Engineering aspects of Hot cells and in-cell Equipments

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Introduction

- **The Hot cell facilities at PIED are used for the post irradiation examination (PIE) of irradiated nuclear fuels and structural materials from the water-cooled research and power reactors. In addition, the facilities are used for ageing studies and failure analysis of out-of-core components of the reactors and also for the generation of the base line data on these materials before irradiation.**
- **Present talk will be divided mainly into three parts:**

➢ **Features of New Hot-cell Facility: better features compared to the old cell facility**

➢ **Online data acquisition and monitoring systems related to the hot-cell parameters**

➢ **In-cell equipment**

I. Features of New Hot cell Facility (NHF)

- **Comply with latest standards (AERB/SS/CSE-1, IAEA-TECDOC-1347, ASME AG-1, ASTM C1533, ASTM C1725 etc.) . Designed based on past experience.**
- **NHF has 2.5 times more shielding capacity and better leaktightness than old hot cell.**
- **NHF can handle / store more irradiated materials with higher activity for PIE.**
- **NHF is seismically qualified and qualified for all postulated accidents. Even for BDBA exposure to public at site boundary is within regulatory limit.**
- **Longer cells and large transfer port facilitate PIE of larger fuel assemblies.**
- **In-cell cranes for material handling reduces the burden on manipulators. It increases the availability of manipulators.**

I. Features of New Hot cell Facility (NHF) (Contd.)

- Dry maintenance free radiation shielding windows
- Extended reach manipulator for better manipulation
- Use of high definition, 30X optical zoom PTZ camera facilitates more efficient visual examination and close control over in-cell activities.
- Cells have rotating roof plugs. Cell top is available for cell access/ manipulation/ viewing.
- All amber areas are equipped with cranes. It reduces operator fatigue and safe material handling.
- Ethernet based instrumentation. All safety related parameter/ indications / feedbacks are available in central console.
- Real time monitoring/ logging of all HP instrument. Status of all equipment is available at central console. Improved safety feature

I. Features of New Hot cell Facility (NHF) (Contd.)

- Real time radiological status of facility is available.
- Real time monitoring/ logging of effluent release.
- Fully automated ventilation system with improved safety systems.
- Surveillance system for security of radioactive sources.
- Mechanised transfer of irradiated material through transfer port. Reduces personal exposure.
- All material transfer system in the cell have electronic interlocks with mechanical interlocks. All indications are available in operating desk. Eliminates chance of accidental exposure.
- NHF has shielded storage pits for storage of solid radioactive waste in drums.
- Facility has solid waste compaction facility.
- NHF has Class –IV, Class – III and Class – II power supply

Features of New Hot cell Facility (NHF) (Contd.)

Comparison of New Hot cell Facility (NHF) and Old Hot Cell Facility (OHCF)

Description	NHF	OHCF
Max. Internal dimension (L x W) in m	16.9 x 2.1	4.8 x 2.1
Shielding capacity (Ci of Co^{60})	2.5×10^5	1×10^5
Shielding (Roof)	Mild Steel	Concrete
Number of work station	Nine	Eight
Viewing	Radiation shielding dry glass window	Oil filled Radiation shielding glass window
Manipulation	Extended reach manipulator	Model – 8 master slave manipulator
Material handling	2T In-cell crane and 2T crane in operating area	Manual or with manipulator
Transfer port	sliding door construction with 500mm square port opening	Eccentric drum construction with 150mm circular opening
Facility monitoring and status logging	Fully automated data acquisition and monitoring system	Manual
Radioactive solid waste management	Shielded storage pits for interim storage	Storage in warm work area

Features of New Hot cell Facility (NHF) (Contd.)

Operating Area of NHF

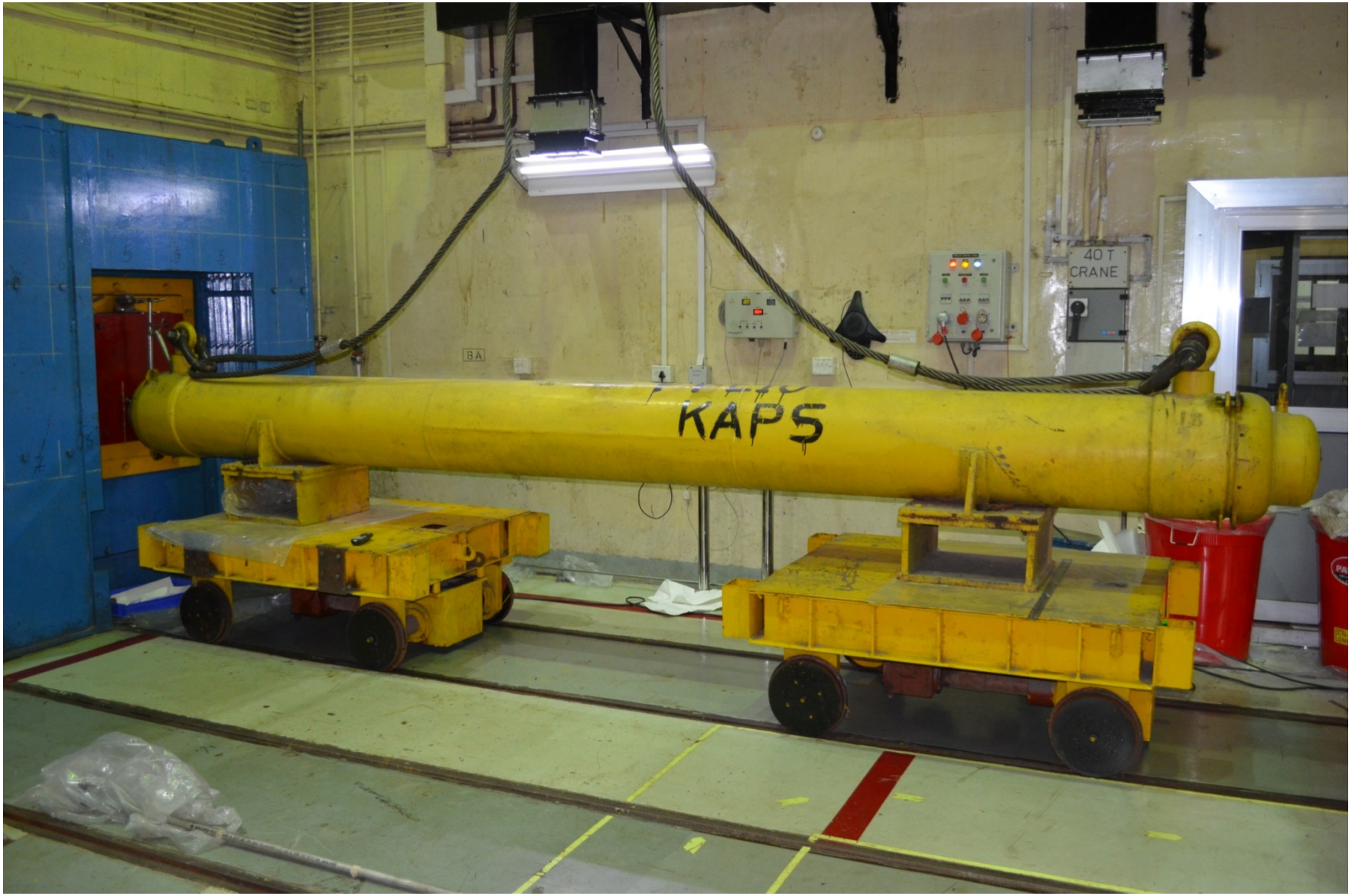
Features of New Hot cell Facility (NHF) (Contd.)

Panoramic view of hot cell roof and warm work area of NHF

Features of New Hot cell Facility (NHF) (Contd.)

Typical hot cell shielding personnel door and material transfer system (ETD)

Features of New Hot cell Facility (NHF) (Contd.)

