

INDIGENOUS DEVELOPMENT OF MINIATURE UNDERWATER RADIATION RESISTANT CCTV CAMERA FOR REMOTISED INSPECTION OF COOLANT CHANNELS OF PHWRS

R.K. Puri, A.K. Haruray, M. Padmanabhan, H.M. Bapat and Manjit Singh

Division of Remote Handling & Robotics
Bhabha Atomic Research Centre

Introduction

Under IX-Plan project, “Development of Tools and Techniques” (Power-6), development of state-of-art technologies for in-service inspection of coolant channels of PHWRs was taken up at DRHR. Under this project, a Miniature Underwater Radiation Resistant CCTV Camera for visual inspection of coolant channels has been developed. The camera has been designed to be compatible with BARCIS delivery system. The development has resulted in achieving self-reliance in high tech area and substantial savings in cost.

Fig. 1 shows the CCTV camera system. The system consists of Camera Head, Camera

Control Unit and the Monitor. The Camera is specially designed with only minimum electronic components (Pick-up tube & pre-amplifier PCB) working in high radiation environment. All other electronic components needed for camera operation are built in the Camera Control Unit, which is located outside radiation environment. The optical and electronic components of the Camera have been specially developed and qualified for use in radiation field of 10^6 Rads/hr for an integrated dose of 10^8 Rads. Gamma Chamber 5000 has been used for irradiation testing of optical and electronics components. CG&CRI and ECIL have helped in the fabrication of optical and electronics components respectively.



Fig. 1 - Miniature Underwater Radiation Resistant CCTV Camera System

Camera Head

Fig. 2 shows the Camera Head. The Camera Head consists of 2/3 inches Yoke Assembly, 2/3 inches Pick-up Tube, Tube Socket PCB, Pre-amplifier and Macro Motor for focus, a Rotating Mirror for radial viewing, a motor for rotating the mirror, and Illumination Head at the front end of camera and water sealing arrangements

and centring provisions. The Camera Head is designed to be interchangeable with BARCIS Inspection Head. The assembly of Camera Head and BARCIS Sealing Plug is loaded into the coolant channel using Fuelling Machine. Fig.3 shows the assembly of Camera Head and BARCIS Sealing Plug.

