# FORUM

## CHERNOBYL

*In August 1986, after the Fall* Issues *had gone to press, the Soviet Union published an official report on the April 26th accident at the Chernobyl nuclear power plant.* Issues *asked two of the authors of the Fall 1986 articles on Chernobyl, Richard Wilson ("Chernobyl: Assessing the Accident"), and Robert Peter Gale ("Chernobyl: Biomedical Consequences"), and another expert, Frank von Hippel, to update findings and projections on the health effects of the accident.*

The estimates of radiation doses to the Soviet population in the Soviets' report on Chernobyl were arrived at through an interpolation formula deliberately designed to be slightly pessimistic rather than optimistic. The estimates were higher than most Western observers had anticipated from early Soviet reports. The August 1986 Soviet Chernobyl report indicated 28 million person-rems lifetime external exposure to the Soviet population, primarily from cesium 137. Exposure from future ingestion of food was estimated in that report very roughly at 210 million person-rems.

After discussions with Western experts in Vienna at the August 1986 meeting of the International Atomic Energy Agency, Soviet experts concluded that 25 million person-rems was more accurate. If we add these figures to my estimate of 10 million person-rems exposure for Western Europe from Chernobyl, the exposure for all of Europe would be 63 million person-rems, and allowing for small doses elsewhere, the world total would be perhaps 80 million person-rems. These numbers might be revised further downward.

The well-worked data on exposure to cesium from bomb fallout suggest that the ingestion dose, which is the most uncertain of these estimates, is somewhat less than the external dose. The integrated doses will be mostly due to cesium 137, and future measurements, both of exposures and of absorbed radionuclides, will provide better estimates in the years to come.

Only for the group exposed to the highest amounts of radiation, the 24,000 people living between 3 and 15 kilometers from Chernobyl (excluding those living in Pripyat), were the exposures at a level—45 rems average—at which human data show adverse health effects. These people will have about a 3-percent increase in cancer incidence. This is likely to be compensated for by the increased health care that they will receive. For the 2 million people living in Byelorussia (downwind from Chernobyl), the Soviet estimate for increased lifetime dose is 0.7 rem. This is considerably less than the difference in the lifetime external dose a person receives on moving from New York to Denver. It is also less than the difference in the dose a person receives from inhaled radon if he or she moves from an average New England house to an average Pennsylvania house. Since few people, if any, worry about these differences in natural background radiation, it would be inconsistent for the 2 million people in Byelorussia to worry about their exposure from Chernobyl and even more inconsistent for less-exposed West Europeans to worry.

At the meeting in Vienna where the Soviet report on Chernobyl was discussed, Soviet academician L. A. Ilyin argued that it is as bad to overestimate the effects of the accident as to underestimate them. As I noted in my article, the individual doses and the dose rates resulting from the Chernobyl plant emissions are so small that the cancer risks are uncertain. Most estimates of risk use a linear dose-response relationship of one cancer per 5,000 to 10,000 person-rems, but animal data suggest that the linear relationship overstates the risk when doses are given at a low rate. Thus the words *will* and *at least* used in a *Washington Post* article on August 25th—"direct exposure will cause at least 5,300 cancer deaths"—are both wrong and irresponsible. We can characterize the effects more accurately by comparing them with the health risks from burning fossil fuel, using similar calculations and assuming a similar dose-response relationship at low doses although the biological endpoints are different. Such calculations suggest that the health effects in Europe of toxic pollutants caused by Soviet fuel burning each year are as bad as the total health effects caused by the isolated accident at Chernobyl.

**Richard Wilson**
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In my recent article I discussed preliminary data related to the medical consequences of the accident at the Chernobyl nuclear power station. Since the writing of my report, the Soviet government has released considerable additional data to the International Atomic Energy Agency (IAEA) and other organizations. Since April, I have returned to Moscow, Kiev, and Chernobyl frequently to continue collaboration with Soviet scientists and physicians.