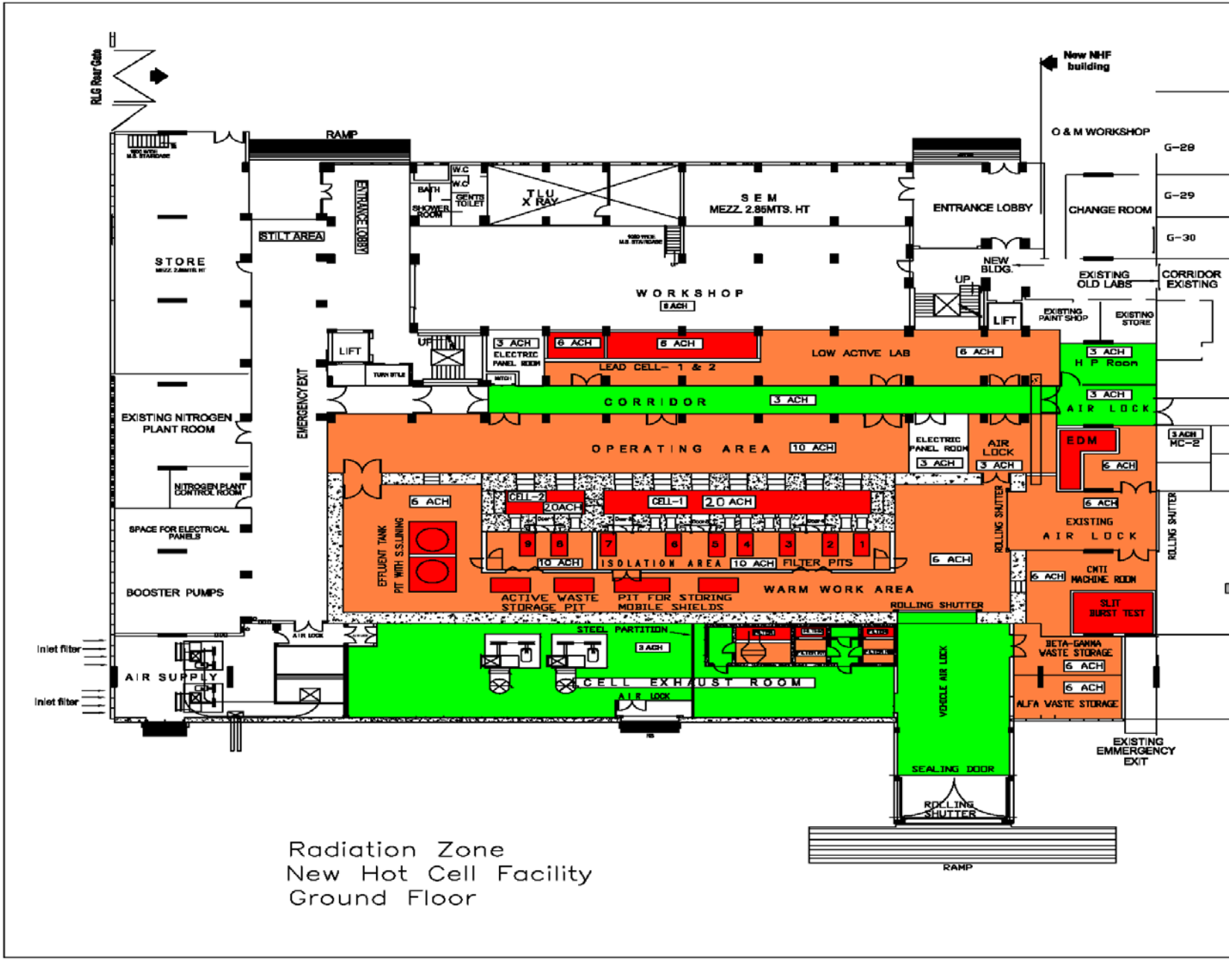


Pressure tube cask docked at transfer port of NHF

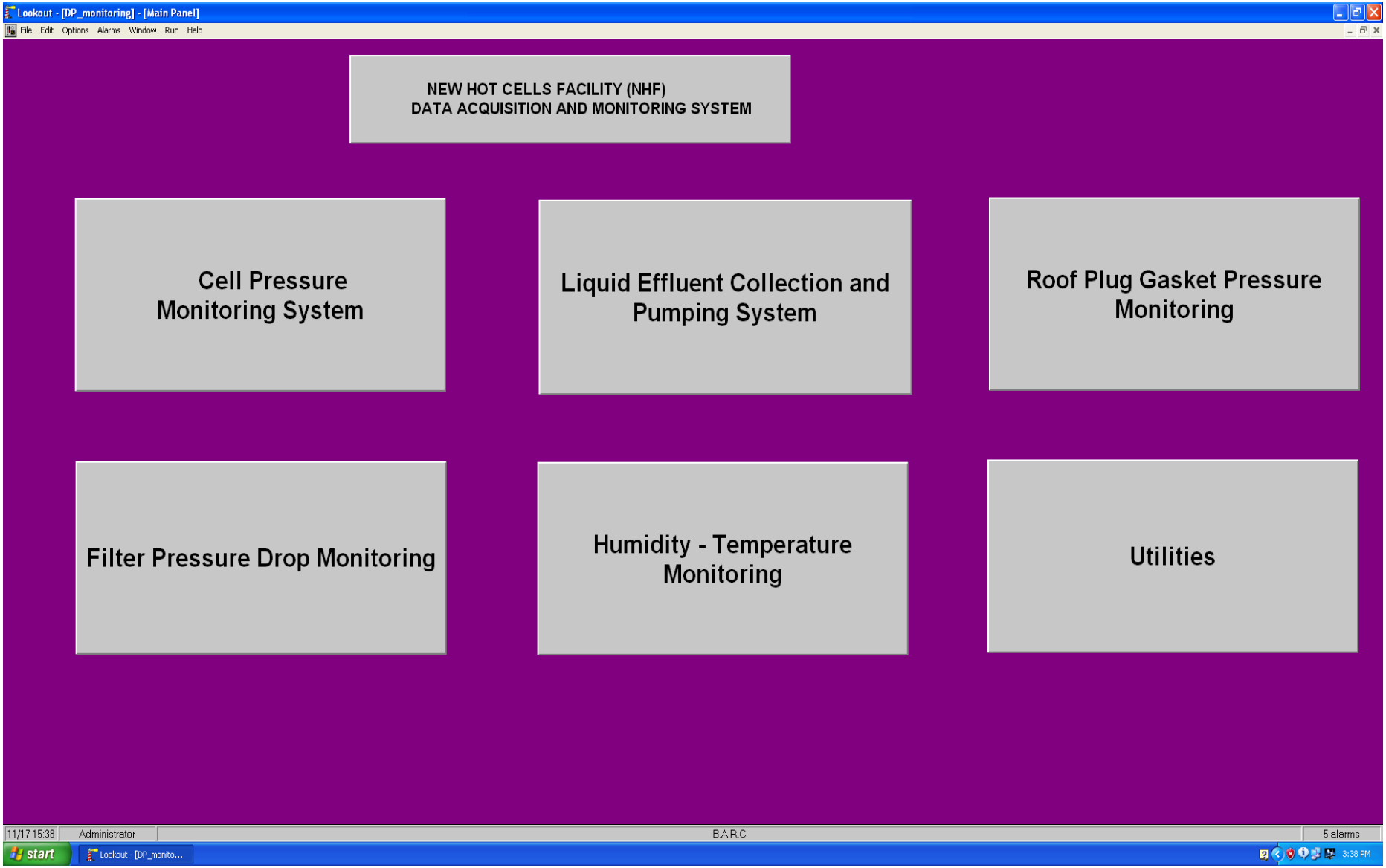
I. Features of New Hot cell Facility (NHF) (Contd.)

Inside View of Hot Cell with In-cell EOT Crane

Features of New Hot cell Facility (NHF) (Contd.)

