3.2 Accomplishment of 10-year Research in NUCEF and Future Development - Criticality Safety Research -

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Since 1995, static and transient critical experiments on low enriched uranyl nitrate solution have been performed using two solution type criticality facilities, STACY and TRACY constructed in NUCEF. The obtained fundamental and systematic data on aqueous solution were used to validate the criticality safety calculation codes and to develop the transient analyses codes for criticality accident evaluation. This paper describes the outline of the criticality safety research conducted in NUCEF.

KEYWORDS: Critical Experiments, STACY, Homogeneous Core, Heterogeneous Core, TRACY, AGNES, Burnup Credit, JACS

1. Introduction

From the view point of criticality safety for nuclear facilities related to the fuel cycle in Japan, experimental studies on static and transient criticality characteristics of low enriched uranyl nitrate solution have been performed using two experimental facilities in NUCEF. Since the initial criticality of STACY in 1995, a fundamental critical data on 10% and 6% enriched uranyl nitrate solution for single core system have been accumulated. In addition, criticality properties for complicated system such as multiple core system and heterogeneous system simulating a dissolver in the reprocessing plant have been studied.

These data are used to validate the Japanese criticality safety computer code system, JACS and to improve Japanese Evaluated Nuclear Data Library JENDL 3.2. JAERI has participated in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) of OECD/NEA since the beginning of this project. The criticality data obtained at STACY have been carefully evaluated based on the benchmark evaluation method of the ICSBEP. Kinetic parameters and reactivity coefficients, which dominate the transient profile, were also measured for various core configuration, and evaluation methods for these parameters were developed. Measurement technique for subcritical fuel system and simulation method are under developing.

On the other hand, transient characteristics have been investigated with TRACY using 10 % enriched uranyl nitrate solution since 1996. Power profile data in various condition of reactivity addition mode were accumulated using an unreflected cylindrical core. Transient

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data of TRACY were used to develop a kinetics code AGNES which simulates the phenomena in the criticality accident of fuel solution system. This code was utilized to evaluate the total fission yield at the first critical accident of Japan in 1999. In order to establish the measures in the critical accident in fuel cycle facilities, spatial distribution data of neutron and gamma ray and spectral data are accumulated.

2. Static Experiments with STACY

In the homogeneous system, single core tank is installed for measuring basic benchmark data such as critical solution height, reactivity effect of reflector and fuel solution temperature[1-4]. For study on neutron interaction effect, two core tanks are installed for measuring the basic characteristics of reactivity from one core to another. Distance and specification of shielding materials between two tanks are changed during this experiment[5]. For demonstrating the criticality safety codes of, JACS, heterogeneous system composed of array of UO_2 rods immersed in uranyl nitrate solution were constructed. Lattice pitch of fuel rods, concentration of uranium in fuel solution are main critical parameters[6].

Subcritical measurements were also performed to develop the criticality safety monitoring techniques[7]. Kinetic parameter such as the ratio of $\beta eff / l$ (βeff : effective delayed neutron fraction, l : prompt neutron life time) is a dominant parameter which determines the transient characteristics at a criticality accident[8]. Temperature coefficient is a main parameter which effects the transient characteristics at a criticality accident. Reactivity effects due to change in fuel temperature were measured with two cylindrical cores of 60 cm and 80 cm in diameter, which contain 10% enriched uranyl nitrate solution.
Since introduction of burn-up credit is a main issue of advanced criticality safety design and control, a series of experiments to demonstrate the neutron absorber effects of main elements of fission products are on schedule[9].

JAERI plans to revise the criticality safety data and handbook by using the latest code system validated with wide range criticality data of NUCEF, and to establish a consolidated criticality evaluation system JACS2, which includes criticality and burn-up codes including main interface for criticality accident evaluation[10]. NUCEF will contribute as a useful facility to obtain fundamental criticality data on various kind of fuels such as MOX and MIX solution.

3. Transient Experiments with TRACY

In order to investigate the criticality accident phenomena of solution fuel, an experiment program using the transient experiment criticality facility, TRACY, has been conducted by Japan Atomic Energy Research Institute. Since the first criticality, more than 200 of the operations of TRACY have been performed and many basic data for low-enriched uranyl nitrate solution were obtained. Data such as power profile and the number of released fissions were measured under various experimental conditions[11].

The obtained data are expected to be useful for the emergency planning for a reprocessing plant, determining the action against an emergency situation and the estimation of the fission yield released at a criticality accident. The experiments using highly-enriched uranium solution were also performed with CRAC and SILENE reactors before, however, there are little experimental data for low-enriched uranium solution.

A one-point kinetics code, AGNES2, has been developed for the evaluation of the criticality accident of nuclear solution fuel system[12]. The code has been evaluated through the simulation of TRACY experiments and used for the study of the condition of the JCO criticality accident. A criticality accident which occurred at a precipitation tank in the JCO company Tokai-works in 1999 was simulated using AGNES2 code for the investigation of the condition which initiated the accident. The geometry of the precipitation tank was very complicated, however, a cylindrical shape was used for the simulation. It contained 18.8% enriched uranyl nitrate solution at that time. The uranium concentration was 370gU/Lit. and the acid molarity was 0.5mol/Lit. The solution was poured into the tank using a bucket when the criticality achieved. Based on the excess reactivity evaluatied a Monte Carlo Code MCNP, transient analyses were made with AGNES2 to study the power profile in the initial burst region. The simulated values show good agreement with the value of the gamma-ray area monitor except the detail fluctuation. From this result, the inserted reactivity is estimated between 1.5$ and 3.0$ [13].

