bend correction, Alcohol cleaning & Final inspection operations like UT, LPE, dimensional, Straightness measurement etc. were carried out for 24 nos. (Cumulative: 193 nos.) of Fuel Sub-Assemblies (FSA) by arranging 6 campaigns at IFSB, FBTR, IGCAR Kalpakkam. With this the development & manufacturing activities are completed for 631 nos of 1st core PFBR SA.
- History dockets of PFBR core subassemblies: History dockets of 4 types of PFBR Special SA (Instrumented central SA, Purger SA, Diluent SA & Source SA) were prepared and submitted to BHAVINI.

PFBR Hexagonal tube welding

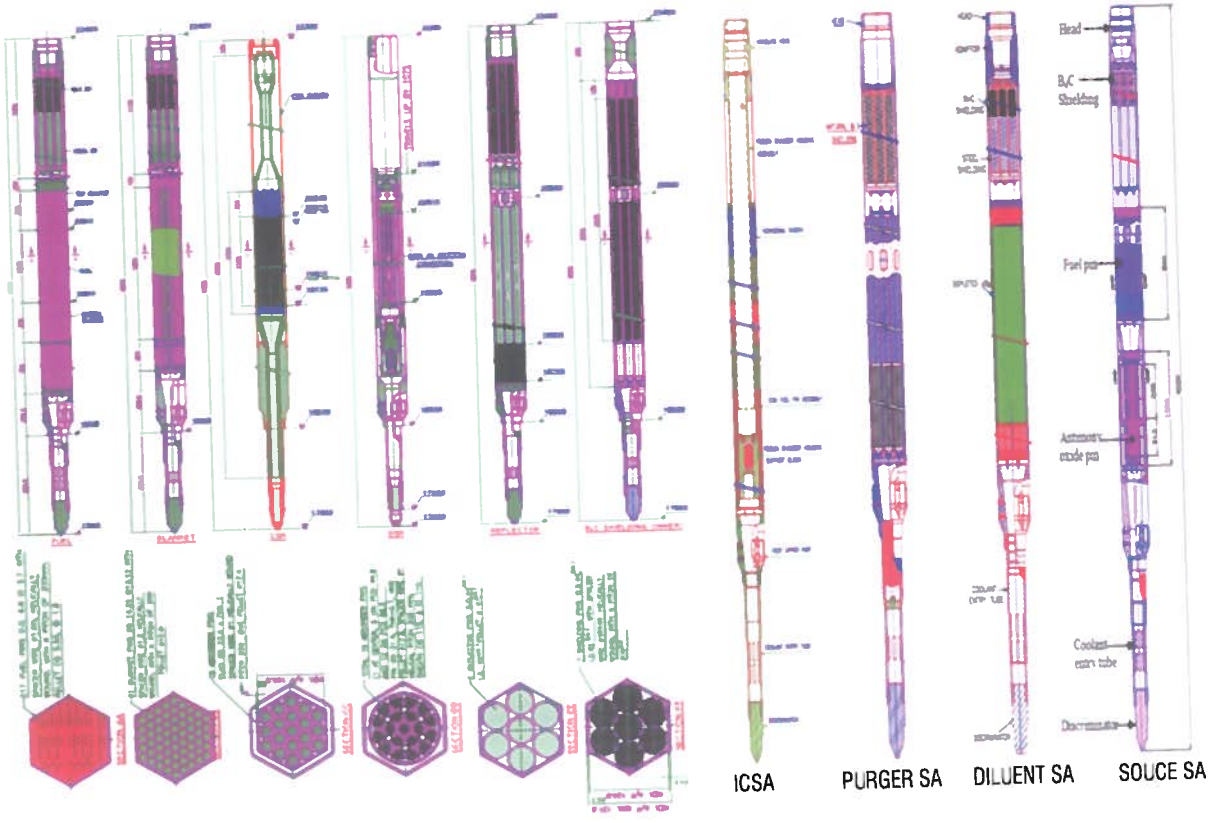
2nd Core Requirements

Components for MOX Fuel Pin fabrication at AFFF towards 2nd Core FSA Pins fabrication:

- 7281 nos. of D9 Crimped Fuel clad tubes, 2400 nos of Spacer wires (bead formed) & 4947 nos of Springs have been delivered to AFFF/BARC as per their requirements.
- 2500m of SS 316 LN rods supplied to AFFF, which are required for plugs & other components machining.
- 1200 nos of Spacer wires were manufactured.



PFBR MOX fuel pin components

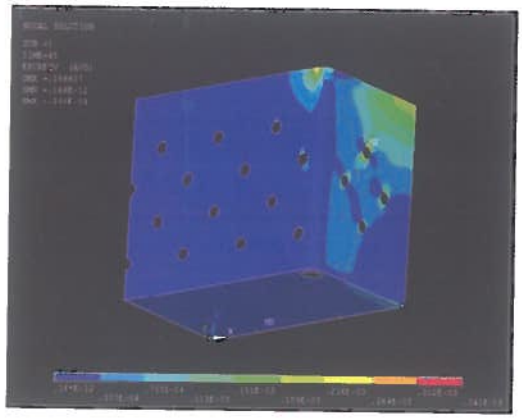


PFBR Initial Core sub-assemblies

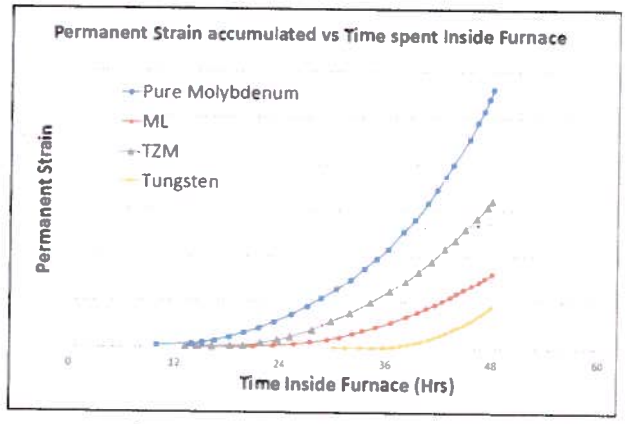
Finite Element Modelling of Molybdenum boat behaviour in continuous sintering furnace

The Boat is basically a charge carrier. It is used to feed, green Uranium Di Oxide (UO_2) pellets inside continuous sintering furnace. It to pass through thermal cyclic loading along with pellet load in the sintering furnace for multiple cycles. This thermo-mechai loading generates creep deformations in pellet carrier boats & reduces the usable life. The complex mechanical behaviou Molybdenum boats inside the continuous sintering furnace is modelled, using Finite Element Method. The analysis was carried ou following methodology.

I. Identification of suitable materials for boats and their respective characteristics.
II. Combination of various material properties are modelled to simulate complex material behaviour under sintering furr atmosphere.
III. Material model consists of isotropic elasto-plastic creep modelling of boat material.
IV. Significance of plasticity in total permanent deformation.



Permanent strain in boat



Accumulative Creep strain in four refractory metals

Both Plasticity & creep phenomenon are considered to get interactive material behaviour at elevated temperatures. Total four refract materials (metals) were compared to analyse their performance in continuous sintering furnace.

1. Pure Molybdenum
2. Molybdenum Lanthanum oxide (ML)
3. TZM alloy (0.50 Ti, 0.08 Zr, Moly)
4. Pure Tungsten

This analysis helped to identify the dominating phenomena for distortion of boats, as it can be plasticity or creep. Understanding simultaneous application of constant load creep & stress relaxation. Results shows the performances of various metals in the furna The most suitable material can be identified by this analysis with the aim to reduce distortions with enhanced working life consider economics.

Activities towards FRFCF Project at Kalpakkam:

The radioactive material to be handled in upcoming Reprocessed Uranium Oxide Plant (RUP) will be in the form of powder, pellet, pi and subassemblies. The Reprocessed Uranium Di Oxide to be handled is produced by reprocessing of the discharged fuel from PFI and is highly radioactive after 10th recycle. The contact dose rate of 10th recycle material is expected to be almost 25 times higher th that of the material handled so far at Fast Reactor Facility (FRF). This necessitates provision of heavy shields and mechanised handli systems to handle this material.

Boat discharge operation from sintering furnace is one of the important operation, considering contact dose. Densified sintered pelle coming out of sintering furnace can impart heavy dose to occupational workers. The discharged boats are required to be handled insi shield and handling operation needs to be mechanised. The introduction of shielding in the production line will bring in numerous oth aspects, which are not experienced so far by the present operating plant at NFC. To have a feel of the difficulties that will be faced duri such operations and handling of pellets, it was necessary to SIMULATE mechanized handling system to finalize the concept and al prototype the new shields in the form of metallic pallets. With the above perspective, following development activities have be completed.

- Fabrication of Mild Steel Shielded Pallet (MSSP) Model.
- Simulation of proposed automatic boat handling system at sintering furnace discharge end.

Mild Steel Shielded Pallet (MSSP) Model:

Mild Steel Shielded Pallet (MSSP) designed to contain three pellet carrier boats at a time. The small scale prototype of MSSP has been fabricated in-house to demonstrate the self-alignment of top shield on bottom shield during mechanised placement. HDPE sheets and steel plates are used in model fabrication. Capacity of MSSP is decided based on the following criteria :

- Reduction in total contact dose at the outer surface of shield.
- Optimization in weight of shield, so that shields can be handled with standard available material handling systems.

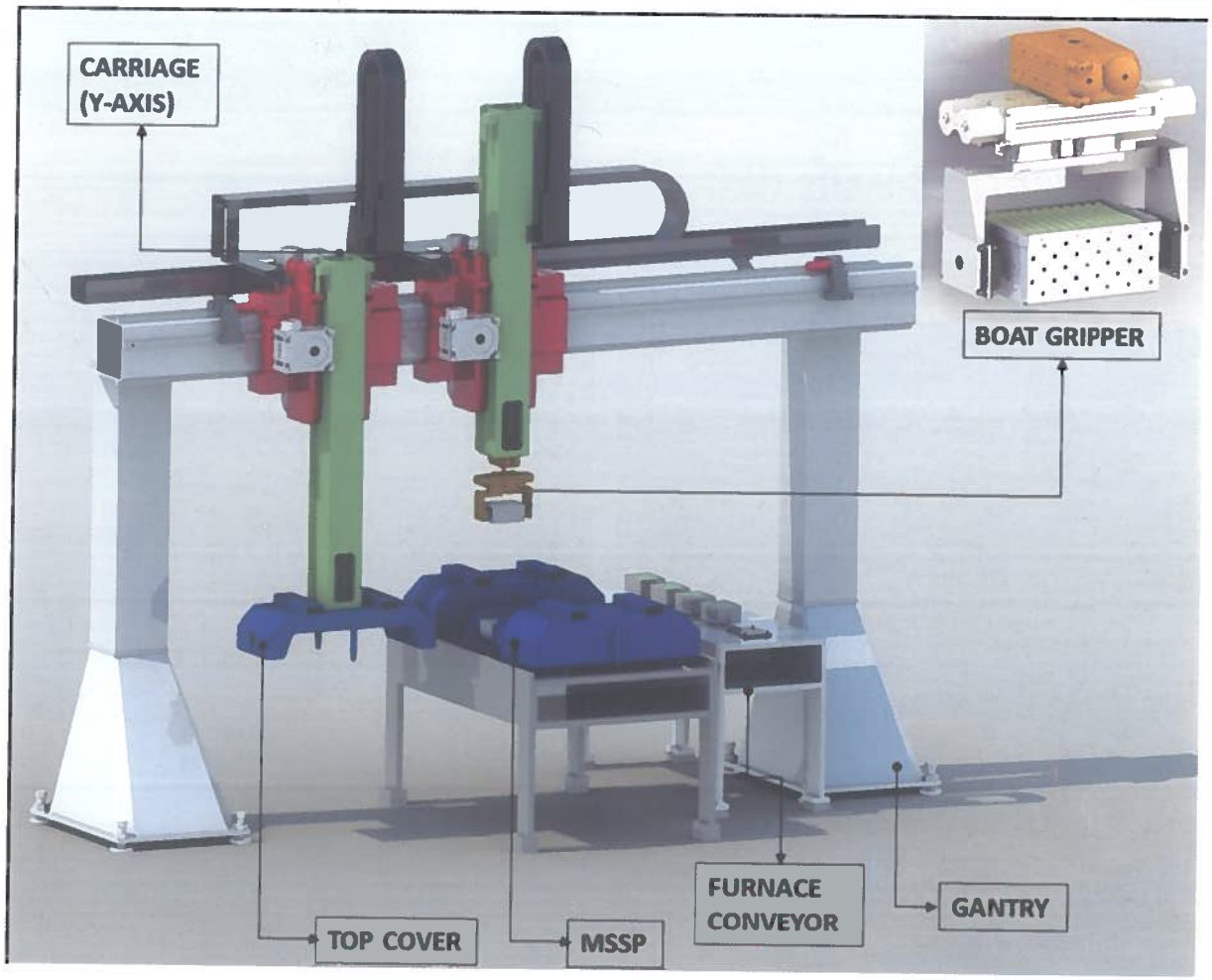
MSSP-Scaled Down Prototype

MSSP design has following specific features:

- Consists of two major parts - (a) Top shield (b) Bottom shield
- Provision of guiding lugs, to avoid misalignments during partial top shield lift. This can also be used to align the top and bottom shields as pair while reassembling.
- Optimized taper angle on both shields for proper reassembling and self-alignment during placement of top cover.
- Provision of lifting C-channels at top shield to lift top cover and at bottom side for safe handling of the MSSP by standard material handling systems.
- The MSSP to be used will be weighing approximately 1400 Kgs due to thick Mild Steel shielding. The design is made in such a way that top shield will self-align with bottom shield during placement. Guiding lugs are provided to avoid misalignments during partial top shield lift for boat pushing.

Simulation of proposed automatic boat handling system at sintering furnace

Charge carrier boats of sintering furnace has to be handled at discharge end of furnace. In present practices, occupational worker manually performs handling of these boats as the contact doses are under acceptable limits. However, in RUP (Reprocessed uranium oxide plant) of FRFCF contact doses are very high, so boats must be transfer immediately into the shields after furnace discharge. Therefore, this concept is develop to automatically handle the charge carrier boats at sintering furnace discharge.



3-D simulation of Gantry with boat & shield handling system

This system will carry out the following activities in sequence in semi-automatic mode:

1. Pick the boat from sintering furnace discharge conveyor using custom-made boat gripper.
2. Lift the top shield of MSSP (700 Kg weight)& move to HOLD location (Mild steel shielded pallet) using Y-Z gantry carriages.
3. Place the boat into MSSP with the help of Y-Z gantry carriages.
4. Close the top shield of MSSP & wait until the next boat comes out of furnace.
5. Repeat the sequence to place three boats inside MSSP.
6. Replace loaded MSSP with empty MSSP.

The Kinematic simulation of the system has been performed in 3-D CAD tool to visualize sequence of operation, functional requirements of standard equipment, hindrances in handling and cycle time to complete the process.

Chairman, AEC visits NFC

Shri G. Kalyanakrishnan, Chairman & CE, NFC and Officials of NFC explaining about ATMF Project site to Dr. Sekhar Basu, Chairman, AEC.

Dr. Sekhar Basu, Chairman, AEC visiting Ceramic Fuel Fabrication Plant, NFC.

Smt. Sheela and Shri K.V. Mirji explaining about Special Materials to Chairman, AEC.

Smt. Meena Ravindran, DCE explaining about SuperNi-42 tubes. Shri G. Kalyanakrishnan, CE, NFC, Dr.R.P. Acharya, DCE are seen in the Picture.

Shri D. Pramanik, DCE explaining on currently developed SS & PT-7M Tubes. Shri C. Phanibabu,DCE, Smt. Meena Ravindran, DCE, Dr. R.P. Acharya, DCE, Dr.Komal Kapoor, DGM are seen in the Picture.

Dr. SekharBasu, Chairman, AEC inaugurating the Electron Beam Melting Furnace at SMP.

DNV ISO 9001:2008

NABCB QMS

DET NORSKE VERITAS 1864 OHSMS

MGMT. SYS. RvA C425 EMS

HIGHLIGHTS 2016- 2017

राष्ट्र की सेवा में परमाणु एन एफ सी NFC ATOMS IN THE SERVICE OF THE NATION

ZIRCONIUM

Zircon sand

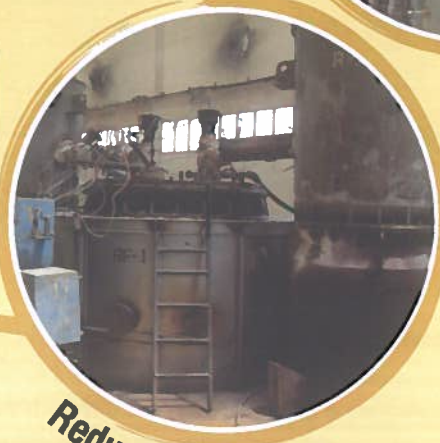
550 Ø Zr-2.5Nb ingots

Solvent extraction

राष्ट्र की सेवा में परमाणु एन एफ सी NFC ATOMS IN THE SERVICE OF THE NATION

Nuclear grade Zirconium spaonge

Reduction Furnace



Zirconium Oxide Plant (ZOP)

Zirconium oxide plant produces Hafnium free Zirconium oxide powder starting from Washed & Dried Frit (WDF) obtained from the caustic fusion of Zircon. Zirconium oxide is used as the starting material for the production of Zirconium sponge.

Major achievements during the year:

- During the year 2016-17, plant has achieved highest ever production of 651 MT of ZrO2, surpassing the previous record of 625 MT produced in the year 2015-2016.
- 20% increase in productivity of ZrO2 through process improvement by extraction and recycle of Zirconium values from Scrub Raffinate solution, an intermediate process stream.

Zirconium Sponge Plant (ZSP)

Zirconium Sponge Plant has achieved highest ever annual Production of 504.87 MT of Reactor grade Zirconium sponge (surpassing its previous record of 450.24 MT in 2014-15) and highest annual Production of 1720.30 MT Zirconium tetra chloride intermediate. In the process, highest 580 Nos. & 577 batches of Reduction & Vacuum Distillation sections respectively have been successfully processed for conversion of $ZrCl_4$ to Zr sponge.

Major achievements during the year:

- **All time high Supply of Zr sponge:**
  ZSP has achieved highest Supply of 567.88 MT Zr Sponge that includes 55.02 MT from the Production of ZC, Pazhayakayal processed at ZSP, Hyderabad.
- **Successful Installation & Commissioning of Reduction Unit-VII:**
  Reduction Unit-VII has been successfully installed & commissioned at NZSP which has better temperature control and redundant control system.
- **Successful Commissioning of Online Chlorine Stack Monitoring System:**
  Online Chlorine Stack Monitoring system, which works on the principle of Absorption Spectroscopy, has been installed and commissioned for continuous monitoring & recording of Chlorine level in Stack.
- **Successful Commissioning of 150 HP Shredder:**
  A high capacity Shredder of 150 HP for Zr sponge sizing operation has been successfully installed & commissioned. This has increased the productivity and eliminated the hazard of finger injuries on hydraulic presses.

150 HP Shredder

1.5 Ton Technology Demonstration Unit:

- This setup comprising of Reduction Furnace, vacuum Distillation unit, 700MT cutting press, 250MT compacting press is designed and procured by ZSP for installation and commissioning at ZC, Pazhayakayal.
- 700 kW Pit type Electrical Resistance Reduction Furnace for 1.5 Ton Zr sponge batch size with in-situ forced cooling arrangement has been designed, procured and commissioned by ZSP at ZC, Pazhayakayal.

- All the process assemblies required for 1.5 ton Zr sponge batch size Reduction and Vacuum Distillation units have been procured and supplied to ZC, Pazhayakayal for carrying out Commissioning trials. AERB clearance has been obtained for carrying out trial production runs.

Improvements in Chlorination Facility:

- Inverted V type SS connectors of 300 mm dia have been introduced for connecting last condensers of chlorinators to exhaust duct lines. This has eliminated the (i) choking of the connectors thereby improving the suction & reactivity and (ii) spillage of Chloride on floor and exposure to operating personnel while cleaning the duct.
- In order to minimize spread of Cl_2 and chloride in work atmosphere during discharge of $ZrCl_4$ into the chloride 'can', successful trials have been carried out for operating the valve with stepped opening using electro pneumatic circuit achieving reduction in fumes coming out during discharge.
- Height of Graphite electrode slab of Oxide Chlorinator has been increased for enhancing rate of reaction through higher bed volume.
- Introduction of Nitrogen/Argon purging in Chlorinators before discharge to reduce the release of residual chlorine during discharge.
- Modification of feeding port of briquettes into oxide chlorinator has enhanced the capacity by almost 30%

Inverted V type SS connectors

Improvements in Reduction & Coking operation:

- Successful trials have been carried out with Forced cooling arrangement using compressed air in one of the Reduction Furnaces after Reduction operation. It resulted in a reduction in cooling time of about 84% (from 5 hrs to 50 minutes) and this will eliminate emergency lifting of a batch.
- All the Reduction Furnaces have been provided thermal insulation at the top for energy saving & operating personnel comfort during preparation for lifting of batch from the furnace.
- An alternative design of Thermo wells has been successfully developed for Reduction units to enable checking and adjustment without the need for cooling the Furnace with associated down time.
- Introduction of alkali scrubbing of Coking liquid effluent to minimize the release of pungent acidic fumes.
- Addition of 2 Nos. of Coking loading & unloading stations and optimization in utilization of space inside the coking retort to increase the capacity of coking operation.
- Introduction of perforations on coking cans to improve heat transfer during coking to reduce cooling time.

Improvements in Vacuum Distillation operation:

- Orifice type fixtures have been provided for McLeod gauges to avoid accidental air ingress into the Vacuum Distillation Unit while connecting and disconnecting the McLeod gauges.
- The following modifications have been carried out in the Heating cycle of Vacuum Distillation operation:
  a. Introduction of 550°C soaking for 5 hrs for all the zones instead of soaking at 200°C for 2 hrs for Top & Middle zones only for effective removal of bonded moisture from the reduced mass
  b. Slowdown of melting through lower rate of temperature rise to minimize overflow of molten mass and batch stuck up.
  c. Introduction of air tight container with Argon purging to prevent moisture pick up in the batches waiting for loading in vacuum distillation.
  d. Introduction of solenoid valve with interlock for opening to prevent unintended air entry into the system due to operator error.

Enhanced safety in Sponge Handling operation:

- Wire rope slings with 'L' clamps have been provided in the 500 MT sponge cutting press to hold the chisel holder in case of bolt failure.
- Curtain type Infra-red sensors for Sponge cutting presses have been successfully installed to prevent finger injury.
- Change of MOC of chisels for Optimization of hardness of Sponge cutting, which in turn minimized breakage

Zirconium Complex (ZC), Pazhayakayal

Zirconium Complex (ZC), Pazhayakayal, Tuticorin, Tamil Nadu is set up to produce 250 tonne per annum of reactor grade zirconium sponge starting from washed and dried frit (crude zirconium hydroxide).

Major achievements during the year:

- Zirconium Oxide Production Facility (OPF) has been continuously operated and 503.2 MT of zirconium oxide was produced against a target of 500 MT with a recovery of around 82.47%.
- Zirconium Sponge Production Facility (SPF) has been continuously operated and 254.209 MT of zirconium sponge was produced against a target of 250 MT with a recovery of around 69.49%.
- About 157.57 MT of zirconium sponge has been supplied to NFC, Hyderabad for further processing.
- 25% of first cycle of In-Service Inspection (ISI) completed during this year. 11 No. of reduction retorts have been subjected to radiography as part of ISI and cleared for further use.
- Around 6000 samples of raw material, chemicals, process and product samples have been analyzed for approximately 55000 parameters.
- Received Industrial Safety Award from Atomic Energy Regulatory Board for the second consecutive year 2015. The plant has crossed 1074 days of operation without any reportable injury accident during this period.
- Implementation of Quality Management System with reference to IS/ISO 9001:2015 initiated. QSHE Policy, Objectives and Procedures have been documented.

Development Works

- Replacement of heat exchanger with cooling tower: The seal water temperature from vacuum pumps of Rotary Vacuum Drum Filters was maintained by a heat exchanger. Due to corrosive nature of seal water, the exchanger tubes got corroded and failed frequently which forced shutdown of the Plant often. Hence, a FRP cooling tower for cooling the seal water was installed and the performance of the cooling tower is excellent. The modification resulted in a saving of approximately Rs.10 Lakh per annum due to the heat exchanger maintenance / tube replacement besides reliable operation.
- Installation of new sigma kneader: A new sigma kneader was installed with a modified powder feeding mechanism and proper cover to minimize dust generation. This modification not only reduced the dust pollution around the area but also helped in containing the losses in feed preparation.
- Experiments of neutralization of raffinate with ammonium hydroxide: Experiments have been conducted for neutralization of raffinate with ammonium hydroxide for better saleability of effluents and the same was implemented in plant scale during caustic lye availability crisis.

Desalination Plant

- Desalination Plant with two streams each of capacity 30 m3/h of product water based on Reverse Osmosis (RO) process is being commissioned at Zirconium Complex.
- Sea water intake system has been commissioned and is in regular operation.

1.5 tonne Zirconium Sponge Batch Technology Demonstration Unit.

- It was proposed to scale up the size of RG sponge batch from the present 700 kg/batch to 1500 kg/batch and a Technology Demonstration Unit is being set up at ZC.
- Necessary clearances for construction and commissioning of units have been obtained from AERB.
- Erection works of Reduction unit and Vacuum distillation units were completed and dummy run of Reduction unit has also been completed.

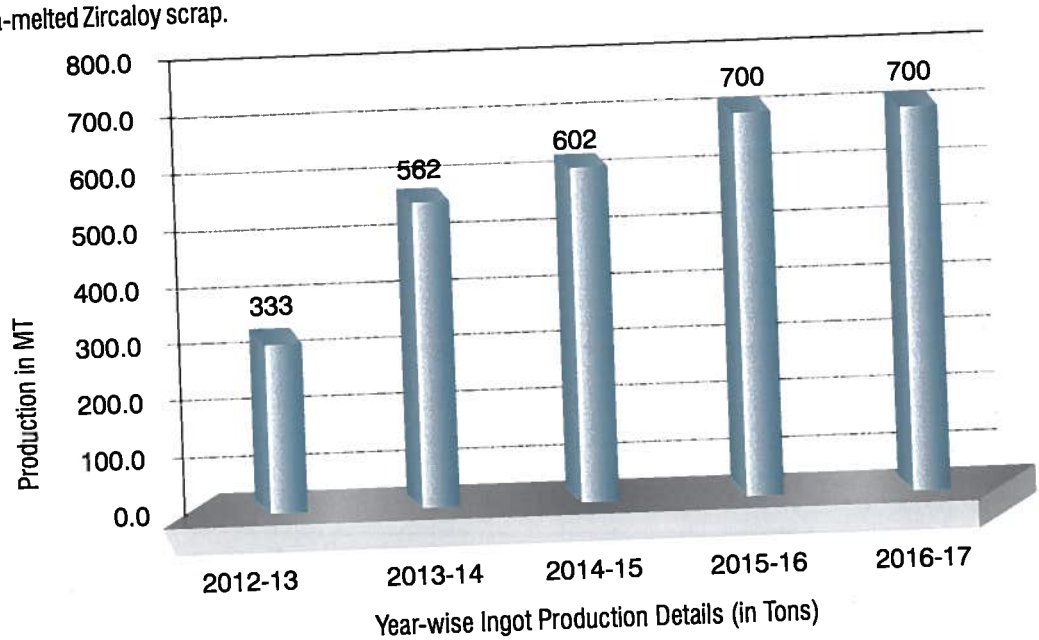
Magnesium Recycle Technology Development and Demonstration Facility (MRTDDF)

- Magnesium Recycling Technology Development and Demonstration Facility (MRTDDF) is being set up at Zirconium Complex.
- Siting and Construction clearance is received from AERB.
- Civil works for construction of plant buildings commenced in August 2016 and are in progress.

Melt Shop

Major achievements during the year

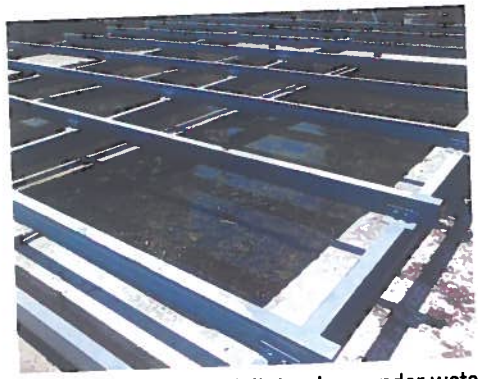
- Produced 700.705MT final ingots surpassing the target of 684MT during the year. This consists of Zr-4 double melted ingots 468.620MT for fuel tubes, Zr-4 Triple melted ingots 159.180 MT for fuel tube end-cap, 33.275MT of Zr-2.5%Nb quadruple melted ingots for PHWR pressure tubes, Zr-2 double melted ingots 32.090 MT for BWR fuel tubes, Zr-Nb-Cu double melted 0.445 MT for garter springs and Zr-1%NbTriple melt ingots 7.095 MT. Melting production was higher than the sponge receipt by re-melting plasma-melted Zircaloy scrap.



Year-wise Ingot Production Details (in Tons)

- 7.09 MT triple melted Zr-1%Nb ingots were melted for strategic applications.
- 170 T of Zr-2.5%Nb Turnings of old specifications were shifted from ZRS open yard to newly constructed RCC pits for sa storage.

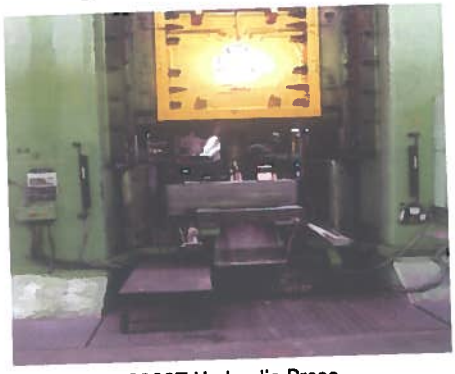
Newly constructed cemented pits



Pits filled with Zr-2.5%Nb turnings under water

- Melting of Zr-0.2%Nb, Zr-5%Nb and Zr-20%Nb alloy ingots was carried out for conducting deformation studies by BARC.
- 158.131 MT of re-meltable grade Zircaloy scrap has been processed through plasma melting.
- Produced 33.27MT of Zr-2.5%Nb quadruple melted 550 mm dia ingots with stringent chemistry for manufacturing of PH pressure tubes.
- 848 nos of zirconium sponge batch evaluation meltings were carried out in 150 Dia VAR furnace. This is the highest ever b evaluation melts carried out in a financial year.
- The process of recycling of zirconium sponge fines into Nuclear grade Zircaloy ingots continued and consumed 5.093 T of sp fines.

- Modified die and die housing designed and manufactured by TRTP were installed in 2000 Ton Hydraulic press. New die is shrink-fit type and is expected to give higher life compared to previous push-fit type die.



2000T Hydraulic Press

Modified die housing

- The development work for recycling of Zr-2.5 %Nb turning scrap through compaction and plasma melting was in progress. Work for thorough cleaning of such turnings scrap for removing carbonaceous contamination is taken up, so that recycling of turning scrap is possible for producing useful ingot

Special Materials Plant (SMP)

Special Materials Plant is primarily engaged in the production of niobium metal granules for Zr-2.5Nb coolant tubes and in production of high purity materials for specialized applications to various Academic institutions, R & D units & Indian industries for their applications in specialized fields.

