UTILIZATION STATUS AND DEVELOPMENT LAYOUT OF RESEARCH REACTORS IN TSINGHUA UNIVERSITY, CHINA

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Abstract

The Institute of Nuclear and New Energy Technology of Tsinghua University (INET), as the largest education institute of nuclear science in P.R. China, operates three research reactors. How to broaden the utilization of our RRs is the challenge we have to face. In this article, current utilization status of the swimming pool reactor will be introduced. The feasibility of developing the RRs into training center and the advantages of High Temperature Gas-Cooled Reactor (HTR-10) for nuclear hydrogen production will be put forward.

1. PREFACE

The Institute of Nuclear and New Energy Technology of Tsinghua University (INET) was founded in 1960 as a top nuclear research and experimental base in China. In the last forty years, it has become a comprehensive research center with multi-disciplinary research, design and engineering projects mainly in nuclear technology. To further broaden academic disciplines of the institute, the full official name was changed into the Institute of Nuclear and New Energy Technology (INET), in September 2003.

INET includes seventeen research divisions, four research centers and several workshops. Since it was founded, INET has set up a twin-core swimming-pool type Experimental Shielding Reactor [1], a 5 MW Nuclear Heating Reactor (NHR-5) [2] and a 10 MW High Temperature Gas-Cooled Reactor (HTR-10) [3]. INET's research covers more than ten fields related to nuclear, chemical, environmental and energy sciences. There are around 500 faculty and staff members and over 300 graduated students.

INET's main task, as a leading research institute in China, is to help the country meet the challenges in the fields of energy, environment and natural resources through excellent research and development based on the very specific conditions in China, INET conducts R&D in science, technology, engineering, and demonstration. We also try to promote commercialization of the technology we develop.

As mentioned above, INET has three test reactors and infrastructure in the nuclear field. It originally focused only on nuclear science and engineering. INET believes nuclear energy and nuclear technology application will continue to play an important role in China and will strengthen its nuclear capability. In addition, INET will also improve its capability in the fields of energy policy and technology evaluation, and new energy technology like hydrogen, fresh water supply, environment technology, and advanced materials.

Through its continual progress, INET intends to become an internationally recognized R&D center based on its contribution and impact on Chinese society.

INET has established partnerships with many international institutions and has relationships with colleagues worldwide. We appreciate all the help and cooperation from our friends worldwide. We are looking forward to a future of successful international cooperation. Since it was founded in 1960, INET has achieved international prestige due to its productive staff and high standards of scientific research in nuclear science and engineering. In recent years, INET has made great efforts to advance its scientific an technological cooperation with many countries, and its international exchange activities are multiplying. It has agreements for bilateral exchanges and cooperation with dozens of universities and has established academic and research ties with over 50 institutes, companies and organizations worldwide. Every year, several hundred scholars and experts visit INET from many parts of the world, giving presentations, undertaking joint research and co-sponsoring graduate students. Additionally, more than one hundred faculty members are invited abroad for many purposes.

In this article, where the 901 reactor is taken as example, the utilization status of RRs of INET will be introduced firstly. In the latter part, the research of hydrogen production by HTR-10 will be present.

2. 901 REACTOR

901 reactor, as the first nuclear reactor self-designed and self-established by China, was founded in 1960 and reached criticality in 1964. It is a twin-core swimming-pool type experimental research shielding reactor with all-purpose design and has safe operated for 43 years.

The design heat power of No.1 core is 2MW with 9 horizontal experimental channels. No.2 core is 2.8MW with 20 vertical channels. Both operate at 1MW level now.

Since it was founded in 1960, 901 reactor has completed a great deal of research, including shielding material experiments, seed irradiation, NTM production, neutron photographic, anti-irradiation reinforcement experiments, nuclear measuring apparatus calibration, neutron activation analysis, NTD silicon production, surplus heating, and so on.

In next section, nuclear track-etched membrane anti-counterfeiting technology will be introduced as the typical utilization of 901 reactor.

3. NTMAC

Theory of nuclear track-etched membrane anti-counterfeiting (NTMAC) technology is based on nuclear track technology. When the polyester is irradiated by nuclear particles, through holes can be formed after the polyester is etched. The polyester with uniform through hole is called nuclear track-etched membrane (NTM), which obtained U.S. patent in 1967. With the foundation of Nuclepore Corporation in 1972, the NTM began to be produced of commerce. Since 1982, INET conduct an investigation in NTM and met demands of clients from pharmacy, food, chemical industry, environment, etc.

INET had developed production of NTMAC label in recent years with its particular 901 reactor and technology of image shaping. NTMAC label produced by INET has reached international advanced level and be adopt by scores of famous enterprises in China.

The production process of NTMAC is list as follows:

— Nuclear track generating:

  a) Reactor generating thermal neutron;
  b) Thermal neutron bombard U-235 target;
  c) Polyester is bombard by fission fragments;
  d) Polyester is damaged and tracks are generate;

— Sensitization of track by ultraviolet ray;
— Image shaping:

  a) Key technology developed by IAEA;
  b) Polyester is printed by anti-etch glue with the fine images naked;

— Etch of track:

a) Polyester is etched by etchant;

— After production.

