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Corrosion Induced Leakage in the Radial Beam Port of the 3 MW TRIGA Mark-II Research Reactor of Bangladesh

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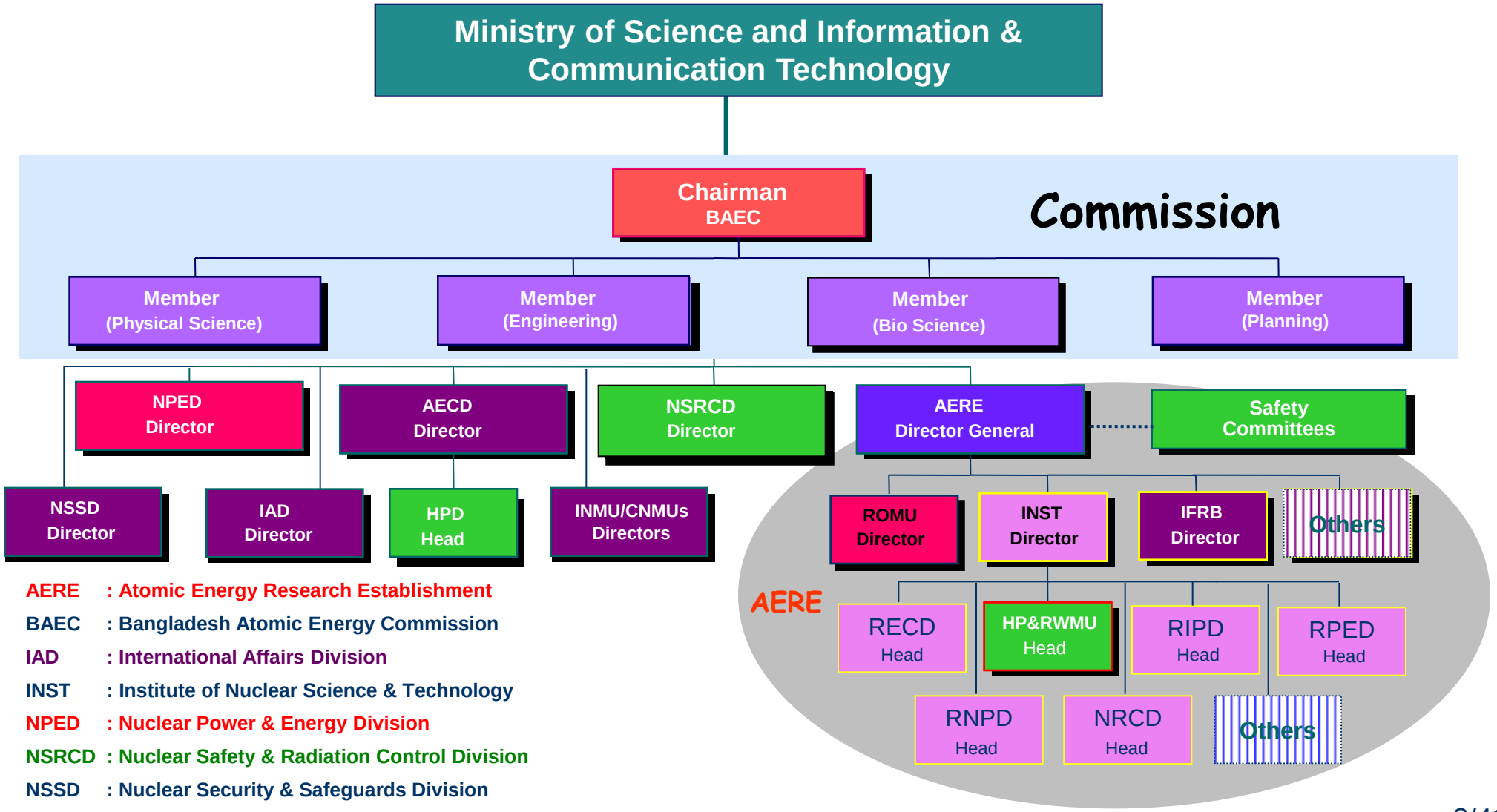
Background Information

Organization Structure of BAEC



AERE : Atomic Energy Research Establishment
BAEC : Bangladesh Atomic Energy Commission
IAD : International Affairs Division
INST : Institute of Nuclear Science & Technology
NPED : Nuclear Power & Energy Division
NSRCD : Nuclear Safety & Radiation Control Division
NSSD : Nuclear Security & Safeguards Division
ROMU : Reactor Operation & Maintenance Unit

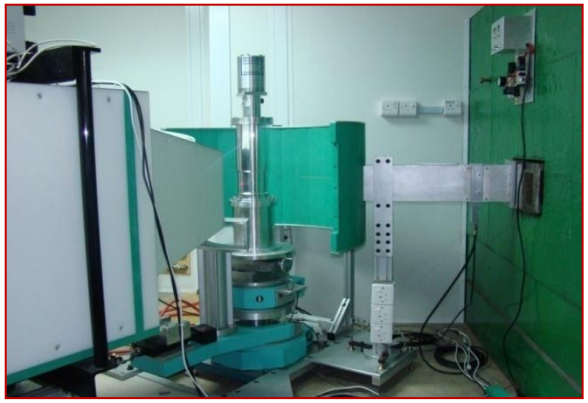
Background Information…

Major R&D Facilities of AERE (Atomic Energy Research Establishment)

3MW TRIGA Mk-II RR

Tc-99 Generator Production Plant

SSD Lab



HR Powder Diffractometer

3MV Tandem Accelerator

NAA Lab

Waste Management Facility

Background Information…

Shield Structure of the TRIGA Reactor

3 MW TRIGA Mk-II Research Reactor

Training

Research

Isotope production

General **A**tomics

Background Information…

Brief History

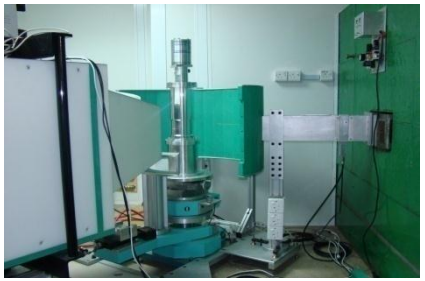
- 1981 May : Construction started.
- 1986 Sep : Criticality achieved (14 September).
- 1997 – ’01 : Suspension of high power operation because of the leakage problem in the N-16 Decay Tank of the primary cooling system.

- 2001 Aug : Commissioning of the renovated cooling system.
- 2004 July : Routine operation for production of RI (I-131).
- 2006 Jan : Safety Analysis Report upgrading completed.
- 2008 June : Issuance of full fledged Facility License,

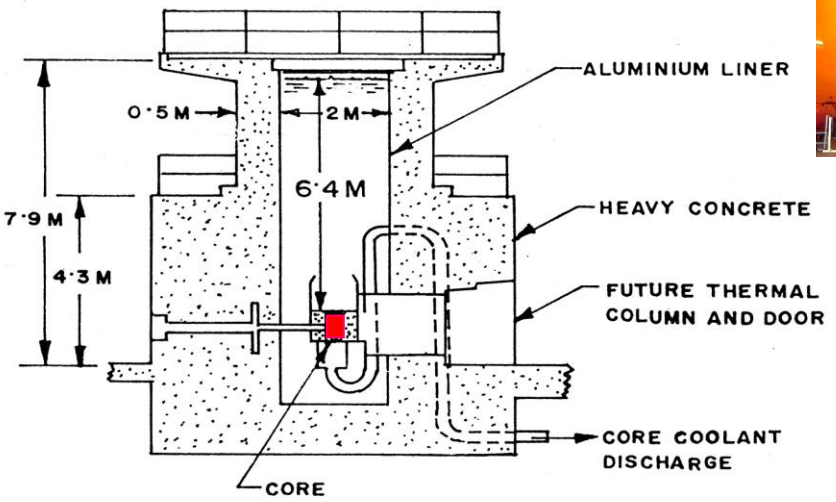
Background Information…

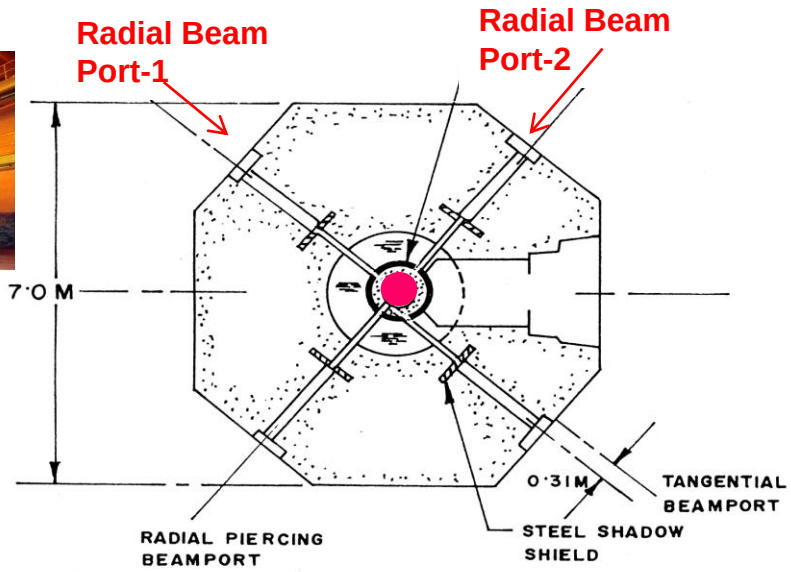
Brief History…

- **2009 Aug : Cleaning of Radial Beam Port #1 (RBP-1) started to make it ready for installation of the High Resolution Powder Diffractometer.**
- **2009 Sep : Detection of leakage of water through the RBP-1.**
- **2010 Mar : Restoration of normal operation of the reactor after rectification of the RBP-1 leakage problem by installing an Split Type Encirclement Clamp around it (RBP-1).**



