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Sodium Removal from the Grapples of the Fuel Handling Facility of "Joyo"

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動力炉・核燃料開発事業団 (Power Reactor and Nuclear Fuel Development Corporation)

Sodium Removal from the Grapples of the Fuel Handling Facility of "Joyo"

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ABSTRACT

Sodium removal from the grapples of the fuel handling facility of "JOYO" is done in alcohol.

The operations of the cleaning facility started as the functional tests of the fuel handling facility began. Since then, criticality test and low power tests had been done and during this period, sodium removal from the grapples, after a certain amount of time in use, were done.

In order to lessen the time for the cleaning process for the grapples of the machines inside the containment vessel, demineralized water concentration in the alcohol was gained to as much as 10 % and good results were obtained. On the other hand, there were very small amounts of sodium on the grapples of the machine used outside the containment vessel and direct charging of demineralized water into the cleaning pot was done experimentally, also with good results.

In this report, the sodium removal experience of the grapples before power up tests and some remarks on the improvements of the facility for the future are presented.

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1. Introduction

The maintenance work of the fuel handling facility of sodium cooled fast reactors are featured in that machines, especially the grapples, have to handle fuel assemblies in sodium or with sodium deposition.

In the case of "Joyo", the In-Core Charge Machine (INCO), the Ex-Vessel Transfer Machine (EXTRA) in the containment vessel and the Cask Car outside the containment vessel acts as these machines. See Fig. 1-1. The grapples of the INCO and the EXTRA are taken to the grapple cleaning facility inside the C/V after every refueling operation for sodium removal in alcohol in inerted atmosphere. During functional test, criticality test and low power tests, the cleaning operation was done 14 times for the INCO and 9 times for the EXTRA. Although there was one case experienced when sodium removal showed insufficient, all the other cases of removal were done quite successfully.

For the grapples of the Cask Car, a similar process for sodium removal outside was planned and an exclusive facility was constructed. It was made clear, however, after functional tests that from structural reasons, the amount of sodium remaining on the grapples were as small as under 5g. Therefore, direct charging of demineralized water into the system was experimentally done and cleaning was successfully achieved.

In this report, these experiences of the grapple cleaning facility are given.

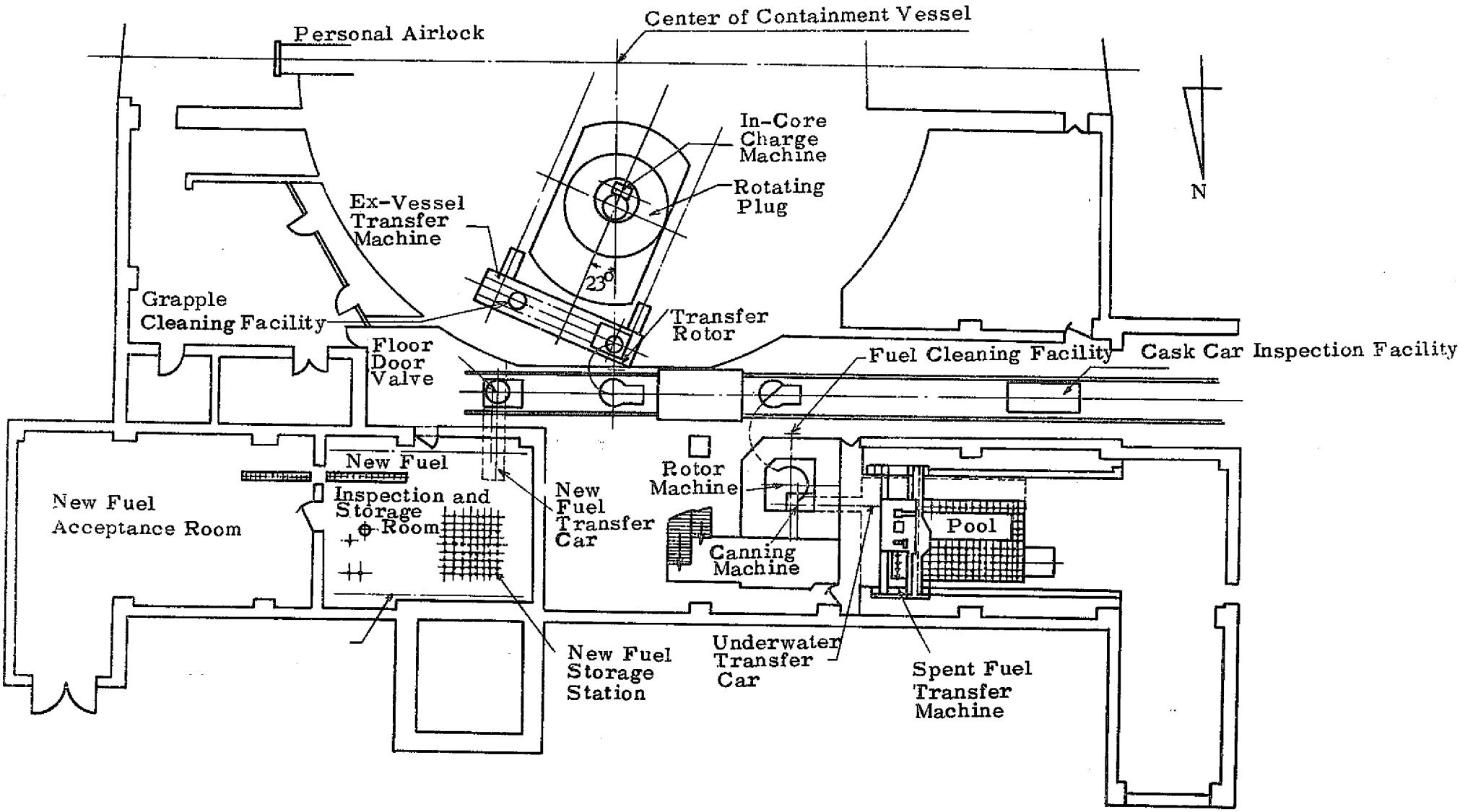
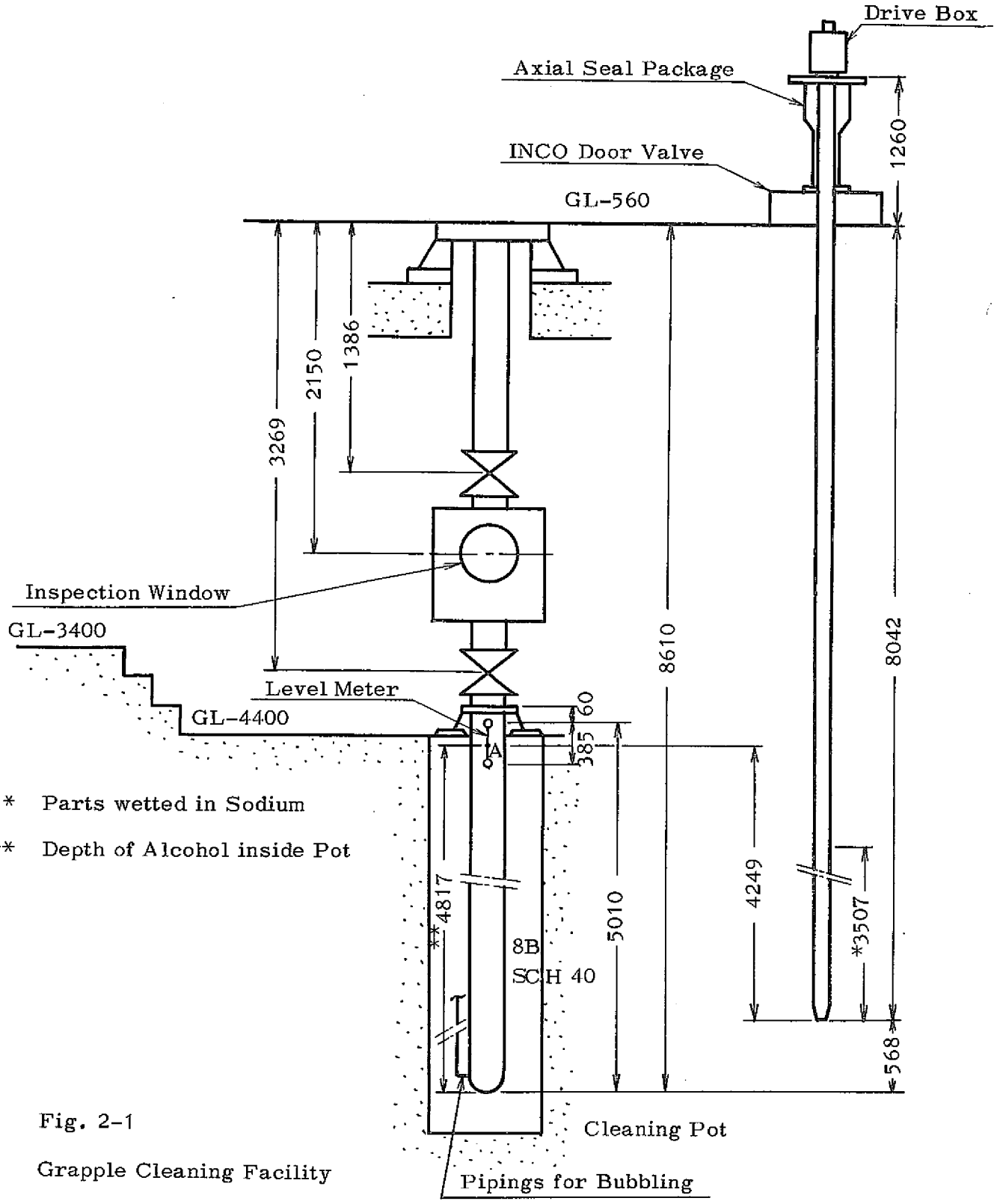


