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AFGHANISTAN AND OIL FORCING U. S. REAPPRAISALS

The most serious implication of the invasion of Afghanistan is the heightened possibility that the Soviet Union will move again, in the coming years or decades, toward a presence in Iran ("invited" or not) and/or greater proximity to the Persian Gulf, perhaps through Baluchistan. This could even arise as a response to our escalation of actions against Iran in our efforts to secure the release of the hostages.

Precisely because this invasion expanded the Soviet home-base, for the first time in a generation, it puts an end to the widespread assumption that Soviet leaders might restrict themselves, outside Eastern Europe, to a combination of covert operations supplemented by use of Cuban proxy forces. Furthermore, changes in Soviet leadership attitudes, associated with Brezhnev's aging, could produce a different set of Soviet tactics. Thus, Afghanistan may presage more aggressive Soviet actions than heretofore and this possibility — though admittedly and obviously not a certainty — deserves the most serious consideration and preparation by Administration strategists.

Worst of all, the West now has developed, in the last generation, an exposed jugular: oil. And, quite apart from the control over the West that it would give the Soviet Union to occupy, or have hegemony over, major oil-producing states, there is the real possibility that the Soviet Union may itself come to require imports of oil. While today it still exports oil, and possesses large reserves, it is having difficulties solving production problems in Siberia; it must foresee, at least in coming decades, if not years, that it will have as desperate a requirement for oil as has the West. Obviously, if it *does* come to need oil, it will have no scruples about using military force to get it.

No doubt, the invasion of Afghanistan had something in it for everybody in the Politboro and need not have been justified in these terms only. Multiple motivations must have made the action irresistible to a government that is exquisitely opportunistic.

The idealogues must have wanted to prevent the loss of a Marxist state — notwithstanding the fact that the Soviet coup there was only 18 months old. They may even think the West is in the grip of the long foretold economic crisis. The KGB may have wanted better control over the borders. The area specialists may have worried about Islamic minorities inside the Soviet Union, and described the preoccupation of the Islamic world with anti-Americanism and the disorganization in Iran. The cold warriors may have seen a way to rid the Soviet government of a policy of detente it did not need. The military may have yearned for an exercise that provided a border buffer to the South.

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FAS ANNIVERSARY, AFGHANISTAN, AND ENERGY ACTIVISM

On December 16, FAS held what was, in effect, the tenth anniversary of its rejuvenation in 1970 complete with attendance by former as well as present officials. They heard Paul C. Warnke speak on arms control, and Jack Gibbons, Director of the Office of Technology Assessment discuss energy issues. A general discussion was held on the next ten years at FAS and Berkeley's John P. Holdron was awarded the 1979 Public Service Award "For the Pursuit of Excellence in the Analysis of Energy Policy." Later, the Council discussed how to respond to an invitation to send a scientific delegation to Vietnam. (The invitation had been twice deferred following Vietnamese government: expulsions of refugees; invasions of neighboring countries; and reluctance to cooperate with relief authorities. Members are invited to give their view.)

On Christmas Eve, the Russians invaded Afghanistan turning world difficulties into dangers. Subsequently, we polled 100 FAS officials to determine how scientific exchange should be adjusted if at all. So far 18% think it should be completely insulated from this political event. 33% support the Administration cancellation of high level visits. 10% would encourage individual scientists to consider boycotting scientific exchange for so long as they see fit. 13% would advertise their readiness to break off federally-funded scientific exchange for years if futher Soviet aggressions take place, as part of the scientific communities contributions to deterring the Russians. And 25% would advocate such a cut-off for a significant period today.

FAS is stepping up activity on energy conservation in general, and preparations for possible oil cutoffs in particular. On January 17, FAS hosted a two day meeting at which organizers of the American Council for an Energy-Efficient Economy (ACEEE) Manifesto (See PIR October, 1979) were introduced to Congressional staffers and conservation lobbyists. They worked during the day with assorted experts on specific conservation issues under the guidance of ACEEE secretary (and FAS Council Member) Arthur Rosenfeld and Ms. Deborah Bleviss, FAS staff assistant for energy. □

But it cannot have been ignored by any part of the Soviet Government that a move into Afghanistan was precisely the right thing to do if one grasped the obvious fact that oil was becoming the be all, and end all, to world politics. Finally, whatever combination of motivations is credited with this action, the invasion becomes, nevertheless, a test of Western will and determination. If the Western reaction is tepid, those most supportive of this maneuver will be vindicated and encouraged to press on.

