FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION
February 1979
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Laser Fusion — No More Secrets?

Exclusive Moscow Conference Report
Soviets Propose International Laser Facility

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Features

News

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Editorial

1979: Year of Breakthroughs

During the past year, the nation has taken significant steps toward the goal of achieving a controlled fusion reactor in this century. Paced by the Princeton Large Torus, which reached ignition temperature using neutral beam heating in July, and continued progress in laser fusion, the achievement of the goal seems assured, especially if we pursue the scientifically less demanding option of the fusion-fission hybrid breeder.

The critical factor in the coming year is the scientific community—how quickly the nation's leading scientists will develop the necessary conceptions to bring us to this goal.

Many members of the fusion community have questioned whether the fusion goal can be reached with a stagnating budget level that is not even keeping pace with inflation. It is true, as *Fusion* has documented, that the Department of Energy budget makes it impossible to pursue the required timetable for scale-up and engineering of the mainline experiments or to support the necessary backup and basic research. However, the real problem of achieving controlled fusion is even more fundamental than the funding.

As shocking as it may seem, there is no one in the fusion community, outside of the Fusion Energy Foundation, who has an adequate conception of what a plasma is or of the processes and conditions by which fusion can take place. There are also very few people who have conceptualized fusion research as the necessary next stage of global development.

Both these conceptual inadequacies are reflected in the scientific and technological goals that President Carter set for the nation this year, which were discussed with the press Jan. 3 by presidential science advisor Dr. Frank Press.

Some of the ideas that Press put forward are worthwhile, especially establishing a national foundation for technical cooperation with the developing sector and rebuilding the research base for technical innovation by U.S. industry. Yet the basic policy content is inadequate. For example, there is a far-off view of fusion, a predominance of "appropriate technology" in foreign policy, and the reduction of the National Aeronautics and Space Administration to a more earth-bound role.

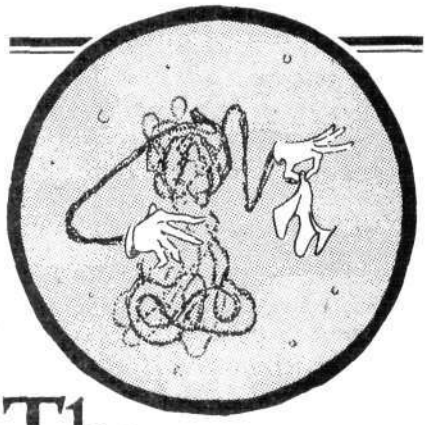
There are two basic fallacies involved in the national science policy, fallacies that permeate circles much larger than those of the official policy-makers: First, that all new scientific knowledge will be simply extensions of already existing types of theoretical knowledge into new physical domains, or new solutions based on that knowledge to already known problems; second, that such new knowledge will be adequate for generating the technologies and resources required for continued human existence and progress.

The Water Resources Example

The example of water resources demonstrates the fallacious nature of both these assumptions. A most conservative estimate of the Water Resources Information Center is that world demand for water will triple from the present 2,000 cubic kilometers per year to 6,000 cubic kilometers in the year 2000. Surface and underground resources can meet a large portion of this required increase, but large-scale diversion of this water or desalination by boiling or filtration is too costly now, based on the construction or thermal technologies—including fusion—that will be available in the foreseeable future. (Similarly, only energy-dense forms of fusion used to power integrated industrial and agricultural complexes can economically provide the variety of raw materials and other feedstocks required for a global population moving beyond the 10 billion level.)

To solve the problem requires a new physical process for desalination, a process

Continued on page 4



The Lightning Rod

My dear friends,

Scarcely a day goes by, it seems, without some tale of flying saucers sweeping across the front pages of the supermarket tabloids and into modern living rooms via the television screen. Killjoys might note that the popular enthusiasm for "men from Mars" seems to exist in inverse proportion to expenditures and commitment to America's own National Aeronautics and Space Agency, charged with conducting actual scientific investigation of other planets. NASA is an all-too-well identified flying object for the tail-gunners at the Office of Management and Budget these days. It seems that the present administration no longer heeds old-fashioned scientists, like NASA's, who haven't mastered the latest astrology text.

After all, this is an age when the armed forces of a sovereign nation (New Zealand, I believe) go on "red alert" to combat a putative UFO invasion. What could be surer evidence of reality than a military response?

Among the old-fashioned, of course, there are alternative hypotheses for explaining the UFO as a physical phenomenon, the most prominent of which revolves around the similarity between descriptions of "UFO sightings" and the known characteristics of "ball lightning," recently

discussed by Nobel laureate Peter Kapitza of the Soviet Union.

But when conditions are such that a man who reports a UFO hovering over his lawn can become the current incumbent of the White House, perhaps physics alone is inadequate to the task before us.

The Gay Gene

One of my medical friends writes that he recently attended a conference in Houston where, he concluded, a most unwholesome British humor appeared to have infected the proceedings. How else to explain presentation there of a paper entitled "Are There Gay Genes?" (subtitle—"Sociobiology Looks at Homosexuality").

Of course, my friend immediately smelled a hoax. Was not the author of the paper identified as one Michael Ruse? Did he not proclaim his lineage as a Professor of Philosophy at the University of Guelph (now a city in the Canadian province of Ontario, but also, as my colleague Thomas Paine was fond of pointing out, the proper surname of George III and his descendants)?

I opined, however, that what passes for a serious scientific undertaking in British public school circles was in all probability underway. Surely scores of Guelphian aristocrats are now busily at work with computerized assistance, earnestly devising a program of Gay Eugenics by which their much-feared population explosion can be overcome.

Sound breeding practices featuring The Gay Gene could produce a human race that operates rather like the black boxes sold in novelty stores. These are equipped on the outside with a single switch; when the switch is thrown, a large mechanical hand emerges from the box and shuts it off. Q.E.D., new conclusive proof that the Second Law of Thermodynamics is the fundamental principle of the universe.

Look for the announcement of this breakthrough in coming editions of the *New York Times* science section. Meanwhile, I remain,

Yr. obt. svt.

"On your mark ... Get set...."

Calendar

February

7
FEF Seminar on "Collective Acceleration of Particle Beams in Plasmas, Part I"
Speaker: Prof. Winston Bostick
New York City
(For more information, see advertisement, page 6.)

14
FEF Seminar on "The Riemannian Tradition: Basis for Theoretical Advance in Plasma Physics"
Speaker: Uwe Parpart
New York City

21
FEF Seminar on "Collective Acceleration of Particle Beams in Plasmas, Part II"
New York City

25-28
INFO '79
Atomic Industrial Forum
Kansas City, Mo.

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

March

5
FEF Seminar on "Mathematical Models and the Status of Confinement Theory"
Speaker: Harold Grad
Courant Institute of Mathematics
New York City

5-8
International Conference of Fast Breeder Reactor Fuel Performance
DOE, ANS, AIMMPE
Monterey, Calif.

12-14
1979 Particle Accelerator Conference
DOE, IEEE, APS, NSF
Stanford Linear Accelerator Center
Lawrence Berkeley Labs (U of C)
San Francisco, Calif.

Letters

MORE ON THE SCIENCE OF EVOLUTION

To the Editor:

I just bought a copy of *Fusion* and was excited to find such a magazine.... Unfortunately, the nice idea was ruined. ... *Fusion* (October 1978) contains an absurd "The Editor Replies" by Dr. Bardwell. How do you expect people to seriously consider your scientific reportage if your minds are obviously clouded with religious gobbletygook?

Face it: evolution is well-established fact. God is sheer wishful thinking. There's a huge body of evidence supporting evolution and not a shred supporting the existence of God.

K.R. Hammond
Oakland, California

To the Editor:

The fundamental presumption of Darwinian evolution is *not* that ". . .the biosphere and . . . man . . . developed solely by chance...." The process comprises two phases. Firstly, chance elements operate to produce a source of genetic variation. Secondly, the variations produced in this way are selectively preserved and reinforced by environmental factors, which are certainly not random. If you are going to attempt to pull apart a more than amply substantiated theory, at least get right what the theory says. Picking out fallacies which exist not in evolutionary theory but in popular misinterpretations of it only confounds ignorance with further ignorance.

Defending notions that are based on religious prejudices and dogma seems a strange posture for a magazine that purports to be scientific to take. If the proponents of such views are able to offer a rational explanation for the overwhelming body of evidence amassed over centuries which better accounts for the facts than evolution, let's hear it. If they can't, why don't they shut up?

James P. Hogan
Acton, Massachusetts

To the Editor:

I found October's letter to the editor on evolution and the reply by Dr. Steven Bardwell perfectly timed. In that reply Bardwell notes that the fight against a Darwinian outlook is one of the most important tasks today—in science and in religion. As if to underline and demonstrate Bardwell's contention, the magazine *Scientific American* has devoted an entire recent issue (October) to evolution, explicitly taking up the cudgel for reductionist Darwinian principles not only as correct but as *the* organizing principle of biology. . . .

Recent articles in *Fusion* have explored the kinds of phenomena that reflect the notion that the biosphere evolves as a whole, constantly increasing its energy throughput—that is, in a negentropic fashion. . . . The introductory article in *Scientific American* by Ernst Mays represents an interesting demonstration of why a reductionist outlook puts its owner on the opposite side to both science and religion. One short epistemological blunder brings this out neatly. Mays writes:

"The individuality of biological systems and the fact that these are multiple solutions for almost any environmental problem combine to make organic evolution nonrepeatable. Deterministically inclined astronomers are convinced by statistical reasoning that what has happened on the earth must also have happened on planets of stars other than the sun. Biologists impressed by the inherent improbability of every single step that led to the evolution of man consider what Simpson called 'the proliferation of humanoids' exceedingly improbable."

If the reader stops to consider a moment, it will strike him that while evolution as it has occurred on earth may well be nonrepeatable, any advanced life

Year of Breakthroughs *Continued from page 2*

conceptualized in terms that are also relevant to fusion research. In both cases, a desired final physical state must be reached by using various types of energy inputs to "drive" the system of interest. For desalination, the formation of droplets of a critical size will result in spontaneous dropping out of salt. For fusion, a self-sustained burn is required. In both cases the necessary conceptual outlook for effective research may be termed Riemannian hydrodynamics—the study of the states of fluid or plasma *organization* and their *negentropic* changes.

In fact, Riemannian hydrodynamics is the conceptual framework that has been directly responsible for all fundamental scientific advances in recorded history from the Platonic Academy, Avicenna and the Arab Renaissance, Roger Bacon, Leonardo da Vinci and the West European Renaissance, and the Tudor effluorescence in England, to Leibniz and the continental school of science culminating in the Gottingen-Berlin pinnacle marked by Riemann and Cantor. This is also the outlook permeating the work of Benjamin Franklin and the other founding fathers of the American Republic.

Unfortunately, practically all mature scientists and their students today think of science as a collection of formulas and intuitive experimental practice. The basic reason for this does not lie in the nature of the physical universe or the "natural" evolution of science (FEF reports on self-organizing plasma phenomena consistently show the contrary to be true). Rather, this misdirection of science stems from the millennial struggle between the Platonic, city-building faction of humanity and its "zero-growth," oligarchic adversary. This struggle persists to the present day, showing itself in the fight for nuclear power and global development against austerity and depopulation.

The Real History of Science

The evidence showing how the oligarchic faction has perpetuated the sabotage of science has been abundantly documented in many recent publications. However, two new projects this year in which the FEF is participating will make the point conclusively. The first is the first competent English language translation and explanation of Plato's extraordinary dialogue, the *Timaeus*. Contrary to the mul-

forms would have to be, of necessity, not just humanoid but human because, as religion makes the point for science, the essence of the human species is not that it looks human or has human physiology or so forth, but that it is absolutely and fundamentally different from the beasts. This quality is, as Bardwell emphasizes in his reply, mankind's unique moral capability of continuing the universal process of creation which means increasingly mastering the laws of the universe. In a word, science.

Ernst Mays is incapable of understanding that quality as defining the human species as a whole since he cannot locate it in himself, a situation that flows absolutely lawfully from his reductionist Darwinian outlook. It's a shame, since this is the quality that makes scientists.

Paul Schwartz
New York City

BRITISH UNDERCURRENTS

To the Editor:

. . . I was in two minds about renewing my subscription because even though I'm a power engineer by profession, the physics of fusion power, tokamak technology and the rest was almost beyond me. Your latest issue (November) which includes Dr. Steven Bardwell's "Elementary Plasma Physics" made me change my mind. Bardwell's article is brilliant, erudite, and well conceived for helping the layman such as myself to understand what the subject is all about. If the FEF wants to educate the public there simply has to be greater emphasis placed on ABC explanatory material.

Secondly—and this might betray a frightful ignorance—I simply do not understand the undercurrent of anti-British politicking in your journal. Frankly, being rather apolitical in outlook, I don't give a hoot whether the top executive of FEF and associated organizations be fascist, socialist, or communistic in character; the concern for fusion energy development is far more compelling and I should hope that the editors of *Fusion* would keep this fact in mind.

A.W. Cockerill
Cobourg, Ontario

The Editor Replies

The next issue should answer in some detail this reader's query about the relationship between Britain and fusion development. As we will document, there has been a specific policy on the part of Her Majesty's government to subvert open inquiry into fusion and to impede the implementation of any new developments that do happen to escape the net of classification and obfuscation.

Fusion has exposed parts of this policy in the past, most notably, the fact that the Soviet electron beam fusion results announced here by Leonid Rudakov in 1977 were classified in the United States under orders from the British government (see *Fusion*, March 1978). And in the March-April issue, we will make absolutely clear the full extent of this British policy—the same antiscience, antiindustry policy that Benjamin Franklin identified as "British" 200 years ago.

titude of subsequent misrepresentations, the *Timaeus* contains all of the fundamentals of epistemology on which real science has been based up to the present. The project has also yielded a reevaluation of the so-called Atlantis myth, which demonstrates that the whole Atlantic basin from Central America to northern Europe was civilized long before Ionian Greece.

The second project is a forthcoming book titled *The New Dark Ages of H.G. Wells and Bertrand Russell*, which will be previewed in the March-April issue of *Fusion*. This book will provide detailed documentation of how the circles exemplified by Wells, Russell, and the Aldermaston weapons center have been committed to the destruction of generalized scientific progress, especially the Platonic tradition carried forward by continental science. In short, the book will prove that the fight for science today is a life-or-death question for the human species.

The FEF is committed to making 1979 the year that sets the stage for scientific breakthroughs in crucial areas of research. The foundation will sponsor a seminar series in New York City this spring in which leading theoreticians and experimentalists from the FEF, the Massachusetts Institute of Technology, the Stevens Institute, the University of Miami, and the Courant Institute of Mathematics will examine the state of the art in plasma research from the most advanced standpoint. If funding support is forthcoming, this effort will be continued with a summer school on plasma physics for advanced students and scientists in other disciplines.

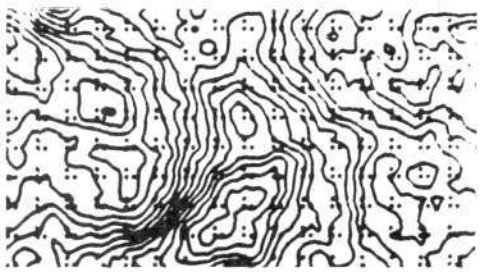
The FEF is also in the process of forming a collaborative team to investigate theoretically and experimentally low-energy desalination processes as a fundamental hydrodynamic process. This study is also an appropriate vehicle by which the corporate R&D sector and universities can train scientists who are ready to tackle the advanced scientific problems of the nuplex and fusion technology era.

Closely related to the desalination project are more general hydrological investigations, centering on hydrodynamic-plasma models of climatology. Rounding out the FEF research program will be related evaluations of basic processes in biophysics, geophysics, and astrophysics. Finally, the FEF also will produce a comprehensive book on the science and economics of fusion for a mass audience.

For all these reasons, we welcome 1979, the year of scientific breakthroughs.

Fusion Energy Foundation

Spring 1979 Seminar Series



"Basic Processes In Fusion Plasma"

The Fusion Energy Foundation will sponsor a seminar series on the frontiers of plasma research during February and March in New York City. The purpose of the series is to provide an up-to-date picture of our knowledge of how plasmas in fusion research devices really behave and to define the limits of the theoretical tools that have been developed to describe that behavior. The scientific staff of the FEF has played a unique role in this effort. This has involved not only looking at progress in the field as a whole, but also evaluating these developments from the standpoint of the epistemological outlook of the theoretical tradition in mathematical physics defined by the line from Leibniz to Riemann and Cantor and their successors of the Goettingen School. This "Riemannian hydrodynamic" outlook locates the crucial aspect of the plasma state in the evolving geometry of its organization. The seminar series will feature an assessment of plasma physics from this standpoint, as well as reviews of frontier areas of theoretical and experimental research by leading workers in these fields.

Feb. 7 — *Collective Acceleration of Particle Beams in Plasmas: Part I*
Professor Winston Bostick
Stevens Institute of Technology

Feb. 14 — *The Reimannian Tradition: Basis for Theoretical Advance in Plasma Physics*
Dr. Uwe Parpart
Director of Research
Fusion Energy Foundation

Feb. 21 — *Collective Acceleration of Particle Beams in Plasma: Part II*
Professor Winston Bostick
Stevens Institute of Technology

March 5 — *Mathematical Models and the Status of Confinement Theory*
Professor Harold Grad
Director, MHD Research
Courant Institute of Math. Sciences, NYU

March 14 — *What We Have Learned from High-Field, High-Density Toroidal Plasmas*
Professor Bruno Coppi
Massachusetts Institute of Technology

March 21 — *The Problem of Electron Transport and the Anomalies of Plasma Physics*
Dr. Steven Bardwell
Director of Plasma Physics
FEF

Date to be announced — *Plasma Solitons — Physical and Mathematical*
Professor Frederick Tappert
University of Miami, Florida

Contact the FEF (212) 265-3749 for further information

News Briefs

FRENCH MINISTER CALLS FOR 4-YEAR EUROPEAN ENERGY PLAN

In a speech to the European Parliament in Strasbourg Jan. 17, French Foreign Affairs Minister Jean Francois-Poncet stressed the need for a common European energy policy, specifically "a second four-year plan for energy research and development and program for research and teaching in the field of controlled thermonuclear fusion." Francois-Poncet said that France's task together with the rest of Europe, is to build the new world economic order via a common European agriculture and economic policy. Europe must seek together a "satisfactory level of economic activity and a reabsorption of unemployment."

For the Third World, the foreign affairs minister called for the massive export of "gigantic nuclear plants" as the only feasible way to assure that those nations have adequate energy resources to achieve the necessary levels of internal economic development.

Francois-Poncet is the president of the European Economic Community's Council of Ministers for the next six months.

BRITISH JOURNALIST BLAMES IRRATIONALITY ON SCIENCE

In a *Washington Post* feature article Jan. 14 that purports to assail superstition, top British journalist Patrick Brogan blames the nonsense beliefs of modern society on science. Modern science is "sheer incomprehensibility," he says. As a result, ". . . There is a widespread distrust of science and scientists. Many of the things scientists have done and are doing—building atomic bombs or recombining genes—are so terrifying that many people take refuge in health food and batik. A scientific Enthusiast can be just as dangerous as your run-of-the-mill cult leader. . . . Science has had three or four centuries to convert mankind to reason and . . . its evident failure is proof that it can't be done."