Major achievements during the year

- SMP achieved highest ever production of 4135 kg of niobium metal granules.
- Produced & supplied 140 kg of micron size zirconium metal powder to meet emergency critical requirement of Defense & Space departments.
- Antimony trioxide filled SS capsules were produced and supplied towards second core requirement of neutron source sub assembly of PFBR.
- Production and supply of special grade high purity Niobium oxide and Zirconium oxide for strategic applications at AFD,BARC
- Supply of RRR grade Niobium ingot for manufacture of 508 x 508 x 6.5 mm sheet for accelerator programme of RRCAT.
- Preparation of cold rolled NbZrC coupons (90 x 10 x 10mm) for high temperature creep tests at RSD, BARC.
- Supplied various high purity materials such as high purity niobium granules, antimony oxide, tellurium, selenium, indium, cadmium, lead, $POCl_3$ etc. on market demand.
- Towards establishment of Niobium Thermit Production Facility (NTPF), to meet the niobium requirement of VSSC / DoS indigenously, activities were continued during the period.

Design, Fabrication & Testing of new standalone single stage PP airlift mixer settler.

a. The new design eliminates inter stage leakages encountered due to failure/leakage of plastic weld joints at stage partitions, thereby improving quality of the product and reduced breakdown frequency.

b. Trials have been taken with niobium solutions. The system is being utilized for production of hafnium oxide at ZOP.

Indigenous Development of Electron Beam Melting Furnace

Towards indigenization of Electron Beam Melting Technology in the country, a collaborative programme has been taken up by BARC & NFC. The total furnace has been built by M/s I-Design & M/s Ador Powertronics based on the design of BARC & NFC.

Electron Beam Melting furnace

Major Events

Dr.N. Saibaba, Ex. Chairman & CE, NFC congratulating Shri G. Kalyanakrishnan on his assuming charge as Chairman & Chief Executive, NFC.

Shri G. Kalyanakrishnan, Chairman & CE, NFC lighting the Lamp to inaugurate "Hindi Day" Celebrations at NFC.

Shri G. Kalyanakrishnan, Chairman & Chief Executive, NFC flagging off the First Shipment of "Processed Uranium Cake' to IREL.

Shri G. Kalyanakrishnan, Chairman & CE, NFC switching on the Board to inaugurate sintering furnace atCFFP-P.

Shri G. Kalyanakrishnan, Chairman & CE, NFC speaking on the occasion of NFC Annual Production Celebrations (2016 - 2017).

Shri G. Kalyanakrishnan, Chairman & CE, NFC handing over the Trophy to the Winners at the Independence Day Celebrations organised at NFC Sports Pavillion.

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Visit of Director, BARC

Shri K.N. Vyas, Director, BARC discussing about MOX Pellets with Shri G. Kalyanakrishnan, Chairman & CE, NFC. Dr. G.K. Dey, Dr.D.S. Setty, Shri S.K. Pathak are also seen.

Visit to Zirconium Sponge Plant
Shri G. Kalyanakrishnan,CE, Dr. R.P. Acharya, DCE(A), Shri N.S. Dayanand and others are seen.

Shri K.N. Vyas, Director, BARC inaugurating the newly installed 32 mm Pilger Mill at NZFP.

Shri D. Pramanik, DCE explaining about Incoloy-800 Heat Exchanger Tubes for 700 MWe Reactors.

Smt. Meena Ravindran, DCE explaining about Extruded tubes at EPP

Shri K.N. Vyas along with Shri G. Kalyanakrishnan, DCEs with Representatives of NFCIWU & NFCSSA during his visit to Dr.Homi Bhabha Convention Centre, NFC.

ISO 9001:2008

OHSMS

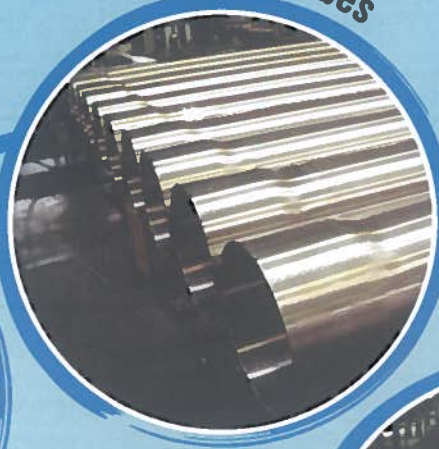
NABCB
QMS

MGMT. SYS.
RvA C425
EMS

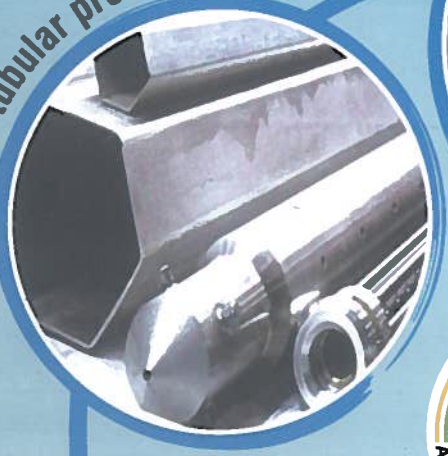
HIGHLIGHTS
2016- 2017

TUBES & COMPONENTS

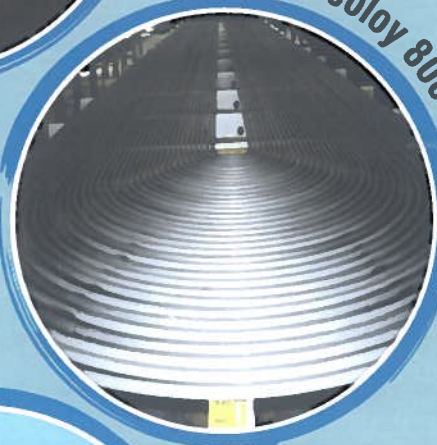
Calandria tubes



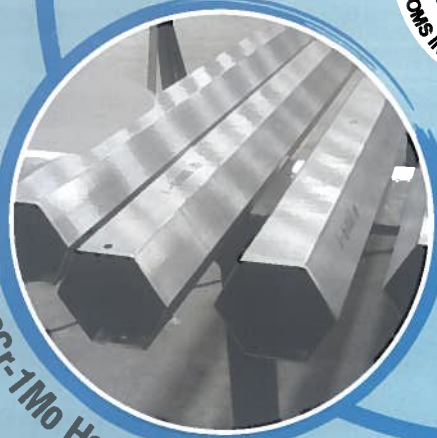
Different tubular products



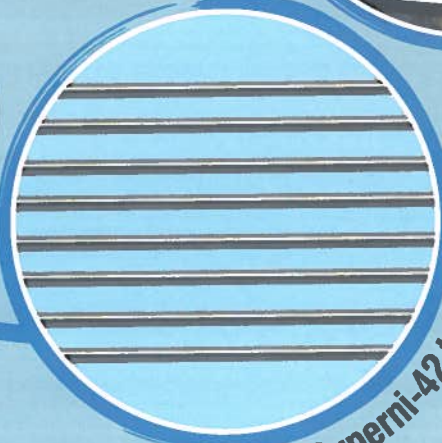
Incoloy 800 U- bend tubes



9Cr-1Mo Hexcans



Superni-42 tubes



Zirconium alloy Fabrication and Structural (ZAF & S)

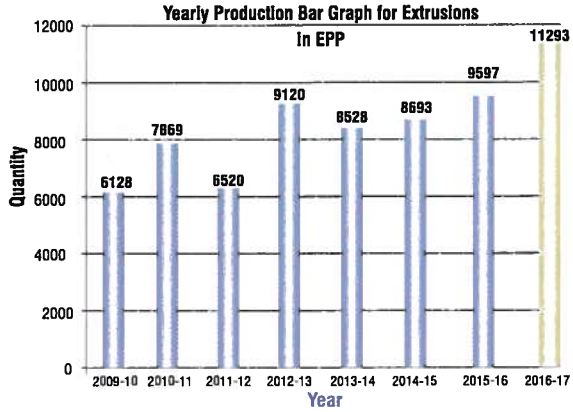
ZAF & S is involved in the supply of Fuel tubes & components for both PHWRs & BWRs, Structural tubes for PHWRs, BWRs & FBRs and Reactivity mechanisms for PHWRs. In addition to this, ZAF & S group is also involved in development of manufacturing technology for special clad and structural tubes for strategic applications in nuclear, defense and aerospace fields.

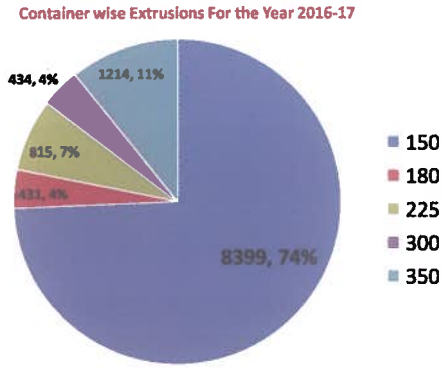
Hot Working

- Primary hot working of Zirconium alloy ingots produced by Vacuum Arc Melting is done by hot extrusion in 3780T horizontal extrusion press into various shapes and sizes. For breaking of cast structure radial forging is also used in case of quadruple melted Zr-2.5%Nb ingots used for producing pressure tubes. In addition to Zirconium alloys of different grades Stainless steel, super alloys, maraging steels, Titanium alloys and other special materials have been hot extruded and expanded in Extrusion and Piercing plant.

Production highlights:

- Highest ever total number of Extrusions in a year – 11293 nos. which is 17% more than previous years.
- 8399 nos. i.e. 74% of total extrusion carried out in 150 dia container.
- Highest ever stainless steel extrusions in a year, 3019 nos.
- Maximum 1302 nos. of extrusions in a single month with 91% carried out in 150 dia container.
- Highest 5693 nos. of extrusion for Zircaloy fuel blanks for PHWR and BWR.
- Hot expansion of 2127 numbers for special steels including MDN-250, 350, 59, 11-10PH and Titan-32 grades of strategic importance. Hot expansion of Zr-2.5Nb PT in 180 dia mm container was successfully established for first time and completed more than 150 nos. for 220MWe pressure tube development.
- Total 6981 numbers of Beta-quenching was carried out for all the Zirconium alloys production.
- Supply of Rs. 62.37 Cr. worth of hot finished tubes in achieving Rs. 125.1 Cr job order against target of Rs 120.0 Cr for the year 2016-17.
-



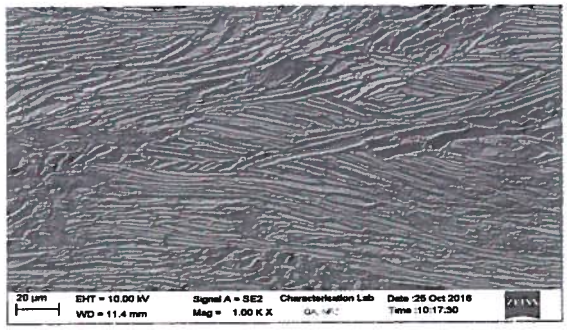


Major achievements during the year:

1. **Development of Radial forging and modified extrusion parameters of Zr-2.5Nb pressure tube for retubing of 220MWe reactor:**

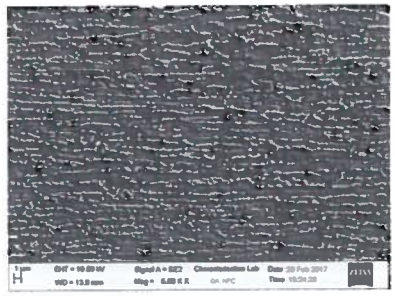
- Following the successful development of Radial forging manufacturing route for 700MWe Pressure tube, there is greater emphasis to improve the metallurgical of Zr-2.5Nb PT of 220Mwe PHWR. Urgent requirement has been placed for such development by NPCIL for immediate replacement of pressure tubes for KAPS-1 and KAPS-2. Under the systematic developmental effort, a complete radial forging parameters including reduction per pass, forging stages, temperature and strain rates were successfully developed, metallurgically characterized and compared with the same at 700MWe route. Most critical activity of ID expansion, beta quenching and extrusion blank manufacturing into 95mm OD x 5.2mm WT with relatively higher extrusion ratio was carried out with stringent tolerances on dimensions and OD and ID surface quality. This blank dimension has the thinnest wall ever extruded for ZrNb alloy. Metallurgical characteristics of texture, grain size, aspect ratio etc were characterized successfully indicating minimal variation between leading and trailing end.
- This development paved the way to successfully manufacturing the single pass pilgered Zr-2.5Nb finished pressure tube for 220MWe which can be supplied to NPCIL for EMCCR.

540 to 180 dia two stage radial forged Zr-2.5Nb Rod

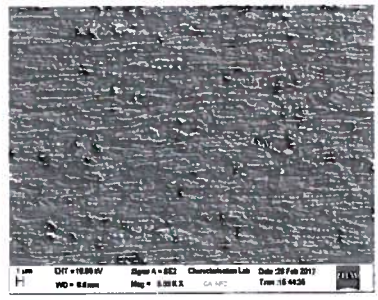


SEM microstructure for 180 dia mm Forged Rod

95 mm OD x 5.2 mm WT X 6.2 m L As extruded Zr-2.5% Nb PT Blanks for 220Mwe PHWR Tube



LE as extruded and SR Blank



TE as extruded and SR Blank

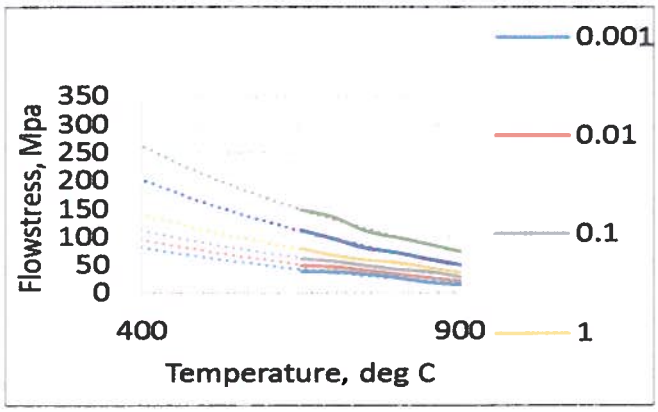
Table 1 Basal pole Texture (Kearn's f) in As Extruded PT Blanks

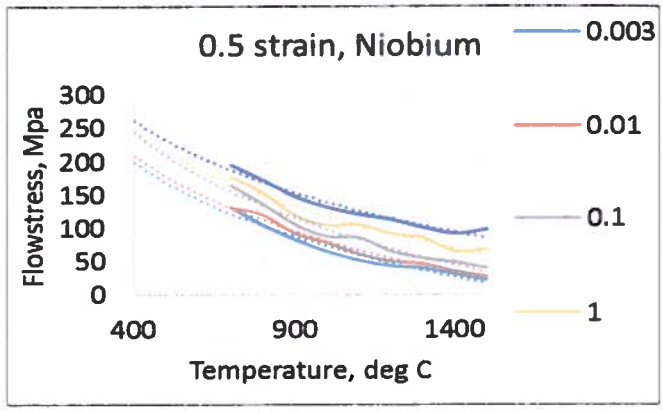
	As Extruded Number End(NE)			Other end (OE)		
Tube no	fr	fr	fr	fr	fr	fr
7004	0.30	0.63	0.03	0.27	0.65	0.03
7005	0.27	0.65	0.03	0.30	0.65	0.02
7007	0.31	0.65	0.04	0.30	0.62	0.02

2. Co-extrusion of multi-filament Cu-Nb based composite billets for Superconductor:

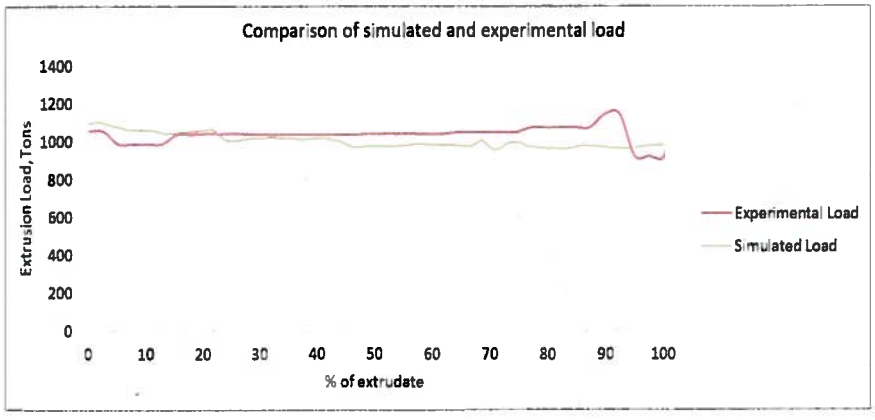
Development and manufacturing of Nb3Sn based superconductor constitutes complex thermomechnical processing including most critical co-extrusion process of multiple Nb filaments incorporated into the Cu matrix at three different PCD. Specially assembled and designed composite billet was co-extruded successfully from Φ 180 mm billet to Φ 50 mm rod as pre form for BARC. The pre form rod will be inserted with the tin and co-drawn to the final dimensions. This composite billet co-extrusion was successfully simulated for Temperature and strain rate using Gleeble hot compression data with suitable interpolation and validated with the shop floor trial. The co-extruded rods were characterized for the uniformity and continuity of Nb filaments over the length of 5mtr. Filaments of Nb with initial diameter of Φ 9 mm in the composite billet was reduced to a Φ 2.5 mm in the extruded rod. 2 nos of co extruded rods were supplied to BARC..

As Extruded 50 mm Dia rod of Nb-Cu



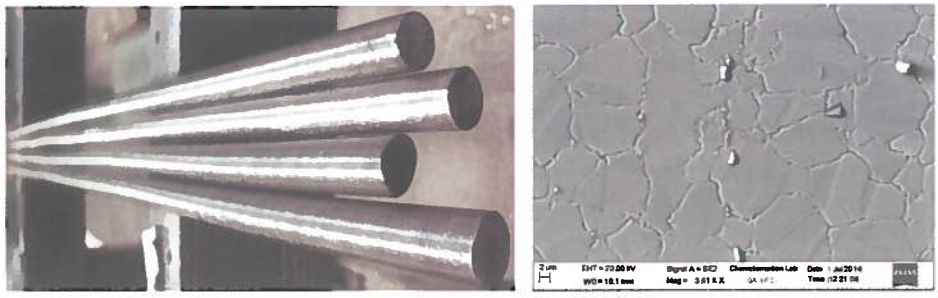


Variation of flow stress values of Copper and Niobium with respect to temperature at different strain rates



3. Extrusion of Superni-42 rods for strategic application:

High nitrogen based Superni-42 has been proposed as the end cap for core components in strategic nuclear application. Being the high Ni-Cr-Mo alloy the workability of the material is very limited during hot extrusion. For the first time the rods were extruded from 150 dia to 24 dia and 30 mm dia stage in two stages of hot extrusions, optimizing the hot working characteristics. Hot extrusion parameters were successfully established considering the micro structural variability in the forged billets. 22 Ø mm hot extrude defect free rods were swaged into multiple passes to reduce to 8 mm finished size. Also, extrusion to 30 Ø mm rod was produced to establish the optimized reduction in swaging to obtain 16 Ø mm finished rod.

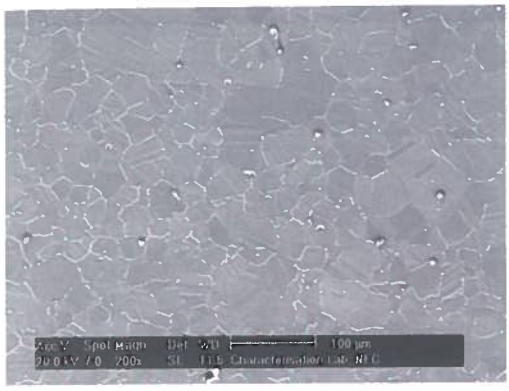


As Extruded 22 Dia Superni-42 Rod and SEM micrographs For Endcap Application of Strategic Application

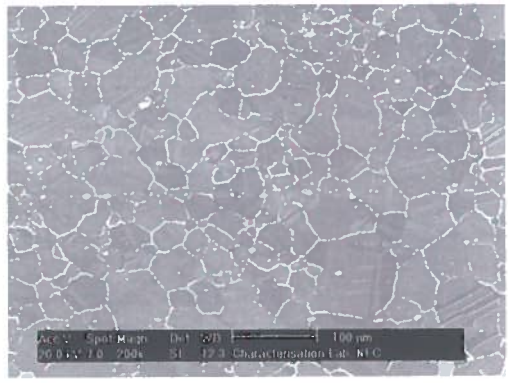
4. Optimization of Heat treatment parameters for Superni-42 tubes and rods in controlled atmosphere(vac. & Ar both) furnaces for strategic application:

Manufacturing and development of superni-42 alloy for fuel clad and end cap constitutes multiple thermo-mechanical processing including extrusion of billets into tubes/rods followed by cold working processes with intermediate heat treatment for restoration of ductility with desired mechanical and metallurgical properties in finished clad tubes and rods. Optimization of heat treatment temperature, soaking time and quench rates under controlled atmosphere are most essential conditions to achieve requisite hardness, average grain size and surface quality. These optimized HT condition ensured to achieve stringent ET and UT criterion of both 8 mm & 16mm dia rods and defect free conditions in intermediate sizes of clad tubes.

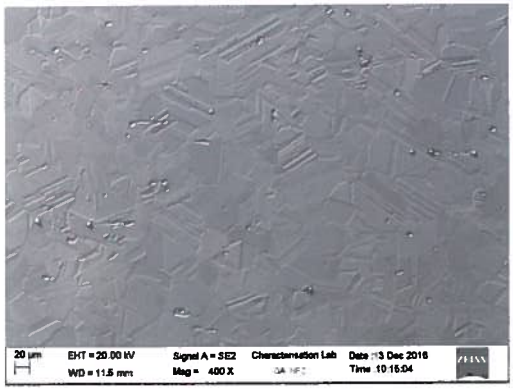
Most importantly the development of entire process sheet for 8 mm dia rod was completed within 3 weeks time to supply nearly 30mtr rod and fulfill NFC commitment to BARC. Further more, for thick wall tubes of 41mm OD X 6mm WT the heat treatment temperature and time was suitably modified to overcome the constraints of quench rate in the HHV furnace.



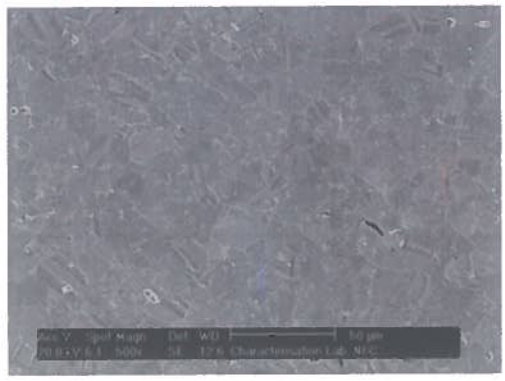
AS extruded & Annealed in VAF_EPP_ Ar atm_
WQ TO Ø 67OD x13 mm WT



AS pilgered & Annealed HVAF_EPP Ar-
Q TO Ø 41x6 @ 1180° C-6Min-Ar-Q



As Annealed 21mm ODx 2.2 mm WT
HHVAF_EPP _Ar Q (1180 °C/2 min- Ar-Q)

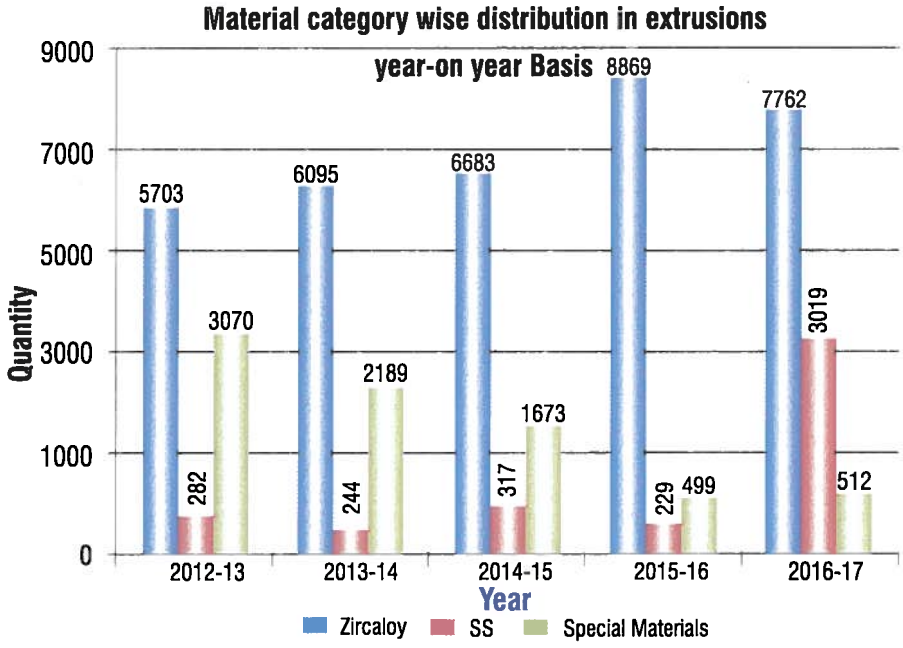


Superni42: Dia 8.0 mm rod (High Nitrogen)-
As annealed 1100/1min/WQ-EPP VAF

5. Hot extrusion of MDN-350 alloy:

Maraging Steel –MDN 350 is very high strength and high fracture toughness alloy which find application for strategic programme of DAE. Alloy tube has highest importance not only due to its applicability but also for its very high cost. The new size of this alloy tubes are required by BARC to increase the process efficiency and throughput and NFC has received total Job order worth more that Rs 125.0 Cr. Presently, 112 nos forged billets were received from Midhani and hot finished tubes of size Ø222 OD x178 mm ID were produced with 100% recovery establishing two stage hot expansion followed by extrusion.

MDN 350 alloy hot finished tubes of size Ø222 OD x178 mm ID



Zirconium alloy Fuel tubes:

Fuel tubes are produced from hot extruded blanks by multiple cold working process (pilgering) followed by intermediate and final annealing. Finishing operations like straightening, grit blasting, polishing and cleaning are carried out on the final tubes before they are subjected to ultrasonic testing. UT OK tubes are cut into small lengths and supplied to assembly plants. In addition to the supply of tubes for PHWRs & BWRs, various special types of tubes in different sizes are manufactured for strategic applications. Annealing and pickling activities were managed in a planned way to cater to the requirements of multiple products such as Fuel Tubes (19 & 37 element PHWR, BWR & AHWR), Pressure Tubes, Garter Springs, Reactivity Mechanism Tubes, Rods, Sheet Products and other special & developmental products etc. of the entire group.

Productionhighlights

Plant had produced 20.07 lakhs PHWR Fuel Tubes during the year 2016-17 which enabled NFC to achieve record production of 1512 tonnes of fuel assemblies.

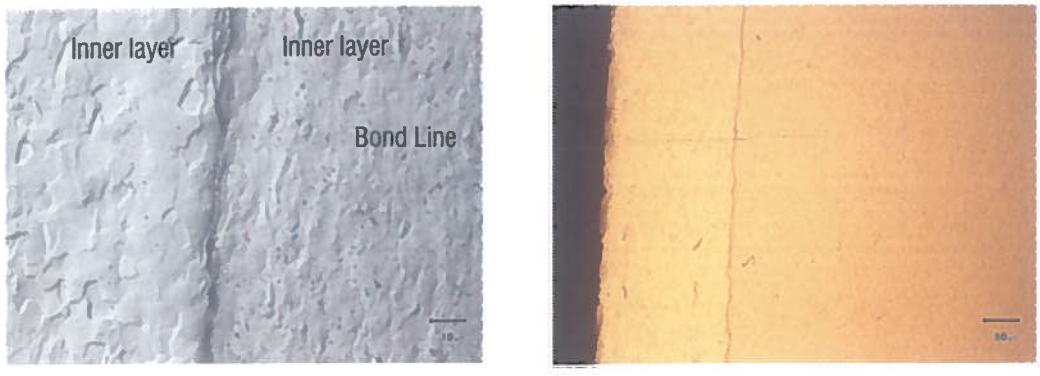
Besides regular production of fuel tubes Plant has also supplied the following tubes:

- 4195 QC OK BWR tubes against a target of 4000 tubes for BWR assemblies.
- Central support tube (20.8mm OD and 2.5mm WT), element tubes (10.5mm OD and 0.45mm WT) and pencil tube (8.1mm OD and 0.7mm WT) for manufacturing of 12 nos. of cobalt absorber assemblies of PHWR reactors.
- Small diameter Zr4 tubes (Helium outer tube, carrier tube, central carrier tube, water inlet tube, water outlet tube) for two reactor charge of various RM assemblies (LZC, VFU, HFU) were produced. Production of these tubes (UT cleared) needs very close control of parameters as they are of extremely thin wall (0.3mm- 0.75mm) and 7m in length.

Product Development

Development of Double clad tube:

Double clad tube having Zr4 outer layer (720 microns) and ZrSn inner layer (180 microns) was developed for Irradiation testing in PHWR reactors. These tubes were found to have excellent bonding and found acceptable with respect to mechanical and metallurgical properties. Further trails are being carried out to reduce the inner layer thickness to around 90 microns by suitably modifying the extruded blank.

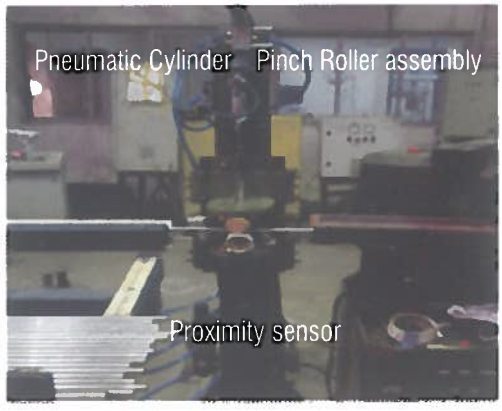


Bonding between outer layer and inner layer

Equipment addition/ Equipment Modification

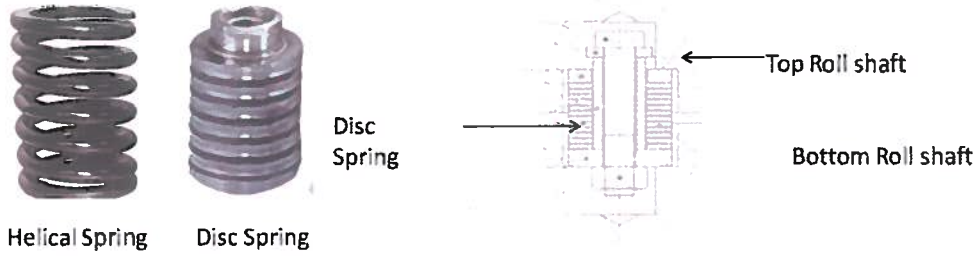
- **Automation of straightening machine**
  Automation of straightening machine at ZFP was carried out. This has improved safety and reduced of manpower.

Automatic tube unloading unit



Pinch roller unit for drawing the tube from straightening machine

- **Introduction of disc spring in 25 VMRs :**
  25 VMR pilger mills supplied by SMS, Germany have helical springs due to which there is often a problem of die to die hitting resulting in more demand for tooling, loss of production and also may result in poor quality.



