FUSION

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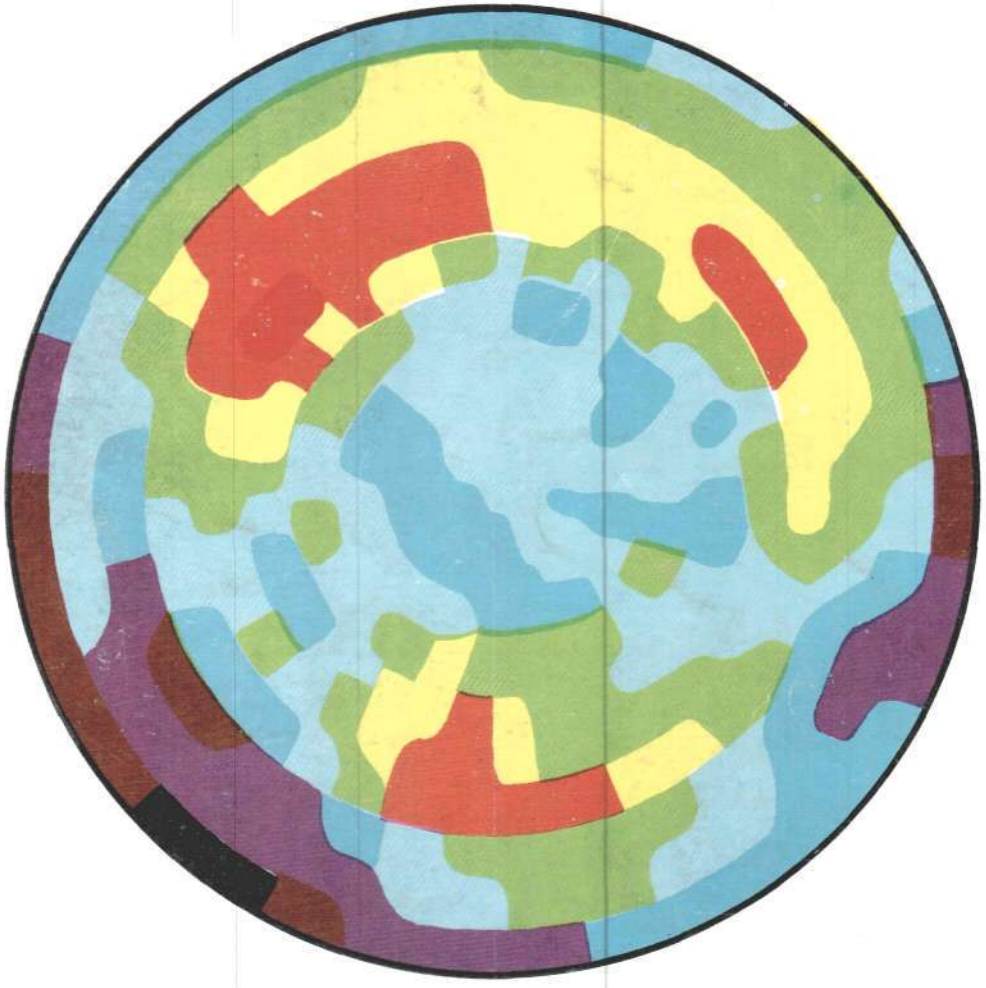

Conference on Nonlinearity Launches FEF Biological Sciences Division

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July-August 1977

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Volume I, No. 1

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Letters

COMBATING BIOLOGISTS' MISCONCEPTIONS

To the Editor:

I am glad to see the awareness revealed in your newletter of May 1977.

At the same time, I disagree with what I feel is your implication of recognition of self-organizing phenomena by biologists. Many eminent biologists still want life initiated by an outside agent, DNA, and they still talk about random mutation and random polymerization as if they were realities. I find they mostly get these concepts from physical thinking which mistakes "theoretical" calculations of variety for evolutionary diversity.

I enclose a few titles with which I have been trying to combat these premises. Good luck to your efforts.

Name withheld upon request.

CONSERVATION AND THE ENVIRONMENT

31 March 1977

To the Editor:

Although I now have no organic connection with the *FEF Newsletter*, I do have an association with the FEF by being on the initiating editorial board of the *International Journal of Fusion Energy* and writing an article for the first issue of the IJFE. I disagree with a number of statements made and attitudes expressed in the March 1977 FEF Newsletter and I hereby wish to express that disagreement, lest readers draw the conclusion that I agree with everything which was written in that issue.

I believe that conservation is an important component of an effective energy policy and I believe that Nader and Commoner have made valuable efforts in this direction. I admire them for their efforts and do not like to see them ridiculed. I also believe that solar energy will have an important place in an effective energy policy. The NEPA, in the way it has been administered, has its shortcomings, for example the wasting of fuel by requiring anti-pollution devices which reduce engine efficiency. However, as a whole the NEPA provides a bulwark

Continued on opposite page

Editorials

Winning the Energy War

The political fight over energy policy is indeed the "moral equivalent of war" — a war in which Mr. Schlesinger and the Carter administration are on the wrong side.

As of the date of this writing, Congress is on the verge of passing an energy package that could mean the loss of the war by the forces for progress in the U.S. At the very least, there will be a number of critical losses: the combination of a well-head tax on gas, a tax at the pump on gasoline, the mandatory conversion of utilities to coal, the killing of the breeder reactor, and the crippling of fusion research represent what may be an irreversible setback to the economic viability and security of the nation.

If the defeat comes, it will not be because it was unavoidable either politically or technologically. The problem is that too many traditional political, industrial, and trade union forces who could have turned the tide made a rotten compromise to pave the way for an energy package that is essentially identical to the administration's no-energy policy.

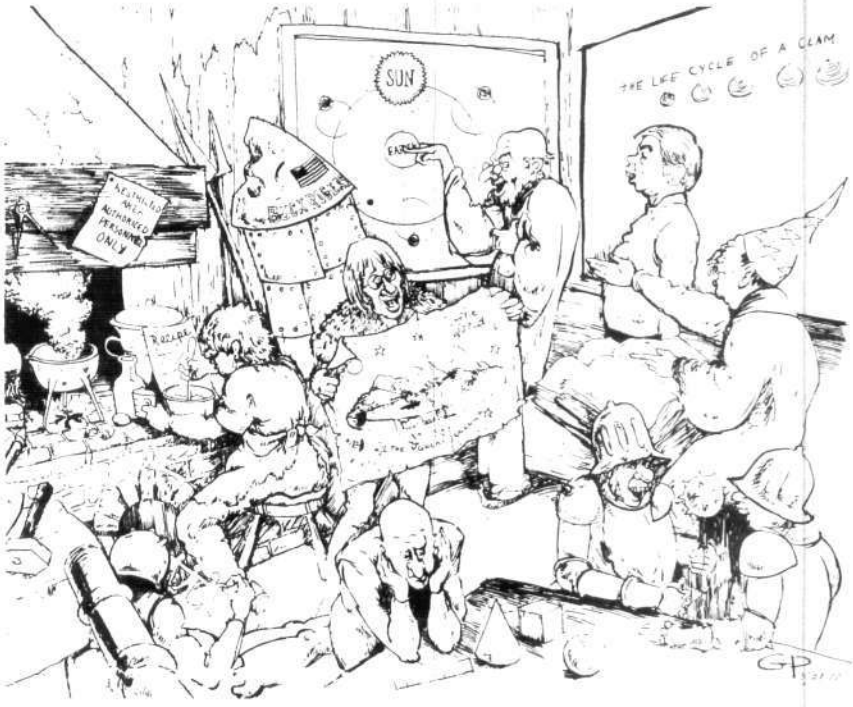
Ironically, this compromise occurred at the same time that private scientific institutions in the U.S. were providing new evidence to demonstrate the near-term feasibility of fusion-fission hybrid breeder and pure fusion reactors. Most noteworthy in this regard is the announced collaboration between the Electric Power Research Institute, the Palo Alto think tank of the utilities industry, and the Kurchatov Institute in Moscow to develop fissile-breeding modules for full prototype development of a fusion-power generating, fission-fuel breeder based on the Soviet T-20 tokamak. This project, geared to hybrid power by the 1980s, and continued progress on the high-field Alcator tokamak of the Massachusetts Institute of Technology show that the administration's excuses for killing the breeder and fusion in the name of conserving our dwindling resources are pure bunk.

The hour is late, but the war is not yet lost. Winning the energy war requires an uncompromising fight for what this nation is actually capable of achieving if its full scientific and technological capacities are mobilized in the interests of national survival and world development.

The Biological Sciences And the Tradition of Pasteur and Franklin

We are certain that Louis Pasteur and Benjamin Franklin would have been active and enthusiastic participants in the founding meeting of the Fusion Energy Foundation Biological Sciences Division at Columbia University May 14. That meeting, attended by 200 biologists, mathematicians, physicists, engineers, and political organizers, rekindled scientific commitment to the principles of Pasteur and his humanist predecessors and successors. Specifically, this invloves a commitment to make all branches of science coherent by a common recognition of the fundamental, negentropic quality of the physical universe and of the necessity for progress in the man-ordered biosphere.

As the conference proceedings made clear, the most practical problems that humanity faces — from economically harnessing fusion power to extending the physical health and mental powers of the human population



"So you see Mr. President, there's no such thing as the E-beam."

— raise the most exciting scientific problems at the frontiers of biophysical research. As with fusion research, however, massive funding cuts and disruption of research in the biological sciences are closing down new experimental and theoretical approaches just as they are beginning to shed light on the nonlinear bases of stability and evolution.

The situation demands that our biological sciences work, no less than the FEF's plasma fusion efforts, be as devoted as were Benjamin Franklin and Louis Pasteur to the mixing of science and politics.

Fusion Goes Monthly

The Fusion Energy Foundation is expanding its bimonthly *Newsletter* into a monthly magazine in order to decrease the time lag between breaking news in the field of fusion and its transmittal to our readership. The new *Fusion* will continue the groundbreaking coverage of nonlinear processes in plasma physics and the biological sciences established by the *Newsletter* and will offer a wider array of scientific news and analysis as well as increased coverage of FEF activities.

The aim of the magazine (as it was in the *Newsletter*) is to raise the general scientific level of the population to that required by a fusion-based economy. In particular, *Fusion* is geared to making both laymen and specialists *participants* in the advancement of science.

A word about the new format: In addition to the departments inaugurated in this issue (a calendar, letters, the Lightning Rod column, news briefs, and FEF briefs), *Fusion* expects to add a book review and classified ad section in the future. We are also pleased to report that by the next issue, new equipment will make possible a larger size of print.

Current subscribers are assured that their *Newsletter* subscriptions will be automatically transferred to *Fusion* magazine with no additional charge.

Letters cont.

which keeps government bureaucracies and large corporations from running roughshod over our rights, resources, and environment which are given to us by the Almighty. Nowhere in this FEF issue do I hear any real concern for the environment or for people who may be harmed by nuclear reactors. Although Jon Gilbertson may be a competent nuclear engineer trained in a good stable, I do not trust his evaluation on the safety of fission nuclear reactors any more than I would that of the old AEC which time and again was caught in lies and laxity concerning safety levels, siting of nuclear plants, etc. The NRC is an improvement over the old AEC, but we must also have checks on them. They are not to be completely trusted any more than we can "leave war completely up to the generals"...

Winston H. Bostick
Professor of Physics
Stevens Institute of Technology

THE EDITOR REPLIES

We have no quarrel with Professor Bostick on defining clear roles for safety regulations with nuclear reactors. But that's not the issue here. "Conservation" and the "environment" are simply nice sounding words for zero-growth, the overall policy of Nader, Commoner, and company. Let's not mix up issues of safety with a policy that would deliberately depopulate the earth and return industry to 14th century levels.

Editor's Note: We invite *FUSION* readers to send us comments.

Calendar

1-13 August
Nonlinear Equations in Physics and Math, Istanbul (NATO Advanced Study Institute)

12-17 September
13th International Conference on Phenomena in Ionized Gases, Berlin, German Democratic Republic

19-23 September
8th European Conference on Controlled Fusion and Plasma Physics, Prague (European Physical Society)

The Lightning Rod

Benjamin Franklin, foremost American intellectual, scientist, and statesman, fought here and in Europe to establish the political and economic conditions that would improve the "common stock of knowledge" and promote scientific discoveries "to the benefit of mankind in general." American youth were not wanting in capacity, Franklin said, yet, "...the best capacities require cultivation, it being truly with them, as with the best ground, which, unless well tilled and sowed with profitable seed produces only ranker weeks."

This column is dedicated to such cultivation and to the destruction of some of those "ranker weeds" that pass for science in the U.S. today.

A Nuclear Fiction

Every civic-minded American by now has heard that the main reason America must give up nuclear energy and "conserve" itself back to the Stone Age is the danger of nuclear terrorism. President Carter says so; James Schlesinger says so; and a lot of the press say so.

Consider this:

A terrorist team, after years of preparation, finally attacks a nuclear power station in the northeast United States. Intricate alarm systems are neutralized by terrorists infiltrated into the plant's staff, and the plant's security forces are taken unawares; after several gun battles with guards through the plant, the terrorists make their way to the control room. The plant is theirs! The terrorists broadcast their demands to the world.

They threaten to overload the reactor and blow it up. Right? They threaten to steal deadly plutonium and poison the atmosphere, killing thousands. Right? Well, not exactly....

Suppose our terrorists try to make good on their threats. They start the reactor into a rapid power increase, but, alas, the safety system automatically shuts down the reactor completely. Subsequent trys to start it up again fail, also because of other fail-safe safety systems. They finally give up when the reactor operators convince them it would take hours to restart the reactor, and that there is no way to bypass the safety systems and cause an overload.

The terrorists then decide that they will move to their fall-back threat: they will break open the reactor and steal the deadly plutonium. (I beg the reader's pardon at this point and ask you to ignore the fact that you can't really steal reactor plutonium: reactor plutonium comes in one-ton rods that are so radioactive they have to sit around for six months before they are moved — with the help of enormous, remotely controlled machinery.)

Just for this purpose, the terrorist team has brought with them satchels of powerful plastique explosive. Their first task is to blast their way into the reactor building from the central room: the reactor building is automatically sealed during operation, with no human entry possible, and is even more stringently sealed after the safety system is activated.

Finally, after blasting their way into the reactor building, the terrorists are faced with a several-foot thick concrete wall and a 12-inch thick steel vessel. Little did they know that reactors are designed to withstand huge operating pressures without failure.

Needless to say, the terrorists' explosives only chipped away some concrete before they ran out of explosives and gave up.

The terrorists are demoralized; nothing seems to work. Finally, the terrorist leader hits upon an idea: what they need to break open the reactor is a small nuclear device. Now, all they have to do is to steal an A-bomb....

FUSION

A Monthly Magazine of the Fusion Energy Foundation

Coming in the September issue of FUSION Magazine:

The Science and Technology of Recombinant DNA Research
Putting the Quarks Back in the Bottle
The Physics Odyssey of the Alcator Tokamak

INTERNATIONAL JOURNAL *of* FUSION ENERGY

Published Quarterly by the Fusion Energy Foundation

Coming in the September issue of the International Journal of Fusion Energy:

— A new translation from the German of Hermann von Helmholtz's *Vortex Filaments* with an introduction by Uwe Parpart
— A Review of Nonlinear Fluid Theory by Dr. Steven Bardwell

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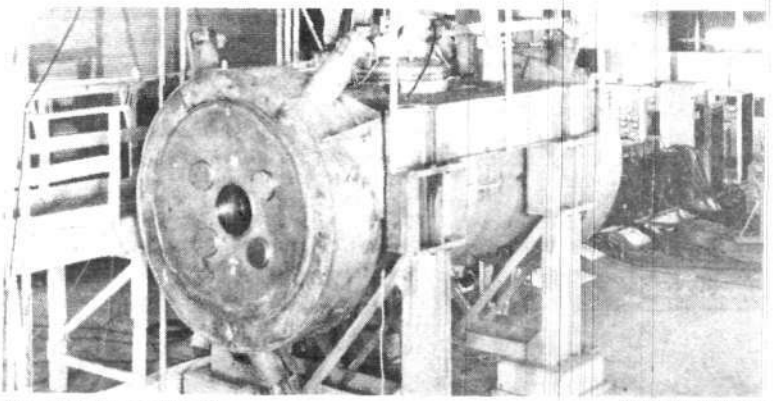
News Briefs

CLINCH RIVER BREEDER IN JEOPARDY

The Senate approved an amendment July 12 limiting the U.S. Energy Research and Development Administration's funding for the Clinch River, Tennessee nuclear-breeder reactor program to $75 million. The amendment, proposed by Senators Frank Church and Henry Jackson, cuts in half the amount for the project voted up by both the Senate Appropriations Committee and the Senate Energy Committee in late June. A House vote is expected in September.

Although publicized in the press as a stinging defeat for the Carter administration, which wanted to kill the project completely, the amendment would paralyze construction of the breeder. (At least $150 million would be needed to commercialize the breeder.)

As of July, a head count taken in the House by a staffer for the House Science and Technology Committee indicated that the $150 million funding proposal would be carried, but he was not sure that the probreeder congressmen would withstand the heavy White House pressure to kill the project.



The Argonne Magnet Argonne Photo

ARGONNE MAGNET ON WAY TO SOVIET MHD PROJECT

The U.S. Energy Research and Development Administration announced that a 40-ton magnet will be flown to the Soviet Union June 20 from Argonne National Laboratory in Illinois as part of the U.S. contribution to the Soviet magnetohydrodynamics test project. When energized, the $2.5 million magnet can produce a magnetic field 300,000 times stronger than the horizontal magnetic field of the earth.

The MHD process for producing electricity is expected to be 20 to 40 percent more efficient than current facilities that use coal, natural gas, or oil.

For more on MHD see *Research Notes*, this issue.

U.S. E-BEAM RESEARCHERS ACHIEVE FUSION REACTION

In interviews with the *New York Times* and the local press June 12, researchers at New Mexico's Sandia Laboratory officially reported achieving what they believe are the first electron beam-generated fusion reactions in the U.S.

The details of the Sandia work remain under classification, but if these initial experiments are confirmed in further work this year, it will clear the path for the feasibility of this approach to harness fusion energy in the near future. The Sandia experiments on its electron beam machine, REHYD, have indicated that electron beams are more efficient than lasers in achieving the implosion of a small pellet of fusion fuel. REHYD used a beam of 1 million volt electrons with currents of up to 250,000 amps. The same experiments were reported by the FEF three months ago after C. Martin Stickley, the director of ERDA's Laser Division, hinted at such experiments in congressional testimony.

EUROPEANS CALL FOR EXPLOITATION OF FULL NUCLEAR POTENTIAL

Dr. Guido Brunner, Energy Commissioner of the European Economic Community, urged the EEC to make a site decision on the location of the long-stalled Joint European Torus fusion project (JET) at a press conference June 17 in Brussels. Any further delay, he said, would gravely damage Europe's fusion effort.

Brunner's press conference followed a meeting of the EEC Energy Ministers that called for the fullest exploitation of Europe's nuclear potential to supply the energy needs of the EEC nations. The Energy Ministers adopted this pronuclear stance in the midst of a flurry of nuclear cooperation deals between the Soviet Union and the Europeans, and the Europeans and Third World nations. Among other developments, Brunner announced that the Soviet Union will be supplying enriched uranium to fuel the West German-built nuclear reactors in Brazil. This is a first for the Soviets, and is viewed as a consequence of the unreliability of the U.S. as a source of enriched uranium since President Carter announced his antinuclear policy.

HOUSE COMMITTEE REVISES CARTER FUSION BUDGET

The House Committee on Science and Technology voted to restore some of the cuts made in President Carter's second version of the federal fusion budget May 16. Overall, the committee revisions amount to about a 5 percent increase for the operating budget and a 10 to 20 percent for the construction budget proposed by Carter.

Most significant, the committee restored the construction budget for the materials test facility at Hanford, Wash. that had been axed by Carter along with the breeder reactor budget.

The budget is now in the House Appropriations Committee with no schedule yet to be reported out.

A comparison of the budget proposals is at right.

OPERATING BUDGET	CARTER	COMMITTEE
Division of Magnetic Fusion Energy	196.9	207.9
Laser Office	101.0	107.0
CONSTRUCTION BUDGET		
Princeton Tokamak	71.0	80.0
LASL Laser Facility	2.9	7.0
Sandia E-beam	1.9	4.4
Hanford materials test facility	0	10.0

(in millions of dollars)

CARTER'S ENERGY POLICY WILL COST 5 MILLION JOBS

Dr. Charles L. Storrs of the Connecticut chapter of the American Nulcear Society told a May 6 FEF conference in New York City that Carter's energy program had some hidden costs:

"In looking at Mr. Carter's 2 percent energy growth program, we find that there are 12 quads of required energy...unaccounted for. This shortfall will be made up by increasing our imported oil... an increase in oil costs from $36 to $70 billion by 1985. Based on Washington Congressman Mike McCormick's conversion for imported oil to jobs, 1 *million barrels of oil equals 900,000 jobs. This amounts to over 5 million jobs lost in the* United States."

HIRSCH: U.S. GOVERNMENT GUTTING RESEARCH

Dr. Robert Hirsch, former head of ERDA's Advanced Energy Systems Division, told a June 17 conference on "R&D in the Federal Budget": "the government is stating that basic research is to be gutted." Hirsch advised the 250 participants at the American Association for the Advancement of Science conference that instead of debating which research programs could most easily be cut they should concentrate on changing the antiresearch policy of the Carter administration. Hirsch is now the director of research at Exxon.

Representatives from government, industry, and the universities heard a string of government panelists at the two-day conference explain the "cost-accounting method" and "zero-based budget" used in the federal research budget. "Basic research is just too iffy," one panelist said. "R&D must be ranked by priorities determined by the potential return on the original investment."

FEF representatives distributed 500 leaflets calling for an all-out basic research effort in physics and biology.

