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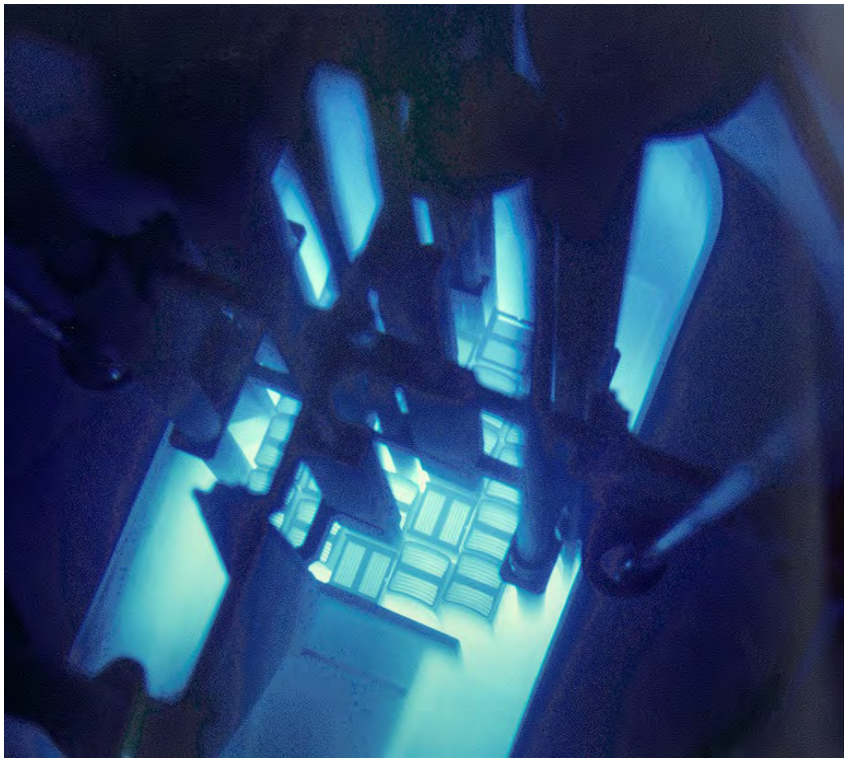
From Fission to Fuel Gone



Presentation to the Institute of Physics - 20th November 2014

Trevor Chambers, Head of Reactor Centre, Imperial College London

Alternate Title

The secret diary of the CONSORT reactor aged $49^{3}/_{4}$

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1961 to 2010 - A Brief History

- In 1961 UK Government announced programme to provide three low power reactors to be available to universities
- Consort Reactor designed jointly by Mechanical Engineering Department of IC and GEC Ltd – commenced in 1962
- Consort commenced operation in April 1965
- Office building containing radiochemistry labs adjoining reactor hall completed in 1971
- Used for over 40 years for research and teaching in reactor physics, reactor engineering, neutron physics, radiochemistry, activation analysis and radioisotope production

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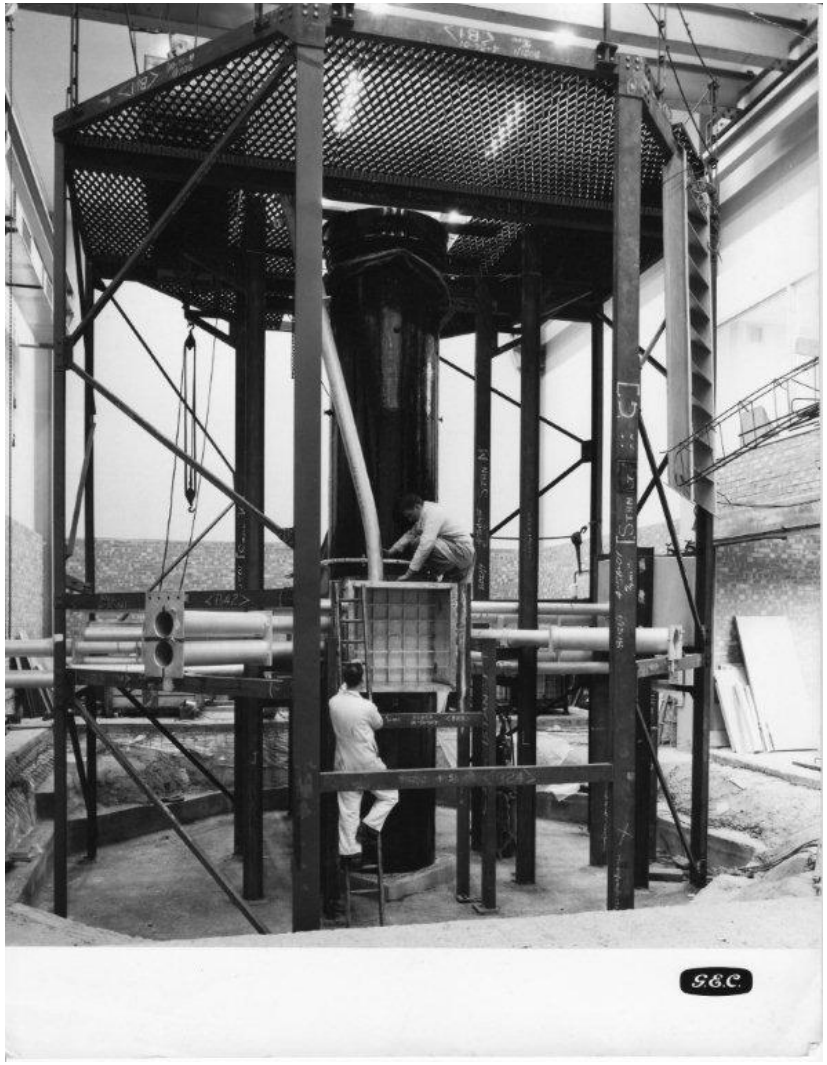
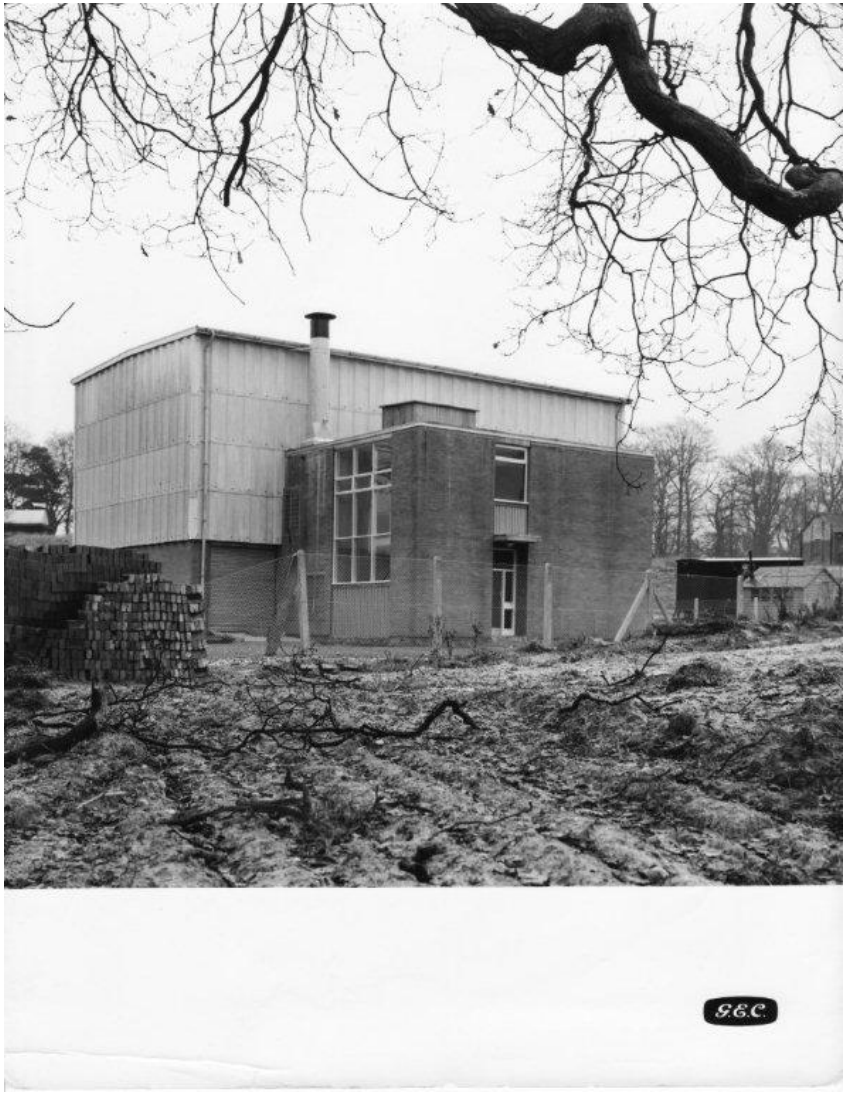
Construction Phase 1963-1965 (1)





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Construction Phase 1963-1965 (2)

Tank shield doors in place

Completion of the vessel

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Official Opening June 1965

PLATFORM PARTY 22/06/65 (L to R)
Sir Harold Melville
Sir Douglas Logan (Principal University of London)
Lord Sherfield (Chairman)
Sir Thomas Creed (Vice Chancellor)
Sir Patrick Linstead (Rector)
Sir Owen Saunders (Pro Rector)
Professor Richards

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1965 - 2012

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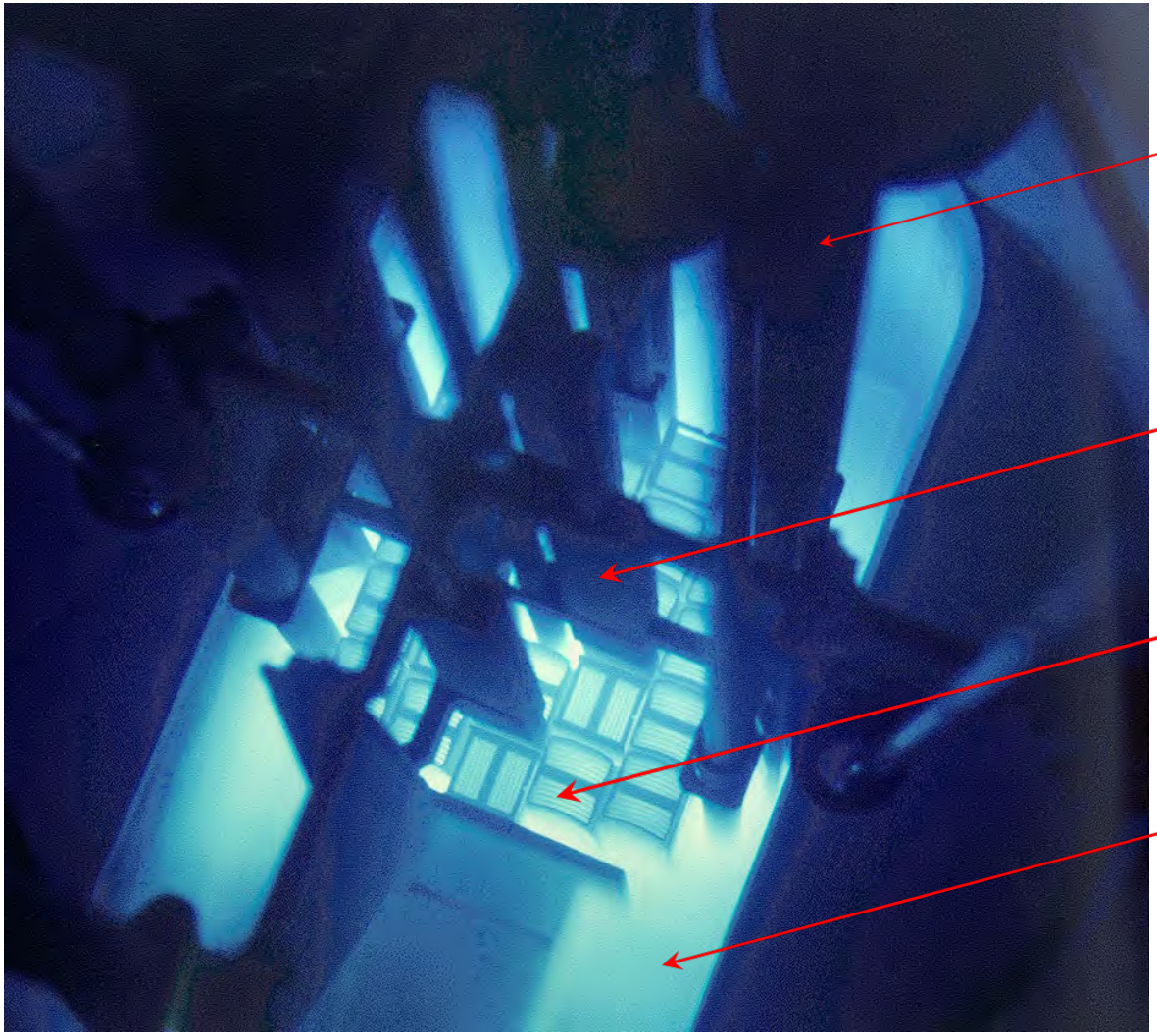
1965 – 2012 CONSORT Core



Irradiation Tube
(8 in total)

Control Rod
(4 in total)

Fuel Assemblies
(24 off U/Al alloy)

Light Water
(moderator)

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1968 to 2012

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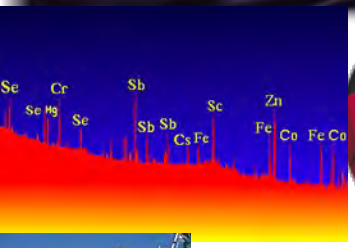
1965 – 2012 Applications

Teaching
& Training

Calibration facilities
for neutron detectors



Isotopes & sources

Trace element analysis for environmental
and waste management

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2011 - Key Decision Making Timescales

- IC Council approved strategy for expeditious decommissioning of CONSORT on 13th May 2011

- Detailed Lifetime Plan produced detailing all tasks, timescales and costs to achieve complete removal of Reactor Centre

- Engagement with DECC and regulators to achieve early defuel

- Continued operations until December 2012 for Training, and Commercial opportunities whilst defueling hardware was produced and safety case approved

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2011 - Decommissioning Management

Key decision

- Imperial College Reactor Centre to manage all decommissioning and retain the Nuclear Site Licence
- Buy in special purpose support for work packages for which the Reactor Centre does not have the skills or resources eg manufacture and installation of defueling equipment
- Reactor Centre staff will carry out the hands on work where possible supplemented by contract support if ICRC doesn't have the skills or resources
- A number of discreet packages of work will be contracted out throughout the decommissioning project

Decommissioning - The First Step - Defuel

For commercial power reactors this is usually part of normal operations

For CONSORT this represented a significant change from normal practise, since re-fuelling was not a standard operation

Defuel posed a number of specific challenges

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Typical Fuel element (Mk 3 16 Plate)

