FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION
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The Harrisburg Hoax—War on Nuclear Energy

The Mirror Machine

Another Frontrunner For Commercial Fusion

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FUSION

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Features

News

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Editorial

The Lessons of Three Mile Island

The series of incidents that began at the Three Mile Island nuclear plant in Middletown, Pennsylvania March 28 proved two things. First, nuclear power plants cannot harm the people living immediately around them, even when such plants are massively sabotaged or mishandled. Second, the political forces pushing for a national nuclear shutdown are willing to be as ruthless and unscrupulous as necessary to impose their policies on the population.

Based on the evidence presented in this issue and on the larger mass of evidentiary material published by the Fusion Energy Foundation and the *Executive Intelligence Review*, there can be no doubt that the overwhelmingly most probable cause of the incident at the Three Mile Island plant was sabotage. As we have stressed throughout the last two weeks, any investigation of the incident that is not based on the fact that the probability of sabotage lies somewhere in the range of 10 million/1 billion to 1 is totally unscientific.

The likelihood of sabotage is fully backed up by both the timing and the way in which new emergency population control procedures were put into effect by the White House. These procedures completely bypassed all local officials and handled news management to maximize public hysteria. Amazingly, these emergency measures were implemented under the Federal Emergency Management Agency *just one day before* the Three Mile Island event, although the newly created FEMA was not legally scheduled to be implemented until April 1.

Why the big hurry?

An equally urgent question concerns the role of the Nuclear Regulatory Commission. Fully incorporated into the command-and-control chain of the federal emergency procedures, the NRC consistently gave out the most inflammatory and speculative information to the press instead of scientific and professional judgments. When the NRC finally held official hearings, the truth of the likelihood of sabotage and the absence of any hazards to the public came out for the first time.

The final and most conclusive piece of evidence of deliberate sabotage of the Three Mile Island nuclear plant is the brazen enforcement of Secretary of Energy James Schlesinger's energy austerity policies on the United States during the course of the Harrisburg hoax and his threats to do the same to the rest of the world.

War or Peace

The global context in which Three Mile Island occurred is an even bigger fight than the battle over nuclear power—a fight that will determine the shape of human history for at least the next century. The fight is no longer simply between the advocates of development versus the proponents of zero growth; it has now developed to the point where the immediate issue is war or peace.

Why have nuclear politics become synonymous with the question of war or peace? If the present drive to shut down nuclear power in the United States and the rest of the developed sector succeeds and if nuclear power is also prohibited in the developing sector, then there will be widespread areas of instability. These will be the flashpoints for superpower confrontation.

The question of nuclear power has moved to the center of the strategic universe precisely because its use invalidates any arguments about limited resources and the necessity for scarcity or austerity. It is just this policy of brutal austerity that the International Monetary Fund is moving all out to impose, especially through the Carter administration. To take one example: Secretary of State Cyrus Vance told the Northwest Regional Conference on the Emerging International Order in Seattle March 30 that discussions of technology transfer and global development are "endless debates on sterile texts . . . . The developing nations must recognize that making demands which the industrial nations cannot meet will only produce international acrimony, not progress."

The Development Alternative

The European Commission posed an alternative to this austerity and antidevelopment policy in an energy policy made public in early March calling for an investment in energy production of $340 billion over the next decade. Simultaneously, several OPEC nations called for a producers and consumers conference, which is aimed at converting the revenues of resource-producing nations and the technological resources of the advanced sector into full industrial and agricultural development for the entire Third World.

In fact, this technology transfer thrust was the centerpiece of the European Monetary System when it was officially implemented Jan. 1, 1979—to bring the technology-rich developed sector into mutual collaboration for development with both the Third World nations, such as Mexico and India, and with the Comecon sector. Since then, however, West Germany has been threatened by the heavies of the Anglo-American NATO alliance with the charge of "treason" to NATO if the European Monetary System actually begins to provide development funds for the Third World in the form of the European Monetary Fund.

In the United States, there was a coordinated sequence of events building up pressure to counter the Europeans. First, there was President Carter's mid-March energy summit at Camp David that planned the implementation of Schlesinger's oil hoax and nuclear hoax; then, March 30, Secretary of State Vance told the Third World to forget about development; then there was President Carter's nationally televised speech April 5 calling for an oil price hike and cutbacks in consumption. These lunatic calls for austerity dovetailed with the Harrisburg incident, which is now being used to send antinuclear shocktroops against the nuclear plants of America and against the very political rule of Chancellor Schmidt.

Although many U.S. industrial, labor, and scientific circles continue to ignore the fundamental strategic realities now defining international relations and nuclear politics, fortunately there are increasing numbers who have been sufficiently jolted by Three Mile Island to wake up to the basic facts of the situation. That is why a massive containment operation has been thrown up to prevent the coalescing of a principled alliance to expose the Harrisburg sabotage and to make sure that the national government is back in the hands of supporters of the American System by 1980. This containment operation includes various private and published slanders against the FEF, the strongarming of industry, labor, and scientific leaders, and appeals to all concerned to scramble after their narrow self-interest at the expense of everyone else.

A Matter of Survival

To win this fight it's not going to be good enough to argue that the environmentalists lied about Three Mile Island. Their real lie is their denial of the human capability to continuously perfect the ordering of the physical universe and reexpand the resource and technological base of the physical universe for human purposes. The American Republic was based on this concept, and its realization for all humanity was the strategic program of the Founding Fathers. If the nation cannot at this juncture find the moral and intellectual capabilities to win back the nation on behalf of those principles, it will not deserve to survive—and it probably won't.

Calendar

May

6-11
European Nuclear Conference
ANS, European Nuclear Society
Hamburg, West Germany

7-9
7th Euratom Conference
European Atomic Forum
Hamburg, West Germany

14-18
International Symposium on Physics and Chemistry of Fission
IAEA
Julich, West Germany

21-24
6th National Conference on Energy and The Environment
American Institute of Chemical Engineers
Pittsburgh

22-25
Conference on Plasma Science
Montreal

May 30-June 1
Conference on Laser Engineering and Applications
IEEE, Optical Society of America
Washington, D.C.

June

3-8
ANS Annual Meeting
ANS
Atlanta, Georgia

16-20
Annual Conference on Nuclear and Space Radiation
IEEE, NPS Radiation
Santa Cruz, Calif.

27-29
The Industrialization of Africa
Fusion Energy Foundation
Paris

The Lightning Rod

My dear friends,

Since I was unavoidably called away from Washington some years ago, there have been quite a few attempts to improve on the work Hamilton, Madison, and others of my colleagues did by way of setting up these United States as a going concern.

That is as it should be. Did we not write, "We the people of the United States, in order to form a *more perfect* union . . ."?

Lately, though, it seems like some peculiar fellows have given up the whole idea of *improvements*, and have set about making the Constitution and the laws over until they resemble the notes on scraps of paper you leave around the house to remind you to take care of those important things you are probably better off forgetting all about.

Take this fellow Milton Friedman, for example. He says that if the Constitution is amended to let him help the President and Congress to keep the Federal accounts straight and the printing presses at the Treasury Department from overheating, the rest of the country will take care of itself.

He reminds me of the bookkeeper my friend Carroll hired when his silver shop ran into some difficulty. Every night the bookkeeper stayed late doing the accounts while Carroll went home. At the end of the year, Carroll had the neatest set of books I ever saw, but the whole inventory had passed out of the shop in the bookkeeper's coat pocket.

One amendment isn't enough for some people. There's a slick-talking United States Senator from John Adams's home town who's got a team of Harvard professors at work on a project to fix up the Constitution from top to bottom. In the meantime, he wants the Congress to break up the telephone company, the transportation system, and Lord knows what else. He doesn't think the USA should make a profit.

A banker fellow who spent some time with this Administration not too long ago had a saying I liked: "If it works," he said, "don't fix it."

(I understand they are going to indict him pretty soon.)

To get back to my first point: When we got this country started, we put right into the Constitution that the government's purpose was "to protect the general welfare." And to do that, we created a national bank, a national system of trade, and a national policy for industrial development. The question is today, just whose welfare do these slick Constitution-fixers want to protect?

Yr. obt. svt.

Letters

To the Editor:

...One question in particular interests me: What rate of growth of energy consumption do you regard as desirable, and for what length of time would it be desirable? A woman representing you at LaGuardia Airport in New York City indicated that it would be desirable to use 15 times as much energy each year as the preceding year—for an indefinite period of time. Did she accurately represent the views of the foundation?

Paul A. Smith
Associate Prof. of Physics
Coe College, Cedar Rapids, Iowa

The Editor Replies:

Since its inception, the Fusion Energy Foundation has been involved in the development of an investment and development strategy for world progress based on advanced capital-intensive and energy-intensive technologies. Our initial studies, which were largely qualitative, demonstrated the necessity and possibility of growth rates of 15 to 20 percent per year. Although this figure now may seem astronomical to observers in the West, Japan and the Soviet Union are proceeding with plans for such rates of growth. In a coming issue of *Fusion*, the FEF will present the first results from a computer model of global development. Using mathematical techniques from Riemannian physics, this model is the first economic-energy model to systematically account for the discontinuous (singular) points in economic development that characterize technological progress.

To the Editor:

I am a biology major in botany at Wayne State University....This letter is a response to the editorial "Time for Declassification" in *Fusion*, Jan. 1979....

As for the use of Galileo and the inquisitions in the editorial I feel this

parallel is unjust. We do need "open door science," but I feel you are comparing apples with oranges. Galileo was expounding upon the Copernican Theory of our solar system. He received a great deal of pressure by the Church. Now what Copernicus and Galileo were trying to understand and acknowledge was an already naturally occurring condition of the solar system, not a development or creation of human beings.

Cynthia Ann White
Ferndale, Michigan

The Editor Replies:

In a forthcoming issue of *Fusion*, Dr. Richard Pollak demonstrates dramatically in an article on "Higher Order Geometries in DNA" that there is no essential distinction between a "naturally occurring condition of the solar system" and a "development or creation of human beings." They are both manifestations of an underlying process of ongoing creation and development in the universe.

To the Editor:

I am discontinuing my membership after subscribing for one year. The magazine was truly fascinating. However, I feel your foundation has certain fanatical tendencies....By failing to truly acknowledge the formidable task ahead in fusion you become utopian. By failing to acknowledge the value of conservation you do yourselves a disservice....

Please change.

Garr Cutler
Eugene, Oregon

The Editor Replies:

As we have emphasized many times, conservation is a red herring. Even as described by its most confident proponents, conservation cannot supply the tremendous energy required for world development. If the question of a human living standard for all 5 billion people on the earth is not the starting point for policy discussion, then we are not talking about the real problem.

Schlesinger: Lying?

News Briefs

SCHLESINGER: NUCLEAR CARTELS, NO BREEDER

In a speech April 11 at an Atlanta conference sponsored by the Edison Electric Institute, Energy Secretary James Schlesinger told the assembled utility executives that nuclear power was a necessity "if we are to maintain our standard of living," but that the fast breeder "won't be built nor will nuclear reprocessing be developed. These are not cost-effective until the price of uranium rises considerably," he said.

Calling Three Mile Island a "warning," Schlesinger said that there had to be structural changes in the nuclear utility industry and that the "weak" utilities should "not get pressured into unnecessarily investing in nuclear capacity."

Although the audience cheered what one utility chief termed Schlesinger's "conversion," the first question from the audience was "Mr. Secretary, didn't you once write that 'politics is the art of lying'?"

FEF FORMS COMMISSION TO INVESTIGATE THREE-MILE ISLAND

The Fusion Energy Foundation is in the process of forming a commission of inquiry composed of leading science, industry, and labor representatives to ensure that "the true facts and circumstances of the series of events surrounding the shutdown of the Three Mile Island nuclear reactor are made available to the American people as quickly as possible," announced FEF executive director Dr. Morris Levitt.

The radio stations that aired the FEF included WRNG in Atlanta; WCAS in Cambridge, Mass.; WDRQ and WXYZ in Detroit; the statewide Illinois News Network; KMAX in Los Angeles; WFEA in Manchester, N.H.; WBEM in New Bedford, Mass.; WPUT in Putnam County, N.Y.; WANT in Richmond, Va.; WPEP in Taunton, Mass.; KSXX in Salt Lake City, Utah; and WOL and WOOK in Washington, D.C. Among the Pennsylvania cities whose major newspapers reported the sabotage charge were Allentown, Harrisburg, Philadelphia, Scranton, Wilkes-Barre, and York.

"Such an investigation has become even more urgent for the well-being and security of the nation," the statement says, "since President Carter's April 5 call for energy austerity . . . . In the wake of distorted press reporting and questionable government practices, the future of nuclear power in the United States—indeed, the role of science and technology in general—has been called into question."

For more information on the commission, contact the FEF New York office.

U.S. PRESS BREAKS HARRISBURG SABOTAGE STORY

Although most national press and media have ignored reports and evidence that there was sabotage at the Three Mile Island nuclear plant, several regional newspapers and radio stations, especially in Pennsylvania, have reported on the FEF charges that the Harrisburg nuclear scare was a hoax.

In New York City, the Spanish-language weekly *Impacto* ran banner front-page headlines announcing "The Nuclear Plant Case Was Sabotage," and an accompanying article reports fully on the special briefing given by the FEF April 6. "The objective of the sabotage was to impose the energy policy of Mr. Schlesinger, who is totally opposed to the development of atomic energy sources, since he is also against the advance of technology," *Impacto* wrote.

FEF staff members were also quoted on the sabotage issue in the April 24 *National Enquirer*, which ran a centerfold article documenting that the nuclear scare at Harrisburg was not based on fact.

SOVIET SCIENTIST HITS HARRISBURG PRESS SCARE

Writing in the Soviet government daily *Izvestia*, the president of the Soviet Academy of Sciences said that: "Coverage by the Western press of the accident

at the nuclear reactor in Harrisburg, in which some basically minor unpleasant consequences were described in an extremely exaggerated manner, was an extension of the campaign against nuclear power."

In reference to the near-term energy crisis, A.P. Aleksandrov noted: "a reasonable energy policy and the utilization of the achievements of science give humanity the possibility of avoiding this crisis. Nuclear energy and coal principally provide the possibility of building energy on a new basis . . . . Within 10 years the first experimental thermonuclear fusion power stations will make their appearance."

Aleksandrov, a nuclear physicist, also noted that some Western countries have threatened to use military force to obtain scarce oil supplies—a reference to Energy Secretary Schlesinger's threats to seize Mideast oil fields.

The Antiscience Mob

HARRISBURG HOAX REVIVES ANTINUCLEAR BACKLASH

The press scare over the Three Mile Island incident signaled a revival of the ragtag antinuclear groups and the antinuclear terrorists, both here and in Europe. In addition to various small demonstrations, two nuclear reactors under construction for Iraq in southern France were destroyed by bomb blasts April 6, and a Swedish power plant was closed down because of a fire.

On the legislative front, Senator George McGovern announced at an April 3 press conference that he will introduce legislation calling for a halt to all nuclear construction until an "independent" safety panel has reported to Congress on the safety of nuclear power. McGovern's press conference included a briefing by representatives of the antinuclear Union of Concerned Scientists, one of whom called nuclear power "the technological Vietnam."

New York Congressman Hamilton Fish also reintroduced a bill into Congress calling for a five-year moratorium on all nuclear plants "until the safety issue has been settled."

LOPEZ PORTILLO TO PROPOSE UN GLOBAL ENERGY PLAN

Mexican President Jose Lopez Portillo announced April 8 that he will put before the United Nations the urgent task of establishing a just system of development and distribution of world energy resources based on his conception of energy as "the patrimony of humanity."

In his greeting to visiting Bulgarian President Zhivkov, Lopez Portillo termed his proposal "a matter which must be urgently considered within the new order as a world reponsibility."

LOUSEWORT LAURELS TO PRINCETON'S BERNARD LEWIS

The lousewort laurels award this month goes to Princeton University professor Bernard Lewis. A specialist in Islamic studies, Lewis is known internationally for his "Bernard Lewis" plan to redraw the map of the Middle East into a collection of ethnic ministates and tribal preserves. He is also one of a group of Mideast specialists who blamed the destabilization in Iran on the Shah's policy of too much progress too fast.

We make the award, however, specifically for Lewis's views on energy, as stated in an April 2 interview. We quote:

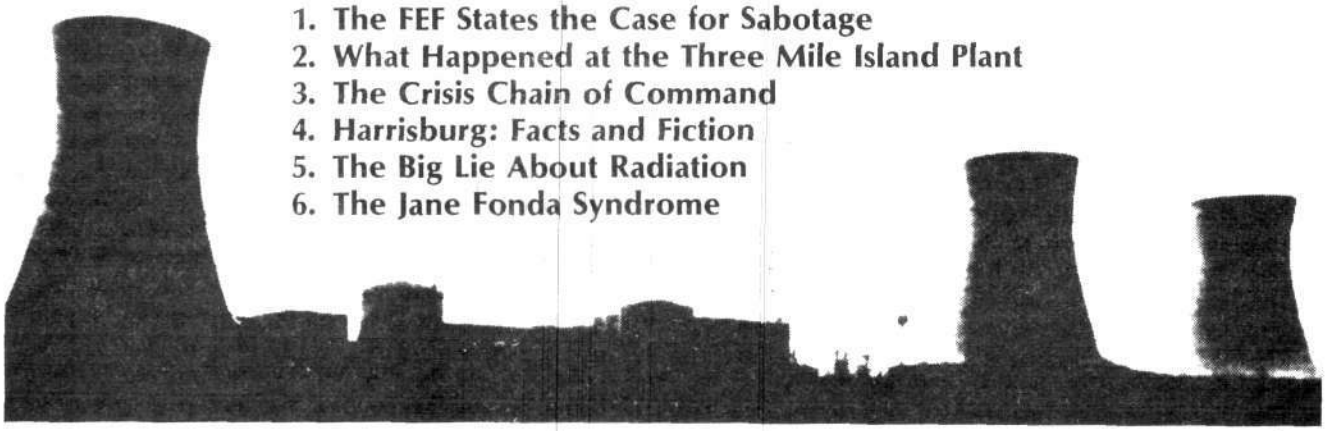
"Solar and wave energy are preferable forms because they are decentralized. With these forms of energy, each state, each locality will do what it wants . . . . This would be a great benefit.

"Nuclear energy should be phased out because it centralizes government and business control. Nuclear energy means the immense strength of a central power, which we must get away from."

Lewis's alternative? Vegetable alcohol. "Under such an energy usage scheme, Kentucky moonshiners can teach the American people how to make energy without, I might add, any technological innovation," Lewis said.

The Harrisburg Hoax

All-Out War on Nuclear Energy



1 The FEF States the Case for Sabotage

The incident at Three Mile Island nuclear plant in Middletown, Pennsylvania began March 28 and unfolded like the H.G. Wells story "War of the Worlds" broadcast by CBS radio in Oct. 1938. As in that bit of masterful psychological warfare that presented a fictional invasion from Mars as "news," there never was any real danger from the incident itself. The danger came from the panic created by those presenting the "news" of the event.

As shown in this special report, the Three Mile Island event was managed by the Federal Emergency Management Agency, a newly created federal agency working closely with the White House and the National Security Council that went into effect March 27—one day before the event and five days before its legally mandated implementation date; Pennsylvania Governor Richard Thornburgh, who was in direct touch with the White House and FEMA and who ordered the evacuation of pregnant women and young children; the Nuclear Regulatory Commission, which issued unscientific and inflammatory reports on the situation that were counter to the actual facts; and the national press and media, which operated like the Goebbels propaganda machine in Nazi Germany, convincing the population of things that were not true.

Soon after the story broke, a Fusion Energy Foundation investigatory team began to ascertain the actual facts of the matter, calling the utilities involved, local, state, and federal officials, and nuclear experts across the nation. As the press reports became more hysterical and the layers of contradictory "official" reports continued to grow, the FEF sent staff member Jon Gilbertson, one of the top nuclear safety engineers in the country, to the Harrisburg area to get the story first hand.

Sabotage

As reported in detail below, the scientific and technical facts of the Three Mile Island nuclear plant incident as determined by the investigation gave the FEF reason to believe that sabotage and not "human error" was the cause of the accident. The FEF team assembled the evidence, piecing together the story of what actually happened from a variety of sources, each of whom had bits and pieces of the event but no overview.

In brief, the FEF thesis was that the chain of events at Three Mile Island could not have occurred without the complicity of some form of sabotage at the scene. Furthermore, the timing of the event was not accidental but fed in directly to an intensification of the Carter administration's policy of imposing stringent energy austerity and a systematic shutdown of the economy in the United States, coordinated with vigorous moves to do the same in the developing sector.

Once the scenario was established, the FEF began to get the real story out. From the New York FEF office, staff members briefed the utilities, government officials, the scientific community, and the public, including a dozen radio interviews. Jon Gilbertson, FEF director of nuclear engineering, held a well-attended press conference in the Pennsylvania state capitol building April 4, and Dr. Morris Levitt, FEF executive director,

briefed members of the press and diplomatic community at a press conference in Washington, D.C. the same day.

By Friday, April 6, the FEF had put together a Three Mile Island dossier and invited press and industry and government representatives to a special three-hour briefing, cosponsored with the *Executive Intelligence Review*. At the briefing, Jon Gilbertson, FEF director of research Uwe Parpart, and *Executive Intelligence Review* counterintelligence specialist Jeffrey Steinberg reported on the evidence and the political context for the incident, and suggested the proper lines of an investigation.

As Morris Levitt put it, a proper investigation would have to use the method of Edgar Allan Poe. This means that the investigators should "not look under beds and sewer covers, but differentiate among those facts that are out in the open that are meant to take you on a wild goose chase as opposed to those facts that are out in the open that can be put together coherently to explain both the specific event as well as the context in which it occurs." Specifically, Steinberg later told the audience, they should look for who was to gain from the Harrisburg incident and who had the capability to pull it off.

To date, aside from the Swedish and Mexican press, the major international press has blacked out the sabotage story.

In This Special Report

Summaries of the special briefing presentations by Jon Gilbertson and Jeffrey Steinberg are presented here, along with a day-by-day grid of what happened, what the press wrote, what the NRC said, and what the press said the NRC said. In addition, the special report summarizes the facts of the major myths: the bubble, the "meltdown," and the radiation scare. It also includes some excerpts from the press and presents a review of "The China Syndrome," the newly released Columbia Pictures film about a nuclear accident that resembles the press coverage in the Three Mile Island event.

(Transcripts of the special briefing are available from the FEF at $50 each, $20 for FEF members.)

2 What Happened at the Three Mile Island Plant

What happened within the first few minutes to approximately two hours after the initiation of the accident March 28 at 4 AM was an incredible chain of events that could not have occurred without deliberate acts of sabotage by one or more persons inside the reactor plant.

The event was initiated by a failure of the main secondary steam generator system flow valve that apparently shut off because of a still unknown "malfunction." This failure then caused the shutdown of two feedwater pumps, because they could no longer draw suction from this flow stream. The turbine tripped out (shut down) almost immediately, and the steam flow was bypassed directly to the condenser.

At this point, there should have been no further problems and normal shutdown of the plant should have followed immediately as standard procedure.

After the main valve malfunction occurred, what should have happened is the automatic start-up of three auxiliary feedwater pumps that would have supplied more than ample cooling for the steam generators during a shutdown condition.

This procedure is entirely normal recovery following such a valve malfunction. The problem that now occurred was that the auxiliary feedwater pumps came on line but couldn't draw water because two parallel valves were closed. These valves would have provided water supply to the three auxiliary pumps, which then would have provided make-up (emergency) water to the steam generator systems.

With no make-up water supply now available to the secondary steam generator system, the nuclear reactor core and the primary coolant system were isolated from their heat sink, with no normal or back-up method for dumping heat. At this point, the primary coolant system began slowly to heat up and the primary system pressure rose. The reactor now tripped out and the nuclear fission process was brought to a stop. All this took place within the first 10 to 15 seconds into the "accident."

Before describing what happened after this, it is important to discuss the improbability of even getting the so-called accident to this stage of events. Furthermore, I shall describe what we already know to have happened and what most probably did happen.

The mathematical probability of the mechanical failure of the main flow valve and feedwater pump systems (failure 1 in the figure) is about *1 in 100*, which means that it is an event that can be expected to occur from time to time if enough reactor years of operation are accumulated. However, the mathematical probability of mechanical failure of the *auxiliary* feedwater flow systems valves and pumps (failure 2) is on the order of *1 in 10,000*, which is two orders of magnitude higher than the first failure. The probability of these two failures happening in series is conservatively estimated to be the sum of these two probabilities, or less than *1 in 1,000,000*—an astoundingly low number, which essentially rules out mechanical failure as a cause of the incident.

In fact, what this means is that the probability of human blunders, or, more likely, human sabotage, is nearly 1 million to 1—the inverse of the low probability of mechanical failure.

We have found out some very interesting facts that back up these probability calculations. The Nuclear Regulatory Commission released information April 4 in a commission hearing that stated the following. First of all, the NRC investigation indicated that both auxiliary feedwater valves had been shut off manually and were out of operation during and preceding the time of the accident. This meant that there was no way that the

make-up water flow system to the steam generators could have been put into operation.

It is totally against NRC regulations to operate a reactor under such conditions; furthermore, it is impossible to believe that reactor operators on duty would ever violate such regulations, unless in a deliberate act of sabotage. The NRC went on to say that these valves had in fact been turned off for over two weeks prior to the accident, which makes the violation even more incredible. How would three different shifts of operators allow such a condition to continue? No one in his right mind would allow the plant to operate with no back-up cooling system available.

The NRC also found out in their investigation that a maintenance crew was working on the main flow valve and pumps during the two-hour period preceding the accident. This is the likely scenario used to manually cause the first failure—and the second failure. The focus of any further investigation obviously has to have sabotage of these two systems as its working hypothesis or it is no investigation at all, just a coverup.

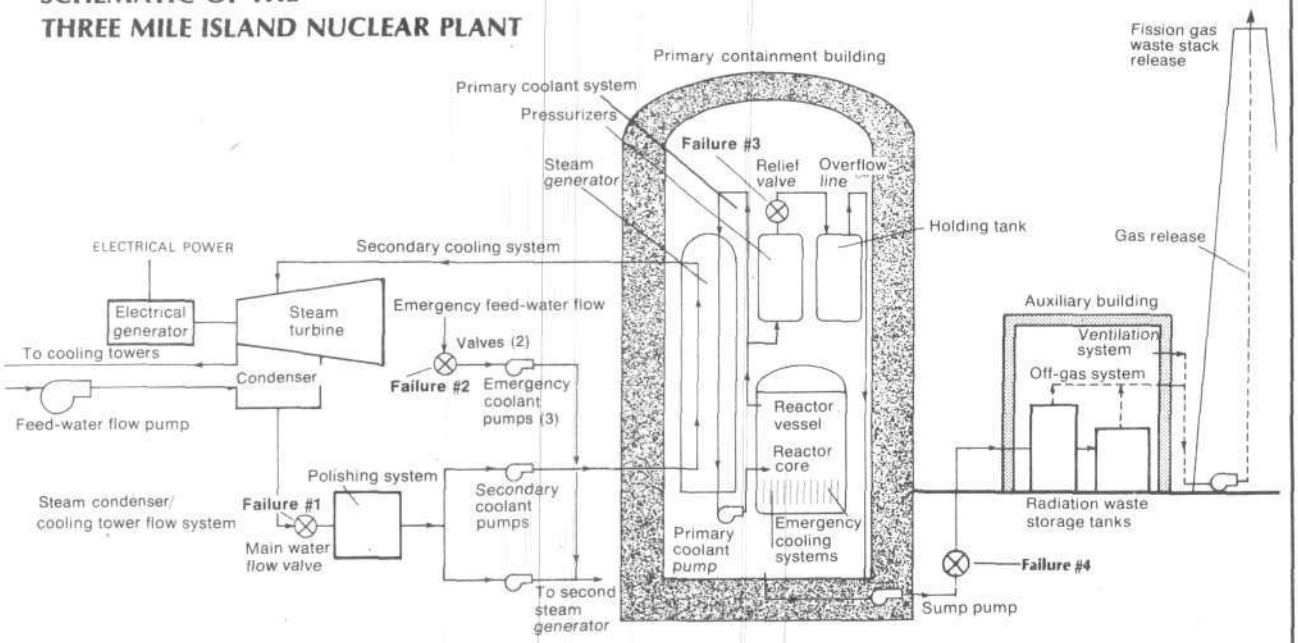
Now, getting back to the chain of events following these incidents of sabotage, we find that after the first one or two minutes into the accident the pressure relief valve on the primary system pressurizer tank opened because the pressure had risen to a pre-set limit. Given the conditions that now existed at the plant, this would have been the back-up method for cooling the reactor core and primary system temporarily until one of the secondary steam generator flow systems was put back into operation.

What should have happened was for this valve to open and close periodically over the next minutes or hours as the pressure built back up to the release limit of 2,350 psi. Releasing this steam pressure and providing make-up water to the primary system through a make-up water pump would have been the way to keep the shutdown reactor core cool during this period.

What actually happened at this point, was an incredible chain of events, again with an extremely low probability of mechanical failure. First of all, the pressure relief valve stuck open and would not close automatically (failure 3), therefore allowing the primary coolant system to continue to blow down into a holding tank. There is a manually initiated back-up to this valve that is activated in the control room by the operator; but this manual back-up either was not activated for a long time period or failed to work, we don't know which. The continual blowing down of this steam started to reduce the primary system pressure, which eventually started to lower the water level in the reactor vessel and core.

At a system pressure of 1,600 psi, the emergency core cooling system (ECCS) automatically detected this condition, as it was designed to do,

SCHEMATIC OF THE THREE MILE ISLAND NUCLEAR PLANT



Odds Are 1 Million to 1 That It Was Sabotage

The mathematical probability of the mechanical failure of the main flow valve and feedwater pump system, failure 1, is about 1 in 100. The mathematical probability of mechanical failure of the auxiliary feedwater flow systems valves and pumps, failure 2, is about 1 in 10,000. But the probability of these two failures happening in a series is—conservatively—less than 1 in 1,000,000.

and the high pressure injection pumps came on and started pumping large quantities of water into the core to correct the situation. It did correct the situation and would have continued to do so for a long time period—several hours—however, *the operator turned it off*!

Also, sometime during the first hour after the accident, the operator turned off the primary system coolant pumps because the pump head was getting low. The sequence of events after this is not well known, except that we know the operator turned the ECCS system as well as the primary coolant pumps on and off again at least one more time. During this manual manipulation of the primary system flow, the top of the reactor core became uncovered two different times. At these points, significant fuel damage occurred and fission product gases, xenon and krypton, were released to the primary coolant system.

At sometime during this first one to two hours, the operators got these flows under control and got one of the two steam generator coolant loops operating, with heat being dumped normally through the cooling towers. Also during this period, the operators were able to get the pressure relief valve on the pressurizer closed so that it was no longer dumping primary coolant water and steam—which became radioactive after the fuel failures—to the holding tank. This tank later overflowed and spilled onto the containment building floor.

What has to be emphasized is that even with all this happening, the effect would have been minimal if the event had stayed at this level. However, sometime during the first hour, the sump pump at the bottom of the containment building came on —supposedly automatically, but we're not sure—and started pumping radioactive water from the floor of the containment building out into radiation waste storage tanks in the auxiliary building. In actuality, this containment building should have automatically been isolated when radiation was detected there, thus prohibiting the sump pump from coming on. Nevertheless, this is how some radioactivity got out of the containment building, and why some *very small amounts* of radioactivity had to be released through the normal gas release stack several times during the second day after the accident and in subsequent days.

3 The Crisis Chain of Command

President Carter issued an Executive Order June 19, 1978 establishing the Federal Emergency Management Agency and an Executive Management Committee under the control of the National Security Council. That order set April 1, 1979 as the date FEMA was to become operational.

The new FEMA was to centralize all "crisis management" functions around civil defense, nuclear disaster, transport strike disruptions, and similar national emergencies under the direct control of the National Security Council, thus completely bypassing all institutions constitutionally designated to handle national emergencies.

The Executive Order creating FEMA was the result of Presidential Memorandum 32 drafted in April 1978 by Samuel Huntington. PMR-32 outlined a specific scenario for crisis management reorganization of the U.S. government—a scenario that was tested during the Three Mile Island incident.

About three years before he drafted that memorandum, Samuel Huntington had authored a book called *The Crisis of Democracy*, a position paper for the Trilateral Commission. Huntington drew the conclusion, in part, that democratic institutions were no longer feasible. The sort of government structure defined by the U.S. Constitution, he said, had too many checks and balances. During the period of crisis he projected for the 1970s and 1980s—specifically including oil crises, energy shortages, and the necessity to impose extreme forms of as austerity—the country would need hegemonic, controlling government institutions, rather than the normal, constitutionally mandated institutions, Huntington said.

Although the levels of radiation through release of xenon and krypton were very low and well within normal limits (see box p. 61), the press turned this into a "radioactive cloud" that gave rise to one of the biggest media hoaxes of the decade.

