Exporting Hydroelectric Energy

Carlos M. Varsavsky

While today most countries face energy shortages, hundreds of thousands of megawatts of hydroelectric power remain undeveloped in Africa, Asia, and Latin America mainly because of small local demand. Unlike fossil fuels, such energy if not used today is lost forever. At the same time, no scheme has yet been found “to containerize” it for export.

For example, in Zaire between 30,000 and 35,000 MW can be generated at a cost well under one cent per kilowatt hour. This energy, however, cannot be used in Zaire or in regions that could be reached from Zaire by means of conventional transmission lines for decades to come. If a way were found to deliver this energy to any of the industrialized nations, it would be an enormous boom to the economy of Zaire, and it would save the world a significant amount of nonrenewable fuels. There are other developing countries with similar potential.

For more than a decade, considerable effort has been spent in developing the concept of the Solar Power Satellite (SPS) [1]. In essence, the scheme consists of a very large array of photovoltaic cells (about 100 square kilometers in area), placed in geosynchronous orbit, which produces dc electricity; this is converted into microwaves and beamed toward earth from an antenna about 1 kilometer in radius. The microwaves are received on earth and transformed back into dc electricity that can be delivered to the existing grid after alternation. A system of the above dimensions would make about 5000 MW available to the public utilities. It will take over 20 years to make such a scheme operational on a commercial basis, and by far the largest technological and cost uncertainties reside in the collecting array of cells, antenna, and associated electronics, to be placed in space. What I suggest is a modification to the SPS scheme, in which a hydroelectric station substitutes for the solar energy collector. The electric energy generated at the station is transformed into microwaves and beamed toward a reflector in geosynchronous orbit, that would send the microwave beam back to earth where the energy is needed. The main advantage of this proposal over SPS is the elimination of, first, the construction and, next, the maintenance of a structure of 100 square kilometers with a substantial amount of complicated electronics about 35,000 km above the earth’s surface. Instead, my proposed system would have in space only a reflecting antenna which would be large but an order of magnitude smaller than the array, and passive, which means no maintenance and very long life. Other advantages are the elimination of blackouts when the earth eclipses the solar collector, the positive economic impact

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on the developing country, and the likelihood of a shorter lead time for implementation. The main disadvantages are the larger investments on earth and some additional losses. A superconducting line from France to Europe or the production of hydrogen, or some other high-energy density material, by electrolysis may also be viable alternatives for exporting hydroelectric energy. I am surprised that practically no attention has been given to these possibilities.

References

Letters to the Editor

To the Editor:

I have read with interest Frank Turner’s article that appeared in the March issue of TECHNOLOGY AND SOCIETY. I agree with most of the points made by Mr. Turner. Indeed, he has brought out the state of the present technoculture and the value basis succinctly. But I would like to add that the problem is deeper and the whole position of science and technology in relation to "development" needs reevaluation from a paradigmatic position.

At present, technology is producer-driven rather than consumer-responsive. This is the main reason why several products with a "special" social purpose are being put on the market. Many people are uneasy about this situation and they would very much like technology to be essentially consumer-responsive. The inexorable law of diminishing returns (a la Ricardo) is operating here, and society must find ways of expressing what it wants more clearly.

Technology’s main contribution has been a rise in productivity and efficiency over the last 100 years. But now, the productivity and efficiency are themselves being questioned—"productivity for whom," "efficiency for whom," to the producer or to the society?

This again is a difficult position to reconcile. A total holistic view has to be taken so that the overall benefits are optimized without externalizing a major portion of costs. This calls for a change in the axis of economics, which at present is given to group benefits.

At a more fundamental plane, the question of "means" and "ends" in relation to science and technology has become acute and no longer be escaped. Science and technology provide us with the means to create almost anything we want, but worthwhile ends have to be developed to direct these means. The blind acceptance of scientific and technological "whats" and "hows" is no longer possible because of the mounting dysfunctional secondary and tertiary effects of technology. It is not enough to have only rigorous analysis of markets to prove the potential beneficial attributes of new technology, but a rigorous analysis of the underlying paradigms to unravel the deeply embedded assumptions is necessary.

