20th Annual Conference of the Canadian Nuclear Society
Montreal, Quebec, Canada / May 30 - June 2, 1999

DEVELOPMENT OF SPECIAL TOOLS FOR THE CLEANING OF REACTOR'S INTERIOR IN HANARO

Yeong-Garp Cho, Jung –Hee Lee, Jeong-Soo Ryu, Jong-Sup Wu, Hoan-Sung Jung
HANARO Applications Reserach, Korea Atomic Energy Research Institute
P. O. Box 105, Yusong, Taejon, 305-600, KOREA
Tel: 82-42-868-8487, Fax: 82-42-862-1763, E-mail: ygcho@nanum.kaeri.re.kr

ABSTRACT

The HANARO (Hi-flux Advanced Neutron Application Reactor) in Korea has been being operated for 5 years, including one year of non-nuclear system commissioning tests since the installation of the reactor in early 1994. The HANARO is an open-tank-in-pool type reactor which has the advantage of free access from the pool top.

The HANARO reactor had special cleaning works twice to remove debris from the inside reactor. This paper summarizes the development of special tools for reactor cleaning and how the reactor's inside had been successfully cleaned within short periods.

The first cleaning work, after the initial flushing of the reactor system in early 1994, was the removal of the silica-gel sands, contaminated during installation, from the reactor pool and all equipment in the pool, including the reactor structure, the reactivity control units and the primary cooling system. Water-jet, pump suction, vacuum suction and whirl methods were used in combination with specially designed tools.

The second one, occurred in February 1997 after two years of reactor operation was the cleaning work for the reactor's interior to remove several metal pieces broken from the parts of a check valve assembly in the primary cooling system. This work required development of many special tools that are all compact in size and remotely operable to reach all areas of the inlet plenum through very limited access holes. The special tools used for this work were two kinds of underwater cameras equipped with lighting, a debris-picking tool named 'revolving dustpan', two kinds of flow tube replacement tools and many other supplementary tools. All work had been successfully accomplished on the in-pool-platform temporarily installed 9m above the pool bottom to maintain the pool water level required in view of radiation shielding. Finally, the reactor internals were inspected using the underwater cameras to confirm the absence of debris and the surface integrity of the plenum as well as all fuel channels.

1.0 INTRODUCTION

The HANARO (Hi-flux Advanced Neutron Application Reactor) is a 30 MW multi-purpose research reactor in Korea with the capabilities of a nuclear fuel in-pile test, the production of key radioisotopes, neutron activation analysis, neutron beam scattering, radiography and other basic research[1]. The HANARO, with the maximum available thermal neutron flux of 5E14 nv, uses 20 % U_3Si fuels. It is an open-tank-in-pool type which has the benefits of free access from the pool top and a sufficient inventory of ultimate heat sink. It uses H_2O as a coolant and H_2O/D_2O as a moderator and has a large D_2O reflector around the core. In order to properly maintain the core cooling and to minimize the radiation hazard caused by ^{16}N release, an upward forced convection flow combined with a bypass flow through the chimney was selected as a primary cooling mechanism. The HANARO has been being operated for 5 years, including one year of non-nuclear system commissioning tests since the installation of the reactor in early 1994. The first criticality was achieved on February 6th, 1995.

In HANARO, we performed twice special cleaning works to remove debris from the pool and the reactor's interior. This paper summarizes the development of special tools for reactor cleaning and how the reactor's inside had been successfully cleaned within short periods.

2.0 CLEANING OF SILICA-GEL SAND FROM REACTOR AND POOL

2.1 Contamination by Silica-gel Sand

After the flushing of the PCS (Primary Cooling System) in March of 1994, we became aware of a significant amount of fine, white sand in the entire primary cooling system and reactor pool, under the reactor plenum, and inside all of the structures, including the reactor. We observed that this sand was widely spread throughout the pool even on the top surfaces of the upper part of the reactor structure and the RCU (Reactivity Control Unit, composed of the shutoff (SO) unit and the control absorber (CA) unit) components that can be reached from the chimney top. We assumed that this material has also got into the RCU tracks, carriages, linkages, etc., as well as down onto the grid plate surface between receptacles, inside the bottom of the plenum, and under the plenum.

