Main techniques used at the LECA facility

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Abstract :

The LECA hot cell laboratory was designed to provide suitable facilities for conducting nuclear irradiation experiments used in the research and development of power reactors in France.
This plant has facilities specifically designed for the safe handling of spent fuel bundles, dismantling and dry hard cutting test samples from fuel rods in preparation for subsequent treatment, double-instrumented rod re-fabrication in hot cells with our laser process.
For post-irradiation examinations, various techniques are used, including weld X-ray inspection and the Eddy Current technique application which is used to locate the pellet gap before shearing.
The re-fabrication technique (CORALIE) uses a laser welding unit to weld the end caps of fuel rods loaded with fuel pellets. The same equipment is also used in making a sealing weld of the pressure hole after helium pressurization of the fuel rod. The technique development includes manufacturing of the properly dimensioned cavity in the fuel pellet stack to house the thermocouple and includes a newly designed pressure transducer.
PLACIDE is a 3-axis flexible high precision milling machine designed to dismantle fuel bundles, fine cutting out samples, metrology, non-destructive tests under the high radioactive environment of hot cells. Coated cutting tools of various profile shapes are operated under full inert gas coverage.
In LECA plant and its extension, experimental fuel rod welds are inspected using X-Ray technique in the re-fabrication cell which validates fabrication.

***Keywords:* Experimental - Fuel - Rod – Instrumentation – Dismantle – X rays inspection**

The objective of this paper is to discuss in detail remote handling equipments (the in-cell remote re-fabrication CORALIE technique, a 3-axis milling machine PLACIDE, a X-rays inspection system) used at the LECA hot cell facility:

1. Coralie bench :

Two elements at the LECA laboratories that will enable us to meet the demand for experimental fuel rod re-fabrication :
Fabrice is the process and CORALIE is the tool used for experimental fuel rod re-fabrication

1.1 Description bench :

CORALIE is a combination of reforming and assembly operations performed by laser and experimental instrumentation. In the figure 1, you see the bench at the time of its delivery and validation with its 6 motorised mvts, the laser tool and its control console.

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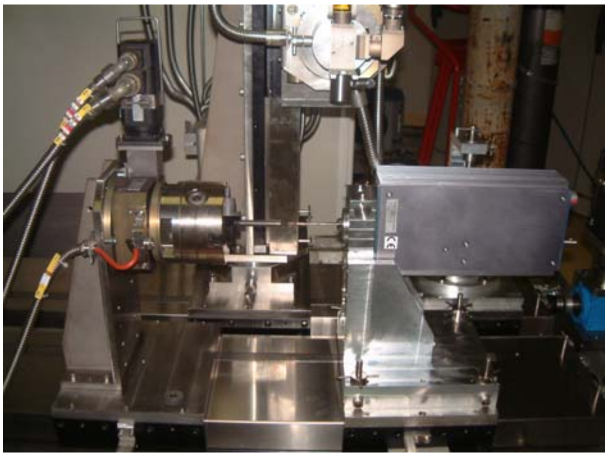


Fig. 1 : Coralie bench

The CORALIE bench was manufactured and placed in the LECA hot cell during refurbishing of the laboratories in order to meet the needs of our partners in terms of instrumentation of spent fuel. The use of a laser replaces to a great extent industrial, the processes used in the past :

- TIG welding,
- diamond-saw cutting,
- TIG seal welding in,
- Marking through etching
- Cladding down-hole drilling

Actually, we have two benches, a cell mock-up for adjustment, qualification and technician training and the other inside the hot cell n° 2 of LECA which is used for fabrication on spent fuel. The control panel with numerical controls for 2 machines enables us to program automatic sequences for complex movements. This YAG-type laser is pulsed and focused which means that it operates in sequence at a given frequency and the beam is focused because it passes through a lens. The beam is carried by optical fiber hardened to resist irradiation. The laser wavelength in the Infra-red, so invisible, put impacts on the material

The main advantages of the laser are its multiple capabilities :

- convenient use in the cell which considerably increases our productivity,
- the possibility using this process of pressurising fuel rods beyond the limits of TIG technology which is at 60 bars, to satisfy new demands requesting pressures of up to 100 bars,
- the precision of the result as well as its reproducibility which will enable us to work on a wide range of thicknesses.

