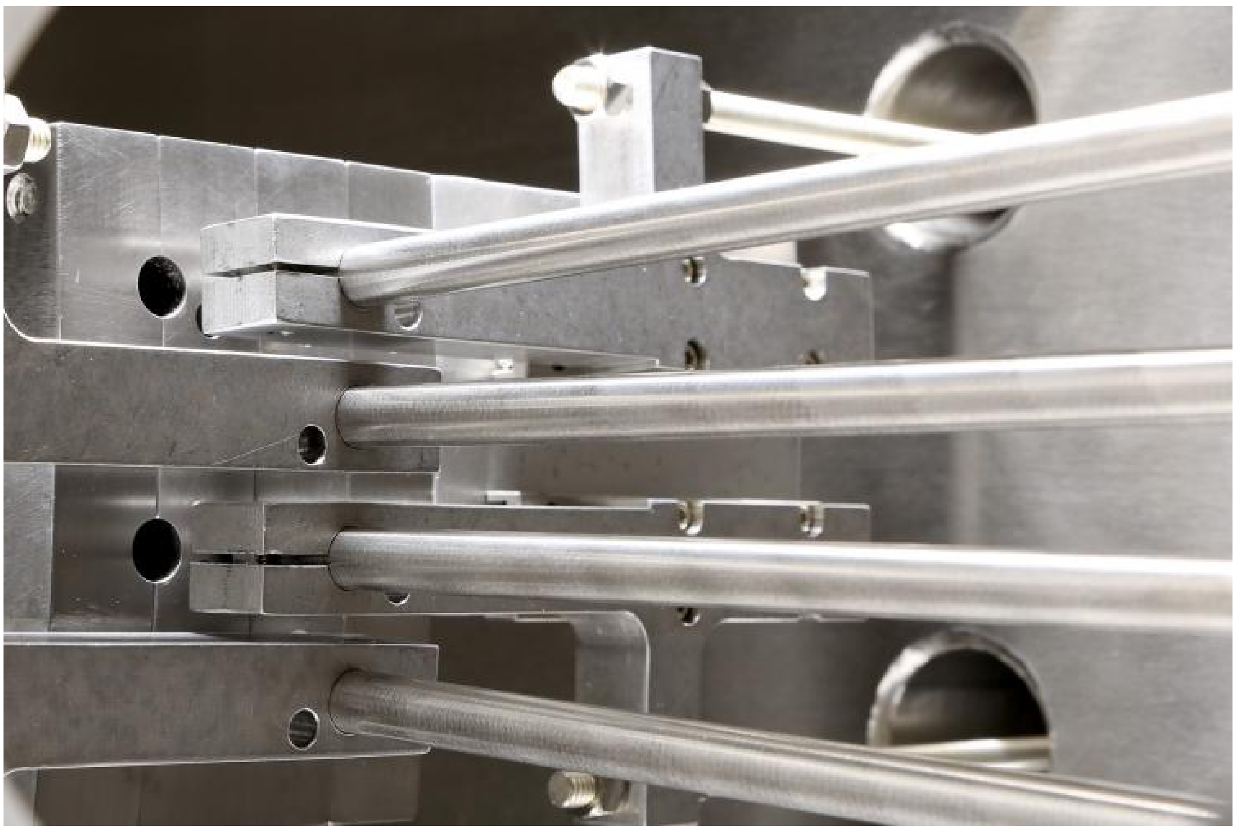
Controlling ITER with fuelers, ticklers, and terminators

September 9 2015, by Leo Williams



The inside of a pellet selector, which directs pellets to different outputs in a fusion reactor.

When it's up and running, the ITER fusion reactor will be very big and very hot, with more than 800 cubic meters of hydrogen plasma reaching

170 million degrees centigrade. The systems that fuel and control it, on the other hand, will be small and very cold.

Pellets of frozen gas will be shot into the plasma—some to keep it fueled, some to manage plasma activity, and some to extinguish the plasma as needed.

