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Development of Decommissioning Technologies for Nuclear Fuel Cycle Facility in Waste Dismantling Facility

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POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION

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DEVELOPMENT OF DECOMMISSIONING TECHNOLOGIES FOR NUCLEAR FUEL CYCLE FACILITY IN WASTE DISMANTLING FACILITY

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Power Reactor and Nuclear Fuel Development Corporation (PNC)

1. INTRODUCTION

Nuclear facilities such as power reactors, reprocessing plants and fuel fabrication plants are generally said to have a limited life of up to 30 or 40 years. When they are superannuated, these facilities have to be dismantled and removed safely, and wastes from such dismantling must be treated under appropriate control. These operations are comprehensively termed as "decommissioning".

Power Reactor and Nuclear Fuel Development Corporation (PNC) has so far dedicated itself to the technical development of fast breeder reactors, reprocessing techniques and MOX fabrication techniques. Programs are based on national policy of plutonium fuel recycle. PNC is now developing fuel cycle facility decommissioning techniques.

At the Waste Dismantling Facility (WDF) located in O-arai Engineering Center (OEC), PNC is eager to validate its technical development efforts aimed at the treatment of surface-contaminated large size wastes from post irradiated FBR fuel and material examination (PIE) facilities.

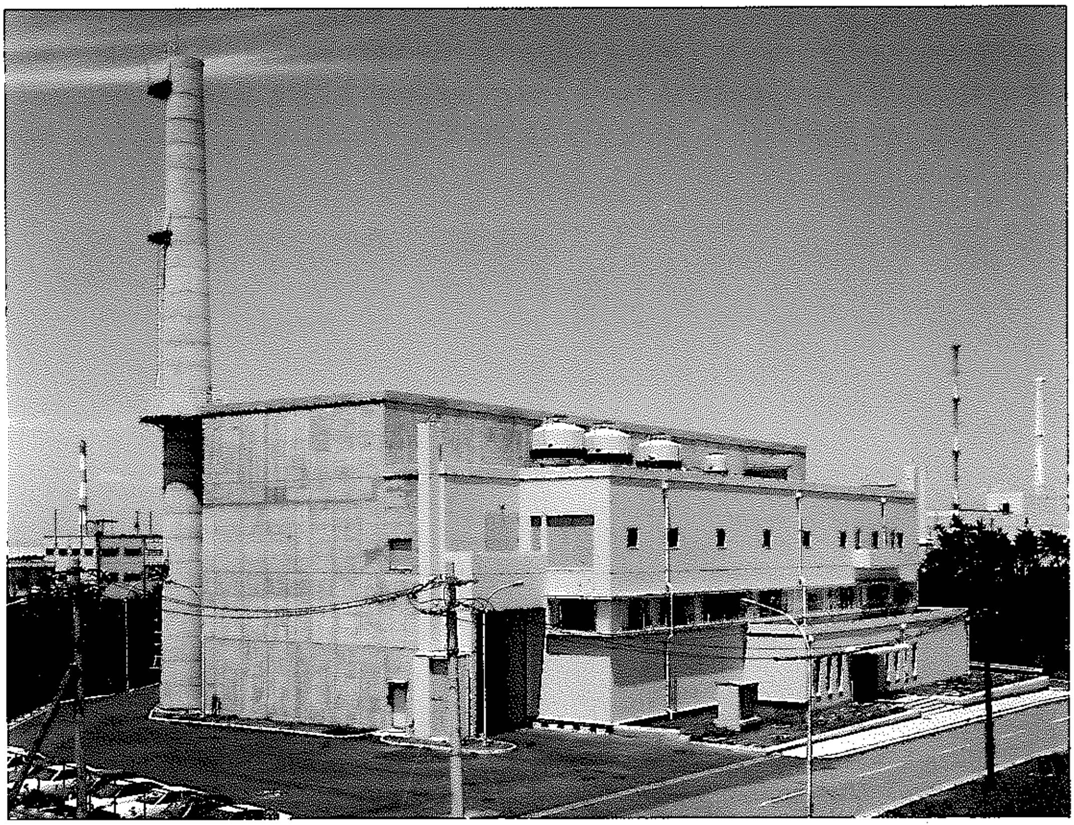


Photo. 1 View of Waste Dismantling Facility (WDF)

2. OUTLINE OF WDF

The plan and the waste stream of WDF are shown in Fig.1 and 2. The WDF is a ferroconcrete building with three stories and one basement. The building area is 1,700 m^2 and the total floor area is about 5,400 m^2.

The wastes are classified into three categories such as high radiation level α wastes (surface radiation level: $\geqq$50 mrem/h), low radiation level α wastes (surface radiation level: $<$50 mrem/h), and β,γ wastes. The high radiation level α wastes are received through the overhead hatch of the α waste loading cell.

The wastes are then sent to the decontamination cell via an air lock chamber and unpacked by means of master slave manipulators. After measurement of the dose rate and surface contamination, the wastes are subjected to surface decontamination by an ice blasting process. Thereafter, they are transferred to the dismantling cell and are cut into pieces with a plasma cutter and a hacksaw (Photo.2 and 3). Compressible wastes are further subjected to a compressing process (Photo.4) and then are packed in metallic containers.

The low radiation level α wastes are brought into the acceptance hall and then are transferred by a cart to the decontamination hall, where the wastes are unpacked and dose rate and surface contamination are measured directly by the workers wearing airline suits. Then the wastes are decontaminated by an electropolishing process. Thereafter, the wastes are dismantled with the plasma cutter into small pieces and packed into containers. The hall is constantly monitored from the 2nd floor control room during these operations.

The β,γ wastes are introduced directly into the β,γ dismantling cell from the overhead hatch of the cell and cut into small pieces by remote cutting techniques. The high radiation level wastes are packed into metallic containers and stored into casks for transportation. The low radiation level wastes are sent to the β,γ loading cell, and after sorting and classifying, they are packed into drums. The process flow sheet is shown in Fig.3.