—Jon Gilbertson

President Carter at Three Mile Island, accompanied by Governor Dick Thornburgh

FEMA on the Scene

Not only was FEMA set to go weeks before the nuclear incident at Three Mile Island, but, according to well-informed sources, the National Security Council "jumped the gun" and set FEMA into operation Tuesday, March 27—one day before the incident. Under the direction of the NSC and a White House Emergency Task Force,

FEMA personnel coordinated the emergency evacuation panic scenario, while the National Security Council's Jack Watson and Nuclear Regulatory Commission personnel managed the content and flow of news.

This news from the top was key to the creation of a climate of panic—making people feel helpless and feel as though there were no rigorous scientific principles to adequately evaluate the crisis situation.

Executive Intelligence Review correspondent Stuart Pettingell described the on-the-scene situation in Harrisburg this way at the FEF special briefing April 6: "We expected to come down into the Harrisburg area and find a ghost town, deserted streets. What we found in Middletown was business as usual, with reporters wandering around trying to find some news.

"There was no competent briefing to the press after Metropolitan Edison [part owner of the plant] was officially gagged by the White House, on the request of Governor Thornburgh. There were no written technical statements out and no technical advisors were allowed to get near the reporters to explain what was going on. So, the reports coming out of Middletown—H-Blasts, gigantic bubbles, and so forth—were based on small shreds of evidence given to the reporters in small doses that these reporters then had to elaborate into 500-word and 1,000-word articles.

"Until April 1, there was not one technical advisor on the scene who was capable of explaining how a nuclear power plant works to the press, which was generally not clear on this. In terms of where the initial incident occurred, for example, everybody assumed it was in the core of the reactor. No one understood how the entire system worked. When the technical advisors finally came in they had to spend virtually the whole night answering reporters' questions to try to clear up the complete unreality about what people thought had gone on.

"To a certain extent, the press is to blame for the sensational coverage for something that was not sensational, but the honest reporters did not have a chance to find out the true story."

4 Harrisburg: Facts and Fiction

Day 1, March 28

The reactor core was brought into stable condition within the first two to three hours, the relief valve was closed, and a main coolant loop and main secondary steam generator coolant loop were put into operation. At this point, core cooling was reestablished and has remained in this condition since then. The top region of the reactor fuel had been damaged and fission gas was released to the primary coolant. Most of the fission gas remained safely within the containment building—except for a small amount that was pumped to the auxiliary building. Therefore, most radioactivity was safely contained inside the containment building, where it should be.

There was no danger of a core meltdown during these first minutes and hours of the incident, because all emergency core cooling systems worked as they were designed. Furthermore, no radioactivity was released to the atmosphere during this first day of the incident, although radioactivity within the containment building was quite high, making building access impossible.

The Press: Early New York radio reports (WINS, WCBS) called it "the worst accident in the history of commercial power."

The NRC: At 10:30 AM, the NRC declared the site an emergency situation and said the turbine had tripped out, cause unknown. There was no off-site radioactivity, but radioactivity was noted inside the containment building. At 5 PM, the NRC reported that they thought there was direct radiation from the containment building and that the turbine shutdown was a result of reduction in flow of feedwater.

Day 2, March 29

During the night of March 28, a small amount of fission gas was released to the atmosphere from the auxiliary building through the gas storage system and out the plant waste gas stack. This gas release was necessary because the water that had been spilled on the auxiliary building floor was releasing some fission gas to the building atmosphere that was vented to gas storage tanks. The build-up of this gas in the tanks eventually got so large that some had to be vented in order to make room for more gas in the tank. The levels released were very low and well within normal release limits. Maximum measured release rates were 1 millirem per hour, determined by a helicopter.

The reactor remained stable and cool at 250 degrees Fahrenheit and pressure of 450 psi.

The Press: "Radiation Is Released in Accident at Nuclear Plant in Pa." (*New York Times*); "Radioactive Gases Escape from Pa. Plant" (*Baltimore Sun*); "Radioactive Steam Clouds Escaping . . ." (*New York Post*). There were stories that radioactive iodine would show up in dairy cows within a week (the allegation showed up in the press April 7).

The NRC: Official release states that "radiation levels in containment building remain high. Continuing release of detectable levels to atmosphere." For the first time, the auxiliary building was mentioned as the source of gas, not the containment building. They said there were 12 millirems of radioactivity per hour at 2 miles from the plant, .33 millirems over the Harrisburg area; these are said to be far below the EPA allowable level of 1,000 millirems per hour.

Day 3, March 30

Metropolitan Edison technicians released gas from the auxiliary building two more times for periods of 45 to 60 minutes during this 24-hour period. Maximum levels of radioactivity reached 20 to 25 millirems near the site boundaries, with much lower levels at distances farther away from the plant. All releases were of short duration and resulted in dose rates far below those considered to be hazardous to the public. Some very low level waste water was released to the Susquehanna River, but was stopped in order to avoid causing any public concern. The radioactivity of this water was well within the limits allowed by NRC regulation.

Gas bubbles were detected in the primary coolant system and were carefully monitored as they collected in the top of the reactor vessel. These bubbles are made up of noncondensable fission gases as well as hydrogen and normally are taken out through the free surface in the pressurizer. This technique was used, but it seemed to be going slowly, mainly because a considerable quantity of gas had been formed during the core and fuel heatup portion of the incident in the first two hours. No problems were occurring and none was expected.

The reactor remained in a stable condition at 280 degrees Fahrenheit and about 1,000 psi.

The Press: "Nuke Leak Goes Out of Control" (*New York Post*) leads with "An uncontrolled release of radiation spewed from the Three Mile Island plant today, triggering some panic in the streets here, where people alerted by Civil Defense whistles, ran for cover." It was reported that Governor Thornburgh said, "These emissions were unexpected and they could not stop it" and that he ordered all schools within a 5-mile radius to close. *New York Times* reports that the NRC said that detectable radiation levels had been spread over four counties.

The NRC: (AM) "At this time the danger is over for people off the site. . . . Our readings show radiation levels have dropped significantly . . . ."

Metropolitan Edison: Officials said that a core meltdown was impossible and that there are no China syndromes possible.

Governor Thornburgh: A spokesman for the governor's office, Patricia McCormack, said that radiation measured 1,200 millirems per hour. "These emission levels are more dangerous than those released Wednesday."

The NRC: (PM) The NRC's Harold Denton, director of reactor regulation, arrived at the site and announced that he and his team would be working closely with utility personnel as well as federal and state agencies and the governor. The gas bubble was reported for the first time. If pressure were decreased, the bubble might expand and might interrupt the primary coolant flow. "In the unlikely event that this may occur, further damage to the fuel rods could take place," the NRC said.

Day 4, March 31

The suspected gas bubble at the top of the reactor vessel was determined to be about 1,000 cubic feet in size and was thought to be growing very slowly. However, the gas level was far above the reactor core and above the

outlet nozzles in the vessel. There was no chance that this bubble could expand down into the core region, since the upward coolant flow velocity would simply sweep any gas out the outlet flow nozzles and break it up into small bubbles that would eventually come out at the pressurizer surface.

In fact, this is what apparently happened to the gas this day and into the next, although this is not completely known. There was no chance of a core meltdown. All emergency core cooling systems were still operable if needed.

The threat of a hydrogen explosion never existed within the reactor vessel, because there was no mechanism in existence that could provide enough oxygen into the bubble to produce the conditions for an explosion. Even if such an explosion could occur (which it could not), there was only enough hydrogen present to produce an impact on the vessel wall equivalent to a medium-sized blow of a hand-swung sledgehammer.

An additional release of fission gas was necessary from the auxiliary building via the waste gas stack. This was much lower than releases from the previous day; it was at a level of about 1.5 millirems per hour, again far below harmful levels and of no danger to the public. All gas releases were planned and timed to be very low; however, the original source of primary water release to the auxiliary building was, of course, unplanned.

The Press: "Nuclear Crisis: Pregnant Women, Kids Flee N-Zone, Thousands Told to Stay in Their Homes, Fear Meltdown of Nuclear Core" (*New York Daily News*); "Race With Nuclear Disaster, Baffled Scientists Struggle to Ward Off A-Plant Meltdown" (*New York Post*). Most of the news is about the bubble and the possibilty of a China Syndrome meltdown.

The Press on the NRC: "Depending on which options are taken and what changes are made, we can get the nuclear core into trouble" (*New York Post* quoting NRC spokesman Dudley).

Day 5, April 1

The gas bubble had all but disappeared by now, although it was not known exactly how this happened so quickly. First of all, the bubble's size was probably not as large as originally estimated. Furthermore, its removal by the primary coolant flow system through the pressurizer was actually much quicker and more efficient than originally estimated. There was no threat of a hydrogen explosion, nor was there ever such a threat according to more detailed calculations and analysis.

Releases of radioactivity were now very low and were measured to be not much higher than background radiation. Total dosages that could possibly have been received by any one individual off-site since the beginning of the incident could have been only 85 millirems, or not much more than a person receives in a normal chest X ray!

The reactor remained stable and cooling at 280 degrees Fahrenheit and a pressure of 1,000 psi. Radiation in the reactor building remained quite high, which is expected given the failures that occurred during the first two hours of the incident.

The Press: "Officials Say Nuclear Plant Cooler But Still in Crisis," "Wider Evacuation Possible If Action Poses Threat" (*New York Times*); "Risk of Explosion at A-Plant Reported Increasing," "Top Priority Is to Collapse Gas Bubble Safely" (*Washington Post*).

The NRC: "When technicians decide to eliminate the bubble, it might be prudent to evacuate residents living 10 to 20 miles from the site" (Joseph Hendrie). As for the meltdown possibility: "I wouldn't give odds. I don't think they've changed much these last few days."

Day 6, April 2

All gas in the vessel and primary coolant system was now gone, and the system was now in a mode where it could begin to be brought down to the cold shutdown condition. The NRC decided to hold the reactor in this condition for a few days to reassess the situation and to determine the best way to bring it to cold shutdown.

Radioactive fission gas releases to the atmosphere have all but stopped and the levels are very low or near normal background radiation. There is no danger to the public.

The reactor continues to be held at 280 degrees Fahrenheit and 1,000 psi,

The Meltdown Myth

Headlines: "Gas Bubble Forms, Core Meltdown Likely."
Facts: A hydrogen gas bubble formed at a size much smaller than originally reported. NRC spokesman at hearings the next week admitted that the existence of any hydrogen bubble was "speculation." A core meltdown was not possible as a result of the size and type of the speculated bubble. Had such a bubble exploded, which was scientifically impossible, it would have had the impact of a hand-held mallet swung at a wall.

Headlines: "China Syndrome Likely From Meltdown."
Facts: The China Syndrome does not exist in scientific or technical reality. The reactor walls are built to withstand any meltdown.

Headlines: "Meltdown to Release Radioactivity to Susquehanna River and the Atmosphere."
Facts: Breach of containment is not possible, which means that the evacuation scenario was not necessary for safety reasons, as claimed by the governor and NRC.

Headlines: "Bubble Will Cause H-Blast."
Facts: The specific conditions for a hydrogen explosion did not exist.

with one primary coolant loop and one steam generator secondary coolant loop in operation.

The Press: "A-Reactor Core Is Cooling, Gas Bubble Is a Hazard" (*Washington Post*); "Key Maneuver Set at N-Plant, Aimed at Reducing Bubble Peril, May Evacuate 600,000 If Move Fails" (*New York Daily News*); "Atomic Era Over, Nader Predicts," "Crisis Viewed As Setback to Energy Policy" (*Baltimore Sun*); "What Hath Man Wrought, Worshippers Ask" (*Philadelphia Inquirer*).

The NRC: On the question of need for evacuation, "This area is sensitive with the state. I need to clear it with the governor and I am rushing to see the governor now. I see some signs for optimism" (Harold Denton). "Hydrogen content in the reactor building has risen from 1.7 percent to 2.4 percent. At about 4 percent, we reach the flammable level and at 8 percent the detonable level" (Harold Denton).

5 The Big Lie About Radiation

The half-truths in the post-Three-Mile-Island press about the dangers of radiation are like the Big Lies associated with Goebbels and his controlled media during the Nazi rule of Germany.

The fact is that radiation, like other natural phenomena, is a strongly positive contributor to the general negentropy of the biosphere, under appropriate conditions. Low-level radiation has been demonstrated to promote healing in damaged tissue, promote cures of certain contagious diseases in experimental animals, and may lead to increased longevity in humans. High-level radiation under human control eliminates tumors, seals damaged blood vessels, and is an increasingly useful surgical tool. Radi-

Continued on page 61

Washington

Congress Redirects Fusion Program

The House Science and Technology Committee has redirected part of the Department of Energy's proposed fiscal year 1980 budget in order to "get fusion as rapidly as possible." Specifically, the committee has undercut the Carter administration attempt to implement last year's Foster Committee report on fusion, which would in effect slow down the highly successful fusion tokamak program.

The committee has also reversed the Department of Energy's proposed budget cuts that would destroy U.S. energy options in advanced technology by restoring funding to continue work on critical programs. This includes more than $183 million to continue the Clinch River Breeder Reactor, $10.5 million for the Barnwell reprocessing and waste storage project, and enough funding to continue work on General Atomic's High-Temperature Gas-Cooled Reactor.

The administration's budget for the DOE was submitted to Congress in February, and the House Science and Technology committee expects to complete its recommendations this month.

In other advanced technology areas, the committee added $3 million to the administration's paltry $72 million request to continue promising longer-hour tests on magnetohydrodynamic generators. The committee also cut construction funding for some of the more dubious coal synthetics projects.

Keeping Tokamaks on Schedule

Several committee members said that they felt the current political situation would not permit them to add enough money to the administration request both to keep the tokamak programs on schedule and to aggressively support the alternate concept fusion programs. Congressman Mike McCormack (D.-Wash.), chairman of the subcommittee on Energy Research and Production, thus opted for strengthening the tokamak and technology-support programs so that the general timetable for fusion would not be set back.

The initial figure for magnetic confinement from the full Science and Technology Committee mark-up session March 21 is about the same total as the DOE request of approximately $362 million, but the figures for the individual programs within this total are different.

The full committee accepted the report from McCormack's subcommittee and reduced the funding for the magnetic mirror machine, the MFTF, at Lawrence Livermore Laboratory by about $3 million, which will stretch out the construction of the machine. In addition, the committee took approximately $8 million from the DOE applied plasma physics budget, which will terminate the imploding liner project at Los Alamos Scientific Laboratory and discontinue the stellarator program and related plasma theory work at the Massachusetts Institute of Technology, the University of Wisconsin, and Los Alamos.

This $11 million will be diverted in part to the technology development division of the fusion program for work on the neutral beam and superconducting magnet research now ongoing at several laboratories around the country. In addition, some of the funds will be used to accelerate the Engineering Text Facility, a tokamak device designed for operation after

the present tokamak devices reach breakeven.

The largest increase, which was not included in the authorization by the Science and Technology committee but which will be recommended to the House Appropriations Committee for appropriation, is the speedup of the Fusion Materials Irradiation Facility in Hanford, Washington. The Science and Technology Committee will recommend that the House Appropriations Committee increase construction funding for the Fusion Materials Irradiation Facility by $15 million and operating expenses by $3 million in fiscal year 1980.

Congressman McCormack said that scientists at the Hanford laboratory told him that the present level of funding for materials testing—a prerequisite to design of a commercial magnetic fusion reactor—was inadequate to have material testing ready by the time experimental results had pushed the program to the commercial design stage.

The intended effect of the McCormack subcommittee's effort is to keep baseline technology development in pace with the present and expected exciting results from current experiments over the next year, despite the delay in the mirror machine construction.

Raising the Ceiling

At its meeting March 28, the full Science and Technology committee will accept amendments to the reports of the McCormack subcommittee and other subcommittees. Congressman Lujan, a New Mexico Republican, has said that he plans to submit an amendment to restore part of the cuts in applied plasma physics, which he characterized as "too deep." McCormack has concurred with this, saying that he has "received quite a bit of flack on the committee's position" and that he in no way wanted to harm valid programs under development.

McCormack's remarks indicated that he feels the full committee should take the responsibility for raising the ceiling for expenditures for individual programs, given the rampant hysteria on Capital Hill about balanced budgets.

—Marsha Freeman

Excerpts from Kintner Testimony
'A Unique Year for Fusion'

Edwin Kintner, director of the Office of Fusion Energy, testified Feb. 27 before the subcommittee on Energy Research and Production of the House Science and Technology Committee. As Kintner ably pointed out, the year 1978 was a critical one for the fusion program, with exciting experimental results and extraordinary offers for international cooperation from every major country.

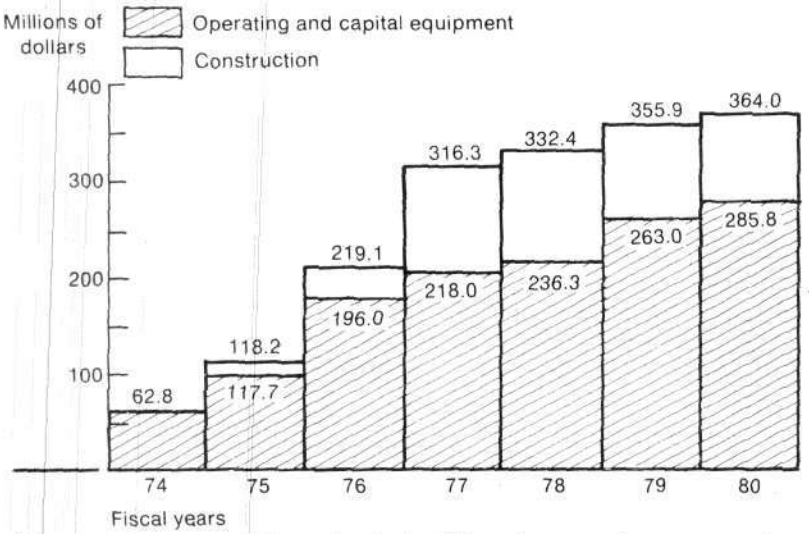
Despite these advances in fusion progress, it was clear to the hearing participants that exciting results would not be enough to ensure continued adequate funding and momentum for U.S. fusion research. As the scientifically aware committee members noted, the committee will have to face an artificially created hysteria for solar power when the full House evaluates the entire Department of Energy budget authorization.

Subcommittee chairman McCormack appealed to the scientists overseeing the critical fusion effort to help take on the antitechnology atmosphere permeating Washington and to give some backup to the congressional efforts to restore advanced science research and development at least to a minimally acceptable level.

Excerpts from the Kintner testimony follow.

The Kintner Testimony

This has been a crucially important year for the U.S. magnetic fusion program. As a direct result of significant program expansion and acceleration begun in 1974, we have, with surprisingly favorable experimental results for Princeton Large Torus and the Alcator A experiment at MIT, obtained sufficient scientific insight into the confinement of plasmas to be confident that we can create, on the earth's



The commitment in 1974 to begin building the experiments to solve the scientific problems in fusion development has brought the program to where it is today. The Carter administration has made no comparable commitment to begin to take fusion into the engineering and demonstration stage. Scientists at the Princeton Plasma Physics Laboratory who oversee the construction of the breakeven TFTR tokamak have said that they will lose a decade from the effort unless funding is allocated now for design of a commercial demonstration machine to be built in the 1990s.

surface and by man's intelligence, the conditions for useful energy production by magnetically confined fusion processes. These conditions existed heretofore only in the sun and other stars. Moreover, we are making good progress on the design and construction of the Tokamak Fusion Test Reactor (TFTR), which we believe will, indeed, translate that confidence into a factual demonstration by 1983.

1978 Accomplishments

This has been a unique year for the magnetic fusion program in the number of new, more powerful devices which were completed and are now entering experimental operation. These include:

(1) The Doublet-III at General Atomic Company, La Jolla, California, which will soon be producing experimental results on the efficiency of confinement of doublet-shaped tokamak plasmas. The Doublet-III is the largest, most powerful fusion device operational anywhere in the world today.

(2) The Alcator-C at MIT, which has the objective of demonstrating for the first time the quality of plasma confinement necessary for net energy production.

(3) The Poloidal Divertor Experiment (PDX) at Princeton, which was designed and built for the investigation of impurity removal and plasma shaping.

(4) The Impurity Studies Experiment (ISX-B) at Oak Ridge National Laboratory, already producing interesting data on such questions as impurity control and plasma fueling and which later this year should settle the important question of the maximum plasma pressures which can be sustained in tokamaks without instability.

(5) The Tandem Mirror Experiment (TMX) at Lawrence Livermore Laboratory, which has just begun experimentation to investigate new ways of improving the plasma confinement, and, therefore, energy multiplication factors, of mirror-type reactors. The TMX concept uses spherical mirrors to close the end of a cylindrical mirror.

Each of these devices is, in its own way, the most advanced experimental tool in the world. There has never been a time when so many new experiments, with so much potential for generating significant new physics data, came into operation in the same year. We look forward to a very interesting period between now and our appearance before this committee next year . . . .

As a further indication of greater confidence in the eventual scientific success of fusion, 1978 saw a number of initiatives for greater cooperation in magnetic fusion development among the nations of the world. In particular, the Japanese government has suggested closer ties with this nation in the development of magnetic fusion, and negotiations have now been carried to the point where concrete cooperative actions, including financial assistance to U.S. programs, seem likely. Similar suggestions have been made by the European Community. Negotiations looking toward furthering that cooperation will take place later in this spring.

Finally, a joint study has been initiated through the International Atomic Energy Agency combining experts of the Soviet Union, Japan, European Community, and the United States, to examine characteristics of the next large fusion experiment beyond the TFTR and its counterparts, the Joint European Torus and the Japanese JT-60. Through these steps the international cooperative nature of magnetic fusion development continues to strengthen.

In summary, 1978 has been one of the most significant of the 27 years since the magnetic fusion began. We have highly encouraging physics results; we now have a strongly supportive departmental policy; we have completed and put into operation many important new experimental devices; we have begun to broaden the base of our investigations; and we have strengthened U.S. leadership in world fusion programs.

Pursell Calls for Fusion by 1990

In a statement released from his Washington office March 8, Congressman Carl Pursell (R.-Mich.) said: "I'm convinced a properly organized and funded program can lead to a commercial demonstration fusion power plant in the 1990s, instead of sometime in the next century. I believe we could accelerate the official Department of Energy timetable by a decade or more."

Pursell praised the congressional addition of $4.8 million to the 1980 budget for the KMS Fusion laser fusion program in Michigan, a major private industry fusion program. The Department of Energy had requested $8 million for KMS. American industry must "take a broader leadership role in accelerating progress on the energy applications of inertial confinement fusion," he said.

Speaking about the administration's overall energy strategy, Pursell said that "the DOE timetable is based on anticipation of restrictive funding levels. I believe we can do better, and the urgency of the world energy situation demands that we do better."

MHD Endures 500-Hr. Test Run

The Department of Energy announced that the Mark VI magnetohydrodynamic generator at the Avco Everett Research Laboratory in Massachusetts had endured 500 hours of testing, the longest MHD operation in the world to date. The run was done in two parts, with the first 250-hour test last spring. When an examination of the generator channel indicated that additional lifetime was left, the DOE scheduled an additional 250-hour run in November.

Analysis of channel material performance will "permit reserachers to calculate expected lifetimes and characteristics of commercial MHD channels," the DOE said. The Avco experiment uses simulated coal burning by injecting fly ash into an oil burner. The mixture is heated to more than 4,500 degrees Fahrenheit and forced through the MHD channel at velocities close to the speed of sound.

"Politics is the art of lying," Schlesinger once wrote.

Another Schlesinger Hoax

The Oil Shortage Is Only a Numbers Game

An analysis of available oil data and an examination of the official statements of Energy Secretary James Schlesinger and the Department of Energy leave no doubt that there is no oil shortage resulting from the loss of Iranian oil production.

All the measures the Carter administration is attempting to impose—drastic oil price rises in the form of taxation, oil price decontrol, and related measures that will severely affect the domestic economy in the months ahead—are not being undertaken because there is an actual oil shortage. The United States is being pushed toward a war economy on the basis of a supply crisis that simply does not exist, despite press scare stories of spot gasoline shortages and the like.

The Facts

Contrary to impression, world oil production in the noncommunist world in January 1979 was up by a total of 2.5 million barrels per day above the same period in 1978. This included a substantial increase in Saudi Arabia's output from 7.6 million barrels per day to 9.5 and an overall OPEC total increase of more than 3 percent.

Total non-OPEC, noncommunist oil production for January was up more than 10 percent, 1.6 million barrels per day higher than January 1978. The 1979 figures include substantial increases in North Sea and Mexican production for the period.

Thus, despite the loss of approximately 5 million barrels a day from Iran for the period, total world production was *up* more than 2.5 million barrels per day above a comparable period when Iran was producing more than 5.2 million barrels.

An estimate done by the Library of Congress for the office of Congressman Albert Gore, Jr., calculates that total world net shortfall in production for this period is no more than 80,000 barrels a day—a far cry from the still-manageable 2 million barrels per day figure being cited by Schlesinger. This figure is so small as to be statistically insignificant.

What reserve did the world have coming into the recent Iran disruption for the first quarter? The Department of Energy officially estimated that worldwide stocks of oil coming into the first quarter of 1979 were 4.317 billion barrels. World stocks, that is oil produced, and either in transit or in storage were 4.276 billion barrels for the same period last year.

That means world stocks coming into the Iranian supply disruption were at record highs even from the abnormal highs of the previous year, when stockpiling in anticipation of an OPEC price rise produced a relative "glut." Thus, world oil production has held up during the period when world stocks were larger than normal to begin with.

The U.S. Situation

According to official published figures from the U.S. Central Intelligence Agency, the domestically available petroleum supply at the beginning of January was 1.32 billion barrels. Comparable figures for the previous two years indicate that this year's U.S. supply was the highest of the last three. In 1978 it was 1.31 billion barrels, and 1.11 billion in January 1977. In short, the U.S. supply was unusually high coming into the period of disruption.

Even taking the estimates put out by Schlesinger directly, domestic demand for petroleum for the month of February, the worst of the Iran shortfall period as it affected U.S. supply, was 21 million barrels per day, up only 1.3 percent from the level for 1978, an unusually miniscule increase in demand.

This is reflected in the fact that, according to the *Federal Register* of Feb. 23, domestic inventories were drawn down by 140 million barrels for the two months, compared with a drawdown last year of 106 million barrels, a difference of only 34 million barrels. Allowing for the higher stocks this year, this amounts to a net drawdown of slightly more than 20 million barrels, approximately 300,000 barrels per day, even by government figures.

The figures on which Schlesinger's Department of Energy is basing ma-

jor government policy initiatives furthermore, in the words of one government General Accounting Office statistician, are "very soft data," based on inferences from numbers made available from major oil companies that give the government admittedly arbitrary figures. Every top government source interviewed admitted this arbitrary character of the current statistics, referring to them as a "numbers game."

On top of this, total imports into the United States for February were up 776,000 barrels per day, an increase of almost 10 percent above the same period last year. It's hardly the kind of situation to be expected if we have the drastic shortage that we are being led to believe with supply cutbacks of fuel oil and gasoline.

Arbitrary Estimates

How does the government arrive at its estimates? A GAO official in charge of providing information to Senator Henry Jackson's Energy Committee admitted: "We take an arbitrary figure to calculate petroleum demand—we chose 3 percent. These numbers are all based on statistical extrapolation from one or two companies. What can we do? We have to come up with numbers, so we picked these. There are no data available from the companies that give an exact picture."

At this juncture, with Iranian oil production resuming, currently at a level of approximately 2.5 million barrels per day, the only basis on which Schlesinger can justify the draconian measures he is attempting to impose on the U.S. economy, in the form of drastically higher energy costs and cutbacks in consumption, is the threat of external disruption of supply from Saudi Arabia, further disruption of Iranian production, or outright terrorist sabotage of refinery capacity. Short of this, Schlesinger does not have the facts needed to support his contention to the public that the shortage is real at this point. Even articles in the *New York Times* have led with headlines such as "Oil 'Facts' Don't Quite Match the Rhetoric," while the *Journal of Commerce* said, "Oil Shortage Fears May be Premature."

At this point it is clear that the combined inventories of the multinational oil majors, led by British Petroleum, Royal Dutch Shell, and Exxon, are bulging at the seams.

The only immediate question of importance is which companies are storing how much of this stockpiled inventory, in tankers off the Norwegian fjords or in storage depots around the world. It is openly acknowledged by oil analysts and others now that this accumulation of company inventory is substantial. Congressman Albert Gore took note of this when he hit the real danger of rising price pressure: "To the extent that their [the oil companies] decisions to build inventories have enhanced the atmosphere of shortage panic . . . as a result, I believe . . . the impending 'price crisis' has become more serious than the current supply shortfall."

Gore added that "Schlesinger seized upon the current shortfall to build support for policies deliberately designed to produce much higher consumer prices . . . . Sharply higher prices risk simultaneous recession and double-digit inflation."

—*William Engdahl*

Mexico, France Plan Technology Transfer Deals

Nuclear energy was a central part of the trade agreements signed between France and Mexico during French President Giscard d'Estaing's four-day visit to Mexico in early March. The nuclear deal includes French technological help to Mexico for uranium exploration, a guarantee of an enriched uranium supply to Mexico, joint participation in the construction of Mexican nuclear plants, and future construction of a Phenix breeder reactor in Mexico.

Horacio Flores de la Pena, the Mexican ambassador to France, characterized the deals signed or soon to be signed overall as "one huge factory" that will allow Mexico to export high technology goods, "90 percent of which would go to the United States, Canada, and Latin America."

As both Giscard and Mexican President Jose Lopez Portillo noted, the agreements made for Mexican oil exports, nuclear energy technology transfer, and similar deals for the electric power industry, the heavy machinery industry, aerospace, communications, transportation, and financing are more than just trade deals. They represent an economic manifesto on how North-South development must be conducted under the new European Monetary System.

President Lopez Portillo greeted Giscard at the airport saying, "You have come to Mexico on the beautiful wings of concord," a pun that embodied the nature of the diplomacy—peace through technological progress. In the final communique issued March 3, both leaders agreed to promote "an active peace, which means not only the absence of warlike hostilities, but requires the elimination of hunger, sickness, illiteracy, ignorance, poverty, and injustice—a task in which all members of the international community have a shared responsibility."

A French Lesson for U.S.

The Mexican-French accords were in sharp contrast to Carter's visit to Mexico in February. Carter, along with National Security Advisor Zbigniew Brzezinski has pressured Mexico to become part of a "North American community," which would include the United States and Canada. As laid out in Carter's Presidential Review Memorandum 41, this called for Mexico surrendering control over natural resources and adapting economic programs to fit the role of a mere raw materials supplier.

The Mexican government said no to Carter, as it had said no to Energy Secretary Schlesinger and his natural gas ultimatums earlier. But Mexico also made it clear that the no to the Carter administration was not directed at U.S. businessmen and exporters of advanced technologies.

The question now is whether U.S. businessmen will learn a lesson from the French.

EC Solution: Go Nuclear

The nine-member European Commission of the common market has called for a massive investment in nuclear and coal development to compensate for decreased reliance on imported oil.

A March 12 EC policy document, to be presented to the March 27 Brussels meeting of energy ministers, lays out a plan for total member-country energy production investment of 370 billion European units of account, which equals in present dollars $500 billion (1 EUA equals $1.35). Of this, the plan projects $70 billion investment in nuclear plants by 1985.

"Since coal will be unable to fill all the gap," the EC communiqué states, "we must also have a judicious expansion of nuclear energy. The nuclear program continues to slip and we are likely to have more than 75 to 80 gigawatts operating in 1985, compared with the 103 gigawatts planned two years ago, except in France."

The EC statement goes on to say that an average of 13 new power stations must be built annually over the next five years, if the European nations are to meet present proposals for nuclear power generation by 1990.

This ambitious program parallels the thrust that the Europeans have made, especially the French, to invest in trade and development deals with the Third World and the oil-producing countries.

France and West Germany are at the center of the campaign for European nuclear development. Directly counter to the policy of the U.S. Energy Department under James Schlesinger, French President Giscard and West German Chancellor Schmidt have made rapid nuclear development the cornerstone of the European Monetary System and its technology transfer deals with developing-sector nations. While the U.S. administration has crippled its nuclear industry under the banner of nonproliferation, the Europeans have made it clear that nuclear power development is a necessity for world peace.

Ironically, the U.S. position on nonproliferation has knocked out of the bidding for the European nuclear program three U.S. firms that historically had been involved with European nuclear construction—Combustion Engineering, General Electric, and Westinghouse.

In addition, while the U.S. administration has used the threat of an oil shortage to push for conservation and crisis management measures as well as anti-OPEC sentiment, the French and West Germans have proceeded with the understanding that nuclear power is the energy source of the future for the West as well as for the oil-producing nations.

The French nuclear program, the most ambitious in Europe, is a pointed political contrast to the devastated state of nuclear power development in the United States. The core of the difference lies in the conception of dirigism—centralized top-down coordination between the government nuclear policy and the private sector investment planning.

The United States dismantled its key government agencies devoted to the development of nuclear energy, beginning with the Atomic Energy Agency and the congressional Joint Committee on Atomic Energy; the French nuclear power development program is a political priority laid out at the top levels of the Giscard government. The central French national electric utility, which operates the nuclear program, Electricité de France, emphasizes that it is carrying out government policy.

Dirigism in Action

EdF announced March 13 that it was planning to construct 30 nuclear power plants by 1985, using assembly-line standardization methods. The first plants will produce 900 megawatts of electricity, but the plants constructed later will be larger, producing 1,300 megawatts each. The plants are designed for domestic and export use, and the domestic plants are planned in groups of four in energy parks to guarantee security and efficiency.