Disc springs are found to have better performance compare to helical springs. Therefore a disc spring which can replace the existing helical springs of 25 VMR roll shaft assemblies was designed. This disc spring has been assembled in 25 VMR ZFP and the mill is in operation since Oct, 2016 without any problem. Required modification and components were made in Tool Room.

- **Revamping of 50 VM pilger mill**
  50 VM pilger mill at ZFP has been revamped. Half ring dies have been converted to full ring dies. Single feed and turn has been replaced with double feed and turn. Production capacity of the mill has been increased.

New full ring dies

New Roll Stand

- **CRTM 65 at NZFP**

  New CRTM received from Russia has been successfully erected and is under advanced stage of commissioning at NZFP and performance trials are being carried out. CRTM 65 mill has the following latest state of art technological features:

  - First time with vertically mounted roll shaft dies inside saddle housing with fast tool change over.
  - Double Feed and Turn mechanism by independent SERVO drives, eliminating conventional Geneva mechanism & transmission shaft.
  - Automatic Loading & Unloading.

- **CPM 32 at NZFP :**

  New pilger mill received from Italy has been successfully erected and is under advanced stage of commissioning at NZFP. The mill is having features like double feed and turn and measurement of roll separating force to facilitate for tooling profile optimisation. This mill is also capable of rod pilgering.

- **Process Modification**

  - Pilgering of 19e pre final pass on 50m VM pilger mill: 50 VM pilger mill revamped components supplied by M/s SMS, Germany are suitable for first pass pilgering of 19e tubes only. Modifications were done in the pilger mill roll shaft assembly by modifying rack & pinions, guides etc. New set of dies designed and supplied by Tool Room. After modification, mill became capable of 19e pre final pilgering of acceptable quality with high production rate. It resulted in better and diversified application of mill.
  - Improvement in recovery of BWR tubes: Due to formation of white stain on BWR autoclaved tubes, rejection was high & beyond recovery. Systematic study was done to find out the cause for the rejections. It was found that presence of adherent Fluoride ions (oxy-fluoride) on tubes, prevents formation of protective black lustrous ZrO2 layer which was prevented by rinsing in Aluminium nitrate & nitric acid solution before autoclaving. Prevention of white staining in BWR autoclaved tubes was done by modified

chemical processing route.It resulted in increase of BWR recovery from 60% to more than 95%.

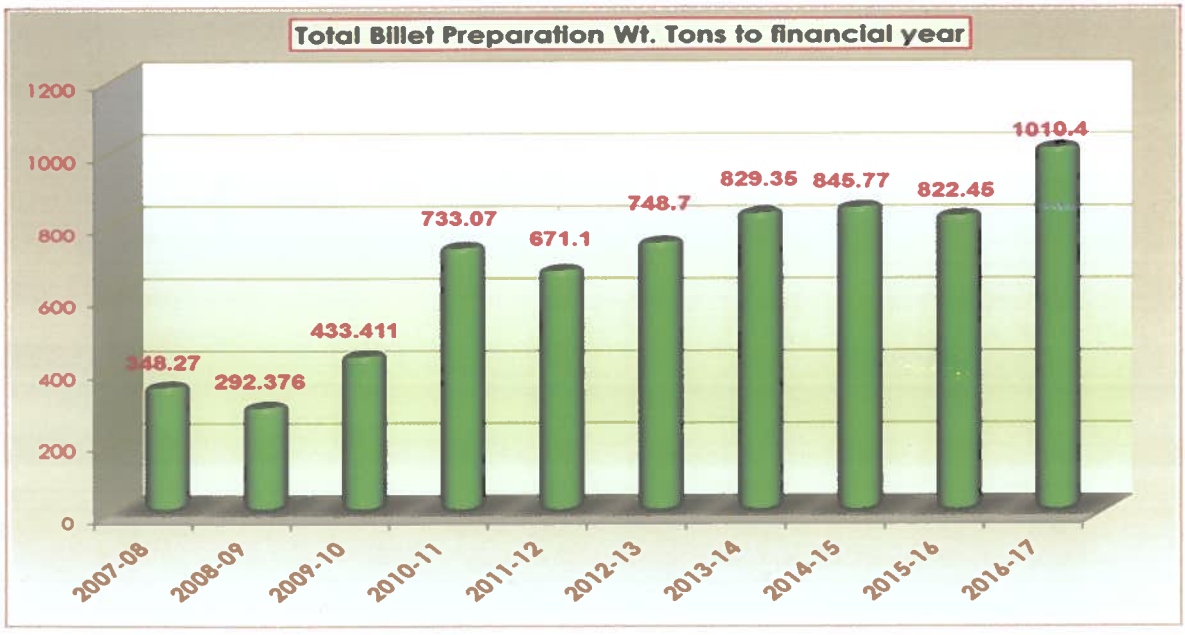
- Reduction of fluoride content in acid rinse water: Acid rinse water generated during Pickling of Zirconium alloy materials contains Fluoride (up to 80 ppm) which has to be brought down below the specified permissible limit of 2 ppm. By conventional lime addition process, bringing down Fluoride conc. below 10 ppm was challenging. Process development by addition of alum at a particular pH helped to maintain fluoride conc. below 2 ppm consistently. This has helped in reuse of the water for other operations, thereby helped in achieving the objective of zero discharge.

  Grit blasting distributor modification : In existing grit blasting unit, fuel tube grit blasting was irregular & non uniform, causing lower visual recovery. Distributor was redesigned and automatic drain valve was placed in line to drain out moisture / condensed water from the air accumulator. Both these factors led to achieving uniform and consistent surface finish.

BPS & BAR Operation

I Billet Preparation:

1. Processed various grades of Zircaloy billets/ingots i.e., Zr-4/Zr-2 billets for Fuel tubes (5741 nos.), Zr-2.5% forged billets (173 nos.)for Coolant tubes (220 Mwe), Reactivity Mechanism billets (325 nos.) for RM tubes, Zr-4 Bar billets (60 nos.) for Bar production.
2. Processed ingots of MDN-250 (224 nos), MDN-350 (113 nos.), STA-59 (223 nos.), SS-321 (159 nos.), MDN-11-10-PH (155 nos.), SS304L (3,789 nos.), for meeting NFC Hot finished product requirements against job orders and Commercial orders.
3. During 2016-17, BPS had processed 11,222 nos. for Deep Hole Drilling for Billet preparation for tubular extrusion. This is 42% more than previous year of 7887 nos.
4. BPS handled Processing of Special alloys i.e., Super-Ni:42, Titanium based alloys i.e., PT-3B & Ti half alloy, Nimonic-75, billets for developmental activities. Many of these alloys are very difficult to machine.
5. BPS for the first time crossed total weight of billets processed more than 1000 Tons, meeting all requirements.



II COMPONENTS:

During this year, the following components were produced

1. PHWR Components:

   19e End Plates :- 1,95,349nos.

   37e End Plates :- 8,364 nos.

Total End plates:- 2,03,713 nos.

- Total end plates produced during 2016-17 is 2,03,713 nos which is more than the previous year 2015-16 (2,01,608 nos.)
- Highest ever end plate production in a month 30,000 in March 2017.

2. All the 10 types of BWR components are supplied completely by February 2017, well before the requirement. This is for 105 nos. of BWR Fuel Assemblies.

III BAR OPERATIONS

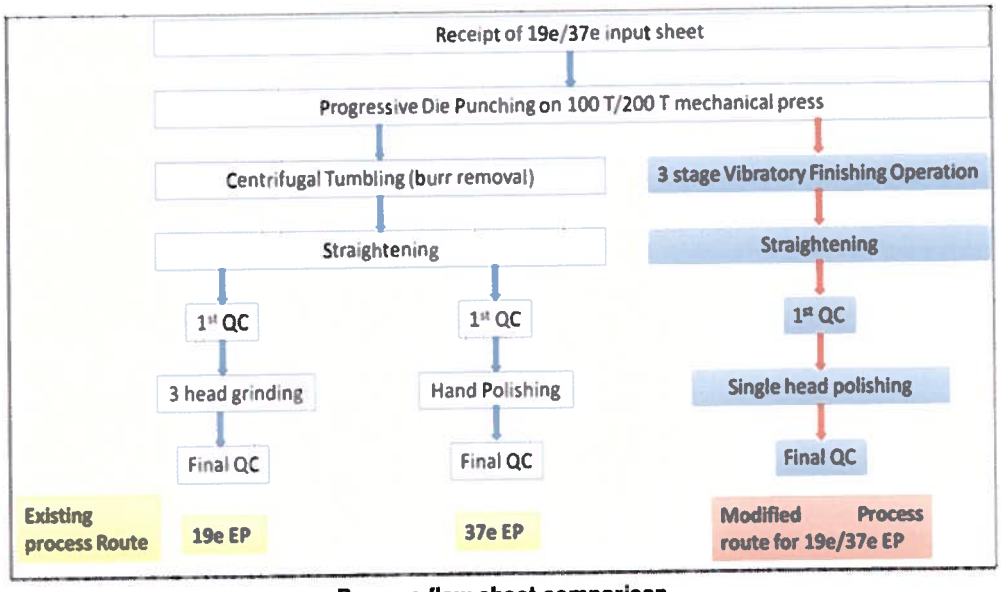
- During this year, a total of 33.78 Tons of Bar material was produced.
- Produced special zirconium alloys i.e., ZNC bar for Garter springs, Zr-1%Nb for special requirements and PT-7M (Ti alloy) for BARC strategic applications.

IV BPS expansion and addition of new equipment :

To cater the needs of enhanced production targets of NFC, BPS expansion was taken under the 12th plan project RMAFCTR. Plant area was expanded by another 24mx24m for the additional equipment. A new UNIVERSAL MILLING Machine from M/s Batliboi, Surat, Gujarat was Erected & Commissioned during March 2017.

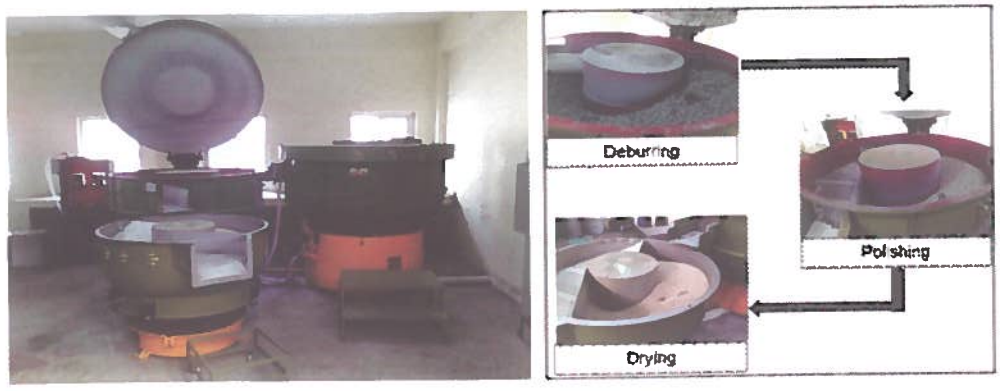
V Developmental jobs

1. Process route for manufacturing of end plates for 220MWe & 540 MWe fuel bundles was modified by introducing 3 stage vibratory Finishing operation in order to improve quality and recovery and overall productivity.



Process flow sheet comparison

- Automatic 3-Stage Vibratory Finishing System consists of 3 stages i.e : De-burring, polishing and drying. In the first stage it removes burr & grinding lines mark from the end plates followed by polishing of the plates in the second stage to get required finish. In the final stage stain free drying of the finished end plates. All the stages are connected by automatic material transfer, which is controlled by PLC. This system was installed & Commissioned during January, 2017.



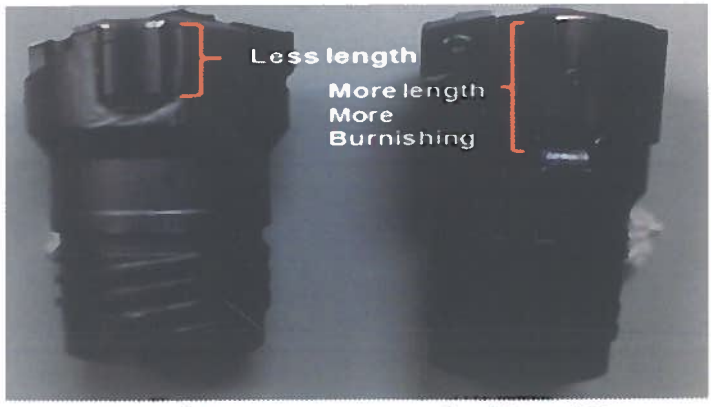
Automatic 3-stage Vibratory finishing system

Advantages of 3-stage Vibratory Finishing System:

- Production rate increased by two folds
- Manpower requirement decreased. Vibratory Finishing system is completely unmanned operation (Load and forget type).
- End plate surface quality improved, uniformity in the end plates achieved.
- Manual handling reduced by introduction of automation
- 37e EP recovery at final stage was very less in the old process route. Now more than 90% recovery.
- Zirconium fire hazard reduced by introduction of wet operations.

2. Single stage Deep Hole Drilling of Fuel Billets using Indexible BTA drill heads

- Improved tooling was introduced for deep hole drilling of Zr-4 FB billets. In place of brazed carbide BTA drill heads Indexible BTA drill head was used and deep hole drilling was achieved in single stage in place of two stage earlier.



Brazed head Indexible head

Following are the Advantages

- Production rate doubled for FB
- Better utilisation of existing DHD machines in BPS
- Better and uniform surface finish around 2.5μ rms compared to 3.1 μ rms in two stage drilling (Required <=3.2μ rms)
- Tooling cost saving by 40%

VI Disposal of accumulated hazardous Zirconium Scrap & Cleaning of BPS stock yard

Billet Preparation shop material storage yard is envisaged for storage of long length ball bearing input billets in 1970's. The storage yard has an area around2900 square meters and contains I-beams of ISMB 300 in vertical position for storage of the above material. Later on, the area has been in use for storage of zirconium turnings in GI drums generated from end cap machining, deep hole drilling & machining. Over a period, more than 2000 drums have been stored in this area containing approximately 80 MT of zirconium turnings. This was a potential fire hazard and all around wild vegetation growth was also there.

In order to clean the area , Coarse scrap of zirconium were thoroughly cleaned, dried and sent to ZSP for further processing and large quantity of fine scrap of zirconium which is highly pyrophoric in nature were incinerated in co-ordination with fire services by following the safe practices at incineration yard. The empty corroded drums were thoroughly cleaned from Zirconium scrap and were dispatched through stores. Thus the area is made free of zirconium turnings. Titanium turnings were also available which were bailed carefully to reduce its volume and stored in a separate container with identification. The entire process has been completed in a short span of six months. In addition to this around 27 MT structural scrap were cut into small pieces and disposed of through stores.

The storage yard after completion of cutting & removing structural

The area thus cleared is proposed to be used for centralization of the bar production operations, enhancing the production capacity of BPS and billet storage for BPS after constructing a shed to meet enhanced production target in future.

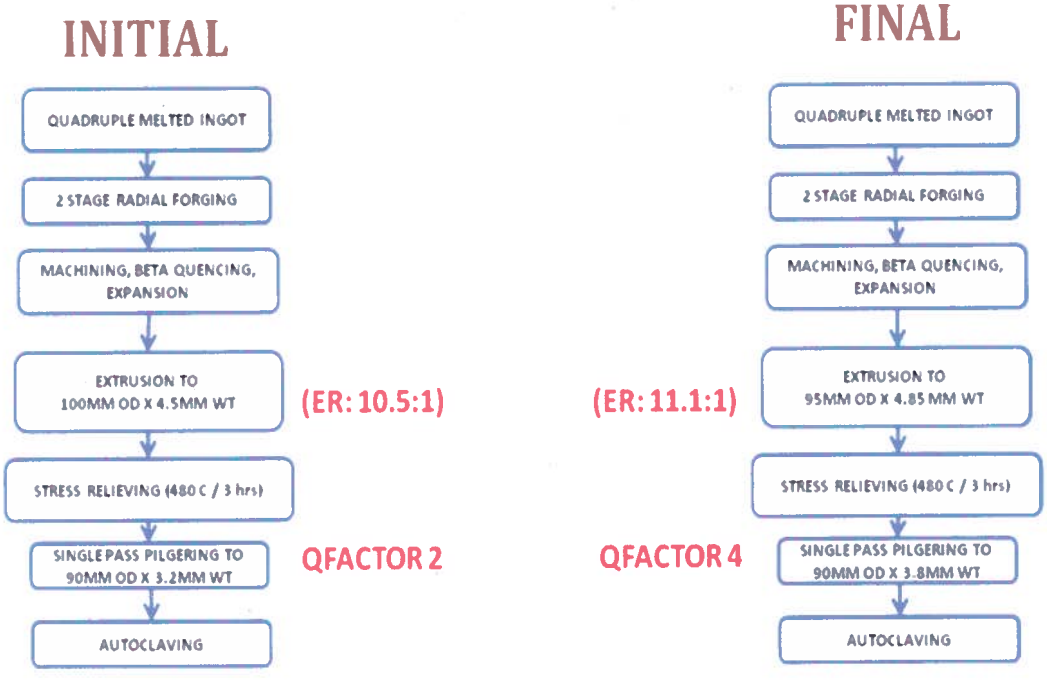
Structural Tubes:

1. Development of 220 mwe pressure tubes using double forged and single pass pilger route.

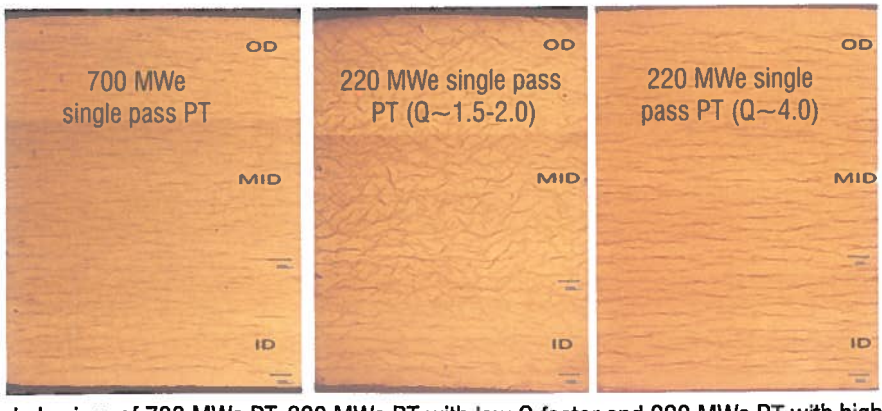
Zr-2.5%Nb pressure tubes are the most critical lifetime core components of a PHWR type power reactor. These tubes have to sustain extremely harsh conditions of temperature, pressure, stress and neutron flux. The manufacturing process for pressure tubes is governed by very stringent specifications for mechanical and metallurgical properties, chemical composition, dimensions and NDT requirements.

NFC had earlier successfully developed a superior process involving double radial forging, single extrusion & single pass pilgering for manufacture of 700 MWe PHWR Pressure Tubes. A similar process has been developed for the manufacture of 220 MWe PHWR Pressure Tubes.. High extrusion ratio ensured an elongated grain structure with a high aspect ratio and strong transverse basal pole texture which is beneficial from the point of view of diametral creep.

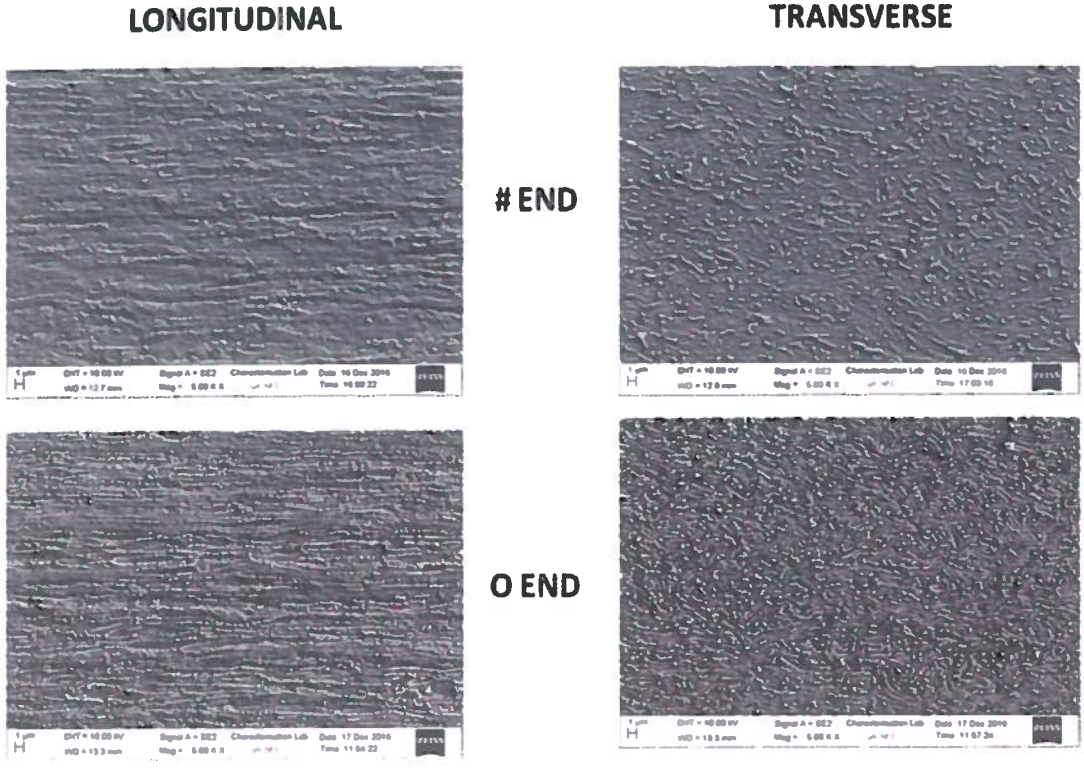
However, due to difference in size involved, several challenges were faced during the development of process for production of these tubes using single pass pilgering. The mechanical properties, hydriding behaviour etc. could not be met in the initial trials. A series of trials were conducted and several process parameters were optimized to ensure that all requirements are met consistently. Most significant amongst these were the pilgering trials with varying diametral and wall reduction ratios. After a series of trials and the subsequent optimisation of Q factor (ratio of wall thickness reduction to diameter reduction) at a value ~ 4.0 (against previous value of 1.5 to 2), predominantly transverse hydride orientation was achieved.



Flow sheets for Production of 220 MWe Pressure Tubes with low and high Q factors



Hydriding behaviour of 700 MWe PT, 220 MWe PT with low Q factor and 220 MWe PT with high Q factor.



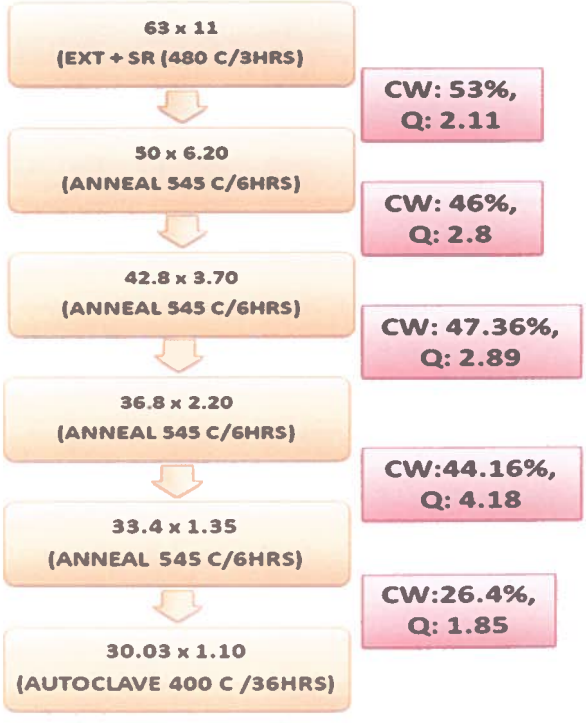
220 MWe pressure tubes with elongated microstructure and high aspect ratio of grains.

After thorough scrutiny of all the results, the APEX committee constituted for this purpose, has accorded its approval for commencement of production activities of 220 MWe Pressure Tubes by new modified route (high Q) for EMCCR of KAPS I and II reactors.

2. Development of scaled down pressure tubes

With an aim to understand the progression of a Severe Core Damage Accident within a PHWR type of reactor, single and multi channel tests are required to be conducted in a scaled down facility. Results obtained from these tests are to be used to validate models and gauge the effect of a similar accident in a full scale reactor.

BARC is developing such a scaled down facility for carrying out these tests. NFC has supplied scaled down Calandria tubes earlier for this facility and is currently in the process of developing scaled down pressure tubes of Zr-2.5%Nb of size 30.1mm OD X 1.0mm WT. Owing to the very thin walled nature of these tubes, several challenges were faced during the development of fabrication process. Extrusion of blanks was carried out at 63mmOD X 11mmWT. Initially a three pass pilgering schedule was developed with intermediate annealing. The greatest challenge faced was the occurrence of longitudinal cracks and UT defects on the ID surface of these tubes during multi pass pilgering. Several trials were conducted by modifying the amount of cold work and Q factors at various stages and finally a five pass (as below) schedule was developed/optimized with intermediate annealing.



Flow sheet developed for manufacture of Scaled Down Pressure Tubes

The defect correction on the ID of the tubes was partially achieved by carrying out pickling of the tubes selectively on the ID. The ultrasonic test charts of these tubes showed significant reduction in the defect intensity to a value below the maximum acceptable. Thus the tubes met all the required specification of dimensions and metallurgical properties.

3. Other production activities

In addition to above, STP was also involved in several other production activities such as:

- Pilgering of fuel tube blanks in various pass schedules at initial and intermediate stages.
- Pilgering of SS tubes of various grades and sizes.
- Pilgering trials for titanium alloy PT-7M tubes.
- Grinding and cutting of fuel tube blanks at various stages.
- Straightening of annealed tubes of various sizes and materials.

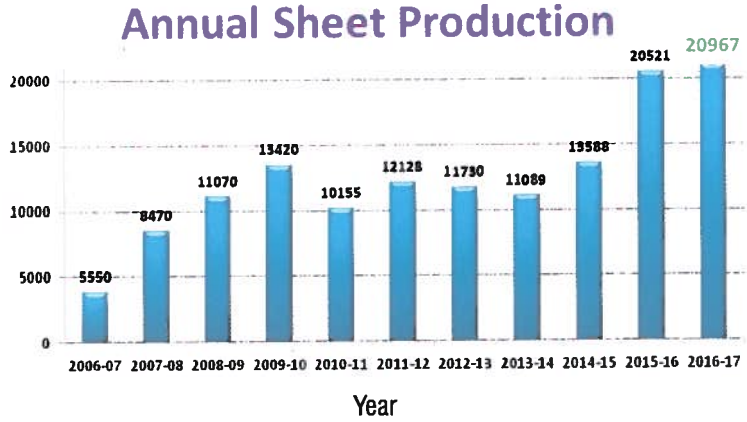
4. Modification / development works taken up / completed:

a) The screw rod type honing head advance system in the Honing Machine No. 2 of STP was replaced with a hydraulic cylinder system (stroke length 7.5 Mtrs.). The sliding bed of the Honing Head trolley was replaced with a Linear Motion Guide System. This has enabled the machine to be suitable for honing tubes of 7.0 Mtrs. in a single stretch without the need for reversing the tube at half way point (due to earlier stroke length limitation) thereby increasing the productivity and quality.

b) One 5 ton EOT Crane of span 22 Mtrs., has been erected and commissioned in the Finishing bay / Packing bay of STP with latest safety features. This has helped in simultaneous use of the cranes for the loading and unloading needs of heavy extruded blanks on the five grinding machines and the CRTM pilger mill available in the bay, thereby reducing the idle time of the machines and increasing the throughput/production.

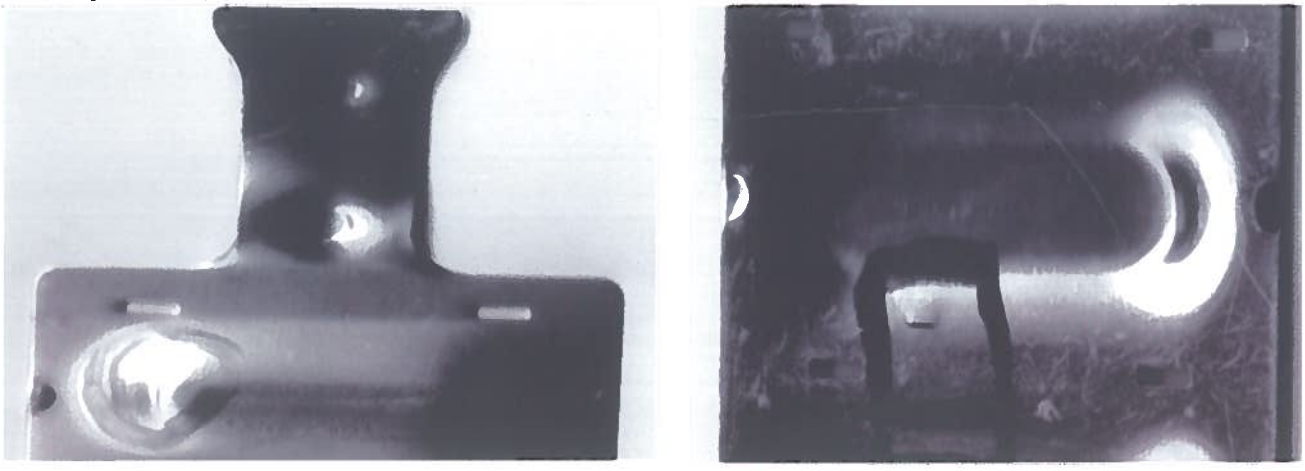
Rolling Mill section:

Achieved highest ever production of 20,967 kg of Sheet material in the year 2016-17 with an enhanced recovery of 48.5% (from earlier recovery of 45.93 % in 2015-16)



Enhanced recovery of 48.5 % by process modifications in hot rolling. Changes in plate thickness rolling and loading patterns has led to reduced lamination defects

BWR strips recovery improvement:



Cracks observed in BWR punched spacers

The critical sheet components such as bar, band and divider spacers of Zircaloy-4 are used in BWR fuel assemblies. These spacers are one of the prominent components in BWR fuel assemblies. These sheet components are manufactured by a series of thermo mechanical processes such as hot extrusion, hot rolling, cold rolling with intermediate grinding and vacuum annealing. The sheets require good formability in normal direction in forming of BWR band spacers and have to meet the stringent dimensional, metallurgical and corrosion resistant properties. Cracks were observed in the final punched spacers and recovery was sometimes as low as 20 %.

Cold working and annealing process parameters were optimized to achieve maximum of 33 % elongation in the final cold rolled and annealed sheet material. The modified process route resulted in finer grain size of ASTM no 10 structure which improved ductility. This has ensured better formability of final band spacers. The rate of forming was also modified to get optimized recovery during forming. These all improvements in manufacturing process route resulted in achieving 100 % formable (crack-free) material.

Resistance Heating Furnace modification:

- Resistance heating furnace used for hot rolling of slabs and plates was under frequent breakdown during hot rolling. This was due to slabs and plates damaging the heating filaments during conveyance. Hence, the furnace has been redesigned with high temperature guiding plates made of SS 310. Incoloy tubes were provided for structure integrity and SS 316 bolts were used for locking with the fixture. This has reduced down time and increased availability of the furnace and thus furnace could be run without down time continuously for 150 ingots of Hot rolling of slabs and plates.

