Outline of NUCEF Facility

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Introduction

NUCEF is a multipurpose research facility in the field of safety and advanced technology of nuclear fuel cycle back-end. Various experiment facilities and its supporting installations, in which nuclear fuel materials, radio isotopes and TRU elements can be handled, are arranged in more than one hundred rooms of two experiment buildings. Its construction was completed in middle of 1994 and hot experiments have been started since then.

Facility Layout

NUCEF is located on the site (30,000m^2) of southeastern part in the Tokai Research Establishment of JAERI facing to the Pacific Ocean. The base of Experiment Buildings A and B was directly founded on the rock existing at 10~15m below ground level taking the aseismatic design into consideration. Each building is almost same sized and composed of one basement and three floors of which area is 17,500m^2 in total (Fig. 1). In the basement, there are exhaust facilities of ventilation system, treatment system of solution fuel and radioactive waste solution and storage tanks of them. Major experiment facilities are located on the first or the second floors in each building. An air-inlet facility of ventilation system for each building is equipped on the third floor.

Most of experiment facilities for criticality safety research including two critical facilities: Static Experiment Critical Facility (STACY) and Transient Experiment Critical Facility (TRACY) are installed in Experiment Building A. Experiment equipments for research on advanced fuel reprocessing process and on TRU waste management, which are named BECKY (Back End Fuel Cycle Key Elements Research Facility), are installed in laboratories and a-g cells in Experiment Building B (Table 1, Fig. 2).

Construction History of NUCEF

Following the arrangements of research programs and the conceptual and basic design of the facility, internal safety review was initiated on 1986. On October 1988, construction license was given by the government after the safety review for more than one year. It took six years to complete the construction of NUCEF. After 150kg low enriched uranium dioxide was dissolved into nitrate solution, the first criticality test was successfully achieved on February 23 this year. Hot experiments in BECKY were also started from the beginning of this year. The first criticality test of TRACY is planned on coming December (Table 2).

Facilities for Criticality Safety Experiments

Major facilities for criticality safety research in NUCEF are STACY, TRACY and Fuel Treatment System.

(1) STACY

STACY was designed so as to obtain critical mass data of low enriched uranium and plutonium nitrate solution which are extensively handled in an LWR fuel reprocessing plant. The core tank of STACY is replaceable to obtain critical mass data of different geometry and size of tanks. Moreover, not only single core system but interacting system with two core tanks can be formed. The core system is installed inside a reactor hood in a reactor room because of the contamination control. Major specification of STACY is listed in Table 3. Reactivity control of STACY is made by feed and drainage of solution fuel to/from the core (Fig. 3).

A contact needle type level meter is used to measure the solution level in the core. Two additional needles are attached to the tip of the level meter to detect the over feeding of fuel solution and to trigger off reactor shutdown (Fig. 4).

(2) TRACY

TRACY is a critical facility by which critical burst is demonstrated with low enriched uranium nitrate solution. Major specification is listed in Table 4. Maximum integrated power is limited to 32MW•sec (1×10^{18} fission). On steady state operation of TRACY, reactivity control is made by feed and drainage of solution fuel to/from the core tank like STACY. For the transient operation, two methods can be applied to add reactivity to the core. One is withdrawal of a transient rod inserted in the center of the core by pressurized air or by an electric motor. The other is feeding of solution fuel to the core tank beyond the critical level (Fig. 5). Another difference from STACY is the vent line system which is directly connected to plenum of core tank and forms a closed loop. Along the vent line, sampling points of aerosol released from solution fuel and measurement devices of iodine are equipped to investigate behavior of aerosol including fission products during critical excursion. This closed vent line system has also the safety function to dilute hydrogen gas and to reduce radio activity that are generated in the core during the experiment (Fig. 6).

(3) Fuel Treatment System and other subsidiary equipments

This system is designed exclusively to arrange solution fuel for STACY and TRACY experiments, which enables the experiments with wide range of composition and concentration of nuclear fuels in both critical facilities. Dissolution, dilution and concentration, separation and solution storage are main functions of the system (Fig. 7). These functions resemble those of reprocessing process, however its capacity is just laboratory scale and all equipments are installed in glove boxes because of low radio activities of solution fuel.

Various destructive and non-destructive analysis equipments are installed in Analytical Laboratories in Experiment Building B to support the critical experiment and the operation of fuel treatment system as well as the nuclear material accountancy (Fig. 8). Some of those analytical equipments, which are listed in Table 5, are used for experiments in BECKY. Among them, Hybrid K-edge/XRF densitometer has been developed and fabricated by Los Alamos National Laboratory under the US DOE/JAERI research cooperation (Fig. 9).

In Alpha-chemical laboratory in Experiment Building A, basic experiments are carried out on process anomaly which might potentially cause critical accidents. In the same laboratory, an in-line test loop is installed for the development of in-line monitor for reprocessing process (Fig. 10).

Facilities in BECKY

Experiment facilities and equipments in BECKY are listed in Table 1. Major experiment equipments are installed in hot cells and 27 glove boxes in several laboratories in Experiment Building B.

(1) Hot Cells

The hot cells consist of three cells; a process cell, a chemical cell and a loading cell. In the process cell, laboratory-scale experiment equipments are installed for research on reprocessing and partitioning processes called PARC Process and Four-group Partitioning of high level liquid waste (HLLW), respectively (Fig. 11, Fig. 12). Spent fuel specimens up to 45,000MWD/t (3kg/year) and actual HLLW (5,000Ci/year) can be handled in the process cell for both experiments. Small amount of spent fuel up to 72,000MWD/t can be treated for research on TRU chemistry in the chemical cell adjacent to the process cell.

(2) Analytical Experiments in Glove boxes and Hoods for Reprocessing Experiments

Some of the glove boxes are attached to the hot cells for iodine treatment research, analysis of dissolution off-gas, and sampling of test specimen (Fig. 13). Chemical analysis with small amount of TRU or radio isotopes are conducted in glove boxes and hoods which are installed in three laboratories of Experiment Building B.

(3) Experiment Equipments for TRU Waste Management Research

Experiment equipments for ceramic solidification of TRU waste and for measuring migration behavior of TRU elements in natural and engineered barriers are installed in nine glove boxes in a TRU waste laboratory (Fig. 14, Fig. 15). Originally designed non-destructive measurement systems for TRU waste forms are installed in a laboratory in the basement of Experiment building B. This measurement systems are composed of experiment equipments with passive and active assay using neutrons and computed tomography equipment using gamma-ray (Fig. 16).