The Soviet report to IAEA estimated a maximum cumulative-dose commitment of approximately 2.4 million mansieverts (manSv) in 75 million persons residing in the European portion of the Soviet Union. There is, however, considerable controversy regarding this estimate. For example, Soviet scientists projected an internal to external ratio of radiation from cesium 137 at one to ten. This unusual ratio was based on atypical features of the ground soil in the affected area of the Ukraine. Most experts believe that this projection is incorrect and that the more likely ratio will be one to one or even ten to one. The impact of these revised estimates would be a 10-fold to 100-fold decrease in the projected cumulative dose-commitment. In contrast, some scientists believe the Soviets have substantially underestimated the potential health impacts of Chernobyl. In this discussion I use Soviet projections. It is important to consider that these data may underestimate or overestimate the worldwide cumulative dose-commitment over a 1000-fold range.

It is possible, using risk estimates developed by several international organizations, to calculate the likely incidence of cancers or of cancer deaths that might occur as a consequence of the Chernobyl accident. In most studies this risk factor is 0.00625 per manSv for excess cancers and 0.0125 per manSv for excess cancer deaths.

Unfortunately there is considerable uncertainty regarding the accuracy of estimations of the risk of radiation-induced cancers. This is particularly true at the low doses such as occurred in the context of the Chernobyl accident. In most instances, these risk estimates are derived from data on higher doses such as those affecting the atomic bomb survivors. These estimates also assume a linear relationship between radiation dose and cancer risk; it is not known if this hypothesis is correct. Finally, these risk estimators are designed to be used prospectively to define acceptable radiation exposure levels. As such, they are intended to overestimate the risk so as to protect humans. As a consequence, use of these estimators is likely to result in an overestimation of radiation consequences. The cancers that develop following radiation exposure occur over a lengthy time frame. An increased incidence of leukemia may be apparent within two to three years. Other cancers may not occur until 20 to 30 years later. Most experts concur that the error range of these estimates is at least ten-fold.

Just as these risk factors can be used to estimate risk in the European Soviet Union they can also be used to estimate the likelihood of excess cancers elsewhere in the world. Most data suggest that the cumulative dose-commitment outside of the European Soviet Union is likely to be between one half and twice as high, or 1.2 million to 5.2 million manSv. The Soviets have also published dosimetric data on the 135,000 individuals who resided within the 30-kilometer evacuation zone surrounding the reactor.

Taking these factors into account, the following projections of excess cancers and excess cancer deaths reflect a range of reasonable estimates for three populations at risk: For the 135,000 people in the evacuation zone, 1,000 excess cancers and 500 excess cancer deaths; for the other 75 million people in the European Soviet Union, 5,000 to 50,000 excess cancers and 2,500 to 25,000 excess cancer deaths; for the other 5 billion people worldwide, 2,500 to 100,000 excess cancers, and 1,250 to 50,000 excess cancer deaths. The estimated worldwide total would be 8,000 to 150,000 excess cancers and 4,000 to 75,000 excess cancer deaths. These ranges are approximate.

These data are controversial. In my opinion the number of excess cancers is likely to be overestimated by this approach for the reasons I described. Even the lower estimates may be too high and the actual number of cases may be considerably lower, perhaps by a factor of 10. These excess cancers would represent a less than one-percent increase from normal levels in the European Soviet population. Nevertheless, each person with an unnecessary cancer is important to us and to the Soviets.

There are other long-term consequences of radiation exposure that need to be considered, including teratogenic (birth) defects and genetic abnormalities. These are even more difficult to estimate than excess cancers. Additional problems will include hypothyroidism, thyroid adenomas, and possibly developmental abnormalities in individuals exposed in utero. Cataracts and decreased fertility may occur in the relatively small numbers of individuals, approximately 200, exposed to the highest doses of radiation.

In these estimates I have avoided extreme positions including that there will be no excess cancers or that millions of excess cancers will develop. Each position has some scientific basis. Unfortunately our data in this area are incomplete. The Armand Hammer Center for Advanced Studies in Nuclear Energy and Health and the National Councils for Radiation Protection of the USA and USSR will together sponsor an international conference on risk estimates of cancer and radiation in January to help resolve some of these controversies.