Manufacture of RRR grade sheet:

The cold rolling schedules of RRR grade Niobium were established and 1 No. of RRR grade sheet of 650 mm x 550 mm x 6 mm dimensions was supplied to RRCAT.

Reactivity Mechanism Assemblies:

- For the forthcoming 700 MWe PHWRs, three reactor charges of ARGT, SRGT & CRGT, one reactor charge of Liquid Zone Control assembly and one reactor charge of Liquid Poison Injection assembly, one reactor charge of Adjuster Rod Mechanisms have been packed and dispatched to site (Total 211 assemblies).
- For RAPS-7, 4 no's of Liquid Poison Injection assembly have been manufactured.
  12 no's of Cobalt Absorber Assemblies have been manufactured. Implemented autoclaving of pencil sub-assembly as per customer requirements. Fixtures have been fabricated to autoclave 400 no's of pencil sub-assemblies in one setting.
- One Start Up Counter assembly, One Inner Flow Tube assembly & one Outer Flow Tube assembly have been manufactured and dispatched to site.
- One reactor charge of HFU & VFU assemblies haven been manufactured. Gadgets have been made for in-situ tube bending in HFU, VFU' assemblies for various configurations and used successfully.
- Equipment developed for bending of TAPS 'O' ring .
- EB Welding of double clad billets(Zr-4 to Zr-Sn) was performed using circular
  interpolation. After copper jacketing of billet, all joints were sealed by GTAW successfully.
- Assistance in preparation of Super –Ni tube UT standards
- Base plate for 300 dia VAR Bottom stool assembly was machined on 5-axis Vertical Machining Center.
- Machined Pellet guiding tray for ED &A on 3-axis VMC
- Integrated end plug for CCB in place of welded end plug, the integrated plug is dimensionally more accurate and reduces process steps.
- Welding of Hydraulic piping of 65 VM pilger mill, 65 EZTM pilger mill & Daneali pilger mill

TAPS O ring bending equipment

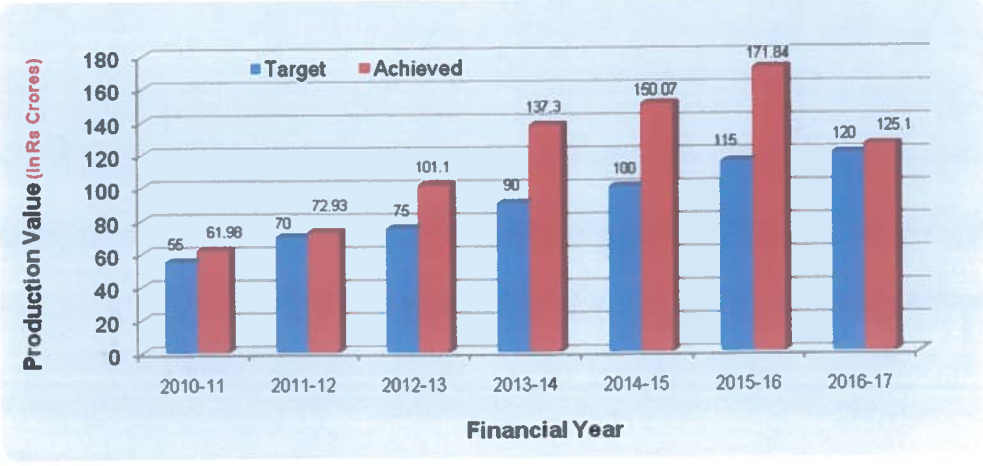
Stainless Steel seamless Tube Plant (SSTP)

Stainless Steel seamless Tube Plant (SSTP) is an exclusive facility involved in development & manufacturing of seamless tubes in variety of advanced grades of Stainless Steels & Special alloys such as SS-D9, 316M, 304L, mod.9Cr-1Mo, Ni-Cr alloys (Incoloy, Inconel, Nimonic, etc.), Ti alloys (PT-7M, PT-3B, PT-1M, Ti-half alloy, etc.), Maraging steels for applications in strategic areas viz. Nuclear, Space & Defence.

During the FY 2016-17, SSTP has successfully manufactured various critical products i.e. SS-D9 Fuel Clad Tubes for Prototype Fast Breeder Reactor (PFBR) & Fast Breeder Test Reactor (FBTR), SS-304L poison tubes for control rod assembly of BWRs, PT-7M tubes for strategic Nuclear application, Ti-Alloy Tubes for GSLV-MK-III, High corrosion resistance SS-304L pipes for Fast Reactor Fuel Reprocessing plant (FRFCF), MDN-59, 250 & 350 Maraging Steel Tubes for Defence Applications, etc.

Performance highlights of SSTP for the period 2016-17 :

Plant has achieved Production Value of Rs. 125.1 crores surpassing Annual target of Rs. 120 crores.



Production Activities :

- D9 Fuel Clad Tubes for FBTR :

  SSTP has successfully supplied 5800 nos. of SS-D9 grade Fuel Clad Tubes required for operating Fast Breeder Test Reactor (FBTR) during 2016-17. These are small diameter thin walled tubes of 5.1 mm OD x 4.36 mm ID tubes with 0.35 mm WT (min) having stringent specifications w.r.t. dimensional tolerance (< ±0.02 mm), surface finish better than 0.5 μRa, mechanical properties, chemistry, retained cold work (20%), ultra-high cleanliness, etc.

- D9 Fuel Clad Tubes for PFBR :

  SSTP has established facilities & standardized processes for manufacturing Fuel clad and other core structural tubes in SS-D9 grade required for 500 MWe PFBR and successfully completed supply of tubes required for initial core in the previous years. During 2016-17, production of clad tubes required for fabrication of replacement subassemblies was taken up. In order to improve recovery, mother blank dimensions were modified from earlier size of 63 mm OD x 6 mm wall thickness to 63 mm OD x 9 mm wall thickness and cold working schedule was revised with optimum percentage reduction at each working stage. This resulted in over all increase of recovery by 25%. During the year 2016-17 plant has produced 14000 nos of D9 clad tubes equivalent to 64 nos of sub-assemblies, meeting stringent quality requirements.

- High corrosion resistant SS - 304L pipes for Fast Reactor Fuel Reprocessing Facility :

  SSTP is executing bulk order for supply of 1290 MT of SS 304L pipes in 20 different sizes ranging from 13.72 to 168.28 mm diameter, 2.24 to 7.11 mm wall thickness for the Fast Reactor Fuel Reprocessing Project coming up at Kalpakkam. These pipes have stringent specifications w.r.t. corrosion rate (< 15 mills per year) in accordance with ASTM - A262 IGC Pr-C test. The pipes were manufactured through combination of hot extrusion & cold pilgering with extensive cleaning at intermediate stages to remove fine traces of oil prior to solution annealing to prevent any Carbon ingress that adversely affect corrosion resistance. Total of 54,079 m of pipes in 11 different sizes weighing 211.044 MT were manufactured meeting the quality specifications.

Developmental activities :

- **Development & Manufacturing of Ti-Half Alloy tubes for GSLV MK-III :**

SSTP has successfully developed & manufactured Ti-half alloy (Ti-3Al-2.5V) tubes of 25 mm OD x 1.4 mm wall thickness for critical application of GSLV MK-III satellite which is scheduled for launch in first half of 2017. Manufacturing route consisting of pilgering pass schedule having controlled cold work & Q-factor and process as well as final annealing with optimized heat treatment parameters were adopted. This has resulted in desired mechanical & metallurgical properties yielding 100% recovery in ultrasonic testing against stringent reference standard.25 mm OD x 1.4 mm wall finished Tubes

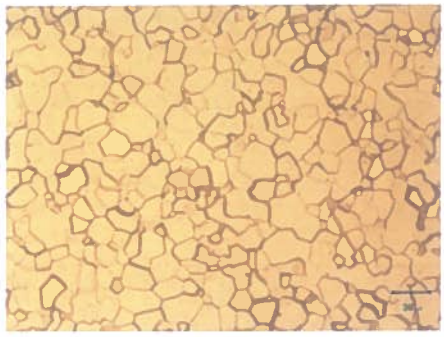
25 mm OD x 1.4 mm wall finished Tubes

- **Optimization of manufacturing process of Ti-3Al-2.5Zr Tube for defence Strategic Nuclear Application.**

Ti-3Al-2.5Zr, a Titanium base alloy is one of the strategic important materials for Defence Nuclear application and manufactured first time in the country as an import substitute, in technical collaboration with BARC & Midhani During 2016-17, the manufacturing process was optimized w.r.t. final vacuum heat treatment cycle and post heat treatment pickling at different stages to achieve desired properties and integrity tested through NDT i.e. ultrasonic and eddy current. It was challenging to meet the quality specifications with regards to stringent ultrasonic defect standard of

3% wall thickness with consistent recovery.

18 mm OD x 2.5 mm wall finished TubesMicrostructure showing complete recrystallizationTubes produced were characterized for texture, corrosion, mechanical properties at room & elevated temperature and the properties obtained were found to be superior, uniform and consistent. Through the optimized process route and with the established process parameters 1000 m of finished tubes were successfully produced and supplied with more than 80% recovery in UT. Plant is now geared up for taking up bulk production to meet the requirement.



Microstructure showing complete recrystallization

18 mm OD x 2.5 mm wall finished Tubes

Tool Manufacturing

Tool Room is responsible for design and manufacture of tools for hot work and cold work applications and has supplied tools to all plants across NFC to achieve record production of 1512 Te Fuel assemblies. The hot work tools include mandrels, dies, expansion noses, die holders, dummy blocks etc, for the 3780 ton horizontal extrusion press, 1200 ton vertical piercing press and 600 ton vertical extrusion press for processing of various alloys of Zirconium, Titanium, Stainless steel, Aluminium, Maraging steels, super alloys and other special materials required for nuclear and strategic applications including space and defence departments.Tool Room carried out the design and manufacture (Machining and heat treatment of various tool steels like AISI H11, H12, H13, O1, D2 and maraging steel 350) of cold pilger mill tools such as dies, mandrels, rollers and support plates for pilgering of seamless tubes in circular and non-circular cross sections (Square / Hexcan) in variety of materials. Tool Room has also catered to the requirement of precision defect standard notches for carrying out Eddy current and Ultrasonic testing of different seamless products manufactured.

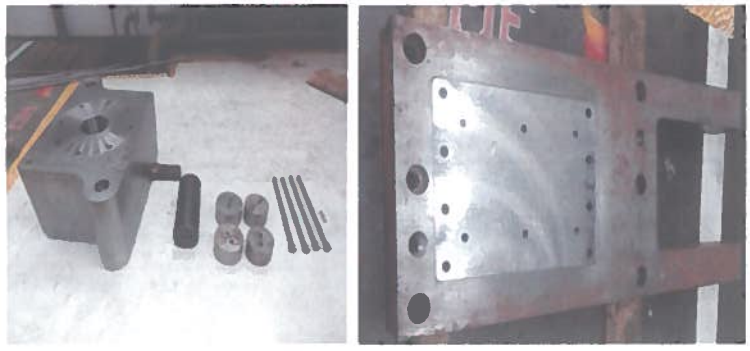
Developmental activities carried out in Tool-Room in year 2016:

1. **Design Modification and manufacture of Die housing assembly of 2000 Te Hydraulic press to increase die insert life, ease manufacturing by introducing shrink fit design & ease of assembly.**

Advantage of Modified die housing (Circular design)over rectangular design.

1. Ease of manufacturing of die inserts due to the circular design.
2. Increased die insert life due to pre-stressing due to the shrink fit design.
3. Ease of assembly due to circular design.

Rectangular die housing assembly design (prior to modification)

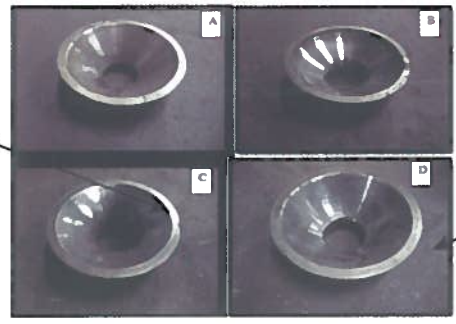


Die House for 2000 Te press (After modification.)

2. **Study to optimize die profile for extrusion of zirconium alloy (Zr-4):**

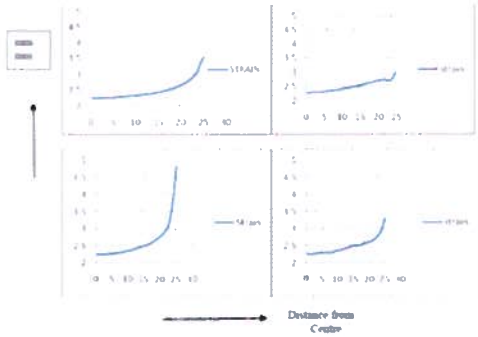
Presently conical dies are being used for the extrusion of Zircaloy products. A systematic study is carried out for understanding the variation induced in the microstructure due to extrusion involving different extrusion die profiles. Four different die profiles i.e. conical, cosine, convex and concave were designed, numerical simulation of extrusion was carried out and dies were manufactured. Finite element modelling (FEM) of extrusion process was also carried out to determine the metal flow, temperature evolution and effective strain distribution, which were then correlated with the observed microstructural changes. Zr-4 alloy billets were extruded on 3780 T Horizontal extrusion press at NFC, using the four profiles. Micro hardness test, Optical microscopy and EBSD experiments were performed to analyse microstructural and mechanical properties of extruded rods through various dies.

Microstructure at centre of rod extruded by convex die

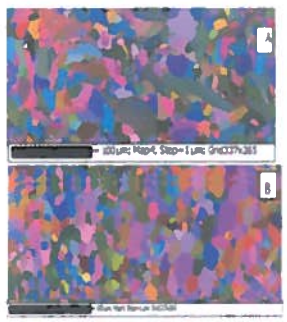


Microstructure at centre of rod extruded by concave die

Pictures of dies having different profiles
(A- Conical Die, B-Cosine Die, C-Convex Die, D- Concave Die)



Variation of strain along the radius of extruded rod
(A-Conical Die, B-Cosine Die, C- Convex Die, D- Concave Die)



Microstructure at periphery of rod extruded by concave die

Microstructure at periphery of rod extruded by convex die

Higher strain at periphery in case of convex profiled die leads to better homogeneity of microstructure across the cross section as compared to conical die presently being used for extrusion of Zr4

3. **Design and manufacturing of tooling for CPM-32 mill to get better quality tubes at higher production rate:**

The imported tooling supplied along with the mill yielded flatness and waviness when tubes were pilgered at higher feed and speed. To produce quality tubes coupled with higher pilger mill parameter, Tool Room has taken up fresh design, manufacturing a pair of dies and mandrel in order to avoid waviness and flatness on pilgered tubes. Tools are manufactured and presently being used at high feed and speed parameters meeting the quality requirements.

CPM-32 Tooling

4. **Design and manufacturing of tooling for revamped 50VMR mill:**

Half ring dies were changed to full ring dies in revamped 50 VMR mill by the OEM of the mill. The OEM's have provided pilger mill dies for 1st pass of 19 element Fuel tubes, 2nd pass 37 element fuel tubes and provided the pinion for the pilger mill suitable to these passes. To diversify the mill scope and have better utilization, Tool Room arrived at required pinion diameter and set of toolings were manufactured for pre-final pass of fuel tubes and being used regularly.

5. **Introduction of magnetic sine-tables for grinding of HPTR support plate:**

Earlier each support plate was to be clamped on sine tables using screws due to which setup time was very high. Conceptualization and introduction of magnetic sine tables has replaced manual clamping by magnetic clamping leading to higher productivity and lower cycle time. Overall productivity has increased between 60% to 100% depending upon type of support plates. Further, the risk involved in lifting sine table (almost 60kg) manually for placing the slip gauges has been avoided by introducing positive locking and lifting mechanism. These are being regularly used for grinding of support plates for 8-15 and 10-20 HPTR mills

6. Manufacturing of tooling with double eccentric side relief:

Tool-Room regularly manufactures die profiles having purely radial and combined radial and tangential side relief. New design was developed for double eccentric side relief and set of tools were manufactured for CRTM-65 pilger mill for first pass pilgering of fuel tubes.

New equipment added to augment the Tool-Room facilities:

4-axis CNC Vertical Milling Centre stroke length of 1050mm (X-axis) x610mm (Y-axis) x610mm (X-axis) equipped with rotary table (A-axis) for manufacture of pilger-mill dies and support plates.

CNC surface Grinder of bed length 500 x 1500 mm and vertical stroke of 595mm for grinding support plate tapers which enhanced the productivity approx. by a factor of 2.

Precision lathe for high speed turning operations of smaller components and for super polishing of compaction punches.

Conceptualization, identification and introduction of servo controlled flexible tapping machine with tapping capacity of M3 to M16 for fast and easy tapping.

Centre-less grinder for HPTR mandrel grinding with adjustable feed stands for accommodating the rods ranging from 2-25mm diameter and 350 and 400 mm in length to cater requirement of mandrels required for production of small diameter tubes for the manufacture reactivity mechanism assemblies and for strategic applications

Major Events

Shri G. Kalyanakrishnan, Chairman & CE,NFC receiving the Guard of Honor during Independence Day Celebrations at NFC Sports Pavilion.

Shri G. Kalyanakrishnan, Chairman & CE,NFC with the ZOP Team on the occasion of Republic Day Awards Function.

Shri G. Kalyanakrishnan, Chairman & CE,NFC and other Senior Executives at NFC Sports Pavilion.

Children of Atomic Energy Central School presenting a Cultural Item during Independence Day Celebrations.

Shri G. Kalyanakrishnan, Chairman & CE, NFC presenting Independence Day Award to Dr.J.Vijay Rao and Medical Team.

Shri G. Kalyanakrishnan, Chairman & CE, NFC presenting Independence Day Award to Accounts Team, NFC.

DNV ISO 9001:2008

DET NORSKE VERITAS 1864 OHSMS

NABCB QMS

MGMT. SYS. RvA C425 EMS

HIGHLIGHTS 2016- 2017

राष्ट्र की सेवा में परमाणु एन एफ सी NFC ATOMS IN THE SERVICE OF THE NATION

SERVICES

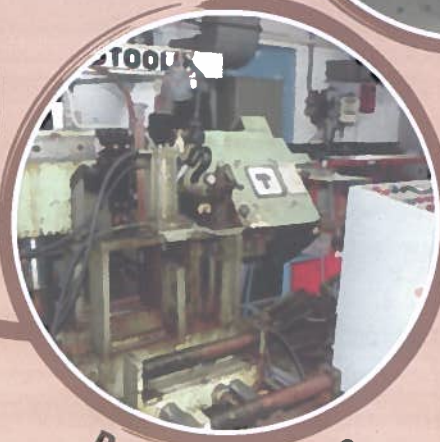
Revamping of Equipment

ID Gauging System for tubes

Scanning Electron Microscope

Bull gear and pinion shaft assembly

Bandsaw machine



ISO Systems

- ISO Cell played a vital role in effective implementation and continual improvement of ISO 9001:2008, ISO 14001:2004 and OHSAS 18001:2007 Management systems of NFC,BARCTS-H and CISF,NFC.
- Apart from regular internal audits (first party), third party audit by world renowned certifying body carried out compliance audit during May 2016 and December 2016
- Based on the requirements of Management the focus areas established, monitored and evaluated were: control on out sourced activities , continual improvements towards enhancing Safety, Environment and recoveries, swachh bharat and scrap management.

Environmental & Pollution Control (EPC) and Effluent Management (EM)

Effluent Management (EM) is responsible for safe disposal of various liquid and solid effluents generated in different plants of NFC to ensure smooth and uninterrupted operations of production plants. EM Section is also responsible for periodic submission (monthly, quarterly and annual reports) of details of hazardous waste disposed to Telangana State Pollution Control Board, AERB, MoEF.

Major activities carried out during the year:

- About 37000 KL of liquid & 2000 MT of solid effluents have been disposed by sale to TSPCB approved vendors which is about 15% and 50 % respectively, more than the quantities disposed during the FY 15-16.
- Revenue generated by sale of effluent is about 3.7 Crores which is the highest ever and is about 1 Crore (35%) more than the revenue generated in the previous FY 2015-16.
- The quantities of Ammonium Nitrate from UOP, Acidic Silt from ZOP and Magnesium Chloride (Gr-I & II), Magnesium Scrap & Zirconium Chloride from ZSP disposed were highest ever.
- About 10 MT of Cotton Waste was incinerated in Active Waste Incinerator Facility and Ash containing about 550 Kg of Uranium was sent to NUOFP for recovery of Uranium.
- 35 MT of non-saleable solid waste (Calcium Fluoride Waste from ZFP & SMP) was disposed to Hyderabad Waste Management Project, Dundigal.

Environment & Pollution Control (EPC) is responsible for operation of waste water management facilities, prior to its use for gardening. It is also responsible for the operation of a Central Decontamination Facility for decontaminating the various types of solid wastes generated in fuel plants, with a view to recover & recycle the valuable uranium. It is also responsible for the treatment of Ammonium Nitrate effluent generated from UOP, prior to its disposal after obtaining clearance from HPU.

Central Decontamination Facility

- Around 219.7 Kgs of uranium has been recovered from decontamination of active solid wastes such as polythene, Pre and HEPA filters, during the year.

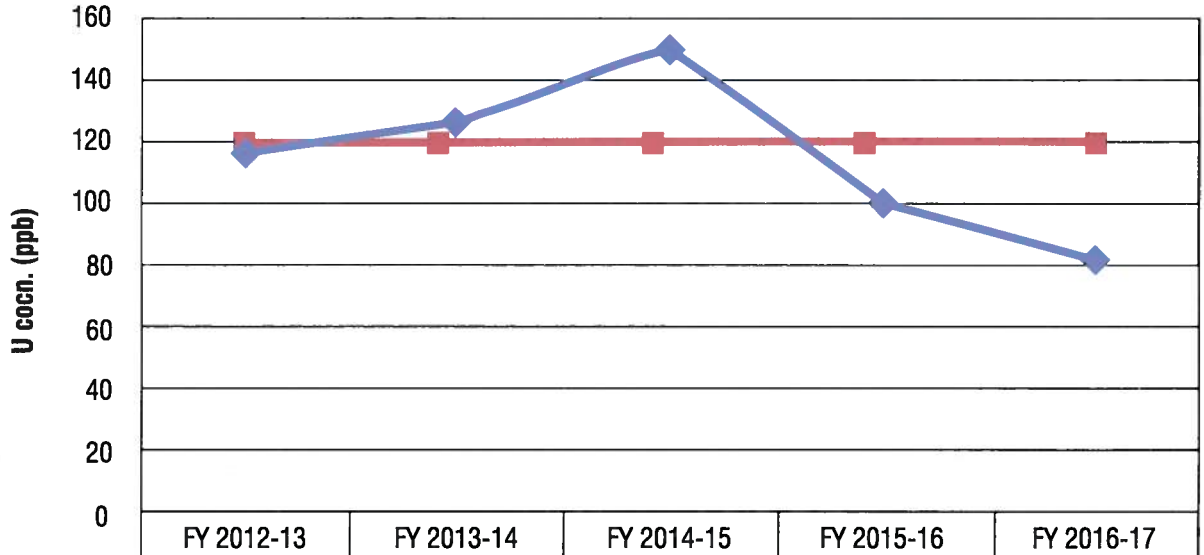
Waste Water Management

- Waste water from active plant areas is collected, treated and is mixed with non-active water, allowed for settling and distributed to gardens within NFC. Total quantity of water pumped from Old & New Settling Tanks (OST & NST) areas during 2016-17 is 120705 KL (From OST: 82169 and from NST: 38536 KL).
- Old Settling Tanks (OST) Area:
  - Average concentration of U in discharge water from OST during 2016-17 is 52.91 ppb as against the limit of 120 ppb and 97.2% of the samples are within permissible limit.
- New Settling Tanks (NST) area:
  - In order to bring down the U concentration in waste water received at New Settling tanks (NST), following modifications were taken up during 2016-17:
    - Lined sump has been constructed and commissioned in August 2016 for collecting separated active waste water stream from tunnel-1, 2 & 3 of NUOFP area by gravity.
    - Commissioning and successful operation of one more in-house developed Electro Coagulation unit at NST area for treatment of active water collected in SS lined sump.

- Second stage treatment of treated active waste water and treatment of water received through non-active routes to NST whenever U concentration in these streams exceed 120 ppb has been incorporated with two numbers of in-house developed Electro Coagulation Units.

- Average concentration of U in discharge water from NST during 2016-17 is 81.28 ppb as against the limit of 120 ppb and 87.3% of the samples are within permissible limit. Average U concentration in NST water over last five years is as given below

Annual Average U conc. in NST Water during last five years



	FY 2012-13	FY 2013-14	FY 2014-15	FY 2015-16	FY 2016-17
U (ppb) at NST	115.7	125.5	149.6	99.9	81.28
Limit (ppb)	120	120	120	120	120

- Electro Coagulation Facility: Around 9 700 kl of non process active wash water generated from Block-A fuel plants & 500 kl of NUOFP floor wash water & Laundry water was treated in Electro coagulation facility at Active Settling Tanks (AST) and the Uranium concentration was brought down to 60 ppb in outlet stream.

- EPC has conducted few studies for reuse of active sludge generated in electro-coagulation facility , for treatment of ammonium nitrate effluent generated from UOP, in order to avoid the accumulation of secondary waste in the plant. Based on successful lab and plant scale trials, the electro coagulator sludge is being used, instead of Ferric chloride, in ETP operations for recovery of uranium from ammonium nitrate effluent of UOP from August 2016.This has resulted in the avoidance of accumulation of secondary waste, as well reduction in the cost of operations, due to elimination of use of Ferric Chloride, which is a bought out item.

Safety Engineering Division

Safety performance for the year 2016-17

1. No. of disabling injuries : 05
2. No. of man-days lost : 6710
3. No. of non-disabling injuries : 08
4. No. of unusual incidents : 11
5. Frequency rate (no. of disabling injuries per million man-hrs worked), F.R : 0.585
6. Severity rate (no. of man-days lost per million man-hrs worked), S.R. : 785.629
7. Injury index (F.R. x S.R. / 1000), I.I : 0.460
8. Longest period worked without disabling accident: 2.88 million man-hrs (26.05.2016 to 26.09.2016)

Highlights:

- 2.0 million accident-free man-hr period was achieved in the year during the period 26.05.2016 to 19.09.2016.
- 93.33 % of the NFC plants worked without any disabling accident.
- 23 training programmes/seminars were conducted covering 270 workmen, 122 officers and supervisors, 450 contract workers, 245 CISF persons, 91 personnel from handling of zircaloy material and 210 nos. of apprentices.
- 119 safety clearances and 762 safety work permits were issued for various modifications and works at different plants.
- 32 housekeeping inspections were conducted by the housekeeping committee for the year 2016-17 and 240 recommendations were made for improving internal and external housekeeping.
- Safety competitions were conducted for employees on safety slogans / posters / spot the hazard / quiz / essay writing. A total of 413 entries were received in these competitions.
- Safety competitions were conducted for contract workers on safety quiz/safety talk. A total of 343 entries were received in these competitions
- National Safety Day was celebrated on 4th March 2017 and prizes were distributed to 99 winners from employees and personnel of outsources agencies of various safety competitions.
- Emergency mock drill was conducted on 21.03.2017 for the scenario of Cl_2 leak and simultaneously, non availability of EOT crane. A feedback meeting was conducted after the drill for improving the preparedness of concerned agencies.
- Safety alerts on accidents/incidents and lessons learnt were issued for the awareness of the employees.
- Issue of Safety training pass implemented for all contract personnel before entering into NFC premises. Issued 2431 nos. of passes till 31.03.2017.
- Introduced the medical examination by Medical Officer of NFC for the contract persons working at a height for more than 3 meters.
- Introduced periodical medical checkup for employees working at high noise areas and EOT crane operations.

Safety Day celebrations on 04.03.2017

NEW ADDITIONS:

- Benardino Ramazzini Occupational Health Awareness Wing was inaugurated by the Chairman & Chief Executive, NFC on 05.12.2016, which constitutes Lecture Hall and Conference Hall at 2nd Floor, OHC.
- New Dental facility was inaugurated by Chairman & Chief Executive, NFC and Deputy Chief Executive (Admn), NFC on 05.12.2016 for the benefit of the employees. Visiting Dental Surgeon is available at OHC on Monday, Wednesday and Friday.
- Bio-Chemistry Analyzer was procured and installed at both OHC and CHC for the benefit of all CHSS beneficiaries.

Inauguration of Dental facility at 1st Floor, OHC and Bernardino Ramazzini Occupational Health Awareness Wing at 2nd Floor,OHC

Health Education Programme for NFC employees along with Spouses

Group Achievement Award for Medical Section Independence Day- 2016

Celebration of International Yoga Day on 21.06.2016 Practicing of Yoga

Dr.(Prof.) Bakhtiar Choudhary on the occasion of celebration of International Yoga Day on 21.06.2016

Health Physics Unit (HPU)

HPU of Health Physics Division, Health, Safety & Environment Group, BARC stationed at the facility plays vital role in providing radiation protection to the employees of NFC and environment around it.

An Emergency Response Centre situated at HP Building, NFC equipped with sensitive instruments to detect and measure radiation and Team of trained & experienced manpower for assessment extent of radiological hazards is kept in state of readiness to respond for any radiological emergency situation. National Occupancy Dose Registry System (NODRS), TLD Unit of Radiation Protection and Advisory Division (RPA&D), BARC is stationed at NFC. NODRS maintains Dose History of NFC employees, connected to Main Server at RPAD, BARC is functional at HP Building, NFC.

Highlights :

About 48000 samples of air, effluents, water and soil from different areas of the facility were collected and analyzed as a part of in-plant and environmental monitoring for radiological and conventional pollutants.

Radiological Surveillance: Around 17,000 air samples were collected and estimated for Uranium from active plants of NFC.

Environmental Surveillance: Around 9,581 estimations of uranium and other chemical pollutants were done in environmental samples collected in and around 5 Kms of NFC.

Industrial Hygiene: Air samples collected from work atmosphere were analyzed for various chemical pollutants like NOx, NH_3, and Cl_2. Around 578 samples were analyzed during this year. Ambient air quality around NFC was monitored regularly. 3749 air samples including those for PM 2.5 were collected from the periphery of NFC from various fixed stations for analyzed for chemical pollutants.

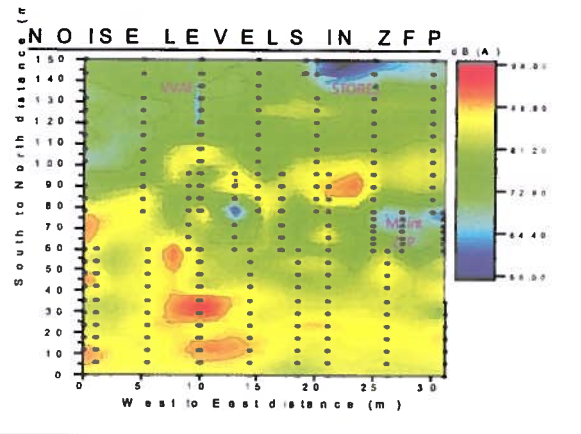
Training: Radiological training was given to regular employees working in Fuel plants of NFC, CISF Personnel of NFC and NISA, Trainees of training school, NFC, etc. Retraining to newly recruited SOT'S and JOT's posted in fuel plants was carried out for enhancing the safety awareness during their work in radiological area.