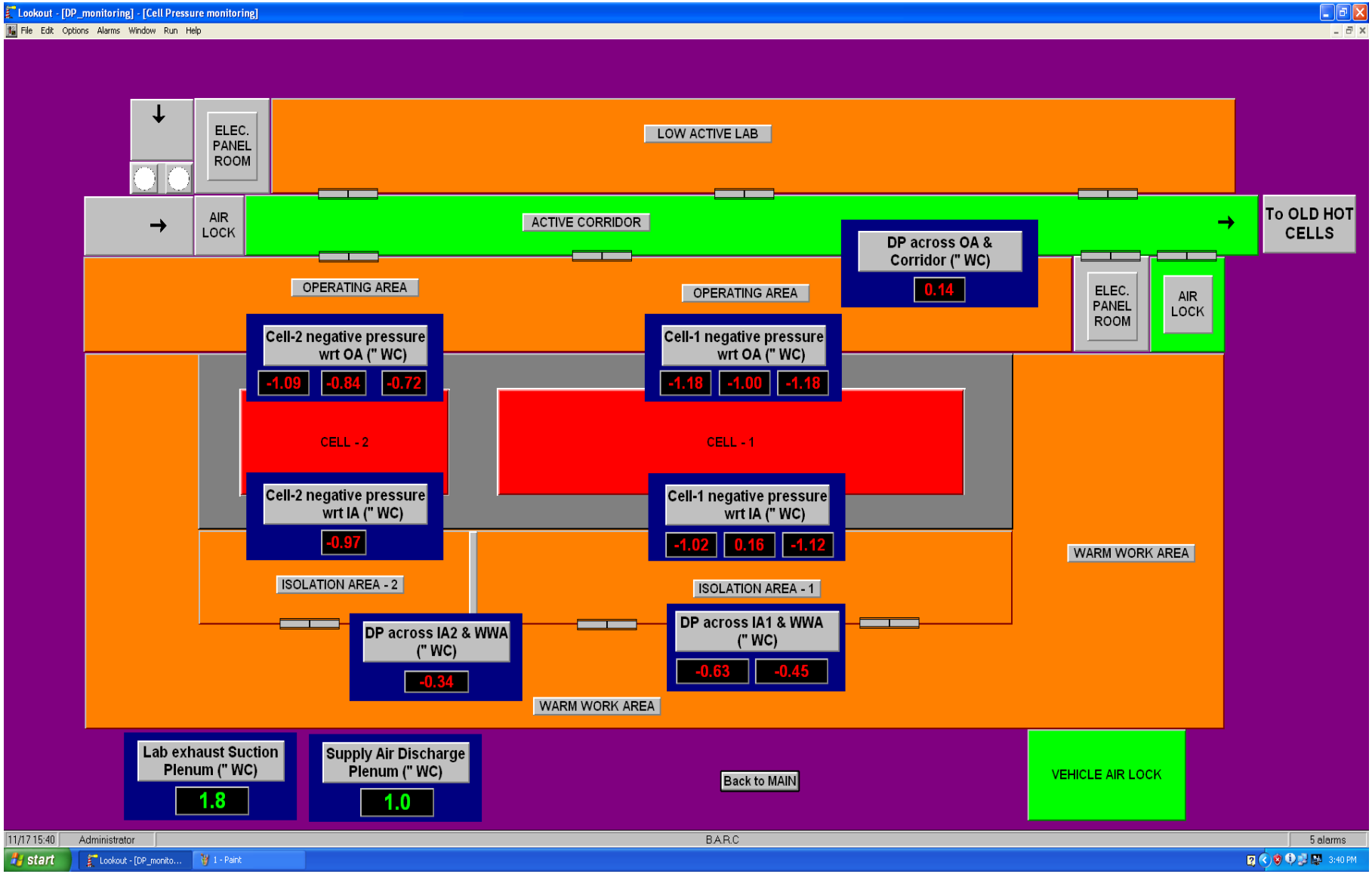


II. Online data acquisition and monitoring systems



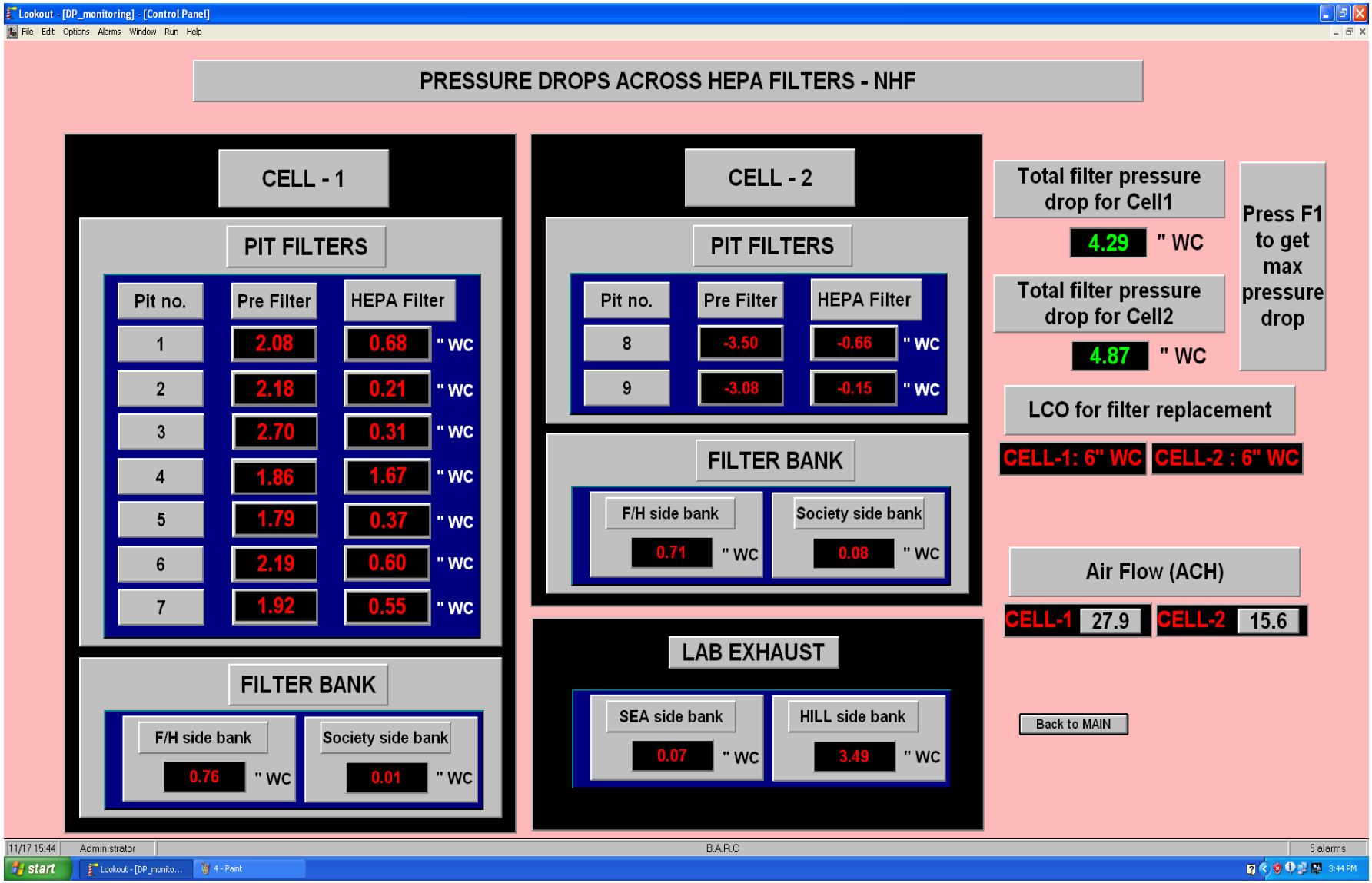
Centralised data acquisition and monitoring system

II. Online data acquisition and monitoring systems (Contd.)



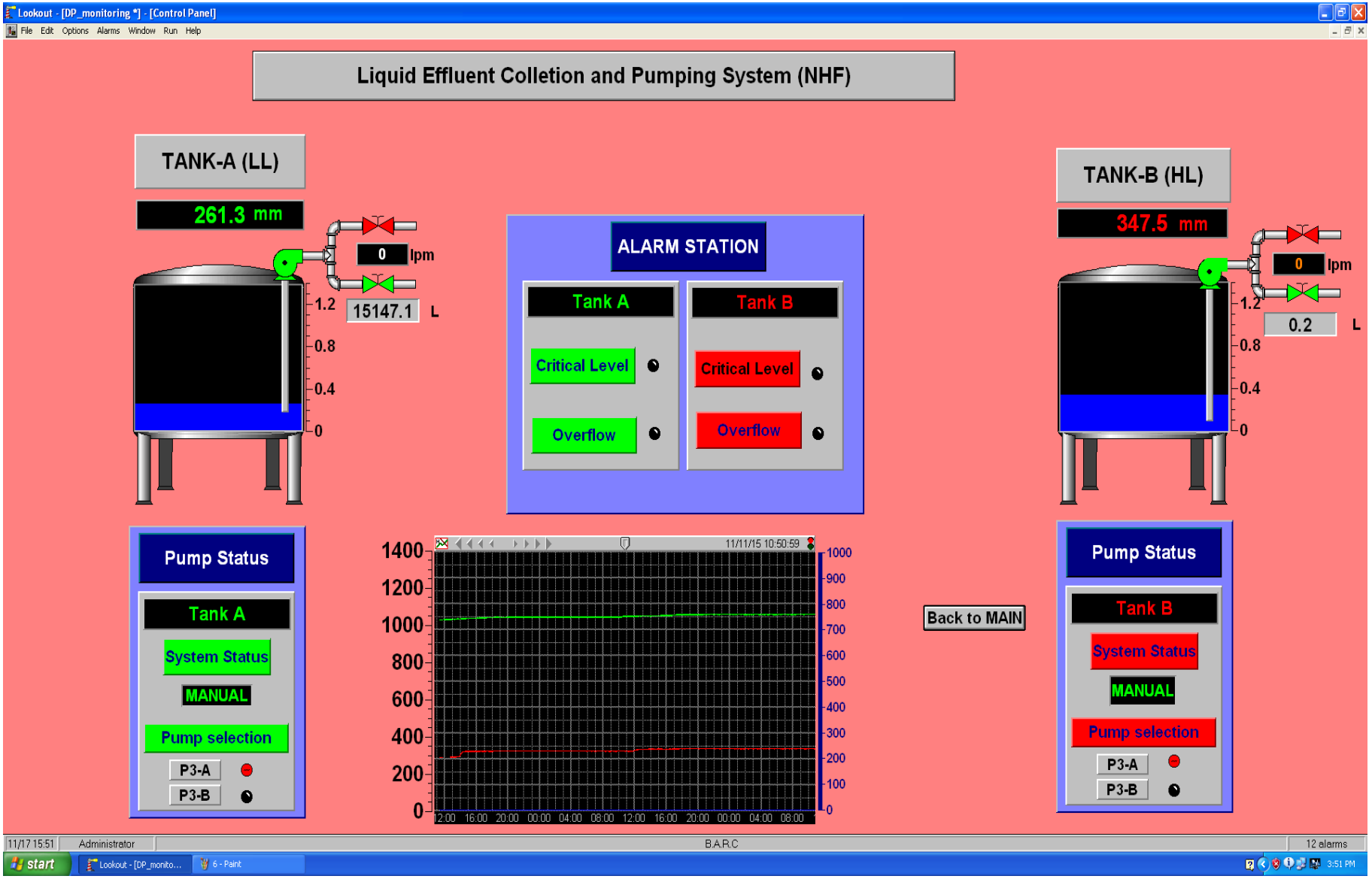
Differential pressure monitoring of radioactive areas