Fig. 1-1 Location of the Fuel Handling Facility of "Joyo"

2. Grapple Cleaning Facility

2.1 Outlines

Refueling for "Joyo" is done by using a fuel handling port with a door valve on the small rotating plug. The In-Core Charge Machine (INCO) transfers a fuel assembly inside the reactor vessel from the fuel storage rack to the core. The Ex-Vessel Transfer Machine (EXTRA) transfers the fuel assemblies in and out of the reactor in a sodium contained pot. The grapples of these machines are both used in sodium and consequently, deposited sodium must be removed before reuse. In order to meet this requirement, there is a grapple cleaning facility inside the containment vessel using alcohol as the cleansor. There is an opening at the top of the tank that enables inspection of the outer surface of the grapples. See Fig. 2-1.



* Parts wetted in Sodium

** Depth of Alcohol inside Pot

Fig. 2-1

Grapple Cleaning Facility

2.2 Composition and Functions

(1) Grapple Cleaning Station

The INCO or the EXTRA is placed onto the station which is placed at floor level of the reactor building.

(2) Grapple Cleaning Pot

A pot is situated at the station with an inspection window at the upper level and a cleaning space below.

1 Inspection

There is an opening in the pot with windows and two others with flanges where gloves can be inserted. Sodium deposition and sodium removal is inspected here.

2 Pot

The pot is a cylindrical type and alcohol is poured from the top on the 1st floor. Argon gas bubbling can be done from the pipings located at the bottom.

There is a ball valve at the top to isolate the inside of the pot from the atmosphere. Waste liquid is sent out by argon gas pressurization in the pot.

3 Supply and Discharge of alcohol

Fresh alcohol which have already been measured is prepared on the floor inside the containment vessel and is sent in by gravity flow into the pot. Waste solvent is sent out to the reactor service building by pipings penetrating the C/V.

4 Argon Cover Gas

In order to keep the cover gas atmosphere inerted, argon gas of 0.05 kg/cm^{2}G is supplied.

5 Operations

Most of the operation is done manually at the inspection area under the first floor. However there is a panel on the floor where instrumentations and indicators are installed.

2.3 Cleaning Process

The facility is designed so that grapples of both the INCO and the EXTRA can be cleaned.

When sodium removal for the EXTRA is done, the machine moves over to the station by itself as in usual refueling operation. When this is done for the INCO, the machine is taken away from the small rotating plug by a crane and is carried over to the station and bolted down. The procedures are shown in Table 2-1.

Table 2-1 Grapple Cleaning Process inside C/V

Process	Contents
Preparation	System Check-up
Connection	Connection of Machine to Facility
Purging	Argon Gas Purging of Cover Gas
Cover Gas Supply	Argon Gas Charge at a certain Flow Rate
Alcohol Charge	Alcohol Supply by Gravity Flow
Grapple Descent	Grapple is completely soaked in alcohol
Argon Gas Bubbling	Bubbling is done at 1 kg/cm^2G
Stationing	Grapple is kept in Alcohol for ~ 12 hours
Grapple test	Visual Inspection and False Operation
Grapple Ascent	Grapple is confined
Disconnection	Machine leaves the station
Post Cleaning Operation	Final Check-up

3. Cask Car Inspection Facility

3.1 Outlines

The Cask Car is a fuel transportation machine, placed on parallel rails inside the reactor service building. New fuels are picked up from the storage and are taken to the Transfer Rotor, a relay station for fuel going in and coming out of the C/V. Spent fuels are picked up from the Transfer Rotor and are sent to the Fuel Cleaning Facility.

