FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION
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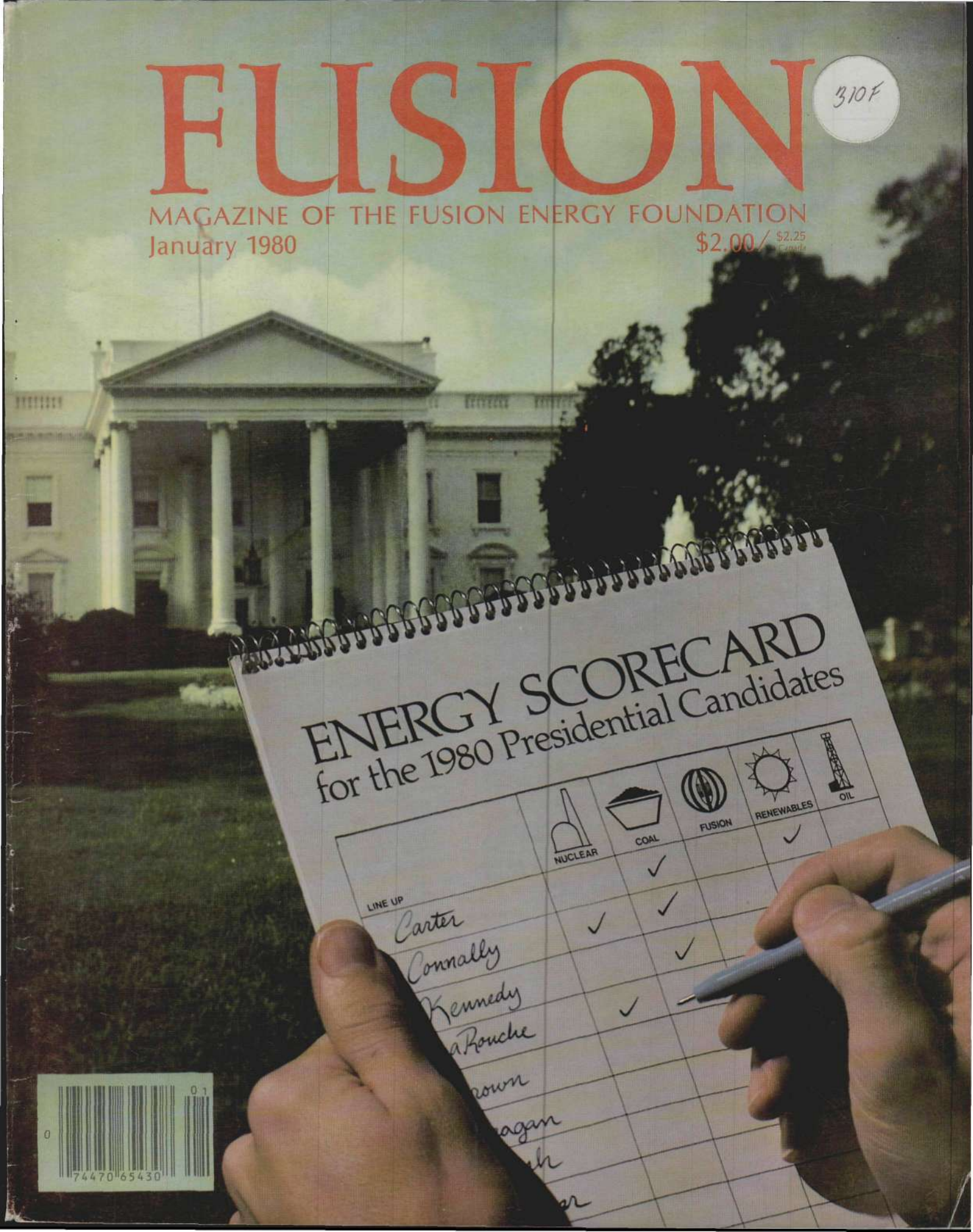

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Features

News

Departments

Editorials

Stop The Crash Of '79

On the back cover of the October issue of *Fusion* we contrasted the nation's potential to achieve fusion in the 1990s with the ugly mug of the Ayatollah Khomeini and the Council on Foreign Relations' plan for "controlled disintegration." Now that the full lunacy of the Iran situation and its extremely dangerous international implications have fully developed, it is not necessary to grant us any special powers of prophecy. It is simply a question of correctly analyzing what the basic policy division is in the world today and how the Iran situation fits in.

From the point of view of one of the adversaries, the situation was summarized as follows in *Business Week* magazine Nov. 19:

> It may be that an Arab banking system funneling petrodollars through the European Monetary System will replace the current domination of the world's financial system by U.S. banks and the IMF. This depends, of course, on OPEC's willingness to play the power broker part. If it refuses, there is another scenario that many still think unthinkable: *open warfare, in which either the industrial West as a group, or the U.S. going it alone, gives up trying to work with OPEC and instead invades the oil fields.*

A Fundamental Division

Behind this bald policy statement lies a different political reality from that the editors of *Business Week* would have you know.

In every nation and major world center, there is a fundamental division

The Lightning Rod

My dear friends:

A fine old man, with whom I have maintained a pleasant and profitable acquaintance for some years, recently wrote seeking my assistance in a matter involving the current crowd in Washington. The venerable gentleman in question, Mr. Kris Kringle, informed me that his lifetime business, which, he averred, had never failed to give satisfaction to its customers, was in some jeopardy as a result of the economic policies pursued in our nation's capital. I told Mr. Kringle that as I no longer had much influence among those who govern our country, my only recourse was to put his case before the public in hopes that an aroused citizenry would hold the administration accountable for his plight.

His troubles began, said Mr. Kringle, when he received notice that he was required to file weekly Environmental Impact Statements "on the operation of toyshop, run on elfpower; and 1 sleigh with reindeer." Mr. Kringle was forced to hire a former Energy Department employee to handle the paperwork.

The new man, Rodney, promptly "blew the whistle" on the Kringle business by informing the DOE that Kringle "was not running an energy-efficient operation." He pointed out that "the North Pole is hardly the ideal location for a toyshop, since so much energy is required to keep it warm." Rodney also complained that "advanced technology is used in this toyshop, in defiance of our national security classifications; and the elves are paid high wages, which contribute to inflation." Furthermore, he added, "the reindeer do not obey the 55 mile an hour speed limit."

Rodney's analysis was fed into the Energy Department's computers, which produced a printout suggesting Mr. Kringle move his business to a warmer climate with a plentiful supply of cheap labor—Teheran. Mr. Kringle refused, and found himself "exposed" on the front page of the *Washington Post*, deluged with OSHA safety inspectors, and the subject of a lawsuit from Ralph Nader.

Nader charged that "Mr. Kringle obviously has something to hide, as his business operates under several different fronts. The Justice Department should investigate the relationship between Santa Claus Enterprises, Kris Kringle, Inc., and the Old St. Nicholas Toyshop Company for evidence of organized crime racketeering."

By the time Mr. Kringle finished paying all the lawyers, he was in sad financial shape. He applied to the Treasury Department for loan guarantees to enable him to carry on, but the Treasury Department replied that "as you have not laid off any elves, we are not in a position to offer the assistance you seek."

When Mr. Kringle responded that "laying off elves at the height of the holiday rush hardly makes good business sense," a copy of the correspondence was leaked to Senator Edward Kennedy, who promptly made a speech charging that "Mr. Kringle has too long been permitted an unjust monopoly on the nation's affections. He should be subjected to the laws of free enterprise, the same as anyone else." Kennedy then introduced the "Kris Kringle Anti-Trust Act of 1979."

Finally, poor Mr. Kringle received a notice from the White House that some help might be extended if the government were allowed to appoint "an emergency financial control board, as you seem to have run your business very badly." But many in Congress, notably Senator Proxmire of the Banking Committee, are saying that "the failure of Claus Enterprises would be good for the country, as it would help to cool off the economy."

There the matter now rests. If you wish to aid Mr. Kringle, as I do, please contact your elected representative, or

Your obt. svt.

between two policies. On the one side is a reorganization of the world's monetary and investment apparatus along the lines of the European Monetary System to provide for high-technology growth in the advanced sector and massive technology transfer and investment in development projects in the Third World. On the other side are deindustrialization, depopulation, austerity, and war—all to preserve bankrupt and incompetent institutions like the International Monetary Fund.

As we document in this issue, the situation in Iran, including the ongoing "crash of '79" scenario, was conceived and implemented by the international "Dark Ages" faction, particularly the British intelligence agencies that created the Muslim Brotherhood. The only solution in the short term lies in the full exposure of those U.S. officials and individuals—like National Security Council head Zbigniew Brzezinski and former attorney general Ramsey Clark—who, along with the fanatics of the Muslim Brotherhood, are responsible for the danger to American lives and to world peace. Simultaneously, U.S. political life must be brought out of its present saturation with disinformation and sheeplike behavior to a vigorous debate on the real issues facing the country.

If the nation is to have a future, full discussion of the basic economic, energy, and related policy questions must begin now and continue until we assure the election of an administration that is committed to U.S. world leadership through development of new energy resources and economic institutions.

Letters

LOVINSESQUE LIES

To the Editor:

Among the many puzzling features of your October 1979 issue is the discussion of conservation economics . . . . You criticize a Carter conservation program which you say (though your arithmetic is at best obscure) would cost $11 billion to save about 1.8 billion barrels of oil over the next decade, or about $6 per barrel. Your preferred alternative is to install, "for that same cost [$11 billion] . . . more than 10 gigawatts of nuclear-generated electrical power."

Ten gigawatts of nuclear plants, operating at 60 percent of full-power full-time capacity, and with transmission and distribution losses of 10 percent, would deliver over a decade a total of 473 billion kilowatt-hours of electricity, with a heat content of 1.7 quintillion joules or the equivalent of only 0.29 billion barrels of crude oil. This looks like a sixfold worse buy than the conservation program you criticize (assuming your data on it). The disadvantage would be at least ninefold if you counted the cost of the grid and fuel-cycle facilities needed to run the plant you assume, and over twelvefold if you included fuel and operating costs. So why is conservation a worse buy?

I agree that it's stupid to replace $20 to $25-per-barrel imported oil with synthetic fuels at $30 to $60 per barrel. But I think it's even stupider to replace it with nuclear electricity at over $100 per barrel heat equivalent. To save money and jobs, we should instead go for efficiency improvements at typically $0 to $10 per barrel and appropriate renewable sources at about $10 to $25 per barrel.

Amory B. Lovins
Friends of the Earth

The Editor Replies

It is a pleasure to be able to treat readers to a first-hand instance of the distortions and outright lies that fuel the hysteria of the environmental movement. Lovins's "calculations" are notorious for their dishonesty,[1] and his letter here is no exception.

Standard energy equivalences show that the energy produced by one nuclear plant is the equivalent of approximately 43,000 barrels of oil daily, so that the 10 plants that Lovins mentions are almost exactly equivalent to the .5 million barrels a day that are purported to be saved by President Carter's conservation program. As is usual for Lovins, he uses totally inconsistent measures for nuclear and other sources —nuclear bears all the transmission losses, power grid costs, and so on, while oil is taken at its full energy equivalent.

However, the much more important point is that Lovins and his friends in the Carter administration are in favor of less energy *whatever the cost*. Abundant cheap energy, which nuclear power provides, scares what little wits these people have left because it promises growth, industrial development, and progress. As Lovins outlined his theory of mankind's future at a speech at Franklin College in New Hampshire Aug. 13, 1979: "The future should be like the past, only more so." Indeed!

Note

1. For a detailed analysis of Lovins's dishonest use of documentation, see J.M. Gallagher, "Lovins's Data Source," *Science* December 22, 1978, pp. 1242-43.

HYDROGEN COSTS

To the Editor:

A minor critique of your article ["Putting a Hydrogen Economy on the Agenda," by Marsha Freeman, Nov. 1979, pp. 25-28] concerns your quoted prices for hydrogen cost. In my opinion they are much too low. Our work shows that costs for thermochemical hydrogen will be in the $7 to $15 per 10^6 BTU ($1978) range, depending on whose estimates and whose cycles you care to choose. Electrolytic hydrogen is no better; at 20 mills per kilowatt hour for electricity, their costs will be in the $10 to $12 per 10^6 BTU range or higher. Advanced techniques being researched at BNL [Brookhaven National Lab] may improve the efficiency of both electrical generation and electrolysis, but the much higher costs of materials for use in the electrolyzers may negate these gains.

For the near-term—year 2000 or so—coal appears to be the major hope for hydrogen production as oil and gas are depleted. This hydrogen will be used primarily as a chemical intermediate and not as a "universal" fuel. We will have to wait for cheap fusion power or something else before that occurs . . . .

Ken Cox
Los Alamos Scientific Laboratory

The Editor Replies

The costs quoted were included in the hydrogen article to provide the reader with some comparison among the various hydrogen production technologies. These costs were lower than those generally cited for two reasons.

First, the data used were considerably out of date, and based on comparative studies done by NASA at the end of 1975. Although these costs do not reflect today's inflation, they are the "real" cost of the technology without the cost escalations of inflation, environmental requirements, and high-interest credit.

In order for a transition to the hydrogen economy to take place, these inflationary costs would have to be removed, not only from hydrogen production but from investment in all newly commercializable technology. Otherwise, no company will be able to afford to build plants that incorporate new technology and industry would continue to stagnate.

Second, there is a fundamental difference between the cost of technology that has an inherent thermodynamic limit, such as the intermediate chemical processes in the thermochemical cycles, and a technology where thermal energy can be used directly to split water, as we will be able to do directly with fusion energy at some point in the future.

Therefore, the eventual use of "waste" heat from fusion electric production, coupled with as-yet-undeveloped materials to withstand fusion temperatures, will provide an inherently cheaper source of hydrogen than any comparative system. Although it is not possible, of course, to predict what that cost will be, the growth and develop-

ment of industrial society has been a function of an ever-cheapening source of energy, and will continue to be so dependent into the foreseeable future.

The proper policy criterion for commercial development of any new technology, therefore, is not what the first-generation facilities will cost, but what the "perfectability," in thermodynamic terms, of the technology will be.

Marsha Freeman

BRITISH SCIENCE

To the Editor:

I subscribed to *Fusion* because I believe that the antitechnology movement, and the countercultural tendency it exemplifies, are a sort of disease afflicting our society, and I was pleased to discover that someone was trying to cure it. However, being a college-educated individual with the usual range of prejudices, I soon found myself bemused by and somewhat incredulous of some aspects of the magazine, particularly the repeated attacks on the British and "British science."

At length, I became so annoyed that I actually went to the library and did some studying, particularly of philosophy, and I believe that it is beginning to dawn on me what it is that you are trying to accomplish. In fact, I look forward eagerly to the next article by Carol White.

I would like to share with you and your readers the following quote from the German philosopher Hermann Cohen, who wrote at the turn of the century: "The mystics and obscurantists who would pass off some so-called poetry for philosophy will eventually be driven away, along with other misguided spirits of this accursed and confused age. Classical thinking will once again awaken in philosophy as well as in art; and from it there will emerge a new direction in politics."

Ralph Gibbons
Portland, Oregon

INCREASING THE HUMAN SPIRIT

To the Editor:

I accidentally stopped at your booth in the Philadelphia airport and signed up for *Fusion* magazine.

On the plane home, I read the October and November 1979 issues, completely fascinated with the subject of fusion technology. What really impressed me, though, was the readability of the articles. I wasn't the best physics student in college, but your authors have the talent for clear, understandable writing. I really enjoyed reading these issues and can hardly wait for December's. However, I am somewhat perplexed by Mr. LaRouche's article in the November issue. I would appreciate his (or your) evaluation of my interpretation of his article.

First, I understood his article to mean that in some way the "human spirit" (i.e. knowledge, love, hate, etc.) is saved over time. And, as time passes the human spirit actually multiplies. My analogy of this kind of growth in a practical sense is the breeder reactor,

Continued on page 68

Calendar

January

22-25
Topical Meeting on Heavy Ion Physics
International Atomic Energy Agency
Trieste, Italy

30
Seminar: "Using the Riemmanian Economic Model to Improve Business Decisions"
Fusion Energy Foundation
New York City

February

26-28
Topical Meeting on Inertial Confinement Fusion
Optical Society of America
San Diego

March

17-19
Third American Physical Society Topical Conference on Diagnostics of High Temperature Plasmas
University of California
Los Angeles

24-26
Seventh Energy Technology Conference
Government Institutes, Washington, D.C.

News Briefs

FUSION IS EXPANDING!

We are pleased to announce that in 1980 *Fusion* will begin publishing 12 months a year without skipping the months of August and April. As the leading publication in the fight for nuclear power and advanced science, we can't afford to skip a month in bringing readers the latest news and analysis they need to win this fight.

The new 12-month *Fusion* subscription rate is $20; for two years, 24 issues, it's $38. Readers who have subscribed at the former rate—10 issues for $18—of course will receive a full 10 issues. At the same time, we have raised our membership rate to $75 annually, in order to help sustain our increased level of activity.

DEUTCH BACKS INCREASED FUSION BUDGET?

Washington sources report that Department of Energy Undersecretary John Deutch startled fusion scientists at a mid-November meeting with Vice President Mondale's staff when he said that the magnetic confinement program budget could use an additional $100 million. Deutch, who oversaw the fusion program as director of the Office of Energy Research and who still has fusion under his direction, has consistently downplayed progress in the magnetic fusion program over the past two years.

The vice president had called the unexpected meeting with representatives from the national laboratory fusion programs to discuss the status of the fusion effort, but he could not personally attend.

Giscard d'Estaing

GISCARD ANNOUNCES PUSH FOR EMS PHASE II

French President Valery Giscard d'Estaing is planning a spring 1980 European leadership meeting for discussions on expansion of the European Monetary System (EMS) into a second phase of lending for Third World development. The French president announced his initiative during a Nov. 27 interview on France's channel 2 television.

The EMS, now a currency link-up among the member nations of the European Community, was designed to spin off a new European Monetary Fund, supported by member nations to extend gold-backed credits for high-technology, development-oriented trade between the advanced and underdeveloped sectors of the world economy.

News from the late November summit of the European Community in Dublin, however, has left a question mark over what the British role in the new fund will be. British Prime Minister Margaret Thatcher clashed openly with continental leaders Giscard and West Germany's Chancellor Helmut Schmidt over the issues of London's North Sea oil price hikes and European Community subsidies to British coal production. After a series of public spats, which political observers characterized as behind-the-scenes British efforts to slow down the momentum toward the establishment of the development fund, Giscard told the press: "We are at the rupture point."

SANDIA DEVELOPS NEUTRON GENERATOR FOR CANCER TREATMENT

Sandia Laboratories in Albuquerque, N.M. announced that it has begun development of a neutron generator for use in cancer treatment, supported by an $800,000 grant from the National Cancer Institute. The new project follows two years of Sandia research indicating that neutron generators could be adapted to produce continuous beams of intense radiation for cancer therapy.

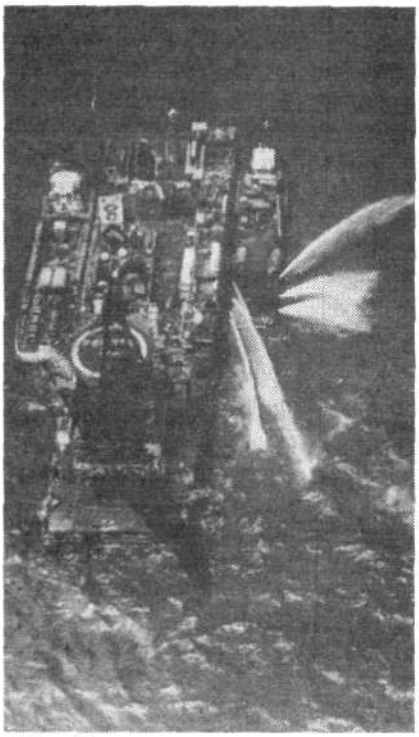
The effectiveness of neutron irradiation of cancers is not fully established, although preliminary research at medical institutions here and abroad indicates that at least some cancers respond better to neutron treatment than to irradiation with conventional gamma-rays or X-rays. The neutron effectiveness is thought to stem primarily from the fact that neutrons interact with the nuclei of atoms, producing atomic fragments that in turn produce effects more likely to damage a cancerous cell than are the effects produced by X-rays or gamma-rays, which interact only with the electrons in an atom.

NO DAMAGES FROM IXTOC SPILL, SAY TEXAS OFFICIALS

"There is no evidence of noticeable damage to Texas fish or wildlife other than possibly redfish larvae," as a result of the Ixtoc-II oil well spill into the Gulf of Mexico, according to a statement released Nov. 15 by the Texas State Park and Wildlife Department.

Controversy over the Mexican oil-well mishap reached a high point in late August when a U.S. State Department official made public an administration demand that the Mexican government discuss "reparations" for damages from the spill. The demand was sharply rebuffed.

"The oil has had little or no effect on shore or wading birds," the department statement said, "and had absolutely no impact on whooping cranes or migratory water fowl."



Ixtoc-II

FEF HOLDS ROME CONF. ON AFRICAN INDUSTRIALIZATION

More than 50 participants representing major Italian industries, the Italo-African Institute, and several African embassies attended the Oct. 24 Rome conference on "The Industrialization of Africa" sponsored by the Fusion Energy Foundation.

The FEF conference presentations, along with those of a similar conference held in Paris in June, will appear in book form under the title *Blueprint for the Industrialization of Africa*.

FEF CALLS FOR INVESTIGATION OF KHOMEINI SUPPORTERS

At a Los Angeles press conference Oct. 26, the Fusion Energy Foundation called for an investigation into the California activities of the Muslim Students Association. Nicholas Benton, Southwest coordinator for the FEF, outlined at the press conference how several hundred supporters of the Ayatollah Khomeini from the Muslim Students Association tried to disrupt an FEF forum at the University Hilton Hotel Oct. 16 near the University of Southern California in Los Angeles. In a leaflet announcing the event, the FEF had criticized the "antitechnology orientation of the Khomeini regime," comparing Khomeini to Cambodia's Pol Pot and charging that Khomeini was trying to bring about a New Dark Age.

Benton said that the students had been fed false rumors that "an agent of the Shah" was going to speak at the forum and that the Iranian consulate had worked with the Muslim Students Association in mobilizing the Khomeini supporters from all over southern California. Benton also noted that until last year, the leading organizer of Iranian Students in California, was Mustafa Chamran, now head of the Khomeini secret service, the SAVAMA.

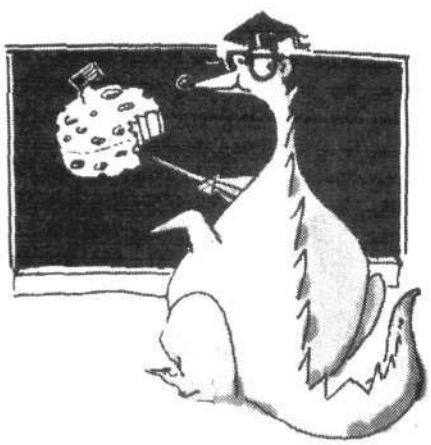
LOUSEWORT LAURELS TO EPA SPOKESMAN

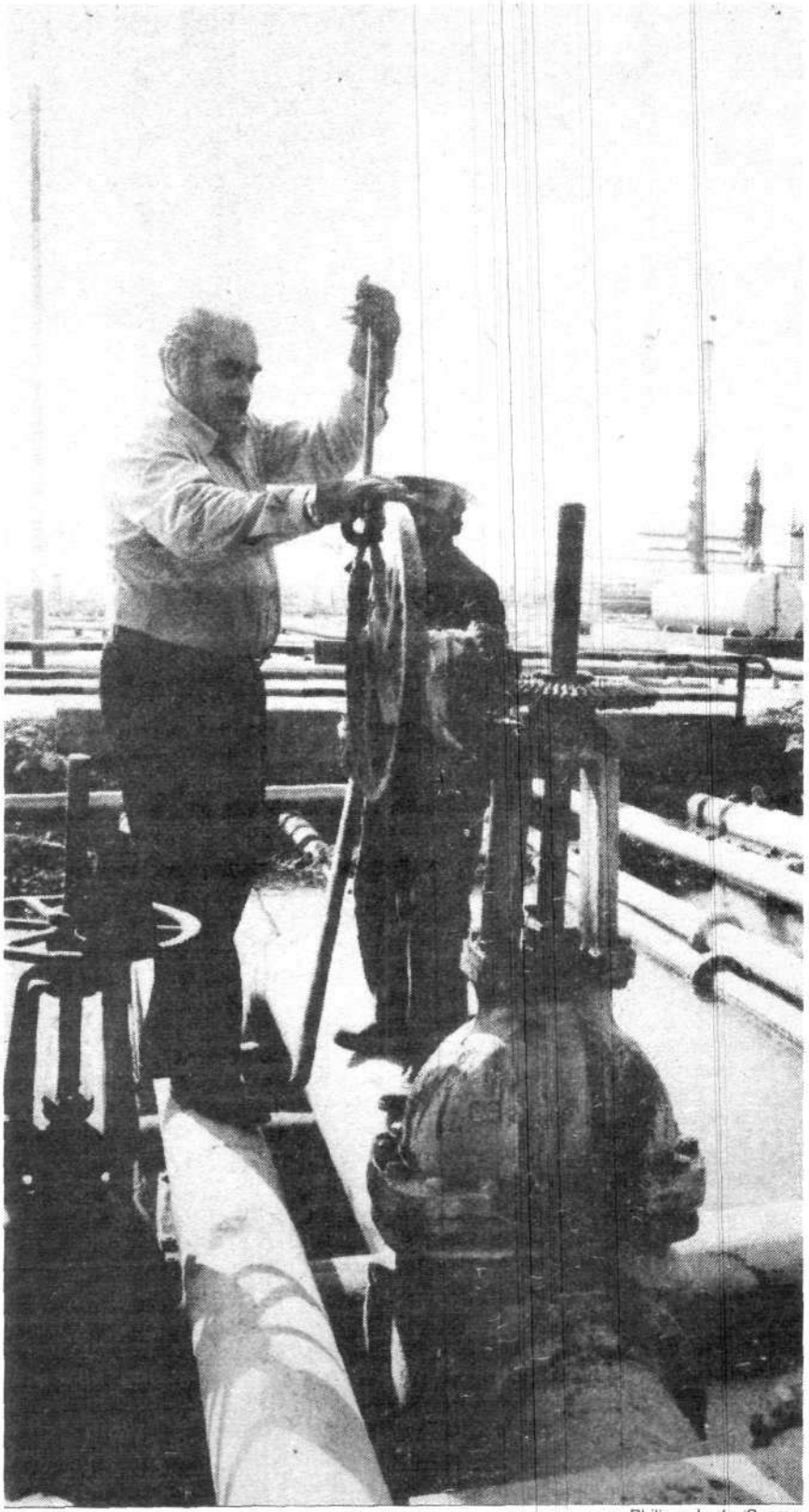
The Lousewort Laurels award this month goes to Douglas M. Costle of the U.S. Environmental Protection Agency for his extraordinary assertion that the 1969 moonshot, which capped a decade-long mobilization of the U.S. scientific and industrial community, demonstrated that there are limits to technological and scientific growth.

Costle, who was President Carter's special representative to the October meeting of the NATO Committee on the Challenges of Modern Society, told the NATO grouping that the moon landing "dramatized as nothing else that there *are* limits—that our global home is a finite and in some ways a fragile place, vulnerable to over-exploitation and environmental insult."

Beginning in the early 1970s, Costle said, "our technology-based way of life began to threaten many of the basic resources essential to the survival of life on this planet . . . . We were obliged to ask whether we had paid too high a price for our knowledge . . . ."

Among the monsters of technology Costle urged the NATO committee to help bring under control were nuclear waste, suburban development, the rising cost of health care, and "the impact of the automobile on our respective countries . . . ."





Philippe Ledru/Sygma

Shutting down Iran's oil production is part of the conspiracy documented here. This refinery at Abadan is Iran's largest, employing 7,000 workers on 16 square km of oil fields.

The Conspiracy Behind the Iran Crisis

As Fusion *goes to press, the situation in Iran remains uppermost in the minds of many Americans. This special report is designed to provide readers with a strategic view of the crisis, an overview that the national media has obfuscated with sensationalist reporting. We hope it will initiate informed discussion on policy solutions that tend toward neither of the two being pushed by the press: a disastrous foreign policy capitulation, or a U.S. military adventure into the Persian Gulf, which could spark East-West confrontation and World War III.*

This report on what is behind the Iran crisis was compiled from several feature-length articles in the Executive Intelligence Review *by Robert Dreyfuss, Judith Wyer, and Criton Zoakas. Readers interested in obtaining the full report on the energy shutdown and the Khomeini scenario, which includes excerpts from all the documents mentioned, should contact the* Review *at (212) 247-8820.*

Since early November, the American population has been angered and confused by the Iranian terrorist takeover of the U.S. embassy in Teheran and the threats against the lives of the 62 American nationals taken hostage when the embassy was seized Nov. 4.

Although not yet known to the hostages themselves, their capture was the result of a deliberate prearrangement involving among others, U.S. National Security Advisor Zbigniew Brzezinski, former secretary of state Henry Kissinger, Iranian Foreign Minister Ibrahim Yazdi, and Ayatollah Kalkali, who represents the Muslim Brotherhood—the entity in real, behind-the-scenes control of everything of significance that occurs in Iran.

The purpose of this deliberately prearranged international provocation was to trigger a series of international shifts in the key areas of world energy policy, world credit and financial policy and, most important, in the area of East-West relations. In summary, the sponsors of the sordid event, among whom are top-ranking U.S. government officials, were aiming at a result publicly stated in the current issue of *Business Week*:

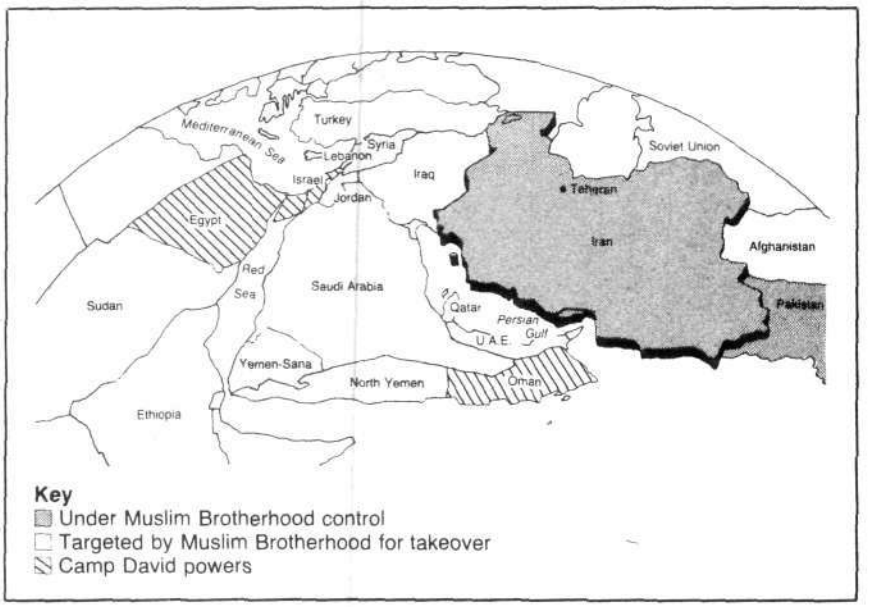
"It may be that an Arab banking system funneling petrodollars through the European Monetary System will replace the current domination of the world's financial system by U.S. banks and the IMF. This depends, of course, on OPEC's willingness to play the power broker part. If it refuses, there is another scenario that many still think unthinkable: *open warfare, in which either the industrial West as a group, or the U.S. going it alone, gives up trying to work with OPEC and instead invades the oil fields.*"

The authors of the provocation at Teheran in fact aim at destroying, by a single stroke, the possibility of the European Monetary System capturing the prize of petrodollars for intended use for generalized Third World development policies. This by itself would, as Brzezinski, Kissinger, and their patrons calculate, destroy the European Monetary System. The deadline for destroying the EMS is some time before the December 12, 1979 ministerial level meeting of NATO in Brussels. If the EMS is crushed by then, then the current Brezhnev leadership in the Soviet Union is expected to be defeated on grounds that its officially stated "war-avoidance" strategy; that is, long-term cooperation with the European Monetary System, will have been crushed. Then the hour of the straightforward military hardliners will have struck in Moscow—which by itself will ensure that the NATO summit will finally overcome the continental European opposition to a renewed arms race under the guise of "weapons modernization."

President Giscard of France and Chancellor Schmidt of the Federal Republic of Germany will see all their foreign and domestic policies crushed and they will soon be expected to face personal political demise in the early months of 1980. What is supposed to ensue is a period of military flare-ups throughout the globe, an international depression that the Council on Foreign Relations has happily dubbed "controlled disintegration," and the beginning of a drive to "restructure" the shambles along what is known among the "old boys" as the "*synarchist*" scheme of things: global reorganization of the world energy markets under the auspices of a UN-driven "international institute of energy" that will have authority to allocate the production, distribution, and consumption of every last ounce of energy, exactly in the way the IMF controls credit flows; global reorganization of all raw materials by means of similar "supranational" agencies; reorganization of the IMF by means of a weakened dollar, regional currency zones, and a dramatically augmented role for Special Drawing Rights.

These were the stakes in mind when the Teheran Embassy caper was launched by Brzezinski and Ibrahim Yazdi. The operation had been arranged initially in New York City, at the Council on Foreign Relation's Pratt House where Yazdi met with Brzezinski's representatives Oct. 5, and later again when the two men met with Arafat in Algiers during the festivities of the Algerian Revolution anniversary. The scheme provided for slow-tempo implementation, resulting in a successful Palestine Liberation Organization negotiation on behalf of the hostages, and USA diplomatic recognition of the PLO. The whole operation went out of control when Ibrahim Yazdi disappeared and Abolhassan Bani-Sadr surfaced to prominence.

Now the Iran chaos has spread to neighboring nations under the direction of the fanatic Muslim Brotherhood.



THE MUSLIM BROTHERHOOD AND THE ARC OF CRISIS

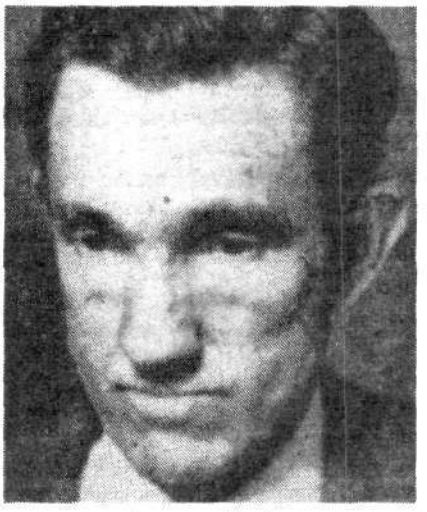
Carter administration National Security Advisor Zbigniew Brzezinski terms the nations shown here, plus the surrounding area, the "arc of crisis." The map indicates the scope of the Muslim Brotherhood's efforts to foment "fundamentalist revolutions" throughout the Middle East, leading to the disintegration of the nation-states of the region and warfare. In Afghanistan, a Muslim Brotherhood insurgency has been held at bay only by strenuous government counteraction. Algeria and Morocco, not shown on the map, have also been slated for Muslim Brotherhood destabilization.