CAAQMS installation: Continuous Ambient Air Quality Monitoring Station(CAAQMS) is installed and data acquisition is going on.

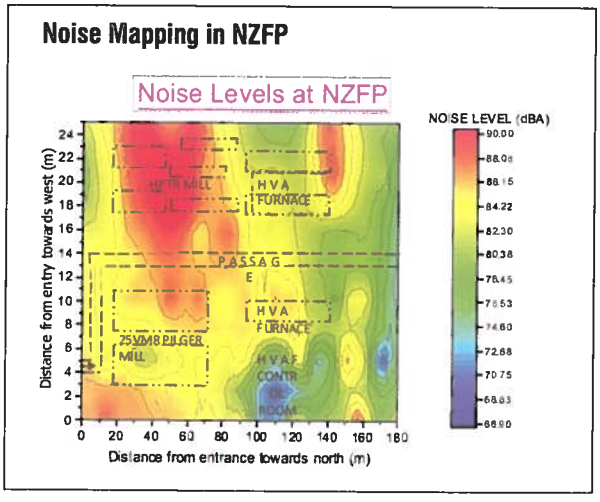
New Instrument for Lung Counting: New detector for Lung counting is installed. The existing is augmented with the new sensitive NaI(Tl) of dimentison 8" X 0.5" and is presently under testing.

Noise mapping in different plants of NFC: Noise mapping was carried out in selective plants of NFC to study the pattern of the variation of noise levels and to identify the hot spots.

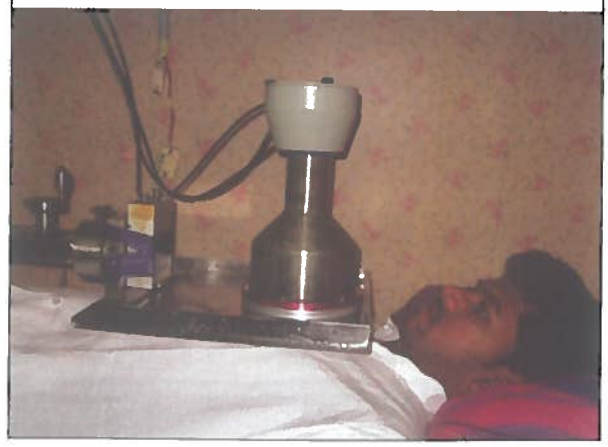
Noise Mapping in ZFP



Noise Mapping in NZFP



Internal contamination monitoring by Lung Counter



Quality Assurance

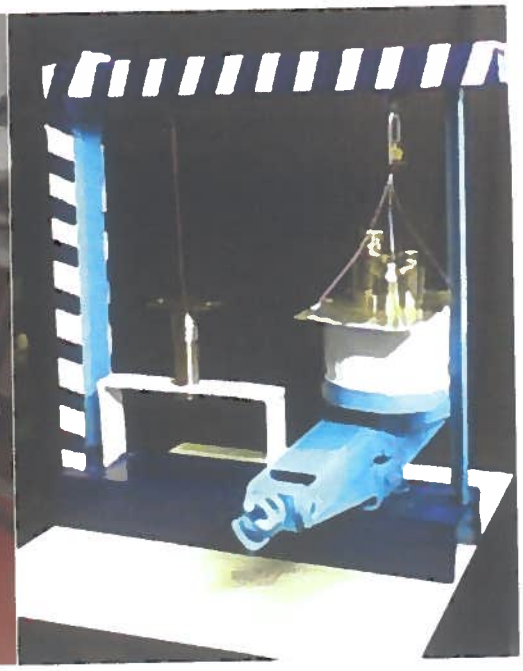
Quality Assurance–Fuels

- Total 1512.2 MT of Natural UO_2 (consisting of 8006 nos. of 37 element bundles and 87748 nos. of 19 element bundles) fuel were QC cleared.
- 105 nos. of BWR bundles were QC cleared.
- A X-Ray unit (Rapiscan) for Block-B and an automatic individual fuel pin weighing system for Block-A was procured and put into use for ensuring correctness of stacked UO_2 pellets inside the PHWR fuel pin

Quality Assurance-FRF

- The entire fuel sub assemblies requirement for first core of PFBR has been QC and QS cleared. In this year 27 fuel Sub assemblies have been QC cleared.
- 8 nos. of diluent sub assemblies required for first core of PFBR have been QC and QS cleared. These assemblies were made for the first time.
- Prototype automated Ultrasonic testing system for evaluation of PHWR end cap welds have been made successfully in house.
- Test setup to ensure holding force of FBTR gripper spring was made in-house.

Prototype Automated Ultrasonic testing machine for PHWR end cap weld evaluation



Test Setup for FBTR gripper spring

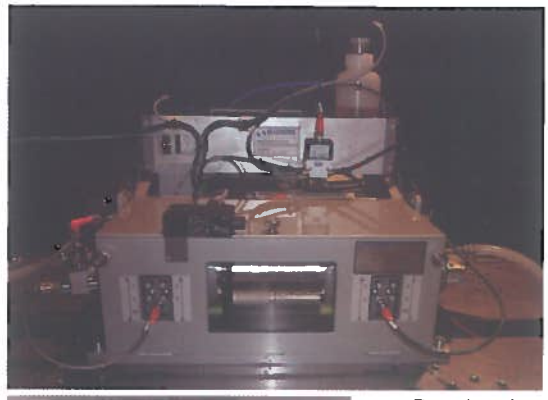
Quality Assurance (ZFP & STP)

QA-ZFP

QA (ZFP) caters to the inspection and quality control requirement for Zirconium alloys structural and components viz. fuel bundle components and tubes for PHWRs and BWRs, structural like Seamless Calandria tube, garter spring, reactivity mechanism assemblies and assemblies for strategic requirement of DAE.

1. QC clearance of 20.07 lacs fuel cladding tubes for PHWRs (19e & 37e) for manufacturing of fuel assemblies to meet the requirement of 1512 MT of fuels and 4195 nos. of BWR fuel tubes for TAPS requirement.

2. UT Rotary head which is the most critical part of Rota-25 automated UT system capable of rotational speed upto 8000 rpm, the second UT rotary head was procured during June'2016. This has further strengthened the Ultrasonic test capability to meet the future targets of fuel cladding tubes.
3. Indigenous development of improved sensitivity ultrasonic probes for Rota-25 automated UT system with long length to reduce water path distance by 10 mm.
4. Introduction of inspection at pre-final stage (dia.17X1 mm) of fuel cladding tube resulting increase in recovery and helps in improving pilgering tool life.
5. QC clearance of 33.8 MT of Zirconium alloy bar material for manufacturing of end plugs for PHWR and BWR fuel assemblies.
6. Zircaloy-4 and Zr-0.3%Sn double clad tube for BARC was successfully ultrasonically tested.
7. Nb-1%Zr-0.1C sheet developed by NFC was ultrasonically tested and dispatched to BARC.
8. Testing and qualification of RRR grade Nb sheet for RRCAT, Indore.
9. **Reactivity Mechanism Assemblies:**
   a. Inspection and testing of reactivity mechanism assemblies for 700 MWe PHWRs such as Poison Injection Unit and Vertical flux monitoring assemblies (VFU). 7Nos. of PIU assemblies for KAPP-3 were dispatched to site after QS clearance.



Rota head
← New design

← Old design

   b. In-house development of fixtures for pneumatic pressure test and helium leak test of VFU-8 assemblies to ensure compliance with respect to assembly integrity, functional requirement and leak tightness in the order of 10^{-8} mbar.litre per sec.
   c. 12 nos. of Cobalt absorber assemblies were QC cleared for 220MWe PHWRs. These assemblies were tested with respect to Dimensions, Helium leak test, Radiography & Load test at 500 Kg.
   d. 2 nos. of Inner flow and outer flow guide tube assemblies were qualified in record time to meet the NPCIL, Tarapur requirement for testing of Cobalt Absorber assemblies in 700 MWe PHWRs.
   e. 16 nos. of PRP Water Pin Assemblies were successfully qualified and delivered to PRP, BARC meeting the extremely stringent requirement with respect to ultrasonic test, radiography & liquid penetrant examination of weld joint.
10. Highest number of long length Zirconium alloy sheets (2360 nos.) UT tested and QC cleared for manufacturing of fuel bundle appendages.
11. Highest number of 19e & 37e End plates (2,03,703 nos.) were QC cleared for PHWR fuel bundles.
12. Highest number of Bearing Pads (33,74,885 nos.) and spacer pads (1,16,41,046 Nos.) were QC cleared for PHWR fuel bundles.

QA-STP

- Qualification of Route for Manufacturing of Pressure Tubes by Double Radial Forging and Single Pilgering for 220 MWe KAPS 1 & 2 EMCCR Project and 11 No's PT were qualified UT , ET, PT and tested for dimensions.
- Trials were made for measuring pressure tube dimensions (ID & OD) by using existing ultrasonic testing unit and fabricated special standards of Wall Thickness and Outer Diameter for establishing the method for dimensional measurement of pressure tubes.
- Ultrasonic testing was carried out of 50 mm x 8 mm Zr-4 Fuel Blanks of 7615 No's and 5376 No's of Long length and Short Length blanks respectively on EEC Unit.
- Ultrasonic Testing of 63 mm x 11 mm Zr-4 Fuel Blanks of 1363 No's were performed on EEC Unit.
- Ultrasonic Testing and Pressure testing of 80 No's of 168 x 7.11 SS 304 Pipes done.

Quality Assurance- SSTP, MI&MT and Characterization Laboratory

Quality Assurance- SSTP

1. **Hydrostatic Pressure Testing of SS 304L pipes of 168.28mm OD x 7mm WT for IGCAR:**
   Hydrostatic pressure testing of SS 304L pipes of 168.28 mm dia. was carried out by modifying the existing Hydro test machine at STP to facilitate the testing of these larger diameter tubes. This large size tubes are tested in a hydrostatic testing system with specialised seals and end fittings for the first time. These tubes have been supplied to IGCAR for the PFBR fuel reprocessing application.

Hydrostatic testing machine for testing of SS 304L pipes of 168.28mm dia.

End-fitting for 168.28mm diameter

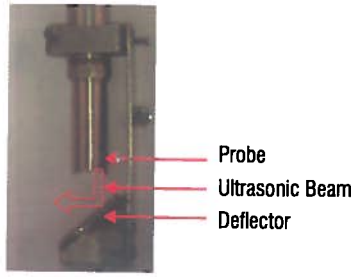
2. **Testing of Titanium-half alloy tubes supplied to VSSC for GSLV:**
   Titanium-half alloy tubes (25mm dia. x 1.4mm thickness) have the strategic application as structural tubes in GSLV. These tubes are ultrasonically tested and other tests like metallurgical, visual and dimensional inspection are carried out as per QAP and dispatched to VSSC.

Titanium-half alloy tubes of 25mm OD x 1.4mm WT

3. **Testing of SUPERNI-42 tubes of 6.9 mm OD x 0.3 mm WT:**
   Eddy Current Testing (ECT) of Superni-42 tubes of 6.9mm OD x 0.3mm WT has been carried out by using 0.3mm diameter through wall hole as the reference artificial defect. About 80 Nos (in length-categories of 0.4m, 0.6m, 1.0m, 1.1m), which are qualified with respect to ECT, Visual and dimensional, and other quality requirements, were dispatched to BARC for further tests.

4. **Ultrasonic Testing of larger diameter tubes (Φ88.9 mm &Φ114mm) at SSTP Tactic Machine:**
   Ultrasonic testing of larger diameter tubes was not possible with the earlier system and maximum testable size was limited to 60mm of tube outer diameter. This limitation was due to small test tank size which was unable to accommodate longer focal length (3") probes, which is mandatory to test larger sizes. Suitable deflector and probe-holder were fabricated to deflect the ultrasonic beam normal to the tube surface. Selection of suitable deflector-material of good acoustic compatibility and optimal positioning are important factors of consideration to accomplish the required sensitivity of ultrasonic testing. In-house-made deflectors and probe holders are used for present UT system.

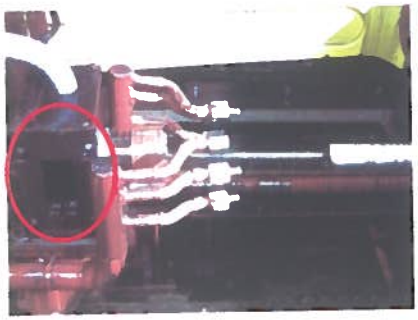
Tube and probe arrangement in UT-Test tank in the previous one



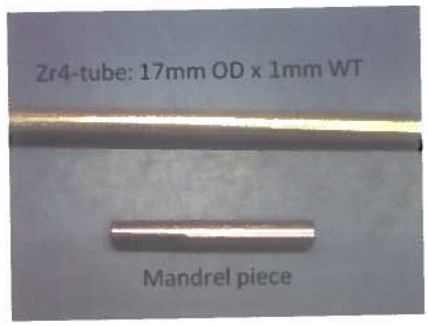
Probe arrangement with deflector

5. Development of broken mandrel detection system for Pilger mill:

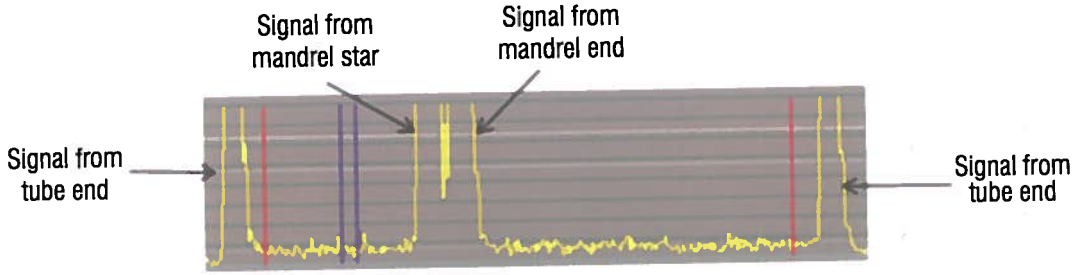
There was a requirement to detect mandrel breakage in Pilger Mill during processing in order to avoid any further abnormal damage to the machinery. This was accomplished based on Eddy Current Testing (ECT) System at QA (SSTP). The ECT has clearly indicated the end-signals of the broken mandrel-piece in zircaloy tube.



Mandrel break-detection system in New Danieli Pilger Mill at NZFP.



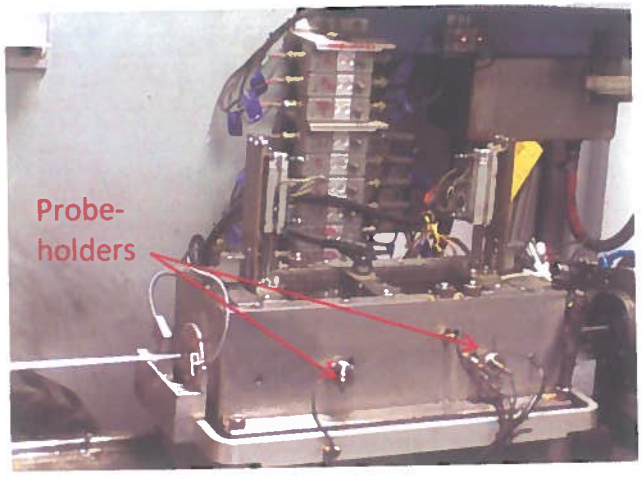
ECT arrangement made at QA (SSTP) using ECT coil with broken mandrel placed inside the Zr-4 tube



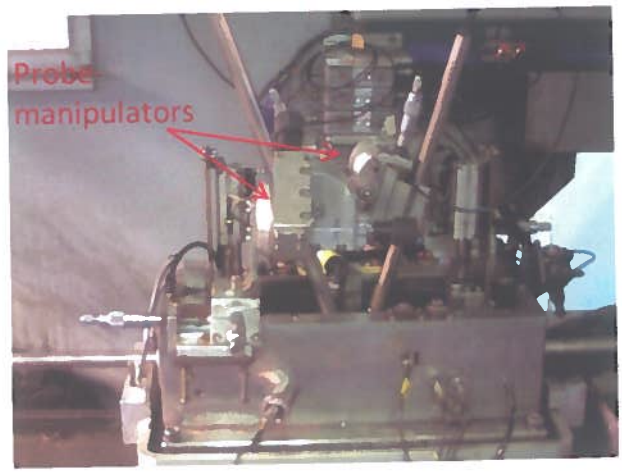
ECT result: starting and ending signals of mandrel-piece are clearly obtained. Similar arrangement can also be used for tube end detection.

6. Modification in FALLON UT system for UT of SS 304L tubes (21.34 mm OD x 2.77 mm WT):

In previous system, provision for angulation of the probes in transverse direction was limited to 19±3° and only Fallon made probes could be used. In the modified system, probe manipulators are incorporated, angulation for transverse probes was increased from 0 to 30°. Probes of any make could be used and oriented in desired angle and position.



Probe holders in the earlier system



Probe manipulators in the present system

Quality Assurance - Material Testing

Failure Analysis of PHWR Fuel Tubes Exhibiting Lower Total Circumferential Elongation (TCE): Studies have been carried out on 19 element fuel tube to understand the failure mechanism in samples with Low Total Circumferential elongation. Effect of various "material and test" parameters have been investigated.

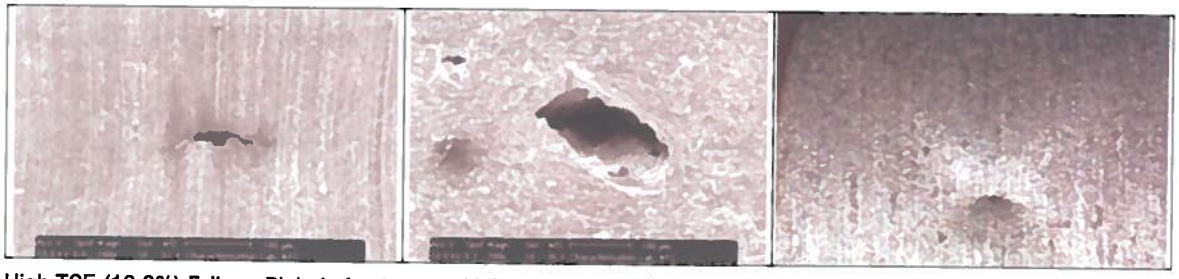
Material parameters	Test parameters
Wall thickness variation, pre-existing defects accepted in NDT test, Final material condition i.e. Stress Relived /Pilgered/annealed and Texture	Rate of pressurization, Stored Energy

Burst test is associated with 'pinhole' fracture or burst type fracture. Mostly low TCE is associated with 'pinhole" type fracture. Samples of high and Low TCE with 'pinhole' fracture after burst test have been observed under Stereo and scanning electron microscope for analysis and comparison. The presence of pre-existing external longitudinal defect was leading to Low TCE pinhole fracture.

SEM Images	Images from Stereo microscope
Wall thickness variation, pre-existing defects accepted in NDT test, Final material condition i.e. Stress Relived /Pilgered/annealed and Texture	Rate of pressurization, Stored Energy

SEM Images		Images from Stereo microscope
OD	ID	OD

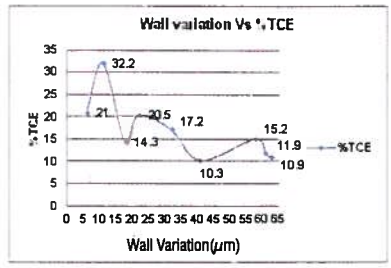
Low TCE(5.4%) Failure, stereo and SEM images showing pin hole due to pre-existing external longitudinal defect



High TCE (19.9%) Failure: Pinhole fracture multiple nucleation points and plastic deformation at Inner surface of the tube , which shows failure due to void nucleation and coalescences with plastic deformation.

Tube with externally attached particle exhibited low TCE of 1.9%

1. It is observed that wall thickness variation affects TCE.
2. Rate of pressurization in burst test has minor effect on TCE. Higher pressurization rate (higher strain rate) leads to low TCE
3. Stored energy of the system up to 270 J has no considerable effect on %TCE.



Pressure Tubes for Enmass Coolant Channel Replacement for 220 MWe PHWRs

Qualification of the pilot batch production from double radial forging- single extrusion and pilgering was done with respect to Tensile properties (room temperature and elevated temperature), hardness and corrosion tests. The properties were also characterized a) as-extruded b) extruded and stress relieved and c) final pilgered and autoclave stages. Tests were carried out on samples from both end of the tube to record the variation in properties.

Refurbishment of Autoclave unit for Corrosion Testing of Zircaloy Products

A 25 year old autoclave unit, which was not under operation due to failure of pressure fittings, has been rectified with the support of maintenance. All the attachments have been fabricated in-house. Hydrostatic pressure test has been performed which is mandatory as per pressure vessel code for safety and certification. Trial runs are successfully conducted.


Fittings fabricated in-house

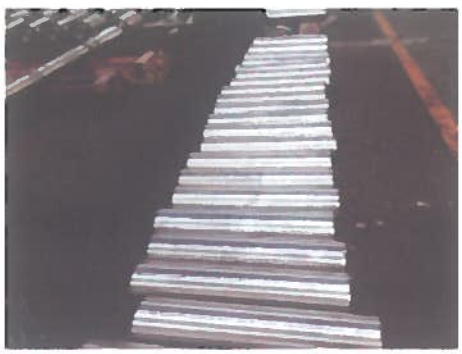
Material Inspection Section

- Inspection and testing of tool steel material: H-11 and H-12 required for extrusion/pilger mill mandrels and dies of ZFP/NZFP was carried out at supplier's place.
- Inspection of hardware for 1500 kg batch: Stage and final inspection of all the hardware like SS 310S Reduction Retort, SS 310S Vacuum Distillation Top and Bottom Retorts, SS 316Spacer, SS 317Top Closure for Reduction Retort, SS 316 Chloride Can, SS 316 Reduction Crucible etc., required for 1500 Kg zirconium sponge batch at Zirconium Complex, Pazhayakayal were carried out at fabricators place.


Spacer 1500 Kg Batch


Vacuum distillation retort 1500Kg batch

- Inspection and testing of around of SS 304L billets: nearly 400 Te of SS 304L billets of different diameter required for making corrosion resistant piping for FRFCF, IGCAR, Kalpakkam which includes macro and micro tests, corrosion tests, ultrasonic testing, chemical testing, dimensional and visual inspection was carried out at supplier's place.


SS 304 L Billets Being UT tested at supplier's site


SS 304 L Billets being visually and dimensionally inspected at supplier's site

- Inspection of 8.6 meters length, 500 mm ID & 16 mm thick SS 310S hot chamber (replacement) for Horizontal Vacuum Annealing Furnace required for annealing of zirconium fuel tubes and rods was carried out at fabricator's place including visual inspection, dimensional inspection, penetrant testing of welds, radiography evaluation of butt welds and document review.
- For the fresh fabrication of 'Vertical Vacuum Annealing Furnace (under "Revamping of Vertical Vacuum Annealing Furnace" project) required for annealing of calandria tubes, pressure tubes, sheet metal, fuel tubes etc, MI section coordinated with MZFG in the drafting and finalizing QA plans, review and approval NDT and other testing procedures. MI section reviewed the butt weld radiographs during fabrication.

SS 310S Hot Chamber for Horizontal Vacuum Annealing

Characterisation Laboratory

1. **Development of "electrolytic hydrogen charging" method for determination of hydride orientation in Zr 2.5%Nb alloy pressure tube samples.**

It is essential to have circumferential orientation of the hydrides in the pressure tubes. A new setup (Fig.1) was developed for this material using electrolytic hydrogen charging technique. Experimental trials have been carried out by varying process parameters, the required hydrogen charging have been achieved in these samples. The amount of hydrogen charged was confirmed through chemical analysis and formation of hydride platelets were observed through optical microscopy. The quantification of the orientation of the hydrides (Fig 2) were carried out using Image Analysis software, which shows in final autoclaved tubes circumferential hydrides are predominant in 700MWe and in recently developed 220MWe pressure tubes through modified single pass route (Fig 3).

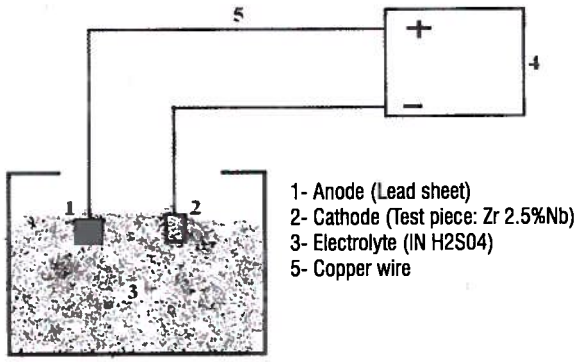


Fig1: Schematic diagram of Electrolytic Hydrogen charging

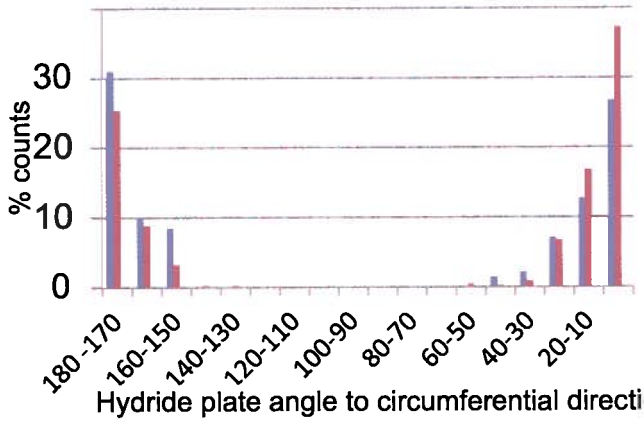


Fig.2 Histogram for hydride orientation using image analysis showing similar orientation in case of 700MWe and 220MWe

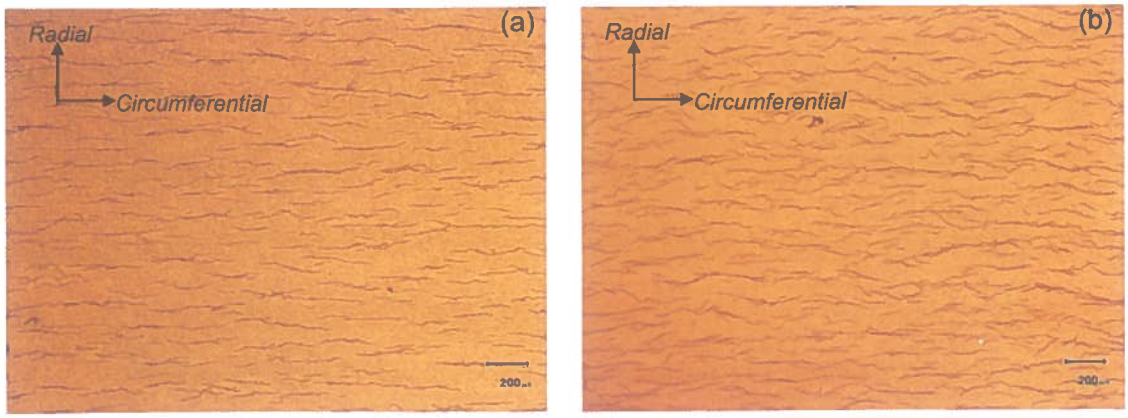


Fig.3 Optical images showing circumferential hydrides in (a) 700 MWe, (b) 220MWe pressure tubes

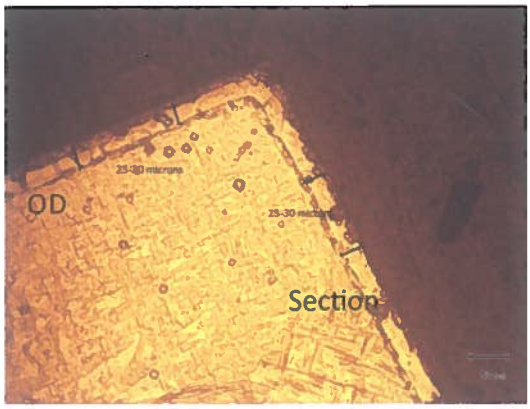
2. **Installation and commissioning of advanced X-Ray Diffractometer:**

Advanced X-ray Diffraction unit (Make- Rigaku, Model – Smartlab) from M/s I R technology, Mumbai has been installed and commissioned successfully. The advantages of this system includes (i) Universal goniometer which is capable of performing both Powder diffraction and Pole figure generation, (ii) Ultrafast and sensitive detector system which reduces the measurement time without compromising the accuracy, (iii) special theta-theta geometry allowing to carry out powder samples at higher diffraction angles

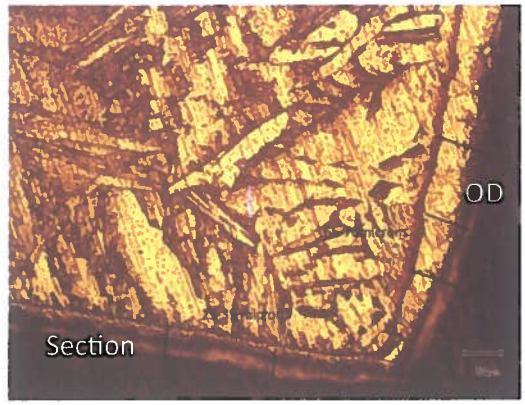
Advanced X-ray Diffraction unit
(Make- Rigaku, Model – Smartlab)

3. **Development of methodology for determination of Alpha casing in PT7M (Ti-Al-Zr alloy) tubes**

A method has been developed as per Russian standard procedure to analyse the alpha case layer in final PT7M tubes as the presence of this oxygen rich layer at surface effects the properties of the materials. In this method, tubes were heat treated at different temperatures followed by water quenching. The treated samples were metallographically polished and etched to observe the case layer on section and on OD. Difference in layer thickness on OD compared to section shows the actual alpha layer thickness. In case of both Imported tubes and NFC fabricated tubes, no alpha case layer has been observed. An experiment was carried out on a tube by deliberately creating an alpha layer and similar procedure was followed. It revealed the difference in layer thickness on OD side and on section side.



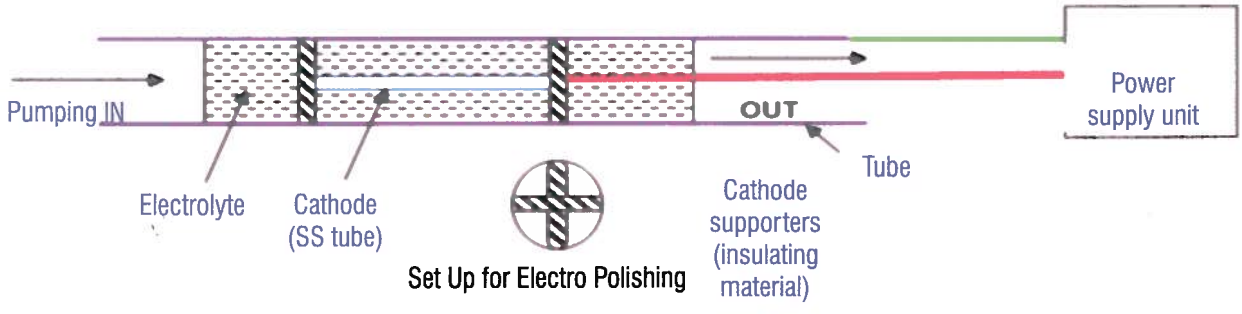
Metallograph (transverse section) showing similar alpha case thickness at OD and section after heat treatment which indicates absence of alpha case



Comparison of the alpha case layer on the fresh section and pre existing alpha case on OD

4. **Inner Diameter side polishing of SS321 tubes through electro polishing technique**

An experimental set up(Fig 1) was designed and brought in to operation for extremely challenging job of ID electro polishing of SS321 tubes. The ID surfaces of tubes were successively electro polished with optimized parameters of electrolyte, polishing voltage and time and current density. The anode probe was fabricated as per customized design to suit in to the ID size of the tubes. The technology was transferred to BARC, Mumbai for large scale application.



