Advanced reactors: An endless landscape

by E. Michael Blake

The term “advanced” is, of course, relative, no matter how it is applied. Power reactors that have been in operation for decades were once seen as advanced beyond older designs. Those same reactors that produce our electricity constitute, in this era, the level of the ordinary, from which new designs are considered advanced. Because there is such a large pool of nuclear scientific and engineering talent worldwide, it seems reasonable to project that what we see as advanced now could be outstripped decades later by even greater advancements.

The larger term “advanced reactors” is used in this special section to indicate designs and concepts beyond most of the ones that are being built now. Because so much has been written about them, both in Nuclear News and elsewhere, we are drawing the starting line just beyond reactor models that are generally thought of as “evolutionary,” with one exception: The AREVA-Mitsubishi collaboration, ATMEA1, is included because we have hitherto given it relatively little coverage, and because it is something of a departure for two vendors whose other designs are known for extensive engineered features and high power ratings.

The following articles and their accompanying graphics were provided by the organizations developing these reactor models, although to varying degrees they have been modified by (or under the direction of) NN’s editors. We will be the first to concede that these articles do not cover all of the ground in advanced reactor development, and any attempt to list every design could run far beyond the interest level of any reader, depending on how the word “design” is defined. Nor do we think that a mention in these particular articles in NN does not constitute an endorsement by the magazine or by the American Nuclear Society.

It can be said that the following articles cover prospects that have gone through considerable research and development, presumably enough to reveal whether the models’ core concepts are based on deal-breaking flaws. Designs have changed and prospects have been reassessed, but for every model in these articles, there continues to be confidence, inside the developing organization and outside of it, that the effort can produce a worthwhile product.

As for the models, designs, and concepts that are not in these articles, here is a brief summary of what has gone before and what may be on the way. We apologize in advance if we have left anything out, although we stand by the following reasons for keeping a velvet rope in place. Excluded are any concepts that 1) can deliver on their promised benefits only through the creation of a worldwide, treaty-altering system of reprocessing and waste disposal facilities; 2) are being advanced by a few people who are looking for crowdsourced funding; 3) pose serious challenges for licensing or regulatory approval, which are blithely dismissed by the proponents; and 4) are being championed mainly to reverse what are asserted to be historical wrongs that supposedly arose from closed-door decisions made early in the Atomic Age, with money purportedly beating down science and justice.

Old-school advanced

The liquid-metal fast-breeder reactor (LMFBR) has a long history, some of it involving energy production, but it certainly remains an advanced concept, given that nearly all other nuclear energy has come from water-cooled reactors and single-use fuel. While there is active deployment now taking place in Russia, with the BN-800 at Beloyarsk reported to be in a startup phase, in most other programs there have been substantial problems that have overwhelmed the potential benefits of liquid-sodium heat transfer and the transformation of uranium-238 into plutonium-239. France’s Super-Phénix generated power during only six of its 11 years of operation, with a total capacity factor of about 8 percent, and no other LMFBRs followed it. Japan’s Monju has twice been halted before initial startup because of technical issues. A prototype fast-neutron reactor is being developed in China, and farther along is the PFBR in India. It is intended as a 500-MWe power plant, and while major construction is said to be essentially complete, there is not at present an announced target date for startup.

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of countries. The total number has changed frequently, but currently there are 10 active members (Canada, China, Euratom, France, Japan, Russia, South Africa, South Korea, Switzerland, and the United States) and three nonactive members (Argentina, Brazil, and the United Kingdom). The reactor concepts decided on by the participants have not changed since their selection in 2002: gas-cooled fast reactor, lead-cooled fast reactor, molten salt reactor, supercritical water-cooled reactor, sodium-cooled fast reactor, and very-high-temperature reactor.

Each concept has a subgroup of GIF members exploring it in various ways, generally through simulations or proof-of-concept experiments; none of the six has progressed to the point where someone would develop a full plant design, let alone propose it for construction and operation. A technology roadmap update in January 2014 anticipates that work during the next 10 years will remain in the R&D realm for all six concepts, and that deployment will take place at some unspecified times after 2030.

Every advanced reactor development effort relies on the belief that the core principle behind the effort—that it is worthwhile to extract energy from the fissioning of certain actinide nuclei—will continue to be valid decades from now.

More recent advanced

It may be in the nature of people who have both the attitude and the aptitude to become nuclear professionals to seek to take the technology further, extract even more of the potential energy, and find new ways to improve the environmental effects. A major difficulty for any such endeavor is that a significant departure must be backed by a vast amount of meaningful data to underscore the technology’s safety and practicality. Among the newer organizations that are pursuing technologies outside the current comfort zone for regulators, at least two are seeking to build on concepts that have some (though perhaps not yet enough) data behind them. We are not sure if these companies, both in the United States, really rise above our small-group-without-money cutoff, but we will note briefly X-Energy, which is backing a PBMR-based concept and notified the NRC early this year that it would apply for design certification in 2017 (and later became less specific); and Transatomic Power, which is pursuing a molten salt reactor similar to that proposed by the Canadian firm Terrestrial Energy (see page 54).

A more established presence in nuclear energy, with a fair amount of fuel-related and consulting business, is Lightbridge,