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C.N.E.N. - Centro di Saluggia

L.F.C.E.C.

"Development for a fuel element for HWR (Cirene Prototype Reactor)".

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1. INTRODUCTION

Since the beginning of its activity in Cirene Program, the CNEN has developed researches and works in the field of fuel element manufacturing for the 40 MWe Cirene Prototype.

This work was started and carried out in the CNEN Fuel Fabrication and Control Laboratory of the Saluggia Center.

The work was aimed at developing and settling the manufacturing and control procedures of the various steps of the fabrication process, at designing, installing and commissioning of the pilot plant and, finally, at fabricating the first charge for the Prototype Reactor.

Now the program has very much proceeded and, in fact on the basis of the fuel technology specifically developed a pilot plant has been set up having the capability of 25 ton/year of UO_2 in assembled bundles.

A first production run for a period of hundred days will be done in the next months in order to settle down the complete fabrication and control procedure; moreover elements produced in this first run, will be selected at random for irradiation tests.

From these experiments it is expected the final confirmation of the suitability of the proposed fuel design and manufacture procedure; it is also expected the confirmation of the data obtained from the previous irradiation test performed in the two Cirene operating conditions loops of the Essor - Ispra - Euratom Reactor and Avogadro - So.R.I.N. - Saluggia Reactor as well as in the two heavy water reactors - Halden BHWR (Norway) ad Agesta 8 HW (Sweden).

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2. PROCESS DEVELOPMENT

The Cirene fuel consists of 18 Zircaloy-2 rods assembled into a bundle by means of two end grids (...). The bundle is characterized by an outer ring of twelve rods, and inner ring of six rods; on the rods are attached 72 spacers; on those of the outer ring are also attached 36 bearing pads, in order to adapt the bundle to the pressure tube.

The single rods, whose total lenght is 497 mm are filled with dished natural UO_2 pellets whose individual dimensions are:

- diameter : $18,80 \pm 0,01$ mm
- lenght : 24 mm
- dish : dept 1,2 mm $^{+0,01}_{-0}$
- shoulder : width 0,45 ÷ 0,50 mm

In the figure 1 a typical bundle is showed.

The Cirene Program fuel development and fabrication started in Saluggia in the second half of 1966.

This activity was scheduled in five itams: survey of the fabrication techniques to be known; selection of that techniques to be directly developed or to be acquired through one or more foreign know-how; development of the various techniques in order to settle down the procedure for each step of the fabrication process (including the fabrication of test sections for out and in pile experiments); design and installing of the pilot plant; operation of the plant.

In effect all the necessary techniques were developed in Saluggia, except for the spacers attachment, whose equipments and know-how were supplied by Canadian General Electric throughout AECL.

In the ceramic area the main effort was devoted to develop a simple, economic and reproducible procedure, suitable for the fabrication of the Cirene pellets.

Researches were in particular performed in order to avoid some structure anomalies due to the unusual size of the pellets and defects in the soundness of the pellets due to the dimensions and close tolerances of the dishing shoulder.

The developed procedure is characterized by a severe acceptance criteria of the UO_2 powder and by a pellets fabrication process in wich the main attention is devoted to the uniformity of the distribution of the forces during the compacting operation.

The developed procedure foresees the following steps: precompacting, appropriate granulating, dry-mix with lubricant, pressing.

The canning procedure was developed taking into account particularly the unusual ratio between the outside diameter and the wall thickness of the tubes (20 : 0,53 mm) and the design criteria of the elements that allows only a very little residual content of moisture in the pellets.

In the assembling area two junction techniques between endplugs and grids were developed: TIG welding and projection welding. The second one was adopted.

As far as the autoclaving operation is concerned, two different procedures were selected: the first one consists of the rods passivation followed by assembling these rods with the two pickled grids; by the second one can be performed the passivation of the whole assembled bundle.

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3. FABRICATION PROCESS

On the basis of the developping work as summarized above, was established the following flow-sheet of the pilot plant:

Ceramic section

- Incoming of UO_2 powder and characterization.
- Precompacting in the range of 0,8 ÷ 1 tonn / square centimeter.
- Granulation in the range of 150 ÷ 800 microns.
- Mixing with dry lubricant (zinc stearate 0,3%).
- Compacting at pressure of 4 tonn/square centimeter.
- Sintering in hidrogen at 1700°C.
- Grinding.
- Ultrasonic cleaning.
- Pre-drying (residual moisture content ranging between 15 and 25 ppm).
- Control of density and dimensions, spot chek for structure and for some chemical characteristics.

Canning section

- Incoming Zy-2 tubes, visual inspection, dimensional measurements, ultrasonic defect control, spot check on mechanical properties and chemical composition.
- Incoming Zy-2 rods, inspection and control as above and finally machining of end plugs.
- Cut to lenght of the tubes.
- Attaching of the spacers and pads by berylium brazing.
- Welding of the first endplug, X Ray ad elium leak detection, metallographic spot check.
- Arrival of UO_2 pellets from ceramic section.

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- Preparation of pellets stack on special trays,
- Charging of the trays in a vacuum oven connected with the second endplug welding chamber.
- Drying overnight of the pellets stacks at 275°C under a 10^{-5} Hgmm vacuum. After this operation the residual moisture content in the UO_2 pellets is less than 5 ppm.
- Remote charging of the tubes (previously ultrasonic cleaned and dried) with UO_2 pellets. This step is operated also under vacuum
- Introduction of extra pure elium in the welding chamber. A by-pass on the elium line allowed the control of the residual content in the elium gas of moisture and oxigen by mean of electro-chemical measurements.
- Forcing of the second end plug in the tube.
- Welding of the second end plug, X Ray and leak detection, metallographic spot check, distructive control of the moisutre content inside the rods (one rod before and one rod after every fabrication bacht).
- Pickling and autoclaving (of 72 hours at 400°C and 10 atmospheres).

Assembling section

- Incoming of the Zy-2 sheet, mechanical and chemical control.
- Fabrication of the end grids.
- Surface, weight, lenght and strightness control of the passived rods.
- Lathing of the flat surface of the end plugs in order to machine a sort of "tingle" for the projection welding operation.
- Assembling of the components of the bundle in one appropriate fixture.
- Resistence projection welding of the grids to each end plug flat surface.
- Dimensional control.

4. PILOT PLANT

The pilot plan have been designed for the capability of 25 tonn for year of UO_2 in assembled bundles: one shift of eight hours every working day, unless the sintering furnace whose operation is continuous.

This capability seems to be coherent with one of the main aims of this program, that is the attainment of such a fabrication costs (direct and indirect) to be extrapolated on industrial scale.

In the ceramic section of the plantare installed two mechanical presses, facilities for granulating and mixing, one four zones continuous sintering furnace (another three zone furnace is installed as reserve), two centerless grinding machines working in series, one ultrasonic cleaner, one vacuum oven for the predrying and continous electronic facility for the automatic control of the pellets dimensions and density.

In the canning section are operating the facilities for the attachement of the spacers to the tubes by berillium brazing (metallizing equipment, punching press, fixtures and posizioner tack welders, induction furnace for brazing), two TIG welder for the first and the second endplug, facilities for pickling and autoclaving and equipment for X-Rays and leak detection control.

The assembling section is constituted by two special lathes equipment (mechanical, optical, electronic) for dimensional measurements of the rods, several fixtures for assembling the components of the bundle, one resistence proiection welder and one equipment for the final control of the bundle.

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The control section is equipped with the appropriate facilities for the acceptance control of UO_2 powder, Zy-2 tubes, rods and scheets and for al the spot check (mainly metallographic and chemical) that are specified to be done during the fabrication.