In a nuclear safety test in the mid-1980s, bundles of non-nuclear fuel rods were heated until they melted to determine safe temperature limits.

NUCLEAR FUEL

New Designs for Nuclear Industry

In the late 1940s an ORNL team led by Eugene Wigner designed water-cooled fuel elements to ensure that the Materials Testing Reactor would produce a high enough concentration of neutrons to determine which materials would hold up best for future reactors. The team designed the fuel elements of uranium sandwiched between aluminum plates surrounded by beryllium, to reflect neutrons back into the core. Wigner's best-known innovation was to curve the plates so they would bow in only one direction under intense heat, preventing constriction of water coolant flow, which determined neutron intensity. This design was a model for cores of U.S. research reactors and submarines.

In 1958 the British, using an early gas-cooled design, produced commercial nuclear electricity. With increased interest in a high-temperature gas-cooled reactor (HTGR), ORNL researchers focused on making fuel that could perform at high temperatures in a reactor cooled by helium and moderated by graphite.

They formed hundreds of spherical particles of uranium dioxide or uranium carbide, coated them with carbon to retain fission products, and embedded the fuel beads in graphite structures. Using the Oak Ridge Research Reactor, Don Trauger's team proved this fuel was stable when irradiated, unlike the design in which uranium carbide particles were dispersed in graphite. The ORNL team's findings caused the Germans to switch to coated-particle fuel in their HTGR. Improved versions of this design were used in two commercial U.S. HTGRs and in test reactors in Germany, Japan, and China.

ORNL researchers are now helping to develop meltdown-proof fuel beads for use in advanced HTGR concepts.

NUCLEAR SAFETY

Understanding the Challenge

ORNL has influenced nuclear safety in numerous ways. It trained more than 900 engineers in reactor design and safe operation. The Laboratory published the journal *Nuclear Safety* for more than 30 years. Since the 1960s ORNL has had a major impact on nuclear criticality safety—using industrial controls to protect against potential consequences of an unintentional, uncontrolled chain reaction during uranium or plutonium processing, storage, or transport. ORNL researchers provided the basis for several criticality safety standards and administered the international group approving this guidance.

In the late 1960s ORNL researchers led by Grady Whitman began studying whether steel walls of reactor pressure vessels exposed to high temperatures and embrittling radiation could withstand the water pressures of reactor operation without cracking. Having conducted research for more than three decades on thermal shock, fracture mechanics, and radiation embrittlement, ORNL became the world leader in producing data that have provided a basis for licensing and operation of light-water-reactor (LWR) pressure vessels.

ORNL research showing that zirconium-alloy fuel cladding became brittle under simulated accident conditions led to new regulations limiting LWR power levels. These results, reported by ORNL experts during national safety hearings, led to tighter requirements to lower the probability that reactor cores would overheat if emergency cooling water were lost. ORNL fission-product-release studies also provided a basis for safety regulations.

When a loss-of-coolant accident occurred in 1979 at the Three Mile Island power plant, ORNL researchers assisted the Nuclear Regulatory Commission in ascertaining causes and consequences of the accident and discovered that less radioactive gas was released than expected. As a result of the accident, ORNL and NRC staff developed the Sequence Coding and Search System, which captures information on nuclear power plant operations for inclusion in a database. The system has been used for numerous safety studies, regulatory actions, and risk assessments.

ORNL researchers developed accident models for NRC that prompted improvements in advanced boiling-water-reactor designs. They also have helped establish regulatory guides for digital instrumentation and control systems in nuclear plants.

1953

Transportable reactor designed by ORNL for Army's use at remote sites

ORACLE, world's then most powerful computer, installed at ORNL

1954

ORNL ecology program started

ORNL's experimental aircraft reactor tested

Tower Shielding Facility first operated, to provide data for ill-fated U.S. nuclear airplane project

First detailed study of chemical reaction using colliding molecular beams of two different reactants

1955