**Robert Peter Gale**
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Earlier this year, before the publication of the Soviet report on Chernobyl, Thomas Cochran and I made some preliminary estimates of the long-term health consequences of exposure to radioactivity from the reactor accident. (Quantitative details and references may be found in the August/September 1986 issue of the *Bulletin of the Atomic Scientists.*) We expected the iodine 131 to provide the dominant radiation doses to the thyroids of the populations downwind from Chernobyl. Over the longer term, we expected that cesium 137, which has a 30-year half-life, would provide the greatest contribution to whole-body dose. Radiation doses were calculated using standard exposure-dose coefficients, and estimates of the resulting numbers of cancers were obtained using a range of dose-effect coefficients derived from the 1980 National Academy of Sciences' report, *The Effects on Populations of Exposure to Levels of Ionizing Radiation.*

For the population of Western Europe, we estimated 2,000 to 40,000 additional thyroid cancers from iodine 131 inhalation, of which a few percent—50 to 1,000 cases—might be fatal. From the whole-body doses of cesium 137 (external and internal) we estimated 3,500 to 70,000 cancer cases of which approximately half might be fatal. From iodine 131 absorbed via the grass-cow-milk route, we estimated 10,000 to 250,000 potential thyroid tumor cases, resulting in 250 to 6,000 additional fatalities, unless public authorities took actions to block this route. We estimated that one-third to one-half of all these cancer deaths would occur in the Soviet Union. We emphasized that because of all the uncertainties involved, our figures were uncertain even in their order of magnitude.

Had we had the information from the Soviet Chernobyl report published in August, our calculations would have been somewhat different. Our original estimates were based on estimates of the distribution of the radioactivity from Chernobyl made in July by a group at Imperial College, London. The Imperial College group used an atmospheric dispersion model in which the magnitude, duration, and initial altitude of the released radioactivity were fixed by early measurements of the resulting concentrations in Western Europe. In effect, the model was being used to interpolate these measurements. In this way it was estimated that about 21 megacuries (MCi) of iodine 131 and 1.4 MCi of cesium 137 were released from Chernobyl—mostly during the first three days of the accident. According to the Soviet report, the releases were in fact of the order of magnitude assumed by the Imperial College group but also of a duration about 10 days longer than the Imperial College group had assumed. This would alter the resulting distribution of radioactivity somewhat but would not alter the order of magnitude of the total population radiation dose.

The Soviet report also projected approximately 5,000 cancer deaths from external irradiation by cesium 137 and 1,500 deaths by thyroid cancer within the Soviet Union. These numbers fall within the range that would be derived from our estimates if account were taken of the fact that, according to the Soviet report, efforts to prevent the consumption of milk heavily contaminated with iodine 131 were less than fully successful in rural areas.

However, the Soviet report also raises the possibility that eight times as many cancers might result from the ingestion of cesium 137 contained in agricultural produce from the Ukraine and Byelorussia as might result from external irradiation. We had assumed a multiplier of only 0.5, based on the average world experience with cesium 137 deposited by atmospheric tests. The difference may be due in part to the major role of the contaminated areas as food producers.

Estimates of long-term health effects will improve as measurements of radiation exposures, thyroid iodine 131 burdens, and food contamination levels are compiled and corrected. Large uncertainties will remain, however, if only because of the continuing uncertainty in cancer dose-effect coefficients. Our knowledge of these coefficients, especially the iodine 131 thyroid dose-effect coefficients, could be considerably improved by a proper epidemiological follow-up of those groups near Chernobyl who received the highest exposures.

**Frank von Hippel**
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The articles by Robert Peter Gale, Richard Wilson, George M. Woodwell, and coauthors Harold M. Agnew and Thomas A. Johnston (*Issues*, Fall 1986) discussed nuclear energy by using the accident at the Chernobyl nuclear power plant as their starting point.

The Chernobyl accident was the result of a major design flaw in that type of reactor (a reactor and flaw not found in nuclear plants operating in the rest of the world) that was amplified by human error. The Soviets have admitted their mistakes and have committed themselves to correcting design and operational flaws.