Currently, 26 nuclear reactor plants are under construction in France. Despite initial delays in construction which put the program one to two years behind schedule, the EdF has unraveled most of initial construction bottlenecks in the first four plants and expects that the fourth unit will be on line in June, just six months behind schedule. While the total construction time in the United States is 10 to 14 years per reactor because of licensing and legal delays, the French program can now complete a 900-megawatt reactor in five years.

The Dec. 20 power blackout in France affecting 22 million EdF customers, which occurred when a transmission line from West Germany fail-

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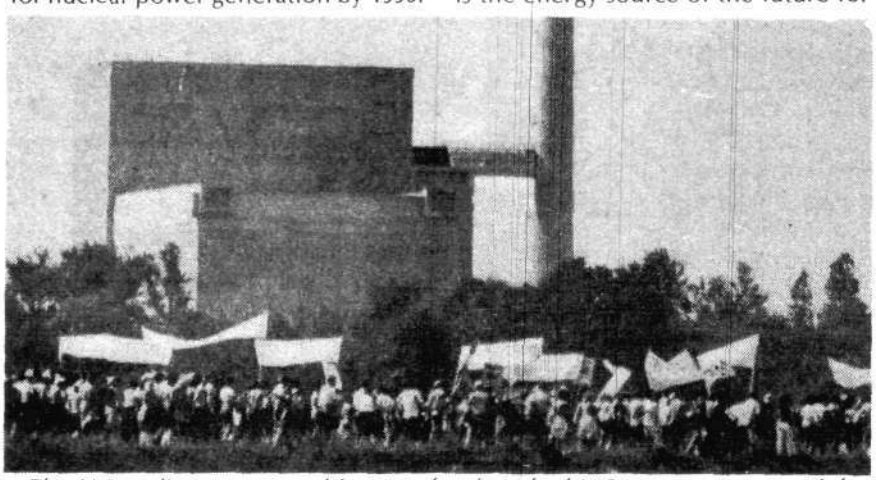


The U.S. policy on nonproliferation has knocked U.S. companies out of the booming European nuclear business. Above, antinuclear shocktroops march on a West German nuclear plant.

An Interview with
Dr. Walter Seifritz

Planning a Hydrogen Economy

Dr. Walter Seifritz, a well-known European authority on nuclear power and the economics of energy, discusses here the necessity for politicians and workers to understand the facts about hard technology and to have the political will to carry through an energy policy based on economic growth and nuclear power.

Seifritz was interviewed in Zurich, Switzerland by *Fusion* correspondent Ralf Shauerhammer just after the second World Hydrogen Energy Conference in August 1978. The conference, which Seifritz chaired, included 500 representatives of 40 countries. It was sponsored by the International Association for Hydrogen Energy, in association with several governmental and nuclear industry groups.

Seifritz, a board member of the Swiss Federal Institute for Reactor Research, teaches at the Technische Hochschule in Zurich as well as at the Technische Hochschule in Hannover, West Germany. Seifritz is well known for his newspaper articles laying out the importance of nuclear energy, in addition to many technical papers and conference presentations on energy economics.

Question: In your opening address, you raised the point that the success of the conference consisted in having responsible politicians recognize the importance of hard technology. What are the most important measures you expect from such politicians, and to what extent was the conference successful in achieving this?

Today's "green spirit of the times" has brought insecurity into almost all levels of the decision-making process concerning energy policy. "Nothing works anymore" is the bitter recognition that poeple have grown accustomed to in the last couple of years. One even gets the impression that politicians are having extraordinary difficulties in formulating a clear presentation of goals for the solution of the energy problem.

They react passively, as a result of the [greenie] antagonism placed before them. This holds for a great number of countries and is probably also conditioned by the persistent world recession.

We want our politicians to break through to a clearly formulated energy policy and to acknowledge the *political will* necessary to carry this policy through....

Concerning the choice between hard and soft technolgy, I hope that the implications of prescribing inherently limited energy sources with the goal of using this as a lever against further economic growth and as a lever for a certain social policy will be understood not only in a technical sense, but also in a social one.

In particular, I expect our politicians to think about what it means when entire square kilometers of real estate that are close to population centers are supposed to change their occupants [to make room for solar reflectors]. How will we ever get to the end of the real estate speculation and the expropriation proceedings, and what will this mean ecologically and in terms of social policy, when billions flow for solar energy panels from those who do not own any land into the pockets of those who own the land?

I also hope that labor organizations will increasingly conceptualize what it means for workers when factories must be shut down because of a lack of energy and an increase in costs of production and service. Certainly it is no speculation to think about which social groups will be hit first. It is precisely the workers and their organizations who should increase participation in the discussion about energy problems and who should make it clear for themselves what this means for them.

This conference demonstrated that one cannot consider the energy problem only as a problem of the production of useful energy from new energy sources; the logistical and environmental aspects on the secondary energy market must be drawn in too. With eveything that we know today, we can point out a viable [energy policy] option with the slogan "nuclear energy first, hydrogen and electricity second"—an option that corresponds most closely to the energy and environmental requirements of a growing world.

HYDROGEN ECONOMY

Question: In general, the discussions about the future energy situation are overshadowed by the gloomy tones of the predictions from the zero-growth Club of Rome. But there wasn't a trace of this gloom at the Second World Hydrogen Conference. Does the conception of a hydrogen economy justify this optimism?

Yes, because this concept of a hydrogen economy has pointed out just how energy and environmental problems can be solved in the long term and permanently.

First of all, hydrogen will take on the role of an energy reservoir, for in the substantial substitution of fossil forms of energy, energy must be produced and correspondingly distributed in a terawatt [trillion watt] scale. This problem can be solved permanently with the help of large, improved nuclear energy installations and with a series of so-called energy islands.

Of course, the Club of Rome study *(The Limits of Growth) has been crit*icized because, among other things, it is based on an assumption that has only the "exhaustion of a resource reservoir" in view. New innovations, the economics of scale in the construction of large installations, and the so-called "learning curves" experienced in the learning process were not considered.

But above all—and this must be stressed—what will be required to be able to make the step into a postfossil era are major financial and material investments, as well as a collective effort. And this will be possible only with continued economic growth and

not with a strategy of self-limitation that looks backwards because only then can the necessary financial investment be diverted from the GNP without too much sacrifice and in a politically defensible way.

The Club of Rome's idea of zero growth is not suitable for solving our future problems. It would mean an unnatural economy based on scarcity, which would exhaust itself in the contest involving fights over the distribution of the increasingly diminishing GNP without having any perspective of the future. I do not believe that young people especially will be happy in the long term with such a hopeless outlook for the future.

Question: What are the decisive scientific orientation points for the substitution of fossil forms of energy?

On the order of magnitude of terawatts of power, and on the basis of the data sufficiently known for the various substitute forms of energy coming into question, generally, only those energy systems will come onstream that have an *inherently high energy density*. Energy systems with lower energy densities, which are typical for the so-called alternative or soft technology systems will not have a role.

Nuclear energy and advanced reactors must carry the main load in the near future. Breeders, high-temperature reactors, and later possibly fusion reactors must succeed in being used on a large scale.

High energy density means relatively small specific investment costs, relatively little land use, and relatively little exploitation of resources, because relatively few materials per unit of usable energy are required. There are no "renewable" sources of energy as the recently released Canadian study, "Risk of Energy Production," emphatically confirmed.

Question: The advanced state of development of the high-temperature reactor speaks for the fact that hydrogen will be produced with nuclear energy in the post-oil society. Are alternative processes conceivable that could compete economically with nuclear-power-based production of hydrogen in the next 50 years?

Certainly, the production of hydrogen by steam re-forming from natural gas and by various coal gasification processes must be kept in view. Today, for example, the standard method to produce hydrogen in large quantities is from natural gas, and it is by far the most economical. In a future transitional phase, hydrogen production by coal gasification is thoroughly conceivable.

However, the conception of a future hydrogen economy is based precisely on the idea that in the long term the only sensible thing is to get hydrogen from a nonfossil raw material—namely by splitting water. And alongside of this process, in the front row, nuclear energy is the most suitable form of primary energy.

Question: In this conference, two presentations described the possibility of producing hydrogen with fusion reactors. How is it possible to integrate nuclear fusion into a high-temperature-reactor-based hydrogen economy?

Integration is totally possible in a significant way. It is most probable that nuclear fusion will not come on stream immediately as pure fusion. Fusion probably will be introduced through the so-called hybrid system. In the hybrid, the abundance of neutrons in fusion will be combined with the abundance of energy in fission, and the hybrid will produce fissionable material. Such a fusion hybrid reactor can breed up to 10 times more fissionable material than a comparable fission breeder can.

In addition to supplying electricity or heat for manufacturing processes, the hybrid system in its first phase would make up the deficit fissionable material for the high-temperature reactors. In this symbiosis, a large hybrid could supply approximately 20 to 40 hydrogen-producing high-temperature reactors with fuel.

In a later phase of the application of fusion energy, one could even think of using a fusion torch to couple the process heat from fusion directly by means of plasma chemistry into the water-splitting process. A couple of Soviet papers were directed to the principles of this operation at the conference.

National

The Progressive Case:

Aiming the

The decision of a federal judge in Wisconsin March 31 to ban the publication in the *Progressive* magazine of an article on how the hydrogen bomb works is part one of an elaborate setup to classify U.S. fusion research in the guise of preventing nuclear weapons proliferation. Like the oil shortage hoax and the Harrisburg nuclear hoax, both run by Energy Secretary James Schlesinger, this attack on fusion is designed to eliminate another positive energy alternative and make conservation, austerity, and wartime crisis measures more credible to the American public.

The judicial confrontation follows classic "left" versus "right" battle lines. The catch is that both sides in the *Progressive* case have the same goal and, in fact, come out of the same political network.

On the "left" side of the affair is the *Progressive*, a rabidly antiscience publication whose contributors often are associated with the Institute for Policy Studies, the "left" umbrella group on top of all the environmentalist organizations, including the antinuclear terrorists. In its last issue, for example, the lead article headlined "Ultimate Terrorism: Security for None in a World Bristling with Nuclear Weapons," was written by Richard Barnet, cofounder of the Institute for Policy Studies.

A second feature in the same issue was called "Tritium: The New Genie," which begs for more classification and government control of research involving the fusion fuel, tritium.

The "right" side of the battle is the government, represented by Energy Secretary James Schlesinger, who contends that the *Progressive* feature reveals vital weapons information. Schlesinger has been backed up in this assessment by a string of officials in the upper levels of the nonpro-

H-Bomb Against Fusion

liferation group in the U.S. State Department and the Arms Control and Disarmament Agency. Not incidentally, *Progressive* contributor Barnet came out of the Arms Control and Disarmament Agency in 1963 to found the Institute for Policy Studies, which subsequently spawned and supported the "left" side in this confrontation.

The Nonproliferation Mafia

Both sides of the controversy come out of the antiproliferation networks centered in Cambridge, Mass., at the Massachusetts Institute of Technology and Harvard University.

Under the guise of preventing nuclear weapons proliferation, both sides in the case are adding the use of tritium fusion fuel and the spread of scientific knowledge at the frontiers of science to their list of so-called proliferation dangers. Ironically, by denying to the world the instruments of economic progress—nuclear fission and fusion energy—these nonproliferation advocates are actually leading the drive toward World War III and thermonuclear destruction.

The facts of the matter are not at all secret. The *Progressive* staff made it plain in their statements about the case that they had fashioned the article to be a perfect vehicle for judicially establishing the government's full power to suppress publication of scientific materials that impinge on classified aspects of nuclear weapons.

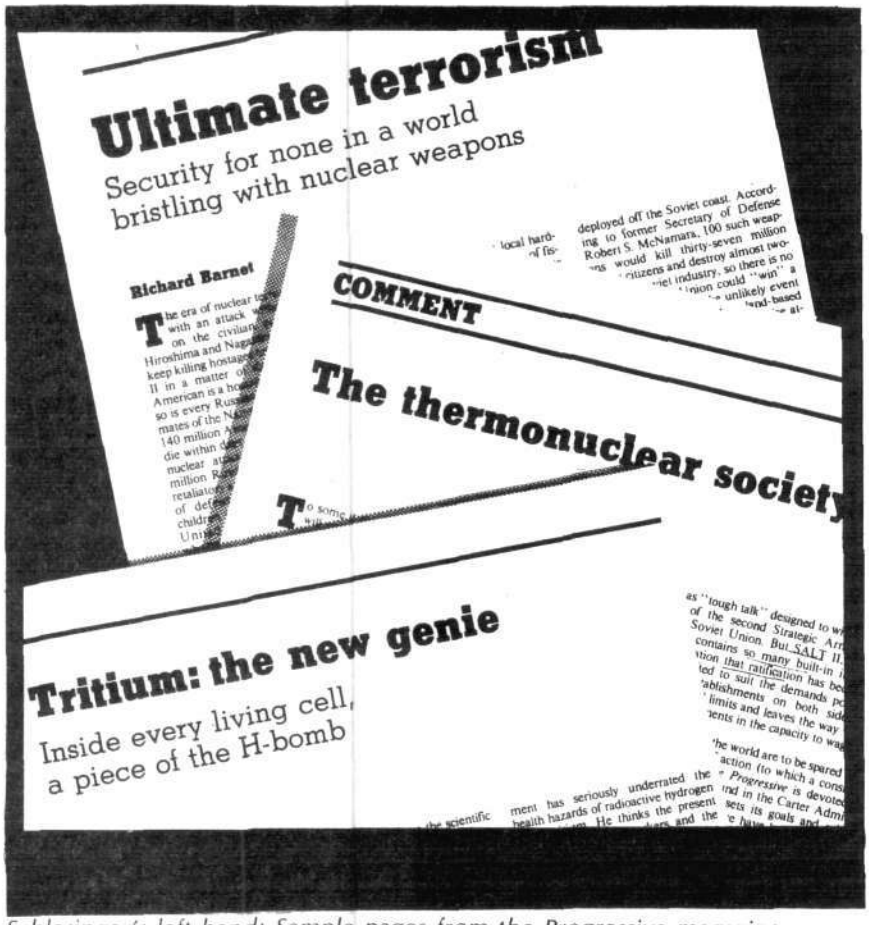
Equally up front, the confrontation to set this case up for the courts was initiated by a top operative in the antiproliferation wing of the State Department, Professor George Rathjens of the Massachusetts Institute of Technology. According to the *New York Times*, Rathjens, a deputy special representative for nonproliferation in the State Department under Gerard C. Smith, received an advance copy of the article from an exstudent and sent it on to the Department of Energy. He thought parts of it should not be published.

The Warhawks

Rathjens is also a leader of the Harvard-MIT arms control group that models itself on the late J. Robert Oppenheimer. A close associate of British intelligence networks throughout his life, Oppenheimer was instrumental in the postwar period using the proliferation argument to wreck the international development of nuclear fission and fusion power.

This Cambridge nonproliferation mafia intersects with the energy committee of the Aspen Institute and the joint efforts of liberal strongholds like the United National Association, the Pugwash Conference, and the Arms Control and Disarmament Agency, which attempt to maintain the United States and the Soviet Union in a controlled adversary relationship in which the Soviets are expected to back down step-by-step in the face of escalating provocations.

One of Rathjens's associates, Harvard professor Paul Doty, is on the Aspen energy committee, which is leading the push for strict conservation and classically fascist measures to control the economy. Doty's assistant, Albert Carnesale, is also a consultant to the State Department's Gerard Smith. In a recent interview, Carnesale admitted that he had reviewed the *Progressive* article at Rathjens's office and had urged that it be suppressed.



Schlesinger's left hand: Sample pages from the Progressive magazine.

Carnesale also works with a joint arms control program of Aspen Institute and the Ford Foundation, a connection that provides the link to the chief warhawk controller of this nonproliferation operation—McGeorge Bundy, former national security advisor and outgoing Ford Foundation director. Bundy is headed for a post at New York University in September where in his first year he will conduct a study of international nuclear affairs.

Bundy was invited to NYU by its president, John C. Sawhill, who is a member of the Aspen Institute energy committee, one of the leading groups that is on top of the crisis management, conservation, and energy austerity plans that are the intended outcome of the *Progressive* case.

Another of Rathjens's arms control associates at MIT provides more evidence that the *Progressive* case is a ploy in which both sides are run by a single network. The virulently antinuclear editor of the *Bulletin of Atomic Scientists*, an offshoot of Bertrand Russell's subversion operation against American science, is MIT professor Bernard Feld. And Feld's predecessor at the *Bulletin* was Samuel Day, Jr.—the current managing editor of the *Progressive*.

The Proliferation Veto

The stage was set for the current H-bomb caper in July 1977 when President Carter named Gerard C. Smith, a former U.S. negotiator at the strategic arms limitation treaty talks, as U.S. Special Representative in Charge of Nonproliferation Matters and U.S. Representative to the International Atomic Energy Agency.

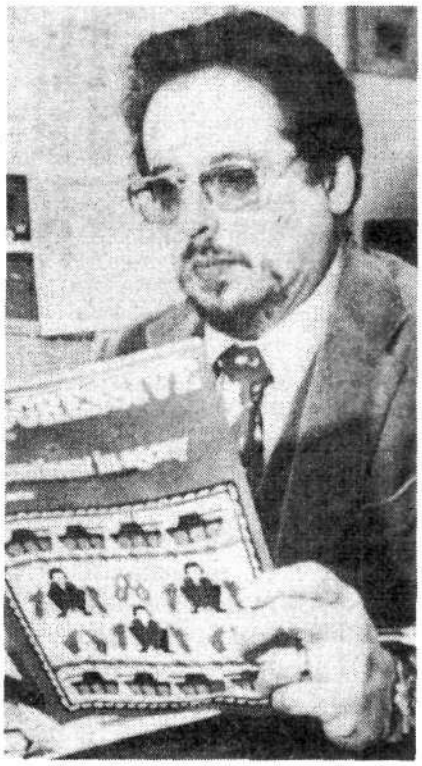
Since then, the U.S. zero-growthers and their Soviet counterparts in the IAEA and the United Nations have used the proliferation argument to veto any large-scale nuclear technology transfer to the developing sector.

Shortly after Smith's appointment, the State Department published a pamphlet titled "The United States and World Energy," where fusion development was cited as a major danger because it could lead to the easy production and proliferation of plutonium (although, oddly enough, the pamphlet also noted that commercial fusion was considered decades away).

The Schlesinger arguments against international fusion collaboration are just a variation on this danger theme. Schlesinger has been the main mover behind the DOE rejection of Soviet offers of cooperation in inertial confinement fusion research on the grounds of national security.

The same week as the *Progressive* court decision, Marvin Moss, one of the leading antiproliferation kooks within the DOE, bragged that the earlier instances of unilateral declassification in the United States by Soviet fusion scientist Rudakov of inertial confinement research (See "The Secret of Laser Fusion," *Fusion*, March-April 1979, for details of the Rudakov case) were "accidents" that would not be repeated now that the Soviets "understand the importance of preventing nuclear weapons proliferation."

The *Progressive* case, which may be dragged all the way to the Supreme Court, aims to cripple fusion work by making this antiscience perspective the law of the land.



Rabidly antiscience: Progressive *editor Erwin Knoll.*

'The End of the Rainbow'

Nova says 'No' to Fusion

If you wanted a TV film to scare people into thinking that fusion energy comes from bombs, that the problems in fusion development will prevent it from ever becoming commercially feasible, and that the scientists working on the fusion program are a bunch of used-car salesmen competing to sell their individual experiments to Congress, then the March 1 showing of the Nova program on fusion is just for you.

Viewed by millions of people over Public Service Broadcasting stations across the country, this latest antiscience Nova program drew blood from scientists inside and outside the fusion community. Several fusion scientists interviewed by Nova for the program reported that their remarks were taken out of context, and one well-known participant said angrily, "I'll never do another interview for Nova."

As a spokesman for the Department of Energy's Office of Fusion put it, Nova made the scientists "look like a bunch of dummies."

The program, titled "The End of the Rainbow," began with repeated shots of hydrogen bomb explosions as the narrator announced that fusion energy is the power in the H-bomb and the sun. Then came comments from Alvin Weinberg, former head of Oak Ridge National Laboratory, saying "we can't count on it or base a national energy policy on fusion"; Amory Lovins, "soft" and small technology advocate, saying, fusion is just "too big"; and David Rose, an antifusion fusion scientist saying how unrealistically optimistic scientists were in the 1950s.

The narrator explained that although fusion prospects in the 1950s were exciting, plasmas became unstable as they were heated and "each beginning became a different kind of

failure." The August results on the Princeton Large Torus were called a breakthrough, but Nova cautioned, "breakthroughs had been claimed before." The Nova narrator then quoted from the French press that there is "ferocious budget competition. . . . Important, yes. A breakthrough, no."

Nova then explained, using the straight Schlesinger line, that the Princeton results were announced at budget time and that even more "immodest headlines" in the press "do a disservice to fusion."

Continuing along these lines, Nova reported that some fusion proponents (guess who?) say "we got to the moon in 10 years with a crash program" and we should have one for fusion. The Nova answer? They presented John Deutch, a top assistant to Schlesinger at the Department of Energy, to tell the viewer: "It is unclear that a crash program is the way to go . . . . More money wouldn't be important at this stage."

The Rainbow Experts

Who does Nova depend upon in the fusion community as the show's resident experts on fusion development? Two antifusion people, David Rose and John Holdren, who have virtually no respect in the scientific community nor credentials that give them the right to speak for experimental fusion research or the future of commercial fusion.

Did Nova have a choice? Aside from the few reputable scientists who were interviewed but taken out of context, there were no comments, for example, from Ed Kintner who heads the magnetic fusion program for the Department of Energy. In addition, Nova chose to cut out an interview filmed with the only internationally recognized scientific organization in the fusion field, the Fusion Energy Foundation.

The two fusion scientists Nova selected to make half of the scientific comments on the show were not just ordinary fusion scientists. MIT engineer David Rose, who stated on Nova that the optimism about fusion in the 1950s was unjustified and that fusion was only one of many possibilities, is known in the fusion field for submitting an antifusion article to scientific journals in 1976 and having it rejected on the basis of its distortions of fact.

In response to Rose's antifusion campaign, Dr. John Nuckolls of Lawrence Livermore Laboratory remarked in 1977 at an American Physical Society meeting in Atlanta, "We have solved all of the difficulties in the last year which Rose had foreseen as insurmountable."

As for John Holdren, a professor at the University of California at Berkeley, he distinguished himself among the fusion community by writing a March 1978 article on the dangers of fusion in the *Bulletin of Atomic Scientists*. Unlike fission, Holdren said, it is still possible to easily exert "greatly strengthened political controls" over fusion.

Holdren's contribution to the Nova show was to expound that tokamaks are probably too big and too complicated to work, that there is always the possibility for nuclear terrorism, that the program has been "hurrying too fast," that we shouldn't build a machine too soon, and, finally, that the kind of technology developed is "not always what society wants."

"We need in-put from the nontechnical people. This could end up being another SST," Holdren said.

Holdren will be a featured speaker at a closed-door meeting in Washington April 19-20 for top foundations that fund the antinuclear environmentalist movement. Holdren's topic? "Nuclear issues—uncertainties and options."

It should not be surprising to viewers of previous Nova programs that the Nova fusion coverage was basically antifusion. Modeled after the science series presented by the British Broadcasting Corporation, Nova is funded mainly by the Ford Foundation, which bankrolled the early antinuclear movement and has pushed a "soft" energy path for the United States.

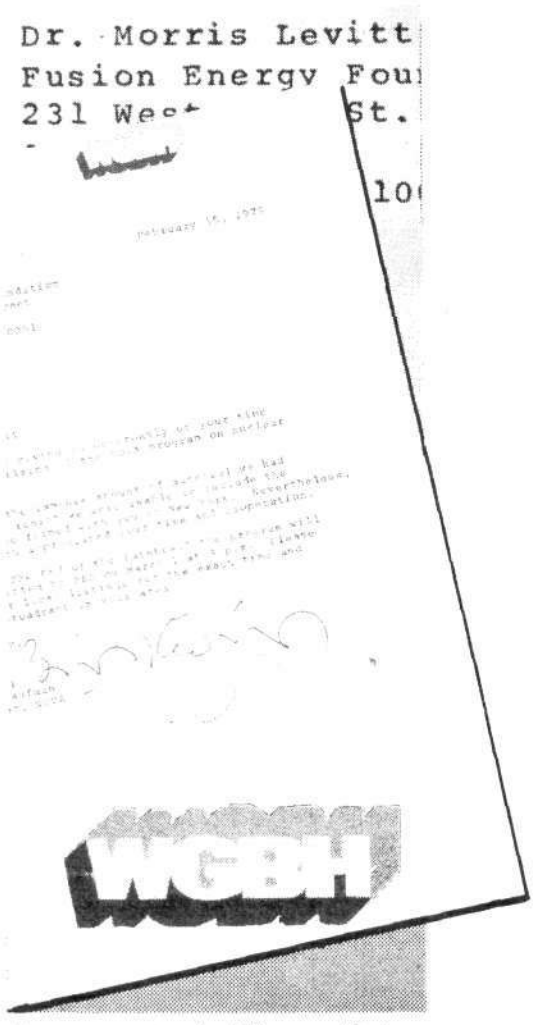
Top Nova personnel were imported from the BBC to help in the discrediting of science and the promotion of flora and fauna rights. The corporation TRW, which gives a grant to the Nova series, has reported that they are rethinking their commitment to the program because of its antiscience stance.

An Alternative

Fed up with the constant media barrage of antinuclear and antiscience propaganda, the Los Alamos Scientific Laboratory recently made its own film about nuclear energy. Los Alamos is distributing the film in cooperation with the American Nuclear Society and Atomic Industrial Forum.

The FEF is now considering producing a film that would give the American viewing public the truth about the necessity and potential for commercial fusion power development. Interested industry, university, and laboratory participants in fusion programs are invited to contact the foundation.

—*Marsha Freeman*



Nova says no to the FEF . . . and fusion.

The Einstein Centennial Symposium at Princeton

Perpetuating the Einstein Myth

The recent Einstein centennial symposia in the United States and Europe have covered up the most central questions concerning Albert Einstein's career and have continued the myth of Einstein as a freak genius.

The primary unmentioned fact is that Einstein was a victim of a longtime intelligence operation run out of Britain to contain the advances of Continental science. The main thrust of that operation was to obliterate the Reimannian tradition centered at Göttingen University in Germany. To the extent to which this plan was successful, working through such institutions as Niels Bohr's Copenhagen Institute, it severely incapacitated Einstein's work, particularly after his publication of the General Theory in 1915.

The more general results of this British operation have been wholly inadequate conceptions of current relativity and quantum mechanics. These both proceed from an inadequate conception of energy and, therefore, cannot begin to comprehend the developmental invariant of the universe.

To understand Einstein and his accomplishments (and, for that matter, all of physics today), one has to understand the Riemannian tradition and why the British empiricists sought to suppress it. The omission of this line of questioning at the Einstein centennial events is accompanied by other key historical distortions. Chief among these is the question of Ernst Mach. A generation before Einstein, Mach postulated that inertia results from the gravitational effects of the distant masses of the universe. This so-called Machian Principle has been celebrated as an enunciation of "relativity theory," but in reality, Mach's notion is as trivial as Newton's fixed reference frame.

What Mach does represent, however, is the weak side of Einstein—his weakness for structuralism divorced from the notion of continuing development, which was played on by his opponents throughout his lifetime.[1] But this Machian approach is in no way responsible for Einstein's actual breakthroughs, and it is well known that Einstein vigorously repudiated Mach.

The positive side of Einstein comes explicitly through his teacher Herman Minkowski, who held Riemann's chair at Göttingen. This tradition manifests itself most strongly in Einstein's undying commitment to the principle of causality in universal law —a commitment shared by his closest cothinkers and contemporaries, Erwin Schrödinger and Louis de Broglie. In fact, one of the most detrimental influences on Einstein's continuing work was that his last 30 years were spent in isolation from those who shared this commitment.

As noted by the historical sketches presented at the Princeton symposium, particularly that of Nobel laureate Eugene Wigner, Einstein did his most productive work while surrounded by his cothinkers in Germany and he produced very little after he came to the United States, where he was essentially isolated for his last 30 years at the Institute for Advanced Study in Princeton, N.J.

The Princeton Symposium

The symposium at the Institute for Advanced Study from March 4 through March 9 was undoubtedly the most prestigious of all the centennial meetings, and its speaker roster included most of those who also spoke at the New York Academy of Sciences symposium and various European meetings. For this reason, I shall focus on the Princeton meeting to demonstrate the Einstein myth creation.

The Princeton symposium was evenly divided between historical sketches and scientific talks. The first day of the proceedings featured a set of historical papers including "Roads to the Relativistic Weltbild" by Professor Gerald Holton, of Harvard University, "Einstein and Quantum Mechanics: The Early Years" by Professor Martin J. Klein of Yale University, and "Einstein on Particles, Fields, and the Quantum Theory" by Professor Abraham Pais of Rockefeller University.

Holton's presentation began with an interesting listing of Einstein's early published work, which documented the vast breadth of Einstein's early interests, ranging from capillary phenomena and the thermodynamics of molecular forces, to kinetic theory and Brownian movement, to the quantized radiation field and special relativity papers of 1905.

Unfortunately, Holton left out of his talk the most crucial aspect of the early Einstein. He made no mention of the Göttingen hydrodynamics tradition, including Riemann and Felix Klein, that produced the actual conceptual basis for the notion of the relativistic field. It is only this tradition, which explicitly investigated the widest range of crucial phenomena as mutually informing, that can explain Einstein's wide range of interests.

The most evident parallel to Einstein in Riemann's work is Riemann's early, simultaneous investigations of geometry, series expansion and real analysis, and complex analysis and the development of his Riemannian-surfaces approach. Since Holton did refer to numerous other predecessors of Einstein, including the thermodynamicists around Ludwig Boltzmann and the nominalist James Clerk Maxwell, the absence of Riemann is not because Holton was restricting the historical period of his talk. In other words, Holton purposely ignored Riemann.

Such deliberate isolation of Einstein from the Riemannian tradition leads a credulous audience to only one kind of conclusion: Einstein's scientific advances came out of "nowhere"; they must be mystical in origin; furthermore, the quality of "genius" is a freak phenomenon. Even the best of the symposia participants, for example, Dr. John Archibald Wheeler, who later gave one of the more interesting of the science talks, is infected by this mystical view of creativity. As quoted in *Newsweek* March 12, Wheeler said: "I don't know how to manufacture such treasures [as Einstein] and I don't know anyone who does. I can only say, when you see one, treasure him or her."

At the conclusion of Holton's presentation, only one member of an audience of hundreds of scientists and historians offered an objection. An historian from the University of Stüttgart pointed out that Max Planck, upon whose research Einstein based his theory of the photon, was an avowed Platonist. In the same tradition, he said, was Felix Klein who played a crucial role for Einstein in developing geometrical concepts for mathematical physics.

Holton did not reply.

The one exception to this blackout on Riemann was Shiing-Shen Chern who did indicate in his paper the real mathematical background of Einstein and the role of higher-order geometry in physics.

Martin Klein began his talk with the incredible statement that "nine-

Wigner on Einstein's Isolation

"I myself first saw Einstein at the physics colloquia held at the University of Berlin each Thursday afternoon. I attended them from 1920 on. Together with other notables, M. Planck, W. Nernst, M. von Laue, to mention only a few, Einstein sat in the first row and listened to the reviews of the papers chosen for this purpose by von Laue—three or four papers every Thursday. If the review of the paper presented a clear picture, no one in the first row made any comment—most of the questions and comments came anyway from the rest of the audience. However, if the article's meaning did not seem clear, there were questions from the first row, principally from Einstein. The answers to these questions, and the questions themselves, contributed greatly to the clarification of the new information contained in the paper discussed....

The physics colloquia acquainted us with the clarity of Einstein's thinking, with his simplicity and modesty, and also with his skill of explaining. However, few of the audience knew each other personally—there were about 60 in the audience. The personal acquaintance came to most of us in the seminar on statistical mechanics which he organized.... He organized the seminar, I feel, because he wanted to establish contact with his young colleagues, because he wanted to know about their ideas and attitudes....

Unfortunately much of this had changed when he came to Princeton.... His interest, deeply devoted to a modification of the theory of general relativity so as to form a common basis for all physics and perhaps even for all science was very different from the prime interest of most of his colleagues and even the students at Princeton. Most physicists were, at that time, most interested in the application of quantum mechanics to a variety of phenomena, including the theory of atoms and molecules, and properties of solids and in particular metals, the basic principles of chemistry. This work also contributed to the unification of science but not of the fundamental principles thereof as was at (sic) Einstein's interest. Some of the mathematicians, including L. P. Eisenhart, were greatly interested in Riemannian geometry, hence the basis of relativity, but their interest was centered on the rigorous mathematics thereof, not on an extension to encompass electromagnetic and perhaps other phenomena. They were averse to speculations.

—Eugene Wigner on "Einstein and The Unification of Theoretical Physics," March 1979.

teenth century physics was a validation of Newton." Klein contrasted this with Einstein's 1905 paper on the quantized light field, and he implied that Einstein derived much from Ernst Mach, since Mach was "an antimechanist." Klein did admit, however, that Mach maintained that scientific theories were "historical accidents."