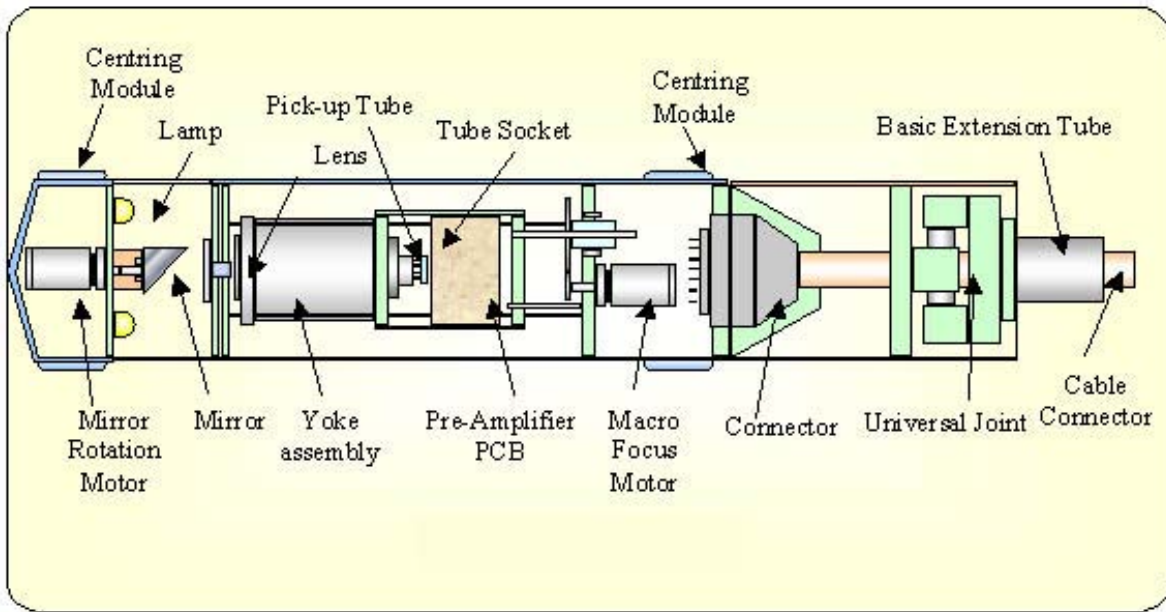


Fig.2 Camera Head

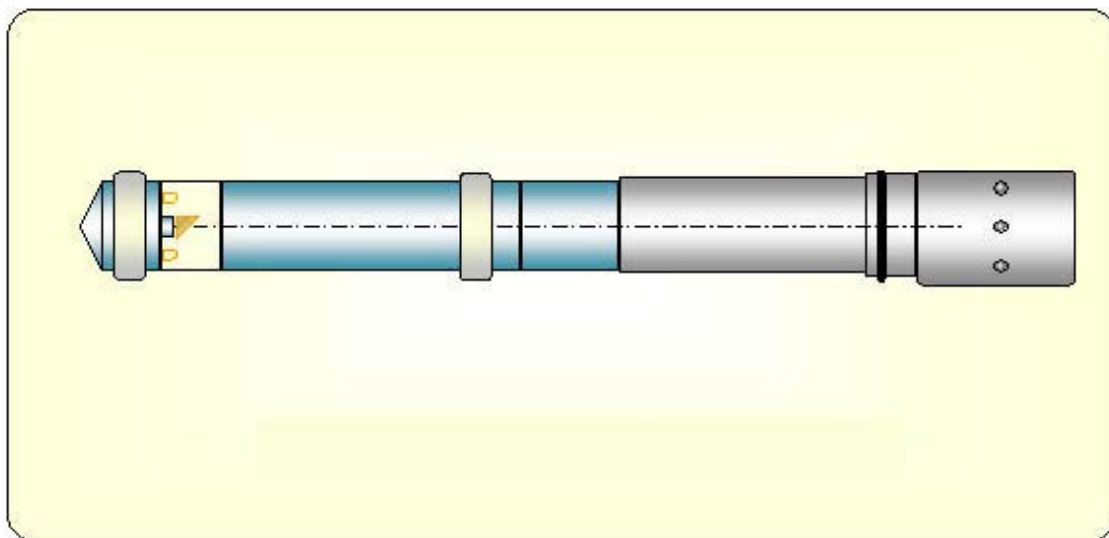


Fig. 3 Camera Head with Special Sealing Plug

Specification of Camera Head

Radiation tolerance	:	100 M Rad @ 1 M Rad per hour
Pickup element	:	2/3" non-browning vidicon tube
Resolution	:	Better than 600 lines at the centre
Sensitivity	:	10 lux on face plate
Illumination	:	3 Halogen bulbs rated at 6 V, 20 W
Controls		Macro focus control
		Illumination control
		Mirror rotation control
Environment (underwater)	:	Rated at 10 Kgs/Sq cm; Working pressure 5 Kgs/Sq cm
Cable	:	Radiation resistant cable length 100 metres

Parts of Camera Head

- **Yoke Assembly:** The yoke consists of the vertical and horizontal deflection coils for the scanning of the beam in the pick-up tube and a focus coil, which controls the beam current for sharp focus.
- **Pick-Up Tube:** The Pick-up Tube is the heart of the camera. This is a 2/3 inches radiation hardened pickup tube. It picks up the image signal and supplies it to the Pre-amplifier.
- **Tube Socket PCB:** The Tube Socket PCB is on the rear side of the Pick-up tube. This PCB supplies the filtered voltages to the electrodes of the Pick-up tube.
- **Pre-amplifier:** The Pre-amplifier is situated next to the Tube Socket PCB. The signals picked up by the tube are fed to the Pre-amplifier before they are given the main video amplifier. This Pre-amplifier PCB is housed in a shielded copper box to avoid stray noise pick-ups. All the components in the PCB can withstand an integrated dose of 100 MRads.
- **Focus Motor:** The Focus Motor is used to adjust the focus. This is done by moving the pick-up tube and yoke assembly on a fixed horizontal axis using the Macro Motor. The motor moves the yoke assembly near or away from the lens depending the focusing required.
- **Illumination Head and rotating mirror:** The Illumination Head is designed to illuminate the dark inside surface of the pressure tube. The Rotating Mirror is provided to obtain radial view of the internal surface of the pressure tube.
- **Multi-component Lens System:** The multi-component lens system is provided to obtain focussed image. Fig. 4 shows optical components. The Optical Components are radiation resistant.