Another characteristic of science and technology has been that it has created a large array of hardware of global interdependence through the globe-girdling telecommunications of communication, transportation, military, and space. But a package of software to support this hardware—monetary agreements, international conflict resolution methodologies, peacekeeping mechanisms, property laws governing humankind’s common heritage of air, water, and other resources, etc., are lacking. Unless this is remedied, the global technology system will become more dysfunctional and susceptible to disruption. Historical and contemporary societies tend to emphasize only one of the three benefit sets—spiritual, social, and material—at the expense of the others. One of the major deficiencies of the present technoculture has been the restriction of benefits to one of these corridors only, thus making a large number of people who do not belong to that corridor “disassembled.” For example, the market economy countries stress the “material” aspect, the centrally planned economies stress the “social” aspect, and many preindustrial societies stress the “religious” aspect.

It may be speculated that the resurgence of interest in several religious cultures is an attempt at fundamentalism as in Islam, by several groups in different societies may be due to such "disassembling" arising out of overreaching the only material” aspect in the metaphor of "development." A new philosophy of “progress” which harmonizes all three benefit sets is the prime need at present.

K. C. Murthy
National Institute for Training in Industrial Engineering (NITIE)
Bombay, India

August 25, 1979

To the Editor:

I was shocked by the indictment of research in the article of Frank T. Turner in the March issue of TECHNOLOGY AND SOCIETY. As a person who would have died without the emergency use of a new and semi-experimental "wonder drug!" I have a personal stake in research and development. Admittedly, most people are more comfortable with the past—they have spent most of their lives there! And as one who neither died of disease, accident, nor starvation because of inferior technology, Mr. Turner can look back in nostalgic pleasure. I can assure him that many others do not—but most of us didn’t make it here!

Ishmeet Singh
University of Tennessee

To the Editor:

In giving recognition to the notable services rendered by Virginia Edgerton, along with a public acknowledgment and support she received from Prof. Stephen Unger, our Editor, Norman Babalhan, has demonstrated some journalistic perception which is all too rare in journalism.

The story of Virginia Edgerton’s sense of responsibility and her personalized initiative deserves to be on the record to serve as an incentive for other and younger engineers. Unfortunately, however, too many other stories of similar conscious initiative remain untold. And some of the untold stories relate to the subversion of engineering disciplines on a tremendous scale. (Fortunately, some examples are now appearing on the record in a new book, Ethical Problems in Engineering, published by Rensselaer Polytechnic Institute.) It is difficult to understand why the arrangers of the program felt the need for introducing the rambling philosophies.
As the new editor, you must have several problems. I hope my comments on these problems are useful to you.

Robert H. Bushnell
Boulder, CO

To the Editor:

In the light of my position paper published in the March issue of TECHNOLOGY AND SOCIETY, I was very pleased to read Prof. Melman's IEEE/AAIA talk.

Not only does he urge the redirection of our technology towards the solution of some of our real problems, but he calls attention to some of the weaknesses of our military-dominated R & D. As this orientation has spread through the rest of the profession to some degree, I believe it is at least partly responsible for the deteriorating status of our consumer-goods industry and technology.

Frank T. Turner
Nova Scotia, Canada

To the Editor:

May I add yet one more comment to the continuing Nuclear Power debate? Mr. Fellenzer's Letter to the Editor. (Vol. 7, No. 27, Sept. '79) and many similar arguments against nuclear power are very convincing. Unfortunately, they are not sufficiently convincing to convince the authors and the industry, of their own position. If, for one, would be far more sympathetic to the industry position if the industry's actions reflected their arguments.

To be specific: if nuclear power is so very safe, why the limits on liability protection (the Price Anderson act)? If, indeed, experience has given the industry confidence in the safety of reactors, isn't it time to repeal the Price-Anderson act? In the meanwhile, as long as someone tells me that reactors are perfectly safe, but isn't willing to stand behind this safety claim, I am very, very skeptical.

Or, in the common vernacular: put your money where your mouth is.

Erwin Vogel
Gulthburg, MD

Ethical Trilemmas
L. B. Cobik

The Institute of Electrical and Electronics Engineers is one of the oldest and largest professional engineering societies. Like its sister engineering organizations, it is caught up in the swirling forces of modern times. The old values seem to be falling away one by one. The respect we once took as our automatic due for belonging to a professional society no longer comes to us. A hundred pressures from a hundred sides pull our minds from the performance of our duties and convert our once challenging work to a tangle of anxieties.

IEEE has been in the forefront of attempts to cope with these anxieties. Perhaps only the civil engineers have been as active. 1974 saw a new 19-point code of ethics adopted by the Board of Directors. 1977 saw the development of procedures for IEEE support of ethical engineers and for handling alleged infractions of the IEEE code by members. 1979 sees the rise of a new mature beast: the formal academic course in engineering ethics. From inside and outside the students are taught a new lesson—what is—isn't always what it is either—squeezes out of us our last drop of patience.