To prove his point that today's society is basically and naturally irrational (the article is titled "The Age of Un-Reason"), Brogan gives detail upon detail of incidents of mass irrationality, asserting all the while that such horrors are normal: "The Jonestown massacre was an event perfectly typical of the epoch," Brogan says.

The crux of the Brogan piece is that he calls "scientific Enthusiasts" as dangerous as "your run-of-the-mill cult leaders" and includes among cult leaders Lyndon LaRouche, chairman of the U.S. Labor Party. The author of "Poetry Must Begin to Supersede Mathematics in Physics" (which appeared in *Fusion* October 1978), LaRouche is well known as a leader in the scientific tradition of Leibniz and Riemann—the tradition Brogan wants to stamp out.

Furthermore, LaRouche has recently attacked the British for their containment of science and for their role in promoting a New Dark Ages, where superstition and austerity rule. (An exposé of this New Dark Ages faction will appear in the next issue of *Fusion*.)


THE WASHINGTON POST

The Age of Un-Reason

Demagogues and Newspapers Exploit Nonsense Instead of Fighting It

THERE IS NO ENERGY SHORTAGE, NEW BOOK ASSERTS

"There will not be any physical shortage of energy. The depths of the earth and the seas contain enough oil, coal, gas and uranium to, theoretically, increase the living standards of the industrialized countries and pull the Third World out of misery," asserts a just-released book in France titled *The Energy War Has Started*. Authored by Lionel Taccoen, director of the information service of the French state electricity monopoly, EDF, the book asserts that a better international entente and massive investments can solve the world's energy problems, using nuclear power. The Third World is too poor to afford any form of energy other than nuclear, Taccoen says. Already, he warns, deforestation has taken on dramatic proportions in Africa, because of wood-burning as a source of energy.

Proposing that France play a leading role in this international effort, Taccoen foresees the need for 300 nuclear plants and fast breeders to be functioning by the year 1985.

DOE

Robert Thorne

THORNE CITES DOE CHAOS AS REASON FOR RESIGNATION

Robert Thorne, who resigned as U.S. assistant secretary for energy technology Jan. 1, cited Energy Secretary Schlesinger's downgrading of the nuclear fast breeder program and departmental mismanagement as the major reasons for his decision to leave. In an interview with *Nucleonics Week*, Thorne called Schlesinger's reorganized department "about as bad as I've ever seen. . .an undisciplined, poorly led organization."

Talk of federal budget cutbacks indicates that President Carter may again try to kill the Clinch River Breeder Reactor program and downgrade the breeder program overall, Thorne said. "I'm afraid we will fall back into just an R&D mode, and all the work we have invested over the past 10 to 15 years will be down the tubes. We need to maintain industrial capability and the R&D program." Thorne singled out the president's Domestic Policy Council for its negative view of nuclear energy, stating that people there view nuclear power as either unsafe or immoral.

NOTED U.S. SCIENTIST SCORES CARTER NUCLEAR POLICY

"The Carter nuclear policy is pointless. Other nations are forging ahead and the United States is being left behind. It is, or it should be, frightening," said Dr. Harold Agnew, director of the Los Alamos Scientific Laboratory. Agnew, who is resigning from the government research laboratory to become president of the General Atomic Company, was interviewed in the *Baltimore Sun* Jan. 17.

Agnew charged that the administration's continued opposition to fast breeder reactors and its ban on nuclear fuel reprocessing in the name of discouraging proliferation of nuclear weapons have contributed more to the problems of the American nuclear industry than to the cause of peace. "The rest of the world is going like gangbusters on nuclear development, and the United States will not even be around to make the rules, because it isn't playing the game. I think Carter's lost it."

CARTER SUBJECTS NUCLEAR EXPORTS TO ENVIRONMENTAL REVIEW

President Carter signed an executive order Jan. 5 requiring federal agencies to undertake an "environmental review" of all actions that might affect the so-called global commons—the oceans, atmosphere, and Antarctica. Export of nuclear reactors is a major item included in the review process.

The White House Council on Environmental Quality, whose top officials are drawn from antinuclear environmentalist groups, was a chief advocate of the new ruling.

One State Department source commented that the president's latest action was an additional impediment that could create further delays in U.S. nuclear exports. We haven't gotten over the shock effect of the 1978 Nuclear Nonproliferation Act and now "the other shoe has fallen," the official said.

The ruling covers exports of reactors but not nuclear fuel. The State Department source said that the Council on Environmental Quality has lobbied hard to get fuel exports covered. This would have allowed the environmentalists to challenge every shipment of nuclear fuel for foreign reactors, a move the nuclear industry had called disastrous. Because this provision failed, he said, the State Department regards the executive order as "somewhat of a compromise."

ERDA

Velikhov (front l.) in a 1977 visit to Los Alamos

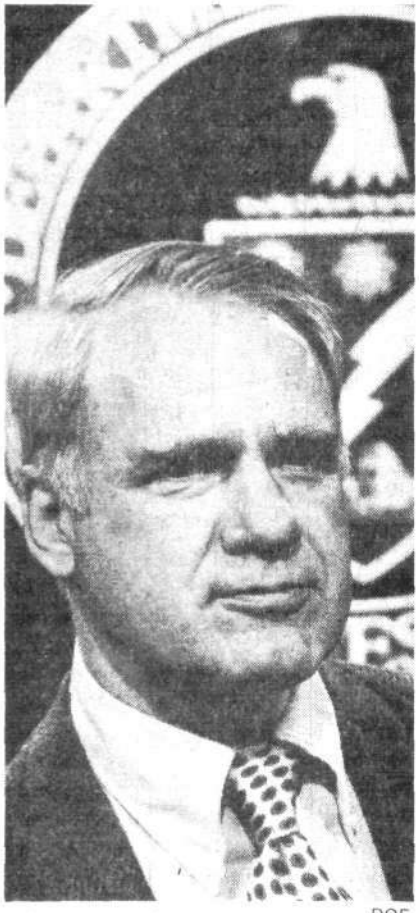
VELIKHOV PROPOSES COMECON PARTICIPATION IN SOVIET TOKAMAK

E.P. Velikhov, the vice president of the Soviet Academy of Science and a leader of the Soviet fusion program, proposed that other members of the Comecon, the economic group of the East bloc, take part in the construction of the next major Soviet tokamak experiment, the T-10M. This tokamak, which was designed to reach breakeven energy output, now has been renamed the T-15 and upgraded to a near-term, reactor-type experiment. It will have the most advanced superconducting magnets made of niobium-tin with a magnetic field strength possibly reaching 50,000 gauss. The T-15 also may be upgraded to use tritium fuel, which is what is planned for the Princeton Tokamak Fusion Test Reactor in the United States.

SCHLESINGER ASSAILS U.S.-MEXICAN GAS DEAL

Energy Secretary James Schlesinger told the National Association of Petroleum Investment Analysts Jan. 10 that purchase of natural gas from Mexico could undercut the Alaskan pipeline project because the Mexican gas was cheaper. According to studies done last year by the DOE and Congress, Mexican gas could be delivered here by 1985 at $1 per thousand cubic feet cheaper than Alaskan gas.

Schlesinger has been cited by industry and diplomatic sources as the key administration figure responsible last year for undoing a gas deal between a consortium of six American companies and Pemex, the state-owned Mexican gas company. At the time, Schlesinger said that Mexico's gas price was too high.



Whose side is he on? DOE

DOE REJECTS ALGERIAN GAS IMPORT PROPOSAL

The Department of Energy in late December rejected a proposal from the U.S.-based El Paso National Gas Company and United Gas Pipeline to import 1 billion cubic feet per day of Algerian liquefied natural gas into Texas for transshipment to California. The scope of the deal is $4.5 billion, and its rejection is a major loss in overall U.S. imports.

The DOE's Economic Regulatory Administration, which has authority to approve such projects, cited the same reasoning that was invoked in an earlier ruling by ERA administrator David J. Bardin. The Algerian import deal was a "marginal source," Bardin said, which the DOE does not want to encourage until more "proximate" sources, domestic as well as Mexican, become available. Bardin also cited the danger of possible "supply interruption."

The DOE decision was received with astonishment in Washington and among industry and diplomatic circles. There was speculation that the DOE's rejection of the Algerian gas deal, as well as a Mexican gas deal last year, was strategically tied to Energy Secretary James Schlesinger's "China card" option of cutting off trade with traditional U.S. allies and forcing U.S. industry into the Pacific China area as the only outlet for government-approved trade.

SOVIET UNION OFFERS NUCLEAR ENERGY DEAL TO MEXICO

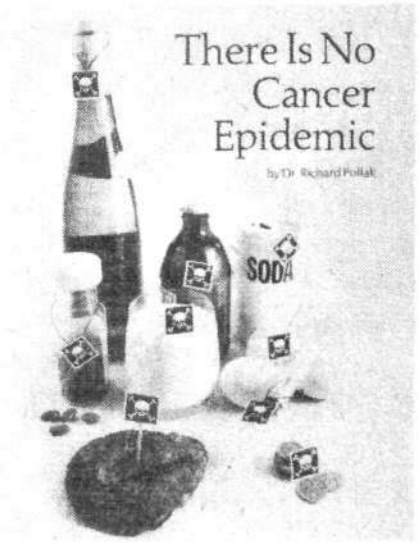
The Mexican government is seriously studying a Soviet Union offer for nuclear technology and uranium enrichment. Under the proposed agreement, the Soviet Union would train Mexican technicians in Soviet nuclear plants and provide technical assistance in the installation and operation of uranium enrichment facilities for Mexico's uranium reserves at low cost. The Mexico City daily *Uno Mas Uno* said that Mexican officials, who are also considering offers from Japan, Canada, France, and other countries, called the Soviet proposal an "exceptional offer" with unusual terms for such a commercial agreement.

A Soviet delegation led by E.P. Volchkov of the Soviet Technabexport met with leading Mexican energy officials to discuss the deal.

SPAIN TO SPONSOR SCIENCE AND TECHNOLOGY CONFERENCE

The government of Spain is convening its first Conference on Science and Technology Jan. 29-31 in Madrid. High-level delegations from Latin American countries are expected to attend. According to EFE, the Spanish news agency, the conference will focus on "translating the components of science and technology and its significance in the new international economic order," a reference to the emerging European Monetary System. The conference will also discuss the financing of concrete joint projects between Latin America and Spain and the technical issues raised by joint scientific investigations.

Spain has one of Europe's most substantial domestic nuclear power development programs, which will give it a major industrial base for joint development projects. In addition to cooperation with Latin America, Spain's foreign minister Marcelino Oreja announced in New York that his ministry is "preparing a foreign aid law that will enable Spain to have a more forceful presence in Africa."



The overall incidence of cancer has declined since 1900.

POLLAK IN RADIO INTERVIEW ON CANCER AND ENVIRONMENT

Radio station CHML in Hamilton, Ontario interviewed Dr. Richard Pollak of the FEF biological sciences staff in a 45-minute program Jan. 10 on the relationship of the environment to cancer. Pollak presented evidence showing that despite vast industrialization, there has been no increase in the overall incidence of cancer in the United States since 1900—once adjustments for increases in population size and age are made. The only exception is lung cancer, Pollak said, which is directly related to the increase in smoking. Pollak also showed how the demonstration of a substance's harmfulness is in most cases a scientific fraud based on unjustified extrapolation from high-dosage tests on bacteria and other lower test organisms to human beings.

Despite the detailed evidence, environmentalist advocate Dr. Cecillione continued to insist to Pollak that people living in certain industrial areas in Hamilton face a greatly increased risk of cancer. "Do you really believe that this so-called progress of the last century, which relies on dangerous chemicals and so on, is really worth it?" Cecillione asked.

Pollak noted that the increased life expectancy from 45 years in 1900 to the current 72 years is a direct result of such risky progress and that it is responsible for providing the materials and preconditions that will make it possible for us to solve the biomedical problems of cancer and other diseases.

PARPART ADDRESSES SEMINAR ON 'RIEMANNIAN' ECONOMICS

Uwe Parpart, FEF director of research, told a New York business leaders seminar Jan. 11 that any linear or "accountant method" view of the economy over time—such as the GNP—could not account for crucial phenomena that create major social and economic problems. Specifically, Parpart discussed the increasing cost of producing the same raw materials over time and the related burden of indebtedness that an economy incurs when investment is stubbornly poured into the same levels of technology based on the same raw materials.

As a solution, Parpart proposed that "to the extent to which we are capable, we have to plan scientific breakthroughs and to realize them in the advancement of labor. This must be the principal determining feature for elaborating a method for measuring economic growth."

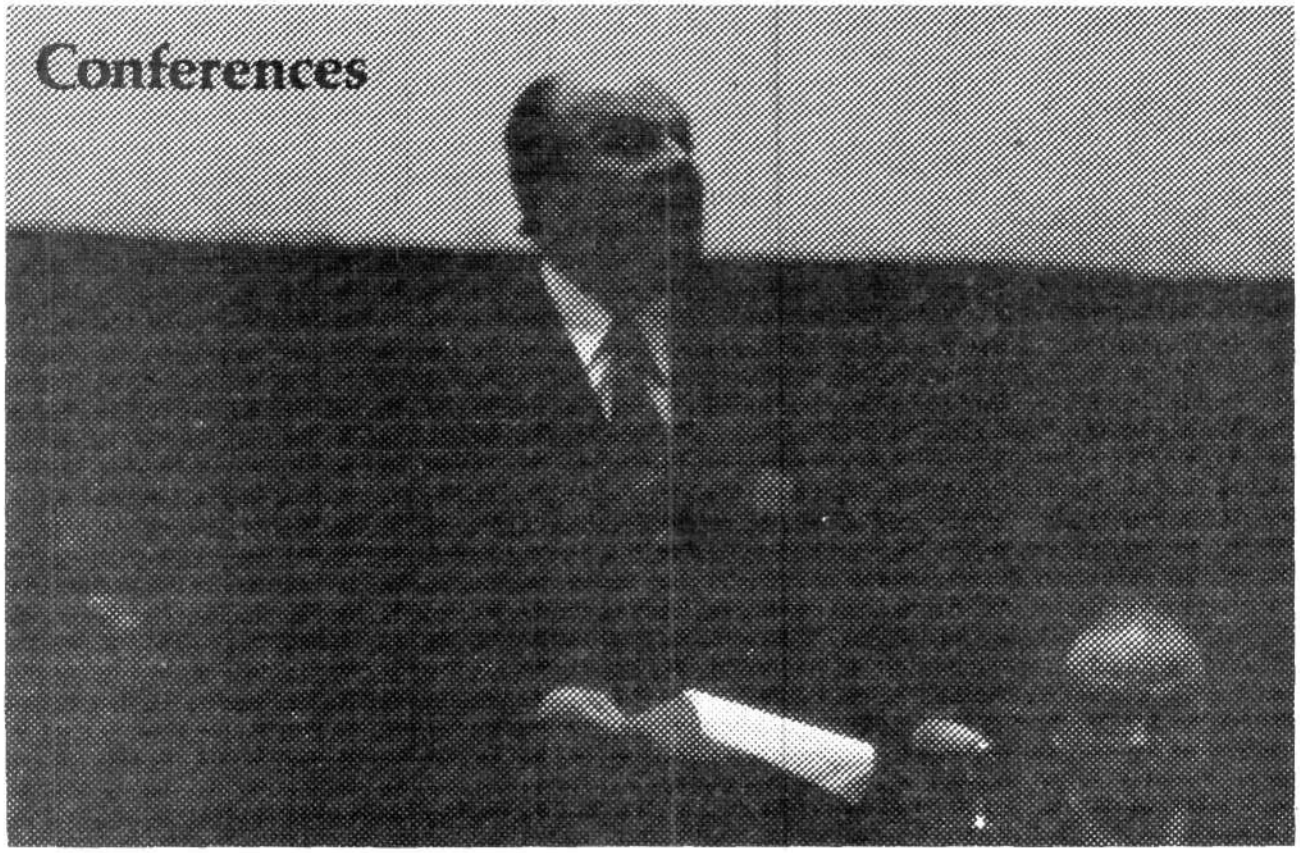
The seminar was the first in a series sponsored by the *Executive Intelligence Review*. An article by Parpart on Riemannian economics will appear in a forthcoming issue of *Fusion*.

TVA HEAD WINS LOUSEWORT AWARD

The lousewort laurels competition this month was tougher than usual. First, there was an influx of UFO reports, which generated two lousewort nominations—Prime Minister Muldoon of New Zealand who put the troops on alert to protect his nation from the UFO devils, and Rupert Murdoch, publisher of the *New York Post*, who plastered several front pages with banner headlines of UFO sightings. Second, as this issue's "Lightning Rod" column reports, one Michael Ruse from Guelph University presented a 60-page paper at the Houston meeting of the American Association for the Advancement of Science discussing the existence of gay genes.

But the UFOs and the gay genes take a backseat to lousewort laurel winner S. David Freeman, chairman of the Tennessee Valley Authority. Freeman recently distributed 120 wood-burning stoves to TVA-area families in an energy-saving experiment. The philosophy behind this move? Freeman told the Commonwealth Club in California Dec. 15, "America should break its bad habits of gluttony acquired during an era of abundance and rekindle a pioneer spirit to meet the challenges of energy and growth in the years ahead."

The lousewort committee agreed that if Freeman continues his proposals to move society backward one century at a time, he will be eligible for further lousewort awards.



Photos by Bardwell

Nikolai G. Basov at the All Union Congress meeting in Moscow

12th Euro Laser Conf.

