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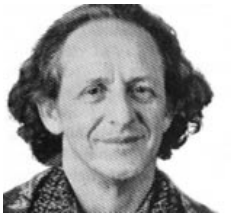

Current Comments

Three Mile Island and the Information Explosion on Nuclear Energy

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Following the nuclear reactor accident at Three Mile Island (TMI) in Pennsylvania last March, the public was inundated by newspaper, magazine, and broadcast reports on nuclear energy. At first, most of these reports attempted to explain the reactor malfunctions that caused the accident. With time, reporters began to analyze events at the site and turned toward other issues related to nuclear energy. Highly complex issues that scientists, economists, and politicians had been debating for years came to light in the proliferation of articles following the accident.

The media blitz that followed the TMI accident can be described as a classic case of an information overload—too much information contributing to the public's confusion. The advantages afforded by access to a great deal of information were offset by the sheer mass and complexity of the often conflicting information. And, as with the debate over recombinant DNA,[1] forming an opinion on the merits of nuclear energy was complicated by these conflicting viewpoints.

While the media have played a positive role in disseminating information to the public during such public health crises as the swine flu debacle,[2] there is good reason to question—as did the Kemeny Commission—their role in this crisis. According to the Public's Right to Information Task Force,[3] a staff group of the Kemeny Commission (also called the President's Commission on the Accident at Three Mile Island),[4] a great deal of misinformation was published during the accident due to the lack of scientific and engineering expertise of reporters and confusion and misinformation emanating from official news sources.

Metropolitan Edison (the company that operates TMI) and the Nuclear Regulatory Commission (NRC) made scientific errors and, on occasion, exaggerated or minimized the significance of events.[4] According to nuclear consultant Ralph Lapp, two days after the accident began, the NRC "blew the accident up into a full-fledged and protracted crisis based on ignorance of reactor technology, i.e., misinterpretation of the hydrogen explosiveness. It was the NRC that urged evacuation based on improper assessment of the risk."[5]

As I mentioned before[2] —and as the media coverage of TMI clearly illustrates—it is time the media began focusing more attention on educated coverage of scientific news. Reporters must become more familiar with scientific concepts and language if they are to interpret the meaning of events for the public. The Kemeny Commission, in its report to the President, addresses this problem.[4] The Commissioners recommend that the major media outlets, and news media near nuclear power plants, train or hire specialists familiar with reactors and the language of radiation. They further suggest that scientific information be presented in a manner that helps readers make their own judgments.

In order to gain an understanding of the issues involved in the nuclear energy controversy, I asked my staff to review the literature published after the TMI

accident and compile a selective bibliography of thoughtful references for the lay person. As far as TMI is concerned, this includes most *Current Contents*® readers.

The bibliography is comprised of articles and books on the most important issues associated with nuclear energy—not just TMI. The majority of items on this list should be available in most American and many foreign libraries. To insure that the bibliography was truly representative I asked the Media Resource Service of the Scientists' Institute for Public Information (SIPI) to supply a list of experts to whom we could send this piece for refereeing purposes. I also asked Ralph Lapp to act as a referee.

It is important to note here, as I discussed in an earlier essay,[6] that SIPI's Media Resource Service played a major role in channeling journalists to nuclear energy experts during the TMI crisis. In recognition of the critical public service provided by SIPI, the Ford Foundation granted $75,000 for expansion of the Media Resource Service. However, SIPI must raise an equal amount through donations to be eligible for the full funding.

There are some industry representatives who believe that the Ford Foundation and SIPI have not merely acted to protect the public interest. Lapp argues that in the past, at least, SIPI was politicized by Barry Commoner, director of the Center for the Biology of Natural Systems, Washington University, and others, thereby reducing its credibility.[5] I don't believe this is true of the Media Resource Service and I will support this service only to the extent that it remains apolitical. Walter Cronkite, in his recent endorsement of the service, recognized this in describing the service as "an objective organization, without bias."[7]

Although I have tried to identify and discuss separate issues in this essay, most of the articles in the bibliography which follows touch upon several related aspects of the controversy. It was impractical to divide the bibliography by subject area.

Not all of the articles are objective. It is impossible to provide totally unbiased information on so controversial a subject. However, the articles included in the bibliography are culled from a wide variety of sources so that the reader may obtain as thorough an overview of this complex topic as possible. Several opinions are presented and I think that, by weighing the arguments, you should be able to reach your own conclusions on the merits of nuclear energy. I might add that we have not made a systematic effort to solicit or search for material published abroad.