But neither they nor the rest of the world are giving up on nuclear energy. Those of us who must deal with the economic, environmental, and political difficulties of energy use and availability recognize how much more difficult the path becomes without nuclear energy. The Chernobyl accident, as tragic as it was, does not alter the importance of nuclear energy's role. Today, nuclear power provides 16 percent of the world's electricity, the energy equivalent to that produced by 6 million barrels of oil per day. With the demand for oil in the industrial countries at about 35 million barrels per day, we can only guess at the impact on world oil prices of a reduction in nuclear-generated electricity. Nuclear energy is also meeting 16 percent of our nation's electrical needs. That electricity provides jobs, helps to sustain economic growth, and extends the life of our valuable domestic fossil fuel resources.

Nuclear safety has been the primary focus of our commercial nuclear energy program since the program's inception in the late 1950s. Since the Three Mile Island incident, attention to safety issues has both broadened and deepened, and we have come to recognize that our industry must be uniformly strong. The Institute of Nuclear Power Operations (INPO), an industry-supported organization that promotes excellence in the operation of our nuclear power plants, is a direct result of the lessons learned from Three Mile Island.

We can measure INPO's success by the improved performance of this country's nuclear power plants. The average electrical output from our reactors is increasing. We have reduced the number of unanticipated outages. We have reduced the volume of our low-level radioactive waste. Radiation exposure is less, and worker safety has improved. Attesting to the quality of the INPO programs, 13 other nations with nuclear energy programs have now joined INPO. In the quest for excellence, "best practices" are now shared by the operators of nuclear plants in 14 nations. Through this effort, 288 of the world's 371 operating reactors are now linked by a common communications system. With that link comes access to other INPO programs designed to enhance safety.

Even with these successes, a yearlong self-evaluation by the U.S. nuclear utility industry has resulted in new initiatives. Through INPO, greater attention is being focused on operational and safety excellence. The nuclear utility industry will strive to improve its interaction with the Nuclear Regulatory Commission, and a unified organization is being formed to constructively address regulatory matters.

Strong initiatives are under way to achieve worldwide safety goals by means of closer international cooperation. The International Atomic Energy Agency, headquartered in Geneva, has undertaken efforts to establish joint safety inspection programs and to gain wider use of its safety standards.

Complementing these efforts, INPO is broadening its international membership to include all of the world's operating reactors in mutual safety assistance programs. World leaders recognize that nuclear energy is an essential resource to many nations, and the programs in those countries will continue.

Now is not the time to be purveyors of panic; instead, let us take positive steps toward enhancing worldwide nuclear safety. In this country we have the leadership to take those steps, and we should get on with it.

**William S. Lee**
*Chairman of the Board and*
*Chief Executive Officer*
*Duke Power Company*
*Charlotte, North Carolina*

The blanket condemnation of nuclear energy in George M. Woodwell's article ("A Technology That Failed," *Issues*, Fall 1986) is amply and knowledgeably refuted in Richard Wilson's article. I wish, however, to add some philosophical considerations to the subject.

There is simply no way "nuclear energy can be systematically and deliberately abandoned as a potential source of power," as Woodwell advocates (p. 35). Once the concept of the energy/mass relationship was truly grasped by mathematicians, physicists, philosophers, and finally engineers, there could be no turning back.

The existence of nuclear weapons in no way detracts from the benefits mankind derives from peaceful applications of nuclear energy. The provision of one-fifth of the industrialized world's electric power, lifesaving nuclear medicine, and scores of unsung but vital industrial applications make energy from the atom an irreplaceable part of modern life.

Nuclear energy does not have an unblemished safety record. It is a human endeavor and as such has all the limitations imposed by the imperfectability of people. But if one weighs the number of lives sacrificed to the peaceful atom against the atom's positive benefits to mankind or compares nuclear power's safety record with any significant source of energy in the world at any given time, harnessing the atom emerges as one of the landmark achievements of the human intellect.

