FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION

January 1979

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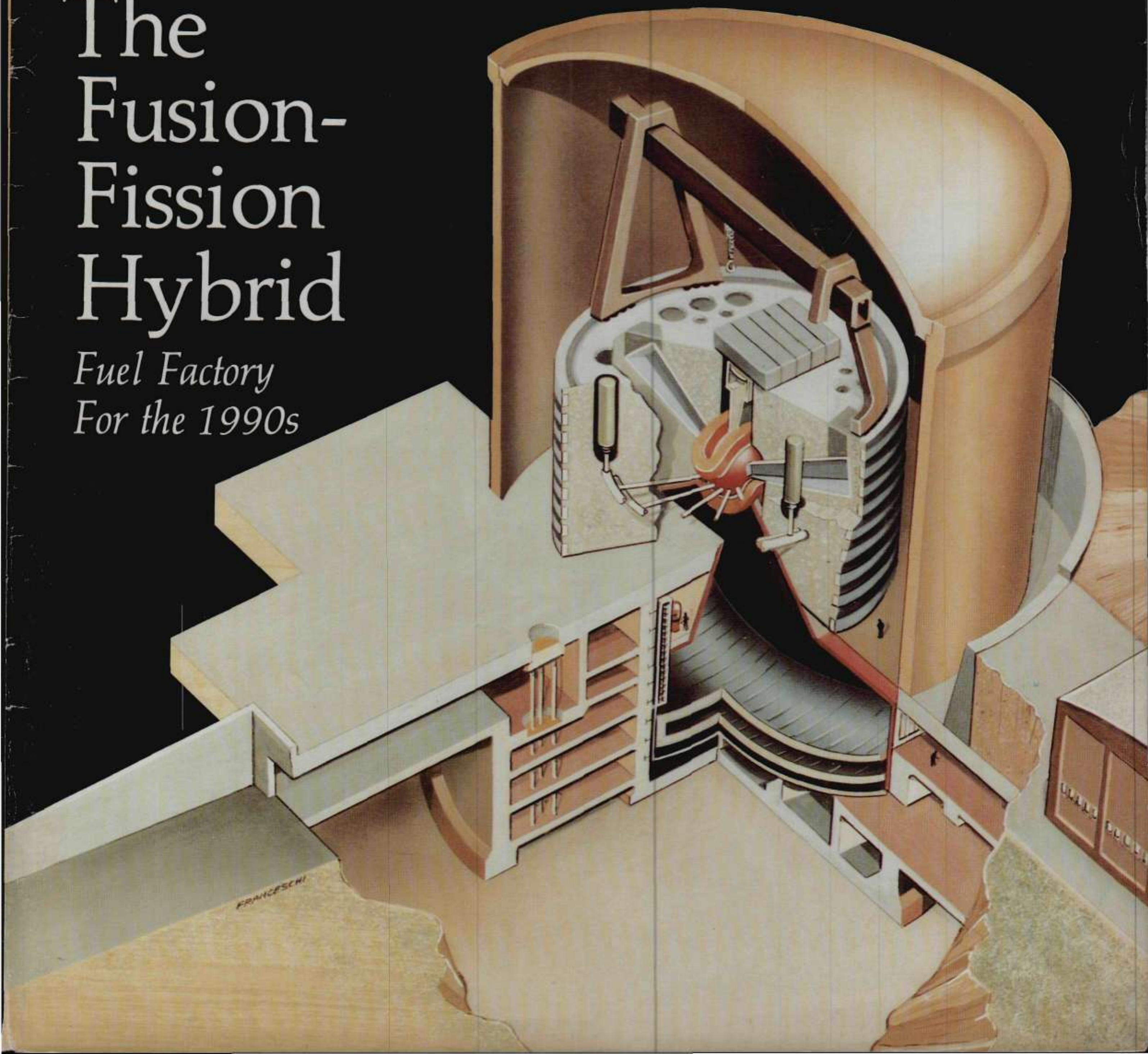
The Fusion-Fission Hybrid

Fuel Factory For the 1990s



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Features

News

Departments

Editorial

Time for Declassification

The opening session of the International Scientific Forum on an Acceptable World Energy Future in Miami in late November witnessed a novel event. Scientist Edward Teller asked Congressman Carl Pursell of Michigan if classification of laser fusion research made it impossible for the congressman's staff to evaluate the status of research in the field. Pursell's answer was "Yes!"

Teller, one of the first researchers on the fusion-fission hybrid breeder and a prime force in the founding of Lawrence Livermore Laboratory, where most of the classified laser fusion research takes place, is also an outspoken advocate of complete declassification of civilian laser fusion research. His opponents on this issue have raised the same specter that has been used to block the development of the plutonium fission breeder in the United States—proliferation of nuclear weapons.

What are the "secrets" of laser fusion, and how is the national security of the United States affected by the classification policy?

The Antiproliferation Argument

The antiproliferation argument for classification holds that of course there are not many secrets to be guarded from the Soviets, who have a comparable research program. The problem, the argument goes, is with smaller, unstable countries. For such a country to build up a significant nuclear arsenal, there are two possible approaches. It can build a lot of simple fission A-bombs, which requires a lot of enriched uranium or plutonium and the associated infrastructure for enrichment and then delivery of the bombs. Or the nation can build a few thermonuclear devices of much higher explosive energy, which requires much less fissile material, only the amount required to initiate the implosion of fusion materials such as deuterium and lithium at the core of the bomb.

The connection between bomb-building and laser fusion research (or other forms of inertial confinement) in this antiproliferation argument lies in the target pellet design. Laser fusion research is ostensibly under control of the Divison of Military Applications of the Department of Energy because laser-driven microexplosions simulate the implosion and explosion characteristics of large-scale bomb systems. Therefore, the proliferation argument goes, if the details of target design and performance are available, this will make it possible for any nation to build thermonuclear weapons.

Before responding to this simplistic argument, let us take note of the earlier history of fusion classification and the current effects on U.S. research. All fusion research, magnetic confinement as well as weapons, was classified by the United States up to 1958, several years after the Soviet Union detonated the first hydrogen bomb in 1953. Magnetic confinement research here was conducted under the rubric of Project Sherwood, which, as former director Amasa

Bishop recalls in his history, was intended to demonstrate that controlled fusion could *not* be easily achieved. Specifically, it was feared that fusion could be used to breed the then-scarce fissile material in an early version of a fusion-fission hybrid.

The Project Sherwood example illustrates the close historical connection between classification and the obstruction of commercial development of nuclear energy. Nonproliferation, whether of fission or fusion materials or knowledge, was also the watchword of the opponents of nuclear energy development during the 1940s and 1950s, including Baruch, Acheson, Lilienthal, Oppenheimer, and Conant.

The Soviets ended this phase of the history by unilaterally declassifying their magnetic confinement program in a famous talk by I.V. Kurchatov at Harwell, England in 1956. A decade later, the initial report of success in the Soviet tokamak opened the door to widespread international cooperation in this area of research, which has played an indispensable role in making the tokamak into the leading fusion device. In 1969 the Soviets also unilaterally presented aspects of their laser fusion research, reporting on the first laser fusion neutron yields. The United States in 1972 partially declassified its inertial confinement program, and some aspects of electron beam and related inertial confinement research were also released in 1975.

Closed-Door Science

The present situation, however, is exactly as summarized by Teller's question to Congressman Pursell. There is no way that the scientific quality of the laser fusion program can be assessed or advanced by interaction with scientists outside the program, since the facts of the basic physical processes taking place in highly compressed matter are kept secret. Thus, when Soviet electron beam researcher Leonid Rudakov lectured here two years ago on the mechanisms of energy deposition, conversion, and compression (involving prominently soft X-rays), his talk and all evaluations of it by U.S. scientists were classified. The FEF so far has been unsuccessful in getting the information released under the Freedom of Information Act.

Two recent cases illustrate the fact that the overall trend in classification is back toward the original blanket restriction. At Los Alamos the research on fast imploding liners (crushing cylindrical conductors and the plasmas inside them with huge, pinching magnetic fields generated by currents in the liner) has been threatened with removal from the civilian program and placement under the more restrictive Division of Military Applications. Meanwhile, a technology ready to contribute immediately to nuclear power generation, laser isotope separation and enrichment of fissile fuel, remains classified and thereby removed from the commercial fuel cycle.

The most fundamental point is that energy-dense plasmas are precisely the area of investigation most likely to yield basic advances in physical theory. The study of the lawful but nondeterminist succession of plasma states (or phases) is crucial to overcoming the apparent paradoxes of modern physics and unifying the present quantum and relativist theories in a more advanced conception of space-time-energy. Inertial confinement research is the best available domain for directly investigating the types of critical phenomena and self-ordering structures that otherwise characterize the microscopic and the astrophysical domains. Classifying this area, therefore, is tantamount to ruling out investigations of cosmological or accelerator-produced fusion. Or, to take an example from biology, it is like classifying the study of DNA.

Surely the nation should already have learned the historical consequences of such inquisitions, whether directed at Galileo or more contemporary figures such as Cantor and Schroedinger.

The most important effect of this kind of action is not on the outside world, but on the United States. A case in point is the inability of U.S. scientists publicly to discuss critical aspects of the controversial approach to laser fusion (in-

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Calendar

January

4-5
Laser Plasma Interactions Conference
Institute of Physics
Bangor, Wales

14-17
AIF Seminar on Legal
and Legislative Affairs
Atomic Industrial Forum
Las Vegas, Nevada

15-17
National Education, Business,
and Labor Conference on
Energy-Related Vocational
and Technician Training, Employment
and Public Energy Awareness
DOE
Washington, D.C.

26-28
Northern Nevada Energy Expo
Nevada Department of Energy
Reno, Nevada

29-31
1st Topical Meeting on
Fusion Reactor Materials
DOE, ANS, EPRI, AMMPE
Miami Beach, Florida

29-2
IAEA Symposium on Thermodynamics
of Nuclear Materials
International Atomic Energy Agency
Julich, West Germany

February

25-28
INFO 79
Atomic Industrial Forum
Kansas City, Missouri

26-28
6th Energy Technology Conference
and Exposition
Government Institutions, Inc.
Washington, D.C.

27-March 2
Tech Ex '79
The Annual World Fair
for Technology Exchange
Dr. Dvorkovitz & Associates
Atlanta, Georgia

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volving large, thin-walled pellets and low laser power) reported by the highly respected Soviet Nobel Laureate Nikolai Basov. Whether Basov's approach is the most viable is of secondary importance. If all the underlying scientific conceptions cannot be identified and debated openly, and the appropriate hypotheses formulated for unique testing experimentally, then there is an inadequate scientific basis for the program.

An even more immediate danger is that ion beam fusion research will be derailed by the classification constraints, even if the present lack of funding is overcome. Leading high-energy particle scientists such as Nobel Laureate Burton Richter of Stanford University have pointed out that there is no known physics obstacle to efficient heavy ion beam fusion. The basic physics of energy deposition of the beam particles into the target is well understood (although collective effects may prove more complicated), and accelerators can be modified or built to produce the beam power required. Dr. Ron Martin of Argonne National Laboratory has argued that the first crucial tests—the construction of an ion source to provide proof of principle—can be done for only $10 million. But Richter has also warned that the program will get nowhere as long as the classification strictures stand.

A Responsible Solution

What then of the proliferation argument? The basic knowledge required for H-bomb design is already widely known. That's how the Soviet Union, Great Britain, and France independently developed thermonuclear capabilities, even though the detailed blueprints of specific weapons systems have presumably been kept secret.

Once a nation has a high enough concentration of scientists, especially those with international experience, and a modest industrial infrastructure, the question of whether or not to build thermonuclear weapons is basically political. The knowledge made available from inertial confinement experiments may be significant for providing information on reliability, megatonnage, cleanness or dirtiness of untested weapons, but it is not in itself decisive.

There are only two things that responsible thermonuclear nations can do to prevent the development and deployment of such weapons by unstable nations. The first is to make clear to all that any nation that deploys nuclear weapons immediately will cease to exist through concerted action by the major powers against the offender, rather than against each other. The second is to launch massive economic development for troubled areas, depending heavily in this effort on transfer of nuclear technology and acceleration of fusion development. Likewise, since scientific progress cannot be outlawed, the amount of international collaboration must be maximized.

As long as those policies are adopted, and the United States is constantly mobilizing its in-depth scientific and technological capabilities to maintain leadership in both civilian and military research, everything possible is being done to ensure war-avoidance and national security. The full sharing of scientific information is indispensable to these objectives, and to eliminating adversary relationships between the U.S. and any other nation.

A world of 7 billion people in the year 2000, with an average standard of living converging on the level now enjoyed in the advanced sector, will require the rapid introduction of fusion power no later than that point in time. All promising avenues of controlled fusion must be fully developed without crippling restrictions.

Classification of any form of energy research has become a threat to national security. It's time to end it.

This editorial statement on classification is signed by the following FEF staff and board members who work in related areas: Dr. Steven Bardwell, plasma physics; Jon Gilbertson, nuclear engineering; William Cornelius Hall, nuclear shielding materials; Dr. Morris Levitt, physics; Uwe Parpart, physics; Dr. John Schoonover, nuclear physics; and Charles B. Stevens, fusion engineering.

The Lightning Rod

My dear friends,

I am distressed and saddened to think my experience in government might have prevented the recent horror at Jonestown, and doubly so when I hear on every side that the Constitution to which I put my name now prevents our public men from doing their duty to apprehend the perpetrators of such sordid crimes. Those who hold to this opinion—among whom I am sorry to see my namesake Benjamin Civiletti of the Justice Department—compare unfavorably in educated intelligence and moral fiber to Louix XVI.

Louis was not the wisest of rulers, but sufficiently respectful of God and Natural Law to refrain from assertions that the earth is flat. He also took advice.

I had the honor once to service King Louis and France in the affair of Pierre Mesmer, a case which could have ended in tragedy as bleak as that in Guyana. It was resolved somewhat more satisfactorily thanks to the efforts of my dear friend Lavoisier, the distinguished chemist, and others appointed to a Commission to investigate Mesmer by the French Royal Society of Medicine, among whom I was one.

In 1778, Mesmer, masquerading as a scientist and physician, came to Paris from Vienna under highly suspicious circumstances. Mesmer publicly espoused a theory of "animal magnetism": he claimed a magnetic fluid governed the health of the human mind and body. Enjoying a great vogue, he treated scores of patients at once, binding them together and

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News Briefs

KAPITSA 'VERY OPTIMISTIC' ABOUT THIRD WAY TO FUSION

At his acceptance speech for the Nobel Prize in physics Dec. 8, Soviet Academician Petr L. Kapitsa told the audience that he would not talk about his low temperature work, for which he was awarded the prize. It was done 40 years ago, and "I've forgotten all about it," he said.

Instead, Kapitsa spoke about his exciting work in thermonuclear fusion over the past 20 years. The highlight of the Kapitsa talk was what he called the "third way" of getting fusion. Terming the tokamak and laser fusion ultimately "impractical," Kapitsa said that to make use of fusion's "cheap energy" we must take advantage of the advanced self-ordering processes in the plasma. Using energy-dense microwave plasma discharges placed inside strong external magnetic fields, Kapitsa said that a few months ago he produced electron temperatures three times larger than those in the sun, under stable conditions. I am "very optimistic" about the prospects for such a path to commercial fusion, Kapitsa said.

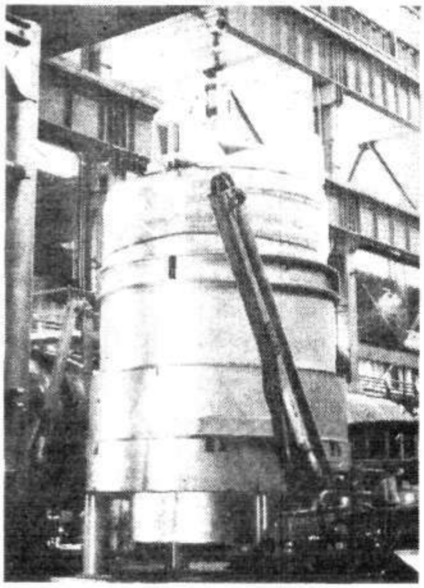
A full report on the Kapitsa speech will appear in the next issue.

DOE TO AXE HTGR, BREEDER PROGRAM

Highly placed Washington sources report that the Department of Energy has decided to eliminate funding for the high temperature gas-cooled reactor (HTGR) in the fiscal year 1980 budget. The proposed DOE budget was sent back to the Department by the Office of Management and Budget in November for a reported 20 percent overall cut of $2 billion.

Also scheduled for cuts are the gas-cooled fast breeder reactor project (cut from $26.9 million to $25 million) and the construction of the liquid metal fast breeder reactor at Clinch River, Tennessee. Reportedly the administration intends to fund improvements for light water reactors instead of developing a breeder program.

One industry source said that a mobilization is underway among the utilities, 70 of whom are involved in the development of the HTGR, to lobby to get something for the HTGR included in the 1980 budget so that when the budget goes before Congress, there will be a budget line that can be increased.



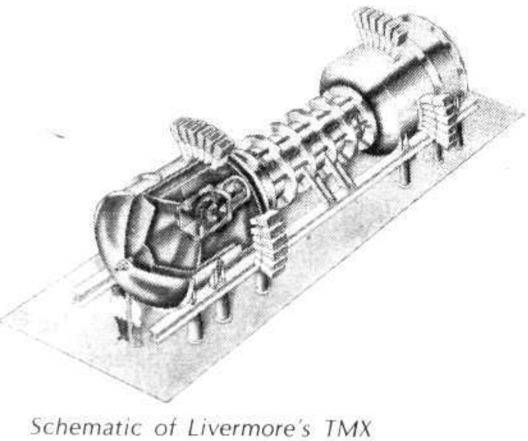
Axed: The Clinch River Reactor

FPCC REVIEWS MAGNETIC FUSION PROGRESS

The Department of Energy's Fusion Power Coordinating Committee held their quarterly meeting at Lawrence Livermore Laboratory the week of Dec. 4 to evaluate the progress of the magnetic fusion program and discuss the upgrading of specific experiments.

The committee discussed the possibility of improving the Tokamak Fusion Test Reactor under construction at Princeton University, which is planned as the first tokamak to reach energy breakeven. It was agreed that upgrading the pulsed neutral beams used for heating from .5 second pulses up to 1 or 1.5 second pulses could extend experimental results significantly beyond breakeven. This would follow the results of previous fusion experiments, where actual results with budgeted equipment outstripped expectations and projections.

The TMX Tandem Mirror Experiment at Livermore, one of the projects reviewed, is completed and in operation, with results expected in the next six months.



Schematic of Livermore's TMX

ELMO BUMPY TORUS CHOSEN AS ALTERNATE FUSION CONCEPT

The Department of Energy advisory committee evaluating various non-tokamak magnetic fusion concepts for increased department funding has chosen the Elmo Bumpy Torus at Oak Ridge National Laboratory as the most

Continued on page 6

Robert Thorne

John Deutch

Continued from page 5

promising candidate for "proof-of-principle" funding in the fusion program. The committee's recommendation has been approved by assistant secretary for energy technology Robert Thorne and is awaiting approval from energy research director John Deutch.

The present magnetic fusion budget of $350 million allocates approximately $15 million for the funding of nontokamak experiments. It is expected that this allocation will be increased, perhaps in fiscal year 1980, by between $1 and $5 million to bring the Elmo Bumpy Torus experiment up to scientific feasibility in the next few years. This proposal is in line with recommendations by the Ad Hoc Experts Group (The Foster Committee) review of the fusion program earlier this year to increase the breadth of the magnetic fusion program.

THORNE RESIGNATION EXPECTED; DEUTCH TO TAKE OVER?

John Deutch, director of the Office of Energy Research in the Department of Energy will take over the duties of the DOE's assistant secretary for technology Robert Thorne when Thorne resigns in the near future, according to reliable reports circulating in Washington. Thorne, who reportedly was pressured by Energy Secretary Schlesinger into resigning, is known as the highest-ranking official in the DOE with a positive attitude toward the development of nuclear energy. The move is seen as a consolidation of the antitechnology faction in the department since Deutch has favored policies that would delay the breeder reactor development and he advocates slowing down the tokamak fusion schedule.

There is also growing speculation in the press that Schlesinger will soon leave the DOE.

FEF CRITICIZES IRG NUCLEAR WASTE REPORT

The Fusion Energy Foundation submitted its comments on the recently released draft "Report to the President by the Interagency Review Group on Nuclear Waste Management" Dec. 4. The FEF scored the Interagency Review Group for its failure to recommend a preferred waste management program, even though the report had made it very clear that there are no technological problems remaining to the safe disposal of nuclear wastes. The IRG report instead proposed to study the various alternatives further and then leave the decision up to "the general public." As the FEF noted, this is a sure way to make certain that nothing gets accomplished.

According to the FEF, the disposal of nuclear wastes is a federal government responsibility and must be considered a matter of national security and priority. Implementing such a program should not be based on a so-called democratic decision involving agreement of state, county, city governments, and individuals but should be implemented by federal directive.

NONPROLIFERATION POLICY A DISASTER, SAYS WASH. POST

The *Washington Post* ran a series of articles titled "The Global Majority: Going Nuclear" during the first week in December that reviewed the problems of Third World countries in developing commercial nuclear power programs. Although many problems exist, the *Post* concluded, these countries are freely committed to nuclear development and are proceeding — with or without the United States.

The gist of the *Post* series is that the administration's nuclear nonproliferation policy has been a political and economic disaster for the United States. "Whatever the Carter administration's desire, there is no long-term way of halting the spread of sensitive technologies to the more advanced developing nations ... it's too late to halt the spread of nuclear energy."

Author Milton R. Benjamin wrote: "From Iran to South Korea, the one phrase that crops up in every conversation is 'Transfer of Technology' .... The new U.S. nuclear nonproliferation act ... is regarded by many foreign officials as a major blunder." Another article headlined, "U.S. Export Policy Cripples American Nuclear Industry," concluded that if the United States would only resume the role of reliable supplier, most developing countries would prefer to buy nuclear reactors from U.S. firms.

N.H. GOVERNOR-ELECT WILL NOT BACK SEABROOK BONDS

New Hampshire Governor-Elect Hugh J. Gallen announced Dec. 8 that the state would not back the $400 million in bonds needed to complete construction of the Seabrook nuclear power facility. Gallen defeated the pronuclear Meldrim Thomson Nov. 7.

If the bond issue fails, it will reverse the major victory won in August 1978 when the Environmental Protection Agency and the Nuclear Regulatory Commission gave the final go-ahead for the Seabrook nuclear power plant. During his campaign, Gallen promised to eliminate the 9 percent construction work-in-progress surcharge paid by customers of the Public Service Company of New Hampshire to help finance the plant. The company has warned that the elimination of the surcharge could force a halt in construction of the $2.3 billion plant.

U.S.-SOVIET ENERGY ACCORDS UP FOR EXTENSION

The U.S.-Soviet five-year cooperation agreement on energy, which encompasses potential joint work in 14 project areas, expires June 28, 1979, unless the United States requests an extension by the end of December. According to Article 9 of the accords, if either side wishes to change the agreements it has to indicate this six months before the expiration date. A spokesman at the U.S. State Department said that the final decision on U.S. extension will be made by the National Security Council.

Although the energy pact covers a wide variety of areas, its most successful program has been magnetohydrodynamics. (Nuclear energy and fusion energy are covered in separate agreements.) The Soviets, according to Department of Energy sources, have hesitated to initiate cooperation in solar, geothermal, and various other soft technologies, all areas on which the DOE is projecting to spend a considerable amount of money in the next fiscal year.

FEF HOLDS STOCKHOLM CONFERENCE

An FEF conference in Stockholm, Sweden Dec. 7 and 8 on the theme "The Next Step in the Nuclear Age" drew 70 participants, including representatives of Swedish and Danish heavy industry, trade unionists, leading nuclear scientists, and several diplomats. The speakers included Jan Rydberg and J.O. Liljenzin of Chalmers Technical University in Gothenberg, Per Persson and Jan Bergstrom of the Royal Technical University in Stockholm, and several FEF scientists.

A full report will appear next month.

UN DEVELOPMENT FORUM WINS LOUSEWORT LAURELS

This month's lousewort laurels multilingually go to the Center for Economic and Social Information, publishers of the United Nations *Development Forum*, a monthly newsletter in five languages devoted to reporting on environmentalist issues. Although the entire November-December issue is worthy of the lousewort, we cite two items in particular. First, this issue initiated a new department called "the appropriate column," which focuses this month on how to build a mud, straw, and cowdung stove.

Second, a little item titled "Native wisdom tops experts." This reports the fact that visiting researchers found that Nigerian farmers had already begun to attack the crop-eating multicolored grasshopper by digging up the egg-laying sites and killing the eggs.

We quote: " 'Thank God these farmers don't publish scientific papers,' said one abashed scientist. Remarks like these are welcome evidence of a growing realization that modern science does not have all the answers and that much can be learnt from the traditional wisdom of Third World farmers."

Washington

Energy Department May Slow Tokamak Program

The tokamak program may be hit with a go-slow budget from the Department of Energy in order to expand alternative nontokamak fusion research programs, according to reports from DOE sources in Washington. Scientists at Princeton Plasma Physics Laboratory have estimated that if the department slows down the tokamak program and does not go ahead now with the design for a prototype tokamak reactor, it could delay the commercialization of fusion as much as 10 years.

Until recently, it was understood that the tokamak as well as other magnetic confinement concepts would be brought to the engineering test facility stage once the concept demonstrated feasibility. Therefore, it was expected that plans for a tokamak test engineering facility would proceed as a matter of course.

The 'Catch-Up' Theory

Recently, however, Dr. John Deutch, head of the DOE Office of Energy Research, made it clear that only one prototype fusion reactor will be built and that is is too early to tell which magnetic fusion configuration—the tokamak, the mirror, or others—will be chosen for the prototype. Deutch has recommended that the alternate nontokamak fusion concepts be allowed to "catch up" to the tokamak program before a decision can be made to go ahead with the engineering test facility for the tokamak.

The engineering test facility was expected as the next step in the fusion commercialization process after the Princeton Tokamak Fusion Test Reactor, which should demonstrate the scientific feasibility of the tokamak geometry by 1983-1984. The logical procedure would be to begin to design the test facility now while the TFTR is still under construction. But Deutch has said that a decision will not be made on which magnetic fusion configuration will be chosen for the prototype until at least the mid-1980s and perhaps even later if the nontokamak designs have not yet "caught up."

To justify a slowdown in the highly successful tokamak fusion program, Deutch and the DOE are using the Ad Hoc Experts Group review of the fusion program, a study completed for the DOE last spring. The experts group, known as the Foster Committee after its chairman, Dr. John Foster of TRW, recommended that the DOE pursue parallel research programs in fusion magnetic confinement alternatives, but did not call for slowing the tokamak program.

Deutch began using the Foster Committee report against the tokamak program in his testimony on fusion before the House Science and Technology Committee Sept. 18 and in the DOE "Policy for Fusion Energy" paper he submitted to the committee.

World Fusion Going Tokamak

The go-slow policy for the tokamak comes at a time when scientists in the international fusion community are in agreement that the tokamak is the most promising fusion design for first-generation reactors. For that reason the Soviet Union, Japan, and Western European governments have made the decision to put most of their effort in magnetic fusion into tokamak development.

In any case, the go-ahead in engineering and design for tokamaks should not preclude development of alternate concepts, because the experience and hardware developed for tokamaks is necessary and applicable to all fusion research.

At a November meeting of the Council for the Advancement of Science Writing in Tennessee, Dr. John Clarke, deputy director of the DOE Fusion Office, assured the group that the Foster Committee's recommendations stress pursuing parallel programs and "absolutely do not" mean a slowing of magnetic confinement work, according to a *Science News report* Nov. 25.

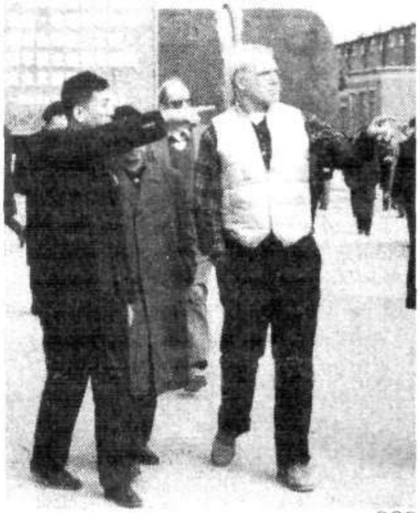
Nonetheless, the latest budget reports indicate that the entire magnetic fusion program will receive no increase in funding in fiscal year 1980. Therefore, if resources are beefed up in the alternate concepts areas, the funds would have to come from the existing tokamak programs.

1980 DOE Budget Under Revision

The Office of Management and Budget sent back the Department of Energy's budget request for fiscal year 1980 for revision, Nov. 29, sources in the department reported. It is expected that the overall DOE budget will be cut approximately 20 percent—$2 billion—before it is presented to Congress by the administration.

The major part of the cuts is expected to come in the most costly DOE program areas. The most likely candidates are the short-term fossil fuels programs, which Congress trimmed by $55 million in fiscal year 1979, and the programs to commercialize near-term intermediate (soft) technologies.

The DOE Office of Fusion does not anticipate a substantial cut in the magnetic fusion program for the coming fiscal year, but it is not clear whether the planned small increase in the magnetic fusion program (from $350 million to $365 million) will stand up to the cost-cutting budget parameters set by the Office of Management and Budget.



DOE

Schlesinger in China

Announce U.S.-China Fusion Plan

An "agenda for cooperation" has been established for cooperation in energy research and development, including magnetic fusion, between the United States and the People's Republic of China, Energy Secretary James Schlesinger announced at a press conference in China Nov. 4. The agenda was the result of his discussions with senior Chinese energy officials, Schlesinger said.

Agenda items include joint development work in expansion and modernization of coal production, hydroelectric facility design and construction, "renewable" wind and solar resources, and programs in high energy physics, nuclear physics, and magnetic fusion.