Background Information…

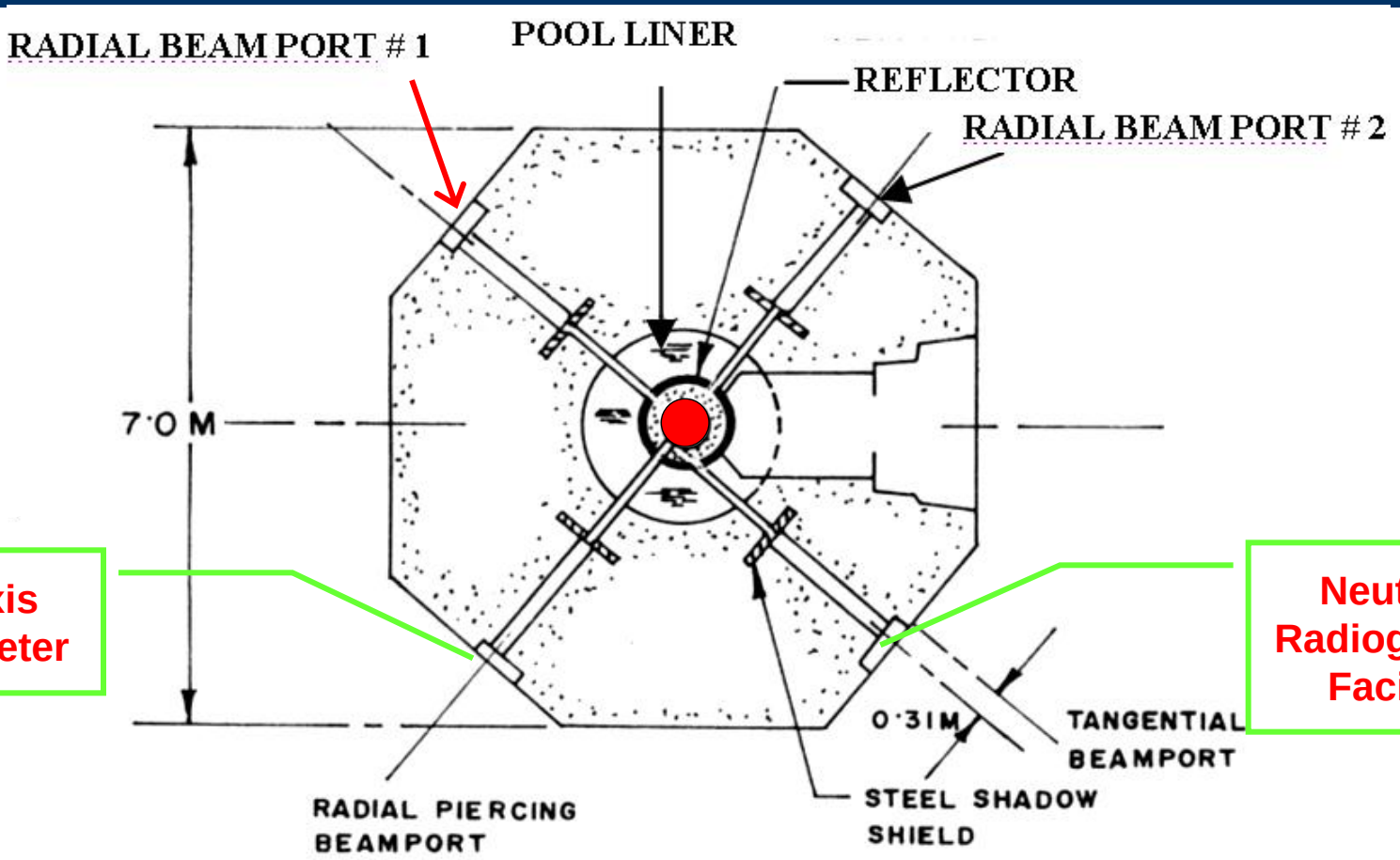




Sectional Views of the Reactor Shield Structure

Leak in the Beam Port

The Beam Ports

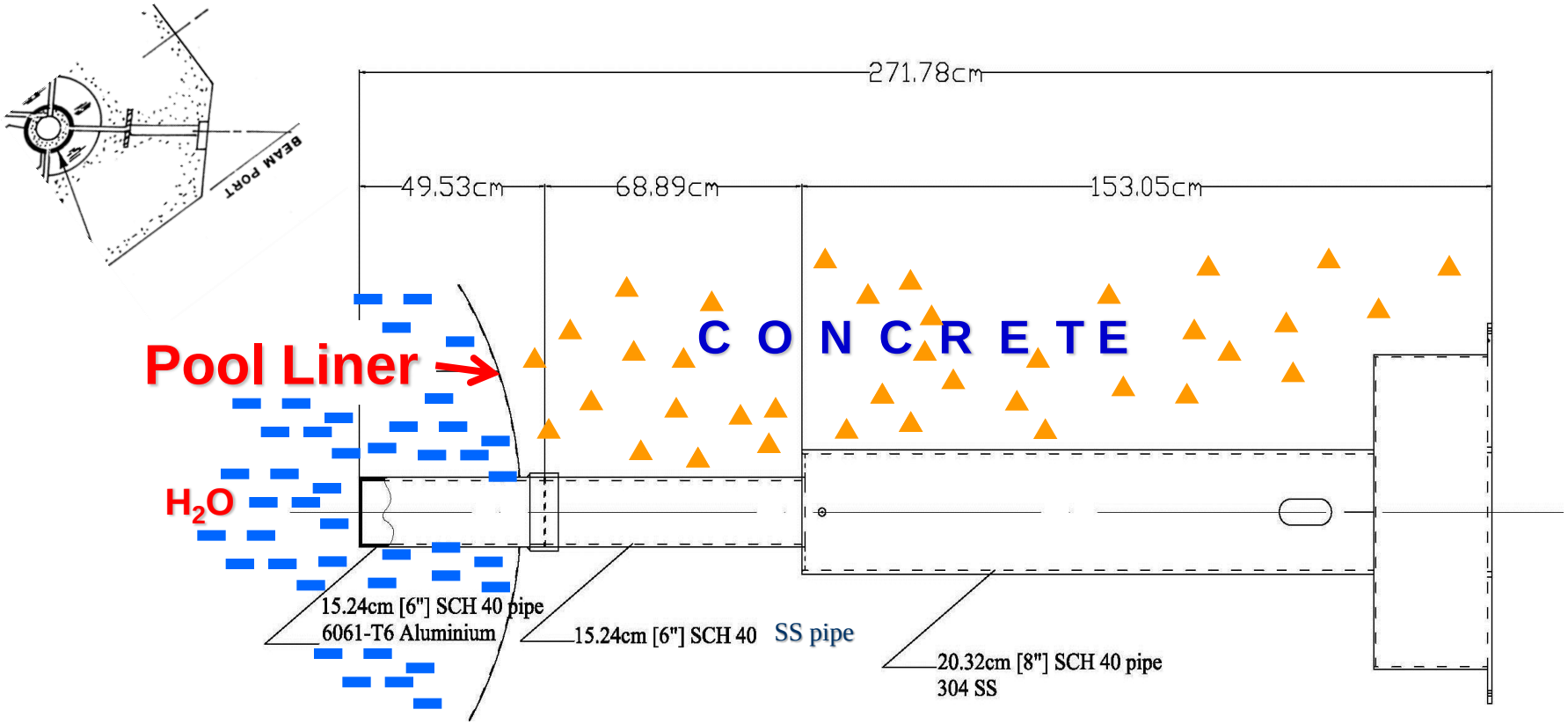


Triple axis Spectrometer

Neutron Radiography Facility

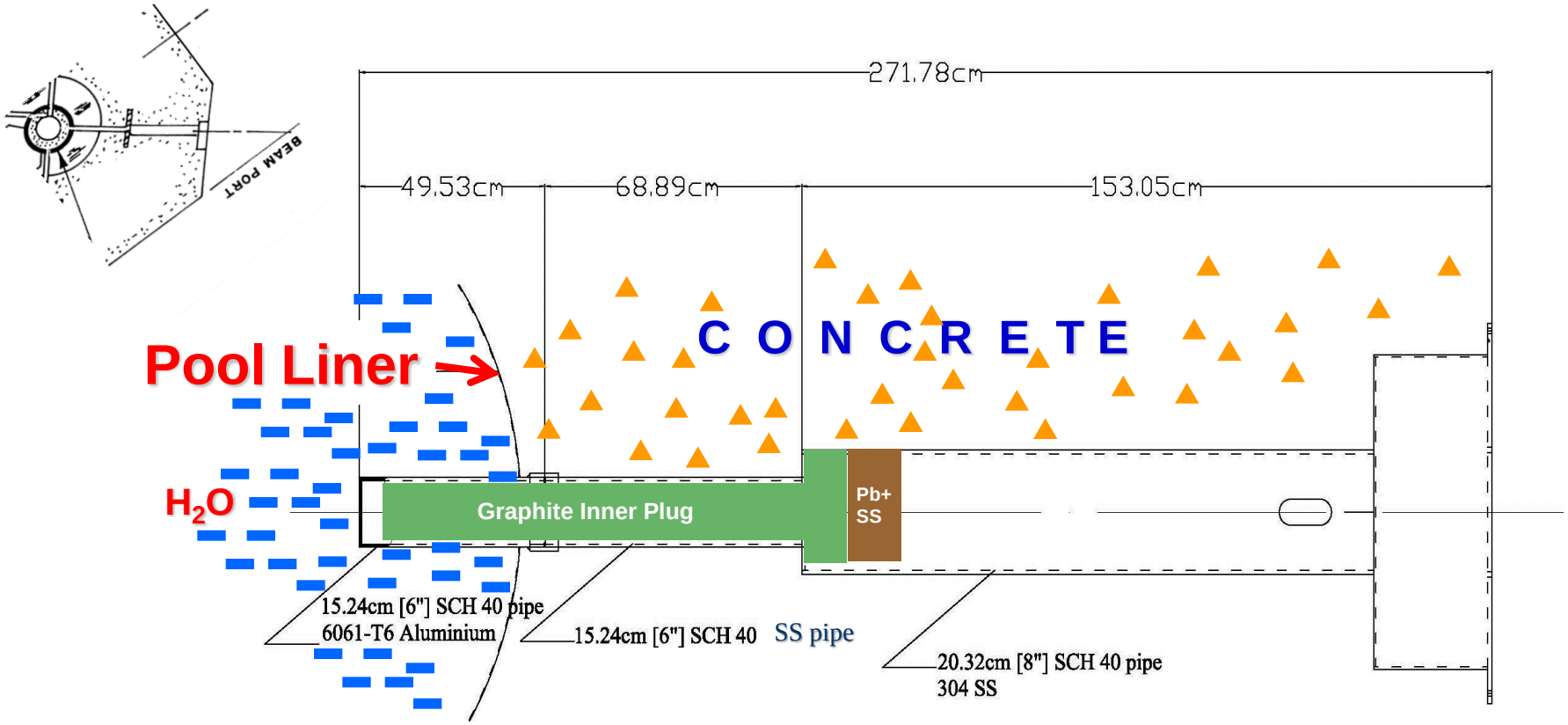
Locations of the Beam Ports

Leak in the Beam Port…



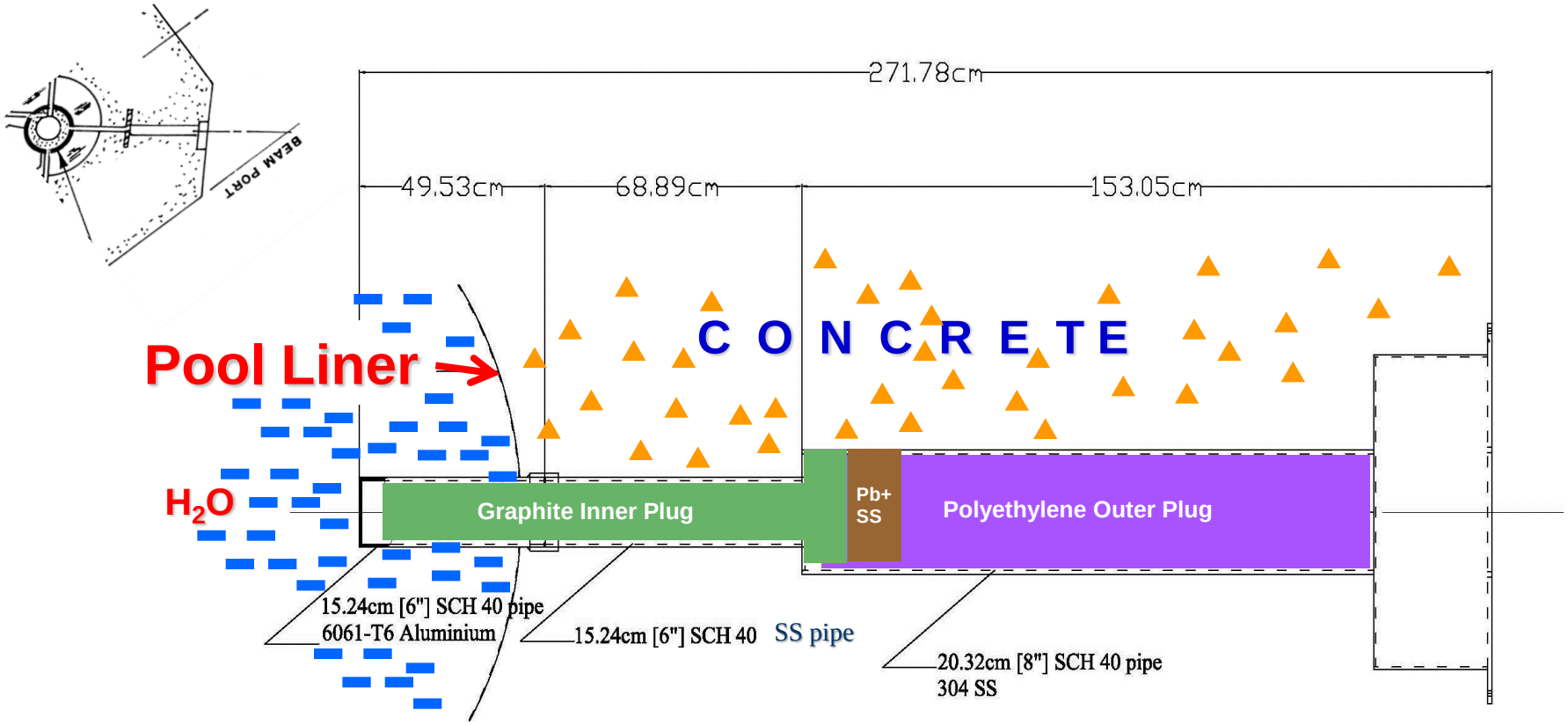