The material reviewed was written by journalists as well as scientists, economists, and government officials. For those interested in exactly what happened at TMI, the articles by Keisling and Perrone,[8] Torrey,[9] and Castro and Cottrell[10] (Oak Ridge National Laboratory) reconstruct the accident. However, most articles in the bibliography deal with the broader issues that arose as a result of the accident. Harold W. Lewis, University of California, Santa Barbara, for example, provides a comprehensive overview of many of the issues associated with nuclear power plant safety in *Scientific American*.[11] Although Lewis discusses most of the issues I have treated in this essay, this article is perhaps most notable for his examination of people's attitudes toward the management of "risks that are not fully understood and for which it is not easy to establish conceptual bounds."

Many of the articles in the bibliography are of a scientific nature, such as those concerned with the effects of low-level radioactivity[12-14] and methods of radioactive waste disposal.[15] Other articles address economic, social, and political issues such as the financial impact of the TMI accident on the nuclear industry[16] and the effectiveness of the NRC in insuring reactor safety.[17] The major part of the bibliography is comprised of those articles examining the questions most vital to the future of

nuclear energy, such as those by A.M. Weinberg, director, Institute for Energy Analysis,[18] and J. Abbotts, former staff scientist, Public Interest Research Group.[15]

The health effect of low-level radiation is one issue that has received a great deal of attention since the TMI accident. This radiation exists naturally as cosmic rays and as "background radiation" from such sources as granite, brick, and one's own bones.[11] Humans can also be exposed to it through medical x-rays and releases of radioactivity at nuclear power plants. The medical and scientific communities have been investigating the health effects of low-level radiation for years. Nevertheless, it seems as though no conclusive answer can be given to the question: "How much damage is caused by low-level radiation?" Evidence that this radiation may affect certain groups[12,19]— such as infants and pregnant women—more than others, further complicates this issue.

Little assurance is offered by members of the scientific community, who frequently disagree about the significance of research findings on the subject. This disagreement is reflected in the highly contrasting interpretations of studies offered by Karl Morgan,[12] Georgia Institute of Technology, and Bernard L. Cohen,[14] University of Pittsburgh.

Morgan's review of low-level radiation studies was presented originally in *Bulletin of the Atomic Scientists*.[12] (An edited version of this article appeared in the British publication, *New Scientist*,[13] immediately after the accident.) Referring to a number of studies on the health effects of low-level radiation, Morgan examines the generally accepted "linear dose hypothesis," which predicts that the effects of radiation decrease at uniform rates as dosages decrease. Drawing on evidence presented in these studies, Morgan questions the adequacy of federal limitations on human exposure to radiation from man-made sources. Like most writers on this subject, Morgan concludes that additional research is needed to more accurately define the risks of low-level radiation.

Many of the views presented by Morgan are refuted by Cohen in a later issue of the same magazine.[14] In his commentary, Cohen challenges the findings of several studies cited in the earlier article as well as Morgan's interpretations of a number of studies. Cohen states that decreases in "maximum permissible exposures" to radiation were instigated by changes in public attitudes and improved technologies that made lower exposures possible—rather than by evidence that existing levels were inadequate, as Morgan stated.

W. Kallinger and W. Granninger, Prüfanstalt für Radiologie and International Medical University, Vienna, Austria, report on a 24-year-old man who is suffering no ill effects from extremely high doses of radiation received as a fetus.[19] This finding does not conform to the findings of many scientists who believe radiation exposures currently permitted by the US government are too high.

Articles and reports on the effects of radioactivity released at TMI also reflect this disagreement over the risks from low-level radiation. According to a preliminary federal report on the release of radioactivity at TMI by the Ad Hoc Population Dose Assessment Group,[20] at most one death and two related health effects might be expected as a result of the accident. Both the Kemeny Commission[4] and a special NRC inquiry group (Rogovin Report)[21] concluded that the health effect of radioactivity released at TMI will be negligible.

Lapp recently told me that, based on data gathered from studies of victims of the Nagasaki and Hiroshima bombings, the release of radioactivity at TMI would theoretically result in at most 0.2 cancer deaths. The Hiroshima-Nagasaki exposure was 2 million person-rem which, according to Lapp, resulted in 200 excess cancer deaths. The ex-

posure from TMI is estimated at about 2,000 person-rem.[5]

In contrast with these other reports and articles, John W. Gofman, University of California, Berkeley, states in his and Arthur Tamplin's, Natural Resources Defense Council, book, *Poisoned Power*,[22] that "no fewer than six" (p. *x*) premature deaths will result from low-level radiation released during the TMI accident.