The tradition-castration continued. "Planck's work played very little role in Einstein's thought," Klein said, a theme that was developed more fully in a commentary on Klein's paper by Institute member Thomas Kuhn. "Einstein, not Planck, developed the quantum idea," Kuhn said, although he prefaced his talk with the admission that what he was about to say would "sound like heresy" to the physicists in the audience—physicists who not only knew the history but were aware of the facts from personal contact with Einstein.

The only person to respond to Kuhn's witting lie was Eugene Wigner, professor of physics at Princeton University, who jokingly objected, "We cannot, after all, throw out Planck completely, can we?"

Concerning the quantization theory, Klein remarked in passing that Einstein was not happy with it. Einstein maintained from the beginning that "there will have to be a fusion of the wave and particle notions of light," and in 1911, he remarked, "My brain is incapable of accomplishing such a thing," with reference to putting the two aspects of light together. In 1924, after the Compton effect had been demonstrated and quantization had become accepted, Einstein wrote, "We now have two theories of light which are not coherent, despite colossal work on this."

However, Einstein's doubts concerning the duality of light and his parallel objections to Niels Bohr's noncausal theory of the atom were widely dismissed by his contemporaries during the 1920s, who made ample use of the Einstein-the-freak myth already created by the Bohr networks.

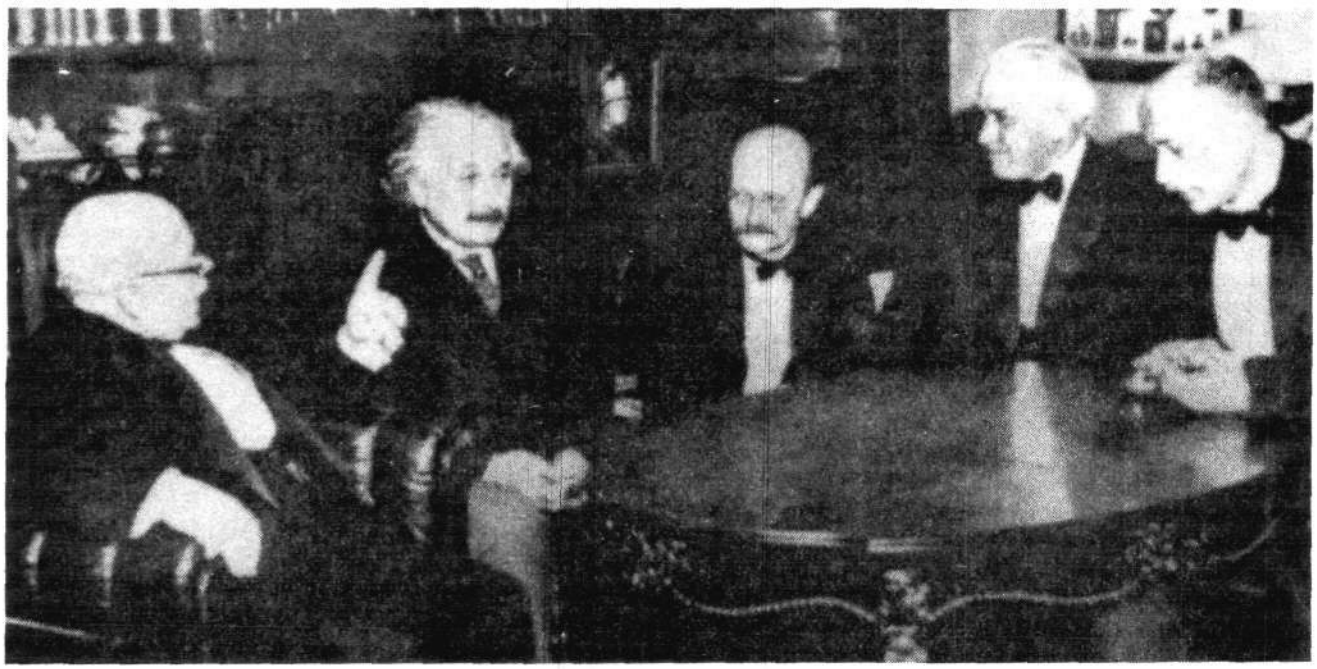
Schrödinger Dismissed

Abraham Pais continued the historical account from the 1920s up to the time of Einstein's death in 1955. "Until 1923, Einstein was the only one believing in light quanta, but after 1926 until the end of his life, he was the only one against it," Pais said. Clearly, Einstein's perception of the problem never changed, while most of his contemporaries vacillated from one extreme to the other around what Einstein explicitly called an "heuristic theory."

Pais then continued the Einstein chronology up to the Great Debates of the late 1920s and early 1930s between Einstein, who was arguing to preserve causality in microphysics, and Bohr, who was arguing against this. Then Pais looked down at his watch. "Since I'm short of time [he was about halfway through an hour-long lecture], I'll skip over my comments on Erwin Schrödinger," he said, thus eliminating from the discussion Einstein's major cothinker in the battle against Bohr.

Pais's closing statements were even more incriminating. He described an episode in which Max Born was crestfallen after Einstein rejected some of his work. A scientist in the audience then asked who, if anyone, Einstein considered to share his point of view as a physicist. Pais answered, "Only two men fit that category, Erwin Schrödinger and Max von Laue." Thus, Pais not only eliminated mention of Schrödinger for "lack of time." but had no intention of even mentioning von Laue, Einstein's cothinker, who also was a close associate of Max Planck.

The crux of the matter is this. Of all Einstein's contemporaries, Erwin Schrödinger most closely and self-consciously followed the explicit tradition and epistemological framework of the hydrodynamics school



Einstein (second from left) with fellow Nobel Prize winners Nernst, Planck, Millikan, and von Laue.

that traced its origins back to the epistemology of Plato, to Leibniz, to Riemann and Cantor's notion of the transfinite, and then to Felix Klein at Göttingen.

Humanists Versus Nominalists

The main point of contention around Schrödinger during the Great Debates was his causal electrodynamic model of the atom, which was based on the most advanced geometrical mechanics from the Göttingen tradition, versus the ad hoc probabalistic models of Bohr and Werner Heisenberg. Contrary to these Aristotelians, the hydrodynamics school was defined by the use of geometrical and phase-space notions to determine the relation of the singularity to the developing manifold.

Historically, this school of science has been strategically allied with the humanist political movements, including the Leibnizian networks whose activity culminated in the American Revolution in the 18th century, and in the industrialization of Germany during the latter part of the 19th century.

The humanist-scientist faction has always been in battle with the nominalist, empiricist, ad hoc school, from Aristotle, to Newton, to Maxwell—the forebears of the Niels Bohr approach. The humanist approach begins with the recognition that the universe is coherent, including the lawfulness of man's mind and his creative capacities. Therefore, it is no accident that the opponents of this view simultaneously cover up the Riemannian tradition, deny causality, and mystify the creative process.

The relationship to politics is explicit. Nominalist Bertrand Russell, for instance, began his career by publishing an attack on Riemann's notion that the metric of physical space is physically determined. The same Russell headed the British Aristotelian Society, worked for British intelligence, and called for a nuclear attack on the Soviet Union after World War II.

Einstein inherited valuable concepts from the humanist tradition, including Riemann, but, tragically, he was cut off from its most advanced concepts.

The extent of this tragedy can be seen in the ludicrous physics—post-Einstein physics—presented in the various symposia.

The talk by Professor Dennis Sciama typifies the problems of current cosmology. The core of the problem is Sciama's taking singular solutions to the Einstein field equations, such as black holes, as realities, instead of taking them as reason for improving the quality of the conceptions. Simultaneously, Sciama used these singular solutions to cover up the importance of crucial findings, such as anomalous energy sources.

At the opposite end of the magnitude scale, but with the same epistemology, was Dr. Steven Weinberg and his talk on quarks, the alleged ultimate particles whose properties are naturally given and otherwise inexplicable. Einstein would have been even more horrified by this display of quarkery than he was by the Bohr conception of the atom. Fortunately, this particular theory may self-destruct as more and more kinds of quarks are postulated to explain new experimental results.

The other big gun in this field, Stephen Hawking, represents the union of quarkery and big bang cosmology. Although he obtained the interesting computational result that black holes do eventually give off energy, his work also avoids the basic question of plasma physics in shaping real cosmology.

One of the more interesting (and not at all ludicrous) of the scientific papers was given both at Princeton and at the New York Academy of Sciences by Dr. John Archibald Wheeler of the University of Texas at Austin. Wheeler has distinguished himself in a broad variety of areas, including atomic physics in the 1930s, nuclear physics and collective theories of the structure of the atomic nucleus, work on U-235 and fission, and work on general relativity in the 1950s.

Wheeler's talk, "Beyond The Black Hole," represented a number of good instincts enmired in the morass of 20th century physics-gone-wrong. He began by presenting several paradoxes in current physics, such as the black hole and the particle-wave duality in light. Then he threw out a number of suggestions for beginning to resolve these paradoxes.

First, Wheeler pointed out that every cosmologist, including the "big bang" school, admits that at one time the current laws of the universe did not exist and, therefore, that they developed. Wheeler did not give a criterion for the development of these laws, but he suggested that the basis of activity in the universe is a "self-interaction" of matter. He heuristically diagrammed this with a large *U* representing the universe, with an eye sitting upon one end of the *U* looking at the other end. Human consciousness is not necessary for this process to be initiated, Wheeler said; It occurs continuously throughout the universe.

In his talk at the Institute for Advanced Study, Wheeler said that the generation of new laws depended on the statistical addition of many of these self-interactions, implying a randomness to the process. But at the New York Academy Proceedings, Wheeler modified this notion, saying that the summation of many small interactions is not to be taken in the thermodynamic statistical sense; however, he did not supply an alternative concept.

Scientific Renaissance

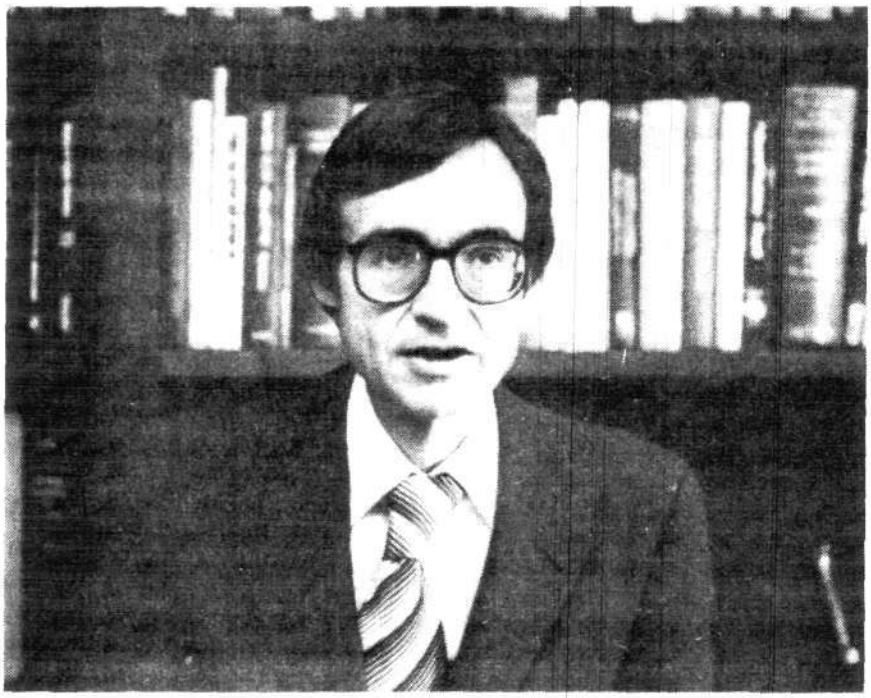
Physicists like Wheeler and Wigner are the best that is left in the wake of the onslaught of the Bohr crowd. As for the younger physicists and students, an entire generation has been lost. The most fitting tribute to the memory of Einstein, to the positive side of Einstein, would be to revive the Riemannian tradition and teach this generation to master the science on which Einstein's work was actually based and to go beyond it.

—*Ned Rosinsky*

Editor's Note: Many of the physics issues raised in this report will be discussed at more length in a forthcoming special Fusion *issue on astrophysics.*

Note

1. Einstein's support for Zionism exactly parallels this weakness, to the extent that Zionism assumes a fixed structural self-conception of Jews as belonging to a race. This view conflicts with the humanist Judaism of Philo, which locates human existence in general human progress of the species.



Sawhill: He demanded—and he got—an energy crisis management plan by April 1.

The 6th Energy Technology Conference

Downhill with Sawhill

The Sixth Energy Technology Conference held in Washington, D.C. Feb. 26-28 was a disappointment to many of the researchers in industry who were expecting a round-up of promising energy technology advances from the past year and for the future. Most of the sessions in the industry-sponsored conference centered on various "soft" technologies, conservation, and the environment.

At last year's conference, on the contrary, four panels dealt with aspects of fusion development, and other panels concerned magnetohydrodynamics and advanced technologies for nuclear energy.

This year, advanced research and development areas received only lip-service. Although the attendance and the number of exhibits had increased, many industrial R & D directors and scientists decided not to attend. And, in fact, the increased number of exhibits reflected more the Carter administration's hopeful push into solar, biomass, and other basically nonindustrial small-scale energy systems than an increase in advanced technology.

Crisis Management

Aside from the not-too-successful attempt to convince industrial energy users that perhaps their employees' biological waste could be used to fuel their production plants, the conference participants were subjected to a luncheon presentation by John C. Sawhill, president of New York University and former head of the Federal Energy Administration. Although it is not listed in his credentials, Sawhill is also cochairman of the Aspen Institute's Committee on Energy, a leading advocate of reduced energy usage, austerity, and soft technology.

Sawhill's talk, titled "Energy—A Call for Action," centered on the fact that despite his warnings of the coming crisis when he was head of the FEA, "we have failed to develop a comprehensive approach to solving our energy-related problems, and as a result, are today floundering."

Sawhill then outlined a nine-point program to deal with the oil crisis. In addition to decontrol of domestic oil and gas prices, reform of utility price regulation, and other measures that would drive the price of energy through the ceiling, he called on the nation to develop an energy crisis management plan that could be implemented by April 1. " . . . We have no Energy Crisis Management Plan currently available to swiftly curtail demand if we have another disruption in our oil supply or if the Iranian situation continues for an extended period. Yet, under the International Energy Agreement [developed by Henry Kissinger] we are compelled to develop such a program."

Sawhill insisted that in addition to the president's already announced consideration for standby gasoline rationing, the plan must include "taxation measures to increase prices of gasoline and heating oil . . ."; that is, federal control of the price and thus the use of domestic and imported energy.

Looting Mexico

The companion piece to Sawhill's crisis management was his recommendation number 5—developing a "hemisphere policy" with Mexico and Canada. Better known in Sawhill circles as a Common Market for the hemisphere—something oligarchist North Americans have advocated for 100 years—Sawhill made it clear that the real purpose of this recommendation is not cooperation for development but looting Mexican oil. "Mexico must be viewed as an important partner to the United States in the development of a hemisphere energy policy. It is the one known source of huge new oil supplies," he said.

Precisely what this means was spelled out in a report published a month earlier by the Blyth Eastman Dillon investment house, "North American Energy: A Proposal for a Common Market Between Canada, Mexico, and the United States." Originally pushed back in the late 1960s as Project Independence, this Common Market idea specifies "steep" taxes, "vigorous conservation mea-

sures" to keep "consumption increases to a nominal level," and "a large, low-cost labor force" for the United States of now-unemployed Mexicans.

Antidevelopment

In short, the Sawhill plan, like the Blyth Eastman Dillon plan and Project Independence, is exactly the opposite of the technology-transfer deals and nuclear power program discussed by Mexican President Lopez Portillo and French President Giscard d'Estaing in Mexico at the time of the Sawhill speech. (See international news section, this issue.) And this striking comparison is one that any of the export and growth-minded industries at the conference could not fail to miss.

Never Again?

The sponsors of the Energy Technology Conference, the American Gas Association, Gas Research Institute, Electric Power Research Institute, and National Coal Association, *probably didn't know what they were* in for when they asked Sawhill to speak.

But with enough negative feedback, and, more important, with a radically altered international and domestic political situation in time for next year's conference, its sponsors could turn the event into a showcase for the creative innovation that is the history of U.S. industry.

—Marsha Freeman

Arthur Kantrowitz:

A 'Time of Timidity'

One of the few bright spots in the Sixth Energy Technology Conference was the presentation Feb. 28 by Dr. Arthur Kantrowitz, the founder and recently retired chairman of Avco Everett Research Laboratory, pioneer in magnetohydrodynamics.

Kantrowitz outlined the history of the U.S. MHD effort and described the present climate in the country for scientific and technological advance as a "time of timidity." The history of the MHD program is indicative of the problem, he said.

By 1964, Kantrowitz said, Avco had developed a Mark V MHD generator that had set a world record, producing 34 megawatts of power for 1 minute. In 1966, Avco submitted a proposal for a pilot MHD plant to the Atomic Energy Commission and the Department of the Interior, with Avco willing to pay half the cost for a demonstration power plant.

"The proposal was only accepted in Moscow," Kantrowitz said, where the U-25 MHD facility has been in operation and there is a commitment to build a commercial plant within six to seven years. "Maybe they will sell us the license," he said. He characterized the current Department of Energy program as continuing the approach it has followed since 1966—"marking time."

Making The Crisis Manageable

"When you make great decisions, you never have certainty. At this time, the United States has decided it cannot take risks, so we don't go ahead . . . . The problems in MHD are not technical. Twenty studies have shown the attractiveness of MHD. This problem in MHD is a microcosm of what has happened across the board in energy.

"We can turn the energy crisis into something manageable. We can have MHD and lots of other things. We could build breeders in less than 35 years with a World War II-kind of effort. MHD won't take 20 years. We have to summon up the courage that once characterized this country."

NAACP Head Reaffirms Nuclear Policy

At a March 3 conference on energy sponsored by the National Association for the Advancement of Colored People in Hartford, Conn., NAACP board chairman Margaret Bush Wilson reaffirmed the organization's official policy commitment to nuclear energy development.

Wilson focused her presentation on the historical development of labor power, specifically the question of human potential and energy. Referencing her own participation in the Tennessee Valley Authority, she presented the 1930s electrification program in the United States as the appropriate model of the role of advanced energy forms in transforming labor.

"The United States is the most exciting country on earth. . . . We have no aristocrats. We have a common heritage. We built the nation. Energy is the new frontier and energy means energy development and energy growth," she said.

When the NAACP board first adopted a pronuclear program in December 1977, the organization came under attack from liberals who challenged its "right" to represent the black community on the grounds that energy is not a "civil rights" question.

A New Form of Slavery

Speaking to this point, Rufus McKinney from the American Association of Blacks in Energy and the South California Natural Gas Co. told the conference: "Blacks have no business in the Sierra Club or the Clamshell Alliance. Those people who impose their environmentalist objectives on energy development are in basic conflict with blacks and poor people. Lack of access to science is slavery."

The Magnetic Mirror Approach to Fusion Energy

by Charles B. Stevens

ALTHOUGH THE TOKAMAK is the most advanced experimental approach to magnetically confining thermonuclear fusion plasmas, the mirror machine approach holds the greatest promise for leading to economical fusion energy and extending the frontiers of science.

Both types of machines confine a hot plasma magnetically, but in a tokamak the magnetic system is circular and closed, while in a mirror system, the magnetic system is open-ended with intense magnetic fields, "mirrors," at both ends of the confinement area (Figure 1).

Why is the second horse in the U.S. magnetic confinement program such a sure bet? For all intents and purposes, the tokamak has been demonstrated experimentally as a scientifically feasible approach to harnessing nuclear fusion reactions. Yet, its principles of operation are not understood theoretically, and its boundaries for evolving more advanced and potentially more economical configurations—although open to interesting new possibilities—in no way are defined in terms of their probability for success or generation of significant new scientific advances.

In the mirror approach the situation is just the opposite. By the early 1980s, the mirror will demonstrate scientific feasibility.

The mirror machine concept was derived directly from astrophysics and was the subject of the first manmade, large-scale astrophysics experiments in the 1950s. Unlike any other approach to fusion, mirror experiments have corroborated the extensive theoretical models developed for their operation. At the same time, the mirror experiments have surprised researchers by demonstrating well-defined, new possibilities—such as the direct conversion of fusion plasma to electricity—that can lead directly to very economical fusion energy production in all its forms, including the fusion torch and fusion-fission hybrids.

Magnets shaped like the stitching on a baseball have helped scientists determine the best method of forming plasmas inside "magnetic mirror" fusion energy devices.

The photographs in this article, taken by David Proffitt, are courtesy of Lawrence Livermore Laboratory at the University of California.

Astrophysical Theory

Scientists determined 50 years ago that stars obtain their gigantic energy outputs from nuclear fusion reactions. Generally, these reactions involve the fusion of the lightest element, hydrogen, to form the next heaviest element, helium (Figure 2). In fact, similar fusion reactions of lighter elements into heavier elements are responsible for the creation of the vast majority of matter—all the elements up to iron.

To ignite fusion, matter must be heated to temperatures of tens of millions of degrees. At these temperatures the electrons of atoms are stripped away from their nuclei and all of the matter present is *ionized*; that is, transformed into the plasma state.

In stars, the hot plasma gas is *confined*—prevented from simply diffusing throughout space—by the gravitational force that the huge mass of the star exerts. Generally, the fusion energy generated in stars escapes only in the form of electromagnetic radiation (light, infrared, and X-ray radiation). However, enough of the fusion energy generated is retained to maintain the plasma gas at a high enough temperature to sustain the fusion reaction.

This method of fusion energy generation is effective, but extremely inefficient and wasteful. Measured in terms of power output to weight ratio, a mouse is tens of thousands of times more efficient than a star!

To be efficient, a fusion energy generator must use an alternative to the gravitational confinement system that the stars exhibit. One alternative, *magnetic confinement*, was first experimentally observed by Sir William Gilbert in the 17th century. Gilbert noted that an ordinary flame, a plasma, is affected by a magnetic field. A more modern demonstration of this is the effect of a magnet on a fluorescent light, which contains a neon plasma.

When a plasma is subjected to a magnetic field, the charged particles of the plasma (the positive ions and negative electrons) are trapped into spiral orbits along the

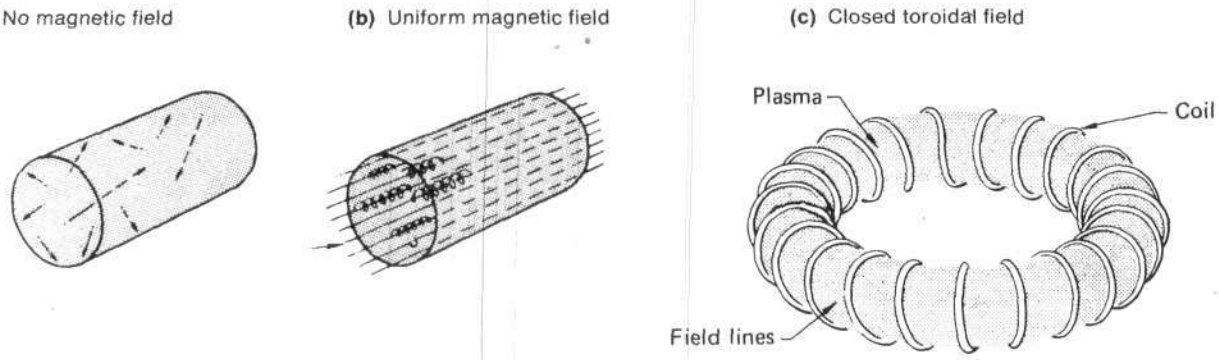


Figure 1
OPEN AND CLOSED MAGNETIC CONFINEMENT

In **a**, *arrows denote the random motion of an unconfined plasma in a cylindrical vessel. In* **b**, *an axial magnetic field is applied to the plasma in the cylinder. The electrically charged electrons and nuclei are then trapped into spiral paths along the magnetic field lines. This type of magnetic confinement is incomplete, however. For complete plasma magnetic confinement, the ends of the cylinder would have to be brought together to form a torus, as shown in* **c** *or closed off, as shown in Figure 3.*

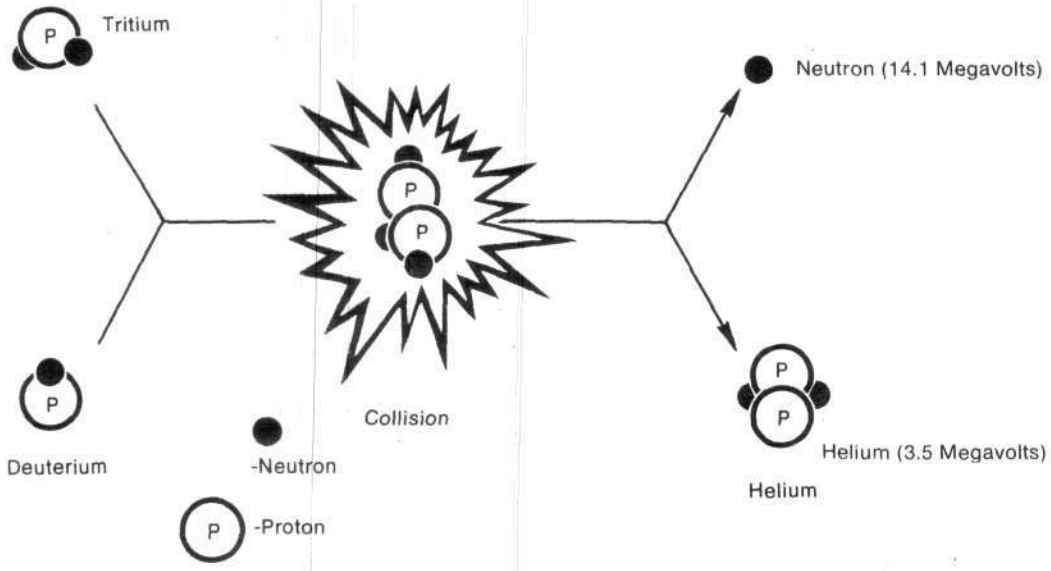


Figure 2
THE FUSION PROCESS

To achieve fusion, two nuclei of hydrogen, the basic fusion fuel, must join together. This produces one helium nucleus for every two nuclei of hydrogen, and liberates energy in the process. There is a net energy gain because the end-product nuclei weigh less than the nuclei of the input fuel. During the nuclear reaction, this mass difference is converted to energy of various forms.

In the deuterium-tritium fusion process shown here, a deuterium nucleus (which consists of one neutron and one proton) fuses with a tritium nucleus (which consists of one proton and two neutrons). The deuterium is a form of hydrogen found naturally in water, and the tritium is another isotope of hydrogen formed in nuclear reactions. The two protons and two neutrons combine to form a stable helium nucleus, with the extra free neutron flying off with four-fifths of the released energy in the form of kinetic energy. (The stable helium atom carries the remaining one-fifth.) This kinetic or "moving" energy can then be easily converted to heat or electricity. The energy needed to start the deuterium-tritium reaction is 10 keV, while the energy produced is 17,600 keV.

magnetic field lines. As the strength of the magnetic field increases, the radius of spiral orbit decreases.

In tokamaks, the magnetic field lines are formed simply into closed circles so that the magnetic field traps a donut-shaped plasma. In the mirror system, the magnetic field lines are not closed and the hot plasma is free to flow out of the device along the magnetic field lines. For this reason, simple mirror devices are called linear, open-ended magnetic confinement systems, in contrast to the circular, closed tokamak-type of device.

The First Mirror Machines

When research began on fusion in the early 1950s, the mirror was one of the first concepts developed. The first theoretical projection for a mirror reactor consisted of a cylindrical vacuum chamber and two magnet coils that slid up and down the cylinder. The two coils form a mirror magnetic field, as shown in Figure 3. As the coils are moved together, they compress and heat the trapped plasma. Then, as the plasma builds up energy from fusion reactions, it expands against the magnetic field, inducing an electrical current in the external coils.

In this way, the mirror machine can directly convert fusion plasma energy to electricity, without the intermediary step of heating steam for a conventional turbine. An additional advantage is that because the mirrors must operate at high temperatures in order to get significant confinement of the plasma, advanced fusion reactions (those using hydrogen fuel) based on the mirror approach would have little or no radiation from the high-energy neutrons that are discharged in the lower-temperature fusion reaction using deuterium-tritium fuel.

In the first mirror experiments, macroscopic and microscopic instabilities arose in the plasma and compression could not achieve the heating required for fusion to take place. After more than 20 years of research, all these instabilities were conquered, and neutral beams—beams of energetic neutral atoms, such as deuterium, that are used in tokamaks—were developed to heat plasmas up to and beyond thermonuclear ignition temperatures (Figure 4).

Although everything worked well, the energy cost of the neutral beams when extrapolated from these results to an actual reactor, was too high; thus, in the early mirror machines, a stable mirror plasma configuration could not go much beyond breakeven—the point where the machine produced more fusion energy than the energy required to heat the plasma to fusion temperatures. In 1975, results on the Lawrence Livermore 2XIIB mirror machine, described below, opened up two new general lines of possibilities, field reversal and the tandem mirror, which are expected to produce stable confinement.

Mirror Geometry

If the plasma flows out the open ends of a mirror device were unconstrained, the device could never sustain an energy-producing fusion plasma. However, because the orbit radius decreases with increasing magnetic field strength, it is possible to achieve a limited type of confinement using linear magnetic fields.

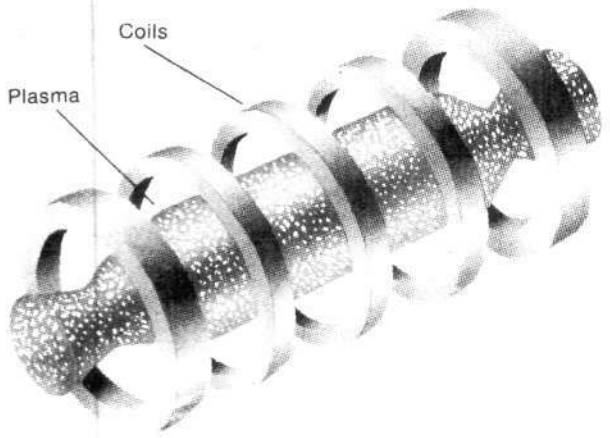


Figure 3
MAGNETIC MIRROR CONFINEMENT

As the plasma particles encounter the stronger magnetic field at the ends of the mirror, the spiral paths of the electrically charged plasma electrons and ions become smaller and smaller and the plasma particles are "reflected" back into the center of the mirror. However, some particles escape out the ends of the mirror.

By arranging the magnetic field so that its strength increases at both ends, as shown in Figure 3, then a substantial portion of the plasma contained between these two points will be reflected back into the center and essentially trapped there.

This type of mirror magnetic confinement is exhibited naturally in the ionosphere of the earth. The ionospheric plasma is trapped by the earth's magnetic field, which increases in strength at the north and south poles. Scientists observed this in the 1950s, when nuclear devices were detonated in the stratosphere and they were able to see the evolution of the thermonuclear plasma as it reacted with the earth's natural magnetic mirror trap.

The Loss Cone

Those plasma particles (both electrons and ions) that are not reflected and are lost out the open ends of the device have specific velocity distributions. That is, the particles lost have a ratio of their velocities along the magnetic field lines to their spiral velocity that is greater than some determinable value. And this value, if graphed in the three-dimensional velocity space (a graph that gives the values for velocity in the x, y, and z directions), will define an upside-down three-dimensional cone. All the particles within this cone area are lost out the ends of the cylinder.

This loss cone has an important effect on the overall properties of mirror devices. Because of the loss cone, mirror plasmas can never have what is called *thermody-*

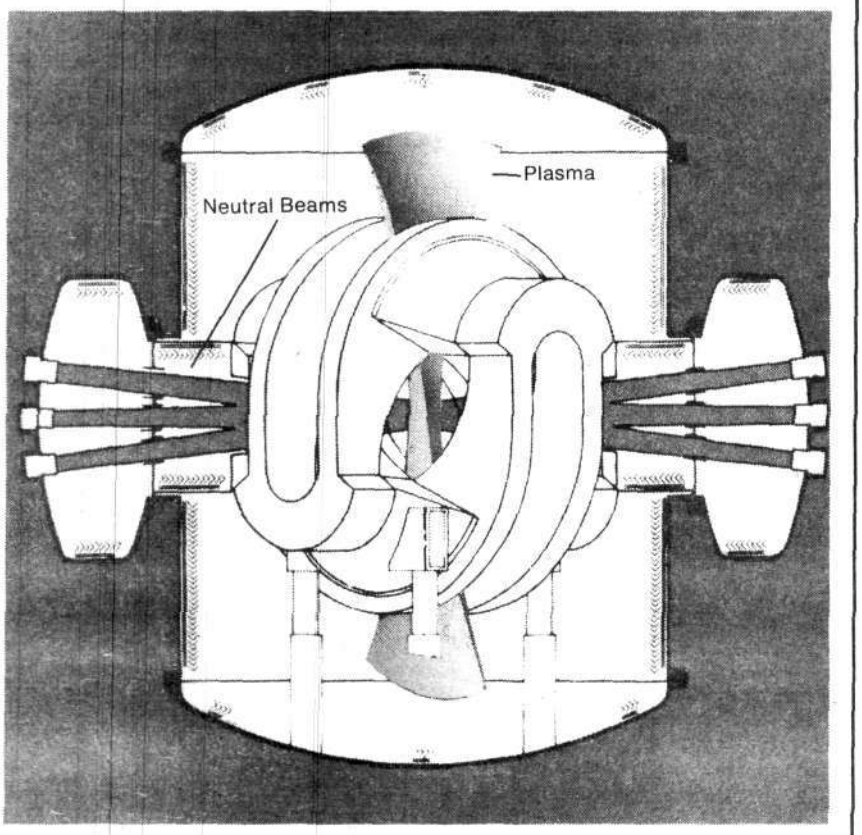


Figure 4
NEUTRAL BEAM INJECTORS IN THE MFTF

Injected neutral beams are shown on their way past the superconducting magnet coils toward the target plasma in a schematic of the Mirror Fusion Test Facility. Note how some of the plasma excapes out the top and bottom regions of the coils. The MFTF experiment intends to minimize this loss, while disposing of those particles that do manage to leave.

namic equilibrium distribution, an average distribution of energy (average in the same sense that there is an average age distribution in the population, with smaller groups of very old and very young persons and most persons clustered in the middle). The loss cone causes holes in the bell-shaped Gaussian curve that normally characterizes this equilibrium distribution, causing various plasma instabilities.