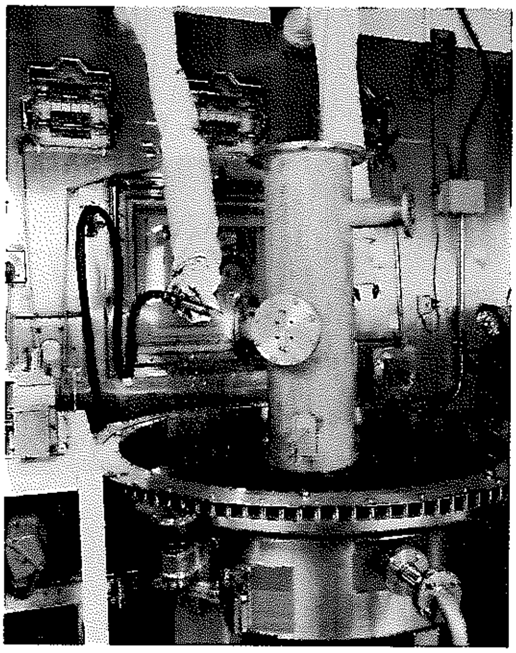


Photo.2 Plasma cutting

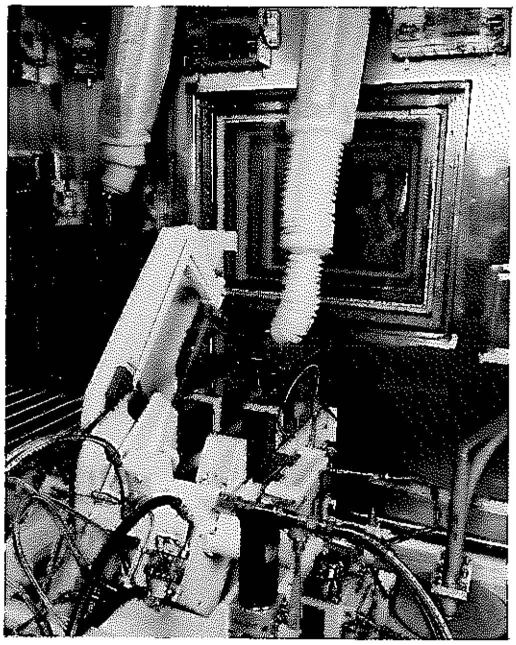


Photo.3 Hacksaw cutting

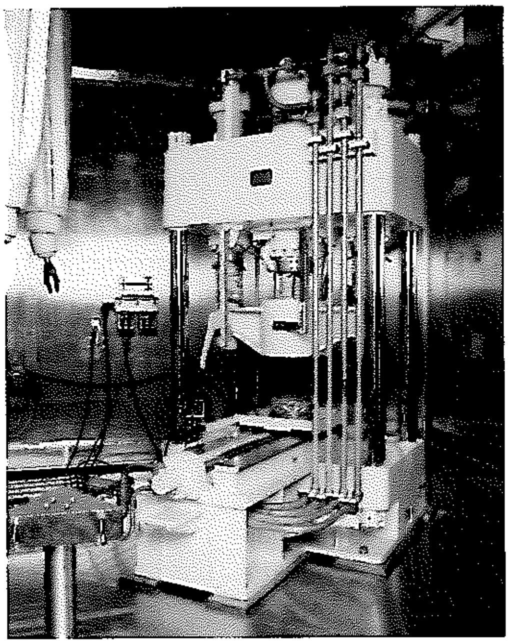


Photo. 4 Compressing Machine

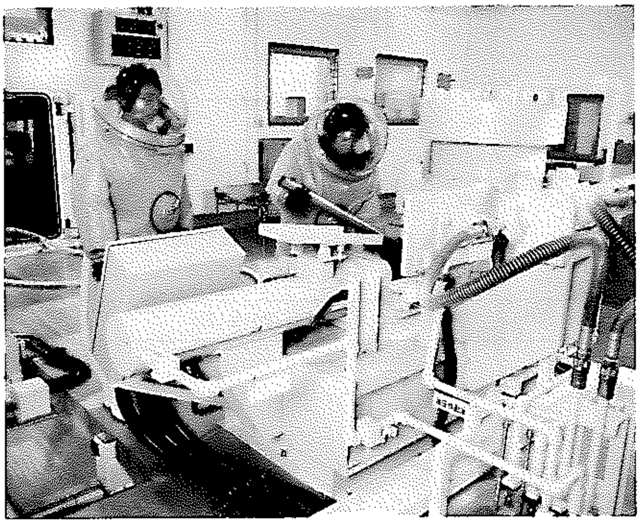


Photo. 5 Operator wearing Frog-man suit

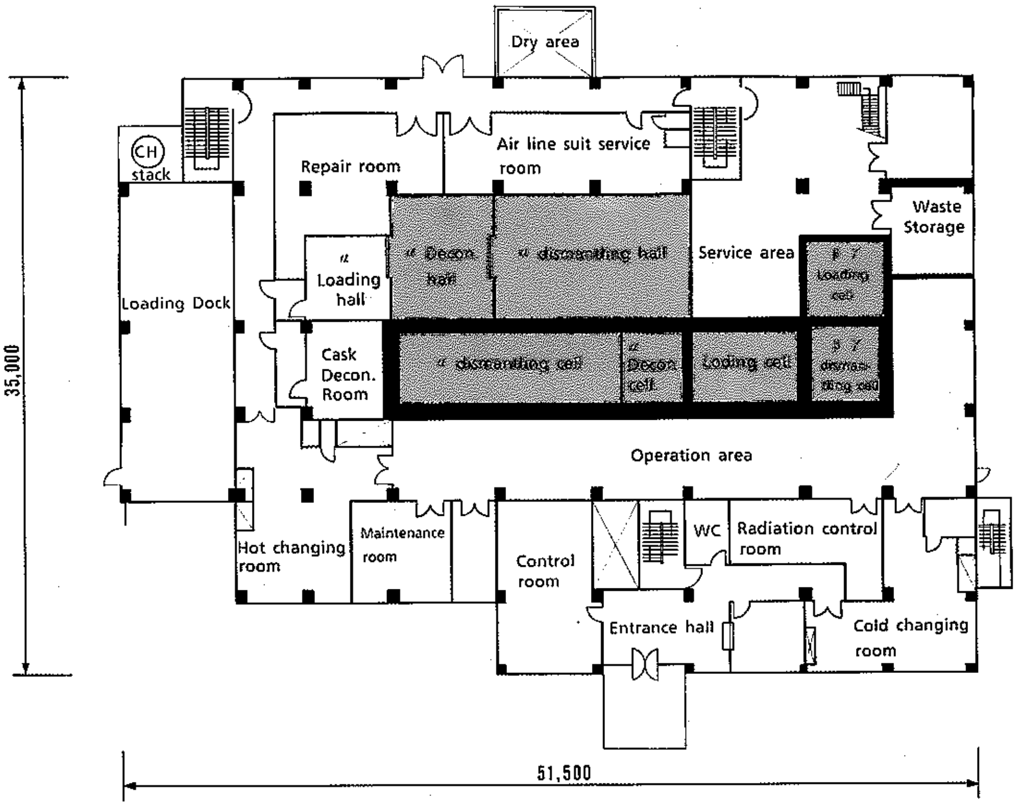


Fig. 1 WDF Plan

Table.1 Specification of Cells

		α Dismantling Cell	α Decontamination Cell	α Loading Cell	βγ Dismantling Cell	βγ Loading Cell
Dimension (m) L×W×H		13.4 × 4.0 × 6.1	3.5 × 4.0 × 6.1	6.3 × 4.0 × 6.1	4.8× 4.2 × 6.6	4.6× 4.6 × 6.6
Shielding (mm)	Front	1000 : Heavy Concrete			750 : Concrete	550 : Concrete
	Roof	1050 : Concrete			500 : Concrete	
	Floor	1150 : Concrete			650 : Concrete	
Lining	Wall/ Roof	SUS 304		Epoxy Resin	Epoxy Resin	Epoxy Resin
	Floor			SUS 304	SUS 304	
Air tightness		<0.1 vol% /Hr		Negative Pressure		