The welding pictures below are provided to illustrate the laser performance : one laser welding (Figure 2) and the other TIG welding (Figure 3).

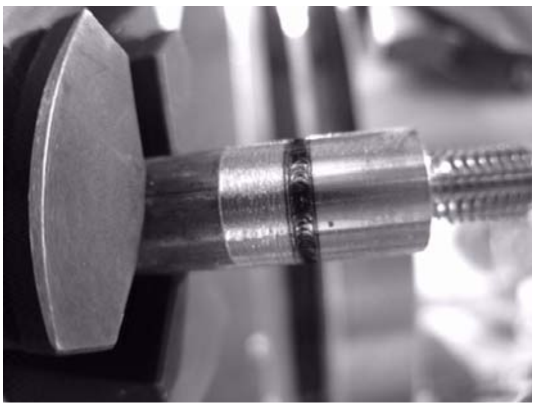


Fig.2 : Laser welding

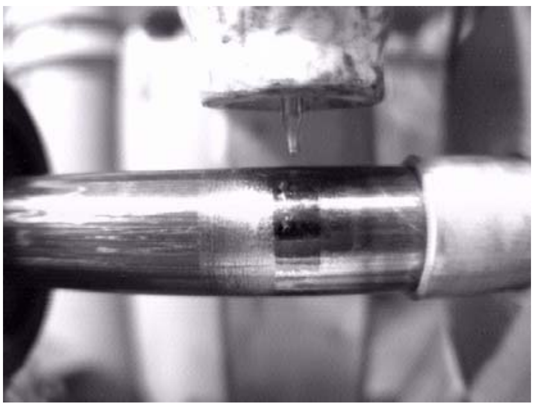
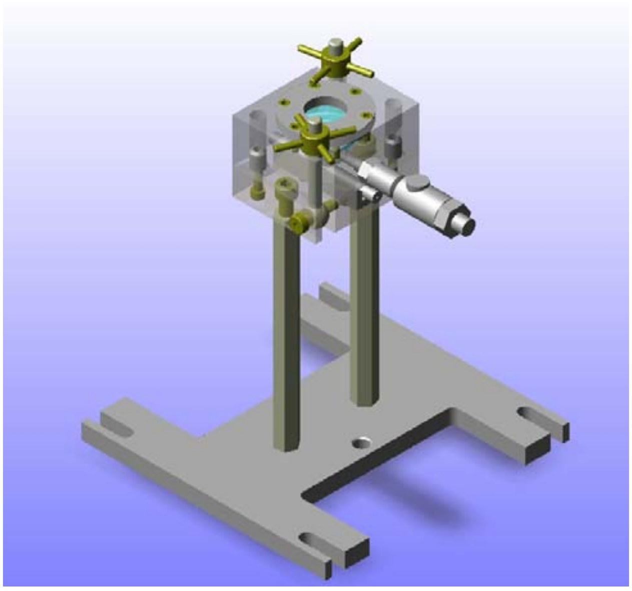


Fig.3 : Tig welding

The seal welding involves the pressurisation and air-tight plugging of the fuel rod by spot welding.
On the left, our seal welder (Figure 4) in perspective with a representation of the fuel rod, the gas feed and the shield window in silica.
On the right (Figure 5), you can see that the fuel rod is pressurised and rendered air-tight by an O-ring gasket here and the focalized laser beam passes through the shield window to close the hole of the seal weld. Indeed, the silica is transparent to the laser of this wavelength.



