NPRE 449, Hw 2

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1 Question 1

1.1 Question

What are the two major types of HTGRS and describe them in terms of their defining characteristics?

1.2 Answer

The two types of HTGRs are prismatic and pebble bed. The biggest difference is in the form of the fuel. Generally, the composition of the fuel kernels is the same, but packaged differently. Both designs use TRISO (tri-structural isotropic) kernels, which are Uranium kernels surrounded by a buffer layer, then an inner pyrolytic carbon layer, then a silicon carbide layer, then an outer pyrolytic carbon layer.

Prismatic HTGRs use fuel pellets, which are cylinders composed of TRISO pellets in a matrix of silicon carbide. There are usually hundreds of these pellets in a fuel assembly.

Pebble bed HTGRs use fuel pebbles, which are spheres composed of TRISO pellets in a matrix of silicon carbide. There are usually thousands to hundreds of thousands of pebbles in a fuel assembly. Each pebble can be reused 6 times before it is burnt-up.

The two HTGR types also have different reactivity control mechanisms. Prismatic HTGRs use standard control rods in both the core and the reflector. There is also burnable poison in the fuel elements. For pebble bed HTGRs, there are standard control rods in the reflector as there is no place for them in the core.

2 Question 2

2.1 Question

Explain the key differences between HTGRs and LWRs including some pros and cons.

2.2 Answer

HTGRs and LWRs differ in many operating parameters. HTGRs use graphite for the moderator and structural material and He for the coolant. On the other hand, LWRs use water for the moderator and coolant and steel for the structural material. The coolant in HTGRs is more expensive and 5-10% leaks every year. In contrast, LWRs use water, which is extremely cheap and abundant. The average coolant exit temp is far hotter in HTGRs at 700-900 °C compared to the relatively cool 310 °C for LWRs. In HTGRs, the fuel clad is SiC and PyC while, in LWRs, the fuel clad is zircaloy. The HTGR can also operate at a higher temperature being able to withstand 1800 °C for at least 150 hours with no failures. LWRs can only operate up until 1260 °C. The HTGRs are far less power dense operating at a power density of 4-6.5 W/cm^3 compared to the higher power density of LWRs at 58-105 W/cm^3. The HTGR also has a far higher migration length at 57 cm compared to the 6 cm of the LWR. There is also a stronger negative reactivity feedback mechanism in the HTGR with -7 pcm/K compared to the -1 to -4 pcm/K of LWRs. HTGRs also have a higher buildup of minor actinides compared to LWRs.

In general, the pros for the HTGR are: robust fuel, high margin between operating temperature and fuel failure temperature, inherently non-proliferation due to the fuel type, and are generally safer. However, the cons are as follows: dealing with Wigner energy at lower temps, leaking 5-10% of the helium every year, expensive coolant, and less ubiquity in the current market.

For LWRs, the pros are: cheap coolant, uqiquity in the current market, more experience with LWRs in industry, and a streamlined regulation process. However, the cons are as follows: low margin between operating temperature and fuel failure temperature, more backup systems as they are inherently less safe, and higher power density (debatable if this is a pro or con).

3 Question 3

3.1 Question

Why are HTGRs pressurized? Describe the implications.

3.2 Answer

HTGRs are pressurized as helium is effectively invisible neutronically and has a very low density. The first quality is consequential as increasing the density of helium does nothing directly to the neutron economy, so an increased density through pressurization only serves to increase the heat transfer capabilities without sacrificing neutron economy.

The implications of this pressurization are that complicated, durable piping in the primary loop is needed to handle the helium. Also, due to both this pressurization and the size of helium, there will be a leakage of 5-10% of the helium per year, which is detrimental as helium is a very expensive coolant.