Controlled Disintegration

As of this writing, events in Iran have long since slipped out of Khomeini's control. That crisis-torn nation is now in the hands of the Muslim Brother-

Henry Kissinger

Zbigniew Brzezinski



Ramsey Clark

hood, the highly organized secret religious society with branches in every part of the Muslim world and organizations of Muslim students around the world. The government of Iran, such as it is, is entirely a creature of this Muslim Brotherhood apparatus, which, as the accompanying box documents, is controlled by British intelligence. That apparatus selected, trained, and then installed the clique of zealots that today surrounds the Ayatollah Khomeini.

More than 60 percent of the population is now unemployed. Nearly every major industrial development project, in all worth some $100 billion, has ground to a halt. Idle nuclear power stations are converting their cooling towers into grain silos. Iran's new foreign minister Abolhassan Bani-Sadr, whose Dark Ages program for Iran is elaborated in the accompanying box, has told the French daily *Le Monde* that the capital city of Teheran will be depopulated. Bani-Sadr was a classmate and admirer of Pol Pot, who carried out the depopulation of Cambodia.

And as the chaos has spread from the cities into the countryside, Iran's oil fields are once again threatened with shutdown. Exports to the United States have already been stopped, creating the conditions for a dramatic new OPEC price increases of up to $30 to $40 a barrel and a new oil shortage hoax.

The controlled disintegration scenario for world energy, of which Iran is the keystone, was spelled out by the Council on Foreign Relations *1980s Project* in its volume on oil titled *Oil Politics in the 1980s: Patterns of International Cooperation*. Authored by Oystein Noreng, an executive of the Norwegian Statoil Company, the report has a remarkable predictive accuracy concerning the current oil crisis.

Controlled Oil Shortage

Noreng's study asserts that the energy crisis of 1973 and the accompanying fourfold increase in OPEC oil prices was the beginning of an "oil revolution." During this period a "new era" in world oil began that the report calls the "second oil regime." The second oil regime, which will persist through the next decade will be a period of "disintegration" of the traditional integrated oil markets that have been under the control of the Seven Sisters cartel of multinational oil companies. This disintegrative process, Noreng said, will produce a dramatic upturn in petroleum prices and will be plagued by frequent disruptions of world oil flows.

"Mr. Brzezinski finds a useful role for Ayatollah Khomeini and for Islamic fundamentalism."

Jody Powell,
White House press spokesman
at a Nov. 13 press conference

In fact, the dramatic rise in the price of oil over the course of 1979, following the shutdown of Iranian crude exports earlier this year, is a symptom of the council's second oil regime.

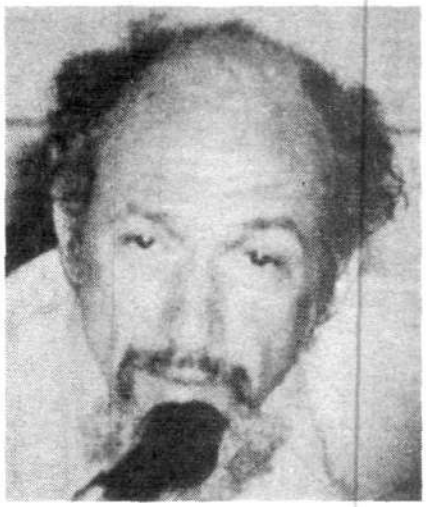
Underlying this scenario for a "second oil regime" is the calculated effort on the part of the CFR's elite membership and their British allies to use energy crises (which they calculate will persist throughout the 1980s) to bludgeon Europe, Japan, and the oil producing nations into a multinational energy cartel. This cartel, to be under the supervision of the multinational oil companies, will control all forms of energy: oil, coal, nuclear, and such exotic forms as synthetic fuels.

Such a cartel will become the energy correlate of the International Monetary Fund and the World Bank monetary institutions. As the report concludes, the success of this scenario depends upon the preservation of the troubled Bretton Woods monetary system.

Either IMF or EMS

This is a slice of the situation as it was frozen at the moment of the writing of this report. The maneuvers that will unfold in the hours and days ahead will decide between two alternative paths; either European-Arab cooperation will collapse bringing the EMS under and launching a crisis worse than the Cuba Missile Crisis of 1962, or the Washington-London axis will suffer a devastating defeat that will launch a worldwide role for the EMS and bankrupt the IMF.

John Sawhill



Richard Falk

Clovis Maksoud

Who Planned The Iran Crisis?

The Shah was brought to New York for medical treatment despite previous warnings that this would cause hostages to be taken in Iran. David Rockefeller and Henry Kissinger, the Shah's so-called friends, conspired to make his trip possible.

According to the *New York Times* Nov. 18, 1979, "the decision (to admit the Shah) was made despite the fact that Mr. Carter and his senior foreign policy advisors had known for months that to admit the Shah might endanger Americans at the Embassy in Teheran. An aide reported that at one staff meeting Mr. Carter had asked, 'When the Iranians take our people hostage in Teheran, what will you advise me then?' . . . For eight months, Mr. Carter had resisted intense lobbying from American friends of the Shah, such as David Rockefeller, the Shah's banker and former Secretary of State Henry Kissinger (to allow the Shah into the U.S.). . . . The Administration was warned repeatedly by the CIA that the Shah's presence in America would provide the excuse for sharp anti-Americanism and probable action against the embassy."

Ramsey Clark, President Carter's official envoy to Iran, in October advised Iran to take action against the United States over the Shah.

Ramsey Clark, the very man who President Carter named officially to represent the United States in Iran last week, in early October sent a letter to the Iranian Foreign Minister Ibrahim Yazdi demanding that Iran take action against the United States to force the Shah to be sent back to Iran. In his Oct. 12 letter Clark stated: "It is critically important to show that despots cannot escape and live in wealth while nations they ravaged continue to suffer. . . .The new government of Iran should seek damages for criminal and wrongful acts committed by the former Shah." That letter was written 10 days before Henry Kissinger and the State Department brought the Shah into New York. Furthermore, Clark had actively organized in Iran on behalf of the anti-Shah faction immediately before the Shah was deposed.

U.S. government emergency machinery was set up weeks *before* the crisis in Iran to impose harsh austerity and energy controls.

In an interview, Mr. Randy Kau, personal secretary to Treasury Secretary G. W. Miller and Treasury's representative to the Federal Emergency Measures Administration (FEMA) said, "We at FEMA had this plan to freeze the Iranian assets two weeks before we did, and I spent the entire two weeks on the phone trying to kill the rumors that we would do it. We'd be negiligent if we weren't planning for this, but people are going up the wall. If we were to admit this, it would collapse the dollar."

At the same time, in mid-October the Department of Energy's John Sawhill established a special "interagency task force" to prepare for a complete shutdown of the Iranian Gulf oil supply to the United States—three weeks before the Iranian secret police seized the U.S. Embassy in Teheran.

What Is the Muslim Brotherhood?

Officially, the Muslim Brotherhood —as a secret society modeled on the freemasonic principles—dates back to Egypt in the period after World War I. At that time, with financial and other assistance from the British embassy in Cairo and the colonial Suez Canal Company, Sheikh Hasan al-Banna built a paramilitary, terrorist gang that for more than 25 years wrought havoc in Egyptian politics until they were hunted down and exterminated by President Gamal Abdel Nasser after 1954.

But the Society of Muslim Brothers, as Sheikh al-Banna called it, is a far deeper conspiracy.

Its roots lie in the mystical, anti-

rational tradition of ancient Islam, as opposed to the humanist, city-building Islamic tradition. In fact, the Muslim Brotherhood can be said to have begun with the cultist revival of pre-Islamic varieties of the Isis-Osiris myth in the 8th century by the Asharites and, later, by the infamous Sufi mystic, cultist Al-Ghazali.

During the 19th century, these old traditions were revived by Oxford University Orientalists who sought to preserve the British Empire by encouraging the growth of mysticism, superstition, and cults among the population of the Muslim world.

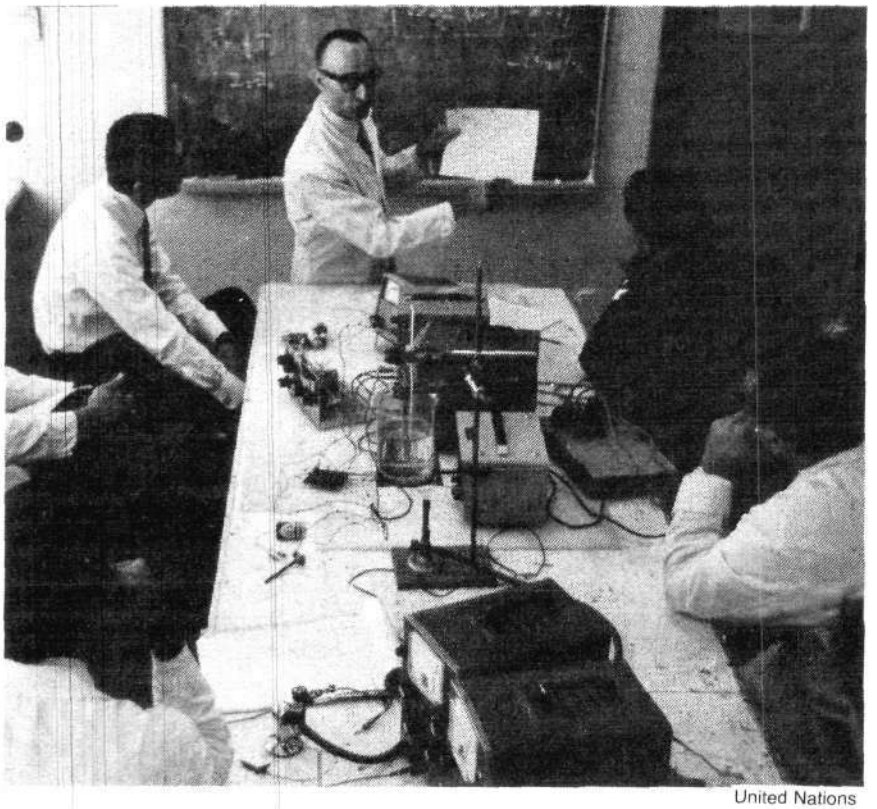
From these roots, the Muslim Brotherhood—or the Ikhwan, as it is called in Arabic—developed into a conspiratorial underground organization that today has branches of varying strength in every part of the Muslim world.

When Nasser crushed the Ikhwan in Egypt, its leadership was forced into exile. Although some of the Ikhwan leaders went to Syria, Jordan, and Pakistan, for the most part they ended up in London, Geneva, and Munich.

Now organized into what are essentially front groups such as the Islamic Foundation in Leicester, England, or the Islamic Council of Europe based in London, the Ikhwan is still led by men who are wanted for murder and assassination, political terrorism, and subversion in many Arab states.

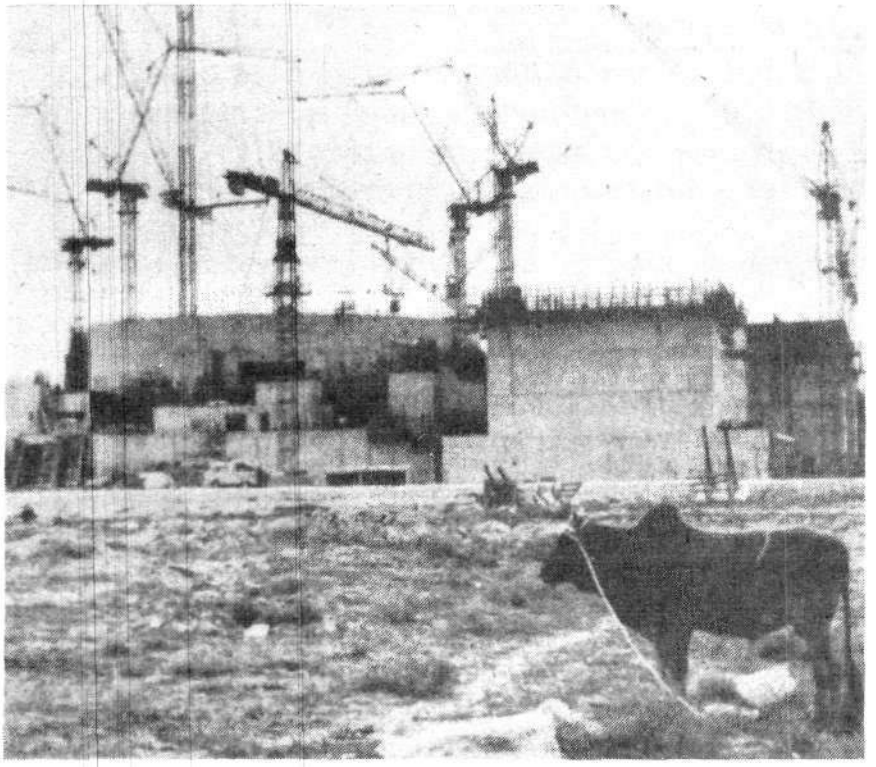
The Muslim Students Association, headquartered in Plainfield, Indiana and claiming 400 chapters across the country, is a major U.S.-based front for the Ikhwan cult. In the recent period, the MSA has sharply escalated its advertising and organizing activities in the United States. It is from the networks associated with the MSA, antiterror experts believe, that pro-Khomeini Arab terrorists will be deployed to spark a bloody wave of domestic terrorism if the Iran crisis remains unresolved.

Other leading U.S. supporters of the Muslim Brotherhood include: Clovis Maksoud, special envoy to the United States from the League of Arab States; Bernard Lewis and Richard Falk, both of Princeton University; Ramsey Clark, former U.S. attorney general; Angier Biddle-Duke, U.S. ambassador to Morocco; and Eqbal Ahmed, of the left-radical Institute for Policy Studies.



United Nations

Iran's high technology—now a thing of the past. Above, a seminar at Teheran University Nuclear Center. Below, a nuclear power plant under construction at Bushgir.



Iran Under the Shah: Third World Leader in Nuclear Development

Prior to the takeover of Iran by the Ayatollah Khomeini, Iran was implementing the most aggressive nuclear development in all the Third World. The Shah of Iran had set a national goal of putting 22 nuclear generating plants into operation by 1995.

At the time of the Shah's overthrow, four of these plants had been contracted, two from West Germany, and two from France. West Germany's Kraftwerkunion had completed 80 percent of two 1,200 megawatt electric (MWe) nuclear plants at Bushire on the Persian Gulf by the time of the July 30 cancellation of the projects by the Khomeini regime. France's Framatome had completed the site work on two additional 900 MWe plants on the Karun River. The joint value of the four uncompleted plants was estimated to total $13 billion.

The regime of Reza Shah Pahlavi was also an aggressive force in the international fight for nuclear energy. During summer 1977, the Iranian Atomic Energy Organization hosted an international symposium in Persepolis on future uses of both fission and fusion technologies. The meeting, attended by 41 countries, was sent an official greeting by the Shah, expressing his support for fusion energy as the best future alternative to petroleum.

Shortly after the Persepolis symposium, the Shah visited the United States, where he launched a public campaign in favor of nuclear energy. A number of U.S. firms were on line for contracts to build nuclear plants in Iran. Westinghouse and General Electric, for example, were jointly slated to receive contracts for up to eight plants. These deals were blocked by red tape at the federal level.

There is no arguing that the Shah's regime suffered from profound limitations: the monarch's own inability to understand the necessity for a transition to full republicanism and his foreign policy gullibility, particularly where the United States was concerned, to mention only two. But Iran made progress under the Shah, as that nation's dismantled nuclear program attests. The Shah was toppled not because of his faults, but because of the strength of his development policy. His commitment to nuclear energy put him at odds with the same international circles that oversaw the ouster and juridical murder of Pakistani Prime Minister Zulfikar Ali Bhutto, the nuclear power advocate whom Henry Kissinger vowed in 1976 to destroy.

The Shah also funded a major research and development program in nuclear energy, which included training Iranian physicists abroad, to aid in expanding the nascent fusion and laser research program at the University of Teheran.

In the early 1960s, the Shah expressed his hope that the nuclear grid he envisioned for Iran could be extended into the country's agriculturally rich areas along the Caspian Sea. He hoped to use nuclear capability to power a far reaching desalination system to feed new irrigation capacity. Had it been implemented, this plan would have begun the process of solving one of Iran's worst problems: its inability to produce enough food for a growing population and its dependence on foreign food imports.

Following the cancellation of the Bushire nuclear project this summer, the French press revealed that Khomeini's Revolutionary Council was considering transforming the cooling towers of the unfinished plants into grain silos.

The Training Of Iran's Dark Ages Ideologues

"Teheran is a monstrous, parasitical city, which absorbs by itself half the national consumption, and imposes an abusive burden on the state budget. We will depopulate it by creating industrial and agricultural production units in the provinces . . . ."

—Abolhassan Bani-Sadr
Foreign Minister of Iran
November 10 to Le Monde

With these words, Abolhassan Bani-Sadr, the new foreign minister and strongman of Iran, made clear what the goals of the Khomeini regime are: the imposition of genocide, mass starvation, and fanatical religious martyrdom. In September, Bani-Sadr, then assistant economics minister, had declared that his model for Iran was the Pol Pot regime of Kampuchea, which depopulated the city of Phnom Penh, murdering almost all of its 2 million inhabitants. Now that policy is being carried out in Iran.

A closer look at Bani-Sadr shows that it is a policy by no means indigenous to Iran, or even Kampuchea. Bani-Sadr was trained by the same French university professors who developed the Kampuchea model and personnel for implementing Pol Pot's genocide against his own nation.

The institutions that trained Bani-Sadr—the Sorbonne University in Paris's Ecole Practique des Hautes Etudes and the Centre Nationale des Recherches Scientifique are supported by the

most backward elements of Europe's so-called black nobility as breeding grounds for zero-growth ideology and terrorists. In the case of Cambodia and Iran, these terrorists succeeded in becoming the government.

Bani-Sadr, a classmate of the recently deposed Cambodian prime minister Pol Pot and president Khieu Samphan, wrote his Sorbonne doctoral dissertation on the subject of agrarian reform under the direction of Professor Georges Balandier. As Bani-Sadr's interview with Le Monde makes clear, the students of Balandier were trained in the view that "agrarian reform" means deindustrialization, deurbanization, and an end to economic growth.

"The monetary system and the foreign trade which enslave Iran to the international capitalist market will be fundamentally rearranged," the new Iranian foreign minister told the French daily. "The enterprises which were going to provide us with nuclear power plants—of which, by the way, we had no need— were half American in their financing . . . The project for a Teheran subway was luxurious, too costly and ambitious. We are seeking a simple, practical and cheap means of transportation for a city that will shrink . . . ."

Contacts with Khomeini

The sociology department of the Centre National des Recherches Scientifique where Bani-Sadr advisor Balandier did his postgraduate studies, contains a nest of radical enviromentalists with ties to most of Khomeini's key advisors. In recent years, Bani-Sadr himself has maintained semiformal ties with that institution.

In 1978, the center dispatched a special team of energy experts to Iran who criticized the country's nuclear program and proposed wind power instead.

In January 1979, officials of the center were named official advisors to the Ayatollah Khomeini. Prominent among them are Jean Pierre Vigier and Rene Dumont, the former connected to the Bertrand Russell Peace Foundation, which played a prominent role in anti-Shah activities among Iran's oil workers, and the latter a leading ideologue of the Friends of the Earth back-to-nature group.

Washington

Fusion Postcard Campaign Begins

Some of the 75,000 postcards supporting an increased fusion budget that were inserted in the December issue of *Fusion* have begun to reach the office of Congressman Mike McCormack, a Washington Democrat. The postcards, addressed to McCormack as the leader of the fusion fight in Congress, are part of a Fusion Energy Foundation campaign to support the congressman and the House Science and Technology Committee's battle for a more aggressive commercial fusion development program and to let Congress know that the majority of Americans are protechnology and pronuclear.

In response to the inflow of postcards, McCormack stated:

"I am hopeful that the Department of Energy will accelerate the funding for the magnetic fusion energy pro-

Hirsh Panel Reconvenes To Plan Fusion Upgrade

The fusion advisory panel to the Energy Research and Production Subcommittee of the House Science and Technology Committee will hold another round of hearings on planning a more aggressive U.S. fusion development program Dec. 10 and 11.

The panel, chaired by Dr. Robert Hirsch, former head of the U.S. magnetic confinement program, will first hear detailed program plans from the DOE office of Fusion Energy on how the DOE could meet subcommittee chairman Congressman Mike McCormack's goal of a fusion demonstration plant in the 1990s.

The next morning, the panel will meet in a closed-door session with members of the subcommittee to evaluate the details of the DOE plan, including required budget commitments.

In the afternoon Dec. 11, the subcommittee will hold formal on-the-record hearings. Expected to testify are either Energy Secretary Duncan or Deputy Secretary John Sawhill, DOE fusion director Ed Kintner, and probably Hirsch, representing the advisory panel. The written testimonies will be on the record for the subcommittee's future use in Congress and with the administration.

The advisory panel includes leading fusion scientists from the government laboratories and industry and has pushed for an accelerated U.S. fusion program.

to Make Impact

gram so that we may have a demonstration plant on line by the year 2000. The expression of support by many Americans, both in the scientific community and from the general public, indicates that there is a broad cross-section of support for fusion energy as a source for the generation of electric power in the next century."

McCormack's staff noted that they expect the receipt of thousands of FEF postcards will be a mandate for public support of an increased fusion budget and a more aggressive fusion timetable. All postcards received, they said, will be answered with a letter from the congressman's office.

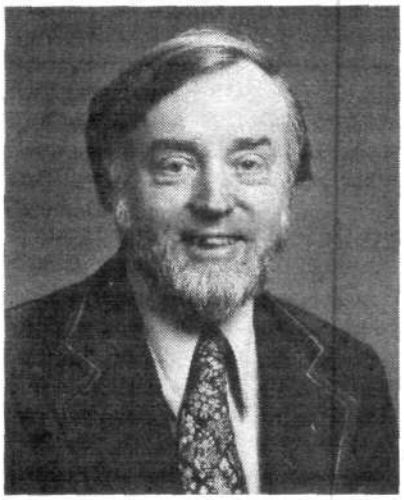
More Postcards Available

Bulk copies of the postcard are available from the FEF office, Suite 2404, 888 Seventh Avenue, New York, N.Y. 10019, Tel. (212) 265-3749.

U.S., Japan Discuss Cooperation on Elmo Bumpy Torus

A meeting will take place at Oak Ridge National Laboratory in Tennessee Dec. 6-7 to discuss joint research on the bumpy torus fusion programs in the United States and Japan. Under the framework of the U.S.-Japanese fusion cooperation agreement signed earlier this year, fusion scientists will try to initiate more formal cooperation to enhance the ongoing informal joint work between the Oak Ridge Elmo Bumpy Torus and the Nagoya Bumpy Torus in Japan.

The Japanese experiment, located at Nagoya University, was modeled on the Oak Ridge machine and is the only other bumpy torus fusion experiment in the world in addition to Elmo.



Dr. Stephen O. Dean

Industry-Based Fusion Group Formed

Dr. Stephen O. Dean, director of fusion development for Science Applications Inc., announced on Nov. 9 the formation of Fusion Power Associates, a nonprofit corporation that will pursue the development and commercialization of fusion power.

The new industry-based association, with charter members representing the leading U.S. high-technology companies, will launch a public education campaign to develop "greater awareness and understanding of the potential of fusion energy." The goal of the group is to help "bridge the gap" between the scientific research on fusion energy and its engineering development.

Dean, president and chairman of the Fusion Power Associates board, remarked, "Fusion science has progressed rapidly in the past few years. It is now important, if not urgent, to pursue more actively engineering and technology development of reliable, practical fusion energy systems. Fusion has the potential to revolutionize industrial civilization."

Fusion Power Associates is a unique combination of the laboratory scientists who have been responsible for the scientific breakthroughs in fusion research over the past two years and the industrial contractors who will be in the forefront of innovating production industries in frontier technologies for commercial fusion development. Members of the board of directors also include scientists in both the magnetic and inertial fusion programs, which will facilitate the flow of information and experience in the programs. This will become more important as various fusion systems reach commercial demonstration.

Dean was a pioneer in the U.S. fusion program and has played a leadership role in guiding fusion research for the past 17 years. Well-known as a spokesman for an aggressive fusion program, Dean's views on fusion development were highlighted in feature article in *Fusion*, Oct. 1979.

Joining Dean on the board of directors are Henry J. Gomberg, KMS Fusion; Donald L. Kummer, McDonnell Douglas Astronautics Company; Bernard J. Eastlund, BDM Corporation; Ronald C. Davidson, Massachusetts Institute of Technology; Nicholas A. Krall, Jaycor; Sherman Naymark, Quadrex Corporation; Tihiro Ohkawa, General Atomics Company; Paul Reardon, Princeton University; Leonard F. P. Reichle, Ebasco Services; Peter Rose, Mathematical Sciences Northwest; Glen Sorenson, ILC Technology, Inc.; Alvin Trivelpiece, Science Applications, Inc.; James M. Williams, Los Alamos Scientific Laboratory; Gerald Yonas, Sandia Laboratory; and Donald P. Zeifang, National Association of Broadcasters.

Dean said that the new group will be considering the sponsorship of public information conferences and meetings on fusion and publication of educational materials, "to foster cooperation among all public and private organizations, including government, universitites, national laboratories, and industry."

Livermore to Begin Fusion Hydrogen Study

The office of Fusion Energy at the DOE has just awarded a $400,000 contract to Lawrence Livermore Laboratory in California to look at fusion systems designs for the production of hydrogen. The study will begin by ex-

amining various design combinations with fusion mirror machines and will also consider other magnetic fusion concepts.

Although the energy payoff from the development of fusion is often looked at only in terms of cheap and plentiful electric power production, the payoff expected from hydrogen fuel production will also have a revolutionary effect on the economy.

The study will begin immediately, with funding allocated for fiscal year 1980 and will focus on ways of coupling the heat from fusion to a variety of thermochemical hydrogen cycles now operating in bench-scale models. Blanket designs to transfer the fusion heat to the thermochemical cycles will include liquid metal and solid materials.

Three thermochemical cycles, all involving the use of sulfuric acid, will be considered. These are processes under experimentation at Westinghouse, General Atomic, and Los Alamos Scientific Laboratory that can potentially use the heat of fusion or advanced nuclear reactors.

MHD Budget Cut $5 Million

For the first time in nearly a decade, the budget for research in magnetohydrodynamics (MHD) has sustained an absolute cut in funds, with a 1980 fiscal year budget of $75 million. From 1971 until last year, the MHD budget had been steadily increasing, as the technology matured and the joint experimental work with the Soviet MHD program became a proven success in data exchange and actual joint experimentation.

In the 1979 fiscal year, the budget leveled off, as did other high-technology programs like fusion, but this downhill slide has accelerated in the past 12 months. The administration request for about $75 million for fiscal year 1980 was increased to $130 million by the Senate, but the House maintained the DOE budget request. In a joint conference committee, the lower House figure prevailed, setting the budget at $5 million below the 1979 figure.

Congress In Deadlock on Synfuels

In a stalemate that could throw President Carter's synfuels program into the next session of Congress, the House and the Senate are now deadlocked on two very different versions of a coal synthetics bill.

Led by Senator Henry Jackson, a Washington Democrat, the Senate Energy Committee rammed a slightly modified version of his omnibus energy bill through the Senate Nov. 9. The $20 billion bill includes virtually everything President Carter requested in his midsummer energy address to the nation.

What neither Carter nor Jackson have publicized is that the Senate bill will guarantee that the price of OPEC oil will double by 1985. Spokesmen from the DOE synfuels program have admitted that the market price for the synthetic liquid fuels they intend to produce from coal will have to be about $42 per barrel to make the synfuels projects economically attractive to investors. However, if the government guarantees that price to the synfuels producers —as the Senate legislation requires it to do—OPEC and other oil-producing nations are not going to keep their price of oil at the current $22 to $26 per barrel.

Also not publicized, as Congressman John Wydler (R-NY) pointed out in a recent press release, the synfuels technology that is being rammed into the commercialization stage is untested and may very well not work. At the same time, the advanced energy technology that is in a nearly assured stage of technological development, such as the breeder reactor program, MHD, and fusion, have been cut out of the president's solution to the energy crisis.

The Eighth Sister?

Despite the denials of Energy Secretary Charles Duncan, the Senate synfuels bill will bring the U.S. government into the oil business as follows:

The Senate bill establishes a special fund called the Energy Security Reserve in the Department of Treasury to prevent the synfuels program from being held hostage to the as-yet undetermined fate of the president's windfall profits tax. This fund will finance a new, independent government agency called the Synthetic Fuels Corporation, which will be authorized to finance and own synfuel plants here and outside the United States—hence joining the Seven Sister multinationals as a major producer.

The Senate passed an up-front authorization of $19 billion for the first five years of the corporation, with a remaining $68 billion to be authorized by Congress in 1985. In the current fiscal year, $2.2 billion is authorized for a series of projects.

It is generally recognized that the projected synfuels projects, totally separate from those already under development in the Department of Energy, could not possibly absorb $2.2 billion this year, but as congressional sources admitted, the bill is more a "vote

Antinuclear Activist Joins Justice Dept.

Tony Roisman, former attorney for the National Resources Defense Fund and well-known antinuclear activist in Washington, D.C., has been appointed an assistant deputy attorney general in the Department of Justice to head up a special task force on "hazardous waste." The task force will be directed against chemical companies accused of dumping chemical waste.

During Senate hearings on the Three Mile Island incident, Roisman suggested that instead of having Metropolitan Edison substitute power to replace that lost by the stricken TMI plant, the people of Harrisburg should learn to live without nuclear energy.

of confidence" than a blueprint for the projects themselves.

The House has refused so far to be intimidated into passing, or even considering, a boondoggle of such magnitude. Last summer the House passed the Moorehead amendment to the Defense Production Act, which authorized $3 billion for synfuels development. Although the production goals of the Moorehead amendment were set at 2 million barrels per day by 1990, which is a more aggressive plan than the much more expensive Senate bill, the money was authorized not for the government to become an eighth sister among the oil multis, but for tax credits, incentives, and price guarantees for a private-industry synfuels effort.

Furthermore, while the Senate bill states repeatedly that the synfuels funding will go only to nonnuclear projects, such a constraint does not exist in the Moorehead bill. House Banking Committee sources have pointed out, in fact, that hydrogen production from fusion would be considered a possible project for commercial development under the House legislation.

According to sources in the disgruntled Senate Energy Committee, Congressmen Mike McCormack (D-Wash) and Charles Dingell (D-Mich) are determined to prevent the House Moorehead bill and the Senate Jackson bill from going into a House-Senate conference committee, claiming that they are two "totally different" bills. If the House is to consider such a near-$100 billion synfuels program, they insist, hearings would have to be held in the appropriate House committees.

The same Senate sources are hoping that during the Thanksgiving recess, the recent cutoff of oil from Iran wil produce gasoline lines in the home states of the "resistant" Congressman. And that under this kind of pressure the House can be blackmailed into supporting a Senate-style synfuels bill.

If the House forces stand firm and the two bills do not go to conference, no legislation will be passed into law before Christmas, and the synfuels fight will be put off until the next session of Congress.

—*Marsha Freeman*

National

Shutting Down The U.S. Nuclear Industry

The NRC Implements the Kemeny Report

Using the recently released report of the President's Commission on Three Mile Island (the Kemeny Commission) as a pretext, the Nuclear Regulatory Commission has declared a "temporary" moratorium on the licensing of seven nuclear plants about to come on line. Furthermore, NRC official Harold Denton announced that the commission will not grant any new operating or construction licenses until after a "pause" for adopting a new, tougher set of siting, safety, and emergency standards for plants—a policy supported by Congressmen Morris Udall of Arizona and Senators Gary Hart of Colorado and Edward Kennedy of Massachusetts.

The NRC has also formulated plans for the shutdown of all nuclear plants located within 10 miles of a major urban center, according to the Nov. 5 congressional testimony of NRC chairman Joseph Hendrie.

In addition, the NRC has contributed to the closing of five out of six of the nation's commercial nuclear waste disposal sites, thus threatening the shutdown of all nuclear fission plants, as well as a vital cancer, medical diagnostics, and treatment program that depends on these waste disposal facilities.

Urban Targets

At the top of the NRC's target list are the nation's flagship utilities like Con Edison in greater New York and Commonwealth Edison in Chicago, both of which rely heavily on nuclear power plants close to city limits. The NRC has told the *Washington Post* that it will either shut down or severely restrict licensing at both the Con Edison Indian Point plant and Commonwealth Edison's nuclear facilities in Chicago. Con Ed's Indian Point plants now provide more than 25 percent of the electricity used in New York City and suburban Westchester County. Commonwealth Edison's two Zion plants now produce 15 to 20 percent of all electricity for Chicago and northern Illinois. If it *could* be replaced by oil-produced electricity, the cost to customers would be in the hundreds of millions of dollars.

The Kemeny Commission report

It is no coincidence that the NRC's plans to shut down nuclear facilities converge with the policies of Federal Reserve Chairman Paul Volcker, high-interest policies that are gutting the auto industry, construction, savings banks, and the municipal bond markets. It is also consistent with such regional energy plans as Encono, which calls for "regional energy self-sufficiency" based on a transfer of masses of the population out of the cities and the replacement of high-technology industry and energy resources with biomass, wood chips, and other labor-intensive sources.

As with the oil hoax shortage de-

scribed in this issue's special report on Iran, the Nuclear Regulatory Commission's nuclear shutdown policy is not new; it has been on the drawing boards at the New York Council on Foreign Relations for at least five years. The council's *1980s Project*, which features the theme of establishing "controlled disintegration" in the U.S. and world economies, prescribes a future of urban depopulation, zero growth, and low technology. Nuclear power is inconsistent with this 1980s blueprint.

Not coincidentally, one of the leading members of the Kemeny Commission, Princeton professor Theodore Taylor, is the author of the *1980s Project* study of nuclear proliferation, excerpts of which appear in the accompanying box. Another Kemeny Commission member, Patrick Haggerty, general director of Texas Instruments, has council connections as a member of the board of the Trilateral Commission, the council subcommittee that selected and groomed Jimmy Carter for the presidency on an anti-nuclear program. Haggerty also has served on the National Security Industrial Association, which is concerned with restricting exports of "sensitive" technologies.

It is the council's strategy that informed the official and unofficial conclusions of the Kemeny Commission report described in this section. Of special note is the commission's recommendation that no utility can be expected to run nuclear plants properly and that no plant should be licensed in a region until a thorough evacuation plan has been worked out for the population.

As *Fusion* documented at the time of the Three Mile Island incident, such plans for evacuation are the touchstone of the National Security Council's plans for setting up emergency dictatorial control over the U.S. economy through "crisis management." The Federal Emergency Management Agency went into operation at the time of the Three Mile Island accident to begin implementing these plans under NSC supervision.

One week before the Kemeny Commission released its report, the National Security Council came out with the results of its major study on nuclear energy. Headed by former Rand Corporation President Henry S. Rowan and "nuclear terrorism" expert Albert Wohlstetter, the report concluded that the Carter administration should continue to stall the development of the breeder reactor in the interest of stopping nuclear proliferation. This study was then echoed by NRC Commissioner Victor Gilinsky, another former Rand expert, who claimed that all nuclear reactors pose the threat of nuclear terrorism because they all breed plutonium.