Details of Radial Beam Ports

Leak in the Beam Port…



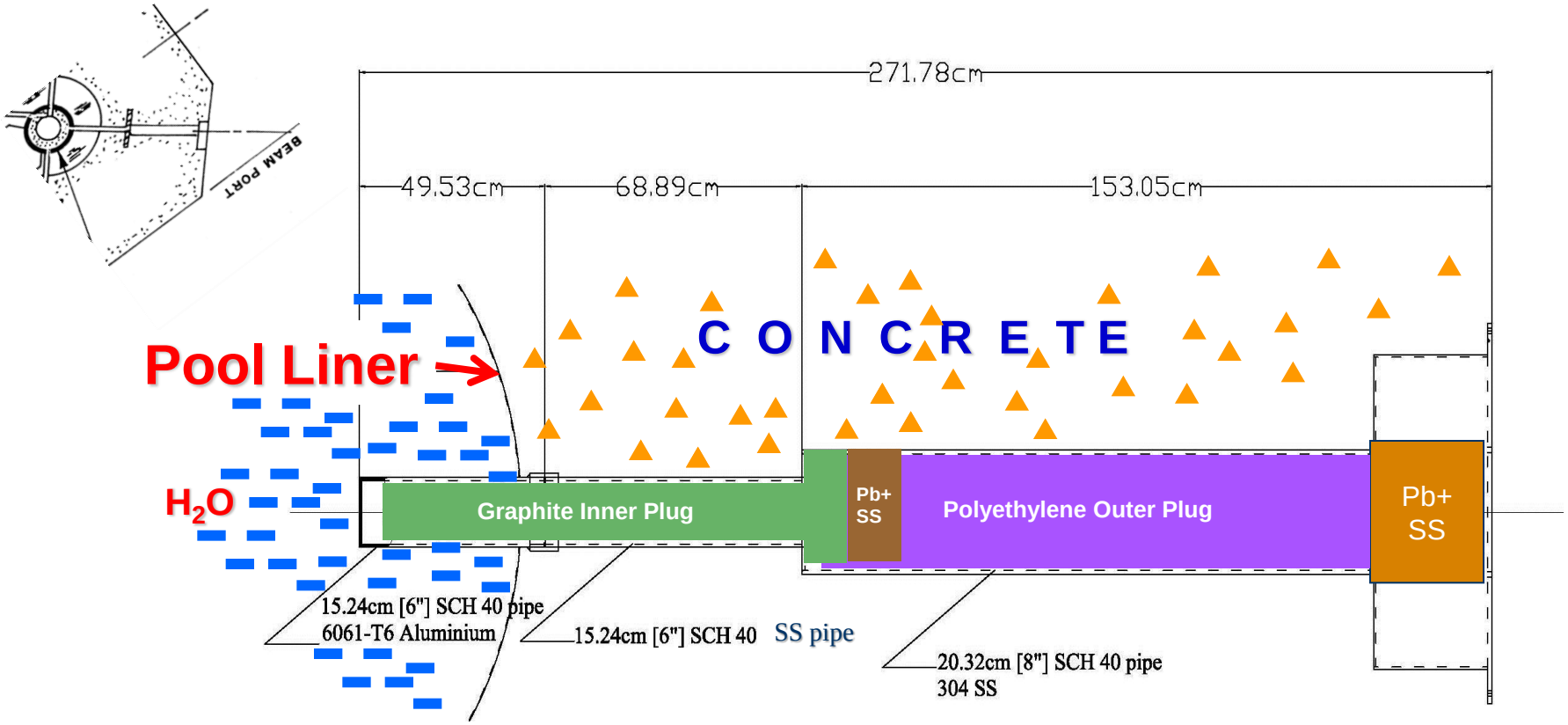
Beam Port Plugs

Beam Port Leakage Problem...



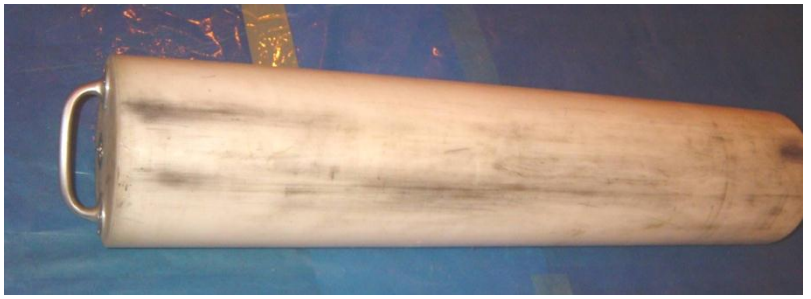
Beam Port Plugs

Leak in the Beam Port…



Beam Port Plugs

Leak in the Beam Port…



(a) Outer Plug (21.8 kg)

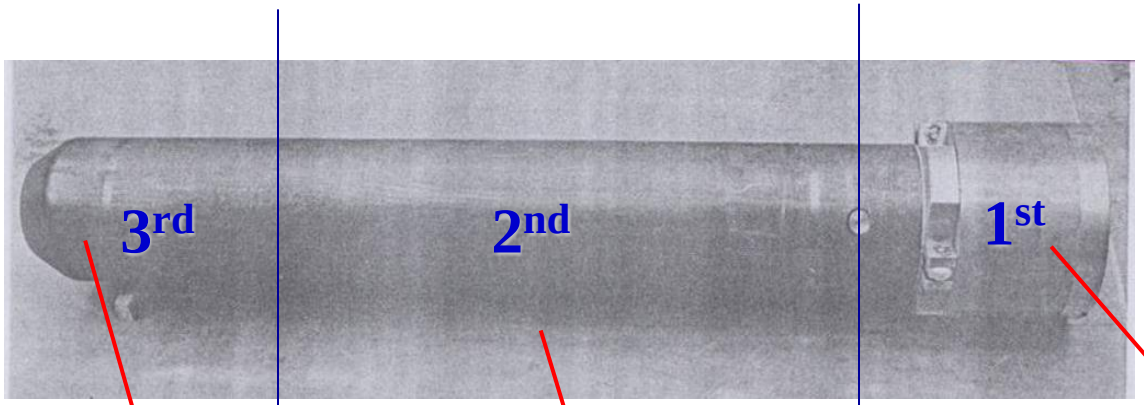
(b) Inner Plug (90.7 kg)

