Transactions of the **13th International Conference on Structural Mechanics in Reactor Technology** (SMiRT 13), Escola de Engenharia - Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, August 13-18, 1995

Mexican experience in nuclear fuel fabrication

Nocetti, C.A., Torres, J.R., Leon, E.
National Institute of Nuclear Research, Salazar, Edo. de México, México

ABSTRACT: The fuel fabrication process developed at the Instituto Nacional de Investigaciones Nucleares is described. The design of a new pilot plant, the changes in the process recently introduced and several fabrication problems solved during the fabrication of BWR fuel assemblies that are particular for this small pilot plant, are commented.

1 INTRODUCTION

Shortly after Mexico bought the country's first two reactors, in 1976, it was planned to irradiate in them a small amount of fuel produced in the country. This fuel fabrication program was assigned to our Institute. The development strategy selected was to buy the specifications from a fuel designer and to develop the fabricaton process, Q.C. techniques, Q.A. organization and to train our personnel to comply with these specifications. We concentrated our efforts in pellet and rod fabrication, assembly, plant and equipment design and radiological safety applied to these areas. Activities like powder conversion, tube and component fabrication were not considered attractive since only a large nuclear program would economically justify them. Several irradiation projects carried out with the Kernforschungzentrum Karlsruhe (KfK) (Nocetti 1986, 1991) permitted us to progress in the pellet and fuel rod fabrication techniques. When we were ready to start assembling fuel, we signed a technology transfer agreement specifically for the fabrication of eight fuel assemblies. We received throughout the project economic cooperation from IAEA and KfK and recently from Spain. The paper deals exclusively with ININ's own developments aside from the technology transfer.

2 FABRICATION PROCESS DEVELOPED

Fig. 1 summarizes the process we have developed (Nocetti 1993) in our three initial projects. We have indicated there, the raw materials and components we normally purchase. The alumina pellets were used only in a KWU design and the assembly components indicated are just an example, since the amount used depends on the particular bundle fabricated. Our process has of course similarities with other processes used elsewhere (Mathieu 1978, Assmann 1979) but, it is specially adapted to produce small amounts of BWR fuel from different designers. Some of our equipment is not commonly used in industrial plants. For example, we use for sintering molybdenum batch

furnaces with a maximum temperature of 1800°C bacause of the flexibility obtained in planning small production batches. A normal sintering lot is 20 kg, which we can comfortably blend and press in one day. We use for the sintering process dry hydrogen. We still use wet grinding with silicon carbide wheels and tap water as refrigerant. Surface finish and chipping are then easily controlled. The only inconvenience is that a drying is then required. Since clients do not like a wet process like the one described, we are going to change to a dry grinding process as soon as we can solve the extraction problems. We design our own welding chambers (Cabral 1986). Our third generation design, containing mechanisms to control GBS (grain boundary separation) is currently in use. As can be seen from the flow chart, we have not yet incorporated the passive gamma scanning we are developing. We are then obliged to perform complicated administrative procedures and lengthy qualifications to guarantee that no mistakes with enrichments are made during pellet loading. Every activity is checked by a Q.C. inspector at the side of the loading station. Pellet integrity and gap verificaton is carried out with fuel rod radiography. All this Q.C. operations slow down rod production considerably. Assembly is manual and we describe in point 3 how we perform it in order to avoid costly mistakes.

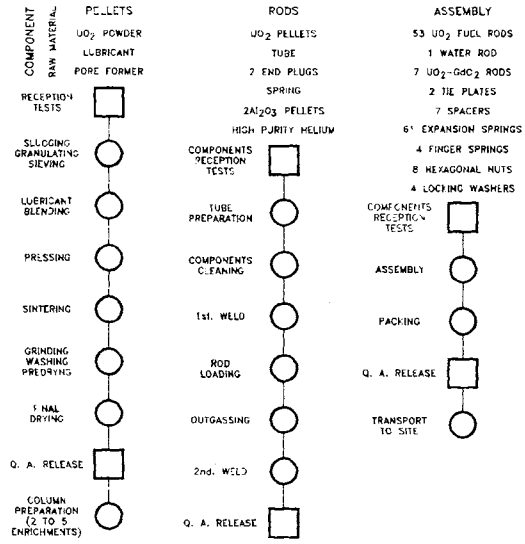

Fig. 1.—Flow sheet of fuel fabrication at ININ.