Provisions for Future research program

There are a few rooms remained for future use in NUCEF. One is a space in a laboratory II whose floor sustains heavy steel cells (Fig. 17). Another one is a room adjacent to reactor room T where was originally a space of tall pulse columns tests for criticality safety research. Preparation of ventilation is already made to both rooms. Some of the rooms will be also supplied for future use if their research program is finished.

Current schedule of NUCEF

Hot experiments has just been initiated in NUCEF. Critical experiments of STACY with plutonium solution is planned when all equipments for plutonium handling are completed. Criticality burst experiment with TRACY is to be started after hot performance tests by the regulatory body is finished in middle of next year. However, some basic data on criticality excursion with low enriched uranium nitrate solution are expected to be obtained even in the performance tests.

BECKY will gradually enter into the phase of hot experiments with irradiated fuel or actual HLLW, and steel cell installation is expected to be started within a few years (Fig. 18).

Table 1 Facility Groups in NUCEF

Research Area	Major Facilities	Regulation
Criticality Safety	- STACY - TRACY - Fuel Treatment Facility - Chemical Analysis Equipments	Reactor, RI
Reprocessing (Group Partitioning)	- $\alpha\gamma$ cells - PARC Process Experiment Facility - Four Groups Partitioning Facility - Experiment Equipments for TRU chemistry	Nuclear Fuel Facility (BECKY), RI
TRU waste	- Equipments for TRU waste Solidification - Performance Test Equipments for Barriers - Equipments for Passive and Active Assay	

Table 2 Construction Milestones

1986 ~	Safety Assessment
1988 Oct.	Construction License
1993	Completion of Buildings
1994	Function Test in Cold State
1994 Sep.	Dissolution of Uranium Dioxide
1995 Feb.	First Criticality of the STACY
1995 Dec.	First Criticality of the TRACY

Table 3 Major Specification of STACY

Power	Max. 200W
Excess Reactivity	Max. 0.8$
Fuel	U nitrate solutionm, Pu nitrate solution and Mixture nitrate solution
Isotope ratio	^{235}U enrichment: 4%, 6% and 10% ^{240}Pu ratio: 5%~25%
Core Configuration	Basic homogeneous core: Unit cylindrical or slab tank Interacting homogeneous core: Identical cylindrical or slab tanks Heterogeneous core: A cylindrical tank and fuel rods
Core Dimension	Height of fuel solution part: 40cm~140cm Radius of cylindrical core: 21cm~100cm Thickness of slab core: 10cm~50cm Width of slab core: 70cm(Fixed)
Reactivity Control Method	Feed and drainage of fuel solution
Shut Down Method	Normal operation: Drainage of fuel solution Emergency: Insertion of safety rods or sheets

Table 4 Major Specification of TRACY

Power	Static operation mode: Max. 10 kW Transient operation mode: Max. 5GW
Integrated Power	Max. 32 MW-sec (1×10^{18} fissions)
Fuel	Uranium nitrate solution Enrichment: 10% Concentration: Max. 500 gU/lit.
Reflector	none or water
Core Dimension	Shape: Annular Inner diameter: 10cm Outer diameter: 50cm or 80cm Height of fuel solution part: 40cm~100cm (Height of core tank is 200cm)
Initial Temperature	<40 °C
Maximum Pressure	880 kPa

Table 5 Major Analytical Equipment

Equipment	Analytical Method	Application
Density Meter	Vibration Tube Method	Solution Density
Mass Spectrometer	Surface Ionization Mass Spectrometry	Isotope Composition
Automated Potentiometric Titrator	Redox Titration Neutralization Analysis	Concentration of U or Pu Concentration of HNO_3 or TBP
Hybrid K-edge/XRF Densitometer	K-edge Absorption X-ray Fluorescence Spectrometry	Concentration of U or Pu
γ-ray Spectrometer	γ-ray spectrometry	Concentration of γ nuclides
α Spectrometer	α Spectrometry	Concentration of α nuclides
ICP Emission Spectrophotometer	ICP Emission Spectrophotometry	Concentration of impurities
UV Spectrophotometer	Absorption Spectrophotometry	Concentration of U, Pu Impurities, etc.
IR Spectrophotometer	Absorption Spectrophotometry	Concentration of TBP residues in solution
Liquid Scintillation Counter	Liquid Scintillation Counting	Concentration of ^{3}H, ^{14}C, etc.
NaI Scintillation Counter	NaI Scintillation Counting	γ Activity
Gas-flow Counter	2π Gas-flow Counting	α and β Activity