Typical data of pulse withdrawal mode were adopted as a benchmark problem for international comparison of the criticality accident evaluation codes at the Working Party on Nuclear Criticality Safety in OECD/NEA. Studies on transient characteristics with a water reflected core are planned in TRACY.

4. Future subjects

Relating to the fuel solution system encountered in the reprocessing plant, following experiments and analyses are important in nuclear criticality safety field.

- Acculmuation of critical data on neutron absorber such as gadolinium to evaluate the reactivity effect.
- Study on reactivity effects of main Fission Products for introducing burn-up credit level-II.
- Development of sub criticality evaluation technique applicable to equipments on site.
- Systematic benchmarks for validating criticality safety code and nuclear date for plutonium system such as MIX solution and MOX powder fuels.
- Development of integrated criticality evaluation system composed of the burnup calculation code and criticality calculation code.
- Study on transient behavior for water reflected system of low enriched uranyl nitrate solution and to evaluate the cooling effect on power profile.
- Development of critical accident evaluation system for both nuclear characteristics and spatial distribution of neutron and gamma ray for dose evaluation

- **Validation of criticality safety and transient code for plutonium fuel system.**

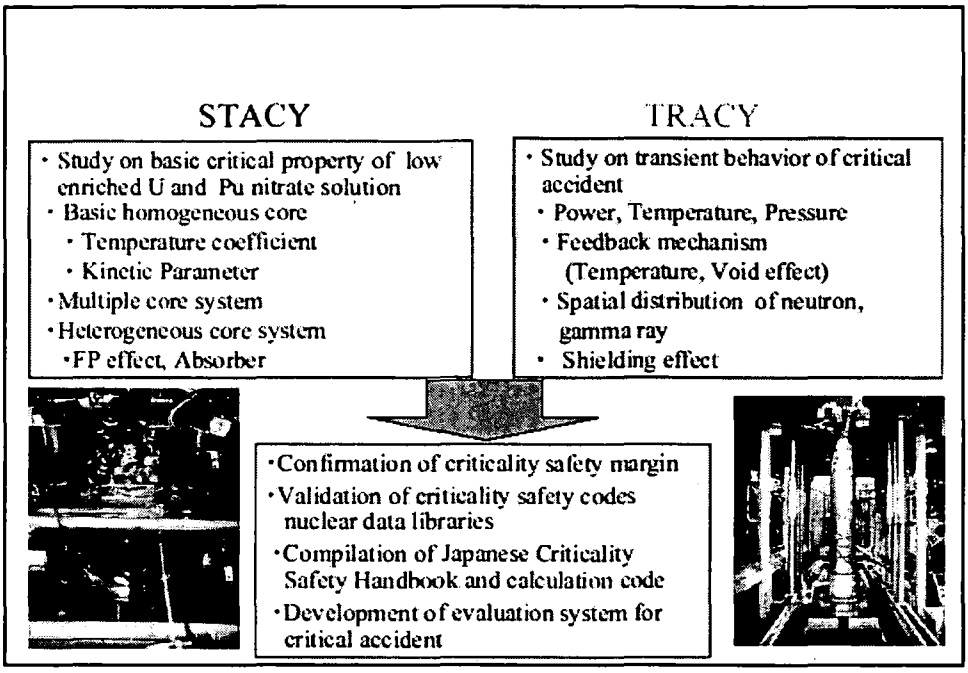

Figure 1. Research subjects of STACY and TRACY for fuel solution system

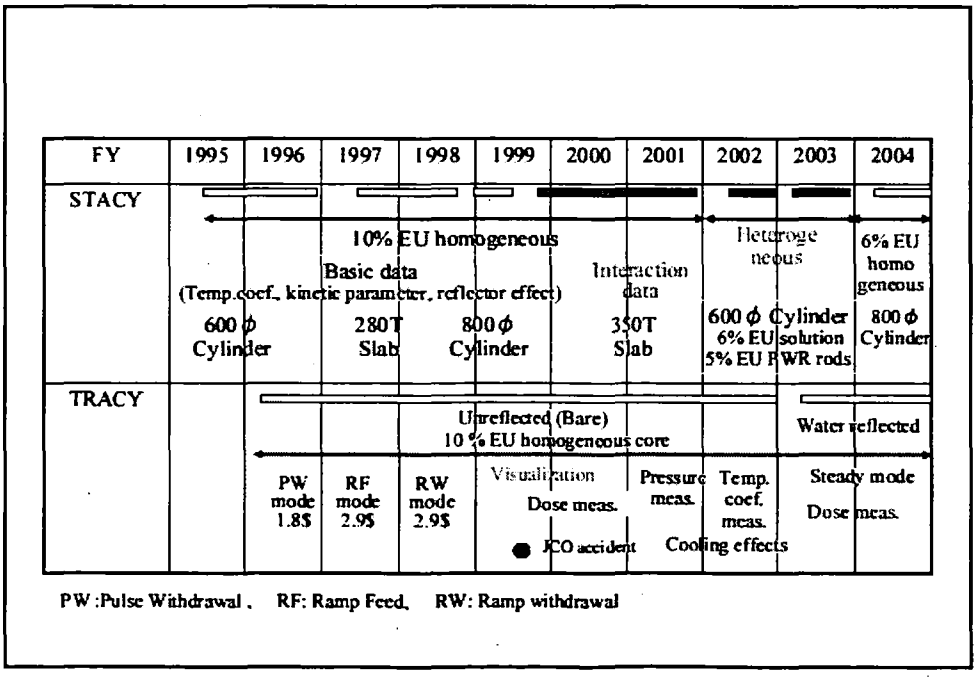

Figure 2. History of critical experiments in STACY and TRACY

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