Camera Control Unit (CCU)

CCU provides the user with the following facilities

- Focus control
- Illumination control
- Radial mirror rotation control

Apart from fulfilling the usual functions of a camera control unit i.e. focus control, illumination control and mirror rotation, this unit also houses the following camera electronics.

- Signal Generator
- Horizontal Scanning circuit
- HV Converter
- Video Amplifier

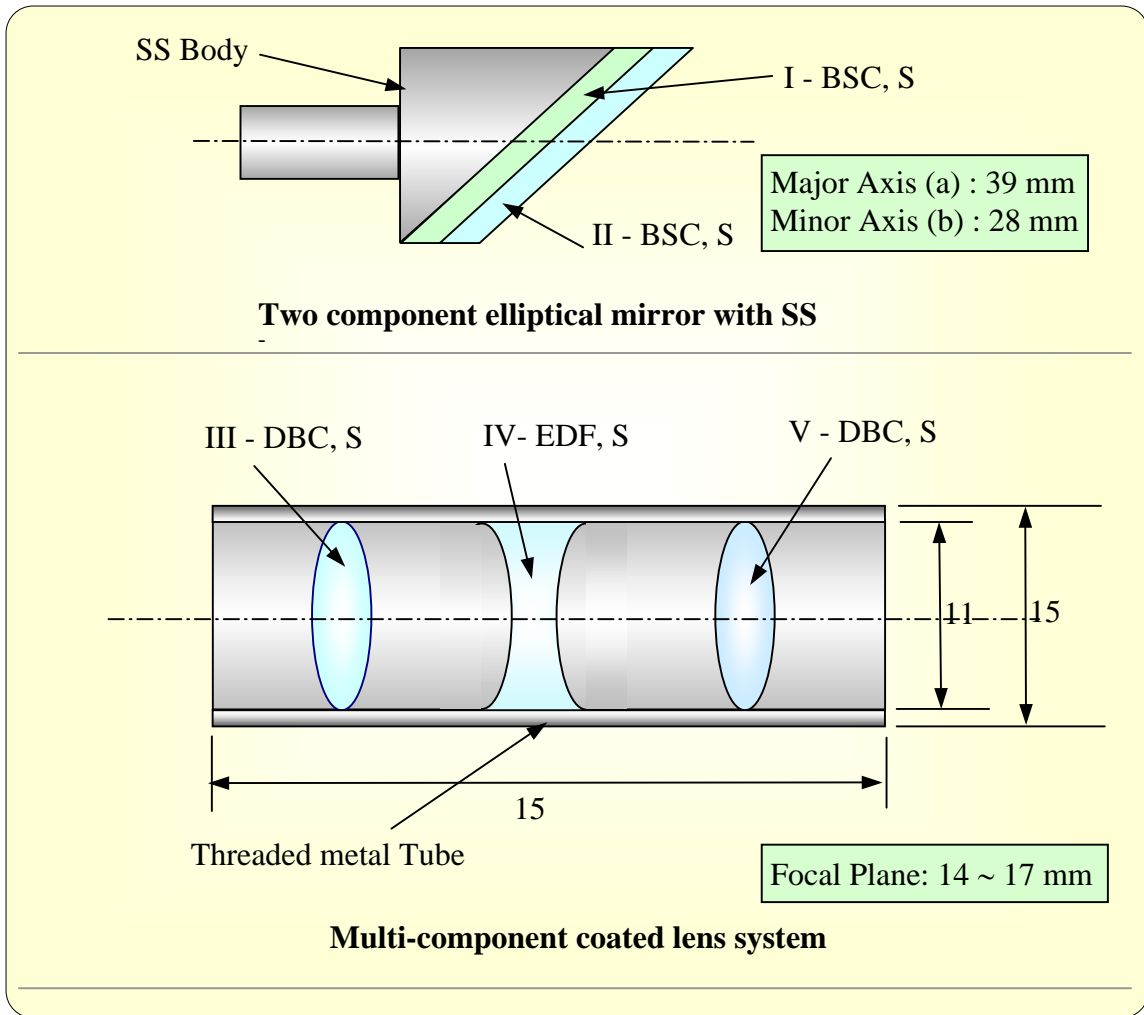


Fig. 4 Optical component of camera

Sr. No.	Glass type	Lens dimensions in mm	%CeO ₂ Doping
I	BSC, S (<i>Borosilicate</i>)	39 (a) x 28 (b) x 4	0.5
II	BSC, S (<i>Borosilicate</i>)	39 (a) x 28 (b) x 2	1.8
III	DBC, S (<i>Dense Barium Crown</i>)	φ 10 x 5	0.5
IV	EDF, S (<i>Extra Dense Flint</i>)	φ 10 x 6	0.5
V	DBC, S (<i>Dense Barium Crown</i>)	φ 10 x 5	0.5

Specification of Camera Control Unit:

Standards	:	CCIR-B
Bandwidth	:	> 5.5 MHz @ 3 db
Sensitivity	:	10 Lux
AGC	:	10/1
Signal to noise ratio	:	40 db
Power supply	:	230 V Ac 50 Hz
Power Consumption	:	50 VA
Video Output	:	1 V p-p with 75 Ω termination

Normally these components would have been housed inside the camera itself. In order to make the camera radiation resistant only essential electronics is housed inside the camera and the all the above-mentioned circuits have been moved into the CCU, which will be situated in the control room.

Applications

It was decided to visually inspect the Calandria tubes before installing the new coolant tubes in

MAPS-2. The camera was successfully used for inspection of 16 Calandria tubes in August 2002. Fig.-5 shows broken pieces of garter springs in the calandria tube and Fig.-6 shows marks of garter springs (at GS location) on the calandria tube. Fig.-7 shows the camera being inserted into the calandria tube through Lattice Tube Protection Sleeve in MAPS mock-up station.

