BOOKS

A Parade of Horribles: The Soviet/Russian Nuclear-Waste Record

Behind the Nuclear Curtain: Radioactive Waste Management in the Former Soviet Union

Don J. Bradley
Battelle P., Columbus, Ohio, 1997. 716 pp. $95.00 hc
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Reviewed by Thomas B. Cochran

Don Bradley has demonstrated that he is the undisputed heavyweight authority on what is known in the West about the management, or more appropriately the mismanagement, of radioactive materials in the former Soviet Union. For years Bradley and his colleagues at Battelle's Pacific Northwest Laboratory have been collecting and analyzing data on nuclear waste and related topics in the former Soviet Union for the US Department of Energy. (See the article by Bradley, Clyde Frank and Yevgeny Mikerin in PHYSICS TODAY, April 1996, page 40.) This latest book represents an update of Bradley's three-volume *Radioactive Waste Management in the USSR*, released in 1990–92 by Pacific Northwest Laboratory.

Behind the Nuclear Curtain is an exceptional piece of work. It now becomes the paramount reference book on the subject. Written primarily for nuclear and health-physics professionals, Bradley's book is well researched, and the data are extensively referenced. There are some 300 tables, figures and photographs, which make it a particularly valuable resource.

After an introduction and overview, Bradley provides us with a short chapter on waste management agreements between the US and the USSR and its successors; this material should have been relegated to an appendix. This is followed by a description of the Russian Ministry of Atomic Energy and other institutions with nuclear waste management responsibilities. The next 16 chapters review the entire Soviet/Russian nuclear fuel cycle—both civil and military—from uranium mining to high-level nuclear-waste management. There are separate chapters devoted to the principal plutonium production sites—Ozersk (Chelyabinsk-65), Seversk (Tomsk-7) and Zheleznogorsk (Krasnoyarsk-26)—as well as to the Chernobyl accident, nuclear weapons testing, naval waste management and ocean dumping, and waste transportation.

Two things are striking about this work: what is revealed and what remains secret. *Behind the Nuclear Curtain* reveals that, historically, the management of Soviet/Russian nuclear waste was both criminally negligent and tragic, and that this tragedy continues. At Chelyabinsk-65, at least 130 million curies of radioactivity have been released directly to the environment, some 120 million curies of it directly into Lake Karachai. To put this into perspective, 120 million curies is about 50% of the high-level waste-tank inventory at DOE's Hanford site in Washington state and about three times the total cesium-137 and strontium-90 released as fallout from worldwide atmospheric nuclear testing. As a result of planned and accidental releases at Chelyabinsk-65, about 500 000 people received an "elevated radiation dose," and about 18 000 were relocated.

During the two-year "recovery" period following the 1957 waste-tank explosion at Chelyabinsk-65, approximately 30 000 workers received radiation doses greater than 25 rems. At both Tomsk-7 and Krasnoyarsk-26, over a period of more than 30 years, about 1.5 billion curies of liquid high-level waste have been injected into aquifers several hundred meters deep, a practice that continues to this day without clear evidence that this practice will not have a significant long-term human health impact. Krasnoyarsk-26 operates a dual system of injection and discharge wells; as radioactive waste is pumped in, underground water is drawn off for civilian needs.

Anyone versed in the language of nuclear technologists can find a parade of other horribles in *Behind the Nuclear Curtain*. Bradley leaves it to others to translate these into the human health consequences understandable to a lay audience. Given the limited distribution of these data in Russia, *Behind the Nuclear Curtain* should be translated and distributed there, along with its yet-to-be written sequel for public readership.

It is clear from *Behind the Nuclear Curtain* that much, if not most, of Russia's nuclear legacy remains a dark secret. Bradley reveals that the Tomsk-7 site has several ponds that rival or possibly exceed the contamination in Lake Karachai. Yet there is no discussion of these in the unclassified literature. Also, there is no discussion of the plutonium fires, accidents and environmental releases from the plutonium-pit manufacturing facilities at Chelyabinsk-65 or Tomsk-7.

A single shortcoming of *Behind the Nuclear Curtain* is that it does not include data more closely associated with nuclear weapons. For example, the inventory of plutonium in spent civilian fuel is estimated, but there are no estimates of the plutonium and tritium produced by the military production reactors, even though these estimates could have been easily derived and would be useful to the arms control community. Also, the nuclear weapons laboratories are all but forgotten, and there is no mention of weapons assembly or disassembly plants. These omissions are unlikely to have been oversights, but are more probably a consequence of Pacific Northwest Laboratory's intelligence mission, the Department of Energy's classification rules and PNL's and DOE's desire to retain a good working relationship with the Russians. On the other hand, no other organization could have produced such a fine book on this subject.

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The Sun as a Star

Roger J. Tayler
Cambridge U. P., New York, 1997. 242 pp. $64.95 hc ($24.95 pb)
ISBN 0-521-46464-1 (0-521-46837-X pb)

With first light at the 60-inch telescope at Mount Wilson Observatory in 1908,

George Ellery Hale began the modern reflecting-telescope revolution. Hale desired "more light" to explore solar phenomena in other stars. He wrote: "Thousands of stars, in the same stage of evolution as the Sun, doubtless exhibit similar phenomena, which are hidden from us by distance. . . . In spite of the necessity, because of their feeble brightness, of basing our conclusions on spectra a few inches long, representing the combined light from all parts of the stellar disks, material progress could be made in this way." (*Ten Years' Work at a Mountaintop Observatory*, Carnegie Institution of Washington, 1915.)