Kemeny Report: Nuclear Is 'Dangerous'

The centerpiece of the recent campaign against nuclear power is the report released Oct. 30 by the President's Commission to Investigate the Three Mile Island Accident.

The all-but-stated conclusion of the report was that there should be a moratorium on nuclear plant construction. The week before the report was released, commission members had voted at least twice on whether officially to recommend a nuclear moratorium. It passed both times with a 6-4-2 and 6-3-3 margin, but was not included as a final official recommendation in the report (7 "yes" votes were needed to make it official).

Yet, the commission's unofficial "secret vote" was leaked to the press and translated into front-page headlines: "Kemeny Commission Backs Nuclear Moratorium."

The report is notable for its lies and contradictions; facts are applied only when they do not interfere with the overall antinuclear thrust of the report (a phenomenon to be expected from a thoroughly biased group). First of all, the report lies about the possibility of sabotage. As for the contradictions, although the report says that the TMI incident presented no health hazard, it nevertheless decrees that nuclear energy is inherently "dangerous." However, despite such alleged "danger," the report emphasizes that the incident was primarily the result of human error.

Here are the major conclusions of the commission:

The Nuclear Regulatory Commission, an independent agency headed by five commissioners, should be abolished and replaced by an executive branch agency with a single executive.

This is based on what the commission calls "evidence that some of the old promotional [nuclear] philosophy still influences the regulatory practices of the NRC . . . . There is no well thought out integrated system for assurance of nuclear safety within the NRC."

A permanent presidential oversight committee should be established to continuosly monitor the performance of both the new federal agency and the private companies that design, construct, and operate nuclear reactors.

The Kemeny Commission blamed the Three Mile Island incident on the incompetence and/or bad organizational practices of the utility, the reactor manufacturer, equipment suppliers and others. "Our investigation has revealed problems with the 'system' that manufactures, operates, and regulates nuclear power plants. There are structural problems in the various organizations, there are deficiencies in various processes, and there is a lack of communication among key individuals and groups.

"In the testimony we received, one word occurred over and over again. The word is 'mindset.' The most serious 'mindset' is the preoccupation of everyone with safety of equipment, resulting in the downplaying of the importance of the human element in nuclear power generation. The NRC and the industry have failed to recognize sufficiently that the human beings who manage and operate the plants constitute an important safety system."

Before any utility is granted an operating license for a new nuclear power plant, state and local emergency plans should be reviewed and approved by the federal government.

"We are disturbed both by the highly uneven quality of emergency plans and by the problems created by multiple jurisdictions in the case of a ra-

diation emergency. We found an almost total lack of detailed plans in the local communities around Three Mile Island.

"We favor the centralization of emergency planning and response in a single agency at the federal level with close coordination between it and the state and local agencies—a recommendation to put the Federal Emergency Management Agency in charge of all emergency planning for nuclear plants.

A variety of changes should be made in the recruiting and training of reactor operating personnel, in the instruments available to help operators understand the condition of reactors and the availability of equipment to measure the accidental release of radiation.

It was the commission's view that operator error, confusion, and misjudgment were primarily responsible for the nuclear incident. "These shortcomings are attributable to the utility, to suppliers of equipment, and the federal commission (NRC) that regulates nuclear power."

Sabotage Ignored

The entirety of the Kemeny Commission conclusions ignores the evidence of sabotage baldly evident in the text of the report: There is a "remote possibility" that the emergency feedwater valves that failed to deliver water to lower the reactor core temperatures "were closed by an overt act," states the report. However, the commission made no effort whatsoever to investigate how this might have happened.

The importance of these closed valves during the initial phase of the accident was presented in the November issue of *Fusion* in a special report that reviewed the Nuclear Regulatory Commission's investigation of Three Mile Island. That investigation showed that the closure of these valves caused particular pressure, temperature, and pressurizer level conditions in the reactor that led the plant operators to act essentially *the opposite* of how they should have acted.

In a recently released report on the same incident, published in the November 1979 issue of the IEEE magazine, *Spectrum*, Babcock and Wilcox, builder of the TMI reactor, agreed, adding that the loss of emergency feedwater flow was important: "Had there been auxiliary [emergency] feedwater in the system, the temperature of the reactor coolant might have remained relatively stable until the problem of the condensate pumps was corrected and the normal feedwater reinstated."

Both the NRC and the Kemeny Commission knew of this situation. Yet, despite the fact that three different investigations have concluded that the emergency feedwater valves were closed by someone none of the official investigating bodies has chosen to pursue the question.

Instead, the Kemeny Commission investigation focuses ad infinitum on what went wrong after the incident started and why the TMI operators, owners, manufacturer, and the NRC had "so much trouble" dealing with the "accident" once it started.

Technology Is 'Dangerous'

What about the commission's other recommendations? The Kemeny Commission had to admit that the Three Mile Island incident posed no danger to the public. Yet they recommended evacuation plans that the NRC has already begun to implement.

Here's the Kemeny Commission evaluation of the danger: "Based on our investigation of the health effects of the accident, we conclude that in spite of serious damage to the plant, most of the radiation was contained and the actual release will have a negligible effect on the physical health of individuals. The major health effect of the accident was found to be mental stress"—for which the residents of the TMI area have the nation's press to thank. If, as the commission admitted, there was no physical danger, why the evacuation plan?

The commission recommended a presidential oversight committee to monitor the nuclear industry, because: "The analysis of this particular accident raises the serious question of whether all electric utilities automatically have the necessary technical expertise and managerial capabilities for administering such a dangerous high-technology plant."

Therein lies the basis upon which the commissioners determined what they would investigate and, in fact, what they would recommend: Nuclear and other high technologies are "dangerous."

—Jon Gilbertson

Next month: The ongoing nuclear shutdown.

1980s Project: 'No Nukes'

Kemeny Commission member Theodore Taylor spelled out the U.S. nuclear shutdown plan in 1977 in the study he did on nuclear proliferation as part of the Council on Foreign Relations' *1980s Project*. Here are excerpts from the study, *Nuclear Proliferation: Motivations Capabilities and Strategies for Control:*

> In the context of a *planned phaseout of nuclear power*, in which the use of recycled plutonium is rendered unnecessary, a safeguards strategy compatible with our principles can most practically be founded on a simple international convention that spent fuel not be reprocessed *anywhere* for plutonium recovery, except possibly at a few international centers under international control. *Such a scheme has an attractive simplicity* . . . .
>
> On balance, we believe that a once-through system evolving into a *planned phase-out of fission power* could be effectively safeguarded with an international will to do so . . . .
>
> The prospects are excellent that *solar energy* can be developed and implemented on a large scale in a period of time comparable to that required to develop fully safeguarded breeder systems . . . .
>
> As we have insisted in this study, *any energy future that we choose will be difficult and painful* [emphasis added].

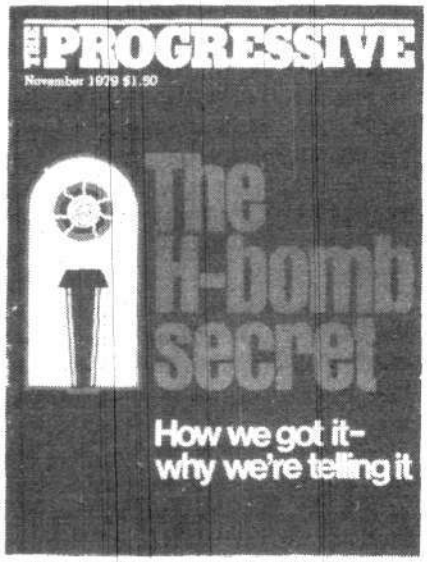
The Real Secret in The Progressive Case

In the November issue of *The Progressive* magazine, managing editor Samuel Day, Jr. reported that the Department of Energy was forced to drop its celebrated case against that magazine after the Fusion Energy Foundation entered an *amicus curiae* brief showing that the so-called secrets the government wanted classified had been in the open scientific literature since 1859.

As Day noted in his article on the case, "The Other Nuclear Weapons Club—How the H-Bomb Amateurs Did Their Thing," what was really on the minds of the government officials like James Schlesinger before and during *The Progressive* case was whether or not to take on the Fusion Energy Foundation. The FEF had published a series of articles that made public for the first time the scientific origins of the H-bomb in the 1859 paper by Bernhard Riemann on shock waves and the development of these ideas by leading German hydrodynamicists and aerodynamicists during the 20th century. (See, for example, Uwe Parpart's article "Riemann Declassified" in the March-April 1979 issue.)

Furthermore, the FEF had named special U.S.-British nuclear intelligence arrangements as a controlling factor in the decision to classify areas of inertial confinement fusion research not for the purpose of protecting the national security but to slow down scientific progress in order to justify the present economic austerity policies.

Rather than prosecute the FEF, the government took injunctive action against *The Progressive* to prevent publication of much more general material already available in the public domain. If the government had won its case, the precedent would have been set for legal action against the FEF on issues secondary to those raised by the foundation's reports.



You read the real secret in Fusion.

The FEF then entered a friend-of-the-court brief in *The Progressive* case based on the stated intention of the Atomic Energy Act of 1954 to promote the proliferation of peaceful uses of nuclear energy and of scientific knowledge. This legal intervention was followed by the publication by several newspapers in mid-September of a letter written by Charles Hansen (described as a "nuclear weapons hobbyist" by Day) reiterating supposedly secret material. The government withdrew its case against *The Progressive* and author Howard Morland within two days—Sept. 17—restating, however, its intention to continue to vigorously use its classification and punitive action prerogatives.

Since then, sources within the American Civil Liberties Union (which defended *The Progressive)* have reported that the government is bitterly divided between those in the Department of Energy who want to stop the spread of alleged fusion "secrets" and those in the Justice Department who consider this a risky proposition. At stake here is whether the proliferation and classification issues will continue to be used to kill advanced nuclear development, or whether the way will be cleared for the fundamental scientific research necessary to achieve economical fusion energy in this century.

The Security Issue

The irony in the government's present classification policy is that at the same time it propels the United States toward a strategic confrontation with the Soviet Union, it also weakens the overall economic and military capabilities that the nation must be able to deploy in such a confrontation.

This holds true not only for the policy of eliminating existing nuclear technologies, but also for the policy of retarding those pacesetting areas of fusion research that will determine the ultimate strategic, energy, manpower, and military capabilities of this nation.

A prime example of such research is electron-beam fusion. The Soviets recently reported that the research team under Dr. Leonid Rudakov had successfully completed and tested the first stage of the Angara-5 multi-electron-beam fusion machine.

That result is significant in two ways: first, in terms of Soviet plans for a net energy producing machine by the early 1980s; second, because of how such research is scientifically classified in the United States.

The Soviet Fusion Coup

The Soviet Union announced a schedule for completion of a pilot facility and the beginning of an actual program based on the successful pilot project. Speaking Oct. 5 at the dedication of the first of 48 electron beam units for the Angara-5 facility at the I.V. Kurchatov Laboratory in Moscow, Dr. Rudakov said: "When it is completed, we hope to obtain a controlled thermonuclear reaction as a result of which the facility will be producing more energy than it consumes. Angara-5 will demonstrate that an industrial pilot plant can be built."

The Angara-5 results are an impressive milestone in one of the crucial approaches to fusion energy (the Soviets have several other mainline approaches as well), but they are not unexpected. Rather, they fulfill a long-stated schedule and confirm the Soviet commitment to investing in advanced technology even where there is no short-term "pay-off."

The technological advances embod-

ied in Angara-5 also imply important applications to Soviet nuclear warfighting capabilities.

Neither point was lost on the editorial board of the *New York Times* whose recent front-page coverage of the Angara-5 results was unusual, given their generally hostile attitude toward any kind of advanced technology approach to energy, including fusion.

As Dr. Rudakov stated, when the full 48-module Angara-5 electron beam system is completed in about four years, several million amps of very high energy electrons (several million volts) will be utilized to compress and heat a pellet of fusion fuel 2 centimeters in diameter to the extremely high densities and the 100-million-degree temperatures found in the interiors of stars. A minihydrogen explosion will result that will generate more energy than that used to generate the electron beam fusion reaction—breakeven.

The Rudakov Case

Dr. Rudakov's team was the first to obtain ignition of minute amounts of fusion reaction in 1975, using the electron beam pellet approach. He came into the public limelight back in summer 1976 when he conducted the first of several tours of U.S. research facilities. During these tours, he summarized the Soviet e-beam research results and some of the physical processes hypothesized to be involved in e-beam fusion.

Rudakov's lectures and the subsequent commentary and evaluation by a number of U.S. scientists were immediately classified top secret by the Department of Energy. Since that time, the government has rebuffed all efforts the Fusion Energy Foundation initiated to obtain release of the Rudakov documents. Most recently, the DOE handed down a several-page decision that cited every possible pretext and legal precedent for not releasing the Rudakov papers.

Since it is evident that such a decision is not in the best interest of U.S. national security, the question here, as in the issues the FEF raised around *The Progressive* case, is just whose interests is such a classification policy protecting?

—Dr. Morris Levitt and Charles B. Stevens

Riemannian Computer Model Shows

Volcker Credit Policy Is Economic Disaster

The first computer-based Riemannian analysis of the consequences of Federal Reserve Chairman Paul Volcker's credit restriction policy has demonstrated that auto, agriculture, construction, and several other leading sectors of the U.S. economy will take a sharp drop in 1980-81.

The model, discussed in detail in the July issue of *Fusion*, uses Bernhard Riemann's analytical tools to show the mutual effects of 25 different economic sectors on one another.

The model was developed by the Fusion Energy Foundation staff at the request of Lyndon H. LaRouche, Jr., a well-known economist and a Democratic presidential candidate. The model quantifies LaRouche's basic economic distinction between *productive* and *nonproductive* economic activity, separating out from the mass of wasteful and unnecessary economic activities those categories of an economy's consumption that result in further production.

According to the LaRouche method, without making a fundamental distinction, for example, between a $1 million sale of concrete used to build a gambling casino and a $1 million sale of concrete used to build a steel plant, no economic model can successfully predict the impact of any policy decision.

How the Model Works

In the latest computer implementation of the LaRouche model, the economic activity of the U.S. economy is broken down into 24 productive sectors (steel, agriculture, etc.) and one nonproductive sector. The model consists of 76 coupled differential equations for the capital investments and profits (surplus) in each sector. After specifying the state of the economy today (the initial conditions for the differential equations), the model then produces forecasts for the economic activity of these sectors and provides several integrated measures (reproductive indices) of the whole economy.

The most important of these is the *free energy index*, the ratio of reinvestible surplus to equilibrium reproductive costs of capital and labor. This ratio must rise at an accelerating rate to ensure long-term health of an economy. The model has shown that while short-term periods of constancy of this ratio indicate recessionary conditions, there is a "threshold effect" in which the loss of momentum in an economy, indicated by constancy of this ratio, leads to a rapid severe collapse in three to four years.

As the computer model shows, Volcker's policy provides a shock that pushes the economy beyond that threshold. In fact, only a policy that aggressively pursues capital-intensive and technology-intensive investment could reverse the pervasive decay of the U.S. economy shown by historical values of this ratio over the last decade.

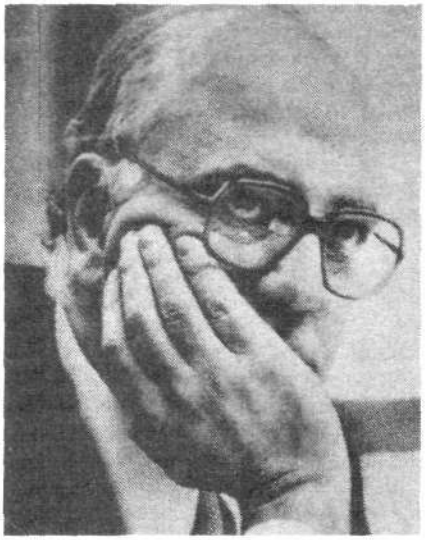
Singularities

The feature of the LaRouche model that has most disturbed conventional economists supporting Volcker's policies is its ability to predict and deal mathematically with singularities. Riemann developed the notion of singularity to describe the appearance in an otherwise smooth manifold of a jump, hole, cliff, or similar discontinuous structure whose significance is a qualitative change in the equations describing the manifold.

The occurrence of a phase change is the analogous situation in physics; a singularity means new interactions, new time and length scales, new symmetries, and higher-order interactions that cannot, in principle, be described within the old manifold.

Most economists deny the existence of singular, discontinuous phenomena in economics.

The analysis of the Volcker credit policy is an excellent case study in the



Federal Reserve head Paul Volcker

Riemannian-LaRouche methodology. The economy should properly be understood not as a collection of consumers and producers who exchange goods, services, and money over a period of time, but rather as a set of different economies, one for each production period, whose economic activity at one period results in a new economy coming out of the old in the next period.

Described in input-output terms, the matrix of production relations describing the economy today evolves not within itself but so as to create a succeeding matrix describing tomorrow's economy.

Thus, the important features of the economy today are not its equilibrium or stability properties but rather, precisely, the singularities that can push it toward a succeeding state. Whether tomorrow's economy is the beginning of a depression or of a new industrial revolution is determined by the capital invested today—and how the structures of that investment shape an economic trajectory toward the singularities in the economy.

The catastrophic impact of Volcker's policies can be understood only by using a model of the economy that deals with these singularities; the model must be able to identify and quantify the interactions in the economy that cause these singularities.

Using Riemann's "spectral analysis," to examine the economy, we see that

Continued on page 70

International

Swedish Nuclear Fight Turns to Referendum

Since the indecisive September 1979 Swedish parliamentary elections, the year-long battle over the future of Sweden's nuclear energy development has shifted to the national nuclear referendum to be held in March 1980.

That referendum should break the stalemate that has been in place since the hapless moderate coalition government of Tjorbjorn Faelldin, in power since 1976, fell in September over the issue of Sweden's nuclear program. At that time, Center Party-head Faelldin was installed as prime minister in a compromise minority government.

During the election debate Faelldin, an antinuclear sheep farmer from northern Sweden, advocated the extreme position of phasing out all 11 nuclear reactors operating or under construction. With the aid of the liberal press, Faelldin stepped up this campaign after the Three Mile Island incident here.

Sweden is one of a handful of countries that developed its independent nuclear manufacturing capability during the 1960s in private sector partnership with the government. Three years ago, the government program called for 14 reactors to be completed by 1990. In addition, Sweden holds one of the world's largest uranium fields, which has remained unexploited because of antinuclear propagandizing among local villagers near the field.

Sweden's antinuclear movement is not indigenous. Although the nation is often portrayed by the media as environmentalist-oriented, the tenacity of the antinuclear opposition in this highly technological society has its roots in the same well-funded oragnizations and individuals that have launched the U.S. environmentalist movement.

For example, the U.S. Natural Resources Defense Council, primarily

Pronuclear Magazine Slandered

Energi, a Swedish-language magazine that has led the fight in Sweden for nuclear development, was hit in October by a wave of front-page slander articles in the liberal press linked to the antinuclear lobby of Prime Minister Faelldin. Heavily supported in its nuclear technology and export policy by the Swedish Federation of Industries, *Energi* has translated and published several articles from *Fusion*.

The press campaign against *Energi*, aimed at cutting off industrial support for the pronuclear effort, maintained (quite correctly) that the magazine was written by members of the European Labor Party. The press noted that this was a cothinker group of the U.S. Labor Party, which the articles characterized by a number of outrageous lies.

In the United States, *Nucleonics Week* picked up the slander story Nov. 1 in a short item titled "Swedish Trade Association Gave $6,000 to Pronuclear Extremist Group." As for the extremism, *Nucleonics Week* noted in addition to the slanders that the European group is "highly active in propagandizing for nuclear power" and had distributed buttons showing an electric light bulb and the words "Nuclear power, yes, thanks."

through the efforts of its virulently anti-technology zero-growth director Dean Abrahamson, helped shape the Swedish antinuclear movement from the same organizations that a decade earlier had received U.S. foundation funds to organize Sweden's antiwar movement.

Abrahamson spent a year in Sweden, from 1976 through 1977, working with members of parliament like Birgitta Hambreaus and with Center Party leader Faelldin and Olof Johansson, his antinuclear energy minister. Abrahamson's efforts including sponsoring on Swedish television the antinuclear propaganda films and other scare stories funded by the Ford Foundation.

As a result of this antinuclear campaign, two nuclear reactors, Ringhals-3 and Forsmark-1, have been prevented from fueling since last June when the parliament passed a law that forbids operation of any new reactor prior to the March referendum. This delay in startup has been enforced despite the fact that the government decided that the reactors could be fueled according to a law requiring that before fueling a safe nuclear waste storage strategy had to be established. Sweden has developed a technology for storage of radioactive wastes.

—William Engdahl

Philippine Nuclear Deal Threatened

Since the U.S. Export-Import Bank approved a loan to the Philippines in October to import two more nuclear reactors from Westinghouse, the environmentalist Center for Development Policy in Washington has campaigned to prevent the sale.

According to *Nucleonics Week*, the Center is challenging the sale on the basis of reports from six former engineers of Ebasco Services, the nuclear architectural engineering firm involved in the deal, that the plant sites do not meet seismic requirements and that Ebasco knew this but covered it up. The statements of the former Ebasco employees have been used to charge that the incident may be a violation of the Atomic Energy Act, a charge that has prompted a Federal Bureau of Investigation inquiry into the case.

West German Utilities Spokesman: It's Nuclear Plants or War

In an article in the Nov. 10 *Die Welt*, Klaus Knizia, a representative of the West German utilities union and a leading pronuclear spokesman from the World Energy Conference, called for 4,000 new nuclear plants to be built during the next 30 years, most of them in the developing sector. Without this "minimal program," Knizia said, there is great danger of war breaking out over dwindling energy supplies.

Addressing the greenies, Knizia said: "The fear of the possibilities of technology and science sometimes takes on suicidal forms, as can be seen in the opposition to nuclear power and other large industrial-technical operations. It is extraordinary that this opposition is found only in the West and not in the East bloc, and certainly not in the poor countries. . . ." When the West refuses to export nuclear reactors to the Third World, how arrogant this must look to those countries living in poverty that can only be relieved "by those products we must deliver to them."

Pronuclear Forces Mobilize Against W. German Greenies

Pronuclear representatives of West German industry and Chancellor Helmut Schmidt's Social Democratic Party have upped their battle against the nation's environmentalist minority that has succeeded in bringing nuclear power plant contruction almost to a standstill.

In early November, the influential Chambers of Commerce of Duisberg and Düsseldorf in the industrial Ruhr region issued a call for all West German parties to stop their squabbling over nuclear energy and move ahead with the stalled construction projects. No new domestic construction orders have been received since 1975, and foreign orders are almost totally frozen, leading to mass layoffs among the major nuclear plant manufacturers.

The same week, a spokesman from RWE, the largest utility, told a meeting in Bavaria of representatives from the energy-related industries that the time had come for the nuclear industry "to stop being on the defensive and to start asking questions of the greenies—starting with Erhard Eppler, a top nuclear energy saboteur in the Social Democratic Party. "There can be no more arguing with environmentalists as if they were equals," the RWE representative said.

Backing up the industrialists, Social Democratic parliamentary leader Herbert Wehner demanded in an interview with the *Esslinger Zeitung* Nov. 9 an end to "arguing with the greenies who don't want to listen to any arguments." The Social Democratic Party's defensiveness toward the "green cabbage," as the environmentalists are nicknamed, only helps the election campaign of Franz Josef Strauss, Wehner said.

Strauss, the chancellor candidate of the opposition Christian Democratic Social Union, hopes to use greenie help to weaken the ruling coalition's chances of reelection next year.

The environmentalists met this pronuclear challenge by officially constituting themselves as the "Green Party" in mid-November, an event immediately hailed by Strauss. The Green Party will hold its founding congress in January and announced its intention to campaign to draw votes away from Chancellor Schmidt, who has strongly supported nuclear energy development.

—Susan Welsh

APS Plasma Physics Meeting, Boston, Nov. 11-16

Advances Reported in All Areas Of Fusion

More than 1,500 scientific papers were presented at the five-day meeting in Boston Nov. 11-16 of the American Physical Society's Plasma Physics Division, the largest fusion-related annual meeting in the world.

The papers covered advances across the full spectrum of fusion and fusion-related projects and represented the work of several thousand researchers. Of particular significance were recent developments on reversed-field toroidal pinches, electron-beam and ion-beam generation, inertial fusion target design, general applications of fusion theory, and the development of a new configuration — the spheromak.

A feature article on the reversed-field pinch appears in this issue, and future *Fusion* articles will elaborate on the other new developments that are reviewed here briefly.

The Spheromak

The spheromak is a proposed device to generate a force-free plasma magnetic field configuration — similar to that proposed by Dr. Dan Wells of the University of Miami (Florida) — in a donut shape that has a minimum of external field windings. The spheromak combines, in one form or another, work from mirror, tokamak, and high-beta pinches, and all of the major U.S. national laboratories have submitted spheromak proposals for funding to the Department of Energy Fusion Office.

The spheromak was first proposed in the 1950s as the most technologically simple fusion device. However, only with the recent general progress in tokamaks and mirrors have researchers in the mainline fusion research program taken up the idea as an experimentally practical project.

Electron Beam Filaments

Dr. Winston Bostick, currently on leave from the Stevens Institute and working at the Kirtland Air Force weapons research laboratory in Albuquerque, New Mexico, and his collaborator Dr. Vittorio Nardi presented detailed experimental evidence demonstrating that minute vortical filaments — less than 1 micron in diameter — are formed by relativistic electron beams. (Relativistic electron beams are electrons with a velocity near the speed of light.)

The beams actually form a series of filaments; the 1-micron filaments form into sheets of filaments that in turn form larger filaments.

Research into this self-organizing process, which contradicts the prevailing concept of entropy, is of the greatest significance for understanding the dynamics of coherent structures in plasma physics.

Ion Beams

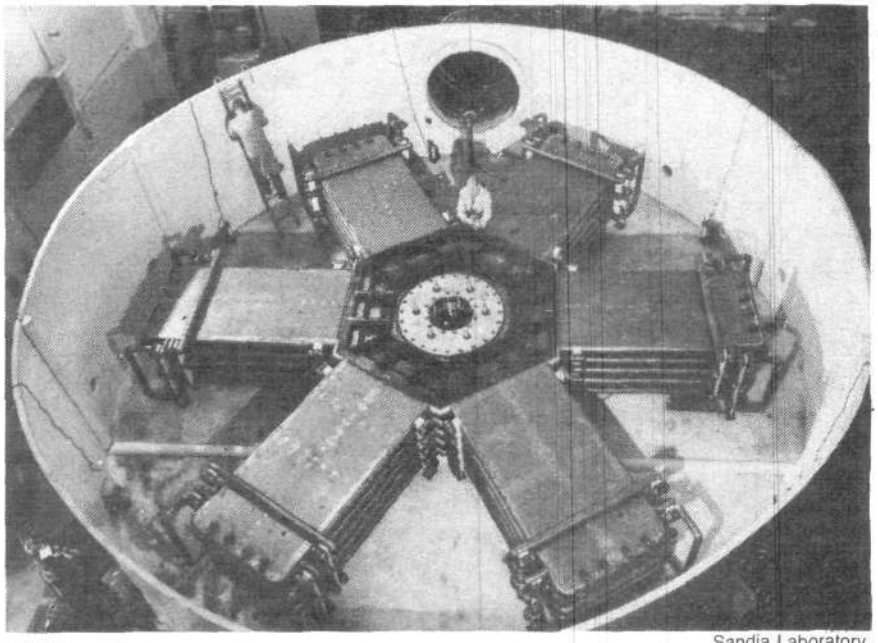
Major progress was reported on the generation, focusing, and deposition of light ions generated in electron beam diodes, with the most spectacular results reported by Sandia Laboratory in New Mexico.

Dr. Gerald Yonas, director of Sandia's Pulsed Power Division, evaluated the recent results in an interview: "Just a couple of years ago, no one believed that you could focus ion beams to any significant power density; we at Sandia didn't believe it could be done. Now we have gotten up to 1 million amps per square centimeter — 100 times greater focusing than just a year ago. We have also experimentally gotten better than 'classical' deposition of the ion beam into a target. This means that the ion beams we have generated are actually 100 times better for the implosion of targets than the 1 million amp electron beam currents we have produced."

FEF Presentations

Charles B. Stevens, director of fusion engineering for the Fusion Energy Foundation, gave two presentations at the conference representing the research work of the FEF staff. The first, a paper by FEF director of research Uwe Parpart, dealt with strong shock isentropic compression and design of target pellets based on this unique new approach to inertial confinement fusion. The second paper, by Dr. Steven Bardwell, FEF director of plasma physics research, concerned the application of Riemannian shock waves to economic analysis.

—Charles B. Stevens



Sandia Laboratory

The Proto I electron beam accelerator at Sandia

Soviet Advance In Computer Algorithms

With a strikingly original application of Riemannian geometric ideas, a Soviet mathematician has discovered what some computer scientists consider one of the few major theoretical developments in computer algorithms since the advent of high-speed numerical methods.

In a paper published in the January 1979 issue of the Soviet journal *Doklady Akademii Nauk SSSR*, L. G. Khachian described the outlines of a procedure for solving the most widespread class of computer problems, so-called linear programming. His procedure can tell if the problem is solvable, and if it is solvable, it can find the solution in a particularly efficient way.

In the usual linear programming problem, one must maximize some function (such as profits), subject to a series of constraints such as production times, inventory costs, and so forth. Previous linear programming techniques all have in theory an exponential dependence on the number of constraints; that is, doubling the number of constraints could turn an easily solvable problem into one that was unapproachable by any conceivable computer.

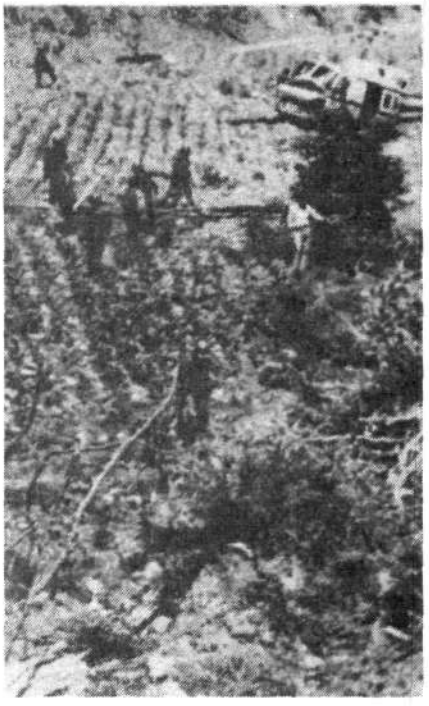
This is not a practical problem with current algorithms, which, for still unknown reasons, are much more efficient than mathematical theory says they should be. Khachian's algorithm, however, is the first provably "polynomial time" algorithm in linear programming. This means that a problem that, for example, for 50 constraints took 5 minutes of computer time, Khachian's solution for 100 constraints may take 16 times longer instead of the thousands of centuries required by the older methods—an increase of n^4 rather than 4^n.

Khachian's algorithm is conceptually much different from current numerical methods in that it uses a global characterization of the solution space to identify the trajectory leading to the solution, rather than the classical local methods. Khachian uses a set of nested minimal volume ellipsoids that he proves will provide a chain leading to the solution.

Khachian's theoretical insights come from a long mathematical tradition, rooted in a Riemannian geometric analysis of the properties of extremal values of functions. However, this method has been applied in the area of computer analysis only rarely. In the late 1950s, John von Neumann proposed an algorithm quite similar to Khachian's, as did other mathematicians several years after von Neumann. About 10 years ago, another Soviet mathematician, A. Sov, derived a very similar but more complex algorithm. None of these proposals was ever successfully reduced to a practical computer code, and, in the intervening 10 years, the sort of global analysis that Khachian used has been largely ignored.

For this reason, Khachian's strikingly simple proposal has sparked great interest in a number of circles. However, his technique is far from being a practical tool. The upper bounds that he proves for the convergence of his algorithm are astronomical numbers when calculated for problems currently solvable. The *dependence* of the time of his algorithm is polynomial, but the size of the polynomial is very large. Current techniques, which have evolved after 20 years of experimentation and refinement, can solve a system of several thousand constraints in several minutes; the upper bound of Khachian's proof gives a figure of tens of millions of years for the same problem.

—Dr. Steven Bardwell



Paraquat spraying in Mexico

Paraquat 'Danger' Is a Fraud

Paraquat, the herbicide used by Mexico to shut down marijuana growing in that country, has been falsely labeled a danger to the health of U.S. marijuana smokers. Testing has shown that the substance is essentially harmless in the concentrations present in marijuana, especially when compared to the far worse effects of marijuana itself on the lungs.

The lie of paraquat's harmfulness began several years ago when NORML, the National Organization for the Reform of Marijuana Laws, the main lobbying group for decriminalizing marijuana and other drugs in the United States, used the Environmental Protection Act to demand an environmental impact statement on the effects of smoking paraquat-contaminated marijuana on the human body.

Falsely exaggerating the scientific data, Sen. Charles Percy, an Illinois Republican, then pushed through a federal law that ended U.S. participation in the Mexican paraquat spraying program last month.

The program is an understandable target for the prodrug lobby. Using sophisticated aerial equipment for locating the fields and spraying with paraquat, the Mexicans have done what was widely considered to be impossible: cut off the drug supply at the source. Since the program began, Mexican marijuana imported into the United States has been slashed by more than 80 percent.

The Medical Findings

Under pressure from Senator Percy's office, the National Institute on Drug Abuse did a series of animal experiments using the smoke of marijuana or other vehicles contaminated with extremely high concentrations of paraquat. According to the final environmental impact statement, although some damage to the lungs of the animals occurred, "the laboratory study needs further examination before it can be properly extrapolated to humans."

An analysis of the question conducted by the *Medical World News* was less charitable. In a Sept. 3, 1979 article titled "'Facts' on paraquat menace in pot were plucked out of air," the paraquat scare was called a "misty projection, a guesstimate . . . done on the basis of zero clinical evidence." Dr. Eric G. Comstock, executive director of the Institute of Clinical Toxicology in Houston said, "Lacking knowledge, they have to guess. They're playing a game that's an artifact of federal activities."

According to one of the lung specialists who participated in the National Institute on Drug Abuse study, the effects of paraquat are difficult to identify clinically because they are "masked by the effects of marijuana itself, which causes far more damage to the lung." Why, then, so much concern about paraquat? The only conclusion possible, from the medical evidence alone, is that the antiparaquat lobby is nothing but a prodrug lobby.

—*Ned Rosinsky, M.D.*

A feature article on the biological effects of marijuana appeared in the Oct. 1979 Fusion.

New Experiments Show Histone Role In Development

How does a duck develop webbed feet instead of a chick's toes?

Although experimenters have established that necrosis (cell death) is the normal process by which certain morphological changes in the embryo—like the development of webbed feet—are achieved, exactly how this process works has not been fully resolved.

At the November biology seminar of the Fusion Energy Foundation in New York, Jonathan Levitt presented experimental evidence demonstrating the role in such development of histones—proteins that are bonded with DNA. Levitt a senior at the Bronx High School of Science, has performed a series of unique experiments with chick embryos and histones. His results indicate that subtle changes in the geometry of the chromosomal structure, reflecting the interactions of the DNA, histones, and other molecules, have a direct correlation to the morphological develoment of the organism.