If any of it remains in the reactor, abrasive sand of this size could cause rapid wear and probably jamming in the moving parts of the RCU. Therefore, it was necessary for the sand to be completely removed from PCS system, pool and reactor structure before any operation of the RCU.

2.2 Cleaning Methods and Tools

The cleaning method and sequence to remove the sand were carefully investigated to avoid making the situation worse because the contaminated area is so wide and inter-related. The basic concept of cleaning the pool and the reactor exterior is by washing with a water-jet and vacuuming. Especially for the cleaning of sand in the gap between the plenum and the pool floor due to shim plates, air suction through one open side was used while the air-jet was supplied through the other open side. For the cleaning of the reactor's interior, water-jet washing from the chimney to the plenum and then suction of water from the plenum were used after removal of all flow tubes (fuel channels), absorber rods and shrouds (guide tube for absorber rod). The suction hose was inserted into the plenum's interior through the grid plate receptacle. To gather the sand to the central region by making a whirl flow while providing suction of water, the water-jet was supplied to the plenum by a specially pre-formed hose inserted through the 6-inch flap valve port which branches from PCS inlet line. The sequence of the cleaning operation is shown in Figure 1. The concept of plenum cleaning is shown in Figure 2.

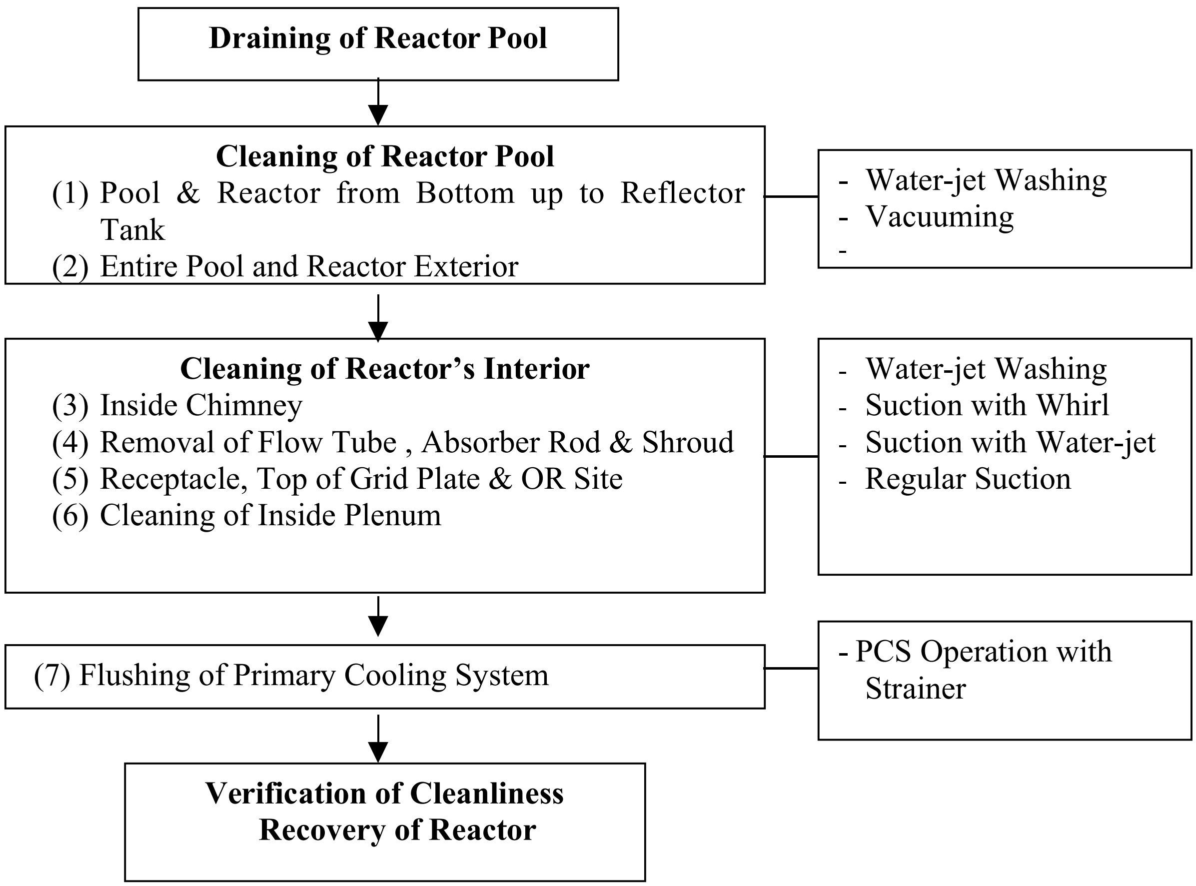


Figure 1. Sequence of Sand Cleaning in HANARO

For preparations before starting the cleaning work, all openings in the reactor chimney base plate were plugged, and the CA tie rod lower ends and their openings on the chimney were wrapped with a plastic cover. The crevice between the plenum bottom flange and the pool floor were sealed with tape. The flange bolt and bolt slots were covered and sealed with cotton wads and tape with an opening at one side for the air-jet supply and another opening at opposite side for vacuuming. The openings were progressively moved around during operation to clean all around.

Many special tools, as listed below, were used for the removal of sand from all the contaminated areas.

1) Air-jet hose with appropriate tube ends for reactor exterior cleaning

2) Vacuum cleaner, for moist/wet service, with appropriate ends, one straight and one right angle for cleaning of cooling ring on grid plate.
3) Special tool for removal of flow tubes
4) Special tool for removal of orifice ring and lock washer
5) Special tool for removal of absorber rod
6) Water-jet hose with special nozzle-pipe end pre-formed by heat torch, inserted through 6-inch port (vacated by flap-valve assembly) into plenum interior, as shown in Figure 2.
7) Suction tube, 4m-long ϕ40mm PVC pipe with special shape nozzle, as shown in Figure 3, inserted into plenum interior through chimney, through receptacle, as shown in Figure 2