Set Up for Electro Polishing

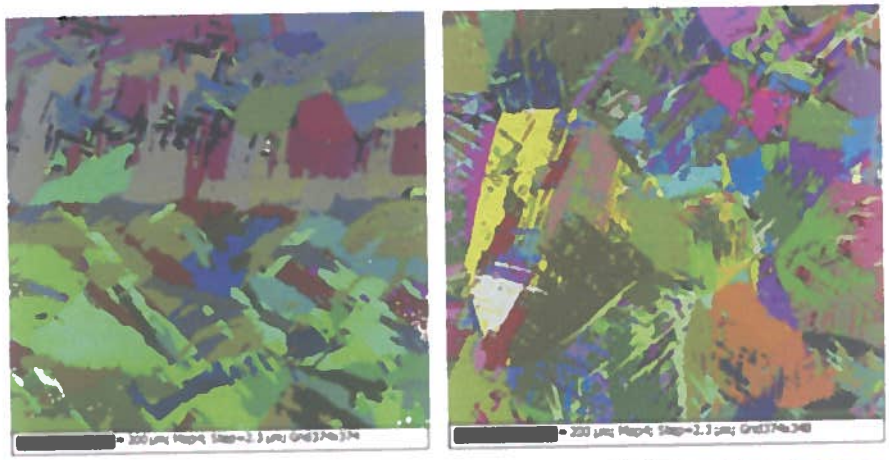
Before Electro polishing

After Electro polishing

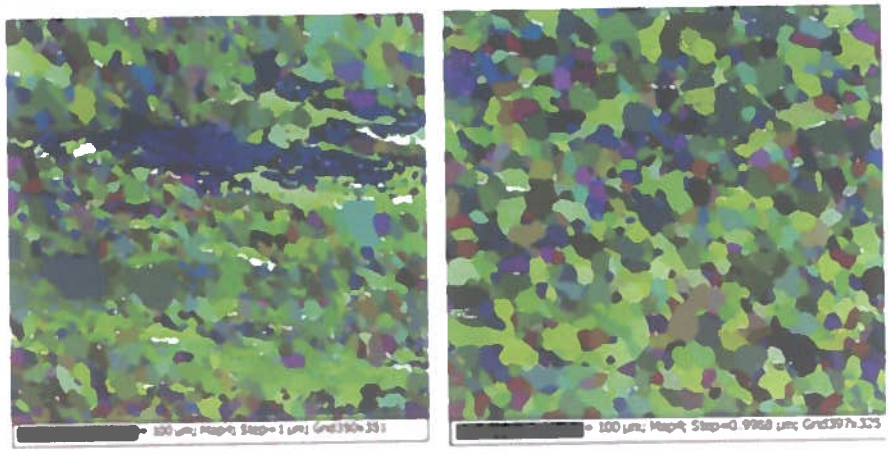
5. Study of Heat treatment behavior in Ti - Al- V alloy (PT 3B alloy) products:

A study has been taken up in indigenous fabricated tubes for achieving the similar metallurgical and mechanical properties of imported samples. Several heat treatments and quenching trials followed by EBSD characterization were conducted in this regard. For hot worked samples, heat treatment at 1000°C followed by Air cooling yielded the similar microstructure, hardness and mechanical properties to that of imported sample. For cold worked sample, heat treatment at 750°C followed by furnace cooling yielded the equiaxed uniform microstructure, hardness and also mechanical properties to that of imported sample.

EBSD mapping of hot worked PT 3B alloy
(a) Imported (b) Thermally treated Indigenous sample



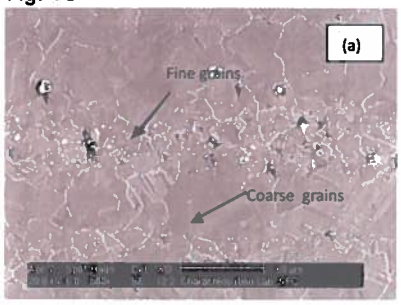
EBSD mapping of Cold worked PT 3B alloy (a) Imported sample (b) Thermally treated Indigenous Sample



6. Effect of heat treatment on microstructure of Superni42 alloy

(b)Heat treatment (HT) was carried out at different temperatures followed by water quenching for high nitrogen grade Superni42 tube and rods. Bands of fine Cr rich 2nd phases (Fig 10 a) were observed and after HT trials Samples treated at 1200°C showed dissolution of Cr rich 2nd phases in the matrix(Fig 10b). Random Ti rich precipitates were found in the samples. Non uniformity in grain size (Fig.11a) is observed in some samples. After different heat treatment trials at 1140 °C the grain size was observed to be fine and homogenous as shown in Fig.11b.

Fig. 10



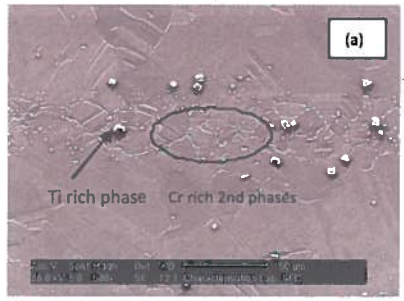
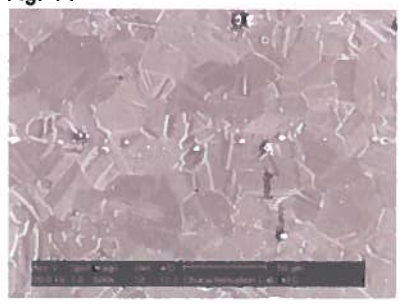


Fig. 11



7. Inclusion rating analysis in Superni42 alloy

InclusionsInclusion study was carried out in Superni42 billet sample of diameter 142 mm (high nitrogen grade). Inclusion rating was given following the Russian standard GOST1778-70. The inclusion rating from the as polished sample was carried out using optical microscopy and the rating was found to be HC-(1a; 0b) and HT-2 which is acceptable as per specification. SEM-EDS results showed presence of point and few line nitrides only. Duplex nitrides with Al-oxideFig. 12at core was found as shown in Fig.12 .

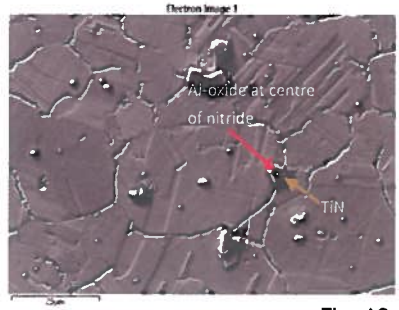
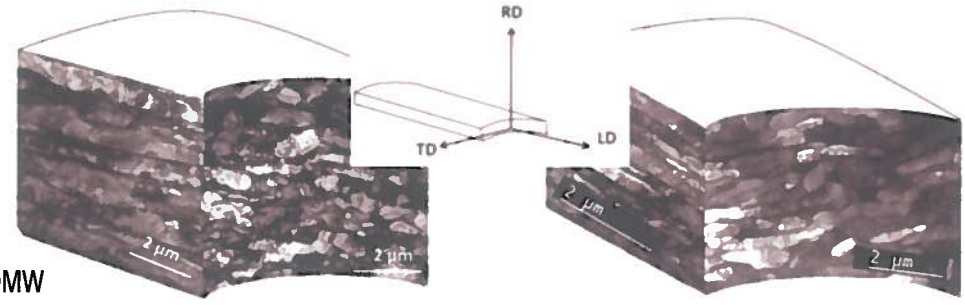


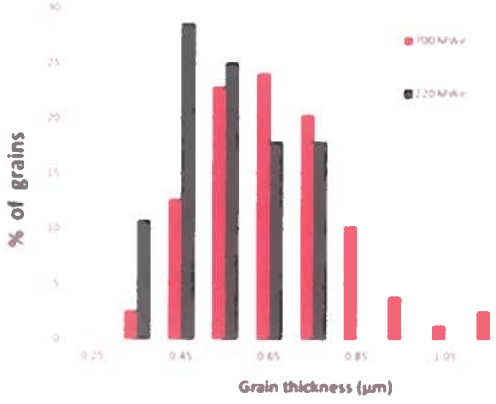
Fig. 12

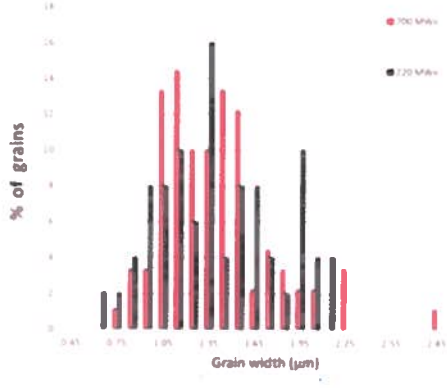
8. Microstructure Evaluation of 220 MWe Zr-2.5Nb pressure tube using TEM (Forged and single pass route)

Development of 220 MW pressure tubes by forged and single pass route was taken up for EMCCR. TEM samples were prepared from 700 MWe, and 220 MWe single pass (S.P.) pressure tubes in the as extruded and final autoclaved stage for both number and other end of the tubes. The width and thickness of elongated alpha grains were calculated from the transverse specimen images. The average width and thickness was taken for calculating aspect ratio and was compared. Fig 13 shows the isometric view of 700 MWe (Fig13.a) and 220 MWe(Fig.13b) using TEM images of transverse and longitudinal sections of final autoclaved tube. The thickness and width overlay comparison histograms shown in (c) and (d) respectively.



(a) 700MW (b) 220MW



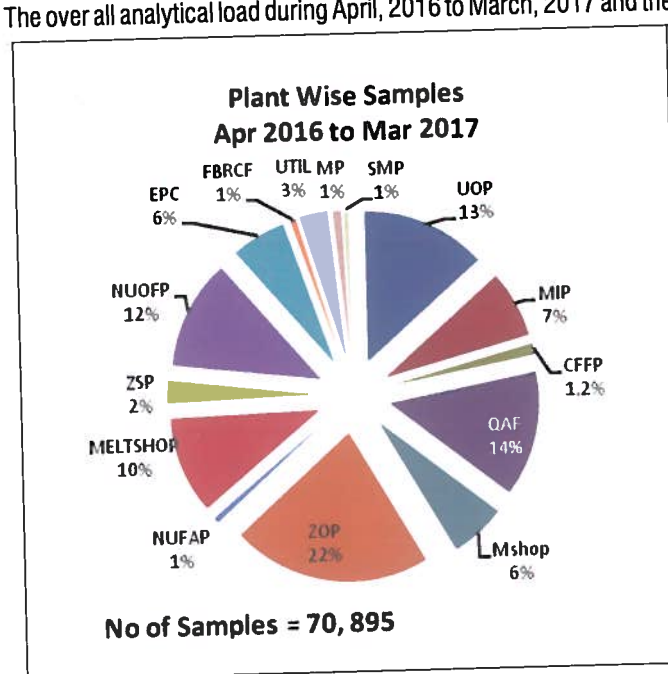


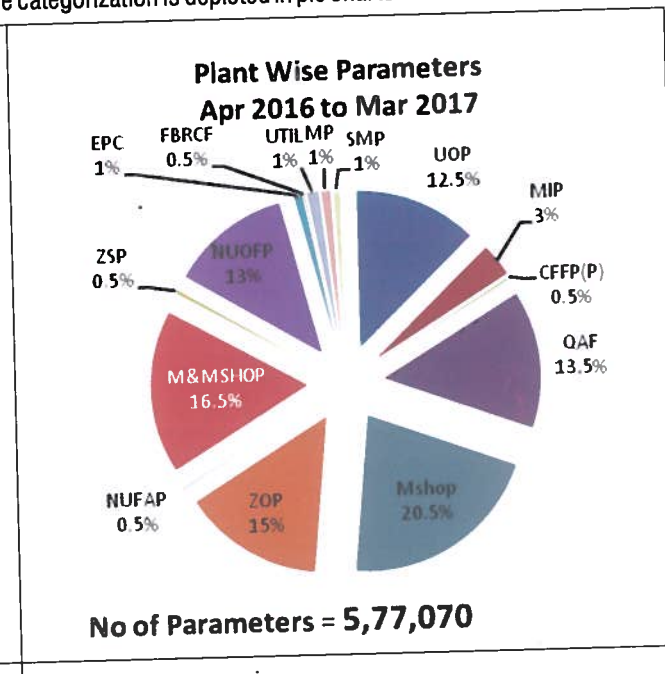
(c) Alpha Grain Thickness Fig. 13 (d) Alpha Grain Width

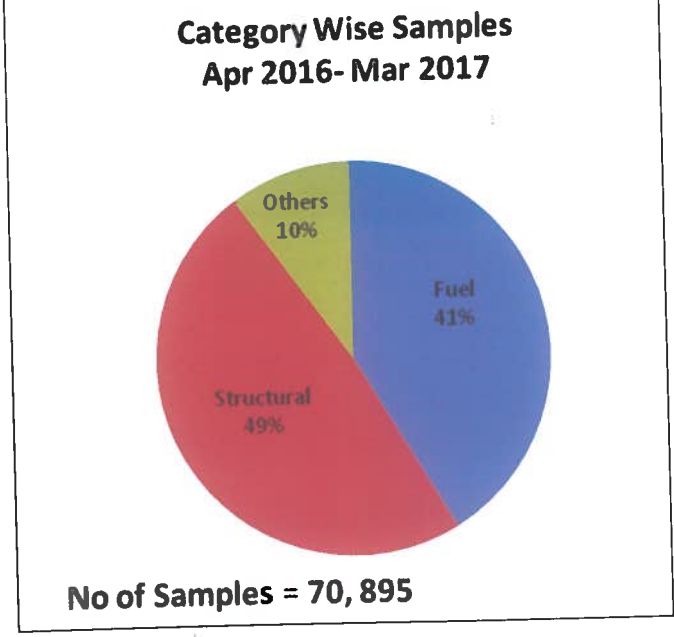
Control Laboratory

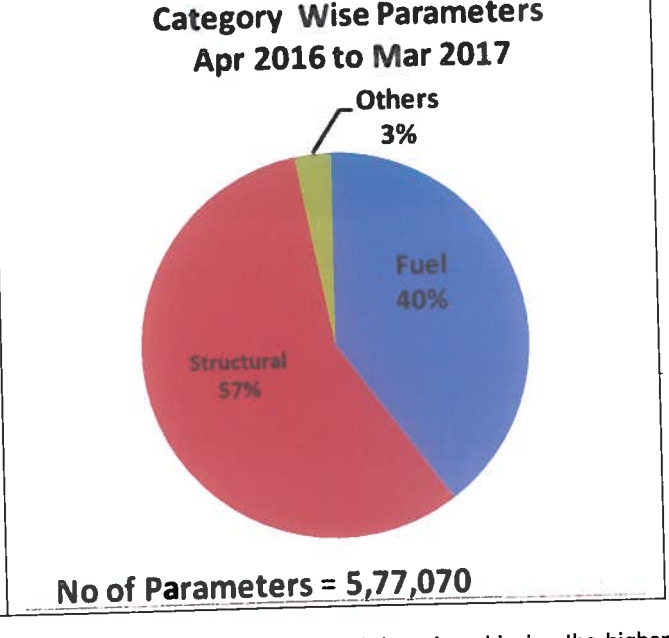
A. Gist of Analytical Activities:

As a centralized analytical facility annexed to an Industry, Control lab continued to play its important role of extending analytical back up to all plants including round-the- clock operating production plants during the period April, 2016 to March, 2017 as well. Analytical services include analysis of legitimate samples pertaining to those of requisite consumables and raw materials procured on tonnage scale, large quantities of process intermediates and finished products. The total analytical load in terms of samples received from various plants during April, 2016 to March, 2017 works out to be 70,895 involving determination of 5,77,070 analytical parameters. This analytical load could be categorized as those pertaining to nuclear fuel as 41%, structural as 49% and the balance as remaining. The over all analytical load during April, 2016 to March, 2017 and the categorization is depicted in pie charts as shown here.









Control lab excelled in providing the timely analytical support to the production plants and enabled them in achieving the higher production significantly more than the set target. This involved a concerted and focused effort from all the members of Control lab in solving the analytical challenges encountered during this period in a time bound manner.

(10) Titrimetry based analytical method was standardized to determine

- assay of sodium gluconate in line with IS 13014:1990
- content of N-NH4 in ammonium nitrate cake
- content of nitrate in a miscellaneous cake from EPC
- permanganate demand in water samples of Utilities

(11) A SS-304 sample cell holder used in XRFS instrument was fabricated in-house at NFC utilizing the services of Workshop, NFC

Different Views of In-house Fabricated SS Liquid Sample Holder of XRFS Instrument

(12) A multi tubular furnace having a provision of forced cooling was procured and this enabled sizeable reduction in analysis time of analysis of chlorine in Zr-2.5% Nb coolant tube material

(13) High pure copper anode required in Glow discharge Optical Emission Spectrometer(GD-OES) was fabricated in-house as an import substitute

(A) Imported Copper anode

(B) In-house fabricated Copper anode

Multi tubular furnace provided with forced cooling facility

(14) Gravimetry based analytical method was standardized to determine for simultaneous determination contents of active zirconium and assay of zirconium in pure nuclear grade zirconium metal powder

(15) Control lab participated in the Inter Laboratory Comparison Experimental (ILCE) study conducted by Atomic Minerals Directorate for Exploration & Research (AMD), Hyderabad for chemical characterization of Niobite-Tantalite sample

(B) Activities pertaining to Maintenance of Analytical Instruments

(1) Microcontroller based control unit for remote operation of chiller systemdistantly located to five LECO analyzers was designed and fabricated in-house for effective monitoring and control. The chiller was provided with the indication of the chiller parameters (Chiller ON/OFF, Coolant Temperature Low/High, Tank Level etc) using Touch Screen HMI.

Touch Screen HMI Display provided at Instrument Room Control Circuit Located Inside the Chiller Unit

(2) A 15 KVA, 3-Phase UPS system was procured as per the pre-installation requirement and installed at Characterization Lab to provide an uninterrupted operation of newly procured Advanced XRD instrument. A dedicated earth pit, UPS and Instrument wiring was provided.

(C) Activities pertaining to Library & Information Management Services

(1) As on March, 2017 Library has 6625 Books, 3000 Journals bound volumes and 1300 IS and other national and International standards

(2) Procured 31 Books including Gratis books and Renewed Annual subscription of 42 National and International journals as recommended by the Library Committee.

(3) International Nuclear Information System(INIS) from 1976 to 2012 bibliographic database on CD-ROM brought out by IAEA, Vienna which covers Nuclear Technology, Material Science and allied subjects is made available in the library

(4) Continued the accessibility of e-journals published by M/s.Elsevier, Singapore under DAE Consortium agreement through Sciencedirect.com for the year 2016-17 also.

(5) Scanned copies of the content pages of core journals and list of new arrival books and e-mailed the same to all users of the library

(6) Updated version of ASTM Specifications and ASME standards (Full text) were made available on NFC Web-server

(7) Equipped Library with Electronic Surveillance System (CCTV Camera) for effective monitoring of Reading Hall usage, movement of the Library Users and also prevent misuse & pilferages of Library books.

(8) Weeded out unbound old journals were distributed to concerned sections for their permanent retention and use.

Maintenance Fuels

Revamping of rotary tray dryer in UOP:

In order to enhance the drying capacity to match the increase in filtration rate from 1200 lph to 2000 lph additional heaters of 24kW were provided and heat losses were also reduced by adding thermal insulation. The damaged trays, tray supports, levelers & scrappers were also repaired and trays were aligned.

Modifications carried out in Solvent Extraction Section to Increase Capacity of UOP:

Slurry Extractor: Zero Settler modification, Fabrication & installation of additional Airlift stages, Feed entry at multiple stages, Stage 7 modification, Provision of pre-heating (using steam) of UN feed with temperature measurement & control.

Mixer Settler-I: Installation of Coalescers in all the 10 stages, provision of steam heating of DM water with temperature measurement & control.

Mixer Settler-II: Installation of a new DM water feed pump in place of gravity feed & implementation of associated instrumentation & control. Installation of Coalescers in all the 7 stages, provision of steam heating of DM water with temperature measurement & control.

These modifications have improved the Solvent Extraction Section output and helped in increasing the UO2 production from 60 Tons per month to 100 Tons per month.

Erection and Commissioning of 2 nos. of Sintering Furnaces at CFFP-P area:

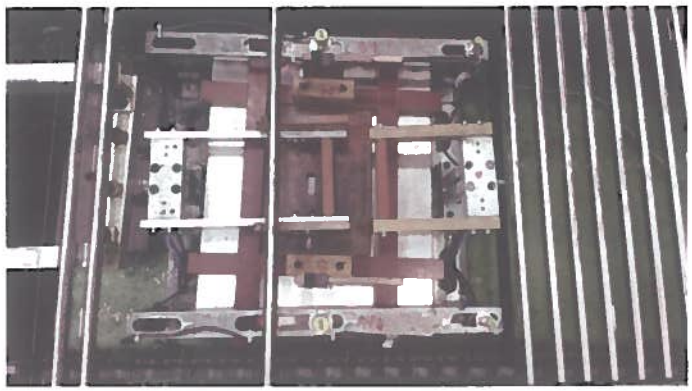
Two numbers of Sintering furnaces after being shifted from NUOFP-P area were erected and commissioned at CFFP-P. Various mechanical works were undertaken involving assembly of the different parts of the furnaces, fabrication, laying of piping for gases (Nitrogen, Hydrogen, Cracked Ammonia, LPG, Compressed Air), installation of gas panel and installation of return line, cooling water pumps along with associated piping etc. Electrical and Instrumentation works such as laying of cables from furnaces to control room, installation of heating elements & transformers, field sensors, instruments, erection of thyristor power panels, control desks & PLC panels, cold checking, testing and commissioning of operation sequences, interlocks, alarms and events were also taken up.

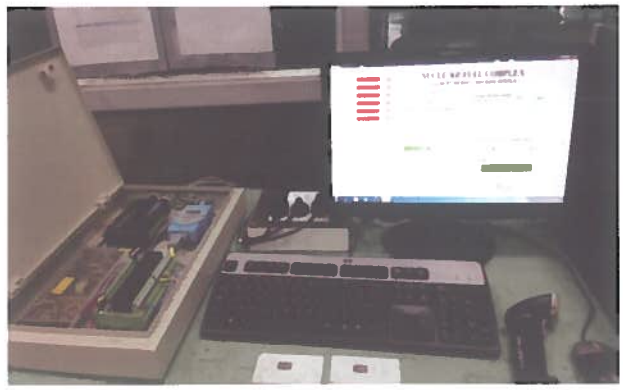
Automation of End Cap Welding machines along with auto cap feeders in CFFP(A):

Implementation of auto mode operations along with automatic cap feeder mechanism. New control panel, PLC logic, HMI, electrical and pneumatic system have been modified to suit the requirement. The modification resulted in improving operator's safety and comfort.

Element weighing mechanism in Double head turning machines in CFFP(A)

In house designed and fabricated PC based fuel element weighing mechanism for measuring the weight of individual elements with a facility for detecting missing pellets, if any, in the element. Necessary software was developed in-house which dynamically assigns the acceptable range for the weight of a fuel pin of the tray, based on the average weight of the fuel pins of that particular lot/tray which is retrieved from MAPDPS (Material Accounting and Production Data Processing System) to decide the acceptance or rejection of the fuel pin. A barcode reader is used for capturing the lot/tray number. The system is installed on the input conveyor of DHT machines with necessary material handling automation. The development has avoided manual weighing of elements to detect the missing pellets thus saving 4 to 5 man-days per day.



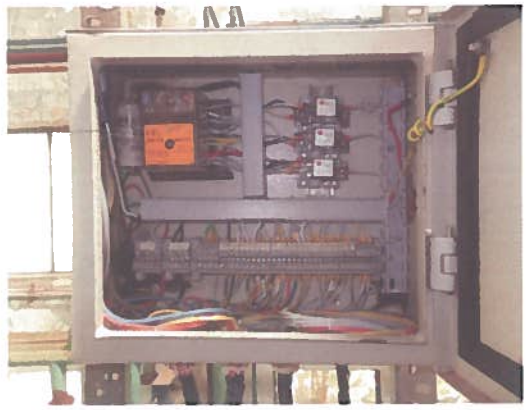


Modification of control system for Automatic Strength Testing Machine in CFFP(A):

A PLC & PC based control system with integrated HMI along with a new application software for data acquisition and processing has been developed in-house for the Automatic testing machine for evaluating the strength of appendage welds on empty fuel tubes. Modified system is provided with an HMI wherein movement of cylinders are graphically displayed for operators' convenience. Flexible user report generation is provided for convenience of the user group for further analysis.

REVAMPING OF INCINERATOR LPG BURNER CONTROL SYSTEM at NUOFP(P)

Incinerator burner control system consists of sequence controller and related hard wired logic to start the burner sequentially was successfully revamped to address the issue of frequent breakdowns because of old wiring, brittleness of wires and aging of contactors.



Revamping of Old Ammonia Cracker Panels at NUOFP(P):

Old Ammonia Cracker Panels whose components have become obsolete were giving rise to frequent breakdowns. To address these issues, in house revamping of complete panel was successfully carried out with improved electrical safety & control logic which resulted in increased availability.

Old Panel

New Panel

Safety light curtains installed on the End Cap Welding machines.

Modification of the End Cap Machines as per the safety committee recommendations in NUFAP:

All the ECW machines are modified as per the safety committee recommendations . To ensure operator safety light curtains were installed and their functionality included in the machine PLC program.

Installation of new controls for C and D head End Cap Welding machines in NUFAP:

Major modification were carried out in auto cap feed mechanism and element pushing mechanism. These machines were made compliant with safety committee recommendations.

New electrical & control panels were installed in place of obsolete panels. Both heads are separated into two machines and accordingly control systems were modified to suit the functionality.

Control Panel installed on C & D Head machines

C & D head machines isolated

RE-VAMPING OF VACUUM BAKING OVEN at NUFAP:

The PHWR fuel tubes are graphite coated on inner walls. The graphite coated tubes need to be heated at a temperature of around 350° C in vacuum of the order of 10^{-3} mbar. As production is being ramped up at NFC it was decided to revive one Vacuum Baking Oven that was not in operation for many years to support the existing Vacuum Baking Ovens. All the mechanical, electrical, control & instrumentation works were completed in short time period. System has been commissioned and production is being carried out and preliminary results are very encouraging.

Loading of the VBF-III furnace with class-B tubes.

Maintenance Zr & SMP

1. Revamping of Reduction Furnaces of ZSP:

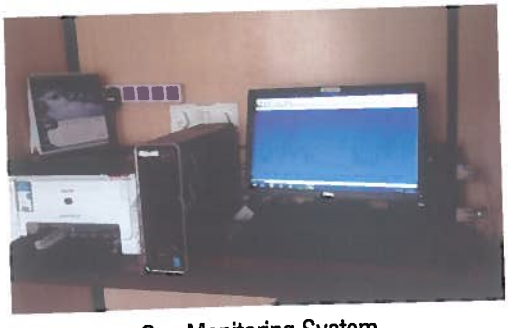
Furnace Terminations

Three Number of 400 kW Reduction Furnaces of ZSP have been completely revamped including replacement of heating elements and fiber insulation modules. The furnaces have rendered more than 10 years of service. Many insulation modules have been deformed and frequent electrical failures were observed in heating elements due to ageing and harsh environment. New Ni-Cr (80/20) strip heating elements were replaced in place of old ones and the fiber insulation modules with fixing hooks of all zones were also replaced. This has improved availability of the furnaces.

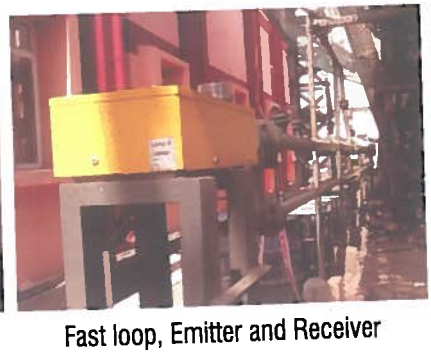
Inside Furnace View

2. Online Chlorine gas analyser for ZSP:

Continuous Emission Monitoring System (CEMS) based on state-of-the-art technology has been provided with Online Chlorine gas analyser and a 10 meter fast loop to detect chlorine gas concentration as low as 1 mg/m^3 in the stack discharges of ZSP. The analyser works on Differential Optical Absorption Spectroscopy in the Ultra Violet range (UV-DOAS) and is not subjected to cross interference. The unit has been commissioned and put in operation.



Gas Monitoring System



Fast loop, Emitter and Receiver

Online Chlorine gas Analyser

3. Indigenization of 6 new Mechanical Vacuum Pumps for ZSP:

Six new mechanical vacuum pumps were assembled in-house by MZG from the indigenized spare components. These pumps were tested for ultimate vacuum level and after satisfactory performance these pumps were handed over to the plant. Two of the assembled vacuum pumps were also supplied to ZC, Pazhayakayal for vacuum distillation unit of 1.5 T Sponge batch. These in-house developed pumps have helped in substantial saving of foreign exchange.

Mechanical Vacuum Pump

Maintenance ZFP

Development and Commissioning of PLC & SCADA System for Vacuum Annealing and Quenching Furnace at ZFP

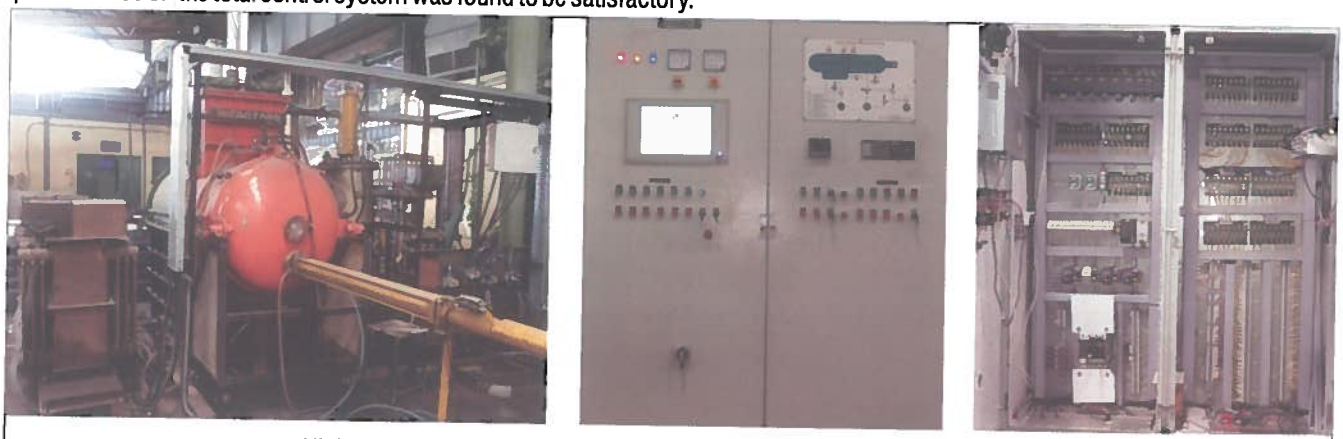
High temperature Annealing and Quenching Furnace is a critical unit for making several components of reactivity mechanism at ZFP. The Furnace control system was based on relay logic which was obsolete, due to which the machine downtime was high during breakdowns as the spares and proper documentation were not available.

