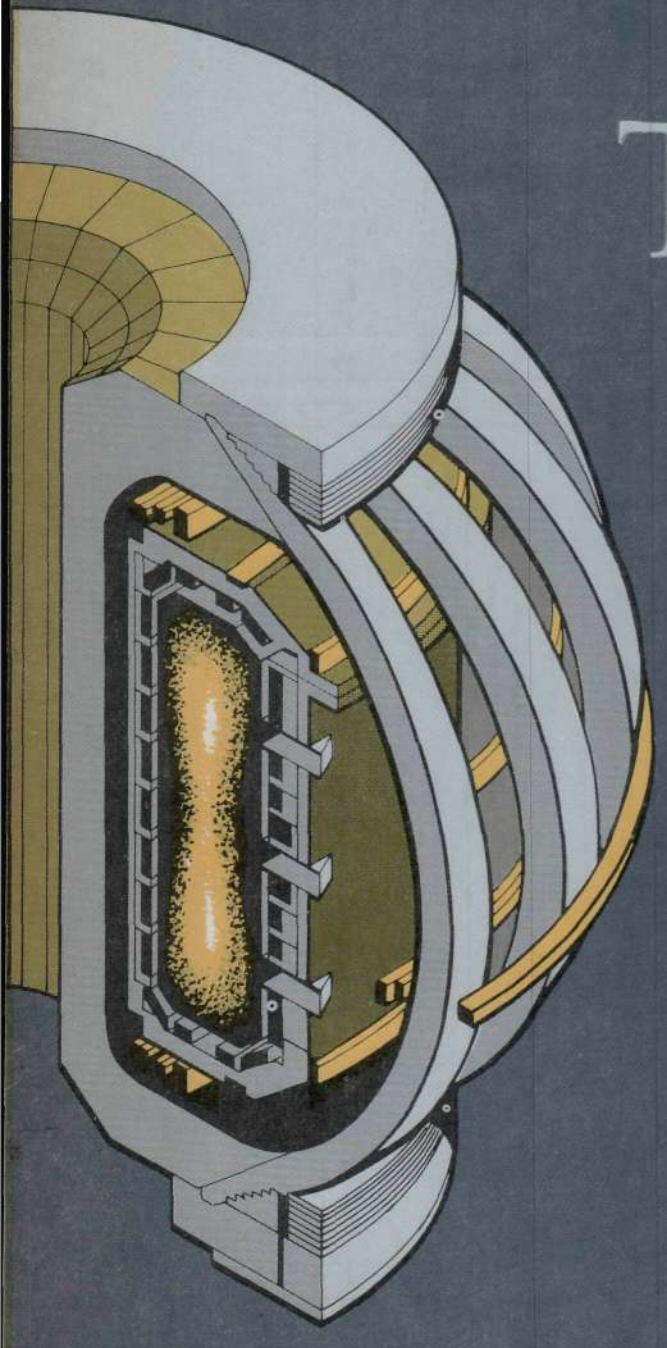
FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION



The World Goes Nuclear

- *The Basic Science of Tokamaks*
- *Fusion Breakthroughs*
- *Will the U.S. Be Left Behind?*

December-January

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FUSION

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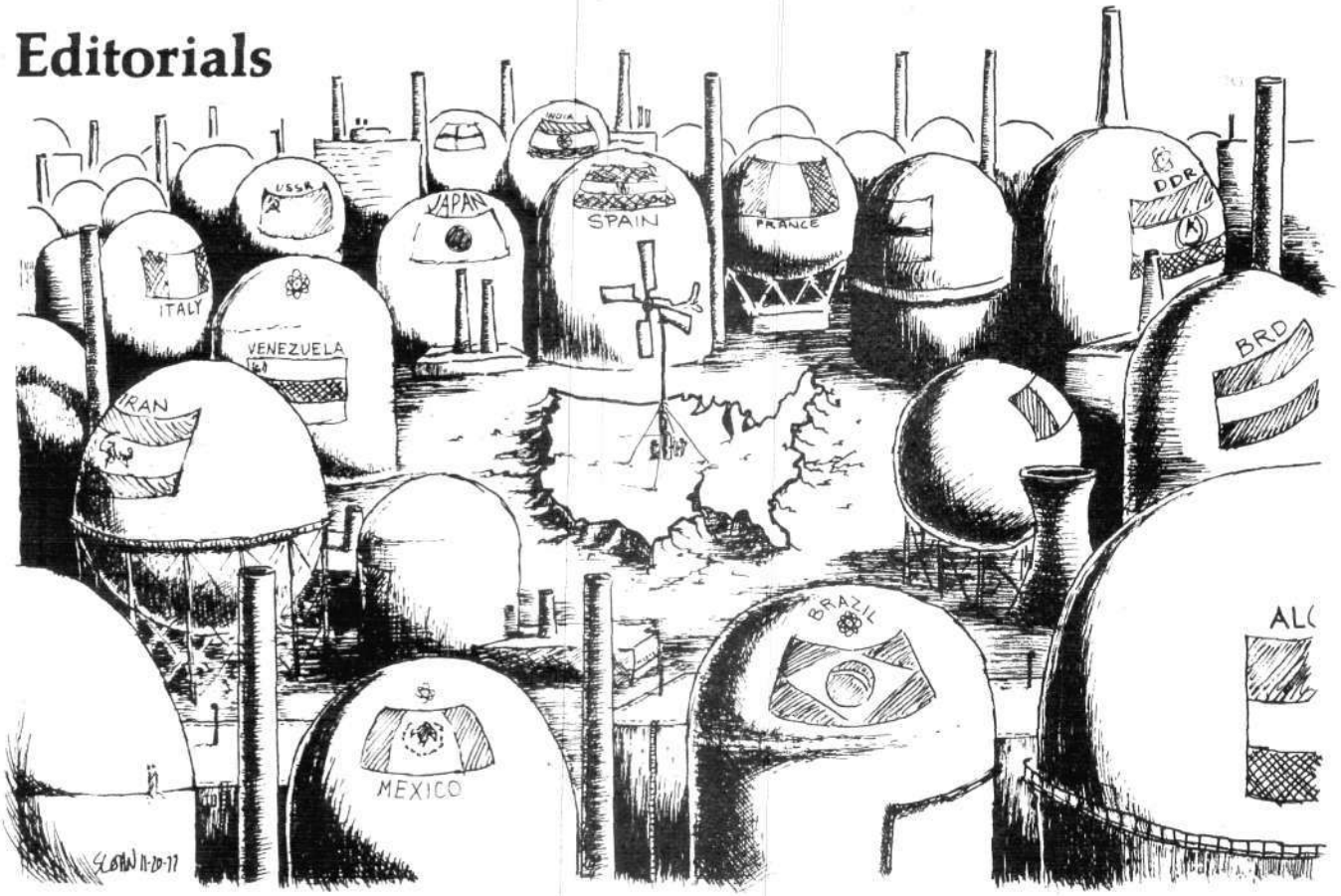


For Nuclear Power in 1978!

With the failure by Congress either to rubber stamp or override the Carter-Schlesinger energy policy before adjourning for the holiday recess, sane forces in the nation have a not-to-be-squandered opportunity to mobilize a labor-industrial alliance for nuclear power and industrial development. Events in the past two months underscore the decisive nature of the battle we must immediately fight to win.

The most striking event was the Nov. 10 outpouring of representatives and members of all the major West German trade unions, 70,000 strong, that filled a stadium in Dortmund to demand an end to the nuclear moratorium imposed on West Germany by a tiny coalition of zero-growth radicals and terrorists. On this side of the Atlantic, a number of leading U.S. scientists invited by the University of Miami to a forum in Fort Lauderdale, Florida Nov. 7-11 joined with Soviet laser fusion director Nikolai Basov in drafting a clear-cut, aggressive statement supporting the accelerated development of fission and fusion.

In between these critical events, there were myriad statements, treaties, trade deals, and commitments to nuclear development on national and international levels involving every corner of the globe. The one exception to the rule was here in the U.S. where the administration of President Carter chose to continue its vain attempt to impose the nightmare of Energy Secretary James Schlesinger's Malthusian ideology on the world population.

At stake is not simply the immediate prospect of breaking the world depression and bringing its potentially explosive areas under control through the massive export of nuclear technology. These are certainly urgent enough priorities for sane and responsible officials. However, other developments place in immediate perspective the economic and social destruction that will result from the current U.S. antinuclear policy. To take Schlesinger's most glaring act against the national interest, the Energy Secretary vetoed the Shah of Iran's offer of $25-30 billion in nuclear technology purchases from the U.S. and made the U.S. an antagonist rather than a full partner in related nuclear

deals. There can be no doubt that as long as Schlesinger remains in power, the question to ask is, "Will the U.S. be left behind?"

The Fusion Weapon

As recent events have made clear, there is broad agreement internationally among leading physical scientists that the combination of steady progress and major breakthroughs in fusion research have proven beyond a doubt its scientific, technological, and economic feasibility and the immediate potentiality for developing and testing prototype fusion reactors in the next decade. At both the Atlanta meeting of the Plasma Physics Division of the American Physical Society and at the Fort Lauderdale Forum on an Acceptable Nuclear Future, conclusive evidence was presented that laser fusion research here and in the Soviet Union has achieved the de facto conditions of breakeven (getting as much energy out from the fusion reaction as was put into heating and compressing the fusion fuel). Furthermore, at Fort Lauderdale, Nobel Laureate Basov proposed a vast international effort centering on the U.S. and the Soviet Union to rapidly achieve commercial laser fusion.

Schlesinger's answer to Basov was prompt and unequivocal. At a press conference Nov. 21 the Secretary ruled out acceptance of the Soviet proposal because he said laser fusion research is "classified" in the U.S. (As one leading laser fusion researcher commented, Schlesinger was lying; most laser fusion work here is published in the scientific literature.) At the same time, certain compliant officials at Livermore Laboratory privately circulated the line—which leading scientists there know to be false—that Basov's disclosures of Soviet laser fusion scientific results prove that the U.S. is years ahead of the Soviets in developing laser fusion!

No matter how much Schlesinger tries, however, it is not possible to "classify" and hide from the American public the devastating consequences for the U.S. and the world if he and his cohorts wreck the opportunity we now have for implementing a global "Atoms for Peace" program as the transition to fusion power.

In fact the proven feasibility of fusion is the most powerful strategic weapon that prodevelopment forces have to shape a competent energy development program and force it through Congress and the White House. Commercial fusion power is feasible by the end of this century, ending scarcity forever. Therefore, we need an energy policy based on the full use of advanced fission and fossil fuel technologies now to get the world in shape in time for fusion development in the next 15 years. A first step is vast refinancing of nuclear exports through the Export-Import Bank.

To take us to a fusion-based economy will require a new secretary of energy, motivated by the American tradition of progress and committed to joining with Soviet leaders like Basov in launching an immediate, top-priority, broad-based program of fusion research and development and massive nuclear exports.

Humanist Science and Politics

In this issue of *Fusion* we begin a new series of articles examining crucial historical developments in science. These will not be the sort of studies that nowadays pass for "history of science" or "philosophy of science."

As our regular readers know, the Fusion Energy Foundation uniquely has located the issue of fusion development as the intersection point of human progress in general and the fundamental scientific aspects of nonlinear physical processes. The new series will make explicit the precedents of this outlook: the rich historical connections between politics and epistemology in motivating the most significant advances of humanist science.

The tradition of humanist science, also known as republicanism (for example, Benjamin Franklin and the Ecole Polytechnique) and Neoplatonism

Continued on page 4

Dear Readers:

In this column I have decided to reprint a modest proposal that I made many years ago to the Royal Academy of Brussels. The timeliness of this proposal became quite clear to me after I had a chance to study the various topics for which the federal government offered research grants this year, such as creating biomass energy from cornhusks. The nature of these contemporary grants reminded me of the spirit of research promoted 240 or so years ago by the learned societies of Europe that followed the fashion set by the Royal Society of London. At the time, the Royal Society offered prizes and grants to scientists for the investigation of such topics as bisexual grenadiers, the odors of cesspools, and whether cats could hatch hen's eggs. As my good friend from Pennsylvania, James Logan, put it, the Royal Society in 1731 had no time to take up his work on corn hybridization because they

were so busy "examining the root hairs of a turnip."

On Perfumes

A Letter to the Royal Academy of Brussels

Gentlemen:

I have perused your late mathematical prize question, proposed in lieu of one in natural philosophy for the ensuing year, viz: "Given any figure, inscribe as many times as possible another smaller figure, which is given, inside it."

I was glad to find by these following words, "The Academy has judged that this discovery, in broadening the bounds of our knowledge, is not without utility," that you esteem *utility* an essential point in your inquiries, which has not always been the case with all academies; and I conclude therefore that you have given this question instead of a philosophical, or, as the learned express it, a *physical* one, because you could not at the time think of a physical one that promised greater *utility*.

Permit me then humbly to propose one of that sort for your consideration, and through you, if you approve it, for the serious inquiry of learned physicians, chemists, etc., of this enlightened age.

It is universally well known that, in digesting our common food, there is created or produced in the bowels of human creatures a great quantity of wind.

That the permitting this air to escape and mix with the atmosphere is usually offensive to the company, from the fetid smell that accompanies it.

That all well-bred people therefore, to avoid giving such offense, forcibly restrain the efforts of nature to discharge that wind.

That so retained contrary to nature, it not only gives frequently great present pain, but occasions future diseases such as habitual cholics, ruptures, tympanies, etc., often *destructive* of the constitution, and sometimes of life itself.

Were it not for the odiously offensive smell accompanying such escapes, polite people would probably be under no more restraint in discharging such wind in company than they are in spitting or in blowing their noses.

My prize question therefore should be: To discover some drug, wholesome and not disagreeable, to be mixed with our common food, or sauces, that shall render the natural discharges of wind from our bodies not only inoffensive, but agreeable as perfumes.

That this is not a chimerical project and altogether impossible, may appear from these considerations. That we already have some knowledge of means capable of *varying* that smell. He that dines on stale flesh, especially with much addition of onions, shall be able to afford a stink that no company can tolerate; while he that has lived for some time on vegetables only, shall have that breath so pure as to be insensible to the most delicate noses; and if he can manage so as to avoid the report, he may anywhere give vent to his griefs, unnoticed. But as there are many to whom an entire vegetable diet would be inconvenient, and as a little quicklime thrown into a jakes

Continued on page 80

Calendar

January

14-15 High Energy Lasers, American Institute of Aeronautics and Astronautics, Huntsville, Ala.

16-18 16th Aerospace Sciences meeting, AIAA, Huntsville, Ala.

20-26 Joint meeting, American Physical Society and American Association of Physics Teachers, San Francisco

24 Conference on Middle East Peace and Economic Development, Fusion Energy Foundation, New York City (see ad inside for details)

29-Feb. 1 Implications of Energy Conversion, American Chemical Society, Colorado Springs, Colo.

30-Feb. 2 American Meteorological Association, 58th annual meeting, Savannah, Ga.

Humanist Science

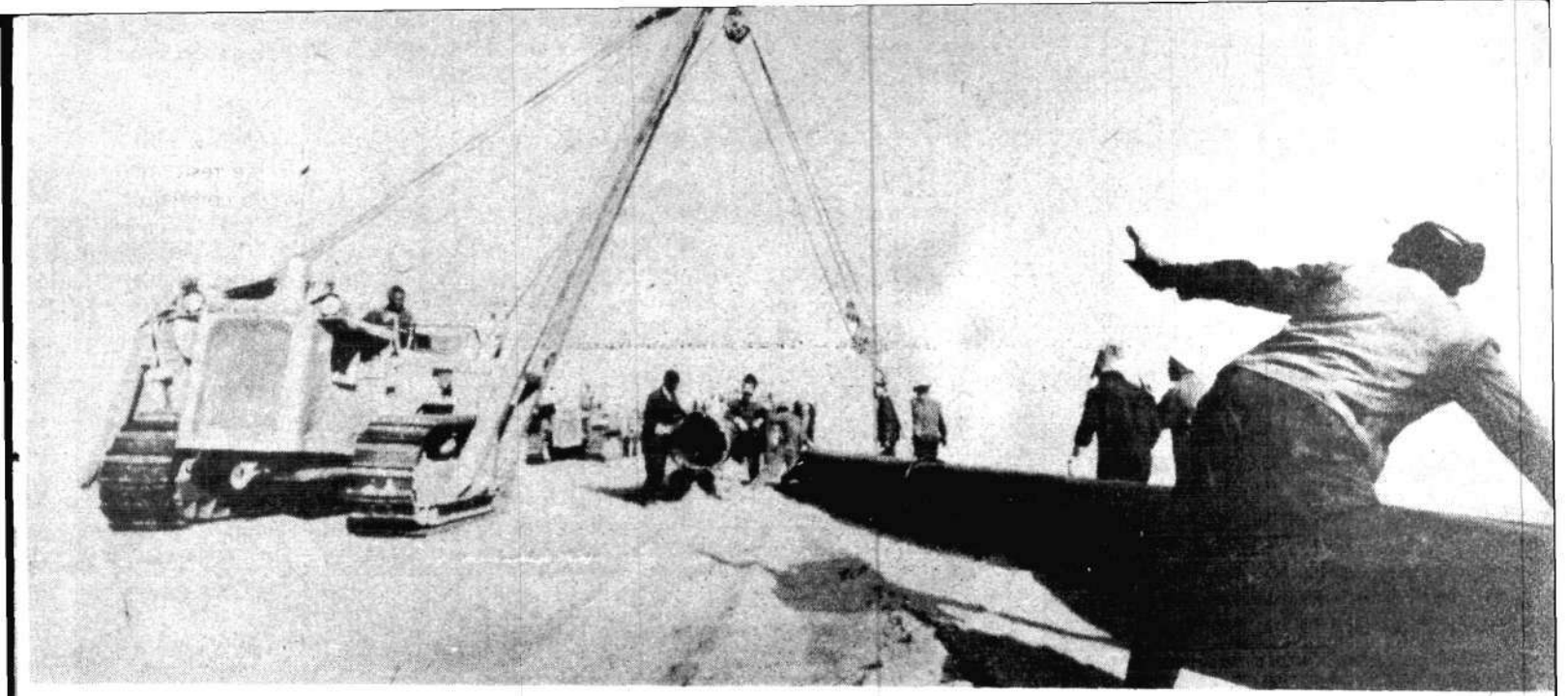
Continued from page 3

(for example, Descartes, Kepler, and Leibniz) is little known today. Instead, students are subjected to the gigantic hoax that modern science and scientific method not only date back to Isaac Newton and Francis Bacon, but that Newtonianism is the most effective, and indeed, the only possible basis for scientific epistemology.

On the contrary, we will show that Newtonianism is nothing but scientific plagiarism, a bad epistemological joke, steeped in the political reaction of the British Empire-cism against which the American and continental humanist leaders fought. Only if we rediscover the actual origins of critical scientific conceptions and trace the line of their creative development in the evolving humanist networks can we solve the related political and scientific problems of *human progress today*.

A NOTE TO READERS

We are sorry that a financial squeeze has prevented us from publishing *Fusion* on a monthly basis as expected. We want to assure our subscribers that they will receive 10 issues of the magazine (this issue being a double issue) for their yearly subscription fees, although at this point we cannot scientifically predict exactly when these issues will arrive. With a holiday boost in contributions from our readers and subscribers, we expect to approximate monthly publication.



Fusion Energy Foundation Conference

MIDDLE EAST PEACE *and* ECONOMIC DEVELOPMENT

January 24, 1978
Americana Hotel of New York
Royal Ballroom B

The prospect for a settlement of the conflict in the Middle East, which has improved in recent months, can be the basis for a vast expansion of trade between the United States and the countries of the Middle East. Such a flow of trade, in fact, is necessary to underwrite a peace accord, since a prosperous and developing Middle East is essential to a stable peace. Generous development credits to Egypt, Israel, a new West Bank-Gaza Palestinian state, and other Arab countries — including needed rebuilding of Lebanon — are therefore essential to a negotiated Geneva settlement.

There will be a discussion period reserved in each panel during which comments, questions, and suggestions from the audience will be taken. Please note that the listed affiliations here are for identification purposes only.

For more information:
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Economic Development of the Middle East

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Morris Levitt
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Mohammed Rabie
Universal Enterprises, Inc.
Permanent Delegate Euro-Arab Dialogue

Farouk Sankary
University of Wisconsin

Energy: Nuclear Fission and Fusion

Steven Bardwell
Fusion Energy Foundation

Stephen Dean
U.S. Department of Energy

Stefan Possony
Hoover Institute

The Cultural Heritage of Islamic Science

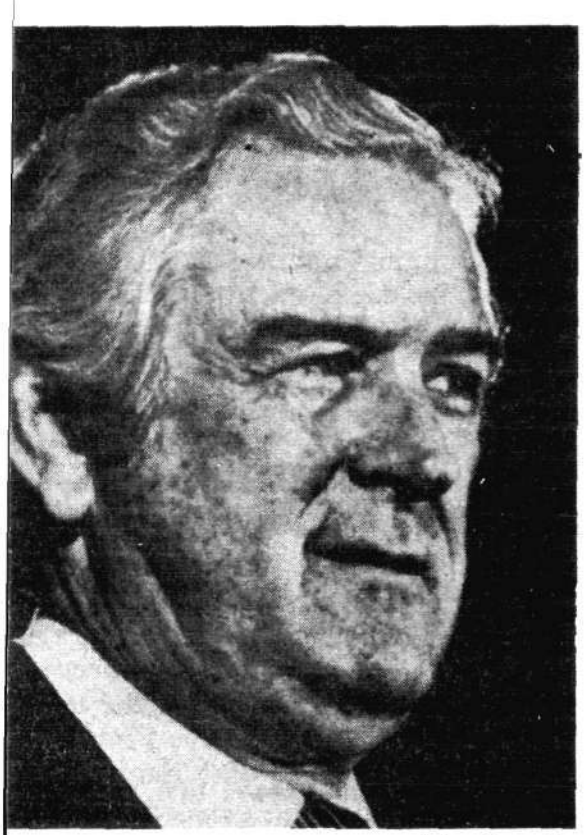
Amin Hilmy III
Ambassador, Arab League
United Nations

Parvis Morewedge
Society for the Study of
Islamic Philosophy and Science

Criton Zoakos
Author, Ibn Sina and the
Dawn of the Humanist Heritage

Keynote Address: "America and the Arab World"

Dr. Clovis Maksoud, Georgetown University



John Connally

News Briefs

ENERGY BILL FLOUNDERING: PROGROWTH FACTION EMERGES

Congress adjourned until late January without any agreement in the House Senate conference committee on the two main sections of the administration's National Energy Plan. Left up in the air were the provisions dealing with natural gas pricing and regulation and with the crude oil equalization tax and related tax measures. Predictions in the U.S. press spanning the political spectrum from the *Washington Post* to the *Journal of Commerce* have put the passage of the legislation as extremely difficult if not all but impossible during the 1978 session.

Although Energy Secretary James Schlesinger launched a last-minute lobbying effort to push through a compromise in natural gas before the recess, the conferees voted down the compromise 16 to 2. Louisiana Democrat Senator Russell Long, the leader of the Senate conferees, had indicated previously that his grouping would take no action on the energy plan until the natural gas issue was resolved.

Behind Long is a growing constellation of forces, including sunbelt industrialists and labor leaders in protechnology unions, who see the country's future in growth, not conservation. As Senator Dewey Bartlett (R.-Okla.) stressed during the waning hours of the congressional session, the lack of an energy bill that promotes production was in part responsible for the recent decline in the dollar exchange rate.

The battle cry of the industrial growth faction was given by former Texas governor John Connally recently in a Los Angeles speech. Connally lashed out at the Carter administration for its no-growth policies and scored the Democratic Party as "the ones who killed the SST, the B-1 bomber, the fast breeder reactor, and nuclear fusion."

GOVERNMENT AUDITORS HIT SCHLESINGER'S MANIPULATION OF ENERGY FIGURES

A federal task force assigned to audit the collection and accuracy of the government's statistics on energy issued a report sharply critical of Energy Secretary James Schlesinger for ordering or approving changes in federal energy statistics in order to motivate the Carter administration's national energy legislation last spring. The report, made public in December, is titled "Activities of the Office of Energy Information and Analysis."

The auditors report accuses the administration and specifically Schlesinger, then White House energy advisor, of manipulating the numbers that provide the basis for the national energy program's controversial assumptions and recommendations "to serve its own political purposes." The report notes that Schlesinger ordered some 21 changes in the computer models used to test policy options. "The net impact of the the 21 changes to the model was to increase the anticipated energy demand by the equivalent of 2.52 million barrels of oil a day by 1985 and to decrease anticipated estimated supply by the equivalent of 1.44 million barrels of oil a day by 1985," the report stated.

ELECTRICAL WORKERS JOURNAL DEMANDS NUCLEAR ENERGY

The December issue of the magazine of the International Brotherhood of Electrical Workers, the IBEW, features an article titled "Are Nuclear Power Plants Needed? Yes!" The article calls for expanded nuclear power development here and in Canada and attacks the "obstructionists" who oppose nuclear plant construction.

"For IBEW members' goal to be achieved, there must be growth....No growth means no jobs....The IBEW continues to support the expansion of the nuclear industry as a means of solving the world energy crisis. It is the IBEW's opinion that nuclear power is safe, reliable, environmentally acceptable, and the most economical way to meet the electrical needs of our two nations."

MEXICO SUSPENDS NATURAL GAS TALKS, CITES SCHLESINGER BLACKMAIL

The national oil company of Mexico, PEMEX, announced Dec. 23 that it was suspending negotiations on natural gas exports to the United States and that it will not extend the talks beyond the Dec. 31 deadline. A PEMEX press release emphasized that the decision to break off the discussions was forced on Mexico by U.S. Energy Secretary James Schlesinger's flat rejection of Mexico's asking price of $2.60 per thousand cubic feet. Schlesinger had threatened that unless Mexico yielded on the price question and accepted a price formula substantially inferior to that which the U.S. already granted to other gas-exporting countries, the U.S. would launch a crackdown on undocumented Mexican workers here.

The PEMEX decision nullifies a $340 million loan from the U.S. Export-Import Bank for a Mexican gas pipeline to the U.S. border, which had been agreed upon pending the price agreement. PEMEX stated that it has accepted alternate financing and materials for a pipeline from West Germany, Italy, France, and Japan.

SUPREME COURT APPEARS READY TO OUTLAW ENVIRONMENTALIST CASES

In two key environmentalist cases involving the stalled construction of nuclear plants argued before the Supreme Court Nov. 28, the Supreme Court justices indicated that the era of carte blanche for the environmentalists' legalist obstruction of nuclear power is drawing to a close. The cases involved the Midland, Michigan plant (*Consumers Power v. Aeschliman*) and the Vermont Yankee plant (*Natural Resources Defense Council v. the Nuclear Regulatory Commission*). The U.S. Labor Party has submitted a brief to the court on behalf of Consumers Power.

The major point raised by the justices was the lengthy delay in construction under the environmental protection. "It is now 1977. We are talking about permits issued in 1971. How can we run a nation on this basis," one justice said.

Although the court will not rule for 60 days or more and may not find that these particular cases present the appropriate issues for reversal of the common law established by the environmentalists, the justices indicated that they understood this must be done soon.

AFL-CIO ADOPTS ANTINUCLEAR STAND

The twelfth biennial convention of the American Federation of Labor-Congress of Industrial Organizations meeting in Los Angeles Dec. 10-13 went on record as supporting protectionism and opposing high technology exports. The 2,000-delegate gathering also endorsed the passage of the nuclear nonproliferation legislation now before Congress, a bill that would effectively end the export of U.S. nuclear reactors and reactor technology, eliminating thousands of jobs.

This self-destructive behavior, which is in no way supported by the rank-and-file majority or the secondary leadership, was endorsed by labor leaders like Robert Georgine, the president of the Building and Construction Trades who had previously gone on record in support of nuclear power and the export of nuclear technology. At the first session of the Building Trades convention in Los Angeles Nov. 31, Georgine credited his union with "keeping the Clinch River project in the public consciousness" despite President Carter's veto, and he emphasized the union's role in defeating antinuclear referendums in seven states last year.

To find out, in jobs and dollars, exactly how destructive the antinuclear policy of the AFL-CIO is, see the article this issue on an energy program to get us to the fusion age.

AFL-CIO head George Meany

Washington

The Energy Program to Get Us to the Fusion Age

In the past two months, the Fusion Energy Foundation has prepared a detailed series of fact sheets and legislative material for Congress on the energy program to get this nation into the fusion age, an age of growth and prosperity. The FEF nuclear energy development program opposes the zero-growth proposals of Energy Secretary James Schlesinger and the Carter administration as well as the various rotten compromises to the administration's energy package devised in Congress. As we show in the excerpts below, the Carter-Schlesinger proposals are incompetent. They would send energy prices up 70 percent and deindustrialize the nation, ensuring a future of continuing depression and vastly lower living standards.

The U.S. Labor Party has circulated the energy proposals prepared by the FEF in bill form as "The Nuclear Energy Development Act of 1977." We urge readers to obtain copies of the full legislation from the FEF or the Labor Party and to let your elected officials in Washington know that you back a program of nuclear development and high technology, not energy conservation and deindustrialization. To obtain the bill, send $1.50 per copy to Campaigner Publications, Box 1920, New York, N.Y. 10001.

The only way to get out and stay out of the present world depression is a ruthless commitment to growing rates of investment in advanced *hard* technologies. Nowhere is this more true than in the most critical technological area of energy generation.

An economically viable global energy program demands:

(1) Nuclear fusion power as the necessary long-term energy solution;

(2) Nuclear fission-based technologies as the most important *qualitative* feature of short-term development;

(3) Plutonium and thorium fission-fuel breeders leading into hybrid fusion-fission breeders as the critical intermediate-term energy technologies.

The basic phases of a program consistent with this policy and with projected target dates for specific technological developments are as follows:

Immediately: Begin assembly-line mass production of light water reactors, including floating light water nuclear plants. Explore coordination with Soviet Atommash mass production facilities. Bring the Clinch River Breeder project up to full funding and start plans for commercialization. Complete spent fuel reprocessing facilities and begin new construction. Begin planning Apollo Project-style fusion effort, with immediate doubling of the budget.

Early 1980s: Phase in the number of commercial liquid metal fast breeder reactors consistent with fueling the growing numbers of light water reactors. (As U-235 is depleted, one LMFBR will be required for every one to three LWR's.) Begin significant fusion-fission hybrid breeder development. Complete buildup of infrastructure of fusion program.

Later 1980s: Increase rate of LMFBR commercial production. Complete

Continued on page 61

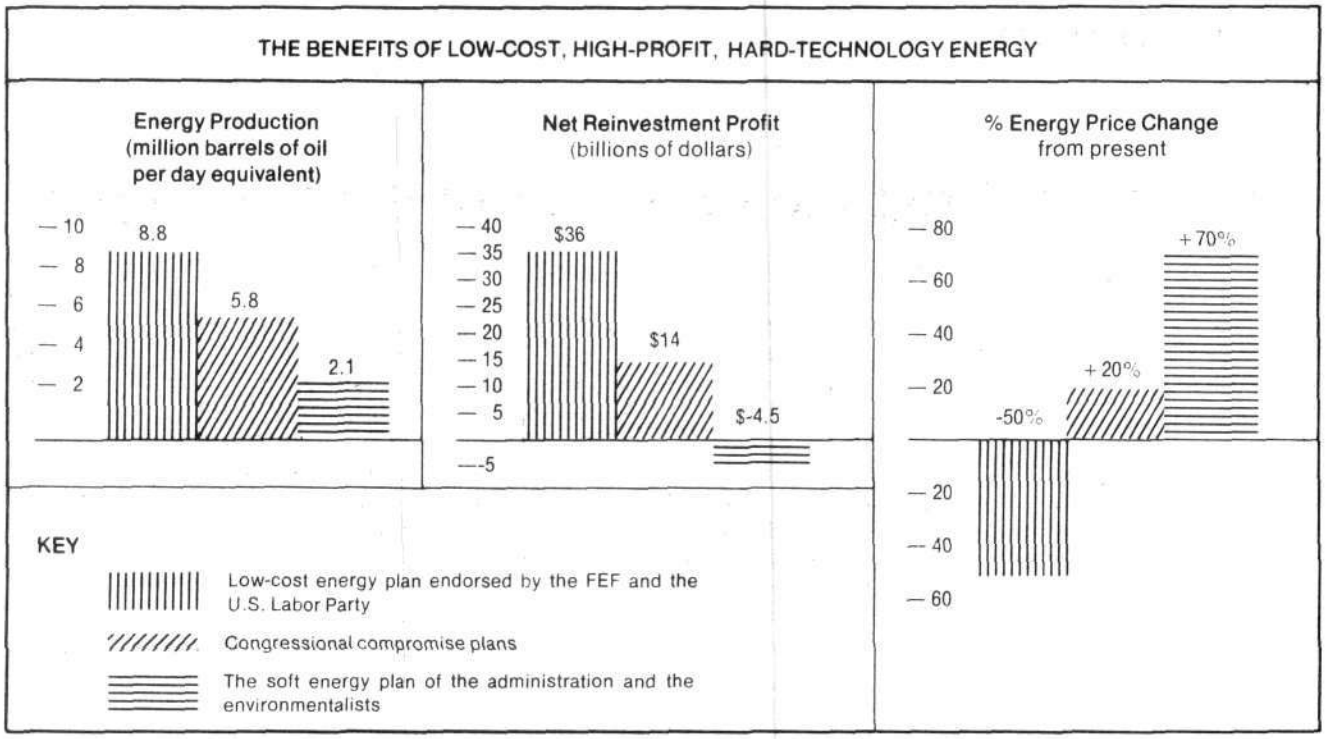
Will the U.S. Be Left Behind? Schlesinger's Nuclear Sabotage

The administration's energy bill lies all but dead in Congress during the congressional holiday recess. Senate energy conferees voted down Dec. 22 the compromise on natural gas favored by Energy Secretary James Schlesinger, and there is no commitment from the legislators to pass the natural gas section or the other main provisions of the Schlesinger energy program in 1978.

Despite the fact that there is no mandate whatsoever for the administration's conservation and zero-growth policies, Schlesinger in his role as energy secretary has already put the intent of the bill into practice outside the law. In the past month, the secretary has turned down the $35 billion offer by Iran for nuclear plant construction (the biggest nuclear export deal ever offered the U.S.), refused the invitation of the Soviets to join in the development of laser fusion power by the 1980s, sabotaged a huge natural gas deal with Mexico, tried to maneuver the oil-producing countries into an oil embargo, and encouraged the environmentalist attacks on nuclear plants via the Environmental Protection Agency and the Nuclear Regulatory Commission that have recently halted the operation of major nuclear plants.

Sabotage

Although he is often portrayed by the environmentalists as pronuclear,



This chart compares the cost and output of a $100 billion investment into a hard-technology energy program, a soft-technology program and combination program such as that proposed by Senator Russell Long [D-Ga].

Schlesinger made no bones about his antinuclear policy at his first press conference as secretary Nov. 21. The secretary justified the administration's refusal to accept the offer of the Shah of Iran for the U.S. construction of several nuclear plants—an offer that would have gone a long way toward wiping out the U.S. trade deficit—on the grounds that a nuclear non-proliferation bill was still languishing in the Senate.

And for those gullible businessmen who still believe Schlesinger's private assurances that he would ease the licensing requirements for nuclear plants, the statement of top Schlesinger aide John O'Leary is to the point. O'Leary, the former head of the Federal Energy Administration, told industry representatives at the Atomic Industrial Forum in early December, "The government is going to do nothing, absolutely nothing" about the delays in power plant construction.

More recently, the secretary personally intervened in negotiations between the Mexican national oil

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The Schlesinger Philosophy

Economics is the science of choices in a world of limited resources....The same dualism that underlies economics underlies the nature and condition of man. For anything you have missed, you have gained something else; and for anything you gain, you lose something....

We have gone around the world spreading the "gospel of plenty" raising the level of expectations....In the nature of things, these rising expectations can never be satisfied....Despite the modification of the original Malthusian dogma over the years, the danger remains that excessive growth of population will wipe out the gains of economic progress. Any economic revolution will be shortly wiped out by a Malthusian counterrevolution and the illusion of growth .... It is unwise to overstate the importance of economic growth per se ....

We must in our strategic policy return to the days before the Industrial Revolution... prepare to fight limited wars....Higher Soviet industrial development rates than attained in our production will have very little strategic significance....The industrial mobilization base is only one of several gauges of power. A strategic menace may be based upon a rather modest economic structure....We must build our military force on the exact opposite of the industrial potential notion.

— James Schlesinger, *The Political Economy of National Security* (New York: Praeger Press, 1960).

Conferences

Soviet Scientist Calls for Crash Program in

Academician Nikolai G. Basov, the Soviet Union's leading laser scientist, told a meeting of the International Scientific Forum on an Acceptable Nuclear Energy Future of the World in Ft. Lauderdale, Fla. Nov. 7-11 that there must be an immediate international crash program to develop laser fusion.

Basov, who made an unexpected appearance at the conference of the leading nuclear scientists and industrial and electric power utilities representatives, described to the group the better than breakeven experimental results of his laser research team. Basov stated: "We consider the task of this talk (both laser fusion and the energy question—ed.) solved, if the participants of the present meeting could see not only our results and conclusions...but at the same time the vital necessity to concentrate the efforts of scientists and to coordinate the investigations in this field on a larger scale than we have now."

The conference was sponsored by the University of Miami Center for Theoretical Studies and included more than a half dozen Nobel laureates and representatives of the U.S., French, West German, and Japanese governments. The conference communiqué calling for an expanded U.S. nuclear program and the text of the Basov speech are reprinted below.

Soviet Commitment Confirmed

The Basov call confirms that the Soviet Union has decided to mount a full-scale political offensive for international collaboration in the development of fusion power. A few months ago, Soviet Academician E. Velikhov, the head of the Soviet fusion program, presented a similar offer here for U.S.-Soviet collaboration with the Linus experiment at the Los Alamos laboratories. At that time, U.S. experts felt that the Velikhov proposal was directed as much toward the still unresolved debate within the Soviet Union as toward the U.S.

Basov is a member of the Supreme Soviet, the highest elected governmental body, and came to the U.S. directly from a meeting of the Supreme Soviet. In addition, it is believed that the Basov research group has the chief responsibility for Soviet nuclear weapons research and is in a chain of command connected to the top echelons of the Soviet military. Consequently, experts view the Basov announcement as a reflection of the policy of the Soviet military leadership, which usually represents the most advanced Soviet scientific and political thinking.

Reliable sources have reported that one of the purposes of Basov's trip to the United States is to work out informal classification guidelines to facilitate further work in international laser fusion research and development.

If adopted by the U.S., the Basov proposal could shave five to ten years off the previous "best-case" estimates for the bringing on line of working fusion power reactors. The timetable implied by the Basov proposal would yield laser fusion prototype reactors by the mid-1980s and working power reactors by 1990.

Basov is a director of the P.N. Lebedev Institute in Moscow, and received a Nobel Prize in 1964 for his work on quantum electronics that resulted in the creation of lasers. He is also responsible for the declassification of much of the Soviet Union's work in laser fusion in the late 1960s.

At the Fort Lauderdale meeting, Basov reported the experimental results his research teams had recently obtained, and he released laser fusion reactor designs prepared by the Moscow Insitute for High Temperatures, which is internationally renowned for its successful work on MHD electric power generators.

Breakeven and Controversy

Basov reported that scientists working on the Kalmar laser system at the Lebedev Institute had obtained pellet compressions of up to 8 grams per cubic centimeter. This, according to Basov, corresponds to a Lawson breakeven parameter of 500 trillion seconds per nuclei per cubic centimeter, *a factor of 10 greater than what is needed for breakeven.*

This result is the subject of controversy among U.S. scientists who first heard it at the Oxford, England laser conference in October 1977. But, as Basov explained, although there are some disagreements on particulars, both he and his U.S. colleagues concur that high gain fusion pellets, like those indicated by the Basov results, are possible.

Basov described at length further experimental results and then outlined the international status of laser fusion research laboratories, pointing out particular areas where intensified international cooperation is needed. "Realization of such lasers (lasers needed for actual power reactors — ed.) is a severe problem, which demands, in my opinion, the concentration of efforts on (an) international scale," Basov said.

Basov concluded his presentation by detailing the plans for two laser fusion energy reactors, the LTPS and LTB-500.

The pure fusion LTPS would have a capital cost of 400 rubles per kilowatt of electrical output to the consumer.

Laser Fusion

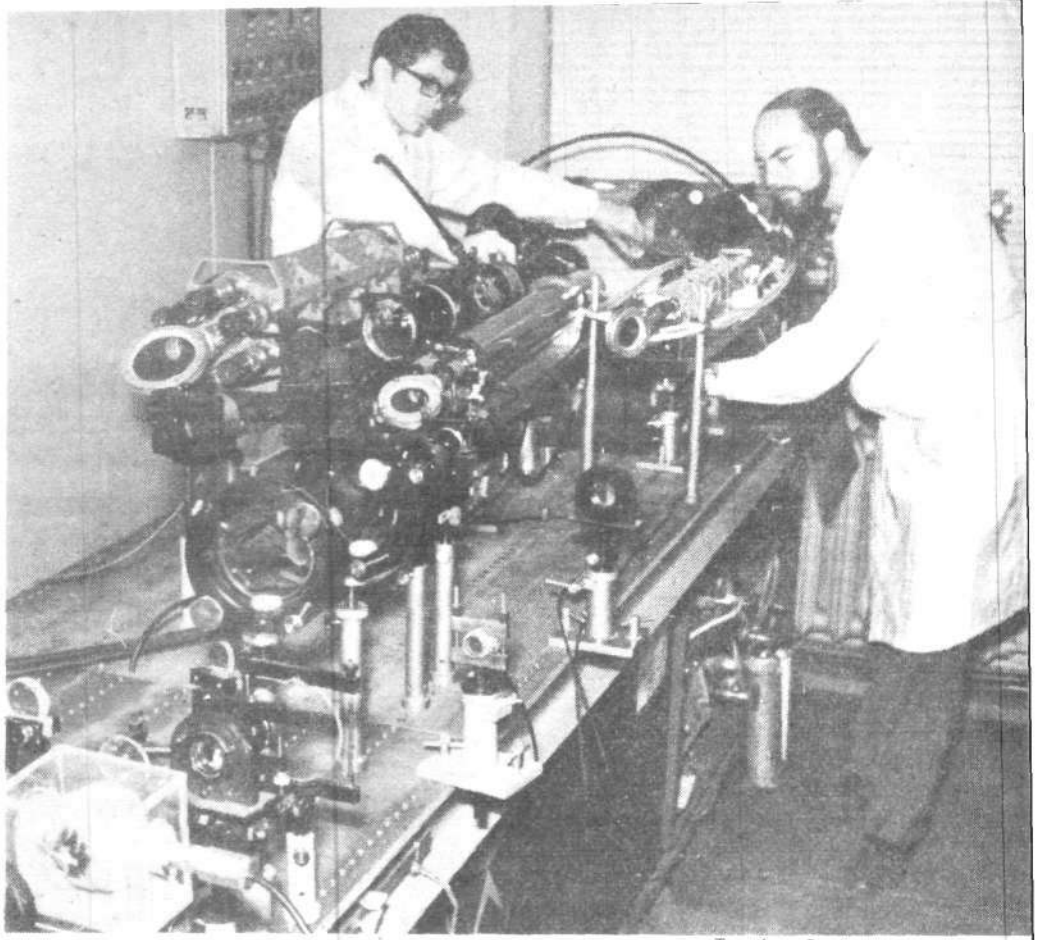
The cost of electricity from this plant would be .5 kopecks per kilowatt hour.* As Basov pointed out, these projected capital costs were of the same magnitude as those for fission fast breeder reactors.