8) Water-jet tube, with 3m long, 10mm diameter steel-tube with jet-hole at right angle at the end as shown in Figure 3.
9) Suction tube, with 3m long, 10mm diameter steel-tube with specially shaped nozzle as shown in Figure 3.
10) Brush to clean receptacle threads with acetone
11) Temporary work platform inside chimney, as shown in Figure 2
12) Vacuum cleaner located as close as possible to chimney top for wet service, joined onto 4m-long ϕ40mm suction tube inserted into plenum interior through receptacle
13) CCTV camera, first with straight-on-view lens(28° view angle) then with 90°-view adapter, inserted into plenum interior through chimney, through receptacle
14) Two pumps, one to force fresh water into injection nozzle pipe, the other to suck water from plenum, discharged to service pool.

2.3 Verification of Cleanliness and Further System Flushing

The cleanliness of the reactor's interior including the plenum bottom was verified using a long stick with a layer of tape, adhesive side outward, onto end of a support rod, inserted through receptacles and taped onto bottom of plenum for examination of remaining sand. This examination was done on other surfaces of the reactor's interior. A CCTV camera was also used to verify that no sand was left elsewhere.

The primary cooling system and the purification system were flushed again with a temporary 160-mesh-per-inch strainer on the PCS line. Prior to the flushing, strainers were installed at the ends of the bypass to trap debris coming out from pipe. The Grayloc joint from the bypass line to the grid plate cooling ring was temporarily disconnected to extend a hose with the 160-mesh strainer at the end of the bypass line. The flushing was continued until no more sand was trapped in the strainer at the ends of the hoses extended to the outside pool.

3.0 REMOVAL OF DEBRIS FROM REACTOR'S INTERIOR

3.1 Debris in Plenum

It was in January of 1997, after the reactor had been in operation for nuclear commissioning tests and service for two years, when we recognized that something existed inside the plenum. A few fuel bundles were found during fuel inspection with the central rod tip of a few fuel bundles unexpectedly worn-out. That kind of wear could not happen without a continuous physical rubbing by another hard material. The finding was that the components of the connecting pin of the check valve assembly installed on the PCS line were worn by flow induced vibration, and the split pins were broken. Then, the link pin and its locking components escaped from the check valve and were finally gathered in the plenum by PCS flow. The lost items from the check valve were a link pin (ϕ20mm, 95 mm long, ⧅28mm in head size), two plain washers (I.D. 21mm, O.D. 34mm, 3 mm thick), and split pins (⧅6.3mm, 80mm long). It was judged that the debris in the plenum, like the plain washers, had caused the wear of the fuel central rod tips during reactor operation. Also, a few broken parts from fuel spacer plates were some of expected debris to be found inside plenum.