In addition, the loss cone produces microinstabilities in the plasma that inhibit plasma confinement. However, more recent experiments with mirror-type machines that increase the size of the confinement device have effectively nullified these instabilities.

There are two major aspects of mirror confinement that are advantages over tokamak systems of confinement. First, mirror machines operate better at higher temperatures; second, the geometry of the magnetic field determines the macroscopic stability of the system. Only recently, with the Princeton Large Torus results last summer, has the tokamak begun to exhibit this kind of behavior.

Temperature

Once the plasma is trapped in the mirror, the chief way in which particles escape is through collisions that change the particle velocities and put them in the loss cone described above. In plasmas, however, collisions between individual particles are not important; the electrostatic field of the plasma as a whole is chiefly responsible for collisionlike changes in individual particle velocities. And in a plasma, this effective collisionality *decreases* with *increasing* temperature. Therefore, a mirror plasma's confinement improves with increasing temperature.

The mirror has already achieved the highest temperatures of any fusion device, greater than 200 million degrees, using the same neutral beam injectors that are used on tokamaks.

Stability

In the early experiments with the mirror system, the magnetic field geometry of the simple mirror shown in Figure 3 proved to be unstable. Whenever the plasma came up against a magnetic field that was concave away from it, the plasma would exchange places with the field and thus macroscopically escape the mirror. As Edward Teller has described this, picture the plasma behaving like a ball of jello that is held between two rubber bands.

To get around the problem of concave inward magnetic field geometry, experimenters developed a new geometry for the field coils, called a *minimum B* or *yin-yang magnet* configuration. These C-shaped coils (Figure 5), dubbed yin-yang after the Chinese terms representing the duality of opposing principles, stabilize the confined plasma by creating a magnetic field or *well* that increases in every direction from the plasma center.

Experimental Results

Although there are many mirror-type experiments in laboratories throughout the world, only the mirror project at the Lawrence Livermore Laboratory in Livermore, Cal-

ifornia approaches the scale of effort in mainline tokamak experiments. The major experiments now in operation at Livermore are the 2XIIB pulsed magnetic mirror machine and the Tandem Mirror Experiment, the TMX. And under construction at Livermore is the world's largest mirror experiment, the $94.2-million Mirror Fusion Test Facility, the MFTF, scheduled to begin operation in 1982.

Other smaller mirror experiments are operated in Japan, Western Europe, the Soviet Union, and at other labs in the United States.

Until the startling results in plasma confinement and density achieved on the Livermore 2XIIB machine in 1975, it was generally believed that the mirror would never be an economical fusion energy source. Research was pursued chiefly for its general benefits to plasma theory and the possibility that the mirror would make a good engineering test facility, which is concerned mainly with materials testing.

Livermore had tested a variety of simple mirror machines before the 2XIIB was created: Felix, Table Top, Toy Top, and Squash Court were the earliest machines with solenoid coils, and Astron, a more sophisticated machine, experimented with field reversal. In the 1960s, the 2X machine tested the magnetic well field configuration, while another machine, Baseball (so named because its superconducting magnet was shaped like the seams of a baseball), concentrated on the use of beams to build up the plasma density. Later, the 2X and a version of Baseball were merged into the 2XIIB machine, whose results made mirror history in 1975.

The problem with the early mirror machines was that although mirrors worked according to theory, that theory predicted that mirrors could never go beyond energy breakeven to produce net fusion energy.

The 2XIIB results from 1975, shown in the table together with more recent results (1977) from the reversed field experiments discussed below, demonstrated that the mirror could reach much higher betas than previously believed practical. (Beta is a measure of the efficiency with which a magnetic field confines a plasma, specifically, the ratio of the plasma gas pressure to the pressure of the magnetic field.) In fact, the 2XIIB experimental accomplishments opened up entire new realms of possibilities of how to use mirrors in economical fusion systems; specifically, the tandem mirror and field reversal.

The Tandem Mirror

The tandem mirror idea, which will take the mirror program back to something like its originally simple cylindrical configuration, was developed independently in the United States and the Soviet Union around 1975.[1] The Soviets are just about to bring a tandem mirror experiment on line and the Japanese have had one working since last summer, with intially positive experimental results reported. Livermore's Tandem Mirror Experiment, or TMX, is just now going into operation. (Figure 6 shows the TMX schematically.)

The basic idea of the TMX is to use the complex mirror with its large assemblies of neutral beams (There are 24

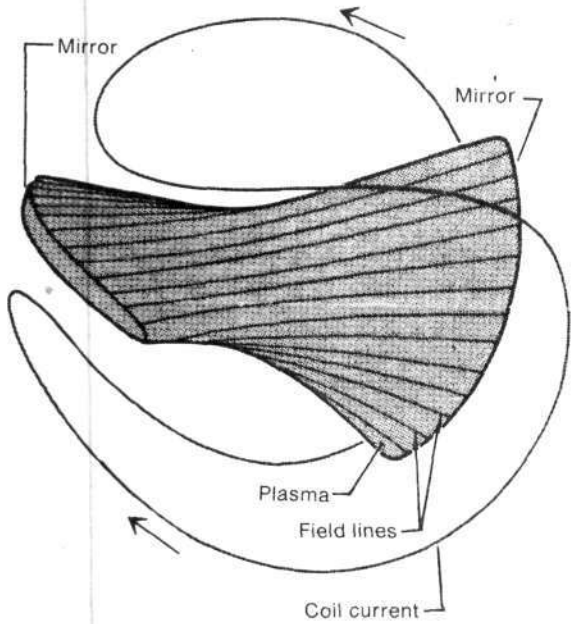


Figure 5
THE MAGNETIC WELL MIRROR CONFIGURATION
A magnetic well, which is also known as a yin-yang or baseball configuration, has a magnetic field strength that increases everywhere with increasing distance from the center of the plasma it confines; that is, the magnetic field is concave inwardly. The electric current that produces such a configuration follows a path that resembles the seam of a baseball.

TYPICAL PARAMETERS OF THE 2X IIB MIRROR MACHINE

ASPECTS	1975	1977
Machine parameters		
Neutral beam		
Aim	Head on	Tangential
Voltage (kV)	20	20
Current (A)	300	500
Duration (ms)	10	10
Stabilizing Stream	Plasma gun	Gas box
Magnetic field		
Field strength B_{vac} (kG)	6.7	6.7
Mirror ratio	2:1	2:1
Duration (ms)	10	10
Length mirror-mirror L (cm)	150	150
Plasma parameters		
Density n (cm^{-3})	5×10^{13}	1.5×10^{14}
Ion energy W (keV)	13	13
Electron temperature (eV)	85	140
Beta $B = 8\pi nW_i/B^2_{vac}$		1.7
Field reversal parameter $\Delta B/B$	0.6 0.3	0.7
$n\tau_E$ ($cm^{-3}s$)	7×10^{10}	1.0×10^{11}
Plasma size		
Radius R_p (cm)	7	6
Length L_p (cm)	20	16
Volume (liters)	5.5	3.2
Vacuum gyro radius ρ_i (cm)	3.5	3.5
R/ρ_i	2.0	1.7
L/ρ_i	43	43

Source: Lawrence Livermore Laboratory

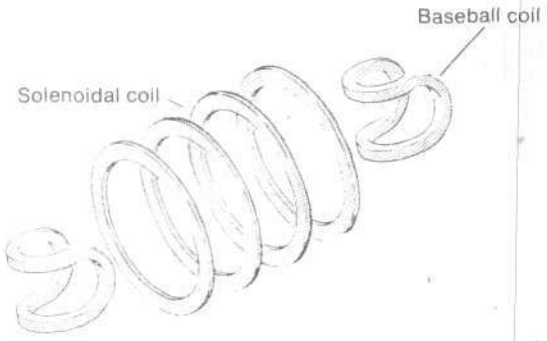


Figure 6
THE TANDEM MIRROR MACHINE (TMX)
The TMX has magnetic field coil configurations in the shape of the stitching on a baseball at each end of a solenoidal magnet coil.

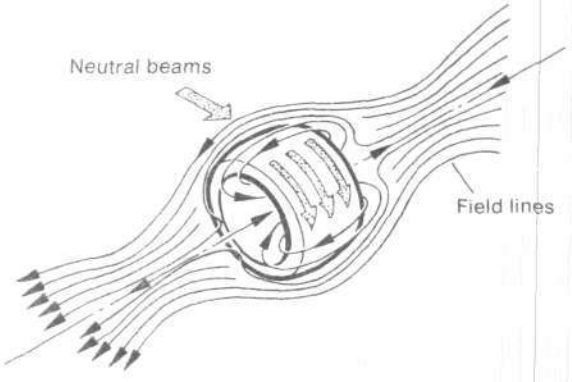


Figure 7
FIELD-REVERSED PLASMA
In this field-reversed mirror configuration, the lines with arrows attached represent the directions of the magnetic field lines. When neutral beams are introduced as shown into the plasma, they induce a plasma current around the hollow cylinder that closes the magnetic field lines around the plasma.

neutral beam injeectors, each the equivalent of 20,000 electron volts) as an end plug for a long cylinder. The cylinder, which consists of a very simple solenoidal magnetic field, contains the fusion plasma while the end plug mirrors contain the nonreacting plasma.

Electrons tend to escape out the ends of a mirror before the ions do. Therefore, positive electrical charge builds up in the mirror. This electrical charge then can be used to stably repel plasma from entering the mirror, turning the mirror into an efficient end plug.

The TMX mirror configuration has a number of major advantages: first, the mirror machine can go way beyond breakeven; second, the simple cylindrical configuration that traps the fusion plasma in the mirror end plugs makes the construction of the reactor much easier and potentially much cheaper; and third, the simplicity of the mirror design means that modular construction can allow easy access and repair.

The physics of the TMX are quite straightforward in terms of the working principles of a mirror machine and will be tested in terms of the mirror solenoid linkup in the TMX experiment over the next year. The larger Mirror Fusion Test Facility at Livermore will experimentally demonstrate the parameters needed for reactor end plugs. Given successful operation of MFTF, which is highly probable, another mirror cell and solenoidal plasma will be added to conclusively demonstrate the scientific feasibility of the tandem idea.

Field Reversal

Without doubt, field-reversed configurations are the most likely form of what will be the advanced fusion generators of the 21st century, even though they are not yet experimentally demonstrated.

In a field-reversed plasma, the plasma literally confines itself, achieving betas in excess of 100 percent (see Figure 7). In a reversed field mirror system, neutral beams induce a plasma current that generates a magnetic field. This field then interacts with the externally generated magnetic field to produce a donut-shaped, closed magnetic field configuration that then traps the plasma very efficiently.

The Mirror Fusion Test Facility at Livermore will carry out major experiments on field reversal, and initial investigations are continuing on 2XIIB.[2] Although the 2XIIB has not yet achieved full reversal of the field, experimental results show the tendency toward reversal. As can be seen in the table, the field reversal parameter delta B/B increases from .3 in 1975 to .7 in 1977. A parameter of 1 is need for actual field reversal.

The Grad-Hogan theory, originally developed for tokamaks, also has major applications to field-reversed mirrors. Developed by the magnetohydrodynamics team under Dr. Harold Grad at the Courant Institute of Mathematical Sciences at New York University, the theory provides a unique method of analyzing the dynamics of field structures that are undergoing major changes in their geometries.[1] Specifically, the Grad-Hogan theory applies to the field reversal and new mirror configurations.

Field reversal, it should be noted, is not limited to

machines that use neutral beam heating. Other proposals for using ion and electron beams to induce field reversal are being pursued in a number of laboratories.[4]

Advanced Reactor Applications

From its beginning in the 1950s, the mirror machine program was partially based on the fact that the mirror's simple magnetic field coil geometries and virtually spherical shape made these machines readily accessible for diagnosis and observation. These properties would make the mirror fusion device ideal for engineering reactor studies, because ready accessibility and the largest surface-to-volume ratio of fusion plasma produced by the spherical shape are essential for this type of work.

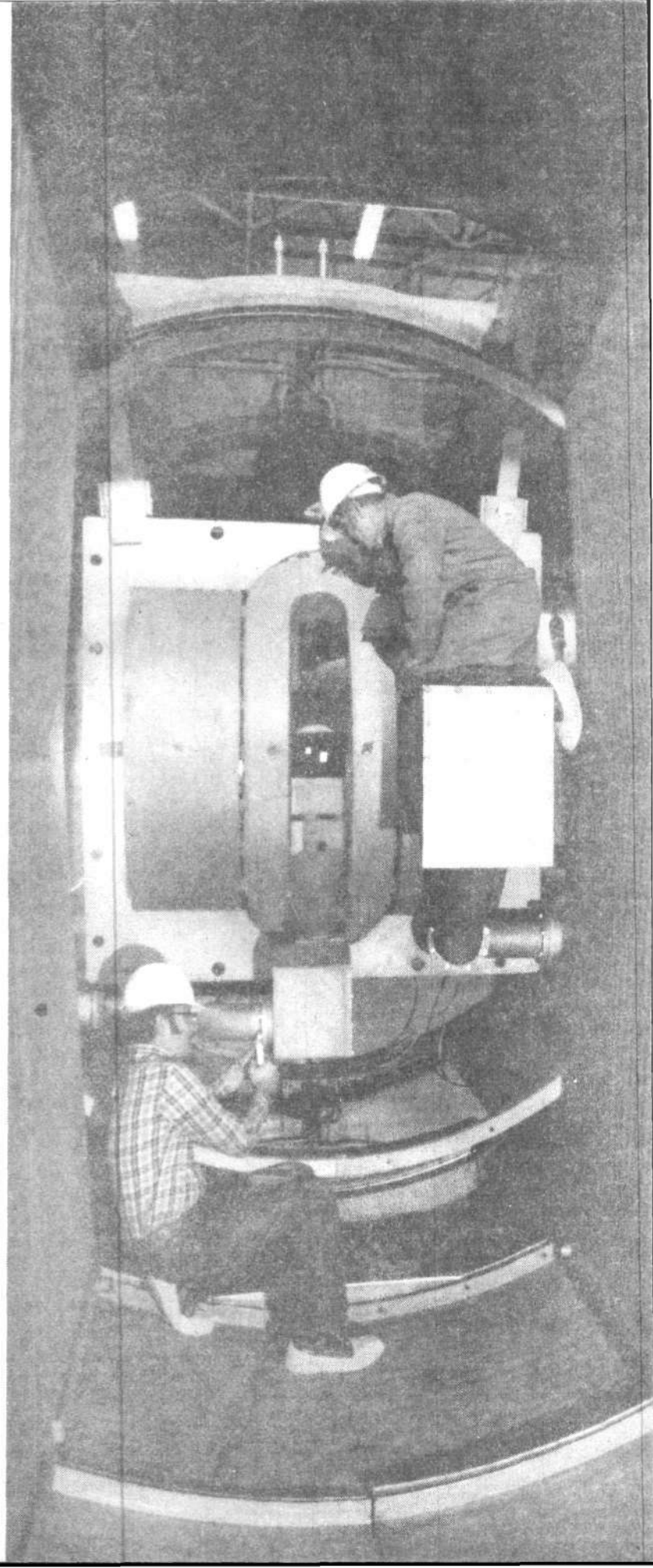
Large surface-to-volume ratio and ready accessibility are also extremely important in the case of fusion-fission hybrids. These types of reactors have blankets surrounding the fusion plasma filled with fertile nuclear material, such as uranium-238 and thorium-232, that will be transformed into nuclear fission fuel, plutonium-239 and uranium-233. The high-energy neutrons generated by the fusion reaction would induce the nuclear transformation reactions in the breeding blankets. Thus, the greater the readily accessibile surface area, the greater the fissile fuel output from such a hybrid device.

The tandem mirror design loses this advantage of a spherical plasma shape (it has a cylindrically shaped plasma), but its overall result is an improvement in the potential economy and ease of reactor construction. This is because the simple cylindrical shape and ringlike field coils that go with it can be mass produced in modular sections, making possible quick insertion of a new module when an old module fails. Similar modular construction is possible for the fertile breeding blanket assemblies in hybrids, in both the spherical and cylindrical geometries.

Charles B. Stevens, a frequent contributor to Fusion *magazine, is director of engineering studies for the Fusion Energy Foundation.*

Notes

1. G. I. Dimov, V. V. Zakaidakov, and M. E. Kishinevskii. *Fizika Plasmy* 2: 597 (1976); and T. K. Fowler and B. K. Logan. Comments on Plasma Physics, *Controlled Fusion Res.* 2: 167 (1977).
2. W. C. Condit et al., "The Field-Reversed Mirror as a D-T Power Reactor," *Proc. of the 2nd ANS Topical Meeting on the Technology of Controlled Nuclear Fusion,* Richland, Washington.
3. Phelps, D. A. et al., "Observations of the Stable Equilibrium and Classical Diffusion of Field-Reversing Relativistic Electron Coils," *Physics of Fluids* 17: 2226-35 (Dec. 1974); Humphries, Stanley, Jr., "Prospects for the Use of Proton Rings for Plasma Confinement," *Proc. 2nd IEEE Conf. on Plasma Sciences,* May 14-16, 1975, 75CH 0987-8-NPS, p. 63; Fleischmann, H. H. and Kammash, T., "System Analysis of the Ion Ring Compressor Approach to Fusion," *Nuclear Fusion* 15: 1143-55 (1975).
4. Bardwell, S. and Stevens, C. B., "Recent Breakthroughs in Tokamak Theory," *Fusion,* Oct. 1978, p. 45.



Technicians making final adjustments on the positioning of the magnetic mirror inside the Tandem Mirror Experiment.

The Delphi

Writing Off Scientific

by Mary Gilbertson

MOST PROMINENT U.S. SCIENTISTS may never have heard the term Delphi technique, but they probably have been victims of the Rand Corporation's vast Delphi project over the past 30 years—a project that is the greatest single impediment to U.S. scientific research today. The Rand Delphi project was key in giving legitimacy to the zero-growth, low-technology movement and in destroying the idea of scientific progress as breakthroughs at the frontiers of science.

The Delphi project began quietly in 1950 under the rubric of "military research." Its aim was to limit and control the frontiers of scientific and technological breakthroughs by manipulating both scientific and science policy. Initially the project work was classified, but in 1962, Rand Report RM-727 was declassified and abridged to allow for more widespread use of the Delphi method to *bring science and technology policy under control.*[1]

Today the Rand Delphi technique predominates in boardrooms, classrooms, and conference rooms across the country—anywhere science and technology policymaking is discussed. Almost every facet of science policymaking has been run through the Rand Delphi mill—from the U.S. Department of Energy and leading U.S. industries, to the United Nations development program and key East bloc research centers. (See box, p. 42 for list of some Delphi projects.) In 1969, the Delphi studies, as Rand calls them, numbered in the hundreds; today, Rand counts thousands of Delphi studies.

Two points should be stressed at the outset. First, the Rand development of the Delphi technique is a continuation of the World War II Strategic Bombing Survey and other psychological warfare techniques that were part of British geopolitics. The British were concerned with containing U.S. science, especially atomic physics, to control its use for their own purposes. This meant preventing the "Atoms for Peace" program that President Eisenhower proposed, because such a world development project would have established the kind of U.S.-Russian entente that the British had feared and fought against since the U.S. Civil War. As documented elsewhere, Britain has always made science and scientists a top priority for

Technique
Discovery

subversion, and since the 18th century, the British Royal Society, and later groups like the Aristotle Society and the British Association for the Advancement of Science had aided the fight for the British colonial system.[2]

Second, the Delphi technique could not have succeeded in penetrating American industry, as well as academic and scientific circles, if key management people had not fully agreed with the antiscience, antitechnology policy outlook the Delphi principle was designed to promote. The most prominent example of this is the Department of Energy, where the Delphi method predominates under the guidance of long-time Rand staff members, Energy Secretary James Schlesinger and his assistant John Deutch.

The Delphi Method

The Delphi technique is a methodology painstakingly developed by Rand to get leading scientists, economists, and politicians to agree on predictions of what scientific and technological breakthroughs are feasible—predictions that are predetermined by the key policymakers running the Delphi project. There are Delphi studies on war policy, space policy, population control, and weapons systems, but the Rand priority area is listed as "scientific breakthroughs."

To promote a policy decision for the future, Rand selects a large panel of experts for a Delphi study. Using the method described in detail below, the Delphi experimenters then get these experts to "converge in opinion" on the prechosen policy decision. This resulting "consensus" is then announced as a policy arrived at "democratically."

Any "dissenters" are carefully forced to change, through a series of psychologically coercive question tactics. In fact, scientists and engineers at the frontiers of science are targeted for isolation and their ideas are deliberately ameliorated in order to develop a consensus around the predetermined Delphi idea.

To replace real science—the kind of free inquiry that leads to development of the higher hypothesis, as put forward by Plato—the Delphi group has substituted what they call *social technology*, a new so-called science that measures scientific and technological developments by their "sociological and economic effects." With social technology, the subject of breakthroughs at the frontier of scientific knowledge disappears from the lexicon. Instead, a cost-accounting system prevails. As the Rand-associated publication *Minerva* put it in an article published in *The Complexity of Scientific Choice*: "Scientific research can no longer be guided by intellect but instead must be guided by economics."

This social technology method is perhaps most drastically in evidence at the U.S. Department of Energy, where cost-effectiveness and consensus politics have taken priority over science as a basis for policymaking. For example, former Rand staffer John Deutch, head of the Office of Energy Research, told a stunned audience of 500 engineers and scientists at the 1978 joint meeting of the American Nuclear Society and the Atomic Industrial Forum that it didn't matter that scientists had solved the problem of disposing of nuclear waste; we need a "democratically arrived-at consensus" on the issue.

Delphi economics, of course, disregard man's entire history, where breakthroughs at the frontiers of science are what contribute to the negentropy—the continued advancement of society at an increasing rate. In place of progress, Rand's Delphi project presents Malthus and zero-growth. Instead of seeing technology as creating growth in the entire society, Delphi prescribes that technologies have to be limited by what society can afford. Necessarily, the Delphi predictions are premised on a controlled austerity.

Perhaps most vicious is the Rand-Delphi attempt to isolate those leading scientists and political leaders who understand that there can be no development of civilization if man is not allowed to develop those "higher hypotheses" that raise him from the bestiality associated with a fixed environment. The Delphi project doesn't want more Beethovens, just as it doesn't want fusion power. (Unlimited energy may create social problems, the Delphi line goes, and, therefore, we must get a consensus that society wants to deal with the social problems fusion will create.)

"Dear Sir, we seemed to have arrived at a consensus.

The Rand Delphi research papers that are public stress the fact that there is no new knowledge. The message is that all is now known and man's role is simply to manipulate given knowledge. (The Delphi experimenters call this the "Lockean Inquiry System.") Thus, it is no surprise that the Delphi project publications take the epistemological position that biological research should stay within the confines of molecular biology and physics research should be dominated by particle theory. In both cases, the task is defined not to be a search for fundamental processes of the universe—the kind of knowledge that will provide a cure for cancer or the development of fusion energy—but manipulation of probabilistic relationships between little hard balls of matter.

There is nothing new about the Rand or the British attempt to contain scientific development. The British Royal Society developed a full arsenal of techniques for the political control of scientific work over the past 200 years. Historically, most leading scientists have had their works "interpreted" by the Royal Society in order to distort and ameliorate their ideas. (Plato, Nicholas of Cusa, Bruno, Galileo, Leibniz, Riemann, and Cantor are just a few of the Royal Society's victims.)

The Delphi technique is merely a more sophisticated weapon in the war against science, achieving an effect on U.S. science just as damaging as the British-controlled policy of classification.[1] In effect, the Delphi method, which by definition "classifies" out of consideration the possibility of breakthroughs on the frontiers of science, has become "the way" that scientific organizations, government divisions, educational institutions, and private industry run their conferences, training sessions, or development programs.

Who Is Being Delphied?

In 1975, a book called *The Delphi Method: Techniques and Applications* published an 11-page appendix listing in small print the major Delphi studies. Selections from that list, as well as from a list provided in an interview with Delphi theoretician Norman Dalkey, appear here, along with brief descriptions of the issues involved.

U.S. Republican Party: 1968 campaign themes were arrived at through the first recognized Delphi Policy Project on National Priorities, with particular emphasis on resources and science and technology and change.

U.S. Department of Energy: consensus on general policy, technology transfer.

United Nations: various development programs, including an investigation of the needs of African nations.

U.S. Bureau of Standards: evaluation of reliability criteria.

IEEE: including a study of reliability factors for nuclear power equipment using a panel of nuclear engineers.

Electric Power Research Institute: now in process of evaluating Delphi technique for its own use.

Gordon Science Seminars: run by Theodore Gordon, head of the Delphi Futures Group in Glastonbury, Conn., these have traditionally included leading international scientists on topics such as laser fusion.

Chase Manhattan Bank: economic and energy policy (they have a section called the Delphi group).

TRW: regarded by Delphi experts as the best-known example of corporate Delphi work, TRW's Delphi unit is called PROBE; most of its published work is in technology and development forecasting.

IBM and AT&T: their Delphi programs are internal and proprietary, as in many large corporations.

National Academy of Science and Engineering: project is called "A Delphi Exploration of the U.S. Ferroalloy and Steel Industries."

National Science Foundation: includes projects called Discuss and New Directions, the latter an antiscience, zero-growth organization.

Most Rand Delphi studies involve panels of experts who produce a consensus. To guarantee a strictly sociological approach to science and technology predictions, Rand Report R-1375 says that "good" scientific panels should have on them "systems experts ... who are accustomed to thinking of the implications of new [scientific and technological] subsystems on the economic feasibility of an entire system, and of the political, legal, social, and ecological aspects of the new development."

The Delphi Panel of Experts

The Office of Technology Assessment, a congressional advisory body initiated by Senator Kennedy is a good example of this "systems" approach. The OTA recently came up with the following statement about fusion energy: "We will have to look at the social, economic, and political implications of the development of fusion energy because fusion would allow a worldwide source of cheap energy ... and we must see first what would happen to society if it had cheap energy."

Since 1953, every Rand report has put forward the method of *controlled feedback and iteration* for manipulating the Delphi expert panels to arrive at a predetermined consensus. The process was developed by Rand Corporation's foremost Delphi experts Norman Dalkey and Olaf Helmer around 1953, and it has remained the basic Delphi technique for getting experts to "converge" on their opinions. As the Rand people brag, the Delphi technique "always works," no matter what the subject.

The Delphi technique proceeds as follows:

First, a large group of experts is chosen to maintain what Rand calls indistinguishability and to assure reliability of convergence around "true values."

Second, the chosen experts are to have no verbal contact with each other. Particular stress is put on this procedure because the Delphi experimenters say that an outspoken scientist can have too much influence on others; in Delphi Randese, he creates "semantic noise." All questions and answers are written, particularly in sensitive areas of policy consideration where the Delphi experimenters feel they can't risk one person listening to another. (It should be stressed that although these expert panels are preferably conducted in writing, the same techniques are used verbally in seminars, boardrooms, conferences, and so forth.)

Third is the Delphi process of creating changing opinions and convergence. I shall describe this by citing at some length from relevant Rand documents.

From RM-727 RH:

> To keep out unnecessary bias, there is a mode of controlled interaction among the respondents. Progressively feed in an opinion of another expert as a fact.
>
> [As a result of the above] Even if the views expressed initially are widely divergent, the individual estimates will show a tendency to converge as the experiment continues. This is almost inevitable in view of the more penetrating analysis of the problem, achieved partly by means of the procedural feedback described above.
>
> Feed in only such data as have been asked for by at least one respondent and suggest only such theoretical assumptions as seem to represent a consensus of a majority of the respondents.
>
> One has to be careful of the "sensitivity" of the

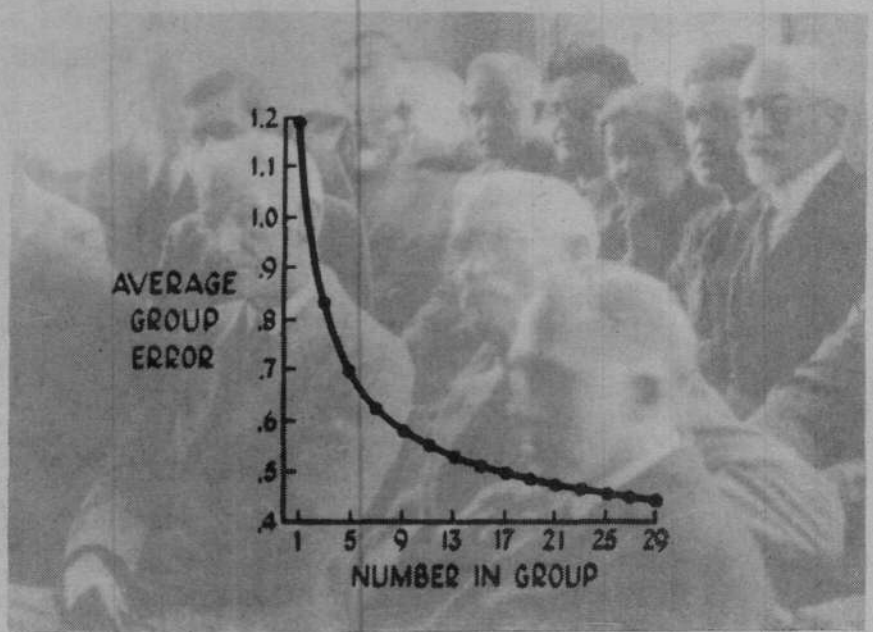
Harvard Medical School: includes "The Future of Medical Care" and "Probes of the Technological Future."

American Institute of Chemical Engineers: a study titled "A Practical Approach to Delphi Technological Forecasting and Long-Range Planning."

Institute for the Future: worked with organizations in Eastern Europe and the Third World on "Forecasts of Some Technological and Scientific Developments and Their Societal Conflicts."

British Chemical Industry: one of several British Delphi projects; others are the *Financial Post* and the Office of Health Economics.

Massachusetts Institute of Technology: includes studies on Puerto Rico, citizen feedback, and organizational research.



The "n-head rule": According to the Delphi experts, the more people in your group, the less error you'll end up with.

individuals' response to changes in the basic assumptions made by the experimenters.

Essentially, the resulting corrections amount to a replacement of the individual expert's estimates concerning some of the components of the main problem by a consensus of estimates by all the experts.

From R-612-ARPA:

> What takes place is shifts toward the group response and reduction in group variability. More generally, if members of the group do not utilize the information in reports of the group response on earlier rounds when generating responses on later rounds, it seems inappropriate to consider those responses as judgments.

Getting Rid of 'Divergers'

The toughest problem for Dalkey and Helmer, and one which they feel they have solved in recent years, is totally getting rid of the "divergent opinion" rather than just watering it down and melting it into the consensus. Dalkey and Helmer concluded that they could make the "diverger" actually disappear by getting him to evaluate his own competence to answer every question whose answer differed from the consensus of the rest of the experts. In effect, divergent scientific views become "classified."

Here are some of the specific questions Dalkey and Helmer use to get rid of the diverger (in Rand Report RM-727 RH):

> You are being asked today for a reconsideration of your original estimates....
>
> Restatement of the primary question is as follows....
>
> The principal purpose of the fourth questionnaire is again to obtain from you revised answers....
>
> In this final questionnaire you will have a last opportunity to revise once more your earlier estimates if you should feel so inclined. The possibility of such a revision suggests itself in view of (i) a piece of information given below; (ii) certain considerations emphasized by the respondents themselves; (iii) a possible discrepancy....
>
> Please appraise your competence....Your ideas differ from the rest.