FBI DENIES FEF RUDAKOV REQUEST

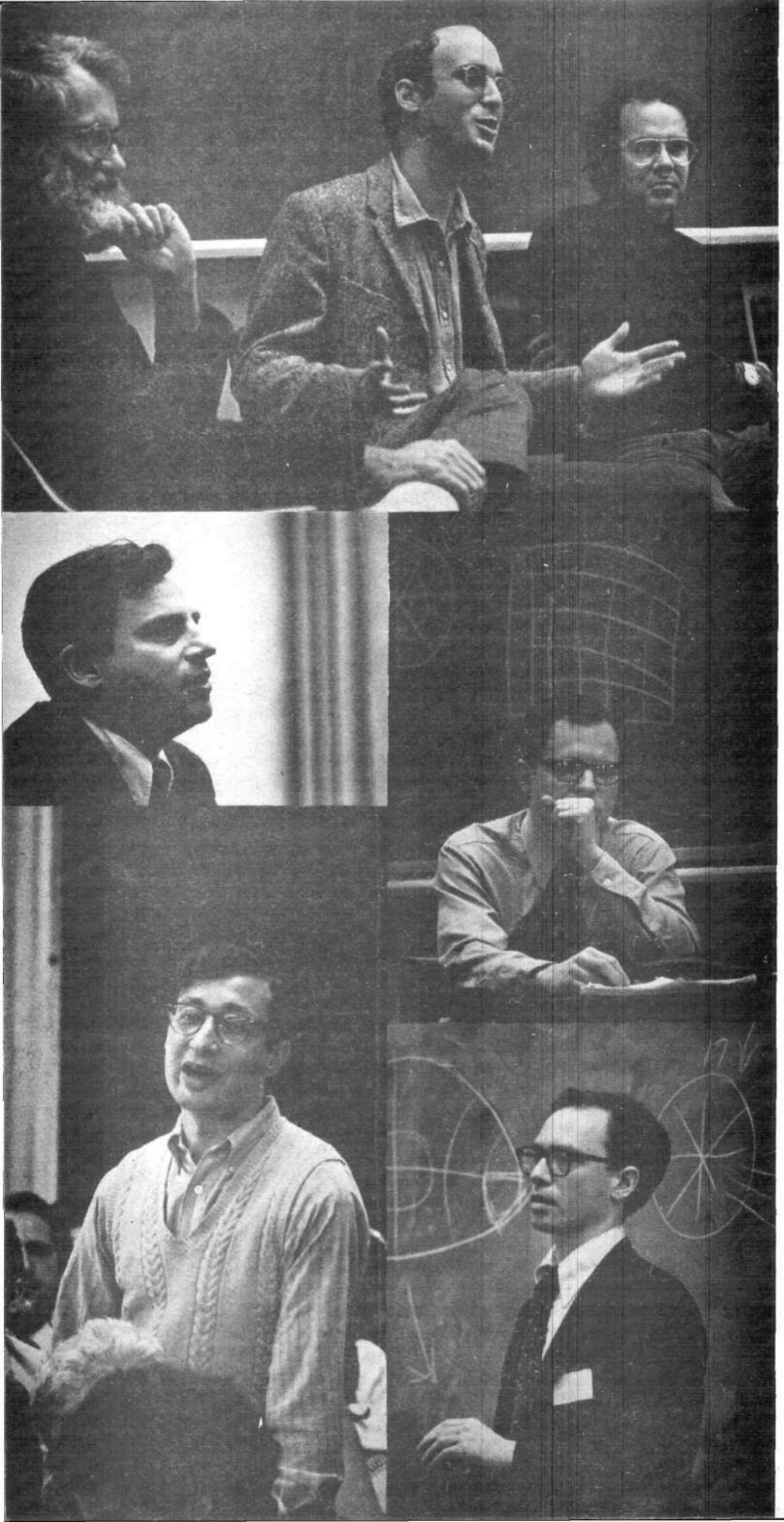
Clarence Kelley, director of the Federal Bureau of Investigation denied a request June 7 by the Fusion Energy Foundation to release Justice Department information on Soviet scientist Leonid Rudakov's discoveries in beam-particle physics. Rudakov discussed these breakthroughs with several plasma physics laboratories and invited American collaboration when he toured the United States in July 1976 and April 1977 (See article this issue on latest breakthroughs).

In denying the request, Kelley said, "This decision is predicated upon a determination that there is insufficient public interest in the subject matter of your request to require the release of personal records under the Freedom of Information Act."

TEXAS FIFTH STATE TO SEND FUSION RESOLUTION TO CONGRESS

Texas became the fifth state to send a memorial resolution to Congress urging a vast increase in funding for the development of fusion energy and basic scientific research. The Texas state senate passed the memorial May 27. One or both houses in state legislatures in Colorado, Delaware, Maryland, and Pennsylvania have already sent similar resolutions to Congress and President Carter. Bills have been introduced in nine other states, and in Washington and Illinois bills have passed one house of the legislature.

For more information on fusion memorials, contact the FEF.



Conference Launches

THE Fusion Energy Foundation launched its Biological Sciences Division with an all-day conference May 14 at Columbia University that brought together 200 biologists, mathematicians, physicists, engineers, and political organizers.

The underlying theme of the historic interdisciplinary conference on "Nonlinearity and the Biological Sciences" was the need for a scientific renaissance that will at last take up the late 19th and early 20th century achievements of Riemann and Cantor, Einstein and Schroedinger, and Vernadsky and Pasteur. As one panelist commented on the beginnings of this renaissance at the conference, "I haven't seen this kind of excitement in my classes for 15 years."

The Paradox of Negentropy

Dr. Steven Bardwell, the FEF's director of plasma physics research, opened the

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The conference participants
Clockwise from top left: Dr. Walter Freeman, Dr. Eric Schwartz, Dr. Robert Thatcher, Dr. Steven Bardwell, Dr. Ned Rosinsky, Dr. Morris Levitt, Warren Hamerman.

Photos by ULANOWSKY

on Nonlinearity
FEF Biological Sciences Division

conference by locating the necessity of an interdisciplinary probe into the nonlinear physical processes common to both living and nonliving phenomena, toward revealing the fundamental negentropic invariant governing the lawful evolution of the universe.

Using experimental slides, Dr. Bardwell showed how plasmas (ionized gases) do not remain in their initial state of random interactions, but evolve through two or three distinct phase-changes by which the plasma concentrates energy density in increasingly intricate self-ordered structures.

How is a scientist to explain this process and its analogues in other realms, Bardwell asked, when the Second Law of Thermodynamics — that all matter tends toward entropic disorder — is regarded as fundamental?

In the heated discussion that followed, scientists wrestled with the problem of bringing this conception of nonlinearity into coherence with their empirical research. "Well, the Second Law holds in a test tube," one biologist joked. Another asked, "What is negentropy all about? Aren't you just trying to get something for nothing?"

Much like their colleagues in plasma physics, Bardwell answered, biologists are accustomed to sweeping the paradoxical evidence of nonlinearity under a religious mantle outside the bounds of empirical scientific inquiry. To "leap over such deadends" and reach urgently required breakthroughs in developing fusion power and in the biological sciences, Bardwell said, demands a rigorous answer to the question of how a system proceeds from one distinct domain of laws and geometries to the next.

Two panels explored the areas within the biological sciences — the metastable yet evolving nature of genetics and the highly evolved, highly ordered processes in the neurophysiology of the brain — as most promising for investigating this negentropic invariant. The scientists making these presentations drew heavily on the epistemological implications of the most advanced existing physics in formulating their biological researches.

At the event were representatives from the National Institute of Health, Walter Reed Hospital, Howard University, Temple University, and Hahnemann Medical School in Philadelphia.

Attendees from the New York area included researchers and students from Albert Einstein Medical School, Columbia University, Mount Sinai Medical School, and Hunter College. Also present were representatives from biomedical and pharmaceutical companies in the New York-New Jersey region.

Several participants condemned the destruction of the biological sciences and other sciences by the antiscience and antitechnology policy of the Carter administration.

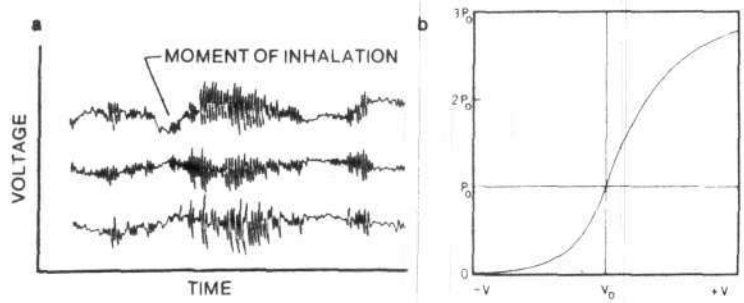
Abstracts of six of the panel presentations, as reported by FEF staff, appear below. Four of the presentations are not summarized here because a fuller statement of the discussion appeared in the May 1977 issue of the FEF Newsletter. (See Warren Hamerman on "The Overlooked Importance of Pasteur," Eric Lerner on "Evolution As a Process of Self-Organization," Dr. Richard Pollak on "Evolution — Beyond Darwin and Mendel," and Ned Rosinsky, MD on "Drosophila Embryology.")

The conference proceedings are now being transcribed for publication, and persons interested in the full transcript should contact the FEF.

DR. WALTER FREEMAN
Department of Physiology and Anatomy, University of California, Berkeley

A Nonreductionist Approach to the Brain

FIGURE 1



[a] *Bursts of EEG activity from the olfactory nerves in the nose and olfactory cortex in a waking cat. At the time indicated by the arrow, the animal inhales, increasing the neural stimulation. This brings the system as a whole up to a higher activity level that is self-sustaining for approximately one second.* [b] *Neurons have two types of electrical activity, discrete pulses and continuous waves. In the above graph, Po and Vo represent the normal levels of pulse rate and wave voltage respectively. As the wave volt changes, the pulse rate also changes, but nonlinearly, that is, not in a straight line.*

Dr. Freeman discussed his studies of neurology in terms of populations of mutually interacting neural sets, not single, isolated neurons, and he attacked the prevailing reductionist point of view that neural dynamics can be understood in terms of the individual cell.

Freeman's microelectroencephalographic work with the olfactory cortex in cats and rabbits (see Figure 2) has located large-scale cooperative activity in groups of neural cells termed neural esembles. He has been able to identify qualitatively different forms of ordered behavior from these ensembles as the level of energy throughput in the ensemble increases. Freeman has found that groups of interconnected neurons, numbering from several thousands to millions, function as unified entities and that the entire group can be raised to a high activity level that is stable and self-maintaining for a period of time. The degrees of stability depend on the previous level of internal excitation, or energy content of the ensemble before it is stimulated.

The stable activity takes the form of a global and coordinated oscillation. As Freeman shows in his model (see Figure 1) this oscillation is a form of "limit cycle" activity and depends on the types of in-

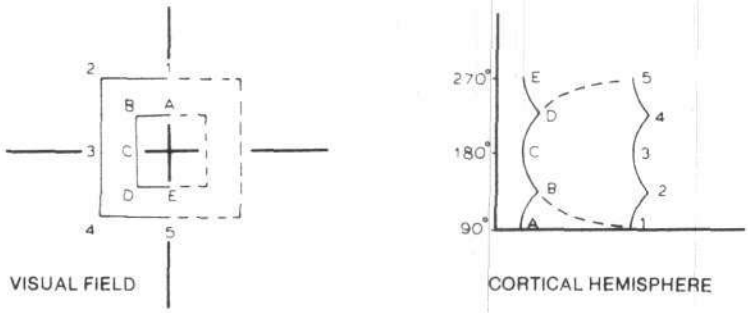
DR. ERIC SCHWARZ
New York Medical College

The Geometry Of Perception

Dr. Schwartz presented strong evidence for a coordinated, highly ordered system of visual perception in higher life forms that may explain a number of previously unsolved puzzles in visual perception, physiology, and developmental biology.

Schwartz's findings may replace the predominant reductionist notions in each of these areas by identifying a physiological basis for the size and rotation independence of visual perception, by accounting for the embryological development of the visual system, and by providing a physiological basis for the evolution of new visual mapping.

FIGURE 3 MAPPING OF SQUARE ONTO THE CORTEX



This diagram shows the mappings of a large and small square as they would appear across the surface of the unfolded and flattened cortex. The image of a square is invariant: the size change merely causes the invariant image to shift across the cortical surface, while a rotation of the square would shift the cortical image vertically.

Both the retina and the primary visual cortex, area 17 (see Figure 2) closely approximate a two-dimensional structure physiologically. The geometry of the visual scene as it appears on the retina undergoes a profound distortion in its physiological projection, the neural anatomical connection, to the visual cortex.

Schwartz has discovered a simple mathematical formulation to describe this geometric transformation, from which one can derive a number of important implications for the areas of visual perception, physiology, and developmental biology.

The topological mapping is characterized overall by the transformation of a radial geometry in the retina to a rectilinear geometry in the cortex. Radii on the retina map into parallel straight lines on the cortex, while concentric circles on the retina map to straight lines perpendicular to the first set of lines. This transformation is identical to the mapping of the complex logarithm

internal connectedness of the ensemble (excitatory or inhibitory). This oscillation is stabilized or "limited" by a nonlinearity in the cell's response to stimulation ; with large stimulation, the pulse response tends toward a finite maximum.

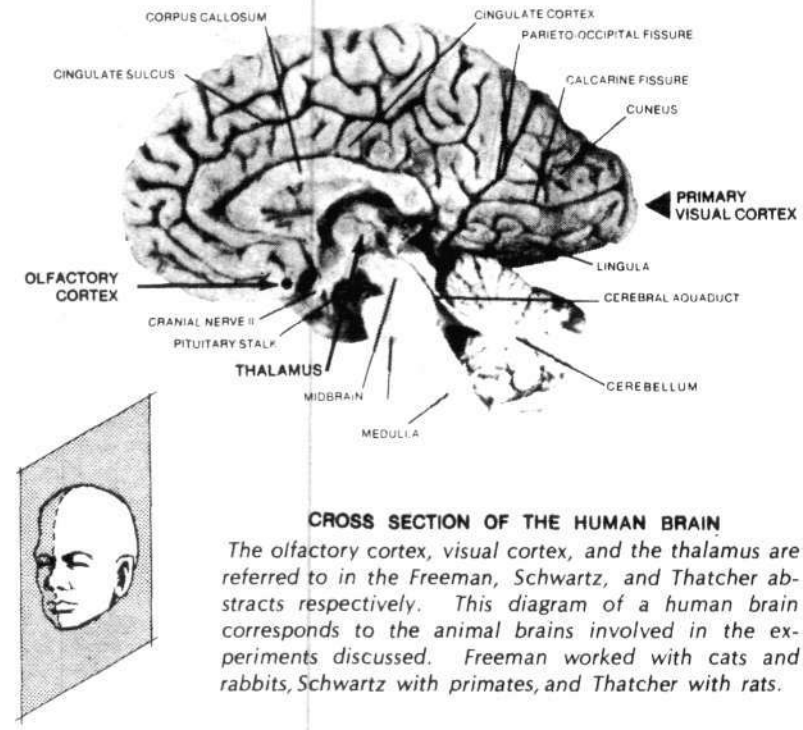
Freeman described how ensembles connect with each other to form higher order ensembles with characteristically higher order oscillatory modes coherent with, but not simply resulting from, the modes of the component ensembles. Freeman has identified at least three distinct levels of this type of hierarchy.

Freeman has used sophisticated microrecording techniques to map these oscillations over the surface of the cortex, and he is now studying the unique qualities of the spatial distribution and phase relations of the oscillations. He is also attempting to model the space-time oscillation characteristics to determine if they can be sufficiently differentiated in form to be comparable to the variety of olfactory sensations.

—Ned Rosinsky, MD

Reference:
Walter J. Freeman, *Mass Action in the Nervous System* (New York: Academic Press, 1975).

FIGURE 2



CROSS SECTION OF THE HUMAN BRAIN

The olfactory cortex, visual cortex, and the thalamus are referred to in the Freeman, Schwartz, and Thatcher abstracts respectively. This diagram of a human brain corresponds to the animal brains involved in the experiments discussed. Freeman worked with cats and rabbits, Schwartz with primates, and Thatcher with rats.

The mapping is size invariant and rotational invariant with respect to the center of the visual field. Rotational invariance is significant because it is much easier to determine that an object is not changing its internal relations but is merly moving in space if that motion translates geometrically rather than rotates. Size invariance, symmetrical enlargement of any image, is a frequent visual event in depth perception. In the mapping this becomes a simple linear transformation. In comparison the rotation of an image in the mapping moves in the perpendicular direction. Such rotations occur not only when images in the visual field are actually moving, but also with a variety of eye movements.

Although it is not implied that actual consciousness of an image, much less any higher-ordered gestalt activity concerning any visual image, is the work of any particular area of the brain or any anatomical mapping correction, it is likely that the initial transformation of the visual scene by the complex logarithm is a precondition and aid to the higher gestalt-forming processes.

Prior to Schwartz's work, there were two explanations of how axons (an axon is the long, thin extension of nerve cell that carries the electrical impulse to the next cell) connect from the retina to the cortex. Every cell is genetically "programmed" to recognize its "hook-up mate" by unique cell-to-cell adhesiveness characteristics, one theory went. The other held that there may be a simple field generated by a diffusing chemical, which, because it is diffusing, exists in varying concentrations that then determine a variation in the activity of the axons, causing a transformation in the mapping. The problems with both explanations are that the first requires an immense amount of genetic information while the second involves a lack of precision in the diffusion-based field and the lack of any evidence that any such chemicals exist, despite much effort to find them. The more devastating criticism is, however, that neither explanation can be a basis for evolution while the physiological implications of Schwartz's model can.

The geometric transformation involves a change in boundary, going from the circular boundary of the retina to a roughly rectangular area on area 17 of the cortex, as well as a change in density of cell distribution. In the retina, the density falls off toward the periphery (as $1/r^2$), while in area 17 the density is uniform. Both changes are described by the complex logarithm, an analytic function that produces mappings of the type generally used to describe fluid flows.

Physiologically the analytic function implies that as the axonal projections of the retinal cells grow back toward the cortex, the axons "try to get out of each other's way" and tend to distribute themselves equally within the continuously changing boundary without crossing over each other or winding around each other. This geometrical determination of the physiological production of the transformation eliminates the previous theories of "unique programming" and chemical gradiant. In addition, since a slight change in the boundary shape of the cortical area has been shown to result in a coordinated shift in the entire mapping (for instance, in the goldfish) this explanation also could account for rapid evolution of new anatomical mappings in the nervous system.

—Ned Rosinsky, MD

Reference:
Eric Schwartz, "Spatial Mapping in Primate Sensory Projection: Analytic Structure and Relevance to Perception," *Biological Cybernetics*, Vol. 25, No. 4 (1977).

DR. ROBERT THATCHER
New York Medical College

The Neurological Representation of Time

Dr. Thatcher's presentation described the neurological correlates of a complex psychological process, the perception of time, and provided evidence for some sort of loop geometry of neural activity.

His findings indicate that time perception is based on a global, coordinated type of activity, involving many areas of the nervous system, and that the anatomical extent of this activity is itself a function of the time interval involved.

To trace the connection between a neurological event and an event in perception, Thatcher used a technique called labeled rhythm. First developed by Soviet scientists in the 1940s, this technique uses a flickering light as a recognition stimulus for an animal while brain waves are examined for frequencies at the rate of the regular flicker.

The newly arising brain rhythm, as an "appropriate" internalization of aspects of perception, is presumed to be only one form of a general capacity for global representation of perceptual events in the neural apparatus; but for experimental purposes it is extremely convenient because of its direct relation to the stimulus. No such direct change in brain waves has been found in connection to the recognition of geometric images, to take one contrasting example.

Experiments were set up to determine (1) if the neurological events related to the perception of different time intervals represented those changes in time by changes in the geometry of the neural events; and (2) if so, then what do such changes imply for the underlying process determining those geometries?

Animals were exposed to a flickering light at a regular frequency and then after a certain period of time were given an electric shock. One group of animals was exposed to light flickering at 3.3 cycles per second, and a second group to light at 8.2 cycles per second. Each group was divided into four subgroups according to the time between the beginning of the light and the shock, using the periods 40, 60, 80, and 120 seconds.

The animals were exposed to the light and shock situation repeatedly until they reacted to the light with a "freeze" or fear response. Twenty-four hours later, the animals were exposed to flickering light at a different frequency, 5.8 cycles per second, and their brain waves were noted.

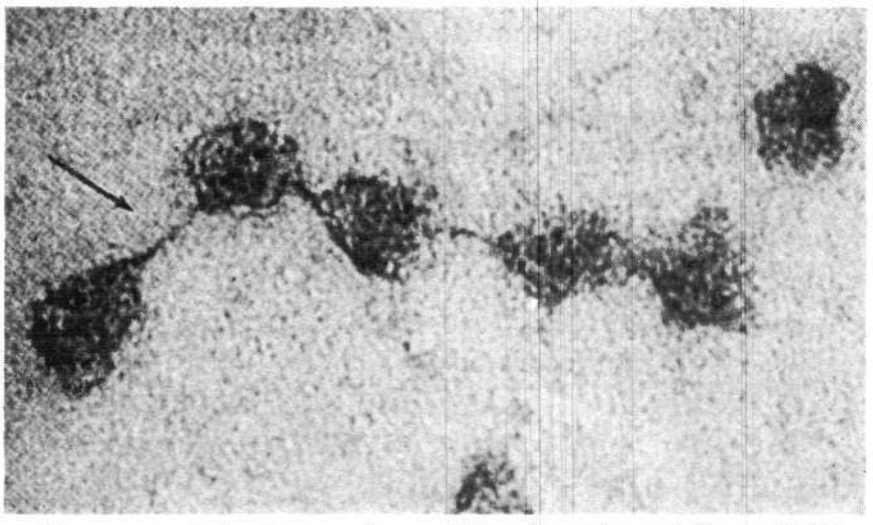
In the 40 and 60 second groups all of the animals exhibited the fear response with the 5.8 cycle flicker. However, in the 80-120 second groups, only 60 percent and 45 percent, respectively, gave this response.

The animals that responded with fear to the 5.8 cycle-per-second flicker were found to have an electroencephalogram rhythm (EEG) at the frequency of the flicker the animal was originally exposed to, not at 5.8. Those animals that did not respond to the 5.8 flicker had a usual EEG.

In analyzing the additional rhythms appearing in response to the 5.8 cycle flicker, data on anatomical location, temporal heterogeneity, and the specific difference in the 3.3 and 8.2 cycle patterns all suggest that the neurological representation of time exists in the form of "loops" of activity.

Specifically, EEG data were recorded in four locations: the visual cortex and lateral geniculate, both sensory-specific areas; and the reticular formation and midline thalamus, both areas that are not sensory-specific (see Figure 2). As a general tendency, the longer the flicker-shock time interval, the larger the anatomical area in which the characteristic frequency (3.3 or 8.2 cycles per second) occurred. This included a progressive motion from sensory-specific areas into areas that are not sensory specific.

Second, in association periods of under 60 seconds the maximum amplitude of the labeled rhythm activity occurred at the time of the expected shock, while in those animals with association periods of more than 60 seconds there were two peaks of labeled rhythm, one at the expected shock time and one before, at an



Ribosomes, cytoplasmic organelles consisting of proteins and ribosomal RNAs connected by a strand of messenger RNA [arrow]. This complex is responsible for the cell's synthesis of proteins.

DR. HAL KRIDER
University of Connecticut

Beyond Reductionism In Genetics

Dr. Krider began his presentation by stating that the reductionist foundations of current molecular genetics are proving inadequate to the solution of the problems confronting today's researchers. The marriage between the Catholic priest and the British ne'er-do-well, Gregor Mendel

intermediate time. This suggests a periodic activity of more than one cycle, with a maximum cycle length of approximately 60 seconds. This also coincides with the period when some animals fail to retain the association at all.

Third, those animals in the 3.3 frequency category show much more robust data, clearer distinction of the labeled rhythm, larger amplitudes, etc., compared to the 8.2 cycle group. Given a loop form of activity, the longer period of the 3.3 cycle would be consistent with a more robust nature than in the 8.2 loop, since presumably more neurons would be involved.

There are questions to be raised concerning the necessity of limiting the explanation for the three findings above to a loop notion. The idea of limit-cycle oscillatory stabilities described in Dr. Freeman's presentation at the conference could be invoked as a possibility as well. On the face of it, this seems to be a superior approach since the notion of loop differs from neural ensemble only to the extent that the neurons are thought to be physiologically functioning in linear arrays.

—Ned Rosinsky, MD

Reference:

E. Roy John, *Mechanics of Memory* (New York: Academic Press, 1967).

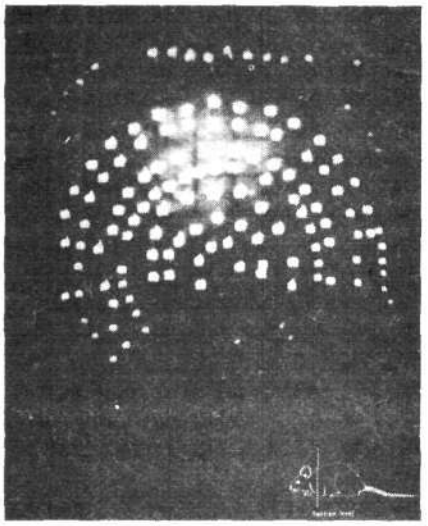
and Charles Darwin, was fruitful at one time, he said, but now the pair is ready for a trial separation.