The qualification of NTMAC is list as follow:

- — Material: Polyester(PET);
- — Diameter of Micropore: 0.004～0.006 mm;
- — Density of Micropore: $4～8\times10^{5}$ cm^{-2};
- — Slope Distribution: 0～50°;
- — Location Distribution: Random;
- — Distribution of Micropore Direction: Random.

There are four obvious advantages of NTMAC.

— High-tech, High-input, High-monopolistic:

a) NTMAC is the product of high-tech and high-monopolistic nuclear facilities. Nuclear material and specified reactor are indispensably that counterfeiters can hardly imitate;
b) INET is the only entity who has the capability of producing NTMAC with reactor;
c) Multi-disciplinary, such as nuclear, chemistry, mechanism, physics and electronic, are synthesized that counterfeiters can hardly master;

— Almost impossible to be imitated:

a) NTMAC labels are imaged by 100 thousands random distributed micropores that no other methods can do;

— Simplification of general identification methods:

a) There are two types of NTMAC label: Drip-Disappear type and Color-Printing type;
b) Daubed the Drip-Disappear type label with transparent liquid such as water or alcohol. The figure on the label will disappear until the evaporation of the liquid;
c) Daubed the Color-Printing type label with color pen. Wipe away the color, the figure will appear;
d) Tear the membrane off the label and then line a piece of paper under the membrane. Daubed the membrane with color pen. The figure will appear on the lining paper;
e) The figure are made of random white micropores can be observed by 20～80 magnifying glass;

— Expert identification methods can be used as judicial expertise means:

a) Column micropores generated by nuclear track can be observed the membrane torn from label by optical microscope;
b) The micropores have strict parameters which can be controlled by the processes of irradiation and etch. The strict code stored permanently on the label by the processes control.

4. HTR-10 AND HYDROGEN PRODUCTION

As we know, hydrogen could become an important and potential option for a sustainable energy system, as it can be used to meet most energy needs without harming the environment.

However, widespread use of hydrogen is not feasible currently because of economic and technological difficulties.

One of them is to produce hydrogen massively with clean, economic and sustainable way.

Traditional hydrogen production methods include steam methane reform and electrolysis. The former is a CO_2 emission process, in which both the feedstock and process heat source are CO_2 emitter. The latter is an expensive way.

Many new methods are developed. Such as producing hydrogen from wind, solar, biomass, nuclear etc, however, we agree that there is no cost effective and environmentally friendly massive hydrogen production way so far. Therefore, we must make our efforts to develop hydrogen production methods. One of the most promising methods is nuclear hydrogen production.

China government has attached top priority on the development of nuclear and hydrogen energies, both of which have been integrated in the National Mid-to-Long Term Plan for Science and Technology of China (2006-2020) announced in February 2006. Development of HTGR has been selected within the 16 Major Programs in the Plan. Hydrogen from nuclear project is included in the Program.

High Temperature Gas-cooled Reactor (HTGR) is well known as the advanced type reactor in the international nuclear industry. HTGR takes the advantages of safety features, high efficiency and wide application. The coated particle fuel with excellent performance at high temperature is used in HTGR. The helium of inert gas used as the coolant and the graphite used as the moderator characterize the HTGR.

The VHTR (Very High Temperature Reactor), a type of HTGR with 1000℃ outlet temperature of helium coolant, is considered as one option of Generation IV system.

In INET, a high temperature gas cooled reactor, HTR-10, has been constructed and reached criticality in 2000. In 2003, the full power operation test was successfully made.

Besides electricity generating, HTR-10 can provide process heat with various temperatures up to 900°C (now the highest outlet temperature is 750°C), which is promising to couple with some thermochemical water-splitting processes as well as high temperature steam electrolysis technique. As an important application of high temperature heat, the nuclear hydrogen programme was initiated since 2004.

There are two options for NH production which INET conducting: IS cycle and high temperature electrolysis.

Principle of IS cycle is based on the following three reactions. We can see that the heat delivered by HTR-10 match that needed by sulphuric acid decomposition well. The IS process shows advantages of reactor matching, high efficiency, security, no-fossil fuel and massive production.

There are some pictures of experimental benches of IS cycle. We still have a lot of work to do to implement our research plan.

The other option process is high temperature electrolysis (HTSE). System principle of HTSE is showed as below. In this process, water vapor needed by electrolysis is offered by HTR-10. The advantages of HTSE process are no associated greenhouse gas emissions, high efficiency, rapid production and technological feasibility.

Despites the advantages mentioned above, we have to face many challenges. Now, we are making our efforts to developing electrode materials and testing apparatus. There are some pictures of experimental results and test benches of HTSE.

In our recent development layout, INET will be constructed into international comprehensive training center of nuclear science and technology.

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