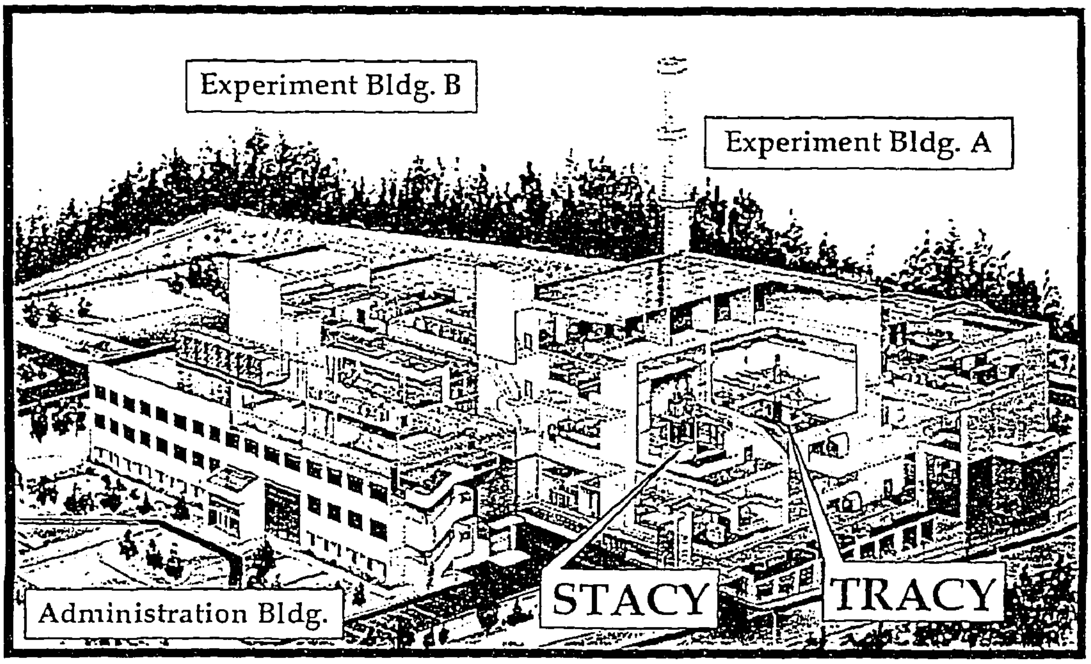


Fig. 1 Bird's eye view of NUCEF

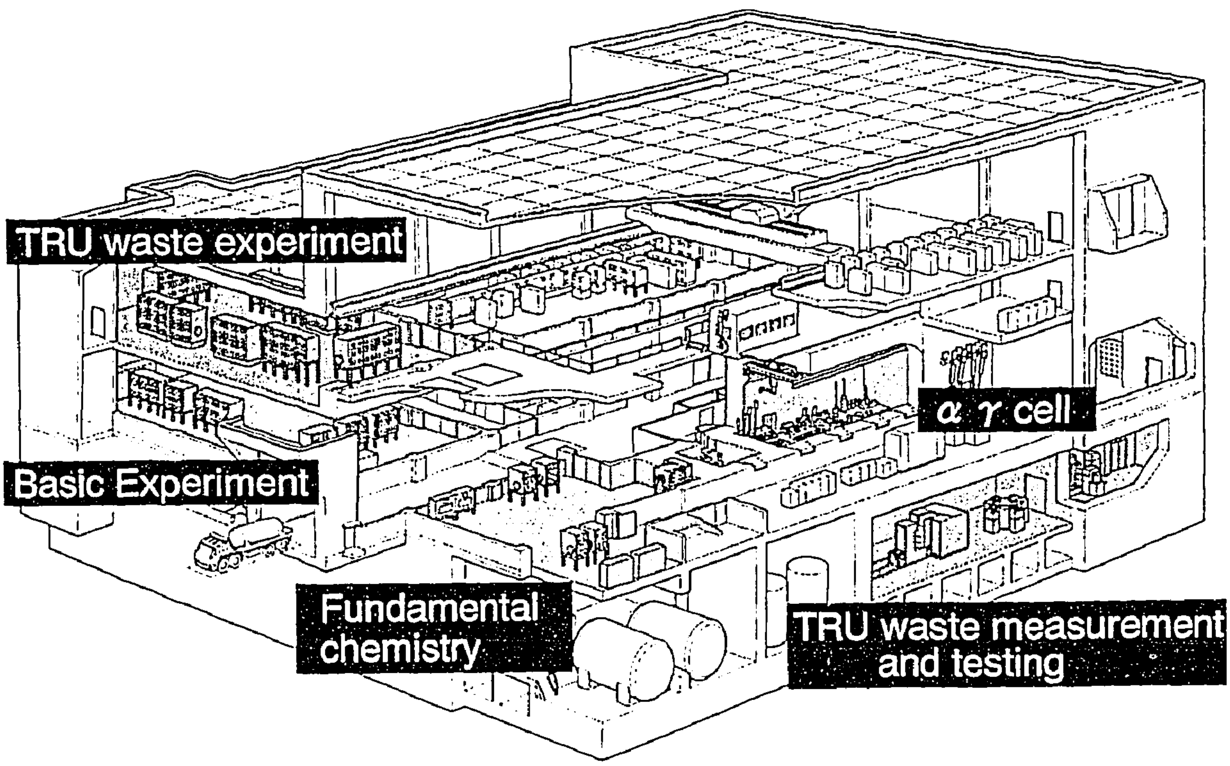
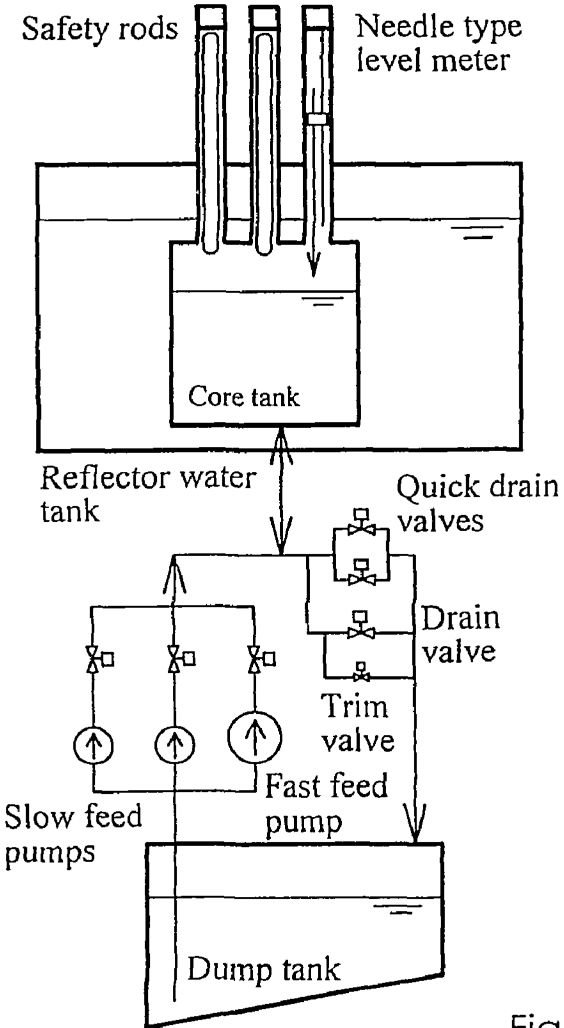


Fig. 2 Bird's eye view of Experiment Building B (BECKY)