The Delphi experimenters are always the ones to choose the panel of experts. What criteria do they use? In his book *Epistemology of the Inexact Sciences*, Helmer says that "a predictive expert in some subject is a person who is rational." Here's how Helmer defines rational:

> We shall call a person "rational" if (1) his preferences (especially with regard to betting options) are mutually consistent or at least, when inconsistencies are brought to his attention, he is willing to correct them; (2) his personal probabilities are reasonably stable over time, provided he receives no new relevant evidence; (3) his personal probabilities are affected (in the right direction) by new relevant evidence; and (4) in simple cases where the evidence E at his disposal is known, and E and H [the hypothesis] are such that dc(E,E) is defined, his personal probability regarding H is in reasonable agreement with the latter; in particular, he is indifferent as to which side to take in a bet that to his knowledge is a "fair" bet.

(A "personal probability," in case the reader is wondering, is defined by Helmer as "a measure of a person's confidence in, or subjective conviction of, the truth of some hypothesis. According to Savage [another Delphi expert], it is measured behavioristically in terms of a person's betting behavior.")

In summary, all this gobbledygook by Helmer means that to be a Delphi expert, you have to be a nominalist in the Aristotelian tradition; Delphi has no use for Platos who strive for the higher hypothesis. Indeed, in a Delphi article called "Philosophical and Methodological Foundations of Delphi," two Delphi experts, Harold Finstone and Murray Turoff, extoll that modern Aristotelian, John Locke: "One would be hard pressed to find a better contemporary example of a Lockean inquirer than Delphi," they write.

Controlling who the experts are is very important to Rand in terms of the outcome the Delphi project wants to achieve. For example, making molecular biology the epistemological center of biological research work is a Delphi goal. In a book called *The Complexity of Scientific Choice*, author Stephen Toulmin laments the fact that the British Royal Society did not have the Delphi method back in 1952 in order to see this goal furthered. To quote from Toulmin:

> ... the "scientific community"—however it is defined—has an internal structure which can sometimes be of great significance: notably an age-and-status structure. This creates practical difficulties, which Polanyi and Maddox [sociologists] both underestimate when it comes to assessing "scientific opinion."... It should be illuminating, for instance, to experiment with the "Delphi Method," developed by the Rand Corporation to deal with just such problems.
>
> In the [Delphi Method] technique, a panel of specialists participates in a sequence of questionnaires, through which they compare and contrast their own opinions against those of other panel members, *without knowing their identities*: so a consensus of opinions can be achieved which is undistorted by considerations of seniority and status. Suppose, for example, separate "profiles" of expectations and priorities had been established in this way in 1952, among biologists aged from 25 to 35, and among biologists aged from 50 up. Might this not have helped to shortcircuit or accelerate the procedures of the Royal Society Committee on Biological Research? Might not the cardinal importance of molecular biology have, as a result, been publicly established rather earlier than 1960?

What kinds of a future do the Delphi experimenters envision? Rand Report P-2982, written by Helmer, specifies

"The notion of visiting the oracle at Delphi to receive 'expert' advice is an old one" (Rand Report R-1375).

the scientific and technological "futuribles" that a Delphi panel of experts—some 80 in all from the United States and Europe—converged on for the years 1984, 2000, and 2500. Here's what the experts predict:

Water-covered portions of the earth may become important enough to warrant national territorial claims;

In the relatively near future, very widespread use of personality-control drugs;

The emergence of weapons of a nonkilling, non-property-destroying nature (of a biological and psychological nature);

The anticipated relatively high probability of another major war caused by mutually undesired escalation and inadvertence.

The Delphi Future

As for the scientific breakthroughs this Delphi group of 80 experts predicted for the future, here is the Rand list of categories and the first "breakthrough" prediction in each category:

Biology: chemical control over heredity—molecular biology

Sociology: communication with animals

Physical science: reformation of physical theory, eliminating confusion in quantum relativity and simplifying particle theory

In a section called "editorial comment," Helmer discusses the social reorganization called for by the Delphi "consensus" around the scientific and technological breakthroughs. Most notable are Helmer's assumptions that the "less able" in the population will remain fixed in that category and that no new occupations will develop in industrial societies.

The anticipated explosive growth in the amount of automation is likely to reshape the societies of industrialized nations considerably, perhaps beyond recognition. While improved and highly automated methods of education will make the acquisition of technical skills available to a larger fraction of the population, only the very ablest of people are likely to be needed to manage the new, automated economy. Since robots are apt to take over many of the services, especially the more menial ones, large segments of the population may find themselves without suitable employment within an economy of potential abundance. Farsighted and profoundly revolutionary methods may have to be taken to cope with this situation and to create new patterns within which a democratic form of society can continue to flourish. "Earning" a livelihood may no longer be a necessity but a privilege; services may have to be protected from automation and be given social status; leisure time activities may have to be invented in order to give new meaning to a mode of life that may have

become "economically useless" for a majority of the populace.

It's not exactly the kind of industrial republic our Founding Fathers fought a revolution to establish!

Given what most people would agree is an unattractive picture of the future of our society, how do the Delphi experimenters seek to convince people that their prediction for a future technology or scientific breakthrough and the resulting social scenario is the same as a *scientific explanation*? Again, I quote Helmer, Rand Report R-353:

> A somewhat simplified characterization of scientific explanation—but one that nonetheless has a wide range of applicability, particularly in the physical sciences is that explanation consists in the *logical derivation* of the statement to be explained from a complex of factual statements and well-established general laws.... With regard to prediction as opposed to explanation, analysis of scientific reasoning often emphasizes the similarities between the two, holding that they are identical from a logical standpoint, inasmuch as each is an instance of the use of evidence to establish a hypothesis, and the major point of difference between them is held to be that the hypothesis of a prediction or of an explanation concerns respectively the future or the past....

And if you don't understand his explanation, Helmer suggests that you turn to the *British Journal for the Philosophy of Science*, volumes 7 and 8, for a full explanation of the scientific basis of "prediction."

Dropouts

All is not wine and roses for the Rand Delphi group in their destruction of science. Rand Report P-2982 discusses the problem of the high drop-out rate of participants in the Delphi experiments. Apparently, many participants felt that the publication of their answers to the Rand questionnaires might affect the future course of history

Operations Research: **Delphi's Technical Counterpart**

The so-called scientific discipline of operations research serves as the technical counterpart to the psychological manipulation technique of the Rand Delphi project.

Operations research, known as OR, began during World War II in the British military and later in the U.S. military as a set of statistical procedures used to plan and evaluate military operations. In the postwar period, OR was used to take over the decision-making process in business and national economies. The leading institution carrying out this infiltration of industry was the Operations Research Club, organized by Royal Society Fellows and meeting in Royal Society rooms.

Its promoters claim that OR methods, primarily linear programming and standard statistical procedures, can substitute for creative decision making when applied to strategic, economic, and military planning. Here's what some leading OR spokesmen have to say about their science and their results:

Charles Hitch, Rand Corporation: "...the typical good operations researcher would be next to useless in the Indian Planning Commission except on component studies defined by others or in the preparation of snow-jobs for mathematically unsophisticated ministers."
"Operations Research and National Planning—a Dissent" in *Journal of the Operations Research Society of America*, vol. 5, 1957.

The Earl of Halsbury, chairman, National Institute of Industrial Psychology (Great Britain): "The development of an invention is not...a safe investment....The development of revolutionary inventions on an intrinsically long time-scale is not financially attractive....Inventions should be thought of less as 'good' or 'bad' than as conforming to an established evolutionary pattern or cutting across it....Inventions cutting across the established evolutionary pattern will tend to be inhibited; those confirming with it will be received by industry with a high degree of spontaneity."
"The Quantification of New Inventions" in *Operations Research Quarterly*, vol. 7, 1956.

The Earl of Halsbury: ". . .we have at the National Physical Laboratory a simulator which will demonstrate Keynesian theory to the nonmathematical. The spectator can raise the bank rate on one dial setting and watch the consequences thereof upon unemployment represented by a calibrated volt or ammeter at another point of the instrument. ...Controversial economics are not possible under these circumstances; one cannot be partisan with respect to the reading of an instrument.

"The Malthusian law is...not a law of Nature but an exception thereto. It applies to Man because Man uniquely among the higher animals has the power to violate instinct through the exercise of intelligence, misdirected and misapplied....Four-hundred millions of peasants in India are rushing headlong upon a food crisis which must sooner or later accomplish their downfall in tragic circumstances because they are below the level of education at which they are accessible to propaganda on family limitation."
"From Plato to Linear Programming" in *Journal of the Operations Research Society of America*, vol. 3, 1955.

Prof. J. D. Bernal, Fellow of the Royal Society: "There is nothing more absurd in eating grass than eating lettuce."

(This remark was in a paper Bernal gave before the British Association for the Advancement of Science in 1948. He was advocating the reduction of Britain's consumption of foreign produced foodstuffs, replacing them with indigenous products like grass.)

on the particular subject by hastening or retarding a media-hyped predicted event by experts. The Delphi answer to such drop-outs? "The notion of visiting the oracle at Delphi to receive 'expert' advice is an old one" (Rand Report R-1375).

A somewhat longer answer was provided by Olaf Helmer, one of the strongest advocates of the Delphi attempt to replace science with social technology. In Rand Report R-3063 (which later became a book, *Social Technology*, published in Britain in 1966), Helmer says:

> The systematic search for futuribles and the democratic choice among them should be institutionalized. Such a systems-synthetic attack on the problem of the future is feasible and natural....A concern for the future has, of course, always been implicit in any scientific undertaking and, thus, is as old as science itself. The support for this new approach is growing so fast, in fact, that full scale attempts at its realization may well be imminent. Substantively our special emphasis is on science and technology and their probable affects on our society and our world.

More than 10 years later, the Delphi antiscience approach—science as sociology—is still growing fast. Helmer's Rand colleague, Norman Dalkey, who is now at the University of California at Los Angeles, said in a recent interview that the Delphi technique is "omnipresent" at major policy-making institutions.

Rand's public information office seconded Dalkey: "The Delphi method is very popular outside of RAND....You see, it's a method, a technique for arriving at a consensus....It has occasionally fallen into disrepute...but it's very popular."

The Damage

In addition to its pernicious effect in the U.S. energy area, the Delphi technique has made an intellectual wasteland out of the United Nations development program. In the UN, the Delphi project has focused not on scientific research and its applications to Third World development but on the most bestial kinds of appropriate technology—low cost, low-energy, manual-labor techniques that the zero-growthers consider appropriate to poverty.

Delphi has so pervaded the technology transfer groups—UNCTAD, UNSCTD, and UNIDO—that comments like the following appear in their official publications: "[We cannot underestimate] the boundaries separating science, technology, and development." This quotation is from the UN newsletter *Development Forum* in an article by Bernard Delapalme, director of science and technology for ELF-Aquitaine and a member of the UN Advisory Committee on the Application of Science and Technology to Development.

In essence, the Delphi prescription that science and technology have nothing to do with development has become the watchword of the international agencies responsible for ensuring that development takes place.

Have you been Delphied?

Mary Gilbertson, a Fusion Energy Foundation staff member, was a high school teacher for 10 years. She is currently working on problems of epistemology and science education.

Notes

1. The material in this article is taken from the public Rand studies that are listed in the references and from interviews with Rand personnel as well as top Delphi experimenters.
2. For details on the Royal Society and British science, see "The Royal Society," by Carol White, *Fusion*, Dec.-Jan. 1977-1978.
3. The damage the British-controlled policy of classification has had on the U.S. fusion program is discussed in "The Secret of Laser Fusion" and "The Case of the Fast Liner" in *Fusion*, March-April 1979. Although the Royal Society does not publicize its connection to the Delphi project, there are some direct links. For example, top Delphi experimenter Norman Dalkey's work on Delphi was published in the Royal Society's *Journal of Statistics* in 1977.

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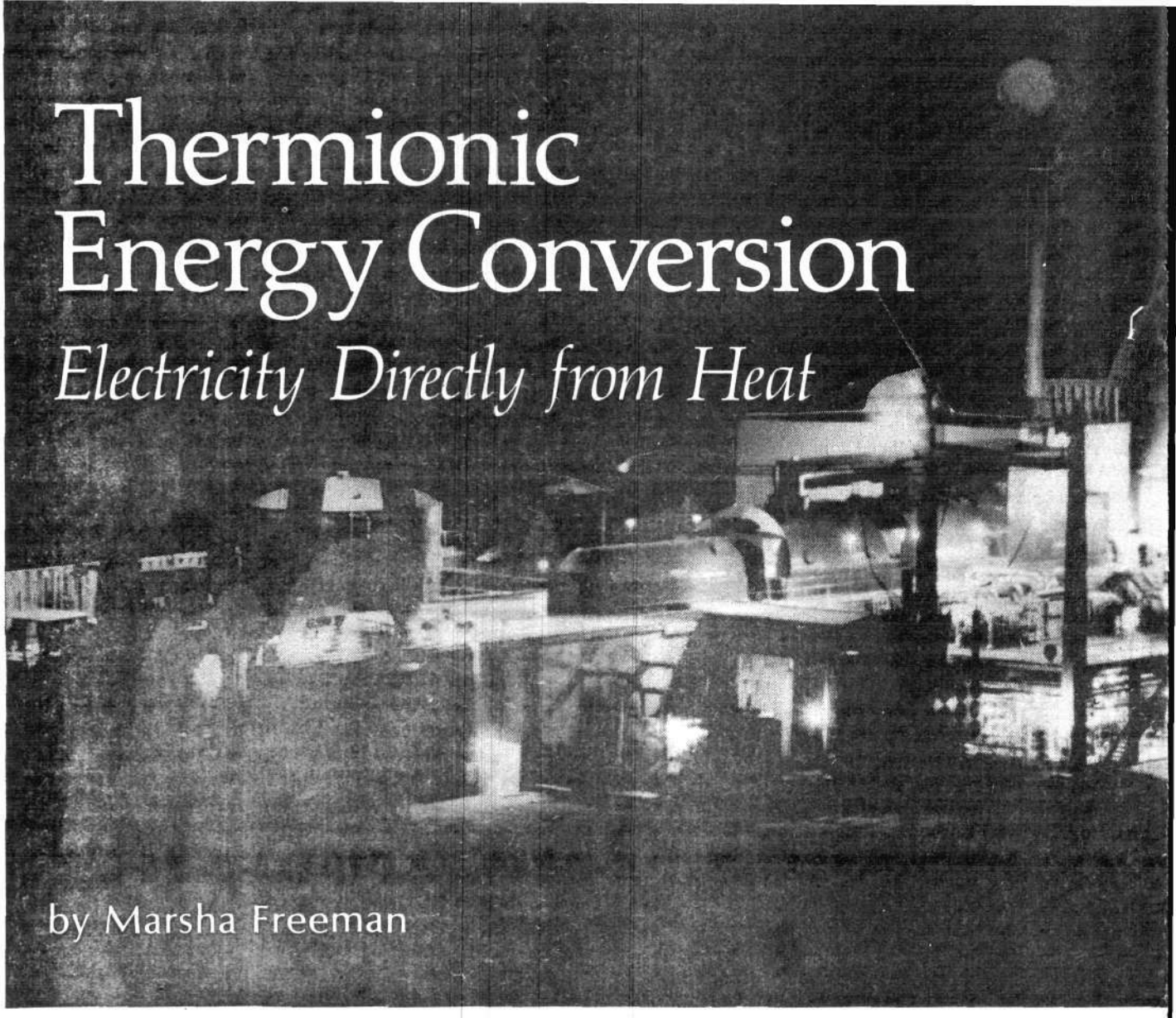
Thermionic Energy Conversion

Electricity Directly from Heat



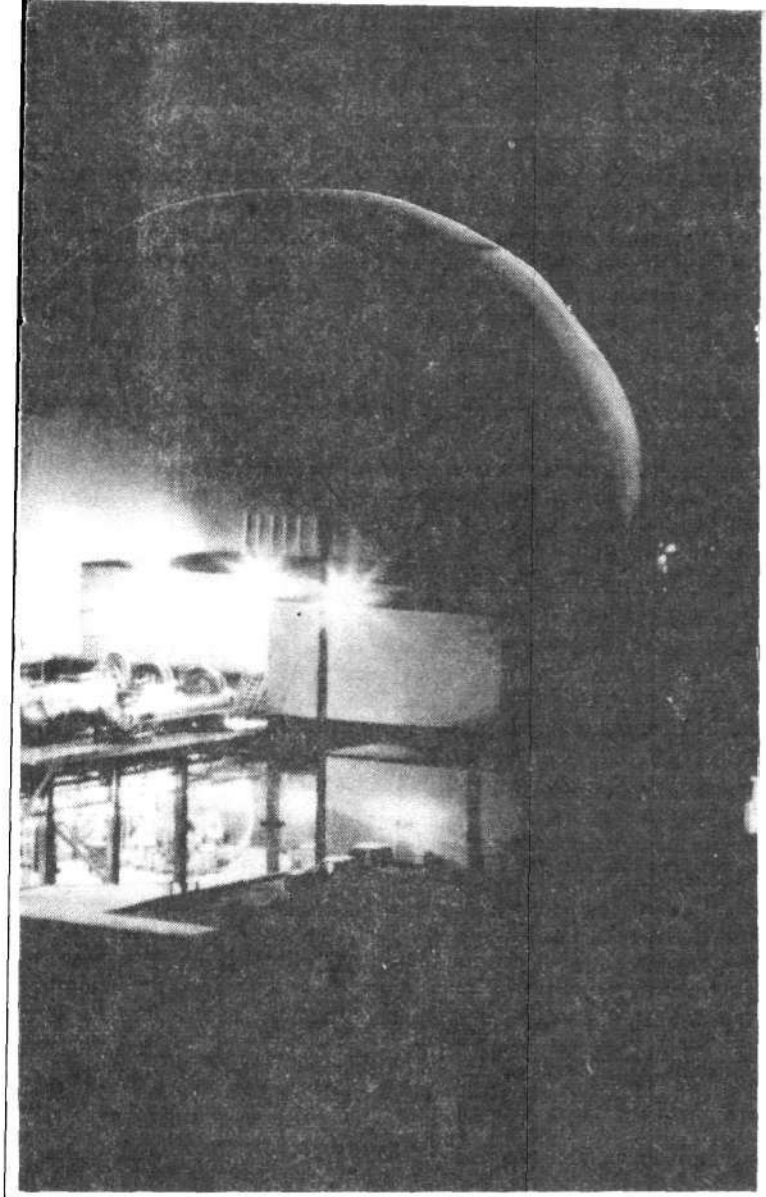
by Marsha Freeman

THERMIONIC CONVERSION of heat energy to electricity will play an important role in the future production of electricity from fusion energy, as well as in the more efficient use of the thermal energy allowed to go to waste in current energy production. Thermionics is based on the principle that electrons will "evaporate" from a very hot electrode and travel to a cooler one, with this electron movement setting up a moving charge and thus electrical flow. In this way, it provides a means of converting heat energy directly into electricity, with no moving parts. The implications of this for future portable generators, undersea power units, space missions, and even automobiles are no less exciting than the possibility of integrated systems in which "waste" heat from fusion, fission, magnetohydrodynamics, fossil fuels, and steam processes can be directly converted to electrical energy, thus significantly increasing the efficiency of such systems.

In 1885, Thomas Edison observed that an electric current could be made to flow between two electrodes at different temperatures in a vacuum. The current produced between the electrodes, which results from electrons being "boiled off" the hotter electrode, the *emitter*, later became known as the Edison effect or thermionics. The thermal energy to the emitter must be high enough to propel the "evaporated" electrons across the gap to the cooler electrode, the *collector*. Thermionics, therefore, is a direct thermal-to-electrical conversion that, unlike conventional steam turbine cycles, requires no moving parts.

Research and experimentation in thermionic energy conversion have always been an international effort. In 1912, O.W. Richardson first analyzed and investigated thermionic emission from a hot electrode experimentally. A patent was submitted by A.I.B. Ghyssaert in the United Kingdom in 1923 for an electric discharge tube based on the thermionic principle. At the same time, Irving Langmuir and his associates theoretically and experimentally characterized the electron and ion emission from cesiumadsorbed films on tungsten.

During the 1940s, A.F. Ioffee described a vacuum thermoelement being worked on in the Soviet Union. By 1956,



actual designs for thermionic converters beyond the limited used of tubes were actively under investigation. In his PhD thesis submitted in that year, G. Hatsopoulus, now president of Thermo Electron Corporation, did a thermodynamic analysis of a converter design using a small gap, which examined the crossed electrical and magnetic fields that could be used to control the space charge problem in thermionics.

By the late 1950s there were several U.S. groups doing work in thermionics, and conversion efficiencies of 5 to 10 percent were measured. Under the impetus and funding of the National Aeronautics and Space Administration space program in the United States, a converter for high-temperature space applications was in the engineering stage in 1963. By 1972, a converter outside the core of a nuclear reactor, designed for nuclear space power, had operated reliably for 46,000 hours, and an in-core converter fuel element had operated for 8,000 hours.

After the curtailment of the U.S. space program in 1973, however, the in-space nuclear reactor program was drastically cut. As the emphasis of energy research then turned toward increased fossil fuel efficiency in the mid-1970s, so did that of thermionics research.

The Parameters of Thermionic Conversion

The amount of heat energy required to vaporize electrons from the thermionic emitter is called the emitter *work function* and is a straightforward parameter of applying the heat needed for different electrode materials. Unlike thermoelectric conversion, thermionics depends upon the break-up of the electron lattice in the electrode material to free the electrons. Therefore it is most efficient at high temperatures. In thermoelectric conversion, however, an electromotive force produces a current flow in a closed electric circuit through an electrode temperature differential, moving the free electrons in the different materials. Thermoelectric conversion, which does not flow through a space gap, has a lower temperature limit than thermionics because the breakdown of the electron lattice structure at high temperatures interferes with the free flow of electrons.

Edison's original observation was of two electrodes in a vacuum (Figure 1). As electrons cross the gap between the emitter and collector, however, a negative space charge from the negative electrons is built up near the collector, impeding further electron flow. The earliest attempts to lower the space charge were to make the gap between the electrodes very small—about 1 mil (1 mil = 0.001 inch). But since this posed serious problems in design reliability, other methods for lowering the space charge were being investigated by the mid-1960s.

The first method was to use low-pressure cesium vapor instead of a vacuum surrounding the electrodes. When the cesium on the surface of the emitter was ionized a plasma was created (mixture of ions and electrons), and the positive ions lowered the negative space charge. It was found, however, that the cesium ionization required temperatures of more than 4,500 degrees Fahrenheit or a high emitter work function.

When the cesium pressure was increased several orders of magnitude, this resulted in a lower emitter work function and higher current densities. The cesium pressure, however, produced a serious amount of electron scattering in the cross-over to the collector, which led to resistive losses in the plasma between the electrodes, an *arc drop*.

Most recently, experiments have shown that the cesium pressure can be lowered if oxygen is added to the inter-electrode space. The use of tungsten oxide on the electrode has increased power density by 70 percent and allowed an order of magnitude drop in the required cesium pressure. Metal oxide deposits on collectors have been used as the oxygen source and have operated stably for over 4,000 hours. In addition, this lowered plasma loss has allowed the use of a larger electrode gap of 50 mils and polycrystalline rather than single-crystal emitters, which are easy and inexpensive to fabricate.

The key parameter used to measure overall thermionic efficiency is termed the *Barrier Index* (BI). The lower the Barrier Index, the greater the efficiency of the conversion process. The BI is made up of the collector work function (approximately the heat of vaporization of the electrons)

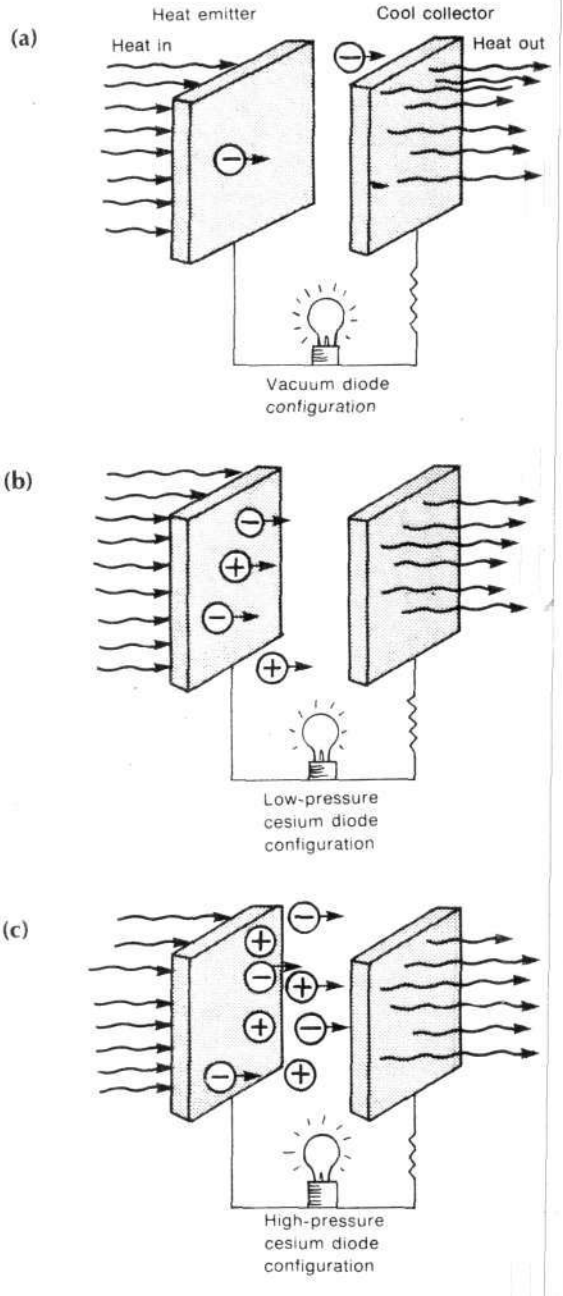


Figure 1
THE DEVELOPMENT OF THERMIONIC CONVERTER SYSTEMS

Pictured here are three stages in the development of a thermionic converter system to try to mitigate the space charge problem. In (a), *the electrodes are in a vacuum, with only the electrons going from emitter to collector. Shown in* (b), *is the flow of both electrons and positive ions when low-pressure cesium is added. In* (c), *the increased plasma density requires lower temperatures than the other two modes when high-pressure cesium is used.*

and the arc drop. The arc drop (or loss of voltage) results from plasma losses due to electron scattering from collision with the cesium atoms, ionization losses associated with the ionization of cesium atoms by the electrons, and sheath losses caused by the potential of a sheath adjacent to the collector.

The lower the BI, the higher the converter performance. Reductions in the BI can be translated into higher efficiency at a given temperature or the same emitter efficiency at a lower temperature. The BI is measured in electron volts (eV), where 1 eV is approximately 10,000 degrees Celsius. Thus, at a given temperature and a given BI, a certain percentage of the electrons can be calculated to cross the gap to the collector.

In 1960, thermionic converters operated experimentally at a BI of 2.9 eV, translating to a 5 percent efficiency at 1,800 degrees Celsius. By 1972, a BI of 2.1 eV was achieved, or a 20 percent efficiency at about 1,800 degrees. This temperature is the approximate range of most fossil fuel plant combusion temperatures. It is estimated that maximum efficiency at that temperature, with a BI of 1 eV, which is the best expected, is about 40 percent.

The Soviets have reported achieving a BI of 1.75 eV using lathanum hexaboride electrodes. In general with today's technology an approximate 15 percent efficiency is attainable. Current research includes the testing of higher-performance electrode materials and methods of reducing ionization losses. Some of those under investigation include using a pulsed diode, supplying the plasma ions from a separate region from the electrodes, or vaporizing the cesium by a third auxiliary electrode.

Much of the U.S. work in reducing ionization losses takes place at Rasor Associates in California. The other major center for thermionics research, Thermo Electron Corporation in Massachusetts, is concentrating on reducing the collector work function to increase output voltage, power density, and efficiency (Figure 2).

Applications for Thermionic Energy Conversion

Because of the narrow temperature range within which any particular thermionic converter system would operate, it would not be feasible to use this conversion process alone for thermal-to-electrical conversion in base-load power plants that have a wide temperature range. A thermionic conversion system, however, has a critical role to play in existing systems where efficiency can be increased by thermionic topping or bottoming (described below), or in systems where mechanical steam turbine cycles are not practical. In the latter case, net efficiency is not the main parameter consideration.

In general, the BI value will determine the potential application of thermionics. In some cases, increased efficiency will be the determining factor. In others, the lower BI will allow performance at a lower temperature, without extreme efficiency losses.

Although the conventional coal, oil, or natural gas power plant has a combustion temperature of about 2,000 degrees Celsius, the steam turbines used to convert this thermal energy to electrical energy typically must operate

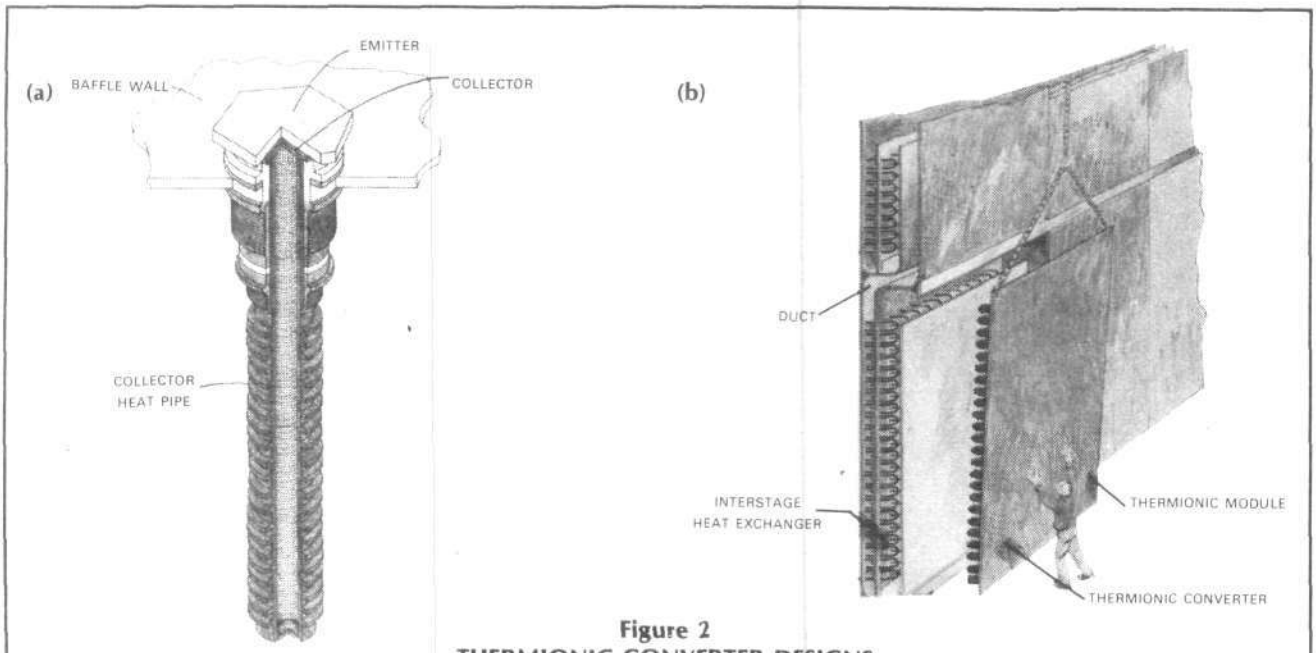


Figure 2
THERMIONIC CONVERTER DESIGNS

An artist's rendering of a thermionic converter design developed by Thermo Electron Corporation is shown in (a). *The emitter is in contact with hot combustion gases. The collector surface is extended into a heat pipe that carries the excess, rejected heat into an interstage heat exchanger, to be used by a steam turbine bottoming cycle. Shown in* (b) *is an artist's rendering of many individual converters arranged in a wall-like structure that will make up the lining of a fossil fuel boiler system.*

at less than 1,000 degrees because of the properties of the materials, a temperature less than half that of combustion. Almost two-thirds of the energy is rejected as "waste heat."

If a thermionic converter is added to turn the 2,000-degree heat into electricity before it reaches the steam turbine, much of this "waste heat" would be a source of energy. Using excess energy before it moves on to the primary energy process in this way is called *topping* an energy cycle. If the "waste heat" is used after the primary process, for example, after a plasma goes through an MHD generator, thermionics is then being used as a *bottoming* cycle.

A thermionic topping cycle, which would operate in the range of 1,500 to 1,900 degrees Celsius, would add about 20 percent to the efficiency of the plant. A much more exciting idea, using MHD-thermionic-steam cycle combination, has the potential to *more than double* power conversion efficiency, even at current levels of technology development. Figure 3 illustrates a cascading energy system.

The fossil fuel burned at a higher temperature (about 2,500 degrees Celsius) would first be directly converted to electricity through MHD (magnetohydrodynamics, in which the ionized gas is moved through a magnetic field). The outlet temperature of the gas would then be appropriate for thermionic conversion, and the steam cycle would, finally, bottom the rejected heat from the thermionic converter.

Increased operating efficiencies in the MHD and thermionic cycles, possible in the next few years, would bring the power system very close to the thermodynamic limit of fossil fuel systems. Initial cost estimates indicate that capital cost per kilowatt installed capacity would be highly competitive with simple steam turbine cycles in use today.

The main development required to link the three systems is a heat exchanger concept that can match the high energy density of the MHD channel to the flux capabilities of the thermionic converters. The basic parameters have been formulated, and the Soviets, who do both MHD and thermionic research at the High Temperatures Institute in Moscow, are considering a thermionic test module in their MHD experiments.

