Nuclear energy: *Not* a Faustian bargain, but a near-perfect providential gift

BY THEODORE ROCKWELL

A nuclear veteran encourages those in the industry to get serious and put nuclear energy in the positive light it deserves.

THE 33RD ANNUAL World Nuclear Association (WNA) Symposium, held September 3–5, 2008, in London, attracted a record-breaking 800 participants to the gleaming, modern Queen Elizabeth II Conference Center, with its huge picture windows facing its neighbor, the venerable Westminster Abbey.

On September 4, WNA Chairman Andrew White, president and chief executive officer of GE-Hitachi Nuclear Energy, and WNA Director General John Ritch, former ambassador to the International Atomic Energy Agency, bestowed awards on three people chosen to represent the educators, the innovators, and the pioneers of the international nuclear enterprise. The awardees were, respectively, Alan Waltar, of Pacific Northwest National Laboratory and former head of the Nuclear Engineering Department at Texas A&M University; Jacques Bouchard, of the Commissariat à l'Énergie Atomique, and head of the Generation IV International Forum; and me, Theodore Rockwell, of Radiation, Science & Health and MPR Associates. (See page 50, this issue.)

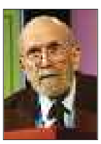
Mingling with the crowd of international nuclear professionals for three days gave me a chance to escape from the U.S.-centered bubble for a moment and get a wider view of the nuclear world. In the WNA and the associated World Nuclear University, John Ritch has built up two new substantive organizations and gotten important people involved, from inside and outside the corporate world. This creates arenas in which basic nuclear issues can be addressed, transcending the national institutions and technical "islands" in which many of these issues are bogged down. We have not yet taken full advantage of this situation.

Other countries now seem to be more urgently intent than the United States on building nuclear plants, which is good, especially when they speak with greater governmental authority. But they seem even more obsessed than the United States is with making nuclear "safer and safer." What's wrong with that? Can a plant be "too safe"? How do we know what's "safe enough"?

First, let me note that in the real world, no member of the public has ever been killed or seriously injured—or even exposed to a serious health threat—by a nuclear power plant or its fuel or waste.[1] So, what excuse is there for deciding that all sorts of extreme safety provisions must be applied to nuclear facilities that would never be considered for non-nuclear facilities, even those where lethal accidents have occurred and continue to occur?

That important policy decision is seldom acknowledged, and yet it is crucial to the future of nuclear. What became apparent from discussions in London is that the nuclear community seems bent on making its product ever more esoteric—kind of a fantasyland, where 200 years of mundane engineering experience and judgment seem out of place. In the 1970s, New Age gurus from Baba Ram Dass to Margaret Mead told young people that their elders had not experienced the coming age, did not understand it, and therefore could not advise them on how to live in it. Experience in the dying age was declared inapplicable to the New World.

At the same time, nuclear gurus were applying the same philosophy to the Nuclear Age. Alvin Weinberg, longtime senior spokesman from Oak Ridge, did not invent this idea, but in 1971 he approvingly characterized nuclear energy as a "Faustian bargain"—a miraculous gift, but with the devil to pay if we slip up.[2] I was in Oak Ridge not long before he died, and when he heard I was there, he asked me to come to his house. He urged me to carry that message onward. "You people in Admiral Rickover's group understand the absolute necessity for unprecedented excellence. To keep nuclear technology from slipping inexorably into mediocrity, we need to keep the Faustian threat alive." I told him I agreed fully with the



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[1] The Chernobyl incident in 1986 is only peripherally relevant to this question. It did not kill or seriously injure anyone *outside the plant*, with the possible exception of the 10 or 12 children with thyroid nodules, whose deaths could have been prevented. But more relevant is the fact that the type of accident that occurred there is not physically possible in the types of reactors being considered for the large-scale construction of new nuclear plants.

[2] Discussed in detail in Weinberg, Alvin M., *The First Nuclear Era: The Life and Times of a Technological Fixer*, published by Springer, 1994. Weinberg first discussed this analogy with his laboratory people in 1970, then "went public" in 1971, a date that he usually used in referencing it.

importance of maintaining the highest quality control, but that is justified on its merits and does not need support from a demonstrably false threat of a public catastrophe. Despite my respect for Weinberg's technical wisdom and leadership in the development of reactor technology, I firmly believe that applying the Faustian myth to nuclear technology has done great harm to the field.

I am not talking about public communication skills. If we learn to portray nuclear energy as acceptably risk free, but make no changes in our current policies and practices, we will surely be seen as hypocritical—advocating policies we don't follow, and thus presumably don't believe. Many nuclear advocates apparently believe that a severe nuclear accident could cause unprecedented public health problems, and they justify promoting nuclear power by convincing themselves that they have made such a casualty tolerably improbable. Unfortunately, when we say we have reduced the probability of an unspeakably devastating accident from 10_4 to 10_6, that doesn't satisfy most people. They know that improbable things happen, and they want to know how bad it could be. This is a legitimate request, but we brush it off because we've been told that it scares people to talk about casualty consequences.

