# Nuclear Air Cleaning Technology of China

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# 1. Status of Nuclear Power and Reprocessing Plants in China

◎China has established a relatively perfect nuclear industry system, covering each part of the nuclear fuel cycle.

◎In pursuit of clean, stable, and safe energy, nuclear power is an inevitable choice for China.

◎In recent years, nuclear power becomes the major engine of China's nuclear industry.

# ◆ Domestic nuclear power plants

**Operating :** *30 units (28GW) not including Taiwan*

**Under construction:** *26 units (27GW)*

**PWR:** *51 2nd / 3rd generation*

**CANDU:** *2 CANDU-6*

**HTGR :** *1 modular, pebble-bed, helium-cooled*

**FBR:** *2 sodium-cooled*

# ◆ Reactor types

◎ The reactor types are diverse,11types altogether

◎ Since *Fukushima* nuclear accident, all new NPPs must utilize the 3rd generation technology or above, otherwise they can not be approved by NNSA of China.

- The 3rd generation : AP1000, EPR, Hualong-1 and CAP-1400
- The 4th generation : HTGR, FBR by China

◎ Only coastal sites are granted for NPPs

# ◆ Active development program

◎ China will efficiently develop nuclear power on the basis of safety, according to the revised *Long-term Development Plan of Nuclear Power in China .*

➢ **By 2020,**

- 58 GW operating
- 30 GW under construction
- 6-8 new units annually
- 4% of total power

- **By 2030,**
  - It is estimated that there will be 110 NPPs in operation, with a capacity of 150 to 200GW.
  - If so, China will become the largest ‘nuclear power country’ by that time.
  - Nuclear energy will take up 8% to 10% of the total domestic energy.

# ◆ Spent fuel reprocessing plants

◎ One pilot plant is operating.

◎ A new 800t/a commercial reprocessing plant will be established using AREVA technology by 2035.

# 2. Tracks of Domestic Air Cleaning Technology

◎ Main air-borne radio-activities in nuclear facilities of China

◎ Aerosol filtration

◎ Iodine removal

◎ In-situ test

◎ Noble gas treatment

# ◆ Main airborne radioactivities in nuclear facilities of China

| | |
|---|---|
| U mining and extraction | Radon, radioactive dust |
| U enrichment and fuel fabrication | $UF_6$ , aerosol containing U |
| Reactors | Aerosol, iodine, noble gas, tritium, activated products |
| Wastes treatment | Volatile gases &aerosols containing Sr-90, Cs-137, Co-60, TRU elements |
| Spent fuel reprocessing | Aerosol, I-129, Kr-85, H-3, C-14 |
| Nuclear facility decommissioning | Air-borne residual radio-nuclides |

# ◆ Aerosol filtration

- The first kind of domestic fiber filter was developed in early 1960s .
- Domestic coarse, medium and high efficiency filters were developed in 1970s .
- Sodium flame and turbine-oil detection systems were set up.

- Mass production of deep-pleat HEPA filters was realized in 1980s.
- Mini-pleat HEPA filters were domestically made in 1990s.
- DOP and uranine methods were established with the helps of NUCON and CEA in early 1990s.

# ◆ Iodine removal

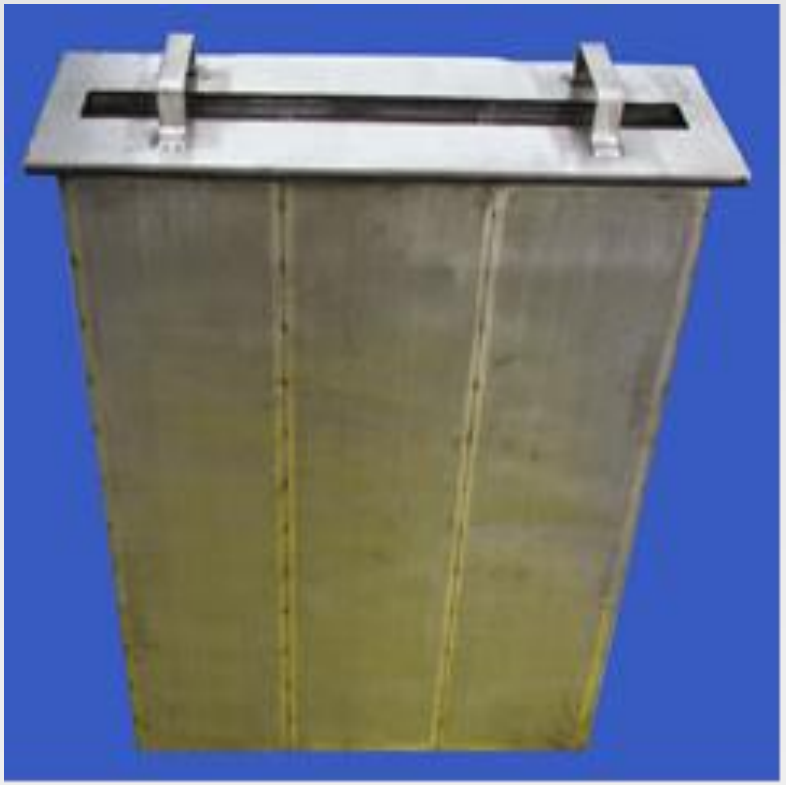
- The first iodine adsorber packed with coal-based AC was developed and used in a research reactor in early1960s .
- Iodine adsorbers with unimpregnated coconut AC were used in domestic submarine in late 1960s.
- Iodine adsorbers with Ag impregnated silica gel were used in early spent fuel reprocessing plant.

