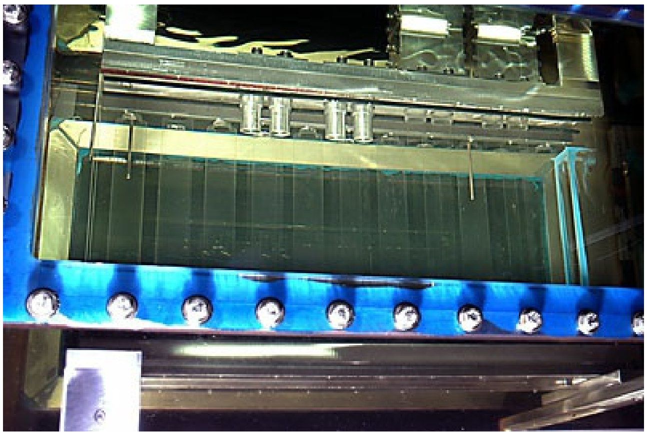


INL's Matched Index of Refraction facility, the largest in the world, lets researchers check the accuracy of computer codes that predict the movement of airborne chemical or biological agents through urban environments.

Quartz and oil: INL's MIR facility helps engineers improve their designs

By Mike Wall, *INL Communications and Governmental Affairs*

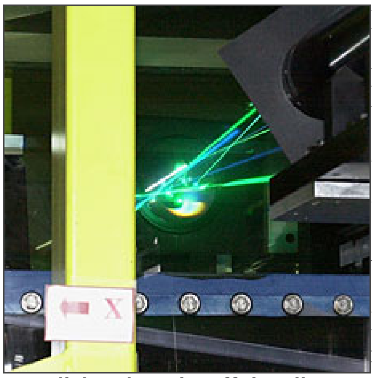
A few years back, scientists at Idaho National Laboratory carved a miniature office building out of quartz and dunked it in a giant vat of mineral oil. Though the oil was clear and colorless, the scale model disappeared when submerged, lost from sight beneath the viscous waves like a tiny Atlantis. And that was the whole point.

MIR is a 27-foot-long recirculating bath that can pump through 3,000 gallons of mineral oil.

The INL researchers were measuring how oil flowed around the building's complex contours, all in the service of national security. They wanted to check the accuracy of computer codes that predict the movement of airborne chemical or biological agents through urban environments. If the building were visible, it would make it hard to observe — and accurately measure — the oil's flow.

This is just one of many experiments that have used INL's Matched Index of Refraction facility, the largest such set-up in the world. MIR's ability to make objects disappear lets scientists test and validate their computational flow dynamics (CFD) models. Validation is vital, helping engineers maximize the safety and efficiency of their designs, for everything from office buildings to nuclear reactors. But without flow systems like MIR, it can be almost impossible to do well.

"You can't just stick a probe into the core of a nuclear reactor," says INL's Hugh McIlroy, who runs MIR. "And even if you could, you wouldn't want to build the reactor without validating your models first."



Laser light — bouncing off tiny silver-coated spheres — tracks the oil's flow.

Lasers, silver-coated spheres and 2,500 gallons of mineral oil

MIR is a huge recirculating bath, 27 feet long by 10 feet tall. It can pump 3,000 gallons of mineral oil through at 1.7 meters per second, though a mere 2,500 gallons is more common during operation.

To run an experiment, McIlroy drops his quartz model into MIR's glass-walled test section. Mounted just outside, nice and dry, are a laser and two digital cameras. McIlroy seeds the mineral oil with thousands of silver-coated glass balls 10 microns in diameter (about the same width as a human red blood cell). Then he turns on the oil-pushing pumps.

Laser pulses blast into the oil flowing past the submerged model. The cameras snap photos as this light reflects off the tiny spheres. Computer algorithms then analyze the pictures to reveal details of the spheres' — and thus the oil's — movement. These algorithms crank out velocity vectors that are as visually striking as they are informative (see slideshow below).

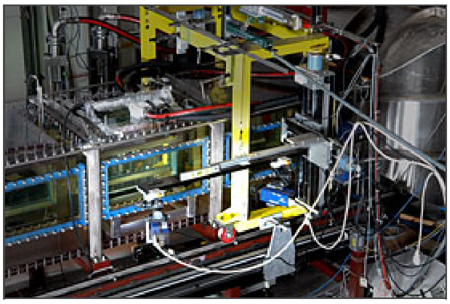
Why mineral oil? On first glance, the stuff is pretty unremarkable — "just baby oil without the perfume," McIlroy says. But at room temperature, mineral oil and quartz have the same index of refraction. That means they both bend light waves to the same degree. So when McIlroy and his team lower their model — be it a miniature building or part of a reactor core — into the goop, it disappears. The laser doesn't get blocked or sidetracked by the model; all it "sees" are the flowing silver-coated balls.

This technique is all very elegant and ingenious. But reconstructing flow patterns requires serious brute-force computational power, too. There are lots of little silver spheres to track, after all; a single picture from MIR's cameras can map out more than 7,000 velocity vectors.

"In three-and-a-half minutes of operation, we generate about 4 gigabytes of data," McIlroy says.

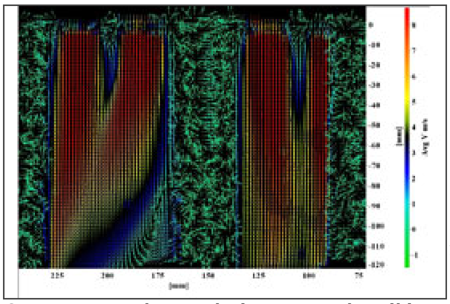
Modeling next-generation nuclear reactors

It may take several months to analyze all that data, on top of 12 to 18 months to design the experiment and build the perfect scale model. But the time investment is well worth it, McIlroy says, for MIR experiments deliver unmatched quality.



Cameras snap photos of the reflected laser light.

Scientists bring their CFD codes to the MIR arena to see how well they map out the mineral-oil flow. If all goes well, the simulations are considered validated; they can then help engineers design and assess real-world projects. And if a code has any weaknesses, MIR experiments will expose them, and researchers can go back to the drawing board.



Computers crank out velocity vectors describing the flow — up to 7,000 per photo.

"Validation is key," McIlroy says. "It's stubby-pencil work, but it's got to be done, and it's got to be done well."

Many research groups have sought out MIR's services since the facility was built in 1995.

Recently, McIlroy has been doing a lot of work for the [Next Generation Nuclear Plant](), an INL-led project that seeks to convert nuclear energy to valuable industrial process heat. Industry currently burns huge quantities of CO_2-spewing fossil fuels to generate this heat, which is used to refine oil, manufacture chemicals and perform many other vital tasks.

McIlroy and his team have been helping NGNP scientists model how coolant will flow through the NGNP's core. They've run several experiments, dropping models of various NGNP parts into MIR's crystalline depths.

"To design a nuclear reactor, you've got to understand heat transfer and coolant flow," McIlroy says. "These experiments are the first steps toward achieving that goal."

View this narrated slideshow about the facility or read the transcript.

Feature Archive