<u>**Fig. 4**</u> : The seal welder

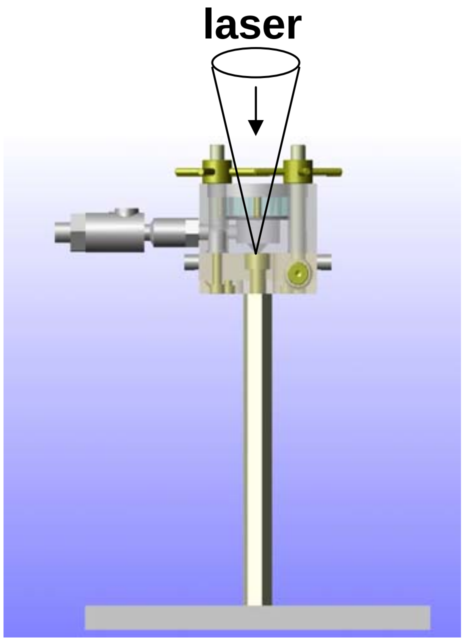


Fig.5 : seal welding laser

1.2 Coralie applications :

1.2.1 Re-fabricated rod (Fabrice rod) :

CORALIE application is FABRICE rod; it is the re-fabrication of an EDF rod in one of its stages; this means that we select an interesting stage using gamma-spectrometry (Figure 6) which enables us to view clearly the pellets and the position of the grids.

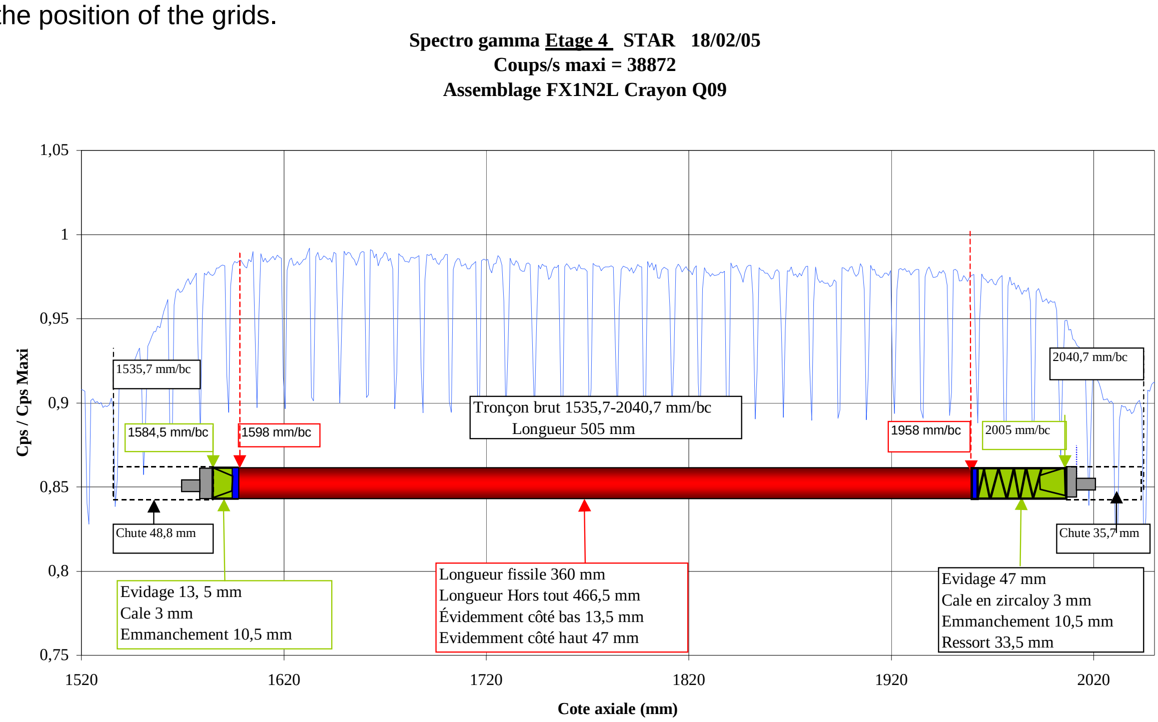


Figure 6 : gamma-scanning profile fuel rod

We may then cut the desired sections and empty the fuel from the cladding at a certain depth. The cladding can be cleaned by removing the zirconia by a few millimetres, and we may then insert pellets at the extremity, a spring and re-seal it with zircaloy plugs. These two plugs are then welded using a laser. We pressurise the rod to the pressure of the father rod at the time of its removal from the EDF reactor and seal-weld it.
These rods, fabricated at the LECA facility are then tested on a power ramp in OSIRIS in order to ascertain their mechanical resistance to the recommended loads.