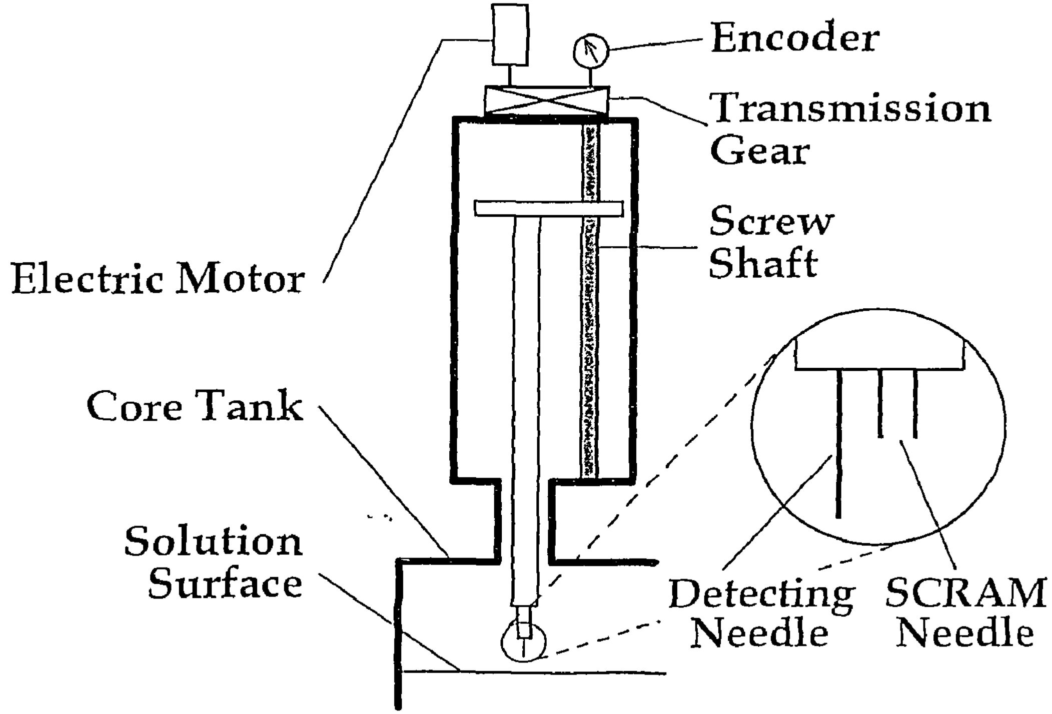


Fig. 4 Level Meter of STACY

Fig. 3 Schematic Flow Diagram of STACY

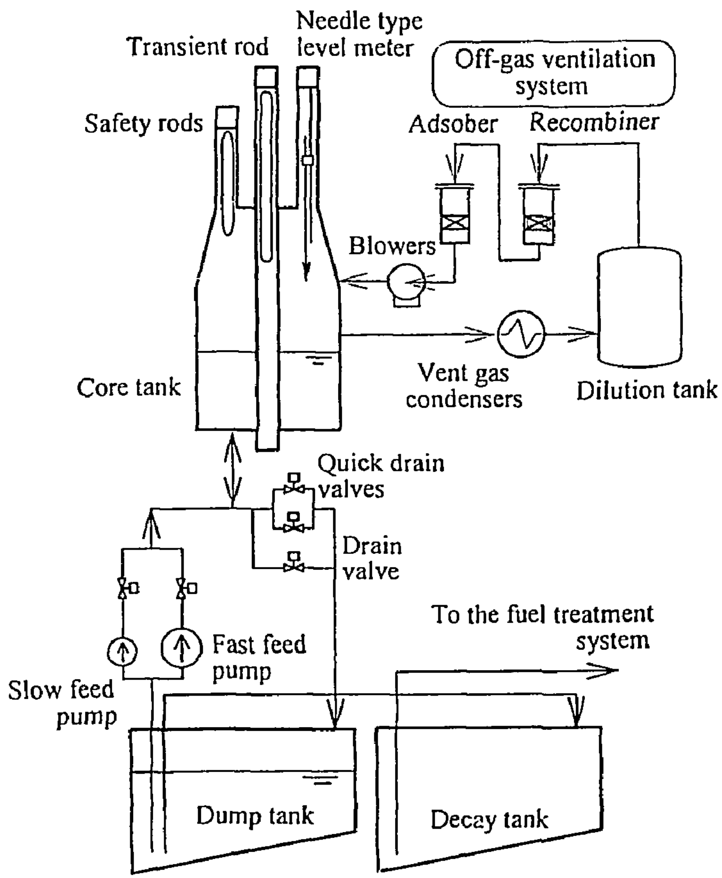


Fig. 5 Schematic Flow Diagram of TRACY

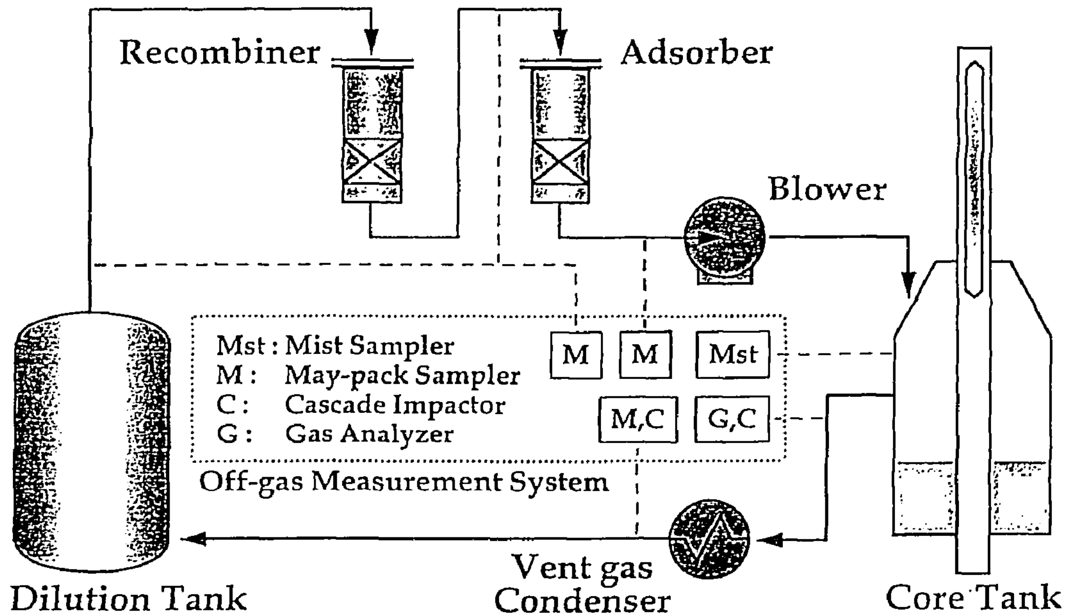


Fig. 6 Off-gas Ventilation System

