Nuclear Fuel Industry in China

Sao Paulo, Brazil
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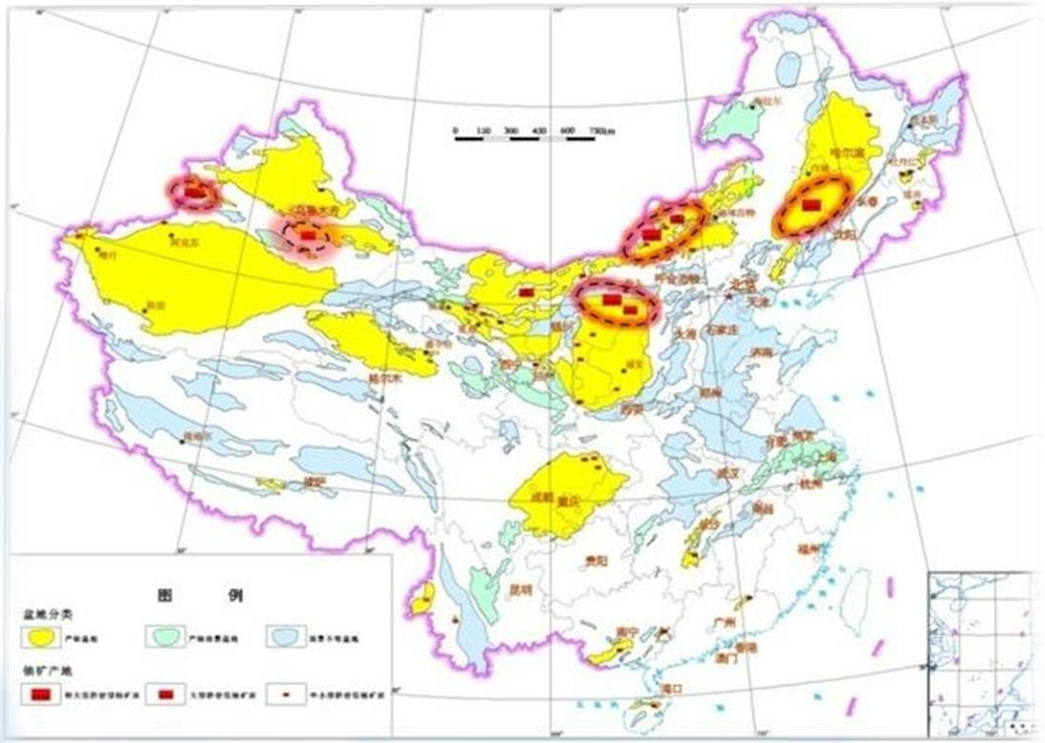
1. Nuclear Fuel Cycle in China

- A completed nuclear fuel cycle system Uranium mining， Uranium conversion and purification, Uranium enrichment, nuclear fuel manufacturing and spent fuel reprocessing.

- China has been adopting the closed nuclear fuel cycle, i.e. the spent fuel shall be reprocessed to recycled Uranium, Plutonium and other elements to enhance the fuel utilization.

- **Uranium exploration and mining**
  - **Uranium resource and several Uranium mine bases have multiple10000 tons-grade of reserve**
  - **participates the international Uranium market to cooperate in Uranium resource business.**



China has owned the technology of Uranium resource exploration and mining and realized the equipment localization.

- **Uranium conversion and purification**
  - Two existing Uranium conversion lines in Hunan Province and Gansu Province.
  - A new integrated conversion-purification facility is under construction and to be expected to start production by the end of this year.

Uranium enrichment

- Centrifugal technology for enrichment is the most important and sensitive technology in nuclear power application.
- China has its own which have been put into industrial application successfully.
- The R&D, manufacturing and industrial application for centrifuges with higher performance are going forward on schedule.
- Capacity can meet the existing and future domestic market and international market to a certain extent.