Something must be done to discourage this kind of activity, or the probability of world war will rise to tangible proportions. It is all very well to say, as some of our members do, that the Soviet Union would not cut off oil to the West, even if they could, because it would know that this meant world war. Unfortunately, things are not quite that simple. There are all too many scenarios in which the West could be starved for oil, without a clear causus belli, in ways that throw the initiative back to us. If, for example, Iran were either invaded on some pretext or pressured to sell its oil to the East, would we destroy the oil rigs in Iran? It isn't clear that events would give such actions legitimacy.

Unfortunately, what the Russians are learning so far cannot be too discouraging. The outcry in the Islamic world is far inferior to continuing complaints of Moslems against the U. S.

Soviet Losses

From the Soviet point of view, the main losses must be the specter of growing coordination of U. S. and Chinese policies. Second, there is the sign that the United States might not always sell grain automatically and the precedent of halting high-technology sales, and scientific and cultural interchanges. Finally, moving the Olympics openly questions Soviet motives and hence would have significant repercussions inside Soviet society — dedicated as that society is to maintaining maximum pretentions in propaganda.

But it seems doubtful that any of this could dissuade the Soviet government — or any other cynical government similarly placed — from considering this invasion successful with its promise of ultimate access to the Indian Ocean, and the Mideast oil fields. Thus, the main problem faced by the West is that this maneuver is likely to be judged in Moscow, on balance, as an effective maneuver.

True, many hope that Afghanistan will be a Vietnamese-style quagmire, but it seems unlikely. Many have forgotten the many special factors that led to our loss in Vietnam. The Vietnamese had the advantages of: a committed superpower, a sanctuary, jungle cover, great military skills, and geographical distance from their major opponent. Afghanistan is not so fortunate.

What does this mean for citizens and scientists, and

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THALER BECOMES FAS COUNSEL

FAS and its Fund have been functioning without a Counsel since the 1960-1970 period when this service was provided by Daniel M. Singer of Fried, Frank, Harris, Shriver, & Kampelman as part of his general oversight of FAS activities during a decade in which FAS had only a skeleton staff.

Since that time, several invaluable services and much consultation have been provided to FAS by Martin S. Thaler, a partner in the distinguished firm of Verner, Liipfert, Bernhard & McPherson. Reflecting its desire for his continued advice, FAS has persuaded Mr. Thaler to accept the title of Counsel. □

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FAS in particular? Afghanistan, with its proximity to Mideast oil, is a reminder that the issues we are all working on are intensely real ones with deadly implications. Nuclear war could now arise from Mideast scenarios much more easily foreseeable than heretofore. In particular, the need to conseve oil is underscored once again; America simply must get itself together to restrain its use of oil. We ought to be saving, by ourselves, at least 2.5 million barrels a day (14% of our use) through rationing and gas taxes — a process that would free enough oil to permit our allies to engage in the requested oil boycott of Iran without driving up the price further.

In assessing a U. S. menu of longer term potential responses, it is only too evident that U. S. economic strength will be tested in various kinds of economic warfare. We must improve our productivity and get inflation under control. Methods of eliminating bureaucratic red tape in science, of linking theoretical and applied research, and of increasing productivity in science-based industry ought to be a serous FAS priority.

Improve Defense Planning

Defense planning has got to be better insulated from politics and better thought through. For example, a precipitate decision on the method of deploying MX was made by the Administration to encourage the possibility of passage of SALT II. Therefore, SALT ratification having been put off, the President should slow the momentum on MX and consider alternatives to it, such as the scheme advanced by Sidney Drell and Richard Garwin to place missiles on small submarines. We cannot now afford missteps in planning on multi-billion dollar programs. We must also be alert to the possibility that MX — when built without any assurance of continuing fractionation limits on Soviet warhead numbers — would lead to the use of anti-ballistic missile systems to protect the ICBM holes. This would require withdrawal, at least in part, from the ABM treaty, a most valuable agreement of indefinite duration. Such an action could start the arms race up again in yet a new dimension — ABM defense.