Beam Ports Plugs

Leak in the Beam Port…

Removal of Inner Beam Port Plug

Leak in the Beam Port…



Removal of the 1st part

3rd part

2nd part

1st part

Broken parts of the radial beam port

Leak in the Beam Port…

Removal of the 2nd part

Leak in the Beam Port…

- **Removal of the 33.02cm long 3rd part was quite difficult as it got stuck with the aluminum part of beam port tube very tightly.**

- **The plug was pulled by a mechanical tension application device after installing a rowel bolt on the plug, but it could not be moved.**

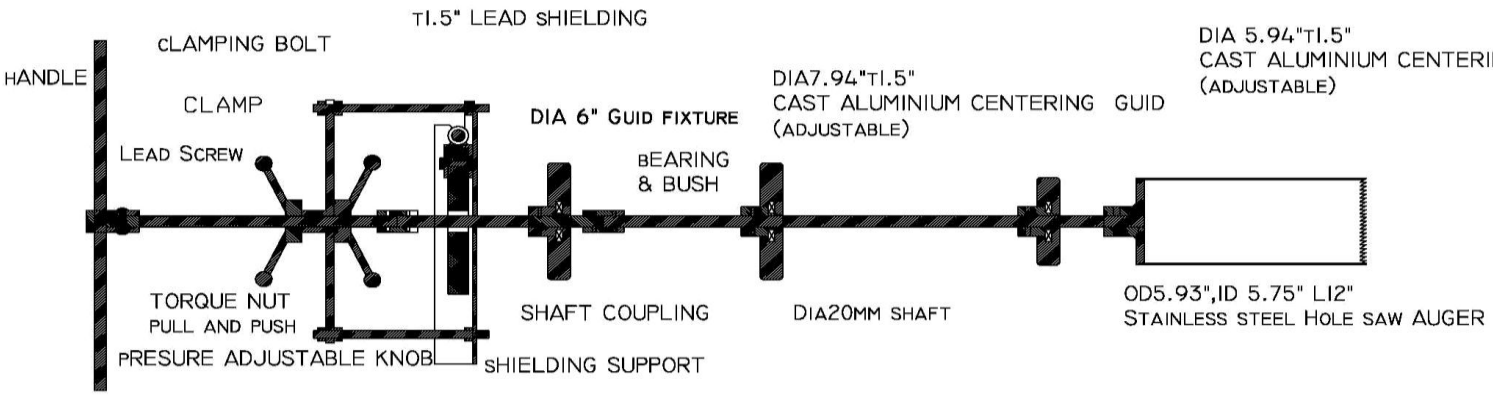
Leak in the Beam Port…

- **Then with the approval Regulatory Authority the graphite plug was trimmed off by using an auger (circular-saw like cutting tool) and then taken out.**

View of the hand driven auger used to trim the graphite plug

Leak in the Beam Port…

The augur and associated fixtures

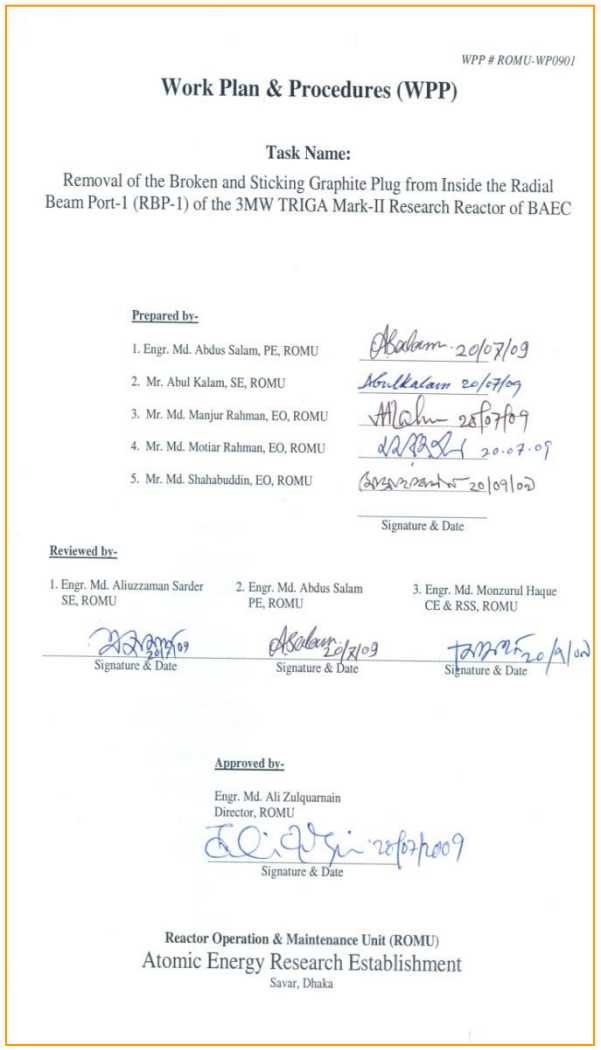


Details of the Auger

Leak in the Beam Port…

- **Before undertaking the work, detailed work plan, emergency response preparedness plan and QA program to be followed for carrying out the removal work were prepared and submitted to the Regulatory Authority.**

Leak in the Beam Port...



WPP # ROMU-WP0901

Work Plan & Procedures (WPP)

Task Name:

Removal of the Broken and Sticking Graphite Plug from Inside the Radial Beam Port-1 (RBP-1) of the 3MW TRIGA Mark-II Research Reactor of BAEC

Prepared by-

1. Engr. Md. Abdus Salam, PE, ROMU
2. Mr. Abul Kalam, SE, ROMU
3. Mr. Md. Manjur Rahman, EO, ROMU
4. Mr. Md. Motiar Rahman, EO, ROMU
5. Mr. Md. Shahabuddin, EO, ROMU

Signature & Date

Reviewed by-

1. Engr. Md. Aliuzzaman Sarder, SE, ROMU
2. Engr. Md. Abdus Salam, PE, ROMU
3. Engr. Md. Monzurul Haque, CE & RSS, ROMU

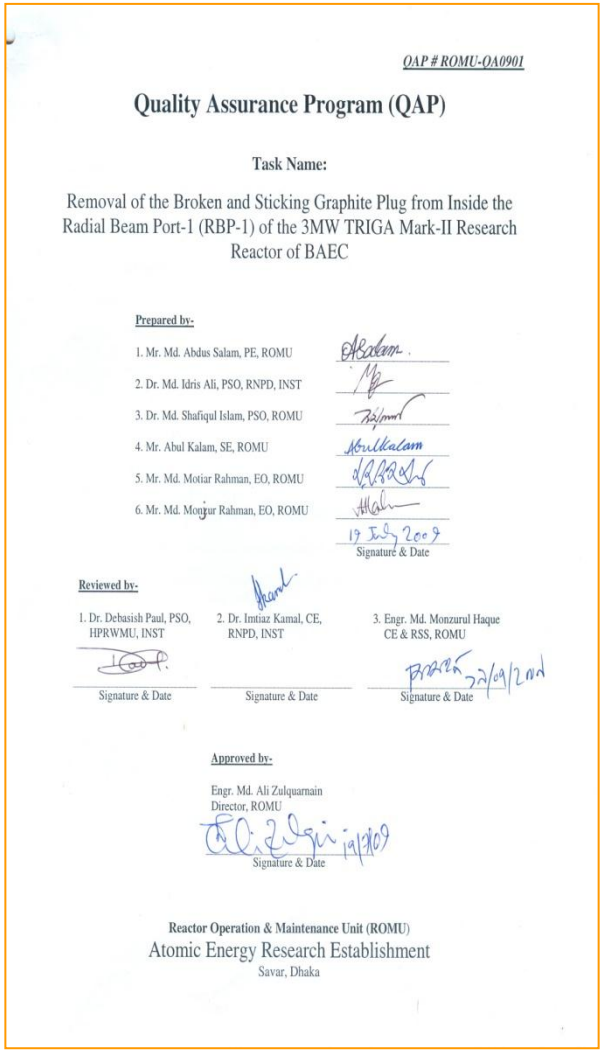
Signature & Date

Approved by-

Engr. Md. Ali Zulquarnain
Director, ROMU

Signature & Date

Reactor Operation & Maintenance Unit (ROMU)
Atomic Energy Research Establishment
Savar, Dhaka



QAP # ROMU-QA0901

Quality Assurance Program (QAP)

Task Name:

Removal of the Broken and Sticking Graphite Plug from Inside the Radial Beam Port-1 (RBP-1) of the 3MW TRIGA Mark-II Research Reactor of BAEC

Prepared by-

1. Mr. Md. Abdus Salam, PE, ROMU
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3. Dr. Md. Shafiqul Islam, PSO, ROMU
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Reviewed by-

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2. Dr. Imtiaz Kamal, CE, RNPD, INST
3. Engr. Md. Monzurul Haque, CE & RSS, ROMU