3.2 Cleaning Methods and Tools

Fortunately, the maximum diameter of the lost items from the check valve was smaller than the inner diameter of receptacle hole, ϕ50mm, which is the only access hole directly from the reactor top when the flow tube is removed from the core. It was estimated that the previous cleaning method used for sand cleaning in 1994, which was suction through the receptacle hole with a whirl flow of water in the plenum, was not proper this time because the debris were heavy metal pieces. Three hexagonal flow tubes were removed from receptacles to insert the special tool named ‘revolving dustpan’, the underwater camera and the lighting through the receptacle holes. For easy operation of the removal of flow tubes, the cleaning work and the inspection of the reactor’s interior, a temporary work platform was installed 3m above the chimney with the pool water level lowered down below the platform level.

The revolving dustpan was specially designed to be inserted through the receptacle hole and to sweep the floor of the plenum by manual manipulation. The design of the dustpan made it possible to sweep all corners, even though the inner diameter of the plenum varies, to catch everything from the biggest debris (link pin) even to very tiny sized unknown debris like any broken parts from fuel spacer plates. The Figure 4 shows the main part of the revolving dustpan, and Figure 5 shows the concept of debris removal using the dustpan.

Besides the revolving dustpan, there were many other special tools used for this cleaning as listed below.

1) Revolving dustpan specially designed, 10m long, as shown in Figure 4
2) In-pool-work platform, specially designed, temporarily installed 3m above chimney
3) Flow tube removal tool, 8m long
4) Under water camera #1 specially designed, 10m long, ϕ18mm camera equipped with three mini-lamps, for inspection of plenum and receptacles, as shown in Figure 6
5) Under water camera #2, 10m long, ϕ18mm camera, for inspection of inside flow tube
6) Supplementary lighting inserted into inside of plenum
7) Weight balancer (spring balancer) for easy and safe handling of tools
8) Suction tube, ϕ48mm PVC tube, for suction of tiny debris from flow tube
9) Dummy plenum and test equipment to verify the performance of the revolving dustpan
10) Video recorder

3.3 Result of Cleaning and Inspection of Reactor Internals

Most of the lost parts from the check valve assembly were found in the plenum, but a few were also found in the flow tube and on the reactor pool floor. Those were successfully removed using the revolving dustpan. The revolving dustpan also made it possible to take out very tiny debris a few millimeters in size and the broken pieces of the fuel spacer plate. The photographs of the typical debris are shown in Figure 7. The cleanliness of the reactor's interior and the soundness of surface condition, especially for receptacles, were confirmed using the remotely operable cameras, as shown in Figure 6.

4.0 CONCLUSIONS

The reactor cleaning works were very successfully completed within very short periods due to the excellent performance of the special tools and excessively hard work by many people. It took three weeks for sand cleaning in 1994 and six weeks for debris removal in 1997, including the preparation of working procedures, the design and fabrication of various special tools, pool water draining, flow tube removal, cleaning, inspection, and recovery of all reactor conditions. Through those cleaning works, we have learned many things like the importance of cleanliness during the installation of the reactor and the related systems, the know-how to clean the reactor from a remote distance, design technology of special tools. Also we learned the necessity of a separate access port to the plenum in case that bigger debris may happen to get into the plenum. Now, the HANARO reactor is being operated with no further problems caused by debris.

ACKNOWLEDGEMENT

This work was performed under the national nuclear R&D program sponsored by the Korean Ministry of Science and Technology. And authors also express thanks to all the people who participated in the special cleaning works for the HANARO reactor.

REFERENCE

[1] Young-Sik Cho, Jonghwa Chang, and Chang-Oong Choi, "Conceptual Study for Moderator Selection of the Cold Neutron Source Facility for HANARO", J. of the Korean Nuclear Society, Vol.30, No.2, pp. 140-147, April, 1998