The disagreement and confusion over the dangers of radiation are also discussed in the *Christian Science Monitor* article by D.F. Salisbury.[23] Other articles that deal with the low-level radiation issue include review articles by J.L. Marx[24] and V.E. Archer,[25] a series in the *New York Times* by R.D. Lyons,[26] W. Sullivan,[27] B.A. Franklin,[28] and L.K. Altman,[29] and the article entitled "A problem seen 500 years ago still defies scientific resolution."[30] Lapp's book, *The Radiation Controversy*,[31] provides technical and historical information on radiation. The most recent edition of this book includes a chapter on TMI.[5] Lapp is a private consultant operating out of Arlington, Virginia, and is well-known to members of Congress.

Radioactive waste disposal is another multifaceted issue that has received considerable press coverage since the TMI accident. These wastes include the damaged fuel rods, radioactive gases, and highly contaminated water spilled in the containment area at TMI. All nuclear power plants, however, will require permanent storage facilities for the spent fuel rods and other wastes that remain radioactive, in some cases, for thousands of years.[15] Unless they are damaged, as at TMI, spent fuel rods are currently stored in enclosed pools at the reactor sites. However, plants could start running out of this storage space by 1983. Permanent storage deep underground, probably in salt deposits or deep granite formations, is the long-term waste disposal method most seriously considered, although this, too, is a subject of heated debate. In addition, many state and local governments restrict or forbid the transport of radioactive wastes through their jurisdictions, making it difficult to transport, let alone dispose of, these wastes. The issue is further complicated by the necessity to tear down or seal up reactors, which are designed to operate approximately 35 years, so that no radiation escapes.

Safety and environmental issues associated with the nuclear fuel cycle are addressed in the article in *Voter*, the magazine of the League of Women Voters.[32] In this interview, John Fowler, National Science Teachers Association, Energy-Environment Materials Project, discusses the hazards related to the mining of uranium ore, the disposal and reprocessing of spent fuel, and the use of breeder reactors, which create their own fuel.

John Abbotts presents a highly critical review of the US government's nuclear waste management program.[15] He provides an overview of the numerous problems associated with radioactive waste disposal and, using specific incidents, reveals how the US government has addressed these problems. Abbotts delineates several weaknesses in the deep underground storage program, pointing out, "Responsible management would require stable geological formations and stable human institutions to guard the waste for many thousands of years."[15] He discusses a number of other issues associated with long-term storage and makes recommendations for resolving these problems. In separate articles, Kerr,[33] Weaver,[34] Church,[35] and Mathews[17] also examine various aspects of the waste disposal issue. Lapp's book, *Radioactive Waste*,[36] provides an overview of this problem.

The issues of operator training and equipment safety have been closely related in articles since the accident last March. Several writers point out that a minor equipment malfunction escalated into a major incident at TMI through a number of operator errors.[4,37] Fundamental questions are being raised

about nuclear power plant operators' understanding of the equipment for which they are responsible and their preparedness for a major accident. Heavy criticism has been leveled against the design of the TMI equipment, which caused more than one hundred warning signals to flash at the time of the accident and led operators to inadvertently allow the core of the reactor to remain exposed.[4]

The report of the Kemeny Commission provides an in-depth examination of these issues and draws several disturbing conclusions.[4] In this highly revealing report (which is based in part on 26 Commission staff reports, an NRC team report,[21] and a detailed chronology prepared by the Nuclear Safety Analysis Center[38]),[5] the Commissioners maintain operators of the TMI plant were not trained for emergency situations and claim educational standards imposed by the NRC "allowed a shallow level of operator training"[4] (p. 49) at all nuclear power plants. The Commission, in effect summarizing what many editorials had suggested, makes several recommendations for improving operator training.

The Kemeny Commission is also critical of the NRC and the nuclear industry for failing to share information on equipment malfunctions and inadequacies. For example, operators at the TMI site were unaware that a relief valve (the power operated or electromagnetic relief valve—PORV), which, by failing to close, severely aggravated the accident, had stuck open before at similar plants. The commissioners examine violations by Metropolitan Edison, failures by the plant designer and builder, and negligence by the NRC that contributed to the PORV malfunction at TMI.[4]

The accident is examined from the perspective of "human factors" engineering—the limitations of human performance in the operation of mechanical systems—in the article by Joel Greenberg[39] and in the Rogovin Report.[21] Greenberg, quoting a number of human factors engineering experts, focuses on the relationship between the design of equipment at TMI and the ability of operators to recognize and cope with abnormal events. The Rogovin Report presents the findings of an independent investigation conducted under the auspices of the NRC. It includes a detailed account of instrumentation flaws that could have been remedied through the use of human factors engineering. Written in a clear and straightforward manner, this report provides a balanced examination of the effect operator error and instrumentation problems had on the reactor accident.