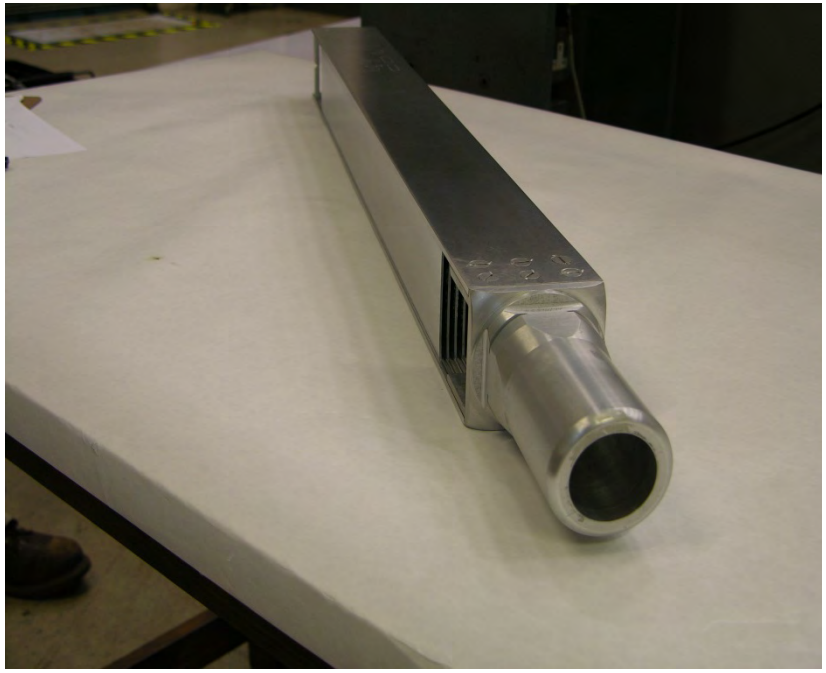
Approximately 915mm long

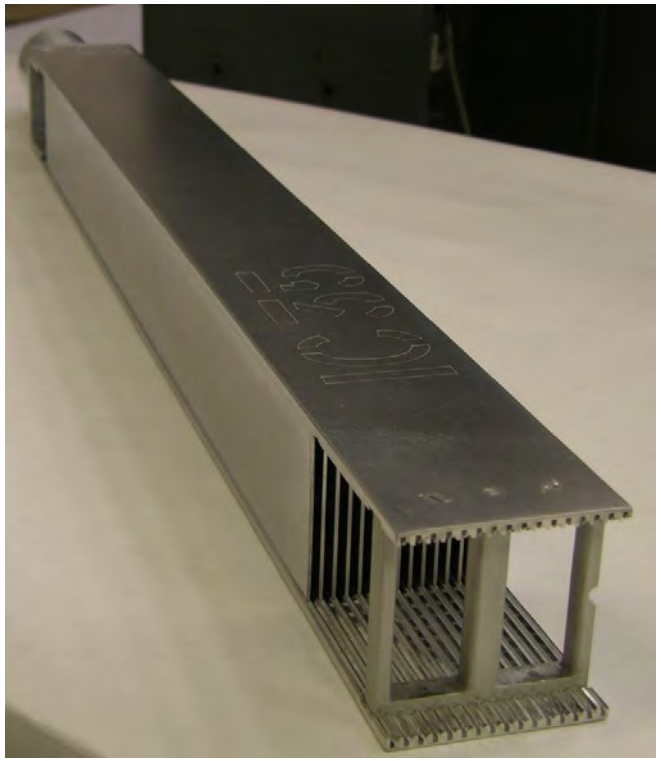
Approximately 75mm square

Aluminium cladding

Aluminium/Uranium matrix

Estimated maximum dose rate 75 mSv/h at 1m





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Defuel Challenges – Reactor Hall Crane

Non-nuclear lift crane

5 Ton SWL

Low lift height above reactor top – approximately 1.7m

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Defuel Challenges – No Defuel Equipment!

Unirradiated fuel had gone in by hand…

But it was definitely coming out remotely!

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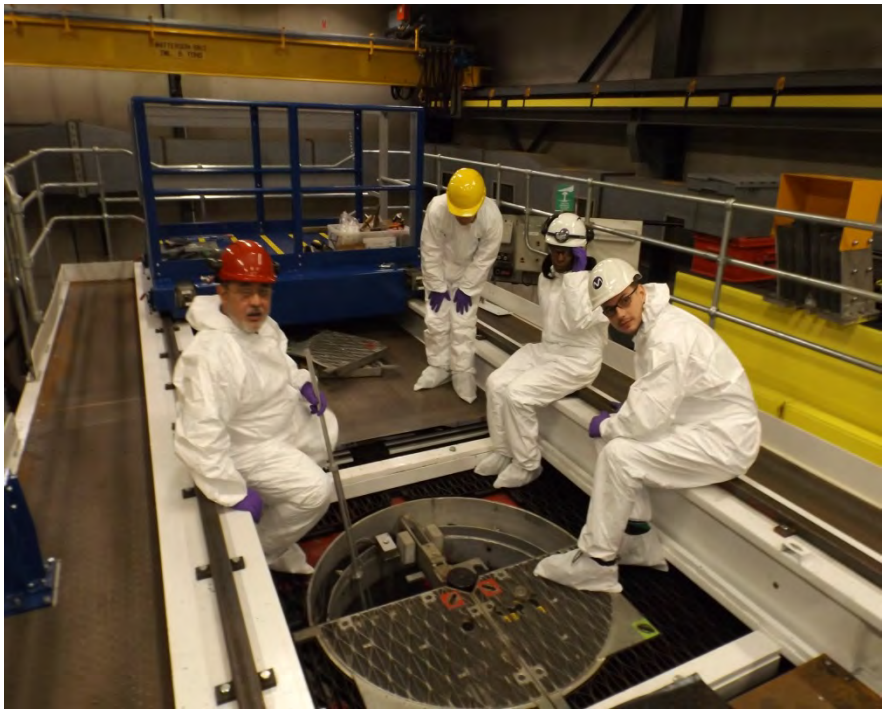
Defuel Challenges – Need for Shielded Fuel Transfer

No fuel flask available to withdraw fuel at ICRC

No shielded transfer facilities installed



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Defuel Challenges – Selecting a suitable Transport Cask

Preference to transfer all fuel elements in one shipment

- More efficient
- Fewer security implications

Power reactor fuel flask unsuitable due to size and weight

Very limited number of suitable flasks available, particularly in UK

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Defuel Challenges – Limited Loading Bay Arrangement

Low headroom

5 Ton non nuclear lift crane

Asbestos cladding surround

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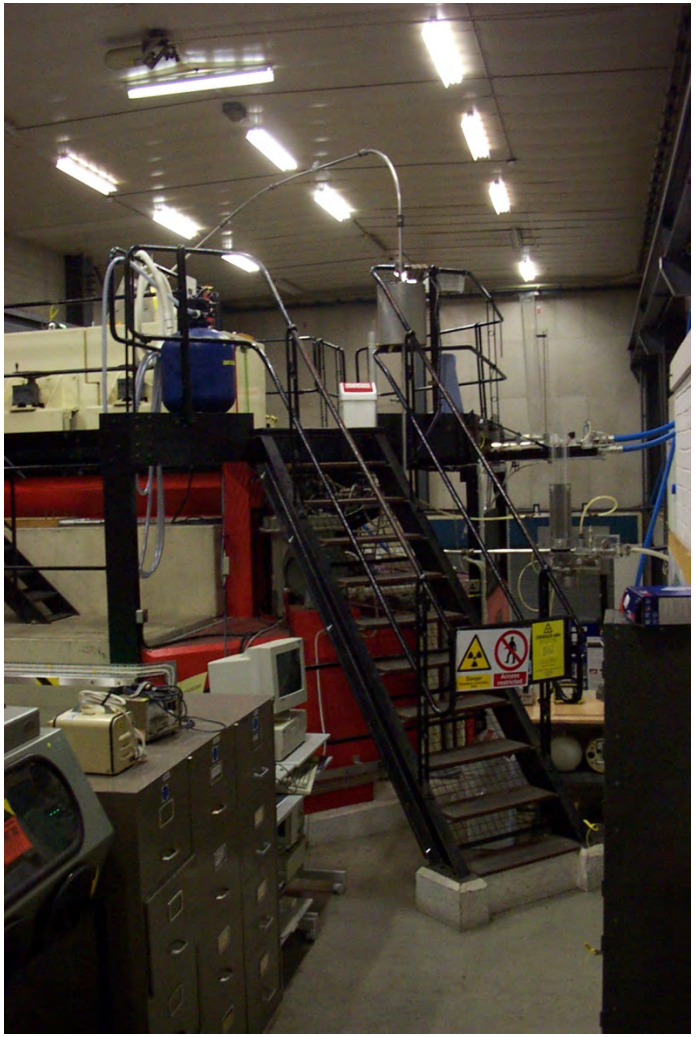
Defuel Challenges – Low Ceiling Headroom

Approximately only 2.3m headroom above reactor top



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Defuel Challenges – Safety Case

The existing safety case covered operation of the CONSORT reactor

Defueling was not covered by the existing safety case

A new safety case was required to be produced and approved by the regulator

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Early considerations for solutions to challenges – How to transport the fuel?

Trawl of certified flasks available in the UK revealed no obvious suitable transport flask for ICRC fuel

Areva MTR fuel transport cask

- Modern standards stainless steel/lead transport cask
- Top loading but without gamma gate
- Would enable transport of all fuel in one shipment
- Could be received by Sellafield

Drawbacks!

- Requirement to devise shielded loading into cask
- Not approved for ICRC fuel
- No approval certificate for use on UK roads

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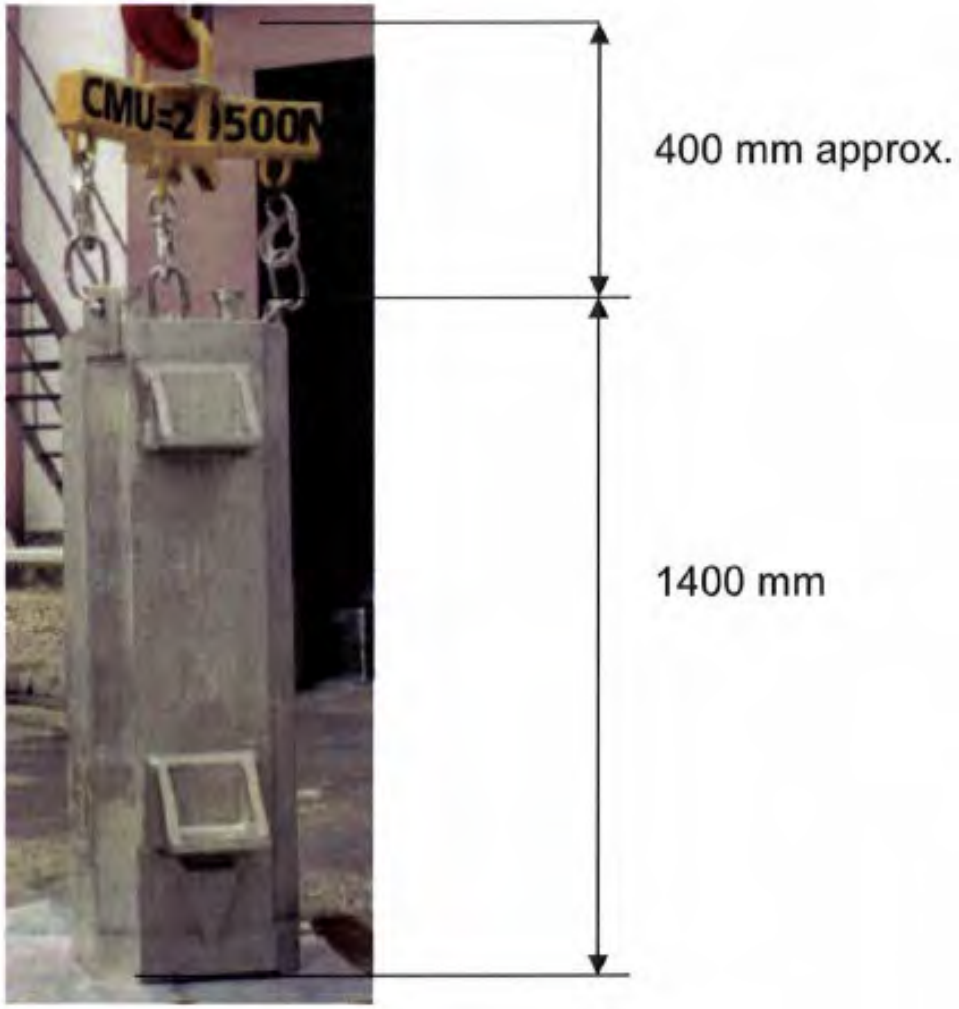
Early considerations for solutions to challenges – How to transport fuel from core to transport cask?

Areva transfer flask

- Bottom loading gamma gated flask
- Enables shielded transfer from core to flask utilizing core water moderator and gamma gate as shielding
- Cavity size is suitable for CONSORT fuel
- Flask shielding is adequate for CONSORT fuel



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Early considerations for solutions to challenges – How to ensure shielded transfer of fuel into transport flask?

Areva Top Hat

- Enables shielded transfer from flask to transport cask using water filled top hat bolted/sealed to flask

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Conclusions for shielded transfer and transport of fuel

The Areva TN-MTR cask is suitable for transporting all fuel elements in one shipment

The Areva TN-MTR cask will require a safety case for use with CONSORT fuel

The Areva TN-MTR cask will require approval for use on UK roads

The Areva transfer flask is suitable for CONSORT fuel, one element per transfer

The Areva top hat will enable shielded loading of the transport cask from the transfer flask

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Early considerations for solutions to challenges – How to move the transfer flask from core to transport cask?

Use Crane?

Upgrade crane for nuclear lifts

- expensive and time consuming
- physically difficult with restricted headroom
- would require operation of shielded flask whilst suspended on crane

Replace crane with new nuclear lift crane

- expensive
- probably require lifting through Reactor Hall roof
- would also require operation of shielded flask whilst suspended on crane

Neither option particularly appealing!

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Early considerations for solutions to challenges – How to move the transfer cask into Reactor Hall?

Move cask on road vehicle?

Raise headroom of loading bay door to allow transport cask on road trailer to pass through doorway

- Would require asbestos removal and exterior wall reconstruction
- Risk for vehicle pneumatic tyre deflation during posting of fuel to cask
- Less secure since fuel is unloaded into cask on road vehicle

Move cask on new special purpose vehicle?

Provide special purpose low loader trolley to transfer cask through existing doorway

- Use large mobile crane to remove from road vehicle and place on low loader trolley

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2011 - Concept Solution

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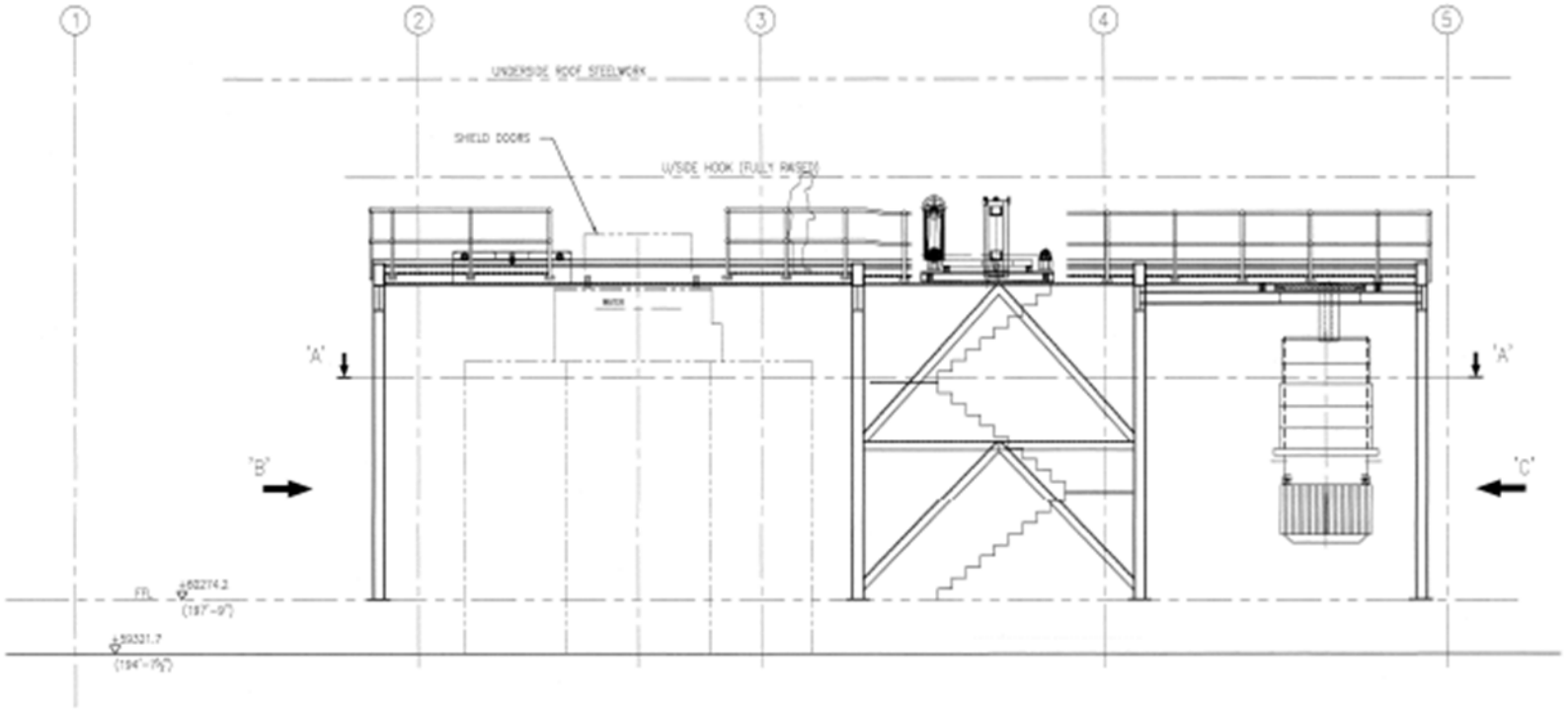
Flaskway