Let us pause to look at some of the sources of pressure. In fact, we do not have to look if we do not wish to. We can, instead, try our selves in the work of the day and ignore the squeere. Such an attitude was most graphically expressed recently by an engineer (not a member of IEEE) who stated the simple truth: "First, to stay out of jail. Second, to put food in the table. Last, to advance my profession."

We can all take this stance. However, I give this warning: you look up one day, even if only from curiosity, your profession may be unrecognizable. Whether you like its new form may be largely a function of the role you play in shaping it.

Traditionally, we are insured to living with dilemmas, the insoluble conflict of opposing duties. The demand for technical solutions which meet the highest standards of correctness, materials, and cost-effectiveness is a challenge which places every electrical and electronic engineer in continual conflict.

For example: your engineering analysis of an automated control system for a railway network shows it to be unreliable and inadequately tested. Your employer rejects your report with threats that any additional action on your part would result in dismissal. You assure your employer that the system is in fact safe, when viewed from an overall perspective beyond your specialization. Delays to rework sub-systems in accord with your report will kill all profit. Do you refuse to accept your role as an employee? This is the dilemma you face by being both a professional engineer and an employee.

For example, you determine that an automatic control system is unreliable and may permit accidents on a railway network. Your employer silences your protests, arguing that your first loyalty is to him. Your desire to protect the public which rides the system leads you to search for other outlets of warning. You can send your report to the city governing the system and its public use. Should you? Should your interest in the public benefit override your commitment to act as a faithful agent or trustee for your employer? Here is a dilemma between your roles as a public citizen and an employee.

For example: after prolonged disputes between the governing board of a railway network, you are dismissed from employment. No longer do you have assigned duties to analyze the automated control system. Nonetheless, you stand by your original findings that the system is unreliable. As an engineer, your professional judgment demands hearing. As a citizen, you have received the benefits of current standards. Consider this dilemma, do you conscientize yourself in the knowledge that you have done all you can? Or do you take extraordinary action, such as "whistle-blowing"?

In dozens of forms, we all have confronted dilemmas between two aspects of our roles. We either resolved them or learned to live with them. In the examples, we recognize dilemmas of the now infamous BART case. It was even more complex than the examples of our professional lives came together. Events vindicated Hjortsvang, Bruder, and Blankeneye, but when each initially faced the problem, matters were far from certain. Each man faced a three-cornered conflict among his role as an engineer, an employee, and as a concerned citizen. Each faced the confusion of a trilemma.

With this multi-faceted problem IEEE as a professional society has had to grapple. From these events emerged the 1974 code of ethics of IEEE and the attempt to develop procedures to deal with future cases wherein questions of ethics arise. Two procedures are emerging: one to handle violations of the code and the other to protect engineers who try to live up to it.

The IEEE code of ethics (with a 1979 revision of its preamble) contains 19 provisos in one page. The procedures occupy nine columns of small print. How can a code of ethics have come to this state?

Let us back up to watch history introduce further pressures on us. Code III of the present form record a set of ideals to which their adherents aspire. The shortest code in my possession contains five or six sentences. Steering begins typically thus: "A member should strive to act..." Such wording and generality are not designed to be enforced.

Second-level codes contain more stringent language. "Engineers shall accept responsibility for their actions." This is simple and plain and enforceable. The irresponsible member may be expelled. If licensing is a function of a given society, a professional may be stripped of permission to practice.

First- and second-level codes are ordinarily written in the language of human interactions. They specify the parameters of relationships. IEEE's basic code follows this pattern. Article I specifies the relationship of the engineer to his profession. Article II relates the engineer to his peers, Article III to his employers and clients, Article IV to his community and the public.

As we graduate from first to second-level codes, we evolve enforcement procedures. Usually these are informal. With the growth of the engineering profession, courts have at the second level been used to protect members economically and socially, enhancing their image and income. Entry standards and exams, licensure, and other such acts typify the prime work of societies with second level codes.

