

## Infrastructure at PSI for the fabrication of Pu-Pellets (MOX and IMF) and segments

**P. Heimgartner, Ch. Hellwig**

*PSI, OFLA/8a, 5232 Villigen, Switzerland*

In the last few years the Paul Scherrer Institut (PSI) has completed the infrastructure in its Pu-laboratories for the fabrication of pellets and whole segments for irradiation tests. Material Pu-fuel for the MOX and IMF Irradiation experiment IFA 651.1 in Halden and the OTTO test in the HFR in Petten were fabricated with this equipment. The infrastructure consists of a dry attrition-mill for powder milling, a hydraulic pellet press, a sinter furnace, a pellet centerless grinder as well as a filling and welding equipment for the pin segment fabrication.

The attrition-mill, designed and built by KAERI, is a new development where the mill jar, where the mixed powder being milled, is separated by a hardened steel grid into an upper and a lower stage. Powder milling is more efficiency specially when several passes through the mill are applied.

The installed hydraulic press with a maximum force of 60 kN is a one acting press with a moving matrix. The pressing process can be well adjusted by the control unit. By exchanging the press adapter the press can be used for inactive work as well as for active work.

The sinter furnace is delivered by AET-Technologies, France, and can be used for sintering of active material up to 1450°C up to 1600°C in oxidative or up to 1600°C in reductive atmosphere.

The centerless grinder is delivered by Agathon AG, Switzerland, and has been modified by PSI for the installation into a glove-box. It is a dry grinding process with a manual pellet feeding. The dust is collected by a vacuum cleaner through an ULPA-filter.

The filling and welding equipment was built in the 80ies especially for sphere-pac pin fabrication. The welding machine based on the TIG technology has been developed for highest welding reproducibility and was build designed and built at PSI.

In this paper the constructions of the implementation into the glove-boxes and the handling will be described.

### Introduction

In the 80ies the Paul Scherrer Institut (PSI, former EIR) had developed a pin fabrication line consisting of filling, welding and inspection equipment specially for sphere-pac fuel where PSI has a large knowledge. In the last few years PSI has completed the infrastructure in its Pu-laboratories for the fabrication of pellets and whole segments for irradiation tests. With these works PSI gained experience and knowledge on pellet fabrication. Material Pu-fuel pellets for the MOX and IMF Irradiation experiment IFA 651.1 in Halden and the OTTO project in HFR in Petten were fabricated with this equipment. In this paper the constructions of the implementation into the glove-boxes, some problems and the handling will be described.

### Attrition-mill

The advanced attrition-mill integrated into the pellet-press glove box at PSI was designed and built by KAERI (Korea Atomic Energy Research Institute) in the framework of the MOX and IMF Irradiation experiment IFA 651.1 in Halden. A two-stage attrition mill<sup>[1]</sup> was developed to improve the conventional batch type dry attrition mill, in view of the efficiency and the problems often encountered during operation: powder sticking onto the inner wall, agglomerating in the edge of lower part of the mill jar and rapid fall-down of the powder.

The mill jar, where the powder milling takes place, is separated by a hardened steel grid into an upper and lower stage and the shaft has various kinds of paddles with specially designed shapes for each part (see Fig. 2). The shapes and arrangement of the paddles are so combined that when the shaft turns, the milling media (ZrO<sub>2</sub> balls) move effectively enough for the powders being milled to stay for longer time in the milling media. Once the powder is passed through the upper stage, the powder will then be continuously milled in the lower stage, where the milling operation will be refined with a smaller size of ZrO<sub>2</sub> balls. After the milling time of 5 to 10 minutes the shutter at the lower jar is opened and the powder is unloaded into a vessel. This process is repeated for 10 to 15 times depending on the characteristics of the powder until the milled powder results in a homogenous, fine powder. The effect of milling on powder

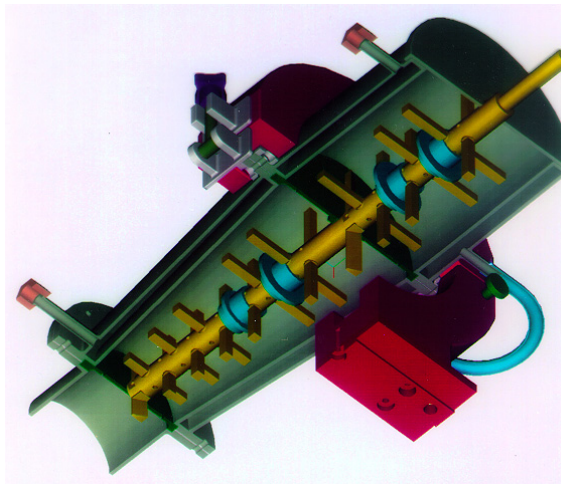
<sup>[1]</sup> Y. W. Lee, H. S. Kim et al, Preparation of simulated inert matrix fuel with different powders by dry milling method, J. Nucl. Mat., Vol 274 (7-14), 1999.

particle size and the pellet green and sintered density is shown in Fig. 3 and Fig. 4. The milled powder samples are subsequently granulated by pre-compacting with pressure in the range of 100 MPa and forced-sieving in a granulator through 1 mm openings in order to simulate actual pellet fabrication, as well as to enhance the flowability. The granulator for green pre-compact is assembled to the Attrition mill and can be operated with the same electrical drive as the mill itself.