DOE officials indicated that the Chinese fusion effort probably came out of the weapons program, but U.S. fusion scientists think that the Soviets were instrumental in developing the program.

International

Schlesinger Predicts Oil Crisis

Speaking in London Nov. 30, U.S. Energy Secretary James Schlesinger confidently predicted a new world oil crisis.

Schlesinger told the London meeting of the Pilgrim Society that recent events in Iran, Afghanistan, Yemen, and the Horn of Africa have badly shaken the stability of the world's largest oil-producing area, the Persian Gulf. "Whatever the intent," Schlesinger said, "the pattern of events has created the perception in the Gulf States of the prospect of encirclement."

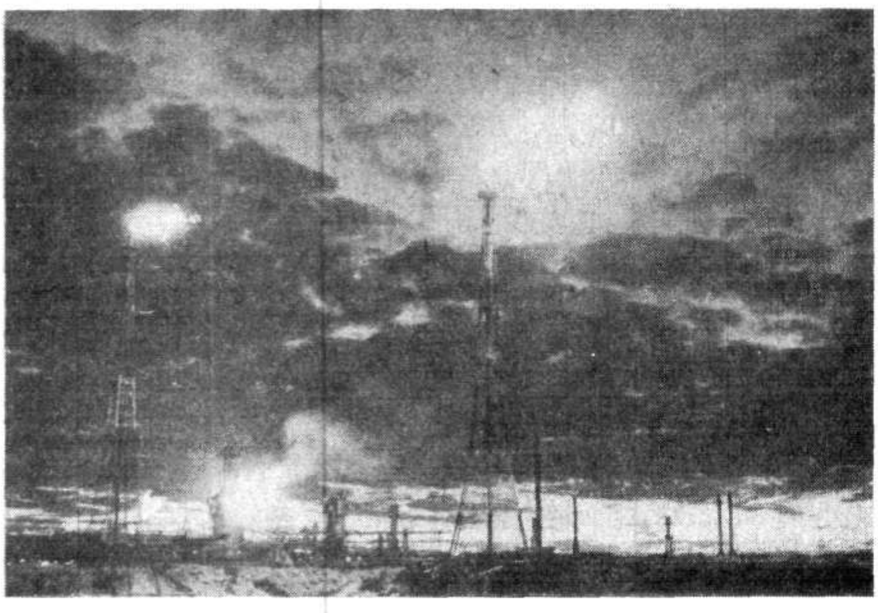
The Schlesinger scenario, which is premised on success of the ongoing destabilization against the Shah of Iran, includes an aggravated rerun of the 1973-1974 world oil hoax. According to the Schlesinger outline, this will provide the pretext for the blackmail of Western Europe and Japan and the forced economic depression here.

However, what Schlesinger did not say is that the stated position of the Gulf governments is to maintain production, since their economic well-being is directly linked to that of the United States and the rest of the advanced sector.

Schlesinger warned that industrial countries had to make "adjustments"—by which he meant severe cutbacks in energy consumption—or face serious economic difficulties.

Schlesinger's oil crisis scenario also includes DOE contingency plans for a gas rationing crisis here. As if to fulfill the Schlesinger scenario, Royal Dutch Shell Oil Co. began in early December to force gasoline prices up to the $1 per gallon level repeatedly predicted by Schlesinger. Shell announced a 25 percent cutback of its supplies and initiation of gas rationing to its dealers. Although Shell claimed shutdown of two of its refineries as the reason, both refineries are reported reopened.

The energy secretary intends to call for legislative decontrol of national gas and oil prices when Congress reconvenes in January to force energy consumption cuts by pushing prices toward the $1 level.



Iranian oil fields: part of the Schlesinger scenario

Venezuela and Brazil Sign Nuclear Deal

Brazil will provide Venezuela with nuclear equipment and technical training for construction of that country's first reactor during the 1990s, according to an extensive bilateral energy and commercial agreement signed in Brasilia Nov. 23. The agreement provides for integration of the petroleum and aluminum industries of both countries, and includes a nearly two-thirds increase in Venezuelan oil sales to Brazil. Brazil will also aid in the exploration and exploitation of Venezuelan uranium reserves.

The treaty is the first case of Brazil reexporting the nuclear technology and knowhow it has been provided through its 1975 nuclear deal with West Germany.

The far-ranging energy package is the most striking example of the activity throughout Latin America around energy cooperation and development. Last month an agreement for energy cooperation was signed between Venezuela and West Germany. Among other things, the agreement calls for an investigation of how West German nuclear technology might be applied to the exploitation of the large petroleum deposits in Venezuela's Orinoco River Basin.

The new energy deals are encouraged both by the new finds of huge oil deposits in Mexico and by the European-Japanese campaign to integrate Latin America into the European Monetary System's plan for worldwide industrialization.

The signing of nuclear cooperation deals also figured prominently in the two-week tour in November of Spain's King Juan Carlos through Mexico, Peru, and Argentina. The king has referred to his role as a "bridge" between the European community and Latin America for furthering development.

Chinese Fusion Projects Underway

China has a handful of small tokamak experiments and is doing limited research and experimentation on nontokamak fusion designs.

The Chinese program was reviewed at Princeton Plasma Physics Laboratory by Dr. Li Jie-Shih last summer. Li, who is from the Institute of Physics of the Chinese Academy of Sciences in Peking, reported that the Chinese are doing fusion and plasma research now at eight locations.

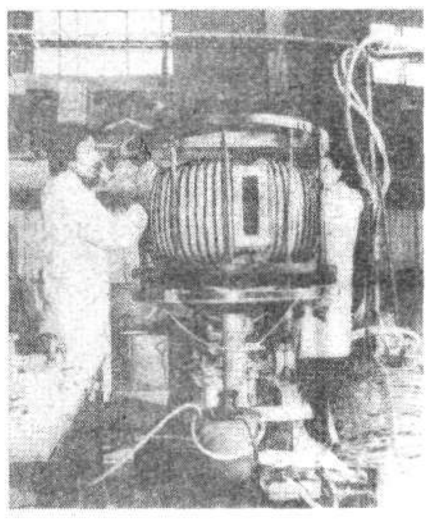
The CT-6 Tokamak is in operation at the Institute of Physics in Peking, along with a small theta-pinch device. A belt pinch is also under construction. At the Southwest Institute of Physics in Lo-Shan county, the Chinese are experimenting with a superconducting magnetic mirror device, and there are two small tokamaks, three pinch machines, and a medium-sized tokamak under construction.

At the Shanghai Precision Optics Research Institute, a neodymium glass laser system is carrying out six-beam implosion experiments, and at the remaining five locations other theoretical plasma work is ongoing.

Li reported that a new research institute, the Institute of Plasma Physics, is being established in Ho-fei, in An-hwei province. Its purpose is to build a tokamak, the CT-8, that will be a little larger than the Princeton Large Torus with a smaller magnetic field strength and neutral beam injection power of about 2 megawatts.

The Chinese fusion program began in the mid-1960s and, according to Li, has a comparatively low funding level and is behind the U.S. program.

Iran's Fusion 'Gets Better By the Day'



Iran's experimental tokamak.

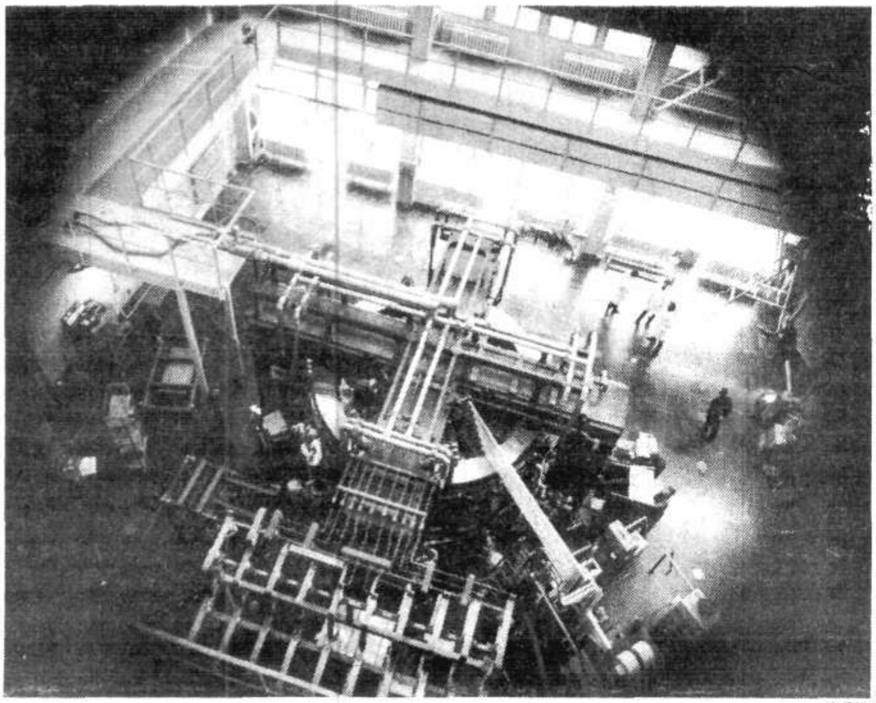
Piran Sioshansi, the director of Iran's nuclear research institute, outlined the goals of his country's small but forward-looking thermonuclear fusion program in a Dec. 7 *Washington Post* interview. The *Post* reported that most developing countries have modest nuclear research programs, but that countries like Iran and Brazil are determined to close the gap between them and the major industrial research giants.

According to Sioshansi, the scientists at the Iranian institute have bought a small experimental tokamak and have built a linear theta-pinch magnetic fusion device, second in size only to the one at the U.S. Los Alamos Scientific Laboratory. "Nobody expects us to have a breakthrough in fusion. But should the first fusion reactor be built in the year 2000, we don't want to have to go around looking for some idea of what fusion is all about," remarked the director.

"I'm sure that whatever they can do at Berkeley in a week, it will take us a year to do. But in certain specific areas," Sioshansi said, "we can already do first class sophisticated research. And like many developing countries, I think we are getting better by the day."

Soviets Plan Test Tokamak By 1990

In a feature article for the Soviet daily newspaper Izvestia Dec. 3, Academician B. Kadomtsev described the Soviet fusion program and the Soviet proposal to the International Atomic Energy Agency for a cooperative experimental tokamak to demonstrate feasibility. Excerpts from the article, titled "An Inexhaustible Source of Energy," appear below.



APN

The T-10 tokamak at the Kurchatov Institute in Moscow was a pioneer in the study of the magnetic confinement properties of tokamaks.

. . . In the spring of this year, Soviet scientists proposed that the International Atomic Energy Agency (IAEA) build an international experimental tokamak reactor, which could demonstrate the engineering feasibility of controlled thermonuclear fusion.

Today about 50 tokamak installations are in operation on our planet. Objective necessity and the whole course of the investigations dictates the need for building ever more powerful, and hence more expensive, installations. The Euratom countries are building the JET—a unified European tokamak. Similar large installations are being built in the USA and Japan. In our country the Tokamak 10-M is under construction, with superconducting magnetic coils.

Naturally, a unification of the efforts of various countries would not only cheapen but also hasten such work. That is why the proposal of the Soviet Union was unanimously adopted by the scientists of other states. The IAEA also accepted it. It was decided to create a working group of specialists on the projected international tokamak, including representatives from the Soviet Union, USA, the Euratom countries, and Japan.

I just returned from Vienna, where the first session of this group was held. A program of work for 1979 was laid out there, to determine precisely what such a tokamak reactor should be, what goals should be posed, and what results should be expected.

If everything goes the way scientists plan, then it is possible to make the following prognoses. Evidently, in the next four to five years of work on the installations now under construction, the physical feasibility of controlled thermonuclear fusion will be demonstrated. It will be shown under laboratory-experimental conditions that the thermonuclear reaction occurs, and occurs in a controlled form.

After this there will have to be a stage of technical demonstration that the reaction can be sustained for a long period of time, at a constant level, on the scale necessary for future thermonuclear power stations; that on this scale it can also be controlled; and that all the reactor's systems are synchronized and operate reliably. The minimum time for the planning and construction of such a reactor is seven or eight years. Thus in 10 years, somewhere close to 1990, we can expect the first results of such work, maybe not yet an industrial reactor, but a test model.

Seven or eight years after that, still in this century, the first thermonuclear electric power station will probably appear, which will show how this gigantic new source of energy can be used for peaceful purposes and how the problem of limited energy resources can be excluded forever from the whole future history of mankind.

As a rule—and history teaches us this—new sources of energy do not completely replace the old ones, but are rather joined with them in some kind of optimal system. If we speak of the turn of the 20th into the 21st century, probably coal, which there will still be a considerable amount of, will still play a certain role. Oil and gas by that time will already be used only for the chemical industry. Conventional atomic energy, plus fast breeder reactors, will be flourishing. Solar energy will be gaining a position for itself. As for thermonuclear fusion, it will probably begin to play an appreciable role some time around 2010 to 2020.

National

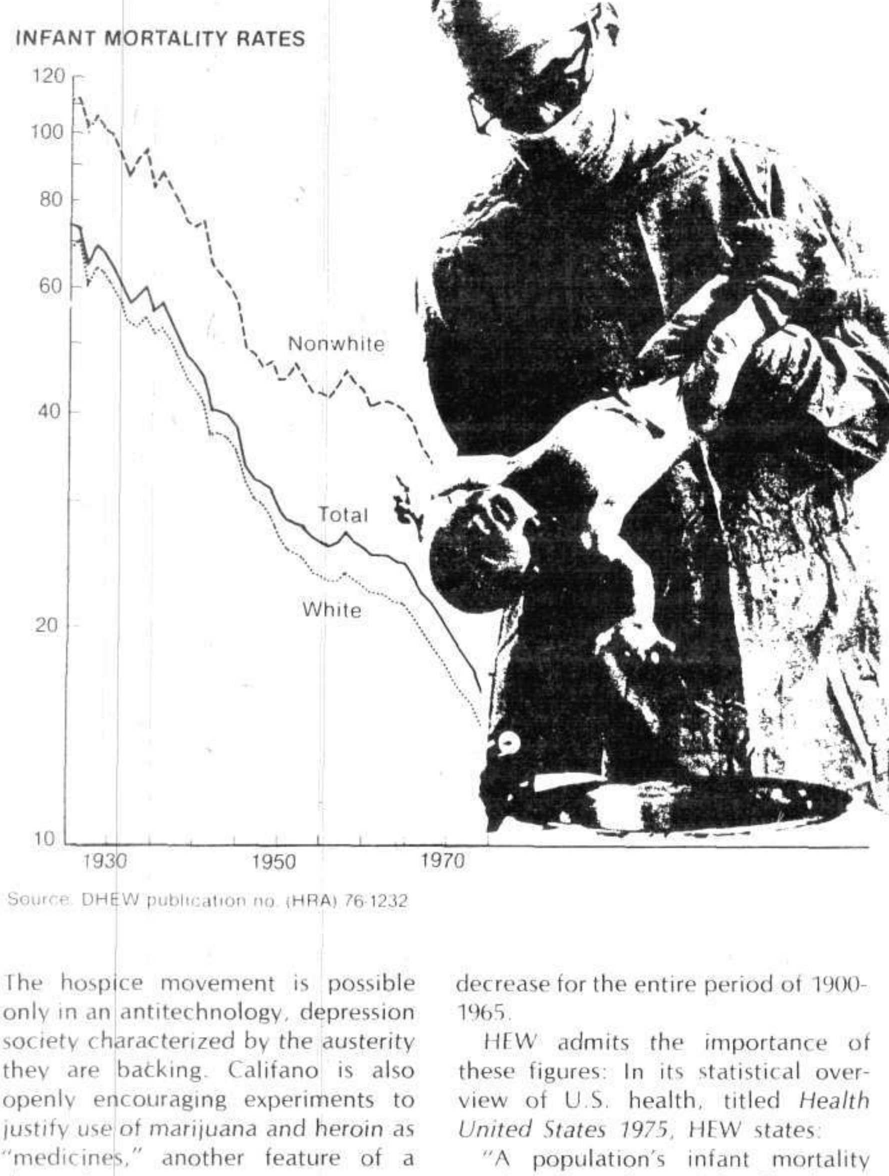
Carter Administration Plans Major Health Cuts

Joseph Califano, Secretary of the Health, Education, and Welfare Department, proposed to solve the problem of rising health care costs by cutting back the size of medical school classes. Speaking to the Oct. 24 meeting of the Association of American Medical Colleges, Califano said that an average physician over his average career of 40 years adds $12 million in health costs, implying that the United States would be better off without these services.

In a parallel move, President Carter's Office of Management and Budget is planning to make drastic cuts in federal health programs in the next budget and may eliminate some major programs altogether. Running to at least hundreds of millions of dollars, according to the *New York Times* Dec. 3, the cuts will include a $160 million cut in research funding for the National Institutes of Health and cuts in state grants for combating drug abuse, preventive medicine programs, and health technology assessment.

Although Massachusetts Senator Ted Kennedy called the OMB proposal a "serious, unacceptable, and unprecedented reduction in our health program," Kennedy's national health insurance proposal and related health legislation would go even further in cutting back health services under the guise of "universal health insurance." Kennedy's legislation, which he has made a bandwagon item for the next Congress, would reduce the quality of care by pushing a paraprofessional "barefoot doctor" policy, limiting funds for basic research in favor of "environmental screening," and decreasing hospital services by at least 6 percent annually.

It is no accident that Kennedy is also active in the "death with dignity" hospice movement or that Califano has endorsed the hospice concept. The hospice movement is possible only in an antitechnology, depression society characterized by the austerity they are backing. Califano is also openly encouraging experiments to justify use of marijuana and heroin as "medicines," another feature of a depression economy.



Source: DHEW publication no. (HRA) 76-1232

Health Programs Mean Better Health

Are the services that are being threatened with cutbacks really necessary? Statistics released by HEW prove that they are. Following the passage of Medicaid and Medicare in 1965, infant mortality plunged, and overall mortality dropped in the 1965-1975 period by a full 50 percent of the decrease for the entire period of 1900-1965.

HEW admits the importance of these figures: In its statistical overview of U.S. health, titled *Health United States 1975*, HEW states:

"A population's infant mortality rate is frequently considered to be an indicator of general health conditions. . . . The decline in the infant mortality rate over the 10 years since 1964 has averaged 4 percent per year. This decade of relatively steady decline follows a decade, from the mid-1950s to the mid-1960s, of mild fluctuations with only a slight decline."

HEW grudgingly admits that the increased access to advanced medical technology for low-income families through Medicaid was a factor in the post-1965 decline in infant mortality: "Children in low-income families have in the past received a considerably lower amount of ambulatory medical care than have children from higher income families. Recently, this difference in use has been greatly diminished. This change can be in part attributed to the advent of Medicaid and other programs aimed at increasing access to care for lower income children."

Equally impressive is the fall in the overall death rates of the aged population associated with Medicare and the dramatic increase in the life expectancy for 65-year-olds. In 1900 the life expectancy of 65-year-olds was 12 years; in 1960 it was 14 years. In the 10 Medicare years, 1965-1975, it increased by 1.4 years to a total of 16.1—an increase of more than 50 percent of the total increase during the entire period 1900-1965.

The present health care system is inefficient and ineffective, but not because of overproduction or overuse of advanced technology. Rather, there has been insufficient support of basic research to develop cures and preventions for the degenerative diseases such as cancer and heart disease, as well as a related, harmful neo-Darwinian reductionist approach to the basic questions of genetics, embryology, immunology, and so on.

Advanced medical technology, such as the computerized X-ray and the CAT scanner, would in fact have the opposite effect, increasing the efficiency of use of medical manpower with rapid diagnostic ability. In addition, the technology would be lower in price if more hospitals were allowed to buy the new technology and if the producers, with the increased sales revenue, were able to further improve their equipment.

—*Ned Rosinsky, MD*

A comprehensive review by Dr. Rosinsky of the U.S. health care system and the Kennedy health bill will appear in the February issue of Fusion.

Death Rights?

The chief spokesman for the right-to-die movement is Dr. Elizabeth Kubler-Ross. Formerly the director of psychiatry at the University of Chicago Billings Hospital, Kubler-Ross is now the chairman of the Hospice National Advisory Committee.

The model for the U.S. hospice movement is the St. Christopher's Hospice in London. There, the Brompton Mix, which contains heroin (legalized in England), cocaine, chloroform water, and other tranquilizers, is used to ease patients into death. Its advocates explicitly promote it as a substitute for expensive medical technology development that could prolong life.

Trained by the U.S. wartime intelligence organization in population control, Kubler-Ross has recruited and trained 75 hospice teams. She has been widely publicized in a cross-country tour to promote both death and her book, *Death and Dying*.

What is Kubler-Ross's private life like? *Newsweek*, May 1, 1978, quotes her claim that she communicates with the dead by traveling outside of her body with spirit guides and by receiving letters from the dead: "In one such visit nine years ago, Kubler-Ross asked a materialization of Mary Swartz, who had died days before, to write a note to a mutual friend, sign it and hand it over to her—which the doctor says the shade obligingly did," *Newsweek* wrote. Kubler-Ross described one of her "out-of-body" flights to the interviewer: "The moment I realized I was going at the speed of light horizontally, I switched and made a right-angle turn, rounded a big hill and went up. I knew I had probably gone where nobody had ever been. I felt super."

One particularly vicious product of the "right to die" movement is the "living will," in which people ask that in case of extreme mental or physical illness they be left to die without medical assistance.

Peculiarly Pronuclear

The Heritage Foundation, which has recently backed nuclear power, is holding a February conference in Washington, D.C. called "The National Conference on Energy Advocacy and the Nuclear Option."

The foundation's avowed advocacy of nuclear power bears watching. At the November conference of the Atomic Industrial Forum and the American Nuclear Society, the official Heritage Foundation representative, Angelina Howard, made a peculiar presentation. "Don't explain the technical aspects of nuclear waste disposal to the public," she told the pronuclear group. "Polls show that has an adverse effect."

Even more revealing is the study published by the foundation called "Closing the Nuclear Option—Scenarios for Societal Change." Written by Milton Copulos, a foundation policy analyst, the study outlines four predicted scenarios for national destruction that will occur if the United States loses the electricity provided by nuclear power. In fact, Copulos, who is supposedly pronuclear, predicts that the destruction of nuclear power is inevitable!

To quote from the conclusion of this Heritage Foundation pamphlet: "... The four scenarios [of national destruction] will only come to pass if certain policy choices are made. They need not occur. Indications are, however, that such situations will be made."

Copulos says that we should not worry if the U.S. nuclear program is destroyed because "an effective growth rate of 4.4 percent could take place under the above scenarios without any significant consequences."

Conferences

Miami Conference Evaluates Future Energy Technologies

Int'l Scientific Forum on an Acceptable Energy Future

The second Annual International Scientific Forum on an Acceptable World Energy Future, held in Miami Beach, Florida Nov. 27-Dec. 1, brought together a distinguished group of world leaders in science and industry to discuss the energy needs of the future and the technologies to meet them.

The starting point for the forum was progrowth and pronuclear. At last year's conference a group of international participants issued a widely publicized communique stating that the world demand for energy would go up and that this demand had to be met by the advanced technologies of nuclear fission and fusion. To quote that *communique*: "There is an urgency to the world energy problem which, especially in view of the long lead-times, brooks no delay in determining and executing national programs and in seeking international cooperation to take up the tasks and share the benefits equally." Because this year's meeting was planned as a follow-up to match available and future technology with projected energy needs, a group of economists were brought in—including Tjalling C. Koopmans from Yale University, Dale Jorgenson and Hendrik Houthakker from Harvard University, and James Sweeney from Stanford University.

Unfortunately, the participation of the economists was not productive. Their monolithic econometric outlook reflected the negative views of environmentalists on energy growth, and contrary to rather elementary facts, they asserted that there is only a tenuous connection between energy growth rates and the GNP. In the strange world of systems analysis, the computer scenarios for the future are characterized by low energy growth and more labor-intensive production, and actually foreclose certain options for U.S. foreign policy, such as using high technology to aid the development of the Third World.

In fact, except for Bent Elbek, from the Niels Bohr Institute in Denmark, all the speakers on economics assumed a low-growth society in which there would be less, not more energy use—the opposite point of view from the conference organizers.

A Narrow View

Conference participants, especially those with an engineering or science background, were aghast at the economists' presentations. For example, an unconvinced Joseph Dietrich of Combustion Engineering asked Sweeney: "Do you really mean to tell me that a 50 percent cut in energy consumption would bring about only a couple of percent reduction in GNP?"

Other participants objected that the economic growth rate projection focused too narrowly on the United States, ignoring world political events that are likely to bring about dramatic policy changes affecting the present projections. Uwe Parpart, FEF director of research, asked Houthakker: "If we consider that Third World industrial development will be the major question affecting world peace in the coming years, can you simply ignore such policy issues when you make your world energy models? Would not a major development program necessitate much higher energy growth rates than those you project?"

Houthakker responded bluntly: "I don't think that energy will be a major factor in regard to Third World development problems, and we are dealing here with energy growth models, not world development. In any case, the less developed countries have many alternate energy sources such as windmills, cow dung and so forth."

The one significant contribution to the economic discussion came from Bent Elbek in the opening presentation, "Evolving Global Energy Balances and Constraints." By comparing energy intensity in different sectors of the economy, Elbek showed that energy intensity does not increase linearly with industrial development but reaches a peak and begins to go down. Advances in new technology, he said, make it possible to use less energy in industrial processing.

For example, Elbek said that Japan uses half the energy for its steelmaking — measured in tons of coke per ton of steel — than is used in conventional steelmaking with less advanced technology. Based on his calculations, Elbek said, we could support a world of 10 billion persons at present West German living standards with only four to five times the present energy. Only advanced fission and fusion are possible candidates for energy sources, to provide the additional energy, he said.

Positive Solutions

The high point of the conference, and the answer to the low-growth systems analysis scenarios, came in the third day of the conference, especially the morning presentations by nuclear physicists Edward Teller of Stanford University and Eugene Wigner of Princeton University on the specifics of future nuclear energy development.

In his talk on the thorium cycle, Teller made his perspective clear. It's a myth that solar, wind, and biomass are "renewable resources." Nuclear energy comes the closest to being "renewable," but "the only inexhaustible resource is human ingenuity." Teller then concisely outlined the fusion-fission hybrid based on the mirror system, and said that it could be commercialized here in 15 years.

Peter Murray of Westinghouse later criticized Teller's reliance on the

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FEF Meeting in Houston

U.S. Industry Must Chart Mexican Cooperation

More than 30 representatives from Texas oil and gas companies, high-technology export firms, and Mexican-American organizations attended an FEF conference in Houston, Texas Nov. 30 on the topic of fusion energy and Mexican oil.

"What is the connection between fusion energy and Mexico's oil? Why is the Fusion Energy Foundation sponsoring a keynote speaker on the Mexican oil finds?" asked FEF director Dr. Morris Levitt in his introductory presentation.

The answer: "If we can maintain the fusion energy program on track to guarantee the unlimited, clean and cheap energy of controlled thermonuclear fusion by the year 2000, then we can exploit existing oil reserves—and here's where Mexico's enormous potential comes in—at vastly increased rates. And that guarantees the basis for surging economic growth in both the advanced sector and the developing world starting now."

After reviewing the advances toward fusion of the past year and the remaining research hurdles, Levitt introduced the keynote speaker, Fernando Quijano, editor-in-chief of the *Executive Intelligence Review*, who had just returned from a several week stay in Mexico.

Quijano specified exactly what was at stake: "Mexico is talking about billions and billions of dollars in imports for its development projects, some of the biggest development projects in the world. At the beginning of this year, the official Mexican government estimate was that it needed $45 billion in capital goods alone over the next 10 years, both domestic and imported.

"Now, with huge additional oil finds revealed two weeks ago, the Mexican government has announced an across-the-board upward revision of all its development goals. We estimate that today a conservative figure for Mexican capital goods needs over the next decade will be $80 billion. Yet the United States, primarily through actions like Energy Secretary Schlesinger's sabotage of a U.S.-Mexico gas deal a year ago, is simply dealing itself out of enormous oil-for-technology deals."

Will The U.S. Deal Itself Out?

Quijano expressed amazement at the lack of knowledge in the United States of Mexico's development efforts, and the potential benefits for U.S. industry in exporting to the Mexican market. "Last week Mexican officials announced that they are gearing for 10 to 12 percent growth per year by the early 1980s, doubling their entire industrial plant in six to seven years. Along with everything else, this points the way to the solution of Mexico's gigantic unemployment problem, and with it, the problem of its unemployed workers seeking employment in the United States. Lopez Portillo has stated it many times, that he wants to see Mexico 'export goods, not people.' Yet people in the United States just aren't being informed about this."

Quijano concluded with the startling observation that perhaps by 1990, any fences along the U.S.-Mexican border would be "to keep U.S. citizens from traveling south to participate in Mexico's industrial boom and prosperity," and not to keep Mexicans from seeking work in the United States.

Dr. Uwe Parpart, FEF director of research, concluded the initial presentations with an attack on the U.S. government shutdown of its own nuclear industry, "which invokes fraudulent 'antiproliferation' arguments against nuclear exports and quack environmentalist ploys against domestic construction," he said. "Every government in the rest of the advanced sector and all in the Third World with nuclear programs — including Mexico — are keener than ever to push ahead with nuclear energy, but the United States is refusing to help itself by helping them."

A New U.S.-Mexico Entente

Much of the extended question period concerned how the meeting participants could reverse the deterioration of U.S.-Mexican relations by implementing the large-scale technology transfer and energy deals that the United States is missing out on.

This private sector initiative, Quijano replied, will be crucial to shift the United States away from its current confrontation course with Mexico over energy, immigration, and technology issues, and onto the track of real high-technology cooperation.

A well-attended press conference before the luncheon, plus three radio and TV interviews, brought the viewpoints of the conference to a wide audience in the Houston area.

During their stay in Houston, the FEF staff also toured the Johnson Space Center.