Based on the above, it was decided to replace the existing control system with a new Siemens make PLC control system.

Total Development right from the PLC panel wiring, associated functional modules testing and the PLC Program for the control of Vacuum Annealing and Quenching Furnace was done IN-HOUSE. the system was commissioned at ZFP with minimum shut down time and it is running successfully till date.

The furnace was tested for both hot and cold trials. The furnace parameters like temperature and vacuum were controlled and tested for operational and safety interlocks. Furnace related operator friendly mimics/screens were integrated in a industrial panel PC with suitable interfaces . It displays all the PLC I/O status, vacuum and temperature actual values and data logging, alarms of the Annealing and quenching operational logic in the different operator friendly screens, which helps the operator in easy and trouble free operation.

Furnace trials were taken for different job profiles and ten such job profiles are already created in the PLC software so that operator can just enter job number to follow the temperature settings. The PLC/PID loop was tuned to give the temperature accuracy of +/-1°C. The performance of the total control system was found to be satisfactory.



High temperature Annealing and Quenching Furnace and control system

Automation of Cut-Tube Polishing Machine/Tube Straightening Machine for Loading/Unloading Operation

Tube straightening machine and Cut-Tube Polishing machine at ZFP are important and critical machines used for straightening operation of fuel tubes and Polishing the fuel Cut-tubes for both 19e and 37e. The existing system requires two operators, one operator for loading of fuel tubes/Cut-tubes and other for unloading of fuel tubes/ Cut-tubes per shift for straightening and polishing the tubes due to manual operation of loading and unloading stations.

Hence it was decided to develop loading and unloading stations for fuel tubes/ Cut-tubes handling and its automation with necessary VFD, sensors, rollers and actuators.

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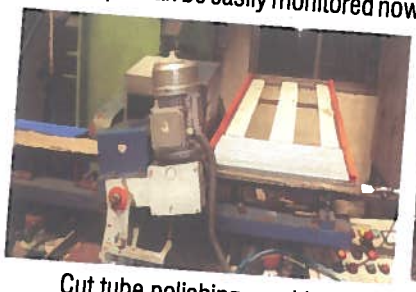
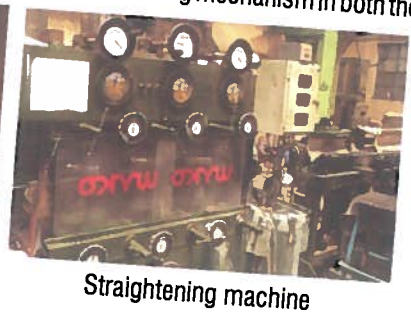
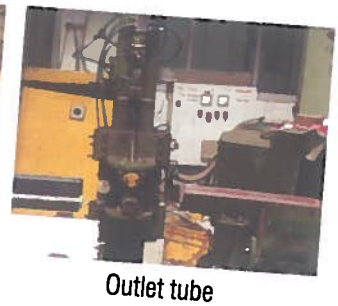
The development facilitated the following:

- Reduced the fuel tubes/ Cut-tube handling marks by the operator and hence improves the quality.
- Instead of two operators per shift only one operator could operate the machine thus reducing the manpower.
- Due to automation, the production rate has been increased considerably.
- In the straightening machine rollers force measurement has been successfully implemented.
- Each shift output can be easily monitored now by Tube counting mechanism in both the machines.


Cut tube polishing machine


Straightening machine


Outlet tube

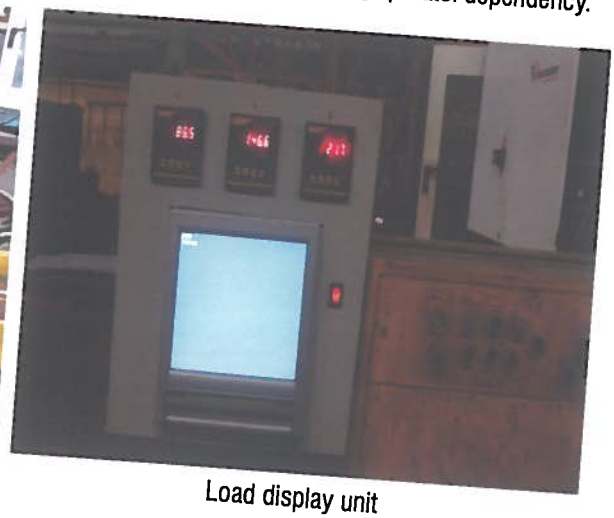
Design and Installation of Force Measurement System And Cast Nylon Rollers In Tube Straightening Machine at ZFP

To reduce rejection of Superni tubes due to residual stresses after straightening operation and to achieve optimal mechanic properties load measuring system and Cast Nylon (Anumide-115) rollers are introduced in the Straightening machine to rectify th above problem so that tubes qualify for Eddy current test. To install the required system (i.e. 3 x 150 Kg load cells) the upper roll housings, Ram, lead screw, Studs & Rollers were modified to house set of 3 load cells into one unit.

Three such assemblies were made and inserted between top rollers and Ram base so that load is directly experienced by these loa cells when tube is passing through the rollers. Individual display units with recorder have been provided to monitor load acting in eacl stage of rollers so that operator can adjust the force requirement for variety of tubes.

This system has helped in optimizing the straightening parameters with uniform set load. This development has resulted in optimizing parameters for final size BWR Autoclaved Tubes, Reactivity Mechanism Tubes & D9 Tubes by minimizing operator dependency.


Straightening machine with new rollers


Load display unit

Design and Fabrication of Furnace for Heat Treatment of Super Ni tubes at EPP:

Heat treatment of Super Ni rods as well as tubes of higher diameters are being carried out in Vertical Resistance Heating Furnace in inert atmosphere. The existing resistance furnace was designed for 1150° C and lower diameters and length tubes and rods. However, heat treatment temperature based on diameter of material was varying from 1150° C to 1180°C. Thus, frequent failures of heating elements were observed. The temperature uniformity which is one of the most critical parameter for heat treatment of Super Ni was also affected by these failures. Since no other furnace operating at this temperature range with quenching facility was available in NFC, it was decided to design and fabricate the furnace within NFC. Accordingly, 30KW, 3 zones, 1200°C, Vertical


1200°c, Inert atmosphere resistance heating furnace

Resistance heating furnace having SiC heating elements was designed and fabricated. The furnace has hot zone of 250 mm dia x 3mtr long and can achieve temperature uniformity of within +/-4°C. The furnace was fabricated in shortest possible time of 1 month. The heat treatment of various Super Ni tubes as well as rods was carried out and all the metallurgical properties were achieved. No failures of heating elements are observed after the work.

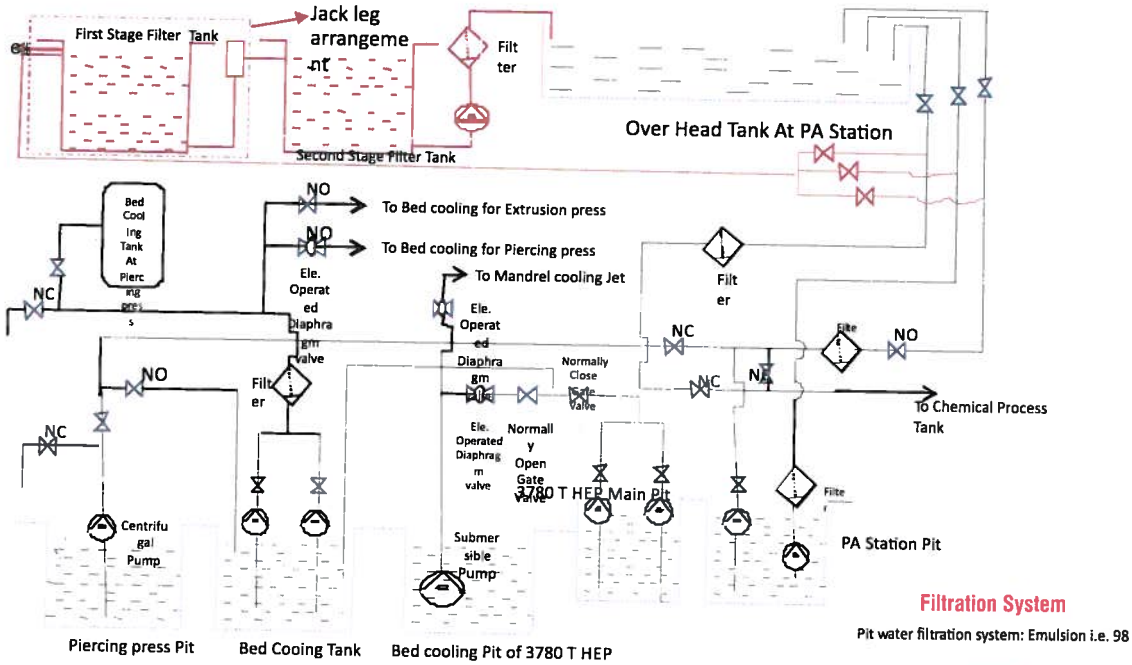
Fabrication of Quenching system for improving the quenching rate of high temperature vacuum heating and quenching furnace at EPP:

Super Ni tubes below 40mm OD were heat treated in high temperature vacuum heating and quenching furnace. Heat treatment requires heating of tubes to 1150°C for few minutes followed by fast quenching. The quenching system is designed for cooling rate of 200°C/min with the help of Argon. However, after heat treatment at 1150°C followed by quenching at 200°C/min, it was observed that the cooling rate was not sufficient and precipitates were observed in the microstructure of heat treated tube. After experiments, it was concluded that cooling rate can be increased by increasing the rate of heat removal from the Argon gas. Accordingly, a system was fabricated to decrease the temperature of cooling water flowing through the primary as well as secondary heat exchanger used for removal of heat of re-circulating argon to 10°C.

After the work, trials were taken on the tubes and it was observed that quenching rate achieved was better than 350°C/min and desirable properties of the tubes were achieved.

Quenching System

Fabrication of Furnace and vacuum de-gassing of double clad billets: It was decided to manufacture double clad tube of Zr4 & Zr-Sn for fuel bundle for PHWR. De-gassing of the billets is required to be carried out for proper metallurgical bond of the two material in the extruded blank. Accordingly, existing furnace was modified to suit the requirement. The de-gassing of the billets of dia 150mm and length varying from 350 mm to 500 mm was carried out at 400o C & Vacuum level better than 10-5 mbar. After successful de-gassing of the billets, the same were handed over for extrusion. Microstructure of the extruded banks revealed proper metallurgical bonding between the two materials. 98% DM Water with 2% cutting oil is used as working fluid for operation of various high pressure presses at EPP. This emulsion is used in closed loop and any leakages are also pumped back into the system. Heavy lube oil and impurities were observed in overhead tanks used for storage of this emulsion. After detailed examination, it was felt that main source of contamination for the emulsion is re-circulation of leaked emulsion. Accordingly, a filtration system consisting of Jackleg tank, intermediate settling tank and mechanical filters were used in series. The system has a through put of 200 lpm and filtering to level of 25 microns. Jackleg tank also allows effective removal of lube oil from the system. The filtration system has been implemented for pit emulsion collection system successfully.



Filtration System

Pit water filtration system: Emulsion i.e. 98

Maintenance Tube Plants

Maintenance (SSTP)

1. Revamping of refractory and drive system of LPG fired Air Annealing Furnace at SSTP:

The furnace is used for air annealing of tubes of various sizes. The furnace has been under operation for more than three decades and has been identified as 'critical for production'. Recurrent issues of excessive load on motor & drive chain failure were observed. With such issues furnace could not be operated which had direct impact on the monthly targets and processing of SS304L order from IGCAR. To address all issues, major revamping of the furnace was carried out. The revamping was categorized in two major section viz. Rectification and Modification. Following are the major jobs executed:

A) Rectification

A.1) Rectification of the furnace brick lining & replacement of rollers refractory bricks,
A.2) Replacement of drive rollers, leveling and alignment of rollers and roller refractory,
A.3) Alignment of sprockets and rectification of issues in drive system,
A.4) Replacement of LPG burner refractory blocks and repair of valves for air-supply.

Salient features of Rectification works:

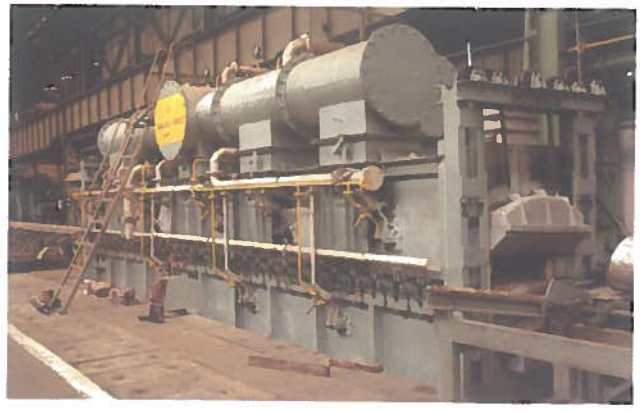
- ✓ Dismantling of rollers (33 nos.), plates (66 nos.), bearings & bearing housings (66 nos.), sprockets & Al-Bronze bushes (33 nos.), flanges for burners (51 nos.), roller half bricks (132 nos.), chain of 24 m length, LPG burners (17 nos.), refractory burner blocks (17 nos.) and over 700 bolts,
- ✓ Cleaning of refractory in the furnace, bearing housings, LPG burners,
- ✓ Removal of old and damaged brick lining, repair of brick walls above & below the rollers with new bricks across the length of the furnace and leveling,
- ✓ Dismantling of LPG burners and damaged LPG refractory burner blocks and assembling with new burner refractory blocks,
- ✓ Dismantling of valves for air, repair and re-adjustment for complete opening/closing of valves,
- ✓ Fabrication of gaskets for burners of various sizes (48 nos.), keys (33 nos.), modified burner glasses (50 nos.), end fixtures (15 nos.), Wing nuts (25 nos) and L-bolts for locking burner blocks (50 nos)

B) Modifications

In view of the shutdown of the furnace, following modifications were executed in order to avoid shutdown of the furnace for these jobs, in future.

B.1) Modified sprockets system and Chain Tensioners,
B.2) Modified drive system for Tube inlet and outlet,
B.3) Modification of Water Quench Chamber,
B.4) Fabrication of Suction pipelines for Water pumps.

The work of this large scale was carried out first time for the furnace and this exercise has resulted in drastic reduction in load on drive system and smooth and uninterrupted operation of the furnace.



LPG Air Annealing Furnace

2. Revamping of single girder EOT crane hoists in degreasing section of SSTP:

Retrofitting of hoists for two numbers of single girder EOT cranes was carried out. This resulted in standardization of CT motors, hoists motors, brakes, power circuit panels, switchgear and wiring for all the single girder cranes in SSTP. Newly commissioned hoists and control panels have resulted in (i) reduced inventory, (ii) easy trouble shooting and maintenance. Also, additional interlocks such as gravity limit switches which were not present in the previous hoist were added to increase the safety of the system.

3. **New control panel for 3/3 straightening machine at SSTP:**

The control panel and control desk were 4 decade old. All the switch gear used in the panel were old and obsolete. The roller motors are dual cage squirrel cage induction motors and the switchgear and control gear were for 3 speed operation. In view of the introduction of VFD, most of the circuit was modified. The control panels for motors and VFD were different and taking more space of shop floor. To cater for all the above problems, a new control panel and control desk were installed and commissioned. The modified panel possess the following advantages

i) Control voltage changed to 24V DC against earlier 230 V AC, making operations more safe.

ii) Most of the unused and unwanted pushbuttons eliminated from the control desk and layout was also changed for providing ease of operation.

iii) The unwanted junction boxes and cables with joints were removed and new cables were laid rendering more reliable operation.

iv) Additional protection features, such as single phasing prevention, provided to all the three phase motors.

v) Reduced space occupancy in the shop floor and increased IP of control panel.

The machine is running satisfactory with new panel.

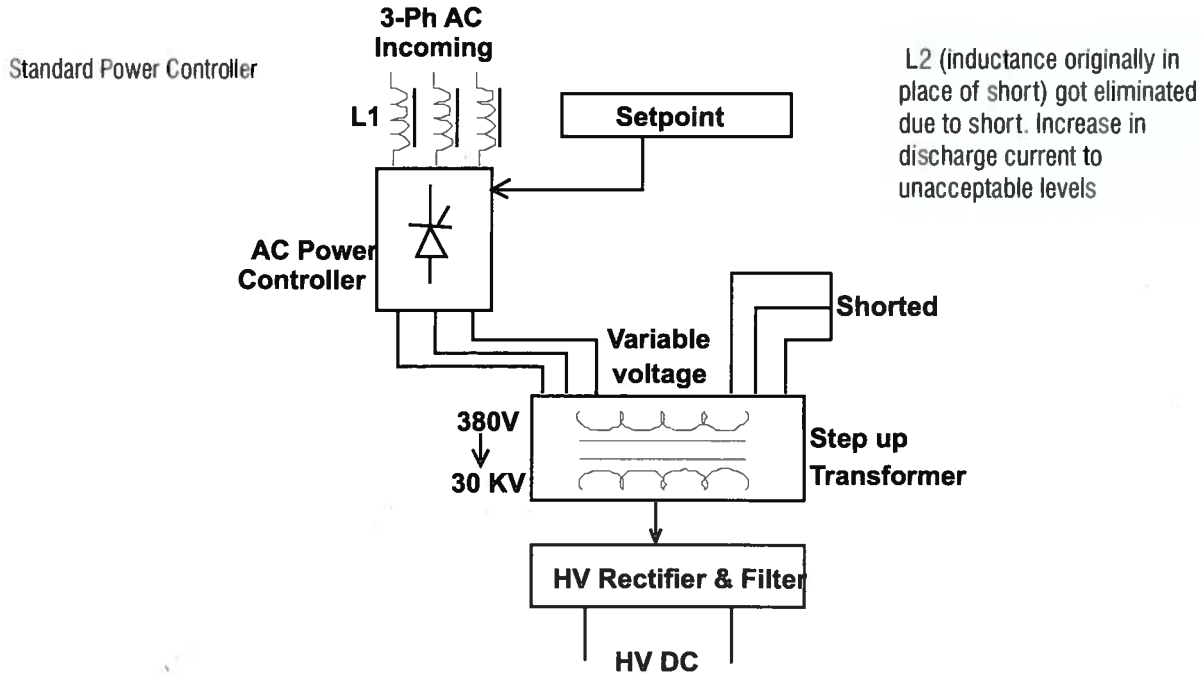
IMS [ST, ML & QA (T)]

Modification of HV generation topology, studies and optimization in EBW-3 at NMS

Electron Beam Welding (EBW-3) machine at New Melt Shop is utilized for EB welding of zircalloy compacts, in a vacuum atmosphere, to prepare consumable electrodes for subsequent vacuum arc remelting process. Topology of high voltage DC source of the equipment was recently modified enabling indigenization & standardization. Previously existing HV generation topology, challenges, modified topology and the studies taken up during the modification process, are briefly discussed in following sections:

1. **Challenges with existing system:** The topology used to vary the voltage across primary of step up transformer was a customized and proprietary solution, with no circuit diagrams for troubleshooting and no spares available. In case of breakdown the repair period might run into weeks due to these limitations.

2. **Modification of topology:** An alternative approach was envisaged to vary the voltage across primary of step up transformer. To implement the idea, a commercially available standard AC power controller was used to generate variable AC voltage, fed into transformer, while shorting the terminals to form a star point, where otherwise current limiting chokes were connected erstwhile.



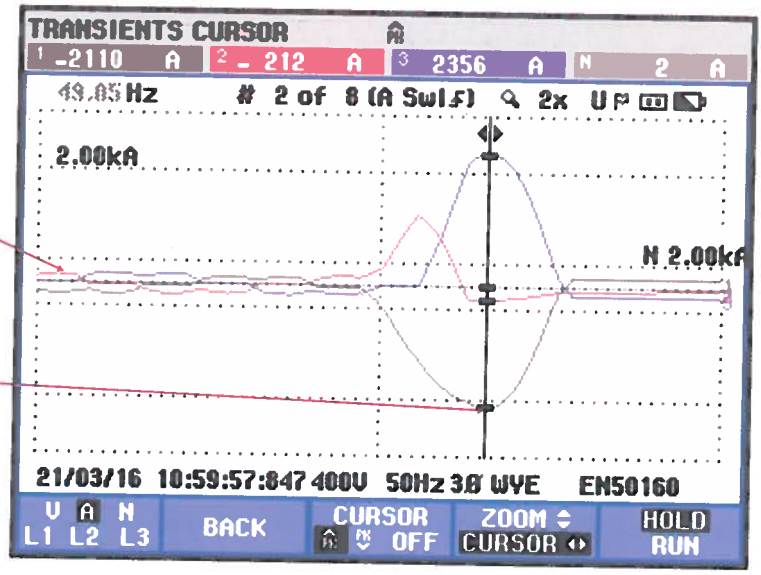
HV Generation Topology - Modified

This, however, introduced a problem of increase in discharge current as current limiting inductor L2 got eliminated.

3. **Discharge Current Phenomena:** Ionization of gases & vapor of volatile elements (released from work-piece during welding) in presence of high accelerating voltage in vacuum, resulting in HV breakdown and consequent sharp rise of welding current to very high levels.

Normal welding current

Discharge event - peak instantaneous currents of 2.3 KA are observed, against rated current of 200 amps.



Primary current of step up transformer

The challenge of limiting discharge current peak and its duration was successfully met by selection & installation of inductor and by programming the controller to trip immediate after detection of discharge.

4. **The Efforts:** Teams from both Instrumentation & Electrical maintenance have relentlessly pursued the indigenization for quite a long period spanning about eight months. In the process, a variety of problems were encountered but eventually solved. Trials were taken on tens of batches and results were compiled, studied and conclusions were drawn.

5. **Conclusion:** The modified power scheme is in operation since about four months and giving satisfactory performance. This effort has resulted in key benefits of:
   i. Indigenization of imported power supply.
   ii. Use of Standard power controller.
   iii. Cost effectiveness. (new supply costs about 50 lakhs)
   iv. Digital technology, as against old analog converter, facilitating almost immediate diagnosis.
   v. Industrial communication, enabling interfacing with SCADA and portraying all important parameters to operator with data logging and report generation.

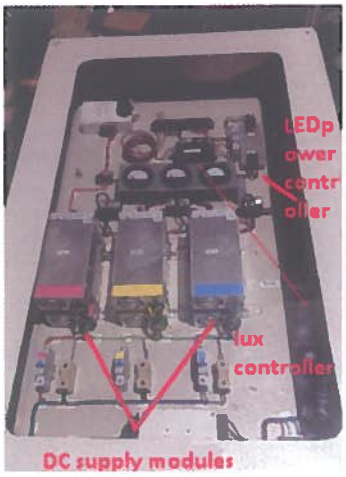
Maintenance Meltshop

Implementation of DC bus LED lighting in New Meltshop

High bay lighting in New Meltshop has been modified by installing 150W DC bus LEDs with auto dimming system utilizing day light harvesting technique.

Key Benefits:

- LED fixtures are fed by centralised DC power supply of modular structure, mounted at ground level, with hot stand-by module, which makes it highly reliable and maintenance friendly.
- Long Life, usually 10-15 years , due to driverless design results in reduction of high bay activities giving following benefits: 1. Low high bay maintenance cost, 2. Improved safety 3.Least interruption of production activities as EOT cranes are not engaged for light fixture replacement, 4. Uniform lighting , which is affected due to usual long delay in replacement.
- It also results in reduction for lighting inventory and consumables, scrap generation.
- Energy saving: Energy saving of 65700 units per year , costing Rs 394200/- due to inherent high efficacy of LED lights. beside additional saving due to auto dimming feature depending on presence of day light.
- Better visibility: Due to high CRI, visibility is much better than HPMV lamp and conventional LED



DC power supply at ground level

LED lights mounted in the bay

"Installation of turbomolecular pump based high vacuum system for the cathode chamber of Electron Beam Welding (EBW-III) unit"

Description of the equipment : EBW-III unit at New Meltshop is used for preparation of consumable electrodes from Zirconium (Zr) sponge compacts and from machined ingots by electron beam welding technique.

The equipment consists of the following major components:-

i. Weld chamber.
ii. Electron beam (EB) gun, which consists of Cathode chamber(CC) & Intermediate chamber (IC)
iii. Vacuum system of weld chamber & gun chamber
iv. High voltage power supply for EB gun, its associated electronic & instrumentation controls and power supply for auxiliary operations
v. Control room with view port, control desk & cabinet.

New vacuum system with Turbo molecular pump for cathode chamber

Work carried out :- A high vacuum system utilizing a Turbomolecular pump (TMP) backed by a suitable two stage oil sealed rotary vane pumps was proposed for the CC as a replacement for the existing DP because the TMP doesn't employ oil for its working, hence chamber will be free from oil contamination. Accordingly a TMP of 700 LPS capacity & a vane pump of 20 m3/hr capacity was selected as an alternative. Power cables were laid & new contactors were arranged. The TMP along with the gate valve & the back up vane pump were installed on the EB gun with all the required modifications like S.S "I" adaptors with ports for connecting vacuum gauges, S.S flexible bellows for TMP to fore pump connection. The gate valve is used for automatic connection of TMP with cathode chamber and for safe isolation of TMP during pressure rise in cathode chamber. With the new system in place, frequent tripping of gun have reducped greatly & Ultimate vacuum of 10-6mbar was achieved in the cathode chamber. The life of gun components is expected to increase greatly.

Utilities

1. New DM Water Plant

The peak demand of DM plant from the production plants has gone up to200 m^3/day from 90m^3/day with increased production targets of NFC. In order to augment the production capacity of DM water , a new DM Plant with 20 m^3/h and 200 m^3OBR has been procured , installed and commissioned successfully, under the XII plan RAUITC project. The plant consists of a Multigrade Sand Filter, Activated Carbon Filter, Strong Acid Cation Exchanger, Degasser, Strong Base Anion Exchanger and two Mixed Beds. After 20 cycles of satisfactory performance, plant is put into continuous operation.

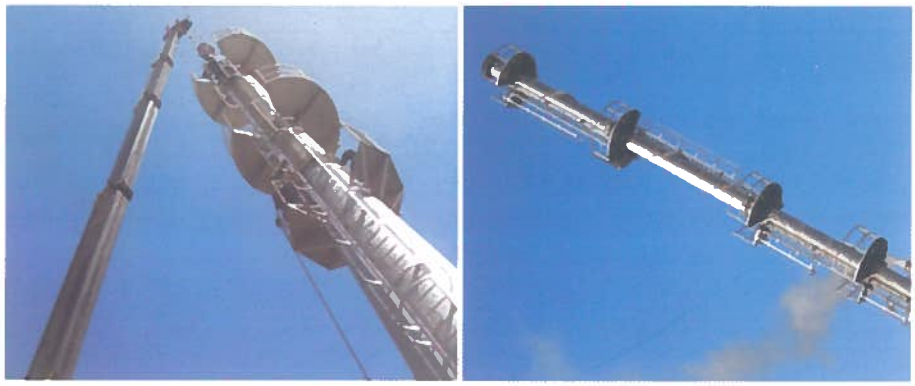
View of the new DM plant

2) Cooling Water Return Line

Cooling water return lines in fuel plants were laid about 30 years ago and transfer the return water to the cooling towers by gravity. Due to augmented production facilities in the plants, the demand for cooling water consumption has gone up over the years. This has resulted inoverflowing at cooling water return inletfunnel constantly due to overload. Under XIIth plan RAUITC project, a separate Return water header (350 NB line) from CFFP funnel to PH2 was laid and commissioned successfully.

3) Replacement of Boiler Chimney at Service Building

The Mild Steel Chimney of about 35 m height and diameter 1.8 m at bottom and 0.75 m at the top located at service building Boiler House was erected in 2003. The chimney appeared to be shaking in heavy winds. Upon thorough inspection of the chimney, it was found that there is loss of its material thickness up to 30% at few locations. It has been decided to replace the 3 portions of the chimney as the base portion was found to be in healthy condition. The dismantling of the old chimney and erection of new one is a risk involved job due to the hazards present at work at height. Two heavy duty hydraulic lifters have been used for the execution of the job and safety precautions are followed meticulously at every stage and the job is completed successfully.



Pictures of chimney erection

4) Utilities – Central Control Room

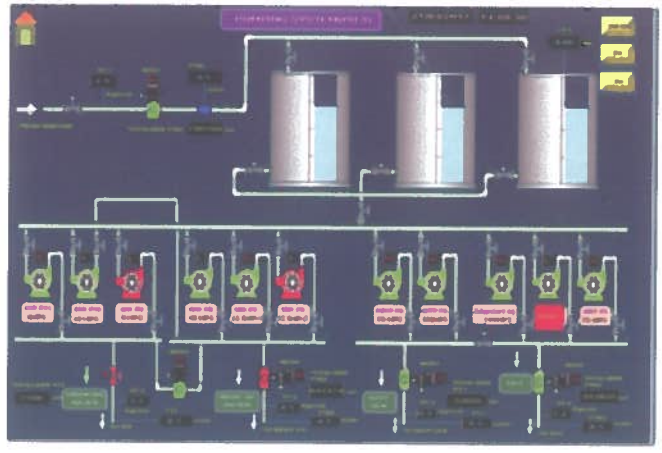
Utilities plant is involved in supply of municipal water, compressed air, steam and DM water etc to the various production plants of NFC. The facilities of utilities like Pump Houses, Compressed air stations, Boiler houses, DM water plants etc are remote and located at far off places in NFC based on functional requirements. These facilities are being operated in round the clock shifts by deploying manpower in various locations. Because of wide spreading of these facilities, it is becoming difficult to maintain/monitor and control of the systems with the reduced man power.

To facilitate remote operation of these plants from a single place, a Central Control Room (CCR) was planned at the services building of Utilities under XII plan project "Renovation and Augmentation of Utility, IT and Communication Facilities (RAUITC)" with distributed control architecture consisting of 8 nos. of RIO(Remote Input Output) racks ,with required field instruments & final control elements installed at remote facilities of Utilities, connected over dedicated LAN with Dual Standby Hot Redundant PLC

based control system and SCADA located at CCR, for Automation of Water Supply plants and monitoring of other Utilities services.

During the month of March-2017, installation and commissioning works of CCR project were completed and the system has been handed over for continuous operation of the Utilities services.

Central Control Room – Utilities, NFC



SCADA-Screen of Pump House-1

General Services

1. **An Electric Bike made in -house:** The employees of Forklift Maintenance Section has fabricated a New Electric Bike, in - house with the spares removed from condemned Vehicles / Material Handling Equipments. A New Electric Bike costs around Rs.36,000/- approx. in the market. The above crew has done this work in addition to their normal duties and completed the task to save an expenditure of Rs.36,000/-, for purchase of a new vehicle.

