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ABSTRACT

Neutron filters/attenuators have been designed and constructed as an upgrade of the JET Gamma-Ray Cameras (GRC's). This diagnostics upgrade should reduce the neutron flux at the gamma-ray detectors in a way that it would make possible gamma-ray imaging measurements in high power deuterium JET pulses, and eventually in deuterium-tritium discharges. The attenuators will be placed within the GRC diagnostics system between the vacuum vessel port and the camera collimator radiation shields in the case of both the horizontal camera and the vertical one. When the neutron/gamma camera diagnostics is used for neutron measurements, the neutron attenuators have to be moved out of the detector line-of-sight. The operation of the neutron attenuators is controlled by means of an electro-pneumatic system. The radiation performance of the GRC neutron attenuators as well as the response of the gamma-ray detectors have been addressed by means of neutron and gamma-ray transport calculations. The GRC neutron attenuators assembly was installed on a test stand, tested over a period of five months and subsequently delivered to JET.

1. INTRODUCTION

In the JET tokamak the plasma gamma-ray emission is the result of the interaction of fast ions (fusion reaction products, including alpha particles, NBI ions, ICRH-accelerated ions) with the plasma impurities. The JET gamma-ray plasma diagnostics has already provided valuable information on the characteristics of the fast ion population in plasmas [1, 2]. The applicability of this technique to high performance deuterium and deuterium–tritium JET discharges is however strongly dependent on the fulfilment of rather strict requirements for the definition and characterization of the neutron and gamma radiation fields (e.g., neutron flux on the detector, level of the gamma radiation background). Such requirements can be fulfilled by using so-called neutron/gamma radiation filters (or neutron attenuators) within the gamma-ray diagnostics system.

Using the neutron attenuation factor as the main design parameter a set of three neutron attenuators of different shapes and attenuation lengths has been designed [3], manufactured and tested.

The radiation performance of the GRC neutron attenuators as well as the response of the gamma-ray detectors have been addressed by means of neutron and gamma-ray transport calculations. The calculated attenuation factor is 10^2 for the attenuators of the two cameras and 10^4 for a long version of the vertical camera attenuator. In order to check the results of the numerical calculations experiments have been started using a neutron attenuator prototype installed on a high power pulsed fusion neutron source, the Plasma Focus Installation PF1000 at the Institute of Plasma Physics and Laser Microfusion (IPPLM), Warsaw, Poland [4].

All the components of the neutron attenuator assembly for the gamma-ray cameras (attenuator casings, attenuator support frames and steering and control system) have been manufactured and tested. Mechanic, electric, pneumatic and hydraulic tests have been performed using a test stand that is a full scale replica of the JET gamma-ray cameras configuration.

2. Design of the GRC neutron attenuators

The main objective of an ongoing JET Enhancements (EP2) Gamma-Ray Camera (GRC) diagnostics upgrade is the design, construction and testing of Neutron Attenuators (NA) for the two subsystems of the gamma-ray imaging diagnostics, the horizontal and the vertical cameras. This diagnostic upgrade should make possible gamma-ray imaging measurements in high power deuterium JET pulses, and eventually in Deuterium–Tritium (DT) discharges. Several design versions were developed and evaluated for the JET GRC neutron attenuators during three design phases: conceptual, scheme and detailed design. The main design parameter was the neutron attenuation factor. The following design solutions were finally chosen and developed at the level of detailed design:

- One quasi-crescent shaped neutron attenuator for the horizontal camera.
- Two quasi-trapezoid shaped neutron attenuators for the vertical camera, with different attenuation lengths: a short version, to be used together with the horizontal attenuator for deuterium discharges and a long version to be used for high performance deuterium and DT discharges. All three neutron attenuators consist of a metal casing (Inconel 600) filled with pure light water as attenuating material.

The locations of the neutron attenuators are shown schematically in Fig. 1 together with the detector lines of sight for each of the two gamma-ray cameras. The attenuators are placed within the gamma-ray diagnostics system in the JET Octant 1 between the vacuum port and the camera collimator body (camera radiation shield), in the case of both the horizontal and the vertical camera (Fig. 1). To move the horizontal camera neutron attenuator to and from the working position two movements are required: first a 90^{o} rotation (to the right when looking towards the plasma) and second a 630 mm translation.