The LTB-500 is a fusion-fission hybrid reactor. Three hundred tons of natural uranium is put in a blanket around the fusion reaction chamber. The fusion microexplosions produce neutrons that convert the natural uranium to plutonium that eventually undergoes fission reactions and thus greatly multiplies the total reactor energy output. Throughout the lifetime of the LTB-500 power plant, the rate of fusion microexplosions would be decreased as more and more fission fuel and therefore, fission reactions are generated. Fifty percent of the natural uranium would be burned up after 30 years. The capital costs of the LTB-500 is 200 rubles per kilowatt of electricity, and it has a production cost of .9 kopecks per kilowatt hour.

Basov concluded that the cost of energy production could be dramatically decreased, even below present-day energy costs, by using fusion hybrids to produce fuel for fast fission breeder reactors.

Nuclear Energy Essential

Every aspect of energy, from fossil fuels to solar and geothermal power was discussed in detail at the Ft. Lauderdale conference by the world's leading experts. The conclusion of the participants was that existing nuclear power technology must be immediately increased; plutonium fuel recycling for increasing the amount of available fission fuel must proceed; the fission fast breeder must be brought on line as soon as possible; and fusion, both pure fusion reactors and fusion-fission hybrid reactors, must be developed as rapidly as possible.



Tass from Sovfoto

These Soviet scientists are tuning the driving oscillator of a laser in a Moscow research laboratory. Basov's research work led to the development of the laser and to the invention of many different kinds of lasers.

The detailed conference proceedings, which will be published in three months, provide a devastating demonstration of how the current energy program of President Carter and Energy Secretary Schlesinger is incompetent and will leave the U.S. in the Dark Ages. As the proceedings summarized, nuclear power is safe, economic, and environmentally clean (in fact the carbon dioxide released from burning fossil fuels may already be laying the basis for a worldwide environmental disaster). Proliferation of nuclear weapons—the old saw put forward by the administration to justify its anti-nuclear export policy—is a *political* not technological question, the participants said, and the Carter administration has already done more harm than good in this area. Projected uranium resources are definitely insufficient to meet world needs without the plutonium breeder and plutonium recycling; no other fuel cycle will work. Magnetic and laser fusion confidently can be projected to achieve power reactors. Whatever Carter and Schlesinger do, the participants concluded, Europe and Japan are going ahead with their nuclear power programs in any case.

Several score of the leading representatives from U.S. industry were present at the conference (including the president of New Jersey Central Power and Light, Phillips Petroleum, Exxon Nuclear Corp.), and a half dozen congressmen.

A special scientific committee of the conference participants issued a major statement on the conference findings, which is reprinted below.

— Charles B. Stevens

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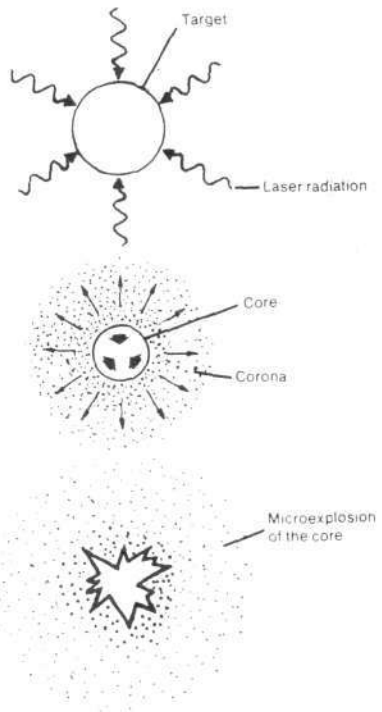
* One ruble is about $1.28, and there are 100 kopecks to a ruble.

The Latest Breakthroughs in

Academician Nikolai G. Basov
Tass from Sovfoto



How laser fusion works: The pellet containing thermonuclear fuel is irradiated spherically by the laser light. Laser radiation absorbed by the pellet heats the target; and the outer part of the target, the corona, expands in the direction of the laser beams. The inner part of the target moves to the center of the pellet and becomes highly compressed and heated. Here thermonuclear reactions are developed, the microexplosion occurs, and fusion energy is produced.

Editor's Note

When this issue of Fusion *was conceived several months ago, the editors decided that a review of the remarkable progress in mainline tokamak research would help readers grasp the overall process of fusion development as well as the basic scientific features of magnetically contained plasmas. Happily, events have intervened since then to warrant a new focus on laser fusion as well. Therefore, in addition to the tokamak feature, what follow are reports on important new developments in both the U.S. and the Soviet Union that have brought laser fusion to the breakeven point, plus excerpts from the speech of Soviet laser fusion director Basov on the broader issues of nuclear development.*

The reaction to Basov's disclosures in some quarters in the U.S. necessitates a word of clarification. It is likely the case that in terms of the latest round of experimental results the U.S. and the Soviet Union are about even. U.S. researchers have replicated electron beam results reported by Soviet physicist Leonid Rudakov in the U.S. during summer 1976. In addition, U.S. researchers have brought to bear powerful lasers and computer simulations in laser fusion work to achieve high pellet gains.

However, these significant achievements have obscured the fact that the U.S. has been relying on applications of high technology to mundane scientific conceptions of plasma processes in order to keep pace with a coherent series of Soviet advances based on more basic plasma phenomena that are self-ordering and self-stabilizing. To the extent that the Soviet program continues to place emphasis on nonlinear mediations of energy flow and concentration while U.S. research relegates these phenomena to the sidelines as too esoteric, there will necessarily be a growing gap between the two programs over the next several years.

U.S. officials and scientists would do well to reflect on the significance of Basov's reference to the creation and ignition of "low-entropy" plasma states in laser fusion. The implication is not simply that plasma targets are strongly compressed before being heated to ignition temperatures at their core, but that the energy input shows up in intense field and particle concentrations [rather than in thermal forms] that dynamically evolve to facilitate further energy inputs to the point of ignition. Even the Soviet

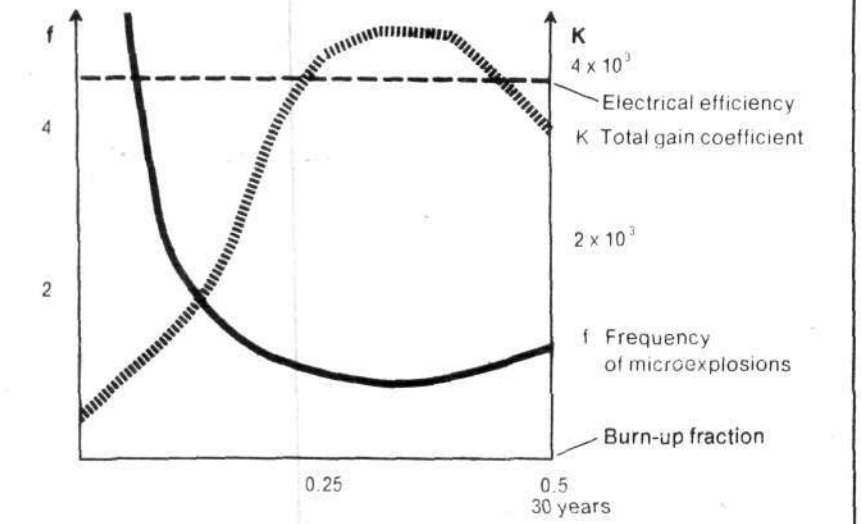
Text of Speech By Nikolai Basov To Florida Conf.

The following are excerpts from the presentation of Nikolai G. Basov, of the P.N. Lebedev Physical Institute at the Soviet Union's Academy of Sciences in Moscow, to the November meeting of nuclear scientists and industrial representatives in Fort Lauderdale organized by the University of Miami Center for Theoretical Studies. The speech, "Prospects and Problems of Laser Thermonuclear Fusion for Future Energetics," was published in English in Moscow as Preprint No. 182 of the Laboratory of Quantum Radiophysics.

Fusion

researchers who have consciously exploited these plasma properties have not recognized that the properties are fundamental *in two related ways. First, they are the most significant determinants of the behavior of energy-dense plasmas; second, they result from the same quality of nonlinear interaction that is the basis for the evolution of the physical universe and the biosphere to higher-order states.*

The question is not who's ahead in laser fusion, but, rather, what scientific epistemology is necessary and appropriate to the achievement of continuously improved reactor conditions.



Basov suggested that the most promising reactor to make use of laser fusion was the laser fusion-fission hybrid. In the hybrid, Basov pointed out, there must be a balancing between the total energy multiplication factor [gain] resulting from the breeding of plutonium and the rate at which fusion reactions take place. As the graph shows, this condition is achieved by using high gain [K] and low microexplosion rates [f] at the end of the cycle and the opposite at the beginning.

It is a great pleasure for me to give a talk at such a representative forum of scientists. I would like to speak about physical investigations that have been underway at the Lebedev Physical Institute since 1962. This direction in laser physics is developing at the present time in many laboratories. It has now become one of the most popular and active fields of physics, and it can be considered as one of the serious directions in solving the energy problem. I am speaking about laser-induced fusion. We consider the task of this talk solved, if the participants of the present meeting could see not only our results and conclusions and one of the possible ways of solving the energy problem, but also at the same time the vital necessity to concentrate the efforts of scientists and to coordinate the investigations in this field on a larger scale than we have now.

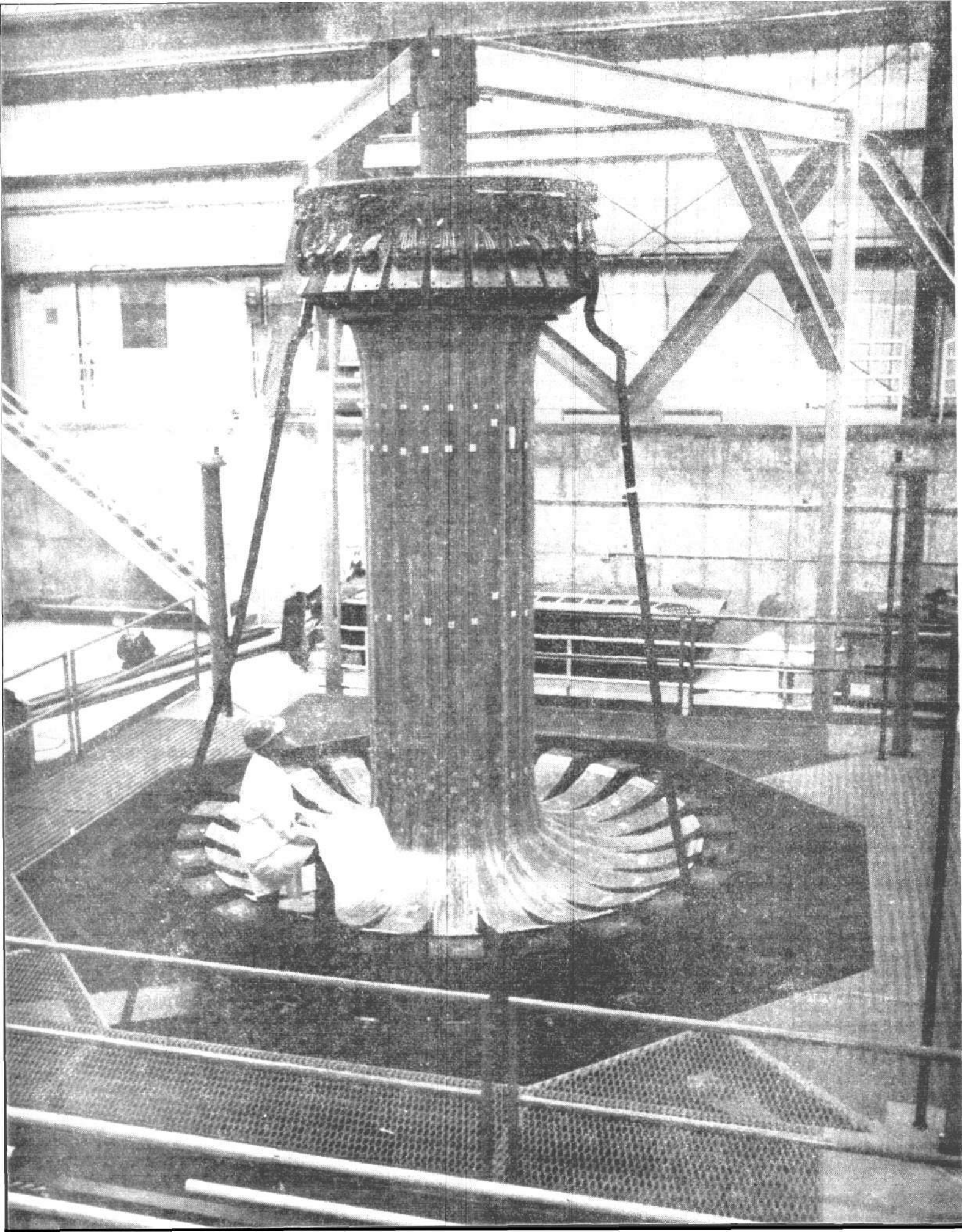
The principle of energy production in laser-induced fusion is as follows. The pellet containing thermonuclear fuel is irradiated spherically by the laser light. Laser radiation absorbed by the pellet heats the target, and the outer part of the target, a so-called corona, expands in the direction of the laser beams. Because of the law of conservation of momentum, the inner part of the target moves to the center of the pellet and becomes highly compressed and heated. Thermonuclear reactions develop in this part of the target; the microexplosion occurs; and the fusion energy produced in this way can be used in a special reactor for the generation of electrical energy. In cases when we can produce more energy, which is necessary for laser pumping, we can use the rest of fusion energy in industry or national economy....

Suitable Lasers

What types of lasers would be suitable for the laser fusion power station in the future? One can give a negative answer to this question, because today no lasers are able to operate with the repetition frequency of 1 cycle per second during a year. However, the answer can also be positive, because there are no physical restrictions to realization of such laser operating conditions. Moreover, many physicists consider this regime to be quite achievable. The realization of such lasers is a severe problem that demands, in my opinion, the concentration of efforts on international scale.

Possible trends may be connected with highly efficient carbon dioxide and chemical lasers. But we should not neglect neodimium glass lasers for this period of work either. Efficiency of some tenths of 1 percent, or 1 percent, would be reasonable for a hybrid type of the laser fusion power station. The efficiency in this scale can be achieved with a better accordance of pulse duration and pumping light spectrum with optical properties of neodimium glass....

One must note two tendencies in the development of laser fusion. One direction is based upon the use of short laser pulses and high radiation flux (10^{16}W/cm^2 and higher). To some extent, this tendency continues the ideas reported by American researchers at the Montreal conference in 1972 about the supercompression with the help of a specially shaped pulse. The Livermore laser installation "Shiva" is intended for a production of such pulses. We suppose it more



The Basic Science of Tokamaks

by Charles B. Stevens

ALTHOUGH IT IS GENERALLY NOT KNOWN in the scientific community, except to a very small number of specialists, the feasibility of harnessing the vast potential of cheap and clean fusion energy via the tokamak has been demonstrated in the past year. Also not generally known is that within as short a period as two years, the Soviet-developed tokamak could prove to be a practical energy-producing system from a technical and engineering standpoint.

This means that even with a conservative projection of an aggressive research and development program, the tokamak system could have a significant, though marginal, effect on meeting world energy needs by the early 1990s and could provide the foundation of world energy resources from the year 2000 on.

In the July-August *Fusion*, I reviewed the status of engineering problems in mainline tokamak fusion power reactor systems. This article will review the overall experimental and theoretical status of the tokamak and the bearing this status has on the rate and practicality of developing actual tokamak power reactors. Its focus will be the Alcator tokamak at the Massachusetts Institute of Technology and the various reactor types proposed on the basis of the Alcator's results.

Some Fusion Basics

Nuclear fusion reactions are the chief driving forces of the universe as we currently know it. The vast majority of active energy in the universe traces its origin to fusion reactions generated in the sun and hot, dense cores of stars.

The rate at which a fusion reaction proceeds depends on the *density* of the reacting nuclei and their *temperature*. The fusion fuel must be brought to temperatures on the order of more than 50 million degrees, and the rate at which fusion proceeds depends directly on the density of the fuel.

At the temperatures needed for initiating fusion reaction, the fusion fuel is in an ionized state—a plasma—with the electrons separated from individual nuclei. The plasma state is dominated by the electric and magnetic forces generated by the motion and relative position of the electrically charged electrons and nuclei. I will discuss this below in detail, but it should be noted here that the dominance of electromagnetic force fields produced by the collective action of the plasma electrons and nuclei determines both the density and temperature of the reacting nuclei and the time span over which it can be maintained.

The conditions required for fusion are generally known as the Lawson criteria (named after the British physicist who first published a paper on them in 1940). With an appropriate fusion fuel such as the heavy isotopes of hydrogen, deuterium and tritium, the lowest threshold temperature that will produce fusion is determined by the *density* of the reacting nuclei and the *confinement time span* over which the density and temperature are maintained.

An overall balance must include consideration of the following:

Energy input — the external source of energy applied to the fusion plasma initially to heat it, maintain its temperature, and confine it to a specific density.

Energy output — the portion of fusion energy (present in the fusion reaction products of the fast neutron and helium nucleus) that directly escapes the fusion plasma, the portion captured within the fusion plasma, the energy lost directly via the electromagnetic radiation produced by the fusion plasma, the energy lost as a result of diffusion of the nuclei and electrons outside the fusion plasma region, and the energy lost because of the conduction of heat out of the fusion plasma region.

The following Lawson criteria are a broad simplification of this complex energy balance. Given a 50-50 mixture of pure D-T, with no other elements present, and a roughly even distribution of energy within the plasma (that is, a Maxwellian temperature profile), the experiment must maintain a temperature of 50 million degrees in a plasma

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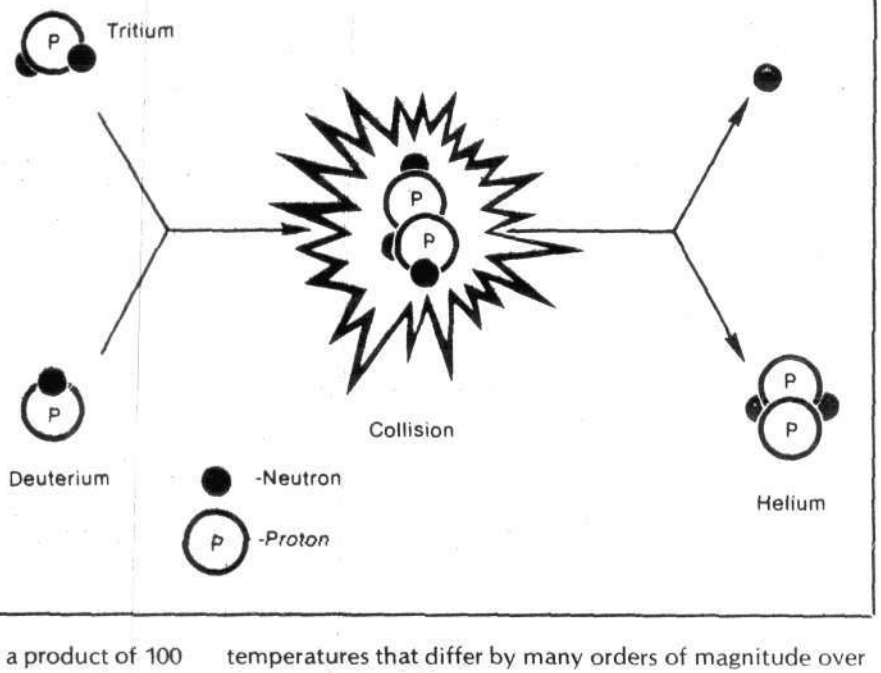
This centerpost for the Doublet III tokamak at General Atomic Company in San Diego, Cal. is designed to withstand the tremendous mechanical stresses created by the magnetic field coils during the tokamak's operation. The Doublet III is scheduled for operation in early 1978, and judging from recent results at Oak Ridge Laboratories with the ISX tokamak, the Doublet will soon demonstrate the feasibility of economic tokamak reactors.

General Atomic Co.

Figure 1
THE FUSION PROCESS

In the deuterium-tritium fusion process shown here, the deuterium nuclei [D], which consists of one neutron and one proton, fuses with a tritium nuclei which consists of one proton and two neutrons. The result is the formation of a helium nuclei with two protons and two neutrons and one free neutron. Since the total mass of the fusion reaction products, the helium nuclei and the free neutron, is less than that of the deuterium and tritium nuclei, the difference in mass becomes expressed in the velocity of the products.



whose confinement time and density have a product of 100 trillion (10^{14}) nuclei per cubic centimeter-seconds in order to produce a net energy gain. For example, a 50-million-degree plasma with a density of 10^{23} nuclei per cubic centimeter need be confined at that temperature and density for one-billionth of a second (10^{-9} second or one nanosecond), to produce net energy. Alternately a 50-million-degree plasma of D-T must be confined at 10^{14} density for one second.

Plasmas

Temperature is a measure of the average velocity of atomic particles—neutral atoms, ions, bare nuclei, electrons, or neutrons. In the following I will use the electron volt (eV) as a measure of temperature. If a group of atomic particles has an average temperature of 11 million degrees centigrade, its corresponding eV temperature is 1,000 eV or 1 keV.

Once a temperature is above a few eV, a collection of neutral atoms become ionized by their energetic collisions. At this point the negatively charged electrons and positively charged nuclei or ions act independently and are no longer paired as in the case of neutral atoms. The motion of plasma ions and electrons is dominated by electrostatic repulsion of like charges and attraction of unlike charges, together with magnetic fields produced by the motion of electric charges; in the case of neutral atoms, the motion is dominated by actual and near collisions. In a normal gas, short-range collisions determine the rate at which the gas atoms diffuse away from each other and the rate of energy or heat conduction. In plasmas both diffusion and heat conduction are dominated generally by the long-range electromagnetic interactions. The distribution of energy in the plasma need not be even; electrons and ions can be sustained at temperatures that differ by many orders of magnitude over short periods of time.

Putting aside the effects of magnetic fields for the moment, if we look at an individual charged particle in a plasma, the electrostatic forces of all of the other charged particles act on it to change the direction of its motion and transfer energy to it or from it. This process is termed *Coulomb scattering* or *Coulomb collisions*.

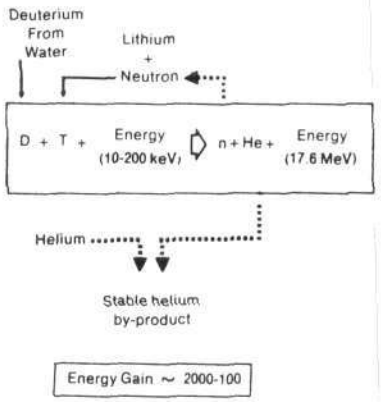
The frequency in a given plasma of Coulomb collisions in which particles change the direction of their motion by an angle of more than 90 degrees is proportional to the plasma density divided by the plasma temperature to the power of 3. This means that the collision frequency increases with increasing density and decreases with increasing temperature (Figure 5).

Magnetic fields can be either externally imposed on a plasma or internally generated by the motion of charged particles. The magnetic field causes the charged particles to experience a force perpendicular to the direction of their motion and the direction of the magnetic field. The magnitude of this force is determined by the strength of the magnetic field and the velocity of the charged particle that is perpendicular to the direction of the magnetic field. A charged particle moving *parallel* to the direction of the magnetic field experiences no force and if the particle moves both across and along the field it will form a spiral.

Even given these necessarily simplified considerations of plasma dynamics, we can discern a wide range of complex behavior. For example, if we induce an electrical current in a column of plasma, the current will produce a magentic field azimuthal (horizontal) to the direction of the current flow. The magnetic field traps the charged plasma particles in spiral-like orbits around the lines of force defining the direction of the magnetic field. It therefore inhibits plasma diffusion across the field.

Figure 2

PROBABLE FUSION FUEL CYCLE



EXOTHERMIC FUSION REACTIONS

Reaction	Reaction energy (meV)	Threshold plasma temperature (KeV)	Maximum energy gain per fusion
$D + T \rightarrow {}^4He + N$	17.6	10	1800
$D + D \rightarrow {}^3He + N$	3.2	50	70
$D + D \rightarrow T + P$	4.0	50	80
$D + {}^3He \rightarrow {}^4He + P$	18.3	100	180
${}^6Li + P \rightarrow {}^3He + {}^4He$	4.0	900	6
${}^6Li + D \rightarrow {}^7Li + P$	5.0	900	6
${}^6Li + D \rightarrow T + {}^4He + P$	2.6	900	3
${}^6Li + D \rightarrow 2{}^4He$	22.0	900	22
${}^7Li + P \rightarrow 2{}^4He$	17.5	900	18
${}^{11}B + P \rightarrow 3{}^4He$	8.7	300	30

The table and diagram above give an overview of the conditions needed to ignite various fusion reactions and the energy these reactions produce. For example, the first reaction listed, a deuterium-tritium reaction, is ignited at 10 keV temperatures and produces an energy equal to 17.6 MeV [or 17600 keV], 1,800 times greater than the energy needed to produce the D-T fusion reaction. Because of its high energy gain and relatively low ignition temperature, D-T is the easiest reaction to produce energy generation, as shown in the diagram. The next fusion reaction listed in the table is the D-D reaction, followed by several lithium reactions and finally the B-P reaction in which boron and protons, simple hydrogen, are transformed into helium. This last reaction is the ultimate goal in fusion since all of the products are charged particles and could be directly converted to electricity at near 100 percent efficiencies.

Figure 3

THE REQUIREMENTS OF FUSION FUELS

Shown at right are the requirements of temperature, density, and confinement time [T,n,τ] versus temperature alone needed for igniting various fusion reactions. The easiest reaction is that of deuterium-tritium, which has the lowest point on the graph in its curve. The next easiest is the catylized D-D reaction, labeled D-D [CAT]. The Alcator tokamak has approached the conditions of Tnτ on the vertical axis needed for a D-T reaction, although only at temperatures of 1 keV. The 2XII Mirror at Lawrence Livermore Laboratory, using neutral beam heating, has obtained temperatures of greater than 10 keV at low Tnτ. In the planning stage is an Alcator device using neutral beam heating to meet all requirements for ignition.

Figure 3

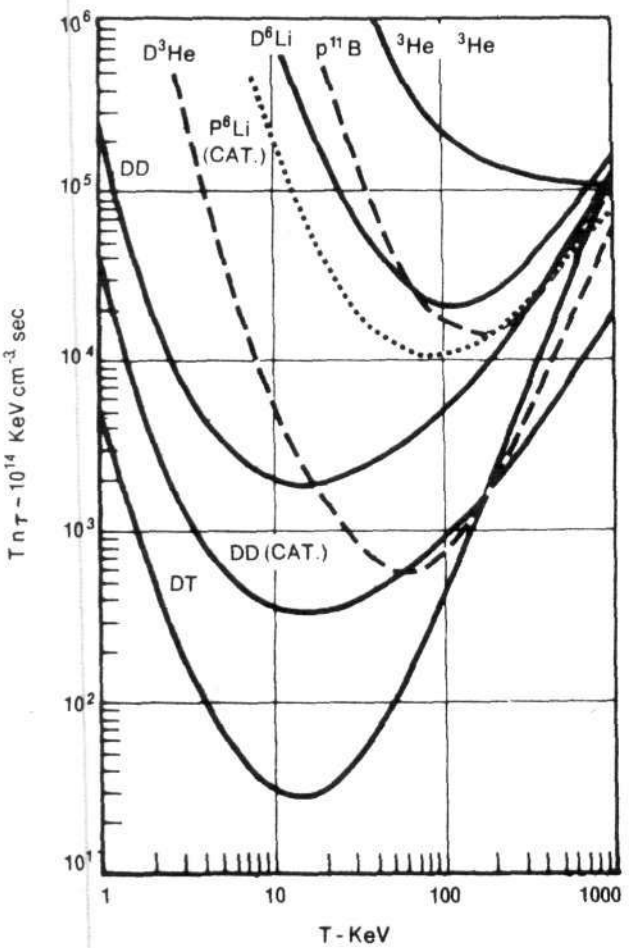
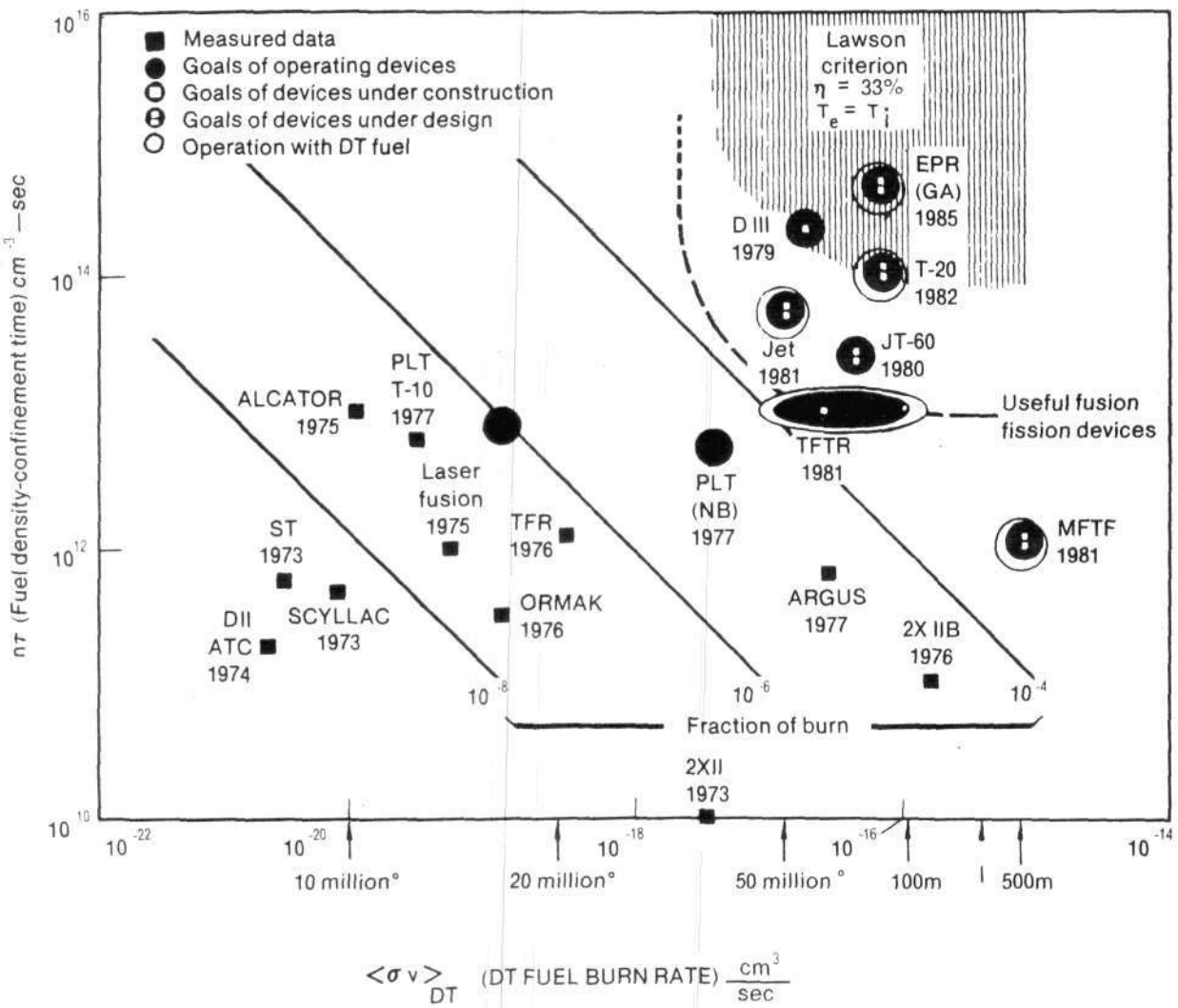


Figure 4

RESEARCH PROGRESS IN FUSION POWER



The basic physical parameters necessary to reach fusion breakeven reactions and better are plotted here logarithmically on a two-dimensional diagram for existing and planned tokamak experiments. The vertical axis shows the Lawson product of density times confinement time, and the horizontal axis shows the temperature of the plasma confined. The upper right-hand region [hatched] is where fusion reactors would operate. The dashed line shows the minimal conditions needed for energy producing fusion-fission hybrids. The oblique lines, marked fraction of burn, show the percentage of fusion fuel confined that would undergo fusion reactions if deuterium-tritium were used in the experiment.

As the figure shows there has been a steady and encouraging progression of experimental results with a number of different approaches. The 2XIIB mirror at Lawrence Livermore Lab has achieved the highest temperature utilizing neutral beam heating. The Argus laser, also at Livermore Lab, has also achieved high temperatures and significant burn of fusion fuel using actual D-T pellets. As shown, the more recent experiments such as the PLT, Alcator, TFR, and Ormak tokamaks have all made great strides beyond the original breakthroughs of the ST, ATC, and DII tokamaks. The next immediate major steps will be the neutral-beam heated PLT and the DIII [Doublet III—see cover]. The following generation of experiments, such as JT-60, EPR, T-20, TFTR, and JET tokamaks, will demonstrate near reactor conditions.

If we increase the current, the magnetic field strength increases and causes the plasma column to be compressed to a smaller diameter. This "pinching" of the plasma column increases the current density and therefore further increases the strength of the magentic field. This in turn leads to further pinching, and so on. At the same time, however, the plasma pinching leads to a higher density that increases the rate of plasma diffusion and eventually balances the tendency toward plasma compression.

Other examples of plasma dynamics are the generation of various types of waves or oscillations of energy in the plasma, plasma-magnetic field interaction, and plasma diffusion.

Impurities and Radiation

As noted in the description of the energy balance of the fusion plasma, energy can be lost in the form of electromagnetic radiation. Any time charged particles, especially electrons, change their velocities either in magnitude or direction (as occurs in plasma diffusion), electromagnetic radiation is released. In working with a hydrogen plasma, if heavier elements — impurities from the wall of a vacuum chamber such as carbon, iron, oxygen, and so on — are present, even in a very small proportion, they dramatically increase the rate at which radiation is generated. The reason is that the greater electrostatic charge of heavier ions increases the frequency of Coulomb scattering.

Also, since heavier ions retain their inner electrons, which are strongly bound to the nucleus, they absorb plasma energy by collisions and release it in the form of radiation. This radiation is produced by atomic processes such as the relaxation of a tightly bound electron from an excited to a ground state. Even impurities of only a few percent can almost completely dominate a hydrogen plasma.

Magnetic Fusion

To obtain net energy one must achieve the Lawson criteria of temperature and confinement-density. This boils down to the insulating of the fusion fuel from the outside world while simultaneously heating it. Magnetic fields provide a good means of insulating a fusion plasma both in terms of confining of the plasma and inhibiting heat conduction.

As noted above, in simplified terms plasma particles can be trapped to orbit in spirals along magnetic field lines. The radius of these orbits is proportional to the square root of the temperature divided by the strength of the magnetic field. Given the appropriate geometry of magnetic fields, it is therefore probable that a fusion plasma can be trapped within a given region and thermally insulated for a period of time.

Coulomb scattering does lead to diffusion of plasma particles across the magnetic fields. The rate of this diffusion, again from the simplified considerations given above, is equal to the square of the orbit radius times the frequency of the Coulomb scattering. Taking a plasma in an infinitely long tube of straight magnetic field, the confinement time of the plasma based on the above considerations would be equal to the square of the radius of the tube divided by the rate of diffusion.

To put it mathematically:

$$t_{\tau} = .9 \times 10^{17} a^2 B^2 T^{1/2} / (n Z_{eff})$$

where t is the confinement time in seconds, a is the tube radius in meters, T is the plasma temperature in keV, B is the magnetic field strength in telsas, and n is the plasma density in nuclei per cubic centimeters.* Z is a measure of the presence of impurities and would be equal to 1 if the plasma were pure hydrogen.

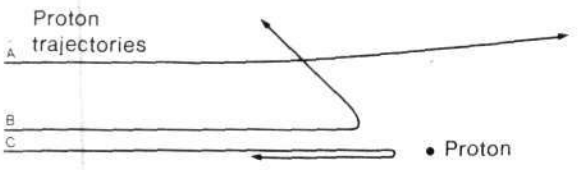
Given a fusion plasma density of 10, at a temperature of 9 keV, in a magnetic field of 1 tesla, and completely pure such that the Z is 1, the radius of the tube need be only a couple of centimeters. This result is generally referred to as *classical diffusion* and it leads to a very optimistic prognosis for the development of breakeven fusion, especially since the confinement time increases with increasing temperature. Multiplying through by n gives the Lawson criteria on the left hand side:

$$n t_c = .9 \times 10^{17} a^2 B^2 T^{1/2} / Z_{eff}$$

Obviously an infinite tube is out of the question. Since the classical diffusion across the magnetic field is very modest, in a net energy-producing fusion system based on the above the confinement time would be determined chiefly by the *length* of the tube. Since nothing is inhibiting the flow of the plasma parallel to the magnetic fields, the length of such a reactor would have to be roughly equal to the thermal velocity of the plasma particles times the confinement time. Taking the above conditions, the tube would have to be several kilometers

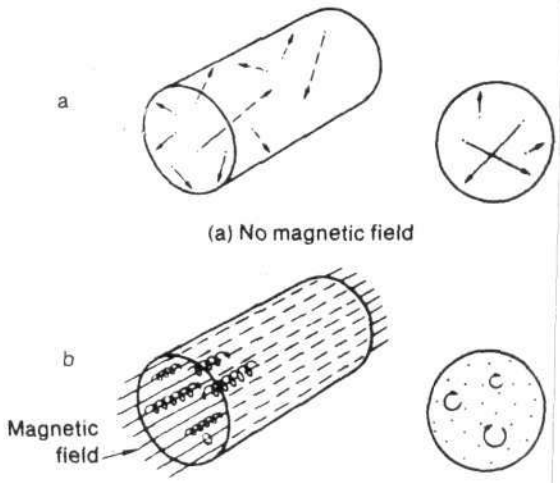
* A tesla is an international unit for measuring magnetic field strength and equals 10,000 gauss.

Figure 5
PARTICLE COLLISIONS IN A PLASMA



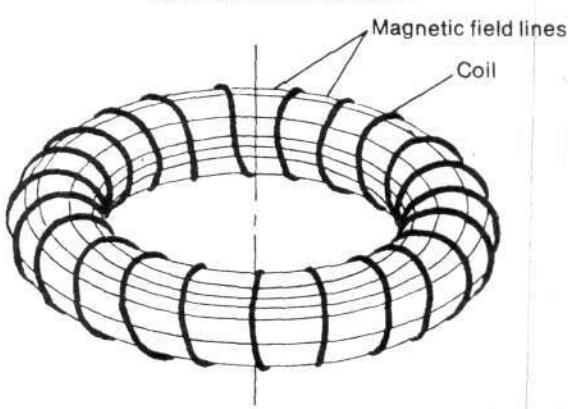
The closer one charged particle approaches a particle of similar charge the greater the repulsion and therefore the greater the distortion of its trajectory. In a plasma of protons [hydrogen], the change in direction of the trajectory of charged particles, that is, the scattering, is dominated by the collective charge of a large number of charged particles and not simply the interaction between only two particles. Collision frequency increases with increasing density and decreases with increasing temperature.

Figure 6
MAGNETIC CONFINEMENT IN A CYLINDRICAL VESSEL



A magnetic field can be used to confine the plasma in a fusion reactor and orient the motion of the charged plasma particles. Without this magnetic field [6a], a plasma of charged particles in a cylindrical vessel would move randomly in straight lines and quickly strike the wall of the vessel. This contact would cool the plasma down below the temperature required for the fusion reaction and would possibly damage the first wall. If a uniform magnetic field is applied [6b], the particles will be compelled to follow helical paths encircling the lines of force, with positive particles spiraling in one direction and negative particles spiraling the opposite direction. The torus shape [Figure 7] was designed to prevent the particles from streaming out the ends of the cylinder. The electrical current in the helical coils generate an axial magnetic field in the torus to confine the fusion plasma. Recent experiments on a straight cylindrical theta pinch device have shown that it may also be possible to stop this particle flow sufficiently to get fusion simply by placing material for use as plugs at the end of the cylinder.

Figure 7
TOROIDAL CONFINEMENT



long! One apparent solution would be to close the tube onto itself, forming a closed donut, and this is precisely what was done in a number of different systems, such as toroidal theta pinch and zeta pinch machines.

Toroidal Systems

There are a host of new problems if a donut or torus shape is used. First, macroscopic interactions between the confined plasma and confining magnetic field cause the plasma column literally to whip itself into the wall of the vacuum chamber within a few millionths of a second. Therefore there is a rapid loss of the plasma's energy by direct thermal conduction.

These macroscopic interactions are termed magnetohydrodynamic or MHD instabilities since they are similar to the dynamics of an electrically conducting fluid where the plasma is taken as one fluid and the magnetic field as a second one.

The qualitative features of one of the best known of these MHD instabilities can be demonstrated with a glass of water and oil. Carefully place the water over the top of the oil without disturbing the oil. Now cause a slight disturbance along the surface between the water and oil. What you will see is that the disturbance generates an oscillation between the two fluids that grows to the point that globs of oil pass through the water to form pools of oil on the surface of the water. Eventually all the oil will be above the water.

This is the famous Rayleigh-Taylor hydrodynamic instability. The driving force for the instability is the gravitational field, and the potential energy harnessed to generate the motion of the two fluids is the difference in the densities of the two fluids (water is heavier than oil).

We can generate a similar instability in magentic confinement, where plasma takes the place of the water and the magnetic field the place of the oil. The driving force is the gas pressure of the plasma against the confining magnetic field, the magnetic field supplies the potential energy. If the confined plasma "sees" a concave magnetic field, this will generate the instability. This is precisely the type of magnetic field produced by a simple toroidal configuration (See figure 8).

Once toroidal geometries were developed that gave relatively stable macroscopic confinement, it was discovered experimentally that the plasma confinement was not nearly as good as that predicted by classical theory. Instead, there were microinstabilities that led to rapid diffusion of the plasma and, anomalously, to fast conduction of the heat energy of the plasma to the vacuum chamber wall.