II. Online data acquisition and monitoring systems (Contd.)



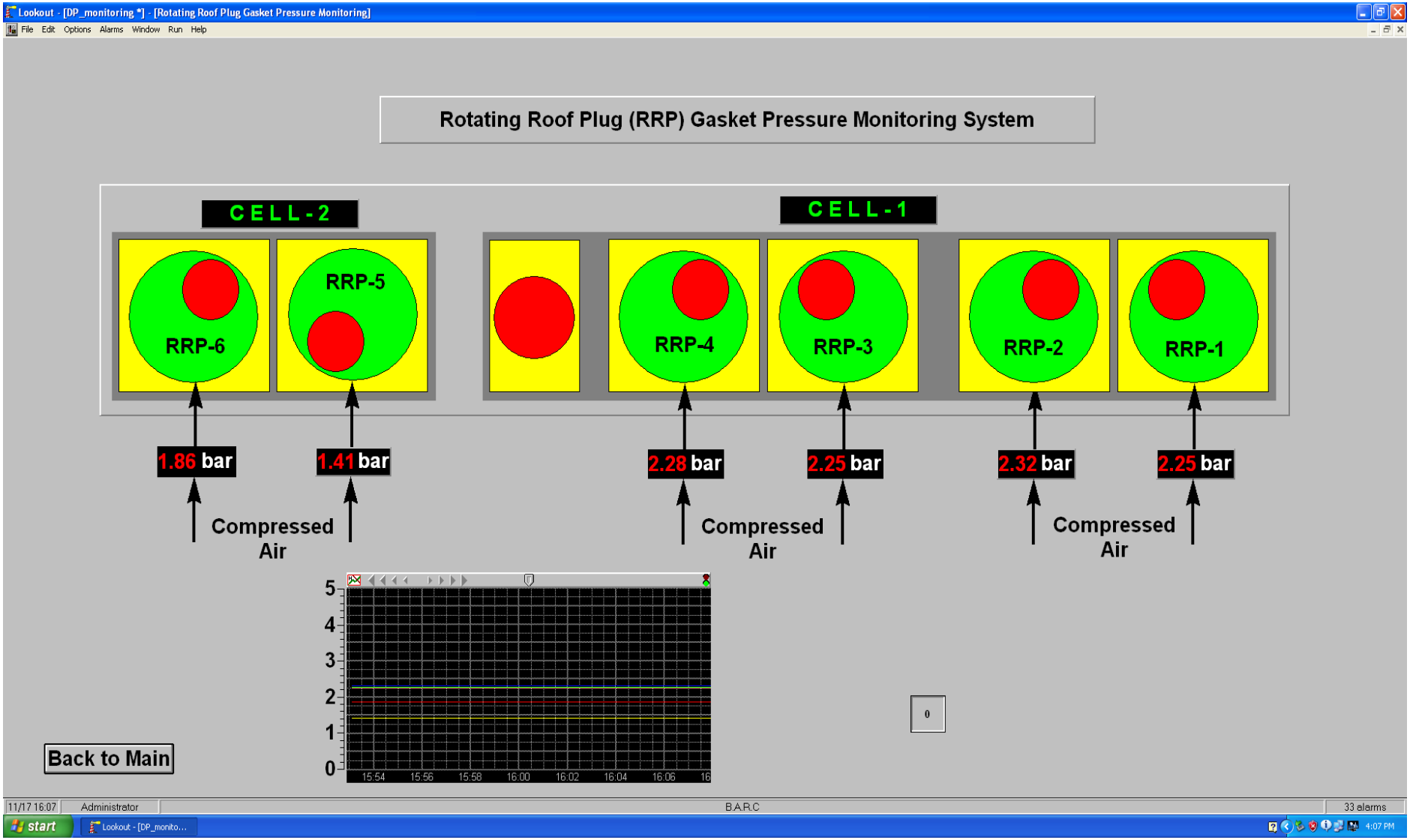
Pressure drop monitoring across the cell & lab exhaust filters

II. Online data acquisition and monitoring systems (Contd.)



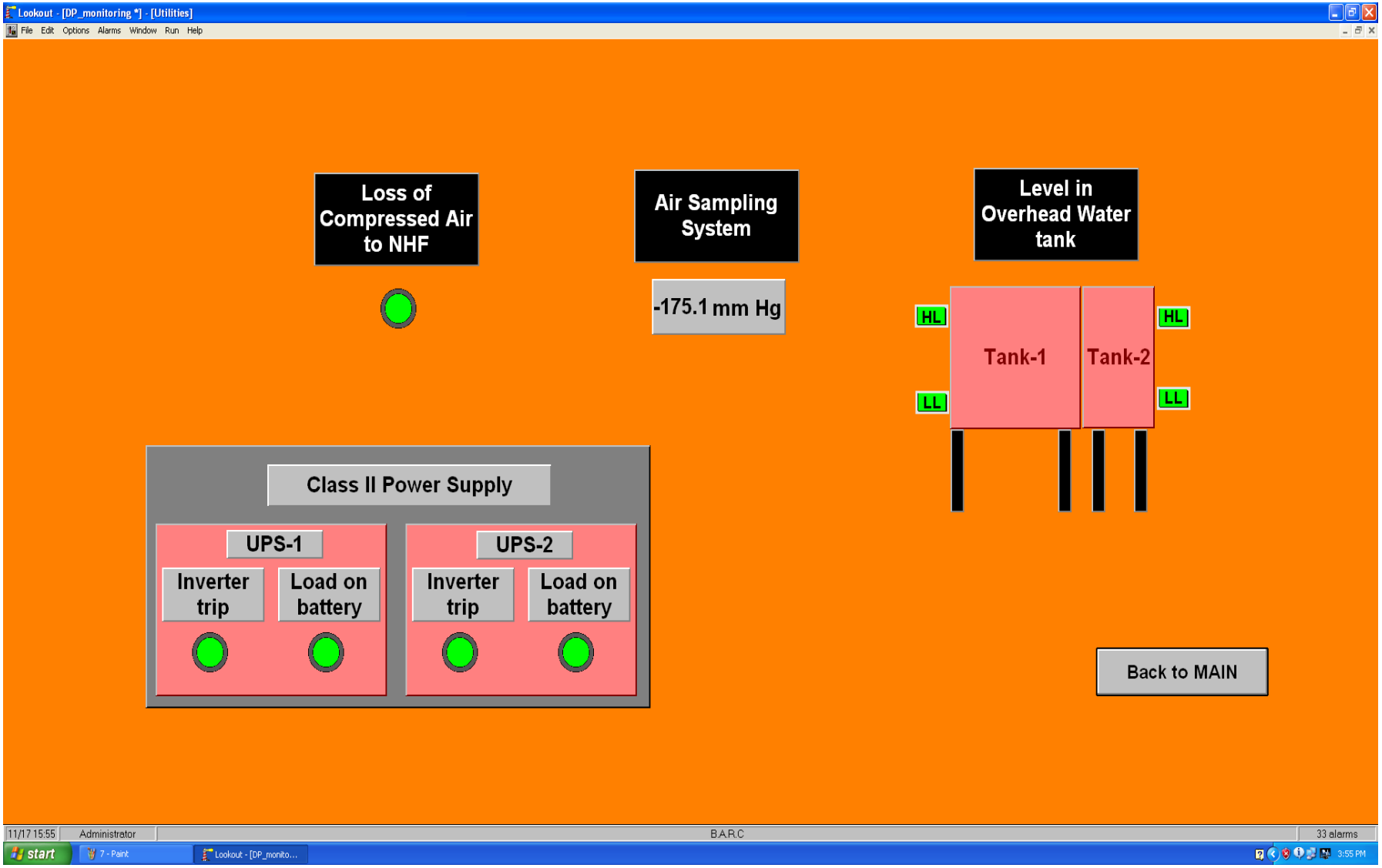
Liquid effluent collection and pumping system monitoring console

II. Online data acquisition and monitoring systems (Contd.)



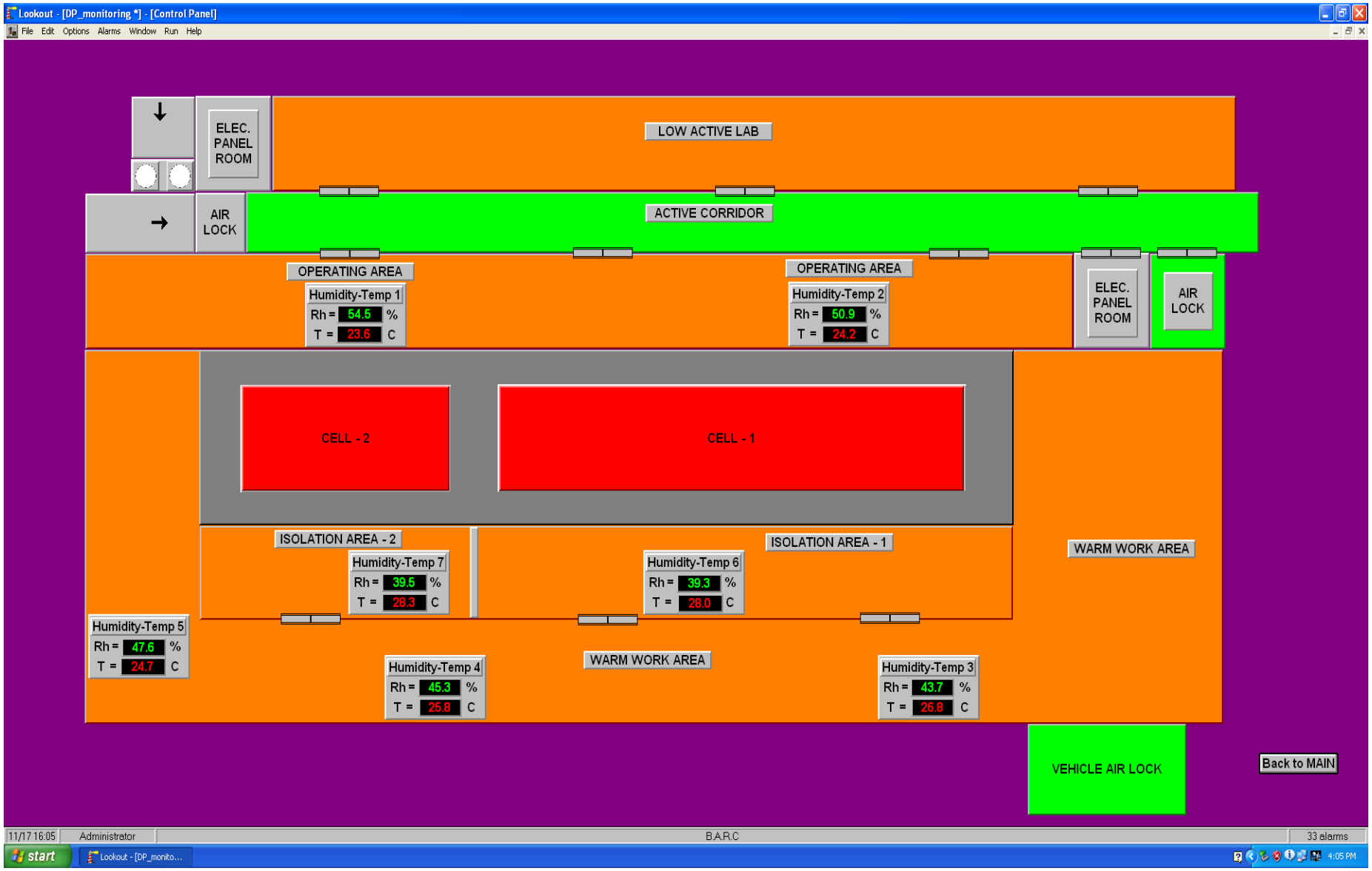
Roof plug inflatable gasket pressure monitoring

