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Development of a Submersible Robot (ROV) to Support Visual Inspection in Triga Type Research Nuclear Reactors

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Introduction

A remotely controlled submersible robot (ROV) was developed for visual inspection of submerged equipment and pipelines, including submerged nuclear reactors and depleted fuel element storage pools.

ROVs are unmanned vehicles operated remotely by a person that allow the operator to remain in a comfortable environment while the ROV works in unhealthy environments.

The equipment was manufactured with components of reduced monetary value and additive manufacturing.

The ROV featured AISI 403 stainless steel shielding to protect against gamma radiation, allowing access to places with ionizing radiation. However, the focus is only on radiological protection against gamma radiation, despite the presence of neutrons from fission. In submerged nuclear reactors. All reactors have control rods that capture neutrons, slowing the reaction and minimizing neutron emissions.

Tests were carried out under gamma ionizing radiation, on the LIG premises, at different dose rates in order to measure the resistance of the ROV circuit to radiation.

b) Assembled ROV

Radiation resistance tests

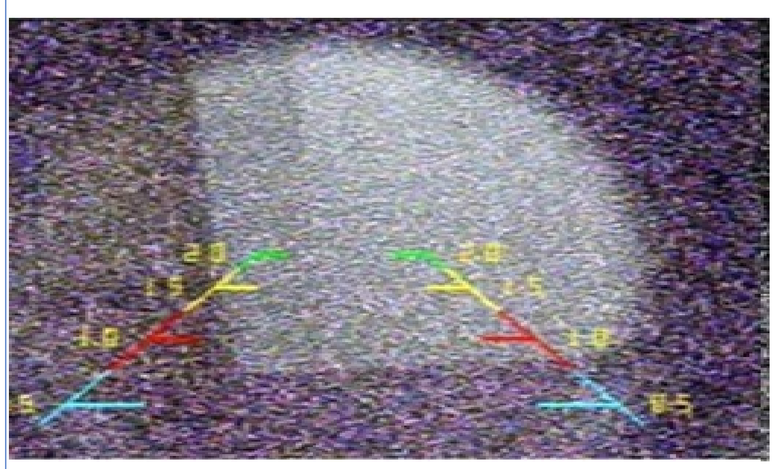
In order to carry out the radiation exposure tests at LIG, a program was made in order to make one of the engines run intermittently to investigate the operation of the ROV between the tests. The main components to be evaluated during the tests are an Arduino Nano® board equipped with an ATMEGA162® processing chip and a generic CMOS camera, commonly used in surveillance devices or automobile maneuvering assistance systems. Table I presents and lists each test performed. It is worth highlighting here the possible variation of 10% more or less of the recorded dose, as well as the activity of the source on the day of the tests, which was 54.696,47 Ci.

Table I: Parameters of the irradiation test done in the LIG.

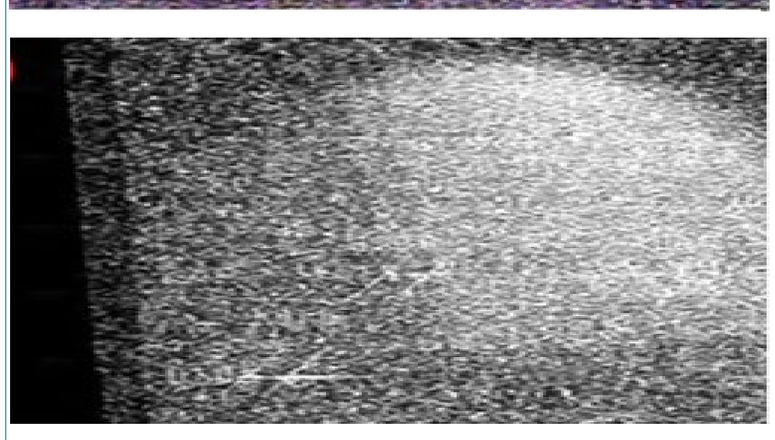
Test number	Total dose (Gy)	Dose rate (Gy/h)	Time (min:s)
1	50	352.72	08:17
2	100	352.72	16:47
3	150	352.72	25:17
4	50	697.50	04:07
5	50	1402.76	01:53
6	100	3074.76	01:43
7	1000	6177.3	09:53

Results and Discussion

During testing, the camera exhibited artifacts due to electron transit during irradiation, with minor permanent damage observed after the second test. A critical failure occurred at 25 minutes during the third test, indicating permanent damage to the camera's semiconductor. This critical failure was repeated in all subsequent tests a few seconds after the irradiation began, the image returning to a normal state when the irradiation stopped. Subsequent testing was done to cause the Arduino Nano® board to fail.



Artifacts created due to electron transit during irradiation



Critical failure at the camera in the 25 minutes mark in the third test.

Conclusions

The ROV was built using robust materials and techniques such as 3D printing, welding, and machining. Irradiation tests were performed and the camera withstood a total dose of approximately 250 Gy at a dose rate of approximately 350 Gy/h, showing critical failure after 45 minutes. The Arduino® installed in the ROV was tested for its ability to operate after exposure to a total dose of 1500 Gy. Although it continued to operate, it was not possible to establish communication with any other device after the test, and only the programming that had already been entered into the Arduino® before the test continued to work. This contrasts with previous tests that showed perfect functioning at a dose of 540 Gy. It is worth mentioning that the Arduino® models used are different models, which may contribute to disparities between the tests.

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