Grapple cleaning of the Cask Car is done at a station located at the end of the railway at the Cask Car Inspection Facility. Sodium removal of the grapples as well as inspection of the machine is done here. The facility consists of an inspection pit where parts can be taken apart and a cleaning pot where sodium removal is done. See Fig. 3-1.

The grapple cleaning system consists of a door valve, a glove box, a cleaning pot, a drain tank, a circulation pump, a vacuum pump etc. When the cleaning operation is done, the grapples are taken down to the tank and disconnected from the driving mechanism using the glove box. Cleaning is done by the circulation of alchohol and drying, by vacuumization. Visual inspection of the grapples can be done at the windows fit onto the pot.

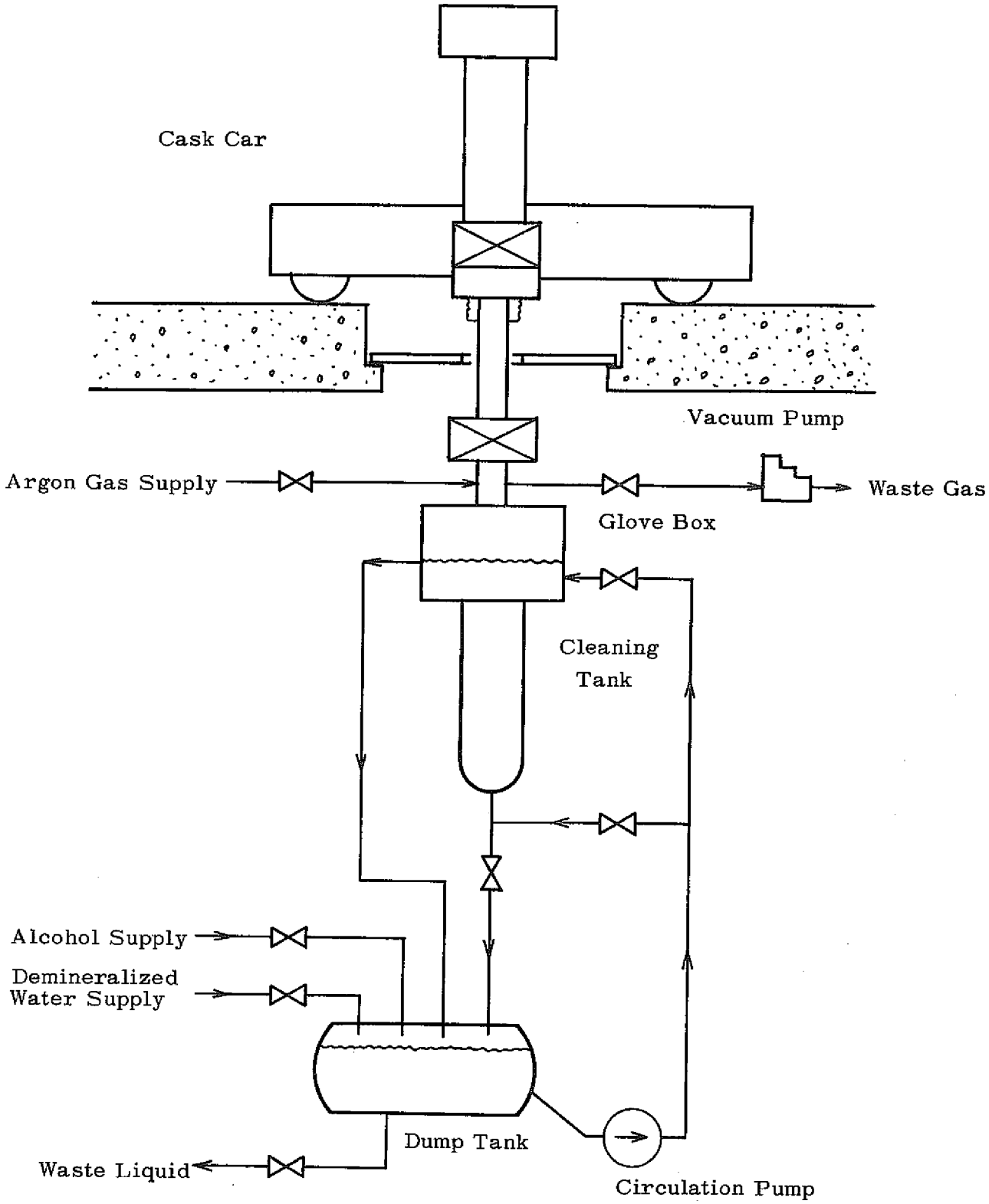


Fig. 3-1 Cask Car Inspection Facility

3.2 Composition and Functions

(1) Upper Guide Tube

(2) Glove Box

A window for inspection gloves are installed at the inspection area to inspect sodium deposition and results of sodium removal. In order to disconnect the wire ropes from the grapple, there are special tools installed inside the pot.

(3) Cleaning Pot

When sodium removal is done, the grapple is separated from the Cask Car and placed inside the pot. Alcohol inside is circulated and the waste is dumped into a drain tank. Trace heaters are installed onto the pot in order to heat and dry the inside.

(4) Drain Tank

(5) Circulation Pump

Alcohol circulation is done to promote the effect of the reactor.

(6) Vacuum Pump

3.3 Cleaning Process

Table 3-1 Grapple Cleaning Process of Cask Car

Process	Contents
Connection	Connection of Machine to Facility
Gas Purge	Argon Gas Purging inside Pot
Grapple Descent	Grapple is placed inside Pot
Disconnection	Grapple is separated from Drive Mechanism
Isolation	Grapple is isolated inside Pot
Alcohol Circulation	Forced Circulation is done for about an hour
Drainage	Waste Liquid is dumped
Vacuumization	Drying is done at about 100^{o}C
Connection	Grapple is connected to Drive Mechanism
Inspection	Visual Inspection and False Operation
Grapple Ascent	Grapple is confined in Cask
Disconnection	Machine Leaves Station

4. Grapple Cleaning Experience

4.1 In-Core Charge Machine

Function of INCO

The INCO is a machine that transfers fuel assemblies from the core to the fuel storage rack which are both located inside the reactor vessel. During this operation, the grapple stays inside sodium with the driving rod wetted to a length of 3,500 mm maximum. The structure is shown in Fig. 4-1.