To forestall such possibilities, and to prevent the SALT process from self-destruction, we ought to maintain existing dialogues on SALT and the Comprehensive Test Ban, and see, in particular, if both sides cannot stay with the existing SALT II limits in a kind of interim approval.

But the real immediate need appears to be a military presence in the Middle East in ways and places that expose America to a minimum of inspired incidents. Without such a presence, deterence of Soviet use of military force in the Mideast will be left only to the Mideastern countries themselves. And it is only too evident that this may not be enough.

Today, as usual, we have no idea what the Soviet leadership is thinking or planning. But as it moves, with Brezhnev's decline, from one "Administration" to another, and with this startling recent reminder of the Soviet readiness to use its forces to absorb other nations, we have got to confront the possibility that more Soviet adventures may occur. □

— Reviewed and Approved by the FAS Council

INCREASES IN KNOWLEDGE AND THE ECONOMY

As NSF's *Science Indicators*, shows, there is good news, but also disquieting signs, in the latest 1978 survey (GPO, $6.00). On the one hand, industrial R & D is back beyond the constant dollar high of 1969 and rising. But why then are corporatioins showing such a decline in patent activity? Starting in 1971 — which really means starting in 1968 or 1969 since patents take a few years to get — patent activity began to fall dramatically in most fields. Unfortunately, a slowdown in patent activity is thought to be a sign of the maturation of an industry.

Perhaps the decline in patent activity is because a greater share of Company R & D funds are going to development rather than to basic research. "D" in Company R & D funding has risen from 66 percent to 74 percent in the total from the early 1960s to 1977. There has also been a decline in constant dollar spending for basic research, and company officials are said to be seeking shorter-term and safer investments.

In the same vein, although *Science Indicators* shows that the U. S. productivity level exceeds all others, we continue to show the least *gains* in productivity of the major OECD states. Is our economy reaching middle age?

On top of these developments, as we all know, something unfortunate happened to our economic system in 1973-74 on our way to the 1980s. Oil ceased to be cheap, and its future price became both high and uncertain. A dramatic example of the impact which this development may have had on our economic system was revealed in December 1979 when Edward Denison released the fifth of his path-breaking series on the sources of economic growth (Accounting for Slower Economic Growth: The U. S. in the 1970s).

It showed that national income per person employed (NIPPE) began a rare and sharp decline in 1974; this measure showed no net gain in nonresidential business for the entire five years from 1973-1978. It has been Denison's custom and method to account for as many sources of growth as he could and then to assign the remaining percentage to "increases in knowledge"

Edward Denison

(and "not elsewhere classified" but he had assumed that the latter factors were minor and off-setting in character). To his consternation and dismay, this residual moved from a positive 1.4 points to a negative 0.8 points producing the absurd result that "contributions to knowledge" were having a retarding effect.

In a chapter devoted to explaining this "unexplained portion of the decline in output per unit of input," Denison considers more than a dozen possibilities, none of which he considers satisfactory.* Of these, the rise in energy prices has the unique advantage, as an explainer, of having occured just when the sharp drop in the residual series began.

Indeed, as *Science Indicators* shows, industrial R & D expenditures related to energy almost doubled from 1973 to 1977 revealing the preoccupation of industry with this problem.

Furthermore, Denison concludes that it "seems certain" that inflation impairs productivity — he simply has no way of measuring how much. It seems likely that the oil price rise redoubled its impact on U. S. productivity via its impact on inflation. Inflation makes it harder for businessmen to make rational calculations about the future — and the higher the rate of inflation, the more variable is the rate and hence the more uncertain the future. There must be expected to be a tendency for businessmen to "hunker down" in the inflationary storm.

Unfortunately, Denison cannot accept the notion that the energy price increase explains the drop in productivity directly. He reviews the number of methods of others, some surprisingly complicated, for determining what might be a reasonable estimate and comes up with the conclusion that the energy price rise explains only a minor part of the loss in productivity.