The marriage of Darwinian natural selection and Mendel's notion that a single gene determines each individual characteristic of the organism has combined with modern molecular genetics to produce the theory that evolution proceeds by, and is determined by, single point mutations in the DNA (deoxyribonucleic acid, the genetic material considered to be the basis for heredity) code. Krider presented startling evidence not only that this notion is inadequate, but that there is evidence demonstrating that the dominant mode of molecular genetics must involve higher-ordered geometric changes and interactions of DNA, not excluding the critical aspects of cytoplasmic and environmental factors.

Continued on page 14

DR. LAWRENCE MINKOFF
Downstate Medical College, Brooklyn

Highly Ordered Cytoplasm Interactions



Cross-sectional FONAR image of a mouse obtained with a 1mm exploring spot.

The commonly held notion that the cell is a "bag of water" with various substances dissolved in it is utterly false, Dr. Minkoff said. There is much evidence indicating that cytoplasm (nonnuclear cell material) is highly structured, with water forming an integral part of that structure.

The research of Minkoff and others into cell structure and geometry, in particular comparing normal tissue to cancer, is of fundamental importance in understanding living processes in general.

The bag of water concept implies a lower-order structure having only localized interactions. In contrast, Minkoff pointed out that pure water is a polar liquid (one whose molecules have an internal imbalance in electrical charges) that appears to be structured. The addition of ions into such a liquid to form hydrated, charged entities, he said, doubtless changes the structure of the system dramatically.

Living tissue contains not only many different ions but also dissolved proteins, other polyvalent macromolecules (those with more than one area charged), sugars, lipids, etc. Therefore, Minkoff said, the resulting structure could be quite complex and highly ordered.

Using a technique adapted from physics, called nuclear magnetic resonance, the existence of such higher-ordered phenomena involving cellular water in cytoplasm can be studied. As a gross indication of the amount of solubilized material in the cell compared to the total amount of water, an E Coli bacterium has less than four molecules of water per charge, including single ionized species and multiionized species like proteins.

The response of a cell (that is, its complex structure) to nuclear magnetic resonance depends on the geometrical relationships between the atomic nuclei of the compounds in the cell. The more regularly the nuclei are arranged, the more rapidly energy is transferred from one to another, and the more rapidly it is released from the entire system. The speed of reemission of absorbed energy is called the relaxation time. More amorphous matter has a longer relaxation time than crystals where the atoms are highly regularly arranged.

Using nuclear magnetic resonance on a living mouse with an Erlich ascites tumor (a type of cancer) implanted subcutaneously, the NMR signal for the cancer was sufficiently slower than that of the normal tissue for the researchers to visualize the tumor clearly. Additional successful experiments were done to monkeys, and a large magnet is now under construction to be used in human examination.

The importance of this technique is that it can detect internal tumors noninvasively (without cutting open the skin) using a focusing method called FONAR.

The implications of the slower relaxation time for cancer are immense. The NMR used is a broad-band frequency, picking up probably all of the water in the cell and most of the other hydrogen (that is, hydrocarbons, etc.). This implies that the change in the ordering of the cancerous cell is far reaching and general. The implications of the ordering of normal cytoplasm must also be fully explored.

Prior to the NMR application, Minkoff and others used the notion of qualities of structure in cytoplasm to explore the general question of the cell's ion uptake. Normally cells have a very different assortment of ion concentrations from

Continued on page 14

UWE PARPART
Fusion Energy Foundation

Coherence In Science

Contrary to the assumption of most biologists, Schroedinger's most profound contribution to the life sciences is not his influential book *What is Life?* Parpart maintained, it is the epistemological basis of Schroedinger's quantum mechanics and his fight against acausality in physics that are profoundly consequential for biology.

Schroedinger's quantum mechanical wave function is related to the 19th century Hamilton-Jacobi treatment of Newtonian physics as ray optics, in which the large masses of objects (in comparison to single atoms) implied extremely short wavelengths for their trajectories, so they could be assumed to be moving in straight lines. When these same formulations are used to describe extremely small masses, such as electrons, the implied longer wavelengths (the wavelength is proportional to the inverse of the momentum) cause diffraction and other interactions that, from an initial assumption of continuity in the wave equation, give rise to the occurence of *discrete* phenomena in the solutions of those equations.

Schroedinger's interpretation of the equation brought him into direct opposition to the Copenhagen school of thought on the question of microphysics. That school accepted the irreconcilability of the particle-wave duality and the implied unknowability of any coherent interpretation of the phenomena. In this regard, Schroedinger was explicitly against probabilistic and uncertainty theories and was searching for a determinate notion of the causal relationships involved in the micro domain.

More generally, the implications of the wave equation itself make coherent the occurrence of discreteness as eigenvalue solutions to the equations, thus relating discreteness as arising from continuity. This implies that an understanding of particles must procedd from the notion of geometries, both in their formation and in their capacity for long-range stability. Ultimately such geometries are preconditions for the continued self-organizing process of the universe as a whole.

—Ned Rosinsky, MD

Beyond Reductionism

Continued from page 13

For example, Krider pointed out, many genes exist in multiple copies scattered through the chromosomes — hundreds or thousands per genome. But comparisons of the DNA of humans and chimps show no particular DNA sequence in humans that is not in chimps, and vice versa; the species differences must lie in the highly reiterated DNA sequences — and virtually nothing is known about the function of this DNA.

Krider discussed some of the fundamental tenets of molecular biology and then elaborated on the dilemma facing researchers. It is generally assumed that genes determine physiology and form in an organism in a direct, linear fashion, each gene coding for a specific messenger RNA (ribonucleic acid), which codes for a specific enzyme or structural protein. Not content with this gross simplification of the actual physiological processes involved, such molecular biologists further assume that most if not all the attributes or characteristics of an organism are directly controlled by single genes or small numbers of genes, and that changes in the organisms as in evolution are a result of random mutations in these controlling genes.

Yet, no single gene has been found that determines a complex form or function. Indeed, although single genes can determine batteries of genes and the timing of gene function, Krider said, "I know of no mutations capable of determining in and of themselves the generation of a new species."

Krider's work with genes that code for ribosomal RNA develops this problem further. His work is based on the following. The r-DNA (DNA that codes for ribosomal RNA) consists of an 18S region ("S" is a unit of measurement of weight and length), a spacer region, and a 28S region. The 18S and 28S regions are constant between species, but there is a very large difference in the spacer regions; that is, the rate of change for these different areas of the same gene complex is very different.

Since the complex exists in multiple, (300) copies per genome (the hereditary material per cell), how are the multiple copies mutated to influence evolution, Krider asked. The DNA could not be mutable by its molecular characteristics alone, he said, but is mutable by virtue of the system in which the DNA functions. "It is not in fact DNA that is directing evolution; the system which is evolving in some sense and to some degrees is directing the structure of the DNA. A two-way street is involved."

Krider elaborated on his own work on the *abo* mutation in fruit flies (*abo* is a mutation that affects the expression of r-DNA). He showed how a series of genes, which could be considered analogous to circuitry in electronics, is involved in regulating the r-DNA. But, he said, no predictions can be made from these understandings of the genetic components. Rather, it is the genetic environment and developmental history that are important. The expression of the *abo* gene is entirely dependent on the developmental history of the cytoplasm (nonnuclear cell material) of the egg from which the organism will develop.

In other words, a "mutation" is not

Highly Ordered Interactions

Continued from page 13

their immediately surrounding medium, for example, sodium concentrations differ by a factor of 20 or more across the cell membrane, as does potassium and other ions.

As an example of the far-reaching significance of the notion of structure in ionic solutions, the theory predicts that the cell functions like an ion exchange resin, with a differential solubility that favors potassium over sodium. This results in a high internal concentration of potassium and a low concentration of sodium, relative to the surroundings of the resin.

The differential solubilities of sodium and potassium in a wide variety of solvents is well known. The difference in water appears to be a result of the coherence of the geometry of the arrangement of the outer "hydration shell" water with the structure of the ambient water medium. In these terms potassium would be seen as a "structure maker" and sodium as a "structure breaker."

This theory of how ion concentrations are maintained contrasts starkly with the membrane "pump" theory that says some kind of enzyme-like protein or other structure exists in the membrane to actively transport ions and other substances across the membrane. Despite the almost universal acceptance of this theory, no

encoded into the DNA, but rather is apparently subsumed by the interaction of the cytoplasm and the DNA which is replicating, and expressing itself. To put it slightly differently, the developmental program is not necessarily encoded into the DNA; a set of interactions that use different segments of information in different ways and different times is directing development.

Krider concluded: "The reductionist approach has yielded many answers. But if we are going to understand how these findings are utilized in the production of a multicellular organism, in the assembly of complex states in three and four dimensions, the answers must not come just from a linear array of nucleotides (the molecular building blocks of DNA — ed.) that are translated into an RNA molecule and then into a protein molecule. There is clearly more there.

"The timing and the organization of the expression of the genes must certainly lie in cytoplasmic principles, some of them heritable, some not, but all of which are important in the final expression of whatever it is we think we are looking at when we are looking at an organized cell, or system of cells, or organisms....

"Where to look? It is clear that there is language, and a set of principles that developmental geneticists do not have at our disposal and that are clearly important if we are going to understand anything beyond this point."

—Dr. Richard Pollak

Reference:
H. Krider and B. Levine, *Genetics*, Vol. 81: 501 (1975).

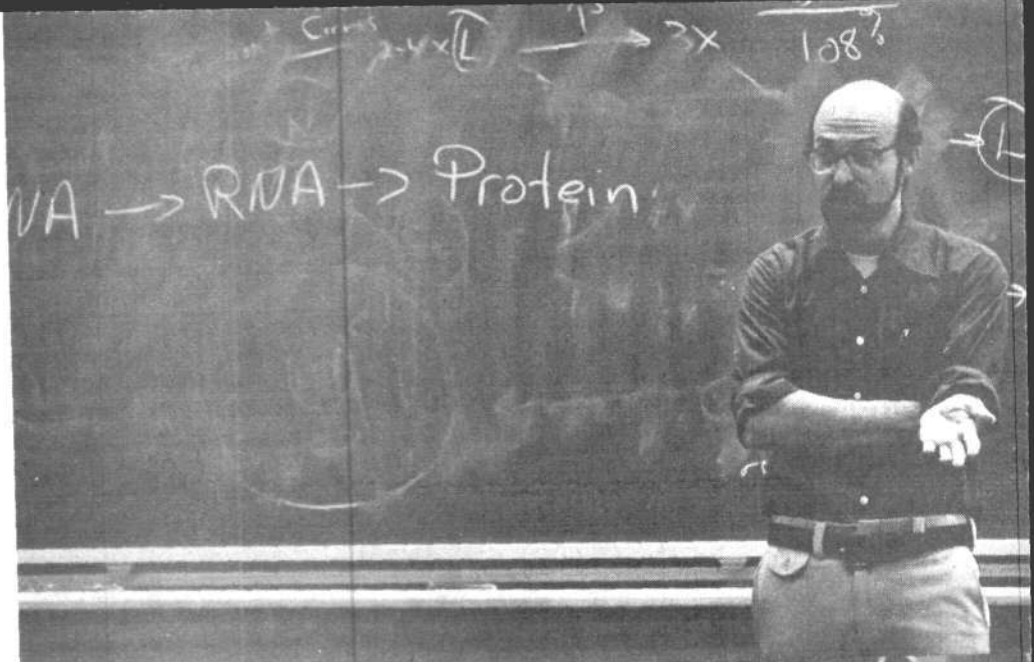
such pump has ever been characterized, and the actual structure and function of the membrane itself are very poorly understood.

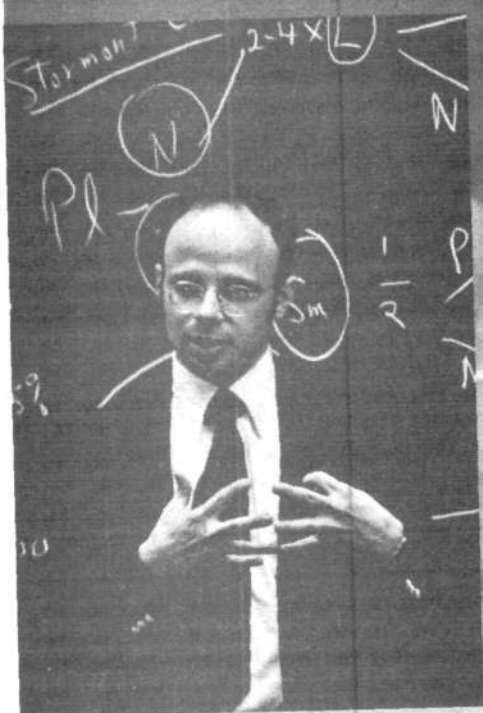
—Ned Rosinsky, MD

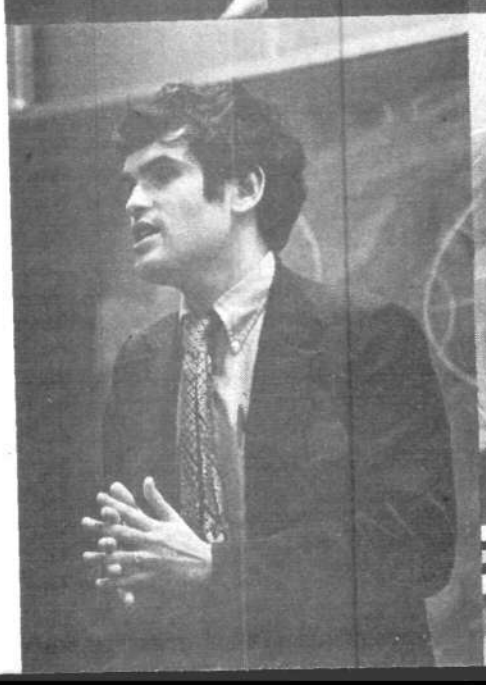
Reference:
Raymond Damadian, Lawrence Minkoff et al., "Tumor Imaging in a Live Animal by Field Focusing NMR," *Physiological Chemistry and Physics*, Vol. 8, No. 1 (1976).

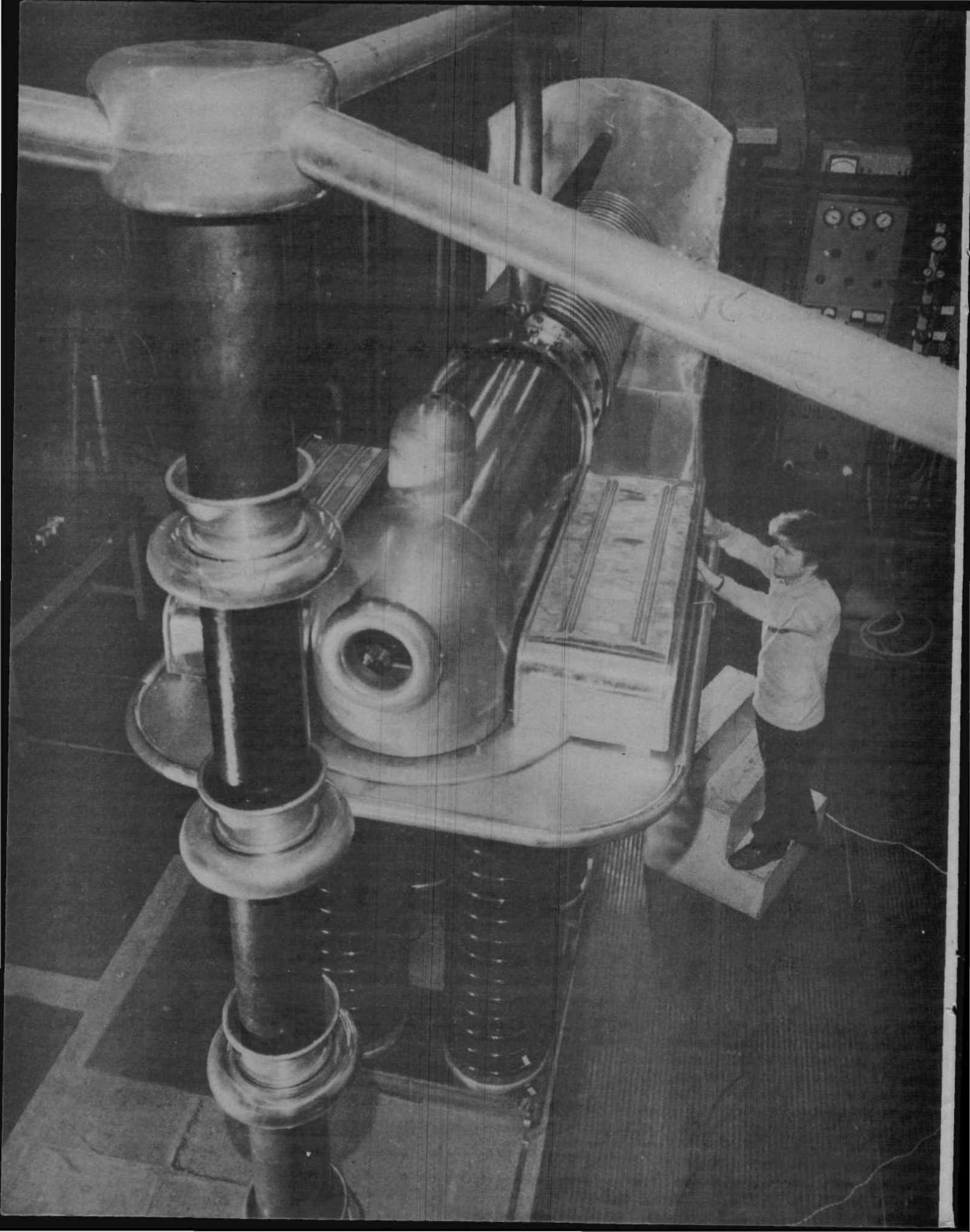
Clockwise from top: Dr. Hal Krider, Dr. Lawrence Minkoff, Uwe Parpart, Eric Lerner, Dr. Richard Pollak.

Photos by ULANOWSKY









The Science Behind The Soviet 'Superweapon'

by Dr. Steven Bardwell

EDITOR'S NOTE

The May 2 issue of *Aviation Week*, a defense industry trade journal, reported that the Soviet Union is on the verge of deploying a "directed energy beam" weapons system that could completely disable any U.S. nuclear weapons launched by U.S. ballistic missiles. The superweapon is a beam of hydrogen nuclei traveling at 99 percent of the speed of light and carrying the energy of 1 million pounds of dynamite that it can deposit on a target in less than .00001 of a second.

The development of the energy beam system, the article emphasized, occurred as a by-product of the Soviet crash program for the development of commercial fusion power. The *Aviation Week* article also identified a political split over national defense policy within the U.S. military and intelligence circles between a group around Major General George Keegan, the just retired head of U.S. Air Force Intelligence, and the military intelligence "establishment" centered in the Intelligence Board of the CIA.

Although unnamed as such in the article, this is the center of the Utopian-Rockefeller military strategists.

The following analysis by FEF plasma physics director Steven Bardwell makes clear what the real issues are behind this "national security" debate and answers the question raised implicitly by the *Aviation Week* article: How could the Soviets with a substantially less advanced industrial base have realized technologies that are upwards of 10 years ahead of the U.S.?

Bardwell's piece initially appeared in *New Solidarity* as the first in an eight-part series on advances in Soviet science, technology, and industry prepared by FEF staff members for the U.S. Labor Party. Under the title *Sputnik of the Seventies: The Science Behind the Soviets' Beam Weapon*, the series was issued as a pamphlet by the U.S. Labor Party. The documentation used for the series was obtained from nonclassified, publicly available sources, and these references are available from the FEF on request.

* * *

IN 1876, AN EXHIBITON in Philadelphia celebrated the 100th anniversary of the United States with a mammoth display of the world's technological achievements. This exhibition proved to the world that the United States was the leading innovator in new and daring technologies. While England and Germany displayed tooled toilet kits and stained glass windows, the American exhibition showed agricultural machinery, industrial equipment, all powered by the world's largest steam engine, the Corliss engine with pistons three and half feet in diameter. "Yankee ingenuity" was a fact.

Eighty years later things had changed. During the late 1940s and early 1950s, leading American scientists and engineers advised the U.S. government that missile development and space travel were impossible. In 1957, the Soviet Union launched and successfully orbited the first artificial earth satellite, Sputnik I.

As anyone over 25 years old remembers, Sputnik I was a psychologically shocking event. How had the U.S. suddenly lost its almost century-old status as the leading *innovator* in technology and applied science? Even more disturbing, how had the Soviet Union — a predominantly agricultural nation — achieved what U.S. scientists had considered impossible?

Twenty years later, the same questions must be asked. According to an informed faction in U.S. military circles centered around Major General Keegan, the recently retired head of U.S. Air Force intelligence, the Soviets have made a series of at least nine technological breakthroughs which allow them to deploy a weapon which is, to quote *Aviation Week*, "capable of neutralizing the entire United States ballistic missile force and checkmating this country's strategic doctrine."

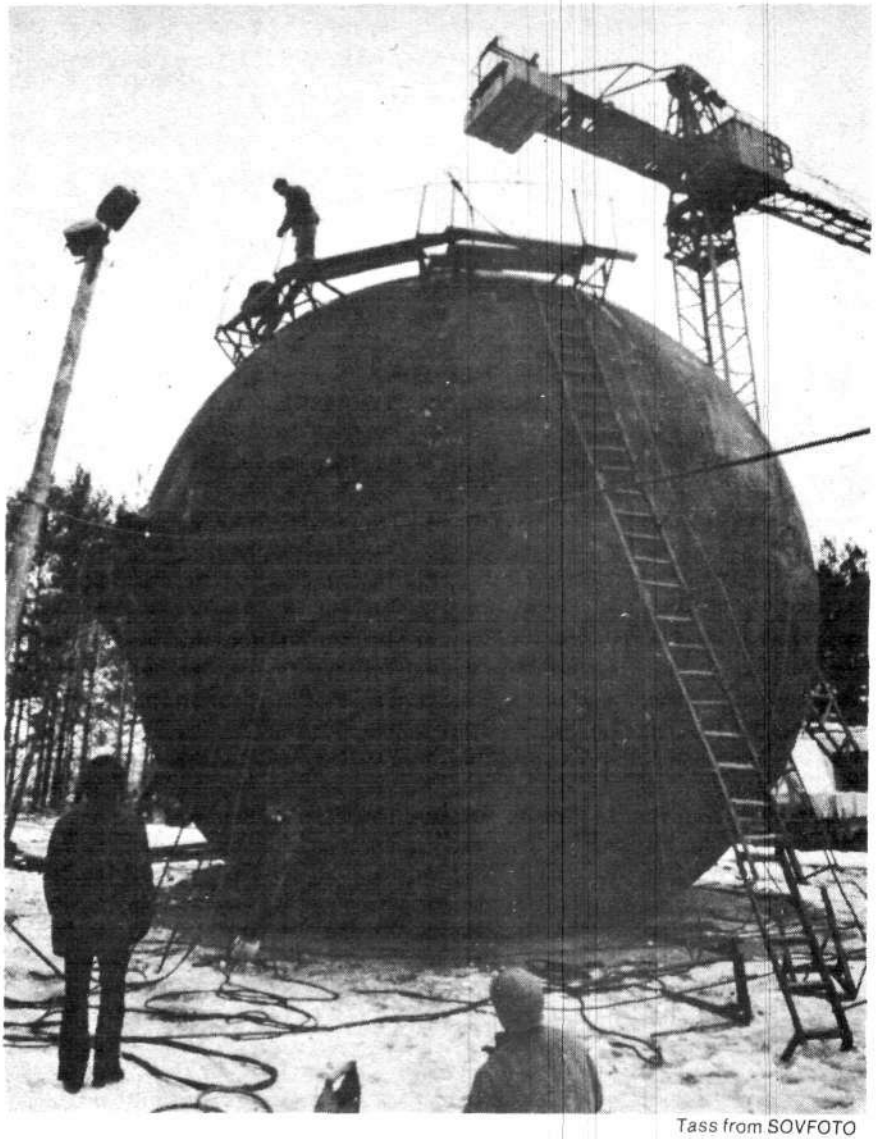
How could the Soviets have succeeded in at least seven areas of technology in each of which the "expert" U.S. judgment was: "impossible for several decades?" How could they have established these technologies on a much less advanced industrial base than that of the U.S.?