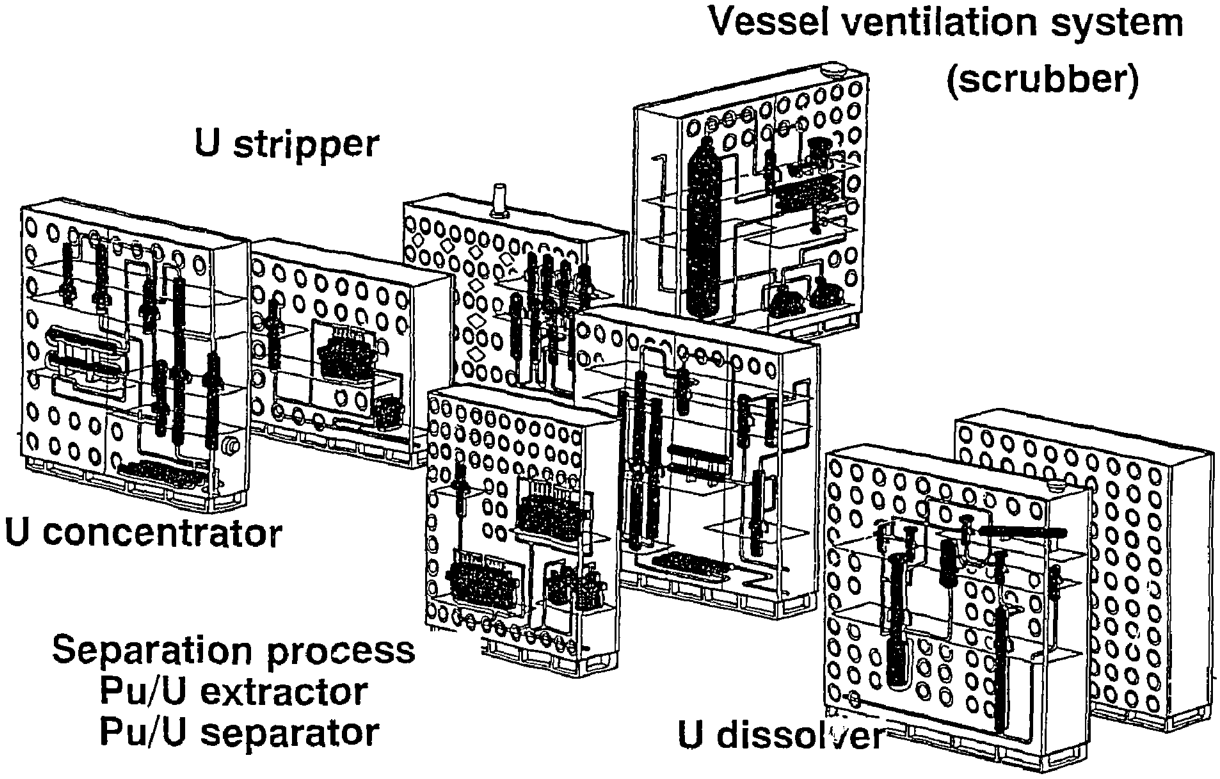


Fig. 7 Layout of Fuel Treatment System

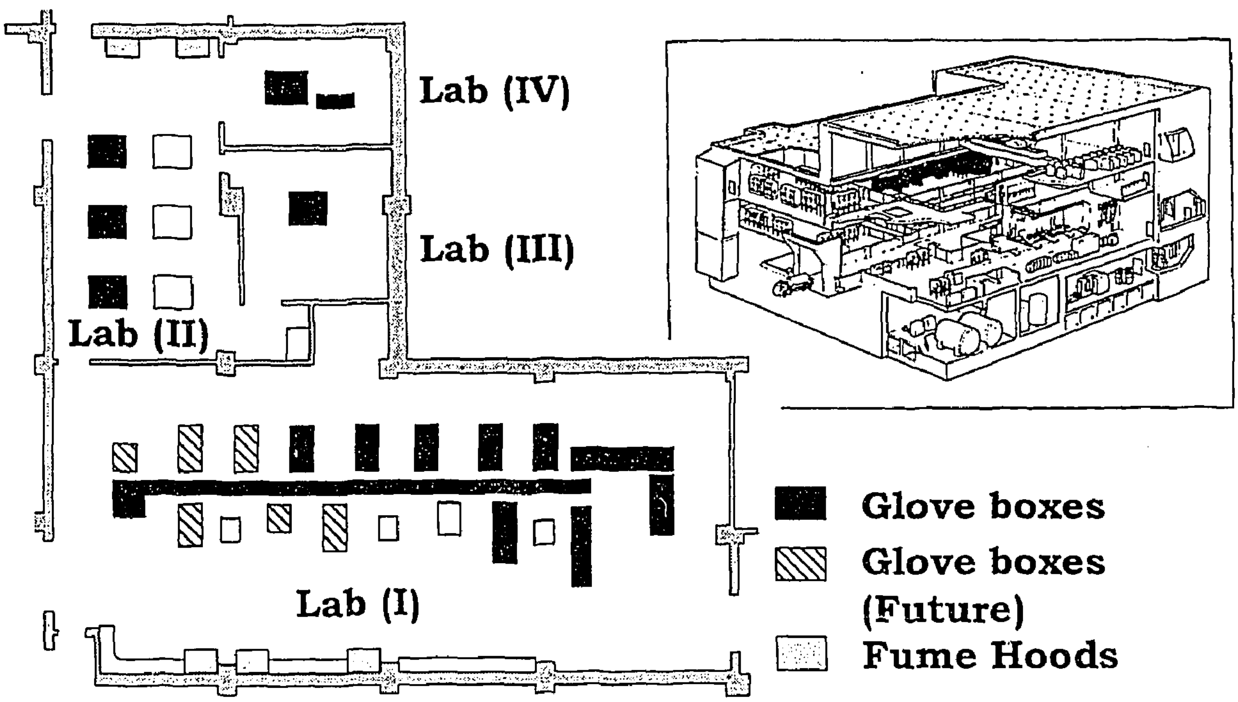


Fig. 8 Layout of Analytical Laboratories and Instruments

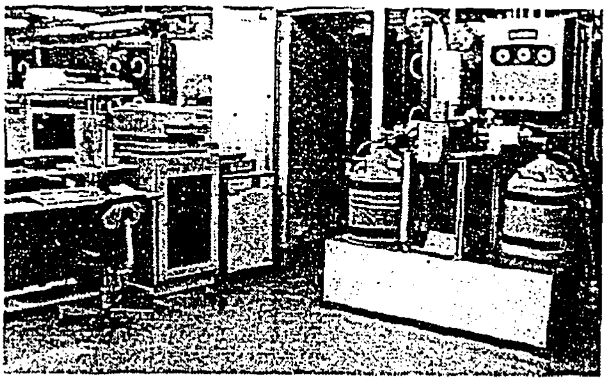


Fig. 9 K-edge Absorption/X-ray Fluorescence Spectrometry