3 RECENT DEVELOPMENTS

We will describe several operation we have developed to assure a very small but still very high quality production. Our first challenge was the design and licensing of the plant. We had to increase the installed capacity from 100 kg to four tonnes. Our Nuclear Regulatory Commission required us to meet all the international standards for a commercial plant, including an environmental impact statement, before a licence could be issued. The plant (figure 2) has an area of 2050 m2. It is divided in two production areas:

pellets, rod loading and second end plug weld (410 m2) first end plug weld, final rod control, assembly and packing (372 m2). The assembly area is twelve meters high with

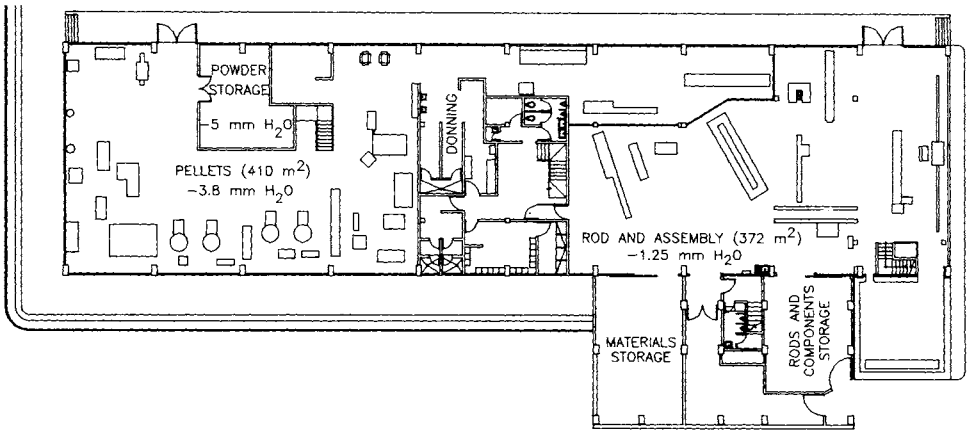

Fig. 2.– Pilot plant (1st floor)

an overhead crane to move fuel assemblies and packing containers. Donning rooms (125 m2) are in the center of the two production areas. The Q.C. laboratories (200 2) and raw materials, finished products and general store areas (232 m2) complete the first floor. Offices (390 m2) are in the second floor, above the donning rooms and the first weld areas. The plant uses many other facilities of the nuclear center: Q.A., analytical laboratories, electronic and mechanical maintenance, shops, etc. All but one of the fuel certification analysis can be performed in the nuclear center. The air conditioning and extraction systems, the most difficult part of the plant design, were designed by people trained by IAEA and with previous experience in the design of the ventilation system for a small (1 mW) Triga reactor. The air conditioning system is traditional: 20 ± 2°C plus moisture control 50 ± 5% for the nuclear materials storage areas and the metrology, calibration and other Q.C. laboratories. We have actually two extraction systems, the general one with pressures according to the radiological risk of each area, and the local extraction system for containing the UO2 aerosols generated in all the pellet and rod loading areas. The powder mixing and scrap recovery, presses and grinding operations are the big contamination producers. The general extraction system has the following design negative pressures (in mm of water column) powder and pellet storage areas: 5 mm (Radon and powder handling problems), pellet area 3.8 mm, rod and assembly 1.25 mm. Air flow is from the less contaminated to the more contaminated areas. Our present experience is that the pressure diferences can be substantially reduced, but we would have to ask for a new licence. The system supplies two changes per hour without any air recirculation for the pellet fabrication and nuclear materials storage areas. In the rest of the plant recirculation is around 40 %. The general extraction system exhaust has dry filters with 85 % efficiency for particles larger than 5 μm and the local extraction exits through high efficiency (HEPA) filters with 99.97% capture for particles larger than 0.3

μm. Prefilters are used as HEPA filters protection. The minimum design capture velocity for UO2 aerosols was 0.5 m/seg. Actual measured values range from 0.6 to 0.8 m/seg. The average transport velocity measured in the ducts is around 13 m/seg. Ducts in the pellet area have a circular welded construction withouth volume control gates before the filters, to avoid powder accumulation.

We have already finished the first fuel assembly. We have to solve an interesting production problem: an hydrogen content higher than normal, in the range of 0.7 ppm, slowly increasing during handling and storage up to 1.2 - 1.4 ppm. It could be reduced after the high temperature drying performed after the wet grinding to 0.5 to 0.7 ppm but it was still unstable. It was solved changing the atmosphere at the end of the sintering process. More research needs to be done, but we think that the pure hydrogen of sintering was trapped in the particular open porosity we have. The changes implemented have reduced Hydrogen content in pellets to 0.1 - 0.15 ppm.