—*Tim Rush*

CDC Washington Seminar

Soviet Scientists Outline MHD Applications

Five Soviet scientists from the Moscow Institute of High Temperatures candidly discussed the Soviet Union's plans for near-term applications of magnetohydrodynamics (MHD) and new results on joint Soviet-U.S. experiments at a seminar held Nov. 5-6 in Washington, D.C. sponsored by Control Data Corporation's Institute for Advanced Technology.

Continued on page 16

Continued from page 15

The Soviet delegation also expressed concern that the United States is not serious about extending the U.S.-Soviet cooperation agreements, including MHD, that expire in June 1979.

The impressive Soviet delegation was led by Dr. E. Shelkov, the Institute's deputy director, and included experts in the fields of new installations and applications, computer analysis, generator channel design and analysis, and diagnostics. Professor Jean Louis from the Massachusetts Institute of Technology moderated the seminar.

In his welcoming speech, Professor Louis described the institute as a "remarkable" institution, formed in 1961 under the direction of Academician Alexander Sheindlin with deputy chairman Kirillin of the USSR Council of Ministers as the advisor. All aspects of MHD work—including oil and coal, nuclear, fusion, and industrial systems work—are done in an interdisciplinary setting, along with investigation of the high temperature thermophysic properties of matter and energy.

The Next 20 Years

In his presentation Shelkov outlined the plans for commercialization of MHD technology. By 1981, the design work for the U-500 commercial prototype MHD generator will be completed, and construction should be completed by the mid-1980s. This natural-gas-fired device will be the first commercial prototype in the world. By 1990, the Soviets are planning to bring coal-burning MHD technology to the commercial prototype stage as well.

By the mid 1990s, plans are to begin operation of fission-plasma MHD generators, which require development of frontier materials and other technology. Into the next century, direct energy conversion MHD will be under intense development for use in thermonuclear fusion plants. From the late 1980s on, MHD will be progressively introduced, first with fossil fuels and then with nuclear energy, to double the efficiency of present thermal electric conversion systems.

In answer to a question on the limits to the size of MHD generators, Shelkov responded that theoretically there is no limit. However, the size of components, such as superconducting magnets, will place an upper limit on optimal size. The Soviets are planning to produce modular MHD generators, of 2.5 to 3 gigawatts each, which can be clustered in groups of perhaps three modules.

Professor E.E. Shpilrain, also of the institute, then outlined some of the nonelectric applications of MHD technology, including earthquake prediction, minerals exploration, and integrated processing. When the coal-based MHD systems are ready for commercial deployment, by the 1990s, it will be practical to maximize the capture of nitrogen oxide pollutants and develop fertilizer production from the MHD by-products.

Shpilrain discussed the Soviet projections on the comparative cost of the U-500 and mass-produced MHD generator plants for the future. His projections show that the cost of the U-500 will be approximately 350 rubles per kilowatt installed capacity (about $525) and that the mass-produced generator will be about 174 rubles per kilowatt installed, or about one-third the cost of a conventional coal-burning plant in the United States today.

Concern over Agreements

At the end of June 1979, the five-year joint cooperation agreements in MHD and other advanced energy technology programs will expire. There is great concern on the part of Soviet scientists, expressed in discussions at the MHD seminar, that the United States is not seriously working on proposals around which to extend the exchange agreements for the next five years.

The United States has approximately until the end of December to submit some kind of proposal for continued joint work to institute officials. There is a direct advantage to the United States to continue the joint MHD work, since the U.S. program is lagging badly behind the Soviet experiments. Both DOE and State Department officials concerned about the extension have promised the Soviet scientists that a U.S. proposal is forthcoming.

—*Marsha Freeman*

AIF-ANS Annual Meetings

Industry Debates Pronuclear Fight

"The public discussion on nuclear energy has nothing to do with the technical issues. The basic philosophical issues are growth versus *no*-growth. The National Resources Defense Council is not just against nuclear power plants, it is against the construction of *any* power plants. . . . The nuclear industry has to stop being so defensive about financing pronuclear organizations and recognize that the Ford Foundation gives more money to the 'no-nukes' than all of industry gives to the organizations that support energy growth."

These remarks, delivered by Dr. Bert Wolfe, vice president of the Nuclear Energy Programs Division of General Electric at the Nov. 13-15 conference of the Atomic Industrial Forum in Washington, D.C. spelled out the foremost issue of concern for America's nuclear industry: Either U.S. nuclear users and suppliers will join with groups like the Fusion Energy Foundation in the fight for energy and industrial growth, or the greatest technological capability that exists in the world, the U.S. economy, will suffer irreparable damage.

In his presentation on the final day of the conference, Dr. Wolfe explained that the "no-nuke" movement has three prominent themes: that society will suffer from the use of abundant energy; that society should be forced to minimize energy use, as expressed in the calls for higher energy prices, conservation, and the expanded use of manual labor, and that the no-nukes are dissatisfied with the social and economic structure of society.

At a speech before a combined forum of the AIF and the American Nuclear Society, Dr. John Deutch, director of the Department of Energy's Office of Energy Research, reported the findings of the recent Interagency Review Group on waste management. These showed that a national waste management program is technically feasible, but that there are social and institutional problems that must be overcome. However, the report failed to put forward a policy for implementing a national waste program.

Scientists in attendance criticized the government's weakness in standing up to the environmentalists.

Speaking on the topic, "Can the United States Nuclear Industry Compete in the International Marketplace?" Gordon C. Hurlbert, president of the Power Systems Company of Westinghouse Electric Corporation, stressed that the United States still maintains the lead in nuclear export capability. Hurlbert observed that due to the increasing productivity of American labor and the accumulated experience of the nuclear industry, the learning curve for the cost of U.S. nuclear plants is way ahead of other nuclear supply countries. This has led to a situation where the U.S. dollar equivalent labor cost for nuclear plants has remained the most competitive in the world.

The importance of American labor and its unique skill level were emphasized by Robert Georgine, president of the Building and Construction Trades Department of the AFL-CIO. Georgine argued that the only real obstacle to commercialization of breeder and other nuclear technology is ideological. Over .5 million high-level jobs could be created between now and the end of the century if the administration would emphasize nuclear development, Georgine stressed.

Some Disorganizing

Contrasted to the generally positive presentations of leaders of the nuclear industry was the call by the Heritage Foundation (a funding conduit most recently responsible for fielding a fusion versus fission line among U.S. scientists) for organizing "citizens groups" to fight Naderism with "reverse Naderism." The Heritage Foundation position was put forward by Angelina Howard, a national leader of Nuclear Energy Women, a group set up by the AIF a few years ago to promote nuclear power among the least informed sector of the population. Howard tried to make the case that American women are more cautious about nuclear energy because they have studied the issues carefully!

"Don't explain the technical aspects of nuclear waste disposal to the public," Howard said. "Polls show that has an adverse affect."

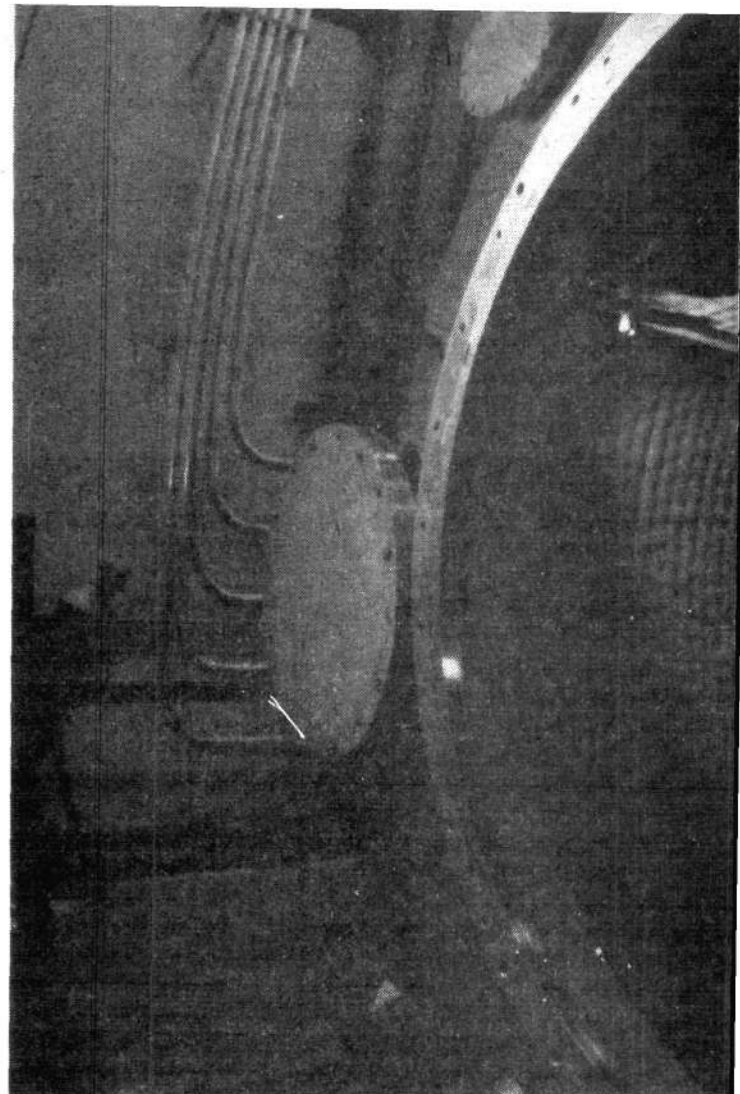
Another Heritage Foundation advocate was Margaret Maxey, a former nun from the University of Michigan. Maxey insisted that the environmentalists "have to be taken seriously because they represent a philosophy, a religious fervor." They are sincerely motivated, and "like millions of others, they are afraid of technology. . . that's why nuclear power is a geopolitical issue." Maxey noted that she had attended a recent luncheon with Henry Kissinger on geopolitics.

—*Marsha Freeman*

The Fusion-Fission Hybrid Reactor

Fuel Factory for Nuclear Power

by Dr. John Schoonover



Technicians install one of two magnetic mirrors in the

THE EARLY DEVELOPMENT of a fusion-fission hybrid reactor, both as a highly efficient fuel producer for conventional fission reactors and as a power source, has rapidly gained support in the scientific community and the energy industry over the past year, especially since this summer's outstanding experimental achievements of the Princeton PLT tokamak team. Most recently such notable nuclear physicists as Edward Teller, Hans Bethe, and Eugene Wigner, the latter two Nobel Laureates, have gone on record calling for the hybrid development and have made significant contributions to the conceptual design of the fusion-fission breeder (Bethe 1978).

At the November 1978 meeting of the American Physical Society's plasma physics division in Colorado Springs, Dr. John Foster, vice president of TRW, explained that the fusion-fission hybrid must become a major focus of U.S. industry. Since it is now guaranteed that fusion burns will be achieved in both inertial and magnetic fusion systems within the next four to five years, Foster said, it is an essential "national need" to prepare now to realize fusion power technology for meeting the U.S. energy demand before the turn of the century. The most rapid development of fusion will be accomplished by the early development of the fusion-fission hybrid, which will ease the physics and technical requirements for harnessing fusion power, he said.

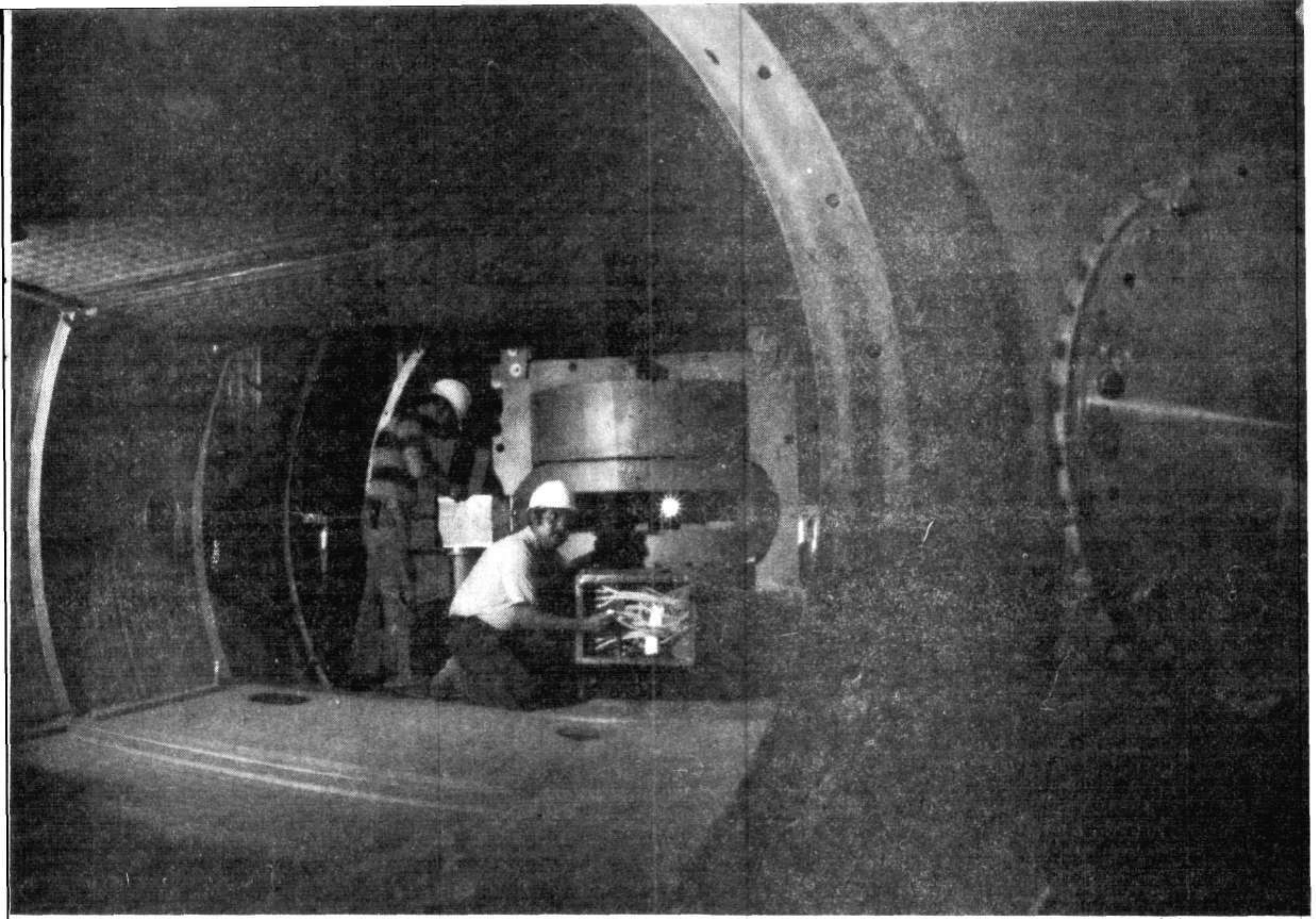
Foster, the chief advisor to the Carter administration representing industry's viewpoint on fusion, told the meeting that the perfection of fusion was the responsibility of industry, which had to get involved now that the nation is entering the second phase of fusion energy development, the industrial phase.

Why the Hybrid?

There are two basic reasons that leaders in science and in the nuclear industry are supporting the immediate development of a fusion-fission hybrid.

First, the hybrid provides what Peter Fortescue of General Atomic referred to at the November Conference on an Acceptable World Energy Future in Miami Beach as "a plateau of usefulness" for the application of fusion energy well before the realization of pure fusion reactors. The hybrid will fill a critical place in the continuum of all forms of nuclear energy development in the next two decades, and it also will provide important engineering tests for future fusion reactors.

Second, the hybrid is a very attractive answer to the



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tandem mirror experiment (TMX) which is now in operation at Lawrence Livermore Laboratory.

question of providing cheap fuel; one hybrid could fuel from 5 to 20 conventional nuclear reactors. In fact, in the initial phase it may be most useful to think of the fusion-fission hybrids not as electricity providers but as fuel factories that generate just enough energy to keep the fusion reactor core going.

The basic concept of the fusion-fission hybrid is illustrated in Figure 1. At the center of the device is a plasma produced by some magnetic or inertial confinement configuration. As generally conceived, a relatively modest rate of fusion takes place in the core area, producing an output of 14 MeV neutrons from the deuterium-tritium fuel undergoing fusion. The neutrons then pass out of the fusion plasma region and enter a blanket composed of so-called fertile material such as uranium-238 or thorium-232, substances that can be fissioned but that cannot support a fission chain reaction. As a result of bombardment by the neutrons, the material in the blanket is transformed by neutron absorption into heavier elements, fissile materials that can be separated out and used as fuel in fission reactors.

There also may be a certain amount of fission induced in the blanket, so that the hybrid operates directly as a power reactor in addition to breeding copious amounts of fuel for other fission reactors. Finally, the blanket also can contain lithium, which interacts with the neutron flux to breed tritium, one of the fuels for the basic fusion reaction.

The Demand for Nuclear Fuel

Although there is disagreement on the time scale involved, authorities in the field of energy production agree that there definitely will be a need for nuclear fuel bred in reactors—either fission breeders or fusion-fission hybrids—if nuclear fission reactors are to continue as a significant source of global energy production (Figure 2). How soon this need will be operative depends entirely on which projection one chooses for the expected world growth rate in the use of nuclear fission plants to generate electricity.

Figure 3 presents two different scenarios for the growth of nuclear-generated fuel capacity on a world scale. In the optimistic scenario developed by the author and his collaborators, new nuclear fuel sources would be necessary by the year 1995, as supplies from mining (at a reasonable price) and reprocessing were exhausted. In this projection, we assume that the U.S. growth in generating

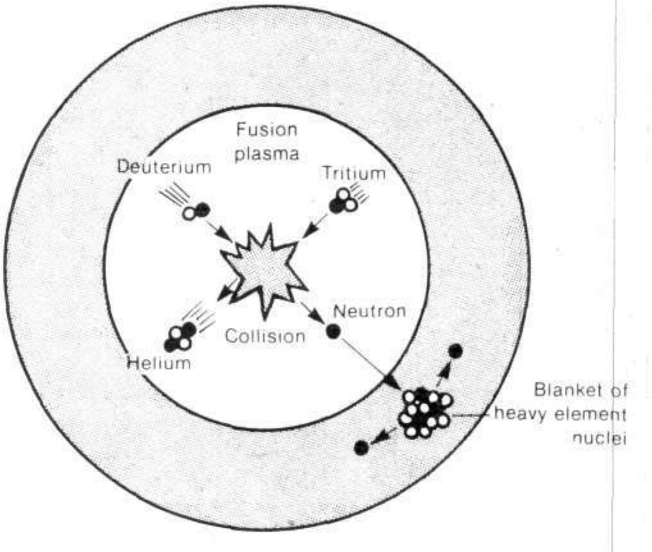


Figure 1
SIMPLE HYBRID SCHEMATIC

Fast neutrons from the fusion reaction enter the reactor wall where they react with the fertile material (uranium-238, thorium-232, or lithium) to form fissionable fuel (plutonium-239, uranium-233) for fission reactors and tritium for fusion reactors.

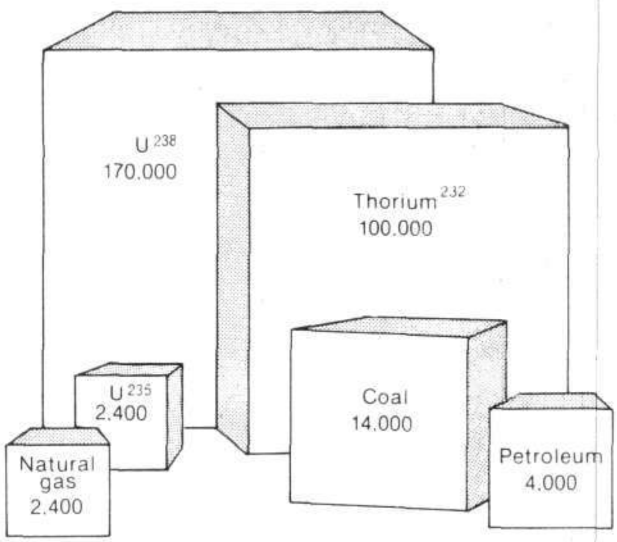


Figure 2
TOTAL WORLD ESTIMATES OF ENERGY AVAILABLE FROM FOSSIL AND NUCLEAR ENERGY RESOURCES

Each cube is proportional to the total amount of energy to be expected from available quantities of that resource. It is evident that without breeding of nuclear fuel, we could not depend on present nuclear resources for any more energy than we can expect from petroleum. With breeding of fissile material from uranium-238 and thorium-232, however, the nuclear fuel reserves can be extended by orders of magnitude.

capacity will continue through the year 2000 at about 3 percent a year. At the same time, per capita installed capacity in both Western Europe and the Comecon countries will reach 75 percent of U.S. per capita installed capacity by the year 2000. In addition, the Third World per capita installed capacity will grow to 75 percent of the present Western European level during that time period.

Given these assumptions, the advanced sector nations will have 50 percent of their total installed capacity generated by nuclear reactors and the developing nations will have 75 percent of their total installed capacity in nuclear by the year 2000. Although these figures may seem high compared to the present U.S. figure of about 10 percent, they are consistent with the projections of committed nuclear nations. For example, West Germany expects to generate 50 percent of its electricity with nuclear reactors by 1985; France projects 65 percent by 1990; South Korea and Pakistan 60 percent by 2000; and Hungary 48 percent by 2000 (Atomic Industrial Forum 1978).

The fusion-fission hybrid must begin to meet the difference in demand versus supply by not much later than 1995.

For purposes of comparison, Figure 3 includes nuclear fuel projections given a low growth rate for nuclear capacity—which reflects the pessimistic assumptions in studies done by the International Atomic Energy Agency and the World Energy Conference (IAEA 1975, Gray 1978).

As the figure shows, even under the pessimistic assumptions the demand for nuclear fuel would outstrip supplies available from mining (at a reasonable price) and reprocessing by about the year 2005. In other words, both the optimistic and pessimistic projections of nuclear growth show that given the now available uranium and the expected new discoveries, the world will *not* be able to supply nuclear plants with fuel unless nuclear fuel is bred.

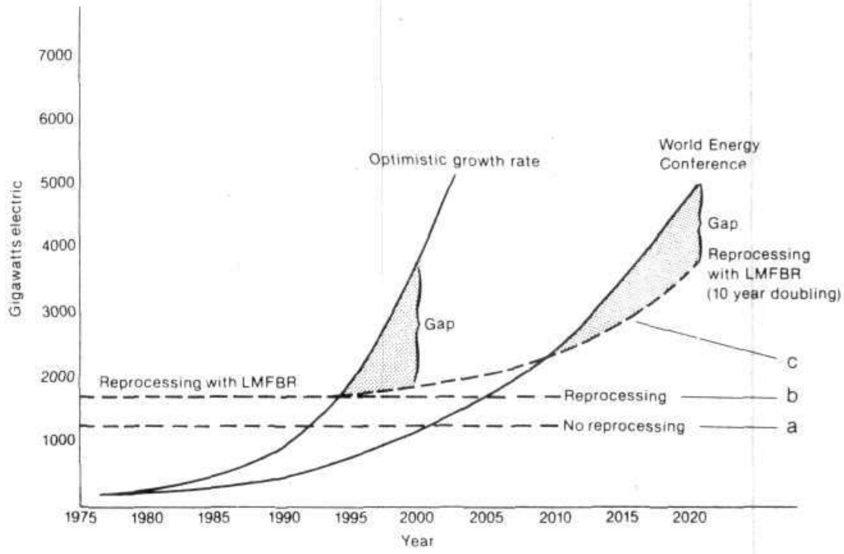
As the figure indicates, the introduction of reprocessing, a now available technique, will provide a few years' additional grace, as will the use of the liquid metal fast breeder reactors. But note that the curve indicating the addition to fuel supplies from LMFBRs assumes that these reactors can be designed with a doubling time of 10 years (the time it takes for the LMFBR to produce enough new fuel for another reactor) rather than the current estimates of 15 to 20 years.

The Hybrid As an Energy Multiplier

A pure fusion system must satisfy stringent requirements to be considered as a power reactor. If it is running on deuterium-tritium fuel, it must operate well above the ignition temperature of 44 million degrees Kelvin in order to sustain the fusion burn, and the product of plasma density times confinement time must be well beyond the breakeven condition of 30 trillion seconds-nuclei per cubic centimeter in order to produce net energy. The fusion-fission hybrid relaxes these conditions because the energy associated with the output neutrons from the fusion reactor can be greatly multiplied before it finally appears as heat or electricity.

In a typical fusion reactor, the fuel mixture of the two heavy isotopes of hydrogen (deuterium and tritium) fuses,

Figure 3
PROJECTED FUEL REQUIREMENTS FOR NUCLEAR FISSION REACTORS



The solid curves represent two possible scenarios for the world growth of nuclear reactor capacity. Dotted lines represent the amounts of reactor capacity that could be fueled by (a) once-through use of uranium resources, (b) reprocessing spent fuel rods, (c) introducing liquid metal fast breeder reactors on a fairly optimistic timetable. The shaded gaps represent the amount of capacity that would have to be fueled by fusion-fission hybrid breeder reactors. For the more rapid rate of growth in nuclear capacity, hybrids would have to be introduced in time to begin supplying fuel by about 1995; for the less rapid growth rate, about 10 years later.

producing the nucleus of a helium atom, called an alpha particle, and a neutron. Four-fifths of the energy produced in the reaction is carried away as the kinetic or motional energy of the neutron (14.1 MeV) while the remainder (3.5 MeV) stays with the alpha particle. In a magnetically confined plasma, this latter energy remains to heat the plasma for further reactions, while the neutron energy is transmitted to the containment walls of the vessel to be converted to electricity (for example, by thermal processes).

In a pure fusion reactor, all the alpha particle energy is used to continue heating the plasma and there is a thermal efficiency of about one-third for the recovery of energy in the blanket. However, even in conventional fusion reactor designs in which the neutrons are used to breed tritium in the blanket for fuel recycling, some additional energy is produced by the fission of lithium-6 at the rate of about 4.8 MeV per fission reaction. Obviously, this is a marginal effect and would not significantly alter the requirements on the plasma. However, if fissionable uranium or plutonium is introduced in the blanket, the energy enhancement is on the order of 200 MeV per fission reaction, making possible a significant increase in the total energy output of the reactor (and at the same time relaxing the conditions for plasma breakeven). If each fusion neutron were to cause one fission, the energy outputs would be increased by more than a factor of 14. By multiplying the number of neutrons that bombard the fissile material, it is technically feasible to get an energy enhancement factor of 35 or even more (Figure 4).

To turn the fusion-fission hybrid into a fuel factory, the blanket region would be used primarily as a breeding region to provide fuel for fission reactors, instead of as an energy producer. The mode of operation is neutron multiplication, followed by neutron absorption in a fertile material, creating new fuel that is then removed from the fusion reactor (Figure 5). The energy multiplication still occurs, but the conversion to electricity or process heat takes place at another location—the fission reactor that receives the fuel.

Fusion-fission hybrid reactors are classified according to the ratio of fissile fuel produced to power generated (Rose et al. 1978, Engel and Deonigi 1976). On the fuel end of the spectrum, the electric breeder hybrid is primarily a fuel producer that may generate no electrical power at all. On the other end, a pure fusion reactor would be a power source only, generating no fuel. In between are power and fuel hybrids that primarily generate power with fuel as a by-product, and fuel and power hybrids that produce fuel with power as a by-product.

Depending on the mode of operation, one hybrid machine could produce enough fissile material to fuel from 5 to 20 fission reactors.

Some Hybrid History

Surprisingly, the fusion-fission hybrid concept is almost as old as both branches of nuclear energy, and the hybrid history is now coming full circle.

The possible feasibility of the fusion-fission hybrid for breeding large amounts of fissile material was one of two main reasons that fusion research remained classified by the Atomic Energy Commission until 1958. The second reason was the theory that there might be a special, quick path to breakthrough in fusion research that would give one nation strategic control of the fusion power source. As the story goes, the development of controlled fusion proved to be more difficult, and the rapid development of fission reactors in the 1950s provided easy access to fissile material.

Ironically, the reversal of the status of these two earlier considerations has brought the hybrid to the fore again: Fusion research in many areas has progressed dramatically during the 1970s, bringing the conditions for hybrids immediately in sight. At the same time, nuclear growth is beginning to outstrip existing fuel resources, making a new fuel source a necessity.

One of the first proposals for a hybrid based on the deuterium-tritium fusion reaction and conversion of uranium-238 to plutonium was put forward in 1953 in a report by F. Powell for a team at Lawrence Livermore Laboratory, which included Edward Teller. At that time, the details of the neutron-U-238 reaction, such as the possibility of nuclear reaction and the number of new neutrons produced, were not well known.

Interest in the hybrid was strong, nonetheless, because pure fusion was so uncertain. Furthermore, the rate at which tritium could be bred from neutron reaction with lithium was not known, making pure fusion seem even more dubious. Interestingly, the fusion process proposed in this early study was not thermonuclear (that is, from a well-confined plasma in thermal equilibrium), but from interactions between 50-keV ions injected by a high-current accelerator. It was estimated that such a device could breed plutonium (and tritium, if lithium was included in the blanket) as well as produce power.