Beating the Bohm Barrier

David Bohm, a student of Robert Oppenheimer* developed an alternative prediction for rates of plasma diffusion, taking into consideration a first approximation of the types of collective plasma behavior and interactions that would lead to more rapid diffusion and heat transport. Compared to the classical prediction for the conditions examined above, the Bohm confinement time is more than

a *million times less* than that needed for breakeven and it gets worse as the temperature is increased. His pessimistic prediction was much closer to the experimentally observed results:

$$t_B = 3.14 \times 10^{-3}\ a^2\ B/T$$

Ironically, Bohm was excluded from the original U.S. magnetic fusion research effort because at that time the research was classified top secret, and Bohm was accused of having "left leanings." For many years plasma theorists in the official research program were unable to figure out how Bohm had derived his apparently correct theoretical prediction and were not permitted to talk to him.

From that time on, fusion researchers have measured the success of their experiments in terms of how much greater confinement than that predicted by Bohm they obtain. Beating the Bohm barrier became the chief goal of toroidal fusion research.

Throughout the late 1950s and early 1960s, no magnetic fusion experiment (except linear systems that rapidly lost their hot plasmas out their open ends) was able to beat the Bohm barrier. In 1968, Soviet scientists at the Kurchatov Institute in Moscow led by Academician L.A. Artsimovich reported that toroidal tokamak experiments achieved a confinement of hot plasma better by a factor of 10 than that predicted by the Bohm formula.

At first Western scientists met the Soviet claim with skepticism. But in 1969, a British team headed by R.S. Pease traveled to Moscow and carried out a series of measurements on the Soviet's tokamak plasma using a newly developed method of measuring plasma temperatures with an intense laser beam. Pease not only confirmed the Soviet claims but demonstrated that the Soviets were significantly underestimating the actual temperatures achieved.

Stellarators and Tokamaks

The tokamak was not new to Western fusion researchers. It was among the first fusion systems designed in the late 1940s and fully disclosed in 1956 by Artsimovich when the Soviet Union unilaterally declassified their magnetic fusion energy research.

In general terms the tokamak is quite similar to the major U.S. design for the stellarator, a toroidal magnetic trap also developed in the early 1950s (Figure 9).

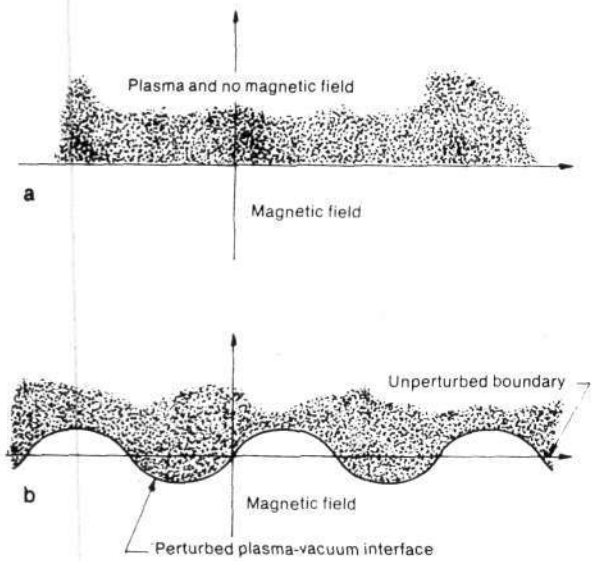
In both systems a diffuse, hot plasma, hundreds or even thousands of times less dense than ordinary air (19th century physicists would describe it as a good vacuum) is trapped in a donut-shaped closed magnetic field. The geometry of the magnetic fields is such that it maintains macroscopic stability. In the tokamak and stellarator this stability is achieved by generating a magnetic field configuration in which the magnetic field lines form helices as they traverse the torus (Figure 10).

Two electrical current-carrying coil systems are used in the stellarator to produce a net magnetic field with this toroidal spiraling geometry. In the tokamak only one external coil is used. The helical twist is generated by an electrical current carried by the plasma itself. The external coil in the tokamak generates an untwisted magnetic field that traverses the torus and is called the *toroidal magnetic field component*. The tokamak's plasma current produces a second, weaker magnetic field in a direction perpendicular to that of the toroidal field. This is termed the *poloidal field component*, and it produces the twist in the overall net magnetic field.

Because the tokamak uses only one external coil for producing its main magnetic confining field, it is much easier to construct and operate than the stellarator. Although there are other major differences, this engineering distinction was critical in determining which system would be developed to a size and strength of magnetic field that could permit the experimental production of large bodies of hot plasma.

Another major distinction is that the stellarator in theory could be a continuous, steady-state thermonuclear reactor, while the tokamak, because it depends on an

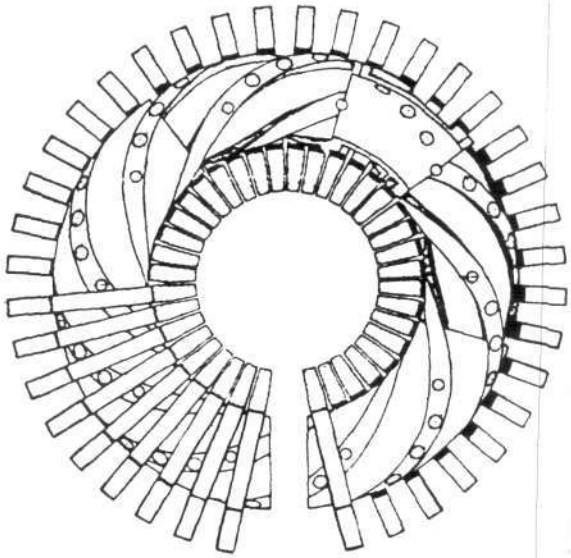
Figure 8
THE RAYLEIGH-TAYLOR INSTABILITY

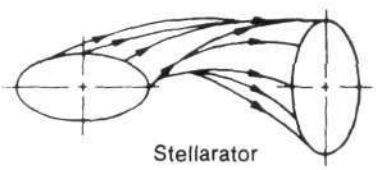


Shown here is a simple form of the Rayleigh-Taylor hydrodynamic instability where gravity is the driving force behind the instability. In magnetic confinement the driving force could be either a temperature or density gradient. In **a**, *a magnetic field prevents a plasma in the ionosphere from diffusing toward the earth by supporting it against the force of gravity. In* **b**, *a small perturbation leads to an oscillation between the plasma and magnetic field similar to that of the glass of water and oil described in the text.*

* Robert Oppenheimer headed up the Los Alamos division of the Manhattan Project and was well known as a sympathizer of the Communist Party USA. In 1954 as part of the anti-Soviet hysteria, Oppenheimer was tried on trumped-up charges of being dangerous to the national security, stripped of his security clearance, and sent off to Princeton University to work in isolation. The show trial was intended to intimidate the scientific community into going along with U.S. policy, and it successfully accomplished its goal.

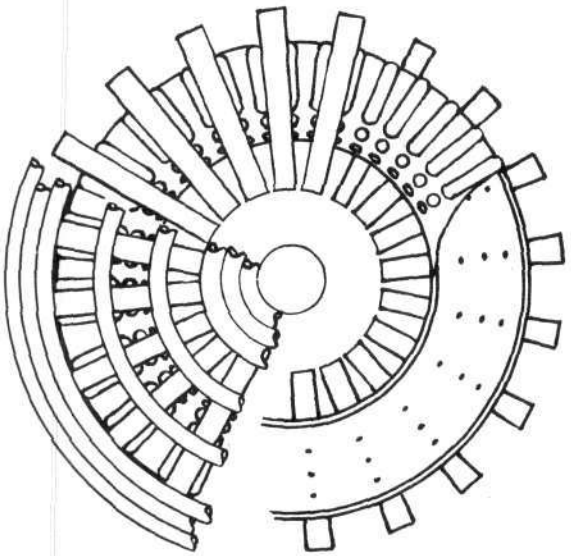
Figure 9
STELLERATOR

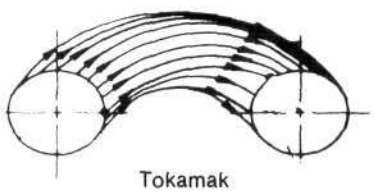




Stellarator

Figure 10
TOKAMAK





Tokamak

These are comparative plan views from above of a stellarator and tokamak showing the toroidal and poloidal field coils of the tokamak and the toroidal field coils and helical windings in the stellarator. The smaller schematic drawings compare the magnetic field geometries of both devices. Note that the tokamak is symmetrical while the stellarator is not.

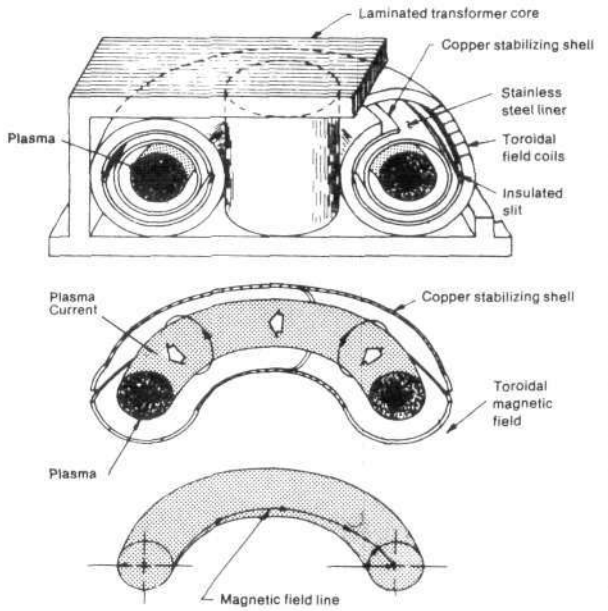
induced plasma current that can be generated only transiently, must be a pulsed device. With a pulsed system, even though the pulse may be as long as an hour (the case in most tokamak reactor designs), the overall system experiences gigantic direct and indirect thermally induced mechanical stresses. Also, large amounts of energy must be stored for the startup and ignition of the thermonuclear plasma during each cycle; in an ideal steady-state system the thermonuclear plasma must be ignited only once.

As shown in drawings of the net magnetic fields produced in a tokamak and a stellarator respectively (Figures 9 & 10), the tokamak magnetic field is symmetrical both to the small and large circles of the torus, while the stellarator magnetic field is asymmetrical. The stellarator plasma column trapped by this asymmetrical magnetic field has a helical twist overall as it winds along the torus. This twist prevents the plasma column from expanding outward until it hits the wall.

In the tokamak this outward expansion originally was stopped by making the vacuum chamber out of a good conductor of electricity. As the plasma expanded toward this conducting wall it would induce an electrical current. This in turn produced a magnetic field that would interact with the magnetic fields of the plasma column to repel the plasma column back inward. More recent designs use external windings that generate this magnetic field to prevent outward expansion of the plasma column. The direction of this third tokamak magnetic field (the other two are the strong toroidal field generated by the large coils surrounding the vacuum chamber and the weaker poloidal field generated by an electrical current induced in the plasma itself) is the vertical direction in the figure and is much weaker than the toroidal or poloidal fields.

Another major component seen in Figure 11 is the laminated iron transformer core that induces an electrical current to circulate the long way around the torus (marked as plasma current). The tokamak is a one-turn trans-

Figure 11
TOKAMAK CROSS SECTION



The tokamak is basically a toroidal [or donut] shaped magnetic container for holding the plasma away from the material walls of the fusion device. Its name came from the Russian words for toroidal [to], chamber [ka], and magnetic [mak]. As the diagram shows, the plasma is contained in a metal-walled torus. The primary coils located in the laminated transformer core induce a current in the plasma that produces the poloidal magnetic field and the toroidal field coils produce the toroidal magnetic field. These fields then combine to form a spiral or helical field that can stably confine the hot plasma.

former, and since the geometry of the confining magnetic fields depends on the field generated by the plasma current, the cycle of the tokamak is limited to the half-cycle of the alternating current pulsed through the iron-core transformer. As discussed later, it is possible for diffusion of the fusion reaction products or other collective plasma effects to lead to the internal generation of a "bootstrap" plasma current, thereby making a steady-state tokamak conceivable.

More recent designs of tokamaks have used an air core transformer, obviating the need for a large iron core structure. The iron core hampers the mechanical design of a tokamak because of the room it requires for the magnetic coils and their massive structural supports.

Operating the Tokamak

The first step in the operation of a tokamak is to evacuate the large vacuum chamber, in itself a major technological task. The chamber must be perfectly sealed, yet, at the same time various access ports must be built in for observing the plasma, injecting hydrogen gas, and introducing devices for heating the plasma. Even a perfectly sealed chamber will not be good enough. The vacuum chamber wall has various atoms and molecules embedded in it (such as oxygen and oil and the materials with which it is constructed) that are released during the discharge of the hydrogen plasma and that diffuse into the plasma becoming the impurity that dominates the discharge, as mentioned before.

To protect the vacuum wall from contact (accidental or otherwise) with the hot plasma, a plate called the *limiter* is placed inside the chamber. The limiter itself, however, is a major source of impurities. Eventually researchers plan to use the vertical magnetic field as a sort of "magnetic" limiter in reactor designs.

There are other major problems to solve before the tokamak can begin operation. The magnetic coils must withstand gigantic mechanical stress (up to hundreds of thousands of pounds per square inch) created by their electromagnetic interaction, and they must not move more than one-thousandth of an inch because such movement would change the magnetic field geometry. The various electrical circuits of the tokamak (the main toroidal field coils, the vertical field coils, the transformer, and various diagnostic systems) must be insulated from one another in the appropriate fashion and switched on and off at precisely the right moment. While the discharge typically lasts less than a second, during this time the various tokamak electrical systems consume enough power to run a small city.

The Plasma Column

After the chamber is evacuated and there are various procedures are carried out to clean or strip the chamber wall of atoms and molecules that readily diffuse into the plasma and form impurities, a small amount of hydrogen gas, either deuterium or regular hydrogen, is pumped into the chamber. Next the magnetic coil circuits are activated. Finally, a gigantic pulse of current activates the transformer.

The rapidly changing flux of the transformer first ionizes the hydrogen gas and then induces a current. The result is a fully ionized, stable plasma column.

How this actually comes about is a question of much debate. It appears that the initial, partially ionized hydrogen gas column undergoes some rapidly developing and dying plasma instability that completes the ionization of the column, but dissipates so that the resulting plasma is quiescent.

Once a stable plasma is confined within the torus, more hydrogen gas is pumped in leading to a build-up of the plasma density as the plasma ionizes this hydrogen gas. The total discharge typically lasts up to 1 second. But the time during which the plasma is maintained at high temperatures, the true confinement or *energy confinement time*, is generally only a few hundredths of a second. As noted previously, the densities of the plasma are between 10^{13} to 10^{15} nuclei per cubic centimeters.

Plasma Heating

The tokamak has built into its design the initial means for heating the plasma to relatively high temperatures, 1 keV temperatures. The current induced in the plasma column heats the plasma in the same way that an electrical current heats any conductor, joule heating. The amount of electrical energy dissipated into the plasma per unit time per unit volume due to a flow of current of density j is $Q = nj$ where n is the resistivity of the conductor, in this case the plasma. In simple terms, the resistivity easily can be seen as necessarily proportional to the Coulomb collision frequency since it is by collisions that the plasma "resists" the flow of charged particles, that is, the electrical current.

The tokamaks of the 1960s and early 1970s achieved significant advances over other types of magnetic fusion systems and very respectable temperatures of up to 1 keV (11 million degrees centigrade), but the temperatures reached were short by a factor of 10 of what was needed to ignite large amounts of fusion.

Resistive heating does not appear to be capable of making this final leap. As noted above, Coulomb collision frequency decreases with increasing temperature, and therefore the plasma resistivity also decreases. Since the rate at which the plasma is heated is proportional to the resistivity, n, at higher temperatures joule heating is no longer effective, and an alternative means must be used.

Among the many alternate means of plasma heating that have been demonstrated are neutral beam heating, microwave and radio frequency electromagnetic radiation heating, and magnetic compression. Another possibility is the use of induced, short-lived plasma instabilities.

Neutral beam heating has been the most successful, with plasmas reaching 2.5 keV ion temperatures, and it is also the most promising in terms of scale-up to reactors.

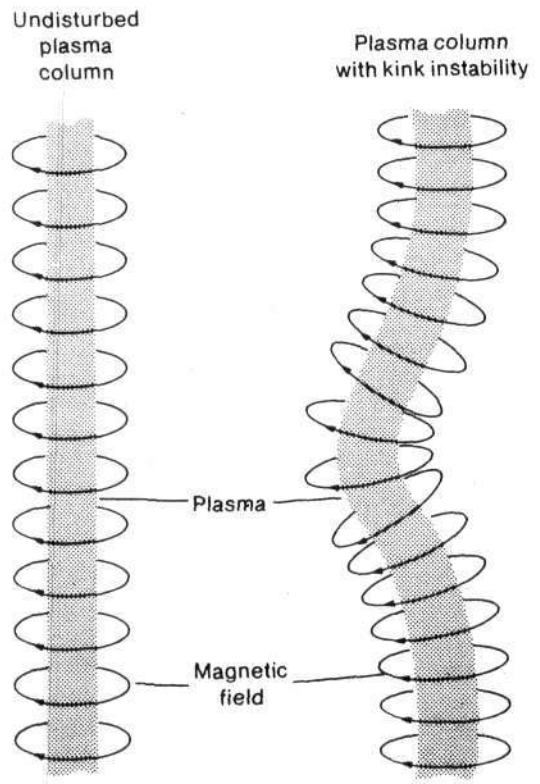
In neutral beam heating, large currents of high-energy ion beams are accelerated in diodes external to the tokamak. These ions, with energies of up to several hundred keV, are re-formed as neutralized by high-energy atoms or molecules. This is accomplished by injecting the ion beams into a neutral gas chamber where charge-exchange takes place; the high-energy ions capture or lose an electron and become neutral. This beam of high-energy neutrals is then able to penetrate the confining magnetic fields of the tokamak and here they are once again ionized by collisions with the plasma and trapped in the magnetic bottle. As these relatively high-energy ions collide further with the lower-energy plasma, they lose their energy to the plasma, thus heating it.

Without even heating the overall plasma to fusion temperatures, the neutral beam can lead to a breakeven regime. As the beam is slowed down in the plasma, it is really a very high energy plasma tail and can undergo substantial amounts of fusion. This type of system has been termed the *wetwood burner* or beam-driven type of fusion.

Electromagnetic radiation heating is not as experimentally explored as neutral beam heating, but experiments have demonstrated that several different approaches based on electromagnetic radiation are promising. Microwave and radio wave heating make use of a large number of fundamental oscillations of the plasma, such as the frequency of the orbits of the electrons and ions around the magnetic fields and hybrid oscillations, to couple electromagnetic energy into the plasma. This approach holds great promise in terms of controlling the plasma and possibly even damping out plasma instabilities because the electromagnetic energy is deposited in the plasma in a well-directed fashion and can be tailored to heat either the electrons, or the ions, or a particular region of the plasma.

In fact, it may be possible to drive impurities out of a plasma (even the helium "ash" of the fusion reaction) making a steady-state regime technologically possible.

Figure 12
PLASMA KINK INSTABILITY



If the helical twist of the magnetic fields in a tokamak is too great, it will generate the kink mode where the plasma column twists itself, as shown, into a kink and destroy the geometry of the magnetic confinement.

Macroscopic Plasma Modes

Unlike a neutral gas, which can be pictured as a collection of hard balls undergoing random collision, the dominating feature of plasma is a series of well-ordered

Figure 13
TORUS RADII

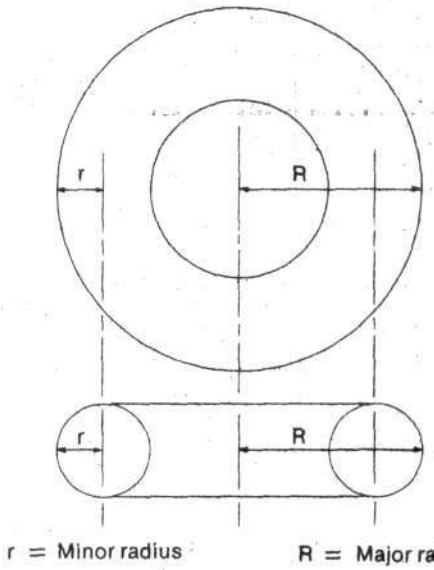


Figure 13

The drawing above shows the major radius [R] and minor radius [r] of the torus. The aspect ratio of a tokamak is equal to R divided by r. In noncircular cross sections, like the Doublet, the aspect ratio is R divided by a plus b [see Figure 14].

Figure 14

To the right are cross sections of the main tokamaks that will be put into operation between 1978 and 1985 showing the size of the toroidal coils and the plasma cross section schematically. R is the major radius, a and b are the dimensions of the plasma column cross section. In a symmetrical tokamak with a circular cross section, a and b are equal and represent the minor radius, r.

The objective of these tokamaks is to reach a domain of plasma parameters close to those of a thermonuclear plasma in order to determine the scaling laws and the behavior of the plasma. The devices use different approaches to solving the problem of efficiently confining the plasma. These future research tokamaks are significantly larger than the current devices in use. Their major radius ranges from 1.4 to 5 meters; the plasma radius from .45 to 2 meters; the toroidal field from 26 to 60 kG; and the plasma current from 2 to 6 mega-amperes [MA].

Up to now, the maximum plasma current obtained in current tokamaks is of the order of 0.5 mega-amperes. This current will reach 1 MA with the Soviets' T-10 and the Princeton PLT when they are working at full performance, and the next generation of tokamaks will reach plasma currents of 2 to 6 MA. The estimated plasma current in a commercial reactor is between 8 and 12 MA.

Figure 14
CROSS-SECTIONS
OF FUTURE RESEARCH TOKAMAKS

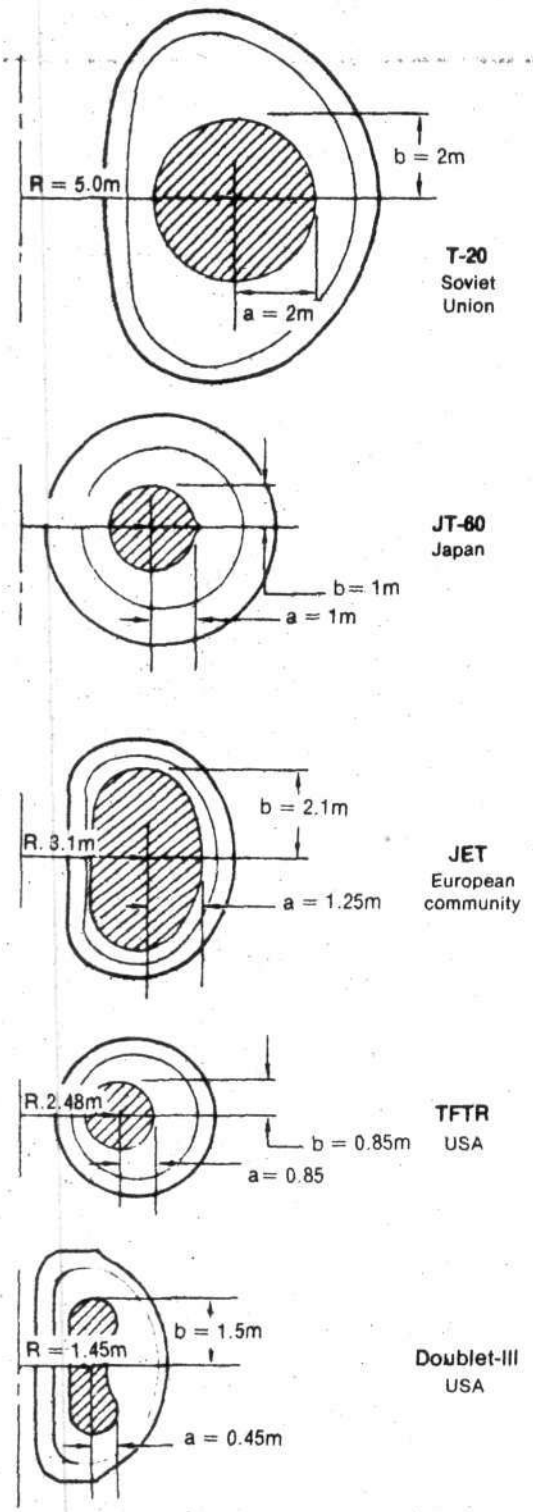
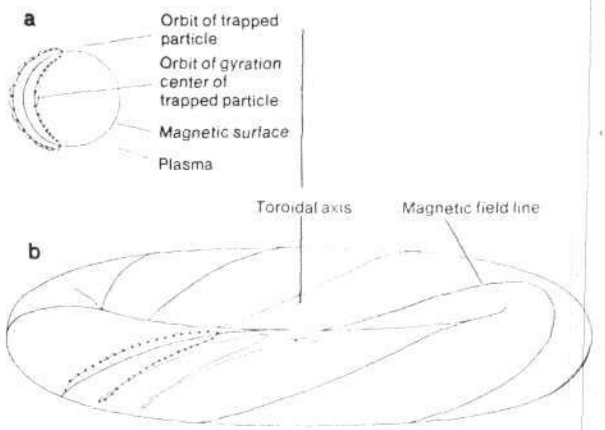


Figure 15
TRAPPED AND CIRCULATING PARTICLES



Shown in **a** *is a projection of the cross section of the torus and the cross section of the particle orbit of a trapped and collisionless plasma particle [a nucleus or electron] in the helical magnetic field of a tokamak. Note the banana shape of the orbit, which in the Soviet Union is called a sickle orbit. Shown in* **b** *is the triple motion of the trapped particle: the gyration in a spiral along the magnetic field line, the banana orbiting, and the drift across the magnetic field lines.*

structures. These structures are best described as oscillators coupled in various ways. For example, the ions and electrons circle around the magnetic field lines at specific frequencies. Macroscopically, the interaction of the plasma with the confining magnetic field can generate MHD oscillations that lead to the rapid loss of the plasma.

If the helical twist of the magnetic fields in the tokamak is too great, one of the most disastrous types of MHD modes will be generated, the *kink mode* where the plasma column twists itself into a kink leading to the rapid destruction of the necessary geometry of the magnetic bottle (Figure 12). Since the poloidal field is what creates the twist in the magnetic field as it transits the torus, this phenomena limits the magnitude of the poloidal field. Therefore this kink mode also limits the magnitude of the plasma current, since the poloidal field is generated by the plasma current and is directly proportional to it.

This MHD limitation on the maximum allowable plasma current is expressed in terms of "safety factor," q. If the plasma current goes below q it will initiate the disastrous MHD kink modes. This q is defined as the number of times a magnetic field (the net field line of both the poloidal and toroidal magnetic fields) travels the long way around the torus while making one complete twist. In general, q must be at least 3 for the outer magnetic field lines in a tokamak while the center lines can have q's as low as 1; thus the average magnetic field line in a tokamak makes three trips the long way around the torus while making a complete twist.

This can also be expressed in terms of the poloidal and toroidal magnetic fields and the geometry of the torus.

$$q = \frac{rB_t}{RB_p}$$

where r is the minor radius and R is the major radius of the torus (see Figure 13) and B_t is the toroidal and B_p the poloidal magnetic fields. Because q must generally equal 3, in order to maximize B_t (and therefore the plasma current to which B_t is directly proportional and which provides the basic heating of the tokamak plasma), the ratio of r to R must be as great as possible; that is, we must have a fat donut.

A tokamak has only one main toroidal magnetic coil winding to support, as opposed to the two needed for the stellarator, and thus the mechancial design of tokamaks permits the "fattest" torus.

In addition to limiting the amount of current heating a tokamak can stably support, the safety factor appears also to limit all other kinds of stably sustainable plasma heating. This further limitation is expressed in terms of relative measures of pressure. The plasma, just as any other gas, has a pressure proportional to density times temperature. In magnetic confinement, the net field in effect counters this plasma pressure in a direction perpendicular to the direction of the magnetic field. This magnetic field pressure is proportional to B^2.

The ratio of the plasma pressure to the magnetic field pressure is called the *plasma beta* and is a measure of the efficiency with which the magnetic field is confining a plasma.

Most significantly, since the plasma beta is proportional to the product of the allowable plasma density and temperature, it is also proportional to the fourth root of the fusion power density output. In other words, a doubling of the plasma beta will increase the fusion power output of a given volume of plasma 16 times. The q limitations appear to limit plasma betas in tokamaks to about .05, just barely large enough to make the power density of a tokamak power plant economical. Current experiments on tokamaks operate with betas much less than .01 but the Oak Ridge tokamak, the ORMAK, obtained betas of more than .015 last year using neutral beam heating.

The Doublet Solution

There are three possible ways around this tokamak-beta problem. First, asymmetrically elongating the minor radius of the torus can achieve a fatter donut, and theoretical increases in plasma beta up to .1. This idea will be explored in the Doublet III experiment at General Atomic in San Diego, Cal.

In the Doublet geometry (Figure 14), the basic idea is that the elongation of the minor radius permits the ratio of r over R to be increased substantially, therefore allowing a higher ratio of the poloidal to toroidal magnetic fields. Experiments at both General Atomic Labs and in the Soviet Union appear to confirm that the overall plasma beta can be increased in this manner.

Next year General Atomic will complete construction of the Doublet III that could definitively test this particular geometry. If successful, the Doublet III will achieve the plasma parameters needed for an actual power reactor.

The confidence of the General Atomic staff increased tremendously last year after successful experiments on the prototype for the Doublet III, the Doublet II. General Atomic now believes that fusion power reactor prototypes can definitely be constructed in the 1980s and commercialized shortly thereafter. Many of the leading scientists on the General Atomic fusion team are associated closely with the expanded Japanese tokamak fusion effort, which appears to be following this fusion timetable. Japanese Prime Minister Takeo Fukuda recently was informed by his science advisors of the necessity for an all-out effort to develop fusion, and reportedly the Japanese government is willing to devote billions of dollars to an Apollo-type program.

The second way around the tokamak-beta problem comes from MHD theory, which suggests that magnetic field geometry can be "frozen" into a stable geometry given sufficient amounts of noncurrent plasma heating, such as neutral beam heating. This method is termed the *flux-conserving* tokamak and could permit betas of up to .3 to .4.

The third approach is brute force. A large toroidal magnetic field can sustain a large enough plasma density so that even betas as low as .02 would be sufficient for small, economic tokamak power plants. This possibility was developed in the MIT high-field Alcator tokamak.

Microscopic Plasma Modes

In addition to the macroscopic MHD modes, plasma theory has predicted a number of microscopic modes, termed *trapped particle modes*, that could lead to plasma instability.

The plasma electrons and ions in a tokamak do not completely traverse the torus. Because the magnetic field is uneven in strength, as in the case of the magnetic mirror, the plasma particles are reflected away from regions of strong magnetic field before they can make a complete trip around the torus. Two of these regions of stronger magnetic field define the limits to which a plasma particle can travel. The particles are thus trapped between these two points, and the lines along which they spiral take the shape of bananas (Figure 15).

Although not all of the plasma particles are trapped into these banana regions, a significant number are. The first deleterious effect of the banana trapping is to increase the rate of diffusion. As discussed previously, the rate of diffusion is proportional to the square of the orbit radius times the Coulomb scattering frequency. With banana trapping, the effective orbit radius is no longer the radius of the simple spiral made by a particle trapped along a magnetic field line, but rather the radius of the banana. In the case of simple classical diffusion, the rate of diffusion decreases with increasing temperature, but the rate of diffusion from plasma trapping in banana orbits can increase with increasing temperature.

Theoretically, the nonlinear effects and modes induced by banana trapping could be disastrous.

Figure 16 illustrates the various theoretical projections. On the vertical axis, D, is the rate of plasma diffusion; alternately, X_e is the rate of thermal energy diffusion out of the tokamak caused by the electrons. The horizontal axis is the plasma Coulomb frequency, υ. The other points marked off on the horizontal axis are combinations of plasma parameters. For example, v_T is the average electron thermal velocity, e is r/R where r and R are the minor and major radii of the torus, v_p is the classical rate of diffusion where $_p$ is the orbit radius, q is the safety factor, and ω_0 and ω_1 are frequencies that measure nodal points in nonlinear couplings of trapped particle modes.

At low temperatures the Coulomb collision frequency is large, thus one starts at the right-hand side of the graphs. Because most plasma particles experience Coulomb collisions before they can complete a banana orbit, this regime is termed *collisional*. Experimentally it has been found to be very close to the predictions of classical plasma theory, taking into account toroidal geometry effects. (It is, therefore, termed neoclassical theory.) This is one of the most important recent results of tokamak research, as discussed below.

Proceeding to the left, which is also the direction of temperature increase, next is the *plateau regime*, which is projected to be dominated by the trapped electron mode. In Ohmic-heated (that is, current-heated) tokamaks, the electrons are hotter than the ions and therefore they are first to reach a regime in which the Coulomb collision frequency is less than that associated with the banana orbit for electrons. As a result, in terms of qualitative behavior (like diffusion and conduction of heat) the electrons are trapped in banana orbits.

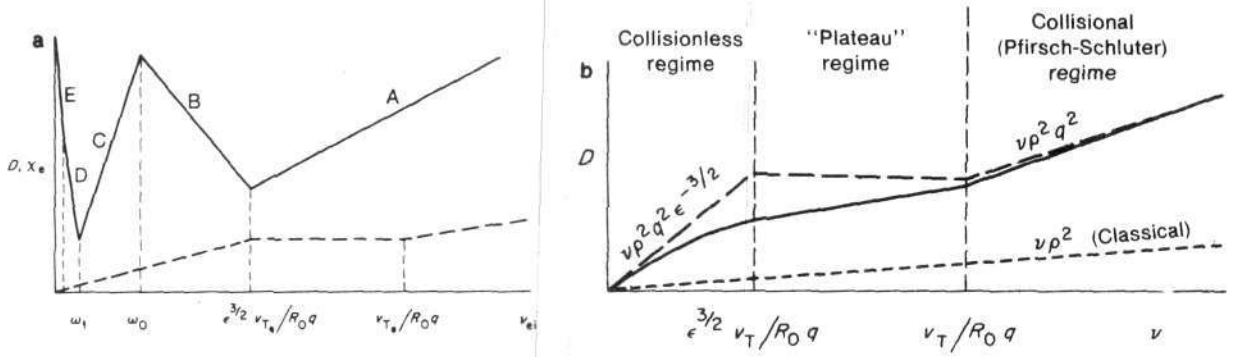
Further to the left are more collisionless regimes. These are projected to have a second-type of trapped electron mode, followed by a series of trapped ion modes where the ions rise sufficiently in temperature so that the Coulomb collision frequency decreases for ions to the point that they are trapped.

In Figure 16, the long-dashed line shows a first approximation for the neoclassical calculation for plasma diffusion in the various projected tokamak regimes. The solid line is a more sophisticated calculation; and the short-dashed line is the classical projection for a straight tube.

Figure 16b also shows the first approximation of the neoclassical projections as a dashed line. The solid lines marked A, B, C, D, E are projections for various regimes taking into account the nonlinear effects of particle trapping. The A regime represents an empirical projection, termed the pseudoclassical, which is derived from experimental results. Lines B, C, D, and E are all purely theoretical projections. There is only the slimmest experimental basis for knowing if they actually exist. And if such regimes do appear in experiments, it is not known whether they will be as good as projected (they are projected to be better than what is needed for a power reactor) or whether the couplings between the trapped

Figure 16

THEORETICAL PROJECTIONS FOR TOKAMAK REGIMES



Shown here are the various estimates for the rate at which a toroidally confined plasma will diffuse through the confining magnetic fields versus the Coulomb collision frequency υ or υ_{ei}. The plasma diffusion coefficient, D, is shown on the vertical axis along with the coefficient for the rate of loss of thermal energy, the thermal diffusion coefficient, X_e, which is proportional to D. The plasma Coulomb collision frequency, v, is shown on the horizontal axis.

Proceeding from left to right on the vertical axis, the temperature generally increases and the plasma depicted becomes more collisionless; that is, the collision frequency decreases. The vertical dashed lines show various points at which the plasma makes qualitative shifts in its behavior. In b, the lower horizontal dashed line shows the diffusion coefficient as calculated for diffusion through a straight magnetic field and is labeled classical; the upper horizontal dashed line is a theoretical calculation taking into account toroidal effects; the solid line is a similar calculation but takes into account with more precision the transition effects and therefore is smoother.

In a, the dashed horizontal line is the same as the upper dashed line in b. The solid line marked off with regions A, B, C, D, and E are more sophisticated calculations taking into account the nonlinear effects of drift wave instabilities that occur in the various collision frequency regimes. Region A is a more or less empirical calculation based on experiment.

particle modes and macroscopic MHD stability could lead to instability and a ruinous loss of plasma.

This is particularly true in the case of asymmetrical geometries attempting to reach higher betas as with the Doublet III figure 8 cross-section tokamak. Harold Grad of the Courant Institute at New York University, one of the originators of macroscopic MHD theory, has recently shown that the assumption that the topology is "preserved" in MHD analysis is false.* In particular the noncircular geometries needed for higher betas will show major and rapid changes in the magnetic field geometry under various conditions contrary to what linear MHD analysis may have predicted previously. The transformation of topologies, Grad has shown, is a manifestly singular and nonlinear phenomena.

In fact, there is a very disturbing phenomenon, termed *disruptive instability*. Under various conditions in different experimental machines of the tokamak type — either when the density is too high or too low — the plasma suddenly blows up. The most recent theoretical speculation on this phenomenon by the Soviet theoretician Kadomtsev maintains that the disruptive instability is a qualitative change in the plasma structure that could be quite similar to what occurs in the plasma focus.**

Further experimental and theoretical work by the French TFR tokamak group, among others, has shown this disruptive instability to be very important in the operation of any tokamak. (See box on page 30.)

The Alcator

The orginator of the initial concept of the MIT Alcator high-field tokamak was the Soviet Academician Lev Artsimovich, the leader of Soviet tokamak research from its beginnings in the 1950s until his untimely death five years ago. Thus Artsimovich was also the real father of the currently very successful U.S. fusion program.

In 1969 Artsimovich made an organizing trip to the U.S. that led to the unprecedented U.S.-Soviet cooperative agreement on magnetic fusion research and a turnaround in U.S. funding of fusion research.*** During the visit Artsimovich discussed in detail with Professor Bruno Coppi of MIT, a good friend, the design for a tokamak with extremely intense magnetic fields, two to three times greater than those on more conventional tokamaks.

Artsimovich gave two main reasons for constructing a high-field tokamak: First, the very high current densities induced in the plasma might give rise to an anomalously high resistivity. This anomalous resistance could then permit a tokamak that is heated only Ohmically, that is, heated just by the current flow, to reach fusion ignition temperatures. Second, the very high current densities

would permit the experiment to explore a wide range of plasma properties.

Under Professor Coppi's leadership funding for the Alcator was obtained from the CTR division of the old Atomic Energy Commission, now known as the Magnetic Fusion Energy division in the new Department of Energy. Initially, the miniscule funding was made available primarily as a token to the university community. In fact, the experiment was essentially written off as a speculative, academic exercise while the main fusion program proceeded at the large national laboratories.

During World War II, MIT was a major center of plasma research and was involved in the development of the Klystron, the oscillator critical to radar, but after the war the institute was left out of the U.S. fusion program. However, physicist Francis Bitter developed an important laboratory at MIT for the construction of large and intense magnetic fields. Bitter's magnet design is used on the Alcator, and the site of the Alcator today is the laboratory named after him.

There were serious technical problems in the first attempt to get the Alcator to work, and its scheduled startup was delayed more than a year. During this early trouble, many leading MIT professors who had initially signed up with the Alcator team decided to abandon the sinking ship before it completely went under. As a result, students were invited in to work on the experiment, and foreign researchers, supported by grants, from South Africa, the Soviet Union, and Holland, were also brought in.

Reaching Breakeven

By 1974, the multilingual experimental team headed by Ronald Parker finally got the Alcator working. Within a year, the experiment achieved larger Lawson products of density times confinement time than any previous tokamak experiment, and at only half the rated magnetic field strength. Shortly thereafter, the Soviets visited the Alcator to corroborate the results.

The Alcator, shown in the picture here, is about one-hundredth the size of the Princeton Large Torus and Soviet T-10 tokamaks, but it has achieved Lawson products of about 10 times greater magnitude. In fact, in terms of Lawson product, the relatively inexpensive Alcator has already outdone the projected results for the $230 million Tokamak Fusion Test Reactor at Princeton that is not due to come on line until 1981. The unprecedented success of the Alcator is the equivalent of someone building a go-cart in his garage and then winning the Indianapolis 500 — by 10 laps.

Because of its high field capabilities, the Alcator has been able to explore a wide variety of plasma parameters. In addition to its tremendous pragmatic success, the Alcator has also been the ideal testbed for theoretical work.

Some of the major scientific problems in achieving a viable tokamak reactor and what the Alcator has done to solve them are listed here:

Scaling of confinement time and density, the Lawson Product. The Alcator broke through all previously projected density limits and achieved the minimum Lawson breakeven product of 20 trillion nuclei per cc.

Correlation with theory. The Alcator demonstrated neoclassical behavior.

Impurities. The Alcator produced almost perfectly pure plasma. (It should be noted that the Alcator results of Z_{eff} of 1 at first were not believed. The Soviets, the British, ERDA, and others checked them over and over again, and all came to the same result: Z_{eff} equals 1.)

Disruptive instability. It never occurs in the Alcator.

Reactor regime operation. The Alcator has demonstrated a wide variety of possibilities for reactor regimes. Most significantly, while all previous projections to reactor regimes necessitated going into the trapped ion region, the Alcator regime could be empirically scaled to reactor conditions while remaining in the collisional regime, a known type of regime.

Plasma heating. Anomalous resistivity did not occur, but there are a wide variety of possible means to heat the Alcator to fusion ignition temperatures. (This is discussed further below.)

In summary, in one fell swoop, the Alcator has solved most of the key scientific problems of tokamak reactors, although it has by no means closed the book. In fact, the Alcator's most significant result is probably that it has demonstrated that all previous tokamaks did not have true plasmas and that they were dominated almost completely by impurities.

Because of its pure plasma, the Alcator may very well be

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* Up through the late 1950s, there was no scientific means for determining whether one had actually achieved a thermonuclear plasma. Laser diagnostics, along with many other significant advances in plasma theoretical and experimental technique in the 1960s, provided the essential basis for today's successful fusion experiments.

** The Kadomtsev theory is discussed by Dr. Winston Bostick in "The Pinch Effect Revisited," *International Journal of Fusion Energy*, Vol. 1, No. 1, 1976.

*** Although the U.S. tokamak program has made substantial original contributions to this research and has grown at a very rapid rate, the Soviet effort is still many times larger and broader in terms of basic research. For each of the various studies here on electromagnetic radio and microwave heating approaches, high beta geometries, neutral beam heating, low q operation, plasma compression, and impurity, there are at least one if not more separate tokamak experiments in the Soviet Union. This is in addition to the mainline devices such as the T-10, which is about the same size as the Princeton tokamak but went into operation six months before PLT went on line.

The Soviets have also emphasized the front end of essential technologies. For example, they now have in operation the first tokamak with superconducting magnets. Because superconductors experience no electrical resistance when operating at temperatures near absolute zero, they can cheaply generate large, continuous magnetic fields. Also, the Soviet neutral beam development is focusing on developing the type of neutral beams that will be needed for working reactors; that is, very efficient and reliable high-power beams based on the acceleration of negative ions.