Sodium Removal Operation

When refueling by the INCO is through, it is carried away and fit onto the grapple cleaning facility. The operation of the machine, there, is done by an exclusive panel. The driving rod with the grapple at its end will be soaked in alcohol to a length of 4,800 mm.

Conditioning

120 ~ 130 liters of alcohol will be prepared at normal temperature and the cover gas of the pot is inerted by argon gas. Since the axial seal mechanism of the driving rod is preheated to 150°C to protect its functions from sodium, the grapple is expected to be 80° ~ 100°C in its initial insertion.

Sodium Deposition

Sodium deposition on the grapple and the driving rod is observed at the windows of the cleaning pot. Sodium drops and black layers are usually seen as in Fig. 4-2. The surface of the driving rod is hard chrome plated.

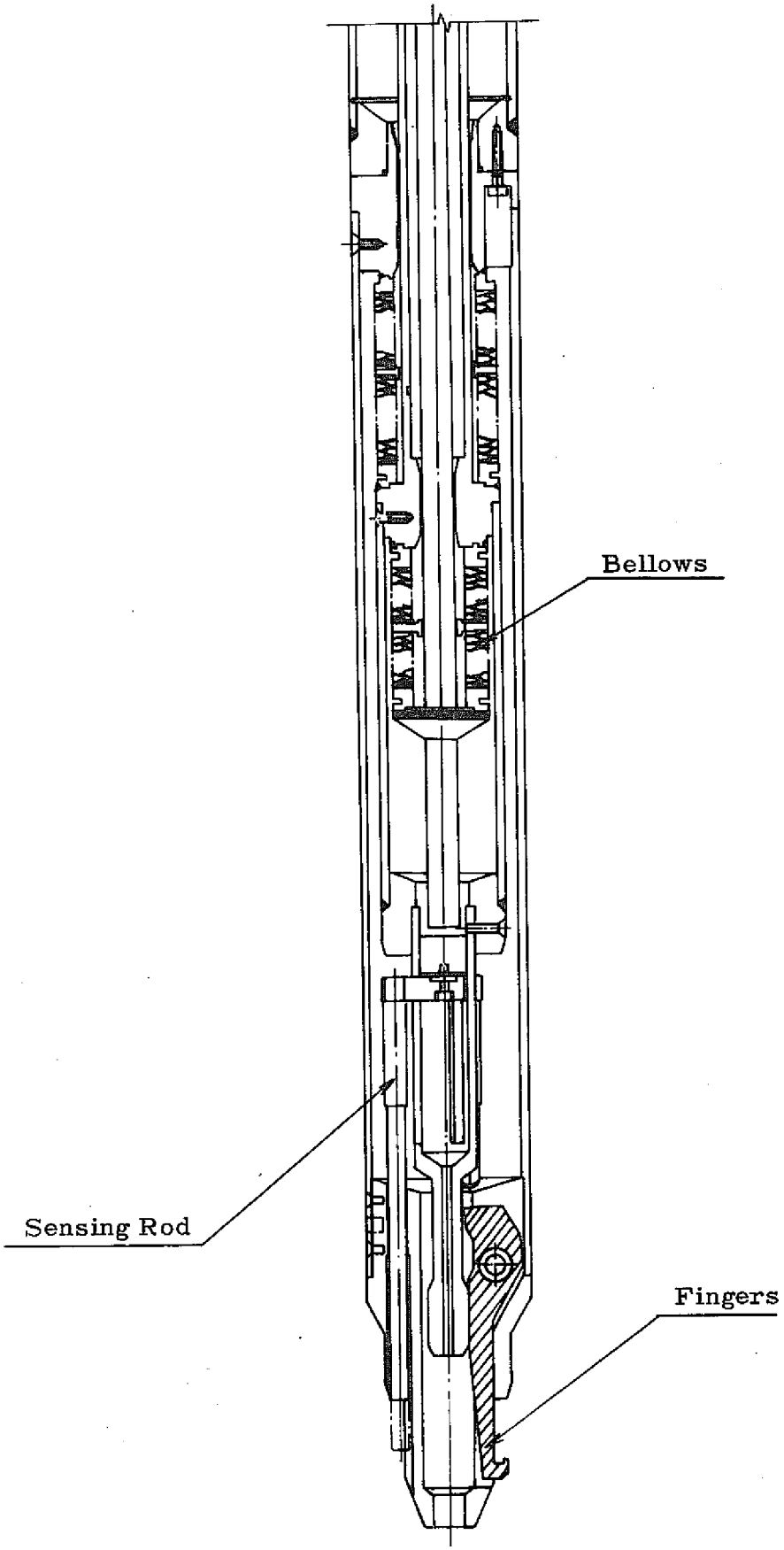


Fig. 4-1 Grapple of INCO

Cleaning

After preoperational inspection, the grapple is brought down into the alcohol (88% ethyl alcohol, 6 to 8% iso-propyl alcohol, 0.5% water). The cover gas is kept at 1,000 mmAq manually at the initial stage of reaction. When pressure rise starts to saturate, an argon gas flow of 50 l/min is maintained.

In order to promote the reaction, argon gas bubbling is done for about 30 minutes.

Process Time

From functional tests, the amount of sodium deposited on the grapple resulted to be about 150g. The total process time needed for the grapple to be kept inside the alcohol was decided to be 4 hours.

A Case of Failure

During low power tests, there was one case when fuel assembly detaching was not detected. The grapple was taken apart and it was found out that the sensing rod, which is supposed to go down by gravity force after detaching and withdrawal of the grapple, did not work. The sodium removal history was also investigated and it was concluded that the latest sodium removal was insufficient.

Effective Cleaning

In order to prevent repetition of lack of removal and to promote the reaction, water concentration in the alcohol was risen to 10% in volume. This showed quite effective.

Presently circulation of the alcohol can not be done but it is under consideration.

Requalification

Visual inspection of the surface and false operation of the fingers at the windows are done in order to decide the end of the operation. See Fig. 4-3.

Drying

Remaining solvents on the grapple are dried in the casing of the door valve. Heating is done at the axial seal mechanism in order to shorten this process.