1.2.2 Fuel rod instrumented dually by a thermocouple and gas pressure gauge (Remora rod illustrated as figure 7):

Another application on this fuel which is now in practice is the fabrication of the doubly-instrumented fuel rod, REMORA 2. This experimental rod has the peculiarity of possessing a **Tc** within the fuel and a pressure/counter pressure sensor.

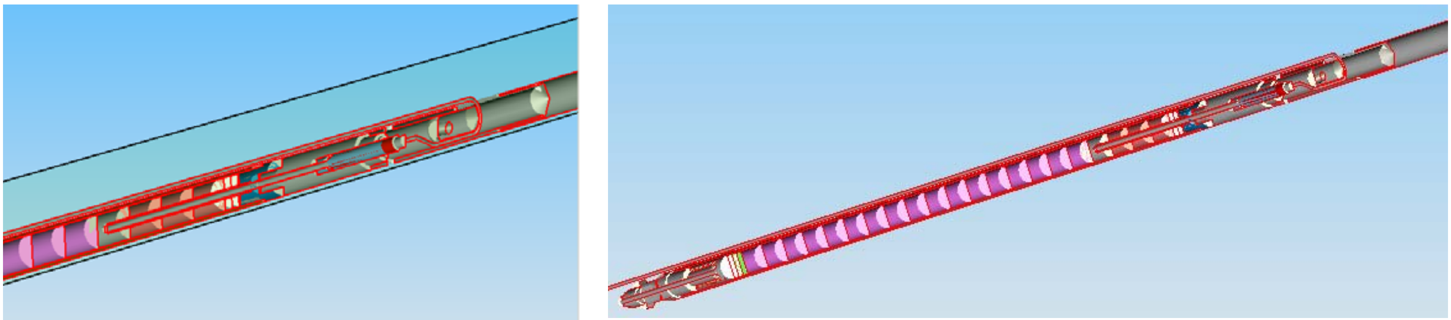


Fig. 7 : instrumented fuel rod

It is therefore a highly upgraded version of FABRICE, that will enable us to follow the on line evolution and the gas release of fuel doped with chrome throughout its irradiation in OSIRIS
A few photos (Figures 8-9) to show what is being done in LECA, we thus see the instrumented fuel rod on the CORALIE bench in LECA hot cell.