Remove the requirement to lift transfer flask with crane by providing elevated flaskway



Flaskway Trolley

Transfer flask mounted on flaskway trolley to carry fuel between core and transport cask along flaskway

Trolley to provide indexing arrangement to enable access to all fuel elements

Trolley to provide indexing arrangement to enable all fuel elements to be lowered into correct pocket in transport cask

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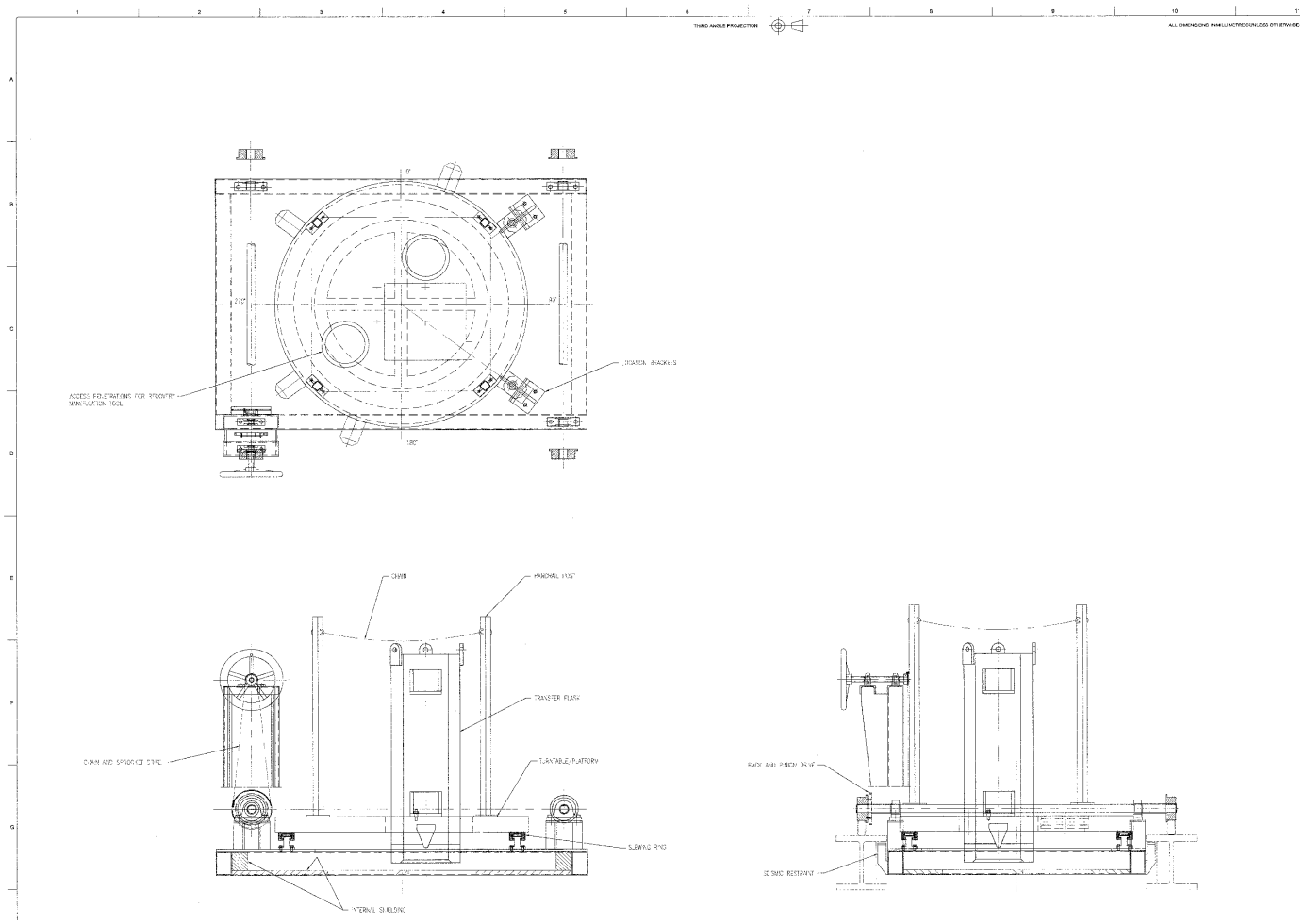
Flaskway Trolley



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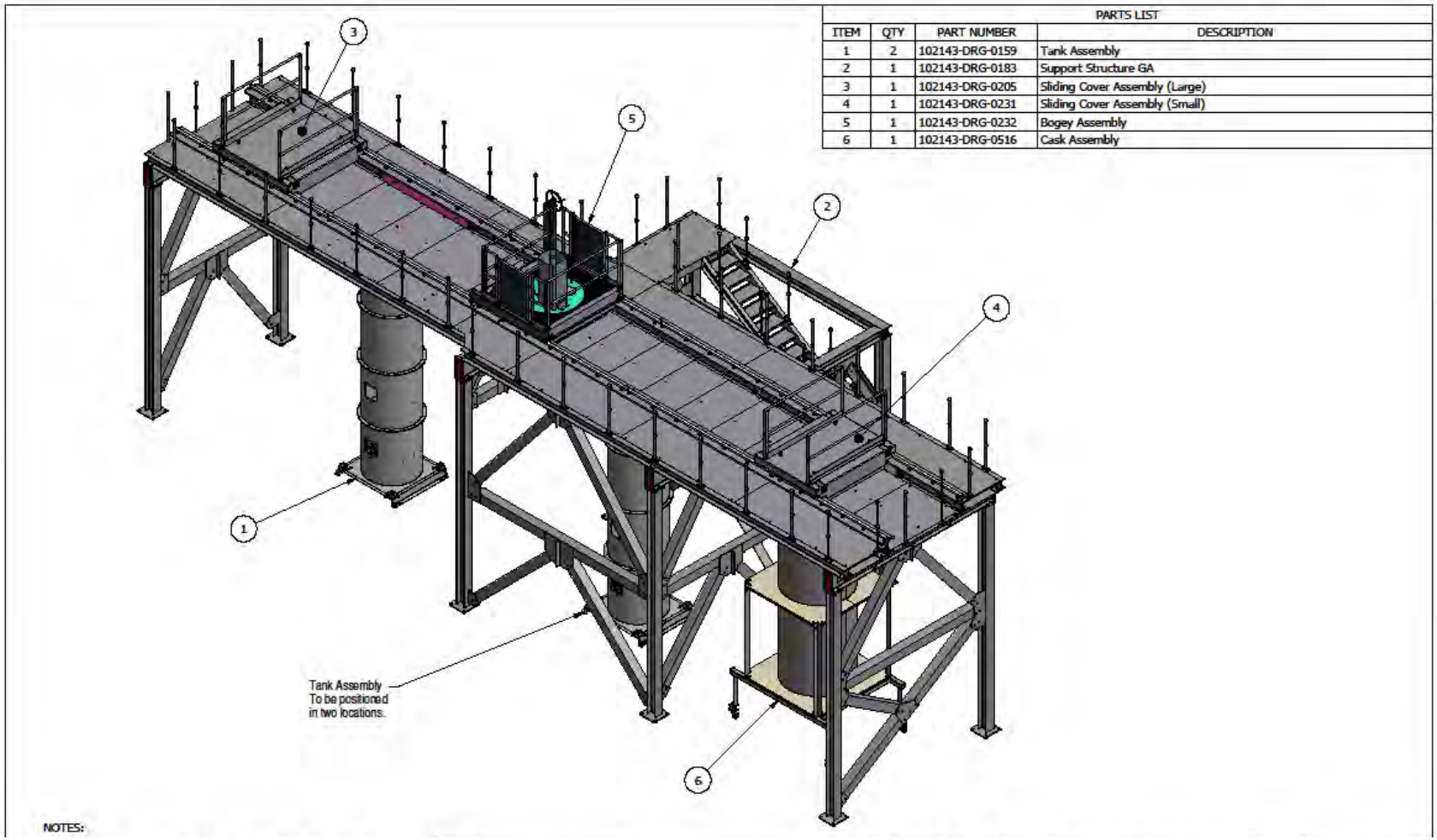
Flaskway and Trolley Assembly



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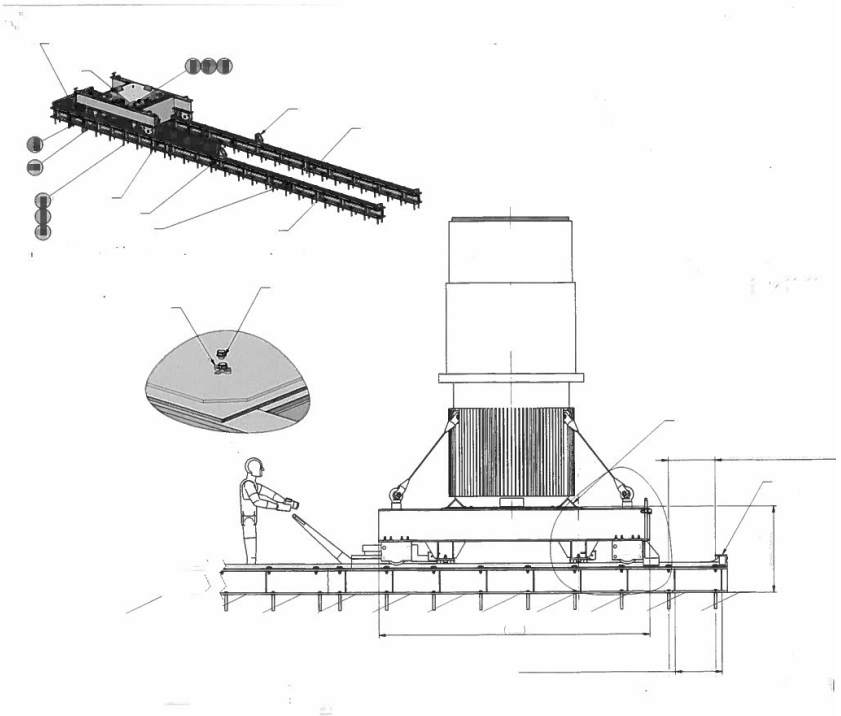
Cask Bogie

Transport cask to be removed from transport vehicle by mobile crane outside Reactor Hall and carried into RH by new cask bogie

Cask bogie to run on new rails to enable accurate alignment with transfer flask on flaskway



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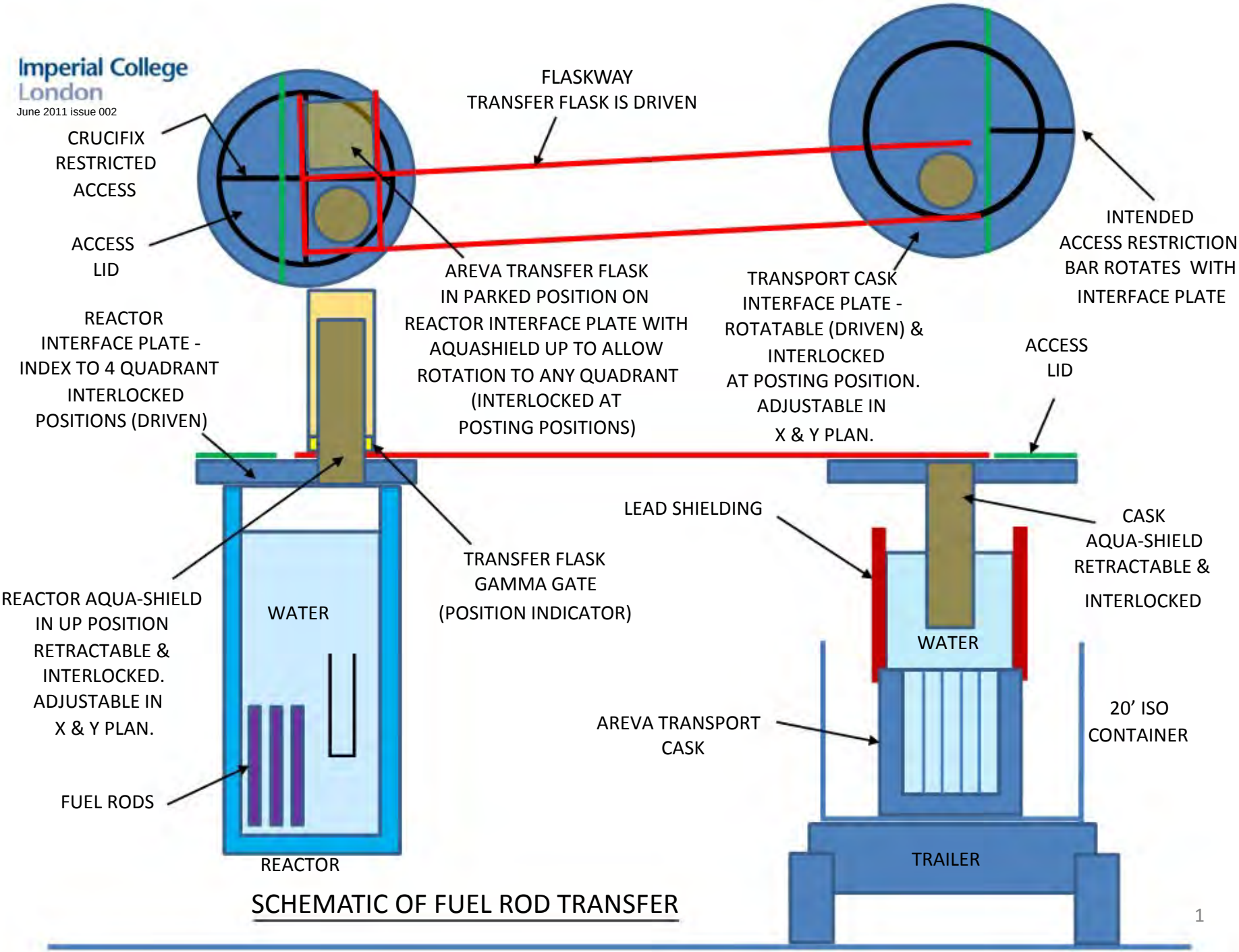
June 2011 issue 002