Levitt showed that the concept of necrosis, or "programmed cell death" as biologists refer to it, cannot be an isolated gene-function correspondence but must be an expression of the coordinated working interaction of the organism as a whole with its parts.

The Experiment

The development of the limb bud in the chick embryo is realized partially through the death of cells in various areas of the bud (see Figure 1), not as a chance occurrence but as a function of the genetics of the developing embryo.

In his experiment, Levitt isolated histone samples from the limb buds of chick embryos at stage 27, the point at which digital formation begins, and at stage 29, the peak of this process when digits become discernible. The indi-

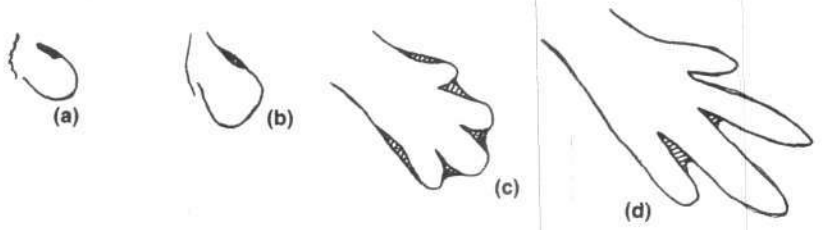


Figure 1
LIMB BUD OF 5-TO-6-DAY-OLD CHICK EMBRYO

Between the fifth and sixth day of the developing chick embryo, the digits of the hind limb are formed. The distal portion of the bud is initially circular (a), but distinct points marking the digit rudiments are quickly formed. As the digit rudiments continue to grow, necrosis occurs in the shaded areas as shown.

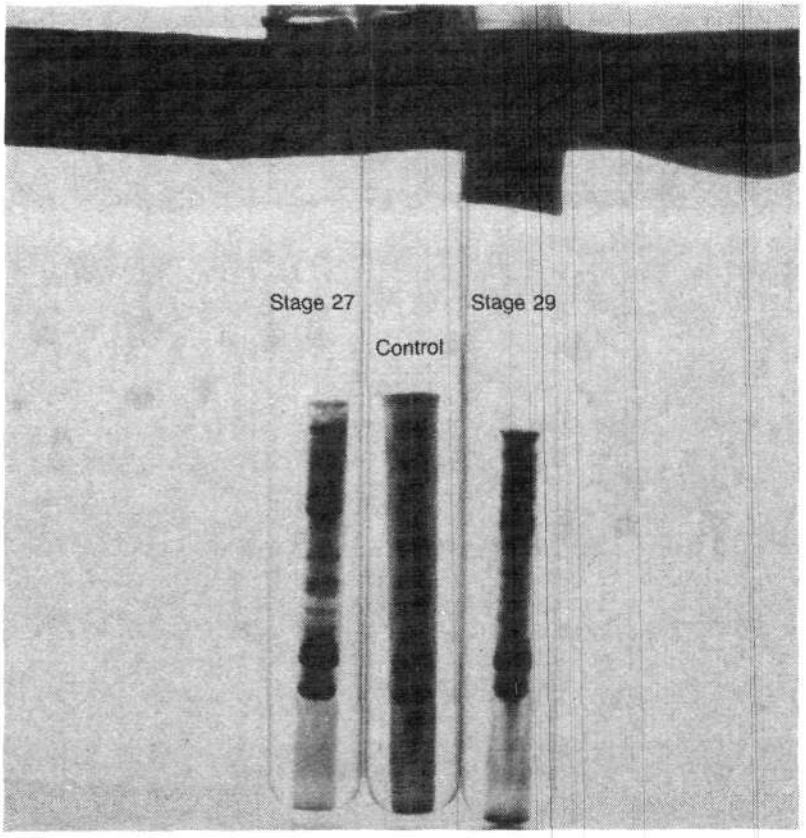


Figure 2
CHANGES IN CHICK EMBRYO HISTONES FROM STAGE 27 TO STAGE 29

The test tube on the left contains histones of Stage 27 chick embryo limb buds; the center test tube is the control sample of calf thymus; and the right tube is Stage 29 of chick embryo limb buds. The bands are obtained by passing an electric current through an acrylamide gel, causing the histones to migrate through the gel. This migration directly corresponds to the changes of the histones. The arrows indicate the areas of change Levitt obtained in the histone banding patterns.

vidual histones were separated by means of acrylamide gel electrophoresis. A third preparation of calf thymus was also separated in order to obtain a control sample showing standard histone patterns.

As Figure 2 illustrates, the histones present show very similar migratory rates with the following exceptions: (1) there is a fraction present in stage 27 that is not apparent in stage 29; (2) a second fraction, common to both stages, appears to be much larger in stage 29 than in stage 27; and (3) the migratory rate of a third fraction has increased from stage 27 to stage 29.

The Theory

The prevailing view holds that the changes in limb bud development are the result of a coded tickertape-type DNA that switches messages (genes) on and off to produce a linear chain of events. Because histones are so similar among various species and various tissues, it is currently held that the histones are not specific enough to play a role in cellular differentiations.

However, a subtle change in the histones present in a particular cell or tissue, such as that demonstrated by Levitt, could realize a cell differentiation such as necrosis, if the genetic qualities of the chromosome are located on a broader, more global level than that of the specific genes that lie along the length of the DNA.

Levitt's work showed that histones play a major role in the evolutionary process, and that the developing organism must undergo a global, self-reflexive process that reorders itself toward a higher level of organization that is reflected on a cellular level as well as on a genetic level.

The evidence does not resolve the question of whether the histone changes are the initiating factors in necrosis or the result of it, but does indicate that geometric changes in genetic structure and respectively in morphological structure must be subsumed by the global behavior of the organism to develop toward a higher level of reorganization.

—Susan Seidman

A full report on Levitt's experiments will appear in a future issue of Fusion.

ENERGY SCORECARD
for the 1980 Presidential Candidates

WE ARE PLEASED to present this "Energy Scorecard for the 1980 Presidential Candidates" as a first step in a *Fusion* magazine campaign to see that the energy issue is discussed in depth in the months before the November 1980 election.

This poll of 10 major candidates is quite remarkable. Although the candidates are often not as specific as the reader would like, the distinct impression from the overall questionnaire is that the candidates here are at their best. They know they are talking to an audience that represents the American majority, and they have focused positively on what is necessary for a progrowth future.

For example, with minor exceptions, the candidates favor upgrading fusion research and furthering international cooperation in the fusion area. Similarly, they are for the development of the breeder reactor, noting that the United States has fallen behind the Europeans in this important technology. And on the much-ballyhooed question of nuclear waste, most of the candidates say that there are available scientific solutions to the problem and that the question is one of political implementation.

What is clear to us from the scorecard is that we and our readers—who now number about 100,000—have a responsibility in the months ahead to ensure that the progrowth, protechnology outlook expressed by most of the candidates here becomes a central focus of the campaign *because the candidates are told by their constituents that this must be the case.* Furthermore, we must see that the economic rationale for a progrowth America is explained in depth—and debated nationally. This means upgrading the level of candidate debate and, even more important, upgrading the content level of media coverage of the campaign.

We would be naive, of course, if we did not maintain a vigilant watch on the candidates to see that they give the same quality of answers on the energy questions to other audiences and to report on any divergences. In addition to continuing news coverage, as the presidential race narrows down we will present a follow-up scorecard focusing in more depth on the crucial questions of how the presidential hopefuls plan to finance and implement America's energy policy and how they see the connections of the energy issue to other political and economic questions.

To aid in this process, the Fusion Energy Foundation is now seeking foundation and corporate funding to sponsor a series of nationally televised debates on the energy issue that will force the different views out into the open in some depth. We also plan a straw poll of our readers on energy and the candidates later in the year. In the meantime, comments from readers are most welcome.

Of the 11 Republican and Democratic candidates invited to participate in the energy scorecard, two declined: General Alexander Haig, who at this time is still an undeclared candidate, and Senator Edward Kennedy.

We have included Kennedy in the scorecard, however, because until just hours before press time, Kennedy's advisors told us they were trying to complete the questionnaire. Indeed, we were ready with a tape recorder to take down the answers by telephone. But in the pressure of the Iran crisis, the Kennedy "issues" staffer responsible for energy told us, they "did not have time to complete the questionnaire."

The answers that appear on the scorecard for Kennedy are taken from a press release and pages 3 and 4 of an undated, untitled policy statement sent to us by the Kennedy staff, a fundraising letter recently circulated by the Kennedy for President Committee, press clippings, and an earlier interview with a Kennedy staffer who specializes in energy. The answers from this last-mentioned source are "unauthorized," (to use the words of the source); they appear on the scorecard without quotation marks.

As for the other candidates, all but Ronald Reagan completed the *Fusion* questionnaire in full, and their statements are reproduced here verbatim, with a very few minor deletions. Mr. Reagan's staff explained that they very much wanted to participate, but that the candidate's policies were still in preparation and would not be ready for our press time. The Reagan scorecard answers are compiled from his nuclear policy statement and a few very brief policy remarks authorized by his staff.

In the case of President Carter, the views expressed are those of the Carter administration, not Carter personally. For the other candidates, the answers appear in the first person or the third person, as they were given to us.

The candidates are listed here in alphabetical order and the questions are listed in the order that they appeared on the *Fusion* magazine questionnaire. NA stands for no answer.

—Marjorie Mazel Hecht

Question 1.

What is your policy on the mix of energy technologies for the United States; specifically, what percentage of the energy grid in the years 1990, 2000, and 2050 do you foresee for coal, oil and gas, nuclear, solar and renewables (wind, biomass, geothermal), synthetic fuels, fusion, other?

LINE UP

Senator
Howard H. Baker, Jr.
Republican

I prefer not to engage in the guesswork of assigning numbers at this point, particularly when many of the technologies mentioned have still to be demonstrated as commercially viable. Suffice it to say that we simply need to do everything we know how to do, and a number of things we haven't even learned yet. We must conserve, increase domestic coal, oil, and gas production in the short term, and plan now for the transition to renewable and advanced technologies for the longer term.

Governor
Edmund G. Brown, Jr.
Democrat

Our energy future is fraught with too many economic and political uncertainties to specify with any degree of accuracy the relative mix of energy sources and technologies that we will be relying upon in the mid to long term. I would, however, promote an energy future for the United States, in which we: phase out our reliance upon currently operational nuclear power plants, increase our efforts to produce oil and gas from onshore and offshore federal lease lands, expand the number of coal power plants using best available pollution control equipment, develop clean fuels from coal such as methanol, aggressively promote the development and implementation of solar, geothermal, biomass, small hydro, wind, and cogeneration technologies, and pursue an ambitious program of energy efficiency improvements in the residential, commercial, and industrial sectors.

George Bush
Republican

In order to fill the energy gap of the 1980s we should immediately decontrol the price of oil; we should remove controls on natural gas; we should expand nuclear power, utilizing our awesome ability in science and technology to guarantee safety; we should also significantly expand our production and use of coal, and we should find new methods of conservation. . . . We must bring on line as quickly as possible both synthetic fuels from our domestic resource base and the next generation of renewable fuel sources. For this longer term let us recognize that the development of energy sources such as solar, hydrogen, and fusion requires the best minds in the free world. As president, I would bring these people together to work to realize the dream of renewable energy resources by the end of this century. The development of synthetic fuels from coal and other domestic hydrocarbons is a vital necessity for the 1980s. . . . The government must immediately undertake to help industry demonstrate and perfect technology. However, the construction of a few pilot plants for the most promising technologies should be the full extent of the government's direct role. Full-scale production of fuels from these sources, and the questions of which technologies to choose, must be left to the private sector. If necessary,

Continued in Question 2

President James Carter
Democrat

The mix of fuels which will constitute the 1990 and future energy budgets of the United States are not determined by government policy. President Carter does not seek to mandate the technology schedule.

The national goal is to achieve a 20% reliance on solar energy by 2000, with rapid expansion anticipated thereafter. The government will continue to sponsor research, development, and demonstration of potentially economic renewable and other technologies, including fusion power.

John B. Connally
Republican

Until the year 2000, three sources of energy will be used to generate electricity in the United States: oil and gas, coal, nuclear power. A Connally administration would stress increased use of coal and nuclear power and diminished use of imported oil. While it is important to develop renewable and synthetic sources, those fuels are decades away from making a significant contribution to our energy production. Fusion is still a question mark, but funding of fusion research should be increased.

 **Congressman Philip M. Crane** Republican	This question should not be answered by the federal government. Federal officials should not decide what is the most economical and accessible form of energy. Not the president, not the Congress, not the DOE, not the bureaucracy—no federal government entity should be deciding what form of energy we must produce and buy. As advancing technology makes coal and other energy sources more efficient, usable, and inexpensive, the consumer himself should be able to judge which is the best product. We can, however, see some important trends for the future. We must rely heavily on fossil fuels, which are more abundant than government policy has allowed us to believe, and nuclear fission. In the future, there is much promise for such technologies as nuclear fusion processes and regional energy sources.	
 **Senator Robert Dole** Republican	Coal should definitely be increased due to its vast abundance. More incentives should be given to the domestic producer of oil and gas. Nuclear should definitely be continued and become an imporant source of future energy. Solar and renewables should be used as complements to our fossil fuel utilization. Synthetic fuels should be developed, but environmental and economic implications should be seriously considered. Fusion is a definite source of energy in perhaps the next 10-20 years; pilot plants should be built. Alcohol fuel utilization is vital; technology is present and resources can create another industry for the American farmer. No mix figures are available at this time.	
 **Senator Edward M. Kennedy** Democrat	"Each time a nuclear power plant is built, 9,000 potential jobs in the coal industry are lost. Each time a nuclear power plant is built, we fail to mine 5 million tons of coal." *—Charleston, West Virginia* *Nov. 2, 1979* The main thing is conservation. By the year 2000, solar must supply one-fifth of our energy.	"Perhaps [synthetic fuel] will prove to be the answer to the energy crisis. But we cannot yet say for certain whether synthetic fuel or any other technology is the answer." *—Conference of the National Urban League, Chicago* *July 23, 1979*
 **Lyndon H. LaRouche, Jr.** Democrat	By 1990, LaRouche expects the following mix of energy technologies: nuclear 28%, coal 20%, natural gas 17%, oil 38%, synthetic gas (coal gas generated through application of process heat from nuclear reactors) 2%, and other (mainly hydro) 5%. By the year 2000: nuclear 35%, coal 16%, natural gas 12%, oil 22%, synthetic gas 10%, and other 5%. By the year 2050, LaRouche believes that the principal energy source will be electricity generated by fusion reactors. The principal portable energy source will be hydrogen gas using for its production the process heat of fission and fusion reactors. Conventional nuclear fission reactors will continue to play a very important role in the first decades of the next century.	
 **Ronald Reagan** Republican	NA	

ENERGY SCORECARD

LINE UP	Question 2. **Briefly state the economic rationale for your policy on the mix of energy technologies.**	Question 3. Nuclear **(a) Do you plan expansion or reduction of the current U.S. nuclear power capacity? If you plan expansion, how many nuclear plants do you plan to build by the year 1990, 2000, 2050?**
 Baker	See answer for Question 1.	Expansion, consistent with safety.
 Brown	The increasing economic and social costs of nuclear power far outweigh the benefits of the electrical energy produced by it. Development of domestic petroleum sources serves to reduce the adverse impact upon our balance of payments from undue reliance upon foreign sources of oil. Coal is our most abundant domestic energy resource, and we should utilize as much of it as possible in an environmentally acceptable way. Development of renewable energy sources . . . makes economic sense. . . . Energy efficiency improvements make the most economic sense of all of these energy options, because it is much cheaper to save a unit of energy than to produce it.	I would not expand nuclear capacity beyond what is currently operational, and I would phase out existing facilities within such time frame as they may be feasibly replaced with alternative energy sources.
 Bush	*Continued from Question 1* the government might guarantee markets, loans, or support initial prices to bring full development on the line. But the inherent inefficiencies of a nationalized production system are antithetical to the American economic system. . . . I recognize that it is critical for us to move forward now with the next generation of energy sources. These sources—as simple as gasohol and solar, or as esoteric as geothermal, hydrogen, or nuclear fusion—offer the promise of being both renewable and virtually non-polluting. Their full development at the earliest possible time is the most important physical challenge facing the world.	Our expectations in the mid to long-term must rely on our technological genius and proven know-how. Americans harnessed nuclear power for peaceful purposes, and the technology in use around the world today to generate electricity from the atom stems from our experience. We must continue to develop nuclear power, taking all steps required to insure that its safety record is maintained and strengthened.
 Carter	The economic rationale for administration energy policy is based on the achievement of the most efficient utilization of available resources, as determined by the competitive marketplace in a replacement cost pricing environment. The administration anticipates that over the remainder of the century, energy conservation, direct coal use, nuclear power (fission), renewable resources, and synthetic fuels will substitute for petroleum and natural gas. During that period, real increases in energy costs and the results of government and private research development and demonstration will yield competitive technologies for the widespread application of renewable resources such as solar.	In April, President Carter named members to the President's Commission on the Accident at Three Mile Island. A detailed report from that commission was submitted and President Carter is reviewing its findings and recommendations. Determinations from that report will have an impact on nuclear power in the United States. The president has noted that some communities—Chicago, for example—depend on nuclear power to meet half of their electrical needs. Nuclear power now produces about 13% of this nation's electricity needs. . . .
 Connally	If government stays out of the energy business, except as a financier of research, the free market will determine the most efficient methods of producing energy in the future. If the market is allowed to decide, these are the choices it is likely to make.	Governor Connally would seek to expand the U.S. nuclear power capacity, including renewed funding of fast breeder development.

 Crane	The individual consumer should decide what is the most inexpensive form of energy. The DOE's budget is larger than the profits of the 10 largest oil companies. Last year the DOE spent more than the oil companies on oil exploration—and what have we received for our tax dollar? The DOE hasn't produced one drop of oil. Economic decisions should not be made by bureaucracies that inevitably miscalculate but by the individual consumer.	America needs energy. Our lives, businesses, and jobs depend on it. Nuclear energy is one of the most promising sources for meeting our immediate and future needs.
 Dole	Economically, incentives given to the domestic oil and gas producer, as well as exemptions for the small independent will result in new and better technology and monies well spent on the development of alcohol fuels in an industry where the feedstock is already available will be cost-effective.	Expansion, but only with maximum enforcement of safety and training procedures and planning. Not certain on number of plants to be built.
 Kennedy	We are concerned with those energy sources that are the most cost-effective, the most compatible with the environment, and the most compatible with a full-employment economy. National policy should not unfairly burden low-income families.	"Supporting a moratorium does not mean that EMK advocates shutting down operating plants or stopping work on reactors under construction. If the safety problems are successfully addressed, and the basic nuclear safety laws rewritten to substantially increase nuclear safety, then nuclear power can *move forward again.*" *—Undated policy paper* The Department of Energy's 1990 projections are not realistic. National nuclear energy power capacity should be reduced.
 LaRouche	Obviously, the scenario outlined here could undergo a strong shift between now and the year 2000. However, the LaRouche policy is based *on the necessity of employing the technologically most* advanced and consequently most productive energy technologies. Only in this fashion can we guarantee a continued sound growth rate for the U.S. economy. Fossil fuels, in particular oil, should be phased out of those areas of application where they are not essential at the earliest possible time and be reserved to serve as feedstocks for chemical and other industries.	The rapid expansion of conventional and advanced nuclear power systems, including the commercial development of the high temperature gas-cooled reactor, is essential for the scientific and economic well-being of the United States. We would plan to build 500 nuclear reactors by 1990; 1,000 by the year 2,000.
 Reagan	NA	Given our burgeoning difficulties with oil and gas prices and supplies, and the serious environmental problems associated with burning coal, to cavalierly close down all nuclear power plants and halt the construction of new ones would threaten widespread industrial disruption and the disruption and discomfort of millions of Americans. . . . In my mind, we have no choice but to continue to operate and construct nuclear power plants if we are *to meet the energy and job needs of Americans. I believe it offers our greatest hope for the solution* of our energy problems over the next two or three decades.

ENERGY SCORECARD

Question 3. Nuclear (continued)

LINE UP	(b) What is your policy on the fast breeder reactor?	(c) Briefly state your policy on the nuclear waste question.	(d) Briefly state your policy on nuclear technology exports.
 Baker	A necessary technology that must be developed. We trail the French and British significantly, a deficiency that must be overcome.	The technology exists for the safe disposal of nuclear wastes. The problem now is political commitment and leadership. A site for the geologic disposal of nuclear wastes must be selected soon, and a demonstration project given top priority.	The administration's policies designed to prevent the proliferation of nuclear weapons have been commendable, and have sensitized the world to a serious concern. But we cannot allow those concerns to bring American energy planning to a standstill, while others proceed and slowly exclude America from the worldwide decision-making process with regard to nuclear technology and proliferation. In short, if you aren't in the game, you won't long be able to help make the rules.
 Brown	I am opposed to development of the breeder for the same reasons that I am opposed to expanding nuclear power plant capacity.	I support the recommendation of the President's Interagency Review Group on Nuclear Waste Management (IRG) which called for the immediate development of a comprehensive disposal plan for high-level and low-level radioactive wastes. Unfortunately, the president has not officially acknowledged or supported the findings of the IRG.	As more and more nations develop the expertise to utilize nuclear technology for peaceful applications, they also develop the expertise to develop nuclear armaments. I am strongly in favor of bilateral and international arrangements which delimit the diffusion of nuclear technology and impose stringent safeguards upon such technology transfers.
 Bush	NA	It is urgent that we squarely face questions of nuclear waste disposal. Numerous energy experts have said that the critical problems surrounding disposal today are not really technical, but political. Once again, it is important that we exercise sufficient political leadership to erase all doubts about both nuclear development and disposal of its waste.	NA
 Carter	In 1977, President Carter said: "I have no objection to the plutonium age coming. I have no objection to breeder reactors. I don't think the time has yet come." President Carter was opposed then, and is opposed now, to the Clinch River Breeder Reactor, which he considers technologically unsound and a waste of millions of dollars of taxpayers' money. . . .	This is a problem for which there are no easy solutions and one which the international community—not only the United States—has grappled with, to date without solutions. Last March, President Carter appointed the Nuclear Waste Management Task Force, which conducted the most comprehensive interagency review of the nuclear waste problem ever done. He also has submitted to the Congress proposed legislation dealing with nuclear and toxic wastes	NA
 Connally	See Question 3 (a)	Governor Connally would deal with the nuclear waste question by disposing of nuclear waste. The technology for safe disposal exists, especially if the waste is reprocessed; reprocessing and disposal procedures are underway in France and Germany.	The argument against nuclear technology exports is a moot point: if the U.S. doesn't export the technology, France, Britain, and West Germany will. The U.S., for the most part, developed the technology; it's high time we began to reap the profits of that development.

ENERGY SCORECARD

 Crane	I am strongly for it. Each time it has come up in the House, I've voted in favor of continuing breeder construction and technology.	Ninety-seven percent of nuclear waste comes from the weapons program. Certainly, we're not going to eliminate our weapons program. The scope and severity of this issue has been greatly overemphasized. We must allow time for private initiative to handle the waste problem without any hindrance from the federal government.	The federal government should not interfere with the right of business to do business abroad.
 Dole	I support the Clinch River Breeder Reactor Program and will continue to do so. This technology provides a research program that will demonstrate nuclear potential equivalent to all U.S. coal reserves.	Hearings held in the Senate committees on this issue have proposed more in-depth research into the alternatives to disposal. Before nuclear power production is expanded on a larger nationwide scale, a safe disposal method would have to be adopted by the entire populus. Questions on the safety of ocean dumping and salt mine dumping still remain in my mind, as well as glass containment dumping. This problem must be resolved in conjunction to the problems addressed in the Three Mile Island situation; the waste cannot be ignored.	I have supported efforts and legislation on nuclear technology export, under the guarantee that these exports cannot be used to the proliferation of nuclear weapons. You cannot deny the fact that France, Britain, and the USSR are already ahead of the U.S. in the fast breeder reactor technology and clearly exportation of nuclear technology would benefit our nation as well as others. However, any exportation, again, must have the guarantee of not being used for nuclear weapon development.
 Kennedy	Don't develop it. It's not needed.	We need a cooperative effort among states in a regional setting to plan for storage of waste.	We support the Carter administration's efforts to curtail nuclear technology exports.
 LaRouche	The fast breeder reactor must become a high-priority development project since significant time has already been lost. Agreements with France for technology exchange with regard to the Superphenix breeder should be seriously considered.	At least 96% of what is now classified as nuclear waste can be recycled to make new fuel in nuclear reprocessing facilities. Such facilities (e.g. the Barnwell, S.C. plant) should be completed at the earliest possible date. The 4% of nuclear waste that cannot be recycled can be disposed of safely either by burying or by prior treatment with fast neutrons and subsequent burial of the waste whose radioactivity has been significantly reduced. The relevant technologies to accomplish this are now in existence or can be be developed quickly.	If the underdeveloped sector of the world is to undergo industrialization during the next few decades, this can be done successfully only by using the most advanced industrial technologies available, not by using the so-called appropriate technologies that are geared to the backwardness of large portions of the Third World sector population. As part of his overall energy program, LaRouche will put forward a comprehensive plan to resume American preeminence in nuclear exports, aiming for a total of up to 1,500 power plants exported by the year 2000.
 Reagan	NA	The question of the disposition of waste materials is primarily a task for the military and the federal government since the waste from power plants represents only a very small percentage of the problem and is no reason to deny ourselves this economical, inexhaustible source of electric power.	NA

4. Fusion

LINE UP	(a) Do you plan expansion or reduction of the current U.S. fusion budget?	(b) What is your view of the current DOE timetable for fusion?	(c) Do you support the development of the fusion-fission hybrid?	(d) Briefly state your view of international cooperation in the fusion area.
 Baker	Expansion.	Overly conservative. The fusion program is considered by most responsible experts to be limited by funding. That is difficult to justify in a time when we continue to spend $70 billion a year for foreign oil.	It is not clear that the economic arguments justify such a development, but in any case, the discussion is a bit premature until we move ahead to the engineering phase of the fusion test reactor program.	The expense associated with fusion energy development makes it sensible that not every country reinvent the wheel in those areas where sensitive technology, from the standpoint of national security, is not at issue.
 Brown	While fusion energy cannot be ruled out as a future potential source of energy, I am not persuaded at this time that the federal R&D budget for fusion development should be expanded beyond its existing appropriations level.	The setting of a date for the commercialization of fusion power is presently an exercise in conjecture. Only after the energy breakeven point has been reached and after a pilot plant has become operational can we be in a position to talk abut the technical and economic feasibility of commercialization.	No, I do not. The option is being put forth by those who want to maintain nuclear fission as an energy option, and I do not support their efforts.	I would support such cooperative efforts insofar as they do not require a major commitment of financial resources by the United States. By pooling information and resources, we may be able to more expeditiously evaluate the viability of the fusion option without undue cost.
 Bush	A specific position on fusion is now being developed.	NA	NA	NA
 Carter	The administration's current mid-range planning (1981 to 1984) calls for modestly increasing budgets for fusion until a decision is made in the mid 1980s on a next-step device.	The current DOE schedule is conservative but prudent. It does not foreclose options until burn physics is understood. At that time, the development can be significantly accelerated.	No	The technical exchanges in magnetic fusion promote the vitality and inventiveness of the plasma physics inquiries. On the other hand, international cooperation on a large next generation machine would be a management nightmare, in the opinion of the administration.
 Connally	Governor Connally would expand fusion development funding.	The current DOE timetable can be shortened if sufficient funds are available; how much it can be shortened is an open question.	NA	International cooperation in this field is vital, especially to the western, industrialized nations.

 Crane	Fusion is perhaps the most promising long-run hope to answer all our energy problems. Our efforts should be enhanced, not diminished.	Once again, the DOE is impeding rather than encouraging progress.	Any technology that could advance our energy production capacity should be thoroughly explored, tested, and, when proven successful, implemented.	As long as international cooperation ensures that we are indeed benefiting from our participation, we should not stand in the way of progress.
 Dole	Fusion development should be expanded.	That timetable is acceptable under the current technology we know of fusion and the developments that are being made.	Not sure at this time.	As in the fast breeder reactor area, the U.S. can only benefit when cooperating with other nations in the field of nuclear energy development and utilization. I have proposed in the Senate that we meet with Canada and Mexico in a summit similar to Camp David to discuss energy. . . . Only if we sit down and talk with these nations will we know a potential of international cooperation.
 Kennedy	The senator supports the present funding for fusion research.	NA	NA	NA
 LaRouche	The current fusion budget should be doubled so that engineering development can begin immediately and so that all promising scientific programs can be maintained. Then we can bring the personnel and infrastructure up to the level that can deploy the several billion dollars per year necessary for an effort on the scale of the Manhattan Project.	The usual date used by the DOE is 2015 for a demonstration fusion plant. With a broad-based science and technology R&D effort, we could—conservatively—reduce that to no later than the 1990s. The timetable should be a by-product of a scientific effort of the greatest breadth and intensity.	The fusion-fission hybrid will be an extremely efficient reactor for the breeding of fissile fuel and will probably constitute the first type of commercially viable fusion-based reactor.	International cooperation in the fusion program has been the most successful of U.S. scientific international collaboration efforts. We have much to gain and nothing to lose by expanding it further, not only with our European and Japanese allies, but also with the Soviet Union.
 Reagan	NA	NA	NA	NA

ENERGY SCORECARD

Question 5. Fossil Fuels

LINE UP	(a) What is your view of the administration's policy of converting oil and gas-burning power plants to coal?	(b) Briefly give your policy on the question of OPEC oil imports.	(c) What is your view of the administration's proposal for a windfall profits tax and price decontrol?
 Baker	A necessity, but a policy which must include all available technology to protect the environment.	Diminishing our dependence on uncertain foreign oil suppliers is the central and most urgent priority of national energy policy.	I have long advocated a return of the domestic energy industry to an orderly market system of incentives. The windfall profits tax is a necessary step in achieving the deregulation of oil, but such a tax should not be punitive if we are to achieve the new oil and gas production that will be needed to hold the line on imports.
 Brown	I support such an approach to the extent that conversions make both economic and technical sense for particular facilities. In some areas of the country, it makes sense to have residual oil burned in utility boilers because no other markets exist for such fuels. In areas close to fields producing heavy oil, it may make sense to permit utilities and industries to gasify such crudes for use in their boilers. However, conversion, where feasible, should be undertaken.	We must reduce our reliance on imported oil by developing more fuel efficient automobiles, expanding our mass transit facilities, expanding efforts to explore and develop domestic petroleum resources, curtailing our consumption of gasoline by changing our driving habits, and promoting energy efficiency improvements in the residential, commercial, and industrial sectors, to name but a few options. I have proposed the creation of a National Oil Import Authority	The president's decision to decontrol domestic oil prices was untimely and inflationary in view of the prevailing wisdom at that time that OPEC would soon thereafter put into effect substantial price increases. Having decided to phase out domestic crude oil price controls, he should have made his decontrol decision contingent upon congressional enactment of windfall profits tax legislation that is much more stringent than what President Carter seems to be willing to settle for at this late date.
 Bush	As president, I will move administratively and, where necessary, by legislation, to permit coal to be burned more readily and to encourage immediate conversion of all coal-capable utility power plants and major industrial boilers from oil back to coal. I will also move to *allow coal to be mined on the vast federal land holdings* and will look with great favor on plans to modernize and upgrade our transportation system so that coal may be efficiently delivered to major markets	America doesn't suffer from a shortage of energy. It *suffers from a shortage of leadership.* Incredibly, the United States is the only major industrialized nation without a comprehensive energy policy some six years after the 1973 Arab oil embargo.	We must move immediately to deregulate both the price and allocation of these basic sources . . . . We must also combine windfall profits tax with a plowback provision economically requiring that additional profits be used in the development and production of new energy supplies. To assist needy families in meeting the inevitably higher energy prices that will face us over the near term, the federal government can and must provide appropriate assistance—I have called for $1.4 billion in aid—so that no one will be faced with the choice of heating or eating . . . .
 Carter	The president considers it essential that this nation lessen its dangerous dependence on foreign oil, if we are to restore America's energy security. The conversion to coal by many power plants is one option that he has proposed. Conversion to coal is an ongoing process. The president has set a specific goal of reducing oil used by electric utilities by 50% by 1990, and legislation which will achieve this goal will soon be submitted to the Congress. . . .	President Carter's policy is to lead this nation in what truly is a battle on energy, with victory being less depedence on oil provided us by OPEC. It is the president's opinion that America is now dangerously depedent on oil supplied by OPEC, to the point that our energy security is threatened, and we are sending billions of dollars overseas and in turn importing inflation and unemployment. Restoring our energy independence, in President Carter's opinion, requires a massive conservation effort	In his energy speech April 5, President Carter proposed the windfall profits tax. He considers it a cornerstone in our national effort to restore America's energy security during the critical decade of 1980-1990. The windfall profits tax would be a tax on the enormous unearned profits that will accrue to the oil industry as a result of the OPEC price increases and decontrol . . . .
 Connally	The U.S. should mine more coal and burn more coal. This is absolutely necessary in order to reduce imports from OPEC. While the administration's policy is to limit imports to 8.5 million barrels a day, our goal should be to eliminate imports.	See 5(a).	The "windfall profits" tax—really an excise tax—should be limited to providing emergency relief for those unable to cope with rising prices. All other profits should be plowed back into energy development and exploration. That function is best performed by energy-producing firms. Deregulation of this industry should be immediate.

 Crane	The government should not be dictating what form of energy people may choose to use. The market should be allowed to determine what is the most economical and effective. The U.S. has the largest proven supply of coal in the world—enough to meet our needs for 100 years. Despite that fact, our own energy, environmental, and mining regulations have kept those coal resources buried.	Our domestic restrictions on oil production in the form of price controls have caused our dependence on foreign oil. The best response to OPEC would be to aggressively develop our abundant energy sources, thus breaking OPEC's stranglehold on our productivity.	The windfall profits tax is absurd. It will ultimately tax the consumer by increasing the cost of oil. Rather than tampering with demand by increasing prices, the administration should be deregulating energy production to increase the supply of energy.
 Dole	As stated previously, coal is our most abundant resource and the conversion by the president is a good concept. However the cost of many of these plants is difficult to bear for these firms and actions dealing with assistance must be taken.	For too long we have depended upon the OPEC cartel for our crude oil supplies, we have ignored the potential of the domestic producer and the alternative energy technologies available here at home. Our imports should be reduced and that can only come about through a national energy policy which gives incentives to the producer and conservation of the consumer.	We need a windfall profits tax that will not punish potential producers, but actually encourage production of new oil and gas. This is why I opposed the Carter proposal because it was nothing more than an excise tax. The version reported from the Senate Finance Committee will provide encouragement.
 Kennedy	NA	"The moral equivalent of war has become the practical equivalent of surrender to the oil companies and to OPEC." *—American Petroleum Institute meeting, New York City, Nov. 13, 1979*	"And where will a substantial part of the windfall tax money go, under President Carter's plan? Back to the big oil companies, to finance and subsidize them in the production of synthetic fuel." *—Undated fundraising letter* I call upon the president today to say to the Congress that he will veto any bill that doesn't provide a return of at least 50 percent of the windfall profits to the general treasury and to the taxpayers of this country.
 LaRouche	The conventional combustion of coal for power generation is neither the most economical nor the most environmentally sound way of phasing out the use of oil in electricity production. Electricity production should be shifted into nuclear by rapidly completing those 120 power plants now in various phases of construction and licensing. The principal feature of coal lies in its transformation into coal gas, its use as metallurgical coal, and as a feedstock for the chemical industry, supplementing oil.	Like it or not, U.S. dependency on sizable oil imports will continue through the next decade. A rational foreign policy vis à vis the Arab oil-producing countries as well as Mexico, satisfying their demand for our technology exports in exchange for their oil, must guarantee a stable price and supply. Oil imports will be reduced as significant new nuclear capacities come on line in the United States.	The major multinational oil companies must be made responsible to U.S. consumption and security requirements. A windfall profits tax is a poor substitute for a firm policy toward the oil majors. If necessary a national purchasing agency negotiating state-to-state contracts between the U.S. and oil-producing countries must be created to bypass those of the Seven Sisters not complying with U.S. policy requirements. The most effective way of increasing U.S. domestic oil production is through tax credit arrangements favoring increased exploration and production.
 Reagan	NA	Reagan favors less dependence for our nation on foreign sources of oil.	Reagan is in favor of oil price deregulation.