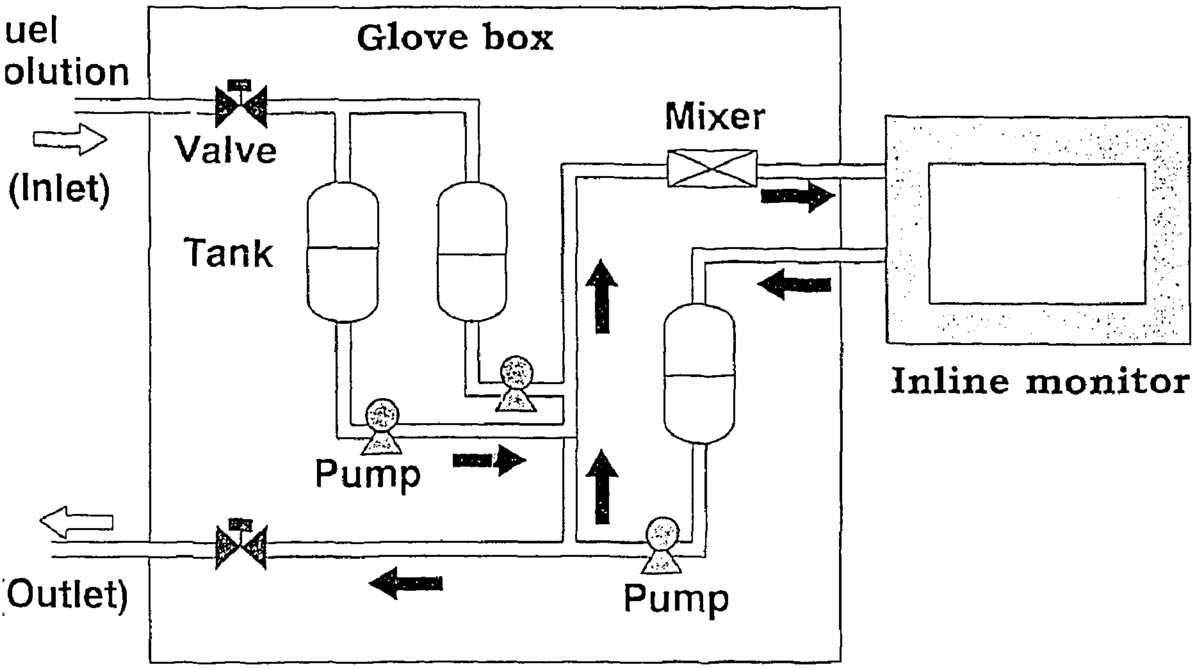


Fig. 10 Schematic Flow Diagram of Equipment for Inline Monitoring Test

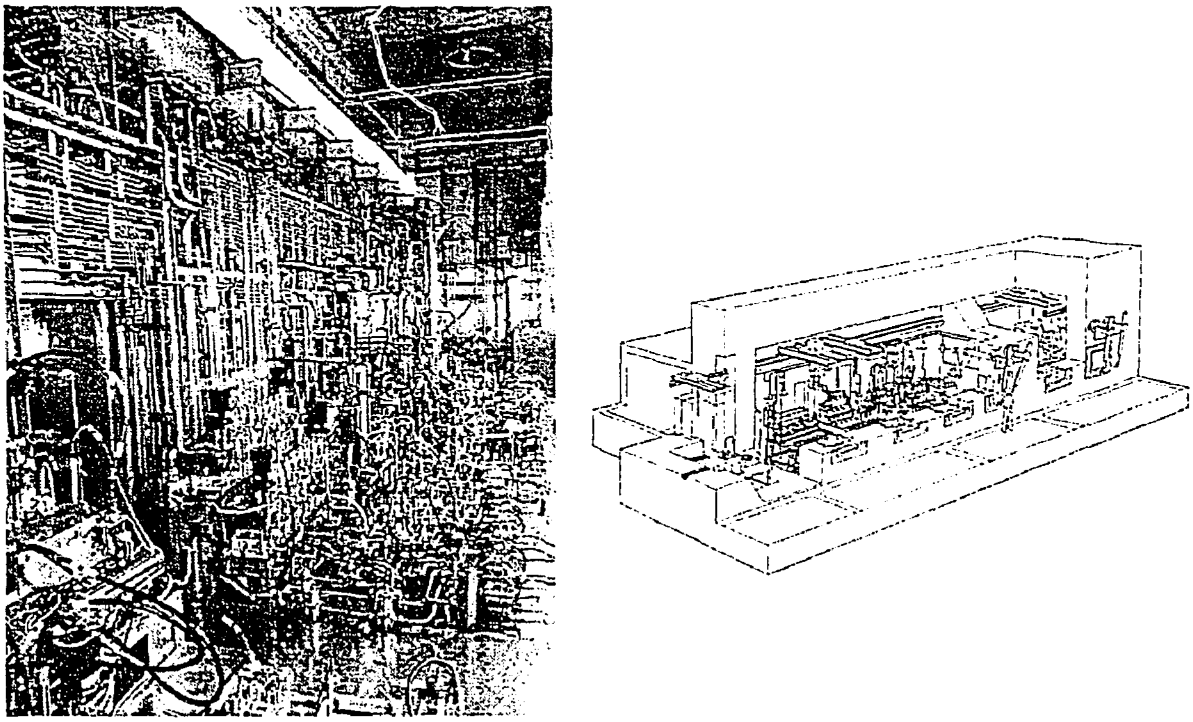


Fig. 11 Reprocessing Process Experiment Equipment

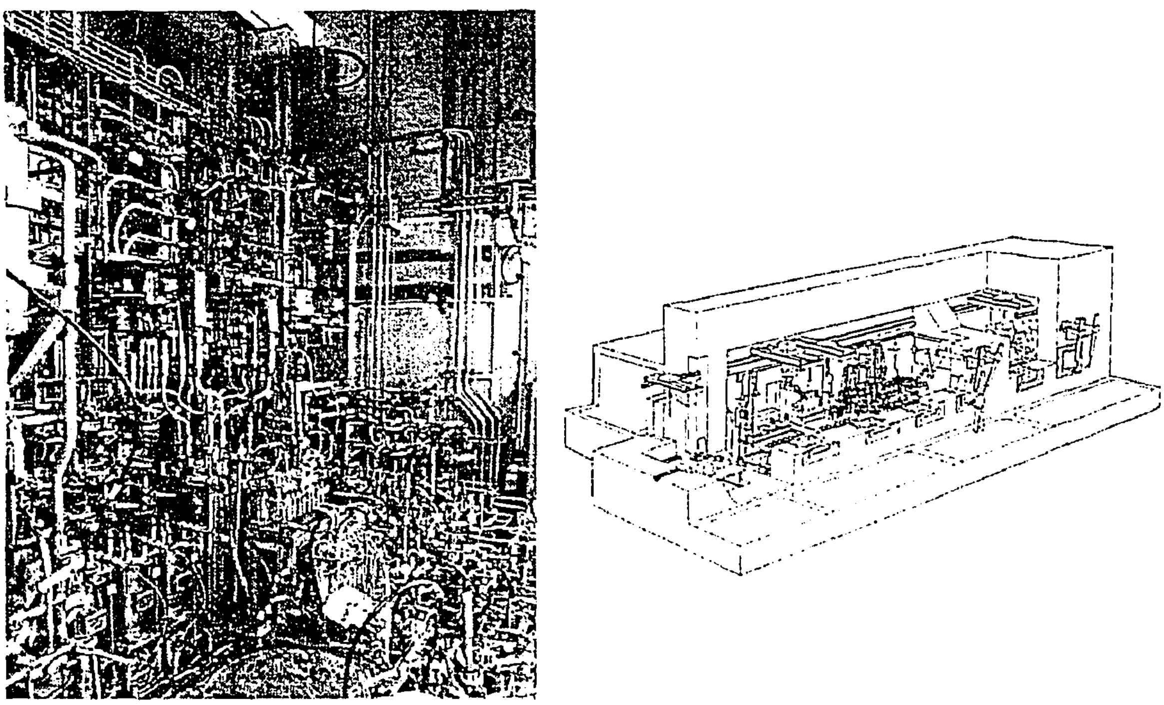


Fig. 12 Equipments of Partitioning Process