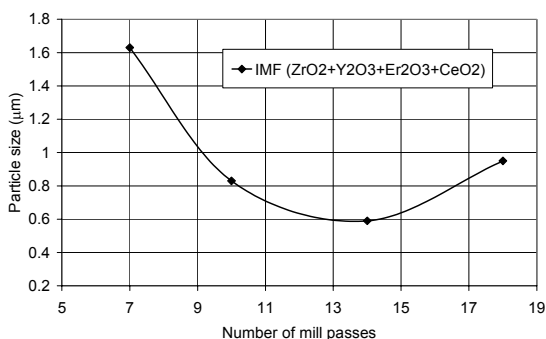
The whole attrition mill with granulator has a size to be placed in a 1 m<sup>3</sup> Box and can be easily handled with the gloves. All parts are designed, that they can be dismantled in the box and taken out through a 300 mm diameter lock. The mill was tested intensively with inactive material like ZrO<sub>2</sub> and UO<sub>2</sub> in the box to optimise the milling procedure and to characterise the milling effect. All parts are checked on function as well as on safe handling. All rotating parts had to be covered, that no gloves can be damaged. After these tests the attrition mill and pellet press were commissioned with plutonium and the first large project was performed with the new equipment without any problems.



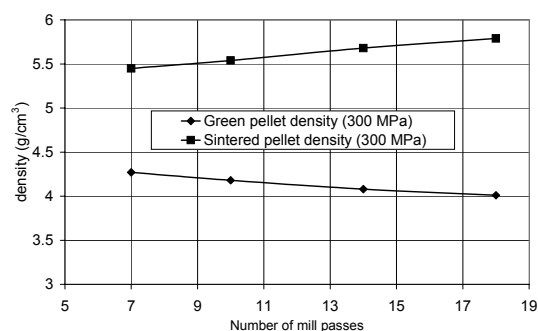
**Fig. 1:** Attrition mill with assembled granulator



**Fig. 2:** specially designed shaft



**Fig. 3:** Efficiency of milling procedure



**Fig. 4:** Effect on green and sinter density

## Pellet press

The pellet press in the Pu-laboratories was installed in 1990 delivered by the Company Osterwalder AG, Lyss Switzerland. The construction for the implementation into a glove box was done by PSI. It is a 6 tons one acting automatic hydraulic press with a moving matrix and an additional equipment to produce annular pellets. One special feature is that the active adapter can be disconnected together with the glove box from the press support and can be replaced by a second inactive adapter. With this construction the same hydraulic aggregate and the control unit can be used for inactive as well as for active work. For safety reason the press area in the box is controlled on the outside by light barrier and sensors, that during compaction no person can reach into it. Before the commission for plutonium work in 1998 the

press was used for inactive tests for the Nitride- and IMF-pellet programme. During these tests several optimisations on the press had to be done to fabricate crack free pellets:

**Design of press tool:**

Together with a tool manufacturer company and the partners within the projects the design of the press tool was improved to produce high quality pellets without cracks. As tool material PSI selected tungsten carbide and the outlet of the matrix has to be designed with a fine conical part with a soft edge. Otherwise lamination cracks will be introduced during ejection.

**Optimisation of the punch movement:**

The ejection part during pellet pressing is the most important step for high quality pellets without cracks. During ejection the top of the pellets has to be hold down with low force by the upper punch till the pellet is ejected totally out of the matrix. Otherwise end capping or lamination cracks can occur. Therefore the press control unit had to be extended with some more features to control the ejection part in a better way.

**Effect of powder milling:**

One important parameter is also the powder characteristics, as it is known specially in the ceramic industry. Intensively milling of the material to fine homogeneous powder is necessary to fabricate pellets of high quality without cracks.

With this optimised pellet press PSI is now able to fabricate crack free pellets of high quality and reproducibility.