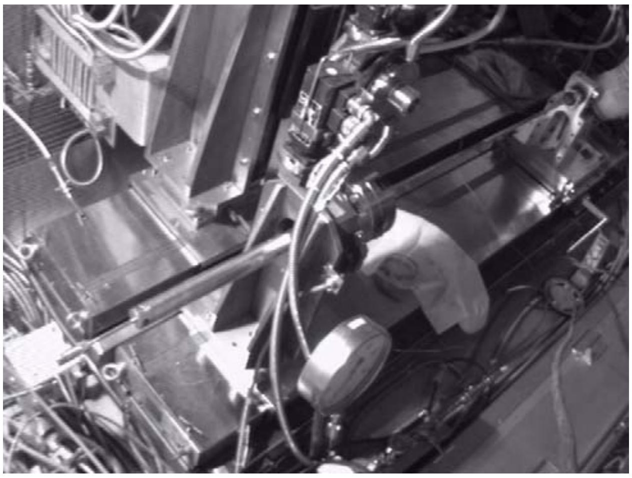


Fig.8 : Instrumented fuel rod

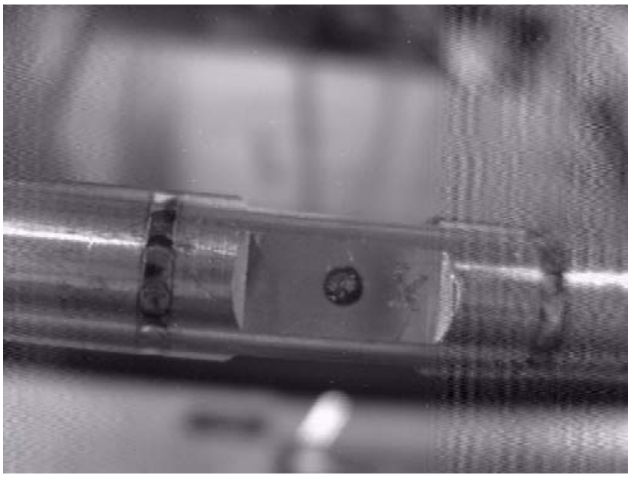


Fig. 9 : seal weld

The weld between the plug and the fuel rod cladding and between the plug and the pressure sensor. And the seal weld! The poor quality of the picture is due to the irradiation of the rod.
We therefore have future perspectives for this bench of new operations which are the following :

- An increase in the productivity for the “FABRICE” rods
- A metrology application with a reproductibility of displacement and an accuracy lower to one hundredth of a millimetre.
- We intend to carry out work on fuels of the Naval Propulsion or of the experimental reactor fuel.
- We shall also carry out calibrated defects for researchers in the program who have requested this.

2 Milling-machine PLACIDE (Figure 10):

The (Fuel research department of the French Atomic Energy Commission (CEA) in Cadarache, France) DEC/SLS/LIGNE Engineering Development Laboratory of the CEA Cadarache research Centre in France has recently developed a remotely controlled system for different inspection and dismantling tasks.

PLACIDE is a programming numerically-controlled milling, particularly being designed for the dismantling of the fuel bundle housing of the Naval Propulsion Fuel, irradiated in an experimental power plant at CEA-Cadarache/TA, France. The machine will also be used to cut out irradiated plates. The 3 axes remotely controlled automatic control device , consisting of a three translatory axes guiding machine and a removable tool cutting device with 1 rotatory axe It has been developed in order to desmontrate our Zircaloy parallelepiped cutting (“fuel bundle” containing fuel plates). This is realised by means of these 3 axes which are bent in the same shape as the fuel bundle.

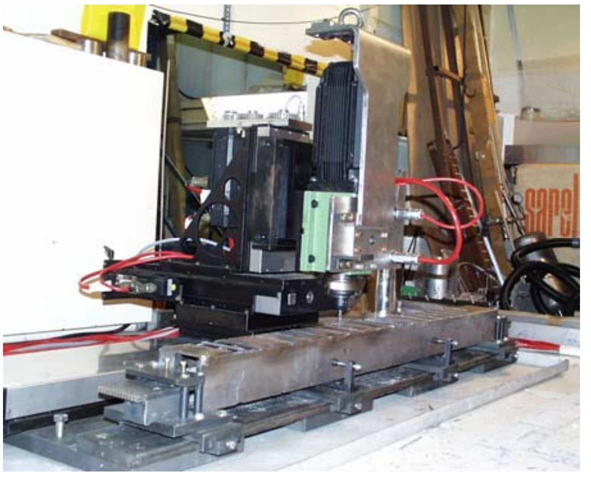


Fig. 10 : Picture of Placide, cutting plates

Technical specifications :

Equipment of non-destructive examination (gamma-scanning, metrology and dimensional inspection) in hot-cell is very important to observe the plates profile of an irradiated materials at a nuclear power and/or research reactor. In both cases, we use translatory axes of PLACIDE. Those equipment should be integrated by remote manipulators, so they are designed, manufactured and modified to make the exercise as easy as possible.