The answer to these questions is simple: Soviet advances in developing the military technology of the "directed energy beam weapon" are not the result of military research. They are not the result of a large military budget or evidence of a "new arms race." There is no new "missile gap."

Unfortunately, some of Gen. Keegan's cothinkers have fallen into this fatal misconception as evidenced by the editorial which accompanied the *Aviation Week*

An engineer monitors the parameters of the new type of ion source created at the Soviet Joint Nuclear Research Institute in Dubna. The ion source produces beams of the nuclei of carbon, nitrogen, oxygen, and neon for injecting into the proton synchroton. The science of the ionized gases required for fusion development and for beam weapons is one of the basic theoretical areas in which the Soviets are qualitatively ahead of the U.S.

Tass from SOVFOTO



Tass from SOVFOTO

Above: An explosion chamber in Novosibirsk at the Institute of Hydrodynamics of the Siberian Branch of the Soviet Academy of Sciences being assembled in 1974. The welding technology studied using the chamber was first perfected as a result of the problems encountered in maintaining the Siberian rail system using conventional welding techniques. At right, Soviet workers operate new rail-laying equipment in Siberia.

article. We are in the paradoxical position that mere military answers to the challenge of the Sputnik of the 1970s will ensure not only U.S. failure to develop such technologies, but will ensure a thermonuclear war which the U.S. will lose.

What Have The Soviets Done?

The real story of the Soviet Union's weapons development is not a military one at all, but, rather, a scientific and industrial one. The key to understanding why the U.S. did not develop such a weapon and why the Soviets were able to, lies in the policies of scientific research, energy development, and industrial progress that each country pursued. Each of the technological ingredients which went into making such a "death ray" possible were the result of the Soviet Union's crash program for fusion development, a commitment to basic science research many times larger than that of the U.S., and a continuing, aggressive policy of industrial development. It is the welding together of these three areas if basic science, energy policy, and industrial expansion that is crucial.

Based on that general method, the Soviets, as an adjunct of their overall industrial policy, have succeeded in perfecting the following chain of technologies:

1) A welding method that has allowed the construction of a huge steel chamber capable of containing an atomic blast. The dumbell-shaped device has spherical ends 70 feet in diameter, with walls 13 feet thick and is probably housed inside a granite hole.

This welding technology is essential in the construction of the large pressure vessels and machining equipment used in the Soviet Union. It was first perfected as a result of the problems involved in maintaining, by conventional welding techniques, the Siberian rail system. Welding experts in the United States agree that it is currently impossible to weld such structures with technologies available in the West.

2) The chamber is equipped so that it can turn the blast from the atomic weapon exploding inside it into a pulse of electricity. Using a technology called pulsed magnetohydrodynamics (MHD), a burst of electrical energy containing the energy equivalent of millions of pounds of TNT can be released in a fraction of a second. This machine, if it were to fire one bomb a second, would generate twice as much electricity as the whole of the United States! The initial work on MHD generation came from plasma research in the Soviet fusion and fossil fuel energy generation experiments. The U.S. abandoned all work on MHD about a decade and a half ago, until Soviet successes with their experimental U-25 plant resulted in a small, currently running U.S. program. The Soviet U-25 plant is now supplying power for the Moscow subway system.

3) The electrical pulses from this generator are conducted along hydrogen-cooled transmission lines. The technologies involved in using hydrogen for maintaining cryogenic temperatures have not been used in the United States, nor have conductors been developed which can withstand such high electric fields and currents. The first Soviet work on this subject came out of difficulties that were experienced in transporting electricity over long distances in Siberia. However, again, the continuing research in this field has emerged in fusion development where the transmission of high-intensity pulses of electricity is necessary for initiating and controlling the fusion plasma.

Dr. Steven Bardwell is the Fusion Energy Foundation's director of plasma physics research.

4) The electrical pulse then is stored in a capacitor of a design still unperfected in the United States. The so-called pressurized water capacitor, using water under 100 atmospheres pressure, can store energy densities 40 times those of conventional capacitors. The problems of energy storage and the switching in and out of such capacitors were first attacked in the fusion program, both in the U.S. and Soviet Union. According to sources in the U.S. weapons program, U.S. laboratories have had difficult problems in perfecting these capacitor technologies.

5) Once the electrical pulse has been stored in the capacitor, the capacitor is discharged in a controlled way and the electrical energy is used to generate a high intensity electron beam. As was reported by the FEF in April 1977 the Soviets have made fundamental breakthroughs in their beam-induced fusion research program under the direction of Leonid Rudakov and have perfected a means for generating electron beams at least twice as intense as any in the United States. These beams are used in their fusion program. The diode construction and propagation methods of the electron beam can also be used in the first stage of the generation of a beam for weapon use.

6) Using the intense beam of electrons, plasma processes can be used to generate a beam of atomic nuclei. There are a number of approaches to this process, but the most interesting known technology (which the Soviets have perfected and is still several years from success in the West) is a method for generating almost monoenergetic, "cooled proton," beams. This plasma technology makes it possible to generate a beam of protons which fires a burst of energy equivalent to a million pounds of TNT up to 10 times a second!

This technology was proposed by G. Budker in the United States in 1967 and met with uniform ridicule in U.S. labs. It is now opening up the possibility of studying matter-antimatter collisions in scientific experiments and is being tested for use in medical applications, water purification, and military applications.

7) Once the beam is generated, it must be guided to its target. (In military applications, this would be an intercontinental ballistic missile). This involves a radar capable of siting the beam and a sufficient knowledge of beam-gas-plasma interactions so that the beam can propagate through the atmosphere to reach the missile. The Soviets have had a long program of study of beam-plasma interactions and have pioneered most of the conceptions involved in the application of propagating beams. This technology is also being applied to plasma electronics — using beams to generate intense microwaves, for example — and to the study and use of the astrogeophysical plasmas, the ionosphere and magnetosphere. Relevant in this regard are the recent experiments the Soviets have conducted with high intensity, broad-band radio transmission, which disrupted Atlantic marine communication channels repeatedly last fall.

If all these technologies have been integrated by the Soviets, as all available information indicates is the case, the Soviet Union is near to perfecting a weapon which is capable of being deployed to destroy any offensive capability of U.S. ICBMs.

How Was It Done?

It is clear even from this quick description that Soviet investment in these technologies could be afforded by a country poor in capital and technology only because such technologies emerged from their otherwise existing industrial and energy policy. This is elementary.

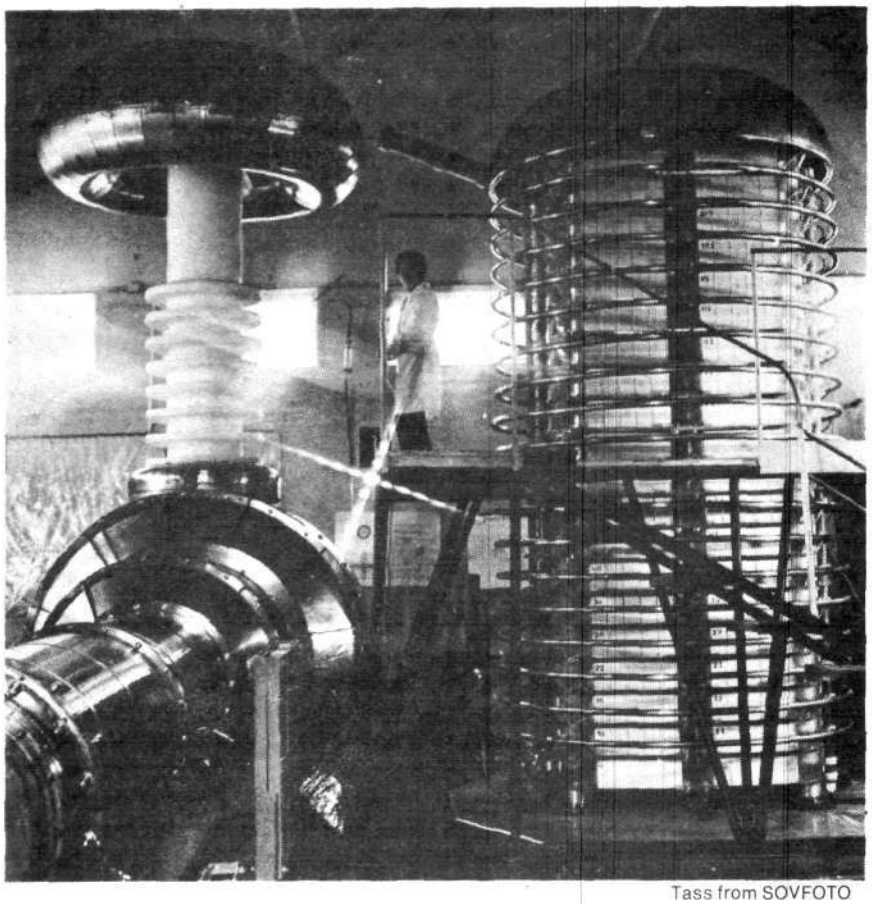
Not so elementary, however, is the role that Soviet basic science research has played in this development. As will be developed in great detail in this series, without a large and growing investment in the research at the frontiers of physics, these breakthroughs could not have been achieved. Especially since the end of World War II, the Soviet Union has had the fastest growing group of theoretical physicists and since roughly the middle of the 1960s, it has had the largest number in absolute terms.

Even more important than the size of this group of researchers is the quality of their training and the freedom of intellectual endeavor in which they work! There are three areas especially where Soviet basic science has excelled, and interestingly enough, each of these areas has a direct relation to the applications cites above.

The first of these areas is hydrodynamics, the study of the motion of continous media, classically fluids, but under certain circumstances including gases and solids. Mikhael Lavrentyev, an applied mathematician who heads the Siberian Academy of Sciences and also the Institute of Hydrodynamics at Novosibirsk, is one of the leading researchers in the theory of shock waves in fluid media. This was the result of a long series of experiments and theoretical study of explosions, in such applications as welding (leading to the explosive welding technique noted above), geologic engineering, and weapons development.

Research in this field is especially difficult and has lagged in the West,

Soviet Life



Tass from SOVFOTO

Angara-I, the high current accelerator of electrons for use in thermonuclear research at the Kurchatov Institute in Moscow.

because the field of hydrodynamics, and especially that of shock waves in fluids, is characterized by nonlinearity — the property of a system whereby its evolution occurs through the generation of complex structures. Even classical hydrodynamics is famous for its difficulty. The description of explosive phenomena is even more difficult because these self-ordered, highly structured phenomena proceed contrary to the common-sense notion of evolution in the direction of decay and disorder.

It is not that the Soviets have developed any new scientific techniques, but they have been unquestionably bolder and more imaginative in their application of the difficult mathematics required. Thus, they have tried to solve the problems, in a causal, analytic, and rigorous way. When similar problems have been dealt with in the West (which has not been as often), the tendency is to solve the equations with a computer, and ignore the conceptual challenge of the nonlinear behavior in the fluid.

The second field in which the Soviets have excelled is in a theoretical branch of physics called "analytical mechanics." Again this is a discipline within physics requiring mathematical skill and a willingness to develop new conceptions of the "natural" direction of evolution. A large school of USSR mathematicians has developed who have perfected the mathematical techniques of Riemann especially and have pursued a theoretical study of the conditions under which a system will evolve in a self-ordering, or disordering, direction.

The mathematical tools developed in this area are applied in the study of large, self-ordering (cooperative) systems, like a laser, or self-accelerated beam. The processes characteristic of the plasma in such a beam weapon, are, also, amenable to these theoretical ideas. Scientists in the United States have lagged behind in this area.

Third, and most important, the Soviets are years ahead in their theoretical understanding of plasma physics — the science of the ionized gases which are required for fusion development and for beam weapons. The Soviets devote now about *twice* as many physicists to studying plasmas as the United States. As the FEF has reported many times, the quality of the plasma physics research in the Soviet Union is considerably superior to that in the United States. The well-known accomplishments of Rudakov in the development of electron beam fusion and the theoretical and experimental work on the Soviet tokamak program under the direction of Boris Kadomtsev indicate the Soviet lead in this area.

The distinguishing feature of Soviet plasma physics is a willingness to tackle difficult problems in a physically rigorous way. The recent Trieste conference on plasma physics is exemplary: at this meeting several groups of Soviet plasma physicists presented new results on the types of self-ordered structures which magnetospheric plasmas can support. These scientific papers were done as part of the fusion development program and conceived of as a basic research problem. (See article this issue.)

Better Read Than Dead?

To a certain extent it is *because* of the Soviet Union's lack of industrial elaboration that they have usurped "Yankee ingenuity." Faced with a problem which *must* be solved but for which the industrial "brute force" tools are not available, a better, more efficient, or cleverer way must be found. Out of necessity the Soviets have pursued basic science and industrial science and industrial development aggressively.

But, the astute observer will note: this is exactly where "Yankee ingenuity" came from — the same commitment to progress, the same brash aggressiveness, and the same willingness to face the challenge of unsolved problems with a combination of intelligence, cleverness, and hard work.

It is *this* tradition of the American Revolution that built the United States into the greatest industrial and military power the world has seen — but, only to the extent that this power was motivated by the humanist commitment to progress. The only "national security" which we have ever had, grew out of, and was maintained by, that commitment to progress.

What does it mean, then, that James Schlesinger calls on all Americans to give up a belief in progress and growth; that James Carter calls on all Americans to support an energy policy which forbids the development of new energy technologies like fusion? What does it mean when this Administration proposes a budget which decreases the country's investment in basic science and, then, pursues policies which are leading directly and rapidly to a thermonuclear confrontation with the Soviet Union?

Some would call this treason.

A Report on the Trieste Conference On Plasma Theory

'General Keegan Is Right'

THE STATE OF THE WORLD'S understanding of plasma physics suddenly became a primary strategic question militarily and technologically, with the April 20 release of President Carter's energy message and the disclosure two weeks later by *Aviation Magazine* that the Soviets had developed an ion beam anti-ballistic missile system.

In an international sense, the ability to control energy-dense plasmas is our only hope for dealing with the energy crisis in the long term; from a national perspective, the same plasma physics is the frontier of military technology.

The Third International ("Kiev") Conference on Plasma Theory, held in Trieste, Italy April 5-9,* provided revealing insight into the world's mastery of plasma phenomena. The most important generalization in terms of plasma physics as strategic question was that the Soviet scientists present displayed an imaginative and aggressive attack on plasma and fusion research that was notably lacking from American scientists.

In the context of a proposed national energy policy that would institutionalize energy shortages and decrease funding in all areas of science research, the evident American demoralization is understandable. The lack of a government commitment to fusion power research, the consequent fading of American science, and the increasing lead of Soviet science however, have consequences far beyond the energy question. Major General George Keegan's claim that the Soviets have developed a weapons systems based on plasma technologies years ahead of U.S. capability deserves serious scrutiny. As Keegan points out (see article this issue), U.S. "national security" is primarily a question of the creativity of American scientists who must develop civilian technologies that guarantee sufficient energy for the production and consumption for a progressing society and also for *military technologies*.

The inescapable conclusion to be drawn from the Trieste conference is that General Keegan is right.

Recent Soviet Results With Solitons and Vortices

One group of Soviet scientists at Trieste presented especially exciting work, both in its potential practical application and its theoretical import. Not accidently, their results have implications immediately relevant to the Keegan disclosures.

Most interesting was the work of a group under V.I. Petviashvili, at the Kurchatov Institute in Moscow. Petviashvili is well-known in the field of nonlinear behavior of plasma waves, and in the past few years he has authored studies of the self-generated concentrations of wave energy, called solitons. The new results the Moscow group presented concerned the long-hypothesized connection between solitons and vortex phenomena.

The basis of the work Petviashvili described is derived from his general conclusion on soliton stability; a soliton can be a self-subsisting structure only if it occurs in more than one dimension. This theorem has serious implications for the bulk of previous work on solitons since very little work has been done outside of the Soviet Union on solitons that were not one dimensional.

Starting from this insight, the problem the Soviet work raises (at least implicitly) is the following: what is the connection between the general classes of self-organized phenomena a plasma exhibits — solitons and vortices? Although this question was not dealt with explicitly by the Soviet group, it has been a persistent and serious problem in plasma research. The conventional physics applied to a plasma indicates that solitons and vortices are entirely different. Specifically, the solitons previously studied all resulted from rapid, electron motion, while vortex phenomena were due to the slower motion of the ions (ions are positively charged nuclei). How can one explain the very striking qualitative similarity between both groups of self-ordered behavior if they are due to entirely distinct processes?

Petviashvili showed that for at least three kinds of waves the soliton solutions of the nonlinear wave equations have the structure of vortices, *when they are solved in more than one dimension*. This result is quite astounding!

Magnetosonic waves ("fast" waves) have a three-dimensional soliton solution that is stable and has the structure of a toroidal vortex (a smoke ring). A closed field and flow structure can be generated by the waves which "ride" along the background magnetic field.

Alfven waves, in a similar plasma regime, can generate a helical vortex filamentary structure of field and flow, which is a soliton solution to the nonlinear equation for Alfven waves in three dimensions.

Electron cyclotron solitons have a similar stationary vortex structure.

Petviashvili backed up these theoretical results with a remarkable choice of experimental data. "No magnetized plasma is sufficiently well diagnosed in the laboratory today to study these structures," he stated. "The best medium for observing the solitons is terrestrial magnetospheric plasma."

The Moscow group presented data from high-energy phenomena in the magnetosphere that could be qualitatively described by this sort of coherent soliton-wave phenomena. They claimed that the characteristic one-second perturbations in the night-side terrestrial magnetic field are a result of the propagation of magnetosonic wave solitons and the fields they generate. Similarly, the so-called pearl string terrestrial magnetic field perturbation is due to the Alfven soliton. Finally, they theorized that the recently discovered terrestrial kilometer radiation is due to the pumping of electron cyclotron solitons. These solitons then scatter

* The meeting is sponsored every two years by the Kurchatov Institute in Moscow under the auspices of the United Nations International Atomic Energy Agency. It is called the Kiev Conference after its first site.

high-energy electrons in such a way that they are freed from their trapped orbits. The consequent precipitation of electrons may explain the coincidence of the kilometer radiation with the polar auroras.

Fusion and Military Applications

Although the Soviet group did not speculate about the applications of their work, there are two areas where it is of immediate interest: controlled fusion research and military research.

It is becoming increasingly clear that the key to efficient, advanced fusion devices will be the naturally energy-dense structures created by the plasma. Experiments on a laboratory scale that mimic the effects reported by the Moscow group (by Professor Dan Wells at the University of Miami, to take one example) indicate very strongly the impact that a controlled generator of plasma vortices can have on creating fusion plasmas with small energy inputs. This line of research is grossly underfunded in the United States, and the poverty that such underfunding has bestowed on the entire U.S. program was very clear at Trieste.

It is unavoidable that an understanding of almost any high-energy phenomena will have military implications. This is especially true when dealing with the incredible total energies available in the magnetosphere and in looking at the important role of ionized layers of the atmosphere in communications and missile defense.

This point is sharply drawn in the context of the problem of propagating an ionized beam (for antimissile or antisatellite use, for example) through the atmosphere. The Soviet scientific successes in this area are of much more than academic interest.

Does It Have To Be This Way?

After the poor showing by even some of the most well-respected American plasma physicists at Trieste, a number of physicists asked the obvious: What happened to America's leading contribution to world scientific development? Why are we slowing down?

There is little doubt that the considerably more rigorous mathematical background demanded of Soviet scientists and a more classically oriented education in physics result in different styles as well as different content to Soviet versus U.S. physics.

More immediately important here, however, is the different atmosphere in which Soviet science is funded and assessed. The role of the fusion research program in each country is typical of the difference. The Soviets spend twice as much scientific manpower on fusion as the U.S. does, because they believe that fusion is the major scientific and technical task mankind must accomplish in this century.

Most damning is a simple comparison of the way the overall research program is run. Soviet scientists do not have to justify their research every year, scrambling to write up grant proposals. Soviet research is coordinated in various institutes run by

Soviet Vs. U.S. Science

The Case of L.D. Landau

ONE OF THE BEST pieces of evidence to consider in documenting the accuracy of Major General George Keegan's allegations of Soviet superiority in science is the career of Soviet physicist Lev Davidovich Landau (1908-60) and his written works (*The Collected Papers of Landau*, New York: Gordon and Breach, 1965).

Landau's work is crucial for evaluating Soviet science policies and capabilities. He was the leading link between the anti-reductionist initiators of Soviet physical science (most notably V.I. Vernadsky) and the present generation of physicists and his scientific investigations followed a coherent line for a period of more than 35 years.

From his 1931 paper with R. Peierls on the breakdown of quantum mechanics in the relativistic (high energy) domain to his final published paper on "Fundamental Problems," Landau was consistently ruthless in pointing out that *in reality* there is no such thing as the interaction at a point of extensionless particles. Landau properly viewed the renormalization techniques that mathematically (in some cases) remove the infinities from computations of the interactions and self-interactions of points as mere technological tricks compared with a theory that could directly account for the actual geometry of physical interaction.

From this viewpoint, Landau developed the perspective out of which flows the current *scientifically* strategic advantages

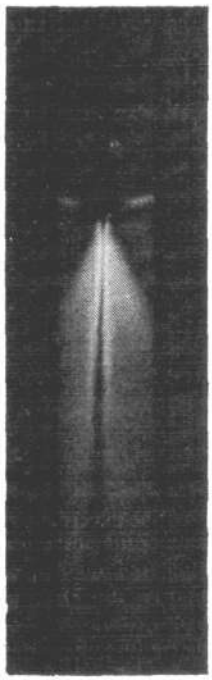
scientists who have a much greater overall degree of freedom of inquiry than their U.S. counterparts.

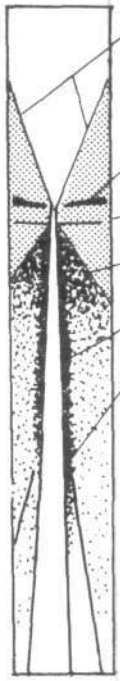
Creative work — which the Soviets exhibited in abundance at Trieste, and which the Americans appeared to be conserving — is not an academic question. One cannot buy it, but one certainly can stifle it.

—Dr. Steven Bardwell

SOLITONS

Soliton is the name given to an astounding property of most wave systems in plasmas in which wave energy becomes bunched up into a highly concentrated localized structure. Solitons maintain their structure after collisions with other solitons and thus are described as particle-like. A more detailed assessment of the significance of these phenomena in plasma has appeared in the FEF Newsletter, September 1976 and March 1977.