Nuclear Applications

The interest in thermionics for conventional nuclear reactors evolved in the space program, since bulky and inefficient steam turbines would be out of the question for space travel. The Soviets have done the most nuclear thermionic research and have successfully tested thermionic converters that are placed in-core in fuel elements (Figure 4). In the TOPAZ series of in-core thermionic converters, the Soviets use nuclear reactors in the 5 to 10 kW range and have registered reliable operations of 5,200 hours on TOPAZ 4.

In addition to thermionic topping both in-core or out-of-core, the Soviets are developing portable nuclear thermionic systems for use in isolated and remote regions. Another situation in which thermionics without a steam cycle might be considered is where water is so precious that it cannot be used for cooling a nuclear plant.

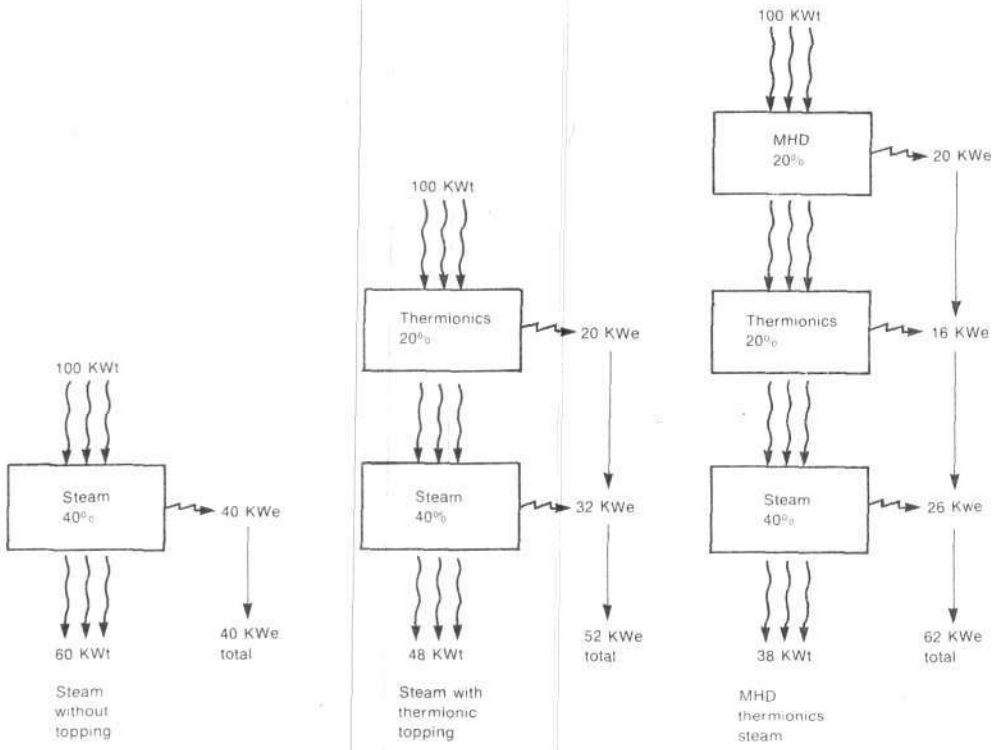


Figure 3
COMBINED CYCLE EFFICIENCY

Shown here are the advantages of an MHD-thermionics-steam combined cycle system. Even at the less-than-optimal efficiency of 20 percent each for the MHD and thermionic cycles, the output of electricity from 100 KW of thermal (heat) energy is increased from 40 kW electric, to 62 kW electric.

In June 1977 at the World Electrotechnical Congress in Moscow, the Soviets announced that the TOPAZ investigations had brought the nuclear-thermionic technology to the point where it was ready for television and meteorological satellites. There has been speculation that the Cosmos 954 satellite that fell to earth last summer was a nuclear-thermionic system.

Because the in-core system is directly exposed to the high temperature of the nuclear reaction, a BI of 2.1 eV is acceptable. Since this is attainable with currently reproducible technology, in-core nuclear-thermionic topping systems are feasible today. The out-of-core design provides more system options, in terms of transferring the reject heat and of nonradioactivity. But because heat is lost in the transfer from the core, the BI would have to approach 1.75 eV in order to be economical. The Sukhumi Institute of Physics and Technology in the Soviet Union is working with different diodes and getting better results than the U.S. projects on lanthanum hexaboride collectors. Sukhumi is reporting BI in the 1.7 to 1.8 eV range.

The Soviets are also considering portable nuclear-thermionic systems for "prospectors" in Siberia that would produce 500 KW, using 90 percent enriched uranium oxide and that would not need any servicing for two or three years.

As for the United States, in January 1977, a team of scientists at Los Alamos Scientific Laboratory did a preliminary assessment of thermionic conversion using a fusion reactor as the energy source. The design considered (Figure 5) was a laser fusion reactor with a high-temperature radiating blanket. The basic conception is equally adaptable to magnetic confinement fusion systems. This fusion thermionic system would enjoy the highest conversion efficiencies since there would be no practical limit to the emitter temperature.

The Los Alamos design was considered as a steam topping cycle where the low-voltage direct current electricity produced thermionically could be used for electrochemical processing, mainly to electrolyze water and produce hydrogen, at about 75 percent efficiency.

Space Power

As mentioned above, the nuclear-thermionic systems were originally developed for expected space requirements. Thermionics with nuclear reactors are still under development in the United States, and as part of the SNAP (System for Nuclear Auxiliary Power) program, SNAP 13 demonstrated a thermionic reactor generator for space. If the planned deep-space missions in the late 1980s materialize, reactors with thermionic converters will be required.

Another form of heat energy has been used for power in space and could provide the source for a thermionic con-

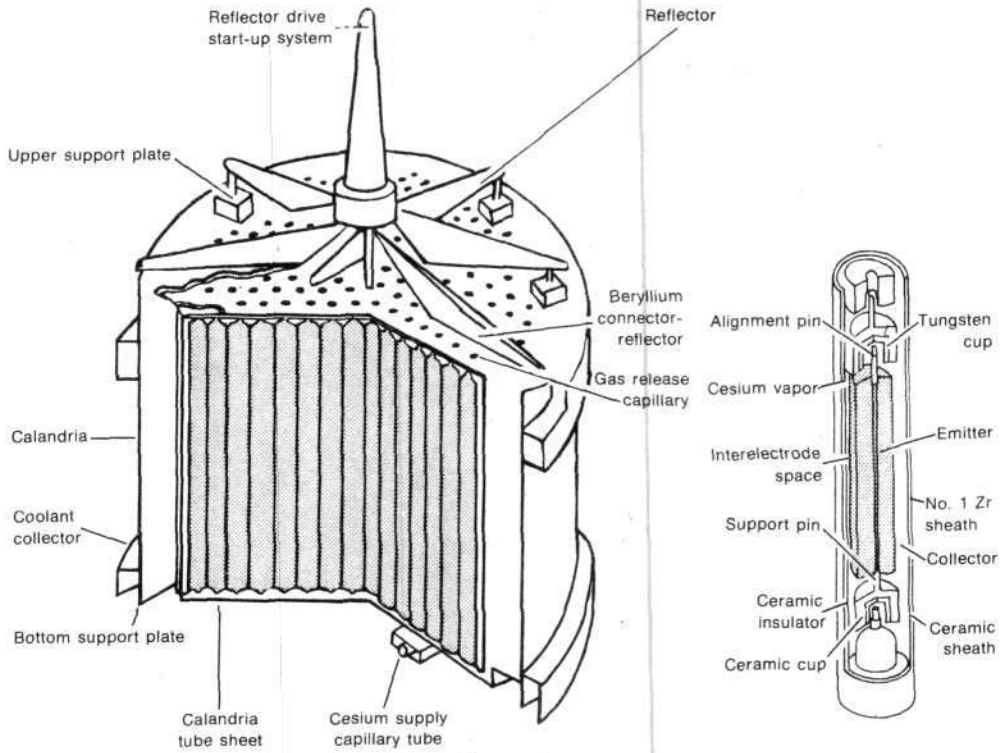


Figure 4
A SOVIET THERMIONIC CONVERTER

The Soviets have developed and tested in-core thermionic converters in nuclear reactors like the one shown here. The converter is part of the fuel element, and the cesium supply and cooling system are built directly into the reactor design.

verter—radioisotopes. Development in radioisotope systems began in 1958 in the United States through joint programs between the Atomic Energy Commission and the Air Force. In 1966, a curium isotope-fueled thermionic generator was tested for space applications, and in 1968 a cobalt system was tested.

If the BI could be brought down to 1.75 eV, thermionic isotope systems would be lighter and more efficient than the currently used thermoelectric systems. At the present BI level, higher-temperature isotopes would have to be developed. At a BI of 1.5 eV radioisotope thermionics would become practical for terrestrial uses. For example, they have been considered as power systems for artificial hearts.

Applications for Further Development

Since 1965, the Jet Propulsion Laboratory in Pasadena, California has had a solar-thermionic development program. Solar units, either for space or terrestrial uses, require a BI of about 1.75 eV and, as is true for all solar technology, are very economically sensitive to collector costs. Compared to photovoltaics, thermionic converters may have a lower material and manufacturing cost per unit of power. Efficiencies of 15 percent have already been demonstrated for solar thermionics and the heat rejected from the thermionic system, around 500 degrees Celsius, can be used in steam cycles or for process steam.

Prototype solar thermionic systems for space missions have achieved good current densities but were not considered competitive because of guidance problems. At present Thermo Electron Corporation is testing a thermionic topping system with a solar system being developed at Sandia Laboratory in New Mexico.

Like the Soviets, U.S. researchers are considering portable thermionic units that could use a variety of heat sources. One such application would involve undersea power units for oceanic exploration. Perhaps the most challenging "portable" system being investigated, which would be economically feasible only at a BI of 1.0 eV, is for an automobile engine.

Possibilities for Cooperation

There are significant thermionic research programs now underway in the United States, Soviet Union, and West Germany with peripheral work being done in France, Italy, the Netherlands, and Sweden. The program in West Germany, approximately the same size as the U.S. effort, has not concentrated on topping or bottoming cycles for baseload power plants, but on varieties of portable and auxiliary power supplies.

These have included applications in emergency, remote, recreational, and military fields, as well as mobile systems for cars and trucks. In cooperation with Mercedes-Benz

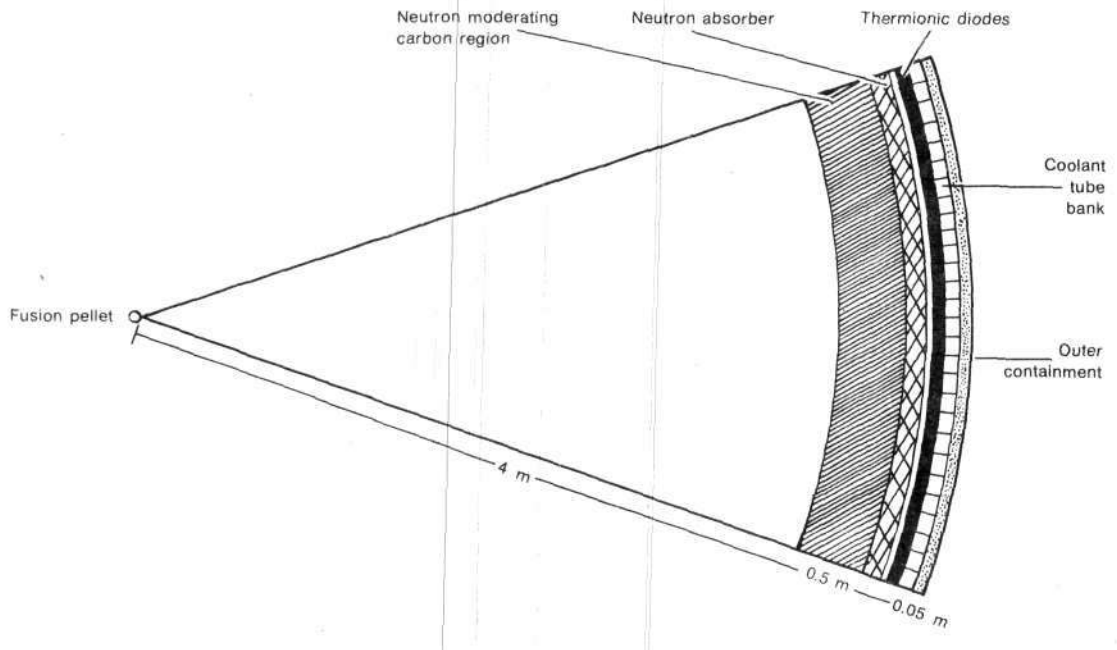


Figure 5
LASER FUSION WITH THERMIONIC CONVERSION

Shown here is a cross-section of a laser fusion reactor model with thermionic direct conversion. The thermionic diodes (emitter and collector) are placed directly after the neutron absorbers. They are heated by radiation from a graphite surface, which in turn is heated by X-ray and gamma radiation and neutron scattering and reactions. The heat rejected from the thermionic converter would be combined with the heat from the pellet debris and used in a conventional steam turbine generating system.

the researchers at the German Research and Testing Institute for Air and Space Travel in Stüttgart have produced a prototype generator of 2,000 W for automobile application.

The U.S. program, at a current funding level from the Department of Energy of about $2 million in fiscal year 1979, is focused on materials and technology development mainly for fossil fuel applications. Some space applications work is also under development. The Soviet program has been estimated, by American scientists visiting their facilities in 1977, to be approximately 10 times the size of the U.S. effort.

The Soviet program encompasses all possible applications for thermionics, with research being conducted at four scientific institutes, at least. Studies include basic plasma theory, cost comparisons of various competing systems, and design, fabrication, and testing. According to one U.S. scientist visiting the Soviet laboratories in July 1977, "The Soviet thermionic electric conversion program has continuity, resources, and commitment, which are sadly lacking in the U.S. program."

A meeting between Soviet and U.S. thermionics researchers July 4, 1977 in the Soviet Union discussed cooperative work in thermionics. The main difficulty has been the lack of adequate funding and momentum from the U.S. side. It is expected that discussions of U.S.-Soviet cooperation in thermionics will continue and that a joint program may be initiated under the Peaceful Uses of Atomic Energy Agreements between the United States and Soviet Union.

Marsha Freeman is director of industrial research for the Fusion Energy Foundation.

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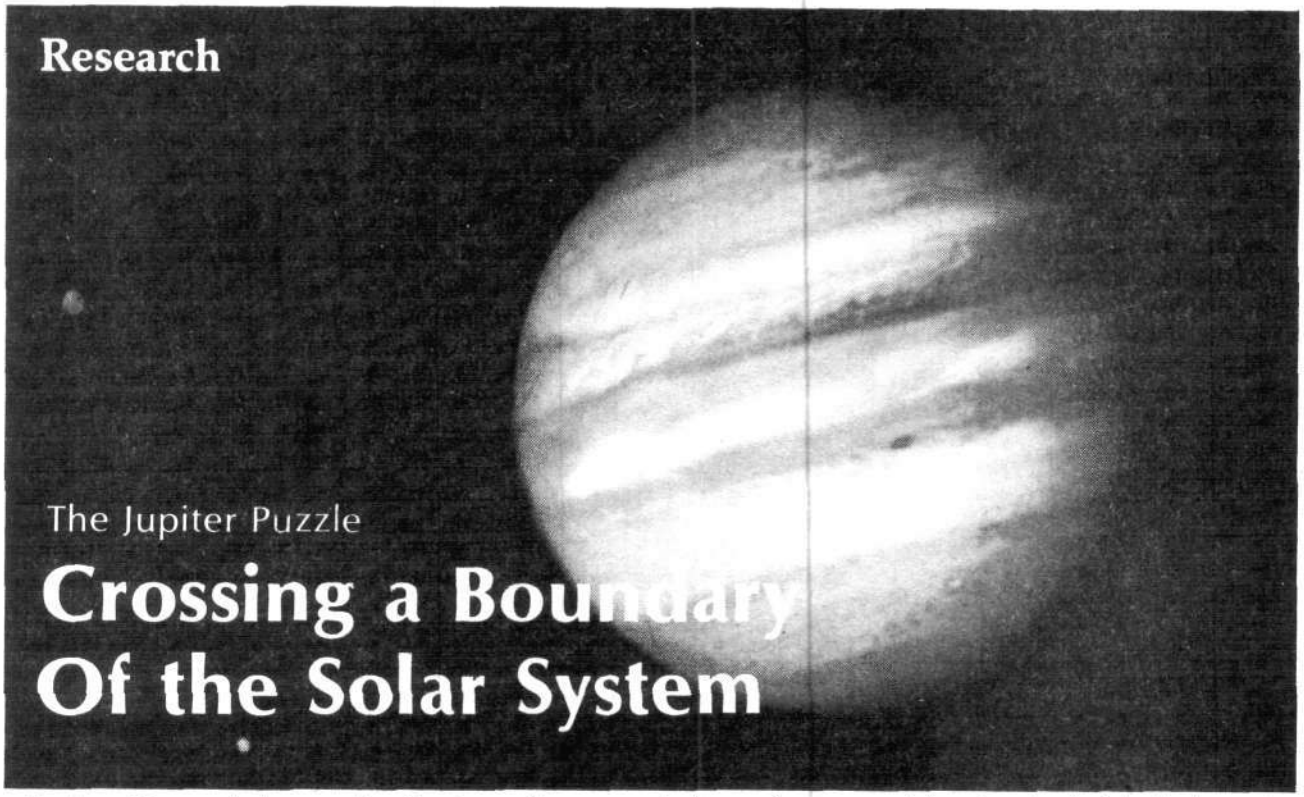


The Jupiter Puzzle

Crossing a Boundary Of the Solar System

The latest Voyager I photographs of Jupiter and its moons challenge the noncausal theories of today's hydrodynamics.

When Galileo Galilei first discovered Jupiter's four moons in 1610, he and Johannes Kepler immediately used the discovery of this miniature planetary system around Jupiter, or mundus Jovialis, to defend the Copernican system. At the time, this was such a politically explosive Platonic reconceptualization of man's view of the universe that inquisitions and pogroms were often waged against Copernican adherents.

Current efforts to scrap the National Aeronautics and Space Administration's basic space thrust, if successful, will be just as destructive to humanity's future as the total defeat of Galileo and Kepler would have been had it occurred in the 17th century. Killing NASA's space effort destroys the nation's ability to go beyond the very frontiers of basic science and cripples the development of the Platonic hydrodynamic tradition in crucial areas like plasma physics.

Today, as Voyager I has swept past the last of Jupiter's four moons, even before the two-week period needed for all the temperature probe results and other data to come into the Jet Propulsion Laboratory in Pasadena, Calif., a wave of excitement has swept through the scientific community. As noted by Bruce Murray, director of the Jet Propulsion Laboratory, NASA's command center for the flight: "We are crossing an important boundary in our solar system."

The mundus Jovialis poses the challenge of understanding a highly dynamic but intricately well-ordered, fluid-gas, spinning layered organization of matter. This in turn interacts gravitationally and electromagnetically in a remarkably ordered way with the rest of the solar system. Through the unanticipated nature of the Voyager I probe results, once again the mundus Jovialis is demanding a still higher Platonic reconceptualization of our understanding of the universe.

The Puzzle of Jupiter

Jupiter has long been considered a puzzling planet, for it radiates 2.5 times the amount of heat it receives from the sun. Early models postulated that this might be because of nuclear reactions inside the planet or heat from gravitational contraction. More recent evidence has discredited such ideas. Currently, there are no adequate theories to account for this energy, although Voyager I has begun to probe some phenomenal energy-generating electromagnetic interactions on the planet.

This is not a trivial problem that can be readily patched over as some foolish scientists, like Gary Hunt of University College in London, have recently attempted in an effort to blunt the excitement and positive impact of the Voyager I probe results. It is precisely this unaccounted-for energy generation that demonstrates how current physics fails to function on a causal basis.

Jupiter encompasses 71 percent of the matter in the solar system that did not end up in the sun and is currently believed to be ordered in three successively encompassing liquid layers, which, in turn, are surrounded by a complexed gaseous atmosphere. The liquid layers include a very small, 30,000 degrees Kelvin (K) iron-silicate inner core, surrounded by an abundant liquid metallic hydrogen—an electrically conductive layer under

tremendous pressure and temperature (11,000 degrees K). This core is further surrounded by an outer liquid layer of molecular hydrogen, interacting with atmospheric layers that include helium and some ammonia, methane, and water. Such a model makes Jupiter the most accessible open hydrodynamic laboratory in our solar system—a huge, spinning layered sphere of liquids and gases.

The pictures of Jupiter's atmosphere that Voyager I has transmitted back to earth, compared to those taken four years ago when Pioneer photographed Jupiter, have amazed many scientists working on the imaging team. "What we're seeing is a rapidly changing planet," said Dr. Bradford Smith, a University of Arizona astronomer heading the Imaging Science Voyager team. "It's clear to us that Jupiter is far more complexed in its atmospheric motions than we ever imagined.... The atmosphere acts as though it were composed of liquids. It's not, of course. It's a gas. But it looks like swirling liquids, stretching out in a stream, splitting, and then coming together again, interlocking."

Voyager I's probes of such hydrodynamic phenomena will be critically important in reconceptualizing the coupled large-scale atmospheric-oceanic weather pattern on earth.

The Great Red Spot

The Great Red Spot, a permanent hurricane that wanders slowly in longitude around the southern hemisphere in Jupiter's atmosphere, has changed remarkably over the past four years. Then red, the spot is now dark brown and has changed in shape. "It's not as uniform as it was four years ago when Pioneer photographed it. And there are atmospheric currents swirling around it that weren't there before," noted Dr. Smith.

But the Great Red Spot is not the only poorly understood phenomenon photographed in Jupiter's atmosphere. A permanent jet stream of frozen ammonia moving at speeds of about 350 miles per hour has been photographed above Jupiter's clouds. Even more important, Voyager photographs show huge cyclones traveling across the planet at up to 200 miles per hour. These overtake and attach themselves to other similar cyclones for as long as 12 days, and then break apart again. "We don't understand the mechanism where one of these storms overtakes another," Dr. Smith explained at a recent Voyager press conference. "We don't know why a lot of things happen that we're seeing."

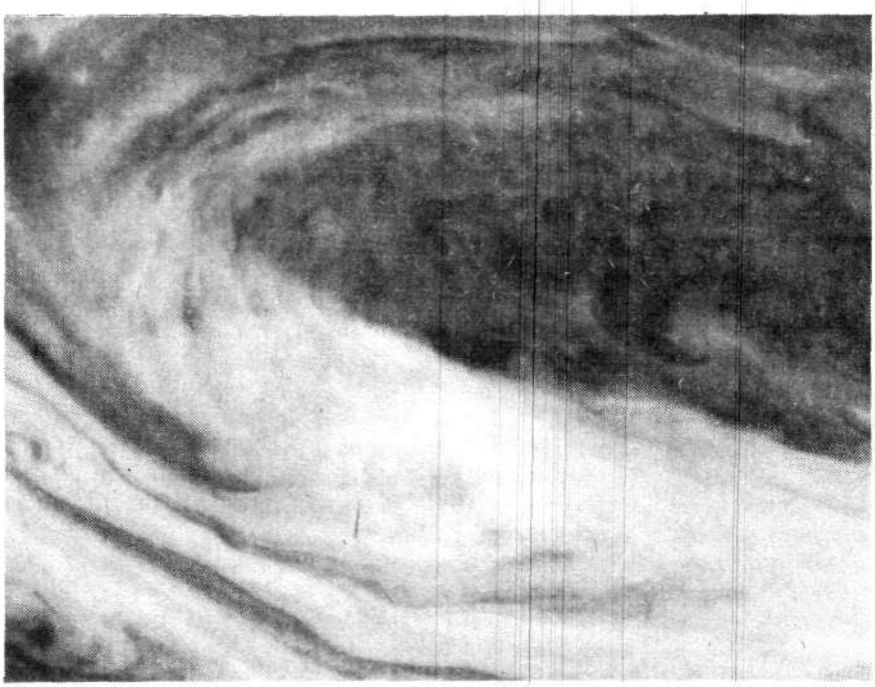
Nobody is more shocked about the hydrodynamics of Jupiter's atmosphere than the hydrodynamicists. Current hydrodynamic theory states that at the high velocities of the phenomena observed in Jupiter's atmosphere, for the level of viscosity or frictional resistance associated with Jupiter's atmosphere (technically speaking, for very high Reynolds numbers), phenomena should be randomly turbulent. Yet, Voyager I photographs universally indicated highly coupled, highly ordered forms of turbulence.

Like earth, Jupiter's upper atmosphere has an aurora, but scientists "did not expect to see the levels of emissions we are detecting," according to Dr. Lyle Broadfoot of Kitt Peak Observatory, team leader of the ultraviolet spectroscopy group. The ultraviolet equipment picked up much stronger emissions in the hydrogen spectrum than the roughly 400-million photons a second per square centimeter that could be accounted for by scattered sunlight. The Voyager I's actual reading of 4-billion photons a second per square centimeter tells you, according to Dr. Broadfoot, "that you are seeing an aurora, the effect of particle bombardment into Jupiter's upper atmosphere."

The Mundus Jovialis

As one moves away from Jupiter's atmosphere, even before arriving at the orbit of the first moon, Amalthea, Voyager I has located a major surprise. There is a thin, flat ring of rocky debris, mainly boulders, circling Jupiter in the equatorial plane only 34,000 miles from Jupiter's atmosphere—well inside of the orbit of Amalthea.

Amalthea, a small, dark, bombarded moon is itself interesting. It is twice as long (180 miles) as it is wide, with the long axis gravitationally held pointing into Jupiter. Amalthea is internally hot and plastic enough so that as it rotates, whatever portion faces Jupiter becomes tidally distorted (elongated) to create its unique ge-



The Great Red Spot, Jupiter's permanent hurricane.

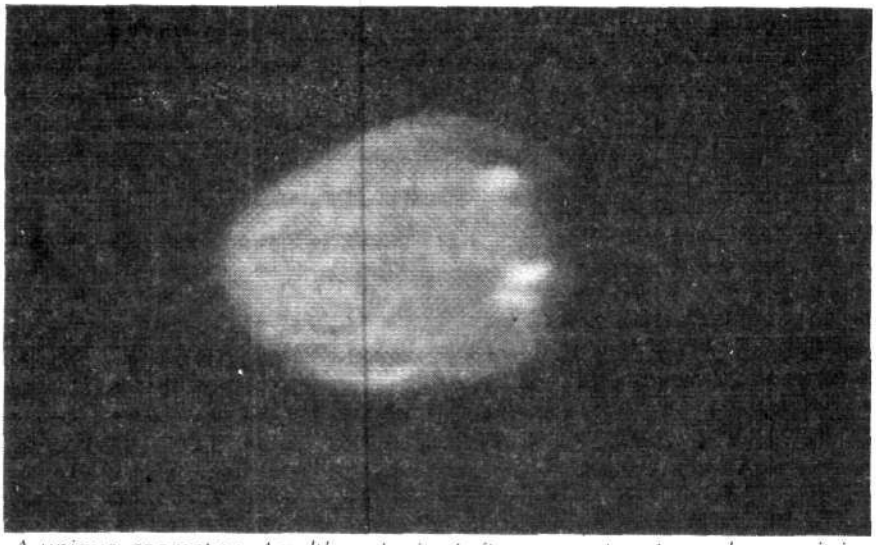
ometry, which is unprecedented in the solar system.

More baffling are the clouds of ionized and partially ionized gases electromagnetically and gravitationally trapped in an interaction between Jupiter and its second moon, Io. Io vaguely resembles a waterless Yellowstone National Park. Mainly mineral flats, with considerable volcanic activity, it puzzles scientists because of its geologically young, unbombarded surface.

Io orbits within an enveloping large cloud of ionized and partially ionized sulphur and hydrogen, called Io's torus. This donut-shaped cloud lies within Jupiter's equatorial plane. Io has, in addition, a narrow plasma flux tube, that moves around Jupiter with Io as Io moves through its orbit. This narrow plasma flux tube is perpendicular to the equatorial plane, delineated by a magnetic bottle following Jupiter's magnetic field lines.

This magnetically bottled plasma flux tube periodically wobbles out of Io's range, probably due to perturbations of Jupiter's magnetic field, which ordinarily is held at a certain size because of the pressure exerted by the impinging solar wind. Shortly following periods of intense magnetic storm and solar flare activity on the sun, Jupiter's magnetic field, delimited by its bow shock wave, may shrink up to 50 percent in size. Initial measurements relating to this plasma flux tube "surprised us out of our chairs," according to Dr. Donald Shermansky, on the ultraviolet spectroscopy team. Its plasmas are estimated to be 100,000 degrees K.

The moon Io and its strangely coupled electromagnetic interactions with Jupiter have been associated with intense bursts of radio emissions of tens of meters (decimeters) wavelength range since the 1950s. At that time, telescopic observations of Io crossing the face of Jupiter were linked to these periods of intense bursts of radio emissions, estimated to be the energy equivalent of a 1 megaton fusion explosion every second. The failure of current physics to begin to tackle these electromagnetic interactions, which under certain limited conditions generate such intense bursts of energy, challenges scientists to reconceptualize this physics on a higher level.



A unique geometry: Amalthea, Jupiter's first moon is twice as long as it is wide.

Equally poorly understood as this magnetically bottled plasma flux tube is the phenomenon of high-energy electrons, which for unknown reasons reach such high velocities that they escape Jupiter's magnetosphere and are found beyond Jupiter's bow shock wave in interplanetary space. Like the rest of Jupiter's poorly understood phenomena, they provide evidence of existing in a highly ordered universe. Once they escape Jupiter's magnetosphere, the electrons spin down the spiraled magnetic field lines of the sun and intersect the earth every 13 months when Jupiter and the earth are connected by the spiral lines of the interplanetary magnetic field.

The larger, outer moons of Jupiter —Europa, Ganymede, and Callisto— or at least the latter two, which were photographed close up by Voyager I, give evidence of being spinning spheres of mud and water covered by layers of ice. Callisto has eight or ten rings that spread out from the largest collision basin on that moon, as if isostatic rebound ripples became frozen into place. The craters on Callisto are shallow and devoid of sharp rims, as would be expected from the proposed ice-mud-water model of that moon. Ganymede is somewhat similar, with even fewer craters.

If all their instrumentation continues to function well, the Voyager I-Voyager II fly-bys will provide an immense amount of information about Jupiter and its four moons, six previously unanalyzed bodies associated with Saturn's system, the planet Uranus, and Uranus's moon, Miranda. The two-spacecraft project costs only $400 million—25 cents per American. Yet, it generates a wealth of information crucial to the further development of mankind.

After Jupiter?

However, unless a major national policy change is made and the NASA tradition of the 1950s is relaunched, Voyager I will not represent the crossing into a new frontier within the space program; it will symbolize the last of a generation of space probes, a relic of a now politically dead commitment to progress.

Aside from the Voyager pair, the already launched Pioneer II scheduled to probe Saturn this September, and a Galileo mission projected to probe Jupiter in the 1980s, NASA has had all future space probes as well as its space colonization efforts cut from its budget.

Whether America's efforts to know our universe is halted is now your choice.

—*Carol Cleary*

The Hundred Years' War on Edison

by Michael Tobin

A Streak of Luck by Robert E. Conot, New York: Seaview Books, 1979. $15.95.

"Thomas Edison and His Electric Lighting System," by Christopher S. Derganc, *Spectrum*, Feb. 1979, pp. 50-59.

I was preparing a tribute to Thomas Alva Edison to celebrate the 100th anniversary of his incandescent lamp when these two works on Edison diverted me. The first, an Edison article by Christopher S. Derganc, appeared in the February *Spectrum*, the magazine of the Institute of Electrical and Electronics Engineers, and so challenged my own Edison research that I issued a prompt response in the form of a letter to the editor of *Spectrum*.

Hardly had I completed my letter when Conot's book on Edison, *A Streak of Luck*, thrust itself into the market place with its publisher's claim that this "landmark study" presents Edison's "complete story for the first time." Of course, I immediately obtained a copy of Conot's book and, after a first reading, decided that the work demanded an immediate review.

In Response to Derganc

Derganc's article, "Thomas Edison and his Electric Lighting System," includes the assertion that Edison "was actually a skilled practitioner of Systems Engineering, not the tinkerer of legend." This is certainly better than many recent works on Edison. Unfortunately, the major thrust of this article is better characterized by Derganc's statement near the end of his piece, "Edison made no revolutionary breakthrough in electric-lighting technology."

Derganc tells us, as if it were a matter of fact, that Edison did not really invent the constant voltage Dynamo; "Edison's dynamo was essentially an improvement on an earlier model invented by Siemens." Then he says that contemporary inventors, Elihu Thompson and Edwin Houston, had publicly advocated a low armature resistance at about the same time Edison did. As for Edison's claim to the Incandescent Lamp? Derganc tells us that at best Edison must share this invention with "Joseph Swan . . . an English inventor [and that another] Englishman, St. George Lane-Fox, patented a high resistance . . . lamp in 1878."

Finally, we are told, "Sawyer and Man anticipated Edison's feeder-main design by almost two years."

What's left of Edison's invention claims in the electric lighting field?