In general, the Soviets emphasize the theoretical side of tokamak research and have an even larger edge when compared to the U.S. in this area. U.S. plasma theoreticians who are not fully appreciated in the U.S. find that their work is followed closely by Soviet colleagues and that their contributions are sought after for Soviet seminars.

the first tokamak actually to be dominated by plasma processes proper. In other tokamak plasmas, the flow of energy is dominated by mere boundary effects, such as the atomic processes of charge exchange, because of the presence of impurities in the plasma.

Equally important, a number of distinct experimental results indicate that the Alcator is quantitatively and qualitatively behaving according to classical plasma theory.

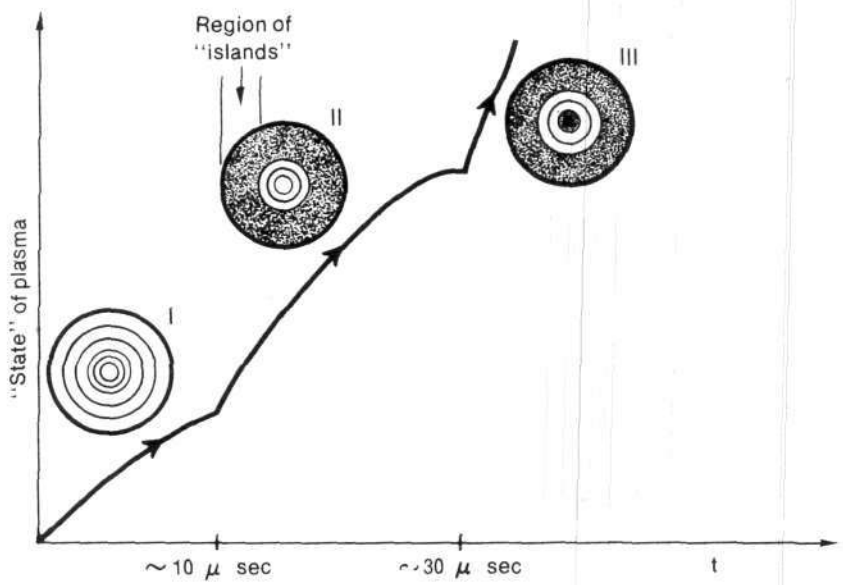
Classical Results

First, the Alcator is proceeding in a direction opposite to that outlined in the discussion of Figure 16 of what is needed for reactor operation. The ultrahigh densities achieved in the Alcator led to a higher Coulomb collision frequency, even with increasing temperature (the Coulomb collision frequency is proportional to the density divided by the temperature.) Thus the Alcator has proceeded from the plateau regime to the Pfirsh-Schluter collisional regime; that is, from left to right on the Figure 16 graph. Significantly, recent experimental data indicate — as neoclassical theory predicts — that the rate of diffusion is increasing with increasing density as the Pfirsh-Schluter regime is encountered. (The upward sloping line to the left, as opposed to the flat, plateau regime.)

Second, other recent experiments indicate that when impurities, in particular oxygen, are purposefully introduced into the Alcator plasma, they take on an asymmetrical distribution, something also predicted by neoclassical theory.

Third, and most startling, are indications that the Alcator is exhibiting another important prediction of neoclassical theory, the Ware pinch.

Figure 17



THE COTSAFTIS THEORY

A schematization of Cotsaftis's theory of the discharge in a low-field tokamak. The discharge evolves along a line indicated above with three distinct stages. In the first stage, the atomic physics of ionization of a two-component gas dominates the evolution. The cross section of the plasma shows the heavier component of the gas shielding the inner, hydrogen plasma. When the gas is completely ionized, a transition occurs to a second stage in which a complex, twisted magnetic field is formed. In the cross section of the discharge, this magnetic field, along with a three-layer plasma is evident. With the further heating and larger current, this second stage becomes unstable and there is a transition to a third stage characterized by an even more differentiated plasma configuration and magnetic field topology. At each of the connection points in the plasma trajectory, the physical laws that dominate the further evolution change qualitatively and then evolve on the basis of the initial and boundary conditions determined by the previous set of laws.

The French

The French Tokamak Reactor group, TFR, is a significant exception to the engineering emphasis in most tokamak research. The TFR is a main line tokamak with the following average parameters:

a = 20cm
n = 6×10^{13} /cm^3
T (ions) = 2×10^7
n = 2×10^{12} sec/cm^3
I = 400 KA
B = 60 Kg

Studies conducted at the TFR on the various instabilities in a low-field machine demonstrated at least two years ago a fact only recently accepted by the plasma physics community at large: The behavior of low-field tokamaks is dominated by atomic physics, not *plasma* physics.

This concept was developed in a series of papers in 1975 and 1976 by M. Cotsaftis, a member of the TFR theoretical group. The Coftasftis papers begin with the following question, a question that distinguishes them from most other work on tokamaks: How can the entire time history of the tokamak discharge — from initial ionization to final loss of plasma — be accounted for, as one connected process?

The Alcator reached high plasma densities by simply pumping in more hydrogen gas. The gas was supposedly ionized by charge exchange and became part of the plasma, thereby increasing the plasma density. It has now been determined that the rate of charge-exchange is not sufficient to account for the observed plasma density increase. Instead, the Alcator plasma apparently is directly ingesting plasma, that is, pinching itself to higher densities.

Neoclassical theory predicts this reversal of outward plasma diffusion in what is called the Ware pinch effect. If this preliminary experimental indication of the existence of the Ware effect proves true, it could have some unusual results. The theory predicts that under some conditions this inward pinching is much greater than the overall outward diffusion of the plasma, thus leading to no net particle loss. In other words, the Ware effect could mean *infinite confinement times.*

Figure 16 gives the overall operating parameters of various Alcator regimes.

Although many of the phenomena noted above and their applications to actual fusion power reactor systems have not been demonstrated absolutely on the Alcator, it is clear that the Alcator is proving that tokamak plasmas are sufficiently understood to project the system to reactor conditions, and that there are numerous and totally different paths to that happy result.

Reactor Designs

There are two general routes to a commercial power reactor based on the Alcator-approach. The first is essentially a conservative projection using existing technology and large Alcator-type devices in a series of

Approach to Tokamak Plasma

Cotsaftis's answer is surprising. The plasma goes through several, well-defined "phase changes," he says. At each of these points of phase change, the physics governing the discharge changes in a basic way, and different physical effects dominate the evolution of the plasma in each phase. In addition, this implies that only the first phase has externally imposed boundary conditions. Each subsequent stage has its initial conditions created by the previous plasma evolution.

Cotsaftis described the implications of focusing on this self-developing evolution and the crisis points that mark the transition from one stage to another: "There are two kinds of time-evolution: The first starts from fixed boundary conditions and evolves according to fixed laws. Classical mechanics is usually done this way. The second has boundary conditions of its own making, handed down to it by its previous evolution. It is mathematically the so-called free-boundary problem. Of course, in real life, only the second type of evolution actually occurs."

Figure 17 schematically shows the time-evolution of the tokamak discharge theorized by Cotsaftis. The plasma follows the "trajectory" in a direction denoted by the arrows. The first stage is that of an ionizing gas dominated by the atomic physics of ionization. The critical feature here is the inhomogenous nature of the discharge, in which the heavier impurities (usually the oxygen atoms), "shield" the hydrogen plasma and allow it to be heated and then completely ionized. The so-called impurities play a crucial role in this first stage, and any treatment of the tokamak that attempts to describe this stage of the tokamak discharge with a one-component plasma cannot succeed.

The effect of atomic physics does not end with the creation of the plasma. Once the inner hydrogen plasma is created, its geometric configuration is the key to determining its further evolution. So, although plasma physics (rather than atomic physics) determines the evolution of the discharge in stage two, it does so with the all-important boundary conditions handed down to it by the atomic physics of the first stage. During the second stage, the symmetric discharge created during the first stage develops a complex magnetic field topology (shown in the cross section of the plasma in Figure 17).

This second stage becomes unstable as the temperature and current through the discharge increase further; and at a well-defined point on the trajectory, a third phase occurs. In the third phase, the plasma develops a more complex internal differentiation and a more complex magnetic field configuration. The formation of magnetic "islands" and the now-famous disruptive instability are features of this third stage.

Cotsaftis has been able to fit the time evolution of most low-field tokamaks within this scheme of discontinuous changes in internal structure and physical regime. Although the final stages of the discharge have yet to be incorporated in his theory, the conception of connected, but discontinuous, differing self-structured physical regimes in a plasma is an important development in attempts to explain nonlinear and self-ordered phenomena in plasmas.

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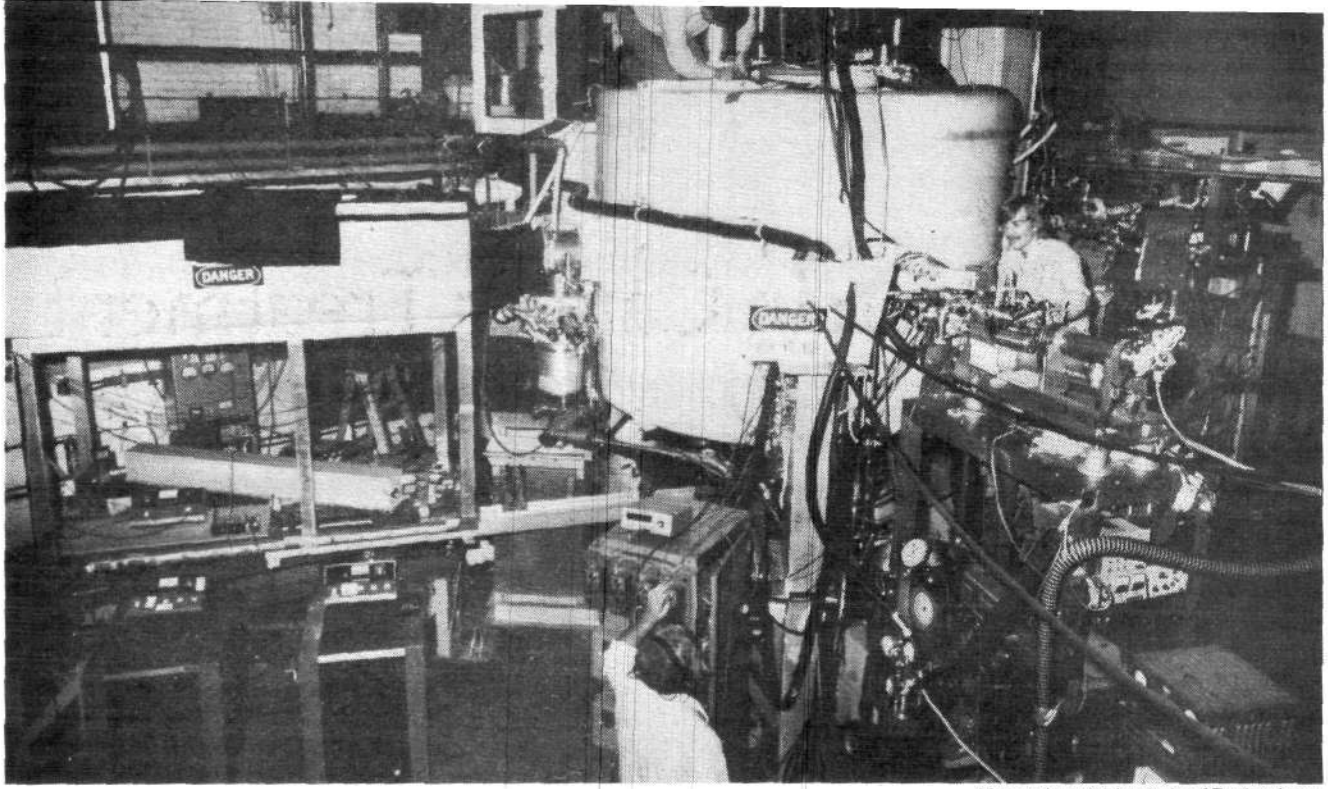
————. "Nonlinear Dynamics at Joule Heated Toroidal Discharges," presented at the Nobel Symposium on Nonlinear Effects in Plasma Physics, Aspenasgarden, Sweden, June 11-17, 1976.



Massachusetts Institute of Technology

This white cylindrical container is actually a refrigerator that houses the Alcator. Liquid nitrogen is poured into this container to cool the Alcator's high magnetic field coils.

stages. In these, the qualitative plasma operation would not be substantially different from the present device, except that they would use the already demonstrated neutral beam heating system to reach fusion temperatures.

The second approach is to continue to push technology to the frontier, using even higher field magnets and attempting to harness any one of a number of the special plasma effects indicated in the present Alcator. The goal here is to go for a reactor-grade D-T fusion plasma right away.

An interesting variant on both approaches would be to use the fusion plasma for breeding fission reactor fuel, or burning up fission reactor waste products. An extremely small neutral-beam-driven Alcator breeder system has already been proposed, and since the Alcator has already achieved the needed plasma confinement parameters, a larger sized device is not needed. However, getting the neutral beams absorbed in such a small device is a major problem. The proposed solution is to ripple the toroidal magnetic field on one portion of the system, thereby enabling the system to trap the high-energy beam in a small tokamak.

After the fantastic results of the Alcator were announced, the U.S. Magnetic Fusion Research Division decided to follow it up. Alcator B, a 1975 design for the next experiment was scrapped and a bigger design, Alcator C, was initiated.

Alcator C will begin full operation early next year. Meanwhile, Bruno Coppi has another Alcator experiment approximately the same size as Alcator C coming on line in Italy right now. More recently, a special Division of Magnetic Fusion Research committee on aggressive experiments contemplated putting neutral beam heating on a follow-up addition to the Alcator C. If successful, this would put Alcator C well beyond what is needed for a reactor regime.

Recent conservative power plant designs based on the Alcator would fit in the basement of the huge tokamak reactor design based on experimental results prior to the Alcator. In fact, the new designs would be considerably smaller than existing nuclear power plants.

Working in Italy, Bruno Coppi has come up with yet another innovative experimental program and new reactor possibilities—the Ignitron. Coppi's idea is to leapfrog 10 years ahead in the fusion reactor development schedule by funding an experiment that could actually produce real reactor fusion plasma regimes. He calls the design *Ignitron* for ignition of D-T, a regime in which the fusion energy output is sufficiently great to sustain the temperature of the plasma.

The Ignitron would be quite small, not much larger than the existing Alcator. The major radius of its torus is about a half a yard — about 20 times less than more conventional ignition reactor designs.

Coppi's basic idea is to go for broke on high magnetic fields, pushing the technology as far as conceivable. With innovative concepts, fusion temperatures could be obtained using straightforward plasma processes and instabilities; and once there researchers could see how an actual fusion plasma behaves.

If the Coppi experiment is modestly successful, one speculation is that high power density reactors, possibly just for breeding fission fuel, could be built rapidly. The reactor core that deteriorates in the fusion environment, because it is so small and cheap, could be replaced every year or so—the throwaway reactor.

FONAR: A Revolution in Cancer Treatment

by Carol Cleary

A LARGE MAGNETIC SCANNING DEVICE called FONAR (Field Focusing Nuclear Magnetic Resonance) that could totally revolutionize cancer treatment and eliminate thousands of cancer deaths each year is now sitting idle in the State University of New York's Downstate Medical Center for lack of the $250 a day needed to operate it. The prototype FONAR device in the laboratory of Doctors Raymond Damadian, Lawrence Minkoff, and Michael Goldsmith provides more diagnostic information than X-ray techniques at only a fraction of the radiation risks. As these researchers have shown, FONAR could be developed further using radiofrequency irradiation, neutron beam, or laser focusing techniques as a treatment to eliminate cancer as a major human killer.

The FONAR funds were cut off by the National Institutes of Health, despite the importance of the ongoing research, as part of the government's campaign to discontinue basic research and devote 75 percent of all cancer research funding to a scavenger hunt for potentially dangerous substances in the environment and in workplaces.

"We have a tremendously potent technology to fight cancer," Dr. Damadian said. "About $900 million is now spent each year on cancer research. I would need only $2.5 million just once to finish the disease. That money would produce an efficient, high-quality chemical imager that could be used for the early diagnosis of tumors, the selection of drugs based on the FONAR information, and technique for FONAR-coupled irradiations to destroy the tumor. We would essentially have the disease under control."

The Current State of Clinical Research

Cancer has always posed a difficult problem for medical research; first, because it involves a breakdown in the normal process of cell division and differentiation on the tissue level, and second, because it often involves a failure of the immune system to contain the malignant tissue. Neither aspect of the disease is well understood. In fact, current medical research tends to focus only on one or two areas of the cancer problem at a time, ignoring crucial features occurring simultaneously on other levels that causally affect the experiment. Consequently, the picture of cancer generated by medical research bears an unfortunate resemblance to the description of an elephant generated by a group of blind men, each focused on a different part of the elephant.

On the tissue level cancers are invasive tumors, generally detected by waiting until the tumor is large enough so that it either becomes visible or is inferred from unexplained symptoms affecting the patient. Generally the cancer can then be diagnosed by X-ray and confirmed by surgical biopsy. This medieval approach of detecting the disease by waiting until the disease is well advanced is reflected in the rate of cure. If detected and treated early, most cancer victims stand a better chance of survival. Cancer of the cervix, for example, is considered nearly 100 percent curable if detected and treated early.

In terms of human beings, some invading cancers produce an immune response in the organism. This immune response may be affected by the patient's psychological frame of mind and his state of nutrition, but this interaction is not understood.

On a structural cellular level, cancerous cells vary widely in their degree of differentiation depending on the type of cancer and other factors, and this often makes it difficult for the pathologist's microscopic examination of the tissue

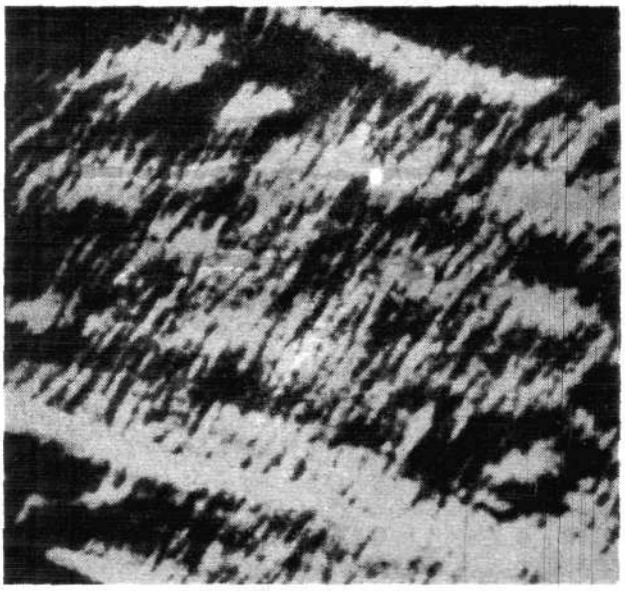
The Politics of FONAR

The National Cancer Institute for Diagnostic Research of the National Institutes of Health considered the renewal of the two-year grant for the FONAR research at the Downstate Medical Center in May 1977. A four-man review team from the National Institutes of Health assessed the project. The first member concluded: "I would recommend that this contract be either renewed or extended...." The second concluded: "It is a valuable thing to have different imaging techniques tested....Some effort in this regard by Damadian is completely appropriate under Diagnosis Committee sponsorship." The third, unfamiliar with the technology, said that the technique looked very promising but he would defer judgment to the first two team members, who were more technologically competent.

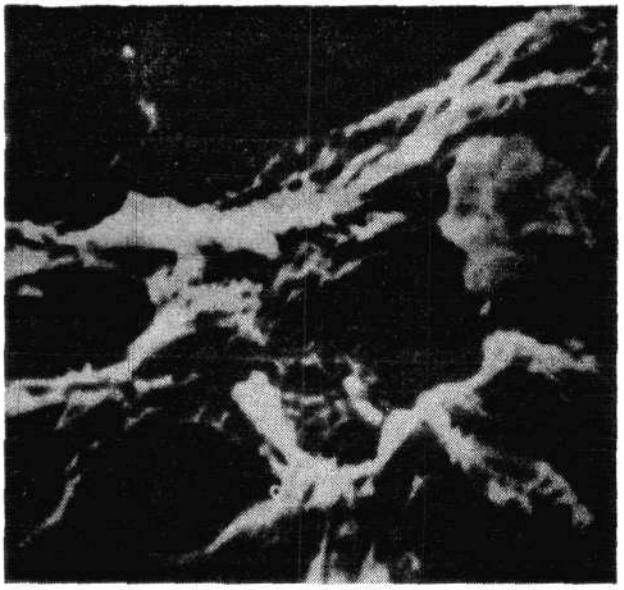
The conclusion? The team chairman decided that the grant should not be renewed.

Figure 1
NORMAL AND MALIGNANT CELLS

a



b



Shown here are electron micrographs of the actomyosin ordering on the subsurface of normal [a] and malignant tissue [b] cell membranes. The lack of normal ordering of actomyosin in the malignant human glioma is a reflection of the subcellular breakdown in ordering often associated with cancerous tumors.

Source: Minkoff and Damadian 1973

biopsy to determine benign or malignant features. Normally in the process of development or wound healing, when dividing cells come in contact with other appropriate cells, they cease to wander aimlessly and begin to differentiate collectively as a tissue. There is also a corresponding decrease in the rate of cell division. Cancer cells, however, often lack this capacity for organized differentiation; frequently they continue to crawl and spread, colonizing new tissues with tumors, and remaining less differentiated and with an uncontrolled rate of cell division. Internally, the nuclei of cancerous cells often divide such that the cells are multinucleated with additional chromosomal aberrations that are not understood.

On the subcellular, biochemical level, cancerous cells develop into an increasingly disordered, water-bloated state. Cancerous cells may contain up to 90 percent water, compared with normal cells that contain only 66 percent water. In addition, cancerous cells often have a disordered internal structure, as can be seen in Figure 1 comparing cancerous membrane structure with the membrane of healthy cells. As the cancer cell's ordering and hydrations shift to a more entropic, bloated phase, so does its biochemical energetics. The mitochondrial oxidative process of cell respiration often fails to function, and the cancer cell's metabolism shifts to the highly inefficient system of fermentation to acquire energy.

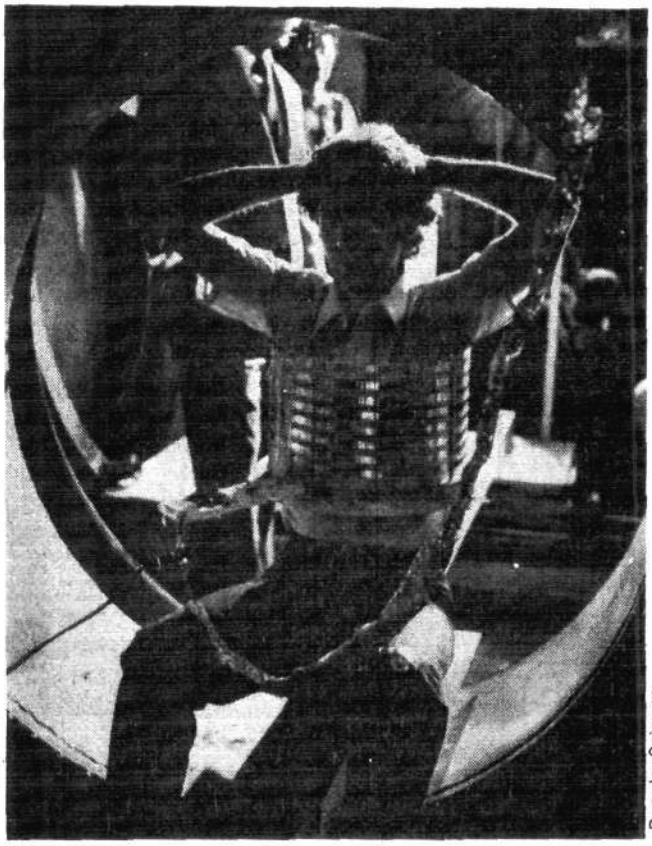
The Promise of FONAR

As an object of study, cancer remains far more complicated an undertaking if approached piecemeal than if studied by a method that causally unifies these different aspects of the problem. The FONAR technique, because it looks at the organismal, tissue, and cellular level of cancer from the standpoint of ordering and energy flow, promises to help unify cancer research and at the same time generate important contributions to understanding fundamental problems in biological research.

In contrast to the current anatomical diagnosis of cancer, the FONAR scanner under development at the Downstate labs can scan a patient quickly and generate a tremendous wealth of information about his internal biochemistry without disrupting it. For hospital use and for periodic checkups the prototype FONAR scanner thus holds the promise of a total revolution in clinical medicine. It could enable doctors to detect cancer and other clinical abnormalities long before they become anatomically obvious, through a routine, harmless scanning. Thus, any necessary treatment could begin while the condition is still in an early, more easily treatable stage.

In the experimentation thus far, the prototype FONAR scanner can distinguish most malignant tumors, benign tumors, infected tissue, and normal healthy tissue. Even the most skeptical in the medical profession agree that the FONAR scanner can distinguish normal tissue from tumors with a very high degree of certainty, and preliminary experimentation indicates that FONAR has the capacity to do much more.

In three out of four cases, FONAR has distinguished between benign and malignant tumors, including some



Popular Science

benign tumors that pathologists often confuse with malignant tumors. Some of the additional diagnostic capabilities are as follows:

In two out of three cases edema (a condition in which the tissue retains water) can be distinguished from tumors. Among solid tumors, which are the most unresponsive to drug therapy, FONAR can distinguish malignant breast or colon tumors from normal tissue with almost 100 percent certainty, and it can distinguish lung tumors from normal tissues with almost 90 percent certainty. Local infections have been picked up by FONAR scanning long before they become clinically obvious, and FONAR has also monitored the rate of energy production (measured as adenosine triphosphate) in living tissue in order to study the degeneration of a transplanted kidney.

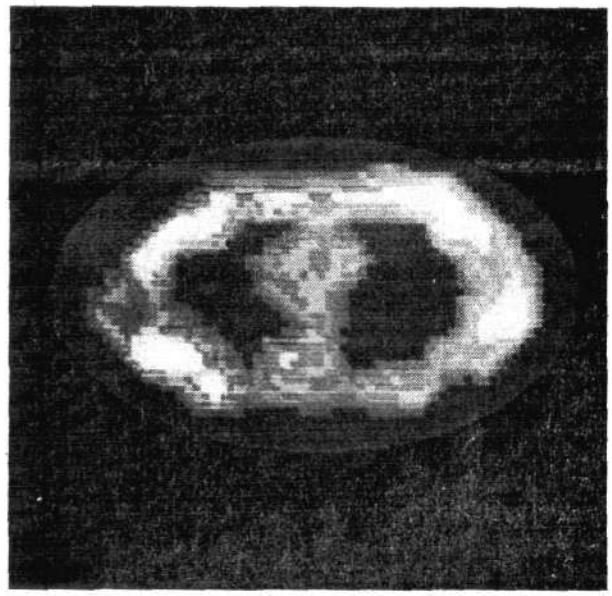
Since FONAR is still in its infancy, we can assume that the information concerning the internal living biochemistry of tissues generated by FONAR scanning could be applied to additional clinical testing — if the technique is developed.

How FONAR Works

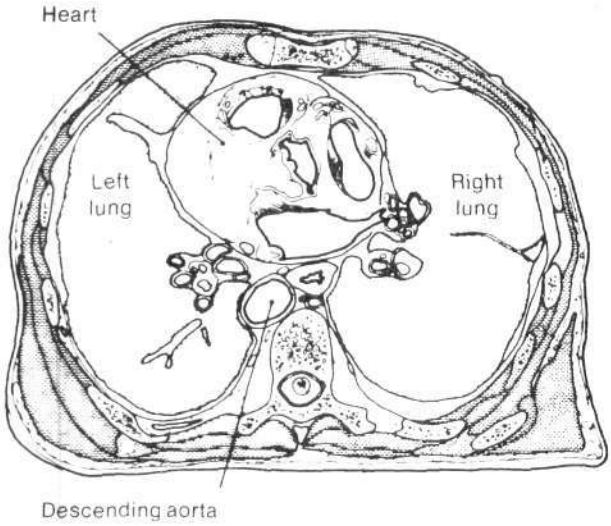
The FONAR scanner uses the bloated disordered properties of cancer to detect the disease.

The patient is placed inside the ring of a superconducting magnet, which contains a radiowave frequency transmitter and pickup coil (see photo). The magnet produces a magnetic field, and after the radio frequency pulse is applied to the patient, the reemitted signal gives an indication of the local ordering of cellular

Figure 2
FONAR IMAGE OF HUMAN CHEST



HUMAN CHEST CROSS SECTION



The FONAR imager and its superconducting magnet with a human subject in place. [left]. Figure 2 shows the first FONAR image of a live human chest and a corresponding diagram of a human chest cross section. The imaging shows the heart in the midline between the left and right lungs and the descending aorta.

Source: Damadian 1977

SOME DIFFERENCES IN T_1* RELAXATIONS IN NORMAL AND MALIGNANT HUMAN TISSUES

High Probability Of Statistical Significance			Tumor Samples Too Small for Evaluation Of Statistical Significance		
TISSUE	T_1 TUMOR	T_1 NORMAL	TISSUE	T_1 TUMOR	T_1 NORMAL
Breast	1.080 (13)**	0.367 (5)	Esophagus	1.04 (1)	0.804 (5)
Skin	1.047 (4)	0.818 (9)	Liver	0.832 (2)	0.570 (14)
Muscle (malignant)	1.413 (7)	1.023 (17)	Spleen	1.113 (2)	0.701 (17)
(benign)	1.307 (2)		Thyroid	1.072 (1)	0.882 (7)
Stomach	1.238 (3)	0.765 (8)	Nerve	1.204 (1)	0.557 (2)
Intestinal tract	1.122 (15)		Adipose	2.047 (1)	0.279 (5)
(small bowel)		0.641 (8)	Ovary	1.282 (2)	0.989 (5)
(colon)		0.641 (12)	Uterus (malignant)	1.393 (2)	0.924 (4)
Lung	1.110 (12)	0.788 (5)	(benign)	0.973 (1)	
Lymphatic	1.004 (14)	0.720 (8)	Cervix	1.101 (1)	0.827 (4)
Bone	1.027 (6)	0.554 (10)	Testes	1.223 (1)	1.200 (4)
Bladder	1.241 (3)	0.891 (4)	Prostate	1.110 (1)	0.803 (2)

* T_1 = time constant.
** The number of cases is indicated in parentheses.

Source: Damadian 1977

material in a limited area of the patient's tissues. The pickup coil receives this signal, and translates it visually into a color-coded grid on a television screen.

Since cancer cells are less ordered than healthy tissue they will show up differently—specifically, the reemission time is longer because of this lack of ordering. A glass of water would show up differently as well; it is even less ordered than cancerous tissue and hence the reemission time would be even longer. And the magnetic field and radiofrequency involved in the FONAR scanner create far less risk of damage to the patient than do X-rays. (No obvious risks or side effects have been detected in the limited experimentation on humans.)

Once a tumorous area is located, FONAR can focus on that area and provide an even more detailed and accurate picture of the tumor. Then the tumor can be treated with focused X-ray radiation therapy or laser beam or neutron beam surgery, treatments that would eliminate much of the tissue damage and trauma associated with today's surgical procedures. In combination with focused X-ray radiation surgery, FONAR has already developed the capacity to locate tumors as small as 1 centimeter in diameter. FONAR also has a technical capacity to focus and detect tumors as small as 1 millimeter in diameter, a capacity that has remained untested, however, because of the funding cutoff.

FONAR itself may be developed in the future to destroy the cancer by radiofrequency radiation. Such irradiation is absorbed by the malignant tumor but not by normal tissue. It is already known that malignant tumors absorb in radiofrequency spectral areas that are not absorbed by normal tissues, but it is not yet clear whether the energy thus absorbed by the tumor would be sufficient to totally destroy it. Even if such treatment proves to destroy only a sizable percentage of the malignant tissue, it would still have an advantage over all current radiation therapy, chemotherapy, and surgical therapy, in that it destroys only malignant tissue and, therefore, could be used repeatedly with less damage to the health of the patient than the other methods.

Without funding, however, this hypothesis remains an untested though intriguing possibility.

The Science Behind FONAR

FONAR utilizes the fact that the atomic nuclei in biological molecules have weak local magnetic fields—they lack collective magnetic phenomena—but they are highly responsive to the collective and local electrochemical changes in ordering and bonding that dominate physiological processes. In the weak local fields, the spins of the nuclei are not coordinated in their alignment. The magnetic fields of these atomic nuclei can be readily altered or flipped into a higher-energy magnetic spin by providing the appropriate wavelength of electromagnetic energy in a stronger, static magnetic field. Once the source of energy and static magnetic field are removed, the atomic nuclei will flip back to their original weak, local magnetic moment. In the process, the nuclei remit the energy absorbed in the magnetic spin transaction.

Based on this exchange of energy, the FONAR technique correlates the degree of cellular ordering of a substance as a whole with the rate at which individual atomic nuclei will flip back, once energized, to their original magnetic moment. The flip back process is called the *relaxation,*

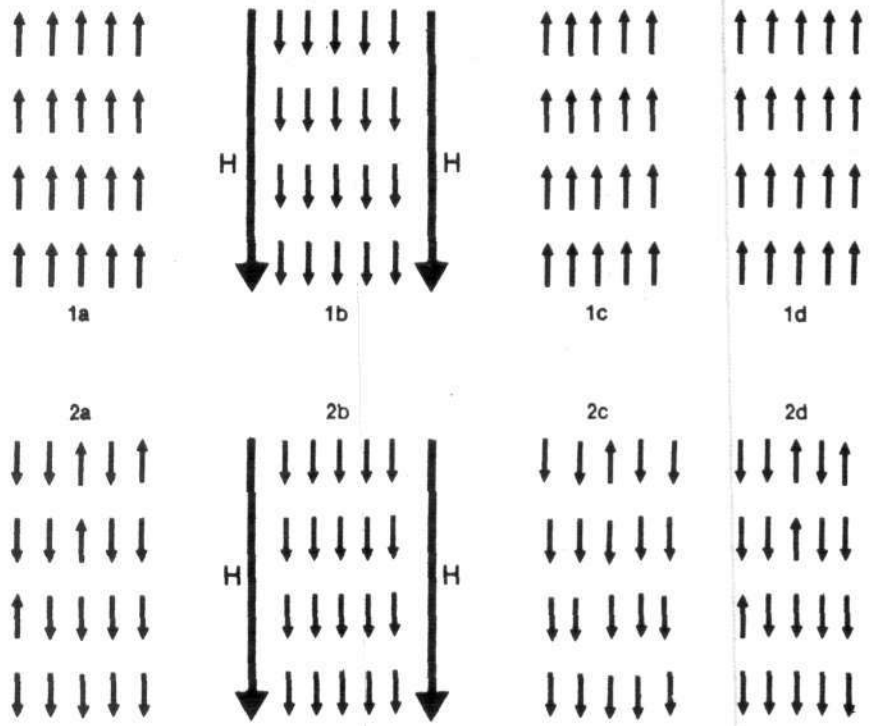


Figure 3
SPIN BEHAVIOR IN ORDERED AND AMORPHOUS SUBSTANCES

In an ordered substance [1a] with collective magnetic interactions, individual atomic nuclear spins are ordered as a group. When the magnet is turned on and the appropriate radiofrequency provided [1b], the spins will collectively flip. Shortly after the magnet and radio frequency are turned off, they will collectively flip back to their original state [1c].

In an amorphous substance [2a] the spins collectively flip in the presence of a magnetic field and radiofrequency [2b]; but after the magnet and radiowave radiation are removed, they flip back one by one, very slowly regaining their original amorphous nonaligned magnetic spins.

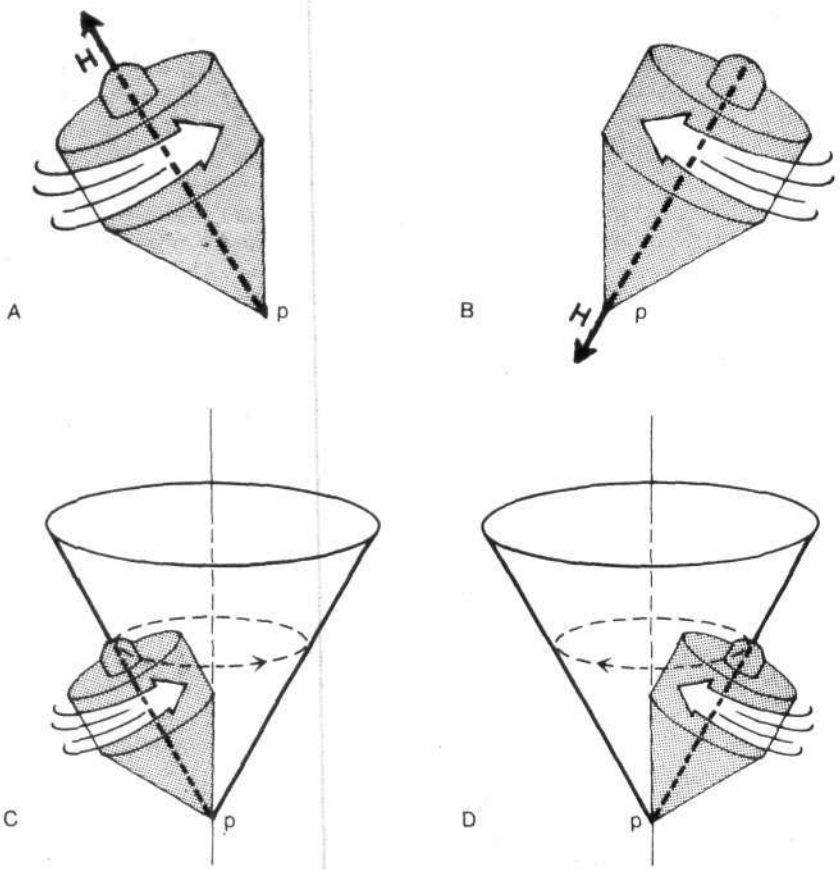
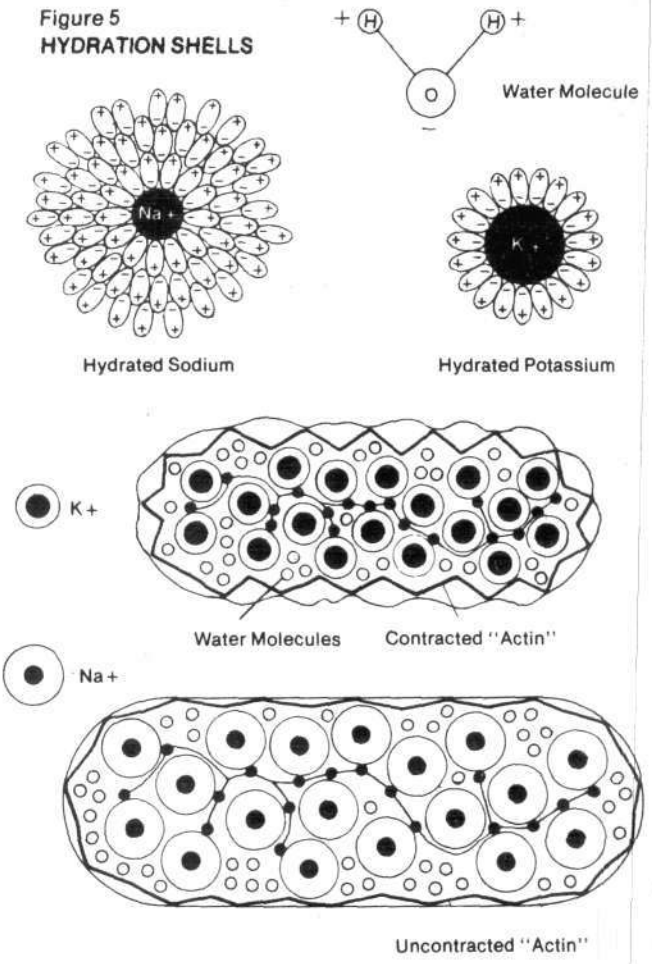


Figure 4
SPIN AND ROTATION

A top will spin in either one direction or another, represented here as a vector pointing up or down. If the rotating top is charged, it generates a magnetic spin, rotating in either one direction, H↓ or the other H↑, as in A and B. The rotating object also moves around a fixed point, p, sweeping out a cone-shaped path of precession, with a distinct angular frequency dependent on the width of the cone [C and D].

Figure 5
HYDRATION SHELLS



Water, H_2O, is a polar molecule. The oxygen nuclei in water molecules have eight positively charged protons, while each hydrogen nuclei has only one positively charged proton. As a result, the electrons shared between the hydrogen and oxygen in the water molecule are attracted more closely to the oxygen, giving the oxygen end of the molecule a net negative pole, and thus a positive pole to the hydrogen end. If a large positive ion such as potassium is placed in water, the negative poles of the water molecules will be attracted to the potassium ion, forming a shell of hydration around this large ion. If a small, positively charged ion such as sodium is placed in water, shells of hydration will also form around it. But, since it does not have the larger surface of a potassium ion, one or two shells of water cannot counterbalance its local positive electrical field. Thus, a larger number of hydration shells must be formed, one upon the other, organizing the water into highly ordered polar layers around the initial sodium ion. This reorders the water into a more viscous, structured fluid. Hence sodium is considered as a structure maker.

The ion exchange resin theory suggests that when the cell is bloated, it favors a more viscous water structuring involving the larger hydrated sodium ions; conversely, if the cell contracts, it will favor instead the smaller, hydrated potassium ions.

and normal healthy tissue which is relatively ordered can be distinguished from less-ordered diseased or cancerous tissue by the differences in their relaxation times. (See Table and Figure 2). By FONAR measurement, crystalline substances are the most ordered, and cancerous, diseased, or embryonically undifferentiated tissues are the least ordered, and their relaxation times can be charted accordingly.

The effect of global ordering on the behavior of these individual atomic nuclei has been known for some time. A highly ordered crystalline lattice, capable of rapidly transmitting energy as collective lattice vibrations, will have a short, abrupt relaxation time. As soon as a few atomic nuclei begin to flip back, the entire collective group of atomic nuclei in that crystal will flip back in a sudden phase change, and there is a rapid collective reemission of energy.

In contrast, an amorphous substance whose structure is disordered, lacks global, collective-mode interactions. The atomic nuclei of such a substance will flip back slowly to their initial magnetic moment, and slowly reemit previously absorbed energy.

Experiments have indicated that the atom consists of a very small, very dense, positively charged nucleus surrounded by a negative electrically charged cloud. The atomic nucleus is, in fact, only .000001 of the diameter of the entire atom, yet its density is 99.8 percent of the total atomic weight.