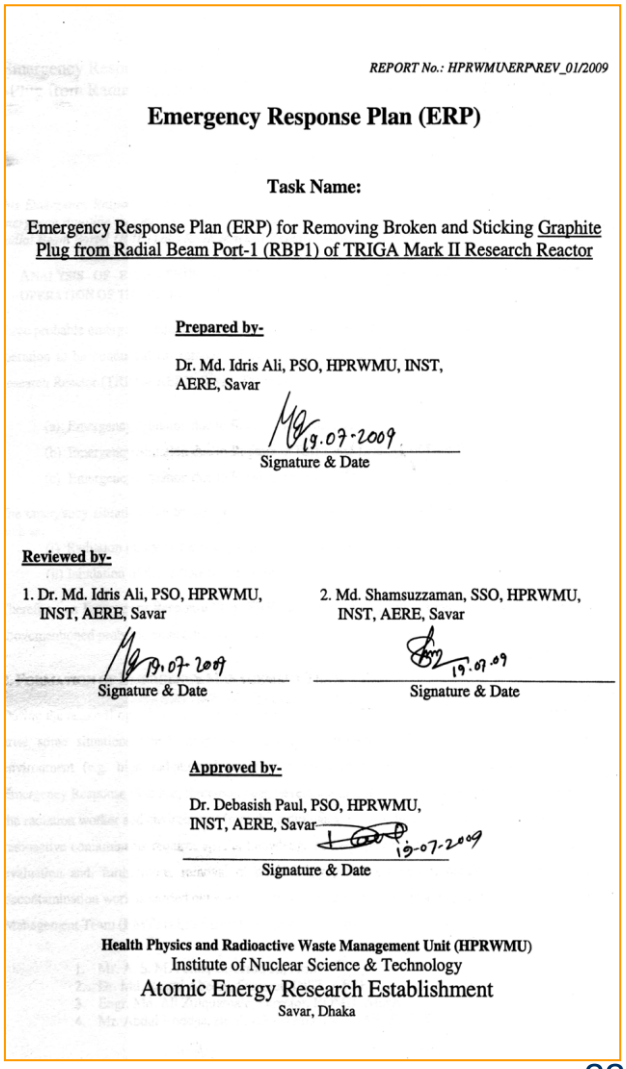
Signature & Date

Approved by-

Engr. Md. Ali Zulquarnain
Director, ROMU

Signature & Date

Reactor Operation & Maintenance Unit (ROMU)
Atomic Energy Research Establishment
Savar, Dhaka



REPORT No.: HPRWMU\ERP\REV_01/2009

Emergency Response Plan (ERP)

Task Name:

Emergency Response Plan (ERP) for Removing Broken and Sticking Graphite Plug from Radial Beam Port-1 (RBP1) of TRIGA Mark II Research Reactor

Prepared by-

Dr. Md. Idris Ali, PSO, HPRWMU, INST, AERE, Savar

Signature & Date

Reviewed by-

1. Dr. Md. Idris Ali, PSO, HPRWMU, INST, AERE, Savar
2. Md. Shamsuzzaman, SSO, HPRWMU, INST, AERE, Savar

Signature & Date

Approved by-

Dr. Debasish Paul, PSO, HPRWMU, INST, AERE, Savar

Signature & Date

Health Physics and Radioactive Waste Management Unit (HPRWMU)
Institute of Nuclear Science & Technology
Atomic Energy Research Establishment
Savar, Dhaka

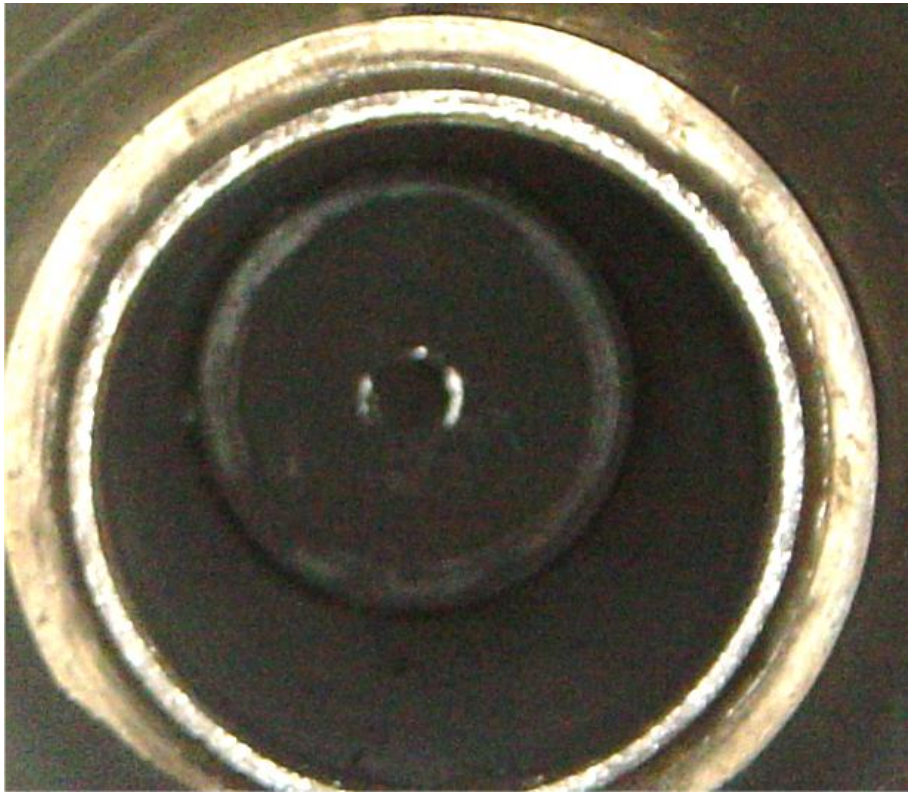
Leak in the Beam Port…

- **While performing the removal operation, extreme care was taken such that the corroded aluminum BP pipe did not get damaged and also that the amount of graphite dust generated could be kept at minimum.**