# Period 1970-1989(1)

- Iodine laboratory test apparatus for nuclear-grade adsorbents was established , meeting 5 conditions given by *ASTM D3803* .
- Several types of AC were selected as nuclear-grade adsorbents satisfying *ASTM D4069* .

# Period 1970-1989(2)

- Type II iodine adsorbers were made , packed with impregnated coconut charcoal.
- Workshop testing system for iodine adsorbers was established, using R-11, R-112 as the tracer.
- The influences of aging and poisoning on adsorbing capacity of AC were studied.



# Period 1990-2010 (1)

- Folding-bed Iodine adsorbers were developed for NPPs.
- Deep-bed iodine adsorbers were developed.

# Period 1990-2010 (2)

- Radioactive methyl iodide method was established with the help of CEA.
- Iodine samplers and real-time iodine monitors were developed for local sampling.

# Period 1990-2010 (3)

- The first on-site testing of iodine adsorber bank of Qinshan NPP was performed by Chinese experts, using NUCON equipments in 1990.
- The commissioning tests of nuclear ventilation systems of Daya Bay NPP were completed by CEA experts using radioactive methyl iodide method in 1991.

# ◆ In-situ tests

- Since 1992, both American ASME methods and French AFNOR methods have been introduced and mastered .
- More than 4000 in-situ tests have been performed up to present. About 60% of them use *French methods*, 40% use *American methods*.

# ◆ Noble gas treatment

- The cryogenic krypton recovery technology was studied for the first spent-fuel reprocessing plant in 1970s.
- The noble gas delay by AC at ambient temperature was researched in 1980s in laboratory, and scale-up test was done in 1994 .

# 3. Recent advances

## ◆Iodine adsorbers

- Type Ⅲ iodine adsorbers have been localized.
- A kind of casing-recoverable type Ⅰ iodine adsorber has been developed to enable repeated charcoal changing.

# ➢ Treatment of spent impregnated charcoal

- The feasibility of treating spent impregnated charcoal with incinerator is experimentally studied, with the focus on possible toxicity of combustion products and their corrosion on the incineration systems.

# ◆ In-situ tests

- Substitution for DOP
  - Some PAO products available in Chinese market were tested to substitute for DOP, and PAO4 was recommended finally considering its higher flash point, lower cost, and compatibility with existing DOP equipments.

*The comparison between PAO4 and DOP*

| Reagent | Density | Viscosity (100℃) | Flash point |
|---|---|---|---|
| | g/ml | $m^2/s$ | ℃ |
| DOP | 0.986 | $4.1\times10^{-6}$ | 202 |
| PEG400 | 1.125 | $7.3\times10^{-6}$ | 224 |
| PAO4 | 0.820 | $3.9\times10^{-6}$ | 219 |
| SHELL 15 | 0.850 | $3.7\times10^{-6}$ | 196 |

- Tests on the substitution of Cyclohexane ($C_6H_{12}$ ) for Freon are proceeding in CIRP's laboratory and on site.

| SYSTEM | Cyclohexane Method | | | Freon Method |
|---|---|---|---|---|
| | Samples | Concentrations | Penetrations | Penetrations |
| DVC | upstream | 41.1ppm | $2.82\times10^{-5}$ | $2.32\times10^{-5}$ |
| | downstream | 1.16ppb | | |
| ETY | upstream | 24.0ppm | $3.95\times10^{-5}$ | $3.86\times10^{-5}$ |
| | downstream | 0.962 ppb | | |



- Pulsive mode halide injection test
  - We made a pulsive halide generator satisfying ASME AG-1 requirements and conducted some research with it. The results showed that this mode could give penetrations as good as a continuous generator.

## ➢ Isotope exchange method for in-situ tests

- The advantage of this method is avoid using toxic dimethyl sulfate to generate $CH_3{}^{131}I$ on site, therefore freeing the plants from toxic chemical management .
- The $CH_3{}^{131}I$ yields we get through experiments are satisfactory for in-situ tests by *AFNOR M62-206 standard.*

- Non-radioactive methyl iodide is studied as the challenge gas of in-situ tests on iodine traps
  - Accurate analysis of methyl iodide at low concentration is the pre-condition of the method. We are developing a delay-time sampling technique to solve the problem. The preliminary results show that 15 minutes of downstream sampling can get enough $CH_3I$ for analysis.

# ◆ Noble gas treatment

- A full-sized normal temperature noble gas delay unit has been established. Test results show that it meets the requirements of noble gas treatment for the 3rd generation reactors.

# 4. Problems

- Apart from imported AP1000, all the rest domestic NPPs have not performed in-leakage testing of their control rooms and emergency centers.
- Unlike NPPs, some nuclear plants and facilities always neglect the periodic tests of their air cleaning systems. That means many deficiencies can not be found timely, in view of the fact that nearly 20% of such systems failed in the past periodic tests .

- Several fire accidents were reported of charcoal adsorbers abroad, however, the safety of iodine adsorbers in fire accidents has not been systematically researched in China.

Therefore the design of the adsorber banks and their fire distinguishing devices are short of reliable data support.

- In some old systems, there are no electrical heaters for iodine adsorbers, hence the iodine removal efficiency can not be ensured if an accident happens in a wet weather.

These problems are all related to nuclear safety and should be solved as soon as possible.

# Expectation and cooperation

- The active nuclear power development plan of China calls for more advanced and reliable nuclear air cleaning technologies to support it.
- China is now more open to foreign technologies. We will pay more attention to the latest nuclear air cleaning technologies, and expect more international cooperation in this field.

# Thank you!