ASTM: Powering the Future

The Resurgence of Nuclear Energy

As the industry's renaissance continues, ASTM International remains key to standards maintenance and development.

BY JAN WALDAUER

Nuclear energy has evolved over the past 50 years, with each generation of reactors bringing improvements to design, security and efficiency of operations. The main use of nuclear energy today is to generate electricity; it is an efficient way of boiling water to produce steam to drive turbine generators. This steam is clean, safe and usually very cost-competitive.

Nearly 440 nuclear power reactors in 30 countries, plus Taiwan, provide approximately 16 percent of the world's electricity today, a share that has remained fairly constant since the mid-1980s. Due in part to increasing energy demands and concerns over climate change related to fossil fuels, significant growth in reactor construction is expected over the next 15 to 20 years, especially in Eastern Europe and Asia. The International Atomic Energy Agency predicts that at least 70 new plants will be constructed by 2030 in such countries as China, India, Russia, Finland and France. In addition, the U.S. Department of Energy expects domestic nuclear energy demands to increase by 45 percent over the next 20 years. As reactor construction increases and technology changes, the maintenance of existing and the development of new industry standards will be required.

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INDUSTRY EVOLUTION

In the 1950s and 1960s, nuclear technology was seen as a source of inexpensive electrical power to lessen urban smog from coal-fired power plants. But due to the industry's infancy, Generation I designs were conservative, and success was somewhat hindered by high costs, multiple designs and low efficiency. Outside the United Kingdom, none of these reactors is running today.

Generation II reactors were developed in the 1970s and 1980s, and many are still in use today, particularly in the United States. While their technology is basically the same as Generation I, many improvements in design and performance can be attributed to increased operator experience, higher performing materials, design standardization and overall industry maturity.

The focus for nuclear plant design has always been safety, as evidenced in the Generation II designs and beyond. "From a safety and reliability standpoint, the incidents at Chernobyl and Three Mile Island were blessings in disguise because they prompted major changes and improvements to components and control systems. ASTM's role in the industry also became more prominent at that time, as the U.S. Nuclear Regulatory Commission (at that time, known as the Atomic Energy Commission) officially adopted several ASTM standards, such as ASTM E185 on reactor vessel surveillance program requirements and ASTM E693 on determination of displacements per atom," notes Stephen Byrne, fellow engineer at Westinghouse in Windsor, Conn., and chair of Subcommittee E10.02 on Behavior and Use of Nuclear Structural Materials, part of ASTM Committee E10 on Nuclear Technology and Applications.[1]

An important distinction between early and later Generation II designs was the desire to increase efficiency and extend operating lifetimes. The first reactors were licensed for 40 years of operation, although most have applied for license extensions for 60 years. E10 began working with the NRC in the 1960s regarding structural materials, and the extension of operating time is driving much of its current work.

Byrne comments, "There are many time and temperature sensitivities involved when increasing the lifecycle of a nuclear reactor, so a lot of our committee work in the 1980s was focused on materials aging evaluations. Our research focused on things like radiation metrology (neutron measurement) and neutron embrittlement (reduction of toughness) in order to provide updated or new standards on structural materials."

Randy Nanstad, group leader for nuclear materials science and technology at Oak Ridge National Laboratory, Oak Ridge, Tenn., and an E10 member, adds, "We continue to update standards for exposure of materials to high irradiation and high temperatures as new information becomes available and because of license extensions and designs of new reactors. The predictive models we use are based on 40-year lifetimes, so E10 is now looking at how to extend those models to develop standards for 60- or even 80-year lifecycles."

CURRENT AND FUTURE DESIGNS

Generation III and III+ reactor designs, created in the 1980s through the present, are more advanced than their predecessors in several ways. They have a more standard design, helping to reduce cost and construction time. They have higher burn-up to reduce fuel use and waste, and burnable absorbers to extend fuel life. Some are designed for load-following, which means that output can be changed quickly to react to fluctuating electricity demands during the day. Perhaps the largest difference between Generation II and III/III+ designs is that the newer reactors have inherent safety features that require no active controls or operator action to trigger. These newer reactors are in use today mainly in Japan and Korea, but other countries are currently building or have ordered them.