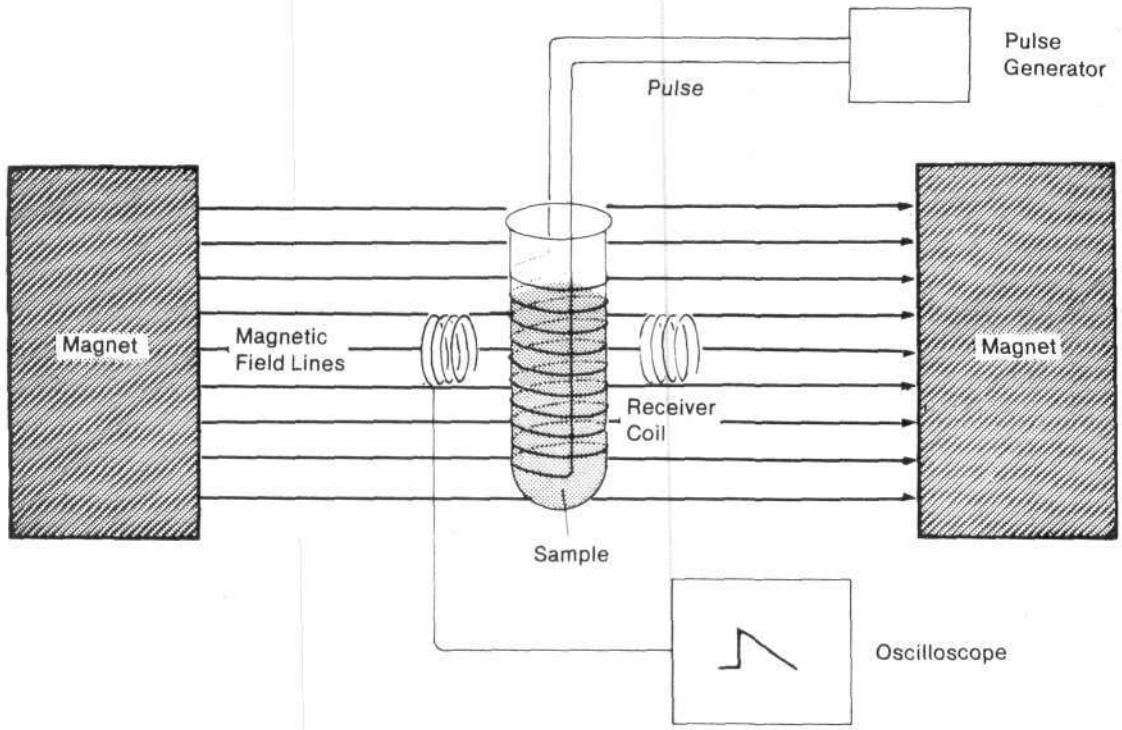
The internal ordering of the atomic nucleus and its capacity to reorder when affected by a quantity of energy are still poorly understood. The process can be approximated as a positively charged ellipsoidal (a flattened spherical shaped) density spinning around an axis through the center of the ellipsoidal geometry. The spinning mass gives the nucleus gyroscopic properties with a distinct angular momentum in a definite direction. The spinning positive electrical charge gives the nucleus a magnetic field that is quantitatively proportional to its angular momentum.

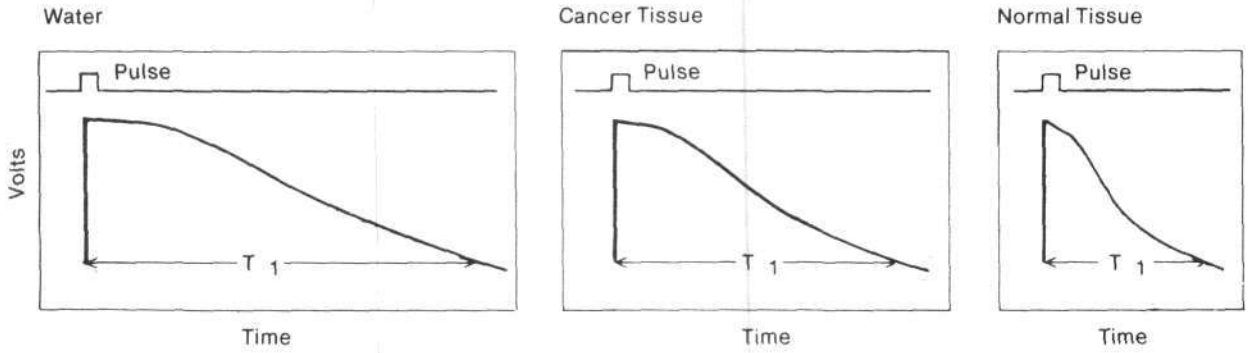
Since the nuclei of atoms of any distinct element have a particular, limited, quantized set of potential magnetic moments or spins, most atoms can be induced to undergo magnetic spin transitions within this set if they are suddenly placed in a much stronger magnetic field and irradiated with electromagnetic radiation of a frequency proportional to the angular (Larmor) frequency of precession. Precession here refers simply to the conical motion of the central axis of a spinning object—a top, a gryroscope, the earth, and so forth—where the axis of the spinning object pivots at an angle around a fixed point, sweeping out a path shaped like a cone (Figure 3).

FONAR's Development

The development of the FONAR technique for measuring the spin transitions of nuclei grew out of the researchers' open inquiry into the biological realms of the very small—atomic behavior in cellular structure. Initially Doctors Damadian and Minkoff were involved in studies of the

Figure 6
HOW NUCLEAR MAGNETIC RESONANCE WORKS





In nuclear magnetic resonance, the technological precursor to FONAR, a test tube sample is placed in a magnetic field and surrounded by a radiofrequency pulse transmitter whose electromagnetic energy resonance is at a frequency that matches the natural frequency of the hydrogen nuclei. Since the radiofrequency resonates at the same frequency, it is absorbed by the hydrogen nuclei, allowing them to flip to a higher energy nuclei spin state. When the radiofrequency transmitter is turned off, the nuclei are unable to sustain the higher energy nuclear spin state and they flip back to the lower energy nuclear spin state. In the process, they reemit energy that is picked up by radiofrequency receiver coils attached to an oscilloscope.

The three oscilloscope time plots here show that after different samples receive the same short radiofrequency pulse of energy [upper pulse plot], they will reemit energy at a different rate depending on the relative ordering of the sample involved. Water, the least ordered sample shown, is slowest to reemit the radiofrequency energy, while biological tissues or crystalline substances are faster. The same principle can be used in the realm of clinical medicine to measure the difference in ordering between cancer tissue and normal tissue. *Source:* Damadian 1977

"sodium membrane pump." This commonly accepted hypothesis states that the reason there is a much greater potassium to sodium ion ration inside the cell than outside is that sodium is actively pumped out of the cell by the cell membrane (see Figure 7).

During these studies, calculations were made of the amount of energy required to run the hypothesized sodium pump and similar pumps that transport potassium, chloride, magnesium, sugars, amino acids, and sulfates in or out of the cell. When the investigators actually grew the bacterium *E. coli* in a minimum energy state and measured all the parameters of energy consumption and synthesis, they found that *only 14 percent* of the needed energy would have been available to run the so-called pumps. Nevertheless, the bacteria continued internally to concentrate the appropriate substances as if such a pump existed.

Most biophysicists who embrance the membrane-pump concept have ignored the data from this experiment. But to ignore it puts beyond the realm of human understanding the process of how ions or small molecules concentrate on one or the other side of the membrane. Instead of accepting the idea of a mysterious *élan vital,* Doctors Damadian and Minkoff came up with an alternative hypothesis to the pump theory.

Damadian and Minkoff proposed that the cell acts somewhat like an *ion exchange resin* (an ion is a charged atomic particle). The less hydrated this resin, or elastic matrix, becomes, the more the cell will select small hydrated ions, because of related changes in the ordering of the water as its concentration in the cell decreases.

These experiments with the ordering of water needed to confirm the ion exchange resin hypothesis led to the use of pulsed Nuclear Magnetic Resonance, the test tube precursor to FONAR. NMR was a necessary development, since the standard biochemical approach to this type of research disrupted and lost the water sample being studied.

Damadian and Minkoff found that the cell components of sodium or lithium have smaller ions, with a greater density and positive charge over the ions' surface. These ions make the water viscous because they force it to structure around the ions in hydration shells (Figure 5). In contrast, potassium has a large ion surface so that the density and positive charge is spread out on this larger surface. This means that there is a relatively smaller number of shells of hydration. Because potassium does not organize so many shells of water around itself, it is called a "structure breaker" in comparison to sodium.

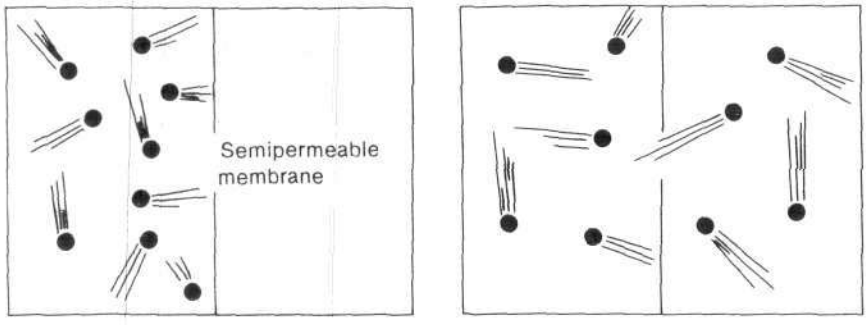
Experiments showed that the less water there is in a cell, the more the cell will concentrate smaller sized ions. Hence the cell concentrates the smaller hydrated potassium ions over the larger hydrated sodium ions.*

One question that must arise is that if sodium ions create more order in the water bathing the cell, why doesn't the cell prefer always to have a system of greater order (regularity)? This is fallacious reasoning and points to the elegance of the Damadian-Minkoff hypothesis. A physiologically active cell could not possibly be a fixed, perfected entity. Each ratio of potassium to sodium concentration in the cell, as well as the concentration and ordering of water associated with that ratio, is lawfully related to a particular metabolic state in which specific enzymes are metabolically active.**

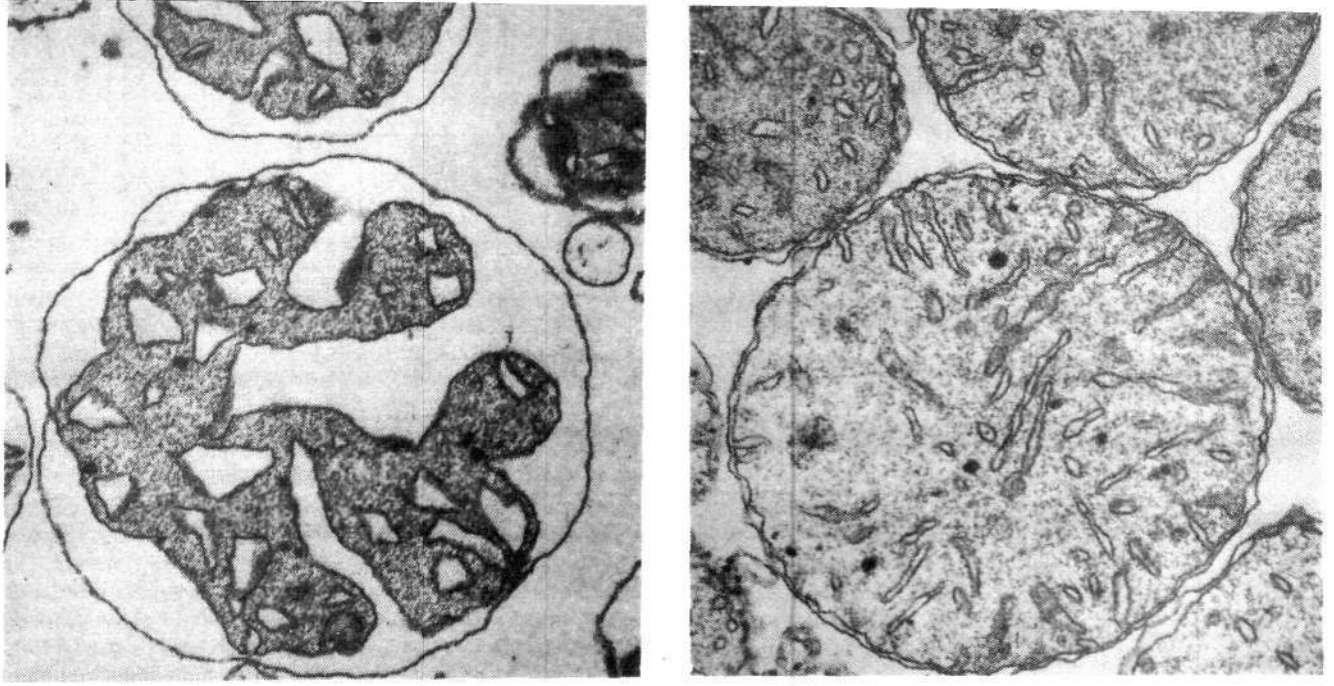
For example, many crucial cellular reactions involve enzymes such as pyruvate kinase, carbonic anhydrase, or the peptidases—all of which are hydrolytic enzymes dependent on the presence and participation of free, unbound water molecules. These free-water molecules are more readily available when the ratio of potassium to sodium is high.

If the concentration of the water lawfully regulates these

Figure 7
ENTROPY AND MAXWELL'S DEMONS



If one had two compartments or cells, separated from each other by a semipermeable membrane — a membrane that will let only certain things travel in and out—the Second Law of Thermodynamics states the following: If one compartment is filled with randomly colliding particles and the other is empty [a], then after a certain amount of time the two compartments will come to an equilibrium in which both compartments will be equally filled [b]. This law allows the entropy of the situation to increase with time, or at least to remain the same. But what about situations, like those in biology, where compartments remain or become obviously ordered. Physicist Clark Maxwell proposed that in such situations an invisible and mysterious force located on the membrane constantly altered the membrane's permeability so that particles could go only from right to left, thus generating a situation in which [b] could evolve with time into [a]. Those who laugh at the use of Maxwell's demons to explain order in the universe should realize that this is an admittance that entropy cannot possibly be a fundamental law of the universe.



Cell mitochondria have regular swelling contraction cycles as they move through the cell. Electron transport and oxidative phosphorylation occur only when the cell is in the less hydrous condensed formation with the matrix water content at 1.2 ml/g protein [shown in the electron micrograph on the left]. In its relaxed, low phosphorylating, low energy throughput state [right], the mitochondria are more bloated, with a matrix water content of 2.1 ml/g protein.

Source: Hackenbrock 1968

metabolic states, then what causes the concentration of water to change? After discovering an actin-like protein in bacteria, Damadian and Minkoff proposed a cytotonus or limited-water state of the cell, at least in *E.coli*, regulated by the periodic contractions of an actin-like protein. This protein, present throughout the cell matrix, would require energy from hydrolysis of adenosine triphosphate, ATP, in order to contract, but it would not require anywhere near the energy projected for the membrane pumps.

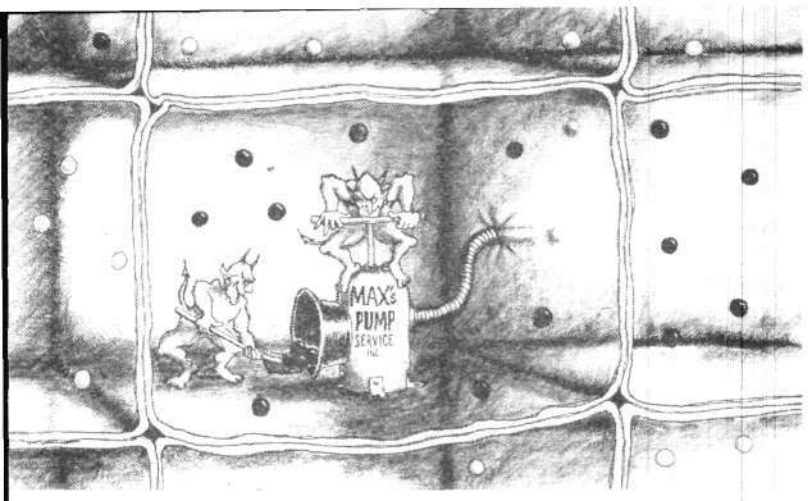
The hypothesis is interesting for two reasons. First, an increasing number of cells in different species have been found to have actin-like or actinomyosin intracellular networks capable of ATP-dependent contraction (Figure 5) that are sometimes associated with microtubular or microfilament intracellular structures. Second, because mitochondria, the intracellular organelles that carry out vital energy reactions for the cell, have a regular swelling-contraction cycle as they move through the cell, a process hypothesized also to be due to an ATP dependent contractile protein.

Dr. Charles Hackenbrock (1968) has shown that active electron transport occurs only when the mitochondria are in a less hydrous condensed formation. Furthermore Doctors Cope and Straub (1975) have shown that the kinetics of some of the events during electron transport of energy from oxidative reactions to phosphorylative reactions, can best be described by mechanisms employing the following: (1) phonons, packets of lattice vibrational energy that depend on the character of the lattice as a whole and are often used in solid-state physics to describe energy transfer through a highly ordered crystalline substance; (2) polarons, phonons traveling in mutual interaction with a charged particle, such as an electron or hole; and (3) infrared photons, packets of electromagnetic energy or light that readily travel through the lipid bilayers of the mitochondrial lamella, the internal membrane shelves that extend into the interior of the mitochondria.

All the work described above is not totally accepted, particularly by those who resent even a limited intrusion of solid-state physics into biology and who also usually maintain a rigid belief in the membrane pumps. But the combined impact of the work of Doctors Damadian, Minkoff, Hackenbrock, Cope, and Straub suggests a hypothesis in which the mitochondria undergoes lawful phase changes utilizing a mixed state. This mixed state involves both the traditional kinetics of enzymes in a watery solution and the solid-state kinetics associated with direct internal electron and energy transfer by distinct cytochrome units bound into the mitochondrial membranes. The fact that electron transport occurs when the mitochondria are in a more contracted, water-limited state is further supported by work in solid-state biophysics that has shown that organic semiconductors—proteins, lipids, nucleic acids—internally conduct electrons efficiently when they are more hydrated, up to a crucial point. At

* The research thus far has limited the use of NMR or FONAR to flipping the magnetic spin of the atomic nuclei of hydrogen and, in a few cases, the atomic nuclei of potassium, sodium, or phosphorous. The magnetic spins of hydrogen nuclei give the broadest picture of the general ordering in a living system, since hydrogen is present both in water and in the hydrocarbon macromolecules of living tissues. However, studies are also underway flipping the magnetic spin of carbon or nitrogen nuclei in order to look at the ordering and phase changes of the macromolecular matrix of living tissues, apart from the multiple phase changes of the ordering of water that occurs during physiological processes.

** The ability of living cells to shift from one ordered mode of interaction in fact constitutes a higher, more differentiated level of ordering than a simple, very regularized ordering.



that point, the internal conduction of electrons decreases in favor of the conduction of electrons or ions among hydration layers, in effect, a sort of short-circuiting of the internal mechanisms of electron conduction.

The Broader Implications

The overwhelming evidence from FONAR research and the cellular research cited above should force a healthy crisis for most biologists. The cell in classical molecular biology is viewed as a simple sac of fluid filled with dissolved ions, globular proteins, and, for the most part, freely floating cell organelles—all of which interact as separate entities by random collision.

This linearized view of cellular kinetics cannot possibly explain the efficiency of cell metabolism. In cell metabolism, there is the potential for thousands of chemical reactions to occur simultaneously. Yet, the cell is differentiated to allow certain ordered metabolic pathways to dominate specific cellular tissue at specific times. How? Classical molecular biology is methodologically inadequate to find the answer.

The problem boils down to whether an honest scientist will ignore the accumulating evidence from new areas of research in order to hang on to entropic laws that explain linearized versions of living metabolism using a crutch equivalent to Maxwell's demons: the membrane pumps.

The "caloric castrophy" experiment (Minkoff, Damadian 1973) was crucial in demonstrating the inadequacy of linearized kinetics—the membrane pump view of cellular activity—and it prompted a scientific search for a more adequate epistemological approach. The alternative approach of treating biological space in the very small as an evolving, highly differentiated continuum created a need for technology that could test the appropriateness of the new approach within the aqueous realm of subcellular space. Using leading areas of nuclear physics and solid state physics, the FONAR technique was developed to fill this need.

In combination with other modern technology that will come out of the testing process, FONAR will open up a new era in the biological sciences. Problems related to differentiation, aging, and evolution can now be approached from a standpoint that considers biological space as an ordered, evolving differentiated continuum. By pushing this epistomological framework to its limits, scientists will uncover the inadequacies in this approach and thus generate an even more sophisticated epistomology and a new era of experimentation and technology. This ordered process of scientific discovery is what creates human progress and technological advance.

To be specific, FONAR will be critical in examining the crucial question of living phenomena in the evolution of the universe. Since FONAR was developed explicitly to look for higher-ordered structure, it can be used to probe intriguing evolutionary phenomena such as the flax experiment (Pollak 1977) or to probe crucial junctions or singularities in the evolution of the planet, points of transition in life forms whose energetics seems to be historically in between the major biologically dominated eras of the primitive biosphere.

Applying the same view to the apparent "messiness in the very small" that characterizes subcellular processes, one can generate a framework that avoids the problems of membrane pumps. When each subcellular organelle is approached as an evolving, differentiated continuum, it does not blend linearly into the single entropic kinetics of the cell as a whole, but is has its own evolutionary history that causally explains its highly differentiated phases of ordering and electrochemical activity. Furthermore, even the boundary surface of a particular subcellular organelle must be expected to have different kinetics and electrochemical behavior, depending on the nature of the environment with which that boundary surface forms a junction. This brings biological membranes out of the abstract realm of a thinly stretched film with mystical qualities and into the realm of an active boundary surface-junction between one ordered electrochemical organization of biological space and another, a realm that can be experimentally tested.

The immediate benefit of FONAR is a revolution in the detection and treatment of cancer that may save thousands of lives. But equally important, FONAR's development as a theoretical tool represents the active frontier of an epistomological approach to biological research that is likely to define the science and technology of future generations.

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The Latest On Cell Structure

Is the cell a natural building block made of components floating in a membraneous sac filled with fluid, as the partisans of the membrane pump put forward? Recent research reported at the Max Planck Institute of Gottingen, West Germany, the German Cancer Research Center in Heidelberg, and the University of Colorado at Boulder indicate that the cell has a highly differentiated continuum of structure previously undetected by microscopy technique.

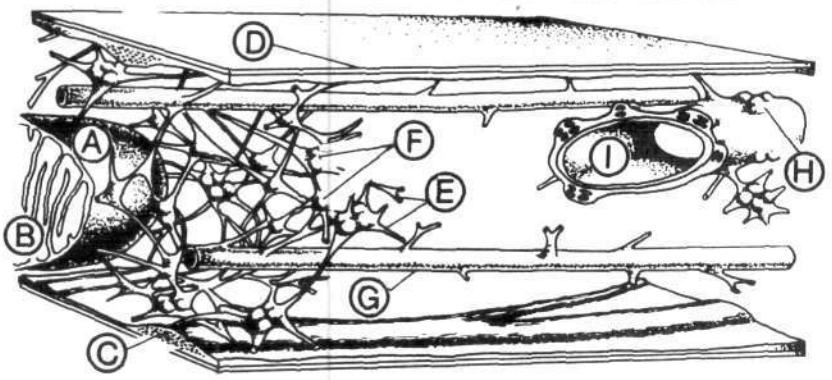
The use of specific antibodies complexed with the fluorescent compound fluorescein, to label the cell's fibrous networks and view them by three dimensional light microscopy reveals a differentiated fibrous continuum. This continuum "includes or contains microtubules, microfilaments, free ribosomes and the membrane-limited vesicles of the endoplasmic reticulum," according to Keith Porter and John Wolosewick of the University of Colorado. Their findings destroy the notion of randomly floating intracellular components and cell organelles, and initial experimentation indicates that the highly ordered fibrous matrix may be crucial in the regulation of normal cell functions and phase changes.

Mary Osborn and Klaus Weber at the Max Planck Institute and Werner Franke at the German Cancer Research Center have studied and photographed the organization of three major fiber systems in kangaroo rat kidney cells, two of which were known to exist previously, but only by techniques which did not allow the study of their overall organization.

The thickest fibers, microtubules, are 20 to 25 nanometers wide and composed mainly of the protein tubulin. Osborn and Weber have shown for the first time that these microtubules radiate in a curved or straight path from the cell nucleus, which contains genetic material, and terminate near the cell surface. This radiating microtubule system disappears at the beginning of cell division. Weber suggests that its tubulin is restructured into the spindles that form during cell division and are involved in the process of elongating one cell into two separate cells and, in some cases, in indirectly pulling apart the duplicated chromosomes of genetic material. The microtubule fiber system is generally involved in cell structure and elongation and is correlated with cell movement and internal cell transport of materials. A smaller fiber system with microfilaments 5 to 6 nanometers wide contains actin-like proteins similar to those in muscle and is involved in cell mobility. Osborn and Weber found this to be arranged in parallel filaments from one side, or pole, of the cell to the other, with a heavier concentration on one side. The last fiber system, called intermediate since its fibers are 7 to 10 nanometers wide, was in a distinct wavy criss-crossed network throughout the cell, but its function is still unknown.

Keith R. Porter and H. Randolph Byers have concentrated on the involvement of fiber systems in the intracellular reorganization of pigment granules. In the red squirrel fish these can be stimulated to aggregate in the center of the cell, causing the fish to change from a red color to a pink-tinged white. Porter and Byers found that fiber network disappears with pigment aggregation and reforms when the pigment granules move back out from the center, apparently following the path of the microtubules. In addition, in vitro, these cells pulsate spontaneously every 10 seconds.

Like the Damadian-Minkoff work, this breaking research opens up considerable space for inquiry into the relationship between the fibrous matrix systems and various cellular phase changes, including those causal relationships that govern cellular division and thus are related fundamentally to cancer. It also demonstrates the fallacy of blurring a highly differentiated continuum, which is technically difficult to probe, into a simple fluid with simple particles in it; this simple particle-simple field approach quickly aborts any further inquiry.



A-mitochondria
B-mitochondrial lamella, site of electron transport
C-microfilament bundles amassed in cell membrane
D-cell membrane
E-intermediate fiber network
F-ribosomes held by intermediate fiber network, site of protein synthesis
G-microtubule
H-ribosomes bound to endoplasmic reticulum
I-endoplasmic reticulum

Figure 8
CELL STRUCTURE

This drawing of cell structure shows how intermediate fibers anchor many cellular components, including ribosomes, which were previously thought to float freely in cytoplasm, to microtubules, cell membrane, and other cell structure.

Julie Ann Miller. 1977. "The Bone and Muscle of Cells." *Science News*. 112:16 (October 15).

The Royal Society

by Carol White

IT IS ONE OF THE MORE astounding frauds of history that the Royal Society and its honorary progenitor Francis Bacon are proclaimed to be the founders of modern science, while the Elizabethans and their continental humanist allies are brushed aside as magicians or, at best, mere followers of the superstitious scholastic Aristotelian tradition. The fact is that Elizabethan scientists were accomplished mathematicians and in the forefront of research in astronomy.

To take just two examples: Thomas Harriot discovered the law of reflection and refraction of light before Willebrord Snell and Descartes and anticipated the work of Galileo as well. He and the network of observers whom he organized collaborated with Johannes Kepler in making the observations necessary to confirm predictions based on Kepler's theory.

Second, Tudor scientists constructed a navy that surpassed every other European navy because of the maneuverability of its ships and the reduced ratio of seamen to ship space, an innovation that lessened mortality due to disease on shipboard. The Tudors developed a superior ballistic capability and a superb confidence in their scientific seamanship that allowed them to dispense with the traditional baggage of land army aboard ship and galley slaves below who could compensate for the shortage of wind power by rowing.

These two examples display in condensed form the vast array of the Elizabethans' scientific and engineering accomplishments. To Tudor science we owe not only the existence of the United States but the very survival of human life in the Americas. Only the Tudor defeat of the Hapsburgs, finalized under the rule of Oliver Cromwell, saved this continent from complete depopulation under the hideous slave-labor policies of the Hapsburgs.

Tudor Science and Royal Society Sorcery

The Royal Society was chartered by Charles II in 1662, although its founding members had maintained more or less informal relationships throughout the previous 20-year period. Francis Bacon is appropriately considered as one of the key founding fathers of the society, along with John Locke, Robert Boyle, and Isaac Newton, although Bacon died 40 years before the society's official life began.

Bacon began the job of destroying the humanist scientific tradition upon which the Tudor renaissance was predicated, the tradition that laid the basis for the enormous flowering of that society. His book *Novum Organum* is such an embarrassing collection of nostrums that even Bacon's admirers are forced to apologize for it. The key to the book is found not in the absurd lists that purport to demonstrate the inductive method, but in its obsessive attacks on William Gilbert, an internationally recognized Tudor scientist.

Bacon qualified for inclusion in the Royal Society precisely for his attack on Gilbert. In this he equaled, if not outdid, Sir Isaac Newton who, with the loyal support of his fellows in the society, plagiarized the work of Robert Hooke and then scurrilously slandered and attacked not only Hooke, but the Royal Astonomer Flamsteed and,

most notably, the brilliant German philosopher and scientist, Gottfried Wilhelm Leibniz.

Founded a century after Elizabeth I came to power, after the debauchery of James I's reign and its years of civil war, and after the restoration to the throne of Charles II, the Royal Society represented a defeat for modern science. Far from founding modern science, Francis Bacon and Isaac Newton represent the resurrection of the most backward tendencies of medieval science, such as alchemy.

It is to the very backwardness of the founders of the Royal Society that we owe the myth that Elizabethan scientists were magicians — not because the society's founders arrogated the sole rights to founding modern science to themselves, but because they secretly were consumed with a passion to discover those magical secrets they mistakenly presumed lay at the base of the magnificent accomplishments of the Tudors.

One of the first tasks the Royal Society undertook was the transcription and study of the notebooks of Tudor educator John Dee, notebooks that purport to tell of conversations with angels. Robert Hooke was assigned to elaborate cryptographical analysis of all of Dee's writings, while Newton applied the same methods to the more than 100 alchemistic treatises he owned.

The secret at the core of the Tudor achievements, which was beyond the comprehension of the arrogant royalist fools who dominated the Royal Society, was the absolute commitment to progress, to human perfectibility. This guided their policy to spread education into the artisan class and rescue science from the dead clutches of scholasticism in the universities. This drove them to establish a new world on these shores. And this led them to recognize as their mortal enemy that Hapsburg dominance — that monetarism named Fuggery, after the Fugger banking house to which Bacon and Newton, on the contrary, had made obeisance.

While the founders of the Royal Society remained mystified by the hermetic secrets they supposed their predecessors to possess, they were quick to appropriate and reestablish the intelligence "agency" that Francis Bacon and the Cecils, William and his son Robert, took over from John Dee and Francis Walsingham, the head of Elizabeth's foreign service. To this date, in fact, the British monarchy continues to use its scientific establishment as a cover for espionage, as exemplified by Bertrand Russell's networks run out of Newton's home college, Trinity, at Cambridge University, which ran Niels Bohr and the unfortunate Albert Einstein.*

It is a fact that from its inception, the Royal Society functioned as an antihumanist institution that not only acted as an intelligence cover, not only plunged into the worst features of medieval mysticism under the cover of Neoplatonism, but also actively suppressed ongoing scientific research by its own members, such as Hooke and Flamsteed, the Royal Astronomer. The society's founders were forced to this, because the real practice of science is fundamentally incompatible with their antihumanism. Francis Bacon and John Locke circulated the lie that the practice of science is the objective study of collections of isolated, empirically verified facts; real science is the practical perfection of the human species.

It is of course the case that members of the Royal Society were responsible for making major contributions to the corpus of scientific knowledge. The work of Benjamin Franklin and Joseph Priestley, as well as that of Robert Boyle, Hooke, and Newton establish this. However, especially after Newton assumed direct control of the society's functioning in the 1660s, the group increasingly

*See the series by the author on "Einstein and the Fabian Universe" in *New Solidarity* August 13, 17, 20, 25, 1976.

Elizabeth I [1558-1603], the last of England's Tudors, is shown here in a portrait painted to commemorate the English victory over the Spanish Armada. Humanist science flourished under the Tudors, laying the basis for industrial development and expansion into the New World.

England's Royal Society, founded in 1660, represented the destruction of the humanist tradition that underlay the great flowering of Tudor society. In this engraving, Francis Bacon, the spiritual founder of the Society, is seated at the right of the bust of King Charles II and Lord Brouncker, its first president, is at the left.

Francis Bacon began the job of destroying the fruits of the Tudor renaissance by attacking Tudor scientist William Gilbert.

became a bureaucratic instrument of British state policy. Since this policy was directed by the Dutch-British, monetarist bankers, the result was similar to that produced today by the monetarists' zero-growth policies.

The Royal Society merely tolerated scientific developments as a cover for its main purpose: enforcing the hegemony of the British-Dutch monetarist role on a world scale. To this end, the society had to smash all opposition among humanist forces on the continent and in Britain. Descartes and Leibniz became the obvious main enemies, but even apolitical scientists like Royal Astronomer Flamsteed had to be destroyed if they refused to accept the society's total control of their work.

While the Newton-Boyle-Locke circle privately practiced a particularly nasty brand of Old Testament mysticism, they demanded nominal adherence to the Church of England and the shibboleths of Newtonian-Lockean empiricism from any scientists who wished to work in their domain. At the same time, these mystics established the official mythology of science as a special discipline.

Newton's *Principia Mathematica* was key in this myth building. Physics and science in general were characterized as "mathematical" and "objective," gibberish known in modern terms as "value free." The notion of progress and the ideas of humanist Neoplatonism were excluded from the proper domain of science as they defined it. No longer could scientists expect to explain themselves and the genesis of their own work scientifically. The proper subject of science, the development of the human species was proscribed, and its various predicates within particular fields of inquiry were severely circumscribed.

Elizabethan Science Policy

Elizabethan scientists were unabashedly political. Not only did they explicitly locate their work as scientists within their broader humanist concerns of developing the creative potential of the human species—man's claim to divinity— but they had a practical concern to defeat the antihumanist tendencies most notably exemplified by the Spanish Hapsburgs. To do this they supported a policy centered on expansion into the New World.

This policy had a threefold purpose: Hapsburg power would be cut at its most vulnerable point, and England would be guaranteed an expanded outlet for trade and manufactures as well as new sources for raw materials and food. In this way English industry also would be activated by the problems immediately posed by the necessary enhancement of naval technology. Then the navy played a role similar to the critical role of the aerospace industry today, as a stimulant to scientific and technological development for the society as a whole. And third, the New World offered the hope of a place where humanists could construct a human society *de novo* without the accumulated feudal crap of centuries that was smothering Europe. It was this hope, expressed for example in Sir Thomas More's *Utopia*, that prompted the first Italian geographers in the circles around Nicholas of Cusa—Toscanelli, Leonardo da Vinci, and of course, Amerigo Vespucci—to lay the groundwork for the exploration and conquest of the Americas.

After the death of Henry VIII's son, Edward VI, in 1553, and with the assumption of Catholic Mary Tudor (reigned 1553-1558) to power and her marriage to Philip II of Spain (reigned 1556-1598), England was laid open to the Inquisition and was in a virtual civil war until Mary's death in 1558. The political tendency of Robert Dudley and Thomas Gresham, which under Edward VI was responsible for the Tudor policy of encouraging industrial development, science, and education, was forced to bide its time and regroup itself around Elizabeth I. But when Elizabeth assumed the throne in 1558, the previously hegemonic Dudley faction faced a competing tendency grouped around Elizabeth's Secretary of State, William Cecil. Cecil, in fact, was directly responsible for sabotaging the Dudley group's efforts to prevent Mary

Tudor's accession to the throne by switching the succession to Lady Jane Grey, a cousin of Henry VIII who was married to one of Dudley's sons.

From the outset the Cecil faction played balance-of-power politics, trying to keep the Hapsburgs in power as a threat to the French. The Cecil policy was to support and finance the anti-Hapsburg tendencies in France and Holland only to the extent that these tendencies would harass and contain the Hapsburgs from directly attacking England.

The conflict between the Cecil and the Dudley factions was violent, though submerged throughout Elizabeth's reign, and the Cecil antihumanists gained complete control only after Elizabeth's death.

Elizabethan colonial policy existed as a compromise between the Dudley and Cecil tendencies. Rather than the expanded royal navy proposed by John Dee and John Hawkins, which would operate at crown expense but under crown control, Elizabeth instead relied upon a privateer-merchant fleet, financed largely from captured Spanish treasure. Positively, this meant that the Spanish were subject to constant harassment and in this way contained. The negative consequences were not only the obvious heteronomy that would follow such a policy, but the replacement of considerations of immediate profit for necessary but more long-range military goals.

Of more profound consequence, this reliance on plunder to support the English maritime fleet obscured the necessity for investment in industrial expansion. Private accumulation, even off the Hapsburgs and their Fugger bankers, is still primitive accumulation — the redistribution of ill-begotten wealth rather than the creation of new wealth.

In Her Majesty's Secret Service

Under these circumstances the Dudley faction was reduced to developing a passive, intelligence capability instead of an aggressive foreign policy. John Dee, recognized as one of the foremost mathematicians by his European contemporaries, and the architect of the policy for colonization, developed a highly sophisticated intelligence service with the collaboration of the head of the crown's foreign service, Sir Francis Walsingham.

In order to gather intelligence on Jesuit and similar activities inside England, Dee practiced astrology, thus keeping tabs on the credulous aristocracy as he foretold their futures. At the same time, he and Walsingham collaborated with Dudley and Elizabeth to concoct a series of deception operations to entrap Hapsburg plotters who were seeking to use Mary Tudor as the focal point of a new coup. Dee also traveled abroad sending information back home in the guise of reports on mystic experiences which he had as a result of crystal gazing, the same reports which were studied and restudied by the Royal Society, signing himself to Elizabeth "007." To this day, unimaginative British intelligence still uses astrology as a penetration operation and to convince the credulous.

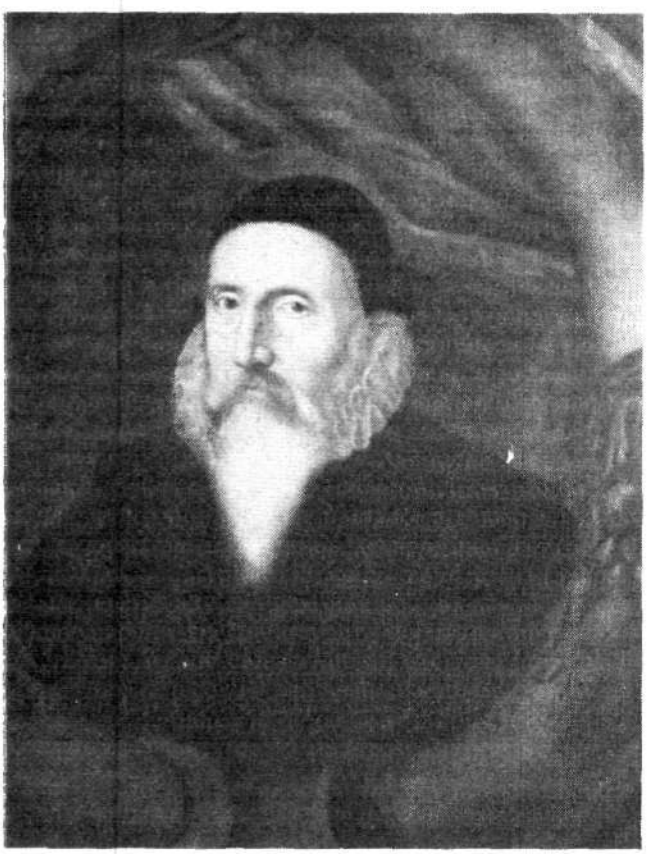
Dee and Walsingham were able to win the collaboration of humanist circles throughout the continent. Through these networks, Elizabeth made available the material aid which she grudged to give openly and in sufficient quantity to administer a decisive defeat to the Hapsburgs. From these networks, sufficient information was finally gathered to convince Elizabeth of the necessity of mobilizing the country at the point in 1587 when Philip II of Spain was planning a naval attack upon England.

Clandestine networks existed throughout the European continent since the time of the Hohenstaufen defeat and the wholesale extermination of the Knights of the Templar and allied humanist forces by the Inquisition. The point is that Elizabeth could have dispensed with most these covert operations had she followed a decisive foreign policy aimed at rallying industrial forces to a policy of defeating the Hapsburgs and colonizing the New World.

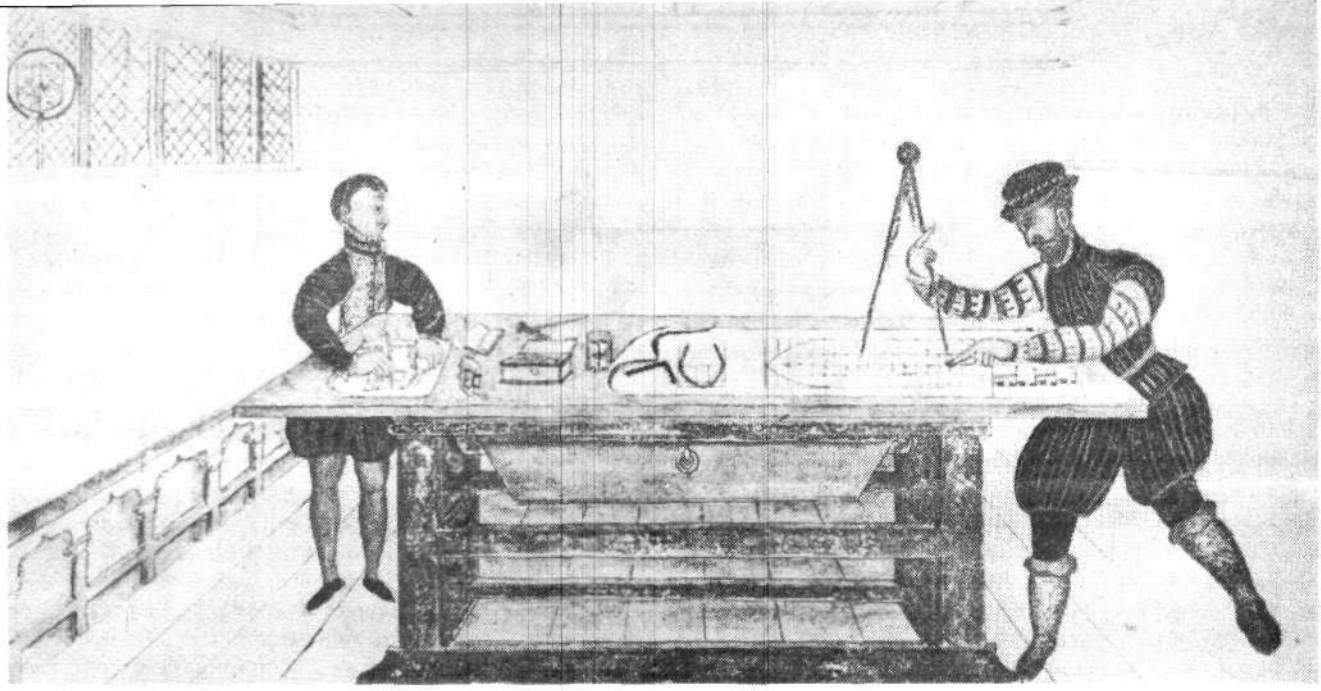
The Dudley faction's members were patrons of the arts and sciences. They controlled mining, steel production, ordnance manufacture, and the navy. Their policy was premised on the continued upgrading of English labor, already the best fed and best educated in all of Europe.