SCHEMATIC OF FUEL ROD TRANSFER

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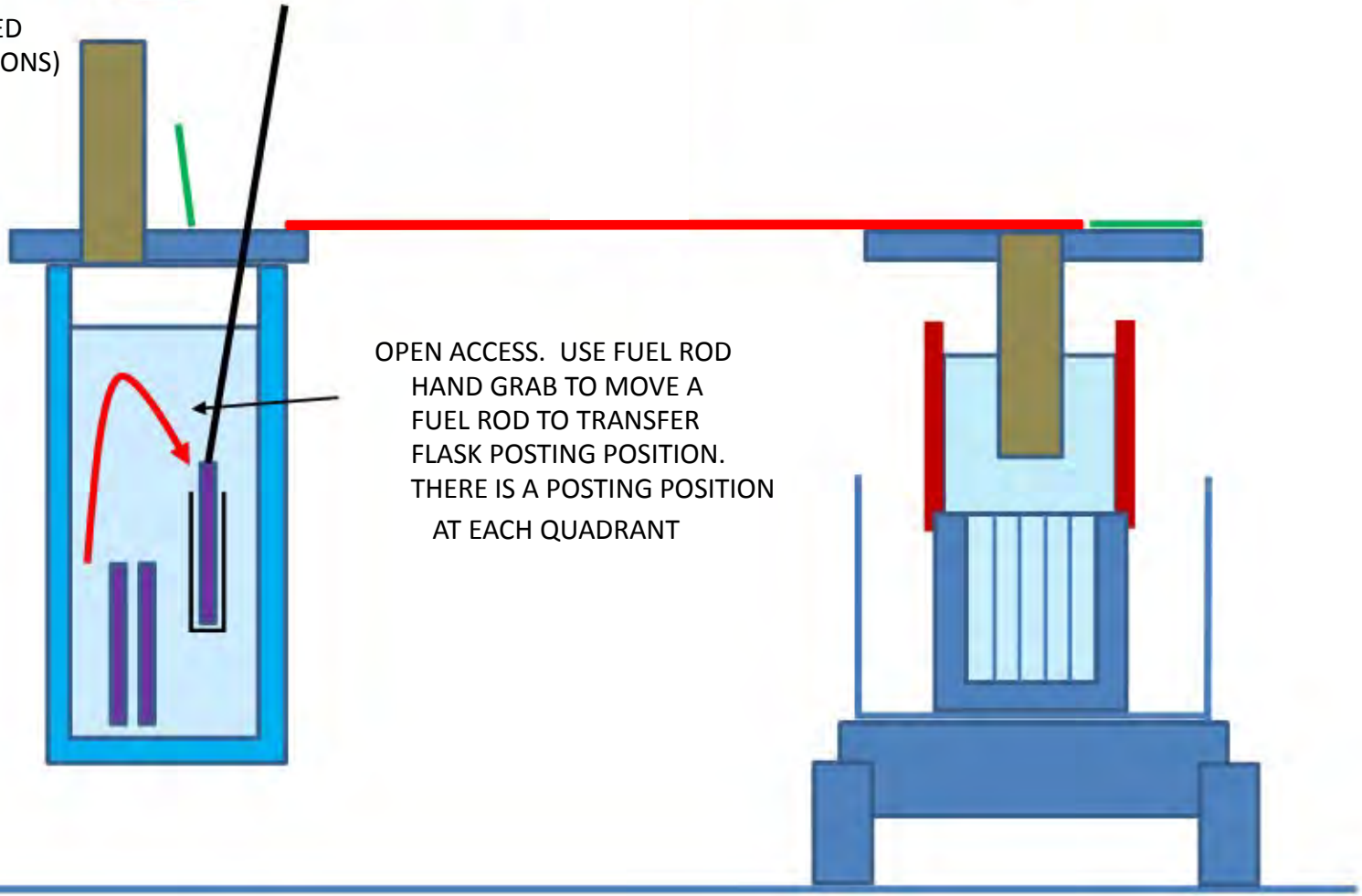
June 2011 issue 002

ROTATE INTERFACE PLATE TO ALLOW ACCESS TO FUEL RODS BEING TRANSFERED (4 QUADRANT POSITIONS)



OPEN ACCESS. USE FUEL ROD HAND GRAB TO MOVE A FUEL ROD TO TRANSFER FLASK POSTING POSITION. THERE IS A POSTING POSITION AT EACH QUADRANT

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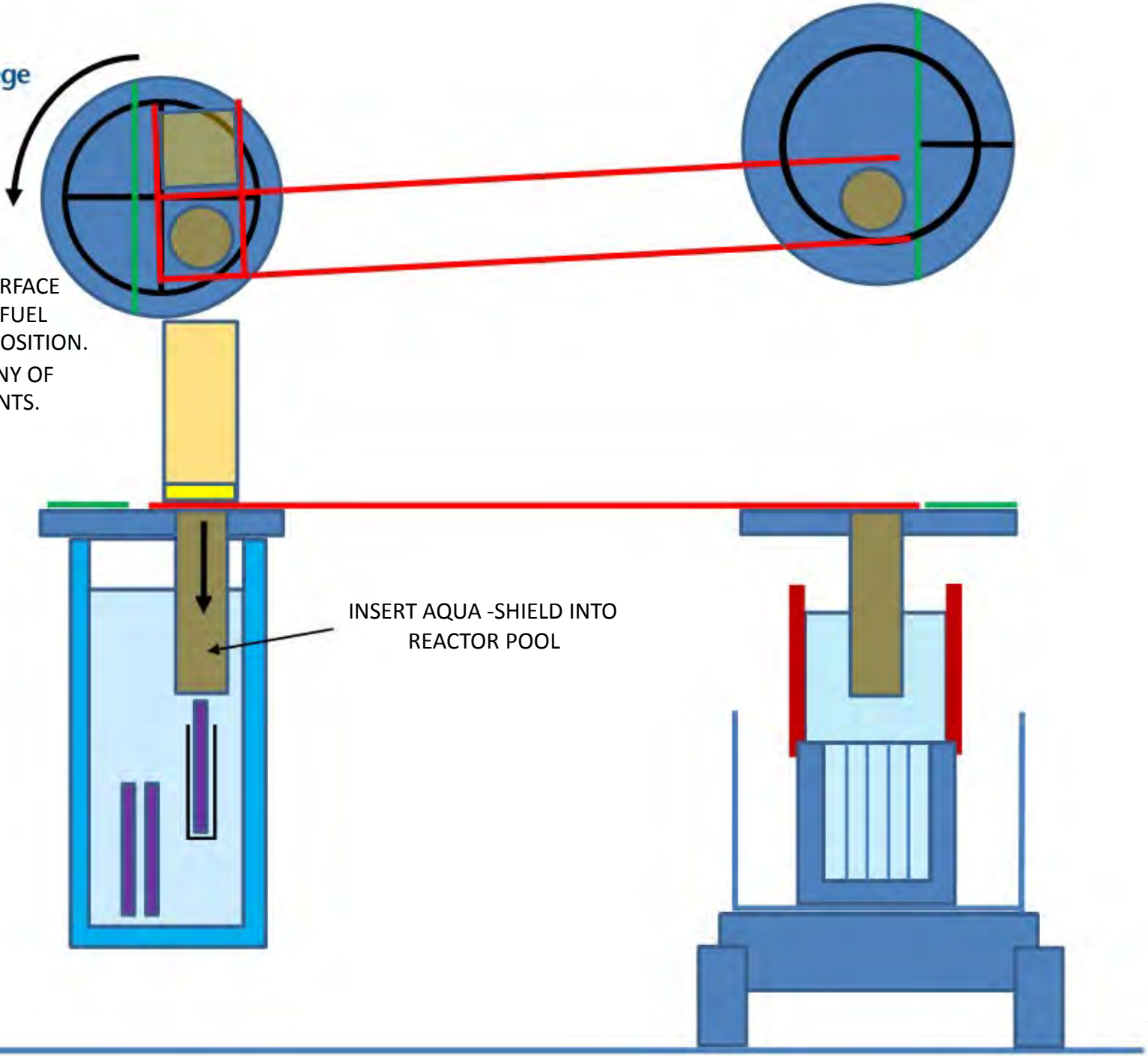
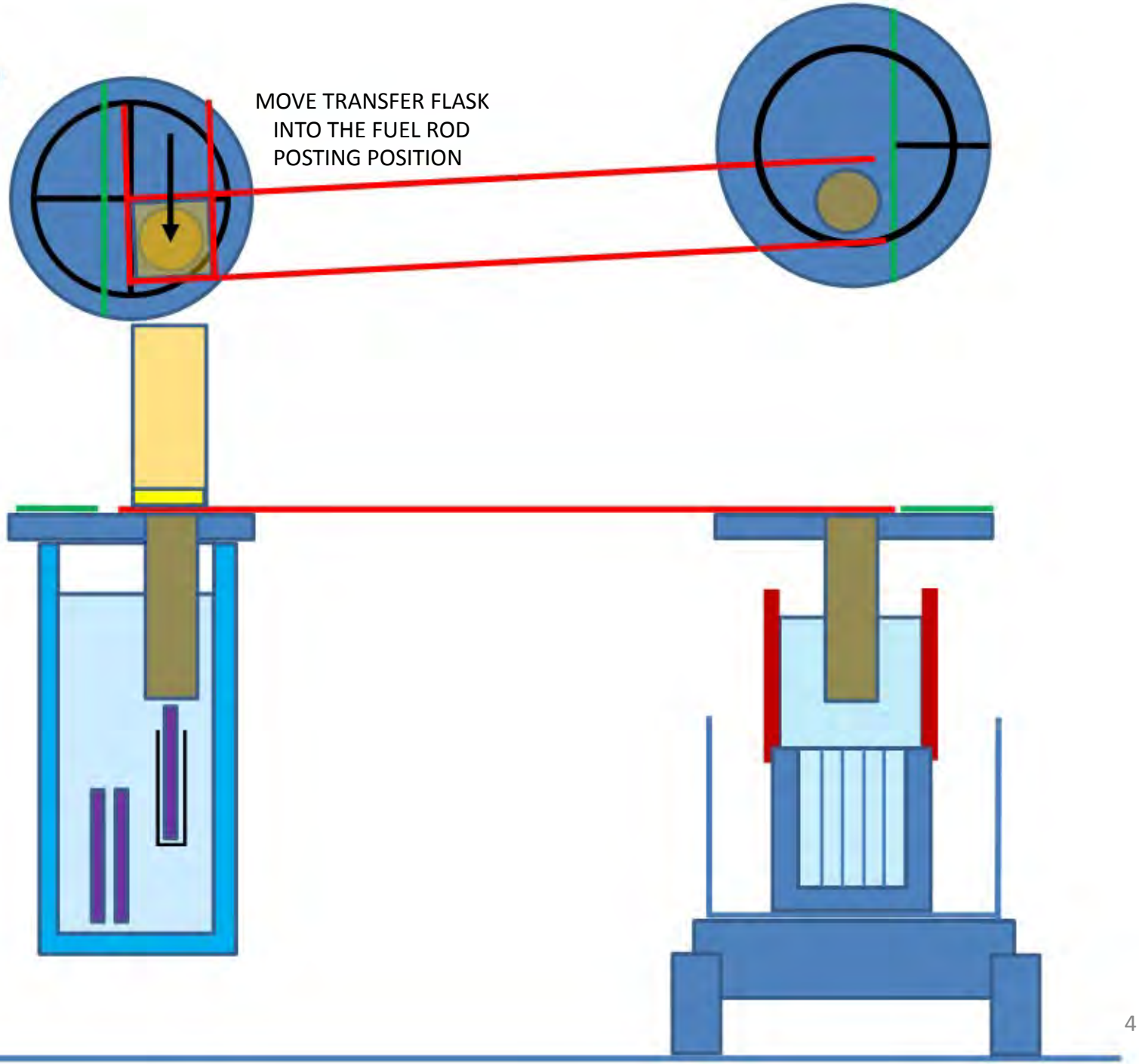
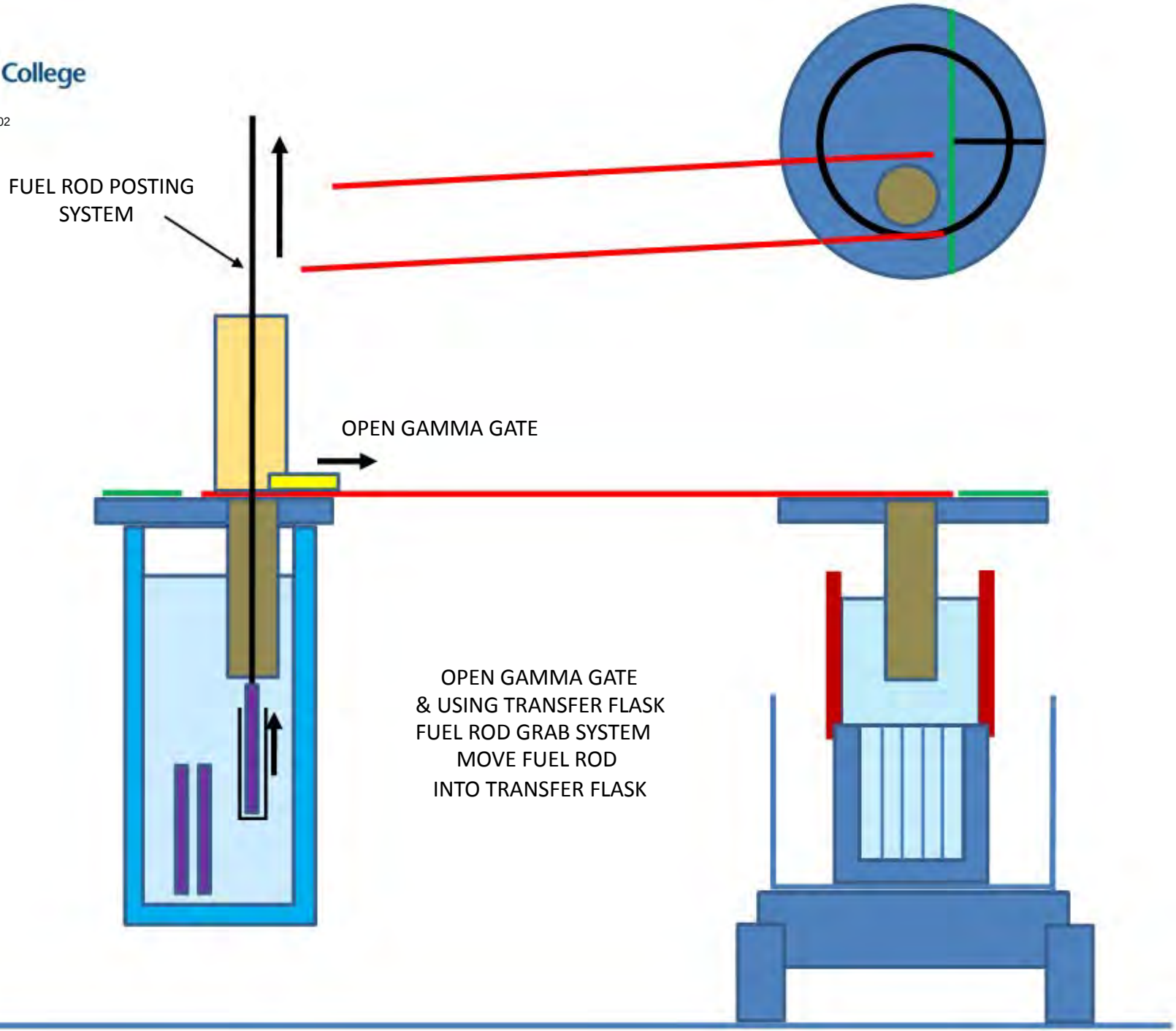
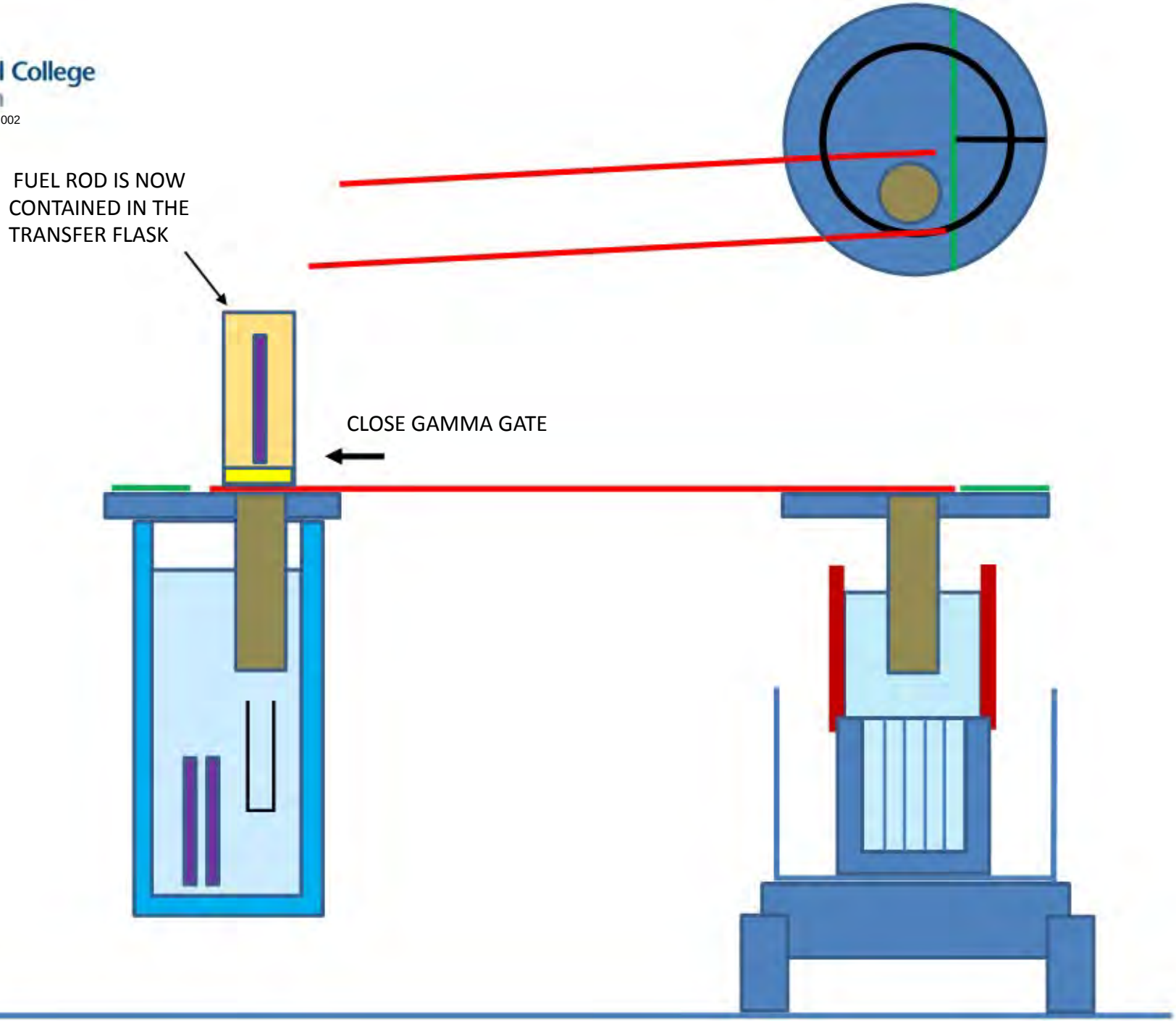
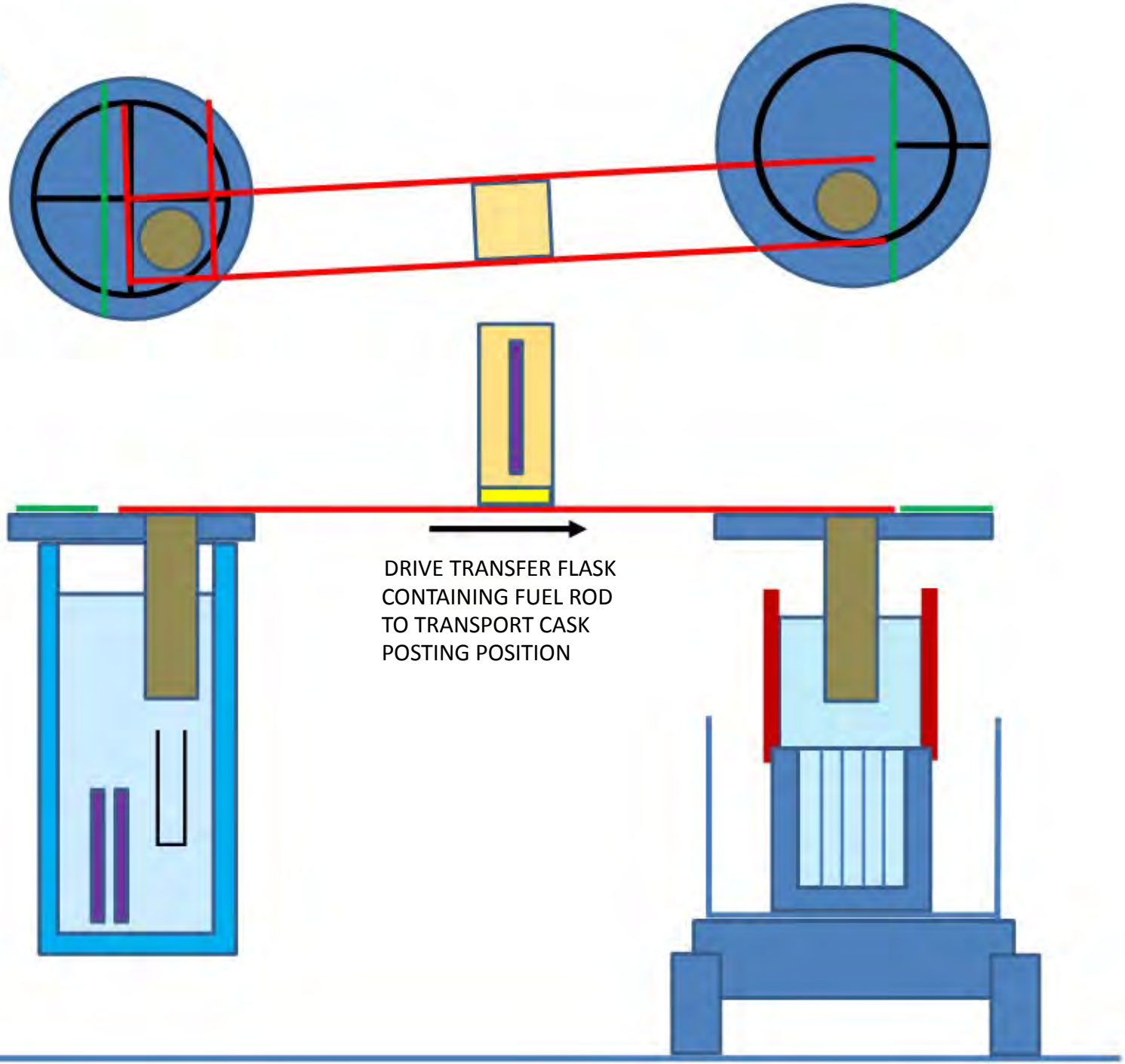
June 2011 issue 002