Roger Tayler's *The Sun as a Star*, a modern précis of Hale's idea, is an excellent introduction to the Sun and its local environment. Tayler (who died in January 1997) admirably reviews, at the vector calculus level, basic plasma physics and magnetohydrodynamics. The book is the companion and sequel to Tayler's earlier *The Stars: Their Structure and Evolution* (2nd ed., Cambridge University Press, 1994), but it stands on its own. The book flows well, with summaries of each chapter and detailed coverage of collateral topics in appendices.

Tayler's solar physics has two facets: First is that of the Sun's slowly varying radiative energy and related topics on the interior. Here the most important research problem is the observed deficit of neutrinos. Tayler deftly summarizes the experimental results and theoretical explanations of the neutrino deficit. His conclusion is that neutrino physics needs revision.

Some of Tayler's information may quickly be outdated by rapid movement in the field. For example, new details on the solar interior are flowing from such helioseismology experiments as GONG (Global Oscillation Network Group) and SOHO (Solar and Heliospheric Observatory) which are separating the p-modes of the five-minute solar oscillations excited by acoustical energy from subsurface convection. Nonetheless, Tayler's book is needed and should remain a useful introduction to the subject for some years.

The second facet of Tayler's approach is the Sun's activity, its spatial and temporal variability. One of his themes is to explore the relation between surface activity and magnetic fields, including radiation and particle emissions. Another is the complex interaction of the Sun's magnetic field and particle emissions with the Earth's space environment.

A third theme comes from the book's title itself, and I found it less thorough than it might have been. Tayler does cover other stars that by virtue of rapid rotation (the result of stellar youth or tidal forces in close binaries, for instance) have extreme levels of surface magnetism. "Starspots" on the star types BY Draconis or RS Canum Venaticorum can cover 10% or so of the stellar surface, compared to the Sun's spot coverage of generally less than 1%. But Tayler omits much work done in the last decade on the activity of Sun-like stars. For example, Wes Lockwood and Rich Radick at Lowell and Sacramento Peak Observatories respectively pioneered high-precision, visible-band photometry showing magnetic features on other stars comparable to the Sun's. Greg Henry (Tennessee State University) and his colleagues run a revolutionary program using automated telescopes that get nightly photometric precision of 100 to 200 millionths of a magnitude. Henry's group has seen on other Sun-like stars the counterpart of the Sun's 0.1% amplitude irradiance change, over the course of its 11-year cycle. Such advances should have been included in Tayler's book.

Tayler places studies of the Sun and its influence on the interplanetary medium at "the centre of modern astronomy." The reason is the proximity and richness of the Sun as a laboratory of plasma physics and magnetism. He marvels at the Sun's complexity compared to, say, galactic nuclei. But Tayler cautions that objects like galactic nuclei may seem deceptively simple, because the spatial and temporal details are lost in their great distance and feeble brightness.

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Crystal Fire: The Birth of the Information Age

Michael Riordan
and Lillian Hoddeson
W. W. Norton, New York, 1997.
352 pp. $27.50 hc
ISBN 0-393-04124-7

Last year marked the 50th anniversary of the discovery at Bell Laboratories of transistor action in germanium. *Crystal Fire* recounts the history of this epoch-making discovery and subsequent events that led to the dawning of the information age. Michael Riordan and Lillian Hoddeson provide a gripping account not only of the transistor discovery but also of the birth of solid-state physics, with its intimate relationships to quantum mechanics and to the world of technology. The book provides insightful analysis of the coupling of research and application as well as the human relationships and the inner workings of one of the world's greatest industrial laboratories.

The early chapters of the book give an eminently readable account of the quantum mechanical foundations of solid-state physics. The authors also trace the more detailed and pragmatic efforts at AT&T to develop vacuum-tube amplifiers for long-distance communication. These efforts were successful enough to convince AT&T brass that hiring PhD physicists to work on problems relating to communications technology was good business! By the mid-1930s, with Bell Labs' research director Mervin Kelly convinced that the behavior of electrons in solid-state materials and an understanding of modern quantum physics might be important in replacing bulky vacuum tubes, Kelly hired William Shockley, who had recently obtained his PhD at MIT.

The implementation of Kelly's vision of replacing mechanical switches with electronic ones to connect telephone subscribers in the Bell system was interrupted by World War II; with MIT's Radiation Laboratory, Bell Labs became a major player in microwave radar development during the war. Major efforts in purification of silicon and germanium led to the development of high-quality crystal rectifiers and microwave radar.

By the time the war ended, Kelly was firmly convinced that AT&T needed to be at the forefront of solid-state physics research, and he asked Shockley to head the work. To bolster the effort, Shockley suggested to Kelly that a theorist of outstanding credentials needed to be added. And so John Bardeen, who had been working during the war at the Naval Ordnance Lab, and with whom Shockley had interacted during his stay at MIT, was recruited by Kelly and offered a position in the solid-state physics group. Walter Brattain, an experimentalist who had joined Bell Labs many years earlier and who worked under Clinton Davisson, was also part of the group, as were physical chemist Robert Gibney and electronics expert Bert Moore.

Riordan and Hoddeson give an insightful and thorough treatment of the history surrounding the 1947 discovery of transistor action in germanium using point contacts and in p-n junctions three years later. They also provide a fascinating account of the years immediately following the transistor discovery, a time when the Korean War was raging and a looming antitrust action against AT&T provided conflicting scenarios for the dissemination of critical materials