Nuclear fuel manufacturing

- Decades years experience in development and manufacturing for nuclear fuel.
- Capable of designing, research and development for Pressurized Water Reactor (PWR) fuel.
- The nuclear fuel for High Temperature Gas Cooled Reactor (HTGR) was designed independently.
- Complete nuclear fuel manufacturing system





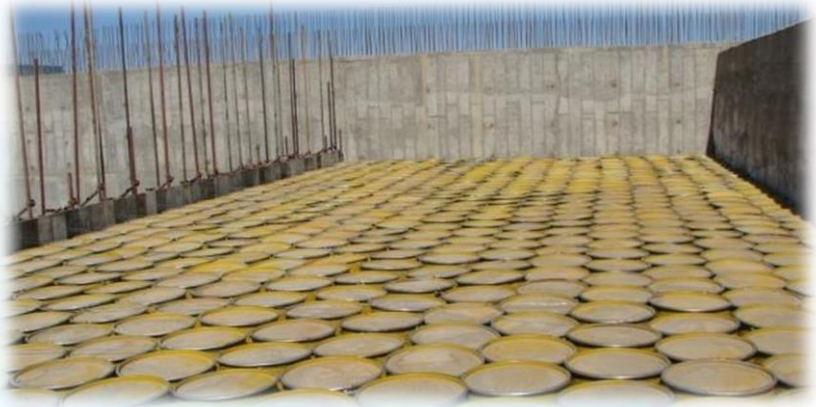
- **Spent fuel reprocessing**
  - A pilot-test scale reprocessing facility has been built independently while the commercial reprocessing facility is under construction.
  - The much bigger commercial reprocessing facility has also been planned.
  - Plan to build big commercial reprocessing-recycle facility.

Low Level Liquid Waste Evaporation Facility

Disposition of the nuclear waste

- Three facilities for low and medium irradiation level waste storage
- The project for permanent storage facility for high-irradiation level waste is under review

Waste interim storage site



Near surface disposal facility

The transportation of spent fuel

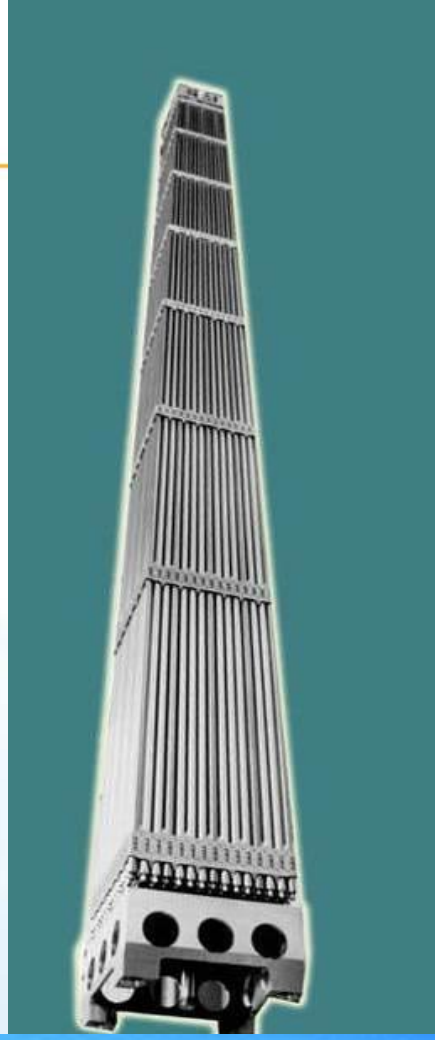
HWRR

- **Decommission**
  - **Experiences in Decommission of nuclear reactors and other nuclear facilities. The successful examples is:**

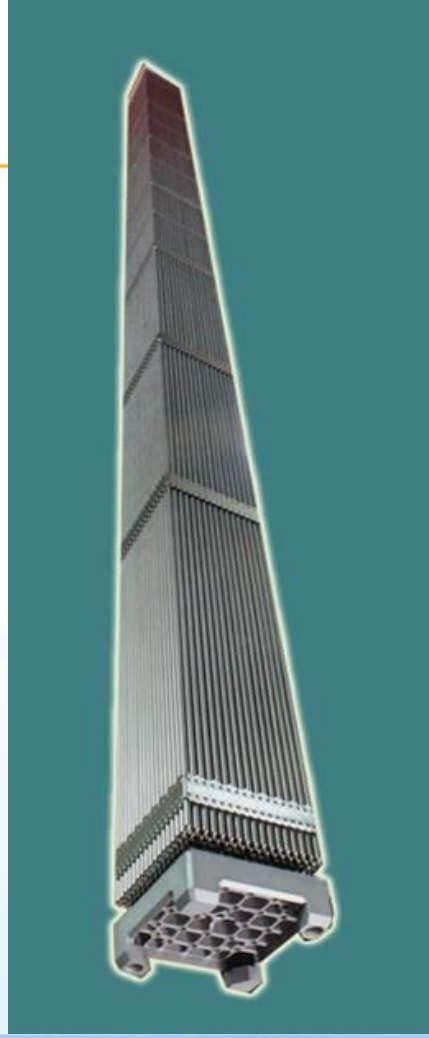
The first nuclear reactor in China 10 MW multi-purpose research reactor shut down at 2007 and under decommissioning