II. Online data acquisition and monitoring systems (Contd.)



Real time monitoring of loss of compressed air, class II power status, air sampling system status and normal water supply status

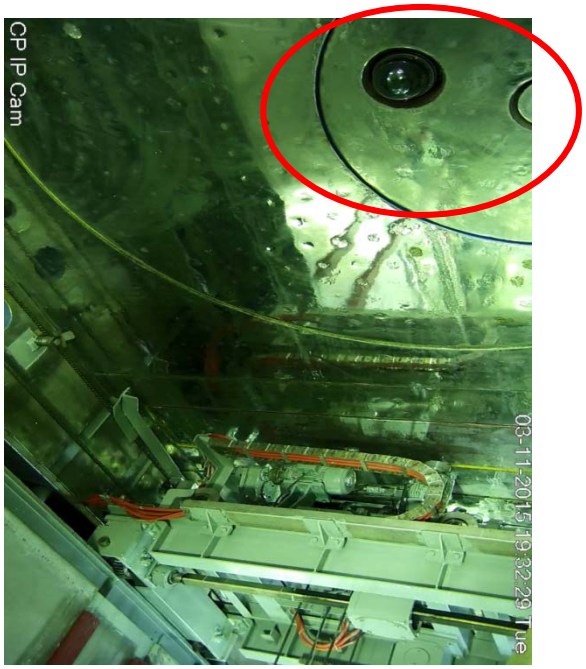
II. Online data acquisition and monitoring systems (Contd.)



Real time monitoring of temperature and relative humidity

III. In-cell Equipments

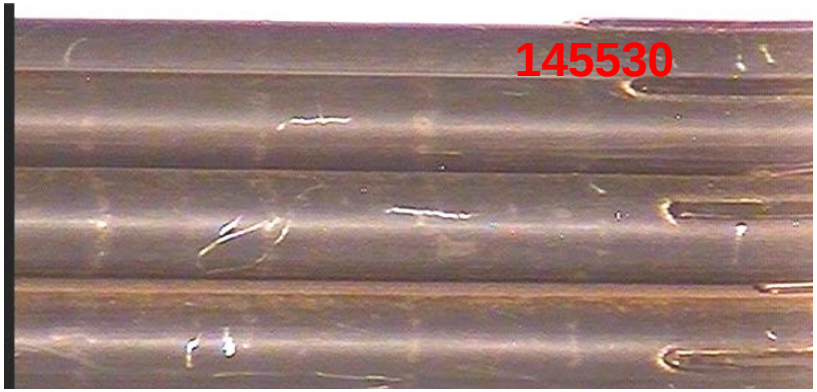
Visual Examination



PTZ camera installed on hot cell roof

High definition PTZ camera with 30X optical and 16X digital zoom installed in hot cell.

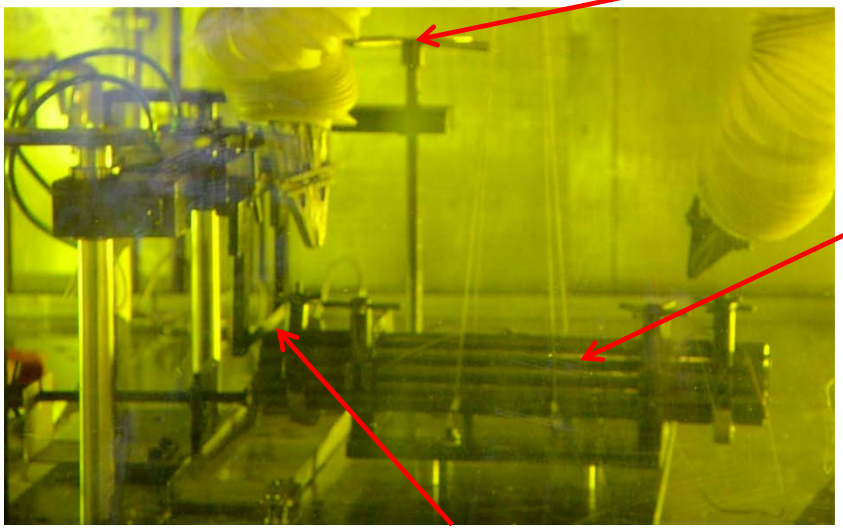
- High resolution images and video
- Very high optical zoom
- Very low cost compare to radiation tolerant camera
- It can work in almost dark condition also like cell black out condition

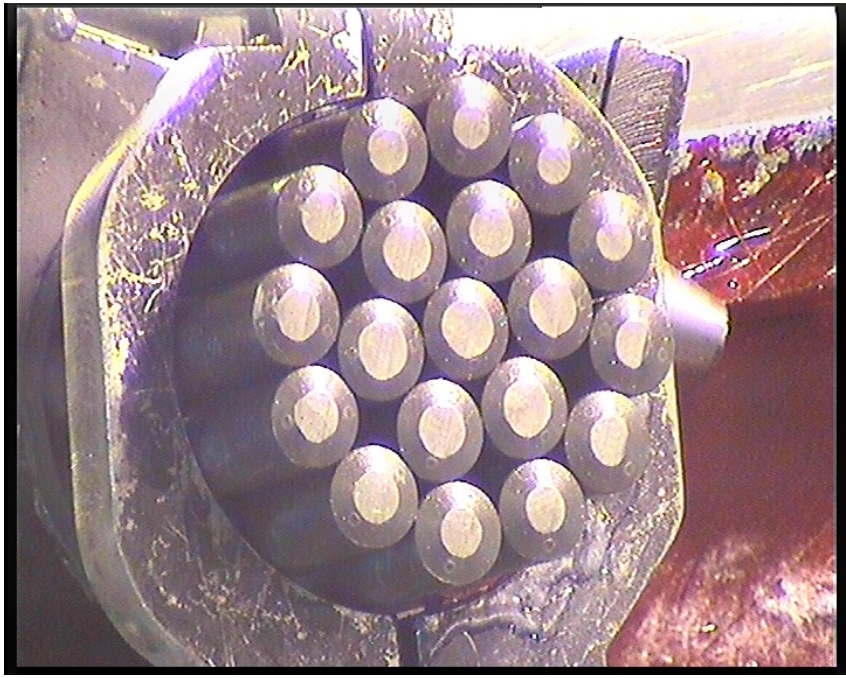


Ridge marks on the outer pins of the high burn-up fuel bundle

III.In-cell Equipments (Contd.)

Bundle Dismantling Machine



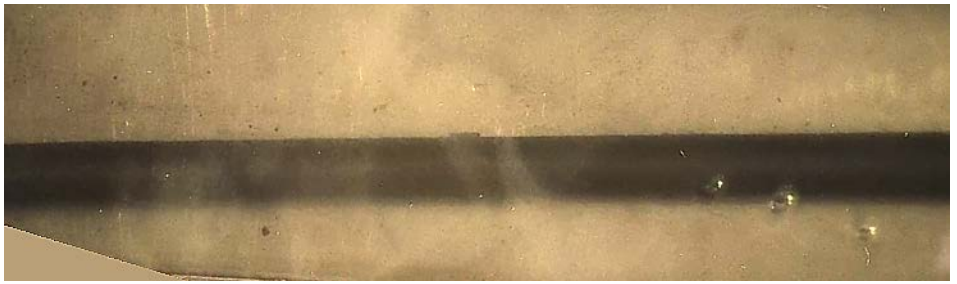


- ✓ **This machine has been used for giving transverse cut to the other components including pressure tube with modification in the fixture**

III.In-cell Equipments (Contd.)