In contrast with many of his colleagues on the Kemeny Commission, Thomas H. Pigford, in the supplement to the report,[4] describes how the TMI accident demonstrated the effectiveness of equipment at the nuclear power plant. Pigford, who is chairman of the department of nuclear engineering, University of California, Berkeley, states: "The accident demonstrated that the 'defense-in-depth' approach towards nuclear reactor safety has indeed yielded significant results.... The accident demonstrated that this system of equipment performed better than expected."[4] (p. 8)

Bill Keisling and Ed Perrone, in *The Progressive*,[8] present a detailed account of equipment malfunctions, and operator reactions to these malfunctions, throughout the accident. This well-researched summary of the accident, while often sarcastic, presents a vivid picture of events at the site and its environs and provides useful background information on the reactor unit which malfunctioned. Other accounts of equipment failures are provided in the Union of Concerned Scientists' publication, *Nucleus*,[40] and in the *Newsweek* article by Mathews and colleagues.[17]

Two issues that seem to thread their way through the literature on TMI concern the NRC's effectiveness in insuring the safety of nuclear energy and the technical qualifications of utilities to operate reactors. Questions have been

raised about the NRC's and Metropolitan Edison's knowledge of safety defects at the reactor that malfunctioned, their failure to communicate information that could have helped to avert the accident, and the lack of emergency evacuation plans at the TMI site.[4] Several investigators have focused on the NRC's organizational structure and the ability of the NRC to respond quickly to major accidents such as the one at TMI.[16,41,42]

Explanations for the structural and attitudinal shortcomings of the NRC and the nuclear industry are offered by R.A. Brightsen, a senior executive with the NRC, in *Fortune*,[43] and by NRC Commissioner V. Gilinsky in *Bulletin of the Atomic Scientists*.[44] In these very candid articles, the authors present historical accounts of the US nuclear industry and the NRC and describe how the TMI accident has affected the government's and private industry's attitude toward nuclear energy.

Unlike the majority of articles following the accident, which focused on the NRC's weaknesses, Pigford's supplemental view[4] of the accident is interspersed with examples of highly effective procedures and regulations instigated by the NRC to insure reactor safety. Pigford's comments shed a great deal of light on the NRC's decision-making and regulatory processes, as well as on the findings of the Kemeny Commission.

The Mathews article[17] examines violations of NRC regulations by Metropolitan Edison and explores the utility's motivation for allegedly putting the TMI reactor on-line earlier than was advisable. The NRC Commissioners' confusion at the time of the accident and basic organizational flaws in the agency are discussed in some detail by TMI Commissioners Bruce Babbitt and Harry C. McPherson, Jr.,[41] as well as by T. Morganthau and associates.[42]

Steps being taken by the nuclear industry to improve safety and provide adequate insurance for nuclear power plants are presented in the *Business Week*[45] and *Wall Street Journal*[46] articles, and in Pigford's supplement to the TMI Commission report.[4] The Institute of Nuclear Power Operations and the Nuclear Safety Analysis Center, which were set up by the industry to promote better operator training and emergency management and to insure that nuclear power plants meet safety criteria, are discussed in these articles. Incidentally, Lapp points out that the Kemeny Commission, in assembling its report, did not take into account industry-wide efforts to apply the lessons learned at TMI.[5]

Several suggestions for restructuring the nuclear industry to improve safety are offered by Weinberg in *The Wilson Quarterly*,[18] which is published by the Woodrow Wilson International Center for Scholars. In this judicious and somewhat novel approach to the safety problems inherent in the current industrial structure, Weinberg calls for the confinement of nuclear power plants to those existing sites having fewest people near them. Lapp describes Weinberg's proposals for these "power plant parks"—isolated areas devoted to generation of nuclear power—as "academic, given the deployment of 72 reactors today."[5]

A lot of newspaper and magazine space has been devoted to speculation on the economic impact the TMI accident will have on consumers and the nuclear industry. Even before the accident, orders for new reactors had been slowing down. This has been variously attributed to the skyrocketing costs of plant construction, the lack of investment capital due to inflation, regulatory and legal delays, organized opposition to nuclear energy, and uncertainty about the nation's energy needs.[16] Peter Gwynne, science editor, *Newsweek*, provides an impartial review of the nuclear industry's health in *Science Digest*.[16] Focusing on the effects of more stringent safety requirements and anti-nuclear protests and court actions, he examines a number of factors that could contribute to a slowdown in the industry.