Dee versus Bacon

John Dee was born in the household of Henry VIII, sent to school under the patronage of John Dudley, Duke of Northumberland, and educated to be a mathematician and



Tudor educator John Dee, one of England's foremost mathematicians and the architect of the Elizabethan colonization policy as well as its intelligence service.



These English shipwrights at a drafting table are part of the Tudor scientific seamanship that made the English navy the best in Europe, with its maneuverable ships and reduced ratio of seamen to ship space.

scientist. During the reign of Edward VI, he was sent to travel on the continent, educating himself in the most up-to-date navigational techniques by association with the Flemish cartographer Gerard Mercator and the scientific circles around him. Dee, who was working with Thomas Gresham to rebuild the English navy, made contact with figures such as Sebastian Cabot, who made available secret Spanish maritime charts to the English.

After the death of Henry VIII's son, King Edward VI, (it is thought by arsenic poisoning), William Cecil sabotaged John Dudley's attempts to avert a Hapsburg seizure of power in the country by preventing the accession of the Catholic Mary Tudor to the throne. Cecil, whose job it was to deploy England's troops, secretly demobilized the troops assembled to defend the country. Thus Cecil ensured the capture of Northumberland (Dudley was the Duke of Northumberland) and Dudley's beheading under the reign of Bloody Mary and her soon-to-be husband Philip, whose father was king of Spain.

In these conditions, with the country virtually at civil war until Mary's death and Elizabeth's assumption of power, Dee busied himself with collecting a massive 2,500-volume library (compared to 451 volumes in the Cambridge University library!) which would be the focal point for the education of a cadre-force that could carry out the colonial policy temporarily aborted by the Cecil-Hapsburg coup. This library, located in the suburbs of London, was available both to Elizabeth and her court and to the sailors and artisans of London. It was the actual seed-institution of what later, in 1599, emerged as Gresham College.

John Dee was more an educator than an original scientist. The first English translation of Euclid's geometry was produced and published under his initiatives and with a preface by him. And around him and through the impetus of his work, the network of scientists organized by men like Thomas Harriot and William Gilbert collected. In this same circle, John Dudley's sons, Robert and Ambrose, in collaboration with Thomas Gresham, maintained the tradition of patronage of science and the arts established by their father as a central feature of their industrial policy.

It awaited Francis Bacon, aptly honored as the father of the Royal Society (although for those who knew his typically British personal quirks, mother might seem more appropriate), and nephew to William Cecil, to coopt and pervert the intelligence network established by Walsingham and Dee; Robert Dudley's psychologically unbalanced stepson, Robert Devereux, Earl of Essex; and most important, the humanist epistemological foundations of the Gresham-Dee scientific establishment.

Francis Bacon and his brother Anthony were so personally unsavory — Anthony in fact was threatened with expulsion from Burgundy, for practicing sodomy with young boys—that even William Cecil found them embarrassing. He deployed them into the intelligence service at the death of Robert Dudley and Walsingham, just after the English victory over the Spanish Armada in 1589. Here they were well placed to accomplish a turnabout, using the previously in-place double-agent network now to conduit Spanish influence into England. Devereux's vanity and chronic overspending were played upon to push him into appearing to organize a coup against Elizabeth. The demoralizing effects of the Essex affair, which ended in Devereux's beheading, and the subversion of the humanist networks temporarily scattered the proindustrial forces and laid the ground for the accession to power of James I.

Newton and the War Against Science

The unsavory Francis Bacon finally achieved public recognition and obloquy under James I when he assumed the post of Lord Chancellor (a position similar to that of

chief justice of the Supreme Court but with more power). Even under the admittedly loose standards of that period his practices of selling judicial decisions were so gross that he was drummed out of office and briefly imprisoned. Although John Locke is a more appropriate person to compare directly with Bacon, both as a core political operator and as an ideologue, nonetheless it is Isaac Newton who is directly comparable to Bacon as a historical figure or personage.

Any competent scientist will admit that no detail of Isaac Newton's world system remains true today. Gravitation as an occult, attractive quality resident in hard-ball fundamental particles and activated instantaneously over enormous distances has been banished from practical science. One could reasonably expect that the reductionist epistemology that underlay his system would also be a thing of the past. Not so. Today there are still quarkish physicists in insane pursuit of the fundamental particle.

A look at Newton's system, unbiased by the centuries of virtual canonization of the man, would deem it pure magic. Perhaps the excuse is offered that this is reasoning ex *post facto*. After all, in Newton's time...Not so. As we shall show, Newton was in fact a magician by conscious choice.

Unlike Bacon, Newton was at least a second-rate scientist. But a cursory examination of his so-called major accomplishments in establishing a world system exposes the preposterousness of any claim on his behalf to scientific eminence. Not only was it Hooke (and Christian Huygens in optics) who had the major synthetic insight both in the case of optics and about the nature of gravity, but, of course, it was Kepler who discovered the "laws" of the elliptical orbit of the planets and developed the mathematical tools in the calculus necessary to describe them. Kepler's was the pioneer work, with able assistance from Galileo's studies of gravitation, Gilbert's study of field theory and Descartes's synthetic treatment of physical geometry. Thus, Hooke's insight that a gravitational force that decreased inversely with the distance between two objects could describe both planetary phenomena and gravitation as it was observed on earth was merely a synthesis of the previous works.

Newton worked out the details of Hooke's hypothesis, conveniently omitting to mention the source of his inspiration and, in fact, falsifying the dates of his "discovery" to cover his plagiarism.

Since Hooke had communicated his thoughts on gravitation only in private correspondence, there was little he could do about Newton's publication of the *Mathematical Principles of Natural Philosophy*. The case of the *Optics* was somewhat different. Hooke had published his own work in the *Micrographia* and Newton had to await Hooke's death before publishing his *Optics* in 1704.

Newton's attacks on Hooke are of only secondary importance. They merely serve to establish Newton's own lack of credentials as a top-ranking scientist. Neither is the attack on Flamsteed of historical importance except as it demonstrates how at this early period, the English monarchy systematically established control of all science within its grasp in order to systematically stifle and bureaucratize it through the Robert McNamaras of that day. Poor Flamsteed got the same treatment meted out to nuclear physicists today. His private working papers were seized and "classified" by the Royal Society as crown property. Under Newton's presidency of the Royal Society, which began in 1703, all of British science came under his direct control.

Along with these and similar dirty maneuvers that succeeded in creating a climate that stifled scientific discovery, the society launched an unholy war against Rene Descartes, Christian Huygens, and Gottfried Wilhelm Leibniz, the leading scientists of the 17th century. Leibniz, a contemporary of Newton, was a particular enemy. He had devoted himself to the development of real scientific societies that would continue and advance the

The Newtonians villified the major contributions of René Descartes [r] and used his erroneous treatment of the conservation of momentum to justify their theory that the world was coming to an end in the near future. Gottfried Leibniz continued Descartes's effort to establish the perfectibility of the universe. For this reason, and for his work to establish scientific societies to advance the accomplishments of past generations, the Royal Society treated Leibniz as their chief enemy.

accomplishments of the preceding century despite the political defeat suffered by humanist forces, as evidenced by the terrible ravages of the Thirty Years War, the failure of the English Commonwealth, and the collapse of the Spinoza-DeWitt antimonetarist tendency in Holland. Leibniz maintained contact with a core network of humanist scientists in every country of Europe including Russia.

Leibniz's Acheivement

Leibniz made major scientific contributions in his own right. It is to him that we owe a coherent, axiomatic treatment of the differential and integral calculus, which otherwise (despite the ludicrous claims of Newtonians) was a collection of useful but unsystematic algorithms or recipes for the solution of particular problems. As well, it was Leibniz who first recognized the relative invariance of energy. He postualted the conservation of *vis viva*, the product of the mass and the velocity squared (one-half of which is nonrelativistic formula for kinetic energy).

Leibniz's discovery of the relative conservation of energy continued the less happy effort by Descartes to establish the perfectibility of the universe by asserting that the quantity of momentum in the universe (the product of mass and velocity) is conserved, which of course is false. The basic demonstration by Leibniz is simple. Attach a mass of 4 pounds to a pendulum and accelerate it to a velocity of 1 foot per minute. Is this the equivalent of a 1-pound mass accelerated to a speed of 4 feet per minute or a 2-pound mass traveling at 2 feet per minute? The answer is no. Two dissimilar qualities can be measured only by locating them as predicates of a universal that subsumes them—in this case the quantity of work done. It can easily be observed that such a pendulum will raise a 4-pound mass with a velocity of 1 foot per minute to the same height as a mass of one with a velocity of only 2 feet per minute.

Aside from several errors in his treatment of momentum, Descartes's law of conservation of momentum would indeed have led to the tendency of the universe to run down entropically through nonelastic collisions. It was this aspect of Descartes's theory to which the Newtonians subscribed, as justification for their theory that the world in fact was coming to an end in the near future.

England's Whigs

Leibniz was clearly the enemy of the Royal Society and they treated him accordingly. They conducted a hysterical fight against him, accusing him of deciphering a one sentence numerical cipher which Newton had included in a letter (after having been informed by Leibniz of his own work on the calculus). They claimed that Leibniz based the elaboration of his own systematic treatment of the subject on this cipher. As part of this attack, Newton reconstructed supposed working papers of his to demonstrate priority of discovery in a whole series of cases, and involved the Royal Society in the tasteless task of defending these prior claims.

Did Newton engineer this on his own? It is unlikely. Newton was a documented manic-depressive psychotic who suffered one breakdown in 1693 reported to have lasted as long as 18 months, and he certainly suffered from paranoid grandiosity. But for the very reason of his known depressive tendencies and mood swings it is unlikely that he would have sufficient tenacity to maintain such fraudulent claims about his own minimal scientific achievements. In any case, through his teacher Isaac Barrow (an accomplished mathematician who acquainted Newton with his own and Wallis's elaborations of the calculus) and the "Neoplatonist" philosopher Henry More, Newton was absorbed into the periphery of English Whig circles from the time he entered Cambridge University. (These should not be confused with American Whigs who mistakenly identified with them by name, believing them to be a legitimately antimonarchist tendency. The English Whig movement traces its parentage directly back to the same Cecil-Bacon circles that decapitated the Tudor humanist tendency a century before and plotted against Oliver Cromwell and John Milton during the Commonwealth.)

Leibniz's own remarkable accomplishments were sufficient to make him a major target for this antihumanist British Whig tendency. Nevertheless there is reason to suppose that the vigor of the attack was motivated by more desperate personal concerns on the part of the Whigs. In a letter to Thomas Burnet in 1713, Leibniz wrote: "The rebirth in England of a theology that is more than papist and a philosophy entirely scholastic since Mr. Newton and his partisans have revived the occult qualities of the schools with the idea of attraction...." Characterizations like these triggered off the hysteria of the Whig group. It is unlikely that Leibniz guessed just how far this circle had plunged into medieval occultism and mysticism, since their alchemistic and other practices were a carefully kept secret.

It was absolutely essential for the Whigs to prevent Leibniz from coming to England with the Hannoverian court in 1715, where he would have been in a position to sniff out and expose their ugly doings. This would explain why the society launched its attacks on Leibniz for plagiarizing the calculus not in the 1680s when he and Newton respectively published their major works, but from 1700 on when the Hannoverian succession was being negotiated and consolidated.

John Locke and British Empiricism

Newton, Locke, and Boyle were all deeply enmeshed in the study of alchemy at the same time that they secretly rejected Christianity, substituting for it a form of Judaism based upon the revelations in the Book of Daniel in the Old Testament.

In this connection it is important to note that John Theophilus Desaguliers, the founder of speculative freemasonry, was a paid experimenter for the society.

The empiricist method institutionalized by the society lays claim to being the foundation for modern scientific thinking. As anyone who has tried it knows, the reduction

of thought to the study of a sequence of disconnected particulars is self-induced brainwashing. It leads not to creative thinking, but to dissociated states and ultimately psychosis of the kind induced chemically by LSD or a sustained high dosage of marijuana. What is incredibly enraging is to find out that the Newton circle believed the system they peddled no more than the brainwashers of today.

It was Locke, the slave-trader, who in his *Essay on Human Understanding* refurbished the absurd scholastic distinction between so-called primary and secondary qualities, number, extension, impenetrability, and figure mobility as opposed to taste, color, sound and so forth, to push the idea that human values are not real. In his words:

> Man making abstract ideas, and settling them in their minds with proper names annexed to them, do thereby enable themselves to consider things, and discourse of them as it were, in bundles, for the easier and readier improvement and communication of their knowledge, which would advance but slowly were their thoughts and words confined only to particulars.

Locke carries his attack on the reality of universals still further in a letter to the Bishop of Worcester in which he asserts that morality is necessarily based upon irrationality. Locke writes:

> Faith stands by itself, and upon grounds of its own, nor can be removed from them and placed on grounds of knowledge. Their grounds are so far from being the same or having anything in common, but when it is brought to certainty faith is destroyed; it is knowledge then and faith no longer.

Since there is no such thing as mankind, then individual men cannot premise their morality on achieving progress for their species.

Locke's modest proposals for the Poor Laws could not be put into effect in England until the further degeneration of that society in the mid-19th century:

> That all men sound of limb and mind above fourteen and under fifty, begging in maritime countries outside their own parish without a pass should be arrested and sent to the next seaport town, there kept at hard labor till some of His Majesty's ships coming in or near there, given an opportunity of putting them on board, where they shall serve three years, under strict discipline at soldiers pay....
>
> Men above fifty or maimed to be sent to the workhouse for three years at hard labor and for children, pauper schools should be set up in every parish to enable both mothers and children to work productively....Children should have their bellyful of bread daily...and to this may be added, without any trouble in cold weather, if it be thought to be needful, a little warm water gruel; for the same fire that warms the room may be made of use to boil a pot of it...(By this means) computing all the earnings of a child from three to fourteen years of age, the nourishment and teaching of such a child during the whole time will cost the parish nothing.

Robert Boyle, Alchemist

So much for his morals but what of the scientific method? Locke was a practicing physician who also participated in Robert Boyle's alchemical researches. The

The leaders of the Royal Society preferred alchemy to science, and Newton had a library of more than 100 books on alchemy. This illustration from an early 17th century text shows the "Garden of Alchemy" with trees symbolizing various metals and the spirit of alchemy on top of a twin-bodied lion.

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following is excerpted from a letter from him to Boyle written in 1667:

> ...having from a passage in your writings taken the first notice of the time of gathering peony roots...that it must be in April, when Sol is in Aries and a plenilunium before the rising of the sun, I rode to a place where was pretty good plenty of male peony, and on the forteenth instant, between ten and eleven in the morning, had some roots dug up, and am promised other to be dug up on the thirtieth instant before sun-rising. If there be any advantage in the time of gathering, I owe the knowledge of it so much to you that I would be an unworthy reader of your writings if I should not return you my thanks and offer you some part of these roots....

Boyle's writings on these subjects were circulated privately or published anonymously. In a letter written in 1681 Locke described the following prescription for a lucky patient:

> Three stone quart jugs — fill them with urine of a patient as it is made, stay them close, bury them a yard underground and lay a tile over them that the earth fall not close upon them; and so bury them in the earth. This was done to the Countess of Shaftesbury without her knowing it and she had not from that time till now any of those violent nephritical pains she was wont to have.

Robert Boyle of course is publicly acclaimed only for his law of the relationship between the temperature, pressure,

and volume of a gas. However, he also published what purported to be eyewitness accounts from travel literature in 1666 in which were described water changing into earth, grasshopper-like animals into vegetables, and twigs into worms. This is of the same caliber as the following observations of one Joseph Glanville reported upon by Newton which purport to describe an experimental demonstration of mental telepathy by a former Oxford student to his fellows, an art learned from the gypsies. Newton notes the following: "A man by heightening his fancy and imagination may bind another to think what he thinks as in the story of the Oxford scholar in Glanville 'Vanity of Dogmatizing.'"

Newton treasured a much thumbed copy of Elias Ashmole's "*Theatrum Chemicum Britanicum* containing several poetical pieces of our famous English philosopphers who have written the Hermetic mysteries in their own ancient language." Ashmole was also a founding member of the society. He contended that through time there is a periodic reappearance of alchemists who "possess the hidden truth although the heedless world hath seldom taken notice of them."

Newton owned over 100 books on alchemy and kept copious notes on treatises not in his possession. The following passages in Newton's notebooks describe the alchemistic researches to which most of his time was devoted while he was at Cambridge:

Flammel in chapter five paints a man and a woman clothed in an orange robe upon a field of azure and blue to signify in this second operation (after putrefaction) you have truly but not yet perfectly two natures conjoined and married a masculine and a feminine or rather the four elements and these natural enemies begin to approach one another amiably and lay aside the enmity of old chaos....Mayer's figures prefixed to Basil Valentine's 'key' - Two women clothed riding on two lions; each with a heart in her hand...the right hand lion farts on a company of young lions behind it and bites the snout of the left hand lion and tears him with her paw. This lion by her farting (which signifies her arial form) and young ones, and being on the side of the hearts next the moon and her biting and tearing the other lion signifies the female....

Newton's Theory of Gravitation

The occultism that Leibniz smelled in Newton's theory of gravitational attraction is clear in a letter Newton wrote to Oldenburg, then secretary of the Royal Society, in 1675:

For nature is a perpetual circulatory worker, generating fluids out of solids, and solids out of fluids, fixed things out of volatile and volatile out of fixed, subtle out of gross and gross out subtle, some things to ascend and make the upper terrestrial juices, rivers and the atmosphere; and by consequence others to descend for a requittal to the former. And as the earth, so perhaps may the sun imbibe this spirit copiously to conserve his shining, and keep the planets from receding further from him. And they that will, may also suppose that this spirit affords or carries with it thither the solarly fuel and material principle of light; And that the vast aethereal spaces between us and the stars are for a sufficient repository for this food of the sun and planets.

As late as 1679, a letter to Robert Boyle shows that Newton was not thinking about gravitation as the attraction between two masses but simply as the fall of bodies to earth:

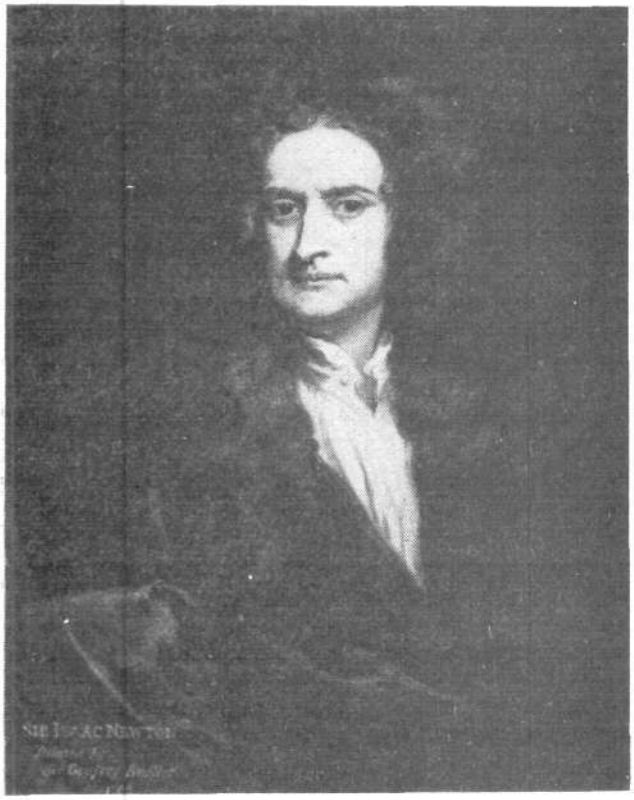
And first I suppose that there is diffused through all places an aethereal substance capable of contraction and dilation, strongly elastic, and in a word much like air in all respects but far more subtle...the cause of gravity....imagine now any body suspended in the air or lying on the earth, and the aether being by hypothesis grosser in the pores which are in the upper parts of the body than in those which are in its lower parts, and that grosser aether being less apt to be lodged in those pores than the finer aether below, which cannot be without the body's descending to make room above for it to go into.

Newton filled thousands of pages of manuscript with speculations on the chronology of the Old Testament as well as interpretations of the prophesies. His is the retributive Jewish God of the Old Testament. While the queries appended to Newton's *Optics* become coherent only when you realize that their author is a secret alchemist desperately trying to cover his tracks before Leibniz's pointed criticism, the last query reveals just how far these magicians had retreated from Christianity and an understanding of the human soul. Query 31 ends:

Now by the help of the principles, all material things seem to have been composed of hard and solid particles above mentioned, variously associated in the first creation by the council of an intelligent agent....Such a wonderful uniformity in the planetary system must be allowed the effect of choice...can be the effect of nothing else than the wisdom and skill of a powerful living agent, who being in all places, is more able by his will to move the bodies within his boundless uniform sensorium and thereby to reform the parts of the universe, than we are by our will to move the parts of our own bodies....For so far as we can know by natural philosophy what is the first cause, what power he has over us, and what benefits we receive from him, so far our duty towards him, as well as one another, will appear to us 'by the light of nature.'

This was Newton's published view. Secretly he held even more primitive views described thusly by his nephew-in-law with whom he lived before his death. "He seemed to doubt whether there were not intelligent beings superior to us who superintended these revolutions of heavenly bodies by the direction of the supreme being."Newton's niece Catherine Barton by the way, refuted his carefully guarded image of moral probity by openly having an affair with Charles Montague, Lord Halifax, Chancellor of the Exchequer, while living in Newton's house prior to her marriage. And there is circumstantial evidence that the core group of the society continued the homosexual traditions of their esteemed forebear, Sir Francis Bacon.

Leibniz was too gentle when he characterized his differences with Newton to a correspondent Louis Bourguet: "Mr. Newton believes that the force of the universe diminishes like that of a watch, and has to be reestablished by a special action of God, while I maintain that God made things from the beginning in such a way that its force



Robert Boyle [1] and Sir Isaac Newton, the founders of the Royal Society, who practiced magic and led the war against humanist science.

would not be lost. Thus his dynamics are very different from mine and do not in my opinion conform to the perfection of divine operations."

Resurrecting the Humanist Tradition

Most of the information in this article comes from the book *A Portrait of Isaac Newton* by Frank E. Manuel, published in 1968. Manuel's conclusions however, are quite different from this writer's. Despite the evidence which he himself presents to the contrary, Manuel perpetuates the myth of Newton's scientific genius. Far worse, he treates Newton's moral turpitude, quackery, and lapses into insanity with a glib: "After all, what can we expect of a scientist?" This debunking of science becomes absolutely clear in Manuel's treatment of Leibniz as just another old fool who would never be satisfied but always demanded sufficient reason.

In most universities today, the alternatives available to students are the irrationalism of the Royal Society empiricist universe or the irrationalism of the modern new left representatives of the monetarists. As the first article in this series on humanist science and politics makes clear, it is time that we resurrected Gresham College, with teachers committed to teaching a scientific world view in the humanist tradition.

We can do no better than end with the words of Leibniz:

> At the crown of the universal beauty and perfection of the works of God, we must also recognize that the entire universe is involved in a perpetual and most free progress, so that it is always advancing toward greater culture. Thus a great part of our earth has now received cultivation and will receive it more and more. And though it is true that some sections occasionally revert into wilderness or are destroyed and sink back again, this must be understood in the same sense in which I have just explained the nature of afflictions, namely that this very destruction and decline lead to a better result, so that we somehow gain through our very loss. To the objection which could be offerred moreover, that if this were so, the world should long since have become a paradise, there is an answer near at hand. Although many substances have already attained great perfection yet because of infinite divisibility of the continuum, there always remain in the abyss of things parts which are still asleep. These are to be aroused and developed into something greater and better and , in a word, to a better culture. And hence progress never comes to an end.
>
> —From *On the Radical Origination of Things*, G.W. Leibniz, 1697.

References

The reader interested in pursuing this subject will find four published biographies of John Dee of which Richard Deacon's *John Dee: Scientist, Geographer, and Secret Agent to Elizabeth I* is by far the most interesting. The scope of Tudor science is documented in *The Intellectual Origins of the English Revolution* by Christopher Hill. Any of a large group of popular accounts treat Bacon's complicity in the early phases of the Essex "conspiracy"; however, these omit references of Cecil's complicity. Daphne Du Maurier's biography of Anthony Bacon not only is entertaining but also corroborates the thesis that the two Bacon brothers were intelligence agents for Cecil.

The Classification of Fusion: Two Case Studies

The Rudakov Case: How the U.S. Uses The Classification Weapon to Sabotage Fusion

by Dr. Steven Bardwell

Documents released Nov. 2 to the Fusion Energy Foundation under the Freedom of Information Act show how the government has used national security classification to sabotage fusion research and, in fact, to sabotage national security. The formerly classified documents constitute several hundred pages of the official Department of Energy file on the visit to the United States in July 1976 by Leonid Rudakov, the head of the Soviet Union's electron beam fusion program, and the astounding research results that Rudakov discussed with U.S. scientists at the Los Alamos, New Mexico scientific laboratory.

As the files show, the Rudakov case spurred six months of bureaucratic bickering and a factional fight within the Department of Energy and the Energy Research and Development Administration. The documents present a picture of a bureaucracy totally befuddled by the Soviet diplomatic initiative of sending a scientist to a U.S. military laboratory to reveal information not only classified in this country but unknown! For the month following the Rudakov visit, the documents show that there was a flurry of telex messages, letters, meetings, and telephone calls, all attempting to hush up as quickly as possible the Rudakov results. One scientist described the attempts by these officials even to classify the blackboard that Rudakov had used in his lectures.

Classification From Whom?

As the FEF was the first to report at the time of his visit, Rudakov presented U.S. scientists with the results of a series of experiments in the Soviet Union that demonstrated amazing new developments in electron-beam induced fusion. The administrators of the U.S. fusion program in the Division of Classification of the Energy Research and Development Administration, ERDA — now the Department of Energy — reacted by classifying the Rudakov papers!

The immediate question is classification from whom? In the year since Rudakov's visit to the U.S., the Soviets have progressed further along the lines that Rudakov described and now report the achievement of fusion plasmas sufficient for commercial power production. In a series of experiments along the same lines as those discussed by Rudakov, they have surpassed breakeven — producing more fusion energy than required to ignite the reaction — by a factor of five!

The result in the U.S. of this classification has been disastrous: crippling of the most creative work in the U.S. fusion power development, as well as in weapons development programs. The devastated situation in U.S. weapons technology is one of the major contributing factors in this country's current negotiating position at the Strategic Arms Limitation Talks (SALT): the stopping of all technological development. The classification of the Rudakov results has, in point of fact, put this country in the position of pursuing a military policy of technological backwardness in the name of war-avoidance and a political policy guaranteed to *provoke a war* that we would lose because of that self-enforced underdevelopment.

The Soviets have counterposed to this an offer of collaboration and expanded exchange of fusion research, an offer that must be accepted in the interest of national security.

The Rudakov Case: A Chronology

In August 1976, the FEF and *New Solidarity* newspaper published a detailed analysis of the Rudakov results (after initial coverage of Rudakov's visit in late July). As the documents show, these articles provoked a second series of ERDA reports, telexes, and so forth, analyzing and reclassifying the scientist's work. The British government then sent a series of quite frantic letters to the Joint Atomic Information Exchange Group requesting an analysis of the FEF and *New Solidarity* articles and the reports by U.S. scientists on the significance of the Rudakov information.

This information was provided to the British, but the released documents show that it is still classified from not only the public in the U.S. but from Congress as well.

In March 1977, Ernest Volkman, a reporter for the Long Island newspaper *Newsday*, published an article (which was reprinted in papers across the country), repeating the

allegation by the FEF that Rudakov's results were being classified from the U.S. public. In response to this article, Senators Clifford Case (D-N.J.) and Henry Jackson (D-Wash.) requested information on Rudakov from ERDA. Both received the same reply despite the fact that the information had been released to the British: "The content of the presentation given by Dr. Rudakov has not been classified by the U.S. government. It is our policy, however, not to comment in detail on the contents of his paper because such discussion could get into classified areas."

These statements, supplied to two U.S. Senators, are simply lies. ERDA did not classify Rudakov's *paper* because it had been published in the Soviet Union the previous month and would soon be available to U.S. scientists in translation. In fact, it would have been illegal to classify publicly available documents, since the public circulation of a classified document would lead so-called uncleared readers into knowledge of the criteria of classification, which itself are classified. But ERDA classified more than just its own analysis of Rudakov's lectures. As the released documents point out in several places, Rudakov's lectures to U.S. scientists contained much more information than was published in the traditionally concise and elliptical Soviet journal articles. *This is the information* that remains classified.

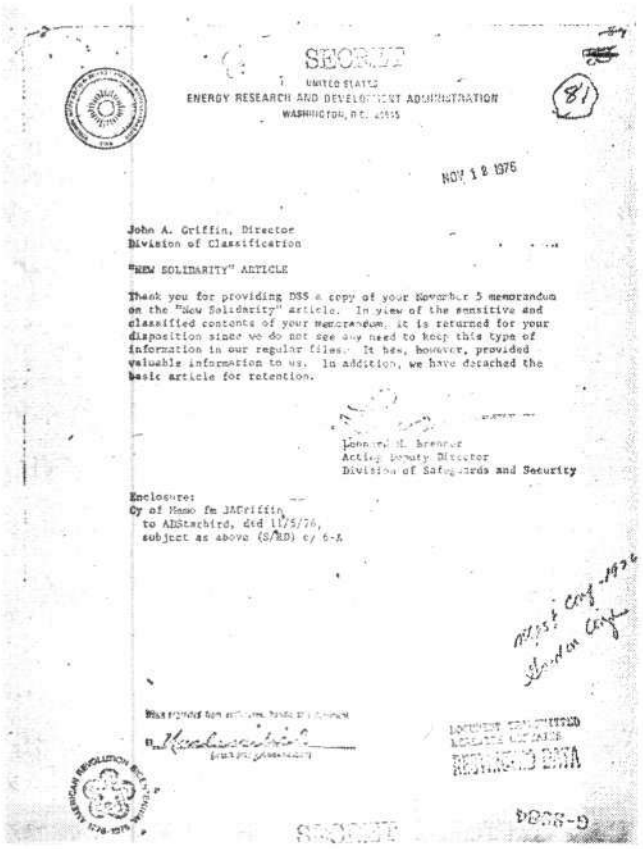
The articles that most disturbed the Division of Classification were those in the Fusion Energy Foundation *Newsletter* and *New Solidarity* newspaper that drew the connection between the scientific results presented by Rudakov and their strategic-military implications. It is the inseparable relation between advanced science, technological progress, and its concomitant military realization that the division felt had to be hidden from the American public. The aim of the classification has been not to hide from Soviet eyes what the U.S. was doing, but rather to hide from Soviet and American eyes *what the U.S. is not doing.*

Rudakov thoroughly fouled up this strategy by destabilizing the premise of continued paranoid hostility between the U.S. and the Soviet Union. He not only released valuable scientific information to U.S. scientists, but he proposed joint work with the U.S. to translate these ideas into the technical reality of nuclear fusion. The diabolical part of this offer is the implied military threat: If you don't want to share with us the fruits of using this technology peacefully, and instead insist on a policy of stifling technological development, then we can put the tremendous energy potential to military ends. But remember, we are ahead in the game.

The Rudakov Results

The scientific results presented by Rudakov can be succinctly summarized as follows:

(1) The key mechanism for transferring energy into a small pellet of fusion fuel using electron beams is to generate intermediate forms of electromagnetic radiation (specifically "soft" or thermal X-rays) that can efficiently heat and compress the fuel. This contradicts previous theory.



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

NOV 1 8 1976

John A. Griffin, Director
Division of Classification

"NEW SOLIDARITY" ARTICLE

Thank you for providing DSS a copy of your November 5 memorandum on the "New Solidarity" article. In view of the sensitive and classified contents of your memorandum, it is returned for your disposition since we do not see any need to keep this type of information in our regular files. It has, however, provided valuable information to us. In addition, we have detached the basic article for retention.

Leonard M. Brenner
Acting Deputy Director
Division of Safeguards and Security

Enclosure:
Cy of Memo fm JAGriffin
to ADStarbird, dtd 11/5/76,
subject as above (S/RD) c/ 6-A

Sample of the documents on the Rudakov case obtained by FEF under the Freedom of Information Act. "The aim of the classification has been not to hide from Soviet eyes what the U.S. was doing, but rather to hide from Soviet and American eyes what the U.S. is not doing."

(2) It had long been thought that the pellet should not be heated at all before it is given the main pulse of energy, since a preheated pellet would be harder to compress, making fusion ignition more difficult. This argument, based on linear and entropic ideas about plasma, is wrong. In fact, the preheating of the pellet is essential for success since it creates inside the pellet not the expected disordered plasma, but a complex self-ordered structure that then allows the plasma to absorb tremendous amounts of energy it could not otherwise absorb.

(3) The classic barrier to successful pellet fusion has been a process called the Rayleigh-Taylor instability, in which the thin-shelled balloon—the tiny pellet's shell—wrinkles and then breaks up rather than being compressed evenly. This instability does not occur. Instead, the plasma pellet oscillates in a complex way, "breathing" in the energy supplied by the electron beam. Similar unexplained oscillations exist in another spherically contained fusion reaction—the sun.

All of this scientific understanding of high-energy, nonlinear plasma processes has immediate application to the building of orders-of-magnitude larger nuclear weapons, construction of beam weapons, and a host of

other advanced weapons systems, as Rudakov's audience at Los Alamos well knew.

Claims of rough U.S.-Soviet parity on these scientific developments have been made by ERDA in the released Freedom of Information Act documents. No one should be misled by this specious argument. The Soviet progress is merely exemplified by Rudakov; it is the result of a broad well-funded, and aggressive research program in which Rudakov's work is more the norm than the exception.

U.S. Fusion Program Crippled

In the U.S. however, the classification of results like Rudakov's which have been subsequently reproduced and elaborated in U.S. laboratories, has been used as the cover for across-the-board stifling of fusion research. When the most advanced research is hidden from general knowledge, the program as a whole is crippled; that is exactly what the classification of Rudakov's results has produced. At Lawrence Livermore Laboratories, the other major national laboratory besides Los Alamos working on electron beam and laser fusion, the most creative work has had its funding cut or has been otherwise sabotaged in the past year. The work on laser fusion at the major U.S. private fusion laboratory, KMS Fusion, has been systematically harassed by classification and is now, because of that, on the verge of bankruptcy. (see article below on the "Kirkbride Report.")

In the name of national security, Energy Secretary James Schlesinger and his co-thinkers at the Department of Energy are using classification as part of a larger policy of systematic deindustrialization of the United States. At the same time, they are preventing the development and export of both fission and fusion and they are trying to enforce a scarcity of energy.

The present policy of classification of fusion, in fact, maximizes the paranoia and hostility on which it is based, and leads to the absurdity of the U.S. sitting at the SALT negotiating table trying to get the Soviets to agree to "mutual" restrictions on new technologies! For the Soviet Union, the question is not: What is the U.S. doing? Exactly because of Schlesinger's classifications, they need now only ask: How far behind is the U.S.?

The Kirkbride Report on KMS: The Factional Battle in Fusion

by Dr. Morris Levitt

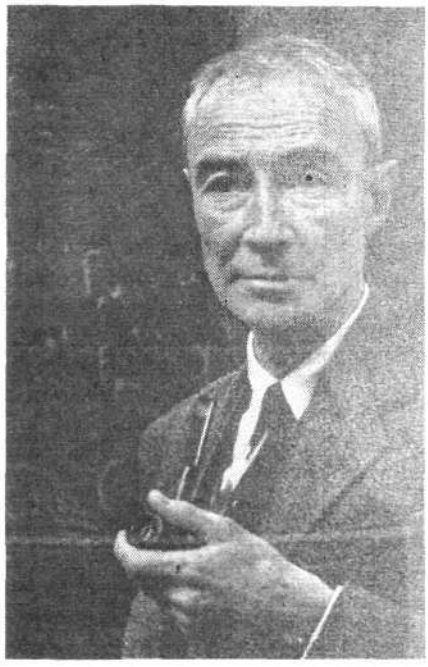
On Aug. 18, 1977 Representative Carl D. Pursell (R) from Michigan entered into the *Congressional Record* a report written by Chalmer Kirkbride, Special Scientific Advisor for the U.S Energy Research and Development Administration, that accused the Division of Military Applications of ERDA of systematically attempting to wipe out the nation's only private sector developer of laser fusion, KMS Fusion of Ann Arbor, Michigan.

We have reprinted below Kirkbride's commissioned report to former ERDA Director Dr. Robert Seamans, as it appeared in the *Congressional Record*, because its candid view of the factional battle over fusion research raises two issues crucial to the development of fusion in the U.S.: First, the fact that the classification of research in the area of laser and other branches of inertial confinement impedes research and serves no useful military purpose; second, that the continued animosity between basic research in the private sector and so-called mission oriented research in governmental programs is detrimental to the goals of fusion development.

In June 1976, Dr. Seamans assigned Chalmer Kirkbride, an engineer with substantial industrial experience, to investigate whether KMS was getting a fair shake in the processing of its ERDA funding requests. After conducting a thorough investigation, Kirkbride's answer was an unequivocal "No!" Worse, Kirkbride alleged that the culprit in the case, ERDA's Division of Military Applications, was abusing its control over classified weapons simulation aspects of laser fusion in order to favor large government labs like Lawrence Livermore in its rivalry with KMS. KMS, a pioneer in laser fusion, was involved with strictly civilian areas of research.

If any further evidence were needed to make the case that no promising branch of fusion energy research should be under the thumb of the security bureaucrats, the Kirkbride report fills the bill. In fact, the major secret these bureaucrats are guarding is that the inertial confinement part of the U.S. fusion program has fallen behind that of the Soviet Union, particularly in the area of electron-beam fusion and in terms of commitment to prototype reactor development. (Why else would ERDA do anything so silly as attempting to classify the summer 1976 disclosures in the U.S. by Soviet physicist Leonid Rudakov on Soviet advances in electron beam driven fusion?)

The immediate conclusion to be drawn from the Kirkbride report is that the U.S. should set up a fully civilian,



Left: five key scientists from the Manhattan Project inspecting the pole faces of the cyclotron at the University of California. From left: Donald Cooksey, Ernest O. Lawrence, Robert L. Thornton, J. Robert Oppenheimer, and William Brobeck. Physicist J. Robert Oppenheimer [right] was the victim of a showcase Red scare trial during the 1950s. Although he headed up the Los Alamos division of the Manhattan Project, Oppenheimer later opposed both the bomb program and peaceful nuclear development.

energy-oriented program for inertial confinement in the fusion division of the Department of Energy and fund it as fully as necessary to get the job done.

Science and Nuclear Politics

The second issue has its roots in the strange postwar history of nuclear energy in the U.S. and will require more than legislation for its solution. A brief summary of the salient features of the 1945-1955 decade makes the point.

There is little question that key policy-makers in the U.S. such as Bernard Baruch, Dean Acheson, and David Lilienthal were opposed to the private sector's development of civilian applications of nuclear energy during this decade. Instead, they sought a U.S. nuclear weapons monopoly and control over strategic raw materials vis-à-vis our nation's adversaries as well as our ostensible allies. The Baruch Plan for international nuclear control and disarmament and the actions of Lilienthal as first head of the Atomic Energy Commission from 1947 to 1950, as veterans of the fight for civilian nuclear power well know, were geared toward that policy.

When the Soviets rapidly moved to overtake the U.S. in nuclear weaponry, U.S. military men and conservatives were especially embittered at the liberals identified in the public mind as the backers of the Baruch policy of nuclear control and disarmament whom they saw as keeping America behind the Soviets.

The issue came to a head with a fierce factional struggle over the question of the H bomb and the subsequent Oppenheimer case. Both the U.S. and the Soviet Union, of course, developed thermonuclear weapons. In the aftermath of this development, Robert Oppenheimer, a prominent, theoretically oriented physicist in the Manhattan Project who had opposed both the bomb program and nuclear energy development, was humiliated in a showcase trial and stripped of his security clearance because of his well-known leftist sympathies.

Not so well remembered is that the outcome of this fight also opened the way at last to the commercialization of civilian nuclear energy via Admiral Rickover's nuclear submarine program and President Eisenhower's launching of the "Atoms for Peace" program.

One of the worst legacies of this period for fusion and related research was the breaking up of the fruitful relationship between "basic" and "applied" scientists that had prevailed during the Manhattan Project (even though this relationship was supported in principle by AEC chairmen Seaborg and Ray through the early 1970s). The critical failure of Oppenheimer's circle of "basic" scientists was to orient politically toward arms control instead of addressing the world's crying need for real investment and development. On the other hand, the hard liners in applied science, although more oriented to production, were hardly better, fixating on maintaining U.S. military superiority. They lent themselves to the McCarthyite slanders against Oppenheimer, while ignoring the fundamental problem of insufficient rates of global technological progress in industry and agriculture.

Today the most innovative plasma physicists scarcely

conceal their contempt for those they call the "empire builders" in the large government laboratories. Having been constantly starved of funds for demonstrably important research, many of these physicists would scuttle the mission orientation of the government's fusion program if given a chance. Although understandable, this is no healthier than the attitude of those scientists who have attempted to run the fusion program like the moon project, as simply an exercise in high technology.

Get the Job Done

To begin to straighten out this situation, it is essential to identify its actual causes and a positive historical model. The collaboration during the Manhattan Project of the reflective, theoretically oriented Oppenheimer and his circle and the nation's leading engineers, industrialists, and the military was extremely effective precisely because there was a proper recognition of the indispensable, unique role of each group, a commitment to get the job done, and the resources to do it. That working relationship fell apart in the postwar decade because the U.S. attempted politically to lead a battered world using a combination of selective investment and ideological warfare. Then as now, the only basis for stability, peace and prosperity, is a massive world development program, led by the U.S. and spearheaded by nuclear technologies. Since that was not forthcoming, many liberals went on in the 1960s to become environmentalists, zero growthers (or at least cynics about massive, high-technology investment in the Third World), and conservatives became parochial partisans of their own industries or ideologies. The scientists were quick to match their lay counterparts in similar unproductive factioneering.

Now is the time to heal the breach. Since most U.S. scientists and technologists are still committed to the Idea of Progress, let's ignore the misleading labels and redraw the lines of battle between the supporters and the opponents of a new Manhattan Project, based on the development of hard technology, for the realization of advanced fission and fusion systems.

The Kirkbride Letter On KMS Fusion

Rep. Pursell prefaced his entry of the Kirkbride report in the Congressional Record *by remarking that "laser fusion offers one of the most promising alternative energy sources. A research and development effort devoted to following all avenues of promising research in this field is essential to any energy policy which is truly comprehensive in scope and serious in intent." He strongly urged Congress and his colleagues on the Armed Services Committee to support the civilian aspects of laser fusion. "The importance of this program," Pursell concluded, "demands that we set aside any internal disputes and work as one to fully develop every avenue for laser fusion and other promising energy-producing techniques."*

To: Robert C. Seamans, Jr., Administrator
From: Chalmer G. Kirkbride
Subject: KMS Fusion contracts with ERDA and the National Laboratories

On June 30, 1976 you referred to me a letter of June 29, 1976 to you from the Director of the Division of Laser Fusion with an attached assessment of the KMS Fusion Research Program. You asked for my comments.