Sodium Removal Experience

As of December, 1977, sodium removal operation for the grapple of the INCO was done 14 times, as is tabulated in Table 4-1. As can be read, the 6 th removal operation was

Table 4-1 Sodium Removal of INCO

Case No.	Duration in Na	Alcohol composition		Duration in alcohol
1	450 hours	Al. 125 l	H_2O 0 l	6
2	270	125	0	4
3	81	125	0	14
4	255	100	20	16
5	52	100	20	14
6	18	100	20	3
7	25	105	15	19
8	3.5	100	20	16.5
9	288	100	20	17.5
10	25	95	25	14
11	146	102	18	14
12	114	110	20	11.5
13	24.5	110	20	16
14	26	110	20	17.5

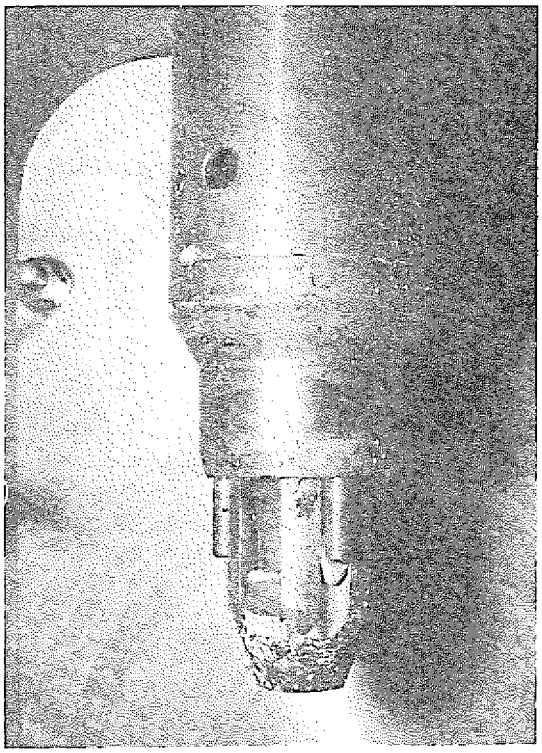


Fig. 4-2 Sodium Deposited on Grapple of INCO

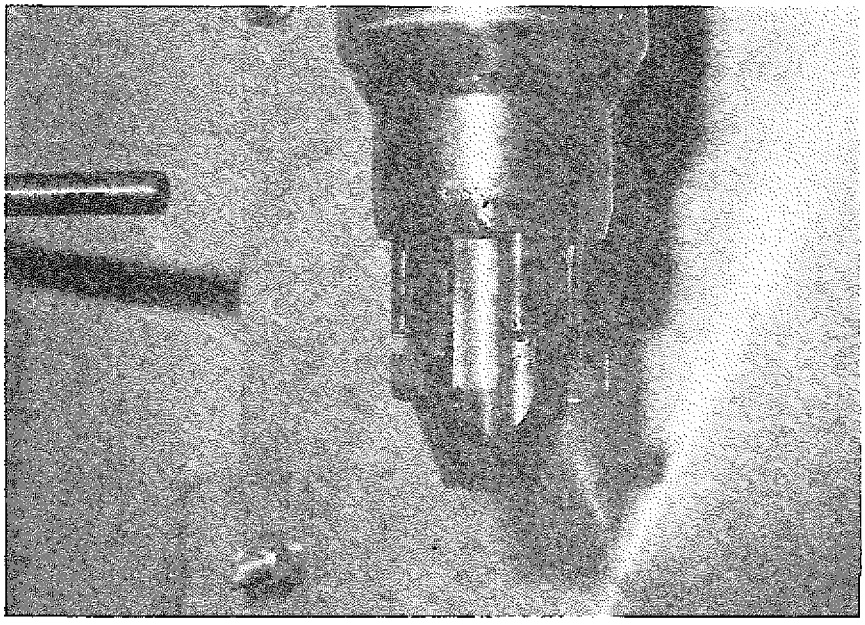


Fig. 4-3 Grapple of INCO after Sodium Removal

a special case in that duration of the grapple in alcohol was only 3 hours. At that time, for progress reasons, the minimum allowable time, then, was chosen for the operation. Consequently, the failure mentioned before had occurred. Since then, sufficient time was secured.

4.2 Ex-Vessel Transfer Machine

Function of EXTRA

The EXTRA is a machine which transports fuel assemblies contained in sodium filled pots from the relay station at the walls of the C/V to the reactor vessel. Fuel pots are transported in a coffin and moves lengthwise and breadthwise inside the C/V.

Grapple

The structure of the grapple is shown in Fig. 4-4. The lifting and pot handling is done by stainless steel tapes. The inside of the coffin and the bottom of the drive mechanism, where stainless steel tapes are scraped are temperature controlled at 150°C during operation, in order to keep the sodium melted.

Grapple Cleaning

Sodium Removal of the grapple is done in the same manner as the INCO. The operation of the machine is done using the panel for normal operation. Owing to the difference in volume, the capacity of the alcohol to be used is 140 ~ 150 liters, about 20 more than for the INCO.

Sodium Deposition

Sodium deposition is shown in Fig. 4-5 and the amount of sodium measured on the grapple was about 90g. The drain structure