Charles Komanoff, Komanoff Energy Associates, New York, compares the cost of nuclear and other forms of energy, makes several suggestions for more efficient use of non-nuclear energy sources, and discusses the institutional barriers to increasing the productivity of these resources.[47] Similarly, the article in *Nucleus*[40] and those by Carlson and colleagues,[48] and Parisi,[49] examine the impact of doing without nuclear energy and offer alternatives for filling the energy gap caused by closing nuclear power plants.

Another, conflicting, assessment of the cost of doing without nuclear power is offered in the *St. Louis Post-Dispatch* article.[50] This article presents the Edison Electric Institute's conclusion that banning nuclear power could cost consumers "...$119 billion by the year 2000."

The methods used for billing customers, or establishing "rate bases," for nuclear power plants are discussed in the articles by Avery,[51] and Smith and Lancaster.[52] The Avery article, which is adapted from a speech, examines the financial costs of the TMI accident to Metropolitan Edison and explains how these costs are affecting the rates charged customers. It also addresses the question of who should assume the risks associated with nuclear power. The latter article addresses the special problems faced by utility regulators in determining how the costs associated with nuclear power plants should be passed on to consumers.

The bibliography also includes a number of articles that, so to speak, step back and view the nuclear energy debate from a broader perspective.

L.S. Taitz, chairman, Conservation Society, UK, for example, examines the role played by energy in economic growth.[53] Providing a fresh outlook on the energy debate, he questions the basic premises that lead to international dependence on cheap forms of energy and concludes that "more drastic changes of life-style...seem inevitable." During a recent conversation, Warren Donnelly, Library of Congress, Congressional Research Service, pointed out that the term "drastic changes of life-style" actually means "doing with a lot less energy...going back to the era of the strong back and weak mind."[54]

A philosophical approach to the economic and technical problems associated with nuclear energy is offered in *Science 80* by Victor K. McElheny, director, Banbury Center, Cold Spring Harbor Laboratory, who examines the risks and benefits that typically accompany rapid technological advancement.[37] Risk assessment is also examined by Lewis in *Scientific American*.[11] Lewis provides an historical account and explanation of methods used to calculate the probability and consequences of reactor accidents. The article includes comprehensive, up-to-date information on the effects of radioactivity released at TMI, as well as a number of diagrams illustrating nuclear reactor operations, risk analysis, and the linear dose hypothesis. Stephen H. Schneider, deputy head, Climate Project, National Center for Atmospheric Research, Boulder, Colorado, in *SIPIscope*, discusses the uncertainties inherent in the development of any energy source and presents arguments for a national energy program that explores as many alternatives as possible.[55]

Although the TMI accident has had the most direct impact on the US, repercussions of the events in Pennsylvania were felt throughout the world. Government officials and citizen groups in several countries have called for more stringent safety controls, and Sweden, in a national referendum this March, voted to support limited expansion of nuclear energy.[56,57] Since the events at TMI may have influenced nuclear energy policies in several countries, the bibliography includes articles on international reaction to the accident. Articles written by H. Rehnvall,[57] A. Lloyd,[58] and A. Johansen[59] in *New Scientist* describe government policies on nuclear energy and show how they have, or have not, changed in response

to the accident. The articles by G. Kaplan,[60,61] S. Rippon,[62] and G. Greenhalgh[63] in *IEEE Spectrum* provide detailed information on the location of nuclear power plants in Europe and Japan and on the status of nuclear energy development in these areas of the world. The November 1979 issue of *IEEE Spectrum*, by the way, is devoted to articles on the TMI accident and the future of nuclear energy. In addition, we have included Harvey Wasserman's examination of the problems and consequences of exporting American made reactors, which appeared in *Mother Jones*,[64] and Anil Agarwal's *Nature*[65] article discussing the status of nuclear energy in Third World countries.

Even with—or due to—the abundance of information available, arriving at a conclusion on the merits of nuclear energy is a difficult task for the layman as well as the expert. The articles on the events at TMI, and nuclear energy in general, raise a number of questions for which there are, as yet, no conclusive answers.

I hope this review has provided some guidance by restating the issues. Obviously, they are very complex. The bibliography can be used as a starting point for further investigation. It contains only a fraction of the voluminous popular media material available, but should assist readers who want a dispassionate review of the presumed advantages and disadvantages of nuclear energy. This is not to suggest that the various advocates should be less passionate. However, simplistic solutions to complex problems are luxuries only demagogues proffer and no one can really afford.

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