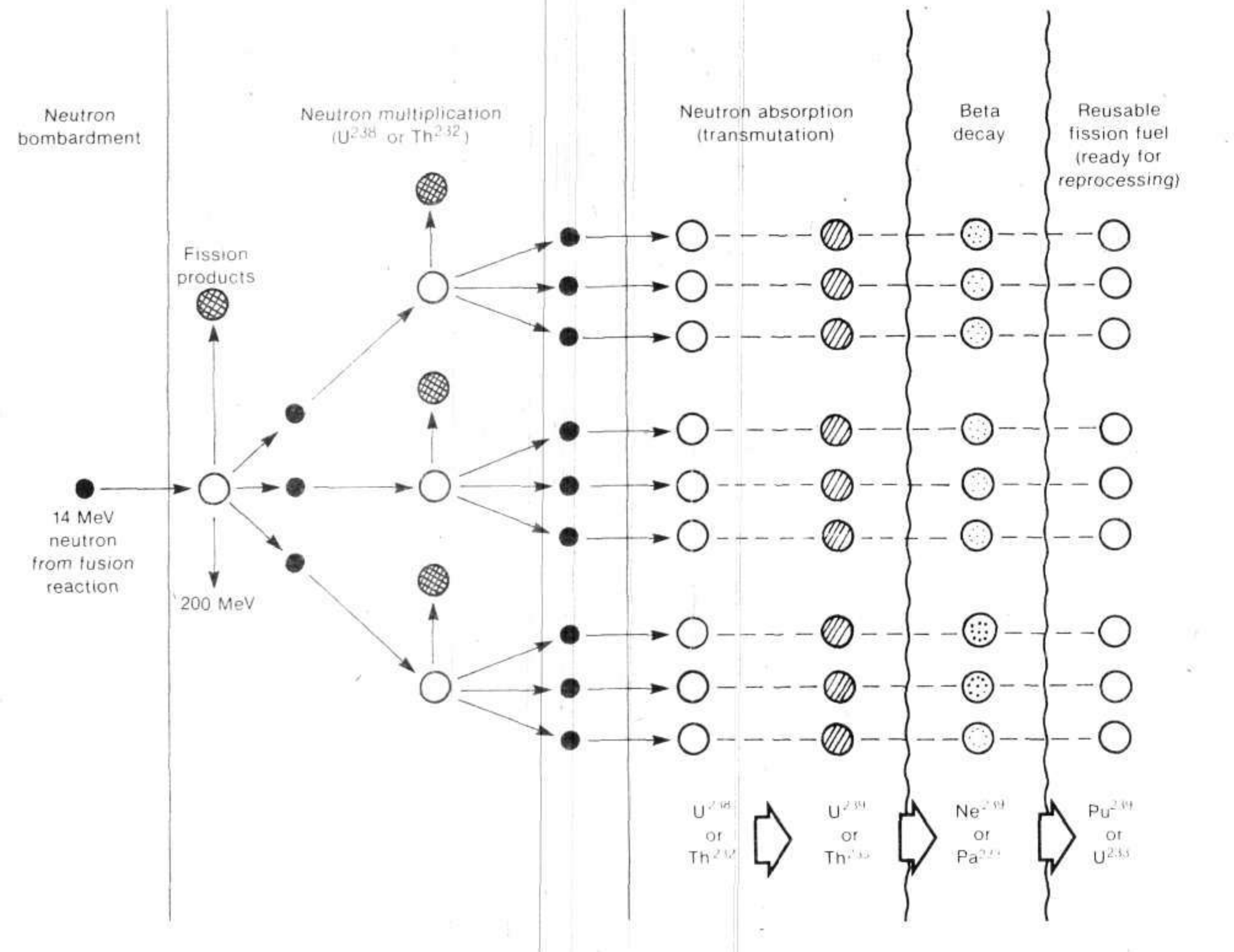


Figure 4

ENERGY MULTIPLICATION AND FUEL PRODUCTION IN THE HYBRID BREEDER REACTOR

Fast neutrons from the fusion reaction enter the reactor blanket where they trigger fission of uranium nuclei. Each such reaction releases energy (about 200 MeV) and two or three additional neutrons. The additional neutrons trigger further fission reactions, while being slowed down. When they enter the breeding region proper, the neutrons are absorbed in fertile thorium or uranium nuclei in the first step of nuclear transmutation into fissile material. In each case (uranium and thorium) two successive beta (electron emission) decays lead to the nuclear fuel uranium-233 or plutonium-239.

In 1955, Lawson and others at Harwell in England proposed a similar hybrid configuration; and two years later, Barrett of Knolls Atomic Power Laboratory proposed a hybrid based on the Princeton stellarator. The more modern era of hybrid design and evaluation began in the early 1960s with experimental studies of the interaction of 14-MeV neutrons with uranium. This was followed with the publications beginning in 1965 at the Massachusetts Institute of Technology and the Oak Ridge National Laboratory of detailed computer studies of the nuclear reactions and their products in more fully specified hybrid designs.

Hybrid Concepts

Three of the best-known lines of fusion research figure prominently in the most promising hybrid designs: mirror, laser, and tokamak. In general, a fusion energy gain of only about 1 (that is, breakeven) is required in the hybrid, which is one order of magnitude less than that required for pure fusion.

The Mirror Hybrid

Although the mirror machine is the only one of the three possible hybrid designs that is not a contender as a pure fusion machine, it may be the easiest to turn into a hybrid. At the recent conference on an Acceptable World Energy Future in Miami mentioned above, Edward Teller presented a proposal to build a mirror hybrid machine that was virtually guaranteed to work and to be economical.

The basic mirror idea is called the tandem mirror. In the center is a long cylindrical solenoid that contains the plasma and is surrounded by the breeding blanket. At either end of the cylinder there are mirror "stoppers" that smoothly connect to the magnetic field of the solenoid and reflect back into the center section most of the plasma moving toward the ends. The end mirrors are of the Livermore baseball design, named after the geometry of the magnetic field coils that confine the plasma inside the mirror section. The center solenoid simply has to be made long and wide enough to maintain overall confinement of the plasma. The Livermore team expects experimental results during the coming year that will provide proof of principle for this concept.

An earlier design by Livermore and General Atomic based on the more difficult spherical geometry around a single mirror machine predicted a net electrical output of 535 megawatts and the production of 1,900 kilograms a year of plutonium.

The Laser Fusion Hybrid

Lawrence Livermore Laboratory and Bechtel Corporation have collaborated to carry out design studies for a hybrid breeder using lasers to drive the fusion reaction (Hansen and Maniscalco 1977). They chose a simple cyl-

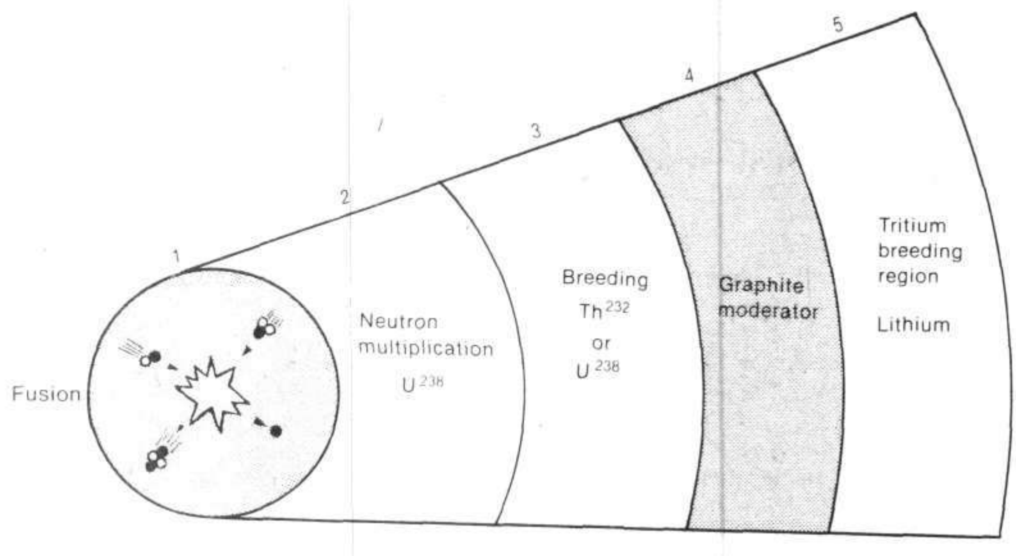


Figure 5
SCHEMATIC OF A HYBRID BREEDER REACTOR

Each wedge shown is part of the circular area surrounding the core. The region (1) in which fusion occurs is surrounded by a shell of uranium (2) in which neutron multiplication occurs along with energy production from induced fission reactions. The next region (3) is entered by slowly moving neutrons, many of which are absorbed to produce fission fuel from the fertile elements embedded there. Neutrons that escape absorption in this region are partially reflected back into it by the graphite moderator (4) that surrounds it. The remaining neutrons after passing through the moderator and being further slowed enter the next region (5) where they trigger fission of lithium to produce tritium for use as fuel in the fusion reaction.

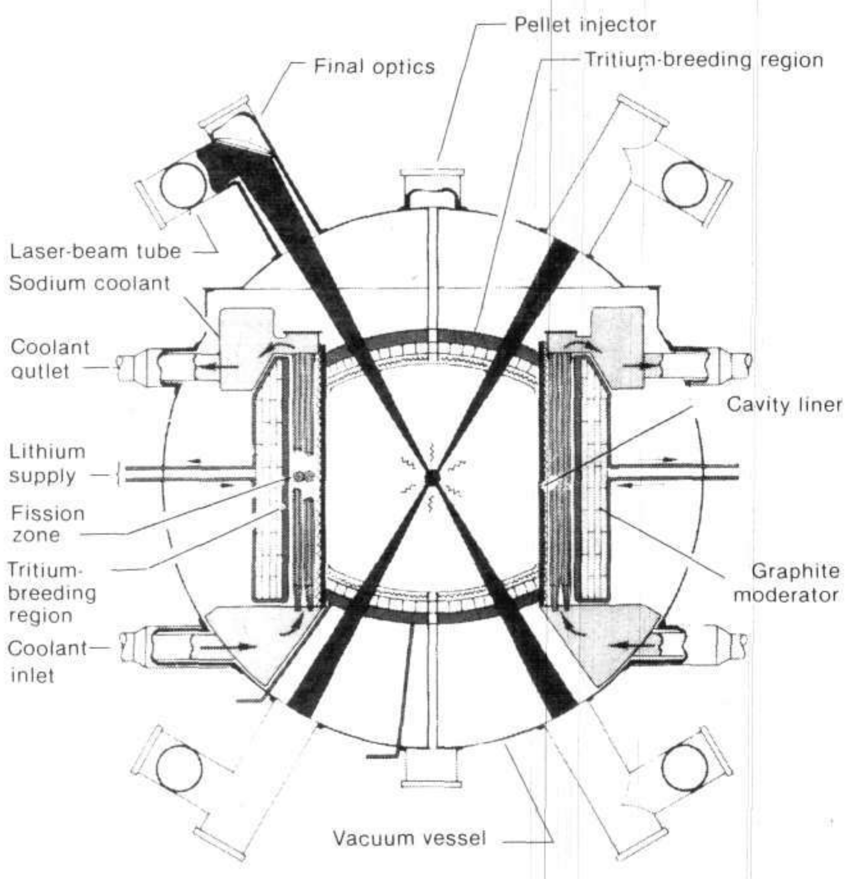


Figure 6
CONCEPTUAL DESIGN FOR A LASER-DRIVEN FUSION HYBRID

This concept, developed at Lawrence Livermore Laboratory, calls for neutron production via laser-induced fusion reactions. The cylindrical walls shown at the sides contain the fissile fuel breeding blanket and part of the tritium breeding capacity. But most of the tritium to fuel the fusion reactor is bred in the end-cap assemblies at the top and bottom of the chamber. Taking advantage of the energy production from fission reactions in the cylindrical blanket, this device is designed to produce net electrical power of 400 electrical megawatts at the same time that it produces 1300 kilograms of plutonium each year.

indrical geometry for the blanket to minimize engineering difficulties (Figure 6). Six laser beams, three each entering from the top and the bottom of the cylinder, focus on the center where fuel pellets would be imploded at the rate of about 20 per second. The entire blanket assembly is 7 meters high, with a 7-meter diameter.

Two types of fissile fuel-breeding systems have been designed, each using a slightly different placement of materials. Both have a graphite first wall supported by stainless steel, which protects the fuel rods from fusion microexplosions. In addition to the fissile breeding region described below, both designs also include a circulating liquid lithium supply that passes around the graphite moderator material. This reflects neutrons back through the lithium and into the fissile fuel production region. Tritium, which is produced by the neutron reactions on lithium-6, is carried directly out of the blanket for processing on a continuous basis and is recycled for fuel fabrication for the reactor.

The earlier breeding design called for a layer of depleted uranium metal, from which most of the U-235 has been removed leaving nearly pure U-238. The fuel is fabricated into 7-meter rods packed in hexagonal array in stainless steel process tubes. Liquid sodium passing around the process tubes carries heat out of the reactor. Fast neutrons entering the process tubes cause fission of some U-238, releasing more neutrons. Some of these neutrons, in turn, can cause fission, further multiplying the energy production in the blanket; other neutrons are absorbed to produce U-239. This product subsequently decays to neptunium-239 then plutonium-239, the desired fuel in this process. Neutrons that escape absorption in this way proceed to the liquid lithium layer where tritium is produced.

In the base line design, 200 megawatts thermal of fusion power were converted into 1,400 megawatts thermal of total reactor power. To achieve this level of energy production, the Livermore and Bechtel designers postulated that a laser operating with 2 percent efficiency would drive a fusion reaction with a pellet gain (energy multiplication by fusion reactions) of 100.

The performance of a scaled-up version of this device was compared to the breeding characteristics of a 2,500 megawatt thermal fast breeder reactor of the liquid metal fast breeder variety (Figure 7). It was determined that the hybrid could breed nearly 10 times the fuel of the fission device for the same thermal output: 2,300 kilograms per year of plutonium for the hybrid versus the 260 kilograms per year for the fast breeder.

This study reached several important conclusions. First, both laser and fuel pellet performance requirements are an order of magnitude less stringent in a hybrid than for a pure fusion reactor. This means that the hybrid can operate with a much lower power density vis a vis the reactor vessel's first wall—about 1.25 megawatts per square meter compared to 10 megawatts per square meter for pure fusion—thus easing the requirements for first-wall materials. Also, the study concluded that the hybrid can produce enough fuel to operate at least six light water reactors of the same power rating and can extend the fuel availability for these reactors by 2 orders of magnitude with little effect on the cost of electricity.

More recent studies of the hybrid blanket indicate that even better efficiencies can be achieved if the fission region of the blanket is modified to separate the regions in which fast fission and neutron absorption occur (Maniscalco et al. 1978). Furthermore, if a lithium coolant is used in place of sodium, it increases the tritium breeding. And greater neutron production is achieved if beryllium rather than graphite is used as the moderator.

Two versions of this system produce either U-233 alone or both U-233 and Pu-239. In the latter case, uranium is used in the fast-fission blanket, and thorium is used in the former. An important aspect of this type of system is that it is capable of using thorium as a breeding material in a highly efficient way, further increasing the potential supplies of fissile material (Figure 8). Although fission breeders do not appear to be able to breed U-233 from thorium efficiently, laser hybrid devices using thorium and uranium-thorium blankets can produce enough fuel for 20.0 and 11.6 equivalent-capacity light water reactors, respectively. With presently known resources of thorium, there is enough to produce almost again as much energy as can be produced by converting uranium-238 to plutonium.

The Soviet Tokamak Hybrid

In line with the Soviet Union's commitment to make hybrid fusion-fission breeders their first-generation fusion reactors, two Soviet researchers, V.L. Blinkin and V.M. Novikov of the Kurchatov Institute, recently proposed an updated version of a hybrid design developed by L.M. Lidsky of MIT (Blinkin and Novikov 1978). The basic concept is to couple a fusion breeder producing U-233 to a molten salt reactor that burns this type of fuel. The advantage of such a system is that it accelerates the production of fuel on the thorium cycle, which probably could not be done at a net breeding rate solely by fission reactors. Best estimates are that the doubling time for this type of breeding in a fission reactor would be greater than 15 to 20 years.

The molten salt reactor itself is an interesting near-future variant of the conventional fission reactor design. Its main distinctive feature is that the fuel circulates through the reactor core in the form of a mixture of fluoride salts in a liquid state, improving the neutron economy.

The Soviet design calls for inserting a breeding blanket into a tokamak-type fusion reactor, the mainline fusion device the Soviets expect to commercialize. The breeding is accomplished as a salt mixture composed of sodium fluoride, beryllium fluoride, and thorium fluoride flows

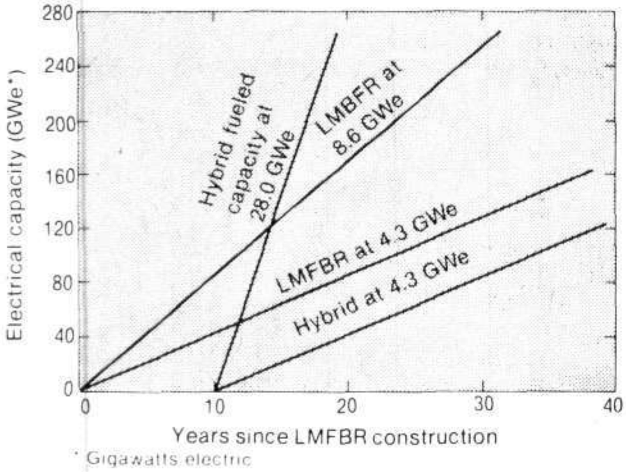


Figure 7
IMPACT OF HYBRID AND FAST BREEDER REACTORS ON ELECTRICAL CAPACITY

As the slopes indicate, fast breeder reactors can increase the nuclear electrical capacity at the same rate at which they are installed, but hybrid reactors can fuel new capacity at about six or seven times the rate of hybrid installation.

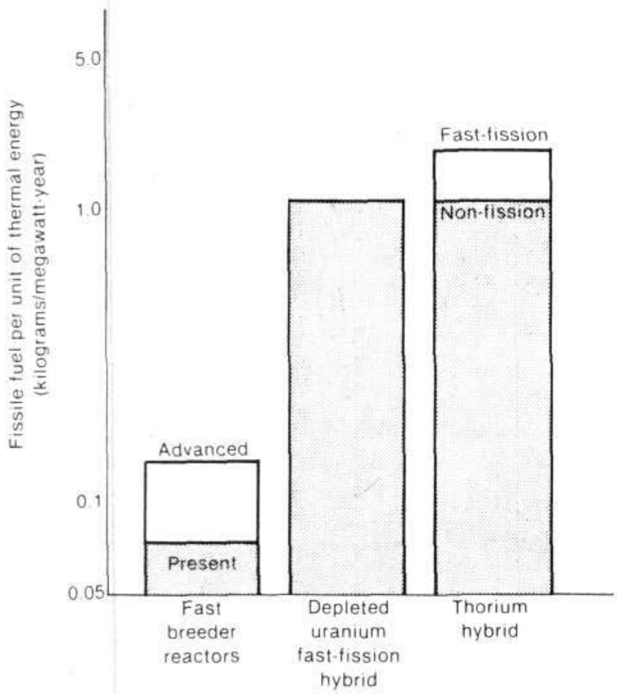


Figure 8
RELATIVE BREEDING EFFICIENCIES OF FAST BREEDERS AND HYBRID BREEDERS

A thorium fast-fission hybrid provides enough fissile material to fuel 20 high-temperature gas-cooled reactors of equivalent thermal power while a depleted-uranium hybrid could fuel 7 light-water reactors of equivalent thermal power. The hybrid produces 10 times more fissile fuel than a fast-breeder reactor.

OUTPUT OF VARIOUS HYBRID REACTORS

	Electric breeder hybrid	Fuel and power hybrid	Power and fuel hybrid
Thermal output (megawatts thermal)	1,000	3,000	4,000
Fuel production (kilograms/year)	1,200	1,800	800
U^{233} reactors fueled (1 gigawatt thermal)	17.4	26.1	11.6
Pu^{239} reactors fueled (1 gigawatt thermal)	9.4	14.1	6.3

through the breeding zone, and neutrons are absorbed in the thorium.

The Soviets decided to forego tritium production in the fusion reactor, so lithium fluoride was deliberately left out of the cooling salt mixtures. In Lidsky's original proposal, tritium breeding was accomplished by using lithium fluoride enriched with the lithium-6 isotope. Alternately, Blinkin and Novikov tried a cooling salt using lithium fluoride with almost pure lithium-7 to keep tritium breeding at a minimum.

In both cases, the results of the Soviet study were quite promising. A reactor using cooling salt enriched with lithium-7 could achieve a breeding doubling time of 3.7 years, supplying fuel for 11 molten salt reactors of equivalent thermal energy. For the sodium fluoride variant, 10.8 molten salt reactors could be supplied with fuel, with a breeding doubling time of 4.9 years.

Hybrid Economics

In whatever mode or device the hybrid is finally developed, *its primary role must be as a fissile fuel factory*. Studies by the U.S. Department of Energy (Kostoff 1978) have shown that projected hybrid fissile fuel costs are expected to range from about $75 to $150 a gram, which is comparable to, if not cheaper than, present fissile fuel prices (Kostoff 1977 and 1978). The projected electricity cost is brought to near a minimum value of 19 mills per kilowatt-hour (nuclear- and coal-produced electricity costs 28 to 30 mills per kilowatt hour) once the fusion Q (ratio of energy output to input) is between 1 and 2 (Bogart 1978).

The increase in complexity of devices from the electric breeder hybrid, to the fuel and power hybrid, to the power and fuel hybrid, and, finally, to a pure fusion reactor is mirrored both in the time scale for their realization and in projected capital costs. The electric breeder hybrid is a relatively near-term device, which could be built for as little as $500 million, by purchasing electricity from another source. Capital costs for the fuel and power hybrid and the power and fuel hybrid are estimated at $1.5 and $2.0 billion, respectively (about double the range of present fission reactors), which reflects the greater complexity involved in extracting both power and fuel as well as the high costs of turbine generator stations, regardless of the power source.

The accompanying table summarizes the thermal power output of hybrid reactors of a commercially viable size along with the amounts of fuel they could produce per year and the number of reactors that could be fueled by their output. It is estimated that the cost of electricity from a power and fuel hybrid would be in the range 20 to 40 mills per kilowatt-hour, which is competitive with present costs.

How Soon?

Given the Department of Energy's current timetables, a commercial demonstration hybrid reactor could be in operation in the mid 1990s. With an aggressive program, however, this time scale could be significantly accelerated so that a demonstration reactor might be on line by about 1990. In fact, hybrid researchers at Princeton have estimated that a crash program based on a tokamak core could produce a demonstration model by 1985. And Edward Teller forecast at the Miami conference that his brute force tandem mirror hybrid could be ready for commercial introduction in 15 years.

Whichever hybrid design is chosen for demonstration, the construction of an operating fission-fusion hybrid would provide a nice basis for celebrating the 40th anniversary of the original U.S. hybrid proposal.

John Schoonover, a nuclear physicist with 11 years experience in research and teaching, is currently the FEF campus coordinator.

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'For Pure Fusion, the Tokamak Is the Only Candidate'

An Interview with West German Fusion Scientist Dieter Biskamp

FEF physicist Dr. John Schoonover recently interviewed Dr. Dieter Biskamp, deputy director of the theory division at the Max Planck Institute for Plasma Physics in Garching, West Germany. Biskamp was visiting the Courant Institute of Mathematics at New York University. In this provocative interview, Biskamp discusses the most promising lines of fusion research, the effects of laser classification, and the nature of the West German fusion program.

Question: Which current fusion concepts hold the greatest potential for commercial realization?

My personal view is that only a very few of the different fusion concepts have a chance of becoming economically interesting. Of the lines that have been developed to a rather high standard experimentally (at least from the physics point of view), I think there are only two that are really worthwhile talking about—the tokamak and the mirror. In my view, you can forget about all the so-called alternatives, both for pure fusion and for the hybrid breeder.

The low beta stellarator eventually may have some features that are superior to the performance of the tokamak from a pure physics point of view, but these small advantages can never compensate for the technical difficulties in constructing the stellarator. The stellarator is necessarily an apparatus orders of magnitude more difficult to build than the tokamak. If people are saying that the tokamak would be a bit too complicated as a pure fusion reactor—that is the view that the utilities express—then the stellarator is completely out of the running.

The fusion alternatives that have recently been discussed, the Spheromak and the Surmak, are physical tools to investigate plasma behavior, but I don't see either machine able to develop to a state where it could be considered as a rival to the tokamak. For pure fusion you need toroidal confinement, and the only candidate for this is the tokamak.

On the other hand, the requirements are much less severe for hybrid fusion. People are claiming that the plasma should be prevented from reaching ignition in a hybrid because the temperature rise in the plasma after ignition would spoil the whole configuration. Hybrid fusion is a driven fusion, and you deliberately keep below the ignition point.

Because of the lower plasma physics requirements, open fusion systems are very attractive. My view is that if the tandem mirror principle turns out to be as successful as it now appears to be—as successful as the first experiments are showing, especially from a theoretical point of view—then the mirror system would be ideal for driven fusion. It is so simple. For example, repairs are much easier than in a tokamak reactor because of the simpler geometry. On the other hand, I can't imagine that anyone is willing to build the straight, open systems as reactors for pure fusion.

All the alternatives have their nice features. That is why they are called alternatives and that is why the money is put into them. However, if you look closely at them, they just improve one side of the whole problem, while their effect on the rest of the problem is still completely unclear. What we have learned from fusion research over the last 20 years is that there are always more problems than you can think of, at least from the technical side.

INERTIAL CONFINEMENT

Question: How do you view inertial confinement systems?

I am not an expert in that field, so I can judge only on what I have heard in the discussions I have had with people who are experts. In my view, inertial confinement driven by lasers will probably never reach a stage comparable to that which the tokamak has already achieved. In principle, the tokamak is now close to $Q = 1$ [energy gain], and developments two or three years ahead will demonstrate this. $Q = 1$ with a laser-driven system is not equivalent to $Q = 1$ as defined in the usual way; that is, that you take the energy put into the plasma and compare that to the fusion energy. Because of the very poor efficiency of the laser, you should compare a Q of at least 30 in the laser-driven system to $Q = 1$ in the tokamak.

On the other hand, there are certain developments in making lasers more efficient. It is possible that a laser system will show up with the efficiency, proper wavelength, and necessary pulse qualities. I cannot exclude that, but I think it is very, very improbable.

The electron beam is much more efficient, but it has its own problems, in particular the problems of having the beam propagate. Even if measures are found to allow it to propagate for a short distance, the necessary optics are so

"We are concentrating on getting through...Igniter ...a super-Alcator."

much more complicated—if feasible at all—that the difficulties of beam propagation countervail the feature of having high efficiency at the outlet of the gun. It is very improbable that this would make any sense economically.

Question: And what about the use of ion beams to drive the system?

The ion beam is the third and most recent alternative, and no one really knows much about it. The physics, by which I mean the interaction of the beam with the pellet, seems to be somewhat simpler. It is assumed to work essentially classically. You know that the interaction of the laser with a pellet (at least in the wavelengths that people are thinking of today, the visible or even infrared range) takes place in the very thin atmosphere, so to speak, of the pellet. Then the energy has to be transported into the interior via processes that cannot be controlled. On the other hand, if you have a situation in which the energy absorbtion takes place via collisions, then penetration is deeper into the system.

Of course, you need pellet shaping too; you cannot simply use a glass sphere filled with so many atmospheres of deuterium-tritium mixture. But even though you need a complicated pellet, the physics seems to be simpler and more easily understood than with the electron beam. The electron beam requires an anomalous energy absorption; otherwise, the beam is just passing through. Although people have seen that a very strong interaction is taking place, it is an anomalous absorption and no one really knows about the detrimental effects.

The high-energy accelerator builders claim that in principle they should be able to produce an ion beam drive with the necessary requirements—beam quality, efficiency, and repetition rate—at a reasonable price. In my view, though, you cannot use any of the present day high-energy accelerators built for elementary particle physics. They produce far too few particles, by a factor of 10^5 or so.

A number of people, especially in this country, are thinking of how to use their accelerator expertise to build fusion ion beams. They need a certain amount of money, not less than about $200 million, to build a facility that demonstrates that the principle works. If for $500 million you could prove that by simply scaling up you would have the ideal driver, it would be a good thing. The laser people, for instance, cannot claim that for the same amount they could produce a laser system suitable for fusion.

Question: Would this involve building entirely new facilities, or do you think it would be possible to modify existing facilities?

Essentially you have to build new facilities, especially since the energies are not as high as those produced in current facilities—the range you need is 500 MeV to 1 GeV. The energy is not the problem; it is the intensity, the beam quality, and how to prevent deterioration of the beam by charge exchange. There are a number of unsolved problems. People who are optimistic are claiming, and the people who are realistic are hoping, that they can solve them.

THE WEST GERMAN PROGRAM

Question: What is the focus of the West German fusion program?

The fusion program is essentially concentrated on magnetic fusion. The inertial fusion branch is rather small. It is housed in a special institute for laser research, the Project for Laser Research, on the site of the Max Planck Institute, but it is separate from the institute. The project is investigating different types of lasing materials, laser chemistry, and laser fusion. The latter is a bit euphemistic, since the project does not intend to use tritium and is using the iodine laser, developed in the last five years for laser plasma interaction studies. It is really not a fusion program, but more a plasma physics program.

The major part of the West German fusion budget is going into magnetic fusion. At the moment we are concentrating on getting through a project called Igniter, which is along the lines of the high-field tokamak. In a sense, it is a super Alcator [the Massachusetts Institute of Technology tokamak]. It is a rather compact machine, with a very high external magnetic field exceeding 10 teslas. The high current in the plasma produces a very high energy density, and the machine requires external heating and some adiabatic compression.

At the present status of this concept, the apparatus would have a plasma radius of 35 to 40 cm in the final compressed plasma state. The compression ratio is about 1.5, and the uncompressed plasma is heated by neutral injection. It requires rather high beam energy, which is one of the problems. It needs around 150 keV, instead of the 50 keV used in the Princeton Large Torus, because of the penetration of the dense plasma. Additional adiabatic compression heating and the ohmic heating should make it possible to get to an ignited state.

In this system, the alphas give their energy to the electrons first, and then the electrons give the energy to the ions via equilibration of energy. This process takes place typically in a thermally ignited plasma. It is probably not possible in the TFTR [Princeton's Tokamak Fusion Test Reactor] or in the JET [the Joint European Torus], or in the Japanese big tokamak to achieve such an ignited state, because these machines can probably never reach the n-tau necessary.* Of course, a lot of energy can be injected into these machines, but in this state it always stays some sort of a driven fusion.