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Byrne summarizes, "Generation III/III+ designs are leaner and meaner. They take the best of previous generations, along with increased operational experience and improved analytical tools, and offer a safe, reliable and green source of energy."

While reactor designs have changed over the years, components involved in the nuclear fuel cycle have remained relatively unchanged. ASTM Committee C26 on Nuclear Fuel Cycle focuses on all aspects related to this cycle, including spent nuclear fuel, waste materials and repository waste packaging and storage.

"The scope of C26's work has been fairly constant since 1969, but the number of subcommittees has expanded to reflect the changing needs of the industry," says Dick Blauvelt, senior consultant, Navarro Research and Engineering Inc., Oak Ridge, Tenn., past C26 chair and current chair of Subcommittee C26.07 on Waste Materials. "Initially C26's focus was the commercial sector, but in the early- to mid-1980s it began to also support national defense work, mainly related to waste repositories. During the Carter administration, reprocessing of spent fuel in the U.S. ceased out of concern for the proliferation of nuclear weapons materials. That certainly impacted Subcommittee C26.09 on Nuclear Processing, and since then the group has been less active on the topic of reprocessing."

Generation IV reactor designs are in the conceptual stages now, not expected to reach commercialization until 2020 at the earliest. An international task force called GIF (Generation IV International Forum) is currently developing six technologies, each representing further advances in safety, reliability, sustainability, economics and proliferation-resistance. All technologies will operate at higher temperatures than today and many will be designated for hydrogen production, which would eliminate the need for fossil fuels.

Although Generation IV designs are still on the drawing board, ASTM committees are already looking at what is on the horizon.

"Material behavior in this new generation of technology will be very different from today," says Roger Stoller, Ph.D., program manager for fusion reactor materials at Oak Ridge National Laboratory, Oak Ridge, Tenn., past E10 chair, current chair of Subcommittee E10.08 on Procedures for Neutron Radiation Damage Simulation and vice chair of the ASTM board of directors. "Generation IV reactors will require composite materials that can survive at very high temperatures as well as bring changes in fuel forms and coolants. All of these advances will require the development of new standards for structural materials, and we are already looking into what that design and testing criteria could be."

Generation IV designs will have a direct impact on C26's work, as designs are focused on closing the fuel cycle to optimize the use of federal geologic repositories for high-level wastes. Though all nuclear wastes have the potential for reprocessing (to recover reusable radionuclides), all will have residual high-level wastes that need to be placed in an appropriate repository. Different reprocessing steps provide different options for handling waste streams, and these are evaluated with regard to regulations and potential cost savings. C26 is looking at these options closely to develop standards as more tailored waste forms for Generation IV designs come on board.

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INTERNATIONAL EXPANSION

The globalization of the nuclear industry is obvious. Many of the issues connected with nuclear power, evidenced by GIF participation, are global. Therefore, it is important that industry standards are developed with an international mindset.

Over the past 15 years, Committee E10's member participation has become more international. "ASTM standards have always been international because they are commonly used around the globe. As a result, we have purposefully solicited international input for our standards updates and development. ASTM has a large and diverse membership base, with a substantial contribution from members in other countries," says Stoller.

Nuclear waste disposal can be impacted by climate, environments and geologies, so the long-term performance of various waste forms and engineering materials will differ in different environments. C26's standards work must take these factors into account and having international representation in and perspective on the committee is very beneficial.

Nanstad summarizes his thoughts on ASTM and its international reputation. "ASTM standards are very well-respected in many countries because they are built by consensus. For those nations just getting into the nuclear industry, they can gain some instant credibility by following ASTM standards."

References

1. The complete ASTM standards titles are E185, Practice for Design of Surveillance Programs for Light-Water Moderated Nuclear Power Reactor Vessels, and E693, Practice for Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements Per Atom (DPA), E 706(ID).

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