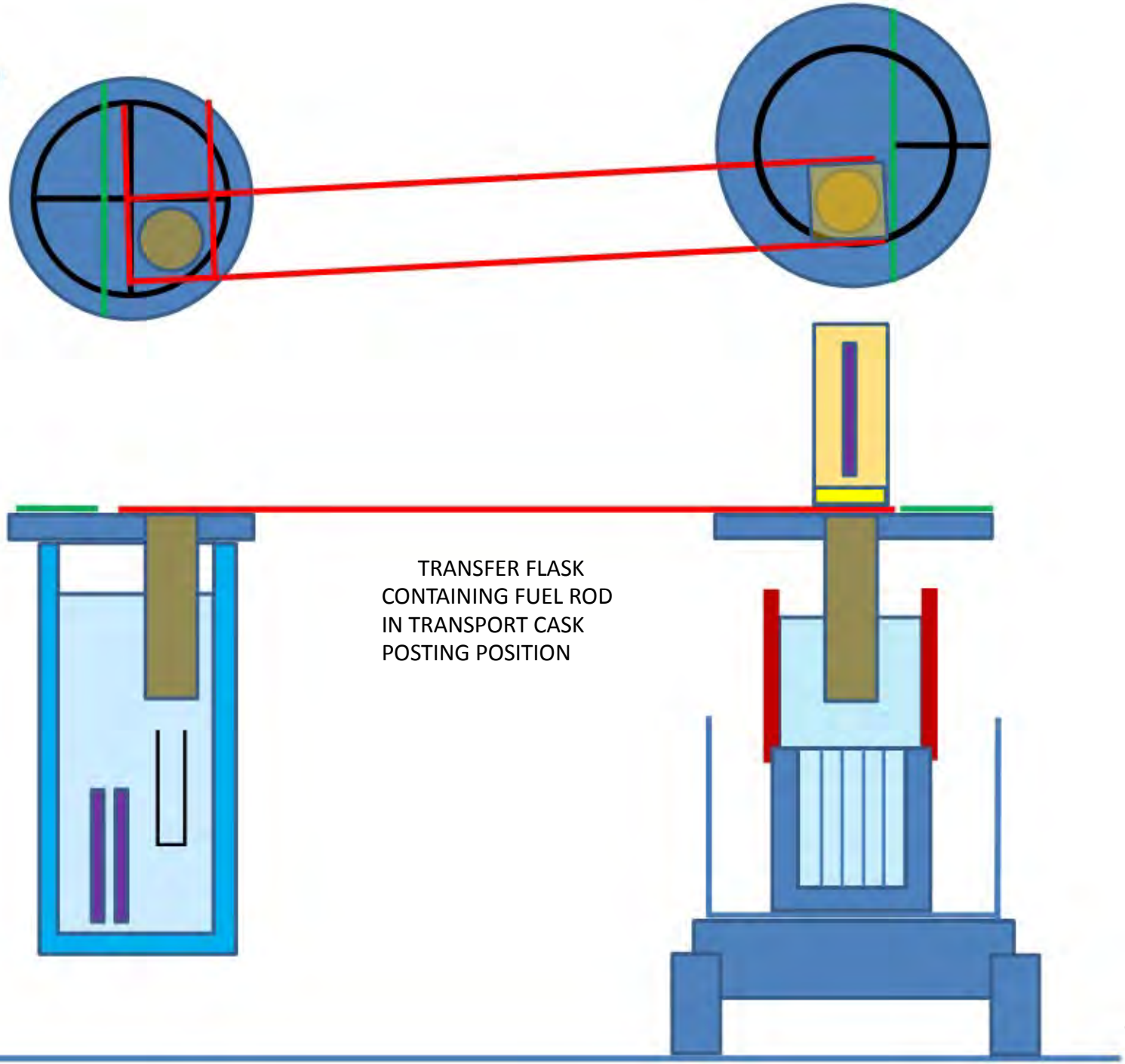



MOVE TRANSFER FLASK
INTO THE FUEL ROD
POSTING POSITION

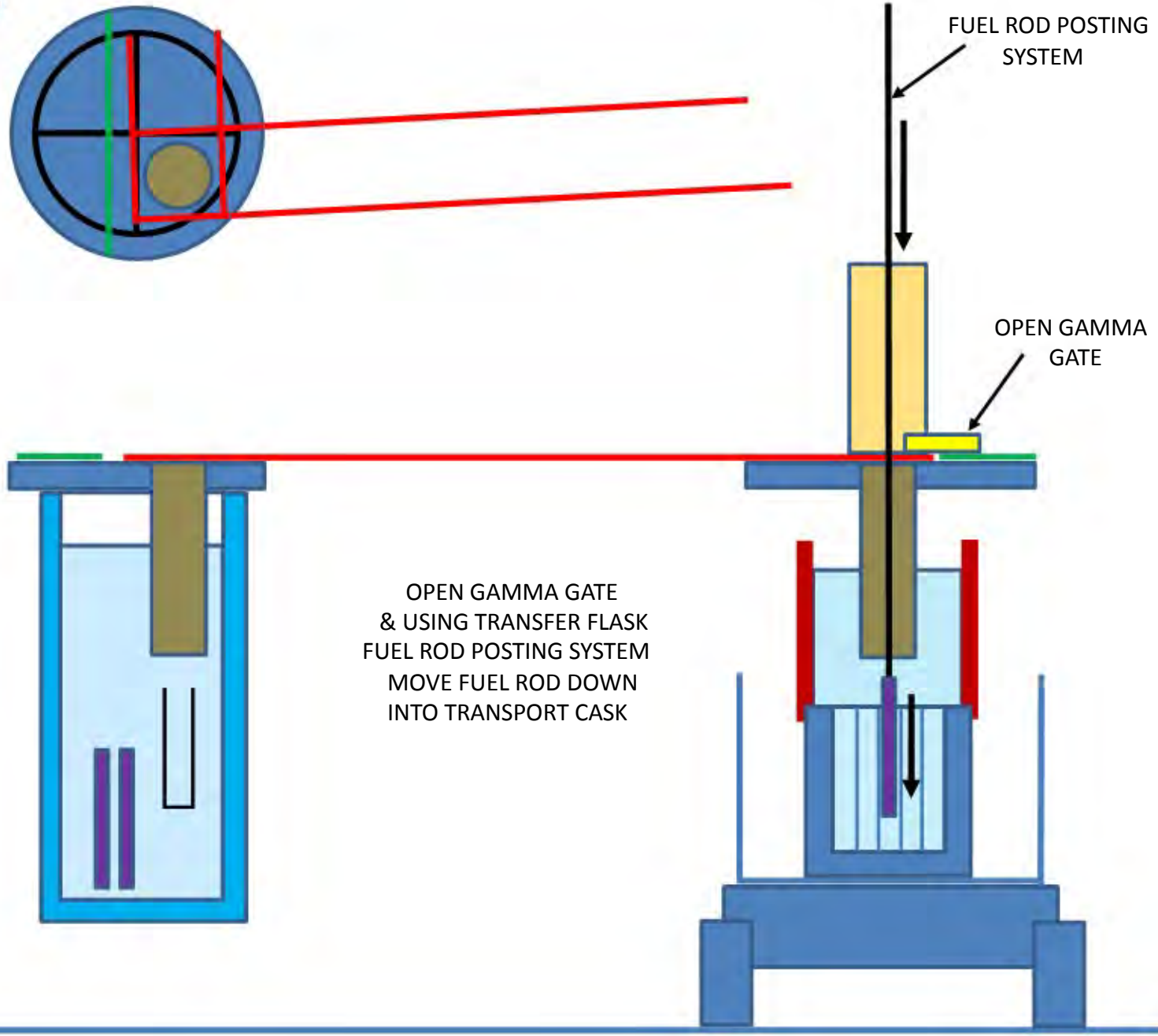

FUEL ROD POSTING
SYSTEM
OPEN GAMMA GATE
OPEN GAMMA GATE
& USING TRANSFER FLASK
FUEL ROD GRAB SYSTEM
MOVE FUEL ROD
INTO TRANSFER FLASK