ENERGY SCORECARD

LINE UP	Question 5. (continued) (d) How much oil and gas do you think the U.S. can produce domestically and at what prices?	Question 6. What energy studies and think tanks have you relied on concerning the energy question?
 Baker	You have to be careful of anyone's numbers in this area; it is difficult to predict the exact supply response of deregulation, but I believe it is large enough that for the foreseeable future, dollars invested in new oil and gas production are a better investment than dollars invested in commercial synfuels production, for example. But I would add that we must, in the interest of national security, develop and demonstrate a variety of synfuels technologies in case we need them.	A wide variety. The striking thing about most energy studies carried out to date is the degree of consensus that exists among responsible scholars. There are variations in emphasis, and some disagreement on how we got in the fix we're in, but the significant conclusions regarding the need for conservation, the role which coal must play, and the dangers of reliance on oil are pretty clear.
 Brown	There can be no categorical answer. The federal government is continually revising its estimates about the size of the domestic energy resource base based upon changing production rates and drilling efforts. Substantial onshore and offshore areas remain to be explored and developed, and I would vigorously pursue such efforts on federal lease lands in an environmentally acceptable manner.	During my tenure as Governor of California, I have been in a position to exchange ideas and information with representatives of energy producers and users, environmental groups, consumer groups, academic experts, and others, and have kept abreast of federal actions on energy policy questions. My appointees to the California Energy Commission, Public Utilities Commission, and Air Resources Board, and other state agencies have been at the forefront of energy policymaking in the United States.
 Bush	We should recognize that government is not going to produce our way out of the energy crisis. Only the producers of this country are going to do that—and we must allow them to do the job. At the same time, because the government, not the oil companies, is responsible for the welfare of the American people, we must and will monitor the oil companies more closely, ensuring that the government and the public have the full facts about their operations . . . The final key to increasing domestic supplies of energy is to cut through the regulatory tangle that extends from Washington to every nook and cranny of our country.	We use a variety of East Coast and West Coast consultants. These include the American Enterprise Institute, the Yale School of Organization and Management, and studies from Stanford University, Harvard University, and other institutions, as well as studies from private sources.
 Carter	This is a speculative question that is difficult to answer accurately. President Carter has told the American people that he cannot mislead them—that the price of oil will not come back down and, to the contrary, will increase again. The long-term oil supply outlook is grim. It is obvious that demand for oil is increasing worldwide, and supplies are getting more scarce. The DOE estimates that domestic oil production will, at best, stay roughly constant over the next decade.	The primary analytic work upon which administration energy policy is founded is performed directly by the DOE, including the recently summarized analyses in the 1978 Annual Report to Congress of the Energy Information Administration. Studies from other sources are evaluated and used to the extent appropriate in developing information in support of policy development. Also, the DOE finances a considerable amount of private studies, including work by the Rand Corporation, ICF Inc., the MITRE Corp., and many others. The results of these efforts contribute to the analytic process.
 Connally	See Question 5 (c).	Governor Connally, a former chief executive of an energy-producing state, is himself an expert in this field. In addition, he receives counsel from the campaign's Energy Policy Advisory Committee, chaired by Frank Zarb.

 Crane	Untapped oil and gas reserves in the U.S. are abundant. If the government would deregulate energy prices, the supply could be increased at a reasonable price.	Among the people I have consulted with are Dr. Morris Adelman, MIT; Dr. Melvin Gottlieb, Princeton Plasma Physics Laboratory; and Ed Mitchell, American Enterprise Institute.
 Dole	There will never be cheap energy to be purchased ever again. If we want to become more energy independent we will have to pay the higher price. I don't really know what it will be in 10 or 15 years but it could be as much as $2 for a gallon of gasoline, maybe $3. To achieve that energy independence we will have to also accept trade-offs between this self-sufficiency and a pristine environment. This will present many difficult decisions to be made.	I have used a variety of sources, private as well as public. Those located in Kansas, such as the Kansas Energy Office, as well as nationwide, such as the American Nuclear Society. As a commissioner on the National Alcohol Fuels Commission, of course I depend on the staff there, as well as the private individuals in production of gasohol.
 Kennedy	NA	NA
 LaRouche	U.S. Geological Survey estimates show that U.S. domestic production at minimum can be maintained at present levels. More optimistic estimates show that it can be increased by 20 percent beyond this level. This should allow maintenance of a stable price.	LaRouche has relied on consultants from the Fusion Energy Foundation and the analysis reports of the Energy Information Administration of the DOE.
 Reagan	Reagan would encourage increased production and exploitation of our own nation's energy resources. To do this, he would favor economic incentives to free enterprise to develop oil and natural gas resources.	NA

ENERGY SCORECARD

LINE UP	Question 7.	Question 8.	Question 9.
	What is your view of the report of the Presidential Commission investigating Three Mile Island?	**What role do you see for "conservation" as an energy source?**	**Would you expand or reduce the present DOE budget for advanced technologies such as MHD, thermionics, hydrogen production?**
 Baker	A responsible report which has accurately assessed a number of the problems that must be dealt with as we seek to insure the safety of nuclear power.	An absolutely essential role for the short term. For much of the next decade, conservation and new domestic production are the only realistic prospect for dealing with the liquid fuels supply problem.	Expand substantially. The time for fine-tuning energy policy and quibbling over millions while we spend billions for foreign oil is past. Development of new energy sources will be difficult and it will be expensive, but failure to do so is simply not an acceptable option.
 Brown	The commission's report is an indictment of the present administration's failure to come to grips with critical nuclear safety concerns.	Energy conservation is one of the strongest cards that we hold to reduce our nation's reliance on energy imports and to improve our sagging economy. It is cheaper to save a BTU than to produce one. We need to undertake bold and aggressive efforts at the federal level through grants, loans, and tax incentives to recapture the substantial amounts of energy that we presently waste in the residential, commercial, and industrial sectors.	I have not yet formulated an opinion on what appropriations levels are desirable to develop such options.
 Bush	The recent Kemeny report, in my judgment, points out many of the safety steps that must be taken.	. . . We still have a long way to go in learning how to use our energy resources more wisely by employing prudent conservation. But in no area has the confusion of the Carter administration over the appropriate role of the government been more evident. I believe in the individual good sense of the American public. . . . In fits and starts we have experimented with resource substitution—from wood stoves in New England to gasohol in Iowa to garbage-fired steam generators in the Boston suburbs. People are proving everyday. . . that it can be done by applying their imagination.	NA
 Carter	President Carter appointed the Commission in April. He said at the time it was formed that its task "was one of the most important which has ever been assigned to a presidential commission." The president planned a thorough and detailed study of the Commission's report and will make his determinations as quickly as possible.	President Carter considers conservation by groups, institutions, and individual Americans to be a cornerstone to our efforts to restore America's energy security. He has pointed out that legislation alone cannot make us less dependent on imported oil, nor bring about widespread use of alternative sources of energy. Conservation is the key. President Carter recently said at a meeting with American labor representatives: "I don't look on conservation or saving energy as a burden or an unpleasant sacrifice. . . ."	NA
 Connally	The President's Commission confirmed what Governor Connally has long maintained: nuclear power, with improved operator training and management, is a safe source of energy.	Conservation is important in that the United States can no longer use energy inefficiently. However, a national energy policy should address increased energy production; the Carter administration's policy is one of sharing shortages.	The technology for all sources of energy should be developed, in the event that they are needed. However, until 2000, oil and gas, coal, and nuclear are what we'll have to live with; we should focus on fusion for the future.

 Crane	I sided with the majority in the House that voted against any moratorium on nuclear plant construction. The NRC should abide by this congressional policy and not heed the recommendations of any other body of lesser stature.	Nobody is against conservation. Conservation, however, will not replace energy production. Moreover, at today's prices, consumers already conserve as much as possible. The real question is how swiftly we can enhance our productive capacity. We cannot save our way out; we must produce our way out.	We should reduce the DOE budget for advanced technologies. This research should be done by private enterprise, which should have an unfettered right to the benefits of producing advanced technologies.
 Dole	Basically, my philosophy and policy in nuclear development agree with Kemeny. Although I have not had an opportunity to take a more thorough look into the content of the report, I agree that moratorium is not necessary and stricter guidelines in construction, training, and maintenance of the plants are mandated. However, the dissolving of the authority given to the NRC is still under question and I'm not certain that we must do away with the Commission, but rather could strengthen and restructure the goal and intent of the Commission.	Conservation is an important component in our energy picture for today and the future. We must conserve to achieve a meaningful degree of independence.	As possibility for significant contribution to the energy picture appears, funding should be gradually escalated for all alternative technologies.
 Kennedy	The Commission's principal conclusion that fundamental changes will be necessary in the organization, procedures and the attitudes of the Nuclear Regulatory Commission and the nuclear industry in order to prevent more Three Mile Island accidents confirms my conviction that new construction permits for nuclear plants should not be issued until these changes are made. *—news release, Oct. 30, 1979*	. . . Energy conservation holds out the promise of a better life for us all. It means achieving the same results by using less energy but using it more efficiently. I have introduced a practical program in Congress to reduce oil imports by real conservation of as much as 4 million barrels a day by 1990. . . . My program has the support of leaders in both parties. With vigorous presidential support, it could pass. The cost would only be $11 for each barrel of oil saved. *—undated fundraising letter*	NA
 LaRouche	The report does not adequately deal with the high probability of sabotage at Three Mile Island. By downplaying the sabotage question, the report attempts to cast unwarranted doubt on the safety and management of nuclear power, which is the safest and most economical form of energy. As for the security question, we should keep those individuals with antinuclear proclivities away from the industry.	The principal source of conservation of energy lies in the continuous introduction of the most advanced technology and industrial processes into the economy. West Germany and Japan can produce a ton of steel with almost 50% less energy than the U.S. uses because their steel industries are more advanced. This kind of energy savings is the only legitimate form of energy conservation.	We must increase the budget for advanced technologies. As long as we must burn fossil fuels, we should immediately develop MHD, because it is the most efficient method for such combustion. Hydrogen is the foremost portable energy source of the future and all methods of hydrogen production must be explored and brought to commercial feasibility as early as possible.
 Reagan	The recent accident at Three Mile Island nuclear power plant and the attendant sensational media treatment of the incident has confused the public and placed the whole industry under a cloud of doubt and suspicion, if not outright hostility. Unfortunately, much of the discussion that has taken place has not been related to the broader questions of our energy needs, our environmental concerns, and even national security considerations. . . . There is no question but that we all want the utmost in protective measures.	NA	NA

ENERGY SCORECARD

Question 10. What kind of energy growth rate do you see as desirable and feasible and with what combination of legislative and economic measures do you plan to achieve it? How do you see the energy question in relation to the U.S. and world economies?

Senator Howard H. Baker, Jr.

We need to recognize the probable link between diminishing American productivity and the spiraling costs of energy. Abundant energy brought about the industrial revolution and built America. It is essential that we bring to an end the implicit subsidies of some forms of energy to the detriment of others. That is one reason it is so important to allow the market to determine which technologies are cost effective. Government's role should not be to run the energy business, but rather to see that all businesses, whether they specialize in coal, oil, conservation, solar, or nuclear energy are permitted to compete on an equal footing. Viewed in this light, conservation technology, for example, is only one of several necessary contributors to energy growth, growth that will continue to be essential to the improvement of the quality of life not only in America, but throughout the world.

. . . The energy problem is the single greatest contributor to our current economic woes. I am afraid that is a message the administration has failed to get across. A number of experts estimate that as much as one-half of the current inflation results from the direct and indirect costs of imported oil. Meanwhile, our friends in Western Europe and Japan see American failure to deal with its energy problem as endangering their own economies, and as the key element in the continuing world oil supply crunch, with its inevitable price spiral . . . .

Governor Edmund G. Brown, Jr.

We must aim for an energy growth rate that is consistent with the economic health and well-being of the United States. An energy future that depends upon the expansion of costly nuclear power and imported oil is a recipe for bankruptcy. As I have previously indicated, we must aggressively pursue energy efficiency improvements to curb our growing energy appetite.

We have had the dubious distinction of being the world's principal energy importer and its least efficient energy consumer. As more and more nations develop economically, their own appetites for energy imports are increasing, and we are reaching a point where the energy pie is not large enough to accomodate everyone's needs . . . .

George Bush

Meeting the grand challenge we are faced with in resolving the energy crisis will permit the world to put behind it chronic energy shortages, expand and reinvigorate cooperation with friends and allies, and create a new era of rising opportunities and economic expansion. Meeting the energy challenge can rekindle the spirit of free men everywhere by demonstrating that even our gravest problems are solvable, and achieving this goal will be living testimonial to international cooperation. Only the United States can lead such a venture . . . .

In the coming decade we must also foster greater energy cooperation among the nations of the Western Hemisphere. The oil and gas of Venezuela offer tremendous hydrocarbon resources which can help to check the energy hegemony of the Middle East. We can offer access to the largest energy market in the world, together with needed infusions of capital and technological expertise . . . .

President James Carter

President Carter believes that the main thrust of our energy effort in the 1980-1990 decade is to conserve energy and become less dependent on foreign oil. With conservation and better use of existing energy supplies, energy use will continue to grow, but not as fast as it has in the past. Through the early 1970s, energy use and national output grew at about the same rate—to produce 1% more Gross National Product about 1% more energy would be required. Now, though, with the increased conservation it takes only about a .6% increase in energy use to support a 1% increase in GNP. We expect this trend toward more efficient use of energy to continue.

To assure energy supplies adequate to support growth of the GNP, the nation must reduce its dependence on imported oil. The president's goal is to reach a 50% reduction in oil imports by 1990 . . . .

. . . The president has pointed out that, because of our dangerous dependence on imported oil, American dollars are drained out of the economy and our balance of payments situation weakened. . . . The president has pointed out that the energy question is not strictly a United States problem. Other nations must import more oil than the United States and are very sensitive to oil price increases. Some are suffering under higher inflationary rates than this nation. It is a worldwide economic problem and the president is determined to do what he can to resolve it not only for this nation, but the international community as well.

John B. Connally

Governor Connally's view on energy growth is to "produce, produce, produce." The role of government is not to finance that growth, but to create an atmosphere in which growth can take place. That's where the Carter administration has failed.

The U.S. economy is far more vulnerable to the energy crisis—it's really an oil crisis—because it has subsidized oil consumption. To their credit, other nations never subscribed to the wisdom of this policy. For example, Japan, South Korea, and West Germany—nations which import practically all of their oil supplies—have maintained high GNP growth rates, high increases in productivity growth, and low rates of inflation throughout this decade of oil shortages.

Congressman Philip M. Crane

We often overlook that we must produce energy in order to conserve energy. We cannot conserve more than we produce. Therefore, if our economy is to continue to grow, if we are to create new jobs, if opportunities are to be available for the coming generations as they have been for ours, if the disadvantaged are to be given a chance to rise above their circumstances—in other words, if we intend to continue to consume, we must produce more. We have struggled for hundreds of years to reach a stage where we can lead a decent life. Now our government is asking us to lower our sights and reduce our expectations; in other words, to accept a recession or depression. This is senseless. What we ought to do is eliminate the government programs that restrict energy production. There should be no special subsidies for energy production, nor should there be any special hindrances either.

Senator Robert Dole

Energy growth must be financed at an equitable level. This can be typified through the Senate Finance Committee version of the Windfall Profits Bill. Encouraging energy growth by allowing the private individual to become involved, be it running his own alcohol still on-farm or allowing the small independent oil producer an exemption from a burdensome tax will allow for energy growth domestically. On exports, again the key is cooperation and understanding. The understanding that we do not want to dominate the market but work in conjunction—in complementary fashion—to find solutions to the energy problems of all nations no matter economy or population.

The energy question today affects our economy and, of course, then the world economy. With the price for energy growing day by day, our inflation grows and our balance of trade deficits expand even further into the future . . . .I believe that only a national energy policy which combines the components of increased oil and gas production, utilization of nuclear energy and expanded development, phased-in utilization of other alternative technologies by providing economic incentives and tax credits, and conservation will achieve the solution this nation is trying to find. We must at the same time let the other nations of this community know how we are combating the problem so that we may help in cooperation with them in meeting any energy problems they may have now or in the future . . . .

Senator Edward M. Kennedy

NA

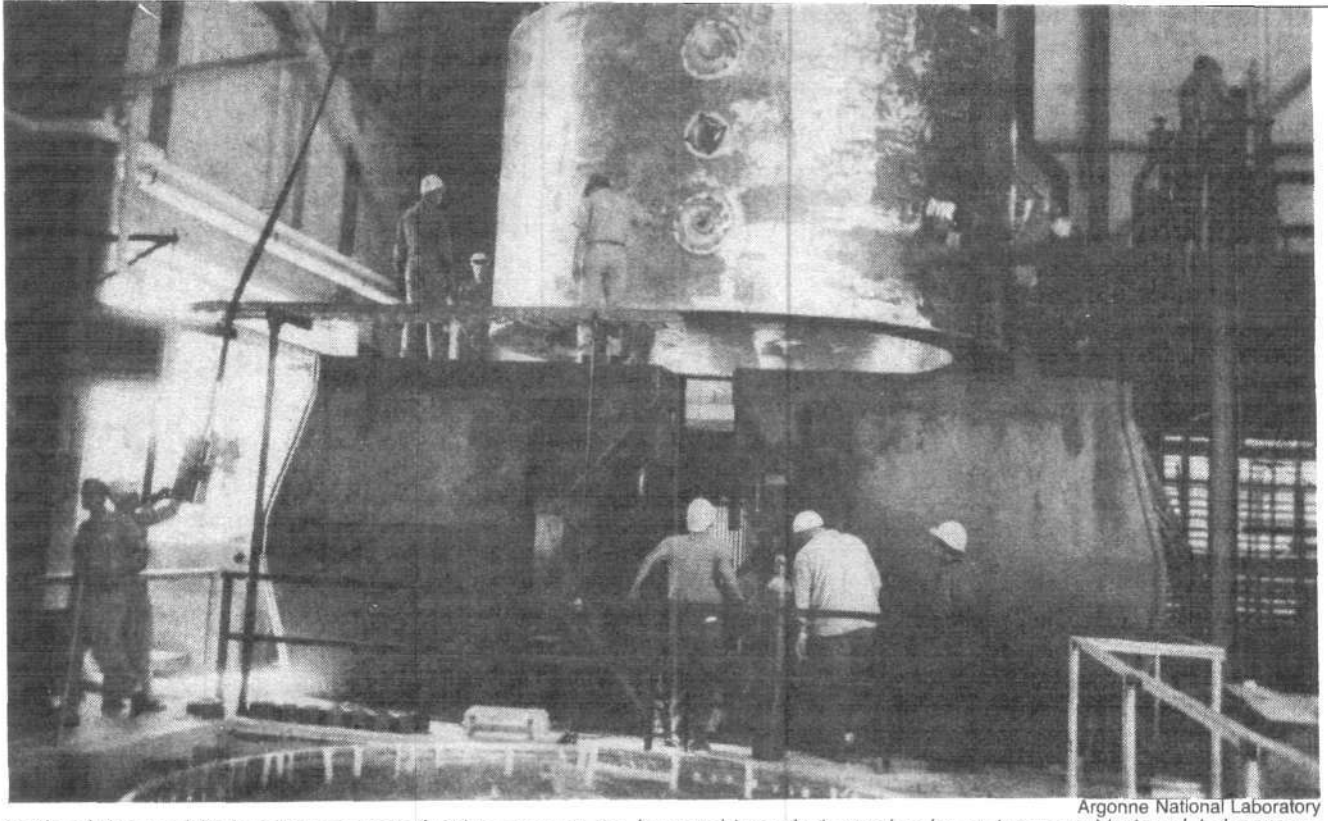
Lyndon H. LaRouche, Jr.

The energy growth rate in the United States is determined by the economic growth rate and by U.S. commitment to technology exports, which must be stepped up massively in fulfillment of a U.S. commitment to industrialize the Third World sector. Therefore, we must immediately return to the historical growth rate of energy production in the United States in the period of the 1960s and the early 1970s of 4% to 5% annually, and we must go beyond this as demanded by the requirements of our economy. LaRouche projects a total U.S. energy consumption of between 180 and 200 quads by the year 2000. Energy growth and exports should be financed through a combination of tax and credit incentives for the development of new energy resources and through broad increases in the total authorization for the U.S. Export-Import Bank.

Historically, as well as in a cross-section of current world economies, it is clear that energy consumption and standard of living go hand in hand.Only an industrialization program based on quadrupling world energy can prevent vast political and economic dislocation and destabilization in the Third World sector nations, with the ever-present danger of a nuclear confrontation and a world war.

Ronald Reagan

NA



Argonne National Laboratory

Coils of the world's largest superconducting magnet are lowered into their steel yoke at Argonne National Laboratory.

The Prospects of Higher Temperature Superconductivity

by Dr. William A. Little

A well-known specialist in superconductivity, Wiliam A. Little has been a professor of physics at Stanford University since 1958. His other specialties include phase transitions, cryogenics, and the theory of neural networks.

* * *

SUPERCONDUCTIVITY is a remarkable state of matter observed in a large number of metals when they are cooled to temperatures approaching absolute zero.*

The electrical resistance of such a metal as the temperature is lowered below room temperature steadily falls. This continues until the temperature reaches the region round about 20°K to 30°K, where the resistance flattens out and becomes almost independent of temperature with a magnitude determined by the material's impurity content and crystalline perfection (see Figure 1).

As the temperature is lowered through the last few degrees toward absolute zero, suddenly within a narrow temperature region near the so-called critical temperature, T_c, of the metal, the electrical resistance completely disappears. This is the superconducting state, where the metal exhibits a number of remarkable properties. For example, if a closed ring of such a superconductor is cooled in a magnetic field and then the field is turned off, a current will be induced in the ring that continues to circulate for as long as the ring is kept below T_c. Such currents have been observed to persist for more than two years without any sign of dissipation. This dissipation-free current transport has many exciting applications and potential applications in technology, some of which I discuss here.

Another peculiar property of certain types of superconductors is that of nearly perfect *diamagnetism*—repulsion of magnets. Magnetic fields cannot penetrate into the interior of these superconductors; consequently, in certain magnetic-field configurations the superconducting object will float in the field. This levitated state likewise persists as long as the metal is kept below the superconducting transition temperature.

Much interest has focused on superconductors because

*Terms followed by an asterisk are described in the accompanying glossary.

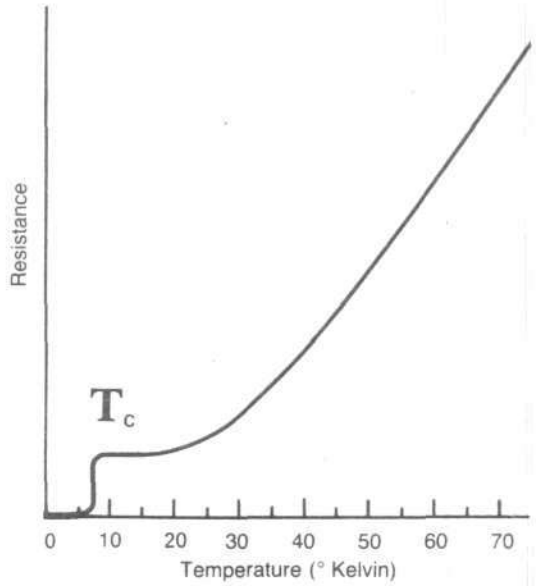


Figure 1
RESISTANCE VERSUS TEMPERATURE OF A METAL THAT BECOMES SUPERCONDUCTING AT 7°K
Plot of the resistance of a typical metal as a function of temperature showing the transition to the superconducting state at the critical temperature, T_c, of 7° Kelvin.

of these unusual properties. For example, the absence of electrical resistance means that currents can be passed through superconducting wires without dissipation of energy or the generation of Joule heat.* This has potentially great economic significance for the utilities industry in terms of power transmission. At present, conventional conductors such as copper and aluminum are used to transport electrical power from generating plants to the cities and to distribute this power within cities and some 5 percent of this power is lost in Joule heating of the conductors. Because there is a vast amount of power delivered in this way, these losses represent an enormous waste of energy—much of which would be saved by using superconducting cables.

Technological Applications

Other important applications are the use of superconductors for the magnetic confinement of plasma in future thermonuclear fusion reactors. The very large fields that such magnets can produce and the complete absence of dissipation of the currents in these magnets are the only economically feasible means for maintaining the high fields in the large volumes needed for fusion reactors. Already very large superconducting solenoids, many meters in diameter, have been developed and are being used in high-energy physics laboratories and for studies of material properties. Such superconducting solenoids have produced field strengths in excess of 150 kilogauss. Even larger magnets, 50 meters or more in size, are being stud-

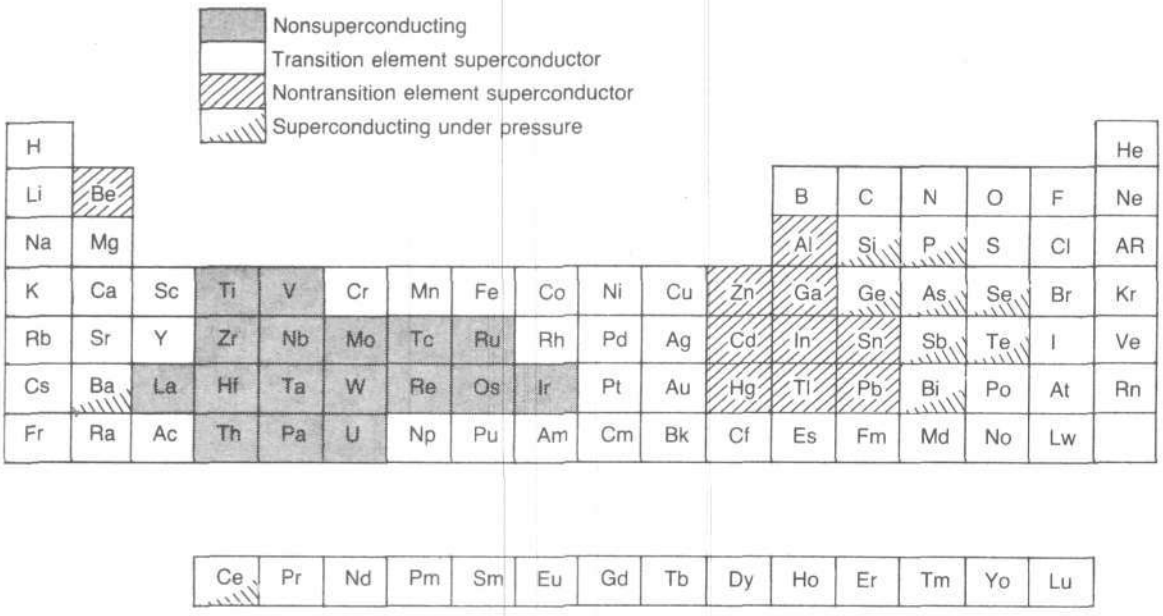


Figure 2
PERIODIC TABLE SHOWING THE OCCURRENCE OF SUPERCONDUCTIVITY AMONG THE ELEMENTS
Twenty-six elements become superconducting at ambient pressure and another 10 at higher pressure.

ied as a means for off-peak storage of electrical energy.

There are a number of other areas where superconducting magnets can be applied. After the British Ministry of Defense successfully developed a 50-horsepower superconducting direct current motor in the late 1960s, interest in the United States and Britain turned to the use of superconducting motors and generators for ship propulsion. The advantages such devices offer to ship propulsion lie in the flexibility they give in the ship's design, in particular to the location of the prime mover, plus a significant saving in available ship space, simplicity of electrical control, and the elimination of reduction gears.

A strikingly compact 1,000-horsepower superconducting motor has been demonstrated here, and 40,000 to 75,000-horsepower motors are expected to be available by 1985 for U.S. Navy use.

Superconducting generators and alternators for land-based use by the utilities companies are also attracting interest because they promise substantial advantages over conventional systems in the larger capacities. Development of a 10 megavolt-ampere generator is underway at the Massachusetts Institute of Technology as the prototype of a future 2,000 megavolt-ampere machine.

Superconductivity is also being studied for applications in high-speed transportation. The Japanese national railways are developing a high-speed ground transportation system linking Tokyo and Osaka that would use on-board superconducting magnets for levitation of the train and an active-track, linear synchronous motor coupled to the magnets to provide propulsion. The train is designed to run at a top speed of 500 kilometers per hour, floating on a magnetic cushion. Preliminary trials at 300 kilometers per hour have been successful and promise the opening of a new era in ground transportation in the late 1980s.

These are just some of the many large-scale technological applications foreseeable for superconductors in the coming decade. There are many more small-scale applications that involve the more subtle properties of superconductors.

As I shall show, superconductors exhibit certain quantum phenomena in which interference effects can be seen in the quantum mechanical wave properties of the electrons. These properties are affected by minute magnetic fields, currents, and voltages. The discovery of these effects has led to the development of a new generation of supersensitive magnetometers, comparators, precision attenuators, voltage standards, and other devices. In fact, the present U.S. primary standard for the volt is based on the so-called Josephson effect* in superconductors.

Another recent entry of superconductivity to technology is the development of such Josephson devices as logic elements for super-high-speed computers. The key property of these devices is that they dissipate much less power than do semiconductive devices, allowing the superconducting devices to be packed more densely and switched at much higher speeds. Delays per gate of 58 picoseconds have been demonstrated, and a machine with a cycle time of 5 nanoseconds is in the design stage. This is several orders of magnitude faster than any machine using

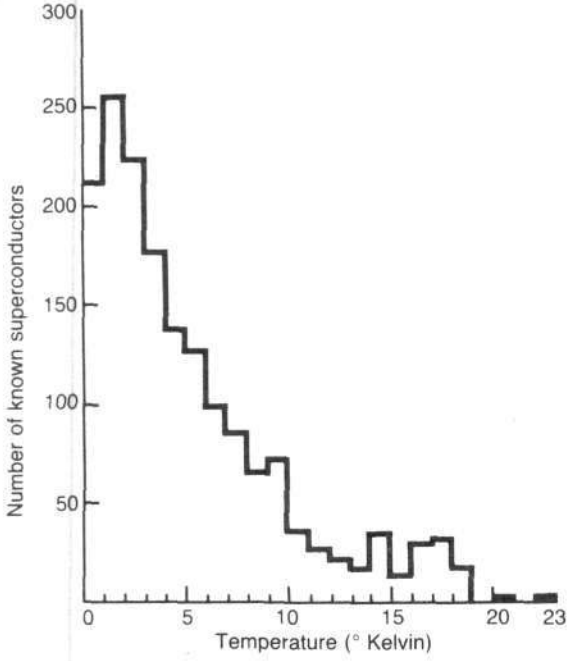


Figure 3
HISTOGRAM SHOWING THE NUMBER OF KNOWN SUPERCONDUCTORS AS A FUNCTION OF THEIR TRANSITION TEMPERATURES
Although the number of superconducting alloys has increased 10-fold in the last 20 years, most of them have a transition temperature below about 5° or 6° K.

conventional logic elements and would bring about a spectacular increase in computational speed. This can be expected to have a major impact on the study and computer modeling of transport phenomena in plasmas, the study of turbulence, and weather forecasting, all of which require very large computing power.

Since the benefits of the development of these new devices and novel technologies seem obvious, one may ask why the use of superconductivity is not more widespread? The answer is simply that the very low temperatures needed for the operation of the superconducting devices is still a significant barrier to their more general use. The devices, magnets or superconducting motors, must be housed in well-insulated dewar vessels and must be cooled with liquid helium, liquid hydrogen, or by some form of sophisticated closed-cycle refrigerator. The cost and complexity of providing such refrigeration is significant.

If one could discover a superconductor with a much higher transition temperature than those known today it would have a spectacular impact upon the technology. First, it would simplify and reduce the cost of the refrigeration system. Second, it would reduce the size and weight of virtually all the larger devices. In general, a superconductor with a higher T_c is able to carry larger currents than one of lower T_c, so magnets with fewer turns and less

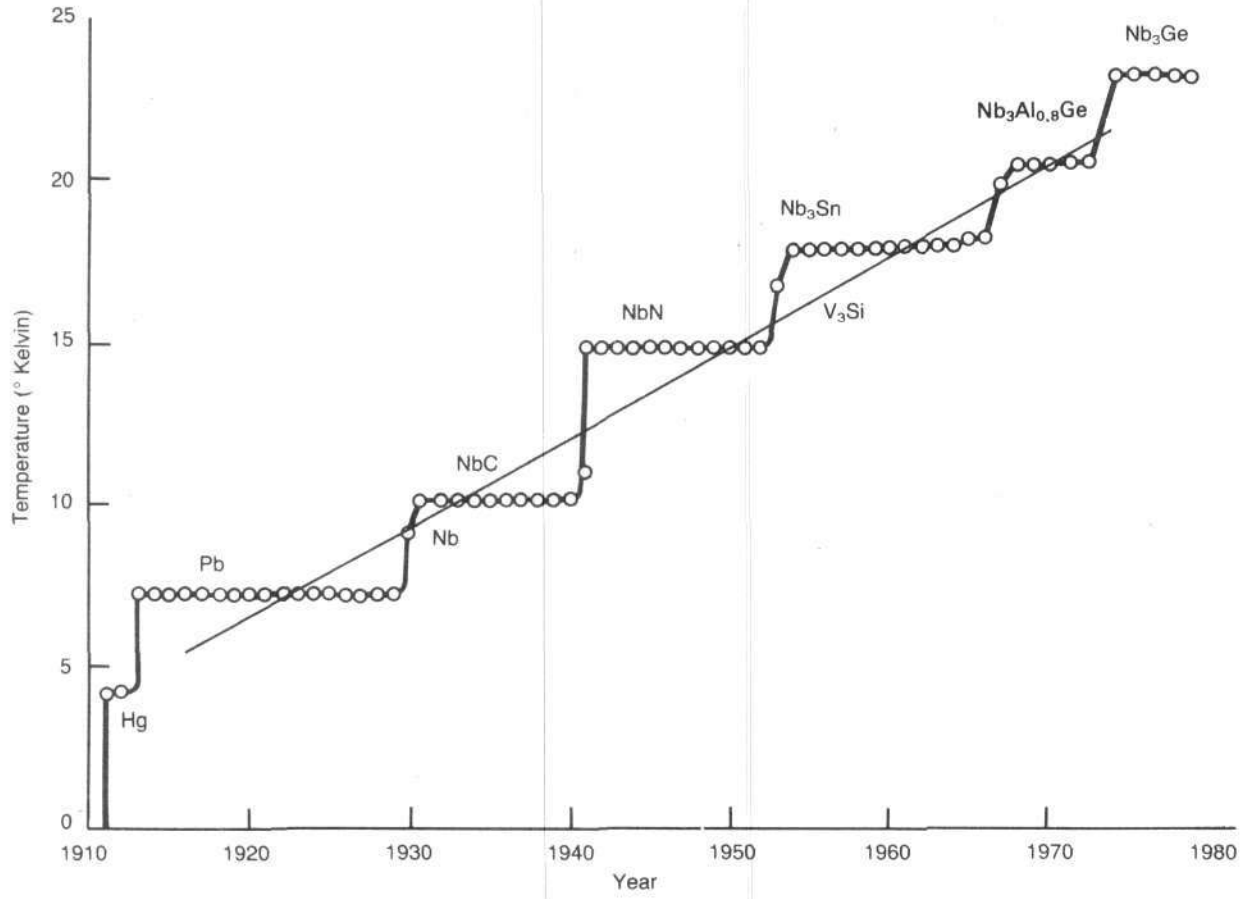


Figure 4
HIGHEST-KNOWN SUPERCONDUCTING TRANSITION TEMPERATURE AS A FUNCTION OF THE YEAR IT BECAME KNOWN

Since 1911, there has been steady progress in finding superconductors with higher transition temperatures. In 1973, niobium germanium was found to have a transition temperature of 23.2° K.

material could provide the same field strengths.