If you want to study alpha particle physics, it is probably sufficient to have such a driven system where you produce a lot of alphas, confine them, and see what they are doing. But if you really want to study what ignition is doing—for instance, are there stable points or is the temperature just going away—you need the sort of Igniter device. You have to determine where the stable burning point is; that is, if the plasma exceeds this temperature, will it come back or will it go further away? Because the plasma has a certain finite pressure due to the magnetic field, you cannot increase the temperature indefinitely. If the temperature is really running away, it necessarily either will run into a beta limit or will just eject plasma so that the density will be reduced and the fusion process will come to an end. This is one of the points that the ignition experiment should investigate.

This concept is worked out and we are trying to get it through the different stages of approval.

We have two big experiments at Garching at the moment. The ASDEX (Axisymmetric Divertor Experiment) is the analogue to the PDX [Princeton Divertor Experiment], with certain variations in the way the divertor field is produced, but with about the same general size and other characteristics. ASDEX is still in construction and should be running within about one year.

The other experiment, our biggest running experiment, is the Wendelstein VII, a low-beta stellarator. This experiment is working and there are plans to build a bigger one, but I doubt that there will be sufficient approval for this within the institute and outside. We also have the Pulsator experiment, a small tokamak.

There is another, smaller German fusion laboratory at Juelich, also restricted to magnetic fusion. They are constructing a major apparatus called Textor, which is essentially meant to investigate wall-plasma interactions, behavior of impurities, and so on.

Question: What are the prospects for getting the ignition experiment through the approval stages into construction?

A number of difficulties derive from the existence of the Joint European Torus. Because JET is a really gigantic combined effort, there is a commitment of all the participating governments to make it a real success. Whenever JET needs more money, it will probably get it—at the expense of the smaller labs, of course. JET is also a rather versatile machine, so whenever a laboratory comes up with a certain idea, JET tells them, "we can do this too."

Question: Do people from Garching and Juelich participate in the JET program?

Officially, we are part of the program. However, there are only a few Germans taking part in it as ongoing administrators, in the construction, and in the preparation of the experiments. Some of our institute participated in the initial design team, from 1973 to 1977. We do not know yet who will join the JET team once it has converted from the design to the construction of the experiment. Since we anticipate getting the ignition experiment through, we are not too unhappy about not giving away some of our staff members; we need them ourselves.

THE CLASSIFICATION QUESTION

Question: There is a lot of talk in the United States and elsewhere about the difficulties classification causes for the inertial confinement program. How do you see the effect of the classification issue on the development of the inertial confinement program, in particular? Do you think that the minimal participation of West Germany in inertial confinement can be attributed to the classification of the program in the United States?

I don't think so. There are political and historical reasons for this related to the fact that laser fusion originally was thought of as essentially a military application. You know that France and England have their own programs, essentially within military applications. There was a political tendency to have the Germans not develop a big program, because of certain feelings that one should not let Germany enter into atomic weapons business. There was the feeling that the others would not be very friendly toward such a program. Perhaps this was the reason that we did not join the big programs in 1972 and 1973 when they started up in the United States.

On the other hand, the overall German spending on fusion is really not negligible. I think it is much more than France is spending. At the moment, I do not think the government will put more money into fusion research. And if one could convince them that it were worthwhile to put more money into inertial confinement, that would mean necessarily that magnetic confinement research would get less money. At the moment I do not think it is possible to increase the German government's financial commitment to the fusion program. I do not see very much chance for a big change; however, there might be small changes of emphasis in magnetic fusion. For instance, people have been talking of entering into the mirror business.

Question: Is the West German inertial confinement program subject to classification?

No. It is a completely open program.

Question: Would you advocate that sort of approach for the rest of the world?

I would see things more realistically. Classification has a very nice feature, too. It implies that research connected to laser fusion is thought of as being of strong value for military applications, even though it might be beneficial later on for fusion research. Therefore, you get much more money for the program at the moment than you would get if you took it out of the military application and put it on an equal footing with magnetic confinement. If the two were getting money out of the same pot, inertial confinement would run into strong competition with magnetic confinement. Although both approaches claim that theirs is the superior one, there really is no fighting going on. The fighting is more between the individual labs in the particular fields.

Overall, I do not think it would have a beneficial effect if you were to enforce total declassification.

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* The Lawson product for determining the energy output of a fusion system is designated by n-tau, where n is the density of the fusion plasma in nuclei per cubic centimeter and tau is the confinement time in seconds. For breakeven, an n-tau of 30 trillion seconds-nuclei per cubic centimeter is needed.

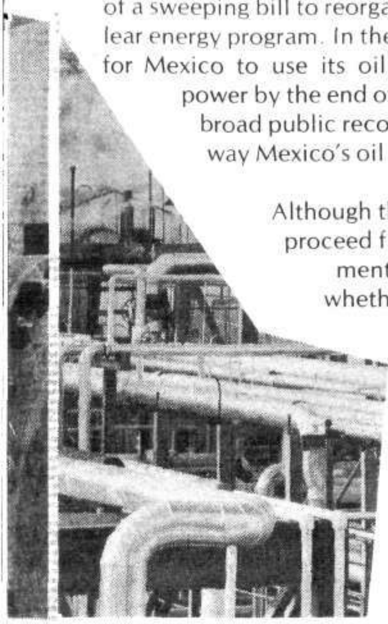
Mexico's Huge New Oil Finds

From Oil Power to Nuclear Power

by Tim Rush and Pablo Silva

Mexico's huge new oil and natural gas finds have put that nation on the way to becoming one of the world's premier oil powers, as well as a leader in fully industrializing the Third World. And at the center of Mexico's detailed plans for vast industrialization are high technology and a strong capital goods industry. In the words of President Jose Lopez Portillo, "We must begin to construct the cities of the 21st century."

The mid-November announcement of spectacular new oil deposits coincided with passage in Mexico's Congress of a sweeping bill to reorganize and upgrade Mexico's nuclear energy program. In the course of debate, the potential for Mexico to use its oil reserves to become a nuclear power by the end of the century became a matter of broad public recognition—a process similar to the way Mexico's oil future first became a public goal two years ago.



Although there is no doubt that Mexico will proceed full speed ahead with its development plans, there is a real question of whether the United States will become a major trading partner in what will be the biggest capital goods market in the world. So far, despite the publicity, few sources in the United States have discussed what it will mean to have a "Saudi Arabia" south of the border. Mexico, however, made its invitation for trade partnership clear. The government, in fact, chose to announce the new oil discoveries just one day before the head of Pemex, Mexico's national oil company, addressed the Chicago meeting of the American Petroleum Institute on the subject of Mexican oil, drawing out the implications for U.S. trade.

Given that the United States is Mexico's largest trading partner, Mexico would very much like to see the establishment of a mutually beneficial trade and development relationship. However, Mexico has made no secret of the fact that if the administration does not respond positively to its offers, the country will take its business elsewhere.

The New Oil Giant

When Pemex head Jorge Diaz Serrano, announced at the American Petroleum Institute's November meeting that Mexico had uncovered a giant new reservoir that might contain as much as 100 billion barrels of oil and 40 trillion cubic feet of natural gas, the oilmen were stunned.

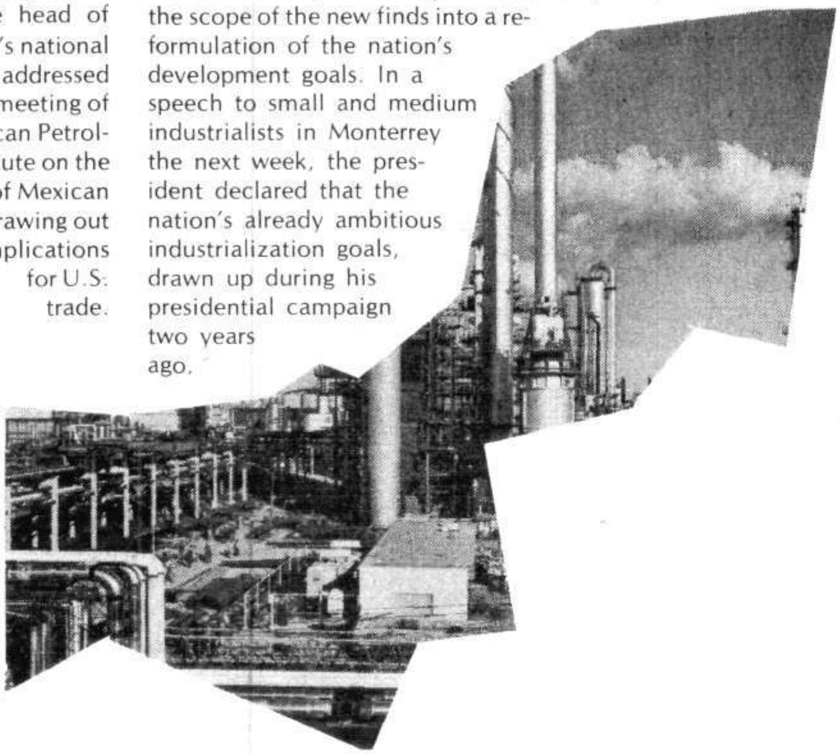
The response was not unwarranted. Since the new find is not included in Mexico's current reserve figures, which already place its proven reserves at 20 billion barrels and potential reserves at 200 billion, Mexico's overall reserves could reach 300 billion barrels!

If Mexico's current recovery rate of 40 to 50 percent holds good in the course of developing these new deposits, the resulting proven reserve category will move into range of Saudi Arabia's 150 billion barrel proven reserve.

Diaz Serrano described the new deposit, called Chicontepec, as "one of the biggest hydrocarbon accumulations in the Western Hemisphere." The field is in the legendary Golden Lane area that stretches 100 miles south from the Gulf of Mexico port of Tampico.

Shock waves rippled through the American audience when Diaz Serrano reported that the first new 100 billion barrel field alone would require drilling 16,000 wells in the next 10 to 13 years—quadrupling the drilling rate prevailing in Mexico since it nationalized the oil industry in 1938.

But the effect of the huge finds will extend far beyond the oil industry itself. Lopez Portillo quickly translated the scope of the new finds into a reformulation of the nation's development goals. In a speech to small and medium industrialists in Monterrey the next week, the president declared that the nation's already ambitious industrialization goals, drawn up during his presidential campaign two years ago.



will be "broadened and accelerated." He announced that his government will unveil a national industrialization plan in December that will fully detail the expanded plans.

In a rapid-fire series of announcements preceding the president's speech, several top ministers established the guidelines of the development effort.

Speaking at a conference on petrochemicals in the state of Yucatan Diaz Serrano declared that the Chicontepec field "represents a magnificant opportunity for definitively industrializing our country." At the same event, Industries Minister Jose Andres de Oteyza announced government incentives to domestic and foreign businessmen who want to invest in the promising petrochemical industry. Two days later, Finance Minister David Ibarra announced the establishment of a special $200 million fund to begin implementation of the government's program for production of capital goods. And in the process of working out special legislation to provide the guidelines for the development of nuclear energy, a group of Mexican congressmen has called for a long-term program that would start immediately with the construction of nuclear plants.

In short, Mexico is moving ahead with its industrialization program at breakneck speed. As its leaders have said in the past, the revenues from oil exports will be used to import the advanced technology and manufactured goods required to expedite this process.

This is how the nuclear program looks on the eve of this take-off phase:

Mexico's official nuclear program calls for building 20 nuclear reactors by the year 2000, and, during the past year, the nation has carefully laid the groundwork to put this major nuclear energy program into gear.

On the domestic front, the Mexican Congress concluded a year's debate in November by approving a comprehensive nuclear energy bill reorganizing the nation's nuclear program. Previously, a small but capable nuclear research and training institute, INEN, held a loosely defined relationship to the pioneer Mexican commercial reactors being built by the Federal Electricity Commission at Laguna Verde on the Veracruz coast. The nation's enormous uranium reserves—10,000 tons of it proven with estimates of potential reserves ranging from 200,000 to 500,000 tons—had lain virtually untapped. In fact, uranium for the Laguna Verde plants was purchased in France and sent to the United States for enrichment.

The new law establishes a Nuclear Energy Commission to coordinate all aspects of the nuclear effort. Its subbranches include a government-controlled uranium mining and refining monopoly called Uramex, and expansion of INEN as the core research and training facility.

During the course of the debate, the pronuclear forces in the country were strengthened by the Aug. 24 founding of the Mexican Fusion Energy Association, working in coordination with the New York-based Fusion Energy Foundation.

The bill represents a major setback for some Mexican government officials who were in open alliance with U.S. Energy Secretary James Schlesinger in attempting to res-

How Much Oil Does Mexico Really Have?

Based on rapid development of the prolific Reforma fields in the southeast states of Tabasco and Chiapas, President Lopez Portillo announced startling new official oil reserves statistics in his state of the union address three months ago: Mexico has proven reserves of 20 billion barrels, probable of 37 billion, and potential of 200 billion.

Entirely outside these estimates, the state oil company, Pemex, revealed the following new discoveries in back-to-back announcements last month:

• 100 billion potential oil reserves plus 40 trillion cubic feet of gas in a field, called Chicontepec, stretching 75 miles long and 17 miles wide in a northern Veracruz state. The formation involved, a vast area of oil-bearing pockets with little porosity, is found at shallower levels than previously exploited, deeper oil in the same region. Pemex director Diaz Serrano announced that up to 16,000 individual wells will be drilled in a 13-year program, to begin immediately.

• 80 billion potential oil reserves plus 30 trillion cubic feet of gas in deposits offshore from the Chicontepec field, in a basin of tertiary formations called Bejuco-La Baja. The estimated depth of the field is 1,800 meters below sea train Mexico's nuclear development. An unprecedented series of attacks from press and congressional sources culminated in early November when INEN director Francisco Vizcaino Murray accused several government officials by name of sabotaging President Lopez Portillo's nuclear strategy and delaying the completion of the Laguna Verde plant. The president has ordered the twin Veracruz reactors completed "at forced-march pace," Vizcaino reported.

Simultaneously, the government has opened intense international negotiations for "oil for nuclear technology" deals. Mexico's nuclear future headed Foreign Minister Santiago Roel's agenda during his trip to France and Great Britain last July. In discussions of long-term deals with the British-Dutch-German nuclear consortium, Urenco, Roel and Vizcaino Murray demanded for Mexico a status "not as a client" but "as a partner" in the consortium.

Mexico also has begun discussions with France and the Soviet Union concerning advanced training programs, where France offered Mexico access to the full seven years of preparatory studies going into France's Super-Phenix breeder reactor. The deals worked out at that time could very well be consolidated during French President Giscard's visit to Mexico in February. In addition, two nuclear collaboration deals were among the core of agreements worked out during the visit of King Juan Carlos of Spain to Mexico City in November.

The only major nuclear supplier country currently outside the Mexican negotiations is the United States, despite the fact that U.S. suppliers won the major contracts for the Laguna Verde plants. Carter administration "antiproliferation" strictures, which have delayed the return of Mexican uranium in the United States for enrichment, have incensed Mexico's leaders, who take pride in their international efforts for nuclear disarmament. Near the conclusion of the nuclear law debate in the Chamber of Deputies, Mexican congresswoman Ifigenia Navarrete, an economist, castigated those foreign countries which, "just like the gods who were angered that Prometheus gave the gift of fire to mankind, now try to prevent the spread of nuclear technology, open to everyone."

The stage is now set for beginning the immediate siting studies and actual construction for a vastly stepped-up program. To keep on the timetable of a minimum 20 reactors by the year 2000, Congressman Hugo Castro Aranda has estimated that 13 reactors must be completed by 1993. In eloquent testimony to the Congress the day the new nuclear bill passed, Castro Aranda declared:

> The construction of a reactor takes from eight to ten years... If we don't make the decision now to build those reactors and to have an ambitious nuclear program in Mexico, by 1985 the same thing will happen to us as has happened in other moments of our history: we will miss the opportunity for development.

Tim Rush and Pablo Silva head the Mexican desk of the Executive Intelligence Review *in New York City.*

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level, and its full extent remains to be fully explored.

How quickly will potential reserves turn to probable and then proven? The transition rate is picking up fast. The proven category is largely a function of putting new fields into production, and Pemex is doing this with astonishing speed. The original 1982 production goal of 2.2 million barrels per day will now be met in early 1980, and current production is close to 1.5 million barrels per day.

What must be emphasized is that all the Mexican figures are conservative; they will most likely be revised upward as more information becomes available. Although potential reserves represent the total oil estimated to exist in known fields, only part of which is recoverable, Mexico's recovery rates are running a very respectable 40 to 50 percent. This is somewhat higher than the international average. According to informed oil sources in Mexico, new Soviet technology may soon boost recovery rates in some Mexican fields as high as 80 percent.

An Integrated Approach to Development

Pemex director Jorge Diaz Serrano sketched the outlines of Mexico's plans for integrated, in-depth industrial development in answer to a reporter's question about future package negotiations with trading partners at a November press conference.

Petroleos Mexicanos [Pemex] is one of the largest buyers from the metalworking industry; this requires steel, and there is a deficit of steel in Mexico. Therefore, at this moment we are studying possibilities that the Japanese will begin to invest in the steel industry.

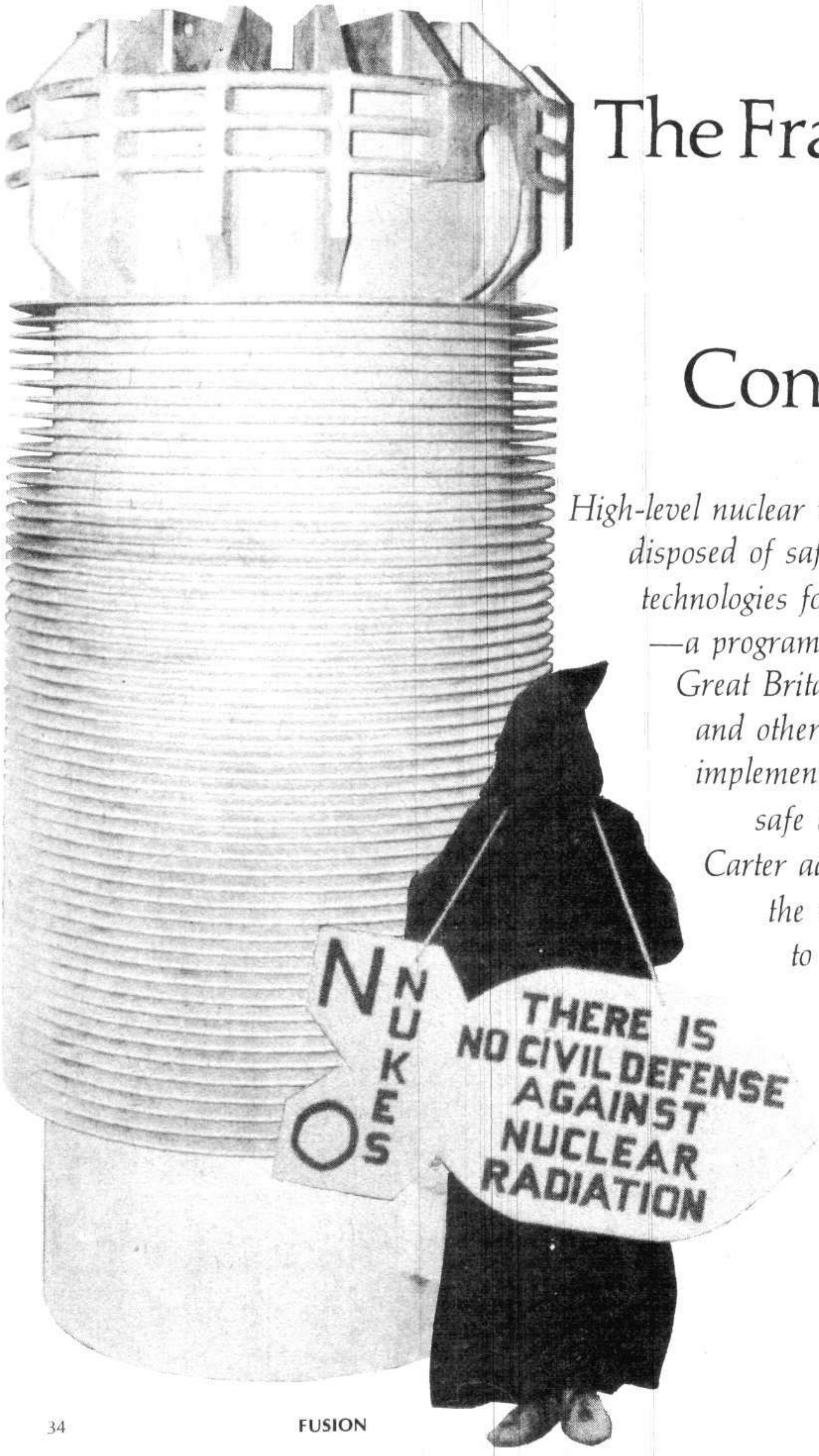
Likewise, if the capacity to produce steel in the country is going to increase, we must start the rehabilitation or the construction of adequate ports.

Remember that Mexico does not have large reserves of iron ore or coal. Therefore, the steel industry (as at the Las Truchas industrial center, for example) must strengthen itself to be able, at a certain moment, to bring iron from outside the country, to bring coal from outside the country, or to bring in natural gas to reduce the iron ore at that spot or at other adequate areas.

Capital Goods

This requires lots of electricity as well, and the Federal Electricity Commission will double its installed capacity within the short term. What does this mean? It means that a large amount of capital goods, a large number of turbine generators will have to be imported.

However, it's preferable to manufacture them in Mexico. We have the capacity and the resources, but we need a partner, possibly Japan, for this to be carried out.



The Fraudulent Nuclear Waste Controversy

High-level nuclear waste material can be disposed of safely by state-of-the-art technologies for underground burial —a program underway in France, Great Britain, the Soviet Union, and other countries. Instead of implementing an acknowledged safe disposal program, the Carter administration is using the waste scare as a way to stop the development of nuclear power.

by Jon Gilbertson

IN SCIENTIFIC TERMS, there is no nuclear waste problem. The safe technology for storing nuclear wastes has been known in the United States for more than 20 years and is now in use around the world.

The fraudulent nuclear waste controversy is a product of several U.S. policy decisions whose cumulative effect is to stop the United States from developing nuclear power. The presidential directive in April 1977 that indefinitely deferred commercial reprocessing of nuclear fuel, the Nuclear Nonproliferation Act of 1978, and the proposed Nuclear Siting and Licensing Act of 1978 have all but removed the U.S. nuclear industry from international leadership.

By far the most dangerous antinuclear weapon coming from the administration is the recently released report of the Interagency Review Group on Nuclear Waste. Ironically, this document states plainly that there is no scientific or technical problem in waste disposal and that the United States could have a high-level waste depository in operation by 1988. Despite this accurate appraisal of the situation, the report offers no plan or policy for implementing a national program for nuclear waste. Worse, the report presents various scenarios for action that include getting approval on nuclear waste burial from states, counties, towns—everyone but the village idiot. In short, this administration report puts the question of nuclear policy at the mercy of the superstition and fear fostered by the zero-growth environmentalist faction.

Mobilizing the majority of the population that backs a nuclear future for America to win the nuclear fight requires defeating the bogeyman of radioactive waste. The ammunition for winning this battle—some plain facts—is presented here.

The Solution at Hand

The solution to the so-called problem of nuclear reactor wastes is now in hand and, in fact, the technology for a nuclear waste program has been available for 20 years. The only steps that remain are to make the policy decision to implement the program and to do it. At this point the United States will not even have to do any groundbreaking work in this area. We can simply follow the lead of the several nations already committed to such a program that are several steps down the road toward the end goal of permanent waste disposal in deep, underground, stable geological formations. These nations include France, the Soviet Union, and Great Britain, as well as several other nations whose nuclear programs are not yet as well developed.

There are three basic parts to a nuclear waste management program: separating the radioactive fission product wastes from the spent fuel, recycling the unused uranium and plutonium fuel included in the spent fuel back into nuclear power reactors, and routing the wastes through a waste storage process. As described in more detail below, the storage process consists of storing the waste in concentrated liquid form in holding tanks for a period of approximately 10 years, solidifying this waste into a very stable glassified form, and sealing it into a metal container to be transported to an underground depository for permanent long-term storage. To cover all possibilities, the depository should be designed so that during the first 100 years of storage, the wastes could be retrieved in case it were decided later to make productive use of the valuable waste products or to dispose of them by new, more advanced technologies.

As this article will make clear by describing where things stand now, the reactor waste problem is simple to solve. This does not mean that there are no things yet to be learned, tests to be run, or new equipment to be designed and manufactured.

The point is that we are not dealing with developing a new technology, such as nuclear fusion reactors, MHD energy conversion systems, or advanced fission reactors. We are talking about permanently burying something for a long time, using technologies that exist now and are known to work. The tasks at hand are to plan and design this waste disposal program; to engineer it; to build and operate the facilities; and, finally, to monitor and collect data after the start of operations so that any necessary improvements can be made in this facility and in future waste disposal facilities as new things are learned.

In short, all that remains to solving the nation's nuclear waste problem is to engineer and construct the appropriate storage systems.

What Happened in the United States

As a nuclear engineer involved for nearly two decades in the development of commercial nuclear power reactors I can say categorically that no group of people is more shocked, confused, and destabilized over the current waste storage dilemma than the people in the nuclear industry; they still don't know what hit them. As far as the nuclear industry is concerned, the waste storage question was resolved 20 years ago, and it was just a matter of implementing a known technology once the volume of commercial wastes became large enough to proceed economically. But what is a straightforward implementation process has developed into a full-blown political battle, where not only nuclear waste processing but also the future of the nuclear industry itself is at stake.

The most frustrating part of the political fight over nuclear power is that one of the key opponents is the president of the United States, Jimmy Carter, who claims to have some background in nuclear engineering. Carter's statements and actions around the nuclear power issue, however, indicate that he does not have command over the simple scientific facts of the matter. In April 1977, President Carter was convinced by his advisors (including Energy Secretary James Schlesinger) to put a stop to the development and construction of commercial fuel reprocessing facilities and any reactors that depended on the separation of plutonium for their fuel, specifically the fast breeder reactor. The immediate results of the presidential directive were the halt in the construction of the Barnwell, South Carolina fuel reprocessing plant and the Clinch River, Tennessee breeder program—facilities that represented the heart of the U.S. program to close the nuclear fuel cycle and to expand nuclear power production in the United States.

This decision shocked other nations around the world. As several international commentators noted, the decision would severely damage the U.S. industrial capability and economy, and it would also produce a similar effect in other nations that depend on these high-technology U.S. exports.

The Reprocessing Factor

For more than 35 years—or since the atomic bomb was under development in 1942—the United States had been committed to a waste program based on separating high-level wastes (fission products) from the spent fuel, storing the unused fuel for future use, and storing the high-level wastes in concentrated, minimum-volume form. The April 1977 directive prohibited such reprocessing, thus eliminating this separation and storage technique for commercial reactor wastes. At the same time, it threw the entire nuclear community into mass confusion, especially the utility companies that owned and operated nuclear power plants. The immediate question for the utility companies was what to do with the spent fuel rapidly filling up the spent fuel storage pools inside the reactor buildings?

Until April 1977, the reactor manufacturers and the

Major Classes Of Nuclear Wastes

High-level waste (HLW) is that portion of the wastes generated in the reprocessing of spent fuel that contains virtually all of the fission products and most of the transuranic elements not separated out during reprocessing. These wastes are being considered for disposal in geologic repositories or by other technical options designed to provide long-term isolation of the wastes from the biosphere.

Spent Fuel (SF) is intact fuel elements that have reached their operating lifetime of about three years and are removed from the reactor into storage in water. Approximately 96 percent of the material is reusable for new fuel, while about 4 percent is considered waste. The current Department of Energy policy is to dispose of the entire spent fuel element, treating it as high-level waste.

Transuranic wastes (TRU) result predominantly from spent fuel reprocessing, the fabrication of plutonium to produce nuclear weapons, and plutonium fuel fabrication for recycle to nuclear reactors. This waste is associated primarily with the equipment, rubber gloves, brushes, and other material involved with the handling of plutonium during the various manufacturing processes. TRU waste currently is defined as material containing more than 10 nanocuries of transuranic activity per gram of material (a curie is a standard measure of the rate at which a radioactive material throws off particles). These wastes would be disposed in a similar manner to that used for high-level waste disposal.

Low-level wastes (LLW) contain fewer than 10 nanocuries of transuranic contaminants per gram of material (or none), require little or no shielding, and have a low but potentially hazardous concentration (or quantities) of radionuclides. Low-level wastes are generated in almost all activities involving radioactive materials and are now being disposed of by shallow land burial.

Uranium mine and mill tailings are the residues from uranium mining and milling operations that contain low concentrations of naturally occurring radioactive materials. The tailings, which are generated in very large volumes, are now stored at the site of mining and milling operations.

Gaseous effluents are released very slowly from reactors into the biosphere and become diluted and dispersed harmlessly.

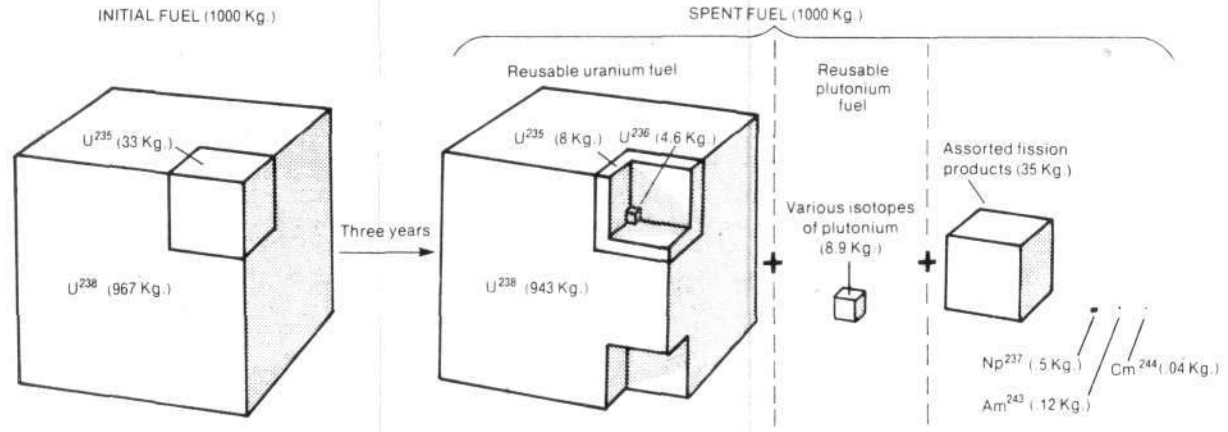


Figure 1
COMPARISON OF MATERIAL COMPOSITION OF NEW AND SPENT REACTOR FUEL

The change in composition of light water reactor fuel as it remains in the reactor over its three-year operating life is depicted here. The fuel starts out enriched in the fissionable isotope uranium-235 to 3.3 percent, with the remainder consisting of nonfissionable uranium-238, both in the form of uranium oxide.