Only a 100 mm translation is needed to move the vertical camera neutron attenuator to and from the working position. The attenuators are placed in very harsh environment conditions (high magnetic fields) and for this reason the GRC neutron attenuators are steered and controlled by an electro-pneumatic system, connected with JET Command and Data Acquisition System (CODAS), under Ethernet standard.

3. CONSTRUCTION OF GRC NEUTRON ATTENUATOR ASSEMBLY

The GRC neutron attenuators assembly consists of three main components: the neutron attenuator for the gamma-ray Horizontal Camera (HC-NA), the neutron attenuator for the gamma-ray vertical camera VC-NA), and the steering and control system. The last is used to move the attenuators from the Parking Location (PL) to the Working Location (WL), both for the horizontal and for the vertical camera. The steering and control system also provides the connection with the JET Command and Data Acquisition System (CODAS). All components of the GRC neutron attenuators assembly were installed on an in-house test stand; the entire assembly reproducing at a 1/1 scale the JET installation configuration for neutron attenuators.

3. 1 GRC HORIZONTAL CAMERA ASSEMBLY

The horizontal camera neutron attenuator functions as a neutron filter when it is in working position (in the plane determined by the gamma-ray detectors lines of sight, fig. 1). To move the attenuator casing in and out the detector line of sight a pneumatic system based on a combination of linear and rotating actuators, is used, fig.2. The pneumatic system consists of two linear and two rotating actuators which move the attenuator casing between the two fixed positions: working and parking positions. The components required for actuators command, flow control valves, pneumatic-electric convertors and block valves, are all installed inside a cubicle (the Electro-Pneumatic Cubicle). Pneumatic hoses (25 m long) run between the pneumatic system and the Electro-Pneumatic Cubicle. The electrical parts are installed inside a 19” 4U rack cubicle (the **P**rogrammable **L**ogic **C**ontroller “PLC” Cubicle). An electrical connection runs between the PLC and the Electro-Pneumatic Cubicles. The structure of the steering and control system is the same for both the HC-NA and the VC-NA assemblies.

3.2 GRC VERTICAL CAMERA ASSEMBLY

The vertical camera neutron attenuator (VC-NA) is installed on the JET gamma-ray vertical camera by means of mounting frames, Fig.3. To move in and out of the working location the attenuator is translated horizontally by 100 mm by means of the pneumatic system.

3.3 CONTROL OF THE GRC NEUTRON ATTENUATOR ASSEMBLY

The GRC neutron attenuators can be locally controlled and monitored by CODAS through the dedicated PLC. This is to be done in accordance with requirements of the GRC diagnostics Responsible Officer. To avoid any unauthorised commands, the PLC Cubicle is fitted with a key lock, figure 4. The attenuator movements can only be requested locally while monitored by CODAS. Nevertheless the PLC can be controlled remotely by means of the Ethernet connection, and this feature was tested also.

During the in-house attenuator assembly tests the movements were initiated using the Operator Unit. The following information is displayed on the Operator Unit: pressure status, neutron attenuators positions for horizontal and vertical camera and event messages (pressure failures and attenuators displacement timeout).

4. IN-HOUSE TESTS OF THE GRC NEUTRON ATTENUATORS ASSEMBLY

The operation of the neutron attenuator assembly was tested before delivery to JET. The in-house tests were carried out on a test stand specifically designed and constructed for this purpose. Its bloc diagram is shown in fig.5.

The system was tested at different pressure values: 5; 6 and 7 bars. For each pressure value, 100 cycles (attenuator from parking to working location and return) were carried out. Table 1 and table 2 show the measured the displacement time mean values for HC-NA and VC-NA. These mean values were obtained for the lowest speed of actuators for which a smooth attenuator movement was obtained.

The mean values of displacement time for the HC include a 30 s delay introduced through the PLC program, in order to obtain a better balancing between the pressures inside the actuator cylinders.

CONCLUSIONS

A complex system of neutron filters/attenuators have been designed and constructed for the JET gamma-ray cameras (GRC). The GRC neutron attenuator assembly was installed on a 1/1 scale test stand and tested over a period of five months. More than 300 mechanical, electrical, pneumatically and hydraulic tests were performed. All tests showed good results and safe operation.

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REFERENCES

[1]. V.G. Kiptily, F.E. Cecil, S.S. Medley, Gamma ray diagnostics of high temperature magnetically confined fusion plasmas, Plasma Physics and Controlled Fusion **48** (2006) R59–R82.