These facts have been known and appreciated for many years and have provided the stimulus for the search for high transition temperature superconducting compounds. I'll review the history of this development to show what prospects there are for any marked increase in T_c.

The Search for High Temperature Superconductors

You can see by examining the periodic table (Figure 2) that a very large number of elements become superconducting. Twenty-six become superconducting at ambient pressure and at least another 10 at higher pressures. Many of these elements and nonsuperconducting elements can be combined with one another to form a vast number of alloys and compounds. Several thousand of these are known to superconduct.

In Figure 3 the number of known superconductors is plotted as a function of the temperature at which they become superconducting. The general form of this histogram has changed little over the past 20 years, although the number of superconducting alloys and compounds that have been characterized has increased 10-fold during this period. As you can see, most of the superconductors have transition temperatures below about 5° or 6°K, and the highest known superconducting transition temperature, which occurs in a specially prepared alloy of Nb_3Ge (niobium germanium), is 23.2°K.

In considering the progress made in the search for higher temperature superconductors, it is interesting to plot the highest known transition temperature as a function of the year in which it was known (see Figure 4). Remarkably steady progress has been made in this figure over the past 60 years; however, this cannot be expected to go on forever. An enormous number of alloy systems have been studied already, although these studies have largely been confined to binary and pseudobinary alloys* and, of course, there are many other ternary and quaternary alloys yet to be prepared and characterized. Nevertheless, there must be some underlying physical reason that the transition temperatures are grouped in this temperature range and

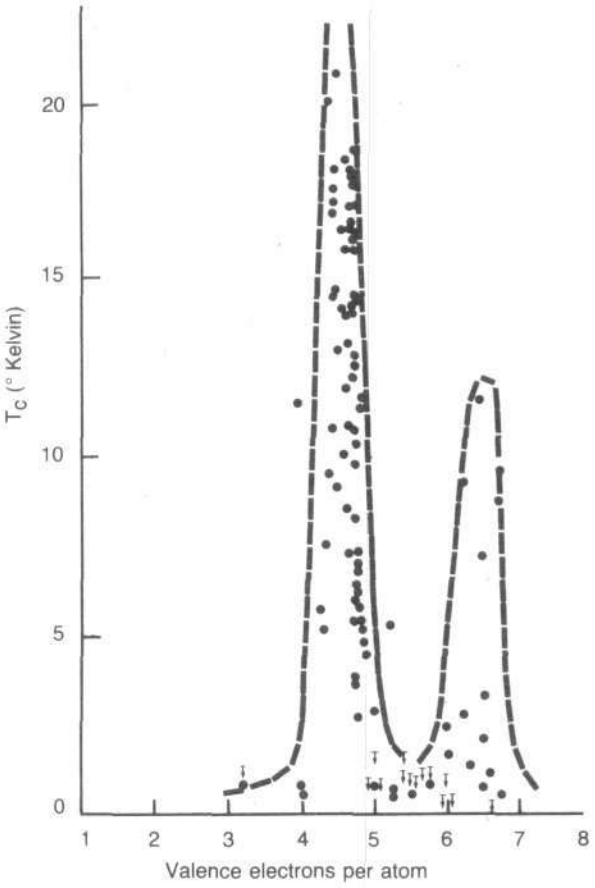


Figure 5
TRANSITION TEMPERATURE OF ALLOYS WITH THE A15 CRYSTAL STRUCTURE AS A FUNCTION OF THE NUMBER OF VALENCE ELECTRONS PER ATOM
Source: B.W. Roberts, NBS publication No. 482, p. IV-3 (1969).

reasons that put a natural limit on the attainability of higher superconducting transition temperatures.

As I will try to explain, there are, in fact, theoretical arguments that show there is a general limitation on T_c. But this does not put a precise numerical limitation on T_c because scientists are still not able to predict the properties of the normal, nonsuperconducting state of new alloys and compounds or to come close to predicting the stability of their various phases. These properties and the stability criteria depend upon small differences in the free energy of the different phases; and these subtleties are, with a few simple exceptions, beyond current powers of computation or analysis.

On the other hand, if these properties were known then the theory of superconductivity would be good enough to calculate T_c with reasonable precision. So inadequacy in predicting new superconductors is not so much a failure of the theory of superconductivity but more the still relatively primitive state of the theory of material science and of the theory of the solid state.

A number of empirical rules have been developed from a study of the transition temperature, crystal structure, number of valence electrons per atom, and electron configuration of the large number of known superconductors (see Figure 5). This has allowed predictions to be made of the composition of new higher-temperature superconductors. B. Matthias, T. H. Geballe, and their coworkers and some other groups in the United States and the Soviet Union have been most successful in this endeavor, and through this type of empirical extrapolation new superconductors have been discovered. Since this is more of an art form than a scientific theory, many others who have attempted to follow the empirical rules have been far less successful in finding new superconductors. We can expect that this metallurgical aspect of the search for higher temperature superconductors will be dominated by empiricists rather than theorists for many years to come.

Nevertheless, it is useful to take a look at the theory of superconductivity in order to understand the general features that limit T_c. By so doing we can get a general feel for the metallurgical problems of discovering new superconductors and of improving the properties of the known ones. We also can obtain a glimpse of a very different research endeavor that, if successful, would take the field in one quantum jump to superconductivity at or near room temperature.

The Theory of Superconductivity

The present theoretical understanding of superconductivity is based on a theory developed by John Bardeen, Robert Schrieffer, and Leon Cooper and published in 1957. This and its various embellishments are known as the *BCS theory*. BCS has been enormously successful in explaining a vast array of experimental data and predicting many new and novel effects in superconductivity. The basic assumptions of the theory are that the electrons in a superconducting metal are bound together as pairs and that these pairs "condense" into a single quantum mechanical state. In contrast to this, note that in the normal state the electrons are not bound in this way but instead move freely and virtually independently of one another. These basic assumptions lead to certain unique properties of a superconductor.

We have learned from the discovery of quantum mechanics in the mid-1920s that there is a wavelike property associated with any particle such as an atom or electron, the so-called de Broglie wave.* In a superconductor where a large fraction of the conduction electrons are paired and these many pairs are in the same state, the de Broglie wave associated with this state is of large amplitude. Consequently, it can give rise to quantum phenomena on a macroscopic scale.

In fact, there is a close analogy between the condensate of paired electrons in a superconductor and the photons in a laser beam. The de Broglie wave and the laser beams are both "monochromatic" and strongly coherent. This makes it possible to observe interference effects in a superconductor when a current through it can reach a point by two or more different paths. Moreover, the variation of

the phase of the de Broglie wave round these paths depends upon any magnetic field that may be present, because unlike photons, the pairs carry a net electrical charge. This causes subtle changes to occur in the interference effects as a function of the applied magnetic field. This property makes it possible to observe exceedingly small magnetic fields and has resulted in the development of the supersensitive devices mentioned earlier.

When two superconductors are separated by a very thin insulating barrier, a nondissipative supercurrent can pass between the two superconductors. This is another example of the wave or quantum property of the superconducting state. In this case, the pairs tunnel through the insulating barrier and interfere constructively with the pairs on the other side. The Josephson effect is associated with this tunneling and with the associated interference effects of magnetic fields upon these tunneling junctions.

The puzzle in understanding the pairing assumption of the BCS theory is why the electrons are attracted to one another and form bound pairs when we know that they carry the same electrical charge and hence should repel one another. The explanation is that the electrons are not moving in a vacuum but rather in the interior of the metal. The metal is built of a more or less regular crystalline array of atoms or, more precisely, of positive ions that result from each atom giving up one or more electrons into the "Fermi sea"* of electrons between the ions. It is the flow of electrons in this sea that constitutes the normal electrical current.

The array of ions or "lattice" is not infinitely rigid but can be deformed, and this deformation is described by sound waves or phonons. As an electron moves through this array of positive ions, the ions are attracted to the negatively charged electron. This results in a slight displacement of the ions and thus a compression of the lattice in the vicinity of the electron. However, the electron moves much more rapidly than the heavier ions, so the most densely compressed portion of the lattice trails some distance behind the rapidly moving electron (see Figure 6). This compressed region has a slight excess of positive ions and hence of positive charge, with the result that it can attract another electron. Thus, as a result of the compression of the lattice, two electrons are attracted to one another. It is not a simple attractive force like the Coulomb force* because the second electron is not attracted to the instantaneous position of the first electron but to the point where the electron was a short time earlier. This so-called phonon-mediated electron-electron interaction is said to be retarded in time, and the retardation makes it possible for this interaction to overcome the stronger but instantaneous electrostatic repulsion.

This is an oversimplified classical description of an essentially quantum mechanical phenomenon; however, it contains the essence of the full explanation. The second assumption of the BCS theory, that the pairs must be in the same state, can be understood from the wave properties of the pairs. If the de Broglie waves of all the pairs are in phase with one another, then they can interfere constructively with one another and all the pairs can benefit from the lattice-induced attractive interaction. However, if they are in different states and hence have different de Broglie wavelengths, then constructive interference can occur in some parts of the metal, but in other parts it will be destructive, thus largely canceling the benefits of the interaction. The energetic advantage of being in the same state and same phase relationship is the driving force for the formation of the pair condensate.

This simple argument provides an explanation of the sharp transition from the superconducting to the normal

Glossary

Absolute zero: a temperature of –459.69° Fahrenheit or –273.16° Celsius or 0° on the Kelvin scale that is thought to be the temperature at which molecular motion vanishes and a body would have no heat energy.

Binary alloy: an alloy composed of two principal metallic components.

Coulomb force: the force said to represent the interaction between two pointlike electrically charged objects at rest. It varies inversely as the square of the distance between the centers of the objects and directly as the product of the amount of charge on each object.

de Broglie wave: the quantum-mechanical wave associated with a particle of matter.

Debye frequency: the maximum lattice vibrational frequency used in calculating specific heats of solids according to the method developed by Peter Debye. This method assumes that the heat content in the solid appears entirely as lattice vibrations.

Doped polymer: *a polymer that has had an impurity deliberately added to it to alter its properties.*

Fermi sea: an ensemble of unbound electrons—such as that in the interstices of a metal—that obeys Fermi-Dirac quantum statistics.

Josephson effect: the tunneling of electron pairs through a thin insulating barrier between two superconducting materials.

Joule heat: heat developed because of resistance when a current passes through a nonsuperconducting material.

Planck's constant: the elementary quantum of action, one of the fundamental physical constants whose value is about 6.626×10^{34} joule second.

Spring constant: a measure of the restoring force of a particular spring; consequently, also a measure of the frequency at which the spring will oscillate.

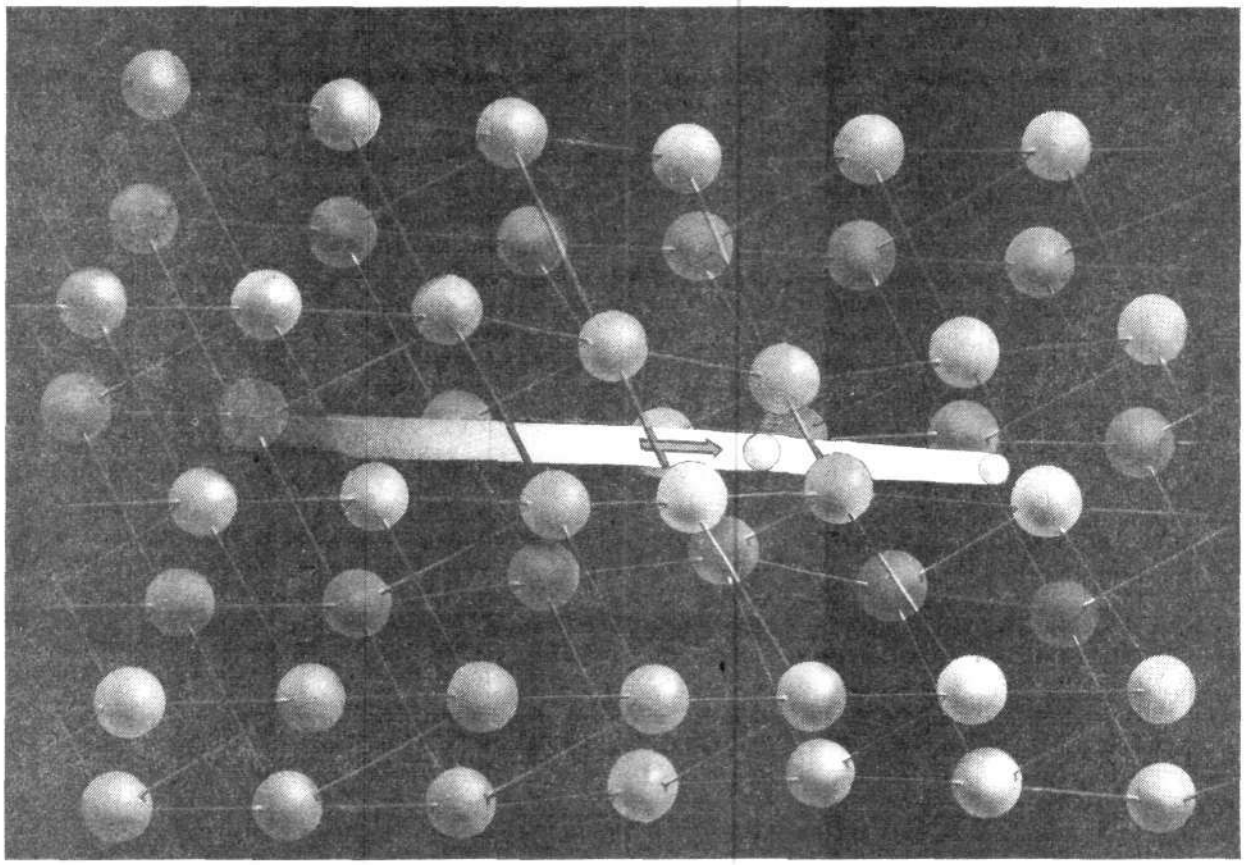


Figure 6
PHONON-MEDIATED ELECTRON-ELECTRON INTERACTION
Movement of an electron through the lattice of positive ions causes the ions to move in toward the electron. This causes a local compression of the lattice and the resultant increased local density of positive ions can attract another electron. This phonon-mediated electron-electron attraction is responsible for the pairing of electrons and superconductivity.

state at T_c. At very low temperatures virtually all the pairs condense into the same state. If the temperature is raised, the thermal agitation of the lattice causes some of the pairs to be broken apart, and this slightly reduces the number of pairs in the condensate. The presence of the unpaired electrons now interferes destructively with the remaining pairs, thereby weakening the net attraction between the pairs. With a further increase in temperature, this effect becomes catastrophic and no pairs can remain bound above a certain critical temperature, T_c, that marks the transition to the normal state.

Let's look at a social analogy to this process. Imagine a society in which marriage is well thought of and where the laws of society are such that divorce is difficult. Most marriageable couples will be paired off. But what happens if the divorce laws are relaxed somewhat? The few intrinsically unstable marriages will break up under these circumstances, thereby reducing the number of bound couples. However, this has an additional insidious effect upon the remaining couples: now moving in the same social environment as the married couples are a number of freely moving unattached divorcees. The presence of these divorcees tends to distract certain of the partners among the married couples and so weaken the attractive interaction between them, ultimately leading to the break-up of these marriages.

With further liberalization of the social mores, this process becomes catastrophic and a new society evolves where no marriage can hope to survive. This last stage represents the analogy of the transition to the normal state of a metal!

The Electron-Lattice Interaction

Understanding the problem of achieving a higher temperature superconductor means understanding the factors that determine the attractive interaction between the electrons and stablizing the "social" environment of the resulting electron pairs. In this regard it is instructive to consider how T_c varies with the stiffness or rigidity of the lattice. The BCS theory shows that in the simplest approximation, T_c is given by the expression :

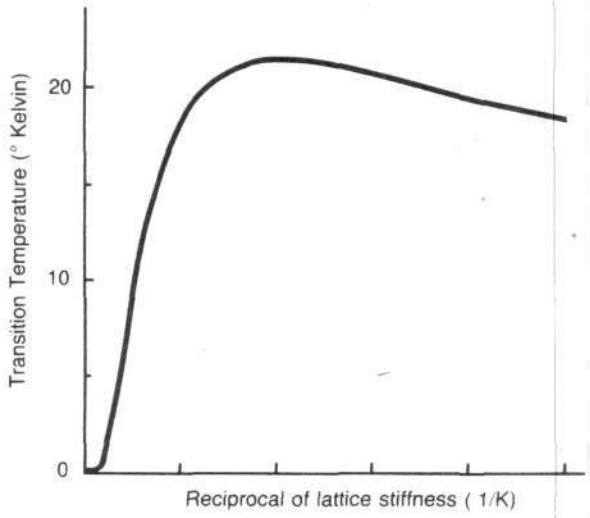


Figure 7
THEORETICAL PLOT OF SUPERCONDUCTING TRANSITION TEMPERATURE AS A FUNCTION OF LATTICE STIFFNESS
In this model the lattice is represented by an array of ions each of mass M attached to the lattice sites by springs of spring constant K. Plotted is the critical temperature, T_c, versus 1/K. With further reduction of the stiffness K, T_c begins to flatten out.*

(1) $$T_c = \frac{\hbar\omega_D}{k_B} \exp\left\{-\frac{1}{\lambda}\right\} .$$

Here ω_D is the Debye frequency* of the lattice, $\hbar$ is Planck's constant* divided by 2π, and k_B is Boltzmann's constant.* The parameter λ is a measure of the strength of the net electron-electron attractive interaction. To a first approximation the ions can be considered to be attached to their positions in the lattice by a spring with a spring constant* *K*, where *K* is a measure of the stiffness of the lattice. If the mass of the ion is *M*, then simple mechanics tells us that

(2) $$\omega_D = \sqrt{\frac{K}{M}} .$$

Suppose now we consider an alloy with a very stiff lattice. An electron moving in such a lattice will not be able to displace the ions significantly. Consequently, from the model sketched earlier, the electron-electron attraction described by λ will be small; and because λ occurs in the exponential term in (1), it will cause T_c to be extremely small. As the lattice is made less rigid, greater compression can occur and λ increases, leading to a rapid increase of T_c. However, with further reduction of the stiffness *K*, T_c will begin to flatten out (as illustrated in Figure 7). This occurs because the preexponential factor $\hbar\omega_D$, which depends on *K* through (2),becomes smaller. Because of the competition between the term in the exponential and the preexponential term, T_c rises to a maximum and then falls. This is part of the reason for the limitation of T_c.

There is another factor that plays a critical role in many superconductors. As the strength of the factor *K* is reduced, the electron-lattice interaction itself begins to contribute to the effective stiffness of the lattice. This a second-order effect, but one that tends to make the lattice unstable. When this factor is taken into account, the expression for ω_D changes from (2) to

(3) $$\omega_D = \sqrt{\frac{K(1-2\lambda)}{M}} .$$

Now as the electron-electron interaction becomes larger with decreasing *K*, a further softening of the lattice occurs through the factor $(1-2\lambda)$, which shows up as a reduction of ω_D. This continues until λ exceeds 0.5, at which point ω_D becomes imaginary. This is an indication of a lattice instability and results in a change of symmetry of the crystal structure. The new structure invariably has a weaker electron-electron interaction and consequently a lower T_c.

This type of instablity is found in many of the higher temperature superconductors such as Nb_3Sn (niobium tin), Nb_3Ge (niobium germanium), V_3Si (vanadium silicon), and so forth, and appears to be the most important factor preting T_c from going higher in these alloy systems. Various methods of preparation, annealing, and heat treatment have allowed researchers to inhibit to some extent the lattice instability, and most of the progress in raising T_c in recent years has come about from a study of these factors.

Estimates have been made of the maximum value that T_c could reach in several classes of alloys if the instabilities did not occur at all. These estimates lie in the range of 20° to 40°K, which is on the order of the maximum T_c achieved to date. Perhaps if researchers could get a better understanding of the stability of the phases of each of the specific alloys, then they could achieve further progress in raising T_c from its present maximum value of 23.2°K closer to 25°K. Most researchers in the field believe that it is unlikely that superconducting alloys with T_c much above this value will ever be prepared.

The one possibility remaining for achieving superconductivity at substantially higher temperatures is based on a *different type of attractive mechanism. It can be shown for* the phonon mechanism of the BCS theory that if the Coulomb replusion between the electron is ignored, then the coupling constant λ that appears in Equation (1) is independent of the mass of the ions. The preexponential factor ω_D then causes T_c to depend upon the ionic mass *M* through (2) such that $T_c \propto M^{-1/2}$. This is known as the *isotope effect*, since T_c depends upon the isotopic mass of the ions.

The discovery of this effect in the 1950s confirmed the role played by phonons in the superconducting state. The presence of the Coulomb repulsion modifies the mass dependence of T_c slightly by adding a usually small, mass-

dependent correction to λ. In principle, superconductivity at higher temperatures might be achieved if researchers could obtain an attractive interaction that involved the deformation of an electronic subsystem rather than the ionic lattice. Then the relevant mass would be the electronic mass not the ionic mass, ω_D would be replaced by a much larger electronic excitation frequency, and T_c would be increased proportionally.

The Exciton Mechanism

Fifteen years ago I suggested that this might occur in a polymer consisting of a conductive spine or chain to which would be attached a series of highly polarizable side-chain molecules. As an electron moves along the spine, it would induce a polarization of the side chains. A second electron would be attracted to the excess of positive charge of this local region in much the same way as in the phonon case discussed earlier. This has become known as the *exciton mechanism* of superconductivity. The difference between this and the phonon mechanism is that the side chain excitations have much higher frequencies than the phonons because they involve the movement of electrons rather than the heavy ions. A simple-minded extrapolation of the isotope effect then leads to transition temperatures for such hypothetical superconductors on the order of

$$\left(\frac{M_{ion}}{m_e} \right)^{1/2}$$

times that for an ordinary phonon superconductor. This factor is huge, and superconducting transition temperatures on the order of 1,000°K are predicted.

Life is not so simple, though, for such a mechanism raises a host of fundamental problems. The suggestion of the metallic state—let alone the superconducting state at high temperatures—occurring in a linear organic polymer raised some eyebrows in the scientific community. The enormous extrapolation inherent in going from the phonon to the exciton mechanism left many theorists uncomfortable, and the chemical problems posed by the synthesis of such a complex macromolecule were staggering. Since then, much progress has been made in understanding and addressing these problems. The past decade has seen a considerable clarification of the theoretical situation and substantial progress in developing ways of synthesizing some such polymers.

A careful examination of all the subtleties of the theory has shown that the basic ideas for such high-temperature superconductivity discussed above are valid, but that the conditions for achieving it put extraordinary strong constraints on the molecular structure of the polymer. It is fair to say that these constraints eventually may show that it might be impossible to synthesize such materials. On the other hand, it is close enough to what researchers can synthesize today that the possibility of obtaining high temperature superconductivity in this way cannot be dismissed at this time.

The challenge of this proposal has stimulated research on the metallic state in organic compounds, polymers, and other exotic systems of complex molecular structure. Some very exciting results have been obtained to date. For example, superconductivity of the conventional kind has been found in the polymer polysulphurnitride $(SN)_x$ at low temperatures. This is the first known polymeric superconductor and marks an important milestone in the long road toward a higher temperature superconductor.

In addition, metallic conductivity has been found or induced in a large number of organic charge transfer salts (of which the best known example is tetrathiofulvalene-tetracyanoquinodimethane, [TTF-TCNQ]) and in certain doped polymers,* notably the polyacetylenes. Also, researchers have devised a powerful new method for synthesizing fully conjugated polymers closely similar to the type of polymer proposed earlier as an organic superconductor. This has yielded a number of interesting new materials unrelated to superconductivity but of considerable scientific and technical interest in their own right.

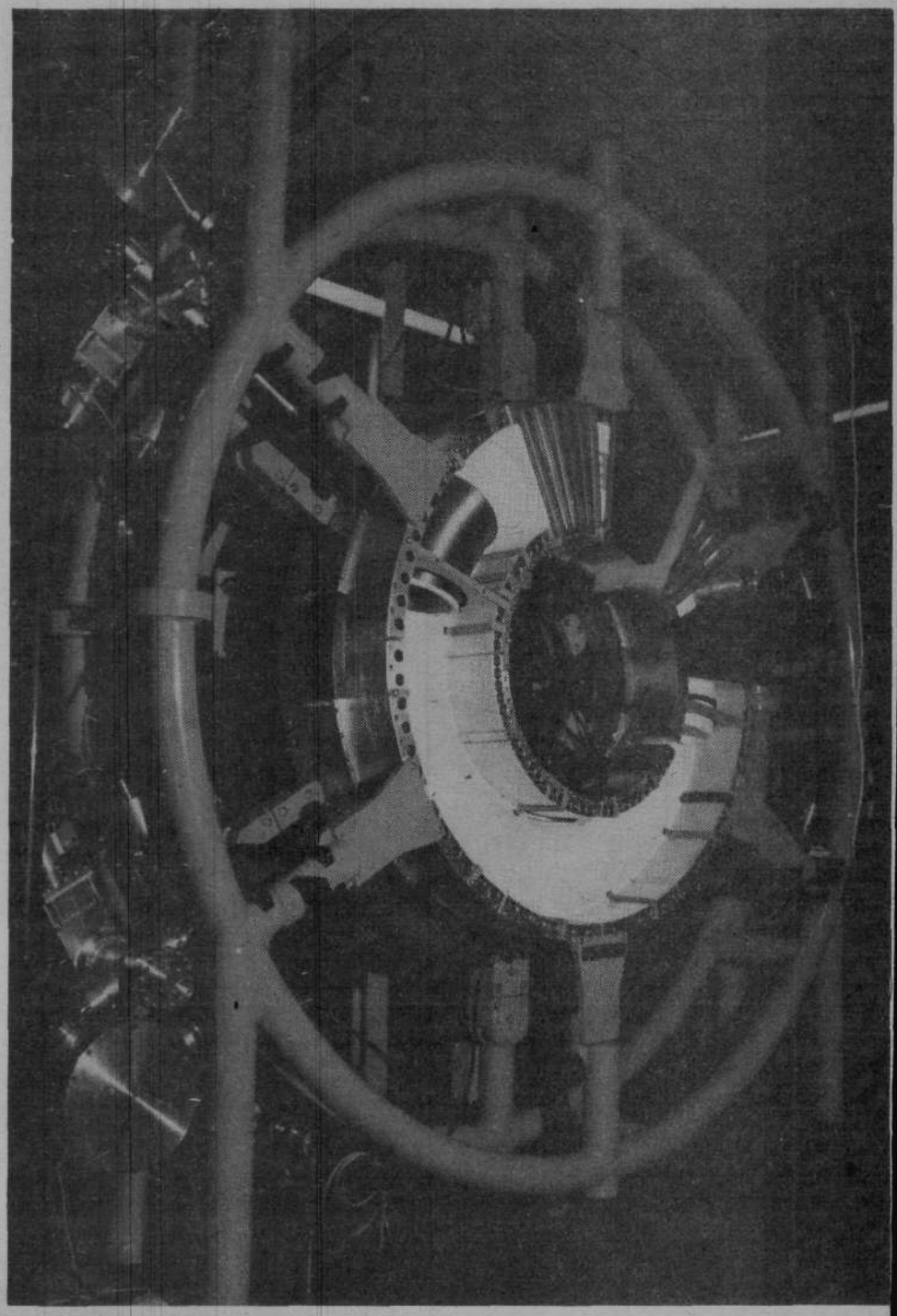
With these spectacular advances, the task of preparing a polymer that could test the original model appears somewhat less formidable now than it did a decade ago. If this should prove successful and researchers obtained superconductivity even at temperatures near 77°K, the boiling point of liquid nitrogen, it would open up an enormous new area of science and technology that could lead to developments more reminiscent of science fiction than of science.

To get there, though, is going to require major advances in understanding the stability of the solid state and synthetic chemistry and in the design and synthesis of structures on the molecular level. The possibility of finding substantially higher temperature superconductors certainly remains, but we should not hold our breath waiting for that great day to come!

Recommended Reading

1. Tinkham, M. 1975. *Introduction to Superconductivity*. New York: McGraw-Hill Book Co. A useful introduction to the theory and phenomenology of superconductivity, including a treatment of the Josephson effect and tunneling.
2. Foner, S. and Schwartz, B.B. 1973. *Superconducting Machines and Devices*. New York: Plenum Press, (NATO ASI Series BI Physics). This contains details of many of the large-scale applications of superconductors.
3. Deaver, B.S., Jr., Falco, C.M., Harris, J.H., and Wolf, S.A. 1978. "Future Trends in Superconductive Electronics." In AIP *Conference Proceedings*, 44. New York: American Institute of Physics. A compilation of research papers on recent work on Jospehson junctions and other superconducting electronic devices.
4. Roberts, B.W. 1969. NBS Technical Note 482; 1978. NBS Technical Note 983. A comprehensive listing of all known superconductors and an update on recent progress in the materials aspect of superconductivity.
5. Matthias, B.T. 1970. "Superconductivity and the Periodic System." *American Scientist* 58: 80-83 (Jan.-Feb.) A brief personal description of the occurrence of superconductivity and the various empirical factors that influence T_c.
6. Gutfreund, H. and Little, W.A. 1979. "The Prospects of Excitonic Superconductivity." in *Highly Conducting One Dimensional Solids*. Ed. J.T. Devreese, R.P. Evrard, and V.E. van Doren. New York: Plenum Publishing Conf., pp. 305-372. A careful review of the factors that limit T_c in conventional superconductors and a detailed description of the prospects and theoretical criteria necessary for achieving very high temperature superconductivity by the exciton mechanism.

The Zeta Moves into



The Eta Beta II zeta pinch fusion device at the University of Padua, Italy has demonstrated that the zeta system is a viable approach to fusion and that the zeta may be the most advanced approach to fusion.

First Place in Fusion

by Charles B. Stevens

FROM THE RESULTS OF scores of fusion experiments over the last several years, it is now clear that virtually every approach to fusion that was developed in the 1950s works.

In fact, the only impediment to the rapid development of fusion energy has been the denial of the minimal resources needed to experimentally demonstrate any fusion system. For example, the reason that the Soviet tokamak fusion device was the first to succeed is that the Soviet Union devoted sufficient resources to build significant experiments. The United States and the Europeans launched small-scale fusion efforts after the Soviets unilaterally declassified their fusion program in 1956, but the programs foundered for lack of funds and did not revive until 1968, when a team of British scientists confirmed the success of the Soviet tokamak results.

The essential point is that significant progress in basic and applied scientific research requires the investment of sufficient resources, and, more important, it requires the freedom to fail. Of course, a policy to foster scientific breakthroughs is completely incompatible with the current "zero-based budgeting" and the systems management method popularized by former Defense Department head Robert McNamara.

The Case of the Z-Pinch

The case of the toroidal zeta pinch approach to magnetic confinement fusion energy proves this point. It also raises the interesting question of why an obviously promising approach to fusion in the early 1960s was declared a failure and was buried by British experimenters for 10 years.

When the U.S. fusion research effort began back in the 1940s, the toroidal z-pinch was the first type of magnetic confinement system to be investigated, mainly because of its simplicity.

A general description of how fusion works can be found in the accompanying box. A z-pinch works like this: A donut-shaped vacuum chamber is filled with a small amount of hydrogen gas (Figure 2). Then a rapidly increasing electrical current is passed through an external transformer that generates an electric field. The field first ionizes and then induces an electrical current in the hydrogen gas in the donut-shaped vacuum and the toroidal plasma acts like a one-turn transformer. The induced axially directed plasma current generates the circular magnetic field that confines, compresses, and heats the hydrogen plasma.

In addition to the physical simplicity of its magnetic field geometry, the z-pinch offers an opportunity for precise experimentation in the most challenging areas of plasma physics theory (see box). In fact, recent experimental results with the Eta Beta II z-pinch at the University of Padua in Italy (discussed fully below) demonstrate that the zeta system not only is a viable approach to harnessing nuclear fusion reactions but also may well be the most advanced approach to fusion—because it makes use of the ability of a plasma to naturally organize itself into a self-confining structure. It was the failure of British scientists to understand this capacity for self-organization in plasmas that led to their dropping the zeta program in 1969.

Before discussing the recent results with the zeta system, I'll review the zeta history.

After a decade of low-level research beginning in the 1940s, the United States dropped its small pilot project toroidal z-pinch experiments because of a number of experimental difficulties. In brief, these first experiments encountered (1) magnetohydrodynamic instabilities (see Figure 3); (2) temperatures that remained low while high rates of plasma energy loss ensued as a result of radiation of electromagnetic energy generated by the interaction of the plasma electrons with impurities (elements other than hydrogen) that migrated into the plasma from the surface of the vacuum chamber; (3) secondary breakdowns (induced electrical currents) at the vacuum chamber wall that hampered attempts to raise the temperature by increasing the voltage of the current to obtain shorter pinch collapse times.

Despite these problems, the British went ahead and built a very large experiment at Harwell in the mid-1950s based on the toroidal z-pinch, the Zeta experiment. The plasma cylinder of the Zeta had a diameter of 1 meter and the overall diameter of the donut was 3 meters. The Zeta was until recently the largest fusion experiment ever built and will be greatly exceeded in scale only with the 1982 completion of the Princeton tokamak fusion test reactor, TFTR.

Throughout the 1960s, experiments were carried out on the Zeta with very significant results. Zeta achieved confinement times greater than .005 seconds, about 100 times better than previous magnetic confinement experiments; densities of 100 trillion nuclei per cubic centimeter; and, most significant, plasma betas of greater than 15 percent. (Plasma beta is a measure of the efficiency with which a magnetic field confines the hot plasma. In formal terms, plasma beta is the ratio of the plasma gas pressure to the pressure of the magnetic field.)

