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A Burst Test Facility for Irradiated Fuel Rod Segments

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Bursting rod segments is the mechanical test nearest to the real straining at reactor operation conditions. It is used to determine the component strength and ductility of fuel claddings at room and operating temperature.

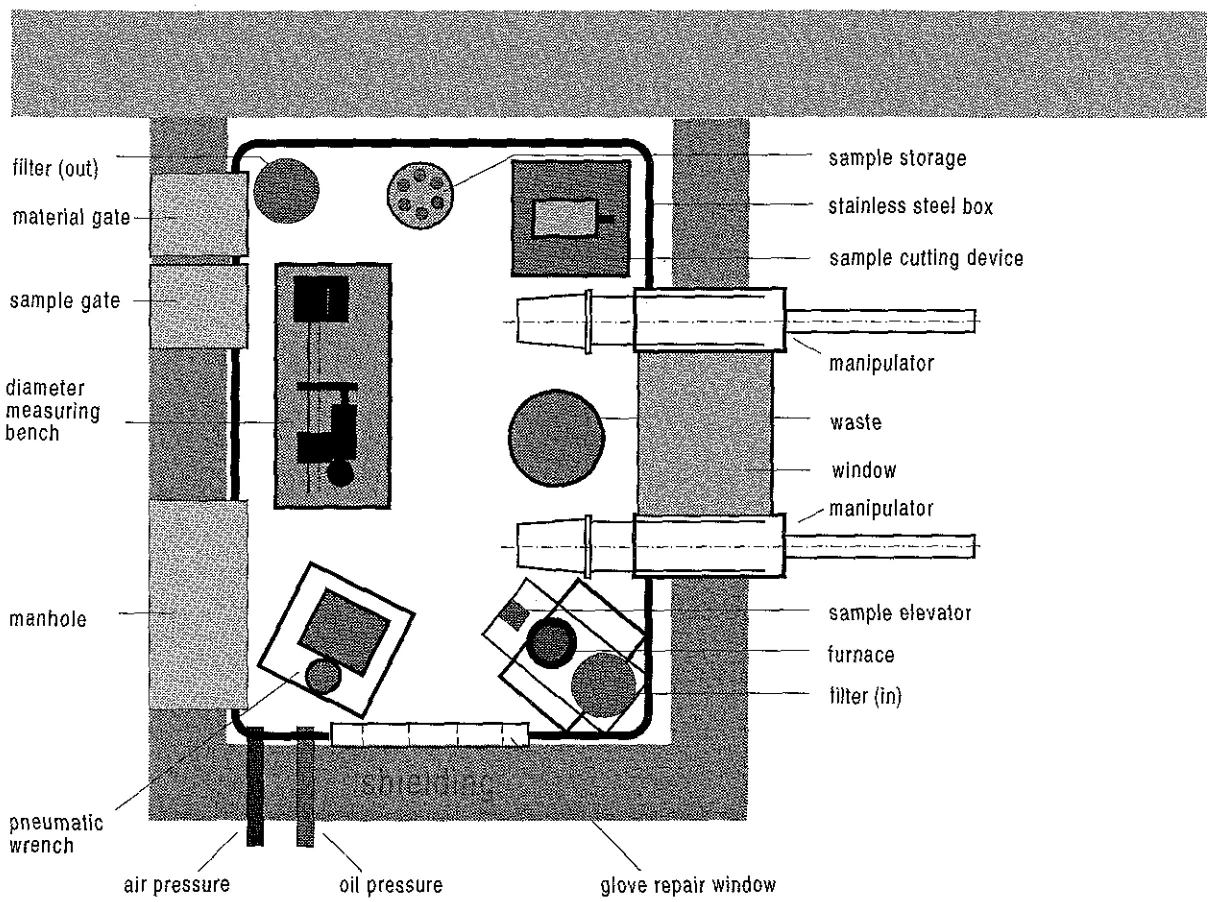
Usually tensile testing on the fuel cladding is performed because, it is the least expensive method. In this method a test specimen is prepared from the cladding (a total tube segment or a dog bone specimen, cut out of the cladding wall) and tested in uniaxial tension. In order to infer the component strength or bursting strength of the cladding, an approximation is required. The so-called tank formula is used. Due to the approximations in the current formulas, the uniaxility of the tensile test and the anisotropic behavior of the cladding material this method for calculating the bursting strength is uncertain.

The direct way to determine the component strength is the burst test. However, a substantially higher effort is necessary compared to the tensile test and no commonly acknowledged standard test procedure is available.