Source: Dr. Dan Wells

COLLISION OF PLASMA VORTEX STRUCTURES

This streak picture and schematic diagram illustrate the collision of plasma vortex structures at the center of a secondary mirror system. Time goes from top to bottom of the picture and diagram. The streak time is 50μ sec. The horizontal slit was placed along the centerline of the machine, between the secondary compression coils.

of Soviet research: In brief, Landau held that particle physics in its point interaction form is absurd and the Second Law of Thermodynamics (which says there is an increase of disorder or entropy) *cannot* be true of the physical universe as a whole or of many of its parts if it holds for any of its parts! (See Landau, and M. Bronstein, 1933, "On the Second Law of Thermodynamics and the Universe," in *Phys. Z. Sowjet 4: 114.*]

Therefore, Landau said, continuum theories such as hydrodynamics are valid in the same domains of nature and to the same extent as are the so-called laws of thermodynamics (concerning the distribution of energy among its possible forms for various systems), although they are not rigorously correct. Continuum theories, however, are the best approximations at present we have to the actual — but not yet fully describable — higher order, nonlinear processes of energy stabilization and transformation.

Landau's work thus constituted a unified approach to the interactions in systems supposedly as different as free particle collisions, fluids, solids, plasmas, superfluids, and superconductors — in each case seeking within existing physics the best possible representation of energy states and associated geometrical configurations and of the limiting circumstances where they break down. As such it directly lays the basis for the unified scientific and technological approach to coherently develop a high-energy density, rapidly pulsed particle beam device.

Landau's many papers during 1940-45 involved the direct application of these principles to military problems and related technologies and are very relevant to the concerns mentioned by General Keegan. For example, see Landau and K.P. Staniukovich, "Determination of the Flow Velocity of the Detonation Products of Condensed Explosives," 1945, in *C.R. Acad. Sci. USSR 47: 291.*]

In his last paper, Landau summarized the basic problem facing physics: "Unfortunately, the nonlocal nature of the interaction (renormalization of point interactions — ed.) renders completely useless the technique of the present existing theory. Of course the *undesirability of this occurrence* is a poor argument against the nonlocal nature of the interaction..." (emphasis added).

In the United States an almost complete disregard of Landau's insights has resulted in a total divergence in physics between the two distinct fields of particle and plasma physics. Those few individuals who approach either or both fields from the standpoint of developing new theoretical hypotheses and crucial experimental tests of the relevant dynamic geometrical forms of energy transformation are the exceptions who prove the rule of dogmatic attachment to a priori particle or field theories.

This particle-plasma physics gap underlies the purported rebuttal of Keegan's assessment prepared by Dr. Richard Garwin of IBM for the Council for a Livable World, which specializes in funding the election campaigns of "arms control-oriented" senators. Garwin's case boils down to this circular argument: beam generation doesn't require all the energy produced in nuclear reactions. If the beam energy content is produced by conventional sources, however, it can be deflected from its target. Therefore, particle beam ABM weapons aren't practical.

The conversion of the huge energy from a thermonuclear blast into a charged particle beam seems impractical to Garwin and other U.S. scientific defense analysts precisely because they are not committed to going beyond particle accelerators to control of the nonlinear regime of collective accereration of ions in plasma.

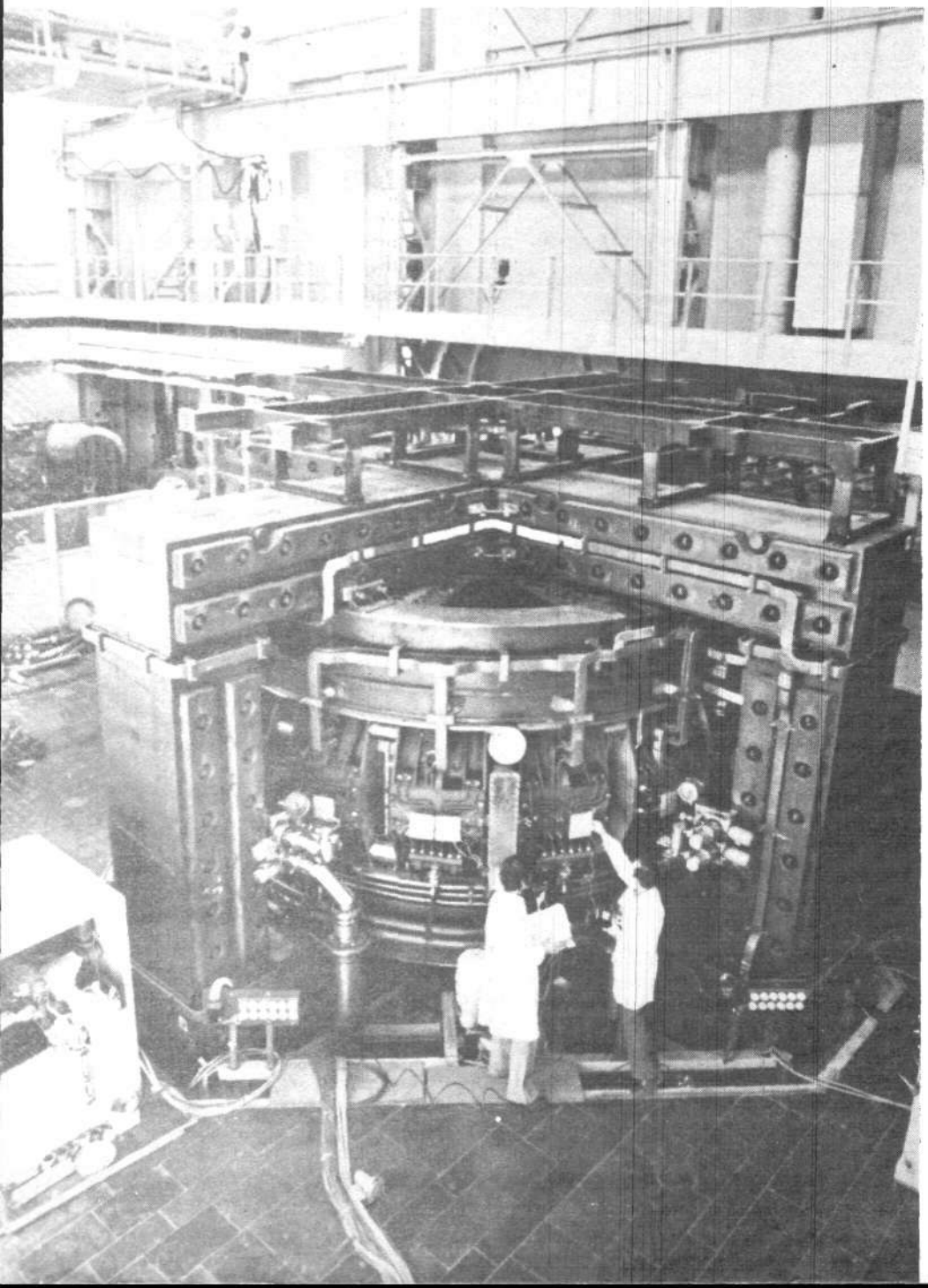
This same qualitative distinction between U.S. and Soviet physics, as might be expected, extends to the area of civilian energy research in the case of controlled fusion and related plasma technologies such as magnetohydrodynamics. The fact that U.S. and Soviet physics may apparently be interchangeable in perhaps 95 percent of the scientific papers published in no way alters the strategic significance militarily and economically of the critical national distinctions arising in research on energy dense plasmas, beams, and related coherent phenomena.

—Dr. Morris Levitt

Mainline Tokamaks

Commercial Fusion Power Development by the 1980s

by Charles B. Stevens



Tokamak 10, the largest experimental thermonuclear machine, in operation at the Kurchatov Atomic Power Institute in Moscow.
Tass from SOVFOTO

INTRODUCTION

"FUSION WILL BE DEVELOPED to practical usefulness; it is only a question of when and by whom." These were the words of Dr. Edwin Kintner, director of the U.S. Energy Research and Development Administration's Division of Magnetic Fusion Energy in his presentation to the May 2-13 conference on nuclear fuel cycles of the International Atomic Energy Agency in Salzburg, Austria.*

In previous congressional testimony Dr. Kintner had issued similar statements, pointing out that rapid progress in technology and experimentation lead to the conclusion that there are no foreseeable *insoluble* scientific or technological problems in the commercial demonstration of nuclear fusion power well before the year 2000. The chief constraint Dr. Kintner said, is money.

Dr. Kintner's analysis includes a number of entirely different approaches and variations on these approaches to the successful harnessing of fusion power — all of which are promising. His conclusions are based primarily, however, on a projection — a most conservative projection — of the commercial development of the mainline tokamak magnetic bottle system.

This paper reviews in detail the factual basis for Dr. Kintner's projection in ongoing experimental devices like the Alcator and as outlined in recent studies completed by three U.S. engineering laboratory research groups: the Argonne National Laboratory in Argonne, Illinois, the General Atomic Company in San Diego, California, and the Oak Ridge National Laboratory in Oak Ridge, Tennessee.**These studies and their conclusions on the near-term feasibility of commercial tokamaks were also the major part of the discussion at the March 1977 meeting in Cambridge of ERDA's Fusion Power Coordinating Committee.

The Oak Ridge report, reviewed here at length, is the most recent of the three (March 1977) and also the most general in scope. The two other studies reinforce the conclusions of the Oak Ridge report, but they are more specifically directed toward one particular Tokamak design.

The most important conclusion of all three studies is that economical *commercial fusion power reactors could be*

demonstrated in the 1980s with a high degree of confidence of success, based on a conservative projection of current experimental data and utilizing existing and readily developable near-term technologies.

The reports are all overly conservative in defining a baseline for the projected timespan necessary to realize commercial fusion. They do not take into account major technological or scientific breakthroughs that could appreciably accelerate the progress toward commercial demonstration of fusion. Nor do they take into account quite practical variations, such as the fusion-fission hybrid or the direct industrial utilization of fusion energy rather than that of fusion-produced electrical power, both of which could lead to the significantly quicker demonstration and development of fusion power.

FUSION BASICS

We begin a review of the Oak Ridge report by outlining the essentials of nuclear fusion reactions and the operation of tokamak magnetic bottle systems.

When matter is raised to sufficient temperatures, the nuclei of the atoms can fuse to form the nuclei of new elements. The ignition of this "nuclear fusion" reaction depends on inducing some minimum threshold temperature and *maintaining* it in an appropriate fusion fuel. The rate at which the fusion reaction proceeds, and therefore the rate at which energy is released, is proportional to the density of the fusion fuel, that is to the number of fusion fuel nuclei per cubic centimeter.

For example deuterium, D, and tritium, T, the two heavy isotopes of hydrogen (isotopes are variations of the same chemical element that differ in the number of neutrons their nuclei contain), have the lowest threshold temperature for igniting the fusion reaction — about 100 million degrees centigrade. The D-T reaction results in the formation of a helium nucleus and the release of a neutron. The reaction products weigh less than the reactants, and this defect in mass shows up as energy in the reaction products according to the Einstein relation that energy is equal to mass times the square of the speed of light. Accordingly, the reaction products, the neutron and helium nucleus, are produced with temperatures of hundreds of *billions* of degrees. Thus, there is an inherent net energy gain of several thousand.

Deuterium is readily obtained from seawater, while tritium has to be bred in a fusion reactor from lithium. The fusion-released neutron, which contains about 80 percent of the fusion energy released in the reaction, induces a nuclear reaction in lithium that results in the formation of a helium nucleus and a tritium nucleus.

The lithium must be situated in a region surrounding the chamber in which the fusion reaction is taking place. This region is referred to as the *breeding blanket* and is a major technological component of a D-T fusion reactor system. In addition to its use for breeding the tritium fusion fuel, lithium could also be used as the working fluid for transporting the heat produced in the fusion reaction chamber to a turbine for generation of electricity or to a second working fluid, such as steam, which would then drive a turbine for generation of electricity.

TOKAMAK MAGNETIC BOTTLES

At the temperatures needed for igniting fusion reactions, matter no longer consists of electrically neutral atoms, but of separate, positively charged nuclei (or ions) and negatively charged electrons. This state of matter is termed the *plasma* state and is dominated by electromagnetic fields.

These magnetic fields appreciably slow down the diffusion of hot plasma in a direction perpendicular to the direction of the magnetic field. The plasma electrons and nuclei then become trapped in helical (spiral) orbits along the magnetic field lines.

In the same way a magnetic field purposely formed in the shape of a donut can trap a hot plasma within its geometry, since the lines of the magnetic field are closed. (See Figure 1.) This entrapment process is a major feature of the tokamak magnetic bottle device.

In a magnetic bottle like the tokamak, the magnetic field both insulates and traps the fusion plasma. If the plasma interacts with the magnetic field — either macroscopically or on a local, microscopic scale — in such a way as to rapidly contact the wall of the chamber containing the fusion plasma, the plasma will quickly lose its temperature and quench the fusion reaction.

Since the rate at which the fusion reaction proceeds is proportional to the density of the plasma, minimum criteria for net energy energy production can be set in the following manner once the ignition temperature is reached: Given a fusion plasma at the ignition temperature of 100 million degrees and a density of 100 trillion nuclei per cubic centimeter (that is the density at which tokamaks generally operate, about a million times as dense as ordinary air), the average time during which the plasma is maintained at both this density and temperature must be greater than one second. This average time is necessary to make the rate of fusion energy production greater than the rate of energy input into the plasma required to maintain it at the 100 million degree temperature. The product of the plasma density and this energy confinement time is called the *Lawson criterion* for fusion energy production (after the British physicist J.D. Lawson).

At higher densities, the necessary energy confinement time is proportionately reduced.

In addition to the plasma temperature, density, and pressure (pressure is equal to the product of the temperature and density), there is a fourth, crucial parameter, the ***plasma beta***. Plasma beta is a measure of the efficiency with which the magnetic fields are being utilized to confine the hot plasma gas. The magnetic field exerts a pressure proportional to its energy density, that is, the square of the magnetic field strength. The ratio of the plasma gas pressure to the magnetic field pressure is the plasma beta.

Most tokamaks currently operate at very low betas, less than 1 percent, and therefore do not efficiently utilize the confining magnetic field.

Figure 1 is a schematic diagram of a tokamak. Low-density hydrogen gas is pumped into the donut-shaped vacuum chamber. A constant current is passed through the large copper coils surrounding this chamber, and these generate a a magnetic field in the ***toroidal*** direction, the long way around the donut.

Next an alternating current is passed through the iron core transformer. The changing magnetic flux generated by this transformer first ionizes the hydrogen gas and then induces an electrical current in the plasma in the toroidal direction. This plasma current also generates a constant magnetic field, but in the ***poloidal***

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* Excerpts from Dr. Kintner's Salzburg presentation are reprinted in the IAEA article in this issue.

**The reports are: *Tokamak Engineering Technology Facility Scoping Study*, W.M. Stacey, et al., (Argonne, Ill.: Argonne National Laboratory, July 1976) ANL CTR-76-1; *Experimental Fusion Power Reactor Conceptual Design Study: Final Report*, C.C. Baker, principal investigator (San Diego, Cal.: General Atomic Co., December 1976); *ORNL Fusion Power Demonstration Study: Interim Report*, Don Steiner, et al. (Oak Ridge Tenn.: Oak Ridge National Laboratory, March 1977) ORNL TM-5813.

direction, the short way around the donut.

The externally generated toroidal magnetic field combines with the plasma-generated field to form magnetic field lines that follow helical trajectories, the long way around the donut. This magnetic field geometry is crucial for maintaining the stability of the plasma.

The electrical current induced in the plasma generates a component to the confining magnetic field and also heats the plasma gas by simple resistive heating. Under ordinary circumstances this type of heating is sufficient only to heat the plasma to 11 million degrees.

At this temperature the electrical resistivity of the plasma rapidly decreases, and an alternative means of heating must be used. One method is to use radio and microwave electromagnetic radiation that can be absorbed by the plasma.

A second, more experimentally successful approach is neutral beam heating: hydrogen ions are accelerated to high velocities, corresponding to temperatures of 1 billion degrees. When these ion beams are shot through a normal hydrogen gas, they undergo charge exchange; the beam ions are transformed into neutral atoms, but they retain temperatures of 1 billion degrees. These neutral beams are directed into the vacuum chamber of the tokamak and can penetrate the magnetic bottle since they are electrically neutral.

Once within the plasma, the high-energy neutrals again undergo charge exchange and become ionized, thus permitting their entrapment by the magnetic field. As the trapped high-energy ions collide with the colder background plasma ions, they heat the plasma.

THE OAK RIDGE CONCLUSIONS

The chief conclusion of the Oak Ridge study is that commercial fusion power can be demonstrated with the mainline tokamak approach well before the year 2000. Technology is not the chief constraint on the timespan, as previous studies had projected. In fact, according to the material in the Oak Ridge report, a relatively low-risk and low-cost program for demonstrating commercial fusion via the tokamak could be completed by the end of the 1980s.

The technology and materials needed for a commercial tokamak are either existing state of the art or readily developable. Since existing or near-term technology is involved, we can project rather definite capital costs for a prototype commerical facility. (The fuel for fusion is virtually free and therefore the capital costs of building the reactor are the main economic determinant.) According to the Oak Ridge Interim Report, tokamaks are at least comparable to Liquid Metal Fast Breeder Fission Reactors. A prototype commercial complex consisting of three tokamak reactors and producing 2250 megawatts of electricity for utilities would cost approximately $2.3 billion in 1976 dollars. This is comparable *both* in capital cost and electric power output to two existing fission reactors.

(It should be noted that this $2.3 billion does not include the costs for developing new technologies involved in fusion reactors — for example, superconducting magnets and neutral beams).

The Oak Ridge report concludes that several developmental stages previously thought necessary can be leap-frogged; resulting in a tremendous savings in time and money. In their plan, the tokamak reactor core for the final commercial prototype plant would be utilized first as a fusion reaction ignition demonstration experiment, then as a power technology demonstration (that is, tritium breeding, heat exchangers, and turbines), and finally as the reactor core of the prototype commercial plant.

The major reasons for this significant conclusion are as follows. Contrary to initial studies, tokamaks can be operated at power densities 10 times greater than those originally projected — that is, 7 megawatts per cubic meter. Second, the optimum size of a tokamak reactor is many times smaller than existing fission reactors, rather than the other way around as previously thought. The actual scale of a commercial tokamak power plant is less than that of a comparable (in electrical output) fast breeder reactor. This small optimum size for a commercial fusion prototype is exactly that needed for an ignition experiment.

It is important to note that the totally separate Argonne and General Atomic studies — which are based (especially the General Atomic study) on entirely different tokamak reactor designs consisting of different kinds of materials — reached the same genreal conclusions as the Oak Ridge study: commercial fusion power can be demonstrated well before 2000.

COMPARISON OF POWER DENSITY IN VARIOUS FUSION REACTOR STUDIES

EXPERIMENTAL FUSION REACTOR DESIGN	FUSION * POWER (MW)	PLASMA VOLUME (m^3)	POWER ** DENSITY (MW/m^3)
ARGONNE	798	544	1.47
OAK RIDGE	513	675	0.91
GENERAL ATOMIC	513	300	1.71
UWMAK-I	5000	6400	0.78
UWMAK-II	5000	6415	0.78
UWMAK-III	5000	2370	2.11
PRINCETON	5305	2190	2.42
OAK RIDGE (1976 study)	2000	266	7.52

*Corresponding to ~ 22 MeV fusion event.
**Ratio of fusion power to plasma volume.

PLASMA PHYSICS

The Oak Ridge study indicates that the chief scientific constraint on fusion power development is plasma physics. Previous studies* had estimated that the materials for the first wall of the fusion reactor chamber would be the chief technological problem and that existing materials would not last much longer than six months in a fusion environment, even at very low fusion power densities.

Actual experiments in a simulated fusion environment changed this entire picture; it now appears that even existing alloys of stainless steel used in fission reactors are not only sufficient but also will hold up even with higher power densities.

Even more startling progress has been made in the plasma physics field. Empirical scaling of confinement time with size has been demonstrated (that is, confinement time increases proportionately with increases in size). Much more significant — and surprising — confinement time is also scaling with increasing plasma density. Successful neutral beam heating has been experimentally demonstrated inducing no

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Charles Stevens, a leading international reporter on fusion research, is a member of the Fusion Energy Foundation staff.

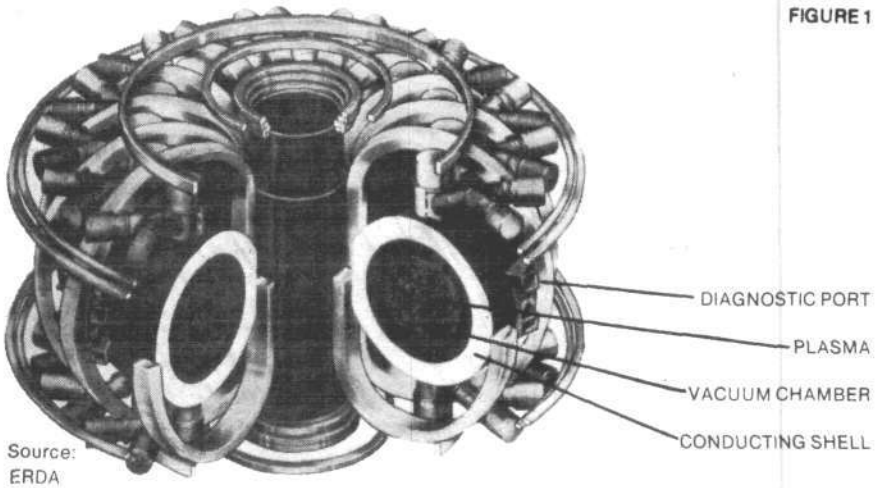

FIGURE 1

An artist's drawing of the Argonne Tokamak Experimental Power Reactor.

plasma instabilities and attaining temperatures of over 20 million degrees. This is within a factor of three of what is minimally needed for ignition.

The Alcator

The high-field Alcator Tokamak at the Massachusetts Institute of Technology has already produced confinement time-density products needed for breakeven fusion energy production. (Breakeven is the point at which fusion energy production is greater than the rate of energy input to achieve the fusion reaction.) This approach can be empirically scaled up to reactor conditions without having to master any qualitatively new plasma regimes. (Regime refers to the temperature and density that make one particular plasma qualitatively different from another.) Such a pathway to commercial fusion, however, would require major developments in magnet technology, since the Alcator approach utilizes very strong magnetic fields, about twice as strong as those used on conventional tokamaks.

Using higher magnetic fields, the Alcator has been able to operate at much greater plasma current densities than any other tokamak, resulting in the emergence of a qualitatively new plasma regime. Among the major problems in other tokamaks but not the Alcator are the possible need for impurities (elements other than hydrogen) to start up plasma discharge, impurities dominating the plasma, and disruptive instability.

Other tokamaks, like the Oak Ridge Ormak, have demonstrated some qualitatively similar behavior to that of the Alcator, but overall the Alcator is unique. This is also true in a programmatic sense. Consider that the Alcator, a Tokamak .01 the size and .02 the cost of the Princeton Tokamak Fusion Test Reactor, which will be completed at Princeton in 1981 at a cost of $225 million, has already achieved twice the Lawson confinement parameter projected for the Princeton Tokamak.

The Alcator research team believes that their experiment is possibly the first tokamak to achieve a discharge completely dominated by plasma processes — plasma processes indicating that the most optimistic predictions of classical plasma theory on confinement are being experimentally achieved in the tokamak.

The Oak Ridge study did not pursue the Alcator approach because the study specified staying within the bounds of existing, readily developable technology.

Mainline Tokamaks and Research Problems

Empirical scaling of other tokamak experiments leads to plasma regimes more than adequate for reactor-grade plasmas. (In fact, such experiments would have to be degraded purposely, to hold the plasma within the desired temperature range.) Existing mainline tokamaks are also within an order of magnitude of the necessary confinement parameters.

Some theoretical projections hold that the pathway for mainline tokamak reactor development will encounter a new plasma regime, the *trapped ion regime*. In the trapped ion regime, plasma ion motions are no longer simple helical trajectories along the magnetic field lines. Instead, this helical orbit is combined with a larger banana-shaped orbit, over which the ions bounce back and forth.