However, the Zeta did not achieve significant increases

in plasma temperature, remaining at the 100 to 200 electron volt level, about 1 to 2 million degrees.

At the time, it was believed that achieving temperatures above 10 million degrees together with long, stable plasma confinement were the most critical steps in developing magnetic confinement fusion energy. Actually, as we know today, it is the question of plasma beta that is most important.

For a minimally economical electric power plant based on the magnetic confinement approach, plasma betas of more than 5 percent are needed; and for truly economical reactors, plasma betas in the range of 10 to 20 percent are required. Only recently have tokamak plasma betas been brought up to about 3 percent.

Why did the British give up on the Zeta? In the late 1960s, the Soviet tokamak fusion experiment reached temperatures of more than 10 million degrees, with all other parameters—except for plasma beta—in the same range as the Zeta. After the British Zeta scientific team visited the Soviet Union and measured the results of the Soviet tokamak, the world fusion community directed its efforts toward the tokamak in order to pursue higher temperatures. The Zeta was declared a failure in 1969, and when the experiment fell off the back of a truck while being moved, the Zeta program was eliminated.

The irony in the rejection of the Zeta approach is that the tokamak is really a type of toroidal z-pinch. In the tokamak, like the toroidal z-pinch, an axial plasma current is induced in a donut-shaped plasma. This current generates a magnetic field in the circular (poloidal) direction, like that in the z-pinch, and this magnetic field is primarily responsible for confinement of the hot plasma.

Tokamaks also have a strong axial magnetic field (the toroidal field) generated by external magnetic field coils that encircle the plasma column. This strong axial field is essential for maintaining the stability of the tokamak plasma. In addition, this axial (or toroidal) field leads to upper limits on the size of a current that the tokamak plasma can stably carry as well as upper limits on the plasma beta. (Zeta had plasma currents of up to 1 million amps, and this

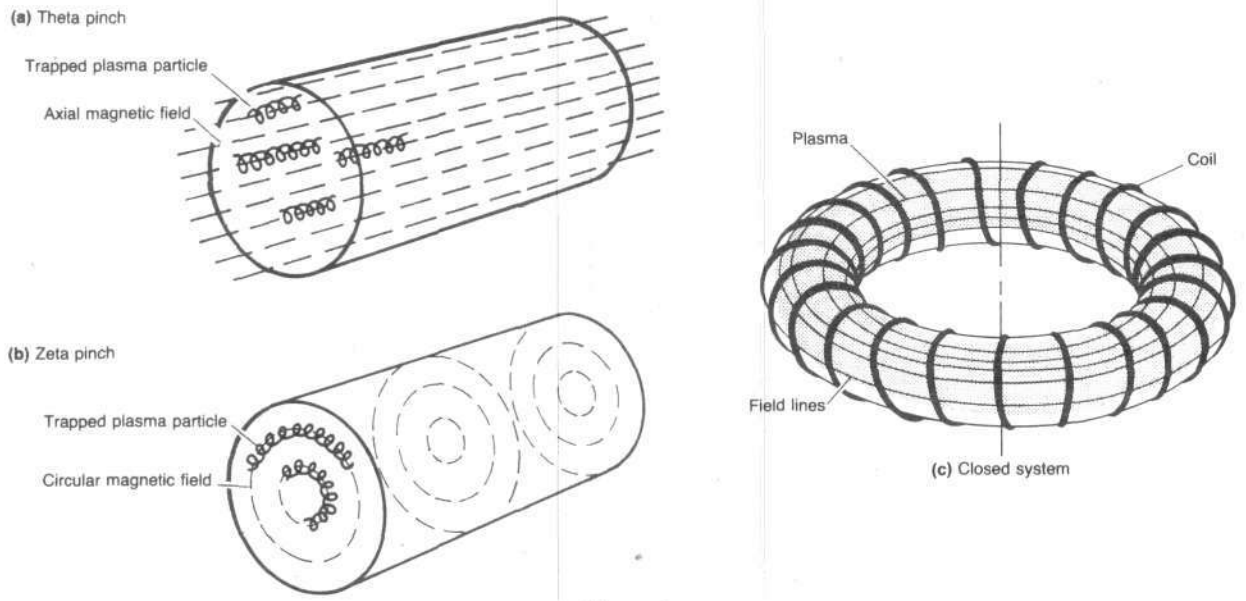


Figure 1
MAGNETIC CONFINEMENT CONFIGURATIONS

In **a**, *an axial magnetic field traps plasma ions and electrons into spiral orbits along the field lines. A plasma current is induced to flow in a circular fashion, the short way around the cylinder. This generates the magnetic field parallel to the axis of the plasma cylinder. If the induced plasma current is made to increase rapidly, then the intensity of the magnetic field will increase. This compresses and heats the plasma, which, in turn, leads to an intensification of the magnetic field. This process of the plasma current generating self-compression is called the plasma pinch, and this type of magnetic geometry is called the theta pinch.*

In **b**, *a circular magnetic field — the poloidal field — traps plasma particles to "closed" spiral paths along the "closed" magnetic field lines. This configuration is called a zeta or z-pinch. The induced plasma current in the z-pinch flows in a direction parallel to the central axis of the plasma — the long way down the cylinder.*

The magnetic field configuration in **c** *has been closed by bringing the ends of the cylinder together to form a toroidal shape — a donut. The field lines now are closed. Also shown is an external coil that generates the magnetic field within the plasma.*

was equaled only last year on the General Atomic Doublet III tokamak.)

With the rebirth of the toroidal z-pinch in the early 1970s in the form of the reversed field z-pinch and in light of recent Italian experimental results, it has become clear that the original Zeta was a roaring success. Not only is the Zeta the basis for a viable magnetic fusion reactor, but also the Zeta approach may be essential to the successful development of the tokamak.

The Zeta's Self-Confining Ability

In high school physics, students are sometimes introduced to what is euphemistically referred to as Maxwell's demon, an unseen creature who devilishly rearranges physical phenomena to be more ordered. Essentially, the demon is a mystical way of explaining how the so-called anomaly of antientropy or negentropy occurs despite the Second Law of Thermodynamics.

The British experimenters encountered a Maxwell's demon in the Zeta device, but one that was quite visible. As the experiment proceeded, the plasma column would appear to become unstable. It would twist itself until a kink was formed like that in Figure 3, which appeared to be the well-known MHD instability.

As the kink developed—actually two of them were observed in a sort of double loop—it would travel around the torus and react with the wall of the Zeta vacuum chamber, an electrically conducting wall. The interaction of the plasma MHD kink and the wall would generate a magnetic field in a direction opposite to the initial z-pinch magnetic field along the outside of the plasma column. Thus, it would set up a reversed two-layered magnetic field.

Eventually, the double kink would disappear, leaving the confined plasma in a more stable reversed-field configuration, and the temperature of the plasma would rise.

Although the researchers observed almost immediately the period in the Zeta when the plasma became field reversed and significantly more stable and hotter, they did not understand how this came about until many years later. The fact that Zeta was a "cold" plasma, having tem-

How Fusion Works

The general methods for harnessing fusion were developed chiefly on the basis of scientific investigations of how stars work. To ignite fusion, the fuel must be heated to hundreds of millions of degrees. The rate at which the fusion reaction proceeds is proportional to the density of the fuel (measured in terms of the number of fuel nuclei per cubic centimeter). Therefore, to generate a significant amount of fusion energy, the density of the fusion fuel must be maintained simultaneously with the hundred-million degree temperature.

In other words, the fusion fuel must be *confined* at the requisite ignition temperature for some minimum period of time at a given density to achieve net energy production. These general conditions for net energy generation are measured in terms of achieving the ignition temperature and the product of the confinement time and the fuel density.

The fusion reaction with the lowest ignition temperature and greatest energy output is that of the two heavy isotopes of hydrogen, deuterium, which has one proton and one neutron, and tritium, which has one proton and two neutrons.

The ignition temperature for the deuterium-tritium or D-T reaction is about 44 million degrees Celsius or 4 thousand electron volts. (One eV is equivalent to about 11,000 degrees Celsius.) The fusion reaction products of the D-T reaction are a helium nucleus, which has an energy of 4 million electron volts (4 MeV) and a neutron with an energy of 14 million electron volts (14 MeV).

The minimum product of confinement time and density needed for net energy production with D-T is 30 trillion nuclei per cubic centimeter per second. Thus, a 50-50 mixture of D-T above the ignition temperature at a density of 30 trillion nuclei per cubic centimeter must be confined and maintained at this density for a duration of 1 second in order to get net energy generation.

Fusion Approaches

The two general approaches to confining fusion fuels above ignition temperatures are inertial and magnetic confinement. The inertial approach duplicates the way in which stars generate fusion in their dense interiors where the gravitational force of the huge mass confines and compresses hydrogen.

Manmade inertial fusion uses intense beams of ions, electrons, or electromagnetic radiation produced by lasers to duplicate the gravitational compression of stars. A small pellet of fusion fuel is compressed and heated to high densities using these intense beams. Because of the high densities achieved, the fuel "burns up" before it has time to "blow up." The inertia of the fuel actually maintains confinement for the few billionths of a second required.

The second general fusion method, magnetic confinement, utilizes the electrical properties of high-temperature matter. When matter is heated to more than 10,000 degrees, its atoms become ionized; that is, electrons are stripped off the atoms and the remaining positively charged ions together with the negatively charged "free" electrons take up separate existences.

This state of matter is the plasma state. Although the other three states of matter—solid, liquid, and gas—are generally all that is found on earth, most matter in the universe is in the plasma state, and stars and the sun are really large plasmas.

In magnetic confinement, fusion fuel is turned into a plasma, and through the interaction with a magnetic field it is confined and insulated. Once stably confined, the fusion fuel can be heated in various ways—with microwaves, lasers, charged particle accelerators, or simply by inducing an electric current in it—to the hundred million-degree temperatures needed to ignite fusion.

Continued on page 58

peratures of only several hundred electron volts compared to the multithousand electron volt plasmas of tokamaks, was essential to the discovery of the double kink and the associated reversed field configuration. The relatively cold plasma permitted experimentalists to measure directly the magnetic field geometry of Zeta throughout the experiment, using small metal coils injected into the plasma.

As a result, theoreticians were able to develop an approximate "linear" picture of what was going on in Zeta; that is, a picture that could account for the dynamics of the field reversal by the double kink but could not fully account for the double kink's appearance and disappearance.

Of course, the appearance of such self-stabilizing structures in plasma-fusion research is not a quirk. Such self-ordered structures in plasma physics experiments have been the rule and not the exception. As for why such structures were deemed an experimental failure, it has to be understood that the very existence of self-ordered structures completely violates all of the tenets of the currently hegemonic empiricist method in science originated by the British.[1]

What was actually going on in the Zeta and its real significance became evident to the British only in the late 1960s with the work of Dr. Winston Bostick and Dr. Dan Wells who investigated "self-ordered" plasma structures both experimentally and theoretically.[2] Bostick and Wells contended that the plasma would almost "naturally" organize itself into a self-confined structure if it were given sufficient energy and freedom instead of being forced into a confinement configuration. In particular, Bostick and Wells pointed at the experimental evidence found in all plasma pinch experiments where the plasma tended to form helically shaped filamentary structures in which the current, magnetic field, and plasma flow all followed parallel helical paths (Figure 4).

Self-Confining Structures

Wells and Bostick pointed out that such structures are "force-free" and therefore "self-subsisting"—self-confining. In particular, Wells developed the theoretical concepts based on the work of Adolf Busemann, the German scientist responsible for much of the work on rockets and jets during World War II, to demonstrate how such structures maintain their stability.

Quite typically, the British Zeta scientists referred to the dramatic development of field self-reversal in the Zeta as

How Fusion Works

Continued from page 57

Magnetic fields confine hot plasmas by trapping the charged particles that make up the plasma into spiral orbits along the magnetic field's lines of force. The two magnetic field lines in Figure 1 provide a general overview of all magnetic confinement. Both configurations begin with a long cylinder of plasma. In *a*, the magnetic field lines are parallel to the long axis of the cylinder and the charged plasma particles are trapped into spiral orbits along these lines. Note that nothing prevents the plasma from streaming out the two ends of this cylinder.

In *b*, the magnetic field lines in the plasma cylinder follow closed paths the short way around the cylinder, and the plasma particles have no direct path to escape from the cylinder. A third possible magnetic field confinement system would combine both variations *a* and *b* with the magnetic field lines forming spirals along the major axis of the cylinder.

When the ends of the plasma cylinder of either *a* or *b* are brought together, a torus is formed. This is the geometry of most confinement geometries since, as is obviously the case with *c*, forming a torus "closes the ends."

Magnetic confinement systems usually depend on externally induced electric and magnetic fields that are generated by passing an electric current through a normal metal conductor in proximity to the fusion plasma. Since normal metals and other materials can support fields of only a few electron volts per atom before breaking up, this puts an upper limit on the energy density of the fields that can be used.

For example, it is impossible for normal conductors to generate magnetic fields greater than several hundred-thousand gauss. This translates into energy densities of less than 10^{20} eV per cubic centimeter. Since plasmas have to be confined at hundred-million-degree temperatures, which correspond to energies of 7,000 to 9,000 electron volts per plasma particle, the densities of magnetic confinement plasmas are between 10^{13} to 10^{16} plasma particles per cubic centimeter. Thus, magnetic confinement plasmas are hundreds of times less dense than normal air and millions of times less dense than in inertial confinement fusion where densities range from 10^{19} to 10^{26} atoms per cubic centimeter.

There are a number of consequences that stem from these conditions. First, because fusion reactions proceed much more slowly at such low densities, the time the fuel must be maintained at fusion temperatures on the average must be millions of times longer than is the case for inertial confinement in order for most of the fuel to react.

Second, any plasma in contact with the vacuum chamber in which the magnetic confinement system is set up will rapidly cool the plasma and quench the fusion reaction. Therefore, fusion plasma must be insulated, confined within the magnetic field "bottle" to prevent it from coming in contact with the chamber wall.

Third, the magnetic field-plasma configuration must be kept reasonably stable. Plasmas can escape from the magnetic bottle by using the energy of the magnetic field to generate either macroscopic or microscopic turbulent motions by which they reach the wall of the vacuum chamber (see Figure 3). These macroscopic instabilities are termed magnetohydrodynamic instabilities or MHD because the plasma and magnetic field interactions in such cases are similar to interactions between fluids.

the "quiescent" period. And Bostick and Wells's work was ignored and ostracized for almost a decade.

Only after overwhelming experimental evidence was accumulated and Bostick and Wells's concepts were applied to tokamak plasma dynamics were these ideas taken seriously in the plasma physics community.

Analysis in the early 1970s of the Zeta results by U.S. fusion researchers led to the rebirth of a toroidal z-pinch research effort here. Simultaneously the British also reestablished their z-pinch program, but on a much smaller scale, and z-pinch programs were initiated in Italy and Japan.

In 1974, the leading British plasma physicist J. B. Taylor presented a theory that attempted to explain the stability of the self-reversed structures found in the Zeta device and later toroidal z-pinches. [3] Interestingly, the chief points of the Taylor theory were exactly equivalent in formal terms to what Dan Wells had published in the *Journal of Plasma Physics* in 1969 and 1970. However, Taylor neglected to refer to Wells's previous papers.

In fact, in the entire international scientific literature Dan Wells's 1969-1970 papers were cited only by Winston Bostick until May 1978, when plasma physicist David Montgomery took note of Wells's papers in an article in *Physical Fluids*.[4] (Wells's work was brought to the attention of Montgomery by the staff of the FEF.)

Coincidentally, Dan Wells's coauthor on a 1969 paper, Joseph Norwood, made extensive visits to Taylor's laboratory in Great Britain at Culham in the early 1970s.

Since that time, the small experiments utilized to investigate the reversed field toroidal z-pinch have been quite successful. In 1978, U.S. scientists from the Los Alamos Scientific Laboratory proposed a joint international effort to pool the meager resources of the various reversed-field pinch programs to construct a significant proof-of-principle experiment. However, the British rejected the proposal and instead insisted that any joint program should limit itself to constructing a machine that would duplicate the original Zeta results and not go significantly beyond that.[5]

The Eta Beta II Breakthrough

This stalemate situation was transformed by the experimental breakthrough of Italian fusion scientists on the small Eta Beta II z-pinch at the University of Padua. Historically, it is most appropriate that the University of Padua should break this British-generated deadlock on the reversed-field pinch: Padua was the chief center responsible for the emergence of modern science in the 17th century

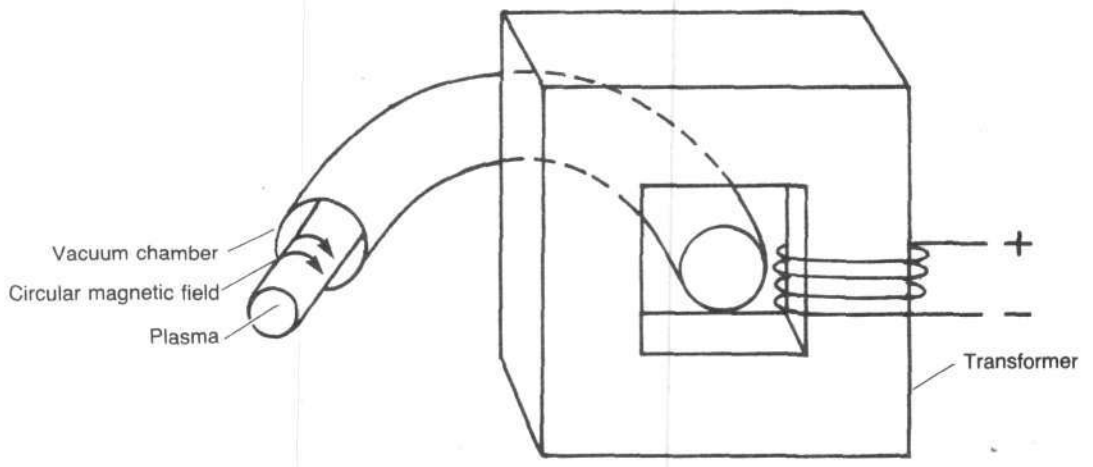


Figure 2
SIMPLE TOROIDAL Z-PINCH

A cutaway view of the simple toroidal z-pinch. In experimental runs, hydrogen gas is pumped into the vacuum chamber to fill up the donut at a low density. Then an electric current is passed through the transformer. This generates an electrical current field that ionizes the hydrogen gas in the vacuum chamber. As the current rises in the transformer, a plasma electrical current is induced to travel around the donut. This generates the circular (poloidal) magnetic field that pinches and initially heats the plasma. As the current continues to rise, it too heats the plasma.

In the later, more sophisticated versions of the toroidal z-pinch, toroidal field coils were placed around the vacuum chamber. These generated an axial (toroidal) magnetic field that helped to stabilize the simple z-pinch against MHD instabilities. Also "vertical" field coils were added that prevented the plasma donut from simply expanding and hitting the vacuum wall. The vertical field coils generate a magnetic field on the outside of the plasma donut in a direction perpendicular to the plasma column. When the plasma expands outward, it interacts with this vertical field and is forced inward as a result.

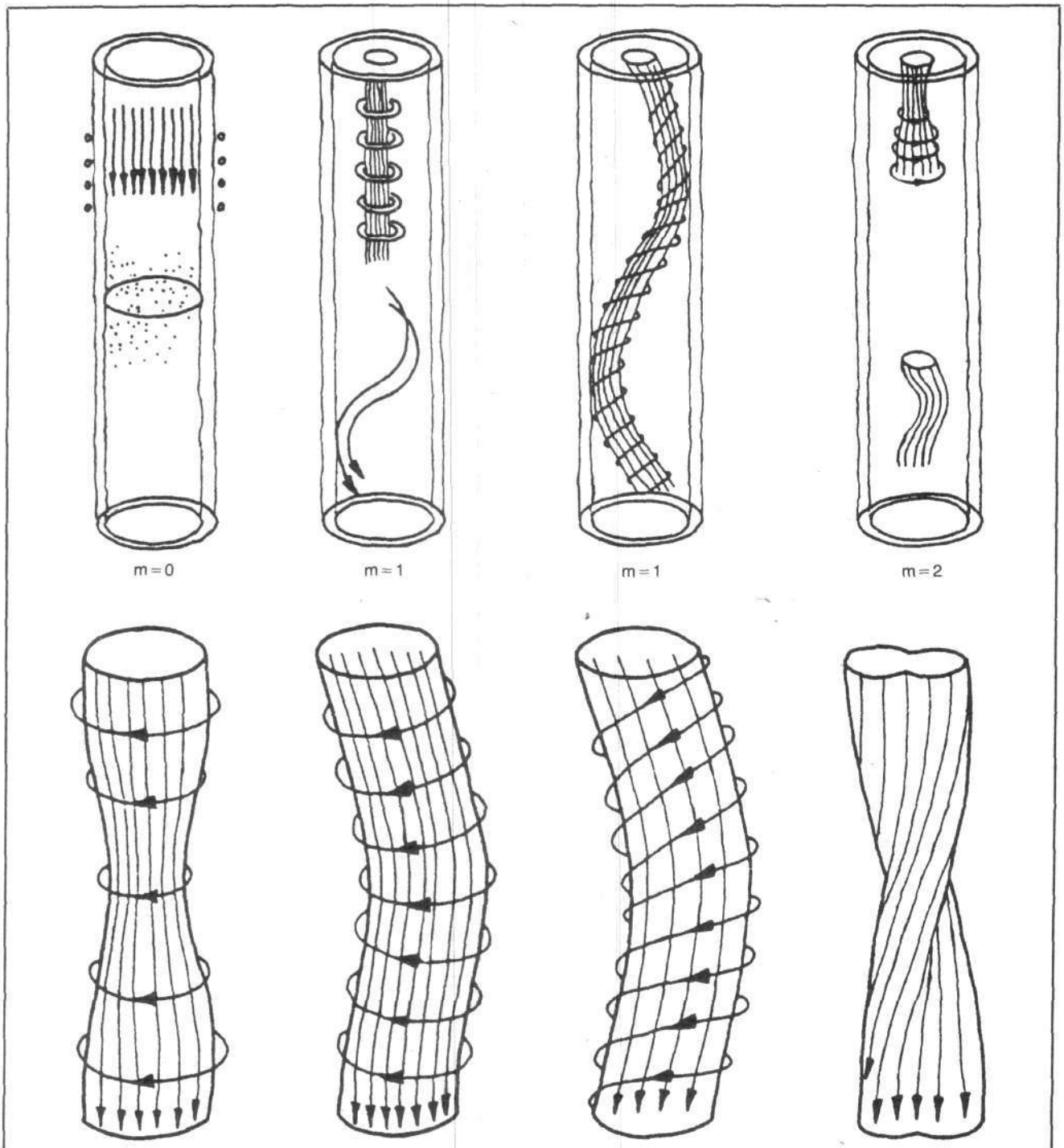


Figure 3
MAGNETOHYDRODYNAMIC (MHD) PLASMA INSTABILITIES

The plasma column in an axial magnetic field can become unstable by taking on the various shapes shown here. In the terms used to identify the various instabilities, **m** *is an integer in a mathematical function of the form sin (mΘ) that determines the geometry the MHD motion (instability) of the plasma column will take. For example m = 0 means that the plasma column will move only in a radial direction (that is, with differing thicknesses). In m = 1, the plasma column motion takes the form of a spiral or simple coil — a kink — and if this continues to grow, the plasma will hit the wall of the vacuum chamber. In m = 2, the column spirals and is squeezed.*

and counts among its renowned alumni William Gilbert, the leading English scientist of the 17th century and the first to investigate plasma phenomena.

With a much smaller experiment and very limited resources, the small team of dedicated fusion scientists at Padua was able to duplicate the original Zeta results. Among the major reversed-field pinch experiments including the Zeta, the Eta Beta II is by far the smallest machine with the lowest electrical current. Yet the recent experiments on the Eta Beta have obtained confinement times of 500-millionths to 700-millionths of a second, temperatures in the range of several hundred electron volts, densities up to 1,000 trillion (10^{15}) nuclei per cubic centimeter, and plasma betas of above 10 percent.

As can be seen in Table 1, which lists the parameters attained by the major reversed-field pinch experiments, this puts the Eta Beta II in the Zeta ballpark and actually represents the experimental duplication of Zeta.

Even more significant, the Italian results in terms of confinement times are a factor of 10 better than other recent reversed-field pinch experiments and demonstrate that the reversed-field pinch is rapidly catching up with tokamaks, which have attained confinement times of 60,000-millionths of a second.

Because of Eta Beta II's high betas and its relatively simple plasma heating and magnetic field technology, the reversed-field pinch could leapfrog over the tokamak in terms of demonstrating its capacity to be an economical power plant. Furthermore, because of the close relationship of reversed-field pinches to tokamaks—they are both z-pinches—it could lead to the development of a better tokamak.

Slow Rise-Time Key to Success

The key to success of the Eta Beta was that the Padua researchers ignored the prevailing theory and used electric currents with relatively slow rise-times; that is, currents that slowly increased over time. Ironically, one of the reasons that reversed-field toroidal z-pinches were reexamined in the early 1970s was the development of *fast* rise-time electrical technology. It was believed that this fast rise-time would: (1) overcome the problem of secondary breakdown at the vacuum chamber wall found in the early z-pinch experiments; and (2) provide the basis for obtaining very high-temperature ions (several thousand electron volts) by the development of a shock wave during the compressing stage of the pinch formation that would lead to significant heating of the plasma ions.

Ignoring this, the Eta Beta team used slow rise-time currents and, as a result, the impurity level in the plasma was kept quite low and they achieved a very stable and long-lived plasma. It turns out that the shock heating, which chiefly affects the ions while the electrons remain relatively "cold," leads to a temperature difference between the electrons and ions and the development of a strong electric field in the plasma column. This electric field tends to pull impurity atoms (elements other than hydrogen) off the vacuum chamber wall.

In addition, the Eta Beta team was able to compare the

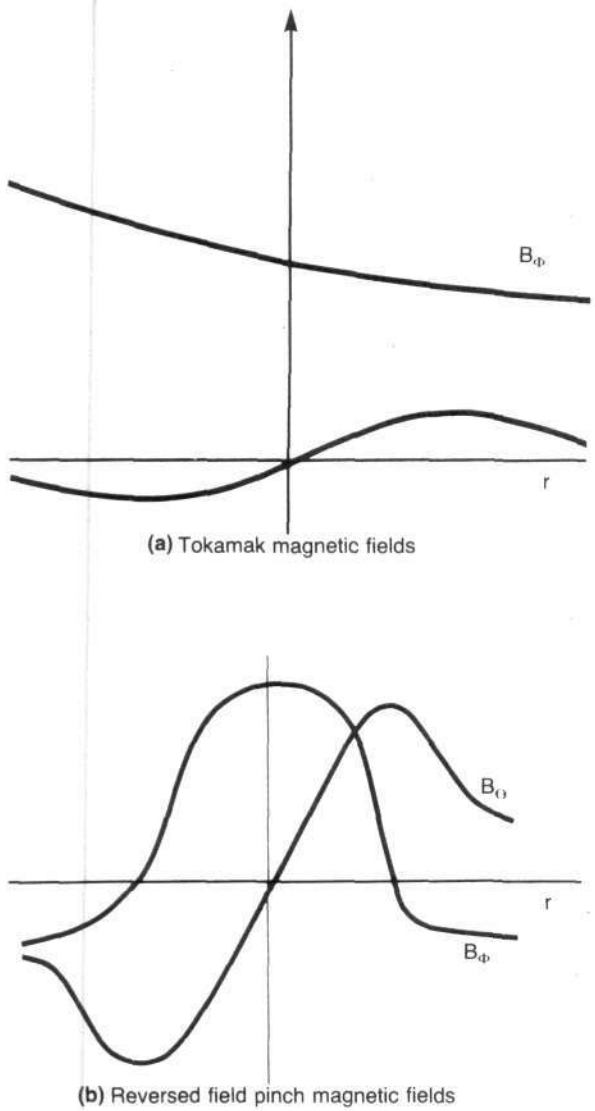


Figure 4
COMPARISON OF TOKAMAK AND REVERSED-FIELD PINCH MAGNETIC FIELDS

In this rough graph, the **y** *axis gives the magnetic field strength while the* **x** *axis gives the position of the magnetic field relative to the center of the plasma column.* **x** *= 0 is the center; the positive* **x** *direction is toward the outside of the overall donut; and the negative* **x** *direction is toward the center of the donut. For the tokamak, the toroidal field, B_Φ, is always greater than the poloidal field, B_Θ. In the reversed field pinch, the toroidal and poloidal fields have regions where they have the same strength. Also, the toroidal field in the reversed-field pinch reverses direction on the outside part of the plasma column.*

Table 1
REVERSED-FIELD PINCH EXPERIMENTS PARAMETERS

	HBTX* Culham (UK)	ZT-40 Los Alamos	Eta Beta II Univ. of Padua	Zeta Harwell (UK)
Plasma current I in millions of amps	.4	.6	.2	1.0
Major radius in cm	80	114	64	150
Minor radius in cm	26	20	12.5	50
Achieved plasma parameters				
Electron temperature			50-150 eV	50-150
Density nuclei per cc			about 10^{14}	about 10^{14}
Plasma beta			about 10%	about 10%

Note: HBTX and ZT-40 have not reported any results yet.

Although the Eta Beta II is much smaller than the Zeta experiment, it has achieved the same level of results.

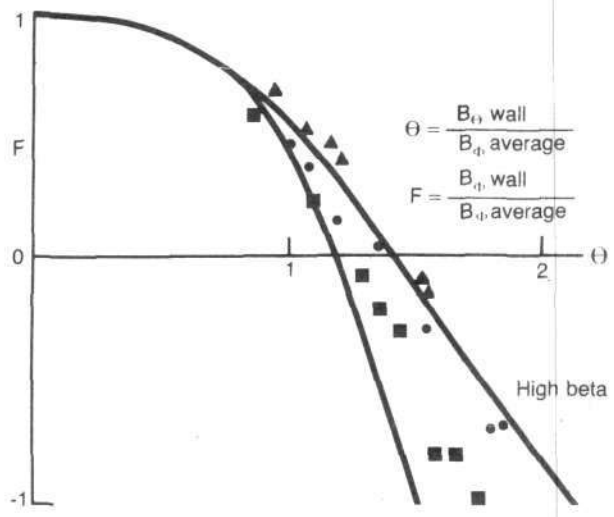


Figure 5
GEOMETRIC RELATIONS OF MAGNETIC FIELD STRENGTHS IN MAGNETIC CONFINEMENT

The graph shows the geometric relations of the magnetic field strengths for magnetic confinement. F, the y axis, is the ratio of the toroidal magnetic field found near the wall of the vacuum chamber, B_Φ, to the average toroidal magnetic field found throughout the plasma. Theta, Θ, here is the ratio of the poloidal field B_Θ found at the wall to the average toroidal field throughout the plasma.

Tokamaks are located in the upper left-hand region of the graph, while the reversed field pinches are the points plotted within the shaded area.

plasma to the "self-reversal" found in Zeta and other experiments and to nonreversed toroidal z-pinch plasmas, because they could program the electric currents to generate the reversed-field configuration. Their results tended to confirm the above-mentioned theoretical projections of Wells and Taylor in terms of the stability of the reversed-field configuration.

To understand how this works, let's look at the magnetic field structure of the reversed field toroidal z-pinch in much greater detail.

A tokamak magnetic field has the geometry shown in Figure 5, a spiraling magnetic field that is a combination of a strong toroidal (axial) field designated by the Greek letter phi (Φ) and a relatively weak poloidal (circular) field designated by the Greek letter theta (Θ).

In both the tokamak and the reversed-field pinch, the fields are generated in the same way; that is, the toroidal field is generated by external field coils and the poloidal field is generated by an induced plasma current. However, in a reversed-field pinch the toroidal and poloidal magnetic fields are about of equal strength.

Figure 6 compares the toroidal and poloidal magnetic field strengths of the tokamak to those of the reversed-field pinch. The *y* axis gives the magnetic field strength, while the *x* axis gives the position of the magnetic field relative to the center of the plasma column. The center is $x = 0$, while the positive *x* direction is toward the outside of the overall donut and the negative *x* direction toward the center of the donut.

For the tokamak, the toroidal field (B_Φ) is always greater than the poloidal field B_Θ. In the case of the reversed-field pinch, the toroidal and poloidal fields have regions where they have the same strength. And, as can be seen in the figure, for the reversed-field pinch the toroidal field reverses direction on the outside of the part of the plasma column.

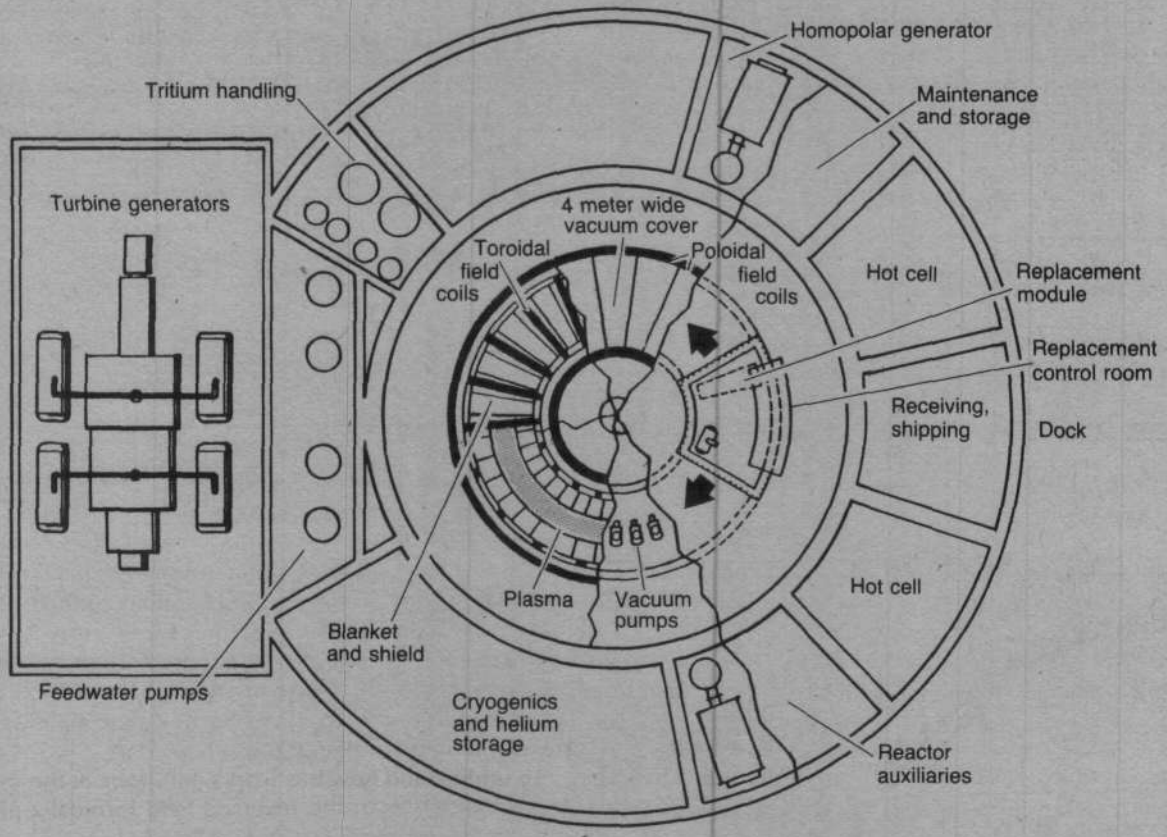


Figure 6
LOS ALAMOS PROOF-OF-PRINCIPLE REVERSED FIELD PINCH

This drawing of the Los Alamos proof-of-principle reversed-field pinch experiment shows the coils, shell, liner, and vacuum pump ports, giving some idea of the size of the experiment. The proof-of-principle experiment, budgeted at about the same amount as the tokamak proof-of-principle (the Princeton PLT), is likely to go much further than the conservative Los Alamos projections, probably providing results more on the level of those expected for the Princeton tokamak fusion test reactor.