A sufficiently long fuel rod segment is used as a sample for burst testing. It is cut out of the fuel rod to be investigated using a diamond cutting machine. The fuel has to be removed from the sample. Elsewhere the fuel is dissolved chemically, and a lot of liquid waste is produced. This was not acceptable at PSI. Therefore it was decided to remove the fuel mechanically. For the fuel removal a special diamond cutting drill was developed. In order to be sure that the cladding inside the wall surface will not be damaged in this process, a layer of fuel is left on the wall. Sufficient fuel can be removed by this process in a short time.

After the drilling procedure the burst sample is tansferred into the burst box. The burst box consists of a 30 cm thick steel shielding contained inside an alpha-tight box of stainless steel. The burst sample is passed into the box through a special sample lock. Tools and other things are passed in through the material lock. For larger repairs a man hole is used.

Shielded Burst Test Equipment



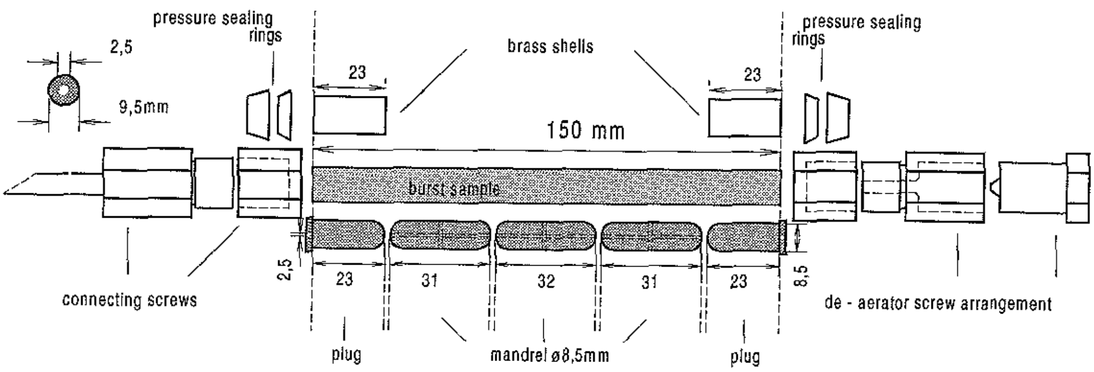
Tank formula: $p = 2 \frac{R_m}{1} s/d$ tensile strength

p: bursting strength
s: wall thickness of the cladding
d: Ø (diameter)

The sample cutting device, the diameter measuring bench, the pneumatic wrench and the sample elevator with furnace are essential pieces of equipment in the box. All the equipment can be operated with the two manipulators.

The pressure in the burst sample is built up using an Oil pressure system. Plugs have to be inserted on both ends of the burst sample. Before bursting the sample diameter is determined in 5 mm steps and along three lines differing by 60°, using the diameter measuring bench. Brass shells manufactured to a tolerance of a thousandth of a millimeter are fitted onto the sample ends. Using the pneumatic wrench the sample is closed at one end and is screwed onto the oil pressure system at the other end. The screwed on connectors serve both for holding the sample and for the sealing between the sample and Oil pipe. The sealing is complicated because of the corrupted surface. However the so called SWAGLOCK connectors have proved sucessful for this application.

Burst sample and fittings



After finishing the screwing operation the specimen is closed by connection to the Oil supply system and the furnace cover. Now an on-line diameter measurement arrangement (Delta D) is placed on the sample and with help of the elevator the "instrumented" specimen is placed into the furnace. With Delta D it is possible to measure the diameter changes during the test up to reaching the bursting pressure. The development of Delta D began with a measuring system based on miniature strain ganges (MSG). MSG did not give reliable results however, due to the sensitivity of MSG to vibrations of the steel-covered connections, especially at high temperatures. Therefore a trouble-free measuring system, called Delta-D, was developed on an inductive basis. It is usable both at room temperature and at operating temperature up to 350 °C.

For tests at higher temperatures a furnace with its opening at the box bottom level is used. Good insulation and an extensive heating surface insure an evenly heated burst sample with a temperature gradient at 350°C.

The burst test sample fails when the burst pressure is reached. The burst or crack opening can have various dimensions ranging from short but bulbous cracks or long and narrow cracks, to cracks that propagate along the complete free sample length. At very high temperatures, brittle sample "explode" leaving several strips. In this case the circumferential elongation can hardly be determind.

The test ends with the determination of the diameter change outside the burst opening, using the diameter measuring bench .The ultimate circumferential elongation is determined by metallography at the maximum burst opening level.