After three years, the spent fuel contains only 0.8 percent U-235, the other 2.5 percent having undergone fission. However, an additional 0.89 percent of mostly fissionable plutonium has been produced. Therefore, more than 1.5 percent of the approximately 3.3 percent enrichment needed for new fuel is still available for recycle along with most of the required U-238. The remaining material, 3.5 percent fission products and 0.6 percent transuranic elements, is also produced as the uranium is consumed and constitutes the actual high-level waste material in a reactor.

The quantities shown are based on an initial arbitrary 1,000 kg of fuel.

utility companies had relied on the future availability of a commercial reprocessing plant—the Barnwell facility—that would take the excess spent fuel, reprocess it, store the uranium and plutonium for future recycling into reactors, and store the high-level wastes in concentrated liquid form. Later, the liquid wastes would be solidified and permanently stored underground at an unspecified depository.

What Are Nuclear Wastes?

Not only did President Carter's decision on reprocessing pull the rug out from under the U.S. nuclear industry, it gave the environmentalists a license to create and promote a fraudulent nuclear waste problem. In fact, environmentalists successfully exploited the ensuing confusion to push through legislation in several states, including California and Wisconsin, that bans the construction of new reactors until the federal government implements a program for the disposal of nuclear wastes.

If this situation continues, it promises to sabotage the development of the plutonium-fueled fast breeder reactor as well as the first viable fusion-based reactor system—the fusion-fission hybrid reactor—(described in this issue). The hybrid, which represents a transitional step in technology between the fast breeder reactor and full fusion reactor systems, will be capable of synthetically producing (breeding) the large quantities of plutonium-239 and uranium-233 necessary for fueling the expanding fission reactor economy worldwide.

Before the president's April 1977 directive, nuclear wastes in the United States were generally classified as high-level wastes (HLW), transuranic wastes (TRU), low-level wastes (LLW), uranium mine and mill tailings, and gaseous effluents from operating reactors or reprocessing plants (see accompanying box). Although all types of waste are important, the most important, and the one causing the major controversy now, is high-level waste; that is, waste that has high radioactivity levels. High-level wastes, which are the focus of this article, include all the fission products built up in spent fuel over an approximate three-year period of operation, as well as small amounts of some transuranic elements that are left over after the reusable uranium and plutonium have been removed for recycling. Figure 1 depicts this breakdown of materials, beginning with the new fuel and ending with spent fuel and left-over products.

The process of generating radioactive fission products and other nuclear wastes goes back to the basic nuclear fission reaction in the reactor. Fissioning of uranium-235, the only naturally occurring fisssionable material remaining in the earth today, results in the production of fission

Time since discharge of spent fuel (years)	Thermal power (watts/MTHM*)		Radioactivity (curies/MTHM*)	
	Spent fuel	High-level waste	Spent fuel	High-level waste
10	1200	1000	410,000	320,000
100	290	110	42,000	35,000
1000	55	3.3	1,800	130
10,000	14	0.47	480	42
100,000	1.1	0.11	58	21
1,000,000	0.39	0.15	21	10

*MTHM is metric tons of heavy metal originally charged to the reactor.

COMPARISON OF SPENT FUEL HIGH-LEVEL WASTES

This table compares thermal power output and radioactivity from spent fuel to the thermal power output and radioactivity from only the high-level waste portion of the spent fuel, as a function of time. The high-level wastes show a significant reduction in both radioactivity and thermal power, especially in the long term, beyond 100 years or so. For this reason there is a definite advantage to storing only the small quantities of high-level waste material instead of the entire spent fuel.

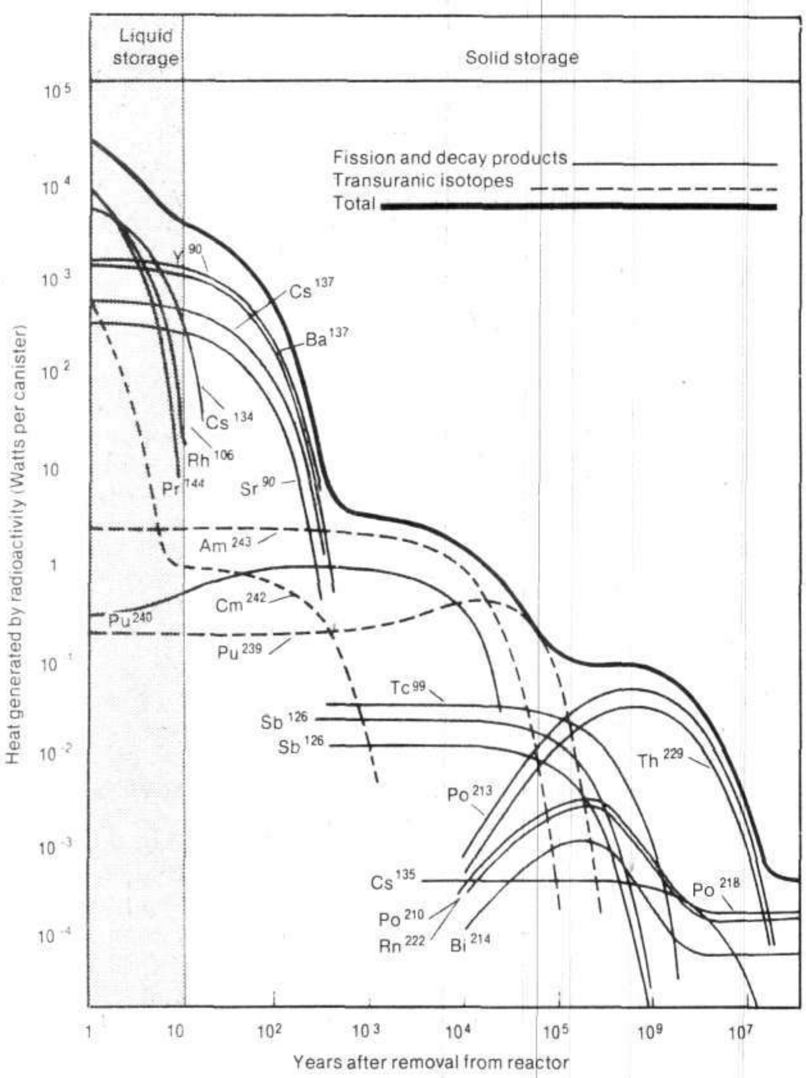
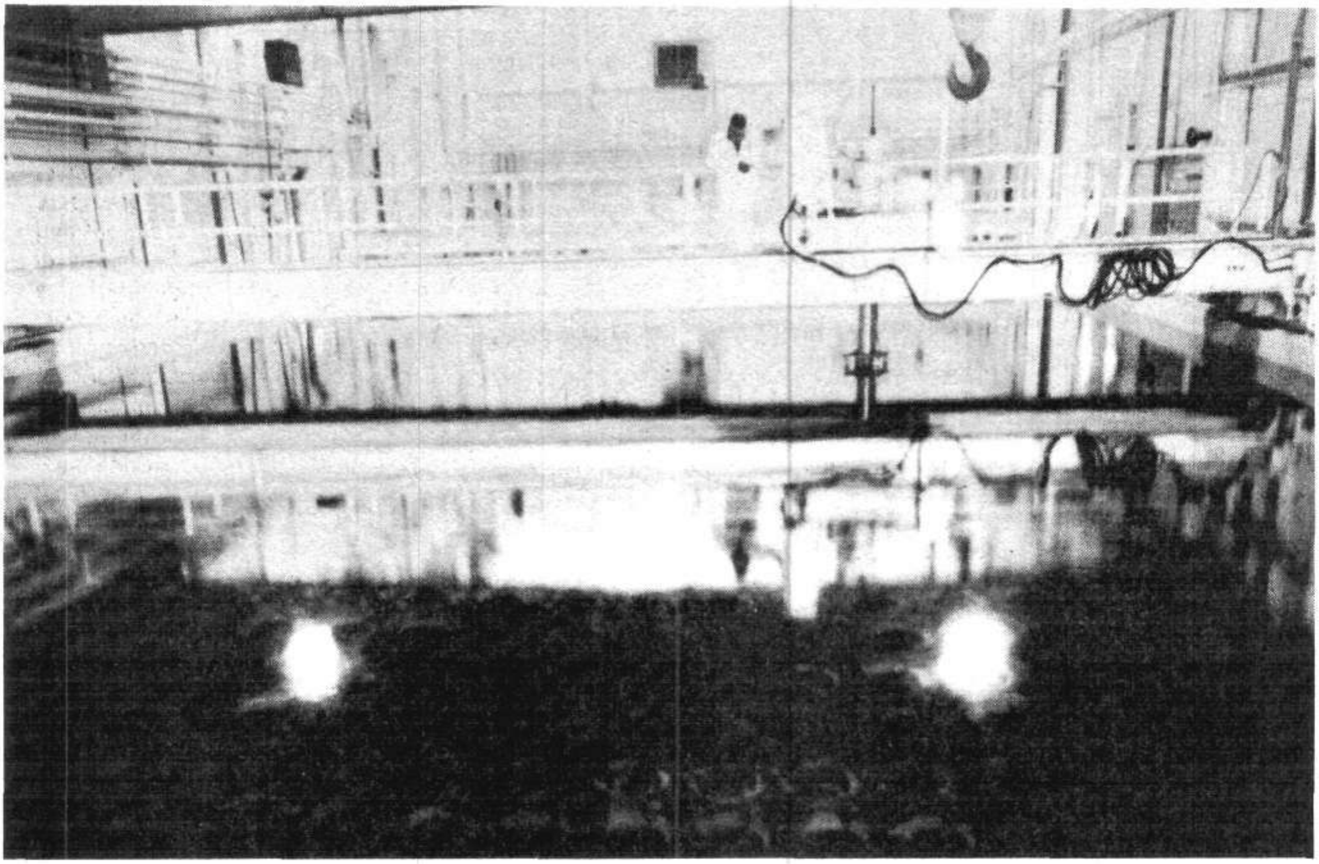


Figure 2
NUCLEAR WASTE HEAT GENERATION OVER TIME

Radioactive decay of the various isotopes in high-level waste generate heat over a very long period of time. Contributions of heat generation for a few of the more important isotopes are shown here, along with the total heat generated in a typical canister of waste material. Cooling requirements for these wastes can be met best if the wastes are in liquid form for the first 10 years. After 10 years, the reduction in heat generation by nearly a factor of 10, or to 3.4 kilowatts, permits storage in solid form.



Irradiated fuel stored in water-cooled basins in the now-closed West Valley, N.Y. reprocessing plant, the only commercial U.S. reprocessing facility.

products, neutrons, and energy as shown in the following equation:

Neutrons + uranium-235 ⇒

fission products + neutrons + energy

Each fission of a U-235 atom usually results in two fission products, which are elements of roughly half the atomic weight of the original uranium atom. The neutrons go on to produce more fissions or are absorbed in other elements that become transmuted into a new element, and, finally, the energy is given off as heat. These fission products are almost always unstable (that is, radioactive) isotopes of these elements and must decay for varying time periods, depending on the element, in order to become stable (that is, nonradioactive). The decay time period can vary from a few minutes to several thousand years or more, as shown in Figure 2. These longer-lived fission products make up the bulk of the high-level wastes that have to be disposed of permanently or for long time periods.

The other source of nuclear waste within the fuel includes the radioactive elements created by a nonfission capture of a neutron in uranium or some other heavy element in the fuel. These are generally called the transuranic elements and include neptunium, americium, and curium, plus small amounts of plutonium and uranium that do not get separated out during the reprocessing operation. Although very small in quantity compared to the fission product waste, these transuranic elements are important because they have very long decay times (see Figure 2) and, therefore, require long-term storage.

Figure 3 illustrates how this nuclear fission waste process fits in with the complete fuel cycle. This fuel cycle with the fuel reprocessing plan was the basis for the U.S. nuclear program until April 1977 (Cunningham 1978) and is now the program for the rest of the world. (The only exception is Canada, which is unique in that it has had a cheap, abundant supply of uranium fuel and does not think that it is economically necessary yet to go to fuel recycle.)

Since President Carter's decision to stop fuel reprocessing, the United States has been left with the situation shown in Figure 4, where all spent fuel is considered to be nuclear waste material (Cunningham 1978). This has increased the amount of waste products, radioactivity, and heat production levels to be handled, since all spent fuel now must be treated as high-level waste (see Figure 1 and the table). In addition, the prohibition of reprocessing essentially throws away 40 percent of the required fuel for new fuel elements—that could be recycled back into the reactor—a combination of uranium-235, plutonium-239, and plutonium-241. Over a 40-year lifetime of a single

1,000-MWe nuclear power plant, this would amount to the equivalent of throwing away more than 130 million barrels of oil or 37 million tons of coal!

Furthermore, if the primary concern is to get rid of plutonium as quickly as possible, the best way by far is to get it back into a light water reactor or the fast breeder reactor to burn it up as fuel, instead of going to the expense of burying it.

The Safe Way to Dispose of Nuclear Wastes

As should be clear by now, the only competent way of dealing with nuclear waste is to integrate the waste products into a fully closed nuclear fuel cycle; that is, a fuel cycle with fuel reprocessing. In a closed fuel cycle, nuclear waste become a by-product to be disposed of in a straightforward manner—a solution backed by the Fusion Energy Foundation, the nuclear industry, the advanced sector nations, and, most recently, by the developing nations.

To implement a program of safely and economically disposing of nuclear wastes in the United States, it is essential that the nation reinstitute a fuel reprocessing policy. Until that time, a temporary measure for waste disposal must be the finding or constructing of adequate storage areas, away from present reactor sites, simply to store the current and future spent fuel coming out of operating nuclear plants. It should be emphasized that this is a stop-gap measure only; the actual solution to the problem must involve reprocessing. Once fuel reprocessing is reestablished, it will be a simple matter of shipping these stored fuel bundles to the reprocessing plant. Currently, there are no plans to bury any of these valuable fuel elements until sometime in the mid to late 1990s, which is long after the nuclear fight will have been won.

The amounts of the nuclear waste now being stored are as follows: The United States has approximately 4,400 metric tons of commercially spent fuel stored either in reactors or in the few available away-from-reactor storage areas. Only about 4 percent of this fuel, 176 metric tons, is HLW that would be separated out during reprocessing. By the year 2000, more than 98,000 metric tons of spent fuel is expected, with about 3,920 metric tons of this as HLW.

In addition, the amount of reprocessed HLW currently in the United States consists of approximately 70 million gallons from the Department of Defense and only 0.6 million gallons from the one commercial U.S. reprocessing plant, the now-closed facility at West Valley, New York.

Reprocessing fuel and separating out the waste will

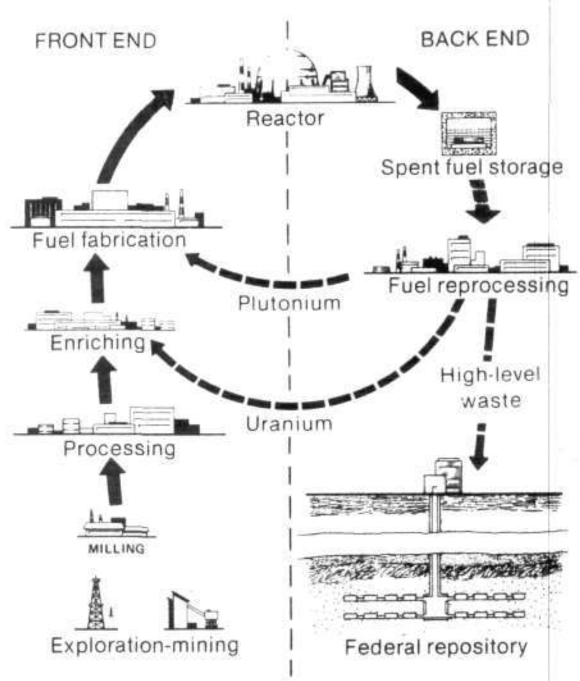


Figure 3
FUEL CYCLE WITH FUEL REPROCESSING
This is the internationally preferred way of processing spent reactor fuel and the relatively small quantities of high-level wastes. The spent fuel is reprocessed for separation and recovery of nearly 96 percent of the material that is reusable. The 4 percent of actual nuclear waste material is then disposed of.

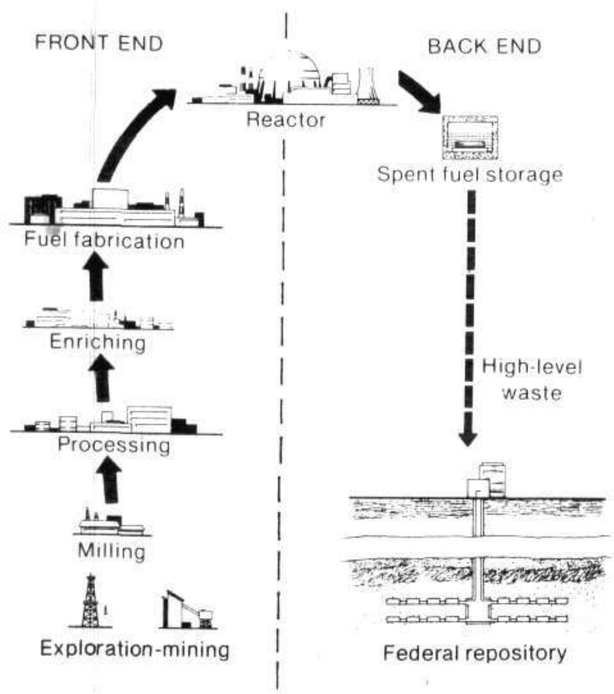


Figure 4
FUEL CYCLE WITHOUT FUEL REPROCESSING
This so-called throw-away fuel cycle is the current U.S. Department of Energy process for dealing with spent fuel. The spent fuel elements, including all of the reusable fuel and the wastes, are stored for a period of time (at least 10 years) and then are buried. None of the valuable fuel material is reclaimed.

reduce by more than 25 times the quantity of waste material that must be disposed of. This, combined with the reduced radioactivity and heat generation (as shown in the table) is an additional important advantage of a fuel reprocessing system.

Storage Technology

There are two technical problems in handling and storing radioactive nuclear fission waste material. The first is the radioactivity from the decay of unstable elements by either alpha or beta particles and gamma rays. This radiation is dangerous to human beings from external or internal sources, and, therefore, it must be kept isolated from the biosphere for as long as the activity remains high.

The second problem is that radioactive decay produces energy in the form of heat and this heat must be dissipated for as long a time period required in order to keep material temperatures below certain design limits. Both the shielding and the heat removal must be resolved simultaneously.

The most technically developed process for high-level waste disposal is to store the waste in concentrated liquid form at ground level for a cooling period of 5 to 10 years (Cohen 1977). At that point it can be solidified into small canisters and buried in a deep underground location in thick, stable rock-salt strata. Liquid storage of the waste and eventual solidification all will take place on the reprocessing plant site (for example, the Barnwell facility) in a completely controlled and monitored environment. For years storage of liquid wastes has been a state-of-the-art technology. In fact, the Department of Defense has used storage in this form since the early 1940s and has highly developed the technique.

As for the question of "leaks": There have been several leaks in World War II vintage storage tanks (for example, in Hanford, Washington a few years ago). However, the present technology has superseded the early World War II storage system several times over by now (Campana 1976). And even with those leaks, there was no damage or hazardous conditions because the engineers had planned for such possibilities and had located the storage tanks in a dry, remote region where the very hard compact substrata prevented the liquid from going anywhere.

Modern storage tanks are constructed as double-walled vessels made out of high quality stainless steel and they have leak-detection instrumentation in the space between the walls as shown in Figure 5. If a leak is detected between these walls, the entire tank is evacuated to a separate spare tank on site as a back-up.

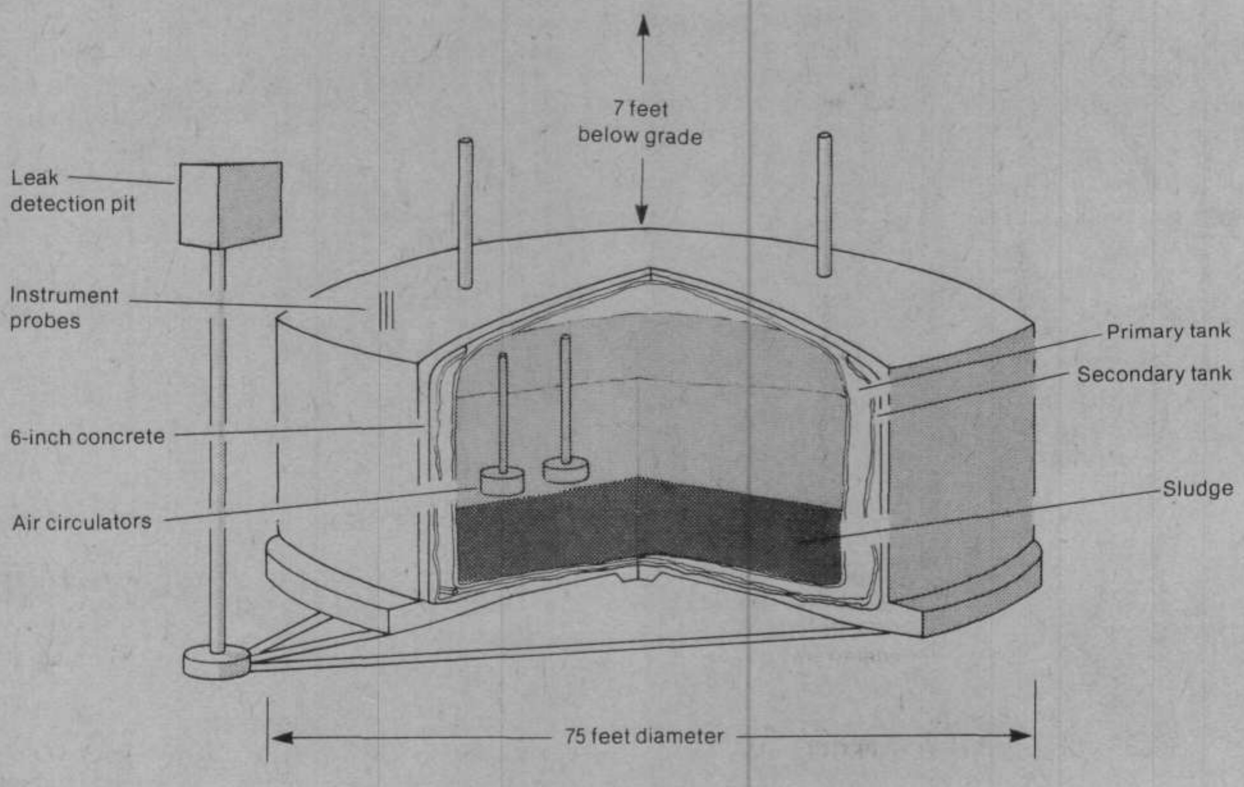


Figure 5
LIQUID NUCLEAR WASTE STORAGE TANK

A modern liquid waste storage tank has double-walled containment with leak-detection equipment between the two walls. Made of the best materials available today, this simple system guarantees safe storage of liquid wastes for the required near-term time periods.

The wastes are initially stored in liquid form primarily to handle the relatively high heat generation rates that occur during the first 5 to 10 years. It is much easier to dissipate this heat by natural thermal convection processes in a liquid than in a solid. After this time period, the radioactive decay levels, although still very dangerous, are greatly reduced such that heat generation rates are decreased by nearly a factor of 10. At these levels, the heat can now be transferred from a solid via conduction, while maintaining relatively low material temperatures. It is at this point that the nuclear wastes can be solidified, placed in canisters and permanently stored underground, totally removed from the biosphere.

DOE

A cross-section view of high-level waste glass test material solidified in a steel waste canister is displayed here by William Bonner, the technical leader of nuclear waste processing at Battelle's Pacific Northwest Laboratories.

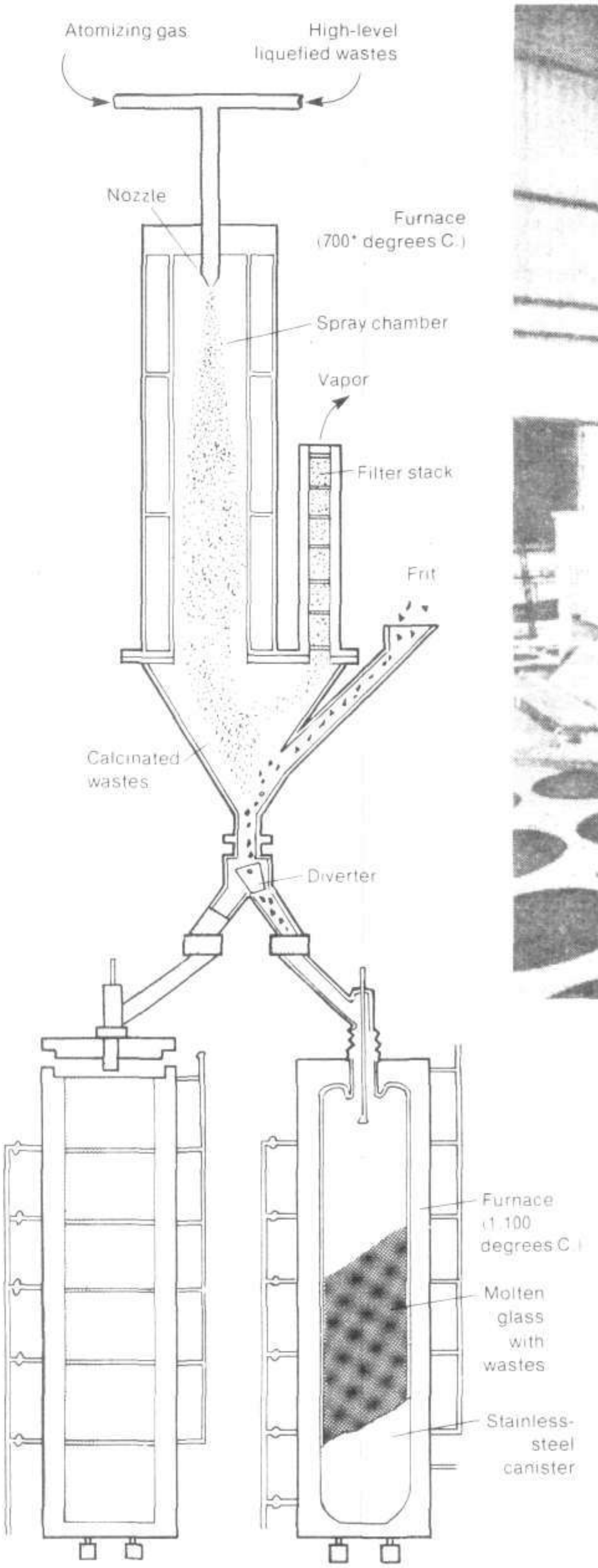
This proposed solidification process is shown in Figure 6, where an automated system converts the liquid waste by evaporation to a fine powder, mixes it with a fine glassy frit material, and converts it to a solid glassy cylinder by heating the mixture to melting and then solidifying it (Cohen 1976). This process is already a developed technology and is now used commercially in France, as shown in the photograph (Lewis 1978). The solid waste cylinder is sealed in a stainless steel canister and shipped to a underground burial site in specially designed shipping casks.

The only part of this waste disposal process that does not exist yet is the deep underground burial site, which can be developed and constructed with state-of-the-art technology. (A schematic illustration of such a site is shown in Figure 7.) The actual storage area would be located 600 meters underground, in the middle of a thick salt layer. The stainless steel canisters would then be placed inside other containers made out of something like cement based on high-conducting iron-oxide that was designed specially to protect against possible salt corrosion. This cement canister would then be inserted in cylindrical holes drilled into the salt. Heat is transferred and dissipated by conduction from the waste products, through the containers, and into the surrounding salt medium (Cohen 1977). The canisters could remain there forever or could be removed during the early decades of operation. This capability for removal might be desirable if it were later decided to use the waste products, their radioactivity, or heat energy in a productive way, or if some modification of canister design were needed. Therefore, it is recommended that at least the first few storage facilities be designed with a retrievability option for the first 75 to 100 years.

Because we know more about rock salt formations and their interaction with nuclear wastes, the first one or two depositories should be located in such formations. Most U.S. experts agree that this is what we should do, and even the most recent assessment completed by the Interagency Review Group on Nuclear Wastes, a multidepartmental task force set up by President Carter in April 1977, recommends this as a first approach that could be in operation by 1988 (Deutch October 1978).

In fact, this operation date could probably be moved up by two to three years if the nation embarked on an accelerated program. Although this crash effort is not really essential since the waste first must be stored in liquid form, it would be desirable in order to solidify and bury the waste now being stored by the Department of Defense.