To avoid the MHD kink instability shown in Figure 3, the tokamak magnetic field configuration must have the following type of relationship to the overall geometry of the plasma donut: The radius of the plasma column *a* (the minor radius) times the toroidal magnetic field B_ϕ, divided by the radius of the overall donut *R* (the major radius) times the poloidal magnetic field B_θ, must be greater than 1. This relationship is called the *q* safety factor:

$$q = \frac{aB_\Phi}{RB_\theta} \quad \text{must be greater than 1}$$

The reversed-field pinch, however, is stable with a *q* safety factor of *less than 1*. It is necessary only that the rate of change of *q* with respect to *R* not be equal to zero.

This MHD stability difference between tokamaks and reversed-field pinches has a number of important consequences. First, since the high *q*'s needed for stability in the tokamak mean that the poloidal magnetic field must be less than the toroidal field, there is an upper limit on the electric current that can be induced in the tokamak. This is because the poloidal field is proportional to the induced plasma current. Therefore, given toroidal fields of equal strength, the reversed-field pinch can use much larger plasma currents.

Second, as a result of this first point, reversed-field pinches can be heated to ignition by electric current ohmic heating, which is quite unlikely in the case of tokamaks. Therefore, reversed-field pinch reactors would not need costly alternative heating systems such as neutral beams, microwaves, and so on.

Third, as a close examination of the q safety relationship for tokamaks shows, in order to minimize the toroidal field needed, the ratio of the minor radius a to the major radius R must be as great as possible; that is, as fat a donut as possible. This creates a number of technological difficulties, especially for power reactors since the access to the inner part of the donut becomes quite difficult.

This is not the case in the reversed-field pinch. The donut can be as thin as desired; therefore, there is easy access to the entire plasma column within a reactor and the donut can be broken up more readily into modular segments.

Fourth, the high q safety factors put upper limits on the simple tokamak configuration, while in the reversed-field pinch plasma betas as high as 50 percent are theoretically possible. This is most important from the standpoint of

The Zeta Pinch And Plasma Theory

The recent results reported from the Eta Beta II z-pinch experiment at the University of Padua—and the light these experiments shed on the older pinch experiments—offer an ideal opportunity for a "critical" experiment in plasma science.

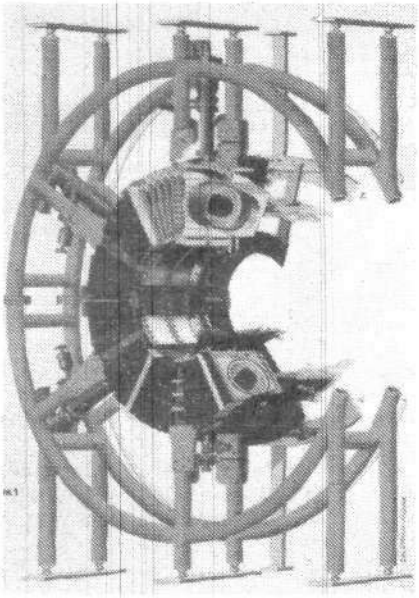
The zeta pinch is uniquely suited to precise experimentation, which was, in fact, one reason for its initial popularity. It has a simple magnetic field geometry (unlike the tokamak or stellarator); it creates a large plasma volume, allowing easy access for diagnostics with lower resolution (unlike the theta pinch or plasma focus); and its relevant time scales are manageable, both for power sources and measurement.

Most important, however, the zeta pinch poses the most challenging questions of plasma physics in an experimentally accessible context—something no recent magnetic confinement results have been able to do.

The most significant of these problems are the following:

The structure of the magnetic field. The initial results from the Italian zeta experiment show dramatically that the detailed structure of the magnetic field is responsible for the dynamics of the plasma. This is probably true for all plasmas, but in no experiment to date has it been possible to prepare a fine-grained map of the time-varying structure of the magnetic field. Theoretical work like that of the magnetofluid-dynamics group at the Courant Institute[1] predicts that the topological properties of the magnetic field and the interaction between this topology and variations of density and temperature are the principal mechanisms behind the evolution of magnetized plasmas. The zeta is a perfect experimental device for testing these findings.

Dynamic plasma structure. The macroscopic result of the complex structure of the magnetic field in experiments like the zeta is the formation of large-scale coherent motion of plasma. However, the phenomena characteristic of this large-scale coherent motion have never been documented in a large plasma experiment—vortex rings, filaments of vortical internal structure, and the like have been carefully studied in the experiments of Bostick[2] and Wells[3] but never in a large magnetized plasma.



The Eta Beta II

Recent theoretical work predicts that any twisted structure—like the plasma in the zeta—can support "kinks" that are solitons[4] and that their dynamics are a function of the new particle-like properties of the soliton. The insights that could be provided by a careful analysis of the dynamics, internal structure, and stability properties of the zeta plasma would immediately be applicable to other large plasmas that are not so easily studied.

Microscopic processes and macroscopic order. Perhaps the most intriguing aspect of the zeta experiment is the evolution of the plasma from initial disorder as the discharge is initiated to a highly ordered final state. The zeta plasma, like that in a tokamak or plasma focus, begins in a state of "strong turbulence," where all its particulate properties are characterized by maximum disorder. However, there are other, nonparticulate properties that guide the overall motion of the plasma so as to create a structured, globally coherent final state. This transition has been studied theoretically, to some extent; for example, in an important series of papers by Montgomery[5] who predicts the formation of globally coherent large-scale structure, much like that found in fluid turbulence and atmospheric motion. This theoretical work leaves open the question of the causal connections between the initial chaotic state and the final ordered state, because of the tremendous mathematical difficulties in the present formulation of the problem. An experiment like the zeta would take us much closer to an empirical test of present theories and provide the critical guideposts to further work.

—Dr. Steven Bardwell

Notes

1. H. Grad, "Reconnection of Magnetic Field Lines in an Ideal Fluid," to be published.
2. W. Bostick, *International Journal of Fusion Energy*, 1:1 (1977).
3. D. Wells, *International Journal of Fusion Energy*, 1:3 (1978).
4. G. Lamb, *Phys. Rev. Letters*, 9:235 (1976).
5. D. Montgomery et al., *Phys. Fluids*, 21:757 (May 1978).

reactor economics. With higher betas, weaker magnetic fields can be used to confine thermonuclear plasmas. This means a significant savings in magnetic field systems, which are a large portion of the total capital cost of magnetic fusion systems. Also, with weaker magnetic fields, the requisite technology is much easier to develop.

In addition, because the power density of magnetic fusion plasmas is a direct function of the plasma beta—it actually increases as beta to the fourth power—reversed-field pinch fusion reactors can be much more compact.

The geometric relations of the magnetic field strengths for magnetic confinement are shown in Figure 5. The *y* axis, designated by the letter *F*, is the ratio of the toroidal magnetic field found near the wall of the vacuum chamber, B_Φ, to the average toroidal magnetic field found throughout the plasma. In this case, theta (Θ) is the ratio of the poloidal field, B_Θ, found at the wall to the average toroidal field.

Tokamaks appear in the upper left-hand region of the figure, while the reversed-field pinches are represented by the points plotted within the shaded region. This shaded area and the area to the right of it are the region of high plasma beta, while to the left of the shaded area beta equals zero.

According to theory, the region between the two graphed lines is the area where the plasma will be stable. Since tokamaks are normally limited to the upper left-hand region of the figure, they are kept at relatively low plasma betas and can become easily unstable.

What happens in the case of the reversed-field pinch when it migrates out of the stable shaded region is most interesting. As the fields change in the reversed-field pinch during the experiment, the plasma begins to migrate out of the stable shaded region toward the left-hand direction. This is where the "self-reversal" phenomenon was encountered in the Zeta experiment. The ubiquitous double kink appears and interacts with the conducting wall of the vacuum chamber. This interaction leads to the formation of a reversed magnetic field in the outer region of the plasma column, and with this self-induced change, the plasma migrates back into the shaded region of the figure.

The double kink then disappears. In Zeta this happened up to three times in a single experimental run, each time with the plasma becoming hotter and more stable.

The Future

With the success of the Padua Eta Beta II, the prognosis for the ZT-40 z-pinch that is coming on line now at the Los Alamos Scientific Laboratory is quite good. Originally, the ZT-40 was to first explore the use of fast rise-time fields—a technology speciality at Los Alamos. But since the success of Eta Beta II with slow rise-times, the ZT-40 will explore this approach first.

Although the funding for the Los Alamos ZT-40 was recently cut, it is expected that the ZT-40 will go a long way to demonstrating the viability of the reversed-field pinch.

Los Alamos scientists have already laid out what is needed beyond ZT-40, in terms of a proof-of-principle experiment, in a preliminary report titled "The Reversed Field Pinch Concept and a Preliminary Conceptual Design for a Proof-of-Principle Experiment" (Report No. LA-7527). This experiment, which would cost $50 million (approximately the same as the cost of the proof-of-principle experiment for the tokamak, the Princeton PLT), would most definitely approach reactor-level plasmas.

In light of Eta Beta II, it is also clear that the proof-of-principle experiment proposed by Los Alamos would actually come much closer to a tokamak fusion test reactor type of experiment for the reversed-field pinch approach since many of the critical issues located in the Los Alamos report—such as impurities, scaling laws, setting up and sustaining of the reversed-field configuration, ohmic heating effects, and long-term control of stability—can now be addressed in Eta Beta II and the ZT-40.

A major advantage of the ZT-40 is that it is nearly twice the size of the Eta Beta II with a minor radius of 20 centimeters compared with 12.5 centimeters for the Eta Beta.

Table 2
Comparison of Parameters for the Reversed-Field Pinch Reactor and Proof-of-Principle Experiment

Parameter	Reactor	Reversed-field pinch proof-of-principle
Minor radius a (cm)	150	60
Major radius R (cm)	1,200	240
Toroidal currrent I_Φ (MA)	20	6
I_Φ sustainment time (s)	10	0.1
I_Φ rise time (s)	0.1	0.01
B_Θ (a) (T)	2.7	2.0
$T_e = T_i$ (keV)	~10	1 to 2
n_o (cm $^{-3}$)	2×10^{14}	2×10^{14}
τ_E (sec)	1.0	0.05
$n\,\tau_E$ s/cm^3	1.5×10^{14}	1×10^{13}
Wall loading (MW/m^2)	1.2	0.58

The minor radius a*—the radius of the plasma column—and the major radius* R*—the overall radius of the donut—are given in centimeters; the plasma electric current (toroidal current I_Φ) is given in millions of amperes (MA); the time that this plasma current, I_Φ, is sustained during operation of the pinch is given in seconds; the time during which the current I_Φ rises to its maximum value is also given in seconds; the poloidal magnetic field (B_Θ) at the surface of the plasma column is given in teslas; the ion (T_i) and electron (T_e) temperatures are given in thousands of electron volts (keV); the density of the plasma n_o is given in number of electrons per cubic centimeters; the confinement time τ_E is given in seconds; the confinement time-density product is given in number of nuclei per cc-seconds; and the fusion energy power density output is given in terms of millions of watts per square meter of the vacuum chamber wall.*

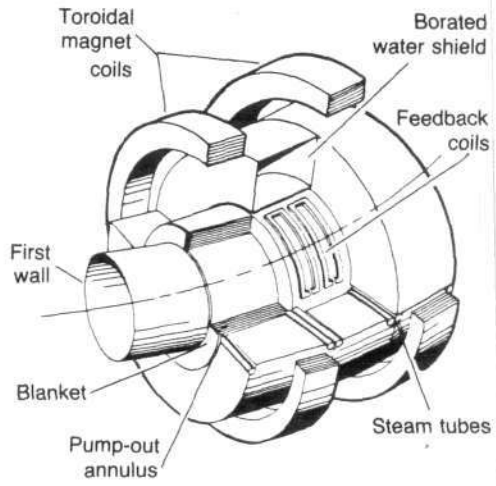


Figure 7
MODULAR SEGMENT OF THE REVERSED-FIELD PINCH
Detailed drawing of a modular segment of the reversed-field pinch that is 2 meters long. Shown are the copper first wall, the lithium oxide bed for breeding tritium fusion fuel, associated steam tubes, feedback coils, water shield, and toroidal field coils.

Therefore, it is capable of reaching three times the plasma current of Eta Beta II—.6 million amps compared with .2 million amps. This means that ZT-40 will achieve significantly higher temperatures.

Also, since all scaling laws give confinement time as proportional to the square of the minor radius, this means that ZT-40 will sustain multimillisecond confinement times (several thousandths of a second). Altogether, this will permit the ZT-40 to investigate key questions that it was previously thought could be addressed fully only in the proof-of-principle experiment.

Table 2 compares the reversed-field pinch and proof-of-principle parameters with those of the projected Los Alamos reversed-pinch reactor design. In fact, because of the recent Eta Beta II results, the reversed-field pinch proof-of-principle experiment would probably attain much better performance than what is projected in Table 2, actually coming very close to the reactor parameters. For example, it would not be surprising for the proof-of-principle experiment to attain 10 million amp plasma currents with plasma temperatures beyond ignition (4.4 million electron volts) and confinement times approaching 1 second.

As noted above, the reversed-field pinch has a number of advantages over tokamaks as the basis for electric power plants: To summarize: (1) ohmic heating to ignition and no need for costly and difficult methods of heating; (2) low magnetic field levels, which drastically reduce the difficulty of developing the requisite superconducting magnetic field technology; (3) thin donut-shaped systems; that is, the ratio of the donut's major radius to that of the minor radius (this is known as the aspect ratio) can be as great as desired. Also, there is easy access to the device and the donut can be constructed in modular segments.

All of these advantages lead to low capital cost reactor design and therefore to a lower cost for electric power, since the fuel costs for fusion systems are negligible.[7] The Los Alamos design shown in Figure 6 gives a direct capital cost of $810 per kilowatt of electrical output and a total investment capital cost of $1,200 per kilowatt, with a 46 mill per kilowatt-hour cost for electric power. All these costs are in the range of those for present coal and nuclear fission power plants.

Scientific Benefits

Because of its close relationship to the tokamak, the reversed field pinch may very well make possible totally new approaches to the tokamak, leading to the development of more economical and versatile magnetic fusion systems. As noted above, the reversed-field pinch may be essential in demonstrating that there are, relatively speaking, no beta limits in tokamaks.[8]

The most important quality of the reversed-field pinch, however, is its significance for basic plasma science. The exploration of the double kink "Maxwell demon" both theoretically and experimentally could provide the basis for entirely new approaches to fusion and important breakthroughs in basic questions in mathematical physics. As is becoming more generally acknowledged, the self-subsisting coherent structures encountered in plasma physics are the keys for unlocking the mysteries of microphysics and understanding the structure of subatomic entities like electrons and protons.

Charles B. Stevens, the Fusion Energy Foundation's director of fusion engineering, is well known as a fusion reporter.

Notes

1. For background material on British empiricism, see Carol White's article "I Don't Make Hypotheses—I Manufacture Data." *Fusion* 2:48 (Dec. 1978); also, by the same author, "The Royal Society" *Fusion* 1:44 (Dec.-Jan. 1977—1978).
2. Winston Bostick, "The Pinch Effect Revisited," *International Journal of Fusion Energy*, 1:1 (1977); D. R. Wells, *J. Plasma Phys.* 4:645 (1970); E. Nolting, P. Jindra, and D. R. Wells, *J. Plasma Phys.* 9:1 (1973).
3. J. B. Taylor, *Phys. Rev. Letters*, 33:1139 (1974).
4. David Montgomery et al. *Phys. Fluids*, 21:757 (1978).
5. "British Turn Down Joint Fusion Work with U.S.," *Fusion* 3:7 (Nov. 1979).
6. The material for this analysis of the recent results on the University of Padua Eta Beta II reversed-field toroidal z-pinch was taken from a series of lectures given by Dr. William Grossman of the New York University Courant Institute for Mathematical Studies in fall 1979.
7. R. L. Hagenson and R. A. Krakowski, "Fusion Reactor Design for Reversed-Field Pinch Reactor" USDOE Report LA-UR-78-2268.
8. B. Coppi et al., *Comm. on Plasma Physics and Cont. Fusion*, 5:1 (1979).

Books

The Graying of Science

Disturbing the Universe
Freeman Dyson
New York: Harper & Row, 1979
283 pp., $12.95

With the publication of this volume, the Alfred P. Sloan Foundation begins a series it claims is devoted to "a public understanding of science." Expanding on this notion, the introduction to the series tells us: "The goal of a general public understanding of science, which may have been reasonable a hundred years ago, is perhaps by now chimerical. Yet an understanding of the scientific enterprise, as distinct from the data and concepts and theories of science itself, is certainly within the grasp of us all" (p. vii).

Such a statement is either lying or incompetent. In either case it reflects the epistemological prejudices of those who today control not only science itself but the political environment that determines whether and what kind of science is done.

How fitting that Freeman Dyson's book should inaugurate this series and drive this point home. The perceptive reader will gain a great deal of insight from Dyson's meandering. He will learn something of the inner workings of that antiscience scientific elite that has taken control of science in this country, helping to impose the low standards of general culture that lend credence to the idea that science is beyond the average citizen's grasp.

Wells's Worldview

The key to Dyson's outlook is his open commitment to the worldview associated with the name and activities of H.G. Wells. Wells's outlook was ultimately antiprogress. To the extent that he favored scientific advances, it was not to the end of technological improvement and the general enhancement of human welfare. For Wells, scientific achievement was a means to maintain oligarchic control over mankind.

This perspective is popularized in a number of Wells's works, including *Things to Come* and *The Island of Doctor Moreau*, where bestialized humanity is controlled by a scientific elite that is in possession of the means of life and death over the beasts and that maintains them in their bestiality.

Wells and his cothinkers knew full well that if generalized scientific progress is assimilated throughout the population, it is impossible to continue such control.

This is precisely the policy now being deployed against the American people. The young are being bestialized by drugs and rock music, while they are inundated with antiscience "nonukes" propaganda.

Serious science students who survive the drug plague are fed a guilt line along with their "hard" science courses: "Science has gone too far, too fast. We have built too many machines. It is time to build postindustrial society. Science should be done, if at all, for its own sake, not for any 'practical' ends."

In parallel with this mass brainwashing, there is a highly skilled scientific research cadre, though it is effectively divorced from its humanist roots. Its best efforts are hemmed in; its best ideas are effectively stifled by a Wells-inspired classification system. Rather than protecting national security, this system serves to retard the development of vital technologies such as controlled thermonuclear fusion. At the same time, scientific achievement is available to the oligarchists to serve their own ends.

Destroying Science

Dyson makes his position clear at the very beginning of *Disturbing the Universe* by quoting from Edith Nesbit's *The Magic City*: "And there's a dreadful law here—it was made by mistake, but there it is—that if anyone asks for machinery they have to have it and keep on using it." Nesbit was an intimate friend of H.G. Wells, using her skills as a writer of children's books to disseminate his antiprogress philosophy.

A few highlights from Dyson's account of his career completes the case and provides a road map for the interested reader to follow the course that if pursued diligently will ultimately lead to the destruction of America's scientific power.

Dyson came to the United States from England shortly after the end of World War II. After a year of study in physics at Cornell University, he went to join Robert Oppenheimer, director of the Institute for Advanced Studies in Princeton. Oppenheimer was a member of the dissolute Children of the Sun cult that grew up primarily among British aristocrats and aristocracy-linked families during and after World War I. (The full Oppenheimer story will be published in a future *Fusion* article.)

Oppenheimer's philosophy embraced the Wellsian antiscience outlook and, in fact, the Wellsian outlook permeated the Institute, subverting some of the nation's best scientific minds. Dyson has remained at his Institute post to this day.

After the passage of the Atomic Energy Act of 1954 set in motion the concerted effort to develop commercial atomic power, Dyson left the pursuit of theoretical physics and became involved in the newly organized efforts of the General Atomic Company to design nuclear reactors. Every indication in Dyson's account leads to the conclusion that the point of his effort was to demonstrate that power reactors could *not* be commercially built and marketed.

First, electricity-producing reactors were not even considered in the studies, and a design suitable for a ship's power plant was ultimately rejected as having no commercial value. If someone were intent on putting a damper on the Atoms for Peace program, this sort of research and development project would be a good way to do it. Furthermore, the chapter in which Dyson describes this experience carries the implicit lie that nuclear power is neither safe nor economical.

And then there is Dyson's role in the nuclear nonproliferation approach to getting rid of nuclear power. Along with Dyson at General Atomic was one

Theodore Taylor, a former bomb designer at Los Alamos Scientific Laboratory. In 1974, Taylor and Mason Willrich wrote a book for the Ford Foundation showing that the theft of nuclear materials could be accomplished rather easily and that terrorists could build bombs from them. Although the book was denounced again and again by competent authorities as a hoax, Dyson became a principal actor in a notorious charade constructed to substantiate the case. Dyson supervised the research of Princeton undergraduate student John Phillips that led in 1976 to the press flap over Phillips's claim that he had designed a workable nuclear bomb from readily available information. As a dramatic gesture, Dyson reports, "I read through his paper, awarded him an 'A' grade, and told him to burn it" (p. 164).

Playing God

In addition to this discrete campaign to eradicate the practical implementation of nuclear power, Dyson also attacks that other major frontier area of new scientific and technological development, biology, especially genetic research. In a chapter audaciously entitled "The Island of Doctor Moreau," Dyson recapitulates Wells's and J.B.S. Haldane's arguments against human intervention to control genetic material and species evolution—what he terms "playing God."

"Two things we have learned from Wells and Haldane. Man cannot play God and still stay sane. And the progress of biology is inescapably placing in man's hands the power to play God. But from these two facts it does not follow that there is no hope for us. We still can choose to be masters of our fate. To deny to any man the power to play God, it is not necessary to forbid him to experiment and explore. It is necessary only to make strict laws placing the applications of his knowledge under public control" (p. 172).

That is, science is all right, as long as it is merely a toy for grown children. If anyone is so audacious as to try to implement scientific breakthrough for general human advancement, though, we will bring the full force of our well controlled, well-deployed antiscience mob to bear to destroy him and his creation.

If there is any doubt as to why Dyson is not—emphatically not—a real scientist, but a leader of the antiscience mob disguised as a scientist his remarks in the chapter entitled "The Greening of the Galaxy" clinch the case.

"In everything we undertake, either on earth or in the sky, we have a choice of two styles, which I call the gray and the green . . . . Factories are gray, gardens are green. Physics is gray, biology is green. Plutonium is gray, horse manure is green . . . . Human technology is gray, God's technology is green" (p. 227).

Readers of *Fusion* are sometimes puzzled by the strength of our editorial attacks on certain scientific epistemological blunders and on individual scientists. Freeman Dyson's book provides an internal map to the psychological state of mind that characterizes the tendency we so vigorously oppose. For that reason it is must reading.

—Dr. John Schoonover

Books Received

Economics and the Design of Small-Farmer Technology. Alberto Valdes, Ames, Iowa: Iowa State University Press, 1979, 211 pp., $15.00.

Management of the Electric Energy Business. Edwin Vennard, New York: McGraw-Hill Book Company, 1979, 403 pp., $24.50.

Energy in America's Future: The Choices Before Us. Resources for the Future, Baltimore: Johns Hopkins University Press, 1979, 544 pp., $10.95.

Saving Energy in Manufacturing: The Post-Embargo Record. John G. Myers and Leonard Nakamura. Cambridge, Massachusetts: Ballinger Publishing Company, 1978. 143 pp., $15.00.

Energy Future: Report of the Energy Project at the Harvard Business School. Robert Stobough, ed. New York: Random House, 1979, 265 pp., $12.95.

Georg Cantor: His Mathematics and Philosophy of the Infinite. Joseph Warren Dauber. Cambridge, Mass.: Harvard University Press, 1979, $27.50.

Water Resources in the Arab Middle East and North Africa. Christiaan Gischler, Wisbech, England: Means Press Ltd., 1979, $23.

Letters

Continued from page 5

which creates more fuel than it uses; or, in beer making, where the master brewing yeast creates more yeast than is used.

Now, consider how this applies to Mr. LaRouche's article. Suppose it is true that the human spirit does increase over time. A curve/graph of this phenomenon would show very slow growth over many years and then a sudden explosion of knowledge increasing at an astronomical rate. If you look at what has happened in the United States, Soviet Union, and other super or near-superpowers, this is exactly what has occurred. For thousands of years nothing much has really happened. Remember that the horse was the principal vehicle of transportation until just recently. Having gone to the moon, we are now reading about the commoner traveling in space via the space shuttle. So indeed, the United States has experienced the slow-to-explosion phenomenon in the growth of human spirit. In contrast, we could examine the developing countries, and by drawing their human spirit growth curves, confirm that most are on the flat, slow growth portion.

The benefit of developing a set or family of curves lies in determining how long it will take for these countries to reach the knee of the curve where explosion of knowledge takes place. And then, determining what we can do to shorten this time by applying appropriate technology, country by country, state by state or whatever. When we are done doing this, we will have developed a plan to lead the world out of the mess it is in today.

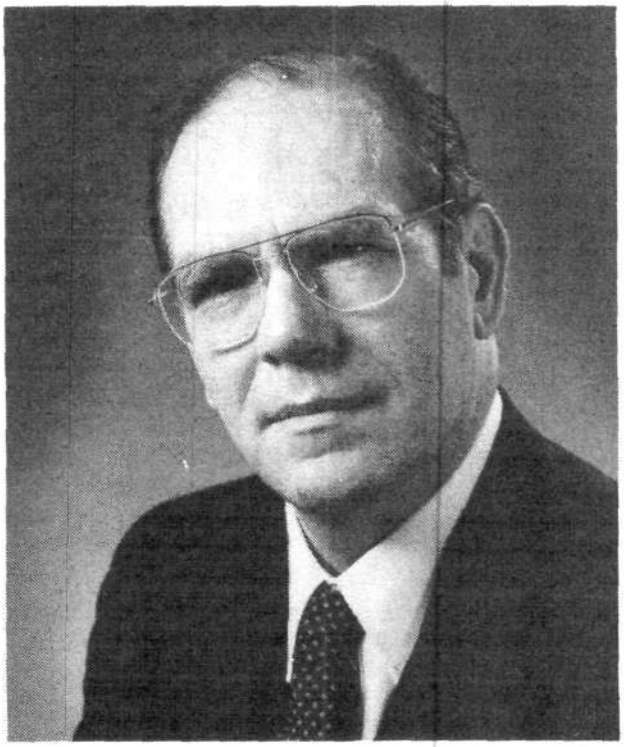
D.R. Roseth
Indianapolis, Indiana

The Editor Replies

It seems to us that you are on the right track. Although Mr. LaRouche was not available for comment, he has discussed your point at length in the article "A Theory of Development for African Labor," in the June 1979 issue of *Fusion*, which we shall send you.

Readers are invited to send comments to *Fusion*, Suite 2404, 888 Seventh Avenue, New York, N.Y. 10019.

On February 26, this man will end the myth that most Americans oppose nuclear energy.



This is Lyndon H. LaRouche, a candidate for the Democratic Party's Presidential nomination. And February 26 is the date of the New Hampshire Democratic primary.

LaRouche is the only candidate who is totally committed to nuclear power. He is the only candidate who has already developed a comprehensive legislative package to provide for the adequate construction of nuclear plants and for the research and development of advanced energy sources like hydrogen fuels and fusion.

A victory for LaRouche will show that the American people reject the pro-environmentalist energy policies of Ted Kennedy.

Help Lyndon H. LaRouche Win in New Hampshire

Send your contributions to: Citizens for LaRouche,
P.O. Box 976 Radio City Station, New York, N.Y. 10019
Felice Gelman, Treasurer. A copy of our report is on file and available for purchase from the Federal Elections Commission, Washington, D.C.

Riemannian Model

Continued from page 22

it is made up of a relatively small number of critical sectors that intersect with one another through exchanges of credits and interlocking bills of materials. We thus have a "network" model of the primary economic interrelations. Auto, for example, uses 30 percent of the steel consumed in the United States; hence, there is a strong link between these two sectors, and so on.

The result is a more-or-less complex set of interconnections between the nodes (the critical sectors) with flows along each link determining the amplitude of activity at each node. The equations describing such a system depend on the strength and time lags of the interconnections.

Spectral Analysis

Spectral analysis is the mathematical tool that, when applied to a network problem like the economy, identifies the singularities. These singularities show up most prominently as resonances and feedback instabilities. Thus, a small change in the flow along one interconnection (because of credit availability, for example), can have a destructive effect that amplifies through the whole economy—as in the present case. Or, a relatively small investment in a critical sector can radiate rapid improvements in large parts of the economy out of proportion to the initial investment.

The analysis presented here of Volcker's credit strangulation is based on a first approximation of this model. The 24-sector model allows for a parametric specification of the changing interconnections between sectors when there is a credit squeeze. This first order effect then propagates through the economy as decreasing investment in one sector reduces its surplus production, which, in turn, decreases the investments possible in other related sectors in the next cycle, and so on.

The power of the model is its ability to capture the highly nonlinear interrelations in the economy, effects that are masked, either consciously or incompetently, in other economic models.

—Dr. Steven Bardwell

FEF News

Uwe Parpart (l.), FEF director of research, presenting an award to executive director Dr. Morris Levitt at the fifth anniversary celebration.

FEF CELEBRATES 5TH ANNIVERSARY

The FEF celebrated its fifth anniversary Nov. 30 at the Grand Ballroom of the Biltmore Hotel in New York City with more than 200 members and *Fusion* readers on hand. The highlights of the evening were the premier viewing of a half-hour color videotape of the FEF "life and times" and a personal appearance by popular *Fusion* columnist Benjamin Franklin.

Copies of the historic FEF videotape are available for sale or rental.

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As a member in the fast-growing FEF, you will receive one-year subscriptions to *Fusion* and the quarterly *International Journal of Fusion Energy*, member bulletins, and special rates for FEF conferences, seminars, and research reports. And your individual membership or sustaining membership will help ensure that the FEF continues its "firsts":

- the first (and only) group to expose sabotage at Three Mile Island
- the first exposé in October of how Iran was part of the Council on Foreign Relations' plan for "controlled disintegration" in the world economy.
- the first to expose that the only "secret" behind the U.S. classification policy is that it's holding back progress in fusion research and advanced science in general.

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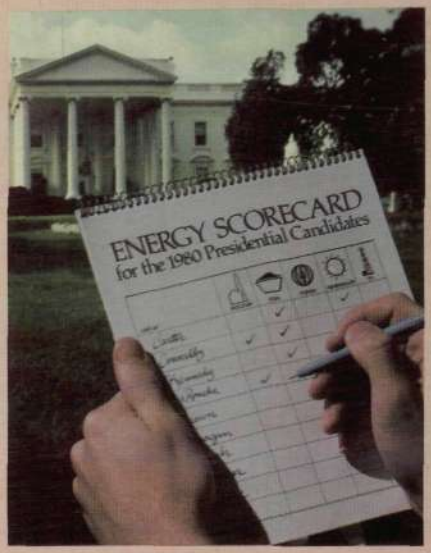


In This Issue

Energy Scorecard for the 1980 Presidential Candidates

We promised readers that we would pin the candidates down on the energy question, and we did. Our featured energy scorecard gives you a full rundown on the energy policies of 10 of the major presidential candidates.

Cover design by Christopher Sloan; front cover photograph by Philip Ulanowsky.

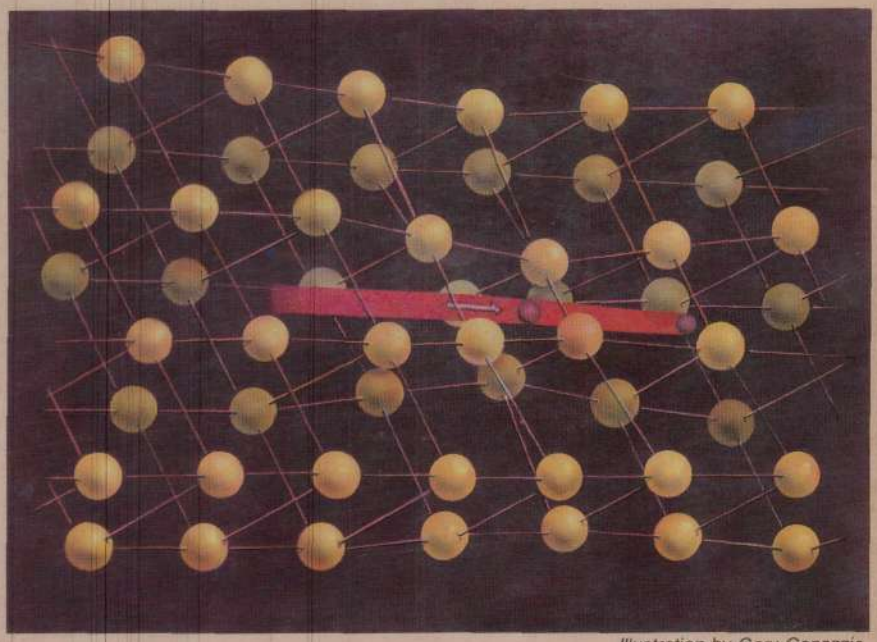
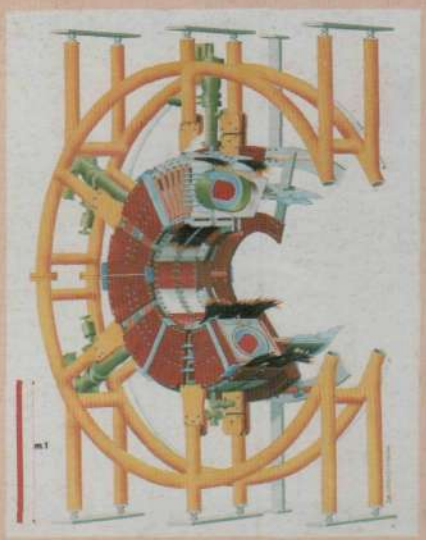


Illustration by Gary Genazzio

Prospects of Higher Temperature Superconductivity

Superconductors have a number of remarkable properties that promise exciting technological applications for transportation and power transmission. A pioneer in the theory of higher temperature superconductors, Dr. William A. Little gives a comprehensive update on the prospects of superconductor development.

An electron moving through a "lattice" of ions —its complex interactions produce superconductivity at low temperatures.



The Zeta Moves into First Place in Fusion

The reversed-field zeta pinch may soon overtake the tokamak in the race for commercial fusion. Charles B. Stevens presents the telling story of one of the first approaches to fusion in the 1940s that has recently come into prominence.

An artist's rendering of the Eta Beta II zeta pinch at the University of Padua, Italy.