In summary, Denison observes that the decline in productivity was typical of the economy as a whole, rather than focussed only on part of it and that "inflation, regulation, soaring energy prices, high taxes, and changing attitudes" may have conspired to push all the residual factors downward together. Examination of Canada, Japan, West Germany, Italy, and Great Britain show that all experienced, after 1973, sharp drops both in rates of output per employed civilian and output per hour in manufacturing. They may also have had reversals in the residual formerly called "increased in knowledge" but no one knows.

In short, something serious happened in 1973 as we all knew. As is not uncommon, economists have difficulty determining, close up, exactly what it was. But subtle factors, perhaps just beyond the resolving power of the economist's microscope, are evidently accumulating to cause even more trouble than might be expected. This is a time for caution in handling the economy. □

*The possibilities considered were: Decline in Opportunity for Major Advances; Decline of Yankee Ingenuity and Deterioration of American Technology; Increased Lag in the Application of Knowledge Due to the Aging of Capital; Diversion of Input to Comply with Government Regulation, Except Pollution and Safety; Government-Imposed Paperwork; Regulation and Taxation: Diversion of Executive Attention; Regulation and Taxation: Misallocation of Resources; The Effects of High Tax Rates on Incentives and Efficiency; Capital Gains Provisions of the Revenue Act of 1969; "People Don't Want to Work Any More": The Shift to Services and Other Structural Changes; Possible Errors in the Data.

ARE GOVERNMENT FUNDING PRACTICES STIFLING INNOVATION?

The Catch 22 in any funding system is the inability of those not funded to complain — by definition they are the unchosen and hence their testimony is suspect.

An exception to this situation arises only when unfunded projects lead to such famous results that the error in funding is dramatically and unanswerably exposed. Perhaps the best recent example arose when Richard A. Muller won the coveted Alan T. Waterman Award in 1978 for "highly original and innovative work in diverse areas of physics;" it reflects, in fact, his work on a wide range of unfunded projects. His subsequent testimony of September 11, 1979 before the House subcommittee on Science, Research, and Technology is a brilliant survey of growing funding problems and is excerpted here.

"My difficulties in obtaining funding were outlined in a letter to Dr. Frank Press, a copy of which is attached. In summary, my projects were rejected by the Department of Energy, the Department of Defense, the National Science Foundation, and the National Aeronautics and Space Administration. In the end I was able to proceed with the projects by 'circumventing the system.' I was advised by my mentor Luis Alvarez (who had been awarded the Nobel Prize in Physics in 1968) that I should spend time and money which had been designated for other work, on my projects. If the projects were successful, he advised me, everyone (funding agencies included), would be delighted that I had done so. Alone, I would not have had the confidence to proceed, but Prof. Alvarez believed in my projects so I went ahead. A few individuals who had control over distribution of funds also took a chance, and allowed me to spend small amounts of money on my projects. This money was designated 'seed money' and I was told in several cases that it must remain 'low profile' since it was inconsistent with the 'mission' of the funding agency.

Seed Money

"It is well-known in the research community that one cannot submit a proposal with an expectation that it will be funded until one has already done a considerable amount of work on the project. When I began research in 1965, our research projects were receiving more than the minimum necessary funds to proceed. The excess money was used by our group to seed new ideas. The scientists working on the project were able to obtain sufficient support that they could spend a substantial fraction of their time thinking about new ideas. When these ideas reached fruition (and fewer than one in ten did so) we would write a proposal. If it was accepted, then it would provide seed money for the next idea.

"After a few years had passed, the situation had changed. In 1972 several of our projects were being scrutinized to make sure that no money was 'wasted,' i.e. that no money was spent on projects which had not been approved. We received the bare minimum amount of money to work on our projects.

"The situation became much worse. In 1976 one of our projects received considerably less money than was needed, and we had to obtain additional seed money to support an ongoing experiment. Tight funding, increasing overhead, and additional constraints on how money could be spent made it more and more

Richard A. Muller

difficult to seed new projects. With the help of Luis Alvarez and others, I was able to begin new projects, but never by working through the 'system' that one reads about in the brochures distributed by the funding agencies. Most of my colleagues were not able to do so.