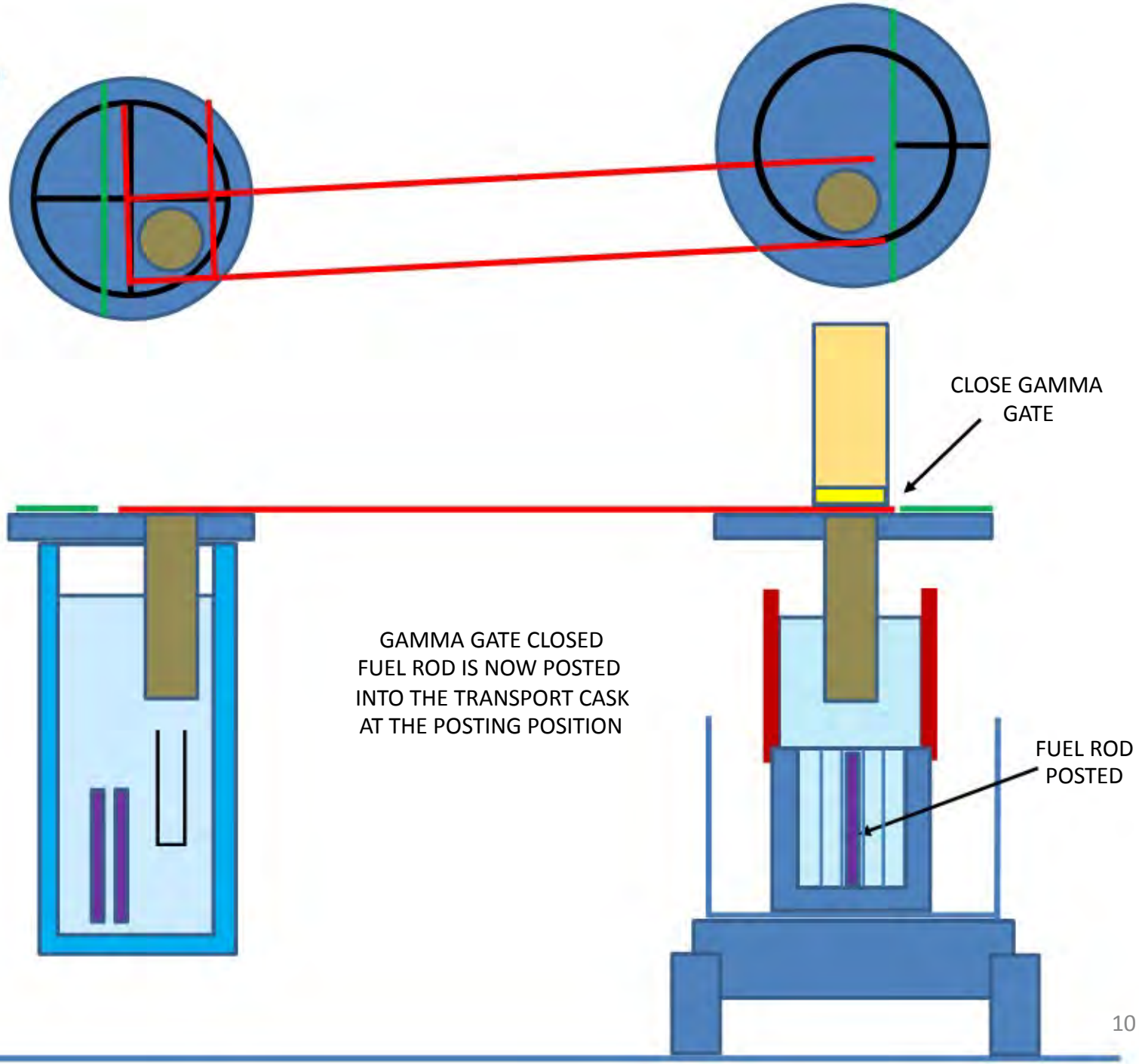

FUEL ROD IS NOW
CONTAINED IN THE
TRANSFER FLASK
CLOSE GAMMA GATE

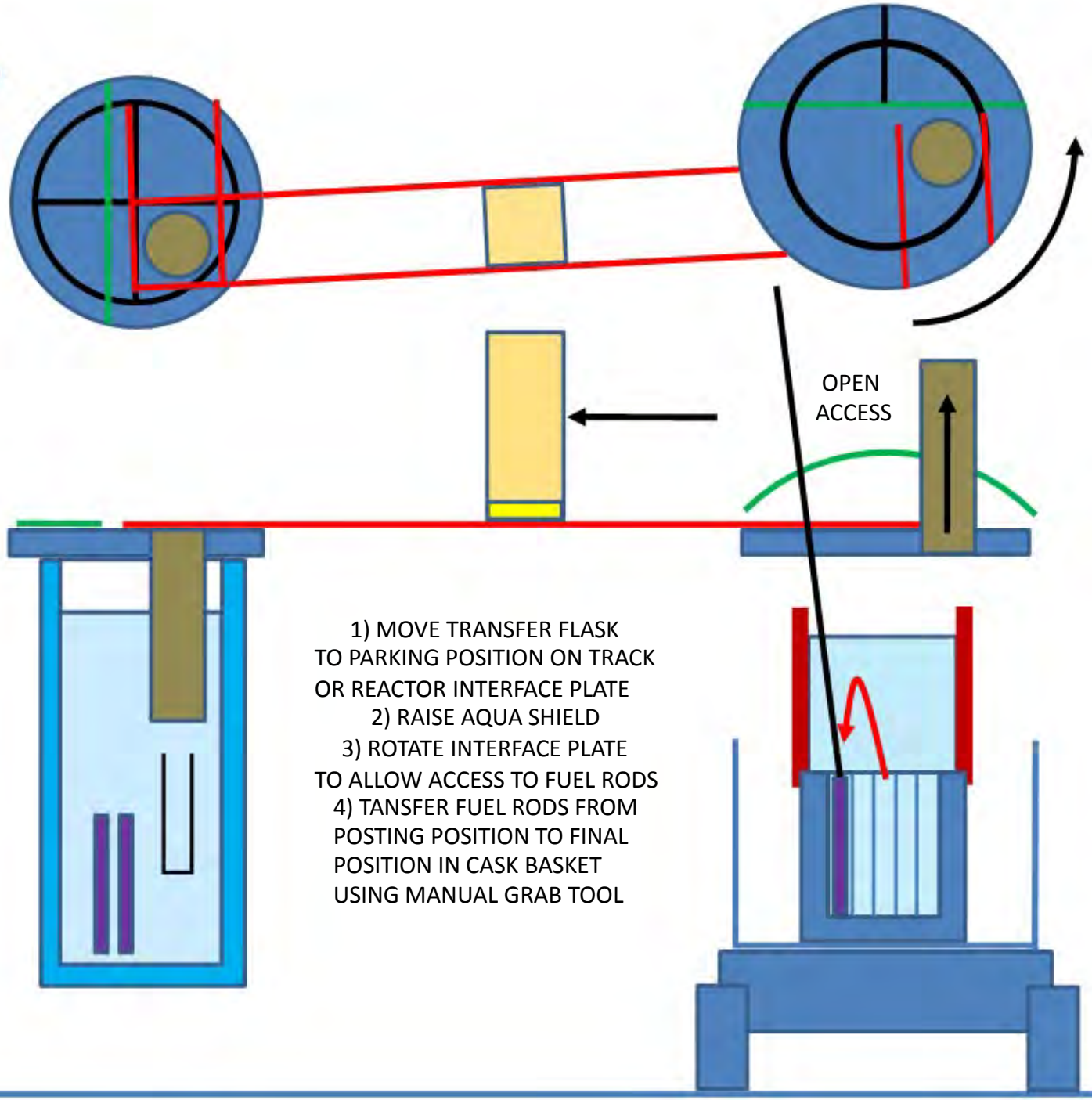

DRIVE TRANSFER FLASK
CONTAINING FUEL ROD
TO TRANSPORT CASK
POSTING POSITION



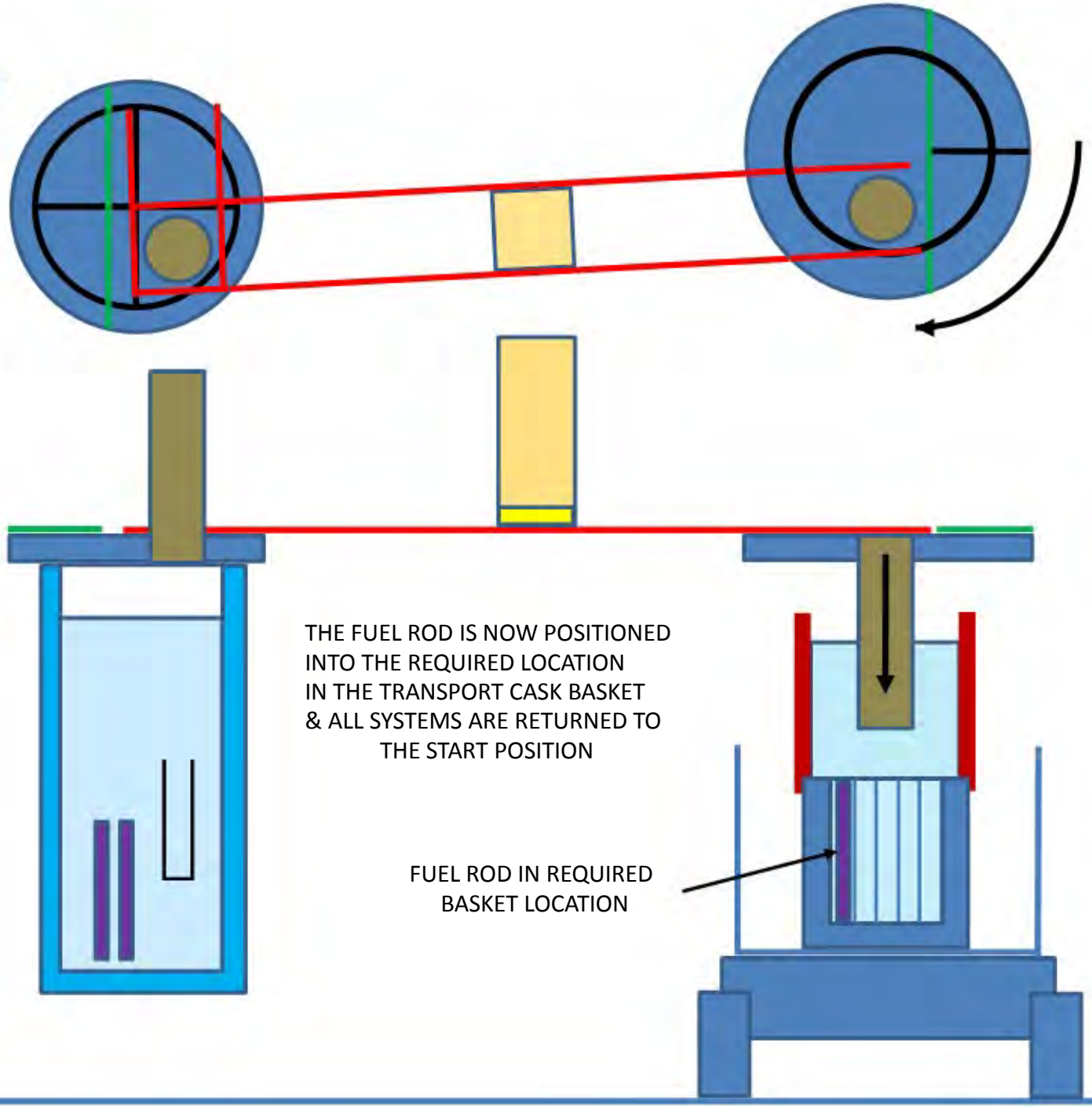
TRANSFER FLASK
CONTAINING FUEL ROD
IN TRANSPORT CASK
POSTING POSITION


FUEL ROD POSTING SYSTEM
OPEN GAMMA GATE
OPEN GAMMA GATE
& USING TRANSFER FLASK
FUEL ROD POSTING SYSTEM
MOVE FUEL ROD DOWN
INTO TRANSPORT CASK


CLOSE GAMMA
GATE
GAMMA GATE CLOSED
FUEL ROD IS NOW POSTED
INTO THE TRANSPORT CASK
AT THE POSTING POSITION
FUEL ROD
POSTED



1) MOVE TRANSFER FLASK
TO PARKING POSITION ON TRACK
OR REACTOR INTERFACE PLATE
2) RAISE AQUA SHIELD
3) ROTATE INTERFACE PLATE
TO ALLOW ACCESS TO FUEL RODS
4) TANSFER FUEL RODS FROM
POSTING POSITION TO FINAL
POSITION IN CASK BASKET
USING MANUAL GRAB TOOL



THE FUEL ROD IS NOW POSITIONED
INTO THE REQUIRED LOCATION
IN THE TRANSPORT CASK BASKET
& ALL SYSTEMS ARE RETURNED TO
THE START POSITION

FUEL ROD IN REQUIRED
BASKET LOCATION

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2011 - Taking the Concept Forward – Defuel Safety Case

With the defuel concept in mind the safety case could be considered

Key features of the safety case:

- To be a modification to the existing safety case
- To drive the safety functional requirements of the detail design
- To justify ONR Safety Assessment Principles were met
- To justify ALARP

Contract for production of the defuel safety case was let via tender process to Areva RMC

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2011 – Taking the Concept Forward - Hardware

So we now had a design concept – how to take that forward?

Let a design, manufacture and installation contract to Amec for the flaskway assembly

Let a design, manufacture and installation contract to Aquila for the cask bogie assembly

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Defuel Stakeholders

Successful defueling required coordination between a range of different stakeholders

- ONR Safety (Safety Case endorsement and permissioning)
- ONR Security (site security during defuel, transport security for consignment by road.
- ONR Safeguards (Safeguards and Euratom)
- ONR (RMT) Transport Container licence for use in UK
- Environment Agency (permissioning)
- Civil Nuclear Constabulary (site security and transport security)
- INS (Transport of the fuel to Sellafield, safety and security Plans)
- Sellafield Site Ltd (Receipt and storage of fuel at Sellafield)
- Department of Energy and Climate Change (DECC)

Coordination between Stakeholders was facilitated by setting up two groups

- CONSORT Decommissioning Regulatory Interface Forum – chaired by ICRC Head of Rector Centre
- DECC Working Group – chaired by senior civil servants directly reporting to ministers

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August 2012 - Careful that's a Listed Building! (Dummy Run of Flask Vehicle and Crane]

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2012 to early 2013 - Flaskway Design, Manufacture and Installation

Contract let by tender to Amec for the design, manufacture and installation of the flaskway

Flaskway built and tested at Amec premises in Warrington prior to shipment to Imperial College

This enabled design issues to be rectified and ICRC staff to gain early insight into operation of the equipment

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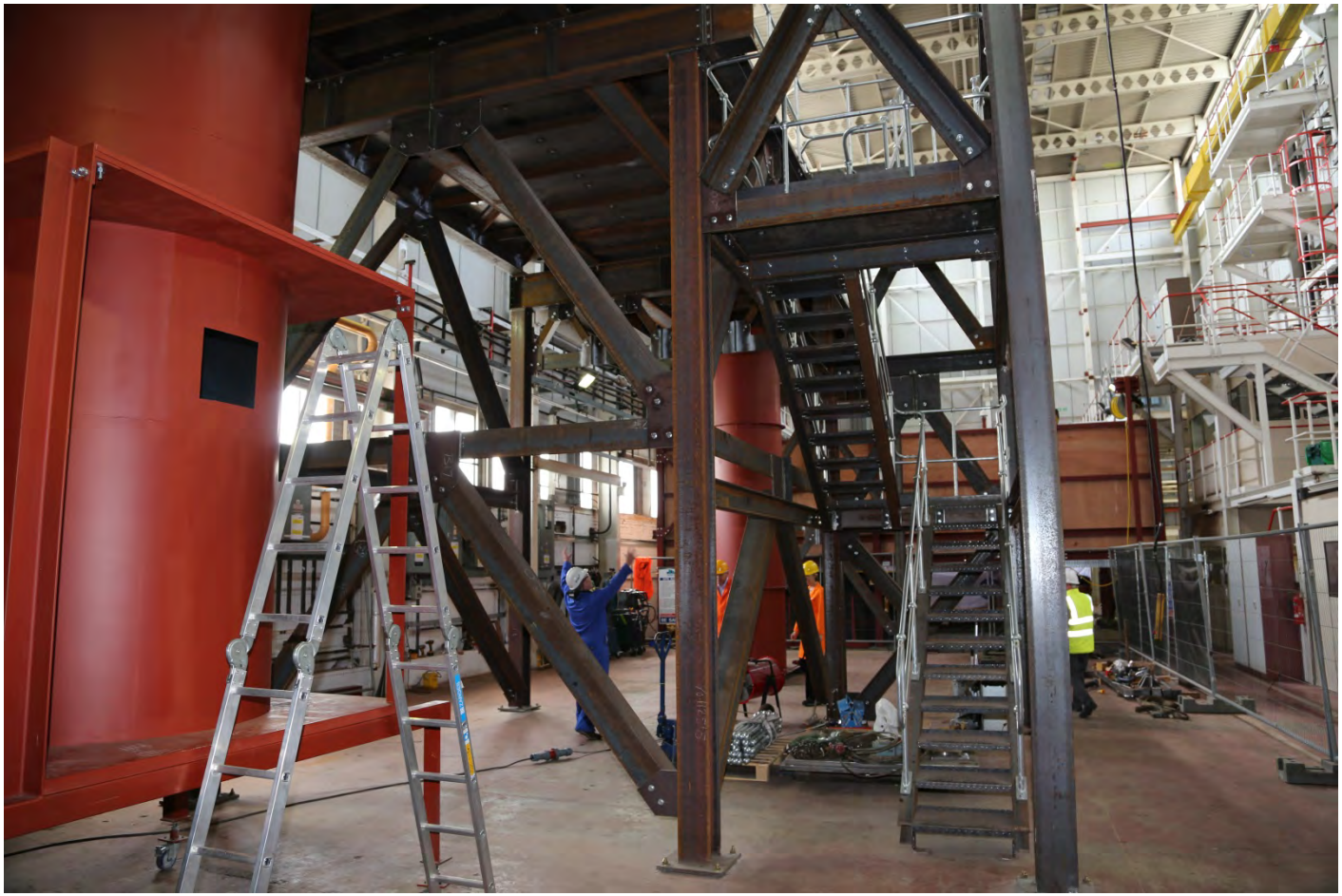
April to July 2013 - Flaskway Dummy Build and Testing at Warrington