The famous Goldfarb case has changed all this. The court held that, in effect, a minimum fee schedule for lawyers enforced through bar associations, is not exempt from antitrust provisions [Goldfarb v. Virginia State Bar (1975)]. In a case involving the National Society of Professional Engineers, the court reaffirmed this position by
challenging the Society's ethical prohibition of competitive bidding [National Society of Professional Engineers v. United State (1978)]. The immediate effect of these cases is to deny professions and professional organizations immunity to antitrust. By extension, immunity from all other generally applicable laws is also denied. Thus, the farther reaching effect of such rulings is to reduce the protections which societies can offer professional practitioners.

The self-governance of the professions is being put to a stiff test. In fact, there appears to be a race between professional codes of ethics and the law for domination. The law seems content to let the professions regulate themselves so long as their mechanisms are open to all relevant parties and so long as the rights of all parties are preserved. Nonetheless, if professional societies do not work out rational solutions to their real and potential dilemmas, the law may well impose irrational solutions.

Even before Goldfarb, however, two strategies were emerging in the effort to preserve self-regulation for the professions. Third-level codes of ethics take one of two forms (which are not totally exclusive):

Level three—A consists of codes with have changed their substance. Instead of addressing human relationships, they prescribe and prescriptive specific forms and activities. Typical are the codes of the American Psychological Association and the American Dental Association. The dentists, for example, forbid the use of secret agents and of course any mention of them, pesticides, prescribe rules for office-door lettering and signs; designate proper means of being listed in directories; etc.

Here now are easily and clearly enforceable principles.

A violation consisting, say, of an oversized door sign, is mechanically detectable. It is clear. And it is law-like. In fact, in these cases, the codes are written, and the language is general, and the enforcement is conducted

as a self-regulating

system.

With this in mind, we see that there is a third level of codes which is even more clear.

The Ethics is this: "The engineer shall apply specialized knowledge and skill at all times in the public interest, with honesty, integrity and honor." ['Public Obligation and the Ethics System: Proceedings of A.S.C.E., 105 (July, 1979).]

While we might sympathize with Professor Wisely's sentiment, it is not clear how this is to be accomplished without degrading the public interest. Nor is it clear how the public is to be satisfied if the public interest is not satisfied.

The first issue of 86 pages contains eight articles in addition to the Introduction and a small amount of advertising.

A brief review of each article will be given.

Harvey Brooks opens with "Technology: Hope or Catastrophe?" in which he surveys the first wide range of current opinions on the world-wide social problems which arise from our increasingly technology. He appears to point out that the current intellectuelle revolts against science and technology is not new but is more significant today simply for the greater size and the greater sign of the total population. Brooks admits to being an optimist while stating that the barriers to solving today's problems are more political and institutional than due to material or technical limits. In the end he presents a statement of hope and a hope which most of the world would echo.

In the long run I would find it difficult to believe that the frailty of humankind will deny the realization of the opportunities which lie within our intellectual capabilities, if not our moral ones. So I do with the proposition that science is more hope than catastrophe. I do not think that it is an either-or issue.

The global complications of today are next reviewed by Harlan Cleveland in the article "Do Global Technologies Require Global Policies?" Although acknowledging the challenges of science and technology on the international order, he indicates that both science and technology are somewhat more constrained today since the science is now widely regarded as too important to be left to the scientists and that we are also rid of the popular assumption which states that "if we can invent something, we had better manufacture it." I doubt whether many would agree that these are indeed settled questions.

Cleveland believes that the internationalization of internal affairs is already far advanced because of the global demands currently placed upon all nations, and that global arrangements for maintaining international law will "be done in a spirit of mutuality or not at all."

Edward Wenk in "Political Limits in Steering Technology: Pathologies of the Short Run," states that we need to build "a regulatory framework by which science and engineering are translated to social purpose. He also believes that the structure and process of professional bodies have a greater influence on the application of technology toward social uses than does any lack of technical innovation. The primary decisions in guiding technology are made by government, with the President as system architect. The decision-making system of government is heavily biased by political expediency, and Wenk then lists a number of other "pathologies of the short run," including the reward structure in industry, the complexity of modern life, an inability to relate cause and effect, shortage of time and media pressure for the quick fix. He concludes with a resounding call for new attitudes: "People, the decision apparatus. Unless they are willing to trade off instant gratification for some vision of the future benefits of humankind generally, and for their own property specifically, we shall be in an impossible situation. Whether the future in its decisions, the political leadership will remain the issue of action. The exist of action which could degrade individual integrity or extinguish humanity altogether. Even before that happens, the reign of the future may undermine even the future capacity to decide."