USSR Proposes International Laser Facility

By Dr. Steven Bardwell & Charles B. Stevens

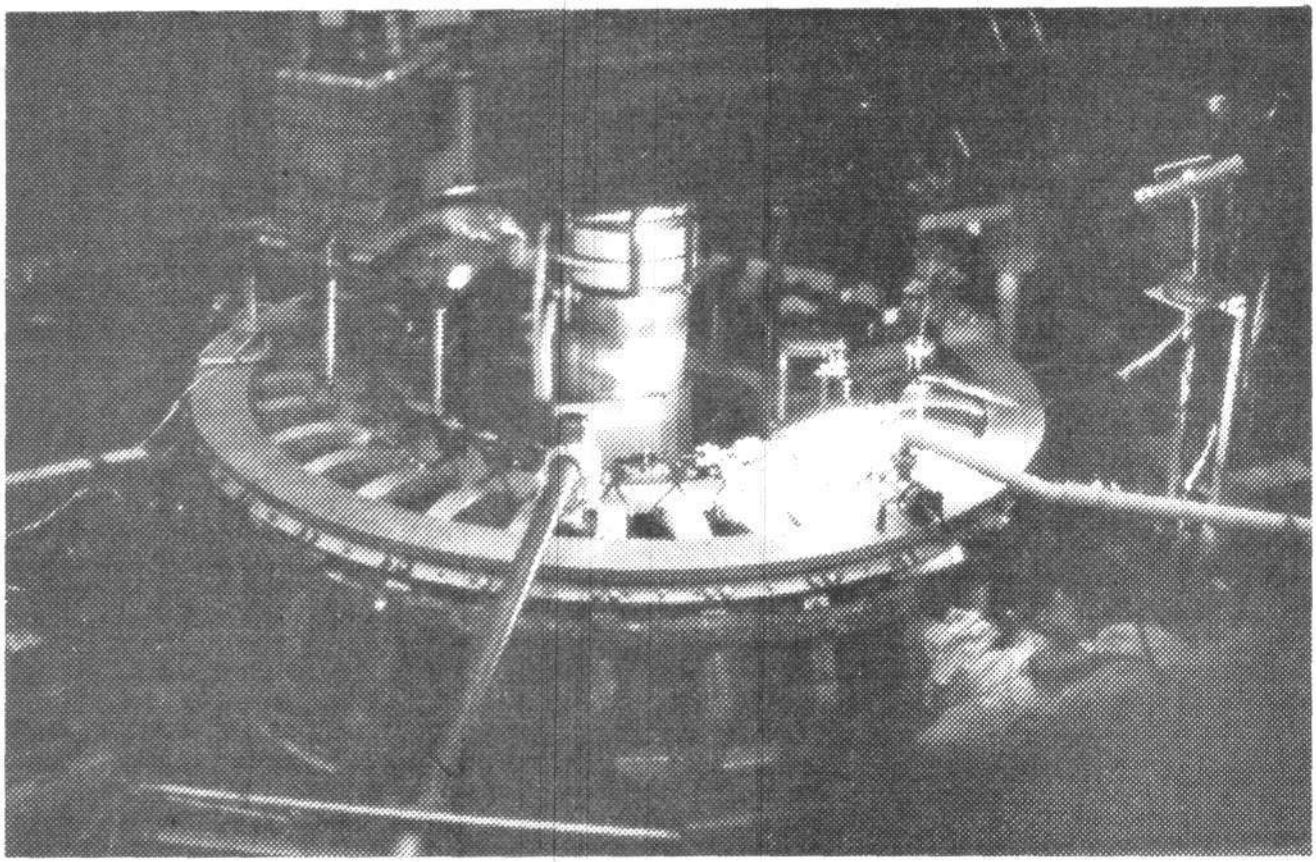
At a special meeting called by the Soviets during the 12th European Conference on Laser Interaction with Matter in Moscow, Soviet Academician E.P. Velikhov announced that the Soviets were proposing international collaboration on the development of a prototype laser fusion reactor system. Velikhov told the Dec. 13 meeting of the Soviet All Union Congress and the many visiting scientists from the United States, Western Europe, and Japan that the Soviet plan would be submitted to the United Nations International Atomic Energy Agency.

Like his earlier proposal for international collaboration on a reactor prototype facility for magnetic fusion research—the Unitor tokamak, which is now in the design stage—Velikhov proposed that the laser fusion facility be built under IAEA auspices.

This unprecedented proposal by Velikhov, the vice president of the Soviet Academy of Sciences for physics, came on the third day of the laser fusion conference, which was held in the Soviet capital from Dec. 11-15. It represents a sophisticated Soviet initiative designed to undercut the policies of classification and suppression of laser fusion that now govern research in the West.

In fact, extensive collateral evidence was gathered at the conference to document how the British military laboratory at Aldermaston is responsible for the classification of Soviet material on laser fusion in the United States (a story that will be reported on in detail in the next issue of *Fusion*).

The Velikhov proposal had an electric effect on the visiting researchers at the meeting. After years of restrictions that have created situations of paranoia, situations where research here cannot legally be discussed with workers outside one's own research group (let alone outside of one's laboratory), the Soviets have reversed the stock anti-Soviet polemic about laser fusion and suggested massive collaboration!



L-2 Stellarator at the Lebedev Physical Institute in Moscow.

The All Union Congress meeting also featured a series of reports from leading members of the Soviet Academy of Sciences and from visiting U.S. and West European laser fusion researchers on the status of fusion, in particular, the work of the laser conference to the assembled representatives of the leading Soviet governmental, union, and industrial organizations.

All Union Congress

Dr. Ian Spalding of the Culham fusion lab in Great Britain began the proceedings by calling for increased international collaboration and by thanking Soviet Academician Nikolai G. Basov for making the European Laser Conference possible.

Dr. Gene McCall, the head of laser fusion experiments at the Los Alamos Laboratory in New Mexico, followed with an educational presentation on laser fusion. He noted that the fission-fusion hybrid concept to use fusion-generated neutrons to cheaply breed fuel for nuclear fission reactors could greatly accelerate the rate at which fusion could make an impact on the world's energy resource needs.

Soviet Academician Rabinovich, director of much of the Soviet Union's magnetic fusion, beam, and microwave research, then juxtaposed the philosophy of the "zero growth" futurologists to the realities of the near infinite resource base the fusion process would make available to all of mankind. Rabinovich's report to the All Union Congress emphasized the near-term spinoffs of advances in technology and science that will accrue from this research effort.

U.S. Nobel laureate Richard Hofstadter, consultant and chief scientist at KMS Fusion in Michigan, elaborated on Academician Rabinovich's remarks with several specifics on the impact of fusion research on medicine and synthetic fossil fuel generation. "I am completely optimistic about fusion and laser fusion in particular," said Hofstadter. Success "will come soon with scientific breakeven in 1983, and then the best engineers in the world will be drawn to this research with the achievement of that most exciting advance. Then it will just depend on having much more money.

Soviet Academicians A.A. Samarsky and Basov both emphasized the importance of fundamental scientific breakthroughs that can be expected in laser fusion research.

Samarsky heads up the leading Soviet mathematical research center, the Institute of Applied Mathematics, and taught more than two-thirds of the Soviet scientists attending the laser conference. He focused on the essential nonlinear character of the processes encountered in the supercompression of matter, a primary aspect of the laser fusion process. These fundamental processes encountered in laser fusion research, said Samarsky, have important implications for the most basic scientific questions.

Others making presentations at the

All Union Congress were L.I. Rudakov, who reported on Soviet electron fusion research; Academician L.P. Feoktistov, who reported on the latest fission-fusion hybrid studies in the Soviet Union; Dr. E. Fabre of the French Ecole Polytechnique.

Laser Research Advances

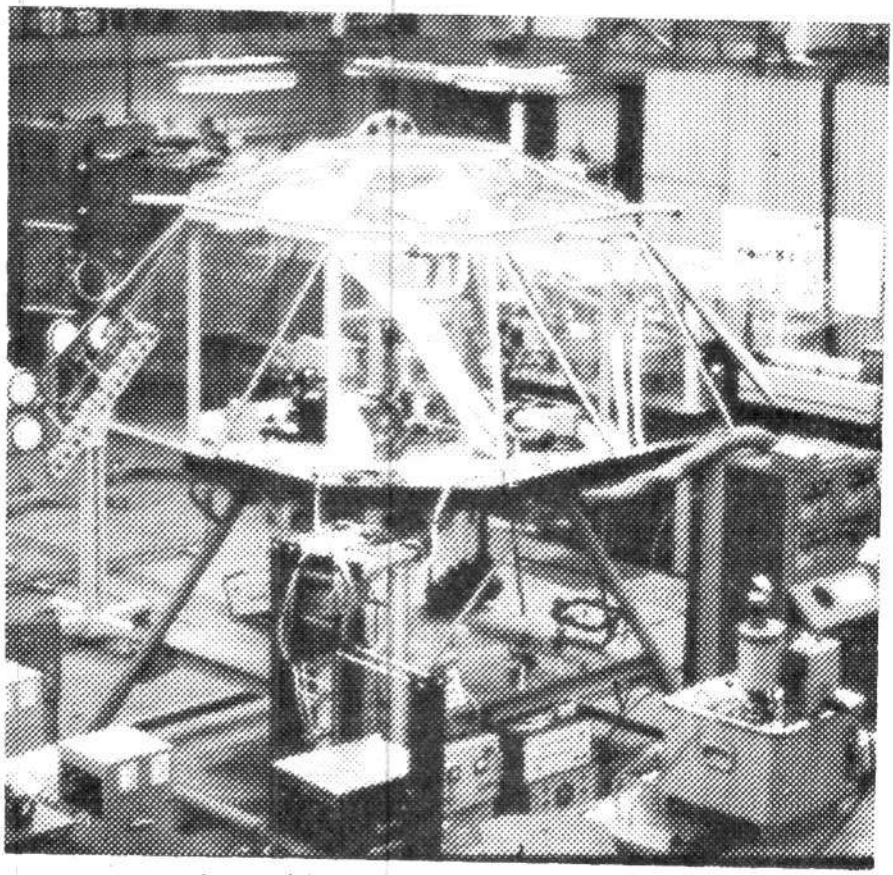
The five-day European Conference on Laser Interactions with matter drew 250 scientists, including about 100 from outside the Soviet Union. Several very significant advances in laser fusion research were reported on at the conference, including the following:

•Scientists from the German Democratic Republic and Poland detailed their collaborative work with Academician Basov on unique laser fusion and plasma focus research with asymetrical types of fusion targets.

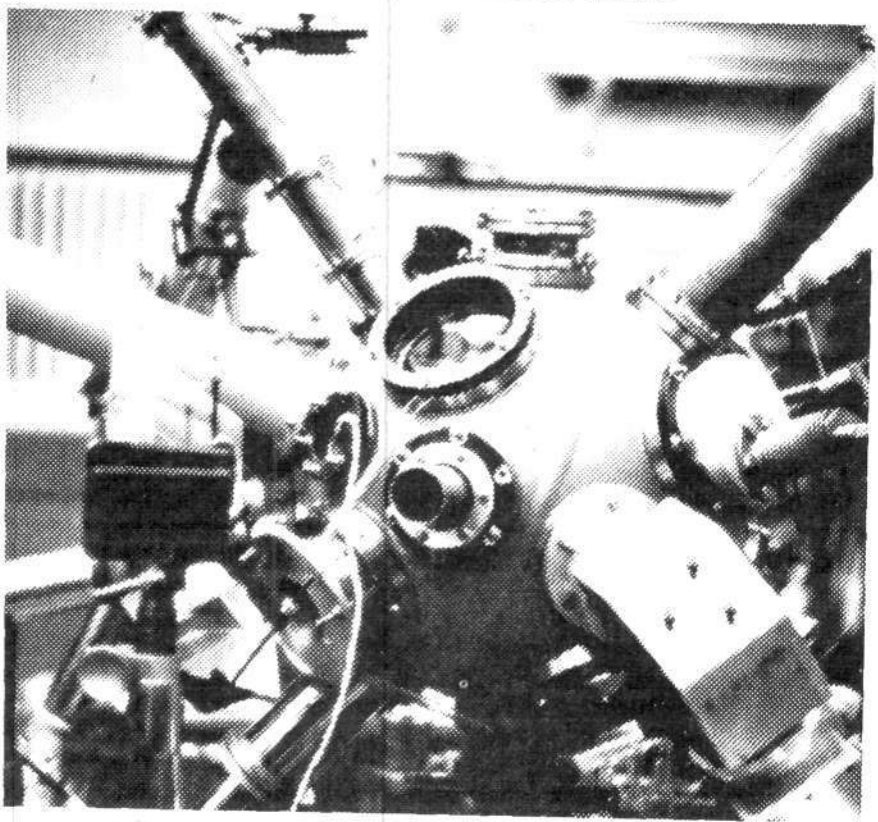
•Dr. V.B. Rozanov, vice chairman of the 12th European Conference, presented Soviet experimental and theoretical results that demonstrated how high-gain laser fusion targets required for power reactors can be ignited. These target designs are based on the nonlinear hydrodynamic and plasma physics investigations of Soviet scientists, together with their unequaled experimental achievements with the Kalmar laser facility at the Lebedev Institute near Moscow.

•Soviet scientists put forward numerous proposals in private discussions for international collaboration on experiments in inertial confinement (laser) fusion and detailed the historical basis for the theories that led to inertial fusion in the first place. These historical studies, upon which many current Soviet investigations and proposals are based, have determined that the unique contribution of the 19th century German mathematician Bernhard Riemann is essential to understanding the inertial fusion process and the workings of stars. Riemann's "self-similar" solutions to wave equations laid the theoretical basis for supercompression of matter.

Subsequent scientific developments have been traced by Soviet researchers to the German hydrodynamicist school of Prandl and his student Busemann. Busemann's work,



Basov's laboratory at the Lebedev Institute



Pellet chamber of the Delphin laser at Lebedev Institute

in particular, laid the groundwork for the U.S. and Soviet hydrogen bomb programs.

This Soviet historical research opened up two areas of intense discussion at the conference.

The first was the implications of Riemann's work for the critical question of laser fusion pellet design. As many researchers have noted, the economic feasibility of laser fusion hinges heavily on the ability to design cheap, high-gain pellets, but this design work is severely hampered by the strict classification that surrounds all questions of pellet design.

It was clear from all presentations at the conference—stated almost openly by the Soviet scientists and left obvious by its omission in the American presentations—that assymetrical, probably cylindrical, targets present tremendous advantages over spherical targets. Since the considerations that lead to this conclusion also bear on efficient bomb design, the question of pellet design has been one of the most closely guarded military "secrets."

The Riemann Question

The real secret, however, is that these considerations on cylindrical targets are discussed in a series of papers done by Riemann in 1859. These papers have had a substantial impact on the Soviet program. (Articles on the Riemann papers and the Soviet response will appear in the March-April issue of *Fusion*.)

The second area of discussion was the obvious question of what happened to these Riemannian results in the West. Several scientists pinpointed the political operation against the "hydrodynamicist" school by the same British circles who run the Aldermaston military operation.

The impact of this deployment in the United States has been staggering. For example, under the direction of Aldermaston, officials in the U.S. Department of Energy have used classification to sabotage international collaboration in the field of electron beam fusion and fast liner fusion experiments. Furthermore, Aldermaston is attempting to classify sections of magnetic confinement research, for the same end.

There is convincing evidence, which will be discussed in a subsequent report, that this classification is part of a larger policy of the British government aimed at a general stifling of scientific research.

In the context of the discussions around Riemann, the paper given by Steven Bardwell and Charles Stevens, FEF director of plasma physics and director of fusion engineering, respectively, on "Energy Densification and Self-Organizing Processes in Laser Created Plasmas" received an enthusiastic response from the predominantly Soviet audience.

The FEF report developed the thesis that solitons, self-generated magnetic fields, and the host of other self-organized phenomena that occur in energy-dense plasmas are not separate, isolated anomalies of plasmas, as the current dogma holds; rather these phenomena are a coherent, characteristic feature. The implication of this methodological conclusion is that the behavior of a plasma (and other physical phenomena) must be governed by some higher-order principle that is made evident in the nonentropic entities.

There was a striking difference between the reception the FEF report received from the audience in Moscow and the reception received from predominantly Western audiences in the past. As one Soviet scientist commented, "There was a real resonance set up."

Many of the Soviet scientists indicated that they had been working on similar ideas both experimentally and theoretically. They noted that it was much more common in the Soviet Union than in the West to realize that the implication of nonentropic phenomena—like those in plasma—is the existence of a qualitatively different ordering principle governing the subspace of physical phenomena.

In one discussion with two Soviet scientists, for example, one of them cut short a technical discussion of plasma physics to say, "The most important part of this is that it raises the question of the existence of God." Upon which the other Soviet scientist replied, "Not his existence, but his nature."

FEF Sweden Conf.

Next Step to Nuclear Power

How to implement a global economic plan based on advanced fission and fusion technology was the main topic of discussion at the two-day conference sponsored by the Fusion Energy Foundation in Stockholm, Sweden Dec. 7-8. The 70 conference participants included representatives of Swedish and Danish heavy industry, Swedish trade unionists, leading scientists in the nuclear field, press, and representatives of Argentina, Czechoslovakia, France, and the Soviet Union.

In his opening speech, FEF European director Hans Bandmann counterposed the disastrous policies of labor-intensive "soft" technology advocated by institutions like the World Bank and the International Monetary Fund to the "grand design" policy pursued by France, West Germany, Japan, and the Soviet Union—a policy for capital-intensive, economic and technological development based on North-South and East-West cooperation. Bandmann pointed out that the August breakthroughs in fusion tokamak research at Princeton Plasma Physics Laboratory and the launching of the European Monetary System by West Germany and France represent "two decisive victories for the grand design policy."

To make this policy a reality, Bandmann said, the world must step fully into the nuclear age, where fission and fusion power will provide the basis over the next 25 years for the full industrialization of the Third World and for a new industrial revolution in the advanced sector leading to large-scale exploration and colonization of space.

A strategy for industrializing the Third World was then presented by Dr. Helmut Böttiger of the FEF, who discussed the building of nuplexes, agro-industrial complexes centered around

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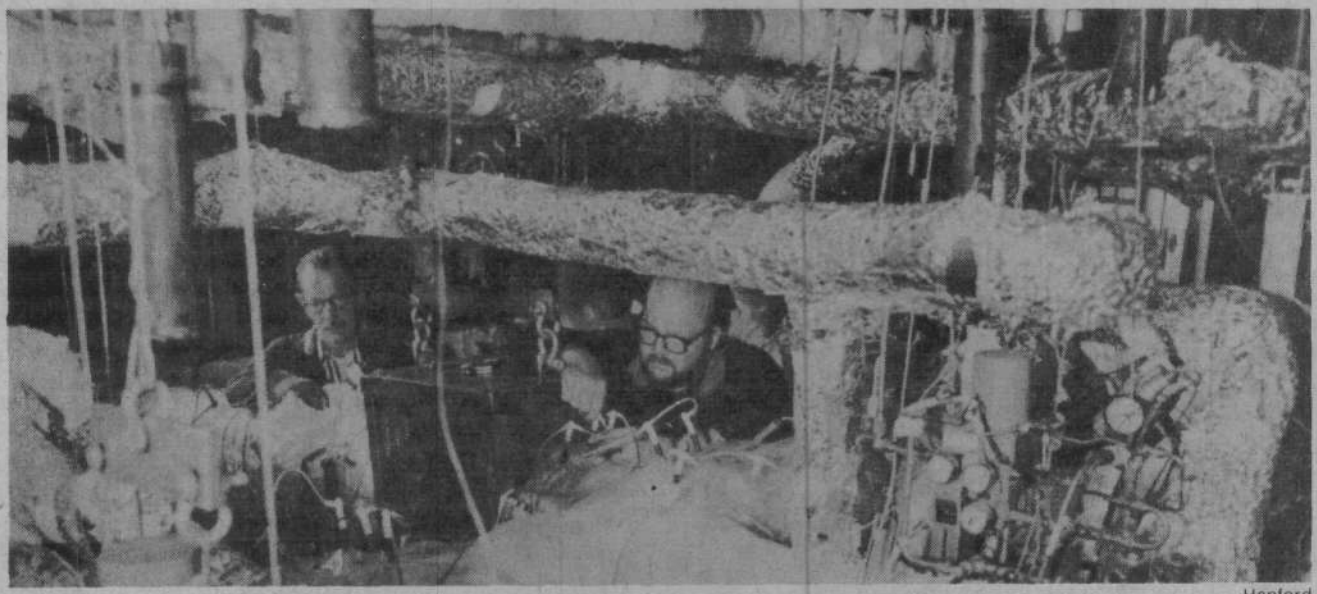

Hanford

Materials testing in hot-sodium pipes at Hanford's Transient Test Loop.