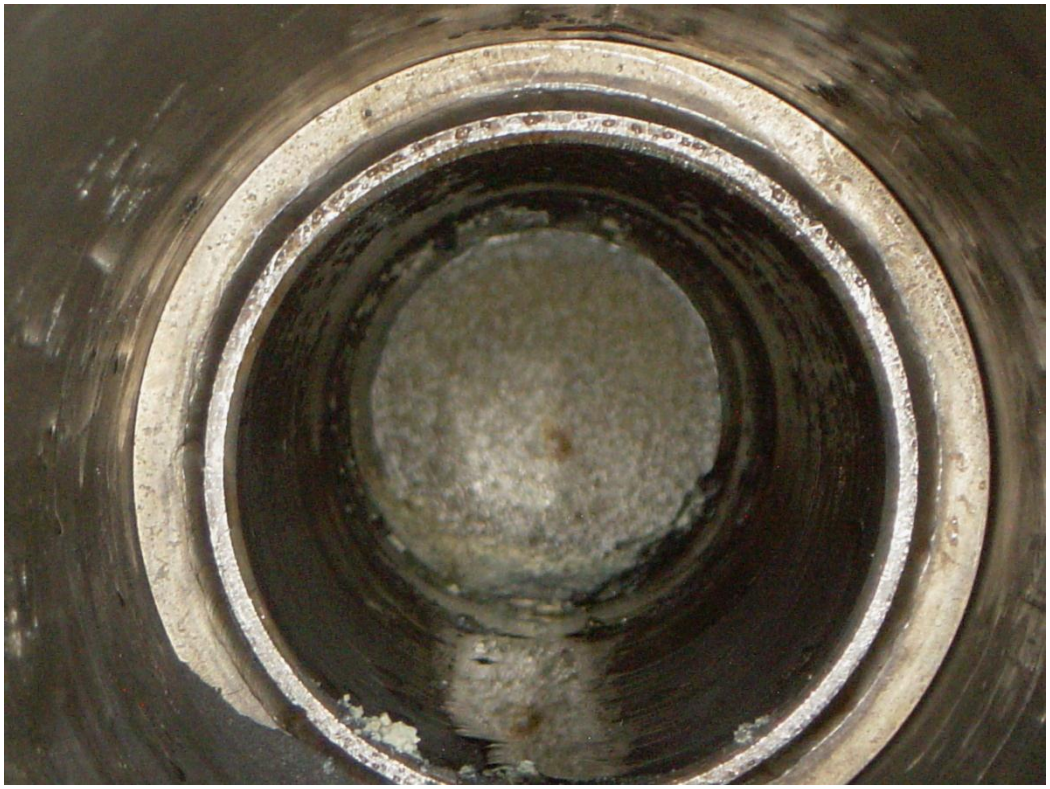
Leak in the Beam Port…

Activities for removal of the 3rd part of the beam port plug

Leak in the Beam Port…



(a) Before removal of the plug

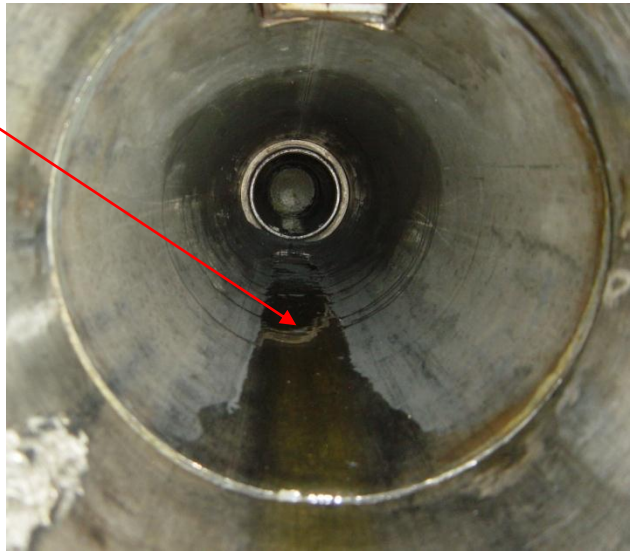


(b) After removal of the plug

Inside Views of the Beam Port

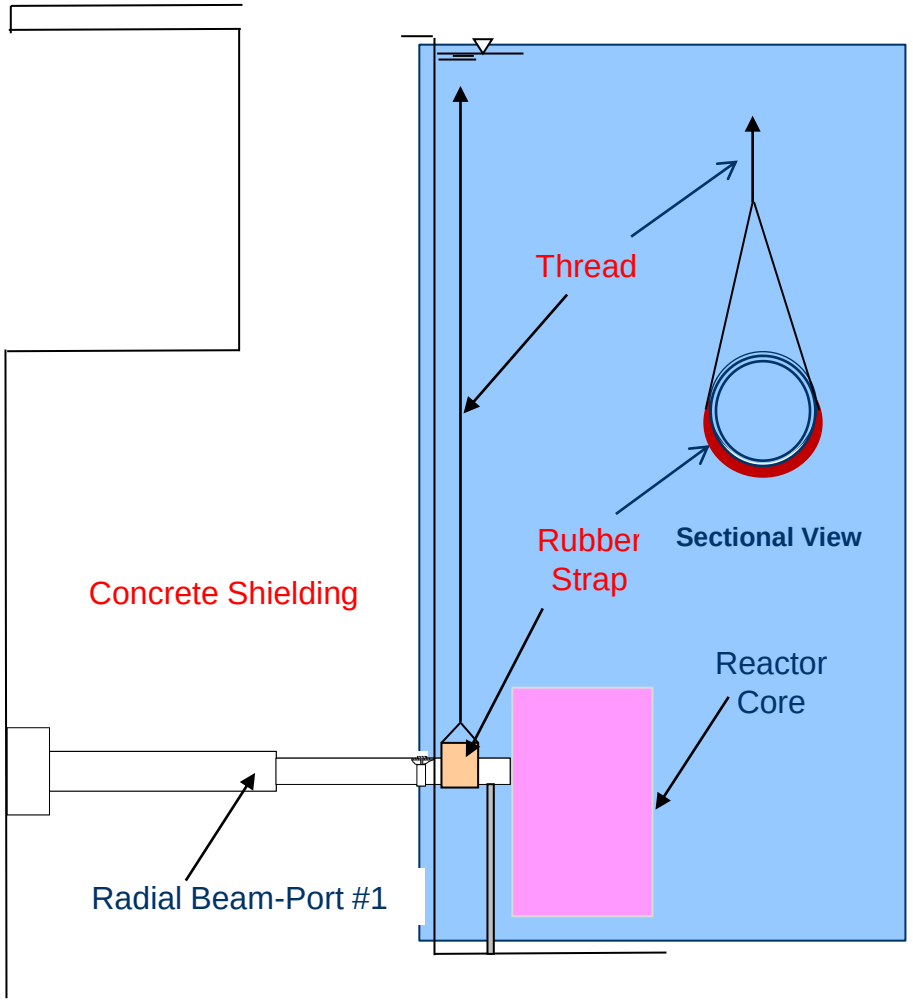
Leak in the Beam Port…

- A couple of days after the stuck out graphite plug had been removed, reactor pool water was found to be leaking through the beam port.



- Leakage of water was stopped temporarily by wrapping a rubber strap around the leaking part of the RBP-1.

Leak in the Beam Port…



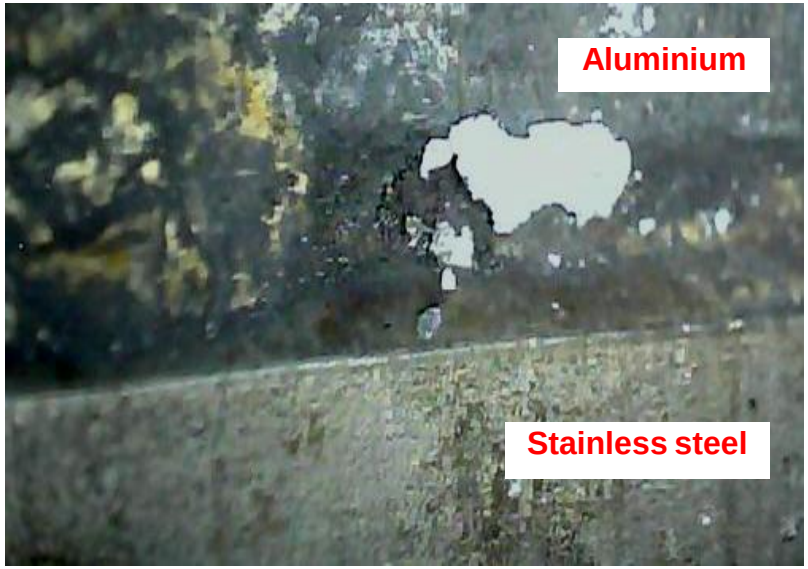
View Showing Installation of the Rubber Strap

Installation of Rubber Strap

Leak in the Beam Port…

Efforts were then made to carry out visual inspection of the beam port using a digital camera and at the same time make a split type encirclement clamp so as to install it around the leaking part of the beam port and solve the water leakage problem.

Leak in the Beam Port…

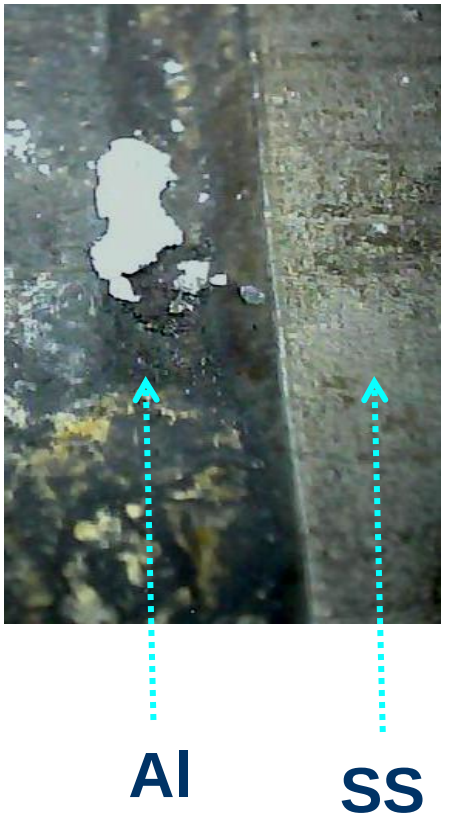


Corrosion at the Al-SS junction

Corrosion Marks Captured by a Digital Camera (web-cam)

Cause Analysis

- The pictures clearly show corrosion damage in the form of metal removal and pits on the inner bottom surface of the aluminium pipe.



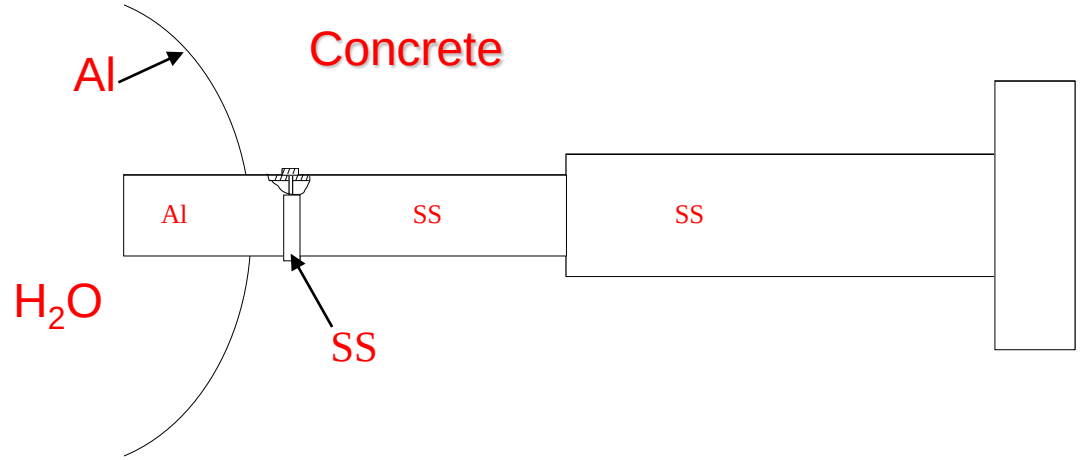
- Brown stains are observed on the surface of the SS pipe, but there does not exists any pit or mark of metal removal.

Cause Analysis…

- **Energy Dispersive X-ray (EDX) analysis of the deposits collected from inside the RBP-1 showed the presence of Oxygen, Carbon, Lead, Silicon and Aluminium.**
- **The friable and porous nature of some of the debris indicate the presence of Hydroxides in it.**

Cause Analysis…

- **The analysis reveled that the damages in terms of corrosion had been initiated at the Al-SS interface where a SS sleeve/ socket had been used to cover the circumferential gap between the SS and Al pipes.**



Causes Analysis…

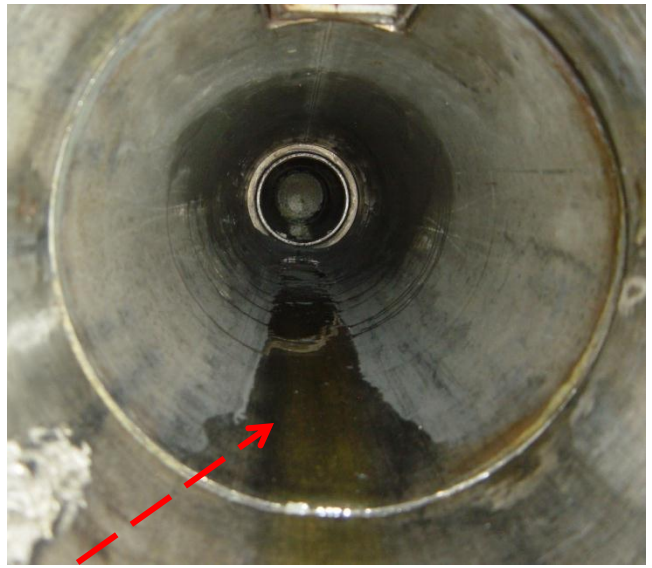
- **The interface with the sleeve/socket around it was not wrapped with sealant during pouring of concrete.**
- **As a result moisture from the surrounding concrete found its way to the gap between the Graphite plug and Aluminium pipe.**

Cause Analysis…

- **Later these moistures initiated the corrosion process onto the Aluminium pipe.**
- **The continual presence of moisture transformed the protective Aluminium Oxide layer into Aluminium Hydroxide, which is porous and cannot prevent air and moisture to seep through it and attack the fresh Aluminium underneath.**