Table.2 Specification of equipment

EQUIPMENT	SPECIFICATION
(PROCESS) 1) Plasma Cutting	• Gas : Ar,N_2 • Current : Max. 250 A • Capacity : SUS 70 mm
2) Hacksaw Cutting	• Capacity : SUS 200 mm
3) Compression	• Type : Uniaxial Press • Object : 259φ × 320 mm • Capacity : 70 Ton
4) Press Cutter	• Object : 200×1000×8 mm • Capacity : 400 Ton
(HANDLING) 1) Roller Conveyor	• Type : Motor Drive with Chain • Capacity : Max. 2.0 Ton
2) Transfer Car	• Type : Self-Drive with Motor Self-Drive with Linear Motor • Capacity : Max. 2.0 Ton
(AIR LINE SUITS)	• Type : Fixed , Free • Number : 2(Decon.),3(Dismantl.) 2(Beta-Gamma) • Temp : 12 ~ 35 ℃ • Humidity : 20 ~ 80 %
(REMOTE HANDLING) 1) Master-Slave Manipulator	• Type : Gas-Tight Rugged-Duty • Handling Load : Max. 23 Kg Max. 45.3 Kg • Number : 5 Pairs 3 Pairs
2) Power Manipulator	• Handling Load : 67.5 Kg (All Position) • Shoulder Hook Load : 450 kg • Number : 3
3) In-Cell Crane	• Capacity : Max. 2.0 Ton

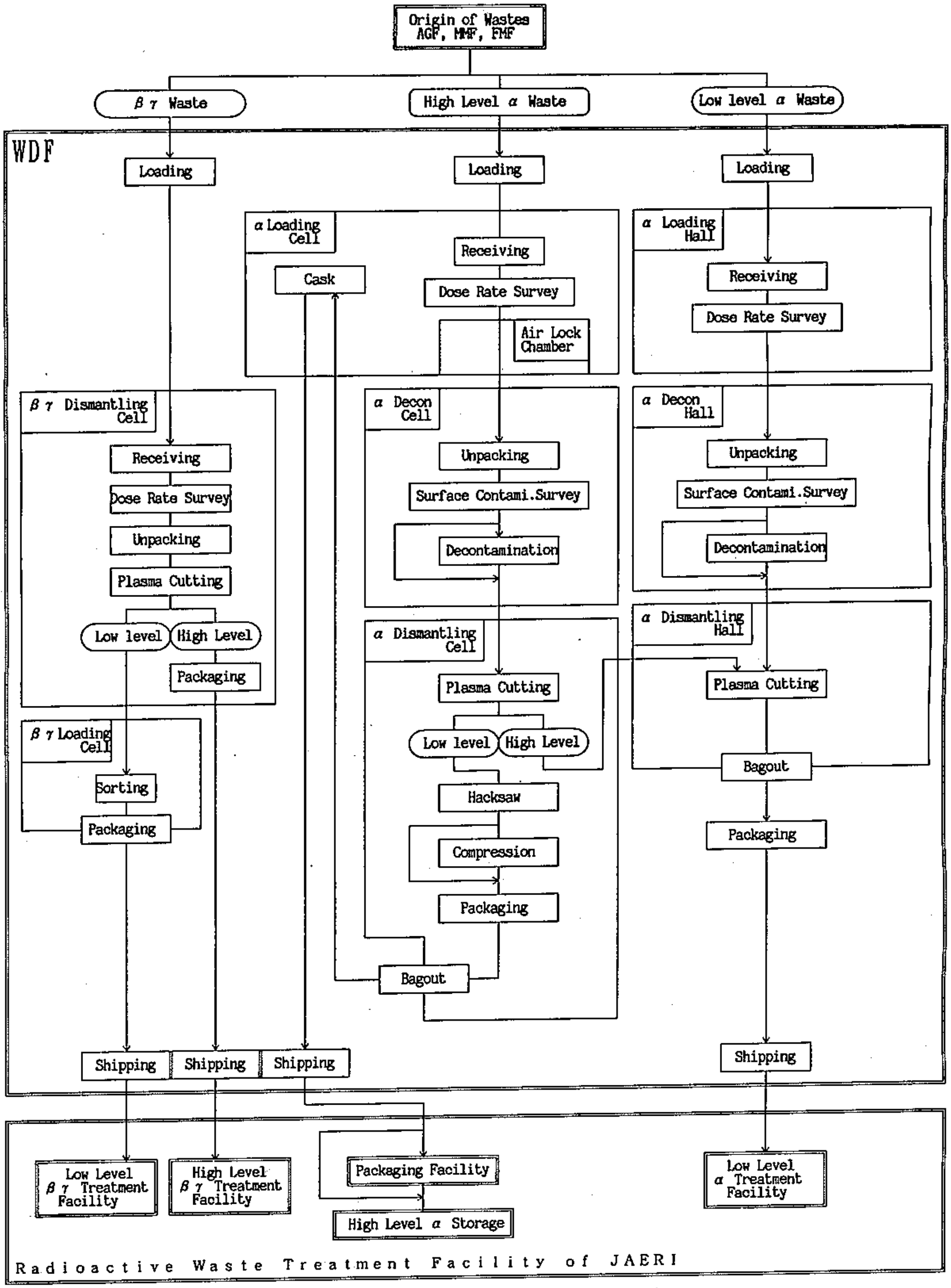
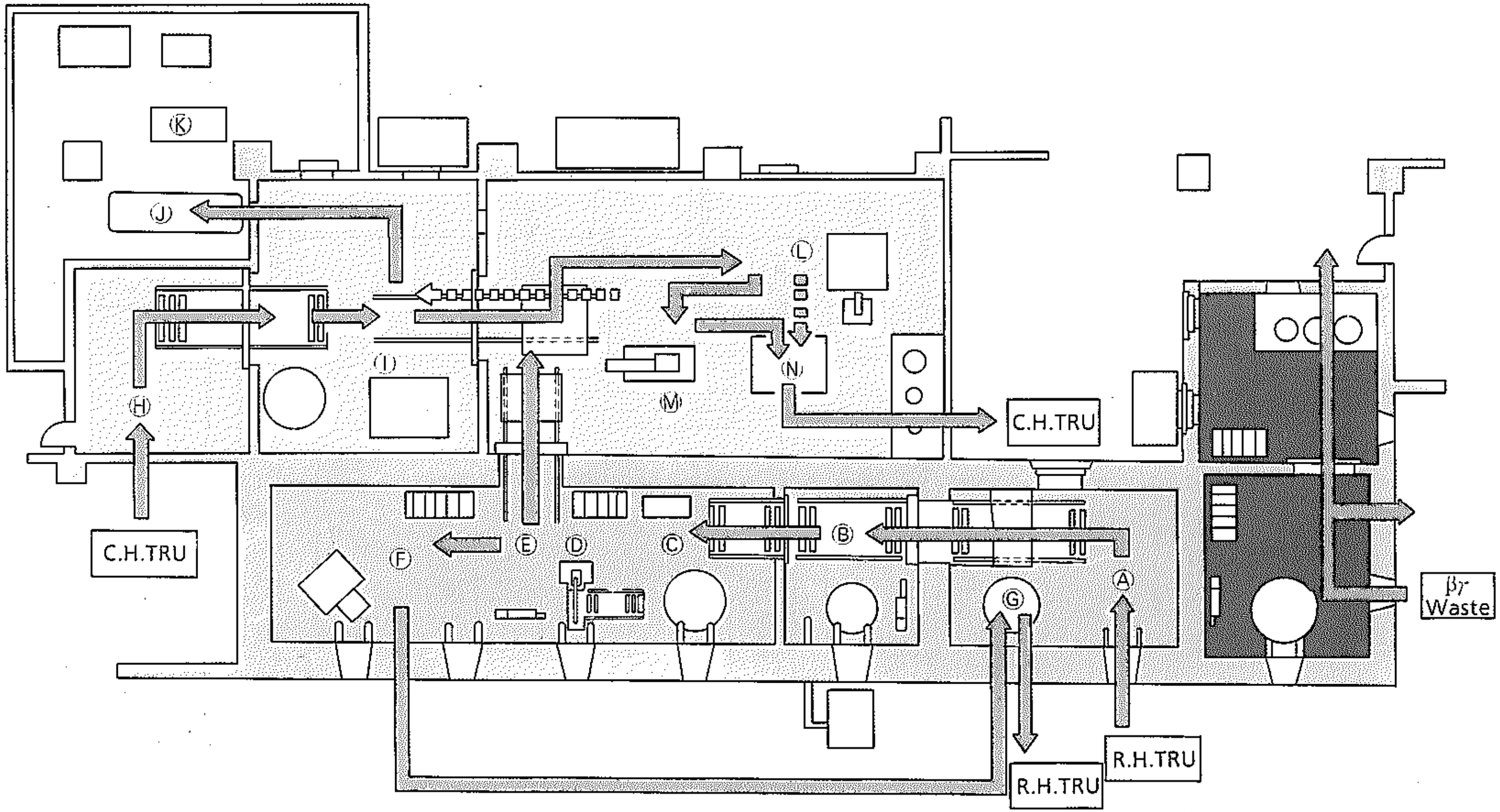