Before getting into my critique, I want to confess that I have become somewhat biased on this project. I cannot tolerate a game in which I think the deck of cards is "stacked" or the "dice are loaded."

I am attaching a detailed critique of the assessment. I have done this in much the same way that I would as an expert witness in a patent lawsuit. I have examined the document, paragraph by paragraph, and often sentence by sentence.

There are several general observations also that I think you should consider in your deliberations. I am presenting these in this letter of transmittal.

When I carried out my investigation that led to my report to you of April 7, 1975, the National Laboratories (NL) and the Division of Military Applications (DMA) wanted to fund KMSF at a $500,000/year level. I emphasized at the time that this was a good way to liquidate KMSF and that unless full funding were done, we should save our pennies. I have told you of the pressures put on me, including the bugging of my telephone, and I believe also my office to pressure me to recommend no funding for the KMSF proposal of January 1975.

The recommendation by DLF [The Division of Laser Fusion — ed.] in their letter to you of June 29, 1976 to terminate funding all KMSF work with the exception of pellet manufacture is yet another disguised way to liquidate KMSF. Unless ERDA can justify full funding, we should not fund at all; but, in my opinion, it would be a serious national mistake not to fund KMSF. It stands out as the only real competition the National Laboratories have in laser fusion. It represents the private sector. It keeps the NL honest. Pertinent to this point, I am attaching a copy of a letter dated June 21, 1976 from C. E. Thomas to J.F. Clayton that I got from Dr. Henry Gomberg.

Unfortunately, there seems to be deep resentment on the part of the NL against KMSF. I suspect this stems from the fact that the NL were embarrassed when KMSF was the first to achieve thermonuclear neutrons by laser implosion. Before that, little or no experimental work had been performed at the NL on laser fusion. Prior to the time KMSF announced to the world that they had produced thermonuclear neutrons by laser fusion, LLL [Lawrence Livermore Laboratories — ed.] had not conducted any laser-pellet interaction experimental work in this field. Their work had been confined entirely to mathematical theory that proved to them that fusion by lasers could not be achieved except at very high incident energy. So it was indeed an embarrassment to the NL when the small insignificant KMSF private company showed to the world how to do it without any cost to the U.S. government. The KMSF achievement was recognized by the Russians and by many other prominent scientists throughout the world before the NL finally (after about a year) were willing to admit that

they were wrong and that KMSF indeed had achieved laser fusion.

At the time of my report to you of April 7, 1975, I did not realize how deep the resentment is from the NL toward KMSF, or I would never have recommended a close working relationship between Los Alamos and KMSF. I now think this is impossible. Also, I think any arrangement that allows for utilization of the NL and/or the DMA in the ERDA contractual administration would be detrimental to the program and not for the best interests of the country. Indeed I think it was disastrous in the last ERDA/KMSF contract.

I recommended orally to you in April 1975 that this contract be administered by Dr. Hirsch's organization, and I still think this was a sound recommendation. I feel stronger about it today than I did in April 1975. The decision was made to put the administration under Dr. Hirsch, and I prepared a proposed announcement of this. But this decision was reversed at the last moment.

Throughout the administration of the ERDA/KMSF contract, the NL and DMA kept KMSF in a contractual straitjacket. They wanted KMSF liquidated in April 1975, and if anything, they want this more today than in 1975. I strongly advise against your continuation of the present methods of contractual administration within National Security and the NL.

I am advised by well-informed people that the administration of the KMSF contract really was handled by DMA rather than by DLF. It has been emphasized to me that Dr. Stickley came from ARPA [The Advanced Research Projects Agency —ed.] and consequently the DLF is nothing but a disguised extension of the military fraternity. Whether this is so or not, many key people in ERDA and many men of substantial scientific stature outside ERDA think it is so. Hence, I urge that this be corrected.

I am making the three following key recommendations:

(1) KMSF should be funded through Phase IIa of the original proposal of January 1975, (about $\$14 \times 10^6$). Also, the program presented in their proposal of March 1976 for a 10 Kj iodine laser should be funded (about 33 million for 1 kilojoule).

(2) The administration of the KMSF contract should be moved from National Security, the National Laboratories, DMA and DLF to the administration of Dr. Robert Hirsch. There is no question in my mind but that the benefits from the ERDA/KMSF contract could have been substantial to the USA had the contract been administered by Dr. Hirsch.

(3) On Page 16 of my report to you of April 7, 1975, I recommended that the question of how the NL should be managed should be referred to the GAC [General Advisory Committee — ed.] for study and recommendation. At present, the NL are a law unto themselves. They account to no one. They submit proposals (with requests for huge funding) directly to the Congress, and they get pretty much what they request. For example they were not held accountable for missing their projections on Argus and Shiva in the same harsh way they propose to hold KMSF accountable for missing their projection of laser power delivery. I think it would be to the best interests of the nation if the NL were held accountable to hard nosed review panels of industrialists and university scientists who do not have conflicts of interest.

Many people feel that there are built-in conflicts of interest in the JCAE [Joint Committee on Atomic Energy —ed.] which together with the way the NL are administered are responsible for the failure of the Atomic Energy Commission. Many people to whom I have talked feel that the productivity of the NL will be no better under ERDA management than it was with the AEC. They feel that there must be some way devised to manage the NL so they are held accountable for the monies appropriated to them from the Congress, so that their productivity is commensurate with the taxpayers' money they spend.

I do not have any well thought out system of management, but somehow I think if the NL can be held accountable to hard nosed panels of industrialists and university scientists, a drastic improvement in management might be achieved. Also wherever possible, I think the scrutiny of the press would be a powerful tool in holding the NL accountable for their major underestimations of costs of their proposed research projects. As I said, I do not have a well thought out plan, but I think this would be a splendid assignment for the GAC and your Panel of Consultants.

I have been amazed at the large number of people who are critical of the lack of accountability to which the NL are held. Also these people think that too often the poor performances of the NL are shielded and covered up under the guise of national security without justification.

Whether this is so or not, the fact remains that the suspicions are there and if the GAC could devise an acceptable plan, it would go a long way toward bringing about a better feeling in the scientific and technical communities. I urge that this problem be assigned to the GAC.

A model of the laser fusion target used in the U.S. Lawrence Livermore Laboratories program, shown here dwarfed by the head of a pin. The LLL laser research began in 1962 as part of the weapons program and is now the nation's largest laser effort.

Breeder Cuts Set U.S. Back In Nuclear Power

The Senate-House Joint Committee vote and the subsequent presidential veto to cut the Clinch River Breeder Reactor Program by 50 percent ensures that the United States will take a back seat while France, the Soviet Union, Britain, West Germany, and Japan continue to lead in nuclear breeder technology. The committee not only chopped the breeder budget from $150 to $80 million, but it tacked on a little publicized amendment to the budget authorization that prohibits spending any of this money on construction. By putting the Clinch River project in cold storage, the congressional vote gives a big boost to Energy Secretary James Schlesinger's efforts to cut off the nation's future energy supplies and to cut energy consumption.

The Importance of Clinch River

As an insider in the U.S. Liquid Metal Fast Breeder Reactor (LMFBR) development program for over 15 years of my career as a nuclear safety expert, I am well aware of all the criticisms of the fast breeder, including the hogwash "technological turkey" charges leveled against Clinch River.

The fact is that Clinch River is a prototype *demonstration* fast breeder power plant and is not designed to produce power competitively with currently operating light water reactors (LWRs) or coal-fueled power plants. No prototype demonstration plant could perform such miracles nor would a competent program even try.

The Clinch River breeder was designed in 1971 as a joint project by the U.S. Energy Research and Development Administration and a group of U.S. utilities to demonstrate that the breeder reactor is safe, that it would operate and produce power for long periods with minimal down time, and that it would successfully breed new fuel (although this was of lesser importance since it has been demonstrated many times before). Perhaps most important, Clinch River was designed to proof-test major new full-sized reactor components and equipment that heretofore have not been tested on the scale required.

Clinch River's primary goal is to establish new technologies in a new operating environment (that is, 1,000

COSTS OF ENERGY PRODUCTION

FUEL PRODUCTION

Energy Source	Capital Costs ($billion per MBDE)	Labor (jobs/MBDE)	Cost ($/BBL)	Price ($/BBL)	Rate of Profit (% per annum)
Coal	3	10,000	1.10	2.75	70
Gas	5	15,000	1.40	3.50	40
Oil	13	35,000	3.60	9.00	10
Oil Shale	20	100,000	7.50	19.00	-1 (loss)
Tar Sands	27	140,000	8.50	21.00	-2 (loss)
Coal Gasification	27	170,000	9.00	22.00	-3 (loss)
Coal Liquefication	40	250,000	13.50	34.00	-6 (loss)
Biomass Conversion	80	500,000	27.00	68.00	-9 (loss)

ELECTRIC GENERATION

Energy Source	Capital Costs ($billion per MBDE)	Labor (jobs/GWE)	Cost (cents/KWH)	Price (cents/KWH)	Rate of Profit (% per annum)
Fission	.8	4,000	.9	2.7	40
Coal	.8	5,000	.9	2.7	40
Wind	4	20,000	4.5	13.5	-1 (loss)
Geothermal	6	30,000	6.7	20.0	-5 (loss)
Solar	10	100,000	11.0	33.0	-7 (loss)

KEY

MBDE – million barrels per day equivalent

GWE – gigawatts electricity (million watts). One MBDE energy is sufficient to produce 20 GWE at normal efficiency.

KWH – kilowatt hours

BBL – barrels

Cost is the true cost of production of the finished fuel at point of consumption (that is, refined petroleum). In all energy production technologies, the vast majority of costs is absorbed by capital construction and capitalization (drilling the wells and building the refineries, and so forth.

Price is the fuel or electric price that will return a profit of 15 percent a year.

Profit is the annual gain or loss on capital assuming fuel is sold at current prices ($7 per barrel of oil or energy equivalent; 4 cents per kilowatt of electricity). Note that for the case of petroleum, the price is calculated after refining; for crude oil; the price would be very close to the actual current price of $7 per barrel. Also note that the apparently small losses of the high-cost fuels are not small at all. A loss of 3 percent per annum would lead to a loss of a third of initial capital in a decade; the loss of 9 percent per annum would lead to a virtually total write-off of capital in the same period.

Jobs means mainly jobs involving construction of energy-producing complexes, except in the case of coal-mining, where ongoing labor costs are substantial.

degrees Fahrenheit liquid sodium and high-energy neutron densities) and to gain invaluable operating experience from this relatively large (380 megawatt-electric) LMFBR. As such, the project is an irreplaceable stepping stone to developing the skilled manpower and new technological base for producing a commerical, cost-competitive fast breeder reactor plant in the next few years and for producing fusion-fission hybrids and pure fusion systems a few years later.

New technologies and their practical applications are not developed by chance, but by an expanding technological and industrial base prepared to bring them on line. The U.S. commercial fast breeder design would be based on the experience and knowledge gained through the design, development, construction, and operation of Clinch River. Clinch River will resolve current problem areas, especially in steam generator, fuel element, safety system, and heat transfer system and design so that future commercial plants can incorporate all of the best fabrication techniques, design efficiencies, and component and operational optimizations in the demonstration plant. The result will be an efficient, economical LMFBR ready for mass production.

If the U.S. is to continue as an industrial leader, we cannot afford to delay Clinch River any longer. Clinch River was designed to be on line by 1980. Given the funding delays and based on its construction schedule, even if started up now, Clinch River would not be completed until 1985 or later. (The French, meanwhile, have had a comparable Phenix demonstration breeder in operation for two and one-half years, and they plan to have a commercial Super Phenix on line by the early 1980s.)

Refuting the Lies About the Breeder

The price tag for Clinch River — including all of the development costs to produce the equipment and components and to pay for the tremendous schedule delays — is a modest $2.2 billion. Considering that a current light water reactor goes for $1 billion and that Clinch River will put this country on the road to a fusion-based economy, this is a small price to pay.

As for the nuclear fuel supply question, a recently completed study by the National Research Council and the National Academy of Sciences estimated that remaining known reserves of uranium are *half* those claimed by Energy Secretary Schlesinger and his Ford Foundation think-tank crew — 1.8 million tons

Energy Program

Continued from page 8

fusion-fission hybrid development for commercialization. (One hybrid can fuel 6 to 10 LWR's or LMFBR's.) Complete R and D on first generation fusion reactors and plasma torch technologies.

Early 1990s: Phase out LWR-type constuction. Bring fusion-fission hybrids on line in conjunction with LMFBR's for high efficiency fission production. Begin commercial introduction of first-generation fusion plants. Expand development on second-generation fusion plants and fusion torch technologies.

Late 1990s: Phase in significant amounts of fusion energy from first generation devices. Introduce commercialization of second generation reactors plus fusion torch technologies.

Early 21st century: Full transition to the fusion economy based on advanced fuel cycles and integrated, fusion-based extraction and production technologies.

The key criterion for selecting an energy technology is *energy density flux,* the rate at which energy flows through a given surface. Energy-dense technologies are *low-cost* technologies because they involve less material, less capital investment, and less labor for the production of a given amount of energy. Such sources have a high inherent rate of *social profit*. That is, for every dollar invested in such an energy source, a much larger amount of wealth is made available for the growth of the economy as a whole. For every job required to increase energy production, four or five jobs are created by the availability of the energy produced. Thus even greater wealth is available for further investment in more energy growth and more general growth of the economy. With energy-dense technologies the cost of energy drops, and the profitability of industry and levels of real wages in the economy as a whole rise.

Conversely, with low-energy-dense, "soft" technologies the opposite is the case. Energy must then cost more, because more labor, capital, and material is required for its production. As labor productivity declines (production per capita), so does consumption per capita, that is, real wages. Soft energy technologies have a *negative* rate of social profit, because they require more of society's total wealth than they produce. Therefore their implementation does not create growth, but promotes the overall collapse of the economy.

The table shows exactly which technologies fall into each of these two categories. The low-cost, energy-dense technologies are fission, gas, coal, and oil — the presently used power technologies. They are used precisely because they are the cheapest available for the period before thermonuclear fusion power comes on line. In electric generation, fission and coal are closely comparable and, on a national average, produce energy at a real (uninflated) price of only about 60 percent the present market price for electricity. This gives some indication of the amount the economy already pays for the overpricing of fuels. The real rate of profit on these sources is very high, above 40 percent per year, currently shared out among the mining companies, the utilities, and, above all, the banks which finance both. This rate of profit indicates how rapidly new wealth can be plowed back into the economy through the expanded use of these energy sources.

compared to Schlesinger's admittedly exaggerated estimates of 3.7 million tons. Taking just the *current austerity rates of growth*, these known reserves leave the world with only a 20-year supply of uranium-235.

The development of Clinch River would end this question of fuel scarcity and high energy prices: Once in operation, the commercial fast breeder reactor and its immediate successor, the fusion-fission hybrid, will expand the present amount of fission fuel supplies well over 200 times by converting the now available but unsuitable uranium-238 and thorium-232 to fissionable plutonium-239 and uranium-233, respectively.

Another bugbear is that fission fuel equals weapons. Since 1949, the claims that nuclear power inevitably leads to the proliferation of nuclear weapons has been disproved to the point that antinuclear arguments today based on nonproliferation of weapons have to be a cover for something else — energy control. It was concluded in the 1950s and reconcluded many times by scientists since then that any nation determined to make a bomb can do it. Such a nation does not need a multibillion dollar power plant system. Furthermore, the low-enriched uranium-235 atomic bomb recently detonated at Los Alamos National Laboratory now eliminates the myth that plutonium had to be stopped since it was the only proliferation producer.

It was also concluded in the 1950s and it is still the case today, that world economic development through easy access by all nations to cheap, plentiful energy supplies, particularly nuclear energy, is the only solution to the proliferation of nuclear weapons. For the umpteenth time — 1 second this.

The construction of Clinch River is an important part of a U.S. program to achieve a fusion based economy. Unless the U.S. is to sink to Third World living standards the Clinch River fast breeder program must be implemented now as part of an integrated nuclear development program leading to fusion-fission hybrids and pure fusion systems during the 1990s.

—Jon Gilbertson

Schlesinger *Continued from page 9*

company, Pemex, and six Texas-based gas companies to sabotage the deal by demanding an unreasonable price of $2.16 per thousand cubic feet, the current Canadian price level and far below what Mexico or Canada can reasonably ask for 1979 gas delivery. Schlesinger warned that if Mexico refused to accede, he would instruct the Department of Energy's regulatory agency to block the entire deal. If Schlesinger prevails, 4 percent of the potential U.S. natural gas supplies go down the drain, along with a loan from the Eximbank worth $400 million in U.S. exports to Mexico.

A Back Seat

Unless the U.S. stops the Schlesinger program of nuclear and industrial sabotage, it is clear that the U.S. will have to take a back seat and relinquish its role as a world economic leader. The nuclear industry here, to take one example, is stagnating and facing bankruptcy. Although nuclear power stations are needed to relieve the heavily overloaded U.S. electric power grid, only three new power plants have been licensed to operate this year, a drop from the five plants put on line during 1976. Only four new orders have been placed this year compared with 36 in 1973, and of the 156 plants under construction or on order, 23 have been indefinitely deferred and 4 were cancelled completely this year.

What this means in terms of the nation's economy was laid out in a special report prepared by a leading U.S. nuclear industrial supplier. The administration's war against nuclear power exports will cost this country's economy more than 2 million man-years of high-skilled jobs and over $4 billion in export dollar earnings over the next few years.

International

The World

In the past six weeks, Western Europe, Japan, the East bloc, and the developing nations have launched an unprecedented number of cooperative nuclear technology projects. The proliferation of civilian nuclear deals reflects a new consensus among the majority of the world's political and scientific leaders — with the notable exception of the United States — that human survival depends on an increased use of nuclear power.

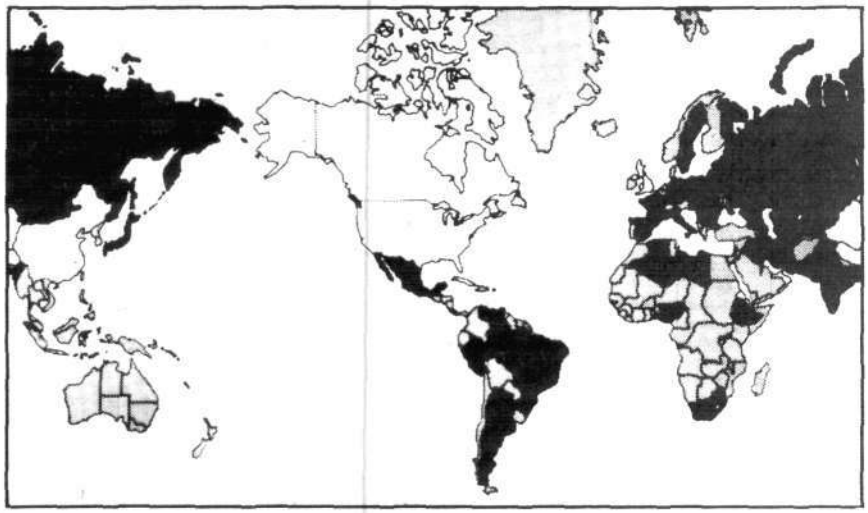
The largest single nuclear deal ever signed took place in early November between the Iranian Atomic Energy Organization and the West German manufacturer of nuclear reactors, Kraftwerk Union. The two signed a letter of intent for the construction of four 1,200-megawatt nuclear power reactors in Iran, an $8 billion deal scheduled for completion in 1983-84. West Germany is now the leading exporter to Iran, and the latest Iranian deal brings to a total of more than $11.5 billion the value of nuclear reactor deals signed by Iran with both West Germany and France in the last year.

Schmidt in the Lead

West German Chancellor Helmut Schmidt took the lead in the world nuclear drive, after a resounding popular mandate Nov. 10 from West German trade unionists in a mass demonstration supporting nuclear power. Schmidt has stressed that a halt to domestic nuclear construction "could be very dangerous for the economy." He has repeatedly stated that if West Germany wants to remain competitive on the world markets, it must maintain the highest levels of technology and a correspondingly high level of wages.

At a Dec. 14 cabinet meeting, the

Goes Nuclear



The world line-up on nuclear power. Countries shaded in black — including the Soviet Union, West Germany, Italy, France, Mexico, and Japan — have announced a national commitment to nuclear power development. Indicated in gray are nations that have yet to announce a pronuclear policy [in many cases because of limited resources] but have made it clear that they are not opposed to nuclear power. The United States, China, and Great Britain are conspicuously antinuclear.

West German government decided to support the completion of three reactors stalled by environmentalist protests and court suits. This means that the government will do everything in its power to get construction going again on the fission reactors at Brokdorf and Wyhl and the fast breeder reactor at Kalkar. The cabinet also decided to support the construction of other fission reactors called for to fulfill the government's goal of 30,000 megawatts of new energy by 1985.

In addition to its deal with Iran, West Germany has a $6.8 billion 1975 deal with Brazil to supply eight reactors and has just confirmed an order with Thailand for the first nuclear reactor in Southeast Asia.

France, Italy Follow Suit

Schmidt's policies have also taken hold in France despite the persistent antinuclear and anti-German propaganda issued by Socialist Party leader Francois Mitterrand and his allies. Typical of the pronuclear forces, Gaullist leader Jacques Chirac, the mayor of Paris, recently told an audience in central France that any moratorium on nuclear power plants would not only eliminate crucial high-technology jobs but would aggravate France's energy problems and wipe out French nuclear export markets.

France has offered nuclear technology to Mexico, and in early December the government negotiated with Egyptian vice president Hosni Mubarak to sell Egypt two nuclear power reactors. European sources also report that France has agreed to supply Morocco with its first nuclear power station.

In Italy, the head of the nuclear energy Center, CNEN, called "delays in nuclear plant construction suicide for energy-intensive civilization." The CNEN official was speaking at an Italian-Soviet conference on energy in Moscow that concluded Nov. 28. The conference set up a joint commission to develop nuclear energy for Italy and to research the feasibility of the fast breeder reactor. The Soviet Union stressed that it was interested in a joint program on the breeder with Italy, France, and West Germany.

According to the Soviet Deputy Minister for Energy Equipment, Italian companies will supply equipment as part of the subcontracts included in the Soviet program to construct 30 nuclear power plants.

The Soviets had negotiated with the Japanese Nov. 15 to supply another four plants. The Soviet Deputy Minister, speaking in Rome Dec. 6, said that the Soviet energy plan called for imported plants to meet the increased energy needs. The Soviet nuclear industry has doubled and nuclear plants will continue to double in output capacity every five years between now and 1990.

In addition to cooperative deals with the Soviets, the Italian state contracting firm for nuclear reactors, NIRA, will aid Indonesia in construction of a heavy water reactor. NIRA will supply uranium-238 and the technology to speed up the construction of Indonesia's first nuclear power plant.

NIRA and another nuclear firm, AMN, also are negotiating contracts for nuclear and conventional power plants with Algeria, Romania, Kuwait, Turkey, and Iraq. NIRA and AMN signed a contract in early December with Atomic Energy of Canada, Ltd. to produce two Candu reactors with Canadian financing.

The Mideast

In tandem with the ongoing peace talks between Israel and Egypt, a nuclear energy conference at Haifa's Technion University Dec. 6 called for a joint Israeli-Egyptian nuclear center in the Sinai Peninsula. Technion professor Shimon Yiftah, president of Israel's Nuclear Sciences Society and a member of the Atomic Energy Commission, proposed that such a center be comprised of several large nuclear power plants linked to large-scale water desalination plants that together could support a giant subtropical farming project to make the desert bloom and serve as a model of Arab-Israeli cooperation.

Der Spiegel

The Dortmund Demonstration: Nuclear Power or the Middle Ages

More than 70,000 West German trade unionists turned out for a Nov. 10 demonstration in Dortmund in support of nuclear power development. The event, the largest pronuclear demonstration to date, marked the turning point in the fight against the West German environmentalists who until then had succeeded in blocking power plant construction.

The demonstration's success was the result of a months-long international effort to pressure the leaders of West Germany's trade unions to fully support the nuclear policies of Chancellor Helmut Schmidt. The U.S. Labor Party had helped organize hundreds of telegrams of support for the Dortmund rally from trade union leaders in the U.S.

Adolf Schmidt, the head of the West German mining and energy union commented on the significance of the event: "Would such a demonstration, such an uncompromising yes to nuclear energy, have been possible six months ago? The trade union rank and file made the difference, and the man in the factory now knows exactly what his future is all about."

French, Italian, and other newspapers commented that the rally was international proof that labor and industry can successfully cooperate in the nuclear fight. In a Nov. 15 article titled "A Nuclear Yes: Spectacular Turnaround in the BRD," the Paris financial daily, *Les Echos* noted that public opinion in West Germany now rightly "associated the extremist and terrorist movement with the action of ecologists hostile to nuclear energy."

Sakharov: Freedom

The following excerpts are from a statement by Soviet Nobel Laureate Andrei Sakharov, a nuclear physicist and a leading Soviet dissident, published in the Dec. 19 issue of the West German weekly Der Spiegel *magazine. Sakharov's article is titled "Political Freedom Only Possible Through Nuclear Energy."*

For quite a long time I have been amazed at the stormy demonstrations of thousands of people, at speeches from well-known and unknown politicians, and at every conceivable kind of campaign launched in the Western countries, all aimed at halting the development of nuclear energy and the construction of nuclear power plants and "fast breeders." I also felt somewhat provoked, but I held back from taking any position in public, especially since there was naturally nothing comparable going on the in the Soviet Union. Nevertheless, I have gradually come to the conclusion that this question deserves to be addressed directly and that I have some things to say about it.

The reason for this antinuclear attitude probably lies in people's lack of adequate information about complicated technical questions. It's not easy to explain to the layman that a nuclear reactor is not a nuclear bomb, or that a coal- and oil-burning power plant is much more dangerous to public health and the environment than a nuclear power plant with the same capacity, or a fast breeder....

The fundamental difference between nuclear energy and energy from conventional fuels, is, first, the extremely high concentration of the nuclear fuel, and second, the small scope of the dangerous waste materials and of the overall process. This simplifies and cheapens the solution of safety and environmental problems in comparison to coal- or oil-generated energy....

Another technical question widely discussed in the literature is the

Depends on Nuclear Development

possibility of theft of the fissionable material from the nuclear power plant or from a chemical metallurgy plant, and its subsequent use in the production of primitive nuclear bombs. As far as the possibility of theft is concerned, I believe that with the aid of appropriate organizational and technical measures its probability can be brought down to a minimum. The plutonium contained in a fuel rod, however, is by no means enough to produce a nuclear device. And in addition to this, no one need envy the thief who decides to steal an irradiated rod out of the nuclear reactor; he will be the first to die from the radiation.

As for the production of a "homemade" nuclear bomb (by small countries), in this matter I ... can assure the reader that it is an extraordinarily difficult thing to do, no less difficult than, for example, the construction of a homemade space rocket. It is very likely that the production of a functioning bomb is rendered even more difficult by the "denaturing" of the plutonium.

The nuclear energy problem has not only technical and economic aspects, but political ones as well. The world's statesmen always act on the assumption — and not without reason — that the quality of a country's economic development and its economic sovereignty is one of the major factors determining its political sovereignty as well as its military and diplomatic power and its international influence.

Such an opinion becomes all the more crucial in a world where two different systems face each other. The level of economic strength, however, is in turn determined by the use of oil, gas, and coal in the present, and of uranium, thorium, and possibly even deuterium and lithium in the future.

This is why I maintain that the development of nuclear energy is one of the necessary preconditions for the preservation of economic and political independence in each country, whether it be for a country which has reached a high level of development or for a developing country.

The importance of nuclear energy is especially important for Japan and the Western European countries. If in the future these countries continue to be more or less dependent on deliveries of fuel material from the Soviet Union and the countries in its orbit, then the West will be living under the constant threat that these deliveries may be halted. The consequence of this will be a degrading political dependence. In politics, one concession always motivates the next concession. It is difficult to predict where this will lead to in the end....

Are the current campaigns against the development of nuclear energy being directed from the Soviet Union or other East European countries? I do not know of any credible information concerning this. If it is so, it would certainly take very little to significantly strengthen this campaign, given the broad distribution of antinuclear prejudices and the lack of comprehension of the necessity for nuclear energy.

People must have the opportunity, but also the knowledge and the right to soberly and responsibly weigh the interrelated economic, political, and ecological problems against each other. Problems related to the development of nuclear energy and the alternatives for economic development must be solved without spurious emotions and prejudices. It is not merely a question of comfort, or of maintaining the so-called "quality of life." There is a far more important question — that of economic and political independence, of the preservation of freedom for our children and grandchildren. I am convinced that in the end the correct solution will be found.

Andrei Sakharov

Mexico Announces Program For Tokamak, Nuclear Power

Francisco Vizcaino Murray, director of Mexico's National Nuclear Energy Institute, INEN, announced in November that Mexico will step up its nuclear training and experimentation program with the acquisition of a tokamak nuclear fusion facility. The INEN director presented a full program of fission and fusion experimentation designed to expand the cadre of trained scientists and engineers in the country. "Nulcear fission is the short-term energy alternative," Vizcaino Murray said, "and fusion energy is the alternative for the medium range and the long term."

Mexico has adopted a program for nuclear energy that foresees supplying a large percentage of electric power generation with nuclear power by the 1990s. The first commercial reactors at Laguna Verde on the Veracruz coast are scheduled to come on line in 1982.

The Basov Speech

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reasonable to use longer laser pulses and moderate light flux (10^{13}-10^{15} W/cm^2), but targets more sophisticated in design. This approach was demonstrated in our report at the Tokyo Conference in 1974. Our installation "Dolphin" is designed mainly for the production of nanosecond pulses. . . .

As we know now the scientists from Livermore laboratory also agree with a principal feasibility of achievement of high fusion yield.

The Reactor Design

As I have already mentioned, the problem of designing thermonuclear reactors is of great importance. Although at the present time there is not enough data for the engineering design, it is necessary to work on this kind of project, because it will help us to discover the lasers and targets needed for the creation of laser fusion power stations. We have such a preliminary project, which was worked out jointly with Moscow High Temperature Institute headed by academician A. E. Sheindlin. Now I shall report some characteristics of this project. We know that similar projects are also being designed in the USA and West Germany....

Efficient transformation of thermonuclear microexplosion energy in one of the types of energy used (electricity, heat, chemical energy, or energy of secondary nuclear fuel) is a complicated engineering problem. In principle, the thermonuclear microexplosion that gives rise to monoenergy particle flux is a unique source of low entropy energy. However, it is extremely difficult to offer adequate schemes for transforming this energy using present technological possibilities or even those of the near future....

A specific feature of laser thermonuclear installations consists in rather high expenses of electric energy for proper needs. So, at laser efficiency of 5 percent, the gain coefficient of the reactor is 100, and the efficiency of energy conversion is of .04. In this case, the proper energy needs for laser thermonuclear power stations are equal to the electric energy delivered to the consumer. Such a high value of proper needs for the laser power station is an order of magnitude higher than a similar value for the up-to-date thermal electric power stations. It reduces considerably the economical index of the laser power stations. Therefore for laser thermonuclear power stations, the problem of using the heat scattered by the laser facilities is extremely important. In our project we have provided a high value of laser energy conversion into electrical energy with the use of a heat transformer. The idea is based on the application of the carbon dioxide laser in which carbon dioxide gas moves with high velocity through the active volume. The temperature of slowing down is of 700°K, and the static temperature in the active region is less than 423°. These parameters allow us to limit the population of the lower laser level and to obtain a sufficient gain coefficient of the laser media. On the other hand, it is possible to use the energy scattered during pumping effectively. The scheme of laser thermonuclear power stations assumes the usage of the laser heat at the first stage of the heat exchanger, that is the usage of the steam generator for heating the water from 543°K to 622°K. The use of the laser heat makes it possible to increase considerably the electric efficiency of laser thermonuclear power stations and to improve the economic index. In our project of a thermonuclear power station, we have tried to combine a unique heat source in the form of a laser thermonuclear reactor with a standard industrial steam turbine....

The economics estimates show that the evaluation of one kW of electric power in laser stations essentially depends on the capital investments in the laser facility, and these are twice as high as the corresponding values of conventional atomic stations. But this value is comparable with that for breeders.

In our opinion, the most promising seems to be a hybrid type of reactor with the blanket on fissionable materials.

By using the energy of fission it's possible to reduce the requirements of the laser facilities, in particular, to decrease the laser efficiency down to 0.2 percent or to reduce the pulse energy. One can also increase the resource of the entire facility, that is decrease the pulse repetition frequency, or simplify the target design, and reduce the cost of the target preparation. The hybrid laser reactor will be a generator of nuclear fuel. It can start to operate with low-enriched fuel.

I shall report some data of the power station on a hybrid laser reactor designed in Lebedev Institute in cooperation with the Institute for High Temperature. In this project we have not changed the energy of the nuclear microexplosion. But we suppose that laser efficiency is lower, say 3 percent, and the used target is simpler in design, and produces a thermonuclear yield of 40. Moreover, the principal idea is based on the use of helium as a heat carrier, which leads to rather high dimensions of the reactor and to the increases in the duration of the fuel burning up. We also suppose that 50 percent of fissionable material should be burned up, and then buried without reprocessing. Nuclear and thermonuclear energy is transformed into electrical energy by means of a helium turbine and a standard steam turbine.

The reactor has a cylindric shape, the "wet" wall is used, the content of fissionable material in the blanket is about 300 tons of natural uranium carbide.

Of great interest are the data on time dynamics of the basic reactor parameters. It is desirable to have a time-constant electric power output of the station. Therefore the increase in the energy gain coefficient of the fissionable blanket due to plutonium storage can be compensated by a decrease in the microexplosion repetition frequency. As a result, the resources of laser and other facilities increase....

Our project of the thermonuclear power station LTB-500 has been presented in the report entitled "Fast Fission and Fusion Reactors" of the International Institute of Applied System Analysis in Vienna. In that report a detailed analysis has been made of various applications of different types of reactors in the areas of energetics, economical estimates, the problem of radioactive waste, risky and accidental situations, fuel and material resources and so on.

In this respect a hybrid laser reactor is not a specific system. But compared to breeders, the laser hybrid reactor is a subcritical state, and unlike breeders doesn't need systems for controlling the subcriticality. The hybrid reactor, in contrast to the breeders, can use fissionable materials with any degree of enrichment; in particular, it can operate on natural uranium. For such reactors there's no problem of redoubling fuel.

We believe that future nuclear energetics should develop in different directions, in order to meet various requirements of national economy. One of the applications of thermonuclear stations is the production of fuel for breeders. If we don't intend to produce electric energy on such a system, that is if we consider a near-to-zero efficiency reactor, then it's possible to reduce requirements toward lasers and targets. At present, we are performing such investigations... .

BASIC PARAMETERS OF LASER THERMONUCLEAR REACTOR	
1. ENERGY OF LASER PULSE	10^5 J
2. LASER EFFICIENCY	5%
3. GAIN COEFFICIENT	100
4. FREQUENCY OF REPETITION OF MICROEXPLOSIONS	10 Hz
5. TYPE OF COMBUSTION CHAMBER	SPHERICAL CAVITY WITH "WET" WALL, RADIUS 5 m
6. TYPE OF BLANKET	HOMOGENEOUS LIQUID LITHIUM WITH NATURAL CONTENT OF ISOTOPES 0.6m THICK
7. HEAT CARRIER	LITHIUM
8. TEMPERATURE AND PRESSURE OF LITHIUM	700°C 2 atm
9. CONSUMPTION OF LITHIUM	390 kg/sec.
10. COEFFICIENT OF REPRODUCTION OF TRITIUM	1.25
RESOURCE OF TRITIUM IN SYSTEM	2 kg
11. CONSTRUCTIVE MATERIALS FOR REACTOR:	
STAINLESS CHROMIUM STEEL (FOR ELEMENTS IN CONTACT WITH LIQUID LITHIUM)	300 t
STAINLESS CHROMIUM-NICKEL STEEL	240 t
12. PROTECTION OF THE REACTOR:	
GRAPHITE REFLECTOR AND MULTI-LAYER BORON CARBIDE ANSORBER	160 t
LEAD LAYER	425 t
13. EVACUATION OF COMBUSTION CHAMBER DOWN TO 1 TORR-FREE FLOWING OUT IN VACUUM	
14. TIME OF EXPLOITATION	2 YEARS

Pure laser fusion thermonuclear power stations with the above parameters have electric efficiencies and costs comparable to up-to-date fission reactors.

Communiqué of Int'l Forum on Nuclear Future

On the occasion of the International Scientific Forum on an Acceptable Nuclear Energy Future of the World, held at Fort Lauderdale, Florida from Nov. 7 through 11, 1977, and sponsored by the University of Miami's Center for Theoretical Studies, the undersigned have considered global energy require-

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Report Fusion Breakthroughs At Atlanta Conf. On Plasma Physics

Scientists from throughout the world discussed major progress in all facets of fusion energy research at the annual meeting of the American Physical Society's Plasma Physics Division in Atlanta, Ga. Nov. 7-11. The overwhelming consensus of the major review papers presented was that almost every approach to harnessing the vast potentials of fusion energy is making significant progress, and many approaches can confidently be projected to be capable of leading to economical power reactors. The chief obstacle, the scientists pointed out, is lack of funds.

The more than 2,000 conference attendees represented virtually every country and laboratory engaged in fusion and plasma physics research in the world.

The most dramatic progress was reported in the development of inertial confinement fusion which utilizes intense beams of lasers, electrons, or ions — and now, as it turns out, BB's.

Dr. John Nuckolls, leading fusion theoretician of the U.S. Livermore Laboratory in Berkeley, gave the most important presentation, an overview of the progress in inertial fusion made over the last year. Nuckolls demonstrated that all of the major scientific and technological problems of harnessing inertial fusion energy had in effect been solved, as outlined below.

*Experimental results both here in the U.S. and in the Soviet Union completely correlated with theoretical computer models.

*New pellet designs in the U.S. and in the Soviet Union based on these models and on already achieved

Communiqué

Continued from page 67

ments for the future and also world development to meet this demand. It was generally agreed that:

1. World demand for energy will increase strongly as the standard of living and the size of presently disadvantaged populations increase over the next several decades.

2. Failure to meet this demand will result in extensive social evil such as poverty, starvation, unrest, epidemics, riots, and wars.

3. No single technology can meet the world future demand. It is likely that all technologies, such as conventional fossil, nuclear fission, nuclear fusion, geothermal, and solar technology will be required to meet the qualitative and quantitative aspects of this demand, just as today no single technology meets all demand.

4. Nuclear fission must play a significant role in meeting world demand over the next several decades, and over this period full exploitation cannot be foregone without excessive risk.

5. An assured nuclear fuel supply of utmost importance to many nations cannot be guaranteed by uranium mining alone. Although the urgency will vary from country to country, in the application of nuclear fission energy fuel reprocessing is essential. Further, the best way to handle spent fuel and to take care of nuclear waste is to reprocess the spent fuel.

6. There are many candidate systems which may be called upon to supplement or eventually replace our presently largely light water reactor technology. These include fast breeder reactors, high temperature gas reactors, heavy water reactors, and homogeneous reactors. Development of these systems should be pursued vigorously on an international basis, although not necessarily all systems in all countries.

7. Practical consideration of the ability to produce and deploy reactors in the numbers necessary dictates that currently successful systems be sustained and their installation encouraged by governments until and unless advanced systems are fully available and acceptable, technically, economically, and industrially.

8. The plutonium-uranium fuel cycle has particular advantages in fast spectrum reactors and the uranium-233 thorium fuel cycle in thermal reactors. Both will need to be developed, including all necessary steps for full implementation.

9. Impressive progress has been achieved toward proving the scientific feasibility of fusion systems based on the principles of magnetic and inertial confinement. Progress has been made also in hybrid systems which suggest, on a longer timescale, economic feasibility. Development of these systems, already involving a considerable degree of international cooperation, should be pursued vigorously on this basis, again, not all systems in all countries. However, the possible successful development of fusion technology should not delay the prudent and necessary deployment of fission technology. It is possible that the first application of fusion technology will be in a hybrid fusion-fission complex.

10. It is recognized that the deployment of fission power or hybrid fusion-fission on a large scale poses problems of safeguard of material against potential diversion, and thus, proliferation of nuclear weapons. We are confident that the international community can and should take the political, institutional, and technical measures which will be effective in diminishing the risk of proliferation while retaining the economic advantages of nuclear power. Therefore,

experimental results, indicate that fusion energy gains greater than 1,000 are obtainable. This means that the chief type of laser currently used in inertial fusion experiments, the very inefficient neodymium glass lasers, can be used in actual laser fusion power plants. (Livermore has already carried out initial tests on the upgrading needed to make this laser suitable for reactor use.)

*New laser fusion reactor designs have essentially solved all of the technical problems: no radioactive waste is generated and the reactors have lifetimes greater than 30 years.

*The prospects for ion, electron, and laser fusion utilizing carbon dioxide gas lasers are similarly optimistic.

*A promising new approach to inertial confinement has been developed using small BB's that are accelerated to great speeds electromagnetically to crush fusion pellets to the needed densities and temperatures.

Nuckolls pointed out that the chief barrier to harnessing laser fusion energy was the lack of funds and national commitment. For example, Livermore has the world's most powerful laser, Shiva, coming on line early next year. This $40 million laser will experimentally demonstrate the new high gain pellet designs, but because of cutbacks by the Carter administration, there are insufficient operating funds to make full use of the laser.

Throughout his presentation, Dr. Nuckolls rebuked David Rose, a notoriously antinuclear nuclear engineer at the Massachusetts Institute of Technology. Rose had published a slanderous attack on fusion energy and laser fusion in particular last year in the MIT student journal, *Technological Review,* and his article was circulated to members of the U.S. Congress during the debates on fusion funding during the past period. In referring to Rose, Nuckolls commented at one point that one should not make final statements about a subject while others are still engaged in their exploration. "We have solved all of the difficulties in the last year which Rose had foreseen as insurmountable."

Rose had refused to debate Nuckolls at this conference and it was learned that when Rose had submitted his paper on fusion to an actual scientific journal, it was rejected because of its distortion of facts.

The conference also heard presentations by Doctors Harold Grad and Fred Tappert of the Courant Institute of Mathematics, among others, that outlined the new scientific frontiers being charted in the course of fusion and related plasma physics research. Tappert, in his invited presentation, outlined the revolution generated in science as a whole by research on nonlinear phenomena, in particular, on the soliton.

An important sidelight to the conference was the raging controversy over the Soviet claims for their high gain pellet designs for inertial fusion. It turns out that the target design of renowned Soviet electron beam fusion scientist Leonid Rudakov not only is unique in its utilization of soft X-rays for driving the implosion of the fusion fuel to high densities, but also is extremely stable during the implosion, making the design many times more effective in terms of achieving higher fusion energy gains.