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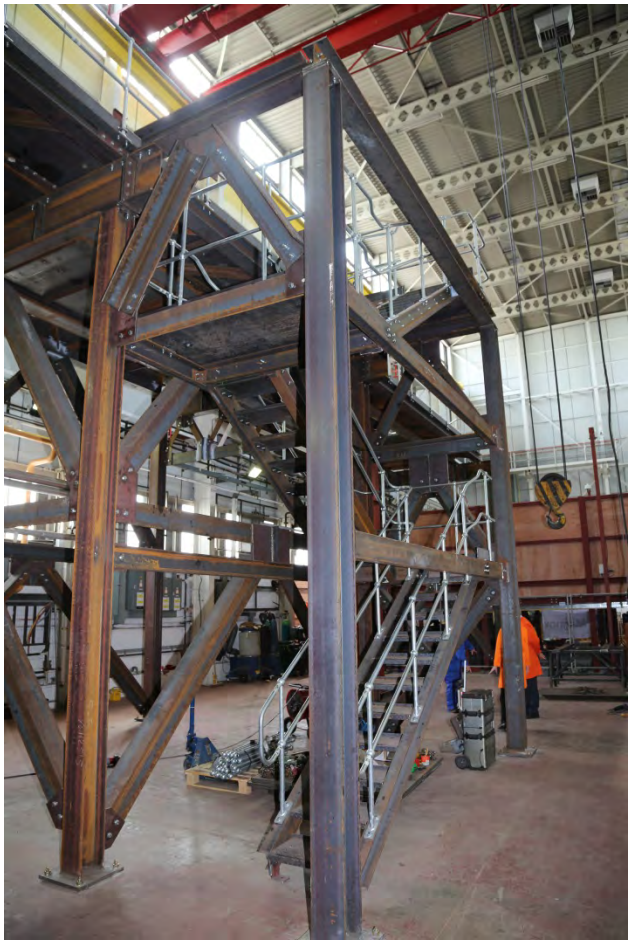
April to July 2013 - Flaskway Dummy Build and Testing at Warrington



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April to July 2013 - Flaskway Dummy Build and Testing at Warrington

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April to July 2013 - Flaskway Dummy Build and Testing at Warrington

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Installation of flaskway and cask bogie at ICRC

Construction site established in Reactor Hall to comply with CDM regs

ICRC appointed a CDM Co-ordinator to comply with CDM regs

ICRC appointed Amec as Principal Contractor

Amec installed Flaskway under ICRC overall supervision

This satisfied requirements of CDM regulations and Nuclear Site Licence

Similar arrangements adopted for Aquila installation of cask bogie

Only one contractor had access to the area at one time

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Cask Bogie Design, Manufacture and Installation

Contract let by tender to Aquila for the design, manufacture and installation of the cask bogie

Cask bogie built and tested at Aquila premises in Winchester prior to shipment to Imperial College

This enabled design issues to be rectified and ICRC staff to gain early insight into operation of the equipment

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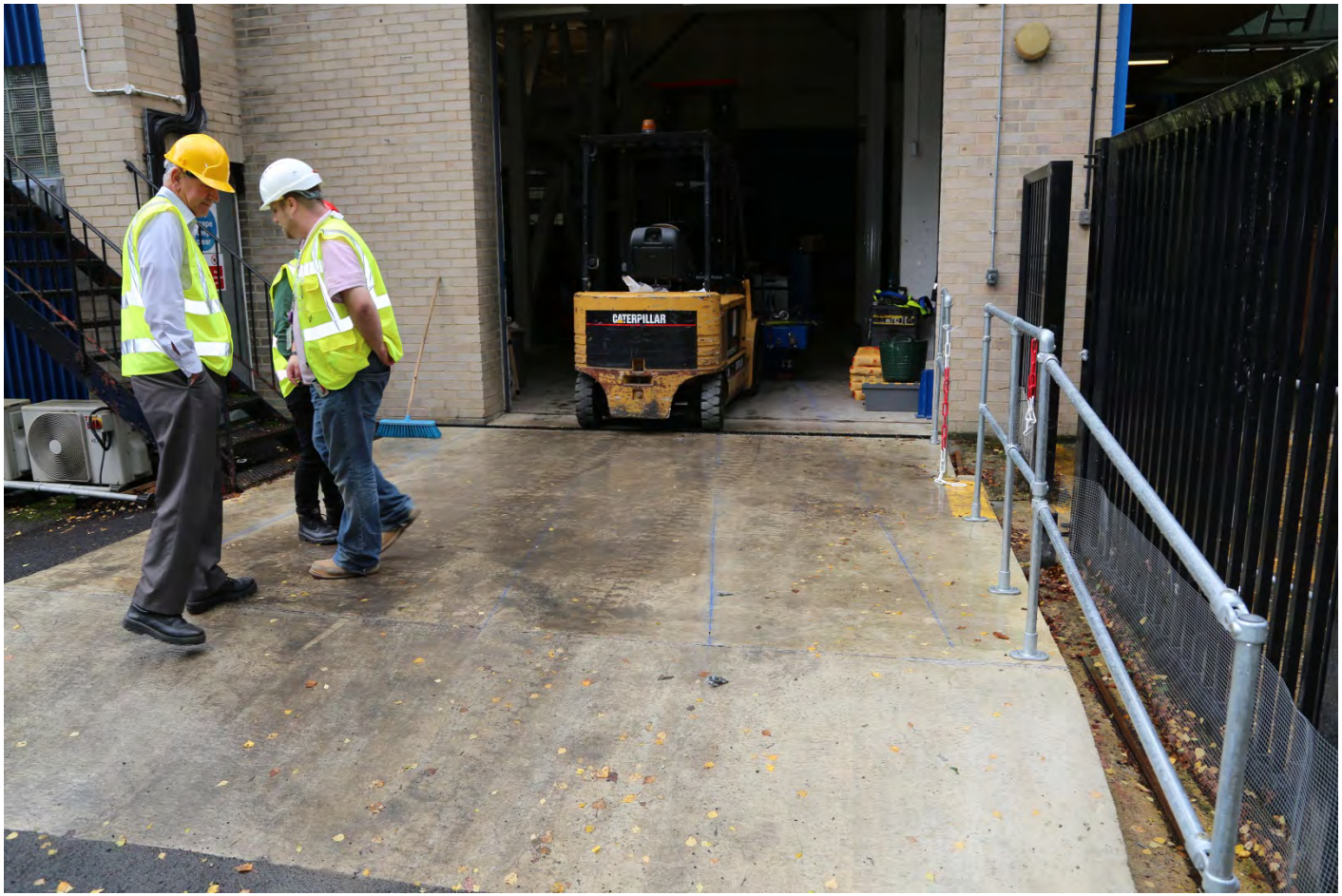
April 2013 - Cask Bogie Installation – New concrete plinth installed



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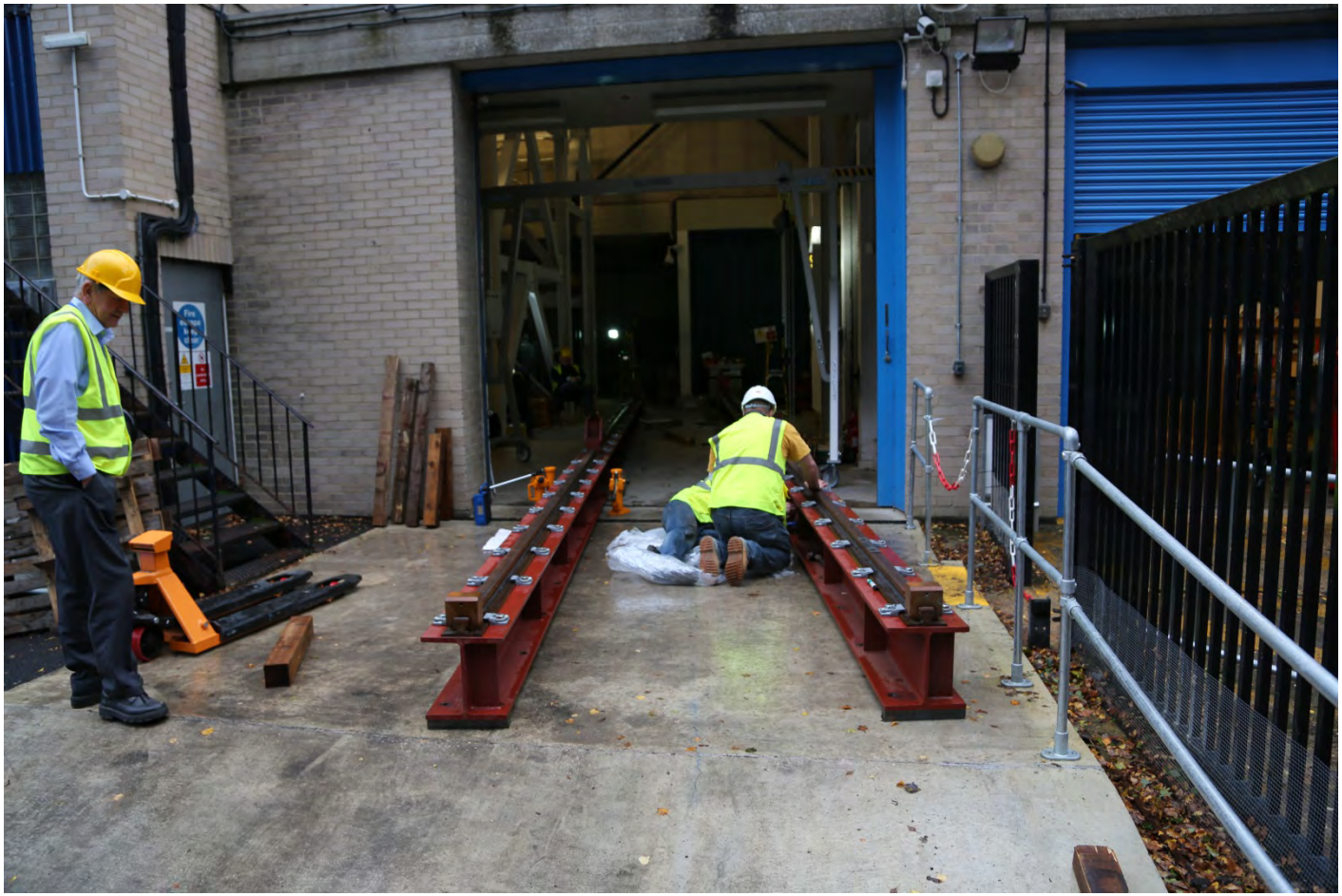
May 2013 - Cask Bogie Installation – Track Assembly



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May 2013 - Cask Bogie Installation – Bogie installed on exterior track

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London

August to November 2013 - Installation of Flaskway

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August to November 2013 - Installation of Flaskway

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Additional Defuel Equipment – Fuel Grab

A fuel grab and posting rods were required to operate remotely through the Areva transfer flask

These were designed and manufactured by a local engineering company, Woodley Engineering

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Additional Defuel Equipment – Fuel Handling Tool

A fuel handling tool to move the fuel elements within core to the fuel posting position and within the cask to the transport position was designed and built by Gemini

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Additional Defuel Equipment – Fuel Handling Tool Balancer

Gemini also designed and manufactured a cantilever framework to counter-balance the fuel handling tool when in use

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January 2014 - Cask Receipt and Installation

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January 2014 - Cask Receipt and Installation

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February 2014 - Cask Top Hat and Shielding Assembly

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February 2014 - Just when we thought it was going well!!

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February/March 2014 – It rained a bit near Ascot!!

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April 2014 – Major Electrical Power Failure at ICRC – Rain probable culprit

Incoming cable to Reactor Centre from main campus short circuits

Also damage to one internal cable found

Urgent repairs carried out

Standby generator used for emergency support

All works completed in record time

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May 2014 - Staff Training/Inactive Commissioning

Plant commissioned by ICRC team following draft Operating Instructions

All operations staff provided with classroom training covering all aspects from the safety case, radiation protection and emergency arrangements

Written test used to certify staff understanding of arrangements

All staff trained by dummy runs to ensure staff familiar with all equipment operation

Staff training files completed

Full dummy run of defuel carried out from dummy reactor tank to transport cask

Inactive Commissioning Phase completed

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May to July 2014 - Security Arrangements

Civil Nuclear Constabulary (CNC) Officers provided 24/7 armed security during the period of defuel

Special facilities provided by ICRC to support CNC operations

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May 2014 - Defuel Safety Case Approval

Review of Defuel Safety Case carried out by ONR-Safety

Readiness Inspection carried out by ONR-Safety to assess readiness of all equipment and staff training

Emergency exercise carried out to demonstrate recovery from an exposed fuel element

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ONR provide 'No objection to Proceed' to Defuel

Regulatory Interface Forum met to review ICRC Readiness to Defuel

All regulators represented led by ONR-Safety

ONR provide 'No objection to proceed with Active Commissioning and Defuel' – 21st May 2014

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End of May/early June 2014 – Active Commissioning

First three fuel element transfers carried out as Active Commissioning

After each fuel element transfer a short Active Commissioning report was produced and reviewed by NSC Chairman before proceeding

Final recommendation for full defuel operations provided by NSC Chairman following third Active Commissioning element

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Early June 2014 - Areva Transport Cask Certification

Certificate of approval gained from the French regulator ASN for use of Areva TN-MTR cask containing CONSORT fuel

Approval gained from ONR-RMT for the use of the Areva TN-MTR cask containing CONSORT fuel on UK roads

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12 June 2014 - At last – Defuel!!

Defuel carried out two elements per day

Two shift system used where possible to spread the load for small team

Each team comprised:

- Defuel Supervisor (DAP)
- Fuel Handling Tool Operator (SQEP)
- Flask Operator (SQEP)
- Control desk operator (SQEP) – to monitor all Control Room alarms during defuel

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Late June 2014 - Oh No Not Again! – This time a Heat Wave

Weather forecast: UK sees hottest day of the year

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It was hot work up on the flaskway!

