Dr. Flint on the rising demand for nuclear graphite

Fast neutrons are produced by decaying uranium atoms. If a neutron hits another uranium atom it could decay producing more neutrons. However, the speed of the collisions is such that almost all the neutrons are ineffective. Nuclear reactors use reflectors to absorb most of the energy of those neutrons slowing and redirecting them so that they interact with and promote uranium decay. There are alternatives such as the heavy water used in the Candu reactors. However, most reactors in the world use graphite. Currently, almost all graphite used in the nuclear industry is artificial. The artificial graphite is mixed with carbon based binders and appropriately heated and shaped into forms.

There are three characteristics that are important in this application: neutron capture, isotropy and density.

1. Neutron capture: Boron, silver, indium, cadmium, cobalt, hafnium and a number of rare earth and some more obscure elements absorb neutrons and are used in nuclear reactors to controllably limit neutron chain reactions. It is important that all of these elements are not found in the graphite. The nuclear industry upper limit for boron in graphite is 5 ppm. It is important that this be achieved preferably without acids as these often create expandable graphite that will cause failure at the high temperatures of the newest generation of reactors.
2. Dimensional stability: The second important aspect of these forms are their precise dimensions. The carbon atom may be dislocated from its graphene layer due to energy transfer resulting from neutron collision. With time new layers of graphene form between the existing layers. This causes the form to crack as it expands

perpendicular, and contract parallel, to the crystal structure. In order to mitigate this effect isotropic (behaves the same in all directions) forms are required. However, graphite is anisotropic with significantly different behavior across the crystal compared to along the crystal. To create isotropy very small graphite particles (<10 micrometers) are used that are randomly oriented within the form.

3. Density: The density must be as high as possible and even throughout the form. This probably precludes the use of ball graphite. Natural graphite does give slightly different performance than artificial graphite due to its higher order and higher graphite content.

The conclusion is that natural graphite can be used, and would probably be preferred both from performance and price considerations. However, achieving both the stringent contaminate levels and the very small particle size at sufficient purity has, in the past, limited its use as the purification of those small graphite crystals has proven to be difficult. There are techniques that have been proven within the wider mining industry and at the demonstration phases that will change this restriction in the future.

The cost of the graphite is a minor consideration for nuclear use when compared to disposal costs. What is far more important is the minimization of dimension creep and crack due to atomic displacements as this will extend the lifespan of the form. With time, and the absorption of neutrons some of the carbon (12) is converted to the radioactive carbon (14). Thus, these forms become very radioactive with a half-life of 5,730 years. Disposal costs of this material is high. Traditionally, this material has been stored or burned. Burning is not really an option as this will increase the total C14 in the atmosphere by about 0.3% per nuclear reactor. One alternative is to recycle the material. This is possible using newly formulated techniques; however the capital required would be considerable as it requires taking apart the graphite forms and reducing them into liberated graphite crystals then rebuilding them into new forms. Whether or not this is performed is an economic versus radiation risk balance.

Recycling facilities currently do not exist, but they could, all the technology does exist, and would probably have a lower point on a risk/cost analysis then simple storage of the material.