[2]. V.G. Kiptily, D. Borba, F.E. Cecil, M. Cecconello, D. Darrow, P.C. de Vries, V. Goloborod'ko, K. Hill, T. Johnson, A. Murari, F. Nabais, S.D. Pinches, M. Reich, S.E. Sharapov, V. Yavorskij, I.N. Chugunov, D.B. Gin, G. Gorini, A.E. Shevelev, V. Zoita, Fast ion JET diagnostics: confinement and losses, AIP 988 (2008) 283.

[3]. V. Zoita, et al., Design of the JET upgraded gamma-ray cameras, Fusion Enginering Design (2009), doi:10.1016/j.fusengdes. 2008.11.026

[4]. M. Scholz et al., "Recent Results of MJ Plasma-Focus Experiment". 6th Dense Z-Pinch Symposium, Oxford, 2005.

	Displacement time (s)	
Working pressure (bar)	**PL to WL**	**WL to PL**
5	48	46.5
6	47	46
7	46.5	45.5

Table 1: Mean values of displacement time for HC-NA.

Working pressure (bar)	Displacement time (s) PL to WL	WL to PL
5	7	10
6	7	8
7	7	7.5

Table 2: Mean values of displacement time for VC-NA.

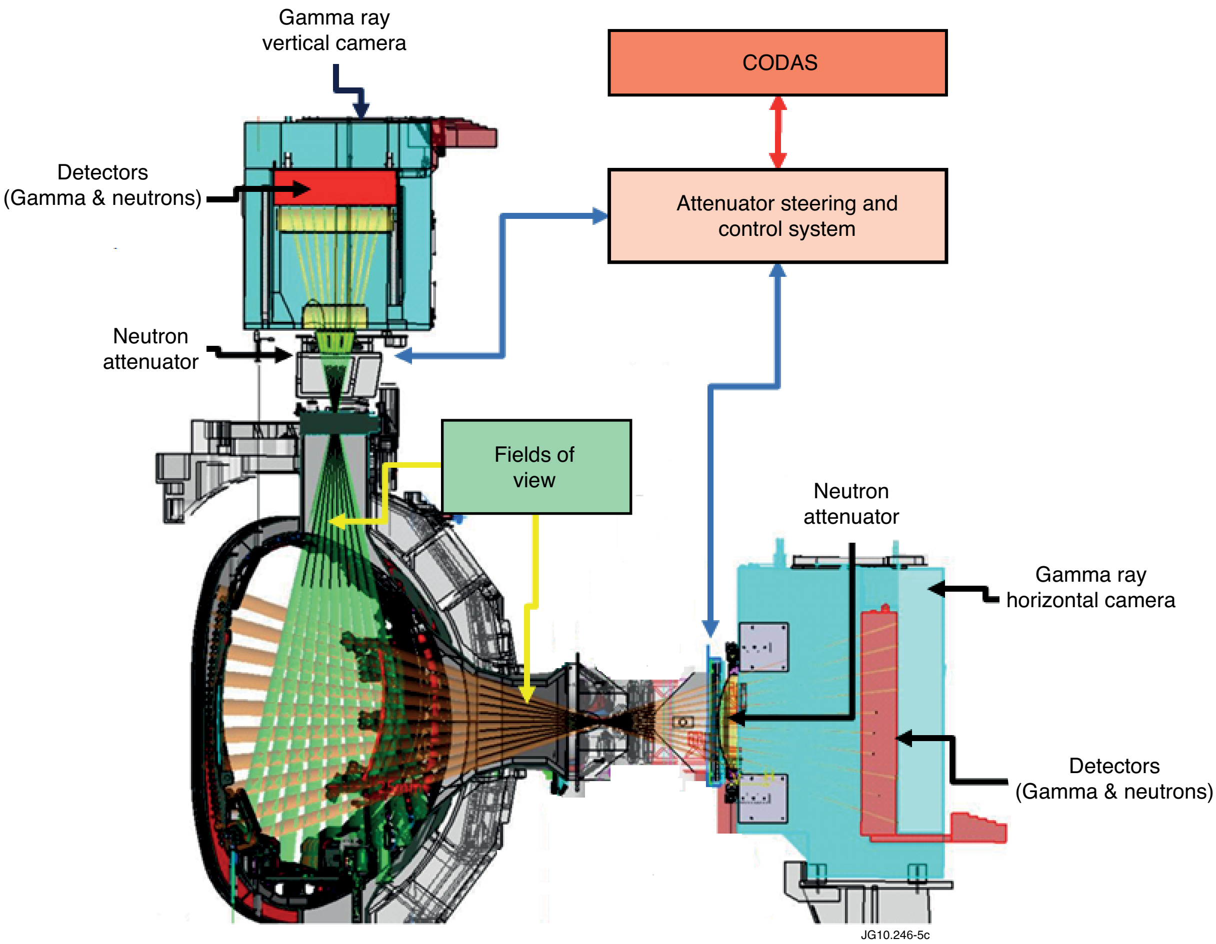

Figure 1: GRC neutron attenuator assembly.