In the process Q.C. area we are introducing all the computerization we can afford. The main reasons for this change are not economic in our case, but are mainly to reduce human errors. Some examples are discussed next. Until we have enough statistics to relax our control practices, two critical pellet fabrication operations are monitored closely: pelletizing and grinding. Our Q.C. plan requires to measure diameter, height and weight in every tenth pellet pressed, to follow green density. Although we could mantain green density within ± 0.1 g/cm3 the price was very high: two inspectors and several hours to produce the final inspection report. With two digital micrometers and the electronic balance interconnected to an old 286, using 75 % of commercial software and 25 % of our own programming, we can provide the press operator the green density control charts withouth interrupting the pressing production and issue a printed inspection report right after the pressing. Similarly in the centerless grinding we controlled-with three inspectors-diameter and surface roughness in one out of fifty pellets. With a laser micrometer and the same system we can follow the diameter variations without delaying the production. This is the first part (that is the reason for using a laser micrometer here) of a 100 % automatic control of diameter separating the bad pellets, which is in the design stage. Roughness control is necessary to adjust the grinding control wheel to keep this parameter within specifications. It is very difficult to automatize roughness control with reasonable cost. With better statistical support we can jump to control one out 500 pellets.

For our production level, only manual assembly is possible. Once the fuel rods are arranged for ordered insertion, a light metallic structure permits the rod positioning with controlled x, y movements. One problem is to prevent wrong rod positioning. A nylon screen with 8 x 8 holes is in front of the assembly position (lower tie plate, water rod and spacers already in place) On two adjacent sides of the screen a set of 8 x 8 optical sensors and on the other two sides a set of 8 x 8 reflectors are fixed. The PC connected to the system only permits insertions in the programmed sequence.

Our process qualifications have been painful. Our modest experience requires us to prove that no mistakes are possible. One example: for the qualification of final weld radiography in addition to proving the radiographic acceptability, we have to produce a metallographic "calibration" of the evaluation of the four main weld acceptance parameters: penetration, undercutting, porosity and minimum wall thickness. Since X-ray evaluation is not an accurate method, a proof of our results was neccesary. We prepared a wide range of defective samples for this purpose, and the "calibration" was produced.

For pore size evaluation only a confidence level for the detection of pores larger than 0.25 mm was found.

We still have a traditional Q.A. organization: Manufacturing, Q.C., (that performs, in addition to the product acceptance, all the required process controls) a group we call Engineering (process engineering, equipment design and maintenance, document control and calibration) and Radiological Safety. Q.A. is performed at the institutional level. It is the ideal solution from the point of view of Q.A. independence. However our Q.A. inspectors are not fuel specialists (this condition is improving rapidly) and their commitment to the project goals is not very strong.

RESULTS AND CONCLUSIONS

The first fuel assembly for irradiation will be delivered in the second half of November. The eight fuel assemblies will be ready at the end of 1995. We are not going to become fuel producers in the short term.The installed nuclear generation of the country (1300 MWe) does not justify a fuel fabrication plant in economic terms. We will keep producing small amounts of advanced types of fuel in a more economic form with a minimum of scrap, nuclear waste and labor costs. We will move from the research and development field to production only if we have an economic incentive, and that depends on the future trend of the nuclear power in our country and in the world.

REFERENCES

Assman, H. & Becker, M. 1979 Technology of the UO2 fuel fabrication by the AUC powder. Trans. Am. Nuc. Soc. 147 - 148.

Cabral, J.F. & Velazquez, E. 1986 Desig and construction of a welding chamber for the fabrication of nuclear fuel, Seminar on nuclear energy in Latin America, Latin America section ANS, Mexico City.

Mathieu, V. 1978 UO2 fuel fabrication by means of the AUC powder process. Trans. ANS 31: 327 - 328.

Nocetti, C.A. 1986 Fabrication of prototype fuel pins for the MZFR reactor, Proc. IAEA conf., 584 - 584, Stockholm.

Nocetti, C.A. & Velazquez, E. 1989 Fabrication in Mexico of fuel rods for irradiation in a BWR reactor. Trans. SMIRT 10, Anaheim CA.

Nocetti, C.A. Rodríguez, J.G. & Muehling G. 1991 Q.C. in the fabrication of Nuclear Fuel in Mexico. Journal of Nuclear Materials 178: 158 - 162.

Nocetti, C.A., Ovilla, O. & Torres, J.R. 1993 Trans. SMIT12, 125 - 130 Amsterdam: Elsevier.