The fact is, just since the Three Mile Island (TMI) incident in 1979, we have spent a billion dollars to build the case that a catastrophic nuclear accident is not merely improbable, but is physically impossible. We are protected from catastrophic consequences not by clever safety gadgets and procedures, but by the inescapable laws of nature and the known properties of the materials and processes involved.

Realistic consequences

In 1980–1981, after TMI, the Electric Power Research Institute (EPRI) reported on its studies that demonstrated that after the worst realistic accident, few if any public fatalities would occur. Each of the many steps that would have to occur to cause serious public consequences had previously been too pessimistically estimated: cooling the fuel, the release of fission products from overheated fuel, and the many processes that remove fission products from the containment atmosphere. The tornado of steam, water droplets, and air dissolve fission products or plate them out on the colder containment structure. Meteorological factors and population density immediately outside the plant have also been unrealistically selected. When each of these and other relevant factors are overestimated, the final product becomes exaggerated by many orders of magnitude. A "conservative" estimate becomes simply wrong. A tolerable situation is described as a catastrophe.

The heavily documented EPRI reports of 1981 were published in all the IAEA languages and presented all over the world by leading nuclear experts such as Chauncey Starr, Milton Levenson, Ian Wall, and Frank Rahn. The conclusions were never repudiated, or even seriously challenged. They were simply ignored, as practices (such as mass evacuation drills and the distribution of billions of iodine pills) continued unabated.

In 2002, after the attack on the World Trade Center's twin towers, I gathered 18 other members of the National Academy of Engineering who were nuclear leaders, and we published an updated report, including analyses of the Windscale, TMI, and Chernobyl data and the large-scale tests of molten fuel at Karlsruhe (*Science,* Sept. 20, 2002, p. 1997, and Jan. 10, 2003, p. 201). This report confirmed, and additionally documented, the conclusion of the EPRI reports that "few if any members of the public" would die from the worst realistic accident.

Fear is a powerful motivator, and by claiming that nuclear power technology is uniquely dangerous to the public safety, we create a great flow of money for research, prevention, and remediation. But we seriously distort policymaking and the specifics of how we design and operate nuclear facilities. What is the basis for believing that this technology is so dangerous? It results from an old weakness of scientists (which, incidentally, helps justify the existence of engineers). Scientists have learned to make "conservative" estimates of risk by multiplying together the various factors involved and making sure that each element of the calculation is a little on the safe side. The great physicist Werner Heisenberg did this when he calculated in his head the critical mass of an atomic bomb. He got such a large number that he concluded that the construction of an A-bomb was a practical impossibility, and therefore the Nazis never initiated a serious program to build one. This common type of error does not give an answer that is conservative; it is simply wrong.

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Edward Teller, also a brilliant physicist, made a similar error. In 1960, he made that kind of "conservative" calculation in his head, and concluded that an accident during the refueling of a submarine could create a lethal radiation zone extending several miles. He wrote an article for *Parade* magazine describing the situation and recommending that refueling be done at sea. The proposed article came to the Atomic Energy Commission (AEC) and was referred to Admiral Rickover for security clearance. Since refueling at sea would be difficult and even dangerous, Rickover asked me if Teller's calculation was realistic. It's not a difficult calculation, and I assured him that the radiological consequences of such an accident would be tolerable. He invited Teller to meet on a submarine with all 13 members of the AEC's Reactor Safeguards Committee, and Teller made his presentation to them. They saw no flaw in it, and Rickover threw me into the lion's den. I presented my calculation, which showed a tolerable one-time emergency radiation dose (25 rad) at 100 meters. Teller said, "I didn't see where you went wrong, but you used engineering units. Please do it again in physics units." Straining a bit, I got through it, reaching the same answer. So Teller said, "Well, let me show you what I calculate, and tell me if you see any error."

He started down the same path I had used, calculating the radiation dose from a cloud of radioactivity. "But it's not a whole sphere, Edward," I objected. "The bottom half of the sphere is underground—no radioactivity. We have to divide your radiation dose by two."

"We're just trying to get a conservative answer," he protested. But I pressed on. There was another factor, about the same magnitude, and then another. These finally brought his number down very close to mine. "Do you all agree with this?" he asked the committee members. They did, and after further discussion he did, too, and he withdrew his article and his recommendation. His "conservative" calculation was drastically wrong. The world might be very different today if Heisenberg had discussed his calculation with an engineer.

More safety features, more safety?

The Europeans at the WNA Symposium were talking proudly of how their latest reactor design, with its core catcher and superior leak-tight containment, is safer than the current plants' designs. This is wrong in concept. Adding provisions to solve a nonproblem merely provides additional potential paths to failure. One of the few serious failures in a full-scale commercial American nuclear power plant was caused by a core catcher—the only plant to have one. It vibrated, broke loose, and partially blocked cooling flow to the core, leading to some fuel meltdown. Although no radioactivity was released outside plant boundaries, the incident led to a book, *The Day We Almost Lost Detroit,* much cited by nuclear critics. (One of the problems in designing a core catcher is keeping the core molten until it can be moved to the basement for handling. Doesn't that tell you something?) Instead of an unneeded add-on, why aren't we promoting features that provide improved performance, such as an annular fuel design?