Innovation

"I have originated several projects which have been termed 'innovative' by the award committees and others, and I would like to make a few personal remarks about my experience. As I look back on the periods when I was beginning these projects, I recall them as some of the most difficult and stressful of my life. In a very well known quip, Thomas Edison said that 'innovation is 10% inspiration, and 90% perspiration.' He was greatly simplifying the process, of course, to make a point. Isabella Conti, who studied innovation in architecture, added two stages, 'preparation, and incubation' which must precede 'inspiration and perspiration.'

"The periods that I found the most uncomfortable were the periods of preparation and incubation. These were the periods when I was most unsure of myself; when my response to colleagues' questions about what I was 'up to' was 'I'm not sure.' One of my favorite quotes is from Werner von Braun: 'Basic Research is what I am doing when I don't know what I am doing.' There were times when I hoped I would get a clear answer that the project would not work, just to relieve the anxiety of doubt. And as I mentioned earlier, only one of ten projects survived. 'Preparation' involved a considerable amount of reading, particularly in new areas of physics. Some colleagues felt I was loafing. Another accused me of 'arrogance' for thinking that I could contribute to a field of research in which I had no experience. I suspect that problems of innovation in physics are similar to those in legislation, for I frequently hear congressmen accused of going on 'vacation' any time that they are not involved in debate or voting.

"The periods of preparation and incubation are the most fragile ones in the innovation process, and more attention must be paid to them in the scientific funding process. Without guidance and support from Alvarez and a few others I would have been happy to abandon some of my projects in the earliest stages. (And perhaps I did abandon such a project, unknowingly, when I missed an important European conference this year, rather than try to force my schedule to meet the requirements for federally-funded foreign travel.) The harm done by many of the restrictions placed on research by the present scientific funding agencies may not be obvious, because its interference with research is, on the average, small. Unfortunately these restrictions interfere most with that tiny fraction of research which is most original and innovative. to stop the growth of a tree it is not necessary to chop down the tree; it is sufficient to continuously clip off the top. I believe the various restrictions were created with the very best of motives, to achieve a measurably good effect while causing unmeasurably small harm. Part of the problem I perceive with scientific innovation in this country is the cumulative effect of many small regulations each one of which does 'unmeasurably' small harm."

Muller then describes the advantages to innovation of being able to teach, and the decline in teaching possibilities for younger scientists as universities become saturated with tenured faculty and regulations sometimes even bar those who volunteer to teach! He observes that funding agencies are discouraged from "risk-taking" and should be judged on their accomplishments, not on their efficiency. Examples are given of the degree to which "compartmentalization" works against the researcher. The peer review system tends to give truly innovative ideas — especially those that cross disciplinary boundaries — mixed reviews because the peers do not always understand it.

Muller argues that the U. S. method of funding science "seems to be adopting more and more of the methods used by the Soviet Union in the running of their economy": plethora of rules and regulations; bureaucratic caution in dealing with requests; and the rigidified misuse of well-intentioned cross-checks, rules and regulations designed to prevent abuse. He deplores the paperwork and restrictions on foreign travel in particular.

Muller made the following recommendations:

"(1) Congress mandate the taking of risks by the funding agencies. A record of complete success in projects undertaken may be an indication of an overly conservative approach to the funding of science. Recognize that attempts to achieve "efficiency" in basic research are often counter-productive. Recognize that innovative projects rarely receive uniformly good reviews from the peer-review system.

"(2) Exempt *basic* research from as many rules and regulations as possible. Set as a goal the maximization of discovery and invention, and recognize that this is often incompatible with the minimization of abuse.

"(3) Blur the compartmentalization of the funding agencies and their divisions by allowing a small percentage of the money spent in each division to be spent in areas other than their 'mission.'

"(4) In the funding of science give more emphasis to the past accomplishments of the scientist, and less to the 'polish' of the proposal or to straight A's from the referees.

"(5) Create an annual award to be presented to a contract or grant monitor for having recognized an innovative project in its early stages and having supported it."