Fig. 2 Waste Stream in WDF



A : Receiving
B : Decontamination (Ice Blasting)
C : Plasma Cutting
D : Hacksaw Cutting
E : Classification
F : Compression
G : Packaging

H : Receiving
I : Decontaimation (Electro-Polishing)
J : Evaluation Glove Box
K : Experiment hood
L : Plasma Cutting Robot
M : Press Cutting
N : Packaging

Fig.3 WDF Process Flow

3. R & D STRATEGY OF D/D TECHNOLOGIES

Technology needed for areas on nuclear fuel cycle decommissioning operations have been identified and prioritized using the results of past power reactor decommissioning studies for each major decommissioning activity. (Fig.4)

In comparison with reactors, the decommissioning of nuclear fuel cycle facilities has distinctive features that objects to be removed are contaminated with TRU nuclides and their contamination conditions, structure, configuration and materials vary.

These factors have been considered in developing decommissioning techniques for PNC's nuclear fuel cycle facilities. Safe and effective decommissioning of nuclear fuel cycle facilities with minimum generation of secondary wastes and cost would be achievable with an integration of the techniques discussed bellow.

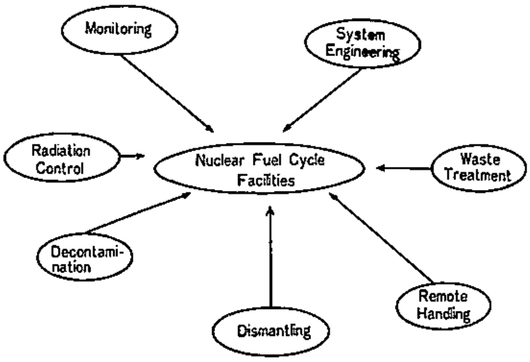


Fig. 4 Development of Technologies on D/D of Nuclear Fuel Cycle Facilities

4. DEVELOPMENT OF DECONTAMINATION TECHNIQUES

Decontamination techniques are classified into two groups, namely, "Primary decontamination techniques" and "Complete decontamination techniques".(See Fig. 5.)

The former envisages the removal of loose contaminants to reduce the exposure dose rate involved in handling nuclides and to prevent spread of contamination. The latter aims at the absolute reduction of radioactivity down to background level.

The WDF is now developing an "Ice blast decontamination process" as a means of primary decontamination as well as an "Electropolishing process" and a "REDOX process" as a means of complete decontamination.

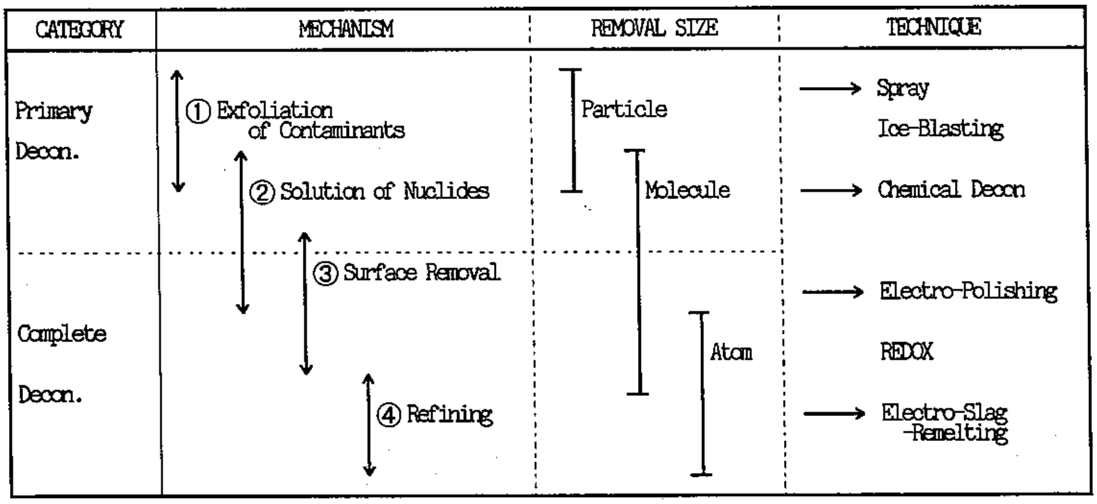


Fig. 5 Decontamination Techniques and Mechanism

4-1 Ice Blast Decontamination

Ice blast decontamination is a surface decontamination process using ice and dry ice mixed particles made by pelletizer, which are blasted onto an object to be decontaminated using a carrier medium such as compressed air.