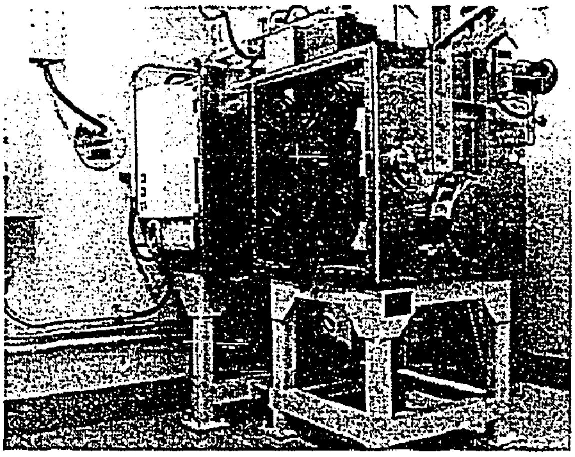


Fig. 13 Sampling Box

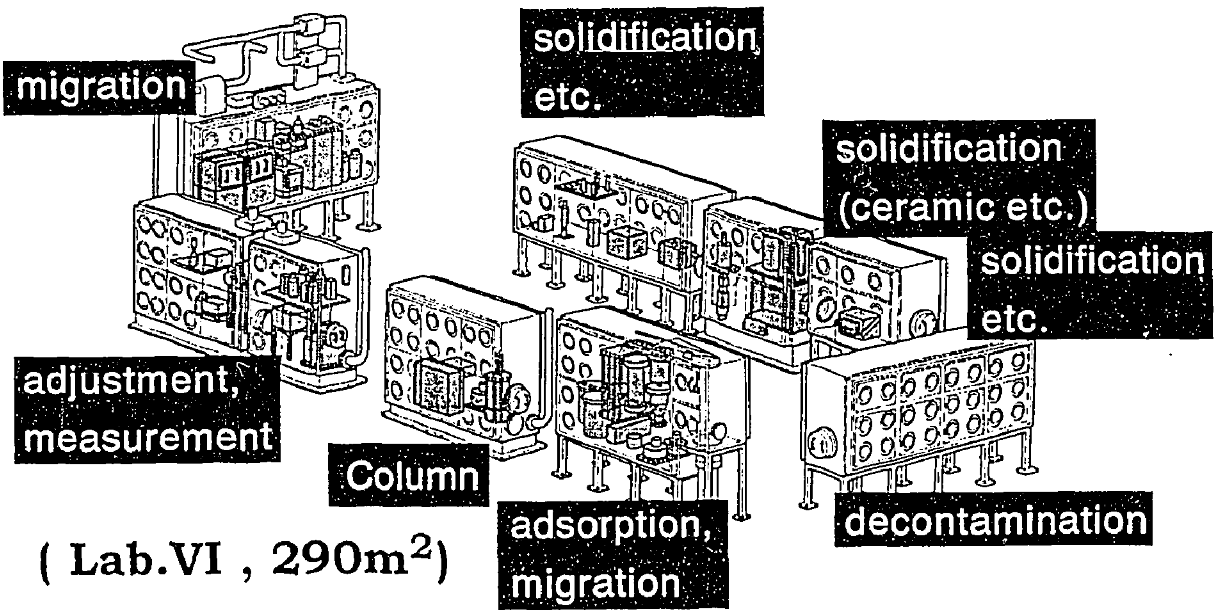


Fig. 14 Glove Boxes for Research on TRU Waste Treatment and Disposal

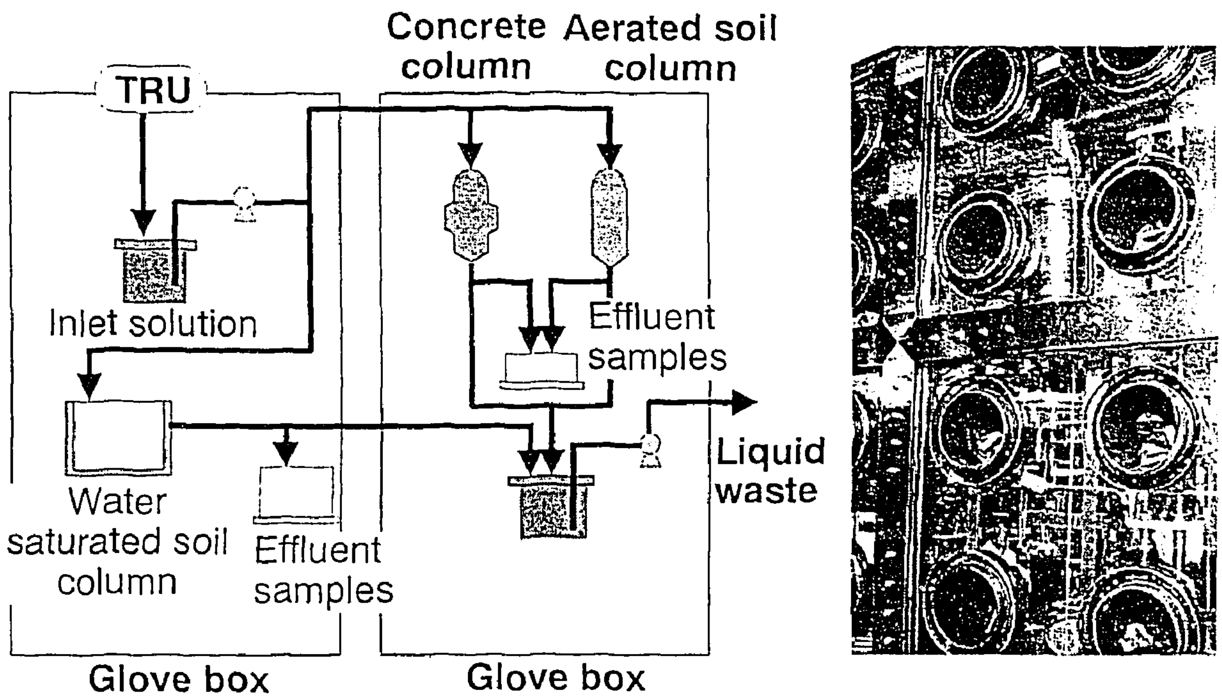
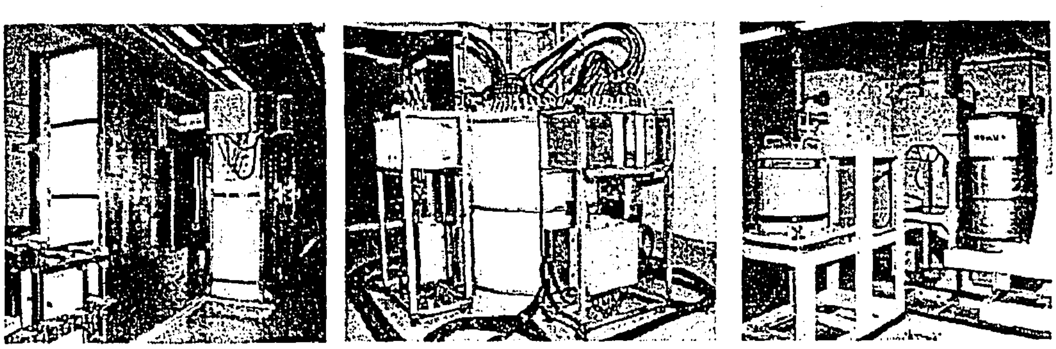


