Fuel fabrication

We will only look at the fuel for Pressurized Water Reactors (PWRs), since this is by far the most common type. There is another LWR type, the Boiling Water Reactor (BWR), for which the principles are the same, but the BWR fuel elements have different geometrical and dimensional features.

First of all, the enriched uranium oxide is compressed into small pellets (like pills) and after an annealing treatment these are piled in long thin rods of zirconium, which withstand corrosion and deformation well at operation temperatures. For some reactor types in which the temperature becomes higher, stainless steel is needed, the disadvantage being the higher neutron absorption rate in this material (those elements may also have a very different design, mainly determined by heat transportation, neutron economy and material integrity requirements).

Each fuel rod contains a spring in order to keep the pellets in place while reserving some space inside the rod for volume expansion as the pellets become deformed due to heat and neutron radiation, and because of gaseous fission products. These rods are arranged in a square array. Including some supporting material, usually able to hold 17x17 rods less the support tubes, we now have a fuel element.

Typical 17x17 PWR fuel elements have 24 support tubes and a central instrumentation tube for in-core neutron flux and coolant exit temperature monitoring, so they can contain a maximum of 264 fuel rods (the Westinghouse standard). In most PWRs only 1/5 or 1/3 of the elements in the reactor core have control rod clusters attached at their top end, with slender control rods located in the support tubes. These control rods are made of neutron absorbing material like cadmium. They are withdrawn on reactor start-up and they are not normally used for power control or shaping, only for emergency shut-down. Instead, power control is maintained by regulating the amount of boron acid dissolved in the cooling water, since boron is a neutron absorber.

Figure 1: PWR fuel element

Typical PWR fuel elements are about 4 m (160") in length and 20 cm (8") in width and height, containing some 400-500 kg enriched uranium (unless explicitly indicated, the oxygen weight in the fuel is never taken into account).

The fuel picture in figure 1 is a scan from a public brochure by EPZ, owner of the Dutch Borssele PWR plant. You may have noticed that this is actually a 15x15 fuel element, which is a historical curiosity as industrial standards develop through time and competitive business.