This process features the utilization of blast impact energy and low temperature to remove nuclides, coatings and oils for improved decontamination efficiency in comparison with that of a spray process with far less secondary waste generation.

The impact energy producted by a blaster in the WDF (with compressed air rated at 6kg/cm²) come up to hundreds of kg/cm².

Fig.6 is a conceptual illustration of ice blast system. The system consists of a pelletizer and a blaster. Only a maintenance-free flexible pressure hose and a blasting nozzle are installed in the cell.

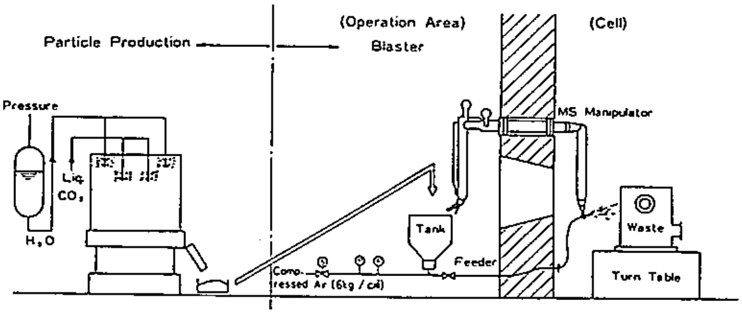


Fig.6 Ice Blasting Decontamination System

The pelletizer is capable of producing blast particles at a rate of about 200kg/h.(Photo.6) The particles are made by converting liquefied carbon dioxide into a fine powder through adiabatic expansion and then compacting these into column shaped particles of 4mm diameter and 5mm length. The pelletizer is provided with a water supply system, which can mix up to approximately 20% water (ice) into blast particles. The objective of mixing water into blast particles is to increase the hardness of blast particles and to facilitate transfer of nuclides to the liquid waste stream during decontamination.

The evaluation of test results obtained so far has verified the validity of this decontamination process. In comparison with pressurized water processes, this method holds down the secondary waste generation to the order of one tenth and achieves higher decontamination levels.

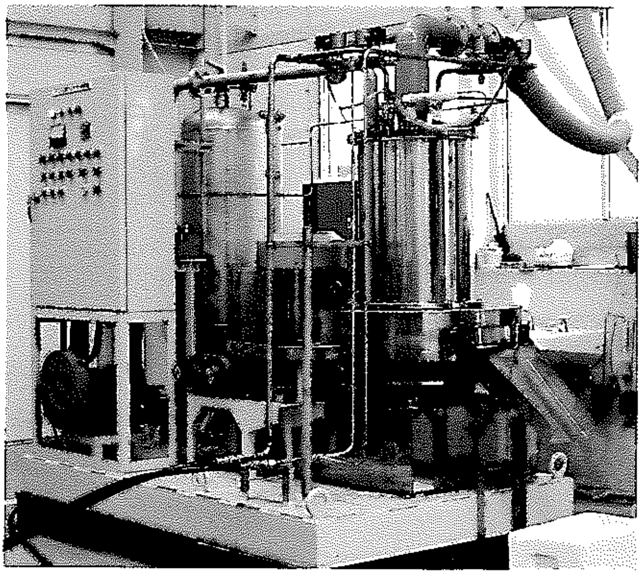


Photo.6 The Pelletizer

Hence, this process will be given increased impetus for development as an effective primary decontamination process that promises wider applicability and further improved decontamination efficiency.

4-2 Electropolishing Decontamination

This is the application of electropolishing, a common industrial technique for surface processing of metals, to nuclear decontamination.

In this process, as the surface of contaminated metal dissolves, nuclides will move into the electrolyte. Theoretically, a decontamination efficiency as high as BG level can be expected.

The WDF started developing this process in 1982 and selected a 5% sulfuric acid solution as the electrolyte in consideration of its electrolytic properties such as polishing efficiency and uniform dissolubility as well as after treatment of spent electrolyte. WDF sets up a demonstration decontamination system (Photo.7) in α Decontamination Hall.

The basic concept of electroplishing system is illustrated in Fig.7.

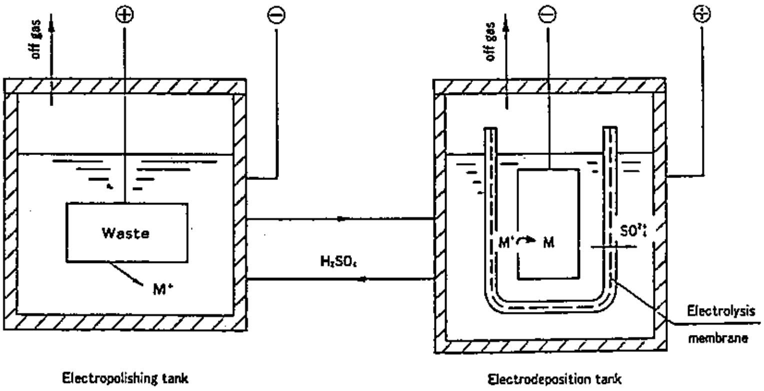


Fig. 7 Schematic Diagram of Electropolishing

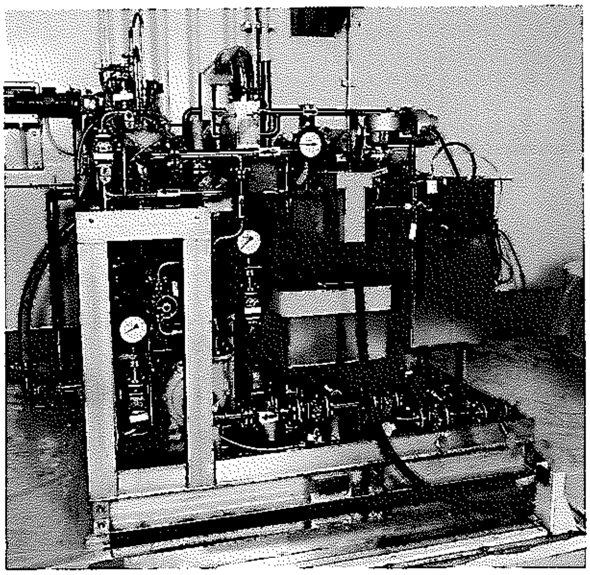


Photo. 7 Electropolishing Decon. system

Decontamination will take place with the application of positive charge to metallic wastes in a conductive electolyte because the charge will displace the metal surface into the electrolyte as cation. Also, successive electropolishing operations will lead to an increased metal ion concentration in the electrolyte, decreasing the polishing efficiency down to 1/3 to 1/4 of the initial value when the concentration rises to 30 g metal ion/liter or more. Finally the spent electrolyte itself becomes waste. In order to recover such a spent electrolyte for reuse, an electrodeposition technique which is reverse to electrolysis is used to recover metal ions from the spent electrolyte. A critical element of this technique is pH control, which can be achieved by providing an electrolytic diaphragm between the regenerative cathode and anode which selectively allows the permeation of the sulfuric acid ion (SO_4^{2-}).