The controversial Soviet pellet designs and the success of the U.S. electron beam pellet fusion research program in using new, innovative pellet designs — which have major implications for basic science and which were described for the first time at the Atlanta conference — will be the subject of a future *Fusion* article.

—Charles B. Stevens

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we do not believe the risk of proliferation should deter the use of nuclear energy.

11. The probability that accidents in existing reactors will cause harm is acceptably small and we believe, with proper use of experience, that this will diminish even as the number of reactors increases.

12. Solar energy may have a part in the mixed energy system of the future. The extent of its penetration will depend largely on economic considerations. It is difficult to determine finally what these economic parameters will be without practical experience on a substantial scale; at present, the parameters appear to be adverse.

13. Meeting the energy demand of the still rapidly rising world population with legitimate expectations of a higher standard of living calls for large-scale mobilization of labor, materials, capital, and technical and managerial skills. It should be governments' constant preoccupation to accomplish this economically and effectively to avoid overtaking the world's productive capabilities and resources of these necessities.

14. 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.

Signatories

Nikolai G. Basov, P.N. Levedev Physical Institute, Soviet Academy of Sciences, Moscow
Hans Bethe, Cornell University
Karl Cohen, scientific director, General Electric Company, San Jose, Cal.
Floyd Culler, director, Oak Ridge National Laboratory
Robert Hofstadter, Stanford University
Behram Kursunoglu, Center for Theoretical Studies, University of Miami
W. Bennett Lewis, Queen's University, Ontario
Marjorie P. Meinel, University of Arizona
Keichi Oshima, University of Tokyo
Edward Teller, Stanford University
Alvin Weinberg, Institute for Energy Analysis, Oak Ridge Associated Universities
Eugene P. Wigner, Princeton University
Pierre Zaleski, nuclear attache, French Embassy, Washington, D.C.
Edwin Zebroski, Electric Power Research Institute, Palo Alto, Cal.

FEF Milan Conf. Boosts Italian Nuclear Fight

The Fusion Energy Foundation's conference in Milan, Italy Nov. 7-9 on "World Development and the Role of Nuclear Power" drew 120 persons, including industrial representatives, scientists, diplomats, government officials, and journalists from Italy, France, Sweden, West Germany, and the USA. The result of months-long organizing among European proponents of nuclear power, the conference provided the Italian pro-development forces with the scientific information and programmatic conceptions necessary to join their counterparts in West Germany and France in the fight for fission and fusion technologies.

How the conference presentations helped set the pronuclear Italians back on the offensive was made clear in the open roundtable on "Energy and Environment" Nov. 8, the session that drew the largest attendance of the conference. Professor Gianfranco Cicognani, director of the fast breeder division of Italy's National Nuclear Energy Center, keynoted the session by stating that fusion can be available commercially by the end of this century and that the fast breeder is an essential phase in the transition to fusion. Cicognani's remarks contrasted to the defensive postures and pessimism about fusion prospects — some expressed earlier in the same conference — of Italian breeder advocates, who have been terrorized by the ecology movement in Italy and the impact of U.S. Energy Secretary Schlesinger's international anti-breeder campaign.

One of Italy's three nuclear fission power plants.

When local ecologists denounced as "dangerous" plans to go ahead with nuclear power projects crucial to Italy's economic recovery, Cicognani demanded that the environmentalists document their claims. Another panel member, Senator Luigi Noe of Italy's ruling Christian Democratic Party and of the European Parliament's Health, Consumer and Environmental Protection Commission, joined with Cicognani in defending nuclear power.

The pronuclear standpoint was reinforced in news coverage of the meeting by *Il Giorno* and *Avvenire*, Milan newspapers of national circulation. *Avvenire*, a Catholic daily, quoted the FEF's European director Hans Bandmann: "There is no alternative to fast breeders and fusion...financed by an international development bank...rapid development of nuclear energy technology represents the only great hope for European industrial recovery." The French weekly *Le Point* took the discussion back to France with a full page report heralding fusion as the unlimited energy source of the future.

In other sessions, Italian experts who act as advisors to the government elaborated on the urgency of the energy-dense technologies that fission and fusion uniquely represent. Nuclear physicist Mario Silvestri of the Milan Polytechnic Institute demonstrated, using mathematical equations, how the "soft technologies" beloved by the ecologists, such as wood burning and wind power, often consume more energy than they produce. Silvestri is energy advisor to the governmental Italo-Soviet trade delegation. Leonardo Biondi, of the R and D section of the partially state-owned petrochemical corporation Montedison, outlined the use of existing energy resources while the transition to fusion power is underway.

Developing a "Zone of Peace"

During the session on "Energy Policy and World Development Policy," Hans Bandmann, Dr. Helmut Bottiger, and Ralf Schauerhammer of the FEF's West German chapter described perspectives for the type of economic growth likely if Italy accelerated energy-trade negotiations with the Mideast-North Africa region. By aiding efforts to rapidly industrialize that region, Italy would take a leading global strategic role, contributing to the creation of a Mediterranean "zone of peace" and fostering economic recovery for Western Europe.

Dr. Johannes Horn, a West German industrial consultant, presented an economic survey based on the demands a newly developed Middle East would place on Western Europe. "Scientific stagnation and industrial decay would end," Horn asserted. "Eventually, development in the Mideast and North Africa would allow Italy and the rest of Europe to concentrate on exporting specialized equipment and machine tools."

FEF representatives stressed, however, that the austerity-oriented international economy casts an unfriendly eye on nuclear energy development. The realization of fusion power and the ability to unlock the rich resources of the Middle East and Northern Africa depends on the ability of the Fusion Energy Foundation and its collaborators to establish government support for growth.

Although most conference participants shunned public discussion of the politics of nuclear energy, in private FEF Director of Nuclear Engineering, Jon Gilbertson, who was on hand to represent the U.S. foundation, was plied with questions on "Is the United States' energy policy really antinuclear?"

— Nora Hamerman

Research

Poles Create Fusion Using Explosives

The director of the Polish Institute for Theoretical Engineering announced at an October conference on laser fusion in Oxford, England that his institute had created a fusion reaction in deuterium gas using chemical explosives to supply the energy required for heating and compressing the deuterium fuel. The disclosure by Dr. Sylvester Kaliski to scientists at the 11th European Conference on Laser Interaction with Matter is a major experimental breakthrough with critical military applications. It promises to have the same stunning impact on the Western scientific community as that of Soviet physicist Leonid Rudakov when he unilaterally declassified portions of the highly successful Soviet electron beam fusion program 18 months ago.

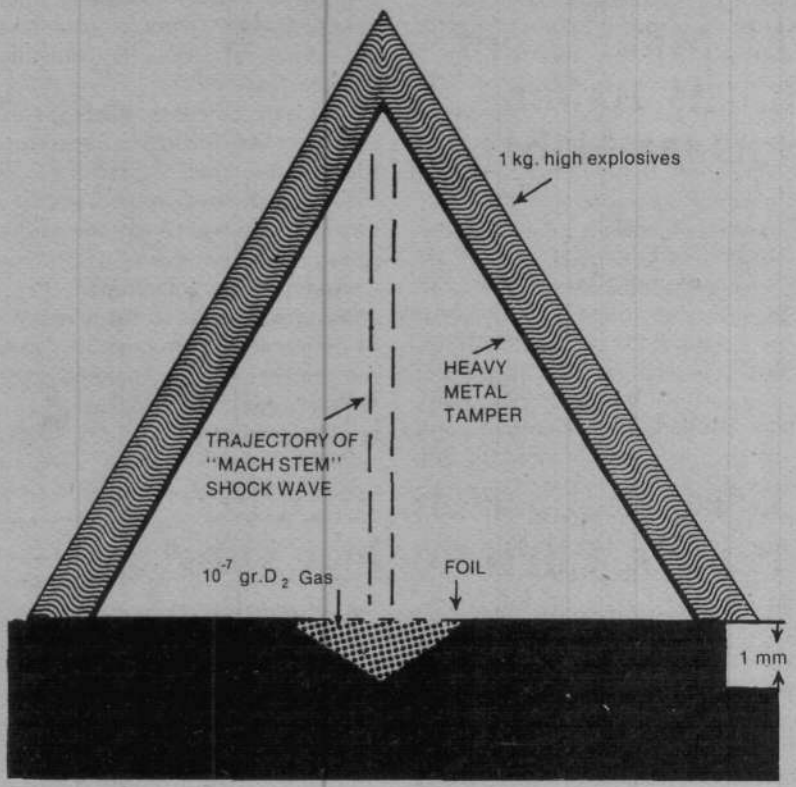
The Experiment

In what Western scientists described as a "brilliant and daring" experiment, Kaliski and his group used a charge of approximately one kilogram of high explosives (about 2.5 pounds) to create temperatures of 5 million degrees and pressures thousands of times that of the atmosphere in a small sample of deuterium gas. Deuterium is the heavy form of hydrogen that undergoes a nuclear fusion reaction in which two deuterium nuclei combine to form helium. The fusion reaction releases tremendous amounts of energy.

Kaliski's experiment resulted in close to 30 million fusion reactions, approximately the same amount achieved by the multimillion dollar carbon-dioxide laser facility at Los Alamos scientific laboratory in New Mexico.

The key to Kaliski's experiment is the unique configuration of fuel and explosives. By the use of an elegant and simple application of well-known explosive technologies, the Poles scooped similar efforts in the American laboratories.

As the accompanying figure shows schematically, Kaliski's experiment takes advantage of a highly symmetrical arrangement of high explosives that forms a shock wave of incredible energy density, driving vertically down onto the target of deuterium fuel, compressing and heating it. The other critical ingredient is a very carefully machined and engineered cone of high explosives. Kaliski's group had to machine the cone within a tolerance of 1 micron (approximately half a millionth of an inch) in physical dimensions, and carefully check by X-rays the explosives to ensure uniform ignition.



THE POLISH EXPERIMENT

About one-tenth of a microgram of deuterium gas, at 1.2 atmospheres pressure with 9 percent argon added, is implanted under the foil in small depression in a large anvil. Then, a double conical shell is suspended above the fuel. The inside of the shell is a heavy metal tamper that carries the momentum of the cone of high explosives surrounding the tamper. When the shell of high explosives is ignited, a convergent shock wave, called a mach stem, is formed that drives vertically down on the deuterium gas, compressing it by a factor of 1,000 in volume and heating it to about 500 electron volts, for about a billionth of a second.

What It Means

The main drawback to fusion energy for both weapons and peaceful use is the tremendous energy required to ignite the fusion reaction. Once it is ignited, the fusion process releases astronomic quantities of energy, but so far it has required either *atomic bombs* for ignition (in the case of the hydrogen bomb), or very large and

expensive electrical or laser devices (in the case of peaceful use of fusion.)

Because of the relatively small expense involved and lack of bulky energy storage devices, the use of chemical explosives for fusion would be very attractive and Kaliski's work represents the first, significant development toward making this a possibility. Kaliski estimated the cost of one trial experiment at $500.

There are significant problems still to be solved, however, scaling up the Polish experiment for large-scale fusion energy production, primarily in devising a geometry of explosives and fuel that eliminates the need for an anvil.

Of immediate importance is the military implication of these results. Kaliski has created the first stage of a real "neutron bomb." As is well known, the source of longlasting and "dirty" radioactivity in a hydrogen bomb does not come from the fusion reaction that supplies most of the bomb's energy, but rather from the plutonium (fission) bomb used to ignite it. If the plutonium could be eliminated, the bomb's energy would be released primarily in the form of neutrons from the fusion reaction.

This neutron bomb has been touted recently by the military strategists of limited or tactical nuclear war, who hope that since the neutron bomb creates little fallout, and can be very small, we can have "little nuclear wars" — a concept the Soviets correctly have likened to the case of the virgin who was only a little pregnant.

Kaliski's announcement of the East bloc's breakthrough in fusion research is clearly seen by the East bloc as relavant to the debate over the neutron bomb in the United States. The Soviet Union has vociferously condemned the concept of a small, neutron bomb nuclear war. At the same time, Kaliski, who is also Poland's minister of science, visited Moscow for discussions with Soviet officials and received an honorary doctorate from the University of Moscow. Immediately afterwards, he left for Oxford to announce the results of his experiments.

In the U.S.

Reaction among U.S. scientists to the "Kaliski affair" so far has been shocked silence. While scientists will privately marvel at Kaliski's brilliance and at the striking success of his experiments, the political and military implications have them stunned. At the very least, it is unnerving to hear a Polish leader giving away information on military research which is so classified in the United States that it has not yet been attempted.

If the U.S. wants an arms race intensified with the development of new technologies, then Kaliski, as Rudakov did before him, has shown that the U.S. is dangerously behind. On the other hand, the Director of the Soviet Fusion Program, Dr. Velikhov, proposed to the U.S. fusion and weapons laboratory at Los Alamos, the same week that Kaliski was in Moscow, that the U.S. and the Soviet Union collaborate on a brute force, crash program for fusion development. That is the choice for the U.S.

— Dr. Steven Bardwell

DNA Researchers Produce Human Physiological Substance

Researchers at the University of California at San Francisco have used the technique of recombinant DNA to accomplish the bacterial production of a human physiological substance previously attainable only through highly expensive and time-consuming methods. The successful experiment brings scientific research to the threshold of a new stage of medicine, industry, and agriculture.

The research team headed by Dr. Herbert Boyer produced the neurohormone somatastatin, a substance produced in minute quantities by the brain. Somatastatin acts on the pituitary gland, found in another part of the brain, which in turn secretes hormones that directly affect almost all bodily functions. Since the pituitary gland is known as the master gland, and the secretion of somatastatin by the brain inhibits pituitary secretion, somatastatin can be called the "master" of the master gland.

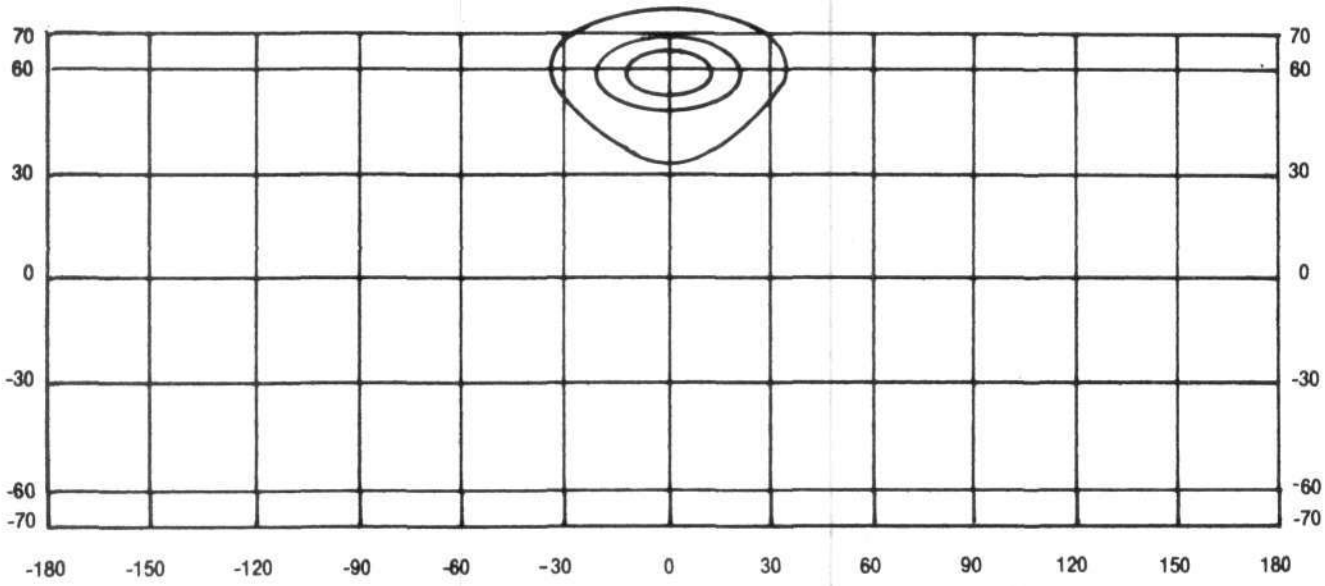
Boyer's team produced 5 mg of somatastatin using 2 gallons of bacterial culture produced by recombinant DNA. (For a detailed description of the DNA process see *Fusion*, October-November 1977.) The researchers synthetically made the gene for somatastatin by linking together various parts of DNA into a particular sequence, attaching this artificial gene to certain bacterial genes, and inserting this recombined DNA into a host bacterium. As the engineered bacteria reproduced, they made copies of the recombinant DNA as well as their own DNA; and in addition, they metabolically synthesized the product for which this recombinant DNA coded.

Previously, to obtain 5 mg of somatastatin it was necessary to collect the material with great difficulty from 500,000 sheep brains.

The head of the U.S. National Academy of Sciences called the accomplishment of the Boyer team "a scientific triumph of the first order." the first time that bacterial cultures with deliberately chosen "foreign" DNA manufactured the substance for which this DNA coded.

The successful experiment now provides the solid basis for utilizing the recombinant DNA technique in areas such as the production of antibodies specific for particular disease-causing agents, treatment of genetic and congenital malfunction, the production of difficult to obtain substances for industry, and the genetic engineering of plants and animals for enhanced productivity.

The promising results of the Boyer team came under immediate, hysterical attack by the environmentalists as dangerous and leading to the creation of "monsters" in the laboratory.



THE GEOSTROPHIC VORTEX CIRCULATION PATTERN

The dominant feature of the FEF climate model of circulation in the earth's atmosphere is the geostrophic vortex in which the vortex has the elongated cross section shown above. The energy for this vortex motion is supplied by the water cycle in the biosphere that drives a localized circulation pattern like that above. The computer model designed by the FEF uses idealized mathematical equations to stimulate the climate-determining features of the interaction of these vortices in the biosphere.

Climate Modeling: A Report on FEF Research

Doing something about the weather — and not just complaining about it — is an essential concomitant of fusion energy. A fusion economy makes such "planetary engineering" absolutely essential because it will require the consumption of tremendous quantities of energy and rapidly expanding agricultural production.

The extreme effects visible today of the stagnation of energy output and consumption pose the long-term problem sharply. The present drought in California, the desertification of sub-Sahara Africa, and the deforestation of Brazil are interconnected manifestations of a global *devolution* caused by insufficient investment and energy use.

Brazil is the most shocking case. Austerity policies mandated to increase Brazil's debt-paying ability, have forced the Brazilians to cut down approximately 250,000 square kilometers of Amazon jungle to clear land for raising cattle and to provide charcoal for fueling the steel industry. This latter idea, for readers unfamiliar with the ecology movement, is called *biomass conversion*, a technology that disappeared in industrialized countries several hundred years ago.

The global effects of this policy, have been devastating, most markedly in the case of Brazil. As the FEF documented qualitatively in Jan. 1976, there is good evidence that the dislocation of weather patterns in the northern hemisphere — the European drought last summer, the abnormally cold winter, and the California drought — are all traceable to the consequences of the Brazilian deforestation and its effect on the highly nonlinear system of global circulation.

The FEF began a research project six months ago to quantitatively elaborate the model originally proposed by FEF physics director Eric Lerner that described the earth's climate as a nonlinear resultant of the biospheric and atmospheric dynamics. This model is based on an analogy with the sort of nonlinear evolution that characterizes a plasma. The energy flow determines the rate and direction of time evolution in the system, but this energy flow is critically mediated by a self-created structure within the atmosphere.

In the numerical model now under development by FEF researchers, the energy flow is modeled by a set of equations that link the precipitation and evaporation of water with the strength of circulation in the region. The self-organized structure that transforms this biospherically supplied energy is the so-called geostrophic vortex, a persistent

circulation pattern, several thousand miles wide, that dominates global climate.

The computer model, now in its third stage of modification, employs a new, approximate form of this vortex motion, with a noncircular cross-section to supply latitudinal stability. The accompanying graph shows profiles from one such vortex, centered at 60° N latitude. The FEF team is now studying the hydrodynamic interaction of a collection of these vortices to gain insights into the dynamics of the self-ordered structure of climate change.

The next steps in the research will involve the inclusion of viscosity (friction) in the hydrodynamic model, followed by the coupling of the biospheric model, to produce a system of equations that should reproduce some of the major features of the world's pleasant climate. These results should be the first approximation to solutions that will allow us to reverse the deforestation in Brazil (by restoring normal weather there) and to remedy the California drought.

Arctic Gas Reserves

The *Gas Supply Review*, a publication of the American Gas Association, reported that there is an estimated 30 quintillion (10 to the 18th power) cubic feet of gas in the cold regions of the earth. The gas is in a hydrated form—molecularly bonded with water and frozen. Quoting United Nations sources, the *Review* noted that the Soviet Union has successfully demonstrated production of natural gas from this type of resource. The Arctic gas reserves are more than 5,000 times the world's proven reserves of oil and natural gas combined.

Agricultural Discoveries Increase Plant Growth

—The recent discovery of a new, naturally occurring plant growth regulator, a potent alcohol called triacontanol that is present in the leaves of many plants, has led to extensive field testing over the past summer, with very promising results for increasing agricultural productivity worldwide. Michigan State University horticulturists found that yields of a variety of crops, including cereals and vegetables, were increased as much as 63 percent by applying minute quantities of the compound as a foliar spray, seed treatment, or soil additive.

The mode of action of the compound is not yet fully understood. The postulated mechanism for the astonishingly rapid rates of acceleration in growth has to do with the partial reversal of respiration and transpiration by interaction of the polar lipoidal structure of the molecule on the plant's membrane.

Leading chemical manufacturers, including American Cyanamid, Inc., are now preparing for widespread marketing of this easily synthesized compound.*

—At Pennsylvania State University, agricultural researchers have conducted successful experiments for the practical use of thermal heat from electric power generating plants for continuous soil heating to increase crop productivity. Results have shown that soil warming speeds crop development and would allow for double cropping because of the early maturity and harvest of the first crop. Warm season crops, with adequate moisture, produced higher-than-normal yields on heated soils.

* "Triacontanol: A New Naturally Occurring Plant Growth Regulator," in *Science*, March 25, 1977.

Nuclear Power Is Safe:

Facts Versus Environmentalist Fiction

Nuclear power is the safest and cheapest energy production method known to man, yet the environmentalists are spending millions of dollars to convince Americans that nuclear power is bad for their health. In the absence of scientific evidence, this well-bankrolled campaign depends on the ignorance and fear of the population and the press conduits that feed on this ignorance and fear. To arm the population with nuclear knowledge, this article presents the facts that refute the six most frequent lies of the environmentalists. We urge readers to pass on this fact sheet to their local papers, community newsletters, schools, and workplaces to ensure that more Americans learn the truth about nuclear power.

[1] **The "Bomb in Your Neighborhood" Myth**

The implicit argument of many environmentalists is that a nuclear reactor is an atomic bomb just itching for a chance to blow up. *This cannot happen.* An atomic bomb requires a precisely machined spherical volume of about 90 percent pure uranium-235 or plutonium-239 metal. Furthermore, the sphere must be of a certain minimum size or it cannot explode. The two halves of the sphere must be brought together by high explosives, and some mechanism must be provided to keep them together long enough for the explosion to occur or they will recoil before anything serious happens.

A nuclear reactor uses uranium or plutonium in the form of oxides, not metals, and the concentration of the active fissile materials ranges from 0.7 percent in the Canadian CANDU reactors to from 3.5 to 7 percent in American light water reactors. There are no conceivable conditions of reactor core meltdown or system failure that could spontaneously purify and concentrate the active uranium or plutonium isotopes in metallic form and cause an explosion.

[2] **The "We Almost Lost Detroit" Myth**

Another myth propounded by the ecologists is that the slightest malfunction in a reactor or its peripheral equipment automatically will result in the release of uncontrollable amounts of radioactive materials. As the myth goes, bodies will pile up in the streets, whole states will become radioactively uninhabitable, the planet will be rendered biologically inert.

Consider the fact that a nuclear reactor vessel is made of solid steel from 6 to 11 inches thick, weighing up to 450 tons. It is sealed and its only openings are welded pipe connections for the multitude of back-up cooling systems designed to complement each other in controlling the temperature of the reactor. Emergency shutdown control rods are activated—by gravity — at the first sign of a heating problem. The main building, the familiar dome, is a marvel of impregnability. The walls are 4-feet-thick, reinforced steel-lined concrete, and it is designed to withstand earthquakes, hurricanes, tornadoes, and jet liner crashes.

Imagine that the worst were to happen. If an accident prevented cooling, the worst thing that could occur — and that with infinitesimal probability—would be that the reactor core melts. The core would drop to the bottom of the vessel, the heat from decay of fission products would melt the vessel, then the concrete floor beneath it, continuing into the soil beneath the foundation. After melting for a few feet into the ground, the material would be sufficiently dispersed to stop long before it got to China.

Now, suppose that a vent miraculously opened so that radioactive gases—the solids would stay put as is their wont—enter the open air. Most probably, they would merely dissipate, and that would be the end of it. But let's call in a light breeze in the direction of a large population center and a temperature inversion capable of trapping the gases at low altitude.

In such a hypothetical catastrophe the probable number of fatalities is none, and the mean number is two. In general, the likelihood of such a death occurring is about the same as a man in the street being killed by a meteor.

These numbers are not made up. The Atomic Energy Commission has spent millions of dollars commissioning experts to determine the effects and probabilities of nuclear accidents. Their results have all been published as the Reactor Safety Study, better known as the Rasmussen Report.

No serious investigator will claim that a nuclear accident is impossible. It is definitely true, however, and a valid comparison, that large-scale nuclear energy production is far safer than any other method yet known to man.

[3] **The Pollution Myth**

In comparison to energy production using coal for fuel, nuclear energy is responsible for only .01 (one one-hundredth) the number of fatalities per unit of energy produced. The long-term effects of black lung disease and hydrocarbon pollution from fossil fuel burning are known to cause thousands of deaths in the general population. By comparison, the radioactive emissions from a nuclear plant under normal operating conditions are trivial.

To understand this, it is necessary to examine normal background radiation in the environment. There are radioactive materials everywhere on the earth's surface. Naturally occurring uranium, radium, and so forth, are continuously emitting radiation. Cosmic radiation contributes significant amounts and is stronger, doubling in intensity with every mile of altitude above sea level. Measured in units of biological

or Roentgen Equivalent
average U.S. resident is
from 50 to 160 millirems
of a rem) per year of
entirely from naturally
sources. Radiation sickness
deaths can occur from a
rems a thousand times
background dose. A
reactor adds only about .01
per year to this naturally
dose, that is about an addi-
thousandth of the dose for
nuclear plant. At that
000 nuclear plants were
the U.S., with no im-
radiation containment,
addition to the average
radiation would be
same amount that he re-
medical X-rays—about
per year.

"Up to Our Middles in Myth

theme of the en-
alists is that nuclear
produce massive amounts of
active waste that there is
safe way to dispose of
and that the waste will be
now until doomsday.
different. If the whole
tion of electricity
nuclear plants from now
the century, the total
radioactive waste would
a cube no more than 250
waste material has an
ay rate so high that if it
to sit for 10 years, 99.9
would transmute to stable
Furthermore, it is not all
reprocessing spent fuel
icant amounts of fuel
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be recovered and
useful sotopes can be
Research is underway to
ods of using the radiation
and efficiently purify both
sewage.
ing that some materials
moved from the en-
a significant period of
can be done. Techniques
continuously being improved.
scientists have devised
a way of embedding wastes in borosilicate glass, which is fireproof, waterproof, and earthquake proof. This material can be put into deep salt formations, for example, and remain out of the way for the indefinite future.

Another possibility, which can be realized once fusion reactors are available, is to subject radioactive wastes to intense neutron bombardment, the very process that created them. As more neutrons are absorbed into the nucleus, a long-lived radioactive isotope can be transmuted to one with a shorter half-life, or to a stable one.

Another much touted waste problem is what to do with a reactor when it has outlived its usefulness. Some nuclear critics claim we will have these tombstones on our landscape for the next 150,000 years. Again the solution is straightforward. When a reactor has become obsolete, all the radioactive parts can be removed, such as the reactor vessel and any other peripheral equipment. Most of the metals can be recycled with no special treatment since they are not radioactive. The radioactive materials will be dealt with as described above. The building itself can be torn down, or new active components can be built into it.

How absurd to assume that a society that prides itself on its scientific and technological achievements will sit around for millenia and stew while a relatively simple problem such as this one goes unresolved!

[5] The Nuclear Terrorism Myth

The threat of nuclear terrorism is a political, not a technical question. If any terrorist group gets access to plutonium or to a bomb, it will not be as a result of the group's ingenuity and scientific expertise. It is now well known that the terrorist groups who have threatened nuclear terror, like the Baader Meinhof gang in West Germany, are spawned and controlled by intelligence networks to carry out destabilizations against prodevelopment governments or factions of governments. If such a group of zombies is actually given the wherewithal to create nuclear havoc, it will be because elements of the military or intelligence services have decided upon such an atrocity. No group could produce a bomb without such help.

The only way to combat this potential menace is to root out the terrorists at their source as West Germany and France are doing right now.

[6] The Proliferation Myth

A still classified report from the Oak Ridge National Laboratory in Tennessee shows that virtually any country with the capability to run a nuclear reactor could also in a very short time construct the facilities to purify reactor fuel to that concentration of fissile material necessary to make an atomic bomb. The Carter administration has been arguing that by withholding reprocessing equipment for nuclear fuels, countries could be delayed, but only by two years or so, in creating bomb-grade material. As the Oak Ridge and other Studies show, stopping reprocessing plants will not stop proliferation.

Again the question is political in nature. The existence of poverty among nations produces the conditions under which the development of advanced weapons systems seems desirable. A program of rapid nuclear fission and fusion energy development on a world scale can provide cheap energy and consequently higher living standards, abundance of resources, the material well-being to defuse the tensions leading to nuclear confrontation. The final solution lies in fostering the total conditions that will allow the development of humanist republics. No nuclear technology, nor any other for that matter, is inherently evil: We must decide how it will be used.

—Dr. John Schoonover

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FEF News

Carol White

COLUMBIA SYMPOSIUM ON ELECTROMAGNETIC FIELD THEORY

The FEF club at Columbia University sponsored a symposium Dec. 8 in honor of the coming publication of the book *Energy Potential: Toward a New Electromagnetic Field Theory* by Carol White. The event, which drew an audience of 200, is part of the FEF series of classes and lectures designed to provide the general population with the scientific education necessary to move the U.S. into the age of fusion power.

The speakers who discussed their ongoing reserach work included Dr. Winston Bostick of the Stevens Institute of Technology, Dr. Eric Schwartz of the New York University, Dr. Philip Lorio of Columbia University, Uwe Parpart and Carol White of the national executive committee of the U.S. Labor Party, and Dr. Morris Levitt and Dr. Steven Bardwell of the FEF. The presentations, which will be covered at more length in the next issue of *Fusion*, were enormously successful in drawing the audience into the excitement of scientific breakthroughs in accordance with the thesis White had put forward in her talk: "All scientists who made fundamental discoveries were political in the sense that they fought for a coherent view of the universe that included human beings."

LANSING CONFERENCE LAUNCHES MICHIGAN FEF TOUR

Lobbyists from several industries, the Farm Bureau, the Chamber of Commerce, and the Bankers Association, a Republican state senator, and 12 students from Michigan State University were among the participants in an FEF symposium in Lansing, Michigan Nov. 17 on the necessity for the crash development of fusion and the full funding of nuclear technology. The well-attended forum launched a statewide FEF tour by Dr. Morris Levitt.

One of the highlights of the Levitt tour was a debate on a popular Detroit radio show on the ABC affiliate WXYZ with the raving zero-growther Mary Sinclair. Of the dozens of listener calls after the debate, not one question was addressed to Sinclair.

Dr. Morris Levitt

LEVITT ISSUES OPEN LETTER ON NONPROLIFERATION ACT

Dr. Morris Levitt, executive director of the FEF, issued an open letter to Congress Dec. 3 to counter charges by supporters of the Nuclear Nonproliferation Act (S 897) that increasing nuclear technology means increasing the danger of nuclear war. "At the present juncture in world history, nuclear power is one of the most valuable weapons we have for world peace and development," Levitt wrote. "A strong dollar and a healthy world economy can be achieved only by simultaneously building up the basic productive capacities of the advanced sector and the markets represented by an economically developing Third World. Nuclear power exports meet that need by generating demand for basic industry....Could it be any clearer that the threat of nuclear war is to be located properly in the failure to proliferate civilian nuclear power and concomitant industrial and agricultural development?"

The letter debunked claims that civilian power reactors produce weapons-grade material and calls for the defeat of S 897 in its present form.

To obtain copies of Levitt's statement, send $1 and a stamped self-addressed envelope to the FEF, GPO Box 1943, New York, N.Y. 10001.

60 ATTEND TORONTO FEF CONFERENCE

"There are tens of thousands of people, a clear majority today in Canada, ready to join the fight for nuclear energy and world development — if that fight is given leadership," Dr. Morris Levitt told an FEF gathering in Toronto Nov. 4. The conference, the first in the foundation's 1977-78 season, focused on the FEF white paper "An Energy Policy for North America."

"All the present trouble in Quebec and the 'for Canadians only' energy policies will be overcome only with a continentwide program for expanded industrial and energy production," the FEF executive director said.

Among the 60 persons at the conference were representatives of four of Canada's largest mining groups, the Toronto International Brotherhood of Electrical Workers, and the Quebec Building Trades.

The Toronto conference concluded a week-long Canadian tour by Levitt and two other FEF members, nuclear engineer Jon Gilbertson and plasma physicist Dr. Steven Bardwell. The three spoke before numerous college audiences, met with media representatives in Montreal and Toronto, and held meetings with collaborators in industry, trade unions, the government, and the universities.

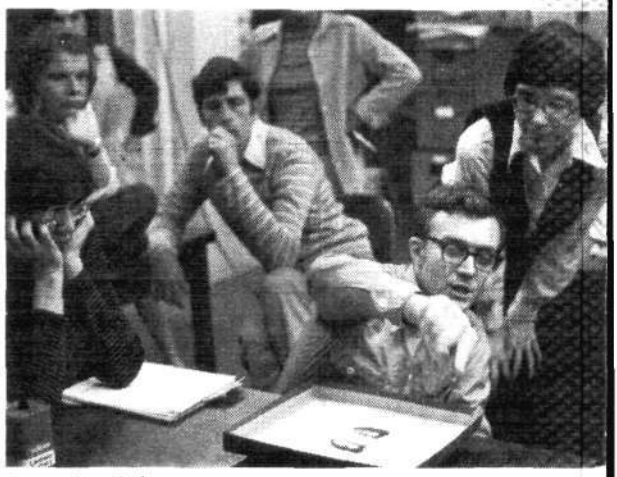
The FEF tour received widespread press and radio coverage, including a feature article in the *Montreal Star*.

FEF CAMPUS RECRUITMENT: A SCIENTIFIC RENAISSANCE

There are FEF chapters on 10 college campuses with more on the way, FEF campus coordinator Dr. John Schoonover reported recently. "The FEF is filling a void in the scientific education that results from the depression crisis of educational funding and the attitude against technology prevalent at many U.S. universities. For example," Schoonover said, "At the University of Pennsylvania in Philadelphia, founded by Benjamin Franklin, physics students are denied courses in plasma physics and nonlinear phenomena. Since nonlinearity is the crux of the scientific phenomena to be understood in order to advance our grasp of potential energy and to move toward the era of fusion power, we have to turn this educational situation around."

Schoonover and other FEF staff members are conducting on-campus lectures on scientific epistemology and advanced technology as well as a series of crucial scientific experiments, as part of the scientific renaissance campaign.

"We are taking intellectual hegemony on campuses and ending the zero-growthers' pretentions," Schoonover said. "At the University of Pennsylvania, our forums draw 80 and more students."



Dr. John Schoonover

EPA FORCED TO RETRACT CRITICISM OF DIESELS

A spokesman for the Environmental Protection Agency was forced to apologize and retract a press release calling diesel engines environmentally hazardous and cancer producing after an FEF spokesman proved that the methodology used by the EPA to make these determinations was fraudulent. The retraction was offered by Dr. Barth for the EPA at the Nov. 28 meeting of the Diesel Automobile Association in New York.

FEF representative Dr. Richard Pollak showed how the Ames test used by the EPA is false methodology for determining carcinogens. "The Ames test uses high concentrations of the tested substances and measures their mutagenic effects on bacteria that are unnaturally sensitive to any environmental intrusion," Pollak said. "These suspect bacterially mutagenic effects at high doses are then extrapolated to predict carcinogenic effects in humans at low doses, an unscientific, arbitrary conclusion."

Dr. Pollak is following up this intervention into EPA politics with a comprehensive study exposing the incompetent scientific basis of EPA's attempts to shut down U.S. industry.

The Lightning Rod

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will correct the amazing quantity of fetid air arising from the vast mass of putrid matter contained in such places, and render it rather pleasing to the smell, who knows but that a little powder of lime (or some other thing equivalent), taken in our food, or perhaps a glass of limewater drunk at dinner, may have the same effect on the air produced in and issuing from our bowels? This is worth experiment.

For the encouragement of this inquiry (from the immortal honor to be reasonably expected by the inventor), let it be considered of how small importance to mankind, or to how small a part of mankind have been useful those discoveries in science that have heretofore made philosophers famous. Are there twenty men in Europe this day the happier, or even the easier, for any knowledge they have picked out of Aristotle? What comfort can the vortices of Descartes give to a man who has whirlwinds in his bowels? The knowledge of Newton's mutual *attraction* of the particles of matter, can it afford ease to him who is racked by their mutual *repulsion*, and the cruel distensions it occasions? The pleasure arising to a few philosophers, from seeing, a few times in their lives, the threads of light untwisted, and separated by the Newtonian prism into seven colors, can it be compared with the ease and comfort every man living might feel seven times a day, by discharging freely the wind from his bowels? Especially if it be converted into a perfume; for the pleasures of one sense being little inferior to those of another, instead of pleasing the *sight*, he might delight the *smell* of those about him, and make numbers happy, which to a benevolent mind must afford infinite satisfaction. The generous soul, who now endeavors to find out whether the friends he entertains like best claret or Burgundy, champagne or Madeira, would then inquire also whether they chose musk or lily, rose or bergamot, and provide accordingly. And surely such a liberty of *ex-pressing one's scent-iments, and pleasing one another*, is of infinitely more importance to human happiness than that liberty of the *press*, or of *abusing one another*, which the English are so ready to fight and die for.

In short, this invention, if completed, would be, as *Bacon* expresses it, *bringing philosophy home to men's business and bosoms*. And I cannot but conclude that in comparison therewith for *universal* and *continual utility*, the science of the philosophers abovementioned, even with the addition, gentlemen, of your *"figure given,"* and the figures inscribed in it, are, all together, scarcely worth a

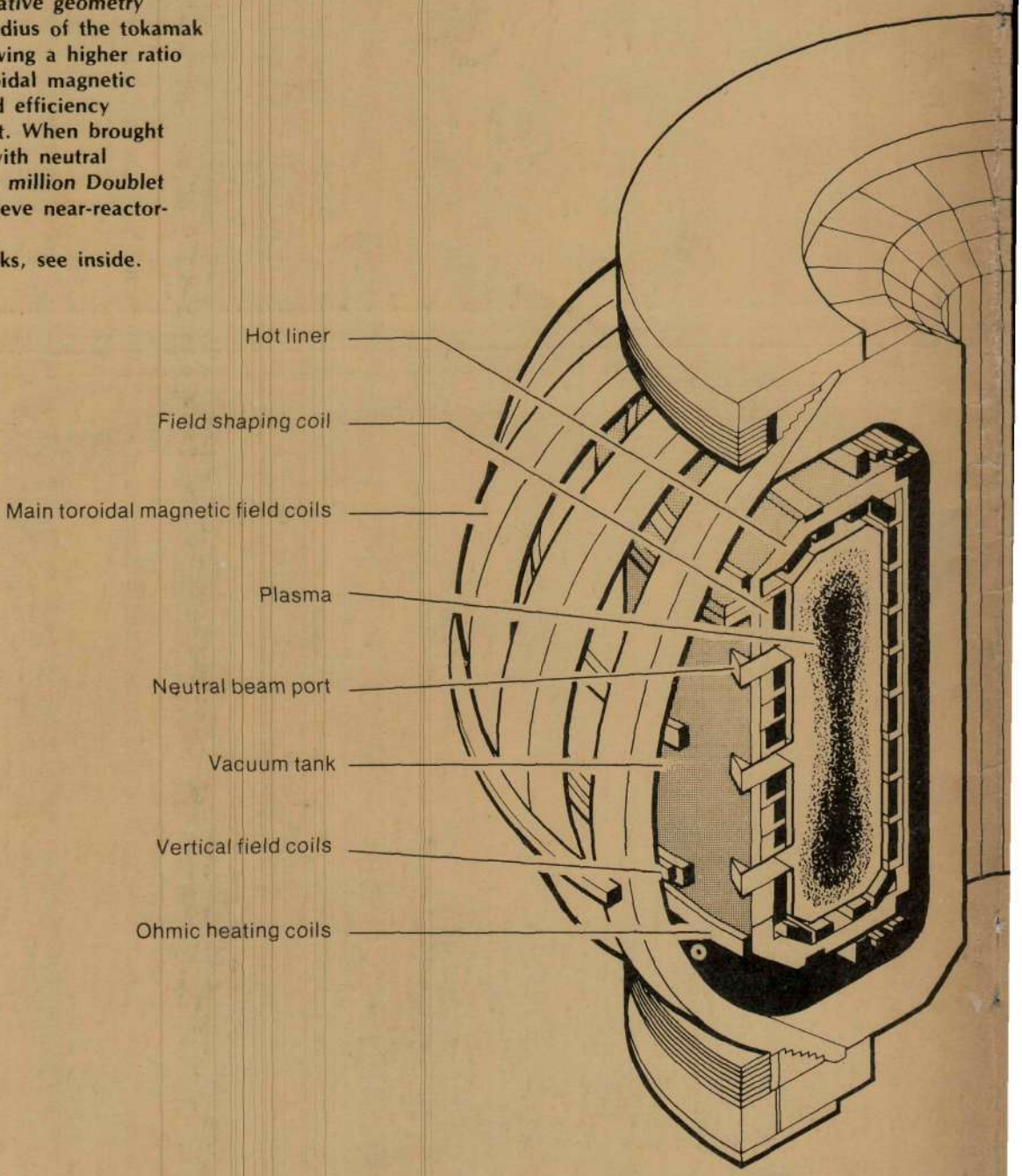
Fart-hing.

The Doublet III

This cutaway drawing shows Doublet III, the tokamak fusion energy device designed at the General Atomic Company in San Diego, Cal. and scheduled for operation in early 1978. Tokamaks are one of the most promising lines of fusion research, and power reactor prototypes are expected to be constructed in the 1980s.

The Doublet's innovative geometry elongates the minor radius of the tokamak torus shape, thus allowing a higher ratio of the poloidal to toroidal magnetic fields and an increased efficiency of fusion power output. When brought up to full utilization with neutral beam heating, the $30 million Doublet III is projected to achieve near-reactor-grade plasma.

For more on tokamaks, see inside.



Cover graphic courtesy of General Atomic Company, San Diego, California.