ENERGY USE AFTER THE KEMENY COMMISSION REPORT

John T. Edsall

Two commentators on the Kemeny Report; a third will appear in the next issue.

John T. Edsall

Hans A. Bethe

In spite of the accident at Three Mile Island, and all the deficiencies it reveals in the nuclear industry, I am not as opposed to nuclear power as I was a few years ago. I still hold that the overriding need is for a far-reaching program for energy conservation and increased efficiency in energy use, going far beyond anything the government has yet suggested; and for intensive research to develop renewable energy sources. However, even so, I do not see how we can get through the next two decades without some significant increase in the use of coal and nuclear power. We have got to stop wasting oil recklessly; it is far too precious a resource, for innumerable important chemicals as well as for energy. I would personally favor a tax of at least a dollar a gallon on gasoline, and probably gas rationing as well, to cut our oil imports.

In judging Three Mile Island we must remember that the accident killed nobody directly; there will probably be a few added cancer deaths over the next thirty years, but these will be fewer than the number of coal miners who die in accidents each year. When we figure in also the environmental damage from strip mining (irreparable in some places), the widespread damage to human health from air pollution due to coal; the effects of this pollution in producing acid rain, with its destructive action on forests and soils, and on life in lakes where fish die from the acidity; the long term threat of increased carbon dioxide in the atmosphere — we realize the heavy penalties for burning coal. If we could guarantee that no future nuclear power accidents would be worse than Three Mile Island, it would probably be a better bargain to put the emphasis on nuclear power rather than on coal.

Of course there is no such guarantee, and the thought continues to haunt many people of a possible nuclear accident, with thousands of immediate and tens of thousands of delayed deaths, with radioactive contamination that might make considerable areas uninhabitable, perhaps for a few generations. Such nightmare scenarios may be unlikely in the extreme, but the picture of one segment of the nuclear industry that we get from the Kemeny Commission report is not likely to reassure the public. The deficiencies at Three Mile Island were grave; both in the inadequate training of the operators to deal with the emergency, and in the design of the equipment. The Kemeny Commission report itself documents the former point extensively. Obviously, if nuclear power is to survive, the training of operators must be much improved, and the criteria for the selection of personnel may have to be more rigorous. But how can one maintain high morale, alertness, and devotion to the job, for expert operators, when everything runs smoothly 99.9% of the time? Technical experts with the requisite ability and training may get bored because the job is not challenging enough, except in the very rare emergencies when it becomes all too challenging. It is not merely the need for better training; there is the psychological problem of maintaining devotion to the job, in a special corps of dedicated workers. Alvin Weinberg in particular has repeatedly stressed the importance of this factor, if nuclear power is to remain acceptable as an important source of energy. The problem may be soluble, but it is extremely difficult.

The deficiencies in the design and operation of the equipment were also serious; an article in *Science* conveniently summarizes many of them; the constant sounding of alarms on the control panel, with more than 100 going off in the early stages of the accident, and no clear indication which were important; the mounting of some important control indicators where the operators could not see them; the incorrect indicator light for the pillot-operated relief valve (PORV), which led the operators to believe the valve was closed when it was really open; the control room computer, running sometimes 2½ hours behind real time, and jamming for 73 minutes at one point; the design that prevented water that condensed in the generators from flowing into the hot fuel core, because it would have had to run uphill to get there — these, and a substantial number of other deficiencies, are all set down. Surely such defects of design are intolerable in a high technology system. The best possible engineering brains are needed in working out designs for anything as complex, and as potentially dangerous, as a nuclear power plant; but those who designed the Babcock and Wilcox plant seem to have fallen down badly.

Such troubles are not confined to the United States. A recent report notes that three of the six pressurized water reactors, operated by Electricite de France, are now shut down for important repairs. Defects are present in the large metal plates that separate the primary and secondary coolants, and in the tubes that connect the reactor chamber with the steam generator, and which also support the entire 400 ton weight of the reactor itself. These defects might lead to component failure within 4 to 6 years, and are obviously a serious threat to the French nuclear power program.