From the decontamination of wastes derived from irradiated FBR fuels, WDF has confirmed the high efficiency of this decontamination process (Fig.8). The WDF's comparative evaluation of this process versus ultrasonic cleaning has verified excellent efficiency of this process (Fig.9) as demonstrated by the distribution of contamination and the SEM observation of polished metal surface. The sulfuric-acid electrolytic decontamination which can remove effectively the contamination embedded in the grain boundaries of metals, is particulary effective.

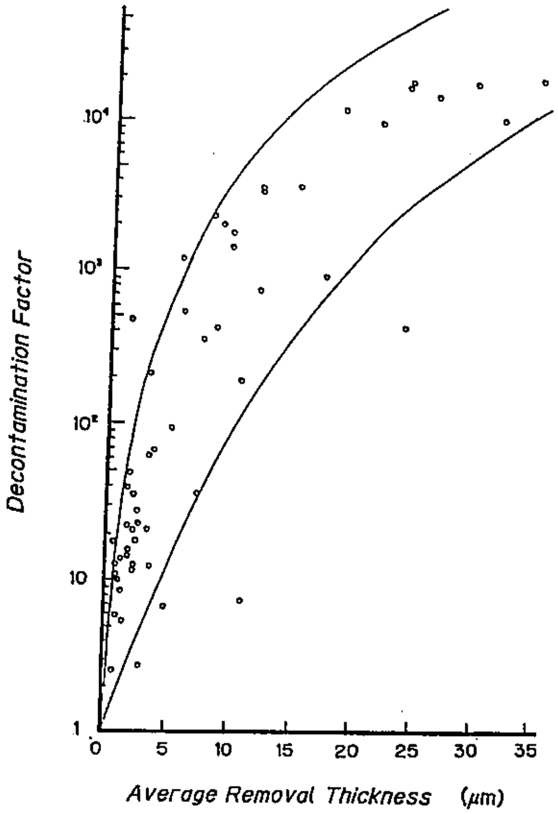


Fig. 8 Relationship A.R.T. and DF

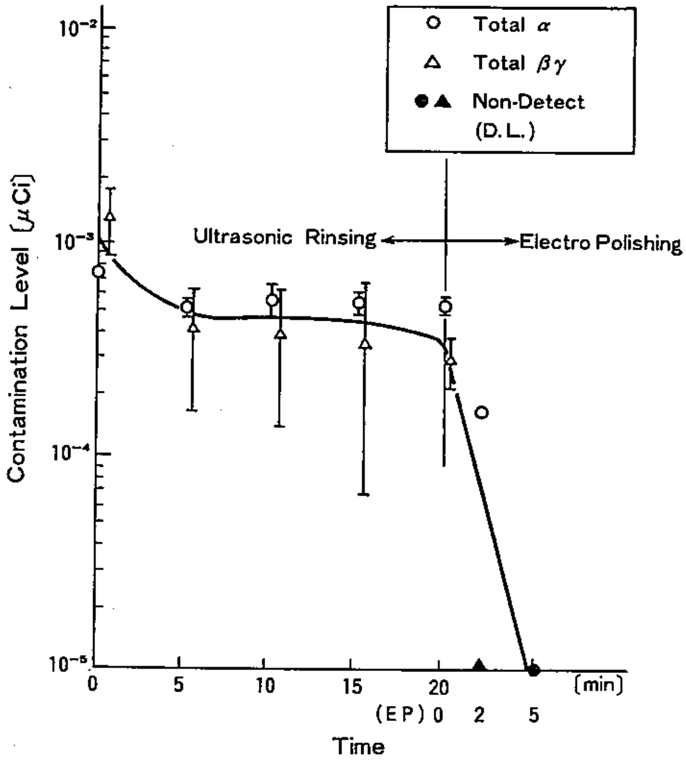


Fig. 9 Decontamination Effect by Ultrasonic Rinsing and Electropolishing

4-3 REDOX Decontamination

This is an electro-chemical decontamination process, where the dissolution of metals and contaminated wastes is accelerated by the addition of quadrivalent cerium ion (Ce(Ⅳ)) to nitric acid to form a strong oxidizing agent. Reduced cerium ion (Ce (Ⅲ)) is oxidized into quadrivalent cerium ion by electrolysis to regenerate the oxidant. Its principle is shown in Fig.10.

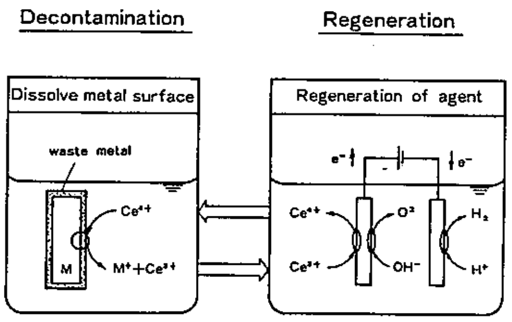


Fig. 10 Principle of REDOX Decontamination

Unlike electropolishing decontamination, this process has its electrolytic and decontamination steps clearly separated. Since its decontamination is based on the electro-chemical reaction between solution and metallic surface, it resulted in a high DF and uniform dissolubility.

The WDF has been operated as a cold decontamination experiment system (with a 100-liter decontamination bath) since 1985 and has verified the validity of its highly uniform dissolubility in polishing tests on plates and valves with different surface roughnesses.

This process, however, is not free from problems due to the strong acidity of quadrivalent cerium ion. Such problems include the selection and evaluation of the equipment component materials and the treatment of spent decontamination solutions. These will be solved through subsequent studies plus hot tests to be conducted on actual wastes.

5. DEVELOPMENT OF DISMANTLING TECHNIQUES

Facilities, machines and equipment used in the nuclear fuel cycle are diverse in construction, configuration and material. Thus, it is essential to evaluate the applicability, safety and efficiency of dismantling techniques under development.