Leak Testing

Liquid Nitrogen-Alcohol Leak Testing

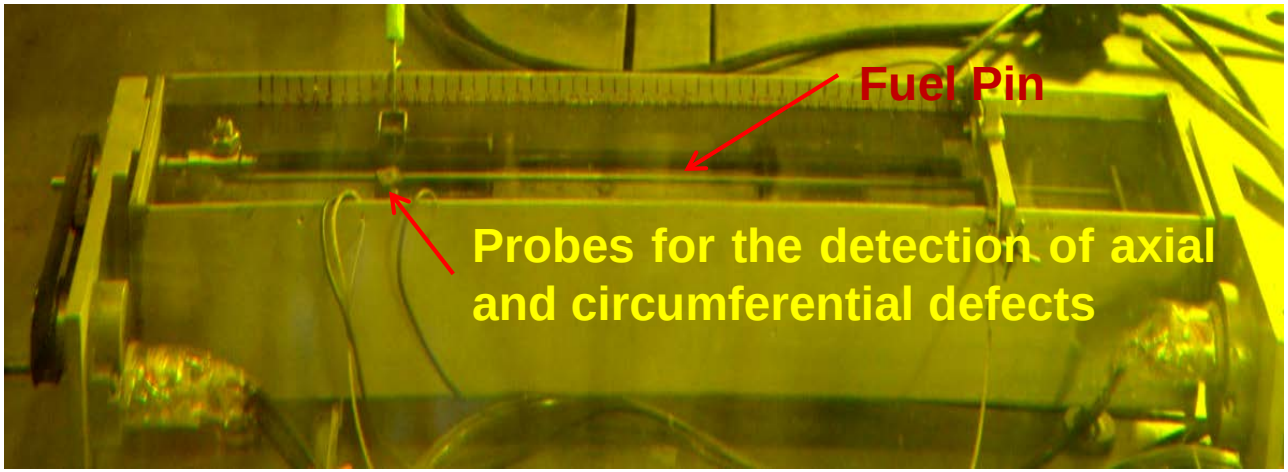


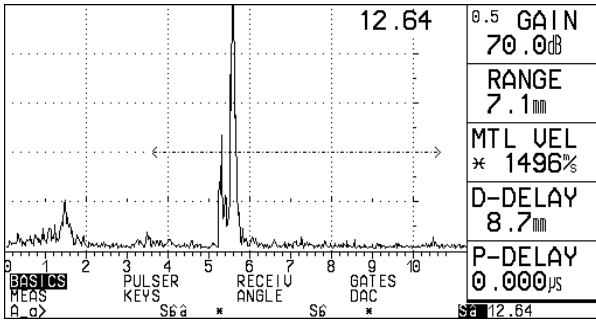
Leak observed in peripheral pin-4 of 540 MWe bundle

Leak observed in peripheral pin-18 of 540 MWe bundle

III.In-cell Equipments (Contd.)

Ultrasonic Testing



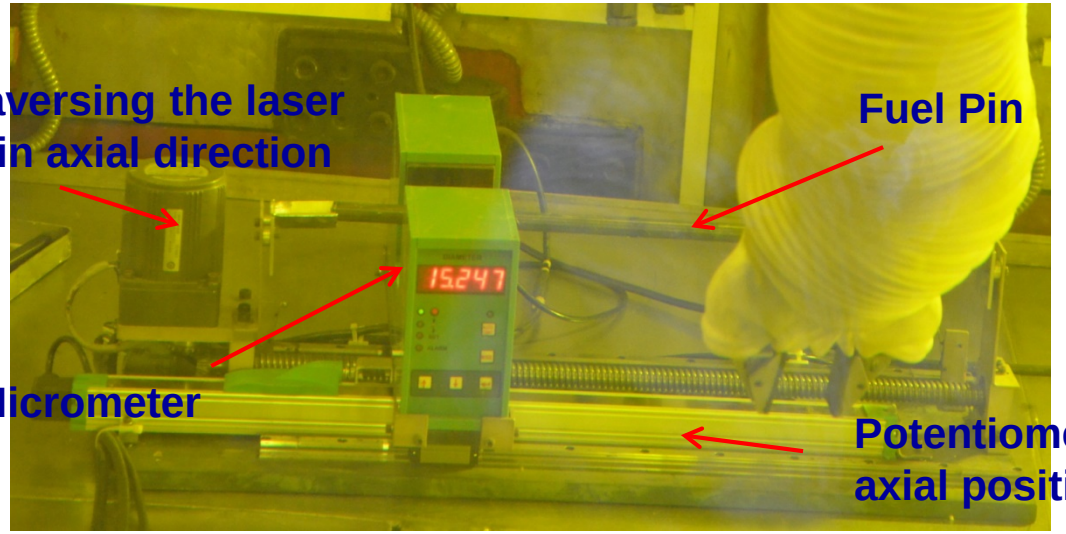


Axial Defect observed in a pin

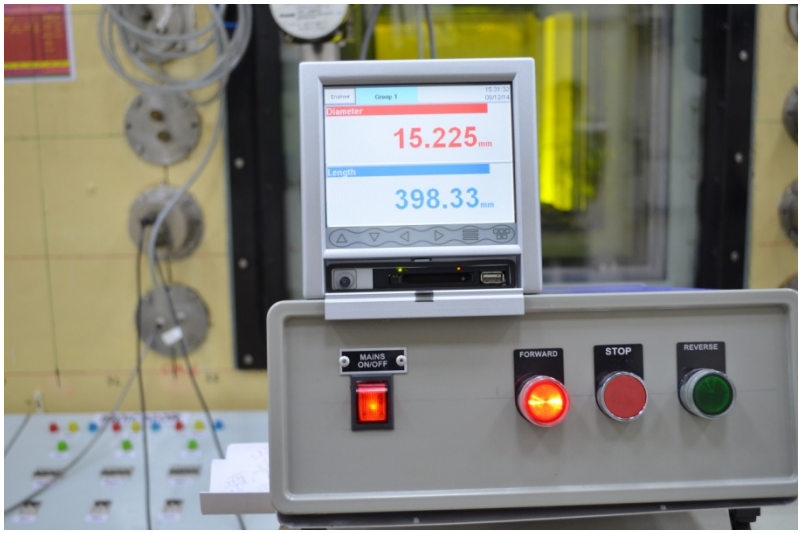
- ✓ **Ultrasonic testing was carried out to check the soundness of the clad and end plug weld. UT signals indicating crack in the clad were observed near the failure locations of all the failed fuel pins.**
- ✓ **The crack tips are identified using this technique for further examination.**
- ✓ **For the examination of the pressure tube from OD side, ultrasonic probes are inserted through sleeves and scanning carried-out at the desired locations using MSMs.**

III.In-cell Equipments (Contd.)

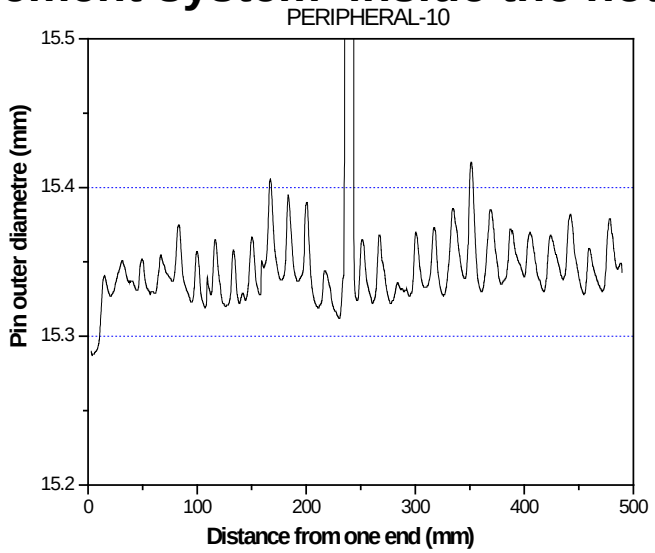
Laser Profilometry



Non-contact laser based diameter profile measurement system inside the hot cell



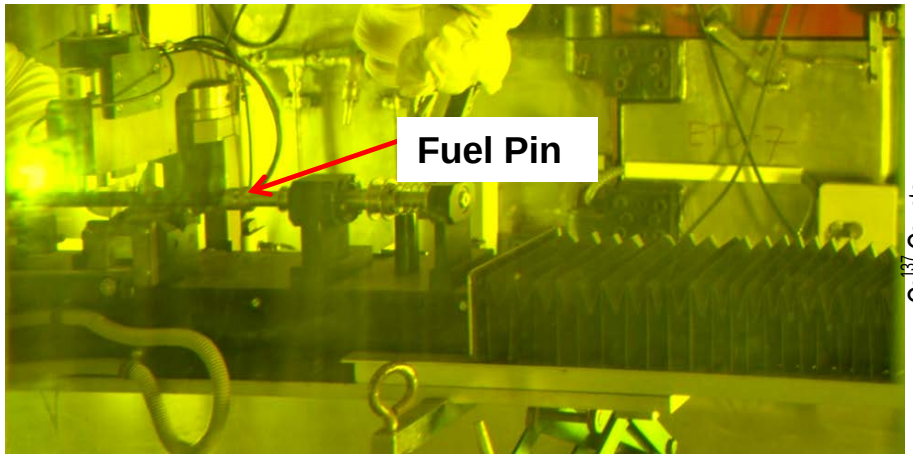
DAQ for diameter profile measurement system in operating area



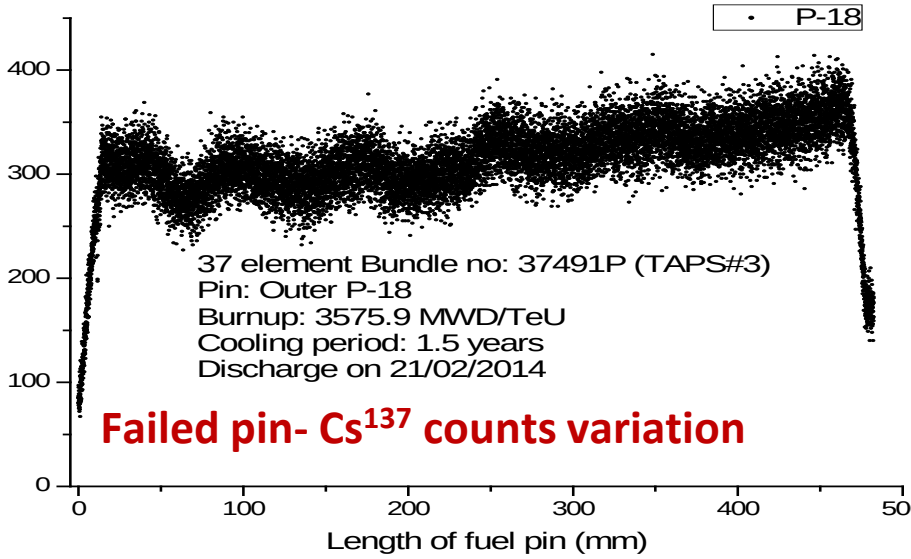
Ridges observed in the peripheral pin of high burn-up bundle

III.In-cell Equipments (Contd.)