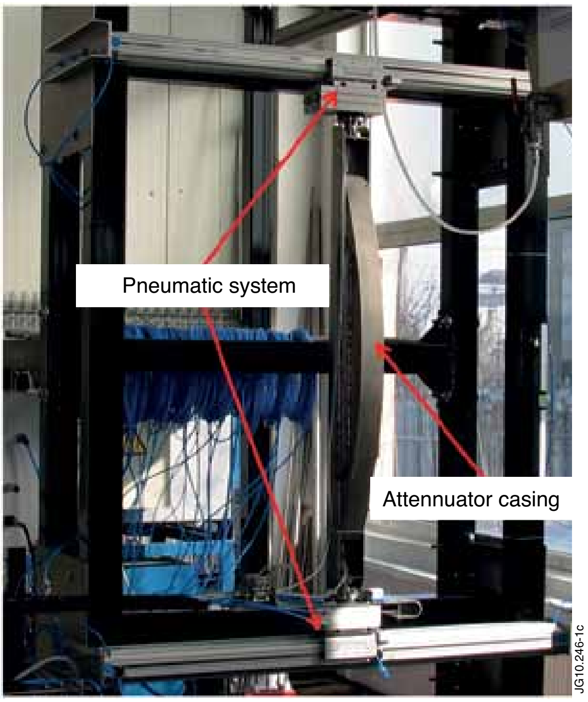

Figure 2: GRC horizontal camera installed on the test stand.

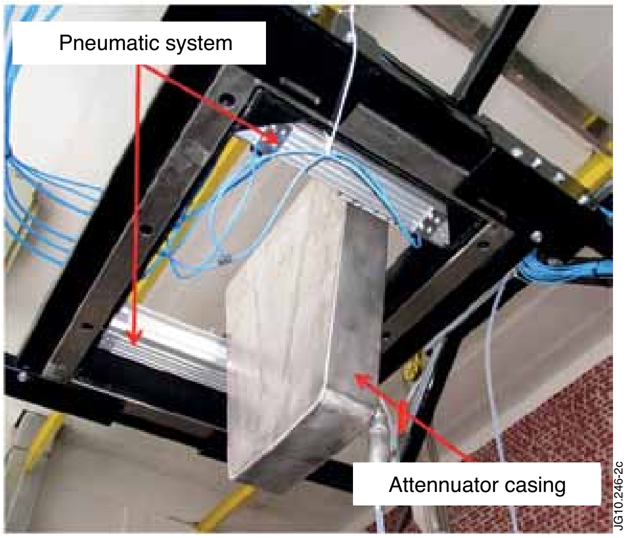

Figure 3: GRC vertical camera installed on the test stand.

Figure 4: PLC Cubicle-Operator unit interface.

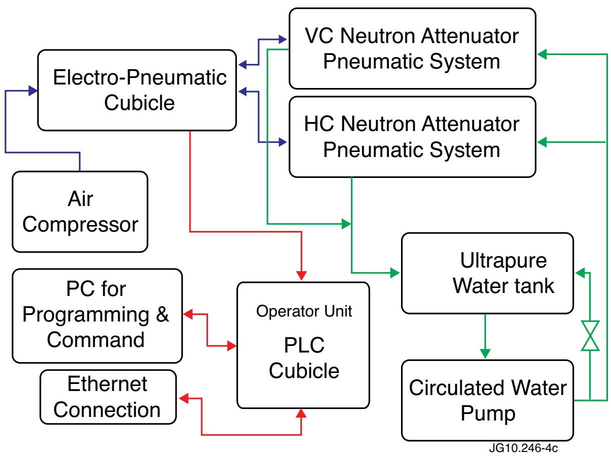

Figure 5: Bloc diagram of the test stand used for in-house tests.