In its efforts to develop dismantling operations, the WDF places greater emphasis on plasma cutting technique which has wide applicability to many components. In the WDF, large-size wastes generated in OEC have been cut by a plasma arc or a hacksaw, and operation of the plasma torch with a master slave manipulator and preliminary plasma cutting robot have been demonstrated. In the same way, various methods, peripheral techniques and remote control techniques for dismantling are being developed.

5-1 Plasma Cutting Robot

In order to dismantle large-size equipment and machines of complex configuration installed in high-radiation and high-contamination areas, it is essential to use remote control techniques for automatic, efficient and safe dismantling and removal operations.

In 1984 a plasma cutting robot (Photo.8) was installed in WDF, as a modified version of industrial robots, as a link in the development of remote control technology to verify its usefulness in the dismantling of wastes from operating plants. This robot was based on a teaching playback method, in which a cutting path on an object is preliminarily taught to the robot and cutting is made to the given cutting path. If the object to be cut has a complex configuration, its teaching procedure takes much time. To solve this problem, some notable improvements have been made,i.e. the addition of a voltage arc sensor which will feedback voltage fluctuations to the robot during cutting for automatic operation. In addition a non-contact type laser distance sensor, a joy stick and a master arm (Photo.9 and 10) have been added.

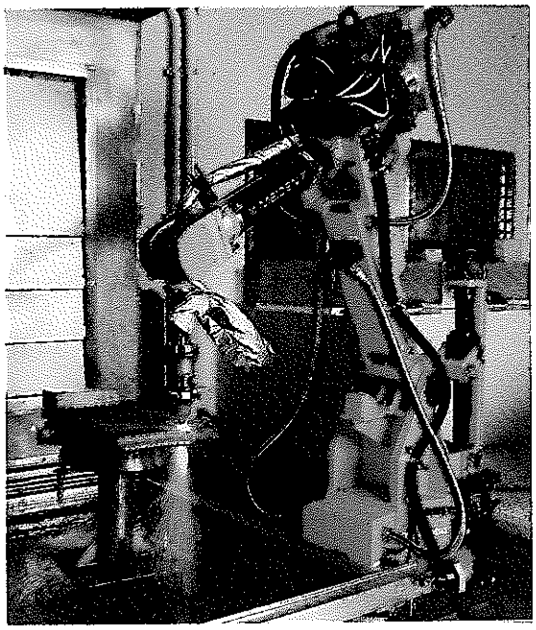


Photo. 8 Plasma Cutting Robot

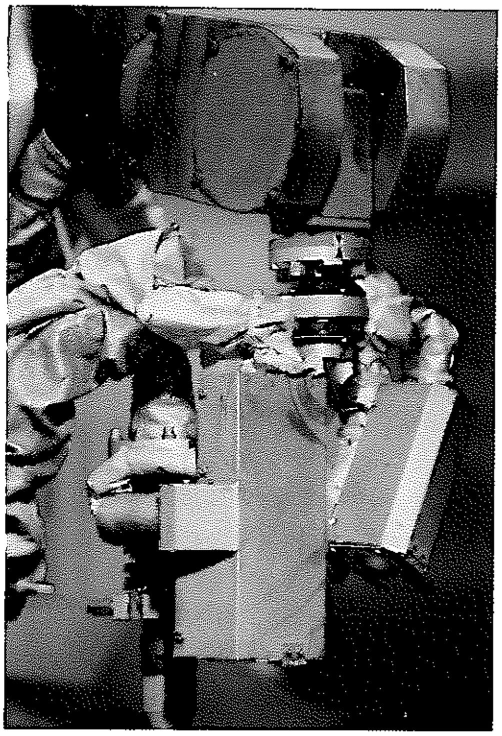


Photo. 9 Laser Distance Sensor

Photo. 10 Controller

Based on the dismantling method, algorism and many other design factors obtained from the WDF robot, a small-size portable robot for decommissioning use is now being developed. Its design concept is shown in Fig.11.

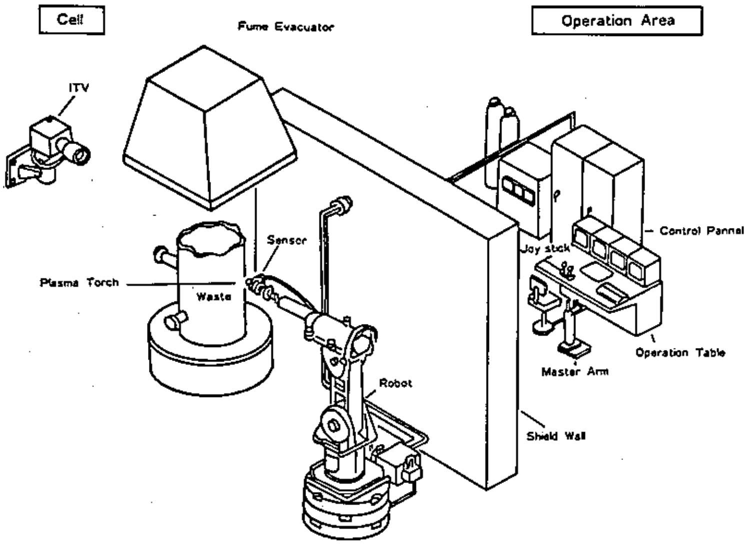


Fig. 11 Concept of D/D Plasma Robot

6. DEVELOPMENT OF MONITORING TECHNIQUES

Efficient and safe decommissioning operation addresses importance to monitoring techniques by which to determine the quantity and distribution pattern of contaminated nuclides.

PNC is developing a radiation image display (RID) which could be replaceable the conventional smear method and direct survey method and provide a reliable and quick means of evaluating the distribution of nuclide contamination by remote control.

6-1 Radiation Image Display (RID)

To improve measurement and evaluation efficiency for decommissioning, to decrease radiation exposure during the work and also to improve the reliability of measurement data, PNC has been developing a radiation image display capable of remote and automatic measurement and image display of the distribution of radioactive substances.

Its operating principle is to run a colimated γ ray detector and distance meter to scan across a contaminated object to be measured and obtain radiation information and distance information, from which a computer will create a picture of the distribution of radioactive substances (evaluation picture) composed of 1,500 to 9,000 plots divided into ten color levels and then will display the picture on a TV monitor as a synthetic image.

The measurement principle is illustrated in Fig. 12. Photo.11 shows the prototype equipment No. 1 manufactured in 1986.