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Attaching Fuel handling Tool to Balance Arm

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Connecting FHT to Fuel Element

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FHT raising Fuel element and transferring to Posting Position

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Aligning Transfer Flask/Trolley over Core

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Lowering Grab through flask to connect to Fuel Element

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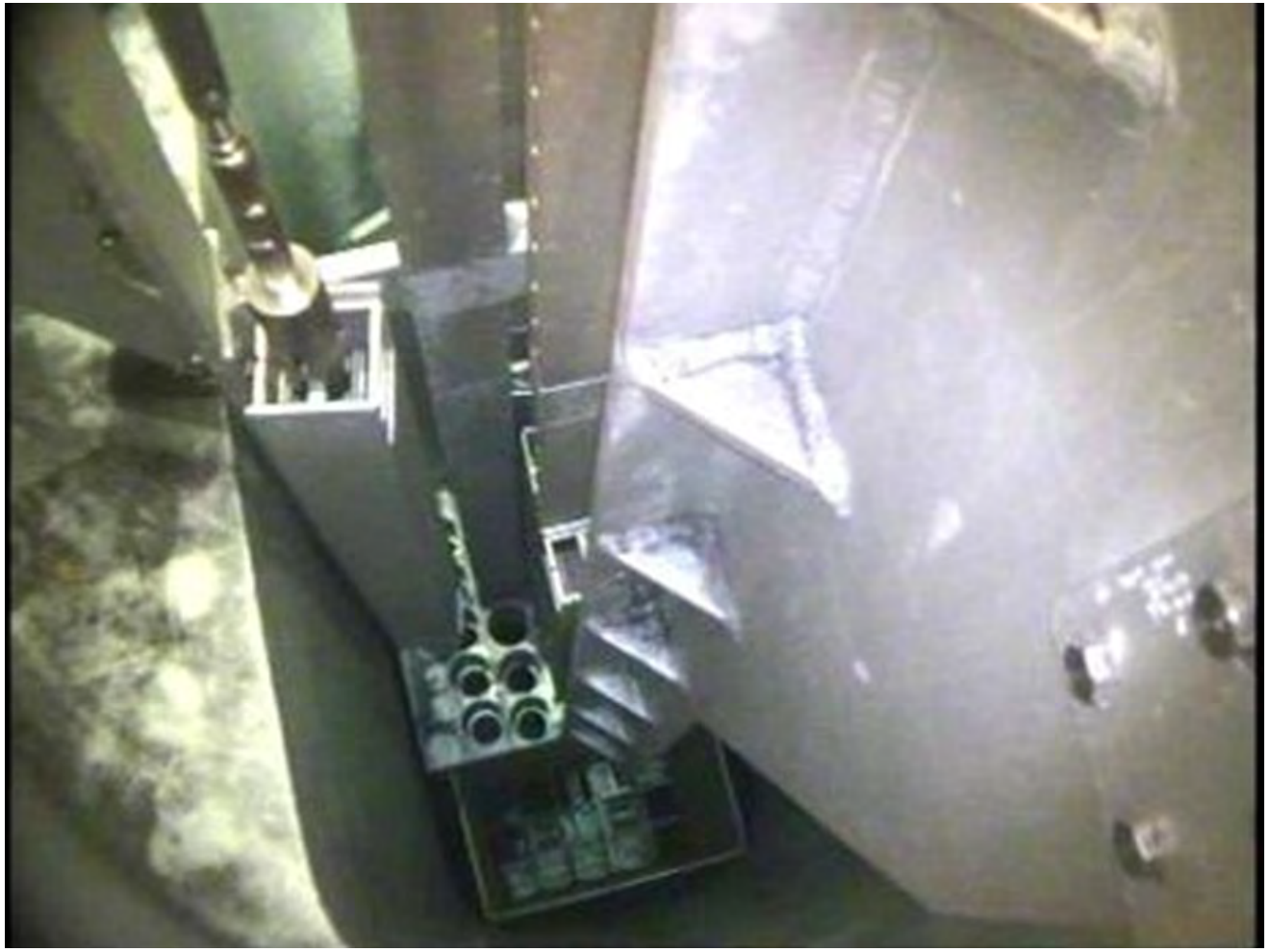
Fuel Element being raised from Core to Transfer Flask



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Fuel Element being raised from Core to Transfer Flask

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Rotating Flask to align with Unloading Position in Cask

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Lowering Fuel Element from Transfer Flask to Transport Cask

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Recording Fuel element Identification Number

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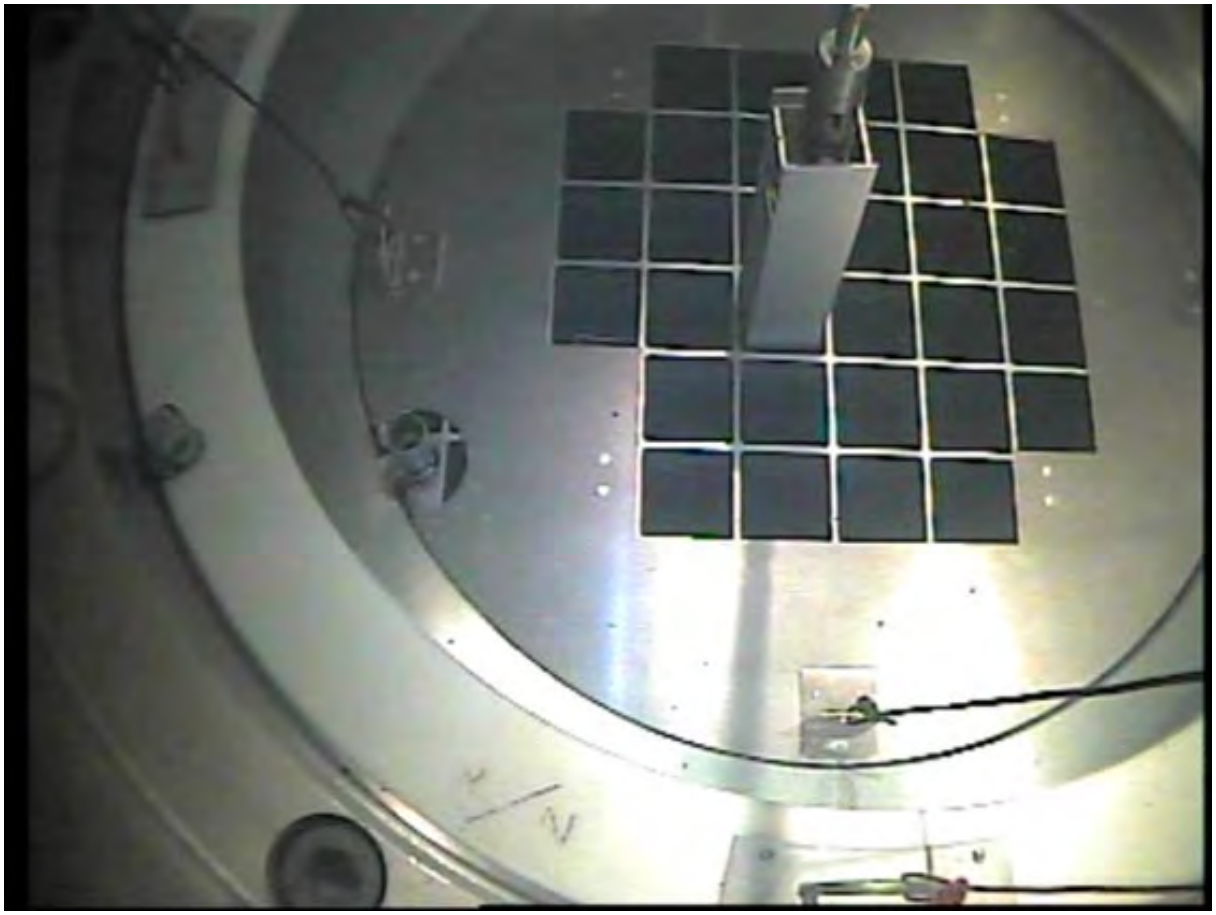
Lowering Fuel Element from Transfer Flask into Cask Loading Position



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Transferring Fuel Element from Unloading Position to Transport Position in Cask using FHT

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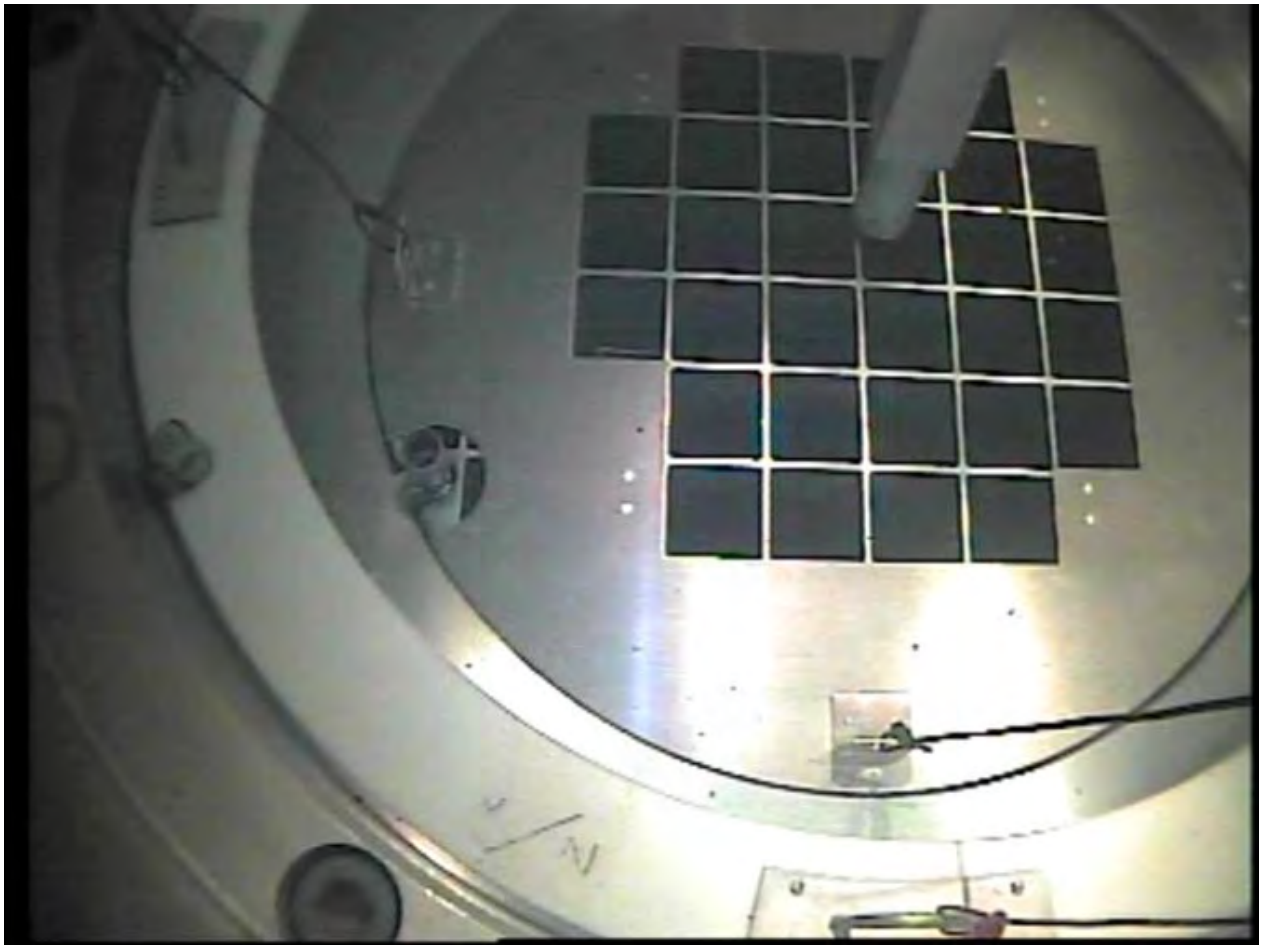
Transferring Fuel Element from Unloading Position to Transport Position in Cask



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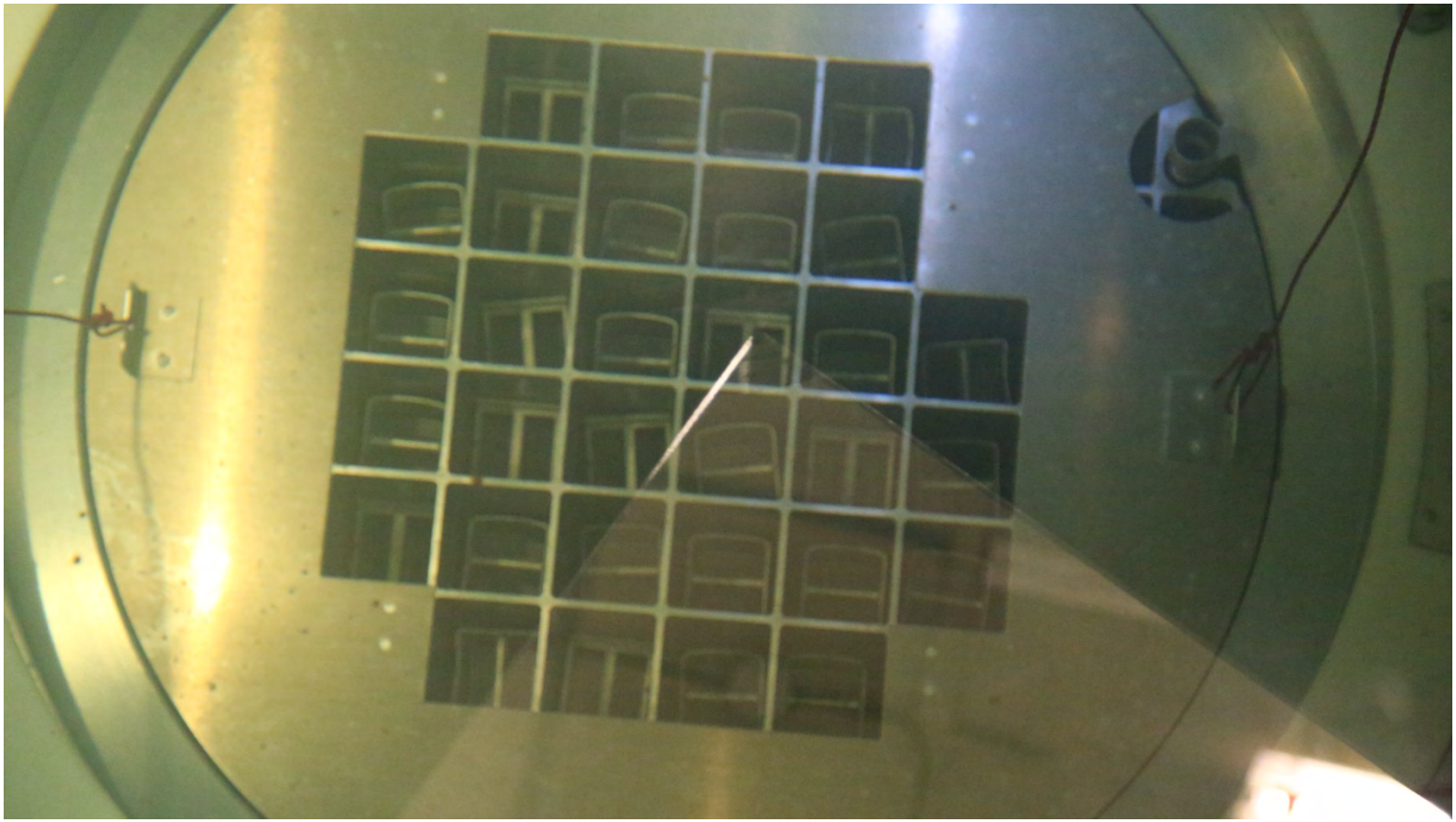
2 July 2014 - Cask Loaded



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Raising cask Lid for Refitting to Cask

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Lowering Cask Lid through Water Filled Cask Top Hat onto Cask

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17 July 2014 - Loading Transport cask onto Road Vehicle

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18 July 2014 - Transport

Transport of fuel complicated by security classification:

- ICRC – Consigner
- International Nuclear Services (INS) – Carrier (required by ONR-CNS due to security classification)
- Transport vehicle and drivers – Areva TNI
- Transport Security Escort – Strategic Escort Group of Civil Nuclear Constabulary (CNC)

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Operator Doses

Design Dose Restraint Target of < 1mSv per operator

EPD’s set at 100 µSv/h alarm rate and 100 µSv accrued dose

Highest total dose to any operator 20 µSv!!

Design, training and practise paid off

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So ultimately what were the key Challenges encountered?

Electrical Failure

Delays with supply of equipment

CNC on a university campus

Timescales driven by unavailability of High Security Vehicle

Need for security clampdown over operations and transport dates

Small team

Hot weather

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Lessons Learnt

Perceived very low/highly unlikely risks can bite – Electrical failure

Aging team – enthusiasm doesn't entirely compensate for years!

Good regulator interaction – Regulatory Interface Forum helped enormously

Dummy runs invaluable to provide confidence for team and regulators

Any questions?