2. Nuclear Fuel Assembly

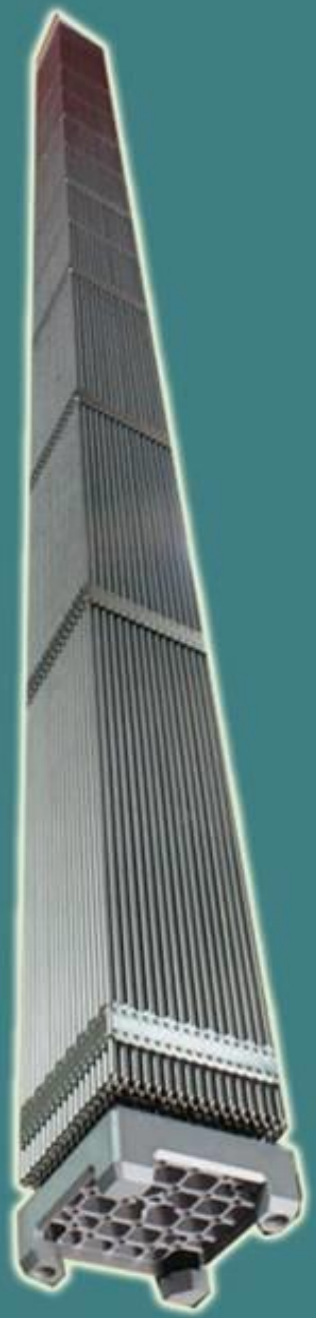
- **FA300 nuclear fuel**
  - 15×15 fuel rod array design
  - Operation in Dec. 1991.
  - Used for the first phase of Qinshan nuclear power plant Actual burn-up of FA300 reaches up to 33GWd/tU
  - 760 FAs has been delivered to the reactor.
  - Exported to Pakistan from 1998.



- **AFA2G nuclear fuel**
  - Started to manufacture AFA2G nuclear fuel In 1998 and load into reactor in 2001
  - 17×17 fuel rod array design
  - 33 GWd/tU max. burn-up
  - 2600 fuel assemblies have been loaded into the reactor.



- **AFA3G nuclear fuel**
  - Started to manufacture AFA3G nuclear fuel In 2001 and load in 2003
  - 17×17 fuel rod array design
  - Refueling cycle prolonged from 12 to 18 months
  - 52 GWd/tU max. burn-up
  - Another 200tU AFA3G fuel plant established in north fuel facility of CNNC
  - Current capacity 1200tU per year
  - More than 6000 fuel assemblies have been delivered to the reactor



- **CANDU-6 nuclear fuel**
  - Started to manufacture CANDU-6 nuclear fuel In 2002 and delivered to reactor in 2003
  - More than 110 thousands of CANDU-6 fuel bundles have been delivered continuously
  - 84 months' record of non-failure of the fuel in reactor.

- **VVER-1000 nuclear fuel**
  - Started to manufacture VVER-1000 nuclear fuel for Tianwan 1# and 2# Units in 2010
  - Hexagonal cross section with 312 fuel rods
  - Loaded in 2011 with 49 GWd/tU max. burn-up
  - 12 months of refueling cycle
  - 270 fuel assemblies have been delivered to the reactor

- **AP1000 nuclear fuel**
  - Construction of the production line started in 2012 and currently is under qualification
  - 400tU per year for the first phase with additional space available for another 400tU for future expansion. The final capacity will be 800tU per year
  - Formal production is expected to start in 2015 for first reloads of Sanmen and Haiyang Utilities.