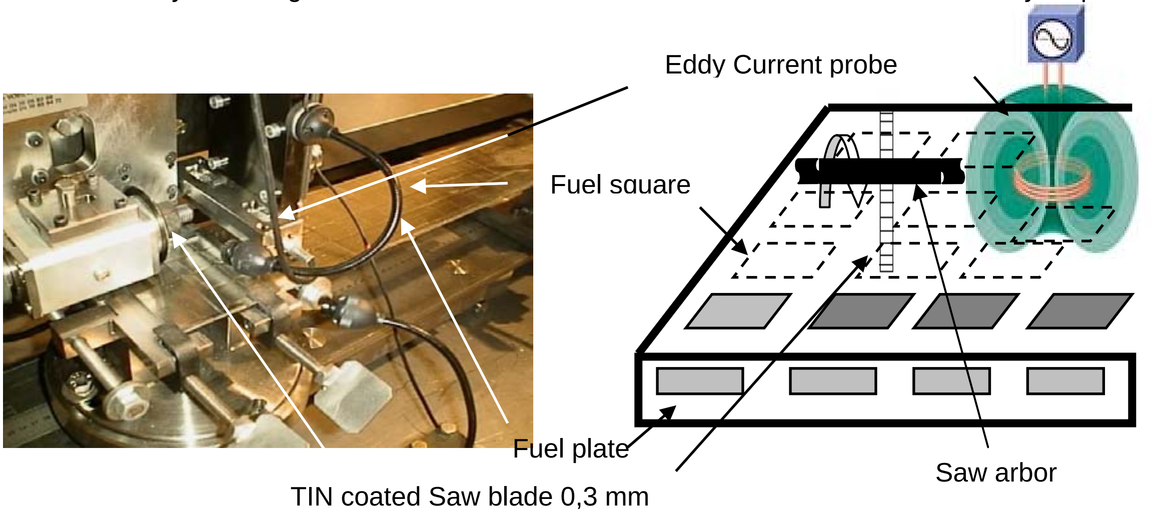


Fig.11 : Fuel plate location by Eddy current probe

An other specially designed twin sensor system (Figure 11) can be removed by means of a guide rail, It is used for different complex cutting tasks. This autonomous device, has been designed for cutting between fuel plates. It is equipped with a video camera, an Eddy Current sensor. Data processing of the signals reflected by the indication located on the density plate allows to locate with a good accuracy the cutting position.

Special auxiliary tooling has been required to provide the reliability and dexterity for performing machining of the samples with a good accuracy, gripping, and other such functions. Over the years, a set of components has been improved upon and adapted to several new applications.

3 X-Rays radiographic Device (Figure 12):

This X-rays radiography facility is employed to inspection on weld seam of re-fabricated instrumentated rods. Indeed, the weld bead shape is crucial for weld quality. X-rays method is usually adopted to detect the weld seam of a high pressure fuel rod in which dangerous flaws exist, such as boundary unblended and crack. Weld inspection, are available now for application in the production line.

The results indicate that the radiographic inspection find extensive application in quality control, in manufacturing processes and non-destructive testing in general.

Experimental work to optimize the welding parameters of TIG/laser method was achieved. Nevertheless, some predominant flaws may occur in the end plug weld joints, such as lack of penetration, voids, cracks and disbonds. The integrity of the welding areas must be investigated by X-ray radiography.

A real-time radiographic examination has been applied to the control of TI and laser welded joints of the end plugs to rod assemblies in a high radioactive environment. This X-rays method enables immediate monitoring of any welding defaults on a TV screen. A conventional hard radiographic film can also be used on this X-rays device.

A remote positioning system for the Fabrice rod was developed to position fuel rods below a X-ray source. Radioscopy pictures are recorded during remote positioning of the rod movement.