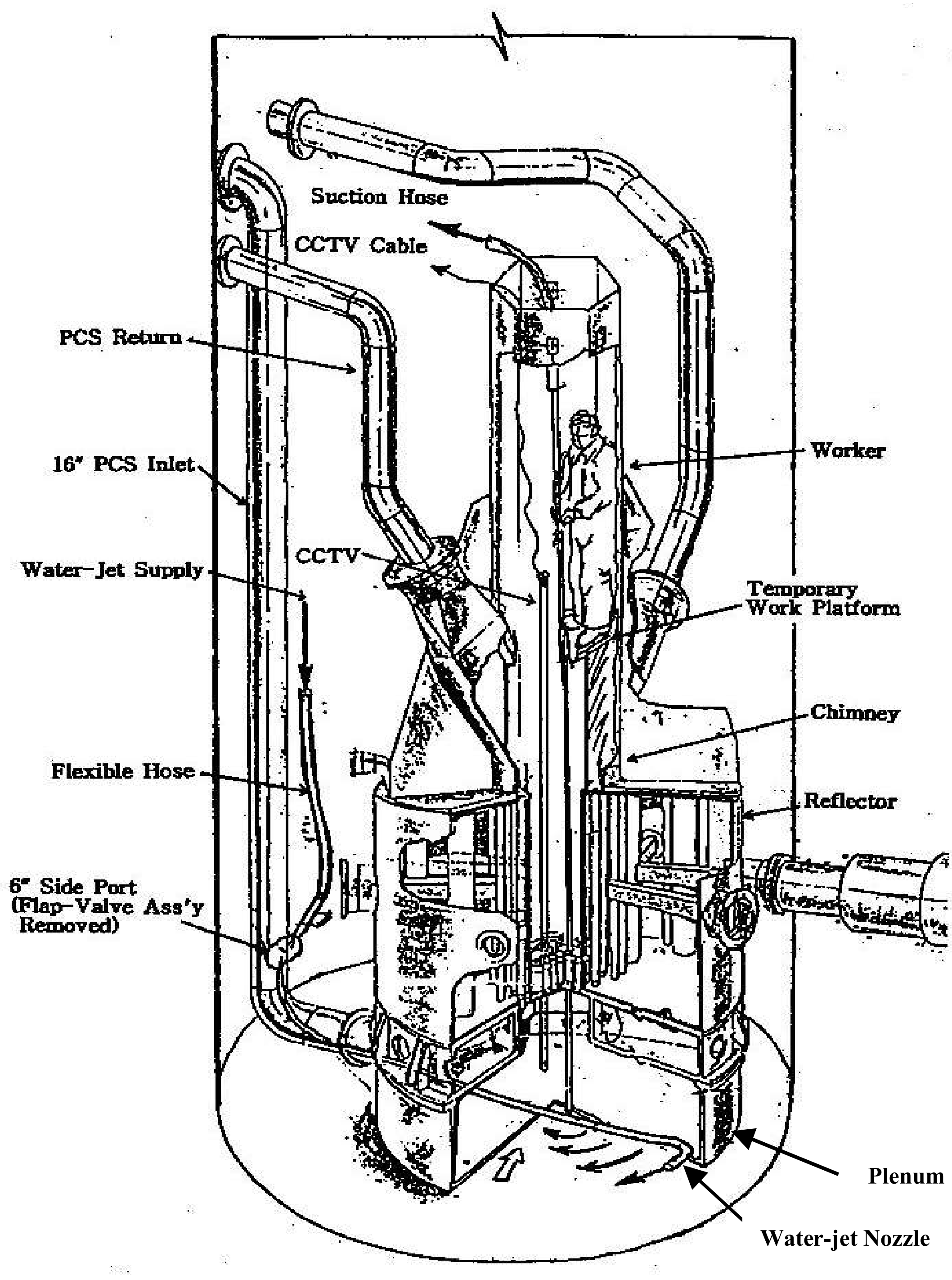


Figure 2. Concept of Sand Removal from Plenum in HANARO

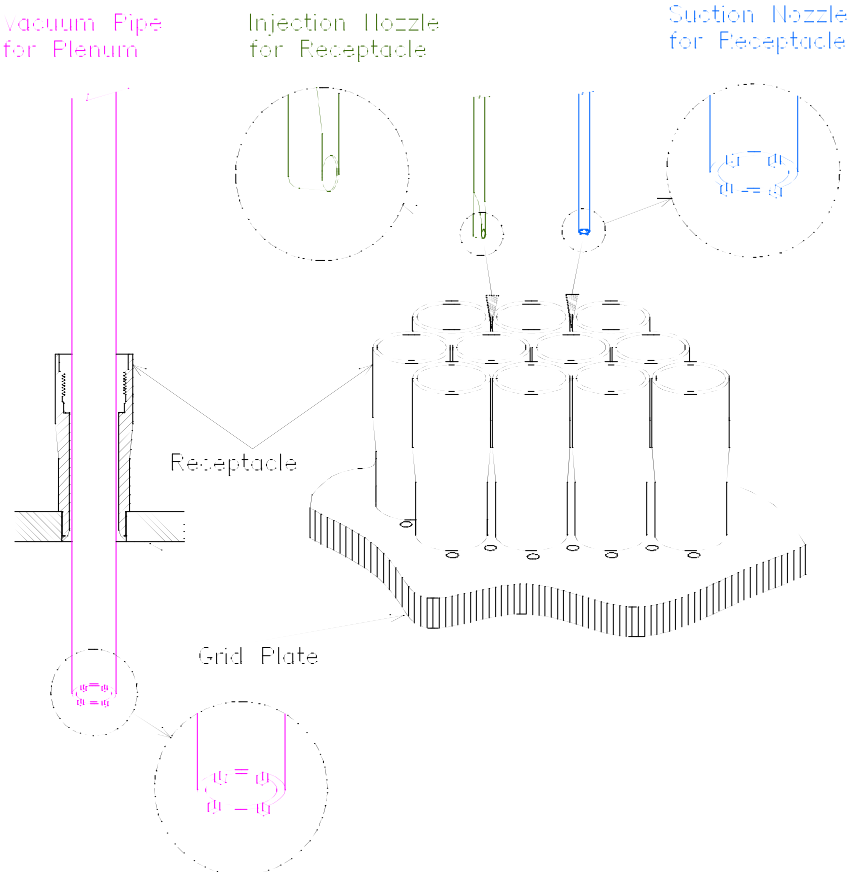