The important question here is that in the trapped ion mode, the radius of the banana, compared with the much smaller radius of the helical orbit determines the step-size for ion diffusion across the magnetic field lines. Therefore, with the larger diffusion steps of the trapped ion modes, it is believed that diffusion would be quicker and therefore overall confinement time much less.

Even the most pessimistic theoretical projections of this regime, however, still point toward the attainment of sufficient confinement parameters for power reactor operation.

Plasma Beta

Plasma beta still remains as a major problem in the tokamak; mainline experiments have attained betas of only a small percentage. According to the Oak Ridge study, betas between 5 and 10 percent (taking profiles of plasma density and temperature into account) appear to be requisite.

Two solutions to the beta problem have been experimentally demonstrated in part. The first is to change the cross-section of the tokamak donut from that of a circle to an elongated figure 8, the shape of the General Atomic Doublet tokamak design, or to a D shape (see Figure 2). This changes the geometry of the magnetic field in such a manner as to increase the stability of the plasma. Recent experimental results from the Doublet II at General Atomic indicate that betas of 10 percent can be achieved in this way.

The second approach, termed the flux-conserving tokamak, is a spinoff of high beta experimental plasma research in West Germany. If the plasma is heated with sufficient rapidity, it was found that the magnetic field lines are frozen into a stable configuration. Neutral beam heating meets the rapidity requirements, and tokamak betas as high as 20 percent have been theoretically projected with this approach.

Impurities

Impurities (that is, elements other than hydrogen) entering the plasma from the vacuum chamber wall also remain a major problem. (It should be noted that, for reasons not completely understood, the high field, high density Alcator operates with virtually no impurity influx.) In the current mainline tokamaks, impurities appear to dominate the plasma regimes, although there are reasons to believe that the impurity problem will disappear with

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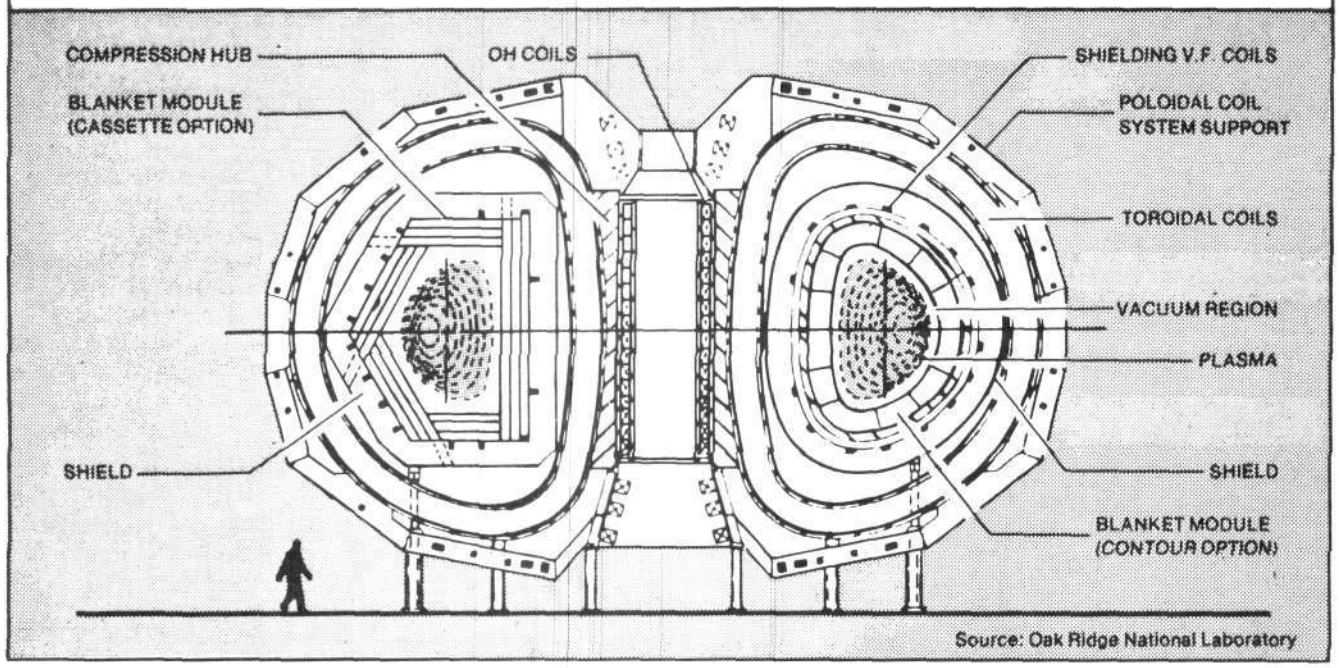
* These studies were concluded prior to the results achieved by the fusion technology program initiated by Dr. Robert Hirsch, former assistant director of ERDA for advanced energy systems. Hirsch was pushed out of ERDA by the Carter Administration in early 1977 because of his outspoken support for fusion.

FIGURE 2

OAK RIDGE TOKAMAK REACTOR
CROSS-SECTION SHOWING MAJOR
BLANKET COMPONENTS



the next stage of experiments. Several approaches to solving this problem, however, have been experimentally demonstrated *if indeed the problem continues to arise in higher temperature experiments.*

The main approach already experimentally explored is that of diverting the outer layer of magnetic field surrounding the plasma donut into an external chamber. In this way ionized impurities from the wall are diverted away from penetrating the fusion plasma, while impurities diffusing out of the fusion plasma are scraped off and also diverted. The divertor approach can also be combined with a gas blanket surrounding the fusion plasma. It should be noted that impurities actually may be needed for the startup of tokamak discharges. If this is the case, then the impurities not only have to be eliminated at the burn phase but have to be purposely controlled throughout the discharge.

Viable Solutions

The most important overall conclusion on the general status of plasma physics research in tokamaks is that while many significant problems remain to be conclusively solved, for every problem there are many entirely different solutions already experimentally indicated as viable. Given a broad-based, strong research effort — especially in high-beta plasma research — there is no doubt from a pragmatic standpoint that all of these problems will be conclusively resolved within the next two to three years.

The successful solution of major research problems does not mean that we will attain full theoretical comprehension. In fact, just the opposite most likely will be the case. From a theoretical standpoint, the tokamak remains an anomaly from the very initiation of its operation through all of its complex regimes. The point is that one does not have to fully comprehend the workings of a steam-engine in order to employ it, although of course such an understanding vastly improves the efficiency with which it is utilized. We will most likely be getting electricity from tokamaks to light our research labs long before we completely comprehend its workings.

ENGINEERING AND REACTOR TECHNOLOGY

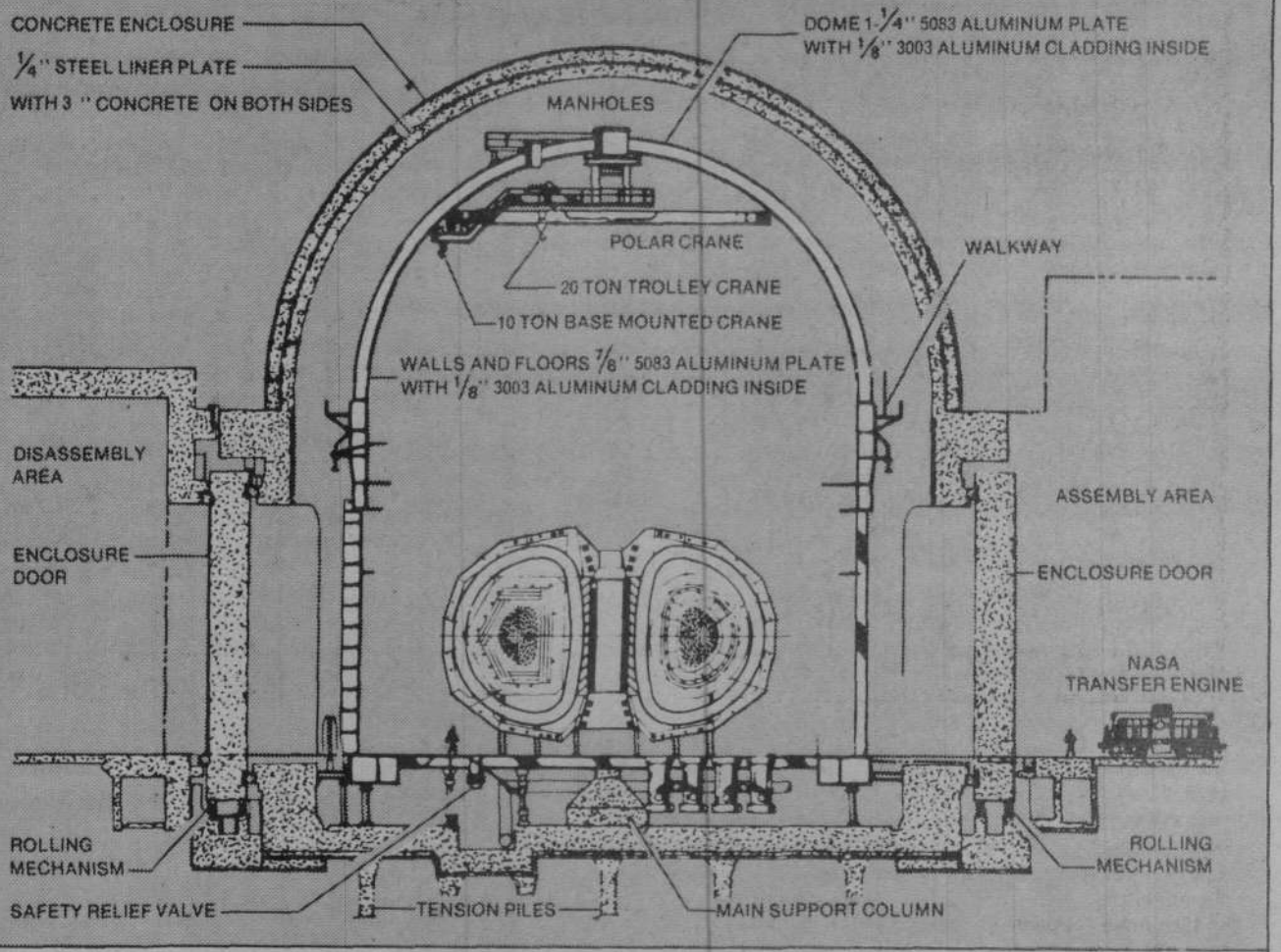
A comparison of total fusion power output, plasma volume (relative size of the reactor), and power density of various experimental fusion reactor and prototype commercial fusion reactor designs based on the tokamak approach is shown in the table. The first reactor is the Argonne design, the second is an older Oak Ridge design, the third is the General Atomic design, and the UWMAK's I through III and the Princeton are the old commercial prototype designs done by the University of Wisconsin and Princeton Plasma Physics Laboratory, respectively. Note that the last reactor, the reference design for the Oak Ridge report described here, has a volume of at least a factor of two less than any of the above.

The Oak Ridge design has a 2000 megawatt thermal (about 700 megawatts of electrical output) fusion power output. Although this is only two-fifths that of the UWMAK series, the Oak Ridge reference commercial design is 20 times smaller.

The primary reason for this dramatic change in projected design size is due to materials research in a fusion environment that permitted higher projected power densities. The design change not only cuts capital costs directly; because of the higher power density and inherent small size, the Oak Ridge reactor could utilize totally different technology options.

For example, the reactor could be contained within a building whose interior was maintained at vacuum conditions. In fact a building meeting the Oak Ridge design specifications was constructed in 1962 for the U.S. space program. This simple design option would greatly reduce the welding requirements of the reactor donut chamber, therefore substantially reducing construction costs. More significantly, it would tremendously ease maintenance access, the most significant technological problem foreseen in the operation of a tokamak reactor. Reactor safety

FIGURE 3



CROSS-SECTION OF OAK RIDGE TOKAMAK IN TEST CHAMBER OF NASA SPACE POWER FACILITY

Source: Oak Ridge National Laboratory

also would be substantially enhanced in terms of tritium containment. Figure 4 shows how the Oak Ridge reference design would appear if it were placed in the existing National Aeronautics and Space Administration facility.

Even more startling is the Oak Ridge conclusion that with projected higher power densities, ordinary copper magnets could be used in commercial power reactors. Ever since the early 1960s it was presumed that superconducting magnets (magnets whose conducting material experience no resistance to the flow of electricity at temperatures around 270 degrees centigrade below 0) were essential, due to resistive heating losses in ordinary conductors. The Oak Ridge study now demonstrates that ordinary copper magnets could be at least partially utilized in commercial reactors. This would further ease access to the reactor core since the delicate refrigeration system needed for superconducting magnets would not have to be opened up during maintenance of the reactor core.

FUSION REACTOR MATERIALS

Figure 2 shows the cross-section of the Oak Ridge reference design. As noted above, the chief carrier of the fusion energy output is the fast neutron released during the fusion reaction. Since it is electrically neutral, the neutron proceeds directly to the first wall and through it for several centimeters.

This fast neutron flux on and into the first wall creates many technological problems. First, each fast neutron knocks several atoms in the first-wall material out of their places in the crystal lattice structure (if a metal is the first-wall material). Next, the fast neutrons will induce nuclear reactions that produce not only radioactive elements but also, in the cae of nickel — an important component of stainless steel — helium gas.

The combined effect induces loss of ductility and swelling of the metal structure. To hold the magnetic field coils in place, the reactor structure must withstand stress of up to 50,000 pounds per square inch. The temperature differential between the inner first wall at 500 degrees centigrade and the -270 degrees centigrade at the magnet also causes large stresses. Furthermore, because the tokamak depends on an induced plasma current, the reactor must have a finite cycle. (The Oak Ridge design cycle lasts 20 minutes with a one-minute down time.) The structure therefore must also go through hundreds of thousands of cycles, a process that leads to quicker stress fatigue.

When the first Tokamak reactor studies (the UWMAKs and the Princeton Tokamak) were completed there were no data on the radiation effects of fusion neutrons, and data had to be extrapolated from existing fission reactor experience. As a result of these projections and the

severe mechanical and thermal stress requirements for a tokamak fusion reactor, researchers concluded that the first wall of the fusion reactor chamber would have to be replaced every six months, leading to very substantial increases in capital costs and long periods during which the power plant was inoperative.

In the last three years experiments have been designed and conducted simulating both the helium gas production and atom displacement produced in the fusion environment. Although these are preliminary and do not take into account the combined effects of the simultaneous stresses, fatigue and radiation, the experiments indicate that at operating temperatures of less than 500 degrees, the initial projections were overly pessimistic — by two orders of magnitude.

Wall lifes of up to 30 years, the projected lifespan of fission and fossil power plants, are now being projected at these temperatures. The Oak Ridge study concludes — conservatively — that five-year life cycles for first walls are more than sufficient from an economic and performance standpoint and that existing stainless steel alloys are quite likely material candidates. The study also suggests that alloy development should definitely be pursued since alloys could lead to higher operating temperatures and therefore greater thermal efficiencies. (It should be noted in this context that the General Atomic reactor design utilizes ceramic materials for the first wall instead of stainless steel.)

CONCLUSIONS

The scientific feasibility of developing mainline Tokamak fusion power reactors has been demonstrated, in effect, given an expanded broad-based fundamental plasma physics research effort. Many technological hurdles remain to the development of economical fusion power based on tokamaks, but these are no longer ephemeral projections; they are concrete problems which for relatively tiny efforts in technological development have already found several viable solutions readily within our grasp.

Dr. Kintner concluded his Salzburg address by noting that if fusion is not developed, "This planet will be paying a harsh penalty environmentally, socially, and economically before 2050 — perhaps earlier." As is clear from Kintner's overall address and the studies reviewed here, the only thing lacking and holding us back from successful fusion in the U.S. is the national commitment and the necessary funds.

The IAEA Salzburg Conference:

Soviets Report Fast Breeder Developments

The Soviet presentation on nuclear fast breeder technology, summarized below, was a highpoint in the proceedings of the two-week "Conference on Nuclear Power and Its Fuel Cycle" sponsored by the United Nations International Atomic Energy Agency in Salzburg, Austria May 2-13.

The commercial introduction of nuclear fast breeder technology was the central question considered by the 2,000 delegates from 60 nations. The conference, a continuation of four previous UN conferences on the peaceful use of atomic energy, gave a comprehensive international overview of the status and technical and economic potential of nuclear power.

The pronuclear, progrowth tone was set by IAEA director general Sigmund Eklund in his keynote address. Eklund said that he saw the IAEA meeting as following in the tradition of the April conference at Persepolis, Iran that backed the development of nuclear power, in particular, fusion power, as the answer to the energy crisis. "... If the standard of living of the developing world in the course of the next century is even to approach those which prevail in Western Europe today," Eklund said, "total world energy consumption will have to reach a level equivalent to five to ten times the six billion tons of oil we presently consume annually....The Persepolis conference has shown how to approach the task of manpower training and other problems related to the transfer of nuclear technology to the Third World." Eklund concluded with a call for international cooperation in favor of nuclear power.

The summary of the Soviet presentation by Mr. Petrosyantz, chairman of the State Committee for the Use of Nuclear Energy, was compiled by FEF correspondent Ralf Shauerhammer.

Novosti from SOVFOTO

A nuclear power plant in Zaporozhye, part of the Dniepr valley industrial area of the Ukraine, constructed in a crash program under the ninth Five Year Plan. The plant is surrounded by a new city built for the workers in the power station.

FROM 1980 ON, the increase in energy demand in the Soviet Union will be entirely taken care of by the construction of nuclear power plants. In addition to fast breeders, new light water reactors will also be put into operation. A pressurized water reactor with an electrical capacity of 1,000 megawatts is planned. The decision to keep the maximum capacity under the 1,300 megawatt range of the Biblis type is based on technical considerations of transport.

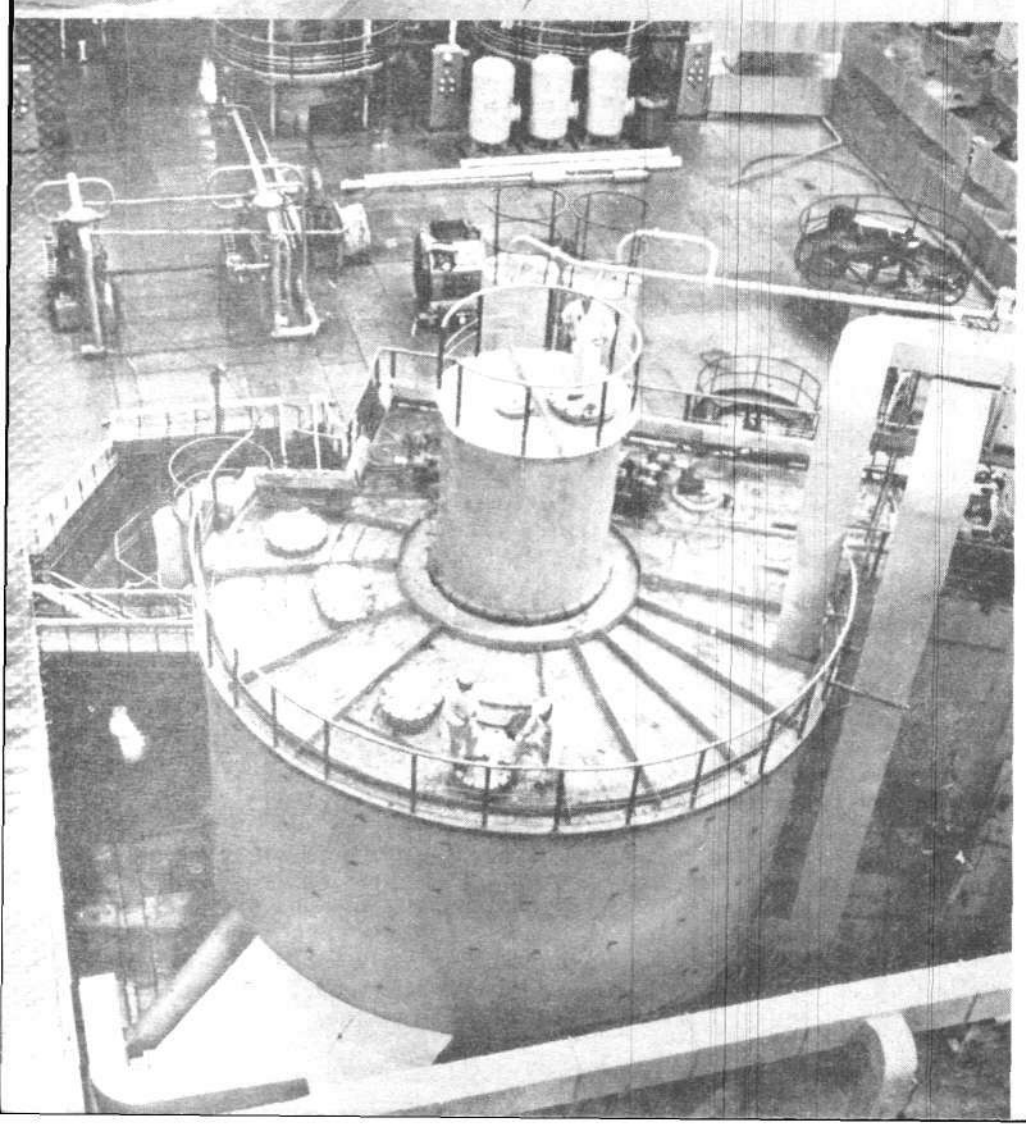
The Soviet experts at Salzburg emphatically expressed their interest in close collaboration with the Federal Republic of Germany in this area, and talks with West German representatives indicated that this interest is by no means one-sided.

The same was true for the British Steam Generating Heavy Water Reactor, which is similar in design to the Soviet modified graphite pressurized water reactor (RBMK). The RBMK will be constructed with an electrical capacity of 1,000 megawatts each, which can then be raised to 1,500 megawatts. The Soviet liquid metal fast breeder reactor BN-1600 is foreseen as a compatible fast breeder model to the RBMK. It is supposed to have an electrical output of 1,600 megawatts and a doubling time (the span of time after which the bred material can be used to operate a second reactor) of six to eight years.

The Soviet Union has pursued research on fast breeders since the end of the 1940s. In the mid-1950s they constructed a number of small experimental reactors, the BR-1 to BR-5. From the outset, major emphasis was put on working out the inherent qualities of the breeder as an integral component of the development of energy technology.

The high energy density of the primary energy medium is shown by the minimal fuel consumption of nuclear reactors. This crucial characteristic is most prominent in the breeder, where the production of plutonium 239 represents the first successful "artificial" creation of a highly

* The Persepolis conference, On the Transfer of Nuclear Technology to the Third World, was sponsored by the Atomic Industrial Forum and the Iranian Atomic Energy Commission and drew delegates from 40 nations. The Shah of Iran in his keynote speech called for the development of nuclear fusion power, and the majority of the conference participants denounced the conservationist, anti-nuclear energy policies of President Carter.



enriched "raw material" for energy. The doubling time is of fundamental significance and mainly depends on how efficiently the reactor breeds and on what quantities of plutonium must be present in the total fuel cycle.

If energy supplies are to be based primarily on nuclear energy, then doubling times below the doubling time of electricity consumption (currently about 10 years) must be achieved. Accordingly, from the outset, Soviet breeder research has put a priority on high breeding rates and rapid reprocessing.

In addition, the size of a fast breeder must be larger than that of the light water reactor, otherwise additional reactors, which take longer to build than light water reactors, could not be constructed at the necessary rate.