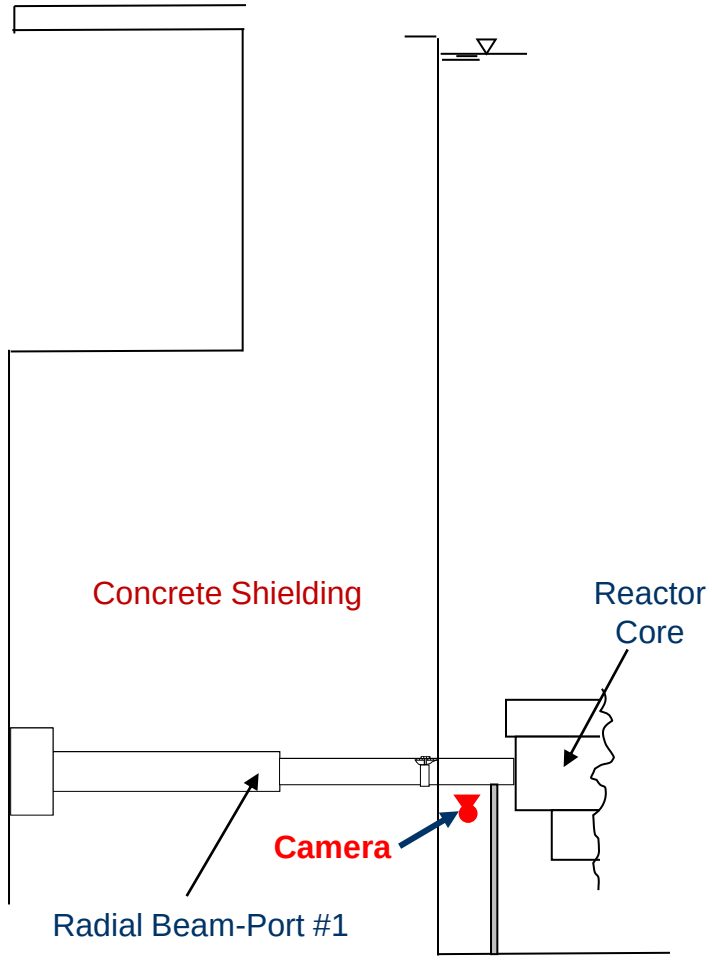
Cause Analysis…

- **The cracks and/or pits resulted as the corrosion went through the inter-granularity of the Aluminium pipe and allowed water from the reactor tank to sip through and drain out of the beam port.**



Repair of the Beam Port

Bottom Part of the RBP-1 as Viewed by the Underwater Camera Supplied by the IAEA

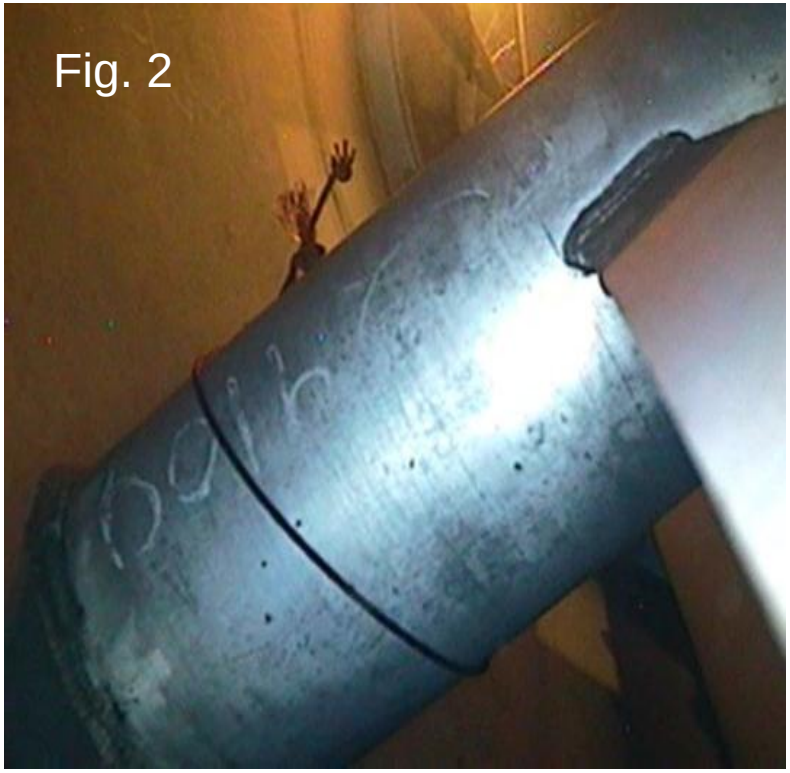


View Showing Arrangement of the Beam Port & the Reactor Core

Repair of the Beam Port…

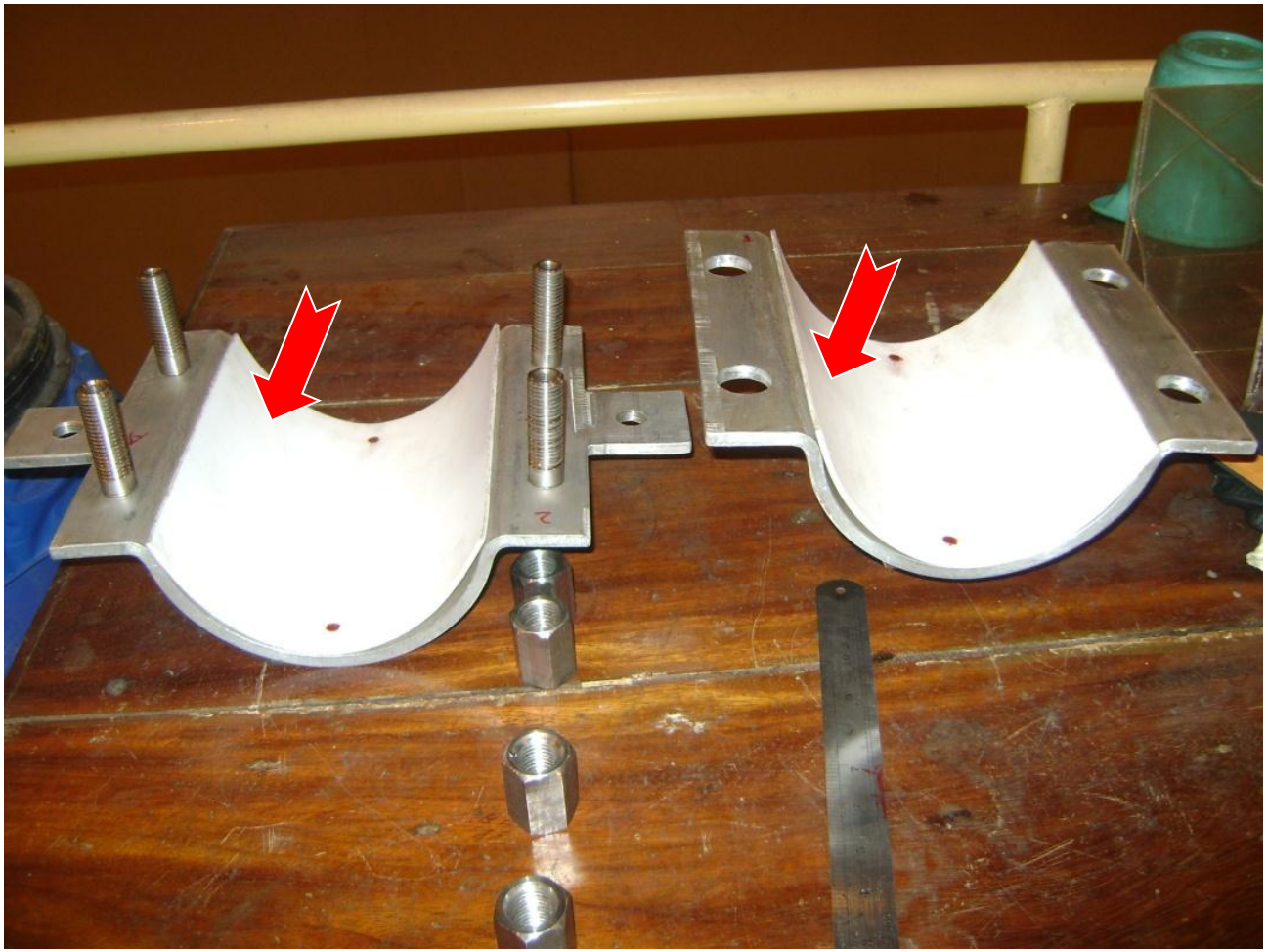
- Inspection results showed that the leaks were located at distances between 15.24cm to 35.56cm from the dead end of the RBP-1.
- As such it was decided to install an Al-clam with Si-rubber lining around the leaking area of the beam port tube.

Repair of the Beam Port…



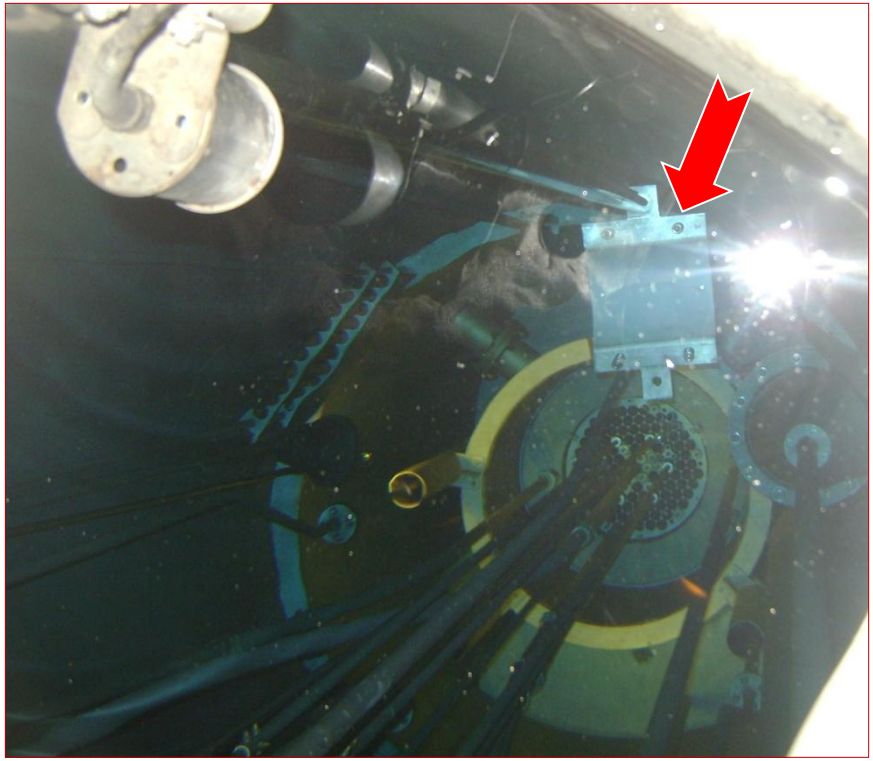
View of the Split Type Encirclement Clamp (Fig.1) that has been installed around the leaking beam port tube (Fig.2) located in the reactor pool water at a depth of about 8m