Figure 3. **Special Nozzles for Sand Cleaning**

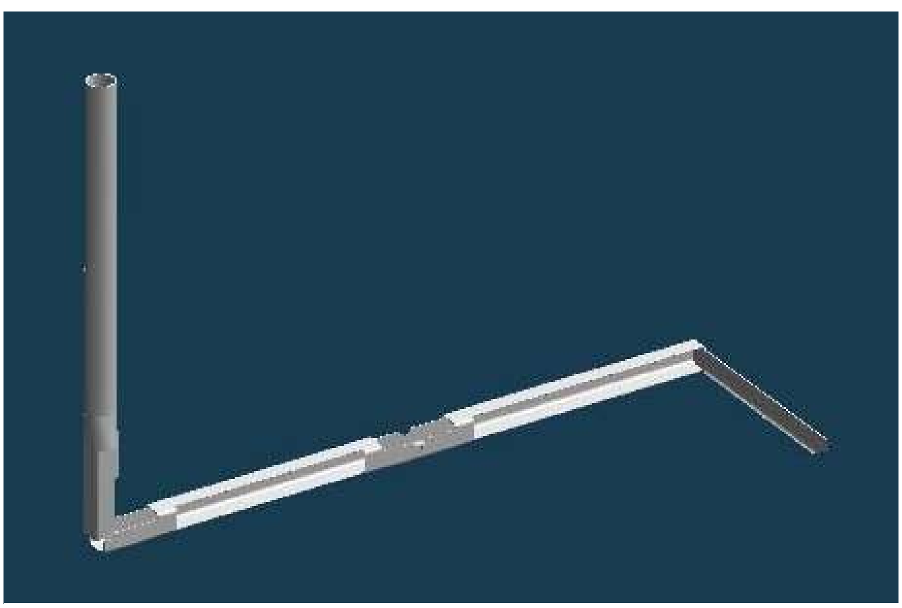


Figure 4. **Main Part of Revolving Dustpan**