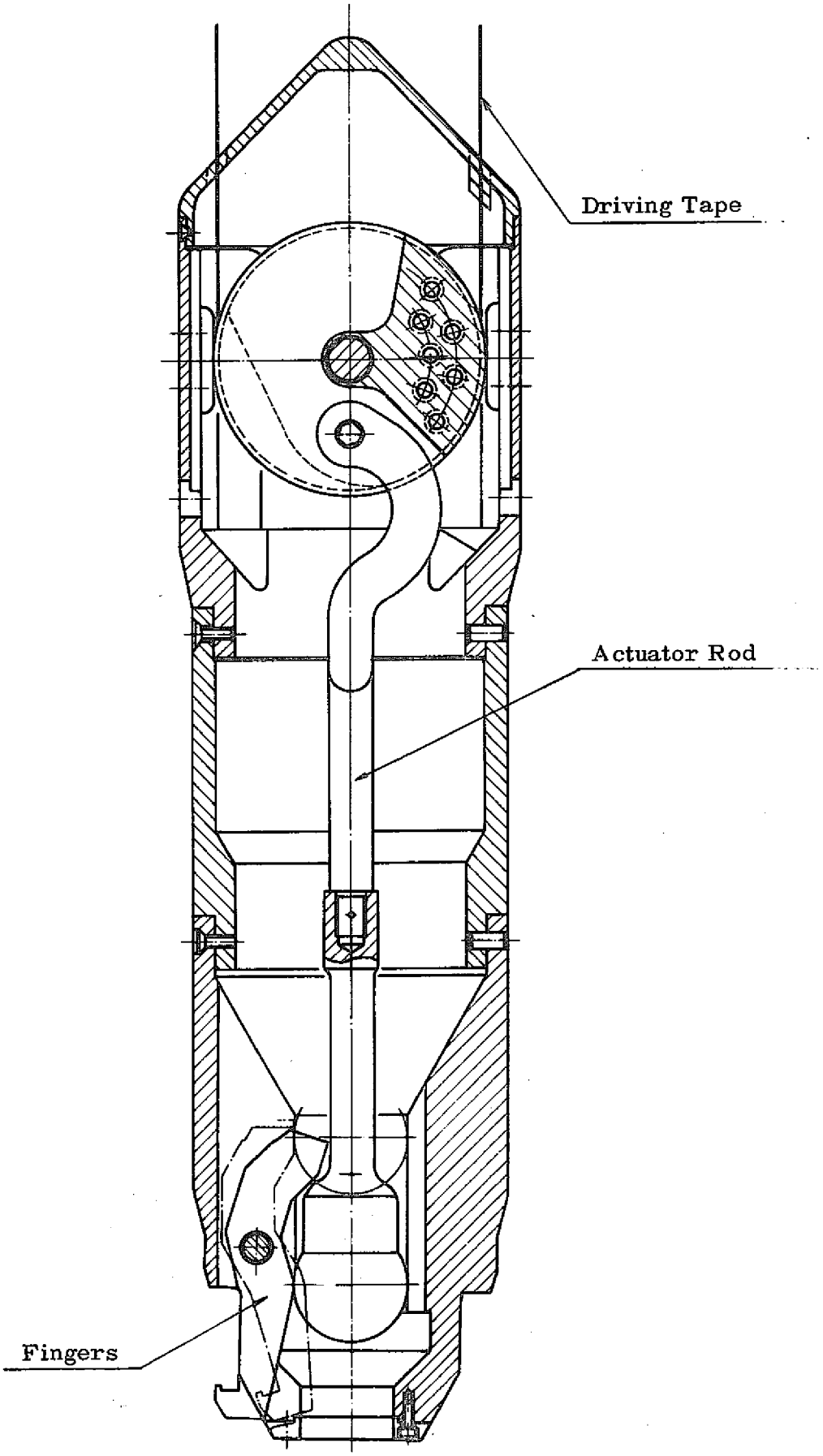


Fig. 4-4 Grapple of EXTRA

and the total surface area explains the amount, compared to the INCO.

Remarks

There has been an overall inspection of the machine besides these sodium removal operations and they showed that hardly any sodium remained. See Fig. 4-6. This is due to the simple and easy sodium removable structure of the grapple.

Sodium Removal Experience

The experience is tabulated in Table 4-2. In the first case, during functional tests of the EXTRA, the grapple was used extremely long and additionally the alcohol used for removal was reused. For this reason the process took nearly 7 hours, longer than the expected 3 hours. During this period, false operation to decide the end of process was tried 5 times, all in failure. Since then longer duration and addition of water into the alcohol has been done.

Table 4-2 Sodium Removal of EXTRA

Case No.	Duration in Na	Alcohol composition	Duration in alcohol
1	140 times	Al. 150 l H_2O 0 l	7 hours
2	Grapple was taken apart and cleaned independently		
3	4 times	Al. 145 l H_2O 0 l	17 hours
4	140	125 20	5
5	20	120 15	40
6	18	125 20	18
7	8	120 20	18
8	6	120 30	18
9	10	120 30	18

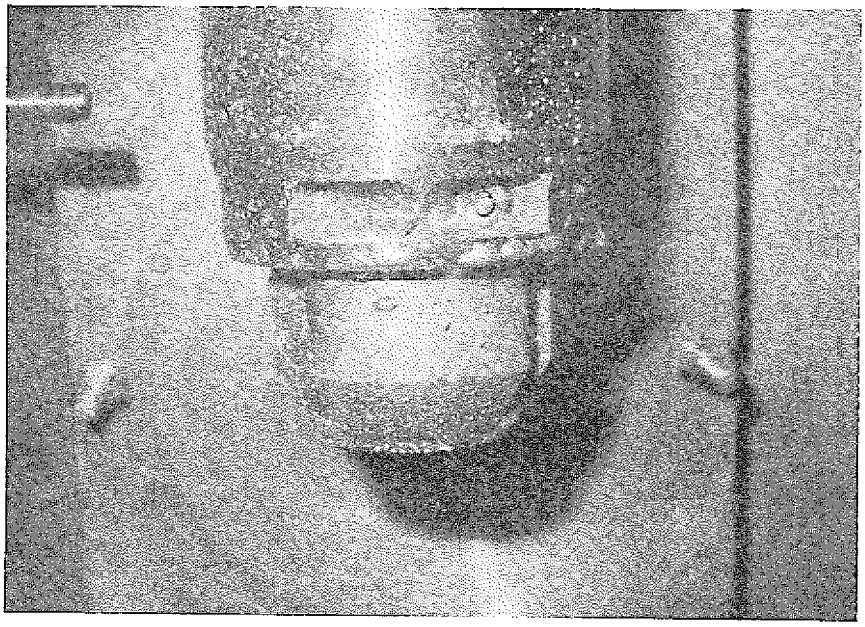


Fig. 4-5 Sodium Deposited on Grapple of EXTRA

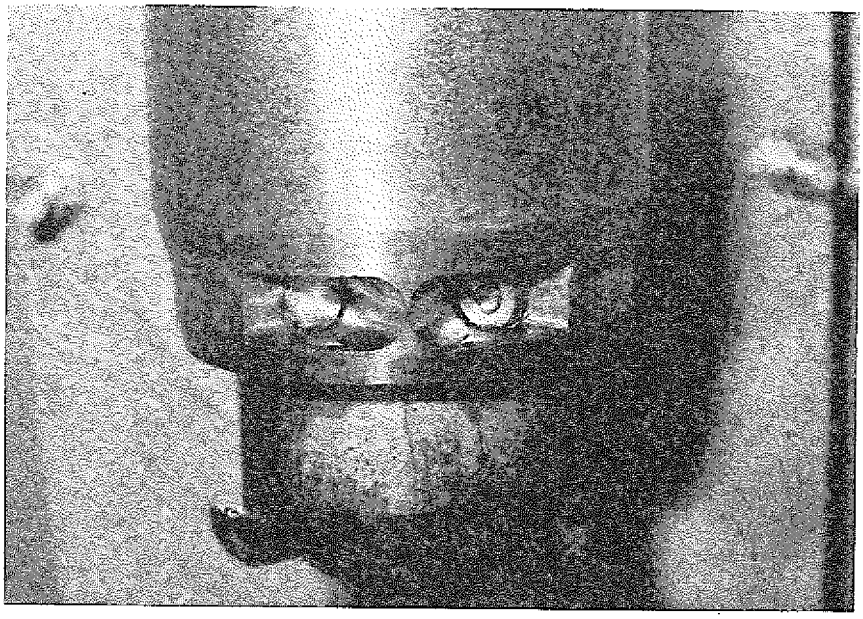


Fig. 4-6 Grapple of EXTRA after Sodium Removal

4.3 Cask Car

Function of Cask Car

The Cask Car travels on parallel rails inside the reactor service building and transports new or spent fuel assemblies. New fuels are picked up from the storage, preheated inside the cask, then are inserted into the Transfer Rotor. Spent fuels are withdrawn from the T/R and are sent to the Fuel Cleaning Facility.