We have seen that the Nuclear Regulatory Commission was certainly not up to the job it had to do, and it is still too heavily staffed with people whose prime concern is the promotion of nuclear power, rather than its regulation. I would agree with the Kemeny Commission in thinking that prime responsibility should clearly rest with the chairman of the NRC, but I am not yet convinced by the proposal to abolish the NRC and replace it by an executive branch agency. This might help, but without a drastic overhaul it might not change things very much, and there

seems little chance that Congress will approve such a drastic change.

Even though nobody was killed, the economic penalties of the accident are colossal; the total cost will be of the order of two billion dollars, for an accident that could have ben prevented with a little foresight (a similar malfunction of a PORV had occurred before, fortunately without serious consequences; but the engineers who then warned of the hazard involved were disregarded by management). In a fossil fuel power plant, a serious accident might cost many millions to repair, but not billions; the nuclear industry simply cannot afford such mistakes; the loss, both in money and in public confidence, is too great.

We must in effect have a moratorium on licensing of new nuclear power plants, to correct deficiencies of design, improve operator training, and make sure that adequate plans for evacuation are worked out for the region around each site. Existing plants can be shut down selectively and temporarily to correct such deficiencies; obviously they cannot all be shut down at once. In any case, we require unremitting vigilance, from the NRC and from watchdog groups who should work to monitor what goes on.

There have been exaggerated notions of what electricity from nuclear power can do for our total energy needs. It cannot run motor vehicles or planes; electrical heating of buildings is very expensive, and inefficient (though use of heat pumps may improve efficiency). Electricity now supplies some 30% of our energy; this figure may increase, but not by much. The setback in nuclear power development, resulting from Three Mile Island, is likely to be substantial, and I think it will have a healthy effect in improving safety standards and quality of design.

A group of my colleagues at the Harvard Business School, in their excellent study of energy problems and policy, conclude their chapter on nuclear power with the statement: "In any case, nuclear power offers no solution to the problem of America's growing dependence on imported oil for the rest of this century" They believe we must look to the unconventional alternatives: conservation and solar power. Basically I agree with them, though I think that nuclear power has a somewhat larger part to play than they indicate. It should be a significant help in reducing dependence on foreign oil — an urgent matter in our foreign policy — but it would be an illusion to suppose that it would help very much. □

COMMENTS ON NUCLEAR POWER AND ITS SAFETY

Hans Bethe
Cornell University

The report of the President's Panel on the Three Mile Island (TMI) nuclear accident has been published, and I find myself in general agreement with the report. I am happy to see that this forthright report got a favorable reception in Congress, both by long-standing opponents and by supporters of nuclear power. It is to be hoped that constructive reforms recommended by the Kemeny Panel will be implemented.

In commenting on the severity of the accident, the Kemeny report says, "Just how serious was the accident? Based on our investigation of the health effects of the accident, we conclude that in spite of serous damage to the plant, most of the radiation 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 stress." To amplify, recent measurements seem to show that the total population exposure was 50-100 man-rem. According to the conservative formula of the BEIR Committee of the National Academy of Science, published in 1972, this means that there is only a 1% chance that even a single person will get delayed cancer from the TMI accident.

Clearly, the safety of nuclear reactors must be improved. In the following I am making some specific technical suggestions, some of which agree with suggestions by the Kemeny committee.

(1) The control panel of reactors should be improved. This was already pointed out by the American Physical Society Panel on Reactor Safety which report in the *Reviews of Modern Physics 47,* Suppl. 1 (Summer 1975), and made the following as their first recommendation:

> "Human engineering of reactor controls, which might significantly reduce the chance of operator errors, should be improved. We also encourage the automation of more control functions and increased operator training with simulators, especially in accident-simulation mode."

The control panel should have a special part for an accident situation. In most reactors, this part will never be used, but it should nevertheless be there. A lot of information is constantly being measured in the reactor, especially the temperature in the hot leg. This should be fully displayed, while at the Three Mile Island panel the maximum temperature that could be displayed was only slightly above the normal operating temperature. The actual temperature in the reactor rose above 2000°F. Since pressure is also measured constantly, the simplest computer could calculate how far the water in the reactor is from boiling, and this safety margin should be displayed.