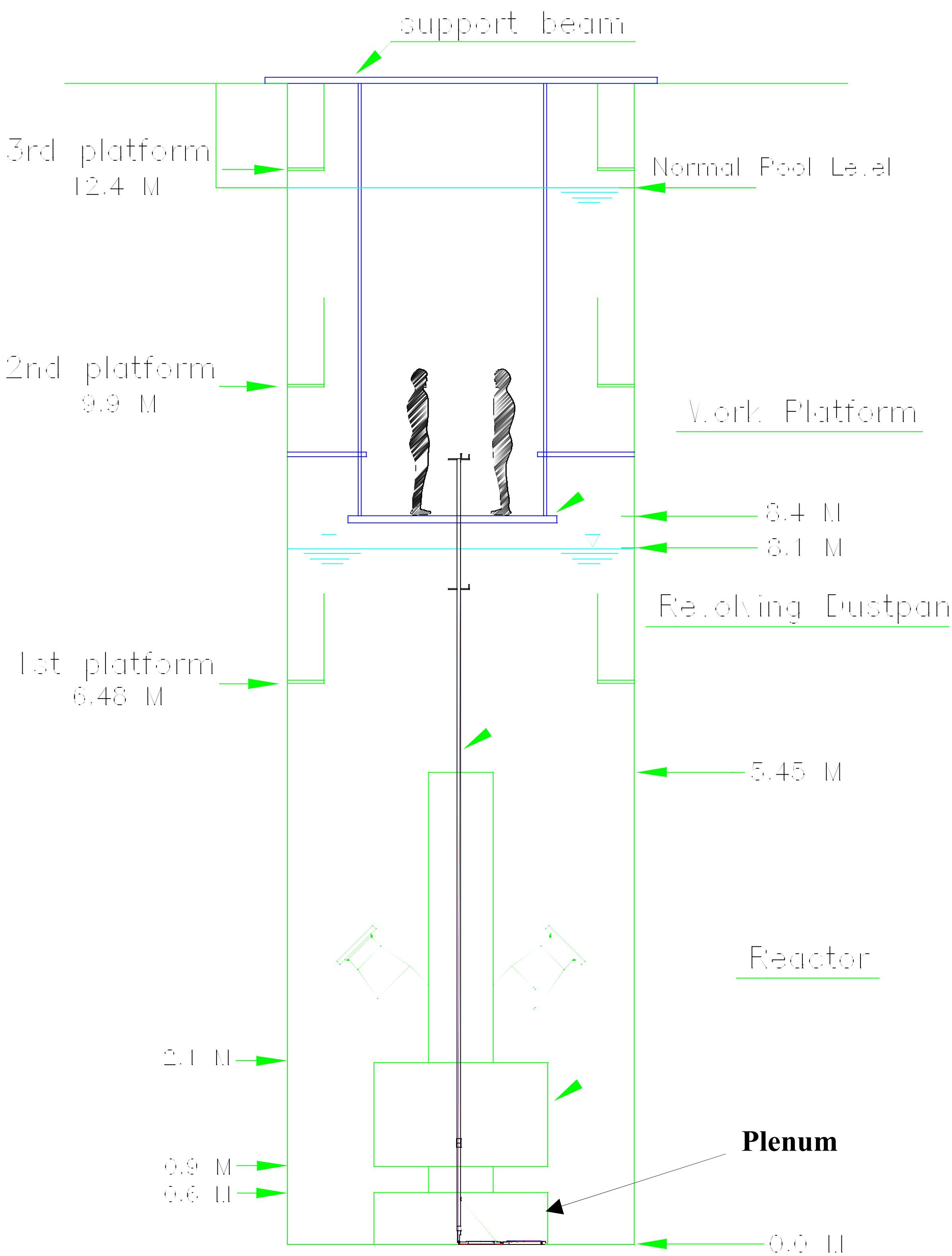
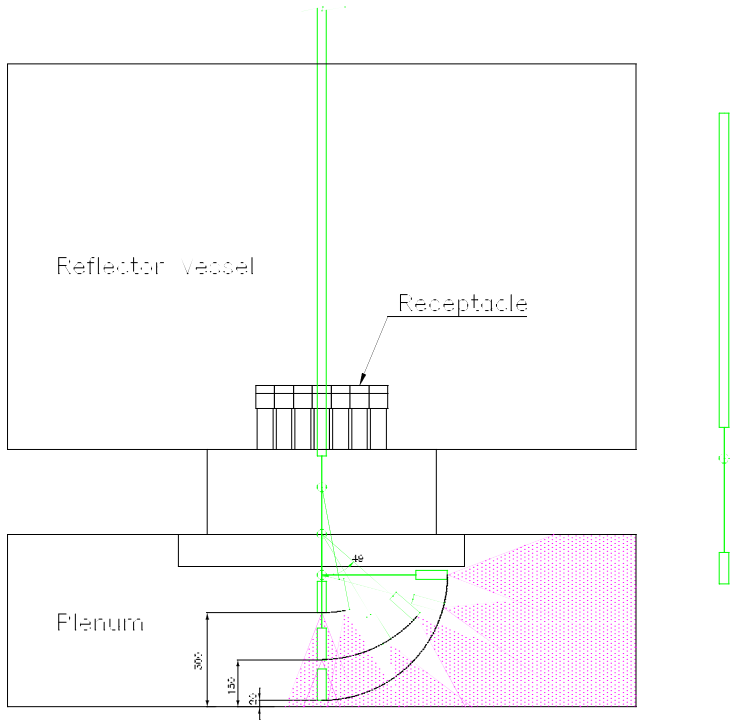
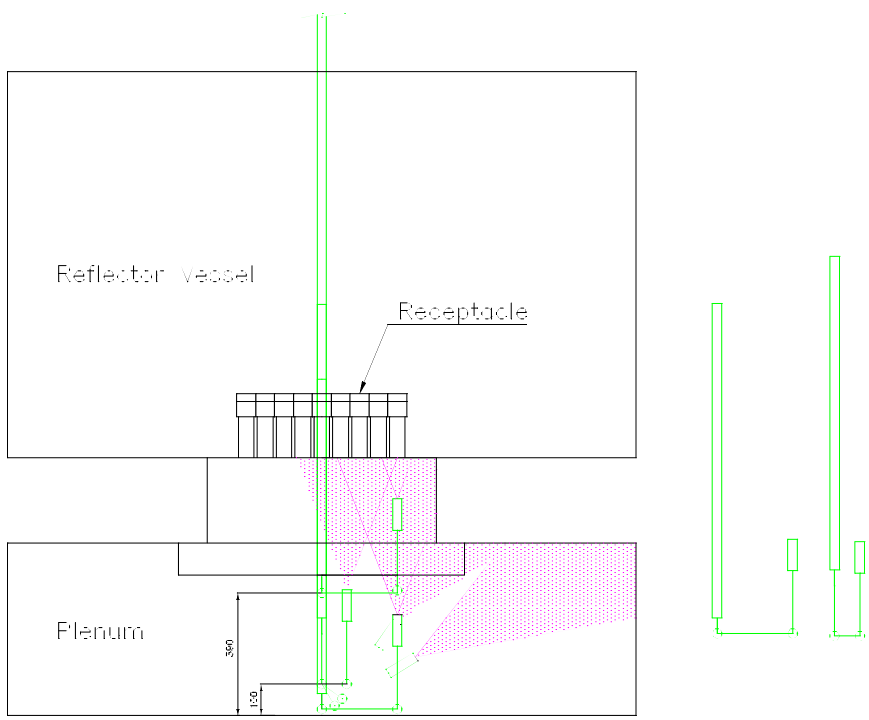