The major advantages of salt over other formations is its good thermal conductivity, a known long-term geological stability of hundreds of thousands of years, very low ground water content, and an ability to quickly self-seal if a crack should form as the result of an earthquake or other disturbance. The major disadvantages are that the self-sealing ability makes it more difficult to keep the depository open for retrieving canisters and that the salt would be corrosive if water somehow got into the storage area. There is general agreement, however, that both disadvantages could be compensated for by available design



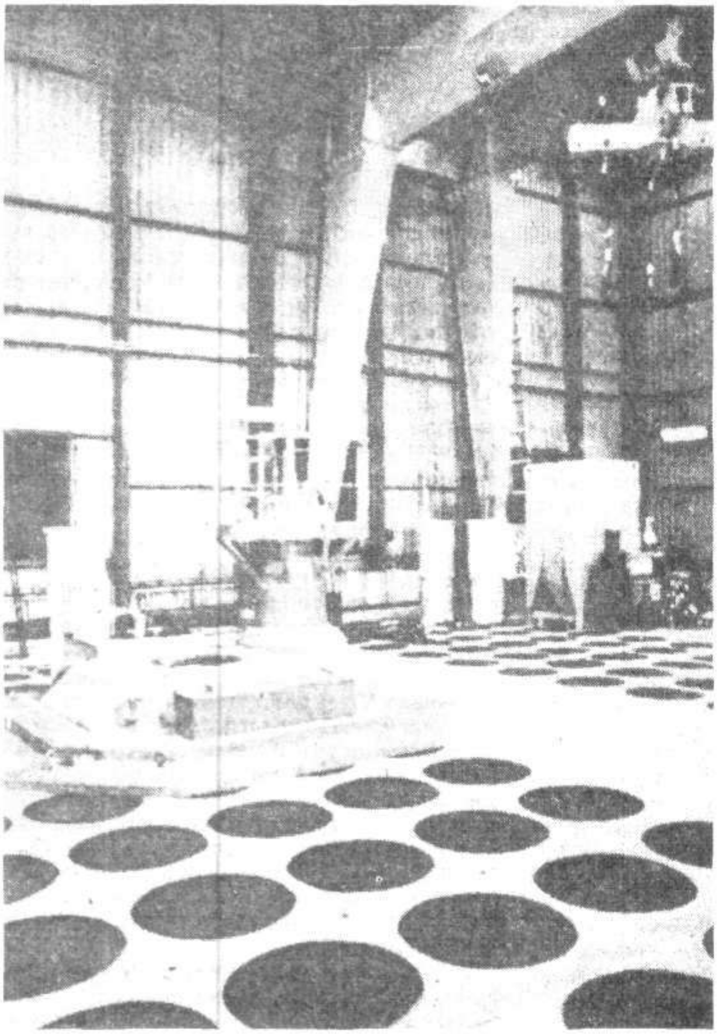


Figure 6
VITRIFYING HIGH-LEVEL NUCLEAR WASTES

A process similar to the one shown in the figure is now in commercial operation in Marcoule, France (photograph). The U.S. process, called vitrification, converts the liquid wastes into solid glass cylinders about 300 centimeters long and 30 centimeters in diameter. In the single-step solidification process depicted here, the liquid high-level waste is converted into a fine powder inside a calcining chamber, mixed with glass-making frit, and melted into a block of glass within the thick stainless-steel canister in which it will eventually be stored. The process is continuous: When the canister is full, the flow is switched by a diverter valve into a new canister. The photograph of the French process shows the concrete storage building where these canisters are temporarily stored before they are removed to a permanent underground depository.

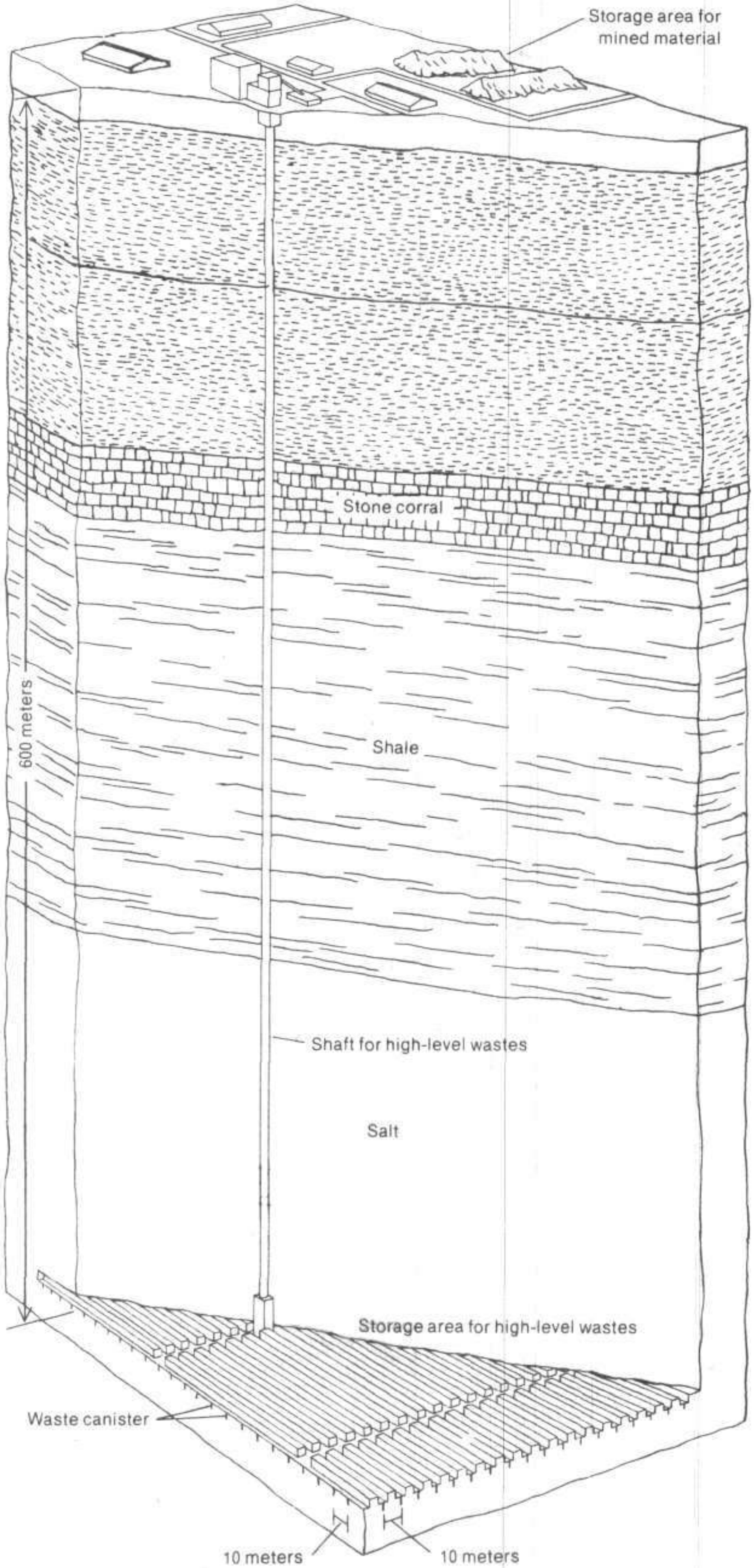


Figure 7
DEEP UNDERGROUND NUCLEAR WASTE DEPOSITORY

Burial of high-level wastes in stable rock salt formations is the method preferred by most U.S. experts now. The solid waste canisters would be lowered down a shaft to a storage area approximately 600 meters underground and then stored in holes drilled in the rock salt. The spacing of these holes would be approximately 10 meters to allow for dissipation of the heat without exceeding the design temperature limits in the canisters and salt formation. Assuming that each canister requires 100 square meters of salt around it for cooling, less than half a square kilometer would be needed to store the high-level wastes produced annually if the United States had an all nuclear electric economy of 400 1,000-MWe plants. In fact, the United States has only about 10 percent of that quantity in nuclear electricity now, or about 45,000 MWe. This will require only a small fraction [.05] of a square kilometer for storage annually.

In addition to the safety studies at the Hanford site, geologists recently uncovered evidence in Gabon, Africa of a natural fission reactor that operated underground billions of years ago for a period of about 500,000 years—considerably longer than the 40 year lifetime of today's nuclear reactors [Campana 1976]. The natural fission chain reaction that occurred was maintained as a result of the uranium isotopic content and the natural ground water flow. Although fission product activity has long since decayed, traces of the plutonium and its radioactive decay products are still evident. The stable fission products and the plutonium decay products both appear to have remained localized, which gives us very good evidence of the safety of storing nuclear wastes underground. Of course, nuclear wastes today will be solidified, containerized, and sealed in a vault, in addition to being located deep underground.

and engineering techniques. The most recent detailed information supporting these conclusions is included in another report of the Interagency Review Group (Ost 1978).

Transportation of Nuclear Waste

A related issue that has received much negative publicity is the question of transporting spent fuel bundles or other radioactive materials. The doomsayers claim there is no safe way of transporting such material and have successfully promoted passage of legislation in several cities, including New York and New London, Connecticut, that prohibits the transportation of spent fuel. Like the unnamed individual who cut off his nose to spite his face, these two city governments have completely prevented the shipment of spent fuel elements from the research reactor at the Brookhaven National Laboratory on Long Island to the Savannah River Defense Department reprocessing plant in Georgia. Since this was the normal way of handling spent fuel and wastes, Brookhaven has been forced to build more temporary storage capacity in the reactor building to store the spent fuel there until the normal shipments can continue.

The easiest way to illustrate the ridiculousness of these transportation ban regulations is to refer to the series of photographs (Figure 8) that show tests of a diesel locomotive running into a spent fuel shipping cask on a flat-bed trailer at over 80 miles per hour. The results were a completely demolished locomotive and flat-bed—and an intact, sealed shipping cask that suffered only a few dents (DOE 1978). Other tests ran a flat-bed truck and trailer head-on into a cement wall at 80 miles per hour and dropped the cask from an elevation of 30 feet onto an armor steel plate, with similar results.

In another study, experts at Sandia Labs in New Mexico looked specifically at the problem of shipping radioactive material through large congested cities, including New York. Not surprisingly, the radiological impacts of such shipments were found to be extremely small and essentially negligible (Du Charme 1978).

Alternative Disposal Methods—Future R&D

Although at this time it is not likely that alternative methods for nuclear waste disposal will be required, there are several more advanced techniques that could be made available at some future time (Gilmore 1977; Deutch February 1978). These include deep burial in rock formations other than salt; disposal in outer space or into the sun; destruction of fission wastes by high-energy particle beam nuclear spallation (see box); and transmutation of

Disposing of Nuclear Waste By Spallation

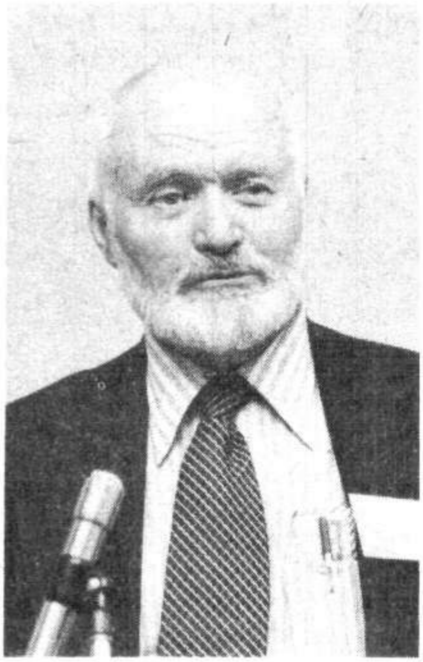
Nuclear spallation—the fragmenting of atoms with high-energy particle beams—would break up long-lived fission products into new elements with shorter decay times. These shorter-lived spallation products would then be stored in depositories, but for a much shorter period of time than the unspallated waste.

This technologically advanced method of disposing of nuclear wastes was put forward in a recent paper by William Cornelius Hall, president of Chemtree Corporation, a company that provides a special high-density concrete for nuclear power plants.

As Hall reviews in his proposal, the concept of nuclear spallation was developed in the 1950s by Dr. W. Bennett Lewis, who was then head of research for Atomic Energy of Canada, LTD, at Chalk River, Ontario. Lewis proposed that the spallation effect be used for generating heat and electricity in much the same way as a nuclear power reactor. However, in spallation a particle accellerator would be used to generate a beam of particles, most likely protons, that would be aimed at target material made of lead or bismuth. The spallation of these dense atoms would produce energy in excess of that needed to run the particle accelerator and could be used as a power plant. At the time, costs of electricity from such a power plant were found to be competitive with other sources.

Hall proposes that the same power plant concept be used in his system but the target material would be the dense, long-lived nuclear waste products. Some or all of the costs could then be recovered by the sale of electricity, and at the same time, the process would alleviate a good part of the problem of storing nuclear wastes for long time periods.

Hall proposed the immediate establishment of a research and development program using one of the high energy particle accelerators already in operation at a national laboratory. Within a relatively short period of time, tests could be run to determine the economic feasibility of the spallation concept.



William Cornelius Hall

Figure 8
IMPACT TESTS ON A SPENT FUEL SHIPPING CASK

The series of photographs shows an impact test in progress, where a diesel locomotive smashed into a trailer-truck carrying a spent fuel shipping cask, at over 80 mph. The results show a completely demolished locomotive and trailer—and a shipping cask with only a few dents in its cooling fins and absolutely no leaks. These tests and others dramatically prove that there is no danger to the public during shipping of radioactive materials.

the long-lived wastes by fission or fusion neutrons to elements with shorter decay times, followed by shorter-term burial.

The most immediate and near term of these methods is deep burial in other rock formations such as granite, anhydrate, shale, and so forth. As the Interagency Review Group recommends, research should continue on an expanded basis into these areas as well as with rock salt formations. It is possible that such formations might be found to have some advantages over salt. Additionally, if for some unforeseen reason the rock salt depository does not appear to be operating according to design expectations during the first few decades of service,the canisters could be removed and transferred to this new rock formation-based depository. And having such a back-up capability should satisfy even the most critical opponents of nuclear power.

Of course, research should be instituted or continued on the other methods mentioned in order to determine their potential feasibility. Probably all of these methods eventually will prove to be feasible but at a much greater cost than the recommended deep underground burial. Nevertheless, if it is judged necessary or desirable in the future to dispose of wastes by any of these methods, enough work should be done now to enable us to make a choice about which method to use.

Jon Gilbertson, FEF director of nuclear engineering, is a nuclear engineering consultant with 16 years experience in design, development, safety, and testing of nuclear power plants and systems. A leading plant safety analyst, he holds a patent on a tested nuclear reactor safety shutdown system. Gilbertscn has written for several nuclear journals and he has testified on nuclear safety for congressional committees, state legislatures, and other groups.

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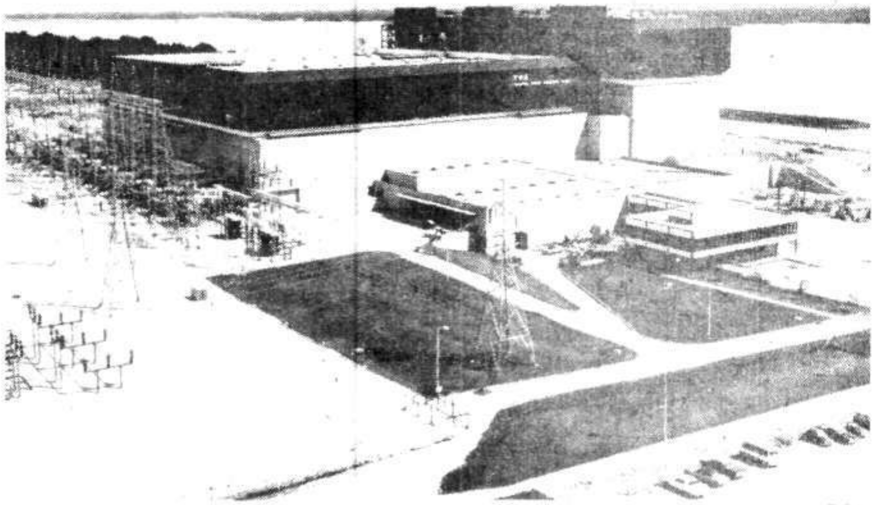
Nuclear Firm Patents High-Hydrogen Mortar



DOE

The new mortar technology would improve on the combustible organic shielding material used in reactors like Brown's Ferry (above).

The Chemtree Corporation of Central Valley, New York was recently issued a patent by the U.S. Patent Office for noncombustible high-hydrogen content mortar technology for use in nuclear radiation shielding. Although Chemtree has previously patented noncombustible mortars, the new technology, CT 1-6-20, is significant because of its high hydrogen content.

Hydrogen is the material that best attenuates neutrons, but most hydrogen compounds other than water are extremely flammable. The new high-hydrogen mortar contains 79 percent of the hydrogen content of water. Noncombustible hydrogenous materials generally contain a much lower concentration of hydrogen atoms and, consequently, do not provide the desired efficiency of neutron attenuation.

Fires at the Senna Power Reactor at Rocky Flats, the Colorado Plutonium Processing facility, and the Brown's Ferry Reactor all involved combustible organic shielding material present in continuous phase (that is, blocks of paraffin polyethylene, and other synthetic plastics, natural and pressed wood, bonded cellulosic products, epoxy cement mixtures, and other combustible carbonaceous material). These materials form a continuous phase that supports combustion and adds fuel to a fire generated either internally or externally in the shield itself. In turn, this causes the fire to spread and intensify.

This continuous phase characterizes the entire shield as combustible; there is no supplementary supporting structure in the form of a noncombustible continuous phase.

Chemtree Corporation's important technological advance is the introduction of hydrogen atoms as a *discontinuous phase* of the finished shielding product. In short, even though the hydrogenous material may be combustible en masse, in this new mortar the hydrogenous material is dispersed in relatively small particles, each of which is surrounded by noncombustible material. Such "fire barriers" between the individual combustible particles prevent propagation

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Loss-of-Coolant Test Results Encouraging

A loss-of-coolant flow test has been run in an actual nuclear reactor for the first time, with very encouraging results. The experiment was run Dec. 9 in a test reactor in Idaho Falls, Idaho called the Loss of Fluid Test (LOFT) facility that was designed specifically to determine what happens in a nuclear power plant if all coolant flow to the reactor core stops. This is the hypothetical accident situation that antinuclear groups used successfully to delay nuclear plant construction in the United States in the early to mid-1970s.

Withstanding the Hypothetical Accident

Even though it is impossible to determine how such an event could happen in "real life," reactors are now designed to withstand this accident by the installation of emergency core cooling injection systems. The results of this test, the first in a series planned over the next two years, indicated that the maximum clad temperature was far below that expected—only 900 degrees F instead of 1,370 degrees—and that the "accident" was over in less than half the time expected. If future tests continue with similar results, this means that the loss-of-coolant accident is not nearly as serious as the antinuclear environmentalists have claimed and that current reactor cooling systems are very conservatively and safely designed.

Continued from page 47
of fire throughout the entire mass. The barriers also prevent oxygen from reaching the combustible discontinuous phase.

Higher Thermal Stability

Noncombustible continuous phase *cement with inorganic bonding* usually has a higher thermal stability than the carbonaceous continuous phase of the conventional high-hydrogen content shield. The higher thermal resistance (stability) of the inorganic bonds will retain the structure and form of the shield, thus providing continued radiation protection.

Chemtree is internationally known for its research and development of metallic mortars used in the nuclear industry for a wide range of applications, from beam collimators and *pipe penetrations to bulk shielding*. Mortars such as Chemtree's iron oxide mortar are stronger and have 2.5 to 3.0 times higher thermal conductivity than other concretes, thus reducing temperature differential and preventing cracking.

—*Mary Gilbertson*

Rochester Laser Completes Phase 1

The experimental laser fusion system at the University of Rochester in Rochester, New York, which began preliminary shake-down operation in mid-July of 1978, has completed a successful series of shots on target fuel.

The series of 30 test shots on the Zeta laser system took place in late October and the most successful shot produced a neutron yield of 3.4×10^8 neutrons with a laser power input of 2.6 terawatts. Since only 6 of the planned 24 laser beams were in operation, the total number of neutrons produced is not that high. However, the yield efficiency for that power input is very good, according to scientists at the laboratory.

After completing these tests and a series of system tune-up shots (not at target fuel), the facility was shut down to add more diagnostic equipment and to fine tune the existing test equipment. Testing will resume again in early January 1979.

Zeta, the first-phase experimental installation, will continue in operation with the 6 laser beams throughout 1979, while the remaining 18 beams are being constructed in banks of four. Completion of the ultimate 24-beam system, called Omega, is expected in early 1980 at which time much higher power inputs and neutron yields will be achieved.

Soviets Build Metro in Quake Zone

A new metro system in the Soviet city of Tashkent, in an active seismic zone, has just opened and has withstood its first earthquake.

The area presented two other challenges in addition to its seismic history: waterlogging soil and scorching summer climate.

To cope with the earthquake problem, Soviet engineers hinged together circular concrete sections so that the entire Metro tunnel can bend at its joints. Stations of box construction are also jointed along the walls and roofs. When the earth shakes, so can the Metro. At 300-yard intervals recording devices tell two central seismological stations how the tremors and stresses affect the Metro.

Instead of blasting a route from point A to B regardless of the obstacles — as is the usual practice — the Soviets avoided the soft soil by twisting the tunnel through the contours of the firmer ground. And to prevent the tunnels from cracking in the dry, hot temperatures, which can reach 113 degrees F., huge ventilators have been installed in every section.

"The metro will last for centuries," said Pavel Semyonov, head of the construction board. He mobilized 350 specialists from all over the country to work in the project.

The system runs a train every three minutes and carries 170,000 passengers during the 19 hours it is open.

Advanced Technology

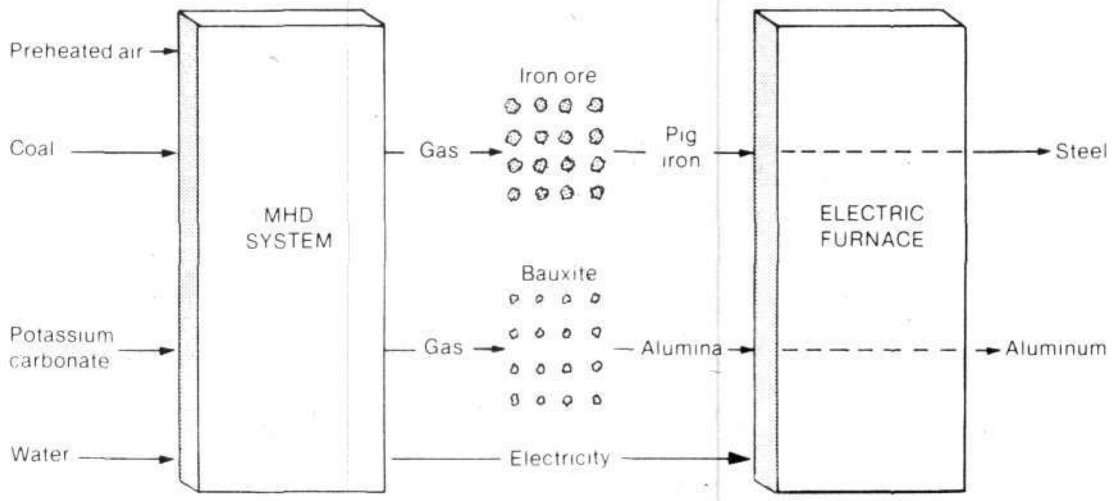
The Integrated MHD-Complex

Magnetohydrodynamic (MHD) electrical generating plants are prime candidates for future integrated industrial complexes. U.S. and Soviet studies, as well as the direct experience of the Soviets, have shown that the MHD method of generating electricity from passing a fusion or fossil-fuel plasma through a magnetic field can increase electric conversion efficiency by 100 percent as compared to current methods. Full utilization of the by-products from this high-temperature process would produce fertilizers, concentrated sulfuric acid (required in industrial processing), and a 33 percent energy savings in steel and metals production. In fact, the proposed MHD steelmaking system is the most efficient method thermodynamically, as well as the only one that is completely self-contained.

Although the United States had begun a serious government-supported program in the early 1970s, inspired by the dramatic Soviet experimental results, recent budgetary constrictions have prevented investigations of the MHD steelmaking process. U.S. industry, however, is likely to take over the research expense since an energy-hungry metals industry must have new technological advances to meet future industrial needs.

MHD has been under development in the Soviet Union in conjunction with their fusion program for nearly 20 years. At present, the Soviet U-25 MHD fossil-fuel generator can supply approximately 20 megawatts of power to the commercial Moscow electric grid, and construction of a 500-megawatt commercial demonstration plant will begin in 1980. Since the Soviets expect to have from 15 to 20 2,000-megawatt MHD generators on line before the end of this century, they are investigating the industrial processing methods that would take advantage of

SCHEMATIC OF MHD METALS PROCESSING INDUSTRIAL COMPLEX



the high MHD temperatures and the ionized properties of the MHD gas.

Alexei Sokolsky, director of the Soviet MHD program, remarked in an October interview with U.S. science reporters that facilities to capture the nitrogen oxide emissions from MHD and produce "free fertilizer" should be built next to the power generator. The extremely high temperatures (over 3,000 degrees F) used to generate a fossil-fuel plasma fixes the nitrogen in the atmosphere; that is, combines it with oxygen to form nitrogen oxide. This nitrogen fixation is required for commercial fertilizer production.

U.S. studies have shown how such a production system could operate in economic competition with the conventional use of natural gas, with the constant rise in natural gas prices tending to make the MHD method economically superior. In addition to fixed nitrogen recovery, the sulfur byproducts can also be removed by the nitrogen oxides, which convert sulfur dioxide to sulfur trioxide. Sulfur trioxide easily forms sulfuric acid, which can then be used to concentrate the nitrogen oxides and separate them, producing concentrated nitric acid for fertilizer and concentrated sulfuric acid for industrial processing. The studies show that the benefit of these concentrated products would offset the purchase of the chemical processing equipment required.

Integrated Steelmaking and Metals Production

The most exciting proposal for MHD applications is in the steel and metals industry. At present, the metals industry in the United States consumes 15 percent of the net energy produced, mainly in coal and electricity. And for finer metal processing, such as aluminum, electricity is the highest cost. For this reason, U.S. aluminum companies (for example, Reynolds Metals) have started to investigate coal-based MHD to provide electricity and the high temperatures needed to reduce oxide ores.

An article in the September issue of *Industrial Research/Development* magazine outlines one such integrated MHD-metals-processing configuration that is applicable to the steel and aluminum industries. Their estimate is a 33 percent savings in energy from coal-based MHD. (A schematic of their proposed system appears in the accompanying figure.)

The temperature of the MHD plasma in the channel where electricity is produced is about 4,500 degrees F or higher; the outlet temperature after electricity conversion is about 3,000 to 4,000 degrees F. At such high temperatures, the coal carbon reacts chemically with oxygen from the iron oxide ore to produce carbon monoxide and reduce the iron ore to pig iron. This pig iron can then be made into high-quality steel in an electric arc furnace, using the MHD electricity (similarly for producing aluminum from bauxite ore).

Taking place at temperatures almost 500 degrees hotter than blast furnace methods, this thermodynamically more efficient method results in a 28 percent energy savings. An additional 5 percent energy savings results from the direct conversion of electricity in the MHD process. This total energy savings of 33 percent could clearly have an extraordinary impact on the cost of steel and metal, restoring U.S. industry to a competitive position in the international steel trade.

The unique benefits of an MHD steelplex are seen by comparing it to nuclear steelmaking: The carbon required for the ore reduction is present already in an MHD coal-based system, but in a high-temperature gas-cooled reactor (HTGR) steelmaking system coal or natural gas must be brought into the process. Also, the high MHD effluent temperature is thousands of degrees higher than the heat in an HTGR, producing a higher overall efficiency.

—*Marsha Freeman*

Books

The Pornographic Pleasures Of Engineering

The Existential Pleasures of Engineering, by Samuel C. Florman, London: Barrie & Jenkins, 1976.

Thank you, Samuel Florman, for your book, *The Existential Pleasures of Engineering*. Although I have been an engineer for more than 10 years, only now after reading your book do I feel free enough to say what I feel, as you put it, "in my heart, in my bones, in my gut": Your book is pure bullshit!

A wiser man than I once said, "Existentialism is not a philosophy, it is a disease. You don't debate (or review) it. You treat it." Let this short review serve then as an antidote or inoculation to the unwary engineer who, perhaps after a meeting with the cost accountants in his credit-crunched firm, becomes momentarily depressed about his efforts and has the misfortune to pick up Florman's effluvium.

It is particularly distressing that this pseudophilosophical pablum is the subject of a major promotional effort among nuclear scientists and engineers. At a November session of the joint American Nuclear Society and Atomic Industrial Forum conference in Washington, members sat through an attack on their capacity to reason by an official panelist promoting the book as a "must." As the conference organizers should know rather painfully, the last thing this country's nuclear scientists and engineers need is a "feel good" book.

Let Passions Rule

Since World War II, Florman says, a fervent antigrowth movement has emerged in the country that has left "the religion of progress lying in ruins about us." As a result, engineers "will have to relinquish the dream of priesthood and seek to define our lives in other terms," he says.

In the course of trying to define the meaning of life, Florman argues that life is itself existential: There is no scientific truth, there are no universal laws, and "passions, impulses, urges, and intuitions are the basic ground of our personal existence."

To prove this, Florman calls forth or quotes from (and I list only the most absurd) Sartre, Camus, Kierkegard, Norman Mailer, Aristotle, Rudyard Kipling, Aleksandr Solzhenitsyn, *Zen and the Art of Motorcycle Maintenance*, and, finally, the following gem from Anne Morrow Lindbergh (which, Florman says, shows the emotional relationship between man and machine): "This little cockpit of mine became extraordinarily pleasing to me, as much so as a furnished study at home. Every corner, every crack had significance. Every object meant something. Not only the tools I was working with, the transmitter and receiver, the key and antenna reel. . . ."

Now, if that's about airplanes, then Xaviera Hollander is an astronaut!

Some Real History

In the first two decades of this century engineers, in particular, had a clear vision of their social purpose. The leaders of the profession, Frederick Taylor, Henry Gantt, and others clearly enunciated policies in the broadest terms, national and international in scope.