In "Nuclear Energy and the Interdependence of Nation," Nicholas E. Ertle proposes that the energy shortage will be in the Third World where increasing population will be met with decreasing supplies of oil. He believes that oil is the only material deliverable in an amount which will meet the needs of primitive people. It should therefore be the objective of industrialized countries such as ours to concentrate on the use of new technologies for our energy sources. Teller naturally focuses on nuclear energy though giving a recognition of other forms of energy sources.

A brief review of the history of space exploration concludes that we have explored the space shuttle program in "The Impact of Our Enterprise in Space," by Hans Mark. The article is thinly veiled propaganda for a full-speed ahead in space exploration. The enticement presented is that the space shuttle will allow "many people (to) fly in space without much training." However, we are then left with:

"In trying to imagine what will happen once we have the shuttle, it may be better to look toward the poets and dreamers rather than the engineers, . . . the fact is that engineers and technical people generally tend to be too optimistic in the short term. We tend to
believe that our near-term problems are less formidable than they really are and therefore overestimate what we can do in the span of the next twelve months. But if we are looking at something beyond the future, we tend to be timid, and it is here that the poets and the dreamers have their day.

Mark then concludes with: ‘...There is no doubt we are faced with limits; every generation has been in the past. What is important is to recognize that the human imagination is not limited by the use of that imagination which allows man to grow, to transcend his limits, and to fulfill his dreams.

In the following article Peter Glaser discusses in considerable detail ‘The Potential for Solar Energy Development.’ Starting with the statistic that the sun contributes to the earth 5,000 times the total energy input from all other sources combined, Glaser presents an impressive quantity of figures related to the various forms of energy conversion which use the sun as the primary source. Among these conversion types are solar water heaters, solar thermal conversion power plants, photovoltaic systems, wind power, ocean thermal energy, bioconversion, and solar power satellites.

Glaser concludes that it is too early to tell which solar conversion methods will prove to be beneficial and believes it necessary to develop all promising solar energy possibilities. He states that ‘...it is conceivable that the inevitable transition to more solar energy resources could be well under way by the first quarter of the 21st century and be completed by the middle of the century.’

“The Five Budge” is the inviting title of an article byario Bunge. He first defines tecnophiles as, obviously, the philosophy of technology. Bunge calls this a budding field since

Philosophy of Alternative Technology: Historical Roots and Present Prospects.” Winner welcomes the 20th century reemergence of “thinking about technology” which has been essentially avoided since a “technocratic orthodoxy” presented by Francis Bacon. Included in the list of standard tenets of this technical orthodoxy are:

- that the things men make are under their firm control
- that technology is neutral
- that what technicians or engineers do is simply a matter of solving problems

Winner then discusses the uses of technology by both capitalism and Marxism and the absence in both economic systems of the development of a valid philosophy of technology. He then leads to the development of alternative technology where ‘...the significance of alternative technology...is the possibility of a fundamental re-evaluation of the place and meaning of technology in human activity.’ Winner finally asks: Is it not clear today that a society based on energy conservation and decentralized technology using renewable resources would, in all likelihood, look very much different from a society based upon massive deployment of nuclear reactors?

Glaser’s argument is that there is an official effort by which current science is not to be a competitive arena of efforts, but rather an attempt to invest new ideas into the research and development of nuclear reactors. The cost is an official attempt to monopolize the research and development of new ideas.

What is the future of the nuclear industry? As noted above, the nuclear industry is a potentially competitive arena of efforts, but rather an attempt to invest new ideas into the research and development of nuclear reactors. The cost is an official attempt to monopolize the research and development of new ideas.

Excerpts from the Kemény Commission Report on Three Mile Island

[Editor’s note: The following excerpts are from the Report of the President’s Commission on the Accident at Three Mile Island, which was released on October 30, 1979. The commission, chaired by Dartmouth College president James R. Kemény, was established by President Carter on April 11 to investigate the accident that occurred at the Three Mile Island Unit-2 nuclear power plant on March 28, 1979.]

Overview

...After a six-month investigation of all factors surrounding the accident and contributing to it, the Commission has concluded that:

1. To prevent nuclear accidents as serious as Three Mile Island, it is necessary to have adequate emergency plans, training of personnel, and adequate organization, procedures, and practices. And—above all—in the attitudes of the Nuclear Regulatory Commission, and, to the extent that the institutions we investigated are typical, of the nuclear industry.