- **HTGR nuclear fuel**
  - Fuel developed by China independently
  - Spherical fuel
  - 300 thousands of spherical fuel per year
  - Used in the first commercial demonstration HTGR reactor
  - Production line is under construction and the formal production is expected in 2015

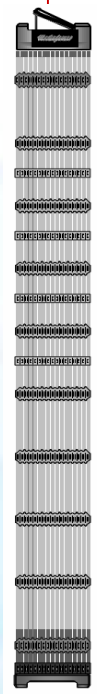
In summary, China has been capable of manufacturing several major types of fuel in the world

FA300
15×15

VVER-1000

AFA
1717

CANDU-6



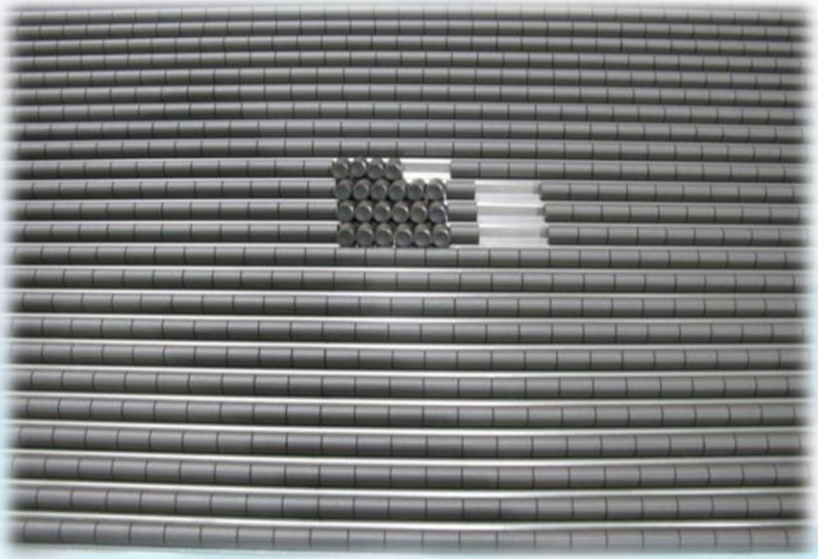
AP1000

HTGR

- **Uranium chemical conversion**
  - **ADU and IDR process have been used in UO2 powder preparation. China can design and construct the chemical conversion line independently and localize the key process equipment.**