Grapple

The structure of the grapple is shown in Fig. 4-7. The operation of the grapple is done by two wire ropes and 2 fingers open and close. Since the Cask Car handles fuel assemblies alone, only the bottom of the grapple near the fingers, about 100 mm in length, is wetted in sodium.

Sodium Removal

When refueling operation is through, the Cask Car moves over to the Cask Car Inspection Facility. The grapple is sent down to the cleaning pot and separated from the drive mechanism by gloves. After the isolation of the grapple inside the pot, alcohol is charged and circulated at 40 ~ 60 l/min.

Sodium Deposition

As is shown in Fig. 4-8, the sodium is spread out equally but the amount is very small. From a chemical analysis, it showed to be less than 5g. The main reason for this is the condition of the grapple in sodium and the argon blow down gas which works during grapple operation in sodium.

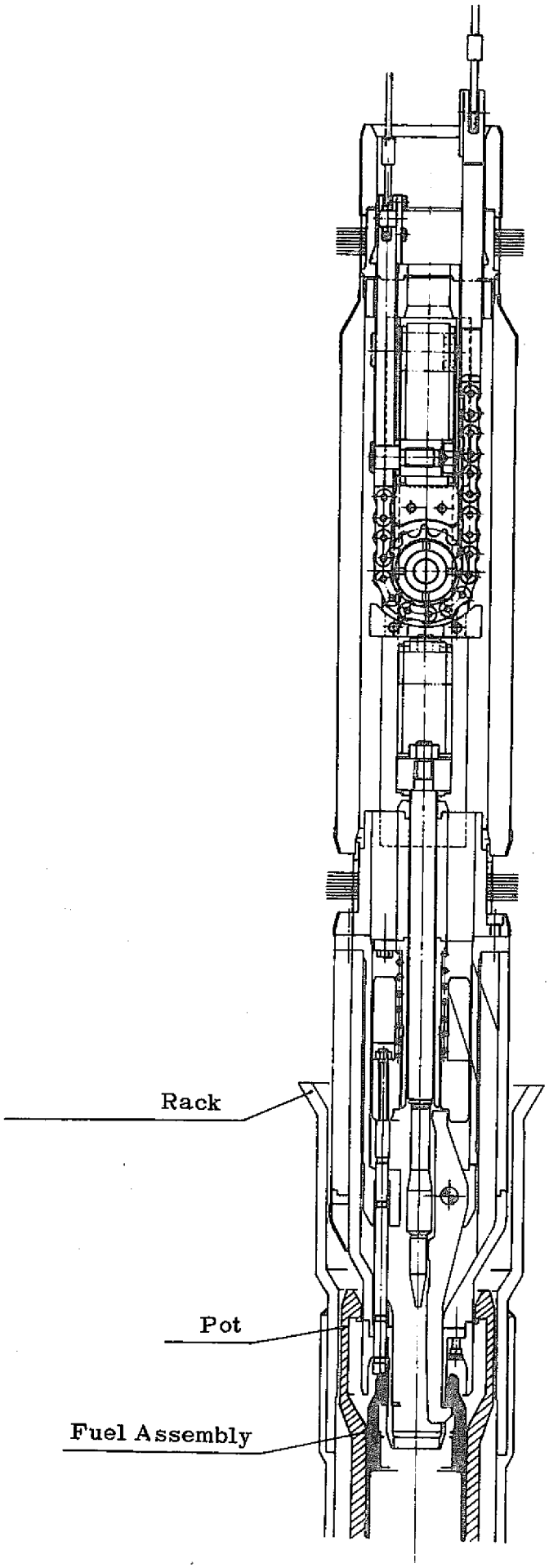


Fig. 4-7 Grapple of Cask Car

Cleaning Process

In the initial stage, alcohol was used as accepted. Compared to the Grapple Cleaning Facility,the alcohol can be circulated and so water concentration into the system was not considered. However, sodium deposition showed to be extremely small and in order to achieve higher cleaning efficiency cleaning by 100% demineralized water was experimentally done. Results were fairly good and presently, 100% demineralized water is used. Water flow rate is 40 ~ 60 l/min and the process takes 20 ~ 60 minutes. During the process, rise of pressure and temperature is not seen. Drying is done by argon gas purging using vacuumization at 100°C.

Requalification

Visual inspection and false operation is done in order to decide reuse of the grapple. There has never been any troubles in this area after handling 180 fuel assemblies and cleaning the grapple 7 times. See Fig. 4-9.