This conclusion speaks of necessary fundamental changes. We do not claim that our proposed recommendations—while important—are sufficient. Our findings do not, standing alone, require the conclusion that nuclear power is inherently too dangerous to permit it to continue and expand as a form of power generation. Neither do they suggest that the nation should move forward aggressively to develop additional commercial nuclear power. They simply state that if the country wishes, for larger reasons, to confront the risks that are inherent in the development of nuclear power, fundamental changes are necessary if those risks are to be kept within tolerable limits.

The report itself, as we say, is an other word occurred and over again. That word is “mindset.”... After many years of operation of nuclear power plants, with no evidence that any member of the general public has been hurt, it is not clear why nuclear power plants are safe, but they have not yet been free of accidents. The public should be concerned about the adequacy of emergency planning. We must recognize this understanding why many key steps that could have prevented the accident at Three Mile Island were not taken. The Commission is convinced that this attitude must be changed to one that says nuclear power is by its nature potentially dangerous, and, therefore, one must continually question the wisdom of approving any large-scale power operations that are not safe.

Technology In Society is a welcome addition to the list of publications related to science, technology, and society and it is hoped that it becomes a reference in the development and solution of our critical problems.

CSIT Meeting

January 19, 1980

The next meeting of CSIT will be held on Saturday, January 19, 10:15 AM to 3:10 PM, in Room 1306A of the Mudd Engineering Building, Columbia University, New York City. CSIT meetings are open to all IEEE members, and all who are interested in the issues for philosophy, which is always in need of the cooperation of those who know something about the object of their musings.

Langdon Winner concludes the series of articles with another philosophical undertook. “The Political

and were used as a basis for the design of plants. A preoccupation developed with such large-break accidents as did the attitude that if they could be controlled, we need not worry about the analysis, "less important" accidents.

Large-break accidents require extreme technology, which therefore must be automatically performed by the equipment. Lesser accidents may develop much more slowly and their control may be dependent on the appropriate actions of human beings. This was the tragedy of Three Mile Island, where the equipment failures in the accident were significantly less dramatic than those that had been thoroughly analyzed, but where the result confused those who managed the accident. Since such combinations of minor equipment failures are likely to occur much more often than the huge accidents, they deserve extensive and thorough study. In addition, they require operators and supervisors who have a thorough understanding of the functioning of the plant and who can respond to combinations of such equipment failures.

Just how serious was the accident? Based on our investigation of the health effects of the accident, we conclude that for the most part the residual was contained and the actual release will have a negligible effect on the physical health of individuals.

The major health effect of the accident was found to be mental strain.

...The ongoing cleanup operation at TMI demonstrates that the plant was inadequately designed to cope with the cleanup of a damaged plant.

...When NRC was split off from the old Atomic Energy Commission, the purpose of the split was to separate the regulators from those who were promoting the peaceful uses of atomic energy. But, we have seen evidence that some of the old promotional philosophy still influences the regulatory practices of the NRC. While some compromises between the needs of safety and the needs of an industry are inevitable, the evidence suggests that the NRC has sometimes erred on the side of the industry's convenience rather than carrying out its primary mission of assuring safety.

...In the licensing process, applications are only required to analyze "single-failure" accidents. They are not required to analyze what happens when two systems fail independently of each other, such as the event that took place at TMI.

...the utility that operates a nuclear plant must be held legally responsible for all reasonable accidents that occur or occur. Some potentially serious scenarios, such as the break of a huge pipe that carries the water cooling the nuclear reactor, were studied extensively and diligently,
necessary technical expertise and managerial capabilities for administering such a dangerous high-technology plant. We, therefore, recommend that higher standards of organization and management that a company must meet before it is granted a license to operate a nuclear power plant...

...we felt that our findings and recommendations are of vital importance for the future of nuclear power. We are convinced that, unless portions of the industry and its regulators make the necessary changes, they will continue to experience over time destroy public confidence and, hence, they will be responsible for the elimination of nuclear power as a viable source of energy.

Commission Findings

A. Assessment of Significant Events

1. The pilot-operated relief valve (PORV) at the top of the pressurizer opened as expected when pressure rose but failed to close when pressure decreased, thereby creating an opening in the primary coolant system—a small-break loss-of-coolant accident. The PORV indicator light on the control room showed only that the signal had been sent to close the PORV rather than the fact that the PORV remained open. The operators, relying on the indicator light and believing that the PORV had closed, did not heed other indications and were unaware of the PORV failure; the LOCA continued for over 2 hours. The TMI-2 emergency shutdown system was not designed to activate automatically once the PORV block valve was closed, the LOCA would exist. Prior to TMI, the NRC had insufficient attention to LOCA’s of this size and the probability of their occurrence in licensing reviews. Instead, the NRC focused most of its attention on large-break LOCAs.