It is neither appropriate nor possible to set back the clock. Rather, we must rededicate ourselves to moral values as we continue to pursue scientific knowledge.

**Donald C. Winston**
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The recent article by Jack N. Barkenbus ("Nuclear Regulatory Reform: A Technology-Forcing Approach," *Issues*, Summer 1986) and the articles on Chernobyl (Fall 1986) offer some useful insights, especially when viewed in terms of the emerging position of the House Science and Technology Committee on nuclear development as well as the recent report of the subcommittee on energy research and production, "Regulatory Policy for Advanced Nuclear Reactors."

Along with our committee chairman, Don Fuqua, I wrote to Donald Hodel, the secretary of energy, in November 1983 suggesting that the Department of Energy (DOE) emphasize a research and development strategy focusing on the Modular High Temperature Gas Reactor (MHTGR), directed toward achieving inherently safe reactors. Our recommended approach, like that of Harold Agnew and Thomas Johnston ("The Future of Nuclear Power," *Issues*, Fall 1986), was based on the need for a more-than-incremental improvement in the public's perception of nuclear power. Since that time some utilities and at least part of the nuclear industry have become very interested in the MHTGR, and some government agencies and organizations have become very interested as well, as the Barkenbus article attests. Unfortunately, DOE has continued to drag its feet on funding MHTGR research and development at the required level, and there is significant resistance from within the nuclear industry as well. Nevertheless, in the post-Chernobyl climate, when there may be little chance of nuclear reactor orders until the year 2000, it is certainly worth assessing the prospects for inherently safe reactors (more aptly called passively safe).

The major findings and recommendations of the recently issued report of our energy research and production subcommittee focus on the great need to move from prescriptive criteria for reactor safety to performance criteria, and on the need to spell out enhanced safety criteria to provide the industry with real benchmarks.

The federal government, the nuclear industry, and utilities now have time to make the critical decision on whether they are going to prove to the public that nuclear reactors can be operated efficiently and without major incident. The next two years will decide if the United States intends to have "a new nuclear machine" before the end of the century.

I believe that Barkenbus and his well-known colleague, Alvin Weinberg, who first attracted congressional attention to the premise of inherently safe reactors, deserve our congratulations for their enlightened effort. I will continue to work vigorously for the MHTGR development program in Congress.

**Representative Marilyn Lloyd**
*Democrat of Tennessee*

It is surprising that your articles on Chernobyl (*Issues*, Fall 1986) lack logical foundation: none of them first showed that nuclear power is competitive and necessary. Harold M. Agnew and Thomas A. Johnston assert that nuclear power will be necessary, and George M. Woodwell asserts that it will not be necessary, but neither paper offers data. Robert Peter Gale and Richard Wilson finesse the whole issue.

In fact, new techniques and methods (many less than one year old) for raising electrical productivity and for financing and delivering that hardware to customers have made big power plants uneconomical to build. Moreover, very detailed analyses now show that there is a practical potential—by improving existing U.S. buildings and equipment—for saving five times as much electricity as nuclear power now produces, at less than the cost of operating an existing nuclear plant, even if the costs of building the plant were excluded. (Typical operating costs are about $0.02/kilowatt-hour [kWh]; building and running a new plant costs about 4 times to 10 times more.)

Advanced technologies for such uses as lighting, industrial drivepower, and water heating now enable utilities to abandon even a newly completed reactor, give away superefficient lights, motors, and appliances instead, and thereby save billions of dollars net. Wisconsin and Minnesota have officially recognized that saving electricity can also abate sulfur dioxide emissions from coal plants at roughly zero or negative net cost. As for speed, the best U.S. implementation programs are empirically reducing long-term peak loads by the equivalent of more than 8 percent of current loads per year, at actual costs to the utility of a few tenths of a cent per kWh. Even faster programs are being planned.