Not much. However, Derganc assures us that a higher reputation can be asserted for Edison as a "systems engineer." It . . . "was Mr. Edison's unique ability to locate, assimilate and then synthesize state-of-the-art of science and technology into an economically feasible system....[That was] Edison's single, immense contribution to the field of electric lighting." Derganc also felt it necessary to add, "It would probably be a misnomer to call Edison a scientist . . . ."

Some Facts About Edison

When Edison announced his "etheric force" experiments in 1875, 12 years before Hertz's more carefully detailed experiments on wave generation, propagation, and detection, he was greeted with hoots—especially from the British scientific community leaders, including Lord Kelvin, Professor John Tyndal, Sir William H. Preece, et al., and from many American scientists as well. From then on, Edison distinguished himself from the theoretical scientists by calling himself an industrial scientist.

In response to Edison's 1878 announcement of his planned electrical system, the same "scientists" declared Edison innocent of the laws of physics and of science in general. Edison retreated a second time and voluntarily relinquished all claims to the title of scientist. From then on, he proclaimed himself primarily an inventor.

As an inventor, Edison fought tooth and nail for priority claims to his own creative inventions as long as he retained control of his own patents. Against Swan, Edison's patent priority claim won even in the British courts. The Lane-Fox "high resistance" lamps were so pathetic that the British did not even field a claim priority. Siemans's constant-current dynamo was, indeed, the best before Edison's and included the beginnings of a segmented armature; but in other respects it was conceptually inferior to Edison's constant voltage dynamo.

The great innovation that Edison introduced was his hypothesis that a dynamo's efficiency need not be limited to a maximum of 50 percent by the law of Maximum Power Transfer. The proof of this was that his dynamo design yielded an efficiency of 90 percent compared to 40 percent for Siemans's dynamo.

Thompson and Houston were competent scientists but were placed into adversary relationships with respect to Edison by London-influenced financial backers who encouraged them and others to pirate Edison's inventions since "priority claims were not settled."

Similarly, the unfortunate American inventor Sawyer, an alcoholic, was directly urged to advance his exaggerated claims by Sir William Preece in American and British publications.

Systems Engineer?

Despite Edison's evident attempt to maintain his reputation as an inventor, Derganc proposes to relieve Edison of his title in exchange for that of systems engineer. Derganc tells us

"... Edison had to be able to move easily within and between three fields of endeavor—science, technology, and economics. In doing so, he acted as a translator, linking the abstract formulations of each field and producing a tangible result that transcended all three."

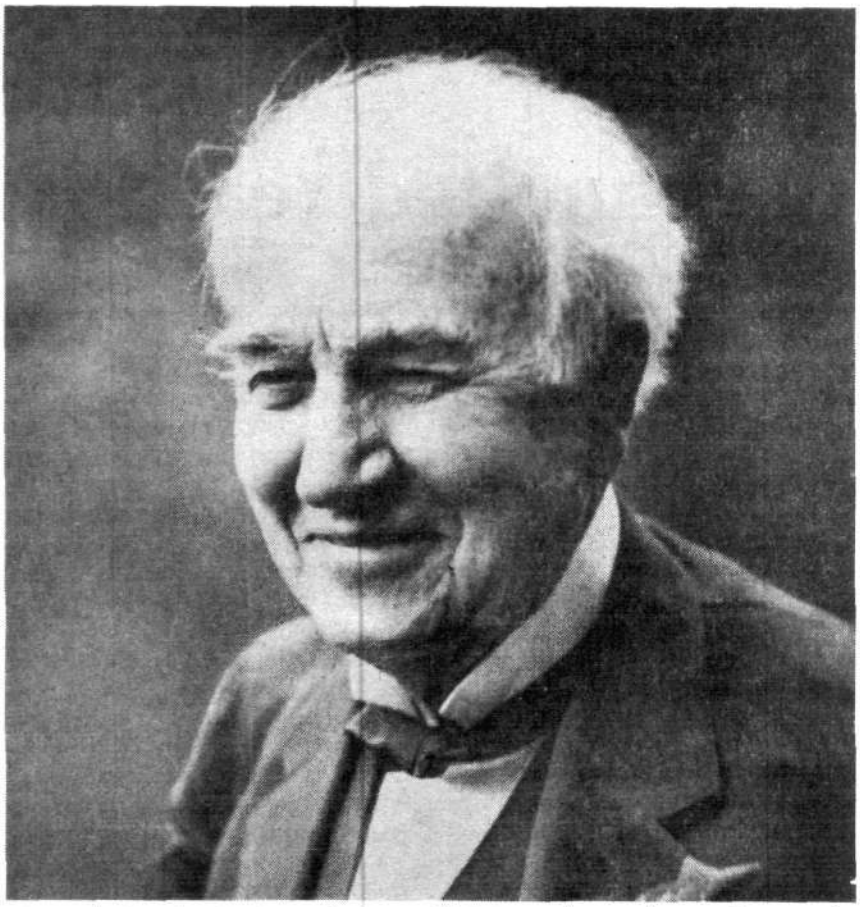
How did Edison, the noneconomist and the nonscientist effect this "translation"? He employed his "long-time friend," Lowrey, as his economic expert, and Francis Upton as his scientific expert. Edison, Derganc says, "manipulated these experts and their knowledge to best advantage in bringing his electric light and power system to fruition."

Now, Derganc's portrait of Edison the "systems engineer" is complete. Edison located, assimilated, and synthesized mainly other people's state-of-the-art scientific inventions and then manipulated experts, Lowrey and Upton, to bring his system into being.

The Historical Edison

This is not a complimentary portrait of Edison. But, more important to us here, it does not correspond to the historical Edison.

Lowrey, for instance, was not Edison's "long-time friend." He is more accurately described as Edison's long-time foe. In October 1878, Edison overlooked Lowrey's 1875 courtroom characterizations of him as a "rogue-inventor" and "a master of duplicity," and accepted, through Lowrey, the financier Morgan's offer of $50,000 and stock in the newly constituted Edison Electric Light Company in exchange for Edison's inventions in electric lighting for the following five years. In addition, Edison yielded to Lowrey's "suggestion" that Edison hire a number of assistants who, except for Upton, were previously in Morgan's companies. These "assistants," again with the exception of Upton, remained Morgan's spies throughout their lives. In later years, Upton proved his independence from those who hired him by paying homage to Edison as one from whom he learned his applied physics:"I cannot imagine why I did not see the elementary facts in 1878 and 1879 more clearly than I did. I came to Mr. Edison a trained man with a year's experience at Helmholtz's laboratory ... a working knowledge of calculus and a mathematical turn of mind. Yet my eyes were blind in comparison with the eyes of today; and ... I want to say that I had COMPANY!"[1]



Even during the 100th anniversary of his incandescent lamp, Thomas Alva Edison and his accomplishments are still being scurrilously attacked.

By "COMPANY," Upton was referring to the scientific community on both sides of the Atlantic which, of course, included all the "scientific" gentlemen Derganc tells us deserved major credit for Edison's system.

In a forthcoming article on Edison, I give substance to Upton's statement as proof of Edison's scientific leadership in lightning development. This is developed within the wider context of post-Civil-War history, when the British, still smarting from Lincoln's defeat of their attempt to fragment the United States and, thereby, more easily to reimpose colonial dependence, chose an alternative tactic to work toward their major strategic objective of forcing technological backwardness on the United States.[2] That tactic, especially as it related to Edison, was to obtain control of his patents and at the same time to hold back the implementation of the light and power industry.

The British tactic, however, did not take the hubristic Edison into account. When Morgan refused to finance the manufacture of Edison's lamps, dynamos, and other lighting components, Edison financed the venture mainly from his own capital accumulations.

London was outraged and ordered an all-out war on Edison, which included the already mentioned patent claim-jumping and the financing of the pirateers. This only increased Edison's stubborn determination to expand his electrical system. Although he was eventually (1889) removed from effective leadership by various destabilizations, including a treachery by his dearest friend, the alterna-

ting current caper, and financial and other sabotage by his "assistants," Edison's activity had by now catalyzed a worldwide industry that moved with a momentum of its own, even after his removal from the scene.

Edison's "forced march" of the electrical industry also catalyzed a generation of leading scientists and engineers, many of whom began their work under him. The introduction of whole new technologies, including alternating current transmission and electronics, followed on the heels of Edison's implemented electrical system.

A Streak of Pornography

Now to Conot's book, *A Streak of Luck*. Perhaps after reading the critique of Derganc's work, this book's title might suffice for some as a review. However that would be a mistake.

Conot's purpose and direction are more focused than his title. He even outdoes this blurb that appears in the publisher's book jacket: "Edison emerges as a lusty, hard-driving Midwesterner whose Bunyanesque ambition for wealth was repeatedly subverted by his passion for invention. He was complex and contradictory, an ingenious electrician, chemist, and promoter, but a bumbling engineer. . . . He . . . was chronically in debt and failed to pay his bills. He lavished money on his teenaged wives but never satisfied their need for affection. . . ."

Does Conot really tell Edison's "complete story for the first time"? No! He buries Edison under a mountain of details, mainly hostile to the real Edison.

But Conot's animus is occasionally useful as a pointer toward his sponsors. For instance, Conot informs us that Edison's "European agents [of his phonograph company] . . . coined the telegraph code name 'Dungyard' for him." Conot omits to name the European country (it is Britain, of course) and he repeatedly and carefully shields the agents sent in by London to control and destabilize Edison.

However, in his enthusiasm to detail hostile views of Edison, he sometimes uncovers an otherwise well-hidden spy. So, for instance, he does us a service by revealing that Francis Jehl, one of the "assistants" that Edison hired at Lowrey's suggestion (who later was commissioned to write his generally glowing "Menlo Park Reminiscences" in time for the 50th anniversary of Edison's incandescent lamp) actually hated Edison and was jealous of him, as shown by his private letter to a friend.

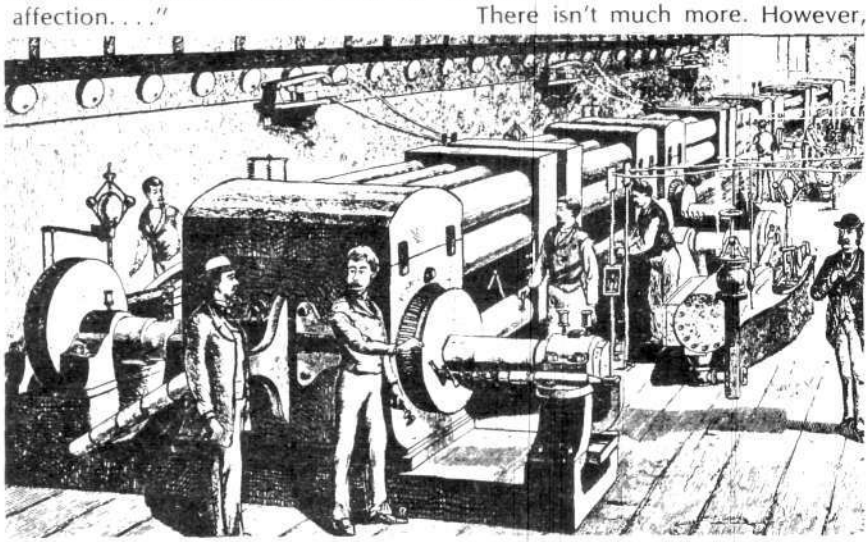
Most striking, Conot reveals his own state of mind by his repeated pornographic references in the book. This becomes understandable if the reader knows that Conot's publisher is actually Playboy Books, a fact learned by calling the book's publishers.

There isn't much more. However, before we leave Conot it is useful to consider the ferocity of his hatred and fear of Edison. He slashes, stabs, and garrots Edison's corpse as if he feared that Edison's ghost (or soul) would otherwise take on flesh and walk with the living. And, indeed, with the help of *Fusion* readers and other engineers, scientists, industrialists, and trade unionists, we will do our very best to bring Conot's worst fears into being.

A Suitable Memorial

The true history of Edison, until now mainly hidden, must be told so as to give courage to those engineers, scientists, industrialists, and trade unionists who are beginning to recognize that they face a conspiracy to reverse technological progress similar to the conspiracy Edison faced. By recounting our past history and simultaneously acknowledging our indebtedness to Edison for his gallant fight, we are morally enabled to take on today's opponents of scientific and industrial development who have by now insinuated themselves within our universities, our publications, and our scientific meeting—including the Edison Centennial Celebration.

As part of this fight, I have proposed that my organization, the Fusion Energy Foundation, and Edison's, the IEEE, fashion a suitable mark of appreciation of Edison's contribution to mankind's prosperity by initiating a petition to the relevant international scientific bodies to designate the unit of light flux, the Lumen, hereafter as the Edison.

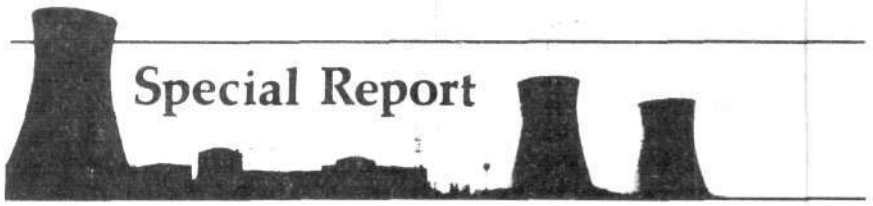


Edison's 1882 jumbo Dynamo, directly connected to a steam engine, could supply power to 1,200 lamps. Here, the Dynamo Room at the Pearl Street Station in New York City.

Michael Tobin, a Fusion Energy Foundation staff member, is a research and development engineer with 30 years experience, primarily in instrumentation and systems design for medical and physiological research. A member of the IEEE, the AAAS, and American Men of Science, he has published widely in his field. His history of Edison will appear in a forthcoming issue of Fusion.

Notes

1. Francis R. Upton, *Memorandum*, 1909, pp. 2-3.
2. Allen Salisbury, *The Civil War and the American System*, (New York: University Editions, 1978).



The Lie About Radiation *Continued from p. 15*

ology is, after all, a branch of medicine.

The fundamental point is that the interaction of the energies of radiation with biological processes is the basis for mediation of the negentropic lawfulness of the biosphere. The environmentalists are trying to take the science of radiation phenomena and turn it into magic; in this way, they hope to become the sorcerers who will lead civilization back to the Dark Ages.

It is undoubtedly true, as Edward Teller pointed out, that more people will have died as a result of the media-induced panic surrounding the Three Mile Island incident than from any alleged radiation-associated illnesses resulting from escaping radiation.

The fact is that low-level radiation, equivalent to that associated with a dental X ray, has *never* been shown to be harmful. All statistical studies to date have been unable to demonstrate an increase in cancer, heart disease, or any other illness associated with low-level radiation. In fact, people living in cities like Denver, Colorado—cities that have a higher amount of radiation because of the increase cosmic radiation in higher altitude areas than that released into the surrounding areas by the damaged Three Mile Island plant—show a slight *decrease* in the incidence of radiation-associated disease.

Indeed, researchers are beginning to demonstrate that low levels of radiation hasten the process of wound healing and other life processes.

The claim that all radiation is harmful is based on those studies involving *high-dose* irradiation, where radiation does lead to noticeable biological effects. Very high doses of radiation are used as a tool for the destruction of certain diseased cells, such as cancer or hyperactive thyroid tissue.

The extrapolation of high-dosage effects to low doses, however, is blatantly unscientific. It is known that certain deleterious effects on genetic material are caused by *multiple* "hits" by high-dosage levels of irradiation. It is believed that there is a "threshold" effect operative in radiation exposures, such that exposure below critical levels is essentially nonharmful.

A Natural Phenomenon

In terms of the Three Mile Island case, the noncontinuous nature of the irradiation caused by the sporadic, low-level release of radiative material from the plant means that any given tissue was not continuously exposed to radiation and allows for normal cell tissue repair of any material that might have been damaged by irradiation.

Finally, it must be pointed out that radiation is and has always been an environmentally natural phenomenon. The average human being is annually exposed to more radiation than anyone standing in the vicinity of the Three Mile Island plant gate. Sleeping with another individual also exposes one to an increased irradiation level just slightly less than one is exposed to at any nuclear plant perimeter. That is because all the materials we eat, drink, and inhale are *naturally* radioactive. (Sleeping with two other people, and we hope the anti-nuclear groupies are listening, leads to an increased radiation exposure well above the level associated with exposure to a nuclear power plant.)

Other incidences of increased radiation exposure have full media support. For example, the increased exposure during airplane flights at high altitude and during sunbathing both have irradiation risks far greater than any exposure-associated-activity around a nuclear power plant.

The final irony in this, as recent stud-

The Radiation Scare

Press and radio reports: uncontrolled, large releases of radioactivity. Civil Defense officials report more than 1,200 millirems per hour.

The Facts: There were short-term, planned releases of very low level activity three or four times for a period of 45 minutes to 1 hour each. The maximum release at the site boundary was 30 millirems per hour. At 3 miles, 3 millirems per hour; and at 20 miles, .3 millirems per hour. As of Tuesday, April 3, the maximum total exposure at the site boundary was 85 millirems; at 3 miles, 8 millirems; at 20 miles, .8 millirems.

The maximum permissable exposure per plant worker is 3,000 millirems per quarter year and 5,000 millirems per year.

One dental X ray gives you 20 millirems, a chest X ray 85 millirems.

Press reports: "Radioactive Steam Clouds Escaping the Reactor."
Fact: No radioactive steam clouds were released.

Press reports: "Radioactive Clouds Moving Toward New York City."
Fact: No radioactivity was moving toward New York City.

Press reports: "Deadly Radiation Moving Toward Harrisburg."
Fact: No radiation was moving toward Harrisburg.

Press reports: "Radioactivity Leaks from Containment Walls."
Fact: Radioactivity was released from the plant stack as normal procedure and at the low levels stated above.

ies have shown, is that the radiation that comes from nuclear plants is appreciably less than the radiation released from coal-burning power plants. The coal-burning plants increase radioactive pollutants because of the high level of radioactivity in lignite that is released into the atmosphere.

By every rigorous environmental criterion, nuclear power, as the saying goes, is safer than sex, sunbathing, jet-setting, coal burning—or dying from the cold if the antinuclear mob shuts down our nuclear plants.

—*C. Cleary and R. Pollak*

6 The Jane Fonda Syndrome

"The China Syndrome," Columbia Pictures, March 1979

Jane Fonda's new movie, "The China Syndrome," has been widely viewed and reviewed as an environmentalist thriller trumpeting the dangers of nuclear power. It is more accurately seen as a psychological warfare exercise carried out to prepare Americans to accept the necessity of fascism in the United States.

"Objective" refutations by nuclear scientists and others of the doomsday scenario envisioned by the filmmakers—a nuclear accident in which "an area the size of the state of Pennsylvania is covered with a radioactive cloud," as one character put it—are almost beside the point. The most important "Big Lie" in the movie is not about nuclear power per se, but about the nature of the human species.

The film makes three interlinked assumptions about the way the world works.

First assumption: The primary human emotion, the driving force of human behavior, is equivalent to that *felt by a dog contemplating the prospect* of his dinner.

Sad-faced Lemmon: Glorifying the victim syndrome.

All the film's major characters obey this simple psychological dynamic. The movie's villains—the power company executive who cuts corners on reactor safety in order to spare the expense of shutting down, the construction company supervisor who fakes records of reactor construction for the sake of cutting costs and delivery time, or the television producer who attempts a coverup of the initial nuclear accident because his only concern is program ratings and public esteem—these Big People are clearly ruled by simple greed, which the movie identifies in straightforward fashion with large-scale economic profit.

Less obvious is the point that the good guys—Jane Fonda as the doll-like TV glamor puss begging for her chance to do "hard news" coverage, Jack Lemmon as the sad-faced reactor supervisor "in love" with his machine, and Michael Douglas as the cynical cameraman at war with "The System"—are also the creatures of their appetites. These are the Little People, "ordinary human beings with plenty of vices just like you and me."

The Victim Syndrome

The film takes great pains to prove the point when Douglas films the plant control room in violation of regulations and jeopardizes Ms. Fonda's career; or when Ms. Fonda acquiesces in the coverup of the near disaster at the plant in order to keep her job; or when Lemmon initially refuses to acknowledge to the outsiders that anything important has gone wrong.

Second assumption: The virtue of the Little People resides in their perpetual status as Victims of the Big People, and that the highest goal to which they can aspire is to recognize that *role, accompanying the recognition* with loud cries of "Rape!"

It is no accident that the film ends not with the massive "meltdown" of the reactor core that is the threat on which the whole melodrama of "The China Syndrome" turns, but with a public statement on television by "the littlest person of them all," a 25-year power company employee and friend of Lemmon whose dominant trait throughout the film is the conspicuous desire to "stay out of trouble." Shocked by the assassination of Lemmon as he tries to tell the truth about the plant's unsafe condition to Ms. Fonda's TV camera, the old fellow is finally moved to take the microphone and demand "an investigation."

***Third* assumption: Science and technology are no more than supererogatory aspects of a human nature thus defined; the power associated with them is thus a magnification of the irrational; and, ultimately, anything can happen and nothing makes any real sense.**

With the subtlety of a steam drill, the movie hammers home the point that all the malfunctions of the fictional Ventana nuclear power plant are ultimately traceable to "human error." Therefore, natural law does not exist.

The drama of the Little People versus the Big People, who control the reactor and the workings of the society that sanctions its presence, is experienced by the audience as a constant succession of vignettes in which the individual, utterly alone, faces a hostile, arbitrary world with dim prospects for survival.

Again and again in scenes at the television station and the power plant, we are presented with visuals in which the "technology" on view is used as a metaphor for organized, systematic

lying. Ms. Fonda's primping into her TV persona whenever a camera appears is one obvious example. Insistence that technical terminology associated with the reactor is ipso facto an attempt to dehumanize language and cover up the consequences of reactor failure is another. And much is made of the fact that, when the reactor heats beyond normal temperatures, the computer printout describes this as an "event," not an accident.

By the time Lemmon takes over the control room of the plant at gunpoint and threatens to blow up a chunk of southern California in order to explain why the plant must be shut down—a favorite scenario for theorists of nuclear terrorism—he seems positively logical!

Thus, the movie operates much as newspersons so in evidence during the events at the "living theater" replay of "The China Syndrome" at the Three Mile Island nuclear plant outside Harrisburg, Pa. There, if nuclear experts succeed in answering a succession of hypothetical questions, they are greeted with the unanswerable inquiry, "Why should I believe anything you say?"

Predictable Jane

Those who have followed Jane Fonda's career in and out of films for the past years have seen all this before, minus the reactor, of course. In the 1960s, there was her marriage to "bad boy" director Roger Vadim, who made such "artistic" psychedelic pornography as "Barbarella," in which Ms. Fonda glorified the irrational as plasticized science fiction sex object. Later came her marriage to "New Left" activist Tom Hayden, who celebrated the Newark race riots with a front-page article in the *New York Review of Books* hailing the looting of liquor stores as a blow for economic equality.

Ms. Fonda subsequently appeared as a prostitute discovering her "feelings" through psychotherapy and "human sex" in the movie "Klute." More recently, Ms. Fonda played Florence Nightingale to a Vietnam War veteran's paraplegic blob of anguish

Some Honest Press Coverage

The *Atlanta Constitution* April 8 exposed the psychological warfare press campaign in an article titled "Faked News Hurts Credit of Media at N-Plant Site." Reporter Barry King then reviewed the following instances of press fabrication:

(1) A camera team from a major national television network asked people from Middletown to stay out of camera range as they filmed the streets. Later these same people watched coverage in which the press described the shot as that of an "abandoned city."

(2) At a firehouse where a radiation monitoring team was stationed, a robin hit a plate glass window and fell to the ground. A camera team filmed the incident and reported on the news that night that "birds are falling from the sky."

(3) A camera team was seen putting "for sale" signs on houses and then filming the result, describing the incident as people packing up and moving out.

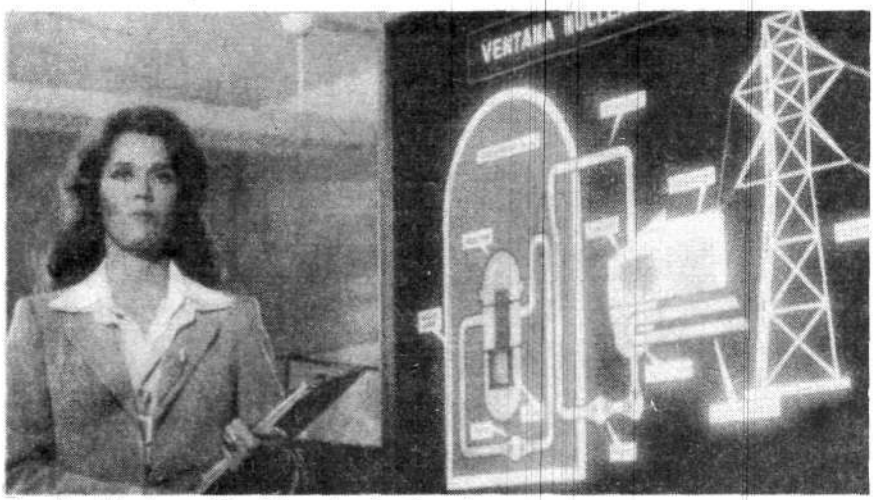
In Europe

The West German financial paper *Handelsblatt* in an editorial April 3 countered the Harrisburg scene: "There can be no taboo on nuclear power . . . . One could dictate zero growth but that policy could not remain limited to GNP, but would also have to be applied to the reproduction of mankind . . . . Do you want the gigantic bureaucracy solely responsible for steering every form of growth, strictly and in police-state style? Such a bureaucracy, which would self-evidently have to be a supranational one, could not be established without war."

In Mexico

The Mexico daily *Diario de Mexico* April 1: "We can understand the uneasiness, but we cannot justify the hysteria that appears to have taken over reasonably sensible minds. Whenever man takes on new forces, the unexpected always arises. If the first person to have used fire, upon being burned had prohibited its further use, this decision would undoubtedly have paralyzed progress."

The Mexico daily *Uno Mas Uno*: "The question is not one of imagining an atomic end of the world, but in constructing a world where science becomes a tool for freedom from poverty, want, and inequality."



Predictable Jane: Glorifying the irrational.

in "Coming Home." Finally, we have Ms. Fonda and Hayden putting aside their Maoist Little Red Books to stump for the candidacy of "Mr. Austerity," Zen Buddhist presidential aspirant, California Governor Jerry Brown.

Why Nuclear Energy?

Nuclear power is not an end in itself, but a mediation of human reason. If we are to raise global living standards to the level necessary to prevent inevitable outbreak of mass plagues and general war and depopulation, we must build hundreds of new nuclear plants. Without the material progress afforded by nuclear energy, billions of currently living persons will not reach the potential for human development now present among the American people.

Ms. Fonda and her financial backers —the same people who brought you Meyer Lansky and the drug culture, Energy Secretary James Schlesinger and his era of permanent scarcity, and Henry Kissinger and his lust to fight World War III—do not believe in reason.

The not-so-hidden message of "The China Syndrome" is this: America needs a General Haig, a man on horseback, to keep all the crazy Big People and Little People in line. As the *New York Times* put it, editorializing on the recent Jupiter space probe: "Science is useful, but myth is the stuff of life."

—Donald Baier

E.C. Solution

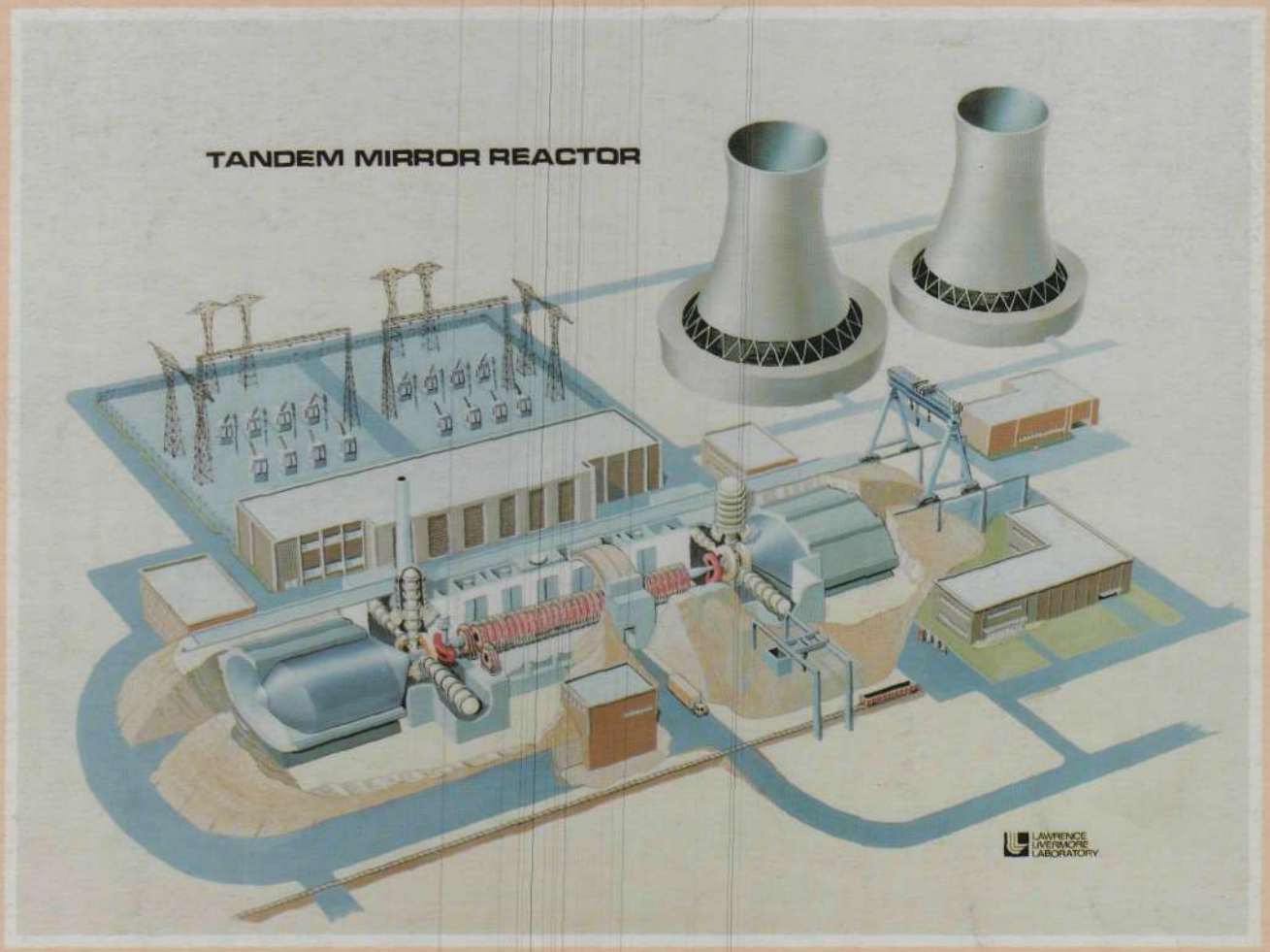
Continued from p. 20

ed, was a direct result of the fact that two of the six reactors scheduled to be operational last year were not available, and financial restrictions had prevented EdF from installing gas turbines for peak demand backup. To fill this temporary deficit, the French government plans to adopt a stopgap supplementary program to construct a 600-megawatt coal-fueled plant and six 80-megawatt gas turbines.

Also planned is the speedup in construction of three nuclear plants already underway—a decision made by the Giscard government last month, partly to offset France's loss of two reactors contracts in Iran and partly to meet the initial 1975 program target of 35 gigawatts of nuclear capacity by 1985—in addition to a 1,200-megawatt fast breeder Superphenix.

The major impetus for expansion of the French domestic nuclear grid came after the 1973 oil price rise, when France was dependent for 77 percent of its energy on imports of oil. France set a policy of reducing this dependency to 60 percent by 1985, taking into account a projected overall 30 percent increase in total consumption. Under the plan, nuclear power will constitute 20 percent of total energy by 1985, compared with 2 percent today.

—William Engdahl



"Mirror" Power Plants by the 1990s?

The mirror machine holds the greatest promise for leading to economical fusion energy, even though the tokamak is now more experimentally advanced. As *Fusion* reporter Charles B. Stevens explains, once the mirror experiments at Lawrence Livermore Laboratory successfully demonstrate proof of principle, the road will be clear for building electric power plants based on the mirror approach by the end of the 1990s.

Above is an artist's conception of a tandem mirror power plant that would produce 1 million kilowatts of electricity. The fusion reaction is generated in the long, cylindrical solenoid region; the magnetic mirror configurations at each end are used to confine the fusion fuel.

Since the length of the solenoid determines the amount of fusion energy produced, mirror fusion plants could be custom designed to generate the amount of electricity needed by increasing or decreasing the size of the solenoid. A cost advantage is that this type of plant lends itself to modular design, and sections of the solenoid could be removed easily for maintenance or replacement.

On the front cover is a neutral beam's view of one of the magnetic mirrors used in the Tandem Mirror Experiment at Lawrence Livermore Laboratory. Technician Bill Thompson is shown checking blueprints beside the magnet. Note that the magnet is shaped like the seam of a baseball.

Cover design by Christopher Sloan. Photograph and drawing courtesy of Lawrence Livermore Laboratory.