Gamma-scanning



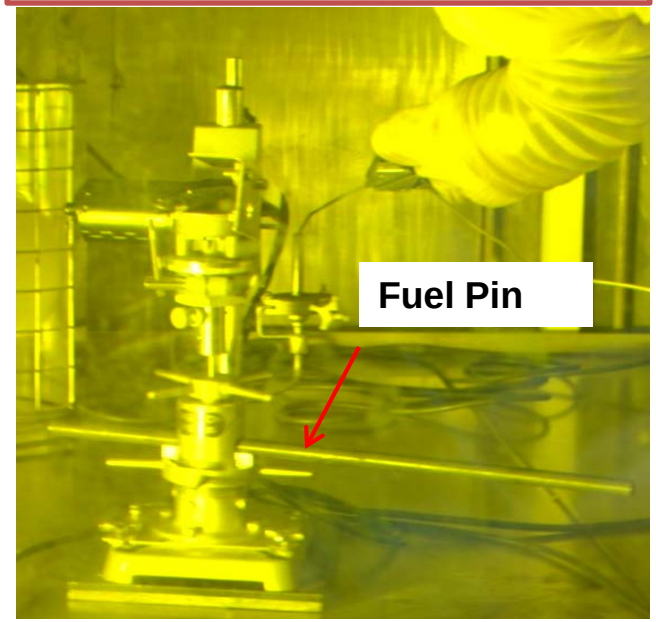
Gamma scanning Set-up



- Gamma-scanning is a nondestructive method for measuring the relative distributions of fission products in irradiated fuel pins that helps to generate information on axial burn-up distribution and distribution of specific fission products.
- Gamma scanning was carried out using a high purity germanium (HPGe) detector.
- A stepper motor controlled scanning stage was used for translation of the fuel pin during gamma scanning.
- The scanning stage provides translational movement to the fuel pin across the collimator inside the hot cell with a speed 0.07 mm/sec.

III.In-cell Equipments (Contd.)

Fission Gas Measurement

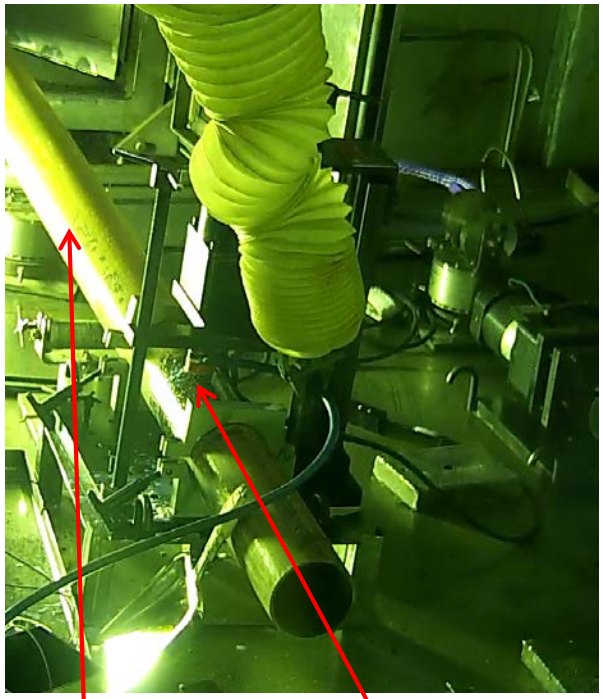


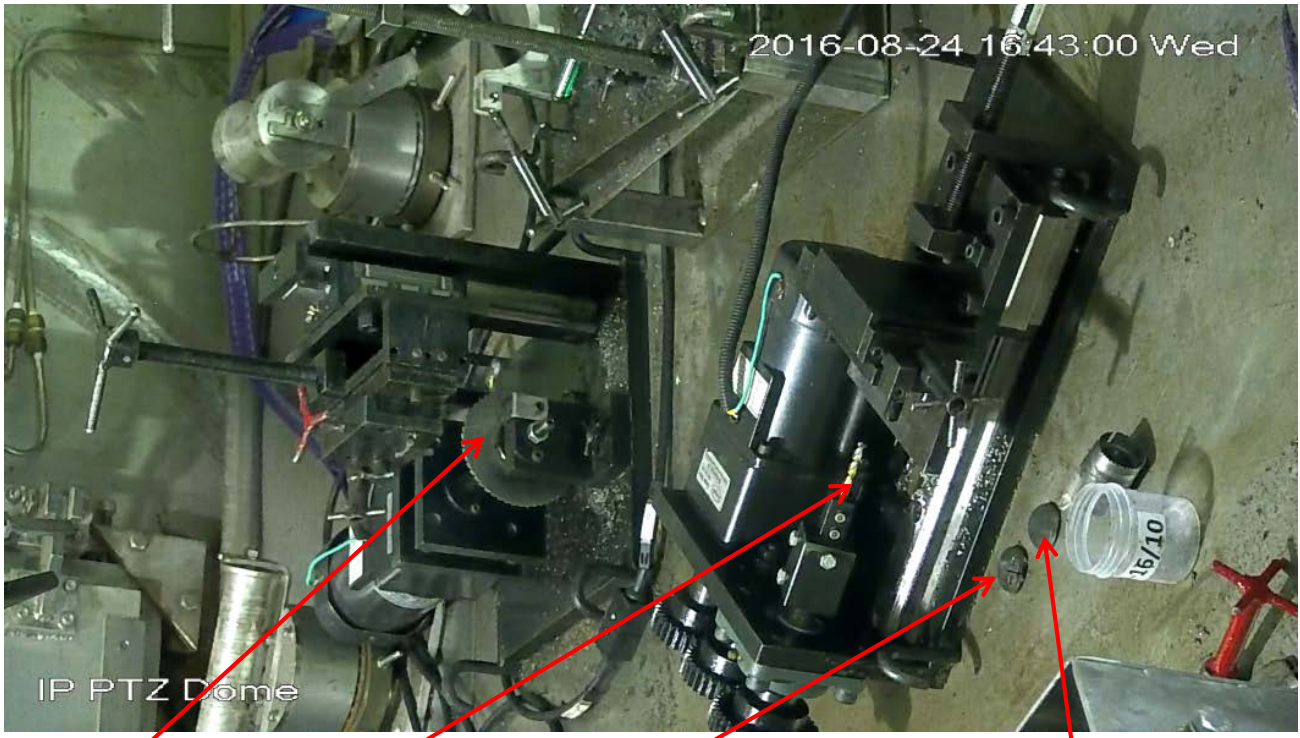
Fission Gas Measurement Set-up

- ✓ The estimation of the quantity of the released fission gases inside the fuel pins and their composition is carried out using the puncture test setup.
- ✓ The setup essentially consists of a puncture chamber fixed inside the hot cell, which is connected to the gas collection and measuring part located in the operating area, by means of stainless steel tubes.
- ✓ The estimation of parameters such as system volume, system pressure, void volume of the fuel pin and the pressure and volume of the released gases are carried out by connecting calibration flasks to the system and by applying standard gas laws.

III.In-cell Equipments (Contd.)

Fracture Toughness Sample (DCT) Preparation Set-up





Full length Pressure Tube

30 mm cutter for trepanning

Cutting wheel for notching

Drill bit for the drilling

Trepanned sample after drilling and notching

Trepanned sample

The trepanned samples are also used for metallography, H/D analysis, TEM sample preparation and any other required tests for the characterization of full length pressure tubes

III.In-cell Equipments (Contd.)