Figure 5. Concept of Debris Removal from Plenum using Revolving Dustpan

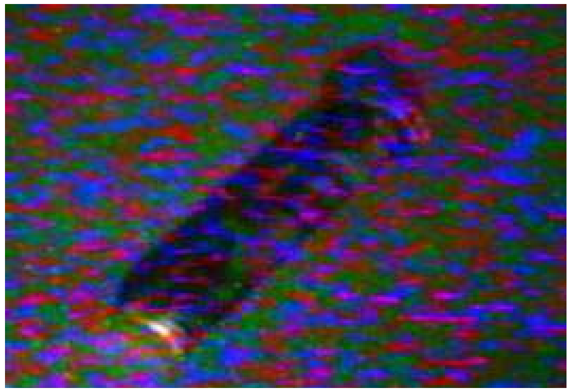


Inspection of Plenum Bottom and Side



Inspection of Stiffener, Receptacle, Orifice, Spider, Plenum Top

Figure 6. Inspection of Reactor Internals using Underwater Camera



Link Pin: ϕ20mm, length 95 mm, head size ⌀28mm

Split Pin: ⌀6.3mm, 75mm long, bent

Split Pin: ⌀6.3mm, 80mm long
with one end broken

Split Pin: ⌀6.3mm, 35mm long, broken part

Plain Washer: ID 21mm, OD 34mm, 3mm thick

Figure 7. Debris removed from Reactor using Revolving Dustpan