Shortly after World War I, Gantt said: "We see then that in as much as production was the controlling factor in the great war, it will hereafter remain the controlling factor in the world. That nation which first recognizes that production, not money, must be the aim of our economic system will, other things being equal, exert a predominant influence on civilization."

"Our immediate problem then is to develop a credit system that will enable us to take advantage of all the productive forces in the community."

During the 1920s the ancestors of the forces that oppose the American system of industrial progress today escalated their campaign to narrow the scope of thinking of the typical progrowth engineer. Since a frontal assault against technology was not possible, these zero-growthers—who were mainly centered in and around the British Fabian Society—instead pretended agreement with growth and technology. "Yes," they said to engineers, "your ideas are good. Apply them to the factories and then to the individual worker."

Instead of input into issues of science and politics that were international in scope, engineers were urged psychologically to return to the factory, to think small, to worry about the *feelings* of the workers. Now, says Florman, engineers should worry about their own feelings, too.

Florman's book takes this one step further; he urges infantilism. This is the essence of existentialism—man, alone, feeling sensual, screaming, "I am like a newborn infant."

As should be painfully clear to a nation barraged with the horrors of Jonestown, Guyana, infantilism is the identity of cult members. In contrast, adults are people who make the self-development of the creative mental powers of the individual the primary basis for the determination of individual identity.

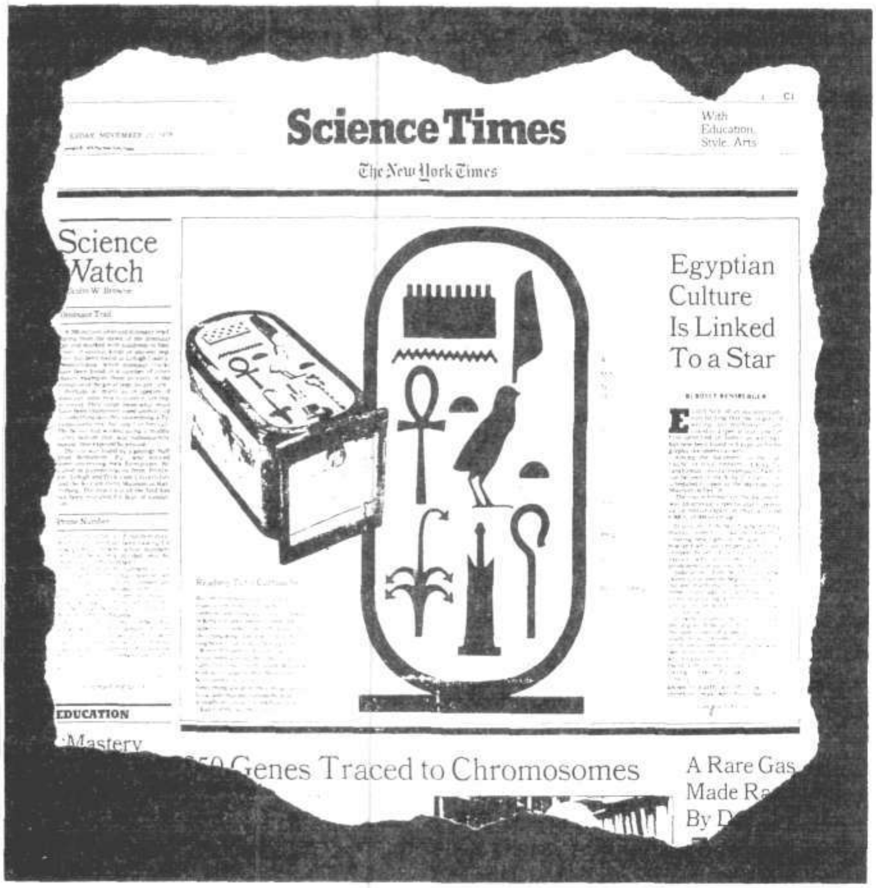
From the time that man emerged from the caves, his activity has been characterized by willful interventions into producing the means of his existence. Advances in human society are not the outcome of some biological urge. All great advances of humanity have been due to the intervention of individuals who understood, as Gantt did, that man has the creative qualities to master the laws of nature.

Individuals who know this will not seek Florman's recommended existential *infantile* pleasures—except perhaps the pleasure of tossing Florman's book into the circular file.

— *Kenneth Mandel*

N.Y. Times Science Section Touts Star Lore

"Egyptian Culture Linked to a Star," by Boyce Rensberger, *The New York Times*, Science Section, Nov. 21, 1978



Science Times

With Education, Style, Arts

The New York Times

Science Watch

Egyptian Culture Is Linked To a Star

EDUCATION

Mastery

Genes Traced to Chromosomes

A Rare Gas Made R

By D

Tutmania invades all the news that's fit to print in the new science section of the New York Times.

The *New York Times* has been an enthusiastic supporter of the royal progress across the United States of King Tutankhamun's tomb artifacts. Like the rest of the media, the *Times* had barraged readers with stories of cultlike mystery and death-worship surrounding these 50 or so gold objects from Tutankhamun's tomb—remarkable only for being the only Egyptian tomb to escape vandalism.

Nevertheless, *New York Times* readers were startled Nov. 21 when they opened to the newly inaugurated *Times* weekly Science Section to find the lead headline asserting "Egyptian Culture Linked to a Star." The article was accompanied by a comic-book reproduction of a cartouche newly reinterpreted to read: "Tutankhamun, Ruler of the Southern Star," instead of the usual "Ruler of Southern Egypt."

The thesis of the article is that the appearance of a supernova for several months in the constellation Vela 6,000 to 10,000 years ago "gave crucial impetus to the development of the nascent arts of writing and mathematics" in Sumer and Egypt. The father of the theory, according to *Times* science writer Boyce Rensberger, is George Michanowsky, a New York-based linguist who has lately turned his interest to Mesopotamian astronomy and published his theory in the book *The Once and Future Star*. Michanowsky's other occupation is as science advisor to the environmentalist Explorers Club.

In a hopelessly unscientific condensing of thousands of years of human development, Rensberger describes the Michanowsky theory thus: "In the centuries following the starburst, the inhabitants of southern Mesopotamia, simple farmers and fishermen in small villages, developed astronomy, mathematics and writing."

Although the supernova apparently did occur and may have inspired awe in early man, the interpretation given is totally without foundation.

Instead of conceptualizing human development as natural, universal, and necessary, the lawful result of man's intelligence, a *deus ex machina*, the supernova, is introduced. Since creative mentation is inconceivable to Michanowsky et al., they assert that the mysterious rays of this supernova must have "caused" men to discover science, writing, mathematics, and technology.

It is indeed true that the priest castes of Sumer, Babylon-Chaldea, and Egypt used "star lore" to maintain the peasantry in awe and subjection. But superstition is hardly the basis for human progress!

The priesthood of Amun-Re around Tutankhamun, in particular, looked to the stars when they led a violent campaign of destruction against Akhenaten's monotheistic revolution. Star lore was central to the creation in Egypt of the Isis/Osiris cult, and was brought westward in elaborated horoscopic form through Ptolemaic Egypt and Imperial Rome to become astrology. This mindless form of Stoicism still affects us today, practiced espec-

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ially by the youth of the zero-growth drug cultures, decorated with their Egyptian-derived ankh crosses and pyramids.

It is intolerable that Michanowsky and the *New York Times* legitimize the star cult as the birth of science. Most of the *Times* article details Michanowsky's notions that the ankh, the pillar, the sedge plant, and other Egyptian hieroglyphs actually symbolize the "Southern Star" or supernova. Thus Michanowsky feels sure he has found in the cartouche of a king who reigned in 1357 BC proof positive of Egyptian recognition that they owed their culture to a continuity of star lore based on a supernova 2,000 to 6,000 years earlier.

The *piece de resistance*, Michanowsky's identification of the Egyptian goddess Seshat with Sumer and the Star, may well be true, as far as it goes. Seshat surely bears resemblances to a host of subsequent "mother"-cults (Isis, the Magna Mater, and the like) and may indeed trace back to the darkest side of Sumerian ideology. But Michanowsky's simplistic suggestion that "the ancient starburst [is linked] . . . through Seshat to the development of writing, mathematics and the other high arts of the world's earliest civilizations," would justify the most backward practices of the ancients as the source of their humanity.

Instead, Egypt and the world can be proud of the civilizing, city-building tendency represented by Tutankhamun's predecessor and father-in-law, Akhenaten. This great ruler set out explicitly to destroy the enforced backwardness represented by the priesthood of Amun-re, and in its place to introduce the religious and scientific concept of a coherent universe informed by one supreme being. Akhenaten's efforts were utterly destroyed, his cities razed to the ground and his temples overthrown by his successor Tutankhamun.

Unlike the *New York Times*, the December issue of *Scientific American* approximates a responsible attitude to Egyptology with its article "The Razed Temple of Akhenaten."

—*Molly Kronberg*

Energia *magazine: "The effort of humanity to advance from fire to the atom can depend on us."*

New Mexican Magazine Dedicated to Energy Growth

Energia magazine, published monthly in Mexico; subscriptions $22 per year in U.S.; 440 pesos in Mexico; Taller Editorial, S.A., Illinois 57, Mexico 18, D.F.

Energia, a new Spanish-language magazine devoted to the discussion of all aspects of energy development, appeared on Mexican newsstands in September. As a readable, attractive science magazine, it promises to provide an important public forum for discussing Mexico's new role as an oil giant. Specifically, *Energia*'s coverage of advanced technology and energy development should aid in educating the general population about industrial growth and energy, as well as providing expert studies and analyses for the use of decision-makers.

In its first two issues, *Energia* has forcefully advocated the development of nuclear energy as a vital part of Mexico's industrial development. In particular, the magazine stresses the need to use Mexico's aggressive oil development program to power the transition to nuclear energy. The magazine outlined this as follows:

"It's obvious that the nation's economic development . . . in the coming years will depend on a substantial increase of reasonably low-cost energy. In the medium term it is essential that hydrocarbons be replaced by a source of energy, which, like nuclear energy, offers the greatest economic advantages and the highest productive yield."

The articles in the magazine's first two issues provide plenty of information to back up this viewpoint: An interview with the dean of Mexico's nuclear scientists, Dr. Carlos Graef

Fernandez, and an article on Mexico's Nuclear Energy Institute are run side by side with a feature on the achievement of the Mexican Petroleum Institute and a historical account of the 1938 oil expropriation by renowned Mexican leader Fernando Benitez.

The second issue also includes an interview with Dr. Morris Levitt, executive director of the U.S. Fusion Energy Foundation. Levitt was interviewed while he was in Mexico in August to report on the recent fusion breakthroughs at Princeton, at the founding conference of the FEF Mexican affiliate.

Energy news items are covered prominently, and the magazine includes regular sections on national, Latin American, and world energy news.

Energia presents its statement of purpose in the editorial of its first issue, titled "From Fire to the Atom." Following are some excerpts: "We find ourselves in a period of transition. . . Perhaps never before has the link between energy problems and the everyday life of nations and its citizens been so clear. . . Man is once again faced with the unavoidable task of focusing his creative genius so as to keep the fire, on which his life and progress depend, lit. To ensure the supply of energy to this and future generations has become without doubt a primary task for the human species.

"Such a task involves not only scientific and technological issues. The advances made in nuclear energy provide undeniable evidence that humanity can resolve the energy dilemma it confronts this very century. There are, however, a multitude of political, financial, commercial, educational, and, of course, conceptual problems that prevent the achievement of this objective. To clear up these problems and resolve them is an unpostponable necessity.

"We intend to contribute to this process. From now on, the effort of humanity—and in particular of our nation—to advance from fire to the atom can depend on us."

Energia has already begun its valuable contribution to this effort. We depend on it to continue.

Lightning Rod

Continued from page 4

placing them in giant wooden tubs filled with water, repeatedly passing magnets over their bodies, staring deeply into their eyes, fondling and stroking them, and encouraging them to caress each other. Rearranging their "magnetic forces," he promised, would effect miraculous cures.

After several continuous hours of such treatment, our Commission observed the following results in his patients:

"Convulsions . . . remarkable for their number, duration, and force . . . known to persist for more than three hours . . . characterized by involuntary jerking movements in all the limbs, and in the whole body, by contraction of the throat, by twitching in the hypochondriac and epigastric regions, by dimness and rolling of the eyes, by piercing cries, tears, hiccoughs, and immoderate laughter. They are preceded or followed by a state of languor or dreaminess, by a species of depression, and even by stupor. The slightest noise causes the patient to start . . . his agitation is increased by a more lively movement . . . his convulsions then become more violent. Patients are seen to be absorbed in the search for one another, rushing together, smiling, talking affectionately, and endeavoring to modify their crises."

I am reliably informed by my friends in the new state of California that our observations of "animal magnetism" correspond closely to current behavior at Esalen Institute "love-ins"; in the places you call "discos"; among "born-again" sun-, tree-, and snake-worshiping cults; as well as in certain government sponsored and private research activities popularly characterized as systems analysis.

In a 1784 report to King Louis, our Commission advised of the threat to public order and morality posed by Mesmer's treatments and warned of the possibility that damage done to his patients could be "transmitted to future generations." Not long after our report was issued, it was made umistakably clear to Mesmer that he was no longer welcome in France, and he departed for Belgium.

There was no question of "limiting scientific inquiry" in the Mesmer case.

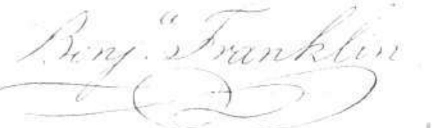
Mesmer was a charlatan, whose magnets had nothing to do with his actual results, as we proved. When his blindfolded patients were told they were being magnetized, they frequently experienced "crises" and convulsions. But if the magnets were brought near without their knowledge, and the same actions performed, *there were no such results*.

I am unable to describe the results of our *unofficial* investigations of the Mesmer case, but Mr. Civiletti and others should be advised to look diligently for the modern Mesmers who "treated" the Rev. Jim Jones if they wish to preserve the integrity of our Nation.

As for the U.S. Constitution, its prohibitions respecting freedom of religion do not protect those "animal magnetists" of today who maintain that True Worship is nothing but a willingness to endure a series of electrical storms in the brain, whereby the mind's light is cruelly snuffed out. Such evil creatures aim only to reduce Science and Religion alike to the common denominator of vulgar superstition yoked to brute force—out of their boundless spite for the Orderly Power of Creation.

I remain,

Yr. Obt. Svt.



Dionysian animal magnetism

Miami Conference

Continued from page 14

thorium cycle in his discussion of the fusion-fission hybrid. The closure of the thorium cycle would come too late, Murray said, and in the intermediate period we need the liquid metal fast breeder reactor.

The concept of developing hybrids as fuel factories was backed up by Nobel Laureate Wigner, who moderated the session. Wigner also reiterated Teller's call for declassification of laser fusion as well as laser isotope separation techniques.

The administration's classification policy as an impediment to research was criticized on the conference's first day by Representative Carl D. Pursell, a Michigan Republican. Pursell termed the energy shortage "a great threat to peace," and called for legislation to establish an energy research trust fund comparable to the one that got the space program off the ground. He also said that private sector involvement was necessary in fusion for the fastest possible development, and that the science and industry representatives had to get involved in the legislative process.

Teller asked Pursell whether his staff had the security clearance necessary in order to evaluate the classified laser fusion research going on. Pursell answered "no" and then agreed with Teller that the laser fusion work should be declassified.

In the afternoon session of the third day, Gregory Moses from the University of Wisconsin gave a thorough presentation on the laser driven fusion-fission hybrid, and Harold Furth, head of the research department at the Princeton Plasma Physics Laboratory, discussed pure fusion reactors and the ongoing tokamak work at Princeton. Moderator Robert Hofstadter, from Stanford University, then chided Furth for being too cautious in his reply when he was asked if the Princeton program could absorb more money.

Primeval Fuel Supply

In the same afternoon session, Thomas Gold of Cornell University made a controversial and scientifically stimulating presentation on "The Primeval Fuel Supply of the Earth and the Outgassing Processes." Gold's thesis is that natural gas is not primarily of fossil origin, but that there is a continuous process of outgassing of the earth. Methane is created in the earth's interiors, Gold said, below the level of fossil fuels and there is an ongoing process combining carbon and hydrogen into CH_4.

Gold presented various ways of determining whether his theory is correct. For example, he suggested setting up monitoring stations on earthquake faults to see what gases come to the surface.

Gold said that his thesis also raises questions concerning the production of oil, and he suggested that the most recently created deposits have the highest hydrogen content because of the continuing methane seepage.

Teller then posed the Gold presentation as an example of how the environmentalist discussion of "renewable" versus "nonrenewable" resources is silly.

There was also some discussion at the same session on the so-called greenhouse effect, the fact that there has been a 25 percent increase in the amount of carbon dioxide in the atmosphere. There has been a variety of ideas about what this means, but as Teller pointed out, the situation has to be investigated. As he noted, the increased carbon dioxide may mean major changes in large-scale atmosphere circulation.

At the end of the session, conference participant Robert Fri attacked the nuclear breeder, saying that to breed plutonium would only aid nuclear weapons proliferation. Fri was countered by William Cornelius Hall, president of Chemtree Corporation and FEF board member, who showed that Fri's arguments were not valid scientifically or politically.

Teller also noted that outlawing nuclear breeders would not work and that the only possibility to ensure peace was more international cooperation and more power to international institutions.

—Uwe Parpart and Marjorie Hecht

FEF News

The State of Science In the American West

FEF executive director Dr. Morris Levitt and director of research Uwe Parpart toured major U.S. research facilities in New Mexico, California, and the Pacific Northwest in late October, as part of an ongoing foundation review of U.S. research and development programs. Levitt's report to the foundation is excerpted here.

The major conclusion to be drawn from our trip is that U.S. physical research that is high-technology-based, much like U.S. military posture, still packs plenty of punch but is increasingly contained. The big project U.S. research effort centered in our major national laboratories lacks two basic ingredients: first, an adequate scientific base; and second, a republican nation-building mission. This is not to say that there are no significant impulses to develop and combine the two qualities in a number of leading facilities. Rather, there is no visible scientific and political leadership in the nation outside of the faction represented by the FEF to make these outlooks hegemonic in the life of the research community.

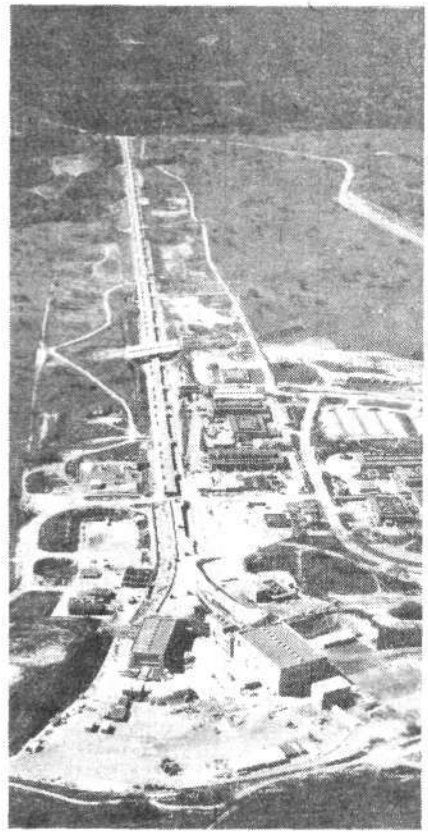
Before taking up the general syndrome, consider some examples. Among the facilities we visited, the following reflected in various ways the strengths and weaknesses of contemporary U.S. science and technology. Each of these sites, it should be stressed, contains devices that were or still are the best engineered in the world: the Doublet III tokamak at General Atomic in San Diego, the Los Alamos Scientific Laboratory (LASL), the Stanford Linear Accelerator (SLAC) at Stanford University, the laser fusion facility at Lawrence Livermore Laboratory (LLL) and the Hanford nuclear complex at Richland, Washington.

The chief project engineer for the Doublet, a former combat jet aircraft engineer from San Diego, proudly showed us the tokamak current conducting coils that had been machined to such high precision that they produced an almost perfectly uniform magnetic field when assembled. But many basic components for the power supplies that energize the magnet are not available in the United States and had to be imported from Japan. And although microelectronic engineers are "a dime a dozen" here, the United States hardly has any power engineers capable of designing the special high-current, fast-switching components and circuits required in fusion research.

Lawrence Livermore's Shiva laser for laser fusion is a masterpiece of optical science and engineering. When work on the facility began several years ago, the projected power output was set at a level about 500 times greater than the power then available from any combination of existing lasers and power amplifiers. The scientists at Livermore had to develop about a half-dozen optical components with performance capabilities far superior to existing components. They not only did this, but also ended up producing about 30 percent more power than the originally targeted level of 20 terawatts.

There was nothing mysterious about this large number of major technological improvements at Livermore. With the necessity for a 10 terawatt laser in mind (to produce significant target compression and burn), the joint physics-engineering-materials teams pursued several new approaches in parallel for the development of each component. This produced a working and flexible system.

What of the future? To go beyond energy breakeven with the present Livermore approach, Livermore must



An aerial view of the two-mile Stanford Linear Accelerator.

build the Shiva-Nova, a device 30 times more powerful than Shiva. However, Livermore does not have adequate funding now for a comparable multifarious development program.

Perhaps the frustration with this situation is also a contributing factor to the continuing underestimation by Shiva's top scientists of the different hydrodynamic approach the Soviets take to laser fusion. Looking at the totality of Soviet research in plasma, MHD, laser, and beam areas is the only way a proper assessment can be made of overall strategic capabilities, including the likely status of specific weapon systems such as collectively accelerated particle beams. Matters are certainly not helped either by the classification system, which prevents outside scientific input to the laser program or even Japanese investment in the U.S. projects.

More fundamentally, one is struck by the separate universes that divide

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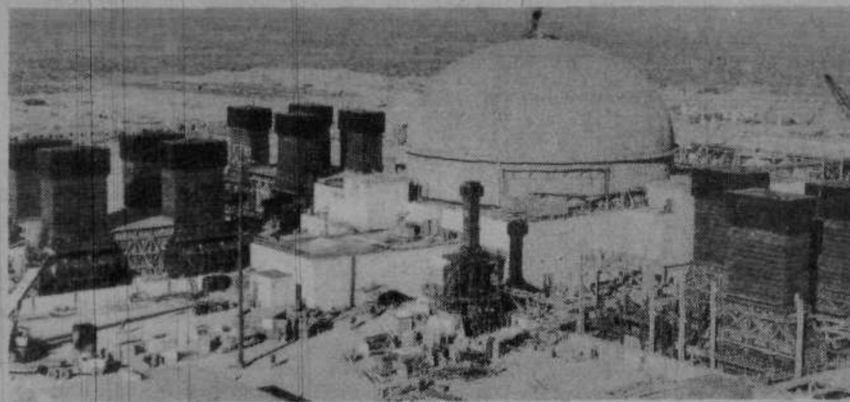
the various major scientific institutions in California. It is a big state, but one can still think of scientific resources as being "neighbors." For example: the astrophysical group at Cal Tech-Mount Palomar; the Stanford Linear Accelerator, which produces the world's most concentrated pure electromagnetic fireball in high energy electron-positron reactions; and Livermore's Shiva laser and plasma focus facilities. This is a unique combination of research facilities in nuclear, particle, space, and astrophysics. Along with Houston and Cape Kennedy, this is the nation's key capability for space colonization and in-space astrophysics research. Imagine the fruitful cross-fertilization of ideas from a collaborative effort among these institutions to deal with common problems of high energy density particle-plasma processes and condensed states of matter. . . .

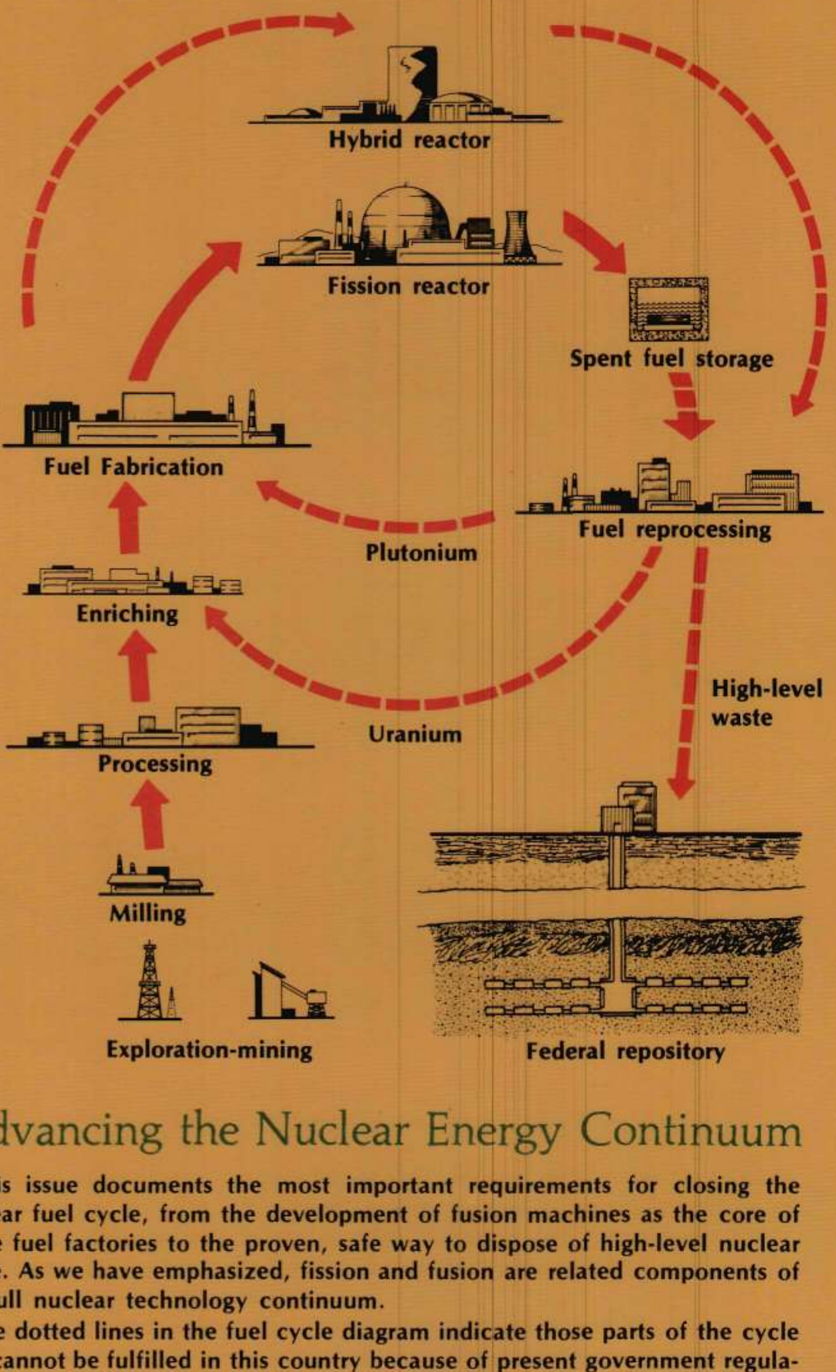
Of the facilities visited, Hanford and the Los Alamos Scientific Laboratory most directly display the potential to regain America's commitment to nation-building here and abroad. As participants in the Manhattan Project, the former installation produced the plutonium and the latter the enriched uranium for the first U.S. atomic bombs. Los Alamos has developed into a relatively broad-based research facility including significant magnetic and inertial confinement laser research. Hanford is an enormous nuclear engineering reservation covering more than 500 square miles.


The sodium-cooled fast flux test reactor under construction at the Hanford nuclear complex.

Consider the potentialities. Hanford sits adjacent to a half-loop in the Columbia River, which is navigable out to the Pacific via Portland, Oregon. From a scant few hundred population in 1943, the area expanded overnight to a Manhattan Project population of 50,000 and then more slowly to the present population of 100,000 in what is called the Tri-Cities area. The reservation, which boasts three nuclear reactors and a breeder test facility under construction, could become the Novosibirsk—the renowned Soviet Siberian science city—of America.

The Tri-Cities area has one of the greatest concentrations of nuclear-industry cadre, can probably accommodate 100 1,000 MW nuclear plants and their feeder breeders, and has one of the world's best basalt geological structures for long-lived nuclear waste disposal. From this follows the possibility of mass production of floating nuclear plants or components for the Pacific basin, a major fusion-fission hybrid development project, and a vast agroindustrial complex based on the area's extensive metal ore deposits and rich irrigated farmland.

Before the resources are brought to bear to accomplish this, however, the scientific culture of the entire area must be brought up to an appropriate level. Los Alamos, on the other hand, has a more developed scientific base and is ready now to do great things. For example, the laboratory's director, Harold Agnew, has proposed that the U.S. government set up a new institute at Los Alamos for the industrial development of Mexico that would provide access to all leading areas of science and technology for scores of Mexican trainees. This would certainly be an appropriate response to the Mexican call for technology transfer to develop its vast material and human resources.



Advancing the Nuclear Energy Continuum

This issue documents the most important requirements for closing the nuclear fuel cycle, from the development of fusion machines as the core of fissile fuel factories to the proven, safe way to dispose of high-level nuclear waste. As we have emphasized, fission and fusion are related components of the full nuclear technology continuum.

The dotted lines in the fuel cycle diagram indicate those parts of the cycle that cannot be fulfilled in this country because of present government regulations—regulations that must be reversed if the United States is to join the rest of the world and go nuclear. Also at stake in overturning the antinuclear provisions is whether this nation is to contribute to providing ample nuclear fuel to power global development and to bring a growing world into the fusion age.

As author Dr. John Schoonover shows, the most advanced process in the nuclear cycle, the fusion-fission hybrid, can be developed as early as the 1990s. As for the semihysterical controversy on nuclear waste, nuclear engineer Jon Gilbertson presents the facts of the matter and an easy solution to nuclear waste that is now in operation in other nuclear countries.

About the cover: The artist's rendition of a fusion-fission hybrid is courtesy of Lawrence Livermore Laboratory.
Cover design by Christopher Sloan.