Repair of the Beam Port…



The Encirclement Clam fitted with Silicon-Rubber lining

Repair of the Beam Port…



Installation of the lower part of the Encirclement Clamp

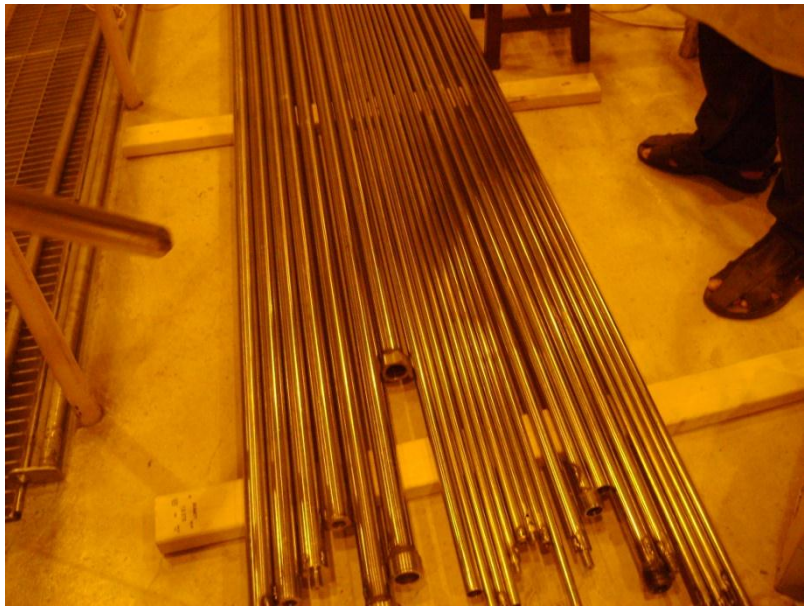
Installation of the upper part of the Encirclement Clamp

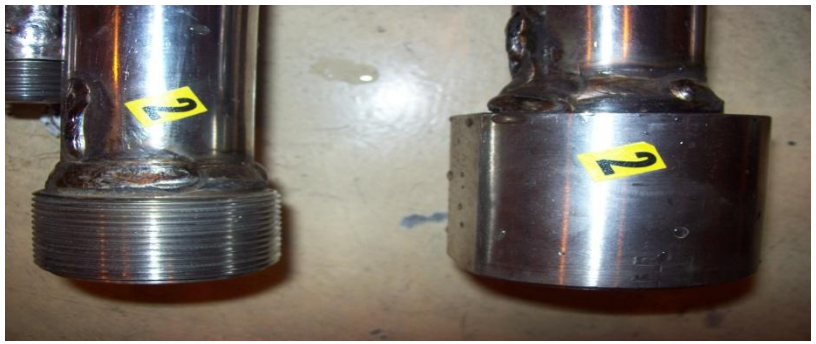
Repair of the Beam Port…



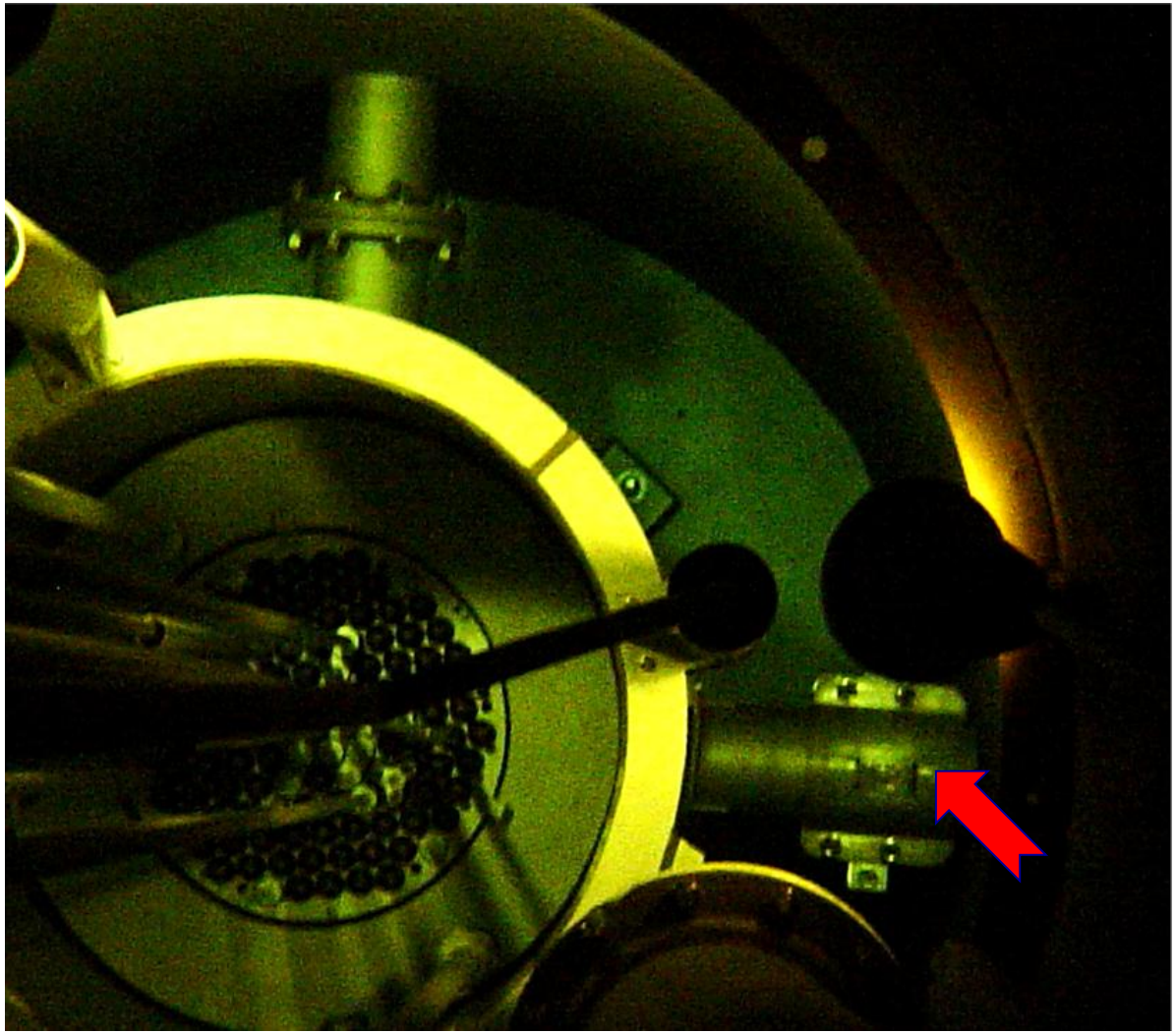



Repair of the Beam Port…





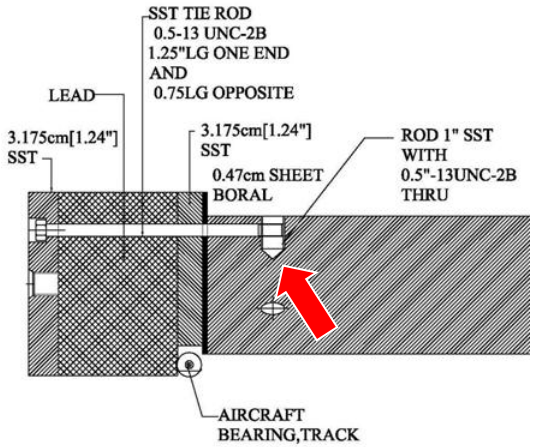
Repair of the Beam Port…



The repair work was completed after successful installation of the Encirclement Clamp around the Beam Port as shown here.

Concluding Remarks

- A minor lapse during the installation work initiated the leakage problem of the BAEC RR.
- All 4 Graphite plugs got broken at the area where nuts were inserted. The design made the plugs very fragile.
- Maintenance manual did not mention any requirement for routine inspection of the beam ports (BPs) & plugs.



Concluding Remarks…

- **The matter of routine inspection of the BPs as well as that of the BP plugs did not come to the notice of any safety reviewers including the IAEA INSARR mission of 1996.**
- **Absence of routine inspection of the BPs was a factor that significantly aggravated the corrosion problem.**

Concluding Remarks…

- **The BP leakage problem of the BAEC research reactor was an issue that could lead to a situation very close to a LOCA.**

- **The matter was, therefore, handled very carefully taking all measures so that such a thing could be prevented from happening.**

Concluding Remarks…

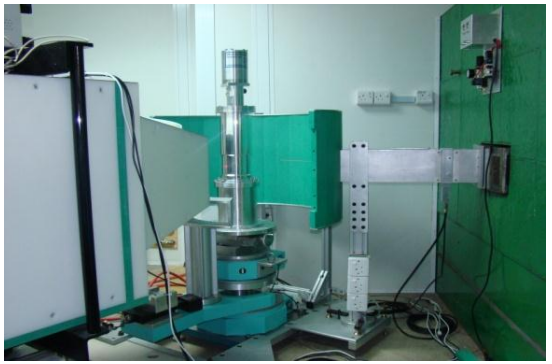
- **Assistances of agencies outside BAEC such as, BUET (Bangladesh University of Engineering & Technology), BITAC (Bangladesh Industrial Technical Assistance Centre), etc. were taken for solving the problem.**
- **Particularly, the underwater camera supplied by the IAEA was found to be very useful.**

Concluding Remarks…

- **It is understood that the silicone rubber lining of the encirclement clamp may get damaged because of neutron irradiation.**

Concluding Remarks…

- **Therefore, while designing the clamp, provisions were kept such that it can be dismantled and reinstalled again with the damaged lining replaced by a new one.**



Concluding Remarks…

- **At the end I would like to express my deep sense of thankfulness to the organizer of the conference for giving me an opportunity to come over here in Rabat and share our experience on the Beam Port leakage problem as well its solution with the RR the experts coming from different parts of the world.**

The END