The idea of using frozen pellets to fuel a magnetic fusion reactor is not new. Researchers with ORNL's Fusion Materials and Nuclear Systems Division have been working on the technology for 35 years. Their handiwork helps run fusion experiments across the world, including America's largest fusion reactor, the DIII-D tokamak operated by General Atomics in San Diego.

Their expertise also made them the right choice to take on the much more challenging job of controlling ITER, which is more than eight times larger than the largest fusion reactor now in existence.

"The pellets are much more efficient at fueling the fusion plasma because they can penetrate fairly deep into the hot plasma before being ablated and ionized into additional plasma," explained Larry Baylor of ORNL's Plasma Technology and Applications Group.

"The alternative method of injecting gas that is primarily used in today's smaller devices will not add fuel efficiently in ITER because of its large size and high magnetic field."

Baylor said his group is working on three types of pellet, which he refers to as fuelers, ticklers, and terminators.

Fuel pellets containing two hydrogen isotopes—deuterium and tritium—will be shot into the inside of the donut-shaped plasma to keep it burning. The pellets will be produced in a screw extruder chilled with liquid helium.

Helium in its liquid state is a chilly minus-452 degrees Fahrenheit, or four degrees above absolute zero. The cold turns the hydrogen into a liquid in the top of the extruder and a solid in the bottom.

At this point the hydrogen has a consistency not unlike toothpaste. The ORNL-designed device uses twin screws to pump the solid through a small nozzle, where it is cut into pellets and shot into the reactor with a device called a "repeating pneumatic gun."

Baylor said the fuel pellets are a little larger than .177-caliber air rifle pellets. To keep ITER going, the system will need to inject about four each second, or 15,000 an hour.

The same system produces the tickler pellets, which are about four times smaller than the fuel pellets. The tickler pellets are designed to prevent a fusion reactor's version of damaging solar flares—bits of plasma that peal off and hit the plasma-facing surfaces on the inner wall of the vessel. They do this by creating a series of smaller flares to diffuse the built-up energy.

"We want to make the flare-like events as small as possible," Baylor said. "We use the same device to shoot small hydrogen bullets to tickle the edge of the plasma so that it stays relatively stable."

Of all the pellets being designed by the ORNL team, the ticklers are the trickiest, Baylor said, because the experience gained from existing facilities such as the San Diego reactor is limited and high repetition rates are needed.

"The most difficult of the three to extrapolate is the tickler, because the ITER plasma is so much larger. It's a higher magnetic field, and hotter, and we cannot very well replicate the edge of the plasma conditions in DIII-D. That one is much more difficult."

The third type of pellet is meant to halt the fusion reactions altogether. It is for times when the whole plasma becomes unstable and threatens to come in contact and severely damage the plasma-facing surfaces of the containment vessel. These pellets are much larger than the others and are filled with frozen neon.

ITER will have around two dozen frozen terminator pellets ready to blast into the plasma. The system won't get much warning of an impending disruption—in some cases only about 20 milliseconds. As a result, the pellets will have to reach speeds over 670 miles an hour to get to the plasma in time.

The tubes that carry the terminator pellets into the plasma will have a sharp bend, causing the pellets to shatter just before they reach the plasma and ensuring that the frozen neon is injected as a spray. The spray will stop the fusion reactions and cool the plasma, turning it back into a gas.

The instabilities are known as disruptions. Baylor said ITER's developers came to appreciate over time the serious possibility that 800 cubic meters of super hot plasma could damage the plasma-facing surface.

"When ITER was first designed, they really didn't worry too much about these disruption events," he explained. "Then, over time, they realized it could be a detriment to machine operation. So it's very critical that we develop a reliable mitigation technique to keep that from happening."

Baylor said the pellet systems will go through final design review during the 2018 federal fiscal year, which ends in September. He said they expect to deliver the systems to the ITER site in southern France starting in 2020.

Provided by Oak Ridge National Laboratory