4. The high pressure injection system (HPIS)—a major design safety system—came on automatically. However, the operators were conditioned to maintain the specified water level in the pressurizer and were concerned that the reactor cooling system was “going solid,” that is, filled with water. As a result, they did not attempt to restore normal conditions. This led to the lack of communication and proper evaluation of the situation.

5. TMI management and engineering personnel also had difficulty in analyzing events. Even after supervisory personnel took charge, significant delays occurred before core damage was fully recognized, and stable cooling of the core was achieved.

6. Some of the key TMI-2 operating and emergency procedures were inadequate, including the training of personnel and the procedures for a LOCA and for pressurizer operation. Deficiencies in these procedures could cause operator confusion or incorrect action.

7. Several earlier warnings that operators needed clear instructions for dealing with events like those during the TMI accident had been disregarded by Babcock & Wilcox (B&W) and the Nuclear Regulatory Commission (NRC).

1. After an incident at TMI-2 a year earlier during which the PORV stuck open, an indicator light was installed in the control room. That light showed only that a signal had been sent to close the valve—it did not show whether the valve was actually closed—and this contributed to the confusion during the accident.

5. Utility management did not require attention to detail as a matter of policy.

a. Management permitted operation of the plant with a number of poor control room practices:
   i. A shift supervisor testified that there had never been less than 52 alarms lit in the control room.
   ii. TMI Commission staff and NRC inspections noted a large number of control room instruments out of calibration and tags hanging on the instrument panel indicating equipment out of service. Operations testified that one of these tags obscured one of the emergency feedwater block control valve indicator lights.
   iii. When shifts changed in the control room, there was no systematic check on the status of the plant and the line-up of valves.

b. There were deficiencies in the review, approval, and implementation of TMI-2 plant procedures.

vi. Performance of surveillance tests was not adequate in that the NRC procedures were not being followed correctly. On the day of the accident, emergency feedwater block valves which should have been open were closed. They may have been left closed during a 2 days earlier.

b. Management did not assure adequate indentification of piping and valves throughout the plant. The Commission staff found that many identification practices were significantly below standard industrial practices.

5. During the accident, the NRC inspection team was not sufficiently informed to respond adequately. The NRC inspectors had not been trained for such incidents and were therefore unable to provide effective assistance.

F. TRAINING OF OPERATING PERSONNEL

2. The TMI training program conformed to the NRC standard for training. Moreover, TMI operator license candidates had higher scores than the national average on NRC licensing examinations and operating tests. Never-
tomers of these failures, nor did it highlight them in its own training program so that operators would be aware that such a failure causes a small-break LOCA.

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   i. A shift supervisor testified that there had never been less than 52 alarms lit in the control room.
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   iii. When shifts changed in the control room, there was no systematic check on the status of the plant and the line-up of valves.

b. There were deficiencies in the review, approval, and implementation of TMI-2 plant procedures.

vi. Performance of surveillance tests was not adequate in that the NRC procedures were not being followed correctly. On the day of the accident, emergency feedwater block valves which should have been open were closed. They may have been left closed during a 2 days earlier.

b. Management did not assure adequate indentification of piping and valves throughout the plant. The Commission staff found that many identification practices were significantly below standard industrial practices.

5. During the accident, the NRC inspection team was not sufficiently informed to respond adequately. The NRC inspectors had not been trained for such incidents and were therefore unable to provide effective assistance.

F. TRAINING OF OPERATING PERSONNEL

2. The TMI training program conformed to the NRC standard for training. Moreover, TMI operator license candidates had higher scores than the national average on NRC licensing examinations and operating tests. Never-
tomers of these failures, nor did it highlight them in its own training program so that operators would be aware that such a failure causes a small-break LOCA.

1. At TMI-2 a year earlier during which the PORV stuck open, an indicator light was installed in the control room. That light showed only that a signal had been sent to close the valve—it did not show whether the valve was actually closed—and this contributed to the confusion during the accident.