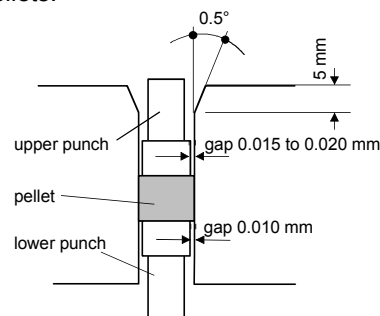


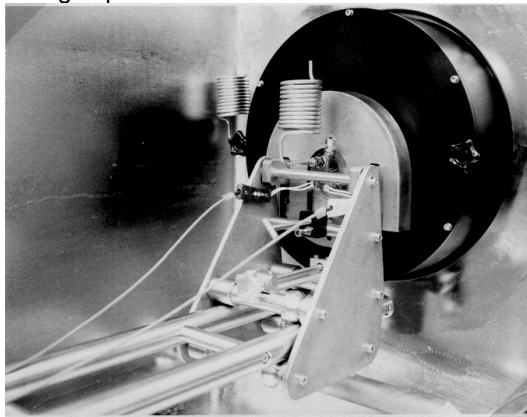
Fig. 5: Front view on the pellet press

**AET Sinter furnace**

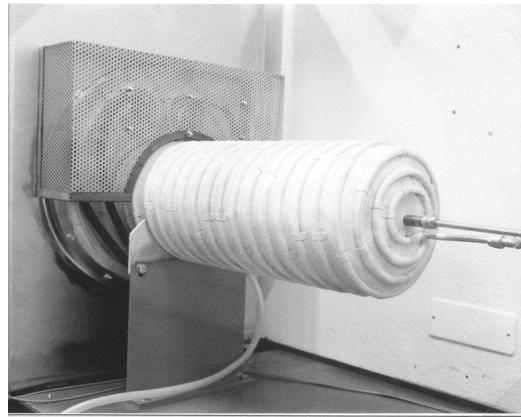
A new sinter furnace from AET Technologies, France, was installed in a glove-box at PSI in 1995 to have the opportunity for oxidative sintering at max 1450 °C. (For sintering in reduced atmosphere a DEGUSSA furnace is available).

The furnace is connected from outside to the glove-box in horizontal position and all infrastructure parts as cooling water system, power supply etc. are placed outside the box. The heat element is protected against corrosion by a cover gas (Ar/H<sub>2</sub>). Inside the box a construction on wheels allows an easy exchange of sinter material as well as of defect inner parts of the furnace. A wide range of sinter gases (Ar, N<sub>2</sub>, CO<sub>2</sub>, air, Ar+8H<sub>2</sub>, N+8H<sub>2</sub>) with or without moisture can be used. The gas inlet is directly over the sample material and assures a well defined sinter atmosphere. The sample material (max. 30 pellets) is

place on a crucible and loaded on a finger-like device horizontally into the furnace. This handling is much easier than in a vertically furnace. The furnace was tested with  $\text{UO}_2$  sinter batches before commissioning in 1998. All equipments were checked on function and some additional features as oxygen detection cell, electronic data acquisition as well as cover gas pressure control were installed. The furnace can be operated automatically with all the safety features as temperature control, cooling water flow detector and cover gas pressure control.



**Fig. 6:** View into the sinter furnace box



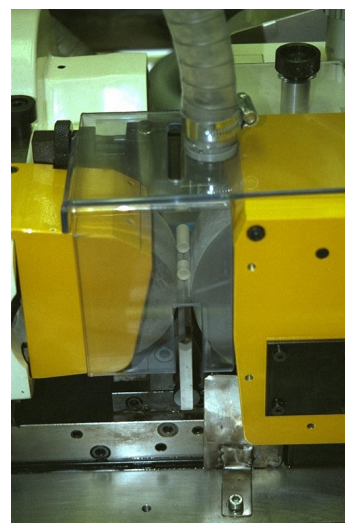
**Fig. 7:** View on the furnace connected to the sinter box