IDR conversion furnace

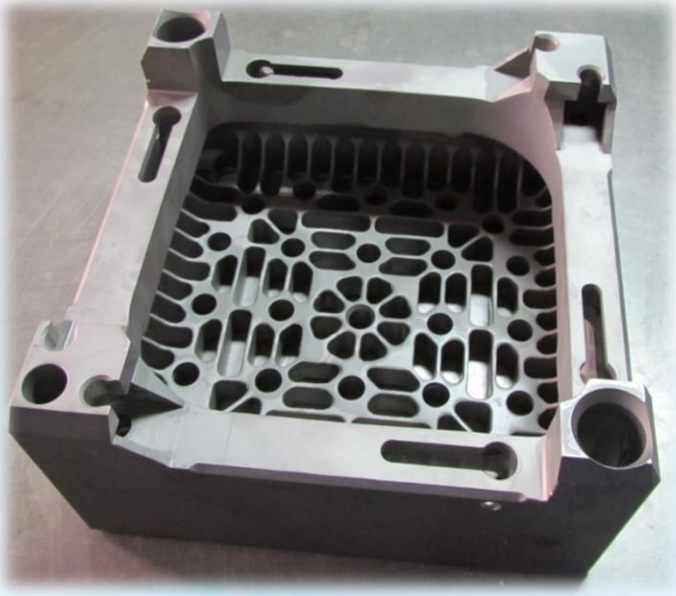
- **Pellet preparation**



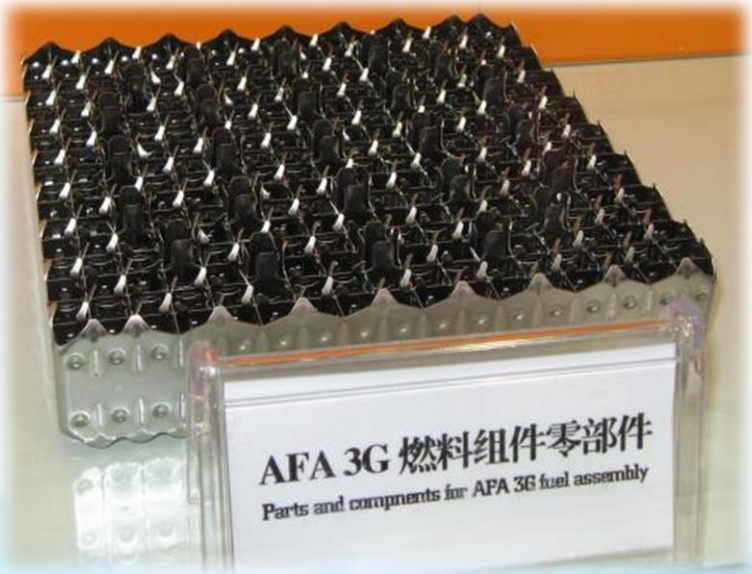
UO2 pellets

UO2 pellet press

- **Component manufacturing**



nozzle



grid

- **Grid manufacturing**

Brazing furnace for strap

Grid laser welder

- **Fuel rod welding**

pressure resistance welder

TIG welder

- **Skeleton manufacturing**

Skeleton Bulger

Skeleton Welder

- **Fuel assembling**

water lubricant system

Fuel rod pulling system

- **Other special material and core components manufacturing**

Ag-In-Cd control rod

Boron glass

Sb-Be pellet

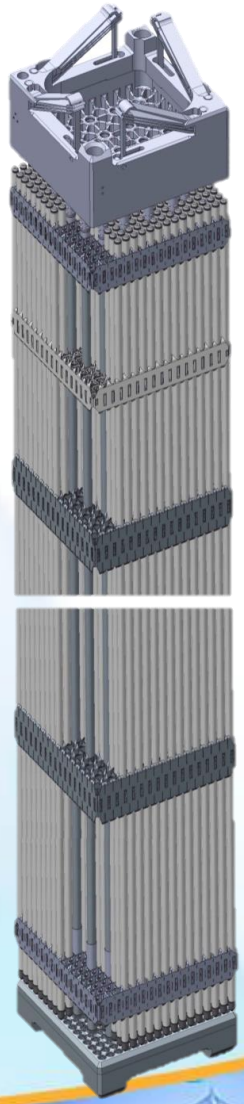
primary neutron source

- **CF serial fuel**
  - **177 fuel assemblies core pattern designed by CNNC;**
  - **CF serial fuel assembly designed and developed by CNNC independently;**
  - **CF3 used in HPR1000.**

Comparison list for CF fuel and other types of fuel

Fuel type	AFA3G	AP1000	CF2	CF3
Fuel rod array	17×17-25	17×17-25	17×17-25	17×17-25
U（Kg/FA）	461	541	459.5	459.5
Fuel rod	264	264	264	264
Length of fuel rod（mm）	3867.1	4583.2	3851.2	3862.2
cladding	M5	Zirlo	Zr-4	N36
Welding process for fuel rod	PR	TIG	TIG/PR	TIG/PR
grid	11	15	8	8
FA length	12ft.	14ft.	12ft.	12ft.
Burnable absorber	Gd_2O_3	ZrB_2(IFBA)	Gd_2O_3	Gd_2O_3

- **CAP1400 fuel**
  - **Fuel Assemblies and components R&D is undertaken and supplied by CNNC.**



- **Other new fuel types**
  - **The multi-sleeve fuel and plate shaped fuel for research and test reactor**
  - **MOX fuel (mixed oxide fuel),**
  - **NUE fuel (natural Uranium equivalent fuel),**
  - **Annular fuel**
  - **Thorium Molten Salt Reactor, ADS transmutation reactor and Sodium-cooled fast reactor and their fuels**
  - **Fuel for 10MW small modularized reactor**

Zirconium product

- Sponge Zirconium-: 2000t
- Zirconium ingot: 1000t
- Zirconium tubing: 3500km
- ……

Sponge Zirconium-

Zirconium ingot

TREX

Zirconium tubing

3. Experience in Fuel Product Exporting

China has more than 20 years of experience in nuclear fuel product exporting

- nuclear fuel
  - More than 700 fuel assemblies to Pakistan from 1998.
  - abundant experience in manufacturing, quality assurance and transportation.
  - good reputation of the exported fuel in-core performance.
- Enriched Uranium
  - China has successfully exported enriched Uranium to US, Europe, Japan and Korea from the beginning of 1990s.
  - The enriched Uranium meets the international standard.

Summary

- a complete industrial system from Uranium mining, Uranium enrichment, Uranium conversion to nuclear fuel R&D and production after years of development.
- most of the major types of nuclear fuel in the world can be manufactured in China.
- Localization for key equipment and material used in different stage of nuclear fuel cycle.
- A whole set of service for nuclear fuel provision can be provided

We wish to carry out wide and deep cooperation with YOU!

Thanks for your Attention!