On the basis of Soviet scientific experience with oxide fuels in the sodium-cooled BR-5 reactor, it was decided in 1964 to proceed with construction on the BN-350 industrial power plant. This reactor was designed for a thermal capacity of 1,000 megawatts, which means a two-hundredfold increase over the thermal 5 megawatts of the BR-5!

The only serious difficulties arose with materials problems in the steam generator. At that location, the materials separating the liquid sodium at low pressure from the high-pressure steam are put under tremendous stress. Even the tiniest leaks very quickly become enlarged, creating the danger of an explosive reaction between the water and the liquid sodium. For that reason, five of the BN-350's six steam generators have had to be replaced. For safety reasons, every sodium-cooled reactor has a second cooling system between the core and the steam generator.

Construction is almost completed on the BN-600 fast breeder reactor, which will then be the world's largest electricity producing reactor. Unlike the BN-350, this reactor is a "pool reactor," in which the

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Atomic oasis in the desert

The BN-350 [below] generates ample electricity for home and industrial use in the desert city of Schevchenko [above] and supplies the power to desalinate sea water. Schevchenko is on the Mangyshlak peninsula in the Kazakh Soviet Republic, an area rich in oil, gas, and deposits of nonferrous metals but with little or no fresh water. The atomic power plant is the world's first fast neutron reactor. Fresh water consumption here is about 132 gallons per person per day.

Novosti from SOVFOTO

sodium system, pumps and first heat exchangers are all located within one large reactor vessel.

This design has turned out to be the simplest to construct for large-output reactors, even though the projected enlargement of the BN-600 design to a 1600 megawatt electrical capacity, involves a reactor vessel with a diameter of 18 meters. Sizes on this order are practicable for fast breeders, since the pressures developed in the reactor vessel are not so great as in pressurized water reactors.

A variant of the BN-1600 is also being considered, in which the diameter of the pool can be made as small as 8 meters by placing it on its side.

In addition to the LMFBR type BN-1600, the gas-cooled GCDFR is also being investigated for technical and economic viability. This reactor is designed for an electrical capacity of 1500 megawatts and will use nitrogen tetraoxide (N_2O_4) both as a coolant and as the working medium. Widely used in industrial applications, N_2O_4 breaks down into $2NO + O_2$ when it has absorbed 442 cal/kg, and so is quite able to achieve an efficient transfer of heat from the core. Aside from its broad spectrum of variant models and good technical safety features, this reactor type has the advantage of extremely high breeding rates that could attain doubling times of from three and one-half to six years! A reactor of this type with an electrical output of 300 megawatts is already completely designed. The Soviet Union estimates that by introducing the GCDFR five years after the sodium-cooled reactor starts up, an almost 50 percent reduction in the consumption of natural uranium could be achieved.

The planned BN-1600 and the reliably functioning BN-350 are, of course, separated by technical barriers comparable to those involved in the step from the BR-5 to the BR-350. But a wealth of experience has already been obtained from the construction and repair work done on the BN-350, and this is a reliable indication that the future problems also can be solved on schedule.

Atomic Powered Desalination

Along with the construction of the enw breeder, new industrial centers will spring up that will alter the Soviet landscape even more than did the BN-350. This latter reactor was set up in Shevchenkov, in the middle of the desert that borders the Caspian Sea. In addition to electricity, the BN-350 currently produces 50,000 cubic meters of distilled water per day for the population of this desert city, making Shevchenkov's per capita water consumption higher than in Moscow.

"For nature-lovers, magnificent city parks are irrigated with the water distilled by the BN-350," the Soviet delegate emphasized, a point that the audience greeted with prolonged applause.

Fusion As a Future Power Source

Excerpts from the report to the IAEA Salzburg conference by Dr. Edwin Kintner, director of the Magnetic Fusion Energy Division of the U.S. Energy Research and Development Administration

NATIONS OF WESTERN EUROPE, Japan, the Soviet Union, and the United States are working together to demonstrate the practicality of fusion power before the 21st century. Many remaining difficult physics and engineering problems make fusion development one of the most formidable scientific and technological challenges ever attempted. However, the outlook is safe, economic, and with acceptable environmental effects.

The United States magnetic fusion power development program aims at producing significant amounts of fusion energy experimentally in the early 1980s and demonstrating electric power production on a commercial scale before 2000. This prognosis reflects the confidence gained in scientific successes from the late 1960s through the present....

1976 was another year of important new advances in fusion.... The effects of plasma size and current were measured at higher values in the Princeton Large Torus (PLT). The data obtained confirmed theoretical predictions of scaling as the square of the linear dimension of the plasma. These results were duplicated in the T-10 device in Moscow. Ion temperatures were raised to 2 keV (a factor of approximately three from minimum temperatures needed for ignition). The product of density times confinement time ($n\tau$) was increased by 100 percent to a new world record high in Alcator at MIT to within a factor of three of the Lawson Criterion for "breakeven." Predicted advantages of elliptical and doublet plasmas were confirmed by direct experiment in Doublet IIA at General Atomic. Perhaps most important for the implications of tokamaks as practical power reactors, a general theoretical consensus developed during 1976, that beta values — the ratio of plasma to magnetic pressure — of up to 10 percent are achievable. Experiments to confirm these theoretical predictions are planned for the next two years. This prediction has great implication for reduced size, and therefore cost, of tokamak power reactors.

There were also major forward steps in the mirror concept.... Ion temperatures were doubled to 23 keV, more than twice the values needed for ignition. Peak values of beta were doubled to more than 200 percent resulting in densities up to 2×10^{14}. Two new ways were proposed to reduce end losses in mirrors, which if confirmed by future theory and experiment, would make this concept far more attractive as a power reactor....

(There were) major gains made in laser fusion during 1976. Ion temperatures of 8 keV and a thermonuclear neutron yield of 1.5×10^9 neutrons (a factor of 100 increase over 1975 results) was achieved. The time-of-flight confirmation of the thermonuclear origin of observed neutrons confirmed theoretical predictions and provided the basis for confidence in extrapolation to future higher-level experiments. The first demonstration of the compression of D-T (deuterium-tritium) gas to high density (10 times liquid density) was achieved and theoretical work predicting improved electron beam energy deposition rates was confirmed experimentally....

(The year) 1976 was also a year of important advances in the technologies

which are needed to support further experimentation in fusion plasma physics, and allow useful commercial application of the physics when developed. More powerful neutral beam heating sources were developed at Oak Ridge National Laboratory, and the design of the neutral beam heaters for the Tokamak Fusion Test Reactor (TFTR), the largest U.S. machine now under development, was completed.

A national program plan for development of the critical materials for fusion was worked out, and steps taken to build a tritium systems test facility to study this important systems aspect of fusion. Three conceptual designs for superconducting magnets for the Large Coil Project were completed by industrial subcontractors. Perhaps most important, two laboratory-industry teams began conceptual studies of the next reasonable facility step in fusion development beyond the TFTR.

Steady Progress

Because there is considerable controversy about the "feasibility" of fusion, I would like to take a moment to show you the steady, continued progress which has been made in world fusion research since its inception in the early 1950s.

(The charts) illustrate the steady progress in our ability to generate, control and heat fusion plasmas since the earliest fusion research in the early 1950s, and they also show how near to the conditions needed to design power reactors we are today.

I believe these charts should cause those outside the fusion community to conclude, as those in the community already have, that success is no longer a question of whether, but of when, where and by whom....

Rapid commercialization (of fusion) can only take place if the industrial knowhow is in place. Thus, it is important to integrate industry into the development of fusion at as early a date as possible. This would have the further real benefit of providing a continuing practical experience input into the program. At this time, industrial commitment is difficult to obtain because of the long-term nature of the fusion program as well as its level of risk. A solution that the U.S. is trying to implement at this time is the utilization of nongovernment (private corporations) organizations for manufacturing components and systems as soon as practicable. In this way, the industrial fusion base will be developed gradually and should be in place for commercial production and, if necessary, rapid expansion when required....

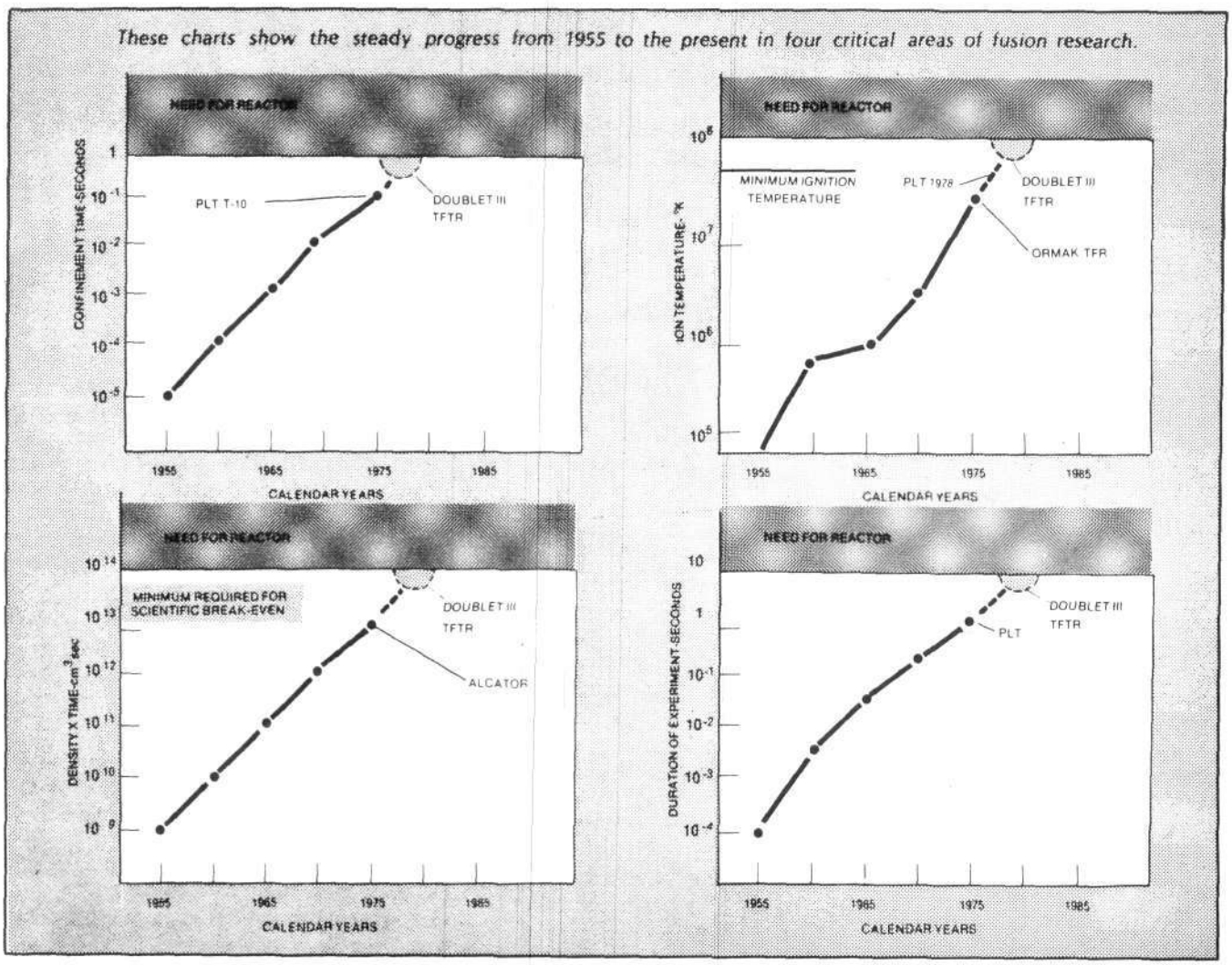
Of two things I am confident:

1) Fusion *will* be developed to practical usefulness. It is only a question of when and by whom.

2) If it is *not*, this planet will be paying a harsh penalty environmentally, socially and economically before 2050 — perhaps earlier.

So we have little alternative but to continue as best we are able and with all the resources of money and intellect we can command to attack this most difficult challenge to man's ingenuity and will.

These charts show the steady progress from 1955 to the present in four critical areas of fusion research.



In the News

Rudakov: Breakthroughs on E-Beam 'Guarantee' Fusion Success

Soviet physicist Leonid I. Rudakov, group leader of the electron beam pellet fusion research at the Moscow Kurchatov Institute, told U.S. scientists that major new breakthroughs on electron beam fusion research guarantee the scientific success of his prototype fusion reactor core, Angara V. The Angara V is under construction by the Efremov Institute in Leningrad and is scheduled for completion in early 1980.

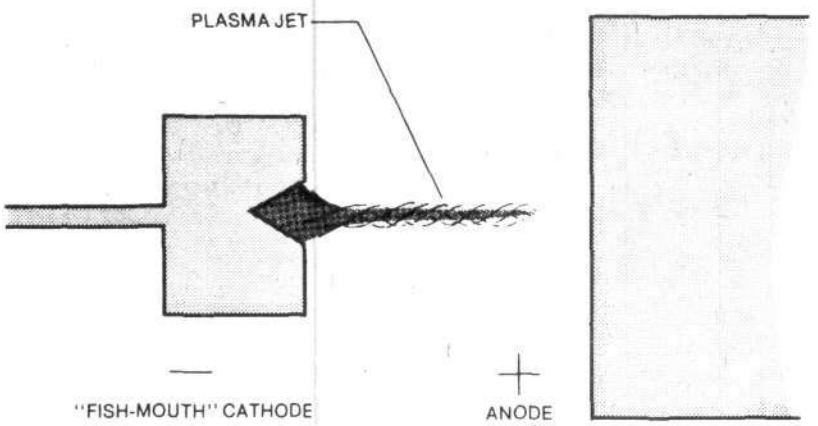
Rudakov spoke at Cornell University and the Naval Research Laboratory in Washington, D.C. in mid-April, his second U.S. tour in nine months. On his first visit in July 1976, Rudakov caused a furor in the scientific community by unilaterally declassifying Soviet experimental breakthroughs in pellet fusion research in his discussions with U.S. scientists. (See "The Rudakov Affair" in the March 1977 *FEF Newsletter* for details.)

The latest discoveries ensure the early realization of online fusion power in the 1980s and indicate that Soviet scientists have begun to master the laboratory generation of energy-dense, highly ordered plasma structures. These are the same type of soliton-vortex structures in the earth's magnetosphere that Soviet scientists theoretically interpreted at the Trieste Conference (see article this issue). Given the broad base of experimental research indicated by Rudakov's success — the Angara V is the most costly fusion project known in the Soviet Union — Soviet scientists may be on the verge of the most profound scientific discoveries of the 20th century.

Highest E-Beam Power Densities Yet

Rudakov reported that his experimental group at Kurchatov, working on the electron beam machine Angara I (a prototype for the Angara V which will consist of 48 Angara I's) had generated the highest power density electron beams ever reported — up to 10 million amperes per square centimeter at over a million volts. These results have led to a new approach to electron beam pellet fusion.

Previously, Rudakov had said that in Angara V a cusped magnetic field would be used to focus and direct the electron beam over several meters between the cathode, where the beam is generated, and the anode, where the target pellet is placed. These several meters of space would allow the cathode generating plate to survive the thermonuclear microexplosion produced as a result of the pellet implosion, which is driven by the intense electron beam.



The Rudakov cathode is simply a cube of metal with a V-shaped wedge cut out of it. In this wedge, or fish's mouth," a plasma jet contains and pinches the beam of electrons.

Now Rudakov says that a disposable cathode will be placed a few centimeters from the target pellet. (In a full-scale reactor, since each microexplosion will produce the energy equivalent of 10 to 100 barrels of oil and the disposable cathode, anode, and target pellet will cost less than several hundred dollars, the overall system will be quite economical.)

This new type of small cathode is not a mere technical innovation. In his presentations Rudakov did not reveal the exact details of how the intense electron beam is produced in the small cathode, just the fact that it was experimentally achieved and the general configuration used.

As seen in the diagram, the Rudakov cathode is simply a cube of metal with a V shaped wedge cut out of it. In this wedge, or "fish's mouth," a plasma "jet" contains and pinches the beam of electrons. Because the electron velocity is nearly the speed of light, these are termed relativistic electron beams.

One would expect that if the space between a cathode and anode were filled with plasma, usually a very good conductor of electricity, it would simply "short out" the circuit, and threfore there would be no concentration of electrical potential and no electron beam. But with Rudakov's plasma jet, an "anomalous" electrical resistance is encountered that prevents the diode from being shorted out.

Both from the general description given by Rudakov, and the experimental results of Winston Bostick of the Stevens Institute and John Luce of Livermore Laboratory, it would appear that Rudakov's plasma jet is a closed field vortex filament, or a number of such structures. In fact John Luce has just recently completed a series of experiments with electron beam diodes producing precisely such plasma filaments.

In these closed field plasma filaments, it is hypothesized that the path of the relativistic electrons, and the direction of both the electric and magnetic fields are all parallel or antiparallel. Because of this the structures are "force-free" and therefore self-subsisting. The general macroscopic dynamic of such a structure is that of producing further concentrations of energy in the form of intense magnetic and electric fields.

A Pasteur Era in Plasma Physics

One U.S. scientist has suggested that investigating the various species of plasma filaments will be analogous to the discovery of microbes and bacteria by Pasteur.

Given the power densities already achieved — up to 10 trillion watts — Rudakov now believes without a doubt that his Angara V will be able to produce microexplosions with up to 20 to 30 times more fusion energy than that used in generating the electron beam.

The electron beam is stopped in a 5 to 10 micron thick outer metal-foil spherical shell in which the energy of the electrons is transformed into soft X-rays that then drive the implosion of an inner spherical shell. This in turn produces the compression and heating of fusion fuel. In experiments at Kurchatov, the energy deposition in metal foils is up to 10 million joules per gram. Rudakov states that this is more than sufficient for thermonuclear ignition and gains of 20 to 30 times more energy than breakeven.

—Charles B. Stevens

IAEA Council: 'Aggressive Fusion Effort Urgent'

The International Fusion Research Council of the International Atomic Energy Agency recently released the following recommendations to the IAEA on fusion development. The council, which met in May, is composed of leading scientists and directors of fusion research efforts internationally. This is their first public review of the status of fusion since 1970.

In view of the great progress achieved in fusion since 1970, the Council is convinced that the time is ripe to urgently make a large and aggressive effort toward the practical demonstration of fusion power at the earliest possible date. Such an effort is needed now and could be maximized by efficient worldwide cooperation and planning in this field.

It therefore suggests that the IAEA make an important contribution to this goal by taking the following steps:

— inviting interested member states and regional institutions to submit to the Agency their estimates of attainable fusion research and development schedules with the objective of helping to coordinate the necessary efforts for a rapid and most economic way of achieving this goal;

— realizing that fusion is now the remaining major goal in nuclear energy research, the Agency should make its fusion activity better known to governments and to the scientific community as a whole;

— organizing a scientific session at the next general conference of the Agency to provide an opportunity to discuss this IFRC report and its implications;

— appointing a scientist to coordinate and stimulate work on the environmental impact of fusion and coordinate studies on future reactor material requirements with special reference to the conservation of helium;

— identifying problems where no large apparatuses are needed and which can be tackled by scientists in developing countries, and giving guidance to developing countries wishing to work in this area;

— stimulating international cooperation by organizing and facilitating circulation of fusion scientists, establishing a "mobility fund" for that purpose;

— expanding the Agency's efforts to find the best means to establish and coordinate computer programs and systems for fusion research;

— continuing to have the International Committee in Theoretical Physics involved in theoretical plasma physics and broadening its work in other scientific areas related to fusion. Participation of scientists from developing countries and their training in major fusion centers should be facilitated.

Research Notes

FREE ELECTRON LASER BREAKTHROUGH AT STANFORD

Researchers at Stanford University reported the first coherent laser light generated from free electrons. This advance, producing radiation where the phase and frequency of waves are identical, makes possible an almost ideal laser: highly efficient (upwards of 20 percent conversion of electrical to electromagnetic energy), high power (almost unlimited), and widely tunable (capable of producing light at any wave length).

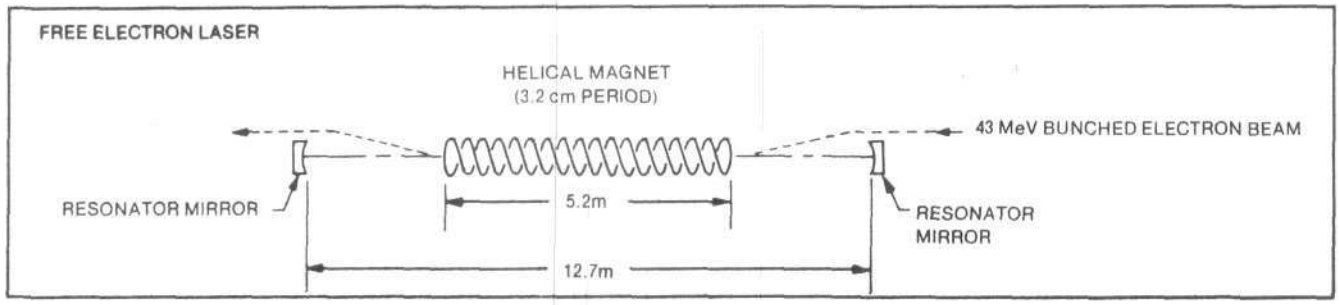
The prototype electron laser operated at a continuous power level of .36 watts with a peak power of 500 kilowatts.

The free electron laser uses the *continuously variable* energy levels that an electron gains by passing through a periodically varying magnetic field. As the energy of the electron changes (it changes as one varies the velocity the electron beam gives the electron), its resonant interaction with varying field changes, and the coherently excited radiation that it emits changes also.

Until this breakthrough, all lasers had operated on the basis of a fixed set of atomic or nuclear energy levels that could be selectively excited and coherently discharged to provide intense, monochromatic radiation. The discovery of appropriate chemical, electronic, vibrational, or nuclear energy levels has led to a wide range of lasers capable of operating in various wavelength ranges determined by the chosen energy levels and at various intensities. Since previous lasers depended on a predetermined set of available energy levels, however, they were severely restricted in their output properties.

AVCO ACHIEVES HIGH MHD EFFICIENCY

Scientists at the AVCO Research Lab in Everett, Mass. announced at the May International Symposium on Engineering Aspects of MHD that their test generator reached a 15 percent enthalpy extraction rate, the highest rate of efficiency from an MHD generator yet achieved. (In the MHD process, enthalpy extraction rate refers to the efficiency of conversion from heat to electrical energy.)



FEF News

FEF Pittsburgh Conference Focus of Battle Against Carter Energy Austerity

Just a year ago the FEF made public excerpts from censored FBI documents obtained under the freedom of Information Act that showed illegal surveillance and interference with FEF activities. Events around the April 29 conference in Pittsburgh cosponsored by the FEF made it clear that these activities continued and in fact were directed from the White House level. Investigations by the FEF determined that the White House had selected Pittsburgh, one of the nation's chief industrial areas, as a model to set the pace of energy conservation and considered the FEF and its ideas the main opposition to this policy.

The Conference on Energy and Technological Development cosponsored by the Fusion Energy Foundation and the Three Rivers Coalition for Science and Technology in Pittsburgh April 29 was an extraordinary success: More than 120 representatives of local, national, and international science and industry attended to discuss the only practicable solution to the energy problem — what FEF director Dr. Morris Levitt termed the "expansion of the human resourse base."

The conference marked a milestone for the foundation as the first time the White House and government agencies openly carried out illegal harassment and dirty tricks to stop the energy policy of the FEF and its supporters and as the first FEF court victory in the battle to stop this scientific witchhunt.

About a week before the conference, the White House apparently decided that the meeting and its scheduled speakers were so potentially damaging to President Carter's energy conservation policy that it ordered the use of illegal tactics to try to halt the impact of the meeting. The FBI and other government officials under the direction of James Schlesinger, Carter's energy advisor, then waged a last-minute campaign to disrupt the conference and intimidate its participants.