5. Utility management did not require attention to detail as a matter of policy.

a. Management permitted operation of the plant with a number of poor control room practices:
   i. A shift supervisor testified that there had never been less than 52 alarms lit in the control room.
   ii. TMI Commission staff and NRC inspections noted a large number of control room instruments out of calibration and tags hanging on the instrument panel indicating equipment out of service. Operations testified that one of these tags obscured one of the emergency feedwater block control valve indicator lights.
   iii. When shifts changed in the control room, there was no systematic check on the status of the plant and the line-up of valves.

b. There were deficiencies in the review, approval, and implementation of TMI-2 plant procedures.

vi. Performance of surveillance tests was not adequate in that the NRC procedures were not being followed correctly. On the day of the accident, emergency feedwater block valves which should have been open were closed. They may have been left closed during a 2 days earlier.

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G. THE NUCLEAR REGULATORY COMMISSION

2. NRC labels safety problems that apply to a number of plants as "generic." Once a problem is labeled "generic," the licensing of an individual plant can be completed without resolving the problem. NRC has a history of leaving generic safety problems unresolved for periods of many years—for example, the problem of anticipated transients without scrams.

8. There are serious inadequacies in the NRC licensing process.

...despite recognition within NRC and various industrial groups that outdated technology in the control room could seriously handicap operators during an accident, NRC continues to license new plants with similarly deficient control rooms. As noted before, problems with the control room contributed to the confusion during the TMI accident. (See also finding A.8.)

The requirement of additional instrumentation to aid in accident diagnosis and control was considered by NRC as early as 1975, but its implementation was delayed by industry opposition as expressed by the Atomic Industrial Forum (AIF).... The lack of instrumentation to display in the control room the full range of temperatures from the core thermocouples contributed to the confusion involved in trying to rapidly depressurize the primary system on March 28.

9. The Office of Inspection and Enforcement (IDE) is charged with determining whether licensees are complying with NRC regulations, rules, and licensing conditions. Some serious deficiencies in this office are:

a. A 1978 General Accounting Office report found that IDE’s enforcement of construction work, relied heavily on the utility's self-evaluation, spent little time observing ongoing construction work, and did not communicate routinely with people involved in the actual construction work. Similar problems exist in IDE inspections of operating plants. For example, the principal IDE inspector for TMI-2 completed an inspection plan document that included no listing of utility records and interviewing plant personnel, but without physically examining any equipment.

f. IDE inspectors have on occasion had difficulties having safety issues that they have raised seriously considered within the office. For example, in 1978 one IDE inspector raised the issue of operator termination of HPI during the September 1 incident at Davis-Besse. For some 5 months, none of his efforts produced any action. He then took advantage of the "open door policy" of NRC and went directly to two of the commissioners. These commissioners indicated through the IDE to merit further examination. Unfortunately, this meeting with the commissioners did not take place until one week before the TMI-2 accident.
Acceptance Statement
Delivered by V. Edgerton, CSIT Award Recipient, April 24, 1979.

I am indeed honored to receive this award. I dedicate it to all 190,000 IEEE members, some of whom, I am certain, are going through the same thing that I went through—but without getting an award.

This award is a pledge to our fellowman, to protect them from equipment malfunction and from technological damage. In the fifties, Albert Einstein warned us that for the first time since the dawn of history we were facing total annihilation through nuclear war. By the sixties nuclear war was unthinkable; we won't have nuclear war, we said. But the thought gradually emerged that maybe equipment malfunctions, as depicted in the movie Dr. Strangelove, would trigger a nuclear explosion and still cause total annihilation. Now, in 1979, we have experienced Three Mile Island. It would be alarmist to imply that TMI could lead to total annihilation, but we cannot close our eyes to the reality of the situation, either.

We can no longer continue to be the docile technicians that are optimum for the modern bureaucratic organization and also, at the same time, protect our fellowman. We had better make a choice. As the second recipient of this very proud award, I would like to state the first three ground rules of engineering ethics. I address them to all employers of engineers, whether they be for profit or not-for-profit organizations: First, an engineer will not do a job just because you tell him to. Second, deliberate design of malfunctioning equipment such that it kills or harms is a crime, and ordering an engineer to do so is also a crime. And third, the person who commits this crime can be jailed.

So my message to all the nontechnical people of the world and those of you who are here and who are not in our field is: I want you to notice that the IEEE is on this now. This is the second year in a row the award has been made. I am getting this award because maybe—we don't know for sure, but maybe—some people are walking around the streets of New York today who might have died, and they are walking around directly because of the IEEE. And I want to address all IEEE members everywhere, and especially the three men in San Francisco who received this award last year, with my message. And that is: Be proud.

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