Utility managers, seeking to cut costs and minimize regret, have already shifted enormous amounts of capital not only to the customer's side of the meter, but also to smaller, faster, and cheaper generating sources. Between 1981 and 1984 U.S. orders (minus cancellations) totaled a -65 gigawatts (GW) net for central stations, a 45 GW net for cogeneration and renewables, and a more than 20 GW net for efficiency and load management. Since 1979 the United States has ordered more new-capacity electricity from wind power and small hydropower stations than from coal and nuclear plants. If the nuclear industry's safety, waste, and proliferation problems were to vanish tomorrow, its order book would continue to dwindle for basic economic reasons.

Nuclear power has cost the United States about $200 billion in public and private funds and will probably cost twice that amount before we have cleaned up the mess. Yet it now delivers only about half as much energy as does wood. Throughout the world's market economies, it is dying of an incurable attack of market forces. It cannot compete with the best buy—efficient use of electricity—nor with the next-best buy—renewable and nonrenewable sources with very short lead times.

Why, then, debate safer reactor designs? Even if there were an inherently safe and nonproliferative kind of reactor in a world of fallible and sometimes malicious people, and even if the proposal did not raise awkward public questions about the safety of existing reactors, any kind of reactor would still be 10 to 100 times too expensive to compete with modern ways to wring much more work out of the electricity already in use. If we take economics seriously, rather than ordering new central stations we will phase out existing ones in favor of the best buys. We all live in Chernobyl—but it is cheaper not to.

**Amory B. Lovins**
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*Old Snowmass, Colorado*

## NEWS GATHERING FROM SPACE

On my desk rests a pile of photos taken by the SPOT satellite, supplied to me by Space Media Network. These are the first results I have seen of the emerging technology described by Peter E. Glaser and Mark E. Brender ("The First Amendment in Space," *Issues*, Fall 1986). SPOT images are extraordinarily better than those from LANDSAT; the next generation of photosatellites will be better still. The superpower monopoly on high-resolution photographs from space has been broken.

Privately owned remote-sensing satellites will be able to serve as independent brokers in arms control disputes without compromising the capabilities of superpower reconnaissance satellites. But it would be wrong to suppose that the main use of private satellites will be for third-party verification of arms control agreements.

Private reconnaissance satellites will become indispensable to news gathering and public information, but they raise as many questions as they answer, especially in the area of First Amendment rights and national security. Immediate danger to U.S. military operations is one of the few constitutional reasons for exercising prior restraint on U.S. journalism. In general, the U.S. media have behaved responsibly, leaving no need for the government to seek injunctions or to insist upon crippling licensing requirements; satellite news should prove no different.

The ability to gather and publish the news should not, therefore, be inhibited by arbitrary regulations governing satellite capabilities or by any sort of clearance board that would pass on the release of photographs before they could be distributed. Overly restrictive regulations could force U.S. satellites to fly flags of convenience as our merchant marine already does at comparable cost to the nation, particularly in times of real emergency.

Indeed, the central question raised by Glaser and Brender is not whether high-resolution satellite images will become available to the U.S. media; they will. The important question is whether the United States will encourage such satellites to fly the U.S. flag and be operated by journalists responsive to U.S. needs, responsible to this country, and representative of U.S. ideals. The news gathering potential from space is of such importance and so commercially attractive that only concerns about technology and cost, not government regulations, should dictate the capabilities and uses of remote-sensing satellites.

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## EXPORT CONTROLS

Rep. Don Bonker (D-Wash.) sets forth one view of the critical issue of technology transfer ("Protecting Economic Interests," *Issues*, Fall 1986). However, the subject of controls on transfer of advanced technology is much more difficult than he acknowledges. There is general agreement that it is necessary to prevent the export of certain sensitive technologies to hostile powers. As Bonker says, no one in Congress wishes to promote "trade that would enhance Soviet military capability or undermine U.S. national security" (p. 97). But Congress had to work very hard to strike a balance in the 1985 Export Administration Amendments Act between the financial interests of individual business firms and U.S. national security and foreign policy interests. Debate on so difficult a subject must be dispassionate to be productive. Unfortunately, Bonker's article does not meet this requirement.

The thrust of his article, after criticizing administration efforts, is to offer his own legislative proposals as