As soon as the pattern of gestapo-style tactics used by the FBI and Schlesinger to break up the conference became clear, the FEF filed a civil damages suit April 27 in federal court against Schlesinger, FBI Director Clarence Kelley, and U.S. Attorney General Griffin Bell. The next day Federal Judge William Knox granted the FEF a temporary restraining order against any further harassment by these government officials. As a result of the court order an FEF conference in New York City the following week, May 6, was free from the Pittsburgh pattern of harassment.

The complaint filed by the FEF in federal district court for the western district of Pennsylvania documented an intensive five-day campaign of blackmail, libel, and other psychological coercion directed at no fewer than 12 of the scheduled speakers in the conference. It also documented the history of government efforts to squelch FEF activities and publications.

In subsequent hearings on the FEF

For commercial generators, a 20 to 25 enthalpy extraction rate is considered necessary and depends on the strength of the magnetic field, the maintenance of high electrical conductivity in the plasma, and effective electrodes.

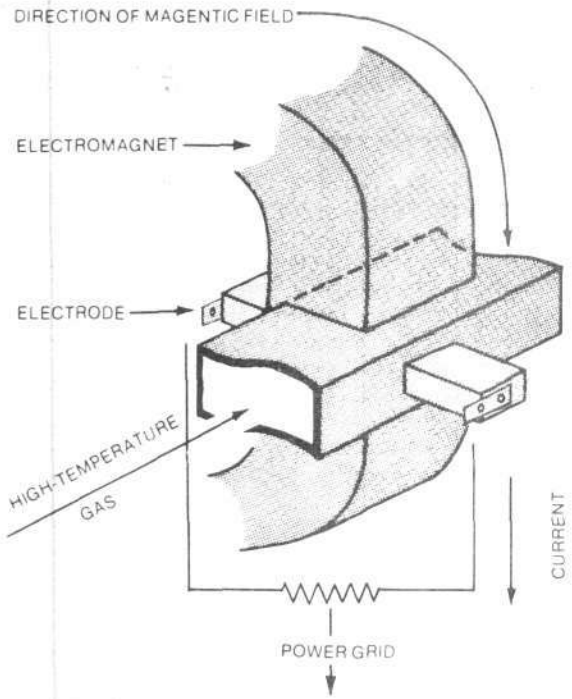
The materials work reported on at the Symposium included recent Japanese, Soviet, and American testing with new electrode materials to achieve a longer duration period without replacement.

SOVIETS COMPLETE PHASE 3 IN MHD PROJECT

Soviet researchers reported in early May that the pilot U-25 plant met the second requirement for successful completion of phase 3 in the Soviet natural gas magnetohydrodynamic system. The plant ran continuously for 250 hours at 10 kilowatts on a natural gas-based plasma. This continuous operating time represents the resolution of a major problem in the development of the MHD process, the production of electrodes and duct material with sufficient durability.

The Soviets outlined four phases in 1961 in a program to achieve commercial fusion by the 1980s. The last criterion that must be met before construction can begin on a 1,000 megawatt commercial demonstration plant (slated for operation in 1982), is testing on a bypass loop of the U-25 with a superconducting magnet. The magnet, to be supplied from Argonne National Laboratory in Illinois, has met its test requirements and will be sent to the Soviet High Temperature Institute next month for testing on the U-25.

As soon as test results are generated, the Soviets will "cut metal" on the demonstration plant. The U.S. projections are at least five years behind those of the Soviet Union.



MHD provides direct conversion of heat energy from a high-temperature gas, or plasma, to electricity. The energy is transferred through the magnetic field surrounding the channel with the plasma to electrodes placed inside the channel. More advanced designs of an MHD generator would include a superconducting magnet.

complaint May 18, Judge Knox denied the motion of the Justice Department to dismiss the FEF suit against Schlesinger, Bell, and Kelley. The case is now in pretrial discovery,and the Carter officials have to answer the charges brought against them by the FEF.

Judge Knox based his decision May 18 on the First Amendment to the U.S. Constitution which he cited in full to the Justice Department's Special Litigation Section that is handling the case.

After FBI agent Bill Martin, one of the defendants named in the FEF suit, testified May 18 that he had not harassed the FEF since the temporary restraining order was issued April 28, Judge Knox denied the FEF's motion for a preliminary injunction on the basis that there was no ongoing disruption of activities. Such an injunction would have barred futher harassment until the case goes to trial. The judge, however, granted leave to the FEF to file suit for another temporary restraining order should the government engage in any further disruptions.

On June 20, the FEF announced that it planned to submit exactly such evidence to the court of continuing illegal harassment against the foundation and its supporters around the FEF's annual conference in Chicago scheduled for June 23-24. (See article this section.)

Justice Evades Justice

The Justice Department brought the Special Litigation Section into the case soon after attempts of U.S. Attorney H. Barr failed to block a May 2 preliminary injunction hearing. Barr had unsuccessfully tried a motion to dismiss the case, a motion to quash a subpoena of FBI Special Agent Bill Martin, the Pittsburgh FBI coordinator of the operation, and, finally, just plain obstructionism by constantly interrupting witnesses in order to keep testimony off the court record.

Despite Barr's flim-flammery, Judge Knox tôok testimony May 18 from FEF Director Morris Levitt and FEF Pittsburgh coordinator Scott Brody about the sudden withdrawal of 12 conference speakers and

THE ERDA FIGHT OVER LASER FUSION

Despite notable exceptions within the federal Energy Research and Development Administration, fusion is treated as a political football, not as an important key to man's survival. A confidential report obtained by the *St. Louis Post Dispatch* under the Freedom of Information Act documents how ERDA spied on and harassed a consulting engineer hired by ERDA to evaluate the work of KMS Fusion, a private laboratory that ERDA funded.

"Although I never caught them redhanded, I am positive I was bugged," the consultant said. "Everytime I had a telephone call or a messinger delivered anything about this (KMS — ed.) to my house, Jim McNally, the physicist in charge of laser fusion work at ERDA, showed up in my office and showed that he knew all about it." The consultant accused ERDA of wanting to liquidate KMS which he said would be "a serious national mistake."

Excerpts from FEF Complaint Against Schlesinger And FBI

Presented below are excerpts from the FEF civil damages suit seeking a temporary restraining order against Carter energy advisor Schlesinger, FBI Director Kelley, and U.S. Attorney General Griffin Bell. The complaint was filed April 27 in U.S. District Court for the Western District of Pennsylvania.

On or about January 1975, Clarence Kelley, Director of the FBI, characterized the FEF as a subversive and dangerous organization.

Mr. Kelley, in furtherance of his determination as to the alleged subversive character of the FEF, directed agents of the Federal Bureau of Investigation to take action, either alone, or in concert with other agencies of the federal government and/or private individuals and organizations, to disrupt and interfere with the activities and objectives of the FEF, and its affiliated members and persons and organizations acting in cooperation or sympathy with it, in violation of the constitutional rights of the FEF, and of such individuals....

Attached as exhibits, and incorporated herein as part of the complaint, are relevant parts of the files and dossiers collected and maintained by the FBI on the FEF, which the FEF has obtained as a result of requests made under the auspices of the Freedom of Information Act (FOIA). These files demonstrate that the FBI, through its investigative efforts, and the above-mentioned files maintains a current knowledge of the future plans of activities of the FEF.

Further pursuant to Mr. Kelley's unlawful orders, the FBI engaged, either intentionally or with gross negligence, has acted to disrupt the activities of the FEF .... an unlawful interference with the legitimate activities of the FEF.

As a specific instance, the FBI, through the dissemination of false and misleading information, and other disruptive activity, to the intended publisher of the International Journal for Fusion Energy (IJFE), a technical publication which the FEF tried to publish as a forum for discussion of developments in the areas of fusion energy research and development, the said publisher withdrew from his prior commitment to the FEF, and the FEF was unable to publish the journal for more than one year subsequent to the original target publication date. The said publisher, Mr. Norman Cohen of Baywood Publishing Company, stated that he discontinued as publisher of the IJFE because of information supplied to him by the FBI, and due to cancellation by the Department of Defense of over $20,000 of government subscriptions to Baywood publications.

sponsors. As Levitt and Brody laid out, the unexpected withdrawals followed a concerted rumor campaign alleging that the Fusion Energy Foundation, the U.S. Labor Party, and the National Caucus of Labor Committees were "violent" and "anti-Semitic" — exactly the slanderous characterization of these organizations contained in Griffin Bell's first annual report as Attorney General.

At that time Judge Knox ordered Special Agent Martin to consult with the Justice Department on testimony as to his activities against the FEF conference, the activities of other FBI agents in Pittsburgh, and instructions received from his superiors concerning the conference.

The Justice Department's Special Litigation Section then filed a mammoth, highly technical second motion to dismiss the case on May 11. The motion to dismiss had four points: (1) that the case was "moot" because the Pittsburgh conference was over and Judge Knox had issued a temporary restraining order covering harassment of that conference; (2) that Schlesinger, Bell, et al. are "immune" from prosecution and damages as government officials (the same argument used by Richard Nixon's lawyers during the Watergate affair); (3) that the Fusion Energy Foundation has not alleged enough "overt acts" to justify a suit and discovery process against the Carter officials; and (4) that Schlesinger, Bell et al. are not responsible for the activities of their subordinates, thus leaving agents like Martin to take the rap.

The First Amendment

Judge Knox's decision took one sentence telling the government that there are enough overt acts to justiry the case and one paragraph on mootness, compared to 11 pages in citations by the Justice Department.

"The conference is now over and therefore it is urged there is no further purpose to this action," Judge Knox begins his response. "This overlooks the fact that the plaintiffs claim they have other conferences coming up and because of the past two years of what they call harassment, intimidation, interference with.... It also appears that the plaintiffs are seeking damages for interference with the conference on April 29 when many speakers and attendees failed to appear. Plaintiffs claim that their failure to appear and a consequent disruption of the conference was caused by spreading of stories, interference by the FBI and others."

The judge's brevity on these points amplified his main arguments against immunity and against dumping responsibility on subordinates like Martin.

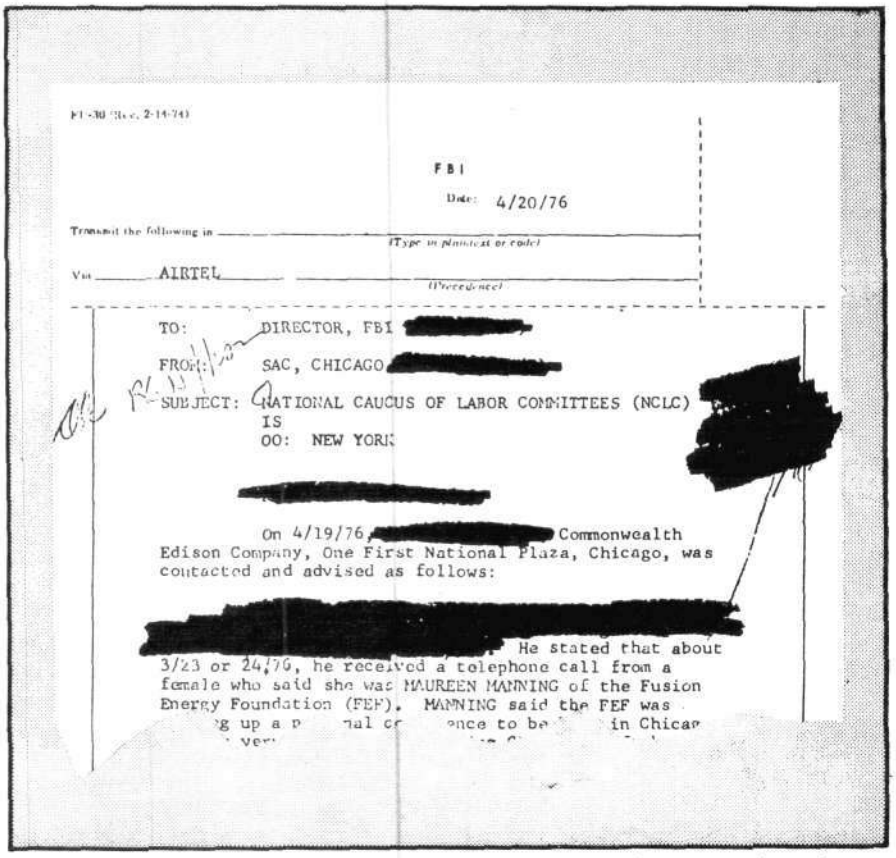
After citing the First Amendment in full, Judge Knox's opinion continues: "Plaintiffs allege an interference with their First Amendment rights.... The facts alleged here would indicate interference with freedom of speech and freedom of assembly by government agents. If this is true, it cannot be tolerated. The First Amendment has been recognized as one of the focal points of our Constitution and if people can be harassed and intimidated while trying to hold a peaceable assembly, then the First Amendment means nothing."

Judge Knox also cited *Ghandhi v. Detroit Police, Clarence Kelley, William Saxbe et al.*, the U.S. Labor Party's Detroit case against the FBI as a "very similar case" in support of his First Amendment decision.

Further, in accordance with their unlawful program of disruption, the FBI contacted numerous leading personages in the fields of fusion energy and science generally, and persuaded them to withdraw from prior commitments to the FEF which resulted in their decisions to decline positions as editors, writers and technical consultants for the International Journal of Fusion Energy....

On two occasions, March 7, 1975 and June 21, 1976, the FEF planned national energy conferences in New York City and Chicago respectively, which conferences involved the contacting of numerous individuals and the investing of considerable funds and person-power, and in each case, the FEF has determined, based upon review of files obtained from the FBI and from conversations with individuals involved, the FBI interfered with and disrupted the said conferences, and as a result diminished their scientific and public policy impact....

Attached exhibits, including files from the FBI, demonstrate that the FBI was aware of these planned conferences in advance, that they conducted extensive monitoring and surveillance of the planning of these conferences, through, inter alia, the use of wiretaps, and informants....



FBI

Date: 4/20/76

Transmit the following in _____ (Type in plaintext or code)

Via AIRTEL (Precedence)

TO: DIRECTOR, FBI [redacted]

FROM: SAC, CHICAGO [redacted]

SUBJECT: NATIONAL CAUCUS OF LABOR COMMITTEES (NCLC)
IS
OO: NEW YORK

[redacted]

On 4/19/76, [redacted] Commonwealth Edison Company, One First National Plaza, Chicago, was contacted and advised as follows:

[redacted] He stated that about 3/23 or 24/76, he received a telephone call from a female who said she was MAUREEN MANNING of the Fusion Energy Foundation (FEF). MANNING said the FEF was [illegible] up a [illegible] conference to be [illegible] in Chicag[illegible]

Page from the censored FBI files released to the FEF under the Freedom of Information Act showing FBI contact with a Commonwealth Edison Company official in Chicago.

Milestone FEF Meeting in West Germany

A conference on Energy and Technological Development sponsored by the Fusion Energy Foundation in the West German industrial city of Essen June 6 drew more than 80 participants from major industries, universities, political parties, and government.

In the first presentation, U.S. FEF member Eric Lerner pointed to the relatively limited supplies of uranium fuel as one important reason why fusion must be developed by 1990. For all practical purpose, he argued, uranium reserves will be exhausted by that time, assuming an annual economic growth rate of 20 percent. Such a rate—contrary to the usual 4 to 6 percent projections of European industrialists—will be absolutely necessary in order to avoid a repetition of the devastation wrought on the European population and economy by the Thirty Years War in the 17th century, or worse.

Lerner's presentation was followed by a discussion of the current status of nuclear fusion research by European FEF member Ralf Schauerhammer and a report by Dr. Seifritz, a well known reactor specialist, on the prospects for transitional technology leading up to fusion methods. Dr. Seifritz emphasized the usefulness of the type of high-temperature technologies worked on in a West German project and its applicability for both "fusion torch" prototypes and the sensible gasification of coal (West Germany's most plentiful raw material).

Two presentations during the afternoon session served to counterpose the push for a fusion-based economy against the short-sighted, cost-efficiency, approach still prevalent in parts of the European energy sector. Representing the first approach was an industrialist, who outlined the immense potential in the field of magnetohydrodynamics (MHD) technology, which deals with the field-generating qualities of high-energy nuclear plasmas.

Conference participants included representatives from the Social Democratic Party's national executive, the Christian Democratic Unnion Research Committee, the West German parliament, Mercedes-Benz, the Thyssen steel firm, and the Procurement Office of the West German Federal Army.

The conference was the second major event sponsored by the FEF in Europe; a Stockholm conference in April drew a similar grouping of industrial and government representatives. A third conference is planned for October in Italy, around discussion of a comprehensive Mediterranean development program.

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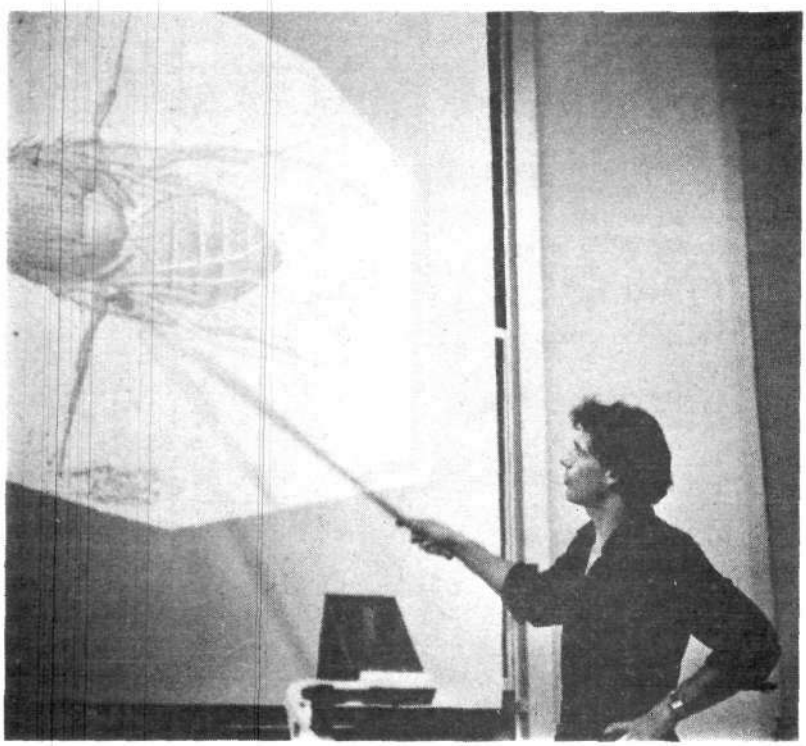
Fifty Attend Chicago Conference

More than 50 persons attended the FEF conference in Chicago June 23-24 on "Science and Technological Development: Solving the Energy Crisis." Four conference sessions included presentations and panel discussions of advanced technology in nuclear energy, prospects for fusion in the 1990s, advanced technology in agriculture and fossil fuels, and the frontiers of science and technology. Among those attending were several students and professors, independent scientists, and representatives from International Harvester, General Electric, and Woodward-Governor, a machine tool firm.

Several participants withdrew from the conference as a result of continuing White House harassment and intimidation against the FEF and its energy policy. Dr. Steven Bardwell, FEF plasma physics research director presented specific evidence of the harassment in a Chicago press conference June 23, and the FEF is asking the Federal District Court in the Western District of Pennsylvania to reopen hearings on the preliminary injunction against the FBI, and James Schlesinger.



Dr. Stuart Kauffman of the University of Pennsylvania Medical School discusses the geometry appropriate for fruit fly embryology at the FEF Philadelphia conference on Nonlinearity and the Biological Sciences June 10 at the Medical School.

The conference, the first follow-up meeting to the FEF's launching of its Biological Sciences Division, involved a key group of biological and biophysical researchers in discussions that ranged over the frontiers of science — from plasma physics, metallic and organic superconductivity, and bioclimatological phenomena, to the critical nonlinear biological phenomena preponderant in embryology and neurophysiology.

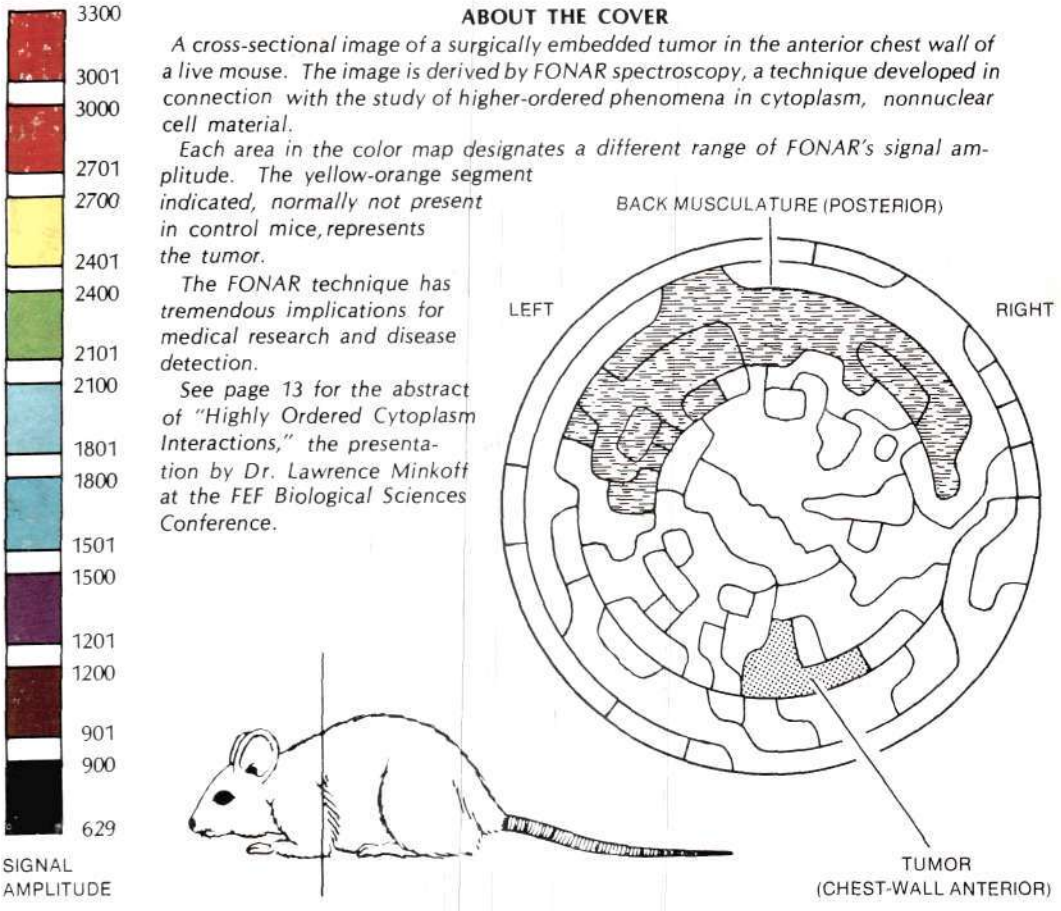
ABOUT THE COVER

A cross-sectional image of a surgically embedded tumor in the anterior chest wall of a live mouse. The image is derived by FONAR spectroscopy, a technique developed in connection with the study of higher-ordered phenomena in cytoplasm, nonnuclear cell material.

Each area in the color map designates a different range of FONAR's signal amplitude. The yellow-orange segment indicated, normally not present in control mice, represents the tumor.

The FONAR technique has tremendous implications for medical research and disease detection.

See page 13 for the abstract of "Highly Ordered Cytoplasm Interactions," the presentation by Dr. Lawrence Minkoff at the FEF Biological Sciences Conference.



Source: Dr. Lawrence Minkoff