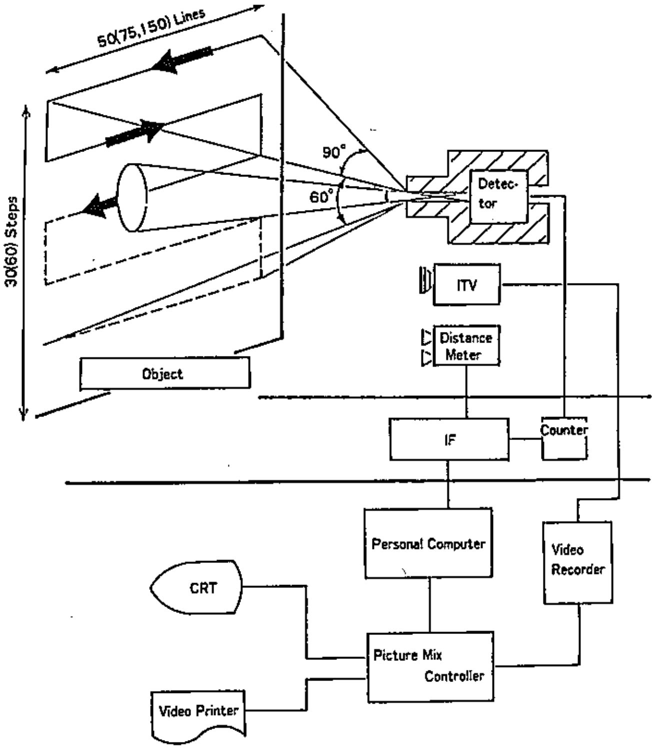
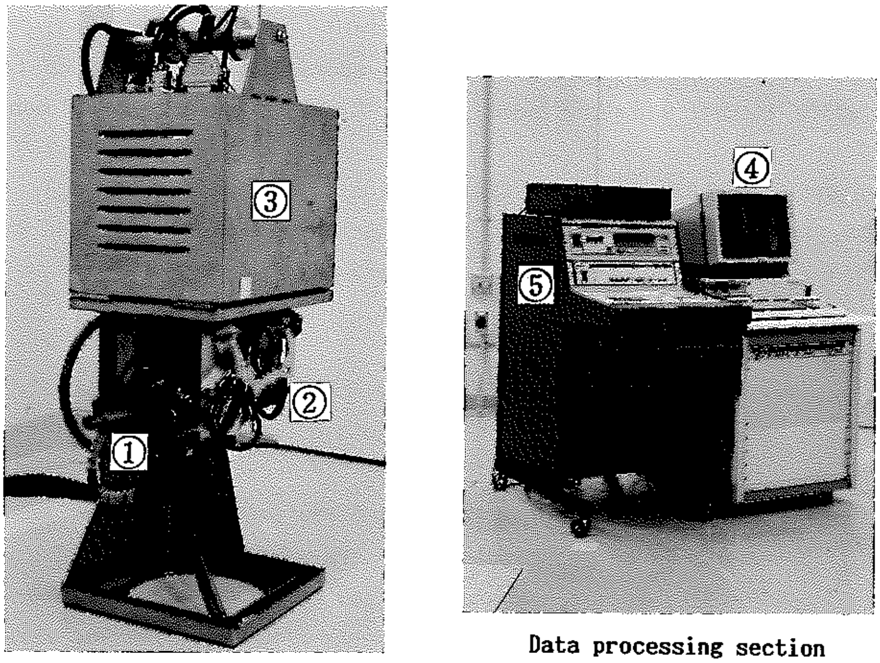


Fig. 12 Composition of Radiation Image Display

Table. 3 Specification of RID No. 1

ITEM	RID (Ⅰ)
γ Detector	CsI(Tℓ)+PD ϕ28×50(mm)
Shielding Material	Tungsten
Shielding Thickness	50mm
Shielding Power (γ Energy: 1MeV)	1/100
Detector Weight	~50kg
Detector Dimension	300(W) ×350(D) ×900(H)
Cable Numbers	5
Measurement Time	10,15,30,60 min
Calculation Time	3min



Data processing section

Detecting section

① Collimator, ② TV camera, ③ Upper box .
④ Personal computer, ⑤ Image display equipment

Photo. 11 Radiation Image Display Unit

Photo.12 shows the results of measurements on a liquid waste tank. The TV monitor shows the entire measurement range. The evaluation picture gives a counting value at each plot in ten color levels (red-yellow-green-blue-non color)with the largest counting value of the plots in the picture placed as the upper limit. The synthetic image of both the screen and the picture provides information about radioactive substances deposited on the bottom of liquid waste tank.

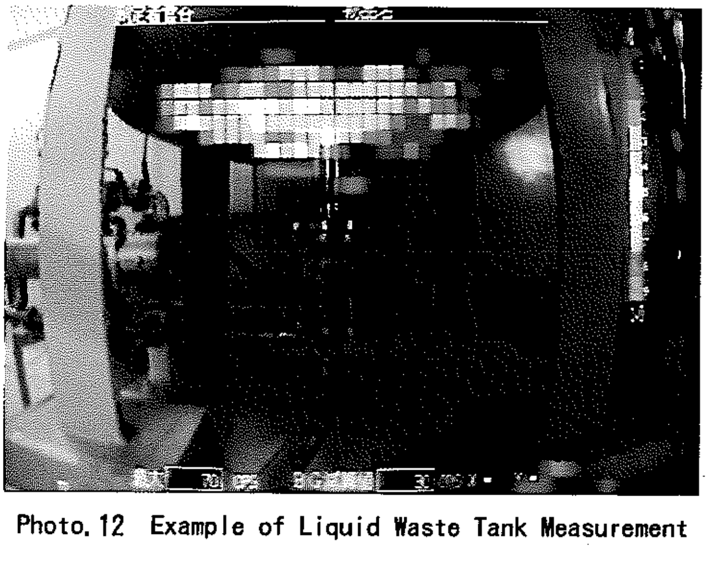


Photo. 12 Example of Liquid Waste Tank Measurement

The applicability of this equipment was evaluated in a test made on wastes and a liquid waste tank. The results obtained from the test are shown below:

(1) Measurement of wastes

The measurement results of a 200-liter drum containing processed wastes are shown in Photo.13.

The evaluation of the result clearly indicates the location of radioactive substances existing in spots.

① Sealed position of radioactive substances

Photo. 13 Result of 200-liter Drum Measurement

(2) Measurement of a liquid waste tank before and after decontamination

A tank containing liquid waste from the cleaning of FBR fuel assemblies was decontaminated with high-pressure water. This decontamination process was evaluated by this equipment. Images obtained before and after decontamination are shown respectively in Photo.14. The measurement was done over 30 minutes and from a distance of 3.5 meters.

It is noted that the high-pressure water decontamination carried highly contaminated deposits, which is observed at the top of tank before the decontamination, to the bottom of tank.

Before decontamination

After decontamination

The display of high-level contamination ① shifted to the display of low-level contamination, ② and ③.

Photo. 14 Evaluation of Liquid Waste Tank before and after Decontamination

7.CONCLUSION

We will continue the development of decontamination and dismantling technologies undertaken by WDF to establish techniques that can validate the safety and economy of various nuclear fuel cycle facilities.

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