Old Electric Bike

New Electric Bike

2. **Making Jumbo Truck In - House :** General Services has fabricated in-house jumbo truck by taking good condition parts from old discarded trucks. This innovative work will help in avoiding procurement of a new jumbo truck which costs around Rs.5,00,000/-. The in -house made truck can serve the requirement for at least 10 years.

Old Jumbo Truck

New Jumbo Truck

Equipment Development & Automation (ED&A)

ED&A has immensely contributed in the fuel production activity through its developmental activities. Key developments carried out by ED&A in this year are listed below,

a) Advanced pick & place system for final compaction press The Linear actuators used in K-1 final compaction press had short stroke length in the Horizontal movement. This limited the No. of rows of pellets on the SS Tray and required the enclosure to be opened for more number of times.

A new pick & place system with increased stroke length of linear actuators and servo motors driven by CC - Linc communication were used for precise movements in horizontal and vertical directions. A positional Accuracy of $\pm 20\,\mu m$ can be achieved with this control system. These systems were mounted in 3 No's of final compaction presses and they are working satisfactorily.

Advanced pick & place syster

This pick & Place system increased the number of rows of the pellets on the SS tray and improved machine availability time for production. This also reduced operator exposure to radio activity during handling of pellets.

Advanced spacer pad welding machine

b) Advanced spacer pad welding machineIn the old spacer pad welding machines, loading/un-loading of fuel tubes on to inflatable mandrel is carried manually for welding of appendages resulting in operator fatigue and causing high chances of inaccuracies during the welding operation. Similarly, all old systems were replaced with various new systems and modifications. They are:

i. Automatic tube loading / un-loading system is introduced using electrical linear actuator for elimination of manual handling of the tube and to achieve precise centre distance of the appendage on the tube. This ensures proper orientation of spacers on fuel tubes and subsequent box formation during assembly of PHWR fuel bundle.

ii. Improved Spacer pad feeding system by optimizing component movements.

iii. Introduction of servo motor for rotation of tube.

iv. Introduction of digital pressure switches, vacuum switches, flow switches and weld checkers for monitoring of we parameters. These features have improved the overall weld quality, productivity and recoveries in the appendage weldir process.

c) LM guides based bunker movement tracks for discharge bunkers of Calcination Furnace - I and Reduction Furnace - I of UOP. Two nos. of Linear Movement (LM) guides based track systems for horizontal movement of discharge bunkers have been fabricated and installed by ED&A in the trenches of the Calcination Furnace-I and Reduction Furnace-I of UOP. Since their successful installation, these track systems are working satisfactorily in round the clock production operations of UOP.

LM guide rails

Major benefits of LM guides are,

i. Three to four operators were engaged to move the bunker on castor wheeled trolley in the trench, whereas the present LM guides based track system requires only one operator to move anc align the bunker with the discharge bellow as compared to earlier.

ii. Alignment of bunker inlet port with discharging bellow on castor wheeled trolley is a very tedious job and whereas LM guides based track system always ensures accurate alignment between bunker inlet port and furnace discharge bellow, which ir turn simplifies bunker fixing job and also increases the bellow life.

d) Design, fabrication and testing of lifting structure for shifting of high temperature sintering furnace: Design, fabrication and loac testing of gigantic base structure and side trusses required for shifting two sintering furnaces in as is condition, each weighing around 20 MT with dimension of 1.6 m wide and 9 m long was carried out at ED&A. The structure design was analysed in FEM

software before fabrication and load testing. The plant has also successfully shifted these two furnaces from NUOFP(P) to CFFP(P) and the same are currently put in to regular production.

e) Automatic Fuel Tube Butting& Feeding Systems: ED&A has developed, fabricated, installed and commissioned one automatic fuel tube feeding cum butting system for ZFP De-burring machine. This system has a tube basket of about 200 tubes capacity and an electro-magnetically operated vibrator unit. This vibrator unit breaks the tubes jamming and bridging etc. & also helps in feeding the tubes continuously on to tube tray of the machine. The tube tray has been fitted with a tube butting cylinder and pusher unit to butt each tube to left side reference plate. The control system of this tube butting cylinder has been integrated with the control system of the machine. This automatic tube butting cum feeding system has been successfully commissioned and put in to regular production operations of ZFP. Similar tube butting system has been installed on two No's of De-burring machine at NZFP. These systems are performing satisfactorily.

Civil Engineering Division (CED)

The Division had a hectic year in completing the ongoing construction projects apart from taking up fresh expansion activities. In addition, the Division is having many more construction projects on the anvil for the coming years also.

Maintenance and upkeep of the existing industrial buildings and structures apart from residential buildings is a perennial activity which is scrupulously carried out. While continuing to develop and maintain greenery in the campus, NFC also participated in the program "Telangana Ku Haritha Haram" (TKHH) of Telangana State Government and planted about 2500 of saplings, both in the factory premises as well as Township area.

The Division also did its bit in increasing the production this year by completing the required civil, electrical and ventilation works for installation and commissioning of 2 Nos of sintering furnaces at Block-A facility.

The 1,200 seated capacity Dr. Homi J Bhabha NFC Convention Center was Inaugurated.

Further Division could almost complete the basic infrastructure works like site grading, construction of compound wall, project office, ware houses, watch towers, time offices, roads etc. at the green field project site of NFC Kota , Rawatbhata, Rajasthan.

The major package for construction of plant and non-plant buildings (of about 1,20,000 sqmtr RCC buildings and about 60,000 sq mtr pre-engineered building type sheds) at NFC Kota site is also recommended for award of work at a cost of about Rs 426.00 crores, after the requisite tendering, evaluation etc.

Few of the major works that were completed / nearing completion include:

- Metallic Waste Treatment Facility building
- Scrap feed preparation building
- Expansion of compressor house at NUOFP area
- Burning yard for Zr scrap
- Non-metallic waste treatment facility

Ongoing works include:

- Construction of Pilot Plant.
- Zirconium Sponge Storage Shed.
- Tube Plant Settling Tanks

Electrical & Ventilation Projects:

- Power Supply substation works and internal electrification works for Dr Homi J Bhabha Convention Center
- Expansion of NZFP substation with transformer, panels etc and electrical installations for finishing bay at NZFP
- Electrical installations for Metallic Waste Treatment Facility
- Air conditioning of Dr Homi J Bhabha Convention Center.
- Providing primary and secondary ventilation system for 2 Nos of sintering furnaces in Block-A
- Providing a.c. systems at ZFP inspection hall and Block-A

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Dr. Homi J Bhabha NFC Convention Center

b)

Main Gate at NFC-K

Ware office at NFC-K

Power Distribution

It is a known fact that electricity is a key input for any industry today and plays a vital role in the performance of the industry. Pow
Distribution Section continued to provide reliable power supply to all production plants at NFC thereby playing its role in the realization
production targets by NFC. Further, the Section has taken up activities to replace obsolete equipment so that the task of extendin
reliable power supply regularly is ensured. Augmentation of electrical substations is also in pipeline with completing the tenderin
technical evaluation and placement of work order.

Estate Maintenance Section

Garden has been laid from colony main gate to EM office. Duranto plants have been planted on the side of the road and Crotons have been planted around tree stems for beautification and healthy living.

About 230 Nos. of damaged toilet doors in the colony and CISF have been replaced with new flush doors. To improve the life of flush doors of bath rooms, 1mm PVC sheets have been glued to the wet sides of these doors.

The illumination of GURUKUL has improved by about 6 times with nearly half electric consumption by replacing conventional fittings with LED fittings.

There was a perennial problem of sewerage flow on to main road from NPCIL guest house, near rear gate, since it's inception. This problem has been rectified in a short span of one week to ten days. NPCIL and CISF have shown lot of appreciation for this.

EMS prepared the volley ball court and made other civil and electrical arrangements for the 32nd inter DAE tournament which has been applauded by all players for the best arrangements.

FIRE SERVICES

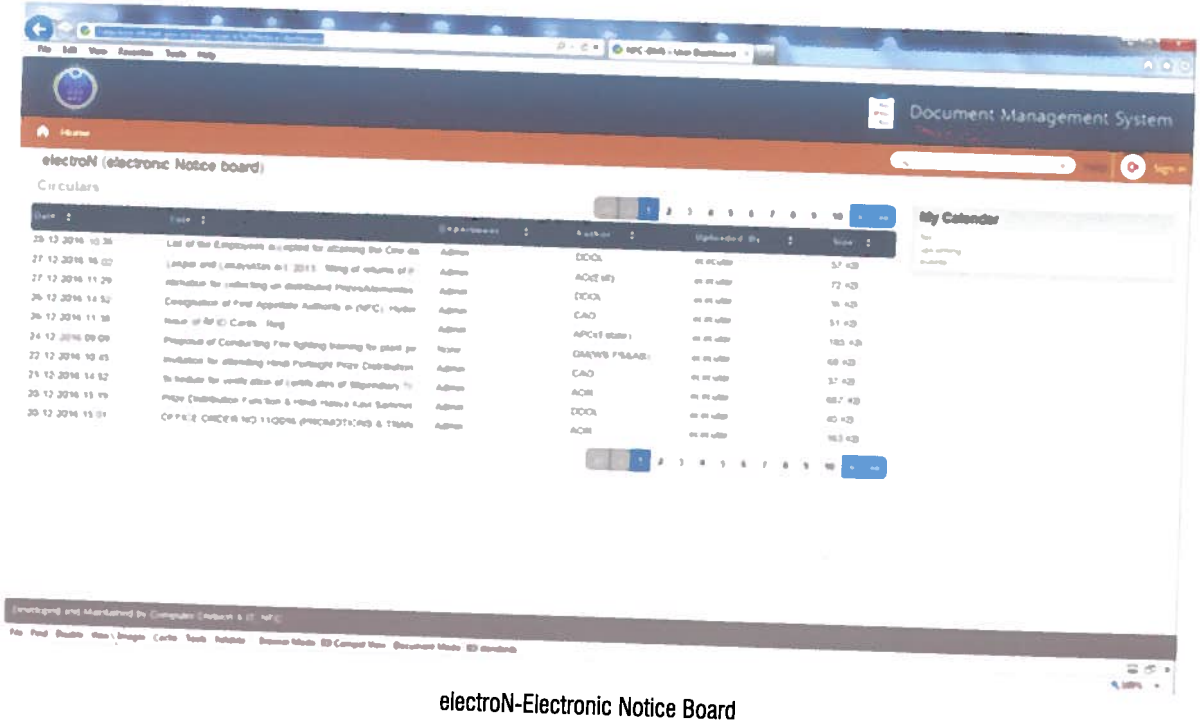
1. Fire Safety Inspections of 35 plants completed during the year.
2. Training Classes conducted for 708 employees in first aid and fire fighting .
3. Fire calls- The Fire Incidents during the year is "0" Fire Accident status.

4. **Rescue calls:**
   a) 4 Members of contract workers rescued from roof collapse at ZFP extension while concreting.
   b) Alkali leakage at ZSP area : Out of two persons affected one person rushed to OHC by himself and other person was sent OHC after giving water shower by fireman.
   c) Nitric Acid leakage from road tanker at Parking area of North Gate. Immediately tanker was shifted to ZOP area for unloadi with two Fire Tenders, one each in front and back , as escort by diluting the acid and fumes and remained stand by up completion of unloading.
5. Fire Drills carried out : 10 Nos.
6. Mock Drill attended 1) Chlorine - 11 No's 2) LPG - 2 Nos. 3) Ammonia - 2 Nos.4) On Site Emergency Drill : 01 Cl2 leakage
7. **Dewatering works:**
   a) Done at LCs of ZFP & NZFP, TRTP Basement and Pilger mills of STP & ZFP areas during rainy season due to blockage of stori water drainage.
   b) Lotus Pond at SEP area.
8. Escort Duties for shifting of strategic materials from Sanathnagar Rly Station 11 Times and From Airport 04 times
9. Drill competitions on Fire Hose, BA Set, Fireman Lift and Rescue from smoke filled room were carried out for fire staff.
10. Zr. component manufactures (Out sourced) premises were inspected along with the committee for adequacy fire safety as pe code of practice.
13. Fire Safety training given to the W/As and CISF staff.
14. National fire service week observed

Computer, IT & PPSD

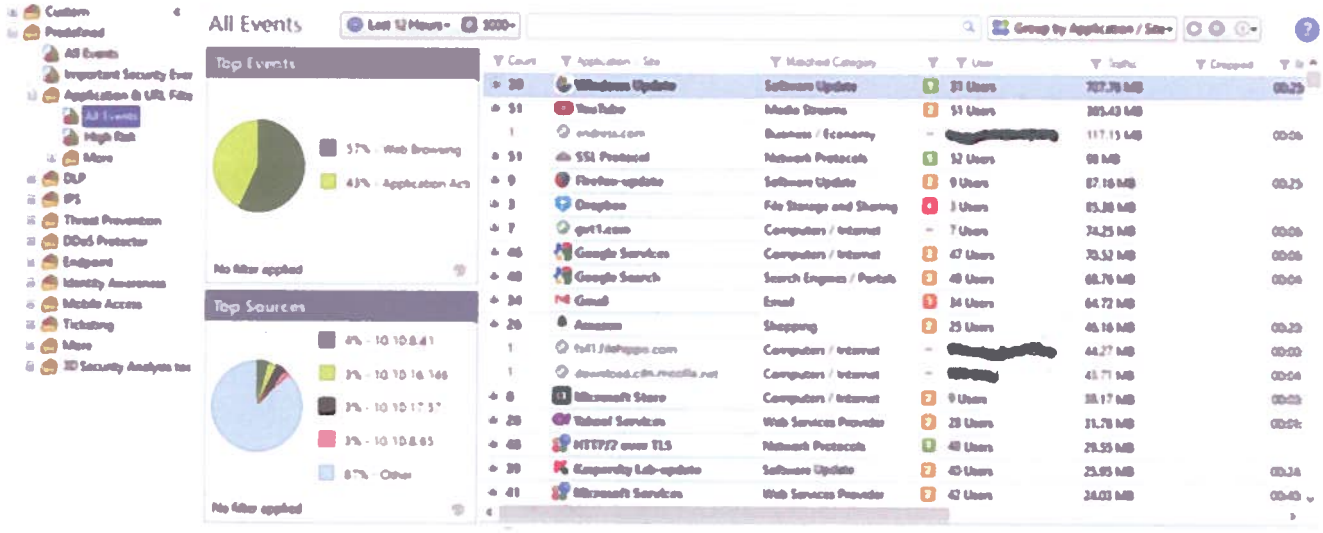
CD&IT:

1. electroN - An electronic notice board (based on open source Document Management System (DMS)) is developed and deployed for providing easy access to circulars on NFCNET to all employees. The platform facilitates easy search on documents containing scanned text also and retrieval. The facility was released on 24th Nov'2016.



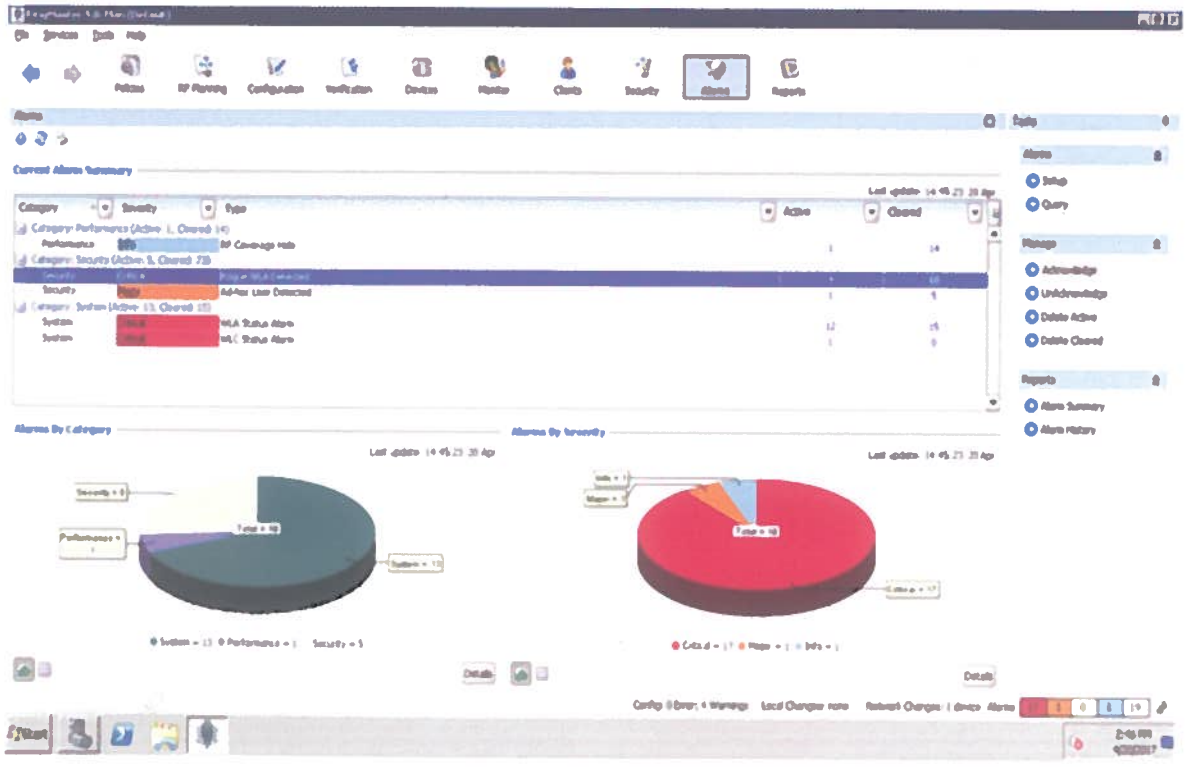
electroN-Electronic Notice Board

2. Usage of e-mail communication has increased significantly in the past 5 years and user base has touched 1200. Email facility is now extended to supervisory staff and Email infrastructure is upgraded with latest hardware and software having rich features including mail retrieval of deleted/lost mails from mail archival server. The new infrastructure was deployed during Aug'2016.
3. NFC is having Firewall Cluster (Proxy for internet browsing, Spam Filtering, Anti-Bot etc) catering to more than 600 users and providing IT security. This system is integrated with newly procured Log analyser software for monitoring of user activities, threats and vulnerabilities. The system helps in making corrective decisions and there by leading to enhanced Internet bandwidth utilization.



Log analyser report

4. The Wireless Network Management Station (NMS) on NFCNET is upgraded by enabling Intrusion Detection System (IDS) feature. This helps in identification and isolation of rogue clients and Wireless Access Points (WAP), thus improving overall security/performance.



Report Generated by Intrusion Detection System

Physical Protection Systems Division:

1. **Installation & Commissioning of Swing Type & P-Type gates at Sarathi Building-**
   - Gates comprises of 2 lanes of Swing type (for employees)
   - 2 Nos. of P-Type gates (for VIPs, Handicapped etc.)
   - P-Gates will give clear Passage of 1500 mm.
   - Gates are Integrated with Iris based Access Control System for NFC & ZC employees
   - RFID based Access Control System is also installed for other DAE Unit staff.
   - An additional CCTV Camera is also installed to monitor Man and Material Movement at the gate.

View of gates from installed Camera

BARC Training School, NFC-Hyderabad

The prestigious BARC Training School at NFC, Hyderabad was started in the year 2001 with its mandate to fulfil the growing requirements of highly skilled scientific personnel in the industries & Minerals Sector of the Department of Atomic Energy. As such the Training School takes pride in having completed its first fifteen glorious years and derives satisfaction of having trained 309 Engineers belonging to the disciplines of Chemical, Mechanical, Electrical and Electronics & Instrumentation Engineering. These engineers are posted in NFC, various Heavy Water plants, BARC, NRB, IGCAR, AERB, AMD and BRIT and have been discharging their duties and responsibilities therein, exceedingly well.

The Inaugural Function of the 16th Batch BARC TS

NFC was held on 1st August, 2016 at Conference Hall of Gurukul building. Shri Rajnish Prakash, Chairman, AECS being the Chief Guest of the function and gave valuable advise to the new TSOs and complimented them for getting selected to the prestigious department after intense All India selection process.

Training School ISO Audit/Certificate Renewal

BARC Training School NFC had been the first Training School among Training Schools of DAE which is certified with ISO 9001:2000 in the year 2008 and the re-certification audit was carried out in April, 2017.

Outreach Programme for encouraging engineering graduates o apply for Training School

In order to enhance the success of OCES/DGFS-17 programme, teams of Senior Officers from various DAE Units such as BARC, NFC, IGCAR etc., were sent to Engineering Colleges in their neighbouring states to conduct seminars to final year students highlighting the ongoing programmes, career opportunities in the department and future prospects. Engineering colleges located at Andhra Pradesh and Telangana states were covered by NFC, Hyderabad to promote the Training School Programme of the Department. A team of Senior Officers from NFC visited the Engineering Colleges, made presentations before the Final Year students of the respective colleges and participated enthusiastically in this exercise to promote the OCES programme.

Ms. Rabiya Azmat, 16th Batch TSO getting introduced to Chief Guest Shri Rajnish Prakash

Shri G. Kalyankrishnan, C&CE, NFC presenting A Memento to Shri M. Bhaskaran, C&CE, HWB

IGCAR TSOs Plant Visit to NFC

Plant visit for IGCAR Training School TSOs(Science & Engineering group) was arranged for two weeks in two batches. The IGCAR TSOs were exposed to various activities at NFC.

Coordination for online test

BARC TS, NFC coordinated with HRDD, BARC Mumbai for conduct of ONLINE TEST by deputing two officers at Hyderabad centre.

Human Resource Development Division (HRDD)

HRDD of NFC played a vital role in organizing several training programmes for the benefit of in-house staff, students, visitors during the year 2016-17.

The following were the main training programmes Organized by HRDD

- HRDD organized a Computer Training programme on basics of computers and usage of MS office for 132 Supervisors / Scientific Assistants of NFC in five batches at ECIT, Hyderabad during 16.09.2016 – 20.10.2016. All the participants were awarded certificates by ECIL on completion of training
- HRDD sponsored several officers for attending various symposiums and seminars both at Hyderabad and outstations based on the need and for knowledge up gradation.
- HRDD conducted 960 hrs of class-room training for Work Assistants who were eligible for track change from Auxiliary to Technical category.
- HRDD conducted Awareness programmes for newly recruited stenographers
- HRDD also organised training programme for workmen as part of Workers Education programme.
- HRDD also training and mentored the various Quality circles formed in NFC and one QC won the 1st prize in the annual QC convention

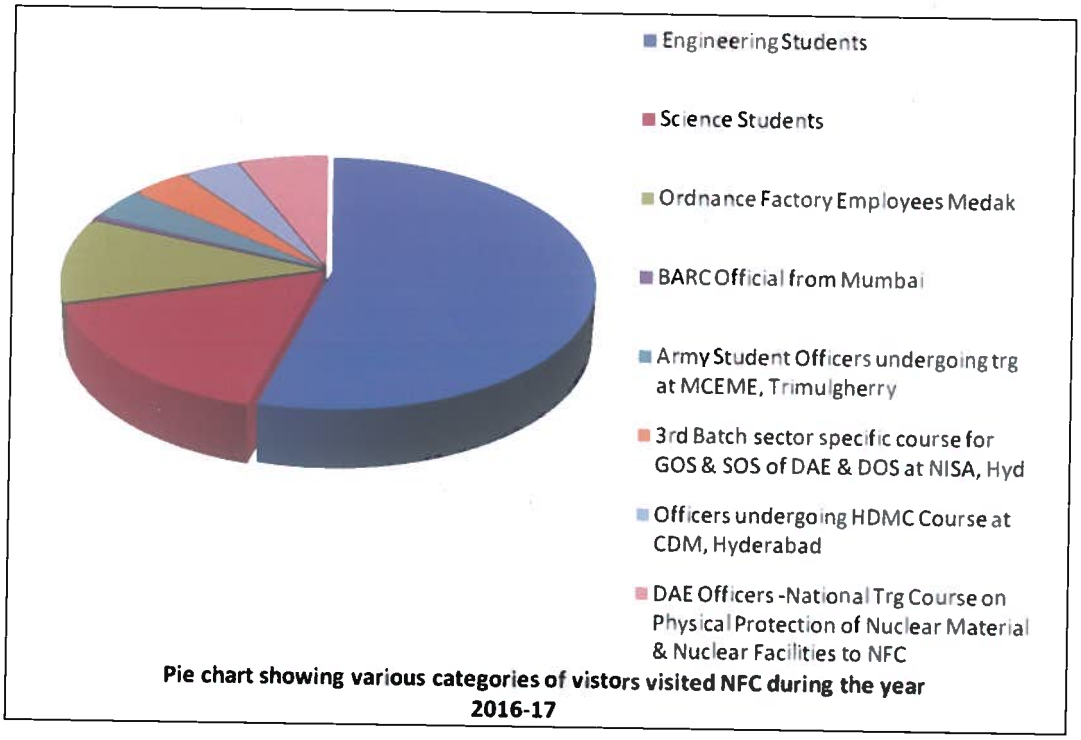
Shri H.R. Ravindra, DGM, HRD welcoming the gathering during the first aid training programme.

Project work for students at NFC

During the period 2016-17, HRDD issued certificates to 422 students for carrying out various project works at NFC. The projects were allotted to the students after meticulously going through the syllabus of the course which the student was pursuing and its relevance in enhancing his knowledge capital and intricacies of the subjects studied. These included primarily (392 nos) in various Core disciplines of engineering such as Mechanical(192 nos), ECE(66 Nos), Electrical(26 Nos), Chemical(40 Nos), CSE(14 Nos), MME(26 Nos), Metallurgy(11 Nos), Civil(17 Nos) and 30 students in other disciplines of engineering such as Automobile, Information Technology, Aeronautical, Materials, MSNTE, Industrial, Mechatronics, MSE, ECM, MS-NT, Production Engineering and also other disciplines like Finance, Marketing and Commerce for MBA students. Students who had been carrying out project work at NFC were from various colleges located in different states of India.

Outreach programmes conducted

HRDD contributed towards the important mission of reaching out to college students and general public through a series of outreach programmes thereby handling a wide spectrum of visitors involving Engineering college students, science students, senior defense personnels and various other type of participants. During the period 2016-17, HRDD handled a total number of 780 visitors. Of these the engineering college students represented 400, Science students were 120 and the remaining 260 were others. The pie chart depicting the category of visitors visiting NFC.



Pie chart showing various categories of vistors visited NFC during the year 2016-17

Management Services

Management Services (MS) is responsible for Production Planning & Control, Project Monitoring & Control and Material Planning. MS plays an important role in the improvement of productivity of machines and materials. It provides an interface between various production plants for meeting annual targets and also serves as a nodal agency with respect to information dissemination. This group contributes significantly for achieving annual production targets and other commitments of the organisation. An excel based template was developed for computerisation of generating costing data at faster speed with improved productivity.

The Projects wing of Management Services coordinates with project coordinators, project engineers, Purchase & Accounts and DAE for effective implementation of the plan projects in NFC.

This wing played an important role in management of funds for 16 projects which are under various stages of implementation. The wing also provided required inputs to DAE to facilitate issuing sanction for 'Augmentation of Amenities and Infrastructure (AAIS)' project & revised expenditure sanction for AWMF project. The proposal along with DPR for the project 'Advanced Tube Manufacturing Facility (ATMF)' at NFC, Hyderabad is prepared and sent for obtaining approval and financial sanction.

Site grading, site infra & construction power activities are in the advanced stages of completion for the green field project NFC-Kota. The tender for Civil, Structural & PH works for Plant & Non Plant buildings with the recommendation for placement of order was sent to DAE & MoF for according approval for order placement. Tenders are in various stages of processing for procurement of long delivery equipment.

Tools in MS Excel for linking various project program's outcome with the Departments vision was developed for the ease in analysing and reviewing the future targets and for generation of reports which will help in effective project monitoring and coordination.

Material Planning Section (MPS) is responsible for the planning procurement and inventory control of all the critical consumables and other inputs for NFC, Hyderabad and Zirconium Complex, Pazhayakayal through scientific material management. Important activities during the period are given below:

1. Towards implementation of safe practices while handling Zircaloy material by the outside firms engaged in supply of PHWR components, safety awareness training classes and "Zircaloy fire demonstration" were arranged to 178 persons over 4 sessions. In order to ensure strict compliance of safety & legal requirements, surprise inspections were carried out at the works of suppliers once in 3 months. 56 number of such inspections were carried out.
2. MPS has identified & successfully developed outsourced parties for supply of 3.25 mm spacer pads, cobalt pencil & element end caps and Zirconium washed & dried frit.
3. Towards increasing the vendor base & to encourage healthy competition in the market, 182 nos. of new suppliers were identified. Similarly for procurement of fabrication items, the facilities of 6 nos. of new vendors were evaluated for assessing their technical capabilities.
4. Alternative products were identified and developed in place of existing proprietary purchases like CRC-ECO & MC-199 (in place of LPS), MAK Tripnol-H(in place of Servo cut 353), AC-724 (in place of DC704) and ULOIL-B-50 (in place of ULVAC-B-50).

MARKETING DIVISION

Orders: Orders worth Rs 9434.40 lakhs were booked for the year 2016-17 against the target of target of Rs 7494lakhs. Major orders booked are –SS 304L tubes/pipes for IGCAR-FRFCF & BARC-NRB SS 321 Tubes for BARC-RPD, 540MWe PHWR Silver Alloy Gaskets for NPCIL, Cobalt Absorber rod assemblies for BRIT , Midhani job orders in MDN-59 and MDN-250 grades and MDN-11-10PH, Zr Metal Powder to Ordnance Factory-Itarsi & BDL-Hyd and Zr Metal Powder for HEMRL, OF-I and VSSC.

Sales: Supplies worth Rs.18093.63 lakhs (including supplies of PFBR Sub Assemblies) effected as against the target of Rs.7494 lakhs. Major orders executed are:

- 10kg Zr Sponge to AREVA, France,
- High purity materials and Zr sheets to BARC
- Ti Full Alloy Tubes to CVRDE
- Al-Mg Alloy Tubes to BrahMos
- PFBR Sub Assemblies to BHAVINI.
- 700MWe Reactivity Mechanisms and Co absorber Assemblies to NPCIL
- Nb Sheets to RRCAT
- Zr Metal Powder for HEMRL, OF-I and VSSC.
- MDN-250,MDN-11-10-PH, STA-59 & MDN-350 tubes for MIDHANI
- SS 304L Tubes / pipes and FBTR Carrier Tube Assemblies to IGCAR
- UNS N08800 Straight and U-Bend tubes for L&T
- 304L Poison Tubes for TAPS 1&2,NPCIL
- POCl3 for Premier Solar Systems and Ruttonshah International Rectifiers
- Ta pentoxide to VSSC.

Customer Satisfaction: Customer feedback on key parameters, viz., Quality, Delivery, Customer relations & Customer Service was obtained in respect of the orders executed and the same ranged from "Very good" to "Excellent" and "Excellent" in majority of the orders.

Promotional And Awareness Events: NFC participated in various exhibitions viz.,

- BHARAT UTSAV - 2016, at JNTU, Hyderabad from 18 to26.08.2016
- Indian Nuclear Energy Expo at Nehru Centre, Mumbai from 20 to 21.10.2016
- Indian Science Congress - Pride of India -2017 Expo (3-7 January, 2017) at S.V. University, Tirupathi