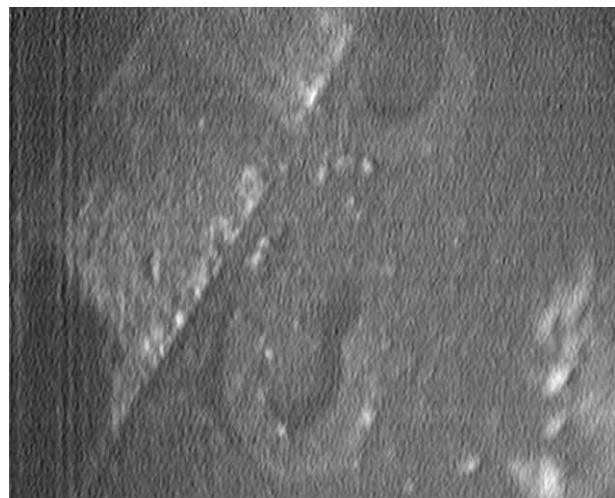


Fig. 5 Broken garter spring pieces

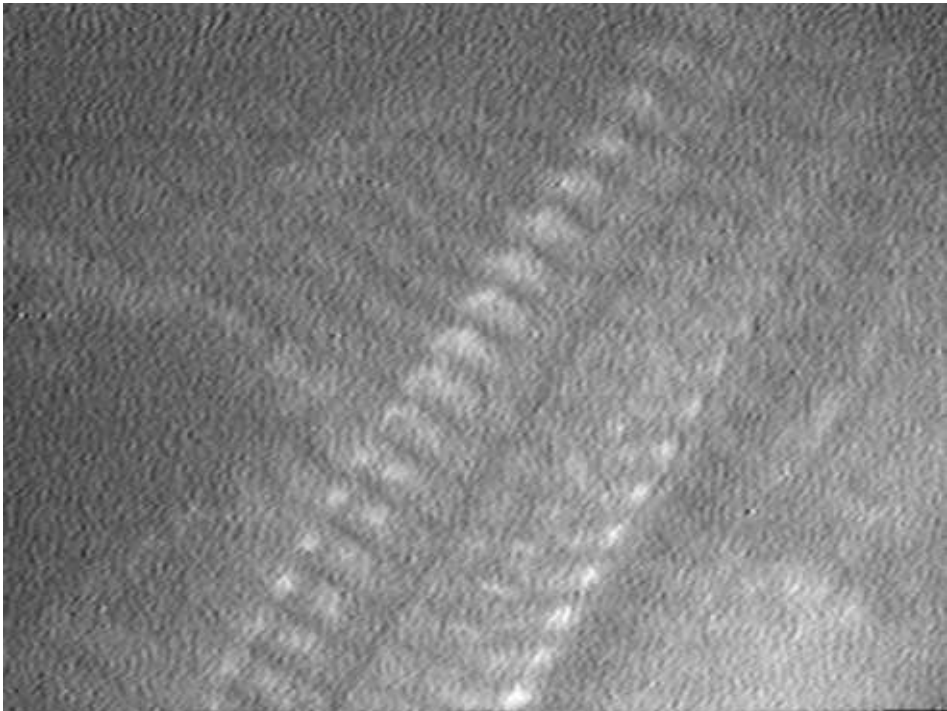


Fig. 6 Garter spring marks on calandria tube



Fig. 7 Camera being inserted into the calandria tube

The camera was also successfully used for visual inspection of ID surface of K-11 coolant channel of KGS-1 reactor in February 2003. Presently the camera is being adopted for visual inspection of Calandria vault of KAPS -1.

Conclusion

The indigenous development of Miniature Underwater Radiation Resistant CCTV Camera for Remotised Inspection of Coolant Channels of PHWRs has been completed. The camera has been designed to be compatible with BARCIS

delivery system. The camera can be used for radial viewing of inside surface of pressure tubes of 220 MWe/500 MWe PHWRs during in-service inspection. The camera can also be used for in-situ inspection of inside surface of calandria tubes prior to installation of pressure tubes. This development has resulted in self-reliance in high tech area and substantial savings in cost. With the experience gained during the development, it will be possible to develop radiation resistant CCTV camera with pan, tilt and zoom for use in hot cells & water pools.

Mr Mahadeva Padmanabhan is the recipient of the DAE Technical Excellence Award for the year 2002 for his outstanding contributions in the development of Miniature Underwater Radiation Resistant CCTV Camera for Remote Inspection of Coolant Channels of Pressurised Heavy Water Reactors (PHWRs), computer-controlled Single Crystal X-ray Diffractometer (SCXRD) and BARC Channel Inspection System (BARCIS)

About the authors ...



R.K. Puri of Division of Remote Handling and Robotics, BARC, is heading the In-Service Inspection Section. He is involved in the development of BARCIS system and Radiation Resistant CCTV camera system. He has also developed

micro-arrayer for DNA chip making, sag-measuring tool for pre-service inspection of coolant channels of PHWRs.



A.K. Haruray of DRHR, has worked on the development of BARCIS and Radiation Resistant CCTV Camera system. He has developed a number of devices, tools and fixtures for various NDT applications.



M. Padmanabhan of DRHR has worked on the development of BARCIS and Radiation Resistant CCTV Camera system. He has also worked on the development of Single Crystal X-ray Diffractometer system. He is the recipient of Indian

Physics Association's S.N. Seshadri Memorial Instrumentation Award for 1999.



H.M. Bapat of DRHR has worked on the development of BARCIS, Radiation Resistant CCTV Camera system and Performance Testing & Evaluation system for reactivity control mechanisms of TAPP-3&4.



Manjit Singh is Head, Division of Remote Handling and Robotics, BARC. He joined the BARC Training School in 1972. Mr. Manjit Singh is the recipient of Homi Bhabha award for securing 1st rank in BARC Training School. He has also received 'BARC Technical Excellence Award 1997'. He has pioneered the development of remotised tools for in-service inspection of coolant channels of 220 MWe PHWRs in India. He has been responsible for the design, development and supply of BARCIS (BARC Channel Inspection System) systems to NPCIL. He has pioneered the development of reactivity control mechanisms for use in research and power reactors. He has been responsible for the development of Cobalt-60 Teletherapy machine, Mobile Robot, Rugged Duty Manipulator & KRUSHAK (POTON – Potato & Onion Irradiator).