Crimping machine

Crimping press

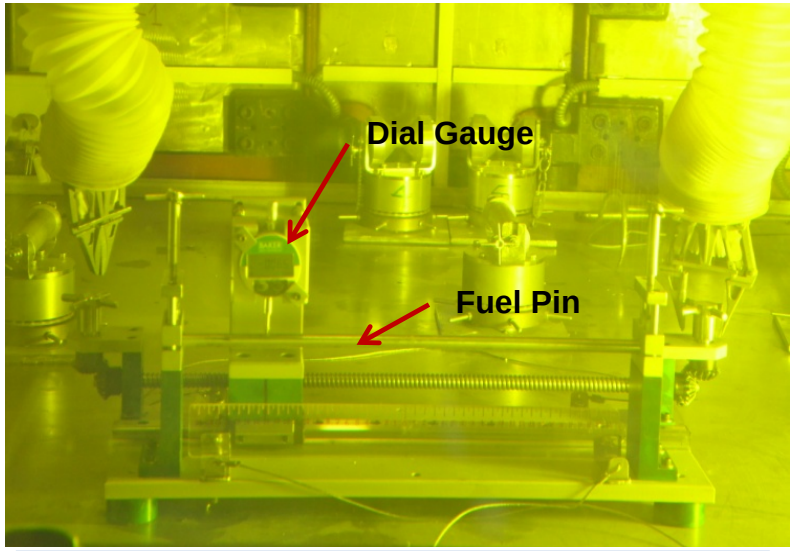
Al can similar to the dimension of fuel bundle

Dent marks after crimping

Crimping machine for crimping of aluminum can

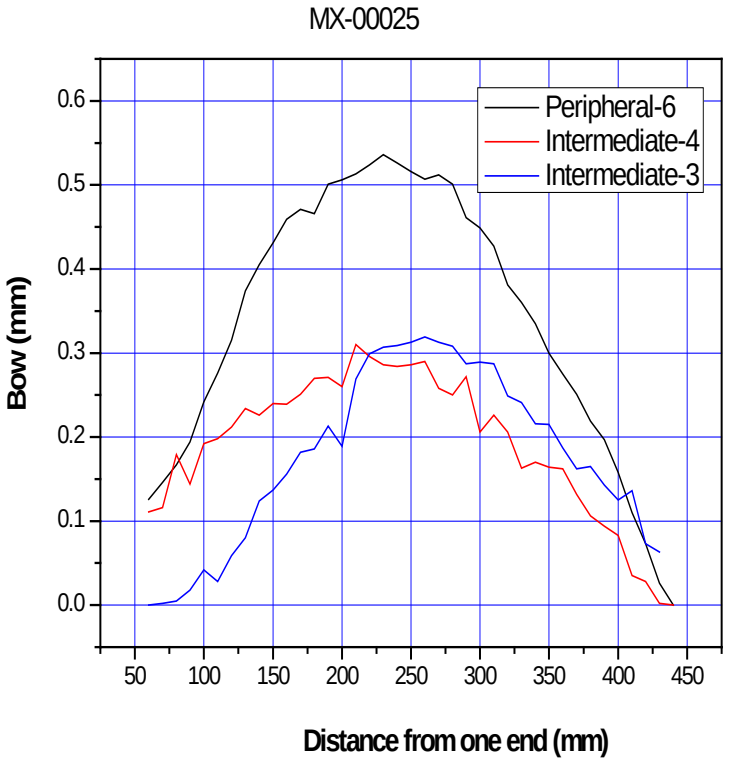
- ✓ For the transfer intact fuel pins to fuel storage pool for storage and further processing which is being done by canning in a specially designed Aluminum (Al) can.
- ✓ Al can dimensions and geometry is equivalent to the PHWR 220 MWe fuel bundle. It has a blind welded cap at one end and a threaded cap at other end.
- ✓ After placing intact fuel pins in the Al can, threaded cap is fitted with the help of manipulators.
- ✓ Locking of threaded cap is achieved by making localized dents on the outer surface of Al can.

III.In-cell Equipments (Contd.)



Bow Measurement set-up

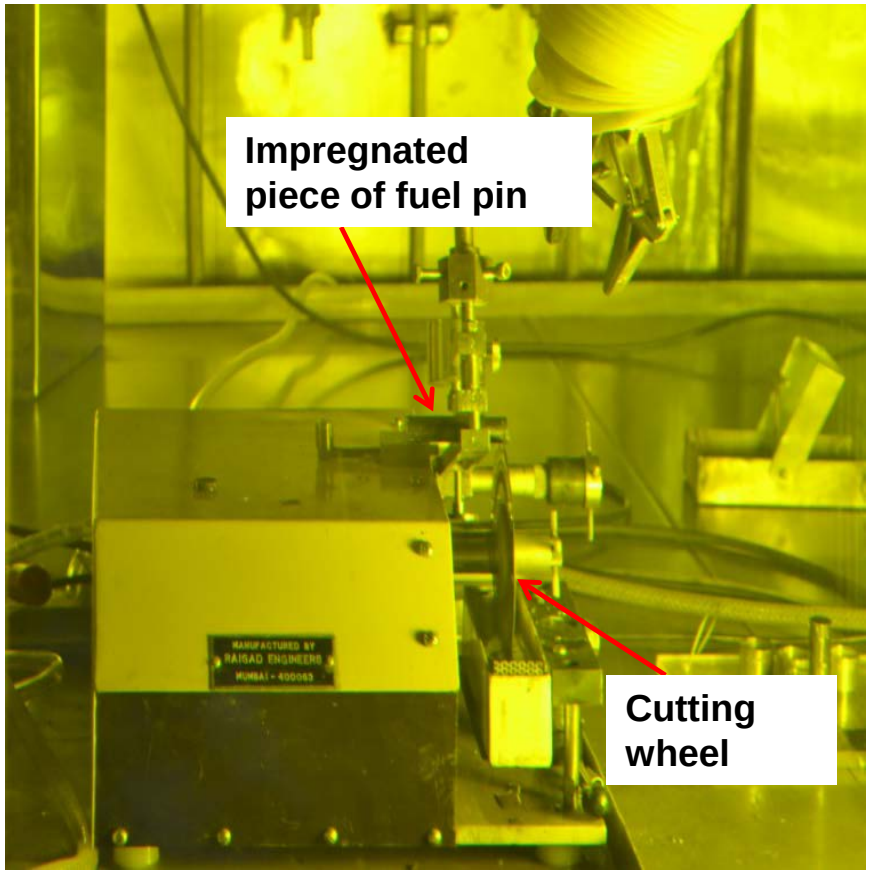
- **Bowing of fuel bundles result in differential flow of coolant which may lead to localized heating and failure of the fuel elements.**
- **During PIE, bow of individual fuel pins are measured in hot cell using movable dial gauge mounted over a leveled flat platform.**
- **The pin is rotated and the bow is measured at different orientations of the pin.**



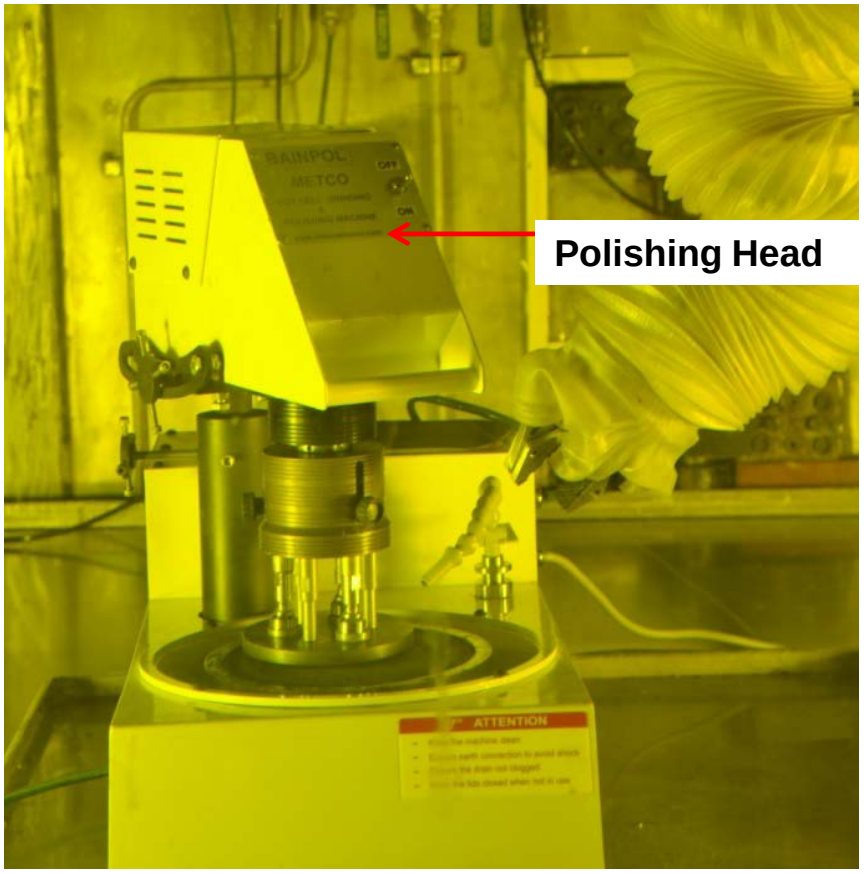
Bow measurement carried-out for MOX bundle

III.In-cell Equipments (Contd.)

Fuel Pin Cutting and sample preparation for metallography



Slow speed cut-off machine



Remotely operated grinder-polisher

Summary

- The NHF has a charging port with the maximum opening (square) of 500mm x 500mm size which will facilitate loading of larger components like LWR fuel assembly, control blade assembly etc.
- The larger length of the cell in the new hot cell being 16.9m as compared to 4.8m in the old hot cell provides the advantage of examining longer components like full length irradiated pressure tube, LWR fuel etc.
- Enhanced shielding capacity of new hot cells
- NHF is provided with in cell crane and cranes in all radioactive areas which facilitates handling of larger irradiated components and heavier shielding cask.
- NHF is provided with lead cells for examination of irradiated material of low activity.
- NHF is provided with automated data acquisition and monitoring system. All safety related parameter, indication and alarms are available in central console.
- Various characterization facilities equipped in hot-cells and lead-cells enable complete evaluation of reactor components.

THANK YOU