Washington

DOE to Consolidate Fusion Materials Testing

The Fusion Office in the Department of Energy has decided to combine two ongoing materials testing programs—one at Los Alamos Scientific Laboratory in New Mexico and one at Hanford, Washington — in order to try to meet the timetable for a commercial fusion reactor. Scientists and administrators in the fusion program have been concerned that the stagnating fusion budget will significantly delay the development of materials that can withstand the intense 14 million electron volt neutron bombardment in a fusion reactor.

The materials irradiation test facility at Hanford was scheduled to be completed by 1983, but current budget levels make this doubtful. The 10-year materials program must be completed by the early 1990s when an experimental fusion reactor will be on line. Unless substantial operating funds are provided for the accelerator neutron source, this will not be possible.

The combined project will be built at Hanford and will include an accelerator, the intense neutron source, supplied by Los Alamos and a test chamber for materials development built at Hanford.

Both the Los Alamos and Hanford projects were added onto the fiscal year 1979 budget request by Congress, since the Office of Management and Budget never approved funding of either project. However, the small amount of money allocated by Congress covered some of the construction costs but no operating expenses. The entire material irradiation test facility project is expected to cost $85 million.

DOE sources report that West German fusion scientists from Jülich will continue at Hanford the joint materials research work begun at Los Alamos, in accordance with the 1976 Euratom-International Energy Agency agreements on developing intense neutron source testing facilities.

Congress to Scrutinize DOE Chaos

The continued resignations and general disorganization in the Department of Energy more than a year after its establishment are now scheduled for a public airing in Congress.

The Senate Government Affairs Committee has announced that it will hold oversight hearings to investigate the administrative disorganization in the DOE when Congress reconvenes this month. In addition, the department will come under scrutiny by the Senate Energy Committee, when it considers President Carter's nomination of Dr. John Deutch as assistant secretary for energy technology. Deutch, DOE director of research, has been nominated to replace Robert Thorne, who resigned effective Jan. 1.

According to staffers on the two Senate Committees, it is common knowledge that many capable persons have left the department and were not "replaced with people of equal caliber." An aide to Senator John Glenn, chairman of the Government Affairs Committee, noted that the committee intends to evaluate

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energy policy initiatives coming from the administration when the DOE issues its second national energy plan in March or April.

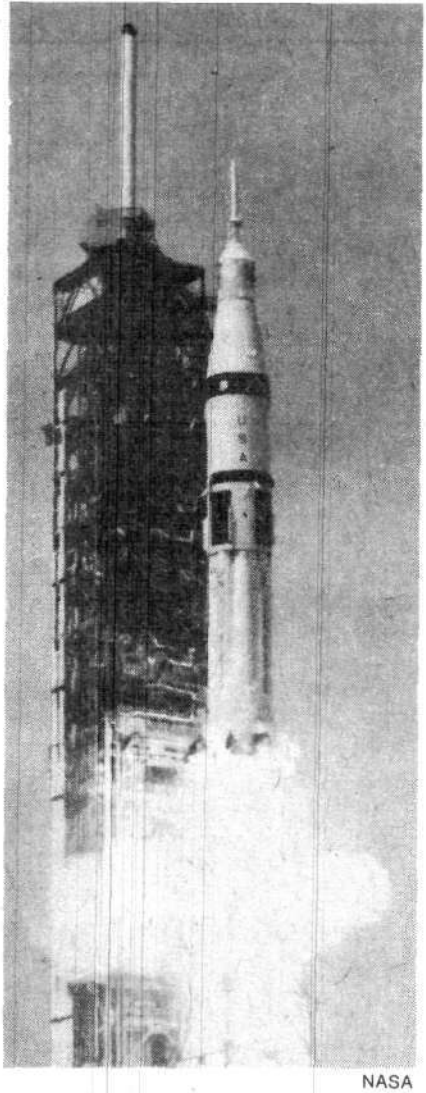
Deutch's confirmation process, although not expected to reach the frenzy of the Thorne hearings a year ago — environmentalists challenged Thorne as "pronuclear" — may be quite lively. As Washington sources report, some of the staff people Deutch plans to take with him from the energy research division are quite controversial. For example, according to a top DOE official in Deutch's office, Deutch's proliferation advisor, Dr. Marvin Maas, is recognized in Washington as a "dangerous" person whose paranoid views on weapons proliferation have disrupted fruitful areas of nuclear energy research.

Dept. of Energy Going 'Soft'

The Carter administration has taken a big step from advanced nuclear and coal development to solar and related soft technologies, according to statements by Stuart Eizenstat, President Carter's advisor on domestic affairs.

Asked at a background briefing on the budget Jan. 26, 1979 why the energy R&D budget is being slashed if the world is in fact facing an energy crisis, Eizenstat replied: "We got a major increase, something like a 30 percent increase, in our solar budget." This increase, Eizenstat said, amounting to more than $600 million in solar "R&D," is being taken from both nuclear and fossil research programs.

The policy shift immediately puts in jeopardy the U.S.-Japan science and technology agreements expected to be signed in March. Energy Secretary Schlesinger had made U.S.-Japanese fusion cooperation dependent upon Japanese investment in the U.S. coal synthetics program. As part of this prosolar redirection, the SRC II coal project is in trouble in the DOE budget.



NASA

The Apollo-Soyuz Test Project Saturn on its way from the Kennedy Space Center July 15, 1975. This was the first joint U.S.-Soviet engineering and scientific space project.

NASA Under Attack by Administration

The National Aeronautics and Space Administration is under attack from the Carter administration as well as the nation's press. A series of recent articles has called for the dismemberment of NASA as an independent agency and a reorientation from basic scientific work to doing "odd jobs" for other government departments.

Administration spokesmen have admitted that the NASA program is undergoing a "reorientation." As the *New York Post* put it in an unsigned article Dec. 26, the Carter administration policy is "bringing NASA down to earth."

Both President Carter's speech at Cape Canaveral Oct. 1 and the Civilian Space Policy statement by Dr. Frank Press Oct. 11 made it clear that NASA will be enlisted to do "practical, commercial, and scientific exploration for improving conditions on earth" rather than large-scale colonization in space or interplanetary travel, the original goals of the agency.

More Revisions Expected in 1980 DOE Budget

The Department of Energy's budget request for fiscal year 1980 will be presented to Congress in mid-January and is expected to undergo significant revisions.

The original budget prepared by Energy Secretary James Schlesinger was sharply reduced from $10 billion to about $8 billion by the Office of Management and Budget in November, and according to government sources, it was slashed another $1 billion by President Carter.

Although the exact budget figures have not been publicly released, indications are that both the nuclear fission research and development and advanced nuclear programs will suffer substantial cuts. *Nucleonics Week* has reported that the advanced nuclear budget will be reduced from a fiscal year 1979 level of $107.6 million to about $44 million in the 1980 fiscal year. It is also reported that the fission research and development budget will be $137 million, compared to $226.3 million in fiscal year 1979.

Furthermore, the White House Office of Science and Technology has stated as policy that the United States will no longer "do things in space just for the sake of doing it" and that "NASA no longer has a unique vested interest in space," because the Defense Department has an increasing role and benefits in the space program.

Knowledgeable Washington sources report that the administration's fiscal year 1980 budget request to Congress for NASA will be approximately the same as funding levels in 1979—about $4 billion. No new program starts will be made, a fact that caused one space-program observer to comment "this kind of orientation will lose us our lead in space."

Even NASA's technological applications programs are under the cost-effectiveness axe. Instead of scientific criteria, decisions on space industrialization are being subjected to "economic" considerations of whether it's cheaper to do it "here or there."

A most insidious aspect of the anti-science attacks on NASA is the assertion in the national press and the White House that the only constituency for space science and exploration is the aerospace industry, legislators with strong ties to this sector, and "a few space-science buffs." As one old-time scientist commented, "What ever happened to good old Yankee ingenuity and the idea of Progress?"

The budget cuts are expected to include reductions in the liquid metal fast breeder reactor program, the high temperature gas cooled reactor development program, and other high technology nuclear energy programs.

Fusion Budget Intact

The DOE Fusion Office has reported that despite anticipated cuts in advanced technology energy programs, magnetic confinement fusion funding is slated for $360.9 million in fiscal year 1980, almost $11 million more than current funding levels. This small increase, however, will barely keep current programs areas moving forward, given the rate of inflation. It also will prevent the startup of several new initiatives.

West German Intervention Restores HTGR Budget

Top Washington sources report that the Department of Energy fiscal year 1980 budget line for the high temperature gas cooled reactor was partially restored after the West German government intervened on behalf of the project. The department's budget request submitted to the Office of Management and Budget had included only enough money to terminate the U.S. HTGR project, one of the most advanced nuclear reactor technologies (see feature article, this issue).

When the planned cutback became known, the West German Ambassador to the United States submitted a letter to the State Department insisting that no budget cut could be allowed to abrogate an international agreement. The West German government has a joint development agreement with the DOE's HTGR program at General Atomic in San Diego, California.

According to Washington sources, between one-third and one-half of the required funding to continue the HTGR project was added to the DOE budget request, which will go to Congress this month.

Industry representatives feel that they will get a more sympathetic hearing from Congress and that Congress may restore full funding for the HTGR.

Recombinant DNA: HEW Delays Guidelines

Responsibility for overseeing research in recombinant DNA technology has been shifted from the National Institutes of Health to the Department of Health, Education, and Welfare.

Although the move has been seen by many in the scientific community as a relaxation of government regulations, HEW Secretary Joseph Califano has continued to keep recombinant DNA research in jeopardy on two counts. First, as *Science* magazine pointed out Jan. 5, Califano has delayed in putting forward guidelines necessary for "realizing the practical and intellectual promise of recombinant DNA and for making risk assessments . . . for months." Second, Califano is appointing nonscientists to the expanded advisory committee responsible for advice on technical matters, which is unlikely to enhance the DNA research.

The recombinant DNA technique, a form of genetic engineering, holds the key to breakthroughs in the fundamental understanding of human genetics such as the causes of cancer and aging. Research results to date have been extremely promising. As pointed out by biochemist Maxine Singer, "Under the NIH guidelines work has proceeded safely and research accomplishments have been spectacular." Recently a group of California researchers used recombinant DNA techniques to induce bacteria to produce human insulin.

There has been considerable dissension among environmentalist groups on the desirability of recombinant DNA research. (The Naderites attack it as a technique by which mad scientists could genetically create monsters.) Nevertheless, lawsuits designed to chill the research are proceeding apace, as are vigorous lobbying efforts to legislate it to death.

To quote again from *Science* magazine (Dec. 22): "The environmentalists have a large stake generally in campaigns that slow the proliferation of technology, and they have a specific investment in slowing down recombinant DNA research. The public interest, *c'est moi*, Ralph Nader might say. And environmental activists sometimes seem to believe that the public interest is embodied in whatever they decide to do."

International

Europeans Pressure U.S. On Fusion Cooperation

President Carter met with Roy Jenkins, chairman of the Commission of European Communities, in December for discussions on scientific cooperation including joint work in thermonuclear fusion. According to a White House press release Dec. 14, both parties agreed on the need to strengthen powers of innovation in science and technology "while cooperating with others to share knowledge and cost to their mutual advantage."

The specific areas of cooperation noted are "nuclear fusion, management of radioactive waste, handling and control of fissile materials, and biological and medical research...."

Under existing U.S.-European agreements, there is a small but significant scientific and technological exchange program in fusion between the United States and West Germany.

The European Community members, in line with Soviet and Japanese proposals, are urging the Carter administration to upgrade the U.S. participation in an international effort to build an actual fusion test reactor. In addition to bilateral agreements, the Europeans are trying to pull the United States more solidly behind the Soviet-initiated Unitor joint fusion reactor proposal, now under development by the United Nations International Atomic Energy Agency.

European Community representatives in Washington said that EC scientific commissioner Dr. Brunner, the U.S. State Department, and Presidential Science Advisor Dr. Frank Press have agreed in their ongoing discussions that joint fusion research is a top priority. Brunner will meet with Press in the near future to work out concrete plans for increased cooperation.

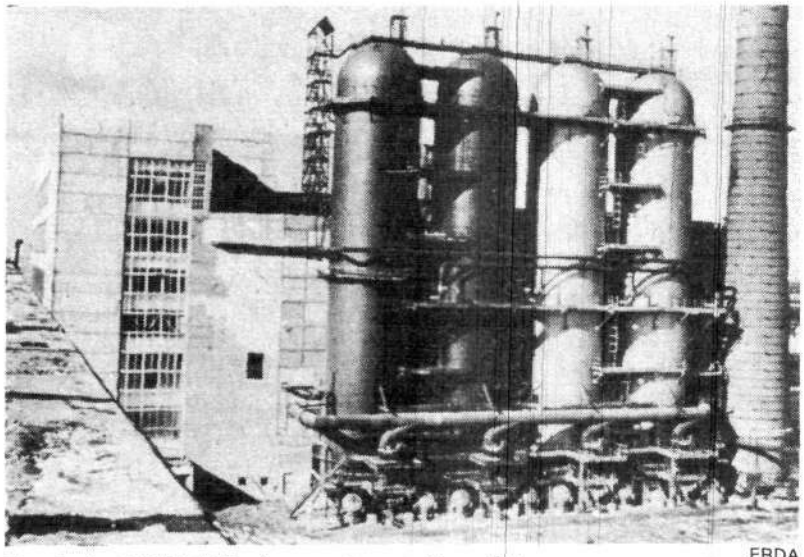
EC sources also indicated that the fusion initiative made by Japanese Prime Minister Fukuda last May was an important factor in pressuring the administration toward more serious international fusion research.

20 Years of Cooperation

U.S.-European cooperation in nuclear energy has proceeded on a bilateral basis since the 1958 agreements on the Peaceful Uses of Atomic Energy that were signed during the Eisenhower Administration with Euratom, the European Atomic Energy Community affiliated with the EC. In 1976, Euratom submitted a proposal to the International Energy Agency, which is part of the Organization for Economic Cooperation and Development, for a cooperative agreement in energy research and development, including joint work in fusion energy.

This agreement subsumed the ongoing bilateral U.S.-EC fusion research within the multilateral IEA headquartered in Paris and proposed joint work on an intense neutron source.

The agreement motivated the joint work as follows: "...It must be remembered that up until now, the



ERDA

The Soviet U-25 MHD plant on the outskirts of Moscow.

U.S.-Soviet Deal on Rocks?

The United States is likely to request that the five-year energy technology cooperation agreements with the Soviet Union be extended, but not for another full five years, according to the Department of Energy international affairs division. The agreements expire in June 1979, and the final decision will be made by the National Security Council.

Both the DOE and the National Security Council have criticized the present energy cooperation agreements. One DOE official complained that the Soviets have focused on high-technology programs like magnetohydrodynamics and have not taken seriously the "soft technology" areas or energy forecasting.

"Energy research and development here and in the Soviet Union may be following different paths" in the next few years, and a two or three year agreement would be more appropriate, one international affairs official said.

major part of fusion power research has been concerned with plasma physics having as (the) main objective the production and confinement of a nuclear reacting plasma. This objective now seems to be within reach and the problems of fusion technology must now be solved. In this respect, it is known that one characteristic of fusion plasma is its emission of an intense flux of neutrons which is much more energetic than those experienced in fission work.... One of the main difficulties in constructing large nuclear power stations based on thermonuclear fusion is the development of materials capable of resisting in particular the flux of 14 MeV neutrons. It is therefore necessary that adequate measures are taken to ensure that when the time comes, the necessary equipment is available to exploit nuclear fusion...."

Under this agreement, Euratom began joint work with Los Alamos Scientific Laboratory on the intense neutron source.

In September 1977, the EC proposed two additional areas of joint fusion work to the IEA. The first was plasma wall interaction on a "textor" experiment operated at Julich, West Germany. This large-scale tokamak-type experiment would be equipped with special diagnostics and would permit easy replacement of wall chambers.

The second area of proposed joint fusion research was the development of superconducting magnet systems for fusion power. To quote from the EC proposal: "It is considered important to develop this technology for the generation of machines which will follow the FET, TFTR, and JT-60. For this purpose, it will not suffice to construct a large-scale superconducting magnet, but it will also be necessary to build a group containing four to six magnets...."

The EC proposed that Euratom would supply a superconducting magnet system to Oak Ridge National Laboratory for fusion experiments.

Both fusion proposals were included in a series of agreements signed Oct. 7, 1977 between the EC and the IEA.

—*Marsha Freeman*

DOE

Schlesinger in China: Let them use coal.

No Fusion on China Agenda?

Implementation of the "agenda for cooperation" agreed to in November by the government of the People's Republic of China and Energy Secretary James Schlesinger is heavily weighted toward the transfer of conventional, already commercial energy technology to China, with little emphasis on advanced scientific work or research and development.

Washington sources report that Schlesinger is using this "China card" — the promise of increased conventional exports to China — to deter export-starved U.S. industry from lobbying for U.S. entrance into the much more vast export capabilities of the new European Monetary System. The leaders of the newly launched EMS, which has the backing of the Western European nations as well as Japan and the Soviet Union, have explicitly pushed for advanced technology trade and development deals.

As further evidence of Schlesinger's lack of commitment to fusion and advanced energy cooperation, one high-level Washington source noted that no representative of the DOE fusion program was included in the U.S. energy delegation to China three months ago.

Sources in the DOE Fusion Office and in the international affairs division said that coal and not fusion cooperation is what Schlesinger has in mind for China. Schlesinger has written a memorandum to Carl Bagge, the president of the National Coal Association encouraging U.S. industry to take the initiative in cooperation with China. Furthermore, these sources said, a delegation of Chinese coal-mining experts visited U.S. coal mines in September, and the DOE is encouraging the U.S. coal industry to reciprocate.

DOE officials generally agree that much of what is referred to as U.S.-China "science and technology" cooperation at least initially will consist of the transfer of already-commercial U.S. industrial technology to China, and that this cooperation will be "nongovernmental."

Although magnetic fusion was specifically included in the Schlesinger-China talks and met with an enthusiastic response from Chinese fusion scientists, DOE fusion sources guess that it will be at least six months before any serious joint projects are discussed in magnetic fusion cooperation.

Schlesinger OKs Nuclear Plant Sale to China

U.S. Energy Secretary James Schlesinger's announcement in early January that the Department of Energy had informally approved the sale of American-licensed nuclear technology to the People's Republic of China has come under attack from U.S. industrial sources as well as other governments. An immediate question posed was why has Schlesinger, who has refused to sell U.S. nuclear technology and nuclear fuel to several U.S. allies, suddenly reversed his position?

The approved sale violates the terms of the U.S. Nuclear Nonproliferation Act of 1978 — legislation that Schlesinger has enthusiastically backed — which in effect bans the sale of U.S. nuclear reactor technology for export on the grounds that it could be applied to weapons production. Together with Schlesinger's overall nonproliferation policy, the act has been used in the past two years as a political wedge against the peaceful transfer of nuclear technology to developing and industrialized nations such as India, Japan, and other U.S. allies.