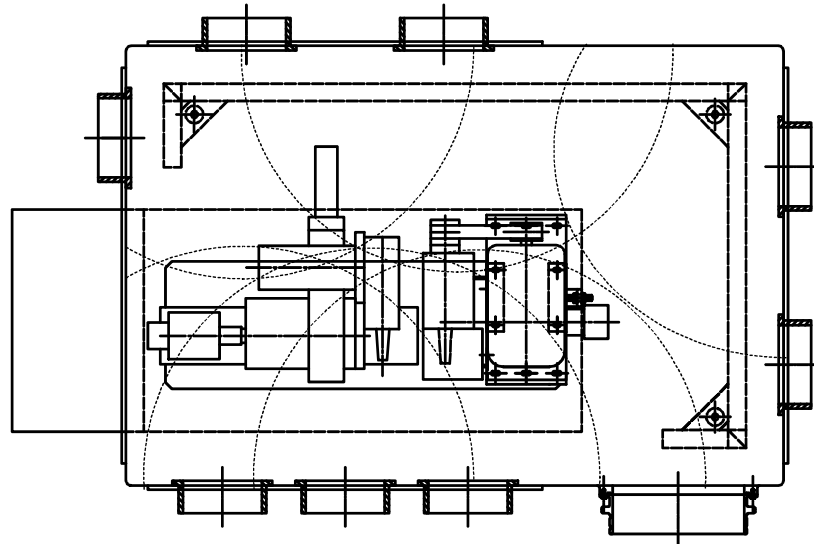
### Centerless grinder

In 1998 a centerless grinder was installed inside a glove-box in the Pu-laboratories for grinding sintered Pu-containing pellets to the specified diameter. PSI evaluated the smallest available industrial grinder on the market and constructed a glove-box, where the grinder could be implemented.

The whole unit with the grinder and regulating wheel was disconnected as one piece from the machine bed and the bottom of the box was mounted between the bed and the grinder unit. Modification on the design of the grinder has been only done for the transmission of the grinding wheel (the motor was placed inside the box instead of its original position in the bed) and for the cylinder for the true running of the regulating wheel (the pneumatic cylinder was replaced by an electrical driven cylinder). All other parts are as original. To reduce the dust production in the glove-box a vacuum cleaner (from NILFISK ADVANCE) with an ULPA filter was installed inside the box. The dust is directly exhausted in the grinding area and collected in the wastebasket. The problem of temperature increase inside the box due to the installed power was solved by running the vacuum cleaner with lower power and by increasing the box air exchange by double the in- and outlets.

In operation, the pellets were manually fed with tweezers into the grinding area, which is closed by a transparent cover that no gloves can reach this area. It is a dry grinding process using a diamond grinding wheel. In one through grinding a maximum removal of 0.1mm in diameter is possible. In practice several passes are applied with a ground amount of 0.05 mm in diameter per step. The pellet diameter is measured with a blade micrometer using a calibrated standard after each step. The amount to be ground is adjusted manually according to the measured diameter.





**Fig. 9:** Overview on the grinder box. The dot lines indicate the area reachable by the gloves.

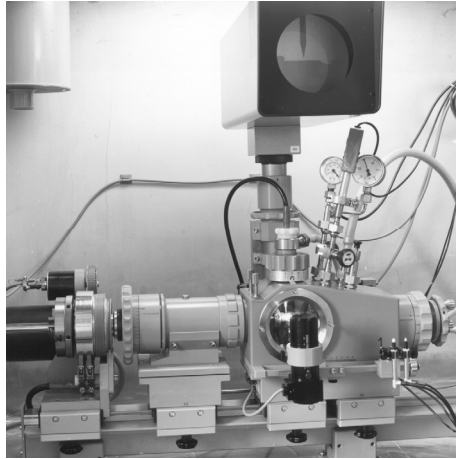
### Filling and welding equipment

In the 80ies PSI built a pin fabrication line to fabricate fuel pins for irradiation tests. The construction of the equipment is flexible so that different pin diameters can be connected to the boxes with only small adaptation.



The filling box itself is mounted under the ceiling and a pin of a maximum length of 2.2 m can be connected vertically to the bottom of the box. The connection is flexible so that the pin can also vibrated for sphere-pac or vipac fuel filling. The pin itself is mounted into a cover tube for easier handling and protection. All parts, which are in contact with the box atmosphere, are once trough parts and will be exchanged for a new pin. With this technique the pin outer surface will always be free of any contamination. After filling the pin is closed temporarily, checked on contamination and transferred to the welding box, where the closure welding is performed.

For end plug welding a welding chamber with TIG process was designed at PSI and placed into a glove box. The welding chamber is used for the automatic evacuation and gas filling of the pin and the closure welding under specified gas atmosphere. The filled gas and the welding gas can be of different kind. The filling pressure is limited to 1.6 bar, therefore pins with high fill gas pressure can not be fabricated with this equipment. The welding process is programmable and runs automatically. During welding the pin is rotating and the electrode with the gas flow is fixed. The reproducibility of the welding quality is tested for each project by qualification tests, which have shown always a high quality of the welds. With the double tube docking system no contamination can be transferred out of the box.



**Fig. 10:** Left side: Filling box with mounted pin. Right side: welding chamber

### **Conclusion**

During the last years, PSI completed its pellet fabrication line in their Pu-laboratories. With this equipment PSI is able to fabricate Pu-containing fuel pellets of industrial quality for irradiation tests in laboratory scale. Mainly the same fabrication methods as used in the industrial fuel fabrication are applied. Several fuel pellets of different kind within international projects have been fabricated with this equipment.