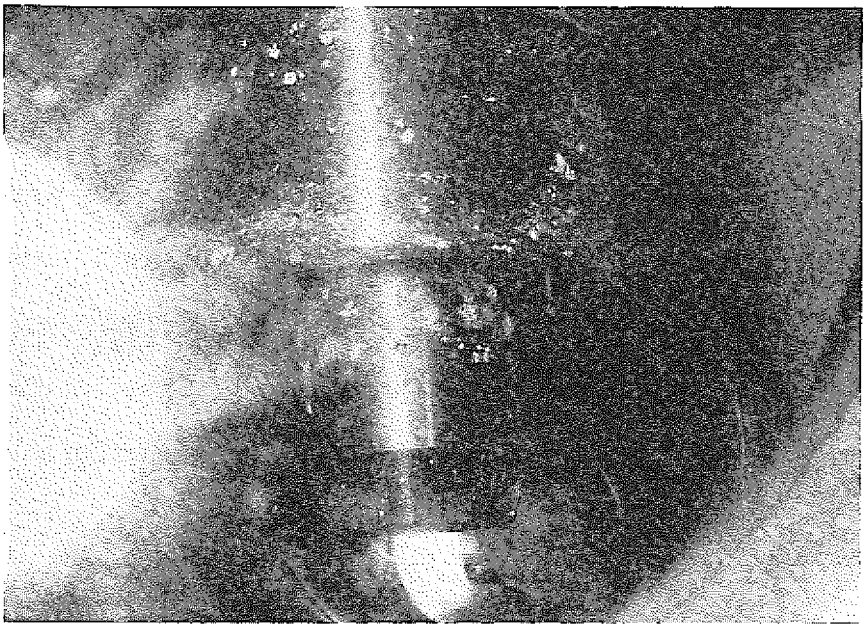


Fig. 4-8 Sodium Deposited on Grapple of Cask Car

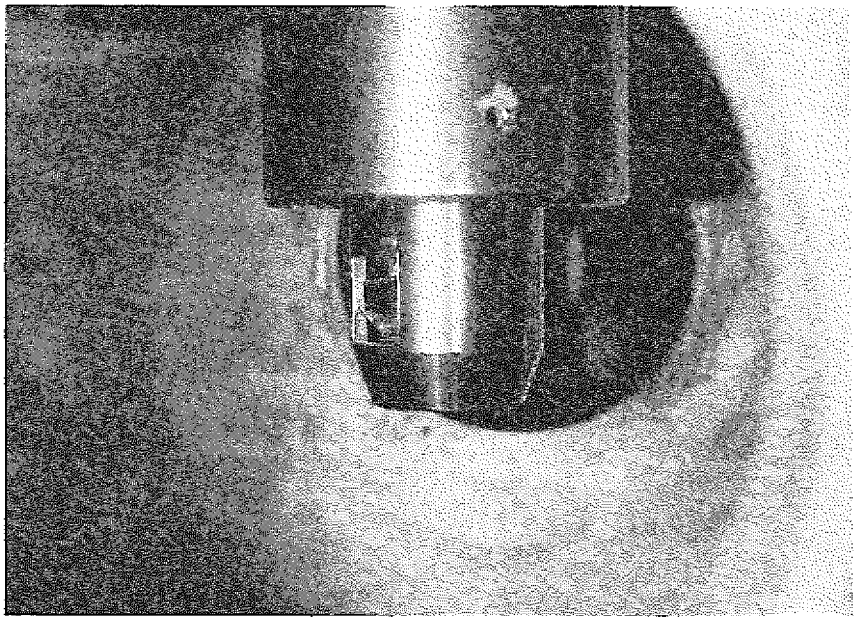


Fig. 4-9 Grapple of Cask Car after Sodium Removal

Sodium Removal Experience

The sodium removal operation has been done 8 times since sodium charge into the plant. Among this, the operation was done 4 times (once with 100% alcohol and 3 with 100% water) using the cleaning facility and 4 times by hand with the grapple taken apart. The reason for the operation by hand was to evaluate the functions of the machine by visual inspection before sodium became radioactive.

Table 4-3 Sodium Removal of Cask Car

Case No.	Cleaning Process	Handled Assemblies Before Operation	Cleaning Medium	Drying
1	Cleaning Facility	3 Spent Fuels 2 New Fuels	Alcohol	vacuumization and natural drying
2	By Hand	6 S.F. 8 N.F.	Alcohol + Water	natural drying
3	By Hand	16 S.F. 17 N.F.	Alcohol + Water	natural drying
4	By Hand	35 S.F. 35 N.F.	Alcohol + Water	natural drying
5	Cleaning Facility	8 S.F. 10 N.F.	Water	vacuumization for 7 hours at 100°C
6	Cleaning Facility	9 S.F. 8 N.F.	Water	vacuumization for 7 hours at 100°C
7	Cleaning Facility	7 S.F. 7 N.F.	Water	Repetition of purging and vacuumization
8	By Hand	5 S.F. 4 N.F.	Alcohol + Water	natural drying

5. Conclusions

Since the installation of the machines till the end of December, 1977, sodium removal for the grapples were done 14 times for the INCO, 9 times for the EXTRA and 8 times for the Cask Car. From these experiences the following remarks were obtained.

(1) In the removal of sodium, additional water in the alcohol promotes the cleaning effect and shortens the process time.

(2) In narrow spaces, such as those between cylinders or annular spaces of the rods and guides, membranes of solvents are formed and the reaction is ceased. In order to overcome this obstruction, bubbling by argon gas was found effective.

(3) During the removal process, circulation of the fluid is recommended.

(4) In such cases as the grapple of the Cask Car where deposited sodium is small, cleaning by demineralized water is effective.

(5) A drying process for the grapples after cleaning is necessary. This is especially so when cleaning by demineralized water follows the alcohol cleaning process.

(6) Through our experience, there was one case when failure of sliding parts were observed. They were taken apart and remaining sodium was observed. It was concluded that, in this operation in alcohol, once the sodium remains after a removal process, it becomes difficult to remove by a similar process.

(7) Waste disposal was initially planned to be done by dilution. However, from the regulations of the Ibaraki Prefecture, the Chemical Oxygen Demand (COD) value was restricted to an alcohol concentration of below 60 mg/l. In order to establish this, the dilution method turned out to be impractical. Presently, the waste is not radioactive and retrievable storage is done, but, in the future, a disposal facility considering reuse of the alcohol is considered.

(8) In the present sodium removal facility, the end of the process is decided by visual inspection and tentative operation. For higher reliability of the effectivity of the process, detection of the progress of reaction is recommended.

(9) The comparison of the cleaning method is shown in Table 5-1.

Sodium removal of grapples have been done effectively in "Joyo". However, to gain higher efficiency and minimize downstream waste, improvements are scheduled ahead.

Table 6-1 Comparison of Removal Methods

Item	Grapples		
	Inside C/V		Outside C/V
	INCO	EXTRA	Cask Car
Grapples			
Driving Force	Rod	Tape (SUS)	Chains
Fingers	3	3	2
Handled Item	Fuel Assembly	Fuel Pot	Fuel Assembly
Preheating	Direct Charging into Sodium	Natural Convection	Argon Gas Forced Circulation
Sodium Atmosphere	Wholly in sodium during refueling	In sodium, only during refueling in reactor vessel	Partially in sodium
Sodium Inspection	Visual	Visual	Visual
Sodium Deposition	~ 150g	~ 90g	~ 5g
Cleansor type	Alcohol with 10% water	Alcohol with 10% water	100% alcohol and 100% water exchanged every time for use
reuse	used 3 times	used 3 times	
capacity	120 ~ 130 l	130 ~ 140 l	~ 180 l
Waste Disposal	Retrieval Storage	Retrieval Storage	Drained to low activity level tank
Operation			
cover gas	Argon	Argon	Argon
grapples	connected to drive mechanism	connected	disconnected
alcohol circulation	natural with bubbling	natural with bubbling	forced circulation
drying	preheating system of the axial seal is used	cask purging system is used	cask purging system is used
Requalification	visual inspection and false operation	visual inspection and false operation	visual inspection and false operation