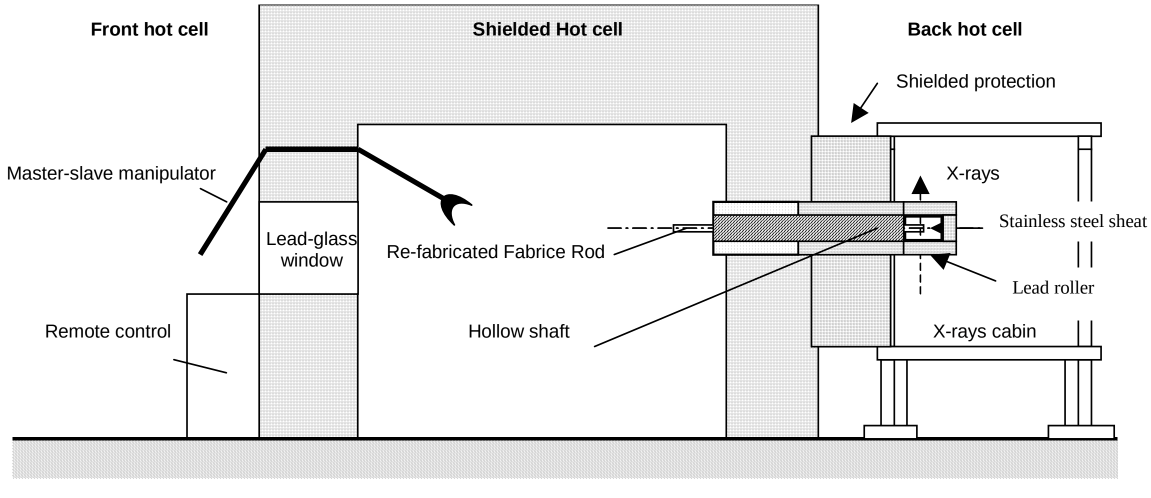


Fig.12 : radioscopy hot cell

Four artificial defects of calibrated dimensions (0,2-0,3-0,4-0,5 mm depth versus diameter) introduced into a Zircaloy **I.Q.I.** (Image Quality Indicator illustrated as figure 13) to measure quality and accuracy of the radiographic technique. Definition, as a property of a radiographic image, is a measure of the detectability of image detail.