Safety is not an independent variable. We cannot add 50 percent more safety at will, and it's deceitful to imply otherwise. Safety results from the interaction among a variety of factors such as materials, design, selection and training of personnel, attitude of management, safety culture, and regulators. Probabilistic risk analysis is an important tool. Used properly, it can help reduce the probability of a serious incident, and that's important. But nothing can replace the knowledge that when all else fails, the consequences of the worst realistic incident are tolerable. The nuclear industry has demonstrated decades of nearly flawless performance and safety worldwide. Nuclear plants do not need more safety features. They need to be simpler and less expensive to build and to operate so that we can maintain that excellent record. We need to build thousands of them, as quickly as possible.

We say that nuclear plants should take their place as equals alongside windmills, switchgrass, and chicken manure. That nuclear mustn't take too much of the market. That a balanced portfolio is the goal. Articles on powering the 21st century nearly always picture windmills. That's nonsense! If your first car is a Jaguar, should your second one be an oxcart?

Nuclear energy is a near-perfect energy source. Its alleged problems are distortions of advantages. (For example, is the longevity of nuclear waste really a problem compared with non-nuclear poisons whose half-lives are infinite? Compared with the toxic waste from making solar collectors that never goes away?)

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The unique feature of nuclear energy that makes it orders of magnitude superior to all of its competitors is that chemical processes such as combustion require *tens of millions of times more material* as fuel (and logically produce tens of millions of times more waste) to generate a given amount of electricity than does nuclear fission. This derives from the simple fact that a chemical reaction releases a few electron volts of energy, whereas a nuclear fission releases 200 *million* electron volts. This basic fact of nature cannot be changed by more research. And, of course, the various types of solar power are even more dilute. Even windmills and solar panels require more steel and concrete per kilowatt-hour than nuclear plants. So when you picture a "clean-coal plant" trying to permanently dispose of millions of tons of toxic metals, radioactivity, and gaseous carbon dioxide, ask whether there is any reason to believe that this can be done more reliably, more cheaply, or with less damage to the earth than by just building another nuclear plant. Let's save the coal as feedstock for medicines, plastics, and other complex chemicals. Let's save petroleum products for feedstock and airplane fuel. Uranium has few other major uses.

All ANS members should read and digest the society's recent Position Statement #82, *Nuclear Power: A Leading Strategy to Reduce Oil Imports.* It states, "As an example, if one-third of our vehicles were plug-in hybrids, a practical goal by 2020, we could reduce our use of oil for motor transportation by about 25 percent from today's levels, sharply reducing our needs for oil imports."

Once the full potential of nuclear power is recognized, we have to ask: Why should we base the future of humankind on restricting energy? That's perverse! The worldwide demand for energy is increasing exponentially. Each year, 130 million bicycles are made, but since 2004 the city of Shanghai has been threatening to ban its 10 million bikes from crowded highways to make way for the burgeoning number of automobiles now flooding the roads. India's new $2500 car is expected to open huge new markets previously thought to be out of reach. These new car owners will demand driveways, houses, and gasoline. Then they'll consider air conditioning, toasters, and computers. That demand will be met, if not by nuclear power then by coal, natural gas, or, if necessary, by burning yak dung and denuding the world's forests. (Did you know that burning wood puts more noxious pollutants into the air than coal-burning power plants? And that some Tibetans have more lead in their blood than inner-city dwellers because they hover over smoky yak-dung fires, and yaks eat plants that concentrate lead? That was a cover story in *Science,* years ago.)

This growing demand for energy will be met, despite proclamations to the contrary by think tanks and politicians. Further efforts to reduce waste and improve efficiency are desirable and will have some effect on reducing demand, but they cannot meet much of the basic need. Energy that cannot be instantly available in large quantities, whether or not the sun is out or the wind blows just right, requires a reliable backup source.

The dictionary definition for *energy* is the thermodynamic one: the capacity to do work, to take action. There is a great deal of action needed and work to be done in the world: rebuilding and extending highways, bridges, electric power lines, rail systems, housing, hospitals, schools, libraries, and factories. Curtailing energy use would be like fighting urban sprawl by outlawing hammers: It defies common sense.

The cry for reducing energy comes from the premise that generating electricity adds to the carbon dioxide in the air and thus may cause serious ecological damage to the planet. But nuclear power does not add significantly to the carbon burden, nor does it add significantly to all the other pollutants that derive from burning hydrocarbons—particulates, SO_2, and NO_X. And so we should move as fast as we can to power the world with the atom. We've seen and heard all the reasons why this can't be done very fast. But if we had all done what the French did, as an immediate response to the OPEC oil crisis of 1973, we wouldn't be having this discussion. If 80 percent of the world's electricity were now nuclear-generated, how different would the world be today? Would we have invaded Iraq? Would the 9/11 attack have occurred? Would gasoline cost $4 a gallon?

We can't turn back the clock 35 years, but it isn't going to get any easier to do what we should have done then. We need to get serious. NN