Edward Teller has a much more far-reaching proposal which seems to me very much worth considering. He proposes that a computer be associated with each reactor which could digest all available information about the state of the reactor and its parts, and which could then answer questions put to it by the operator, such as "What will happen if I turn valve X to the right?"

(2)Operator training has to be greatly improved. This must be supervised either by the Nuclear Regulatory Commission, or by a central industrial agency, such as described below under 5. The responsibility of reactor operators is similar to that of airline pilots, and their pay and prestige should reflect this so that reactor operation becomes a respected and desirable profession. The most important problem may be to relieve the boredom of the operators; a computer like that proposed by Teller, which can answer operator questions, could serve this purpose and provide on-the-job training for the operators.

(3) Operating procedure for the reactors should be improved. In some respects this was done for Babcock and

Wilcox reactors immediately after the Three Mile Island accident: the reactor now scrams before much pressure builds up, the pressure relief valve now opens at a greater over-pressure than before, and the operators are instructed to watch the pressure rather than the water level in the pressurizer. Moreover, the operators have been instructed not to shut off the emergency core cooling or other safety systems.

(4) Emergency procedures. A great deal of emphasis has been placed on the need for having plans for an emergency, but the most important requirement is to know whether an emergency exists, and to have a clear picture of the status of the reactor. This was obviously not available during the Three Mile accident. In many cases, the operators will not be sufficiently expert to have a completely clear picture. It may therefore be desirable at the NRC in Washington. Over this link, all the information which is measured in the reactor would be directly transmitted, without going through the eyes and the mouth of an operator. This link would only be activated in case of an accident. There must then be a truly expert staff at the NRC which is able to fully interpret the received signals. When reliable information on the status of the accident exists, and only then, should it be given out to the news media.

(5) Most encouraging is the spontaneous reaction of industry to the TMI accident. Clearly industry was shocked by the accident. Even more important, industry suffered large financial losses, estimated by the Kemeny panel in the range of 1 to 2 billion dollars, so industry has the greatest interest in avoiding a repetition of TMI.

The three major pieces of the industry program are: the Nuclear Safety Analysis Center (NSAC), which was created under the Electric Power Research Institute (EPRI) at Stanford shortly after TMI; the new Institute for Nuclear Power Operations (INPO), which is expected to be fully operational by early 1980; and a self-insurance program to help individual electric utilities cover the cost of buying replacement power in the event of a prolonged outage at a nuclear plant.

INPO, among other things, will determine educational and training requirements for nuclear-plant operators and accredit training organizations. In addition, INPO will conduct independent evaluations to assist utilities in meeting the standards it sets.

I would hope that the mutual assistance in case of loss will be conditional on compliance of individual utilities with the standards set by INPO for safety, and for the training of their operators.

I have two further comments on the TMI accident. First, it should be pointed out that the automatic safety devices in the TMI reactor functioned well, e.g., the emergency core cooling system.

Second, TMI did not have a meltdown. One of the efforts of the Nuclear Safety Analysis Center at EPRI is to determine how close TMI actually was to a meltdown. Nobody knows precisely the probability of a meltdown; the Rasmussen report predicted one in about 20,000 reactor years but the margin of error is admittedly large. On the other hand, nearly 1000 reactor years have now been logged by civilian power stations in the U. S. and abroad, and no meltdown has occurred.

It is important for the public to understand that a meltdown by itself does not necessarily mean substantial danger to the public. To quote again the Kemeny report,

> "Our calculations show that even if a meltdown occurred, there is a high probability that the containment building and the hard rock on which the T.M.I.2 containing building is built would have been able to prevent the escape of a large amount of radioactivity. These results derive from very careful calculations, which hold only insofar as our assumptions are valid. We cannot be absolutely certain of these results."

Only if the meltdown is followed by a breach of the containment building will there be substantial release of radioactivity. The Rasmussen report estimates the probability of this as one in 100,000 reactor years. But even in this case, according to the same report, there is likely to be no immediate casualty from radioactivity, and the total number of delayed cancers will be about 1000, in a population of 10 million and over a time of about 30 years. During this same period, about 400,000 members of the same population will die from cancer due to other causes. □

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