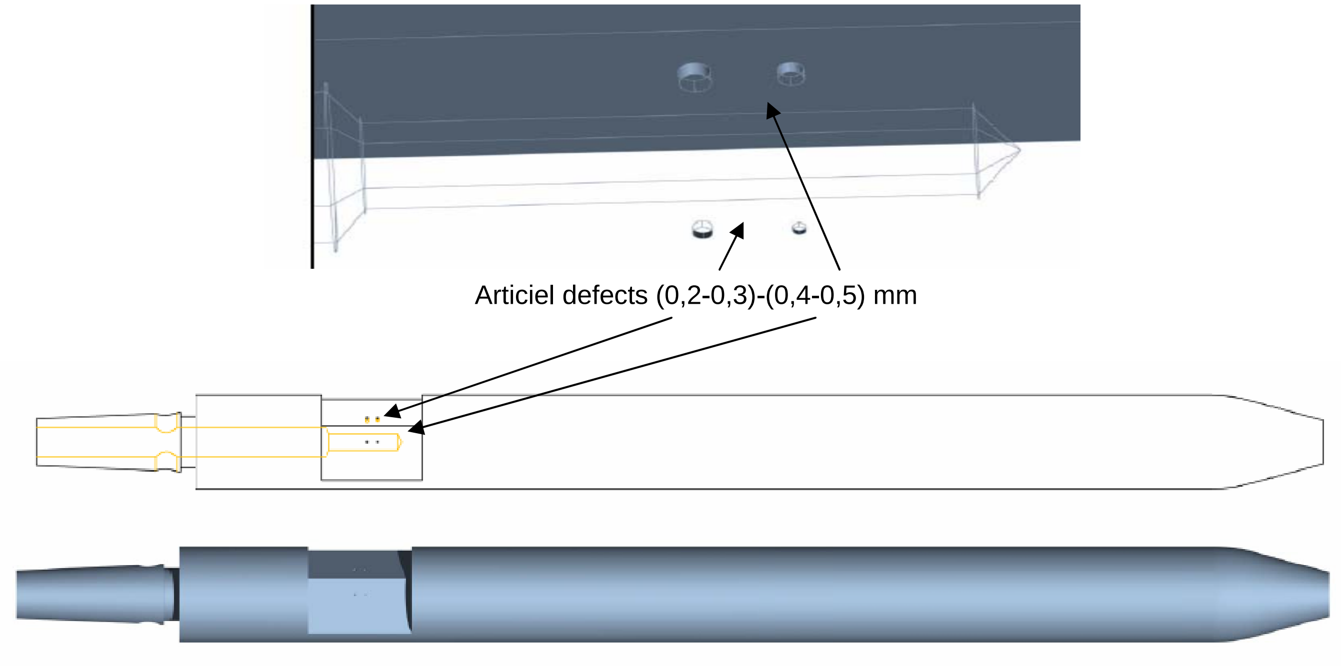


Fig. 13 : Image Quality Indicator

Resolution of the radioscopy technique and accuracy of the acquired measurements approaches 0,3 mm, X-rays crossed zircaloy thick 8 mm

Radiographic inspection (Figure 14), leak test with helium detecting method are used to ensure a good mechanical aspect and the integrity of nuclear welding joints in instrumented rods.

This NDT method requires a experienced radiographer to accurately classify the observed image features as component defects or image artefacts inherent to that particular radiographic technique.

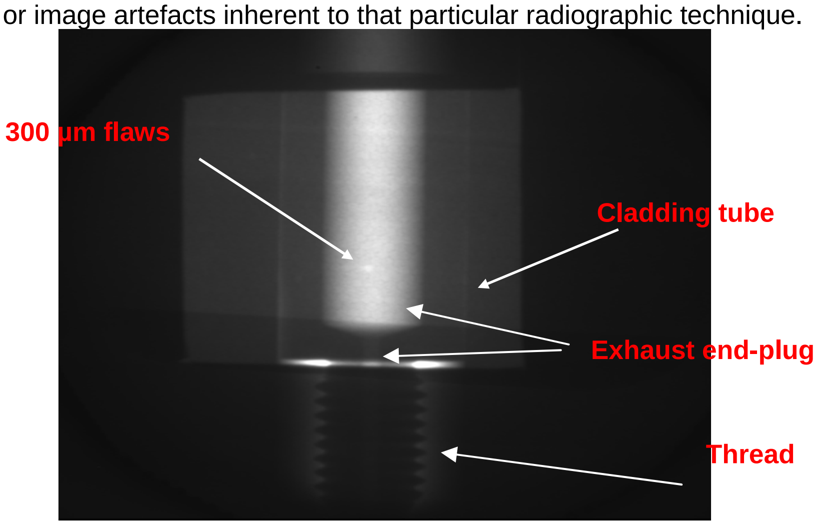


Fig. 14 : Weld radioscopy

The LIGNE laboratory has the “Cofrend EN 473 and ISO 9712” Stamp Certification of Authorization required for nuclear welding interpretation (rejection/acceptance criteria for weld defects). A COFREND inspector from LIGNE Laboratory is qualified and certified for non-destructive, interpretation radiography.

The results exhibit that there is a definite improvement in the quality of re-fabricated and instrumented rods, which is reflected in terms of reduced number of batches of non-conforming products.

The detailed requirements for the calibration, control and operation of flaws X-rays inspection are described. These include the selection of an X-rays device with suitable accuracy, acceptance criteria, corrective action if calibration fails to meet acceptance, records and data, the prevention of adjustments that would invalidate the calibration.

Efforts given to maintain the quality management based on the ISO 9001 requirement able to improved the re-fabrication rods technique, strengthen the customer confidence.

4 Conclusion :

These in-cell remote techniques were developed for re-fabrication instrumented fuel rods (**Coralie** bench) and dismantling (**Placide**).

Now, the machine PLACIDE is used routinely to manufacture mechanical testing samples form irradiated materials, obtained from both fuel rods and other irradiated components. Special metrology tools have been developed to measure fuel plate thickness.

The Coralie process presented can be a suitable technique of welding between thin clad tubes and end-plugs of different size and properties, without any collapse of thin clad.

A qualified expert provided with a diploma given by Cofrend Council, ensures a successful field re-fabrication instrumented fuel rods and strengthen the customer confidence.