Immediately after Schlesinger's announcement, the Indian foreign minister denounced the U.S. administration for applying a "double standard" on the nuclear question. The United States is still withholding from India previously negotiated nuclear fuel for the reactor at Tarapur that provides electricity to the Bombay area.

The approved sale to Peking involves two 925 megawatt power reactors produced through a subsidiary of the French company Creusot-Loire, which is under license from the Westinghouse Corporation to produce nuclear power plants. Schlesinger's office claimed that the sale was approved to prevent the contract from going to a non-U.S. supplier. In view of the limited Chinese market and the vast nuclear market elsewhere that Schlesinger has denied to U.S. suppliers, this reason raises more questions than it answers.

The Taiwan Question

Just before Schlesinger's trip to Peking at the head of a 31-person DOE delegation, a leading industry journal, *Nuclear Industry*, warned that if the U.S. provided nuclear technology to Peking it might jeopardize present and future contracts to supply such technology to Taiwan. The potential loss of nuclear contracts for U.S. suppliers to Taiwan is far greater than the gain to be expected from any deals with Peking, *Nuclear Industry* said.

Westinghouse and General Electric are currently in the process of constructing six nuclear power plant units for Taiwan valued at almost $4 billion. More commercial orders are in negotiation and substantial uranium enrichment orders are also possible.

The head of the Taiwan Power Board, L. K. Chen, has said that if expansion of agreements with U.S. nuclear suppliers is prevented: "we will go to other suppliers. The program will continue."

Taiwan is a full signatory to the requirements of the International Atomic Energy Agency providing for regular inspection and surveillance by the United Nations agency of all nuclear reactors, facilities, and materials in order to guard against proliferation of nuclear weapons production.

According to a State Department source, when the subject came up during Schlesinger's 1978 trip, "the Chinese formal position was that those agreements are among the superpowers and have nothing to do with them." In fact, since its first nuclear explosion in 1964, mainland China has built up a stockpile of several hundred nuclear warheads.

—William Engdahl

Mexican Oil: Reserves Doubled

Mexico's national oil company, Pemex, released stunning new figures in a year-end 1978 report showing that Mexico's proven oil reserves have doubled, from 20 billion barrels to 40 billion. These are the sixth largest proven reserves in the world, and new drilling promises further increases over the next two years.

Probable reserves, which include the "proven" category, jumped from 37 billion barrels to more than 80 billion. Potential reserves are pegged at 200 billion barrels.

Mexican President Jose Lopez Portillo noted the significance of these figures in a Jan. 4 review of the Mexican economy and the nation's goals for the coming year. "Nineteen hundred and seventy-nine can become the year in which Mexico fully enters the modern world.... Mexico is now joining the great arena of world development."

Lopez-Portillo called on the nation to eliminate remaining bottlenecks in every area — capital goods, steel, petrochemicals, agriculture, and transport — so that the economy can fully "take off" in 1980.

The big question is who will provide Mexico the technology for its goal of moving into the nuclear age? So far, the answer from an unpublicized Presidential Review Memorandum 41 prepared by the National Security Council staff for President Carter is "not the United States." The memo was written to define options for Carter's state visit to Mexico in mid-February. Although it promises certain concessions on issues such as the threatened U.S. sanctions against undocumented Mexican workers here (which Mexico views as blackmail), it ignores any statement of interest in exchanging U.S. technology and capital goods for Mexico's gigantic oil wealth.

This technology transfer, however, is exactly the focus of the Europeans, with France in the lead. French Industry Minister Andre Giraud concluded five days of successful nego-

U.S. May Lose Out on Korean Nuclear Sale

The Republic of Korea may contract with the French firm Framatome for the supply of Korea's fifth and sixth nuclear reactors, instead of Westinghouse, according to press reports published in December. A final decision on the $1.4 billion deal is expected later this year.

The Korean government, which has developed one of the most ambitious nuclear energy development programs in the world (see accompanying interview), is uneasy about the Carter administration's nuclear policy. Given the Korean plan to supply 60 percent of the nation's energy needs by nuclear power in the year 2000, government officials are uncertain of the long-term implications of the administration's nonproliferation policy. They also have questioned the dependability of the United States as Korea's major supplier of enriched uranium and nuclear technology.

Late last year, a controversy over the human rights issue threatened to block the extension of credits from the U.S. Export-Import Bank for the purchase of a Westinghouse reactor by the Koreans. This added to the government's desire to diversify its suppliers of nuclear technology, especially to include West Germany and France.

tiations in Mexico in mid-December, in preparation for a state visit by President Giscard d'Estaing set for the end of February.

Giraud stressed the need for "immediately encouraging French-Mexican industrial cooperation." During his visit, Pemex and the government development bank, Nafinsa, signed a 10-year "letter of intent" with the French Foreign Trade Bank proposing a financial mechanism to allow the use of future oil income for immediate purchase of French capital goods and services. Mexican exports of 100,000 barrels per day of crude oil to France are set to begin in 1980.

The French have emphasized that transfer of nuclear technology will be a principal theme of the Lopez Portillo-Giscard talks.

It is clear, at least on the part of Mexico, that the same path remains open to the United States. As Mexican Senator Alnulfo Villasenor stated in a December congressional debate, the best way to fight tension between Mexico and the U.S. is to exchange "U.S. technology, especially nuclear energy," for Mexico's oil riches.

—Tim Rush

The Korean Model: Meeting the Necessity to Go Nuclear

The government of the Republic of Korea recently upped its projection of the number of nuclear plants it will need by the year 2000 from 40 to 48. How the nation plans to meet its nuclear goal and how it perceives the U.S. role in nuclear technology transfer were the topics of this November interview with Dr. Bong Suh Lee, assistant minister for planning and administration in the South Korean Ministry of Energy and Resources in Seoul.

The interviewer is Peter Ennis, a correspondent for the Executive Intelligence Review.

Question: How do you plan to meet the large growth in energy demand expected in Korea over the next quarter-century?

Well, these days no one is planning to build more conventional oil-burning stations, except maybe the oil-producing countries. For countries like ours, which have to import almost all of the oil from abroad, it would be very foolish to plan on that. The power plant scheduled for completion in 1983 will probably be the last oil-burning station we build, and if we can help it, we are not going to depend on oil-burning types. If anything in the hydrocarbon area, they will be coal burning.

But when it comes to coal-burning, what we produce here in Korea domestically is anthracite coal, and all of this is used for house-heating purposes. And even for this purpose, we don't produce enough domestically. So we have to import coal. And if the fuel situation remains the way we think it will, we will have to import more as the years progress. Which means that if we want to use coal for electricity generation, again, we have to import 100 percent of the thermal coal from abroad.

And as you know, although thermal coal is plentiful throughout the world, the transportation problem is very difficult. And also, you have to have land space here where you could have the power station and hinterland where you can store your reserve coal. . . .

Then, what do you have left? Hydro capacity. We have some hydro resources here and of course we will try to maximize them. But up to now we have used about 50 percent of our hydro capacity, and if we maximize its utilization, perhaps we can double what we have at this moment. But the actual quantity is not too much.

Right now, hydro supplies about 10 percent of our needs and our total demand of electricity by the year 2000 will be about 12 or 13 times what it is now. So you can imagine, by the year 2000 hydro can supply perhaps 1 percent, if that, of our energy needs.

Well, there is a huge gap, which will have to be filled with something. naturally, the only alternative we have left is nuclear power. We have set out to see what our total demand is going to be, and then to see how we can meet that demand with the more conventional forms of energy supply systems, and the gap we will try to fill with nuclear power

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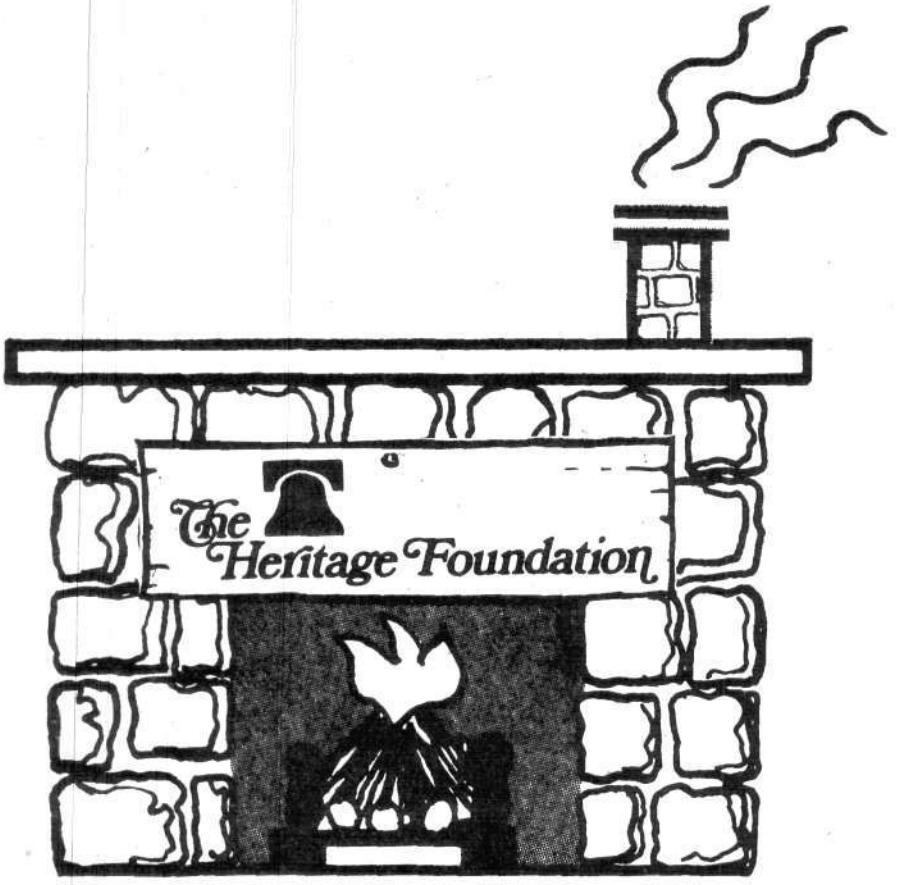
National



Heritage Shows True Colors — Antinuclear

The "National Conference on Energy Advocacy" sponsored by the Heritage Foundation, Feb. 2-4 in Washington, D.C., which has been widely advertised as "pronuclear," will feature solar, geothermal, and wood-burning forms of energy and exclude discussion of thermonuclear fusion power. The Heritage Foundation has sought out leading nuclear power advocates as conference participants and has been wooing national nuclear groups, claiming to be expert consultants in the nuclear field.

One top official of a national nuclear industrial group told the Fusion Energy Foundation that his staff members were asked to meet with Heritage Foundation consultants three times a week to discuss strategy.

No Mention of Fusion

A report made available by sources officially invited to attend the Heritage conference states that none of the scheduled presentations and 14 workshops will as much as mention fusion power. Instead the conference will focus on "alternate energy" sources — the environmentalists' code words for antinuclear. One of the features will be a presentation by the Wood Engineering Corporation on the value of wood burning as a source of energy for the future.

The only deviation from the Heritage Foundation's full-speed backward energy course is a purported defense of the fast breeder reactor.

Most shocking, the report documents that the openly stated aim of the Heritage Foundation is to counter the organizing successes of the Fusion Energy Foundation and the U.S. Labor Party in building a broad-based constituency behind nuclear power and against the zero-growth fringe.

Milton Copulos, the Heritage Foundation officer in charge of the event, told one prospective student attendee that a main purpose of the conference was "to undercut the influence of the Fusion Energy Foundation on the campuses."

The Pronuclear Targets

The Heritage Foundation intends to set up its antinuclear base right in the middle of the pronuclear audience it has targeted. "We're going to create a network of grass roots field organizers

Who Is Milton Copulos?

Reporter Mary Gilbertson recently interviewed Heritage Foundation policy analyst Milton Copulos to question him on his role in promoting primitive forms of energy production. We reprint below the final exchange of that interview, upon which Copulos hung up the phone.

Question: Do you have any idea which direction civilization should go — either into a new dark age or toward expanding development?

I can't comment. I have no comment.

Question: You mean you have no idea about which direction civilization should go?

(Screaming) I can't comment.

... We have a program with quicker answers to the benefits of all the energy resources, solar, geothermal, wood, as well as nuclear. ... Participants in the workshops will get on-the-spot training in what we call 'issues' and 'skills'.... We'll set up a nationwide grass roots network of 300 to 400 organizers run out of the Heritage Foundation," Copulos said.

As for the labor movement, Copulos told one source: "We're playing down the Heritage Foundation's role in organizing the conference because of our known antilabor stance. Robert Georgine of the New York Building Trades is seriously considering speaking, but he might not if the Heritage Foundation's sponsorship were up front."

Copulos also made it clear that the Heritage Foundation was wooing black organizations in the same way it is going after labor. "Our contact man Kenyon Burke, the NAACP's assistant director of programs, is providing us a list of NAACP members even though the NAACP has not endorsed the event," Copulos said.

The Heritage Supporters

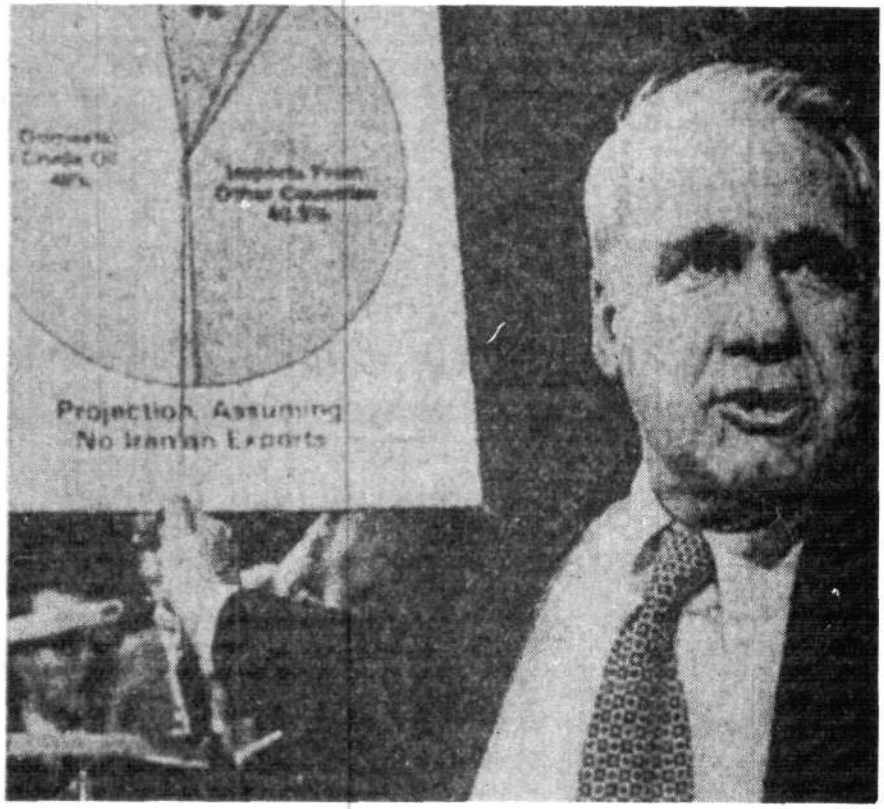
Copulos was gleefully open about the support the conference has from what are supposed to be opposite ends of the political spectrum — the Kennedy liberal "left" and the Heritage Foundation free enterprise-type "right." He boasted that Senator Frank Church wrote the foreword and one chapter of the foundation's energy advocacy brochure and that "the conference will be a real 'left-right' affair."

The Heritage Foundation is run in close coordination with its funding source, the Mont Pelerin secret society, primarily a British group whose economic policies follow those of Hjalmar Schacht, Hitler's finance minister.

The Mont Pelerin Society was set up in 1947 as a countergroup against the supporters of Atoms for Peace and for the International Monetary Fund's low-technology development alternatives to nuclear power.

The foundation's magazine, *Policy Review*, includes at least one known British intelligence agent on the editorial board — Robert Moss.

— Robert Cohen



Schlesinger: Using Iran's instability to fuel a U.S. "energy crisis." DOE

Schlesinger Fuels National Energy Crisis

In a press conference the first week in January on the Iranian situation, Energy Secretary James Schlesinger called on the nation to institute immediate voluntary energy conservation, including lowering thermostats and reducing automobile driving. If the Iran crisis continues to disrupt that country's crude oil exports, Schlesinger said, the United States would have mandatory conservation measures within six months.

Global oil production is "now stretched taut" and the "world cannot stand further shocks," Schlesinger said.

As a remedy, Schlesinger told the press that the DOE had drawn up new emergency energy procedures. However, when asked to describe these procedures, Schlesinger would only say, "If you review the measures taken during 1973-1974, you will have some notion as to the menu." Subsequent inquiries to the relevant DOE office confirmed that the energy secretary is keeping these energy emergency procedures secret or "internal."

No Crisis

Just one day before the Schlesinger press conference, a top State Department official had told the press, "We can weather the [Iran situation] without serious disruption." He emphasized that the Iran shutdown hit at a time when world oil stocks are at an all-time high.