Fig. 15 Performance Test for the Evaluation of Natural and Engineered Barriers



Active assay   Passive assay   Computed tomography

Fig. 16 Equipment for TRU Waste Measurement

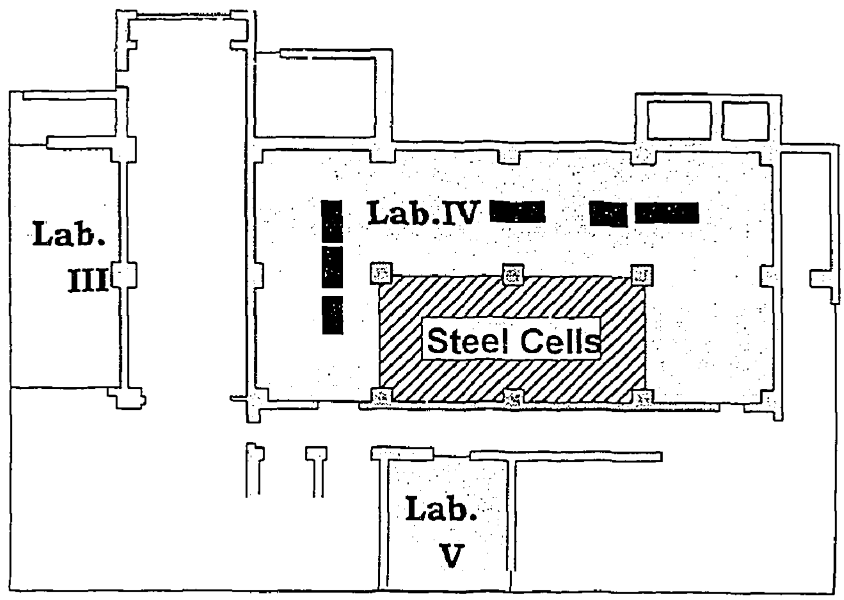


Fig. 17 Key Plan of the Steel Cell Installation

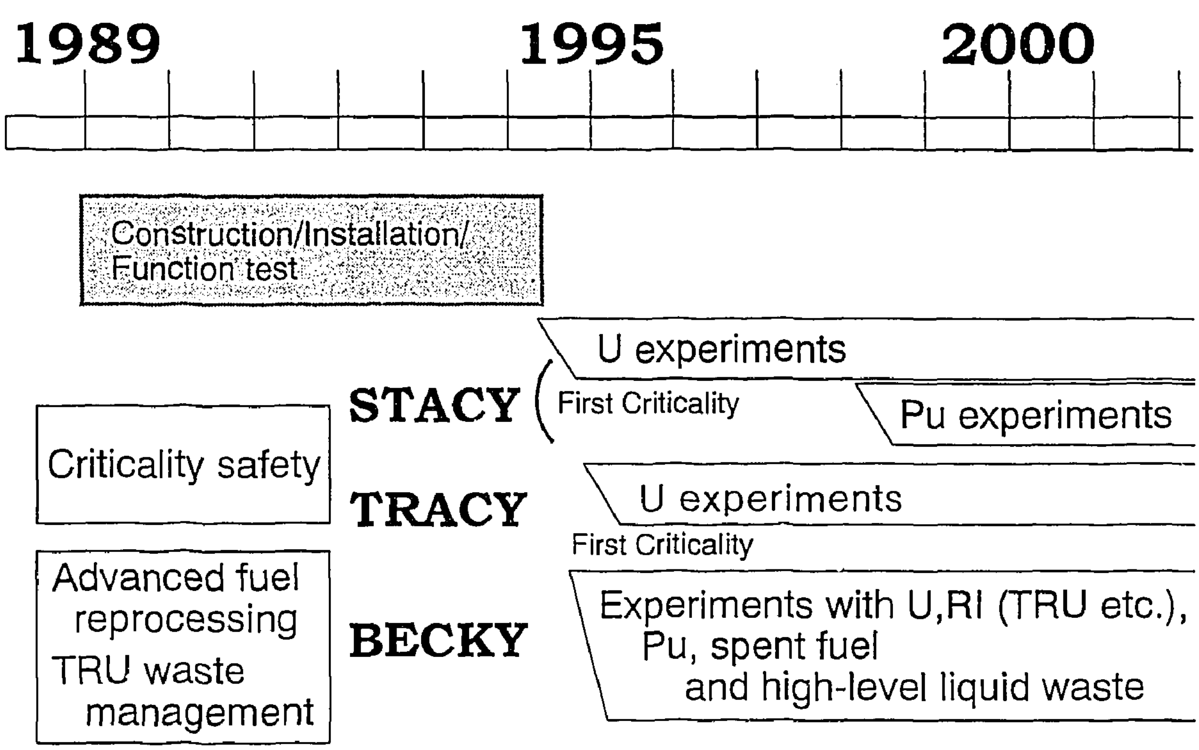


Fig. 18 Schedule of NUCEF Project