In fact, one DOE spokesman who asked to have his name withheld told this reporter that the impact of the Iran crisis will be minimal for the following reasons. First, Saudi Arabia has made what he termed an "extremely significant" political decision to increase production by 1.5 million barrels up to 10 million barrels per day to offset the

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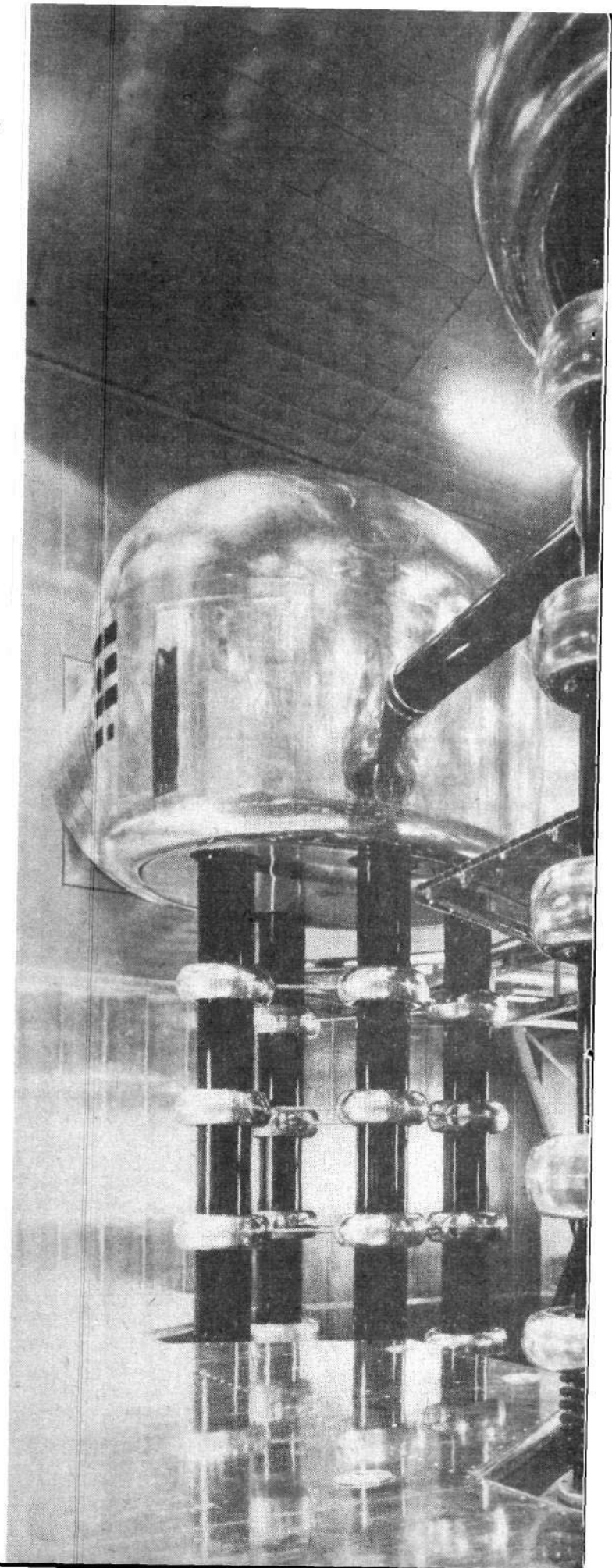
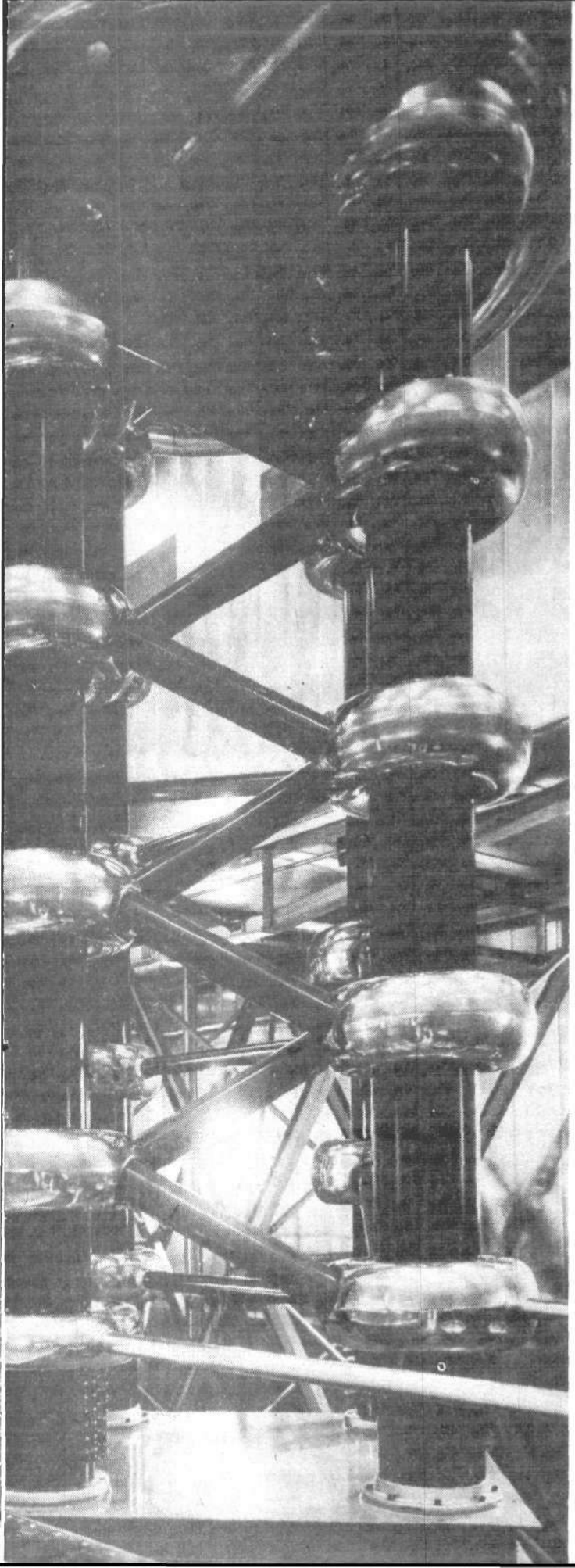
Heavy Ion Fusion

A New Contender For Inertial Confinement

By Dr. John Schoonover
& Dr. Morris Levitt



A typical ion injection system. This Cockcroft-Walton accelerator supplies 800-keV protons to the Argonne National Laboratory's Zero Gradient Synchrotron. In the foreground is part of the high voltage generating system. The shiny metallic structure near the wall on the left contains the accelerating chamber from which ions are fired into the synchrotron, which is beyond the wall. (See Figure 3 for a schematic of the Cockcroft-Walton accelerator.)



Until the last few years there were only two basic ways to crush tiny pellets of fusion fuel in order to achieve the conditions of plasma density and temperature required for fusion. These two driving mechanisms for inertial confinement are powerful laser beams and relativistic electron beams (those with a velocity near the speed of light). Now a third contender, high-energy heavy ion beams (beams composed of ionized atoms of the heavier elements), is attracting broad attention as a most promising way to overcome possible shortcomings of laser and e-beam fusion (Figure 1).

To make the inertial confinement approach to fusion scientifically viable as a reactor concept requires a huge amount of power in a very short time. Several hundred TW (1 terawatt = 1 trillion watts) of beam power must be brought to bear on the target pellet in time that is measured in units of tens of nanoseconds (1 nanosecond = one-billionth second). (These conditions can be significantly relaxed if the fusion process is used as a neutron producer to breed fission fuel, as discussed in *Fusion*, January 1979.)

There appear to be no obstacles at present to producing such high power levels from either laser or electron sources (see table). However, a basic problem with laser fusion is that lasers are not very efficient devices. Typically, only several percent of the input energy appears in the laser beam output, and it is uncertain whether present research, for example on high power gas lasers, can improve this situation by the needed order of magnitude.

Electron beams, manmade lightning bolts, satisfy the energy efficiency condition but have other problems. For example, can the necessary beam power be compressed into the required size despite the tendency of electron beams to disperse, and can it be directed onto the target without also bombarding and damaging the plates of the discharge device? Or, can the beam be propagated over a path that removes sensitive elements from exposure to the energy and debris from the fusion microexplosion? Again, there are no definitive answers at present.

It is also not certain for both methods that even the best possible beam on target will produce the required degree of compression and heating for the fusion of most of the pellet fuel. The processes of laser and e-beam energy deposition and subsequent energy conversion effects are complex and not fully understood.

These basic scientific questions of the phase transitions in dense plasmas are the most important aspect of inertial confinement research. Yet this research continues to be obstructed by the restrictions of classification.

Ion Beam Advantages

Ion beam fusion seems to have advantages for inertial confinement that compare to the tokamak's advantages for magnetic confinement. A hypothetical ion beam fusion machine has the following attractive properties:

(1) Like e-beam devices, it is a high efficiency device (about 50 percent of input appears in the output).

(2) Ion beams of the required energy and power level and compactness in time and space characteristics can be developed largely on the basis of existing accelerator technology. Further, the beam can be delivered on target without damage to the far-removed accelerator components.

COMPARISON OF INERTIAL CONFINEMENT ENERGY DEPOSITION METHODS			
CHARACTERISTICS	HEAVY ION BEAM	ELECTRON BEAM (Relativistic)	LASER
Form of Energy Deposition	Pulses of high-energy, charged heavy atoms	Pulses of relativistic (high-energy) electrons	Pulses of coherent light (photons)
Pulse energy content needed for pellet ignition	1 to 10 MJ	15 MJ	0.1 to 1.0 MJ
Pulse power	160 to 200 TW	Greater or equal to 150 TW	1 to 10 MW (av. over pulse)
Expected beam efficiency	20 to 50%	Approximately 50%	less than or equal to 1%
Expected pellet energy gain	100	15 to 30	10
Achieved pellet gain	No experiments	Very low	Approximately .00001

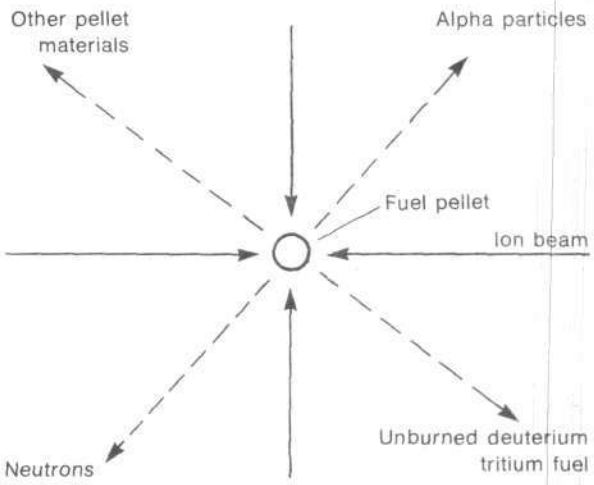


Figure 1
SCHEMATIC OF HEAVY ION FUSION

An intense burst of high-energy heavy ions (atoms above cesium in the periodic table) bombards a pellet of fusion fuel, initially a mixture of deuterium and tritium, the heavy isotopes of hydrogen. The most recent thinking is that the ion burst implodes the pellet by cold compression; that is, energy is deposited in a sufficiently localized manner that the pellet is not significantly heated throughout its volume before it collapses upon itself into high density.

After a period of fusion burn, neutrons, unburned fuel, alpha-particles and other debris explode to the walls of the reactor vessel where their energy can be converted to useful forms. For example, neutrons can be used for breeding fissile fuel in the first commercial heavy ion reactors, and the heat from the reaction can be used to generate electricity.

(3) Heavy ion beams are ideal target drivers. They are absorbed in the outer layer of the pellet and should produce all the compression conditions required for fusion.

Although these considerations provide a powerful impetus for initiating serious ion beam research, they must be subsumed by more fundamental considerations.

First, the ion beam is not a series of discrete particles but an electromagnetic configuration. There is no such thing as a "particle" beam; it actually is an extended plasma that may happen to have a net charge.

Second, this directed configuration impinges on the target, producing a new series of ordered physical states leading up to fusion.

Third, on that count, ion beam fusion is not fundamentally different from laser or e-beam fusion. In all cases a coherent energy input must "drive" a succession of ordered states up to the critical configuration appropriate to sustained fusion.

It may turn out that ion beam fusion is the most direct route to a fusion reactor or hybrid. This in no way eliminates the necessity for comprehending the fundamental plasma processes involved in ion beam fusion or for pursuing investigations of the critical phenomena in all branches of inertial confinement research.

In summary, ion beam fusion seems to have everything going for it—except the funding for actual experimental testing of the concept. There has been a series of yearly U.S. and international workshops on heavy ion beam fusion that have demonstrated that specific concepts are ready for experimental testing. And, important members of the physics community have become supporters of a major national ion beam effort, including Nobel Laureate Burton Richter of Stanford University.

Particles and Energy

The devices that make ion beams tick are the high-energy particle accelerators. For about a half-century, physicists have been developing ways to pack more and more energy into relativistic particles and nuclei. These have depended in various ways on the fundamental interaction between charged particles and electromagnetic fields (as shown in the graphics that follow).

These high-energy beams have been used experimentally to probe the internal structure of matter by studying the reaction products of collisions. However, a consistent problem has been that the physicists doing this work have used totally inadequate conceptions of the processes involved.

To really appreciate what's going on in ion beam fusion, first we must grapple with the concept of a particle and its energy content. This can be done in several stages. In the first approximation, the particle is described by a constant scalar quantity, mass, that indicates its inertial reluctance to be accelerated by some interaction. Once put into motion, the particle also has kinetic energy proportional to the mass times the square of the velocity. An electromagnetic interaction increases the velocity and also the energy. The simplest example of this is acceleration of a charged particle in a uniform electric field.

As the particle enters the relativistic regime, where its velocity is no longer negligible compared to the speed of light, we can make a second approximation to the energy content. In this relativistic regime continued interaction between the "particle" and an "external" electromagnetic field increases the perceived energy content mainly because it increases the apparent mass, m, by making it dependent on the velocity, v. The velocity itself increases only minimally, asymptotically approaching the speed of light, c (relative to the accelerator). This is summarized by the famous Einstein relations

$$E=mc^2 \text{ and } m=m_0(1-\beta^2)^{-1/2}$$

where β is the ratio v/c and m_0 is the "rest mass," the mass at zero velocity.

A third approximation to the energy is evident when the accelerated particle collides with another. Totally new particles may emerge, depending on the total input energy.

This result poses two basic considerations. First is the simple notion of conservation of energy: that the energy of the input beam and target equals the energy in the collision products.

The more fundamental issue, however, is how the process of transformation takes place in a definite way. The question facing high-energy particle physicists is whether a nucleus or a particle is some sort of physical structure or whether it is made up of a bunch of point particles, called quarks.

In turn, this raises the fundamental point of what an appropriate notion of energy actually is. Is energy expressed in the geometrical structure that it determines? Does it require a notion of energy as a state of organization? When this issue is raised at the level of the physical universe as a whole and of the human development of the biosphere, the transformation of energy into higher-order forms is known as the principle of increase of negentropy.[1]

Fifty Years of Accelerators

This history of accelerator development illustrates a crucial feature of this concept of energy. As Figure 2 shows, the maximum output energy of various accelerators has increased as a function of time. For each device there is a growth in available energy up to some upper limit.

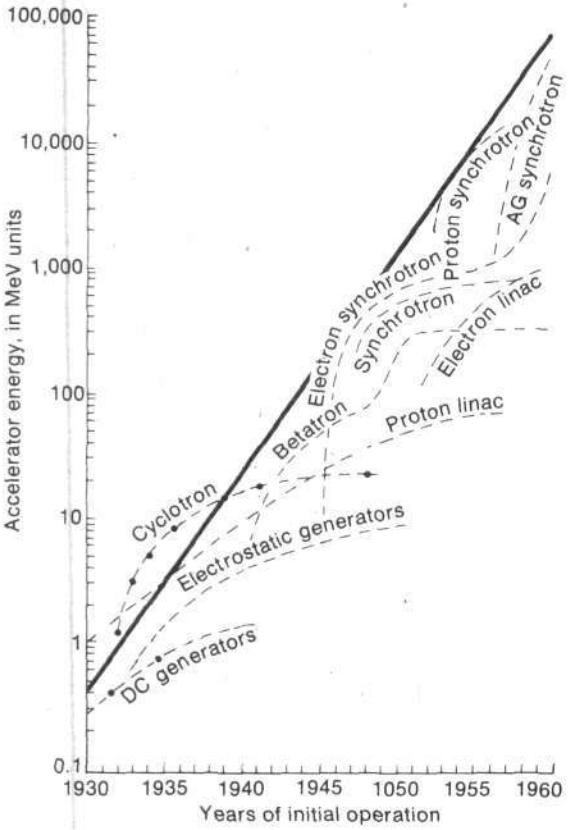


Figure 2
THE EXPONENTIAL GROWTH OF ACCELERATOR ENERGY

The tremendous growth in particle energies available from accelerators over the past five decades has opened up new possibilities for altering matter. At each step of the way, from nuclear disintegration to pair production to the creation of the so-called elementary particles, researchers are not merely exploring a preexisting nature, but are creating and altering nature for the benefit of the human species.

A 1-BeV proton is not simply a proton with 10 times the energy of a 100-MeV proton — it is a qualitatively new tool for man's control of nature. New phenomena occur and new realms of nature are created as a result of such increases of applied energy.

At the same time, new conceptions can be formulated and new problems can be posed and solved. The case of heavy ion fusion is a good example of this process. Scientists know how to produce high-energy ions and how to form them into intense, high-power beam pulses. The problem is how to best apply this knowledge to generate energy from fusion reactions, which, in turn, will open up new potentialities for intensive energy application in both further scientific investigations and industrial production. Accomplishing this goal then expands the potential capability for training future scientific minds to tackle the new problems this generation will pose.

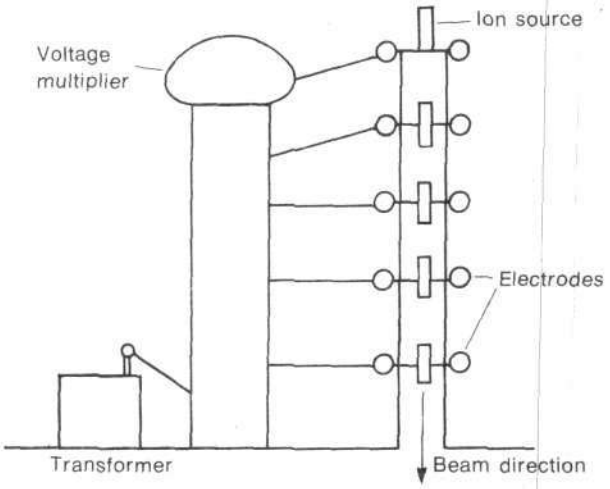


Figure 3
THE COCKROFT-WALTON ACCELERATOR

The Cockcroft-Walton accelerator, the first particle accelerator to disintegrate atomic nuclei, was originally built in the Cavendish Laboratory at Cambridge University. Its operation is quite simple. An array of capacitors builds up a large static electric potential difference between the two ends of the accelerating chamber, the vertical tube on the right in the diagram. Ions emitted at one end are then attracted across the gap, accelerating as they go. In contrast to later linear and circular accelerators, there is only one stage of acceleration, so that the final particle energy is limited by the amount of static potential difference that can be maintained.

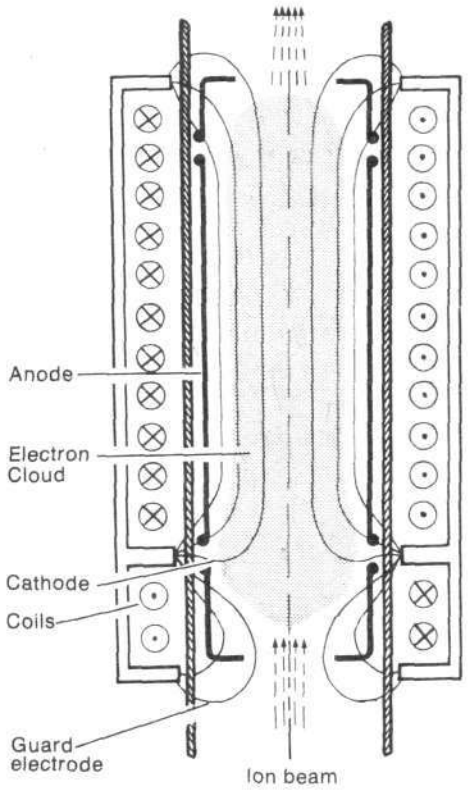


Figure 4
THE GABOR LENS

The Gabor Lens, first proposed by Dennis Gabor in 1947, is being used in heavy ion fusion as a strong focusing lens for heavy ions from Cockcroft-Walton injection accelerators.

A cloud of electrons is confined in the region outlined in the diagram by a combination of electric and magnetic fields. The electrons execute orbits about the cylinder axis, deflected into these paths by the externally applied magnetic field, which balances centrifugal and electrostatic forces.

A strong electric field is generated in the cloud, which acts on ions entering from the left. The effect of the electric field is to attract ions toward the cylinder axis as they traverse the electron cloud. The farther the ions are from the axis, the more strongly will they be attracted toward it, providing a strong focusing effect. This effect is a well-known result from electrostatic application of Gauss's Law. The farther an ion is from the cylinder axis (but still within the charge distribution), the more charge from the cloud interacts with it, attracting it toward the axis. The electric and magnetic fields that shape the electron cloud have virtually no effect on the ions.

Gabor estimated in his original paper that the effect of the electron cloud focusing a beam of 100-MeV protons was more than 100 times the effect that the magnet coil would have by itself. Brookhaven Laboratory is using a Gabor Lens in the injection system now under construction by the Heavy Ion Fusion Group.

However, for the whole set of accelerators there is an *unbounded overall exponential* increase of output energy with time. The process of accelerator development, which draws on the totality of human scientific, technological, economic, and political practice (practices that themselves have been affected by innovations in accelerator design), is a *transfinite* relative to any of its subsumed stages. In the same way, a true energy concept is transfinite with respect to its relativistic and quantum approximations.

All the ion beam fusion machines proposed to date are really combinations of different types of accelerators, proceeding from lower to higher energy levels, just as accelerators have evolved historically.

The most obvious way to accelerate an atom is first to strip one or more electrons from it, turning it into a positively charged ion, and then to subject it to an electric field that will accelerate it toward the negative terminal or cathode. This method is limited only by the strength of the electric field that can be generated. The practical limit involved in order to avoid electrical breakdown or sparking is on the order of a few million volts per meter between anode and cathode.

Since the earliest days of particle accelerators—from the work of Rolf Wideröe who built the first prototype linear accelerator in 1928 and of Cockcroft and Walton who first achieved nuclear disintegrations with an accelerator they designed in 1932—the basic principle has remained the same, although ingenious variations have been developed to reach higher and higher energies.

The standard method for injecting ions into an accelerator is the Cockroft-Walton accelerator (Figure 3). In principle, it is a quite simple device, using a static electric field to generate a voltage difference in an evacuated chamber. Positive ions introduced at the anode will be accelerated across the gap. At this stage in the acceleration process, the point is not so much to supply energy to the ions but to shape a fairly monoenergetic beam that can be introduced into other high-energy accelerators. For this purpose, a voltage gap of only about 500 kV is sufficient.

Since large currents are generated in the Cockcroft-Walton accelerator, the tendency of concentrated charge to spread itself out and defocus, the so-called space charge limit, must be counteracted, even with heavy ions. Consequently, part of an ion beam development program must include testing of a strong focusing system, the Gabor lens (Figure 4), which has been known in principle for 30 years but has never been needed or tested before (Gabor 1947). This type of lens accomplishes focusing using a trapped electron cloud, rather than usual methods that involve multipole magnetic fields.

Acceleration proper of the heavy ions occurs in tandem arrangements of linear or circular accelerators. For low-energy beams, the Wideröe linac (linear accelerator) is generally used, while for high-energy beams the Alvarez linac is more suitable. The induction linac or the synchrotron can also be used.

The Wideröe Linac

The Wideröe linear accelerator (Figure 5), the first multistage accelerator to be built, provided the stimulus to E.O. Lawrence to build the first cyclotron. Cylindrical, coaxial electrodes are aligned along the axis of the accelerating tank in order of increasing length. The electrodes are connected alternately to the terminals of a radiofrequency power supply. At each half-cycle, the charge on the electrodes alternates. An ion entering the gap between adjacent electrodes at the right time will experience an acceleration in the direction of its motion.

While it is inside the electrode, the ion is shielded, experiencing no net electric field. As ions accelerate down the tank, the electrodes must become progressively longer to maintain the correct phase between the ion entering the gap and the charge changing on the electrodes.

The Alvarez Linac

The basic concept of the Alvarez linear accelerator (Figure 6), used at higher energies, is that acceleration is produced by the electromagnetic waves stored in a cavity resonator driven by a radiofrequency generator. In the transverse magnetic mode, a cavity resonator will have an electrical field along its beam axis, to accelerate the ions. The strength and direction of the field will vary with the same frequency as the radiofrequency input. An ion put at rest in the cavity would simply oscillate about its rest position with no net acceleration. However, if the ion is shielded from the reversal of the electrical field, it will experience the acceleration only in one direction, gaining speed and energy as it traverses the length of the track. Drift tubes that shield ions during the time the electrical field is reversed must be progressively longer as the ion gains energy. However, to maintain the boundary conditions for a resonant cavity, the thickness of the drift tubes must be decreased as well.

For high-energy ions the velocity does not change very much with each increase in energy, so the adjacent drift tubes are about the same length. For this reason, if one tube goes out of service, the beam can be maintained. If the velocity were changing rapidly, as is the case at low energies, the necessary phase relations would be completely disrupted, shutting down the accelerator.

For low energies, the drift tube length in the Alvarez accelerator becomes too short to allow for adequate focusing of the beam. This problem could be overcome by using lower frequencies to drive the resonant cavity, but then the cavity diameter has to be greater, eventually becoming unwieldy. The Wideröe design obviates this problem for the lower energies.

Both these accelerators have to be extremely long because many boosts in energy are required to get the beam up to the final energy and because a relativistic beam moves a great distance, even during the short period of time between boosts.

The Induction Linac and the Synchrotron

There is one other linear accelerator design, the induction linac, which employs stacked induction coils along the length of a cylindrical solenoid. The principle here is the same as that used to generate alternating electrical current. Michael Faraday and Joseph Henry discovered in about 1830 that a varying magnetic field generates an electrical field in a process called magnetic induction. The principle is applied in particle acceleration by altering the strength of the magnetic field in a toroidal magnet to produce an electrical field in the direction of motion of ions entering the region. Magnetic induction was first used

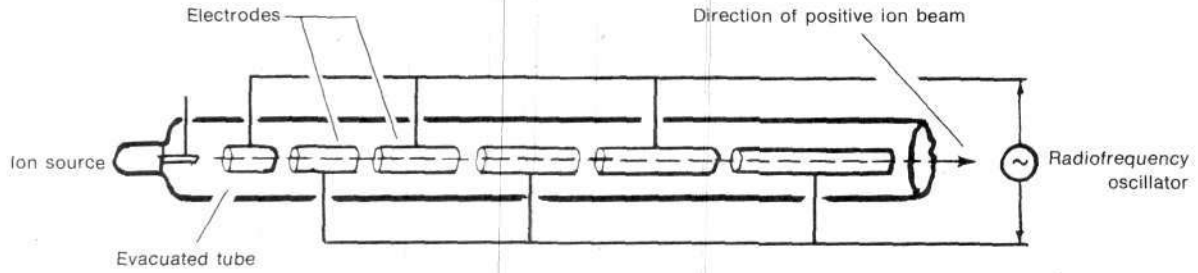


Figure 5
THE WIDERÖE ACCELERATOR

In 1928, Rolf Wideröe published an account of his experiments with a multistage linear accelerator similar to the one shown above. His device was the first first to experimentally demonstrate the feasibility of this principle, although it had been discussed in theoretical terms some years earlier. Each time ions reach a gap between electrodes, they are accelerated through the potential difference between the electrodes. During the ions' flight through the electrode, however, the charge on the electrodes must be reversed. Otherwise, after having been accelerated at one gap, the ions would be decelerated at the next. The charge alteration is accomplished by connecting alternate electrodes to the same terminal of a radio-frequency power supply whose frequency is tuned to the time of flight of the ions through the electrodes.

Note that the electrode lengths increase in the direction the accelerating ions move, so that the time of flight through the electrodes for faster ions is the same as it was for the same ions when they were moving more slowly.

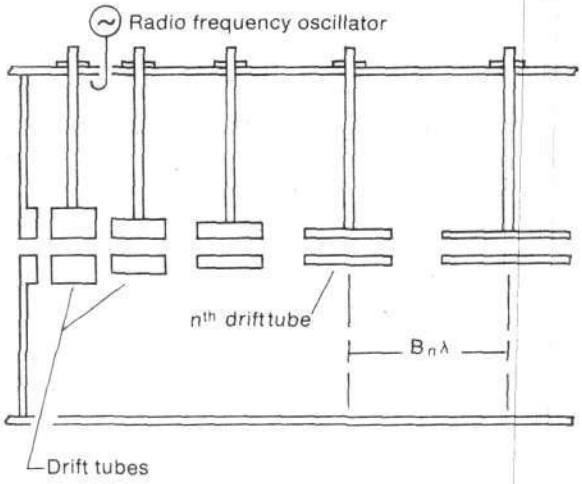


Figure 6
THE ALVAREZ ACCELERATOR

Shortly after World War II, when high-power radar equipment had become readily available and the electronic technique of radio transmission was well established, Luis Alvarez of the University of California at Berkeley (an associate of E.O. Lawrence, who invented the cyclotron) applied the characteristics of an electromagnetic resonant cavity to high-energy particle acceleration. The frequency of electromagnetic (radio) radiation can be matched to the dimensions of a conducting cylinder in such a way that the cylinder is optimally filled with electromagnetic radiation or resonates. The phenomenon is similar in principle to mechanical vibrational resonances, such as those observed on a string or a drum head; that is, the string can be set to vibrate by a sound source outside it that is tuned to its resonant frequency.

A conducting cylinder in a transverse magnetic (TM) electromagnetic vibrational mode will have an electric field directed along the cylinder axis continuously varying in strength and direction along the axis. The magnetic field will array itself in concentric circular field lines about the axis. Although the cylinder length is immaterial to the production of resonance, the cylinder diameter is proportional to the wavelength of the radiation driving it; that is, for lower frequencies, greater diameters are needed for the cavity to resonate.

Alvarez chose to use the axial electric field to accelerate ions through such a cavity. Since the field would be changing direction at the resonant frequency, he found it necessary to shield the ions during half the cycle when the electric field would be in the opposite direction to the acceleration. Drift tubes introduced into the cylinder accomplish this, and their lengths must be engineered to match the time of flight of progressively faster moving ions. Thinning of the drift tube walls with increasing length is an engineering feature to maintain the appropriate boundary conditions for a resonant cavity.

in the Betatron, developed by D.W. Kerst in 1940 at the University of Illinois (Kerst 1940). His original device accelerated electrons in a circular path.

High-energy ion beams also can be produced in closed paths, like circles, which eliminates the tremendous length of the linacs. One of the best-known such devices is the synchrotron (Figure 7).

The principles by which a synchrotron operates are somewhat more complex than those for the linear accelerators (Veksler 1945, McMillan 1945). An ion's path of motion can be bent if the ion passes through a magnetic field perpendicular to the direction of field lines. If the field strength is strong enough and covers the entire area of the beam path, the path can be bent around on itself so that the ion travels in a circle. In this way, the same electrical potential gap at a particular place on the path can be used repeatedly to accelerate the ion.

For nonrelativistic ions, the frequency at which they will revolve in the magnetic field is independent of their energy; the radius of the circle just increases as the ion energy does. However, for relativistic ions, the changing mass complicates the process so that in a constant magnetic field, the ion rotation frequency would shift out of phase with the oscillation frequency of the electrical accelerating field.

The synchrotron overcomes this problem by constraining an ion to revolve in a particular orbit, rather than allowing the ion to spiral outward while it gains energy. Simultaneously the magnetic field increases as the ion gains energy. If the field strength is increased slowly, the ions will gain energy in such a way as to maintain a constant frequency of oscillation. The process is also self-stabilizing because the ion will get less energy if it gets to the gap a little too fast and it will get sped up if it gets there a little late.

In addition to the accelerator itself, there are two other technologies involved in beam handling that increase the beam power: the multiplier ring and beam bunching.

The multiplier ring is basically a magnetic annulus tuned to force ions of a given charge and energy to rotate in a circle with a predetermined radius. Since the incoming beam pulse is longer than the circumference of the multiplier, it overlaps itself, causing current multiplication. (The current is the amount of charge passing through a unit area in unit time. Think of the effect of taking a flexible wire-carrying current and coiling it into several turns.)

Beam bunching, compression of the pulse length, also accomplishes an increase in current. Beam bunching occurs when an electric field is applied to the pulse in such a way that ions at the rear of the pulse are accelerating while those at the front are slowed down. A simple sawtooth or ramp potential will do this.

Ion Beam Design Proposals

How are these accelerator devices hooked up to produce an ion beam fusion machine? The real question is what kind of ion beam is both an effective fusion driver and simple to produce?

The answer lies in the unique features of high-energy heavy ion interaction with the target. Heavy, highly charged ions deposit their energy in a very narrow region

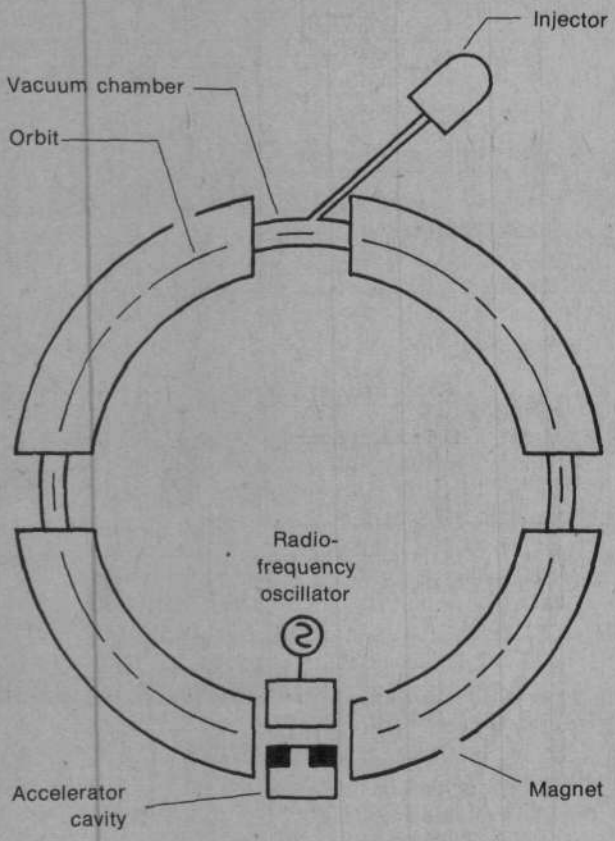


Figure 7
THE SYNCHROTRON

By the mid-1940s, accelerator designers were developing circular accelerators capable of coping with the problems presented by the relativistic effects that appear in ion acceleration to high energies. One of these solutions was the synchrotron, simultaneously proposed by V. Veksler of the Lebedev Institute in the Soviet Union and by E.M. McMillan at Berkeley.

Although a magnetic field cannot by itself accelerate an ion, it is quite useful in bending the path of flight. In particular, ions can be forced to experience the same potential difference repeatedly if they are recirculated through the same region by having their paths bent into circular orbits by magnetic fields of appropriate strength.

By increasing the magnetic field slowly, as the ion energy increases during repeated accelerations, the synchrotron keeps the ions in an orbit of constant radius. As the ion energy increases, the frequency of oscillation of the electric field is increased to maintain synchronization of the time of arrival of ions at the potential gap and the maximum potential difference across the gap. In this way, stable bunching of the ions can be maintained.

Figure 8
THE BROOKHAVEN HEAVY-ION FUSION ACCELERATOR SYSTEM

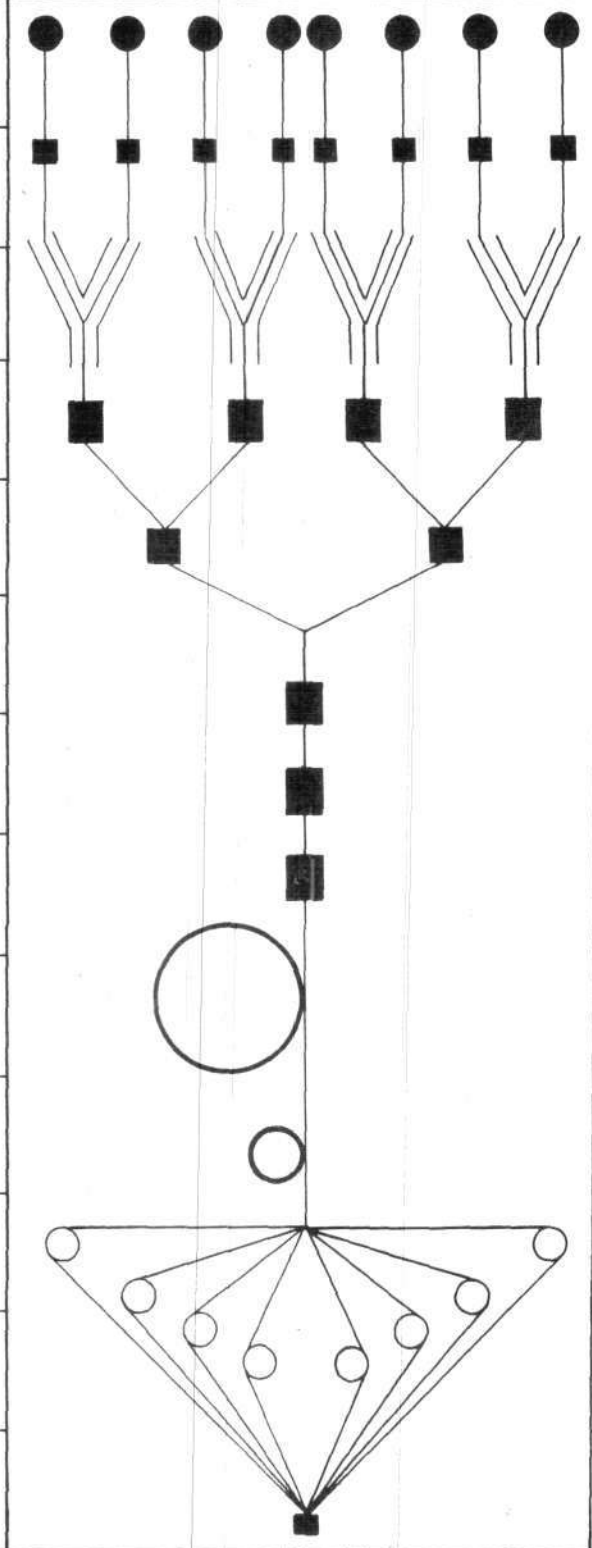
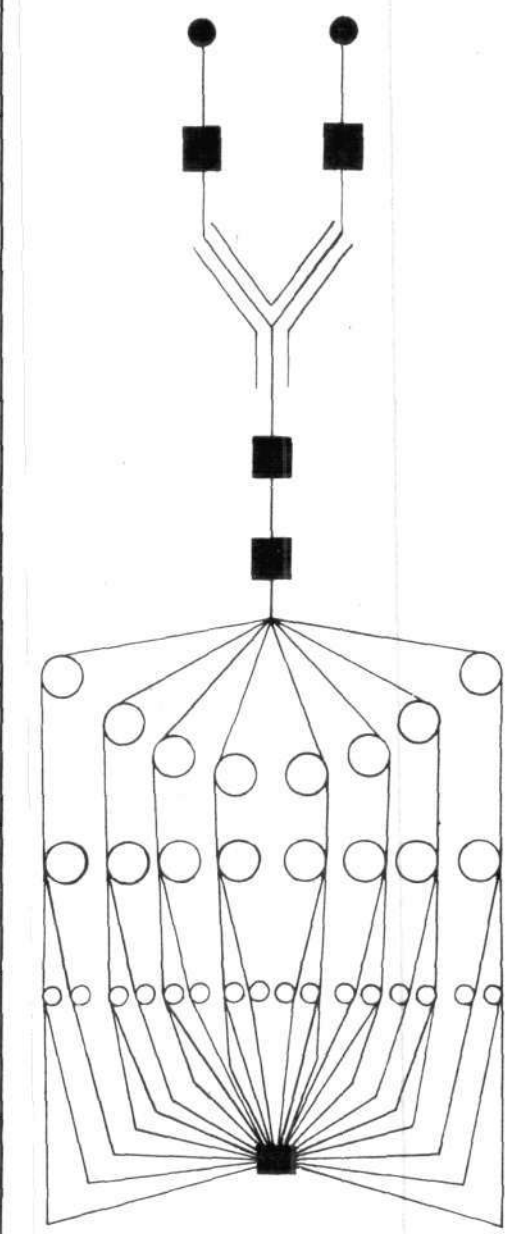
TYPE OF MACHINE	SCHEMATIC ASSEMBLY	BEAM OUTPUT
8 Cockcroft-Walton injectors		40 mA each of U^{+1} at 500 keV
8 2-MHz Wideröe linacs		20 mA each of U^{+1} at 6 MeV
Electron stripper		20 mA each of U^{+2} at 6 MeV
4 4-MHz Wideroe linacs		40 mA each of U^{+2} at 13 MeV
2 8-MHz Wideroe linacs		80 mA each of U^{+2} at 30 MeV
48-MHz Alvarez linac		160 mA of U^{+2} at 120 MeV
96-MHz Alvarez linac		160 mA of U^{+2} at 480 MeV
192-MHz Alvarez linac		160 mA of U^{+2} at 20 GeV
Multiplier ring—1 km radius		1.6 A of U^{+2} at 20 GeV
Multiplier ring—100 m radius		16 A of U^{+2} at 20 GeV
8 Accumulator rings—100m radius with beam compression factor of 30		500 A each of U^{+2} at 20 GeV
8 Beam compressors with factor of 5		2500 A each of U^{+2} at 20 GeV, 10 MJ, 200 TW
Pellet assembly boilers, etc. . . .		Fusion energy

Figure 9
THE ARGONNE LABORATORY HEARTHFIRE III ACCELERATOR SYSTEM

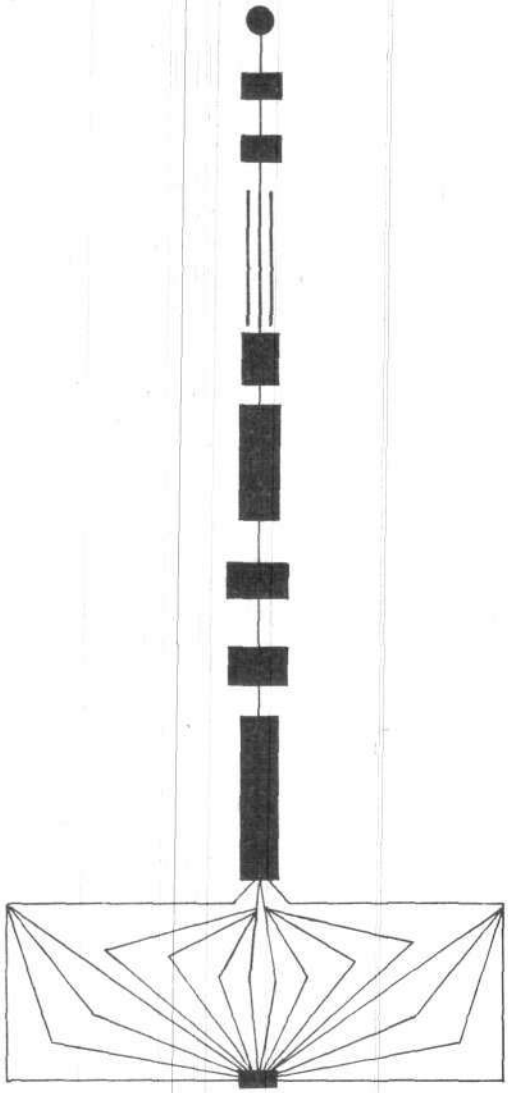
TYPE OF MACHINE	SCHEMATIC ASSEMBLY	BEAM OUTPUT
Beam injection		20 mA each of Xe^{+1}
2 12.5-MHz Wideröe linacs		10mA each of Xe^{+1} at 11 MeV
Electron stripper		15 mA each of Xe^{+8} at 11 MeV
25-MHz Wideröe linacs		30 mA of Xe^{+8} at 160 MeV
100-MHz Alvarez		30 mA of Xe^{+8} at 4.4 GeV
8 synchrotrons		Xe^{+8} at 20 GeV
8 rebuncher rings		
16 compressor rings		64 kA of Xe^{+8} at 20 GeV, 1MJ, 160 TW
24 beams on pellet		

Over the past several years, a significant effort has been directed to applying the achievements of 50 years' experience in ion acceleration to the problem of inertial confinement energy production. Brookhaven, Argonne, and Lawrence Berkeley national laboratories have produced conceptual designs to accomplish this.

In the Brookhaven design (left), multiple stages of linear accelerators are used to achieve a high-energy, high-power beam to compress a fuel pellet for the production of fusion energy.

At Argonne National Laboratory (above), synchrotrons are injected with heavy ions preaccelerated in linear accelerators. The pellet is bombarded by 24 beams.

Figure 10
THE BERKELEY HEAVY-ION FUSION ACCELERATOR SYSTEM

TYPE OF MACHINE	SCHEMATIC ASSEMBLY	BEAM OUTPUT
Beam injection		4 A of U^{+1} 40μs pulse
Pulsed drift tubes		4 A of U^{+1} at 4 MeV
Electron Stripper		6 A of U^{+4} at 5 MeV,
Drift tubes with pulsed compressions		60 A of U^{+4} at 200 MeV, 4μs pulse
Iron core induction accelerator		1200 A of U^{+4} at 200 MeV, 200 μs pulse
Ferrite core induction accelerator		3200 A of U^{+4} at 19 GeV, 75μs pulse
16 beams on target		2125 kA each of U^{+4} at 19 GeV, 7μs pulse, 1 MJ, 160 TW

Using linear induction accelerators, which operate on the same principle as the betatron, the Berkeley group has used a particularly simple design to achieve high-power beams incident on a fusion pellet.

near the surface of the target pellet. This well-known stopping power of ions in targets has been exhaustively studied since the earliest days of nuclear physics. Since this effect holds even for energetic ions, the ions can be accelerated up to the range of 20 GeV (1 gigaelectron volt = 1 billion electron volts). The number of ions in the beam, therefore, can be much less than for low-energy ions and still deliver the required energy (about 10 MJ) and power (200 TW) on target, once the beam is appropriately compressed.

For proof-of-principle experiments, the stated requirements for ion-beam drivers are a total energy of 1 MJ at a peak power of 100 TW, with a repetition rate of at least 1 Hz (1 herz = 1 cycle per second) and an energy deposition ratio of 20 MJ per gram of target material (Martin 1978). Elements like xenon, mercury, and uranium (anything heavier than cesium is a candidate) are considered possible materials to provide the ions. For full demonstration experiments, the stages of acceleration are designed to produce 1 to 10 MJ of ion energy on the pellet in a time interval of 5 to 50 nanoseconds. This figure results in peak

power outputs from the accelerators in the 150 to 200 TW range.

It is generally thought at present that these energies should be sufficient to trigger fusion burn in a deuterium–tritium pellet. The front end of the beam burst encounters a cold pellet that absorbs ion energy in a very thin surface and begins to ablate or boil off material. As more of the beam reaches the pellet, its energy is deposited partially in the plasma now surrounding the pellet and partially in the denser surface material. The net effect is to cause the pellet to implode in reaction to the intense evaporation of the surface. High pressure in the interior allows the fusion reactions to occur, imparting energy to a blanket next to the chamber walls, where it can be transformed into useful forms, such as fission fuel breeding and electricity production.

The major new area to be developed (and, fortunately, a relatively minor cost factor in the overall accelerator) is in the area of high-current injection systems to feed low-energy heavy ions into the accelerators proper. Until now there has been little or no demand for high-beam currents in research accelerators. In research applications a large beam can cause too many reactions to occur for detectors to handle all the incoming information. Furthermore, the overloading of delicate detectors and targets can damage them.

However, with fusion pellets, the point is to damage them. Although research reactors can operate with an injected current of about 1 mA (1 milliampere = one-thousandth of an ampere) or even less, the pellet-driving accelerators will require injected currents 20 to 50 times that amount and will multiply that initial current to the range of 20 to 40 kA (1 kiloampere = 1,000 amperes), by means to be described below.

Three of the national laboratories, Brookhaven in Long Island, New York, Argonne in Illinois, and Lawrence Berkeley in California, have developed design proposals for high-current, high-power accelerator systems to act as fusion pellet drivers (Smith 1977, CERN 1978). And all three laboratories also have small experiments on the injection systems. However, there is almost no ongoing experimental work in this area, primarily because of the lack of research funds from the Department of Energy.

Brookhaven

The Brookhaven Heavy Ion Fusion Group is building an injection system on the Cockcroft-Walton principle to feed a small linac, which should be operational in 1979. They are accomplishing this work against significant odds, including a 30 percent decrease in funding over the past year.

The Brookhaven concept (Figure 8) calls for eight Wideröe linacs to be fed by eight 40-mA beams of singly ionized 500-keV uranium ions from Cockcroft-Walton injection systems (Maschke 1978a, b). After accelerating the ions to 6 MeV, with about 50 percent efficiency, pairs of beams are merged, and a second electron is stripped from the ions with 50 percent efficiency, maintaining the current at 40 mA. These ions are accelerated further in a second Wideröe accelerator to 13 MeV, and beam merging brings the current up to 80 mA and the number of Wideröe accelerators down to two for the acceleration to

A U.S. Consensus On Ion Beam Fusion

What do the scientific experts say about the prospects of ion beam fusion? We reprint part of an article on the Argonne Workshop by the Cern Courier.

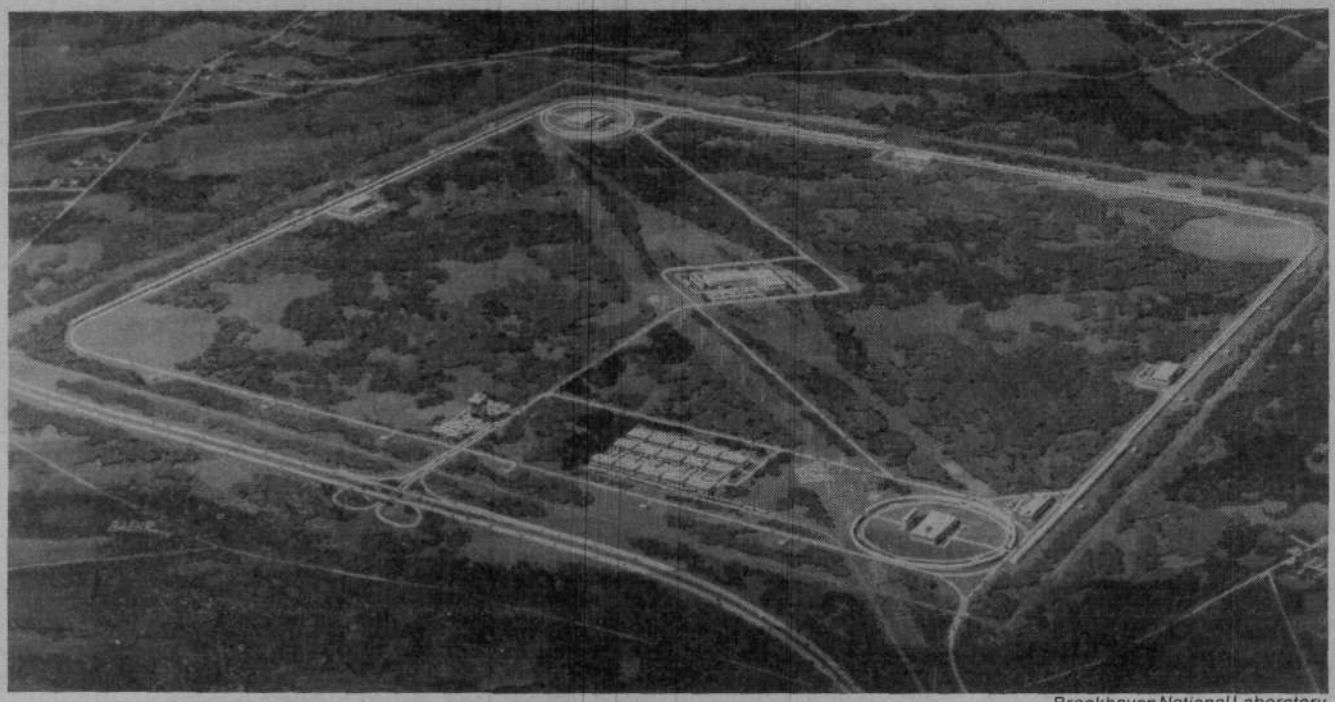
There was a clear consensus that at least one accelerator configuration, that of conventional radiofrequency linacs with accumulator rings, could meet the requirements with confidence, based on current knowledge. There are no profound differences between the Argonne and Brookhaven designs, except in scale and cost. [This refers to an Argonne design different from the synchrotron system described above. The Brookhaven estimate for their 10 MJ driver was $800 million (the cost group at the Workshop gave a figure of $1,000 to $1,500 million). The Argonne figure for their 1MJ system was $360 million (the cost group estimated $400 to $500 million).

The linear induction accelerator is attractive because of the simplicity of the concept. However, judgment has to be reserved because acceleration of ions by linear induction accelerators has not yet been demonstrated. Considerable development is required to bring this configuration into the same confidence ballpark as conventional linacs. Berkeley's cost estimate was between $400 and $500 million (the cost group agreed).

Synchrotron-based accelerator systems are now considered less promising than a year ago. The apparent cost advantage over conventional linac systems has narrowed because of the recognition that, at high field, the bunching factor must be kept low to maintain the small momentum spread required for good final focusing. Hence, the space charge limit is reduced and more synchrotrons are required. In addition, a special ion... is required, the vacuum requirements and the required repetition rate are at the border of technical feasibility.
quired repetition rate are at the border of technical feasibility.

For these reasons, synchrotron-based accelerator systems appear significantly more difficult than systems based on linacs, unless technology demonstrations and cross-section measurements are carried out first to prove feasibility. Argonne's cost estimate for their 1 MJ system was $255 million (the cost group was not able to examine this in detail).

Summing up the meeting, Terry Godlove of DOE said, "This Workshop marks a milestone in the heavy ion fusion program. The claims of the originators of heavy ion fusion, that existing accelerator technology can be adapted and modified to create a driver for inertial confinement fusion in the energy range suitable for a power reactor, have now largely been verified."



Brookhaven National Laboratory

Artist's rendition of the proposed Brookhaven heavy ion fusion driver, which covers an area of about 9 square kilometers. Acceleration of the ions begins in the lower right corner, continuing through a series of accelerations along the right and top sides (see Figure 8 schematic). The large multiplier ring (1 km radius) is underground, but the two smaller rings appear at the lower right and upper left corners of the figure. Final beam compression occurs during flight in underground tubes leading to the center of the square where fusion ignition chambers are located.

30 MeV. Three Alvarez linacs in tandem then accelerate the 160-mA current of uranium ions to 20 GeV. Most of the length of the accelerator system is in this final phase, a distance of at least 5 kilometers.

The beam pulse, which at this point is about 63 kilometers long is wrapped around itself 10 times in a multiplier ring with a 1-kilometer radius. Quite obviously, the rear end of the beam pulse has not yet been produced when the front end begins to wrap into the multiplier ring. A second multiplier ring with a 100-meter radius (one-tenth the previous value) allows the beam again to be wrapped on itself 10 times. The total beam current multiplication in the two rings is a factor of 100, bringing the current up to 16 A.

At this point, eight consecutive beam pulses are stored in accumulator rings stacked four on either side of the pellet chamber and about a kilometer away from it. The beams are intensified further by bunching, as described above, by a factor of 30. On signal, eight 500-A beam bursts leave the accumulator rings and are compressed to 2,500 A in the final dash to the target.

This concept design delivers 20,000 A on target in a single 50-nanosecond burst, depositing 10 million J, with a power rating during the burst of 200 TW. In that very short time interval, the ions cannot significantly disperse, even though space charge limitations are violated; that is, more charge is packed into the beam volume than would be possible over a longer time interval.

There is some preliminary evidence from beam bunching experiments at the Argonne National Laboratory that, in fact, the dispersion does not occur to as great an extent as would be expected if the beam pulse were considered to be a collection of individual particles interacting through repulsive electrical forces. Preliminary indications are that the beam internally self-organizes, that it is a higher-order electromagnetic configuration than would be expected from simple theoretical considerations. These initial results should be vigorously pursued in order to elaborate the understanding of beam physics.

The Alvarez linear accelerators provide a boundary to the total plant area, which is between 2 and 3 kilometers on a side. In the center is the fusion chamber and peripheral equipment. The concept allows for five pellet chambers, any four of which can be operated at one time. The beam pulses switch sequentially from one to the other at a rate of 15 bursts per second, or nearly 4 bursts to each chamber per second.

Argonne

The Argonne design, called Hearthfire III (Figure 9), uses a system of Wideröe and Alvarez linacs to prepare a 30-mA beam of xenon ions with eight electrons stripped and an energy of 4.4 GeV (Martin 1978). Pulses are fed into eight synchrotrons that accelerate the ions to 20 GeV. The beam bursts are then rebunched—they have to be preshaped to fit the synchrotron characteristics—and fed into 16 compressor rings, where they are compressed into 24 beams that deposit 64 kA on the pellet with a total energy of 1 MJ and pulse power of 160 TW.

At present, the Argonne design is generally considered to be too cumbersome for practical application.

Lawrence Berkeley

A third alternative, the Lawrence Berkeley design (Figure 10), is a reasonable contender for implementation (Martin 1978). A major difference between this design and the two previously described is that it involves no storage rings and a minimum amount of beam manipulation. (As more manipulation occurs, greater losses in focusing or in the total pulse energy can be expected.)

In the Livermore design, a high-intensity source delivers singly ionized uranium ions to a standard array of drift tubes used to accelerate the beam to 200 MeV while it is being stripped to +4 ionization and compressed. In this way the current is raised from 4 A to 60 A. Next, iron core induction accelerators accelerate the beam to 8 GeV, while it is further compressed to 1,200 A. Subsequently, a ferrite core induction unit increases the beam to 19 GeV and 3,200 A. (Ferrite is a relatively new material, a metallic glass with low loss properties. It is now being introduced to produce higher efficiency electric motors and transformers.)

After the acceleration phase, a final stage of bunching brings the beam up to 34 kA, split into 16 segments, each of 2.125 kA, that hit the pellet from all directions simultaneously. In this way, the Livermore system delivers 1 MJ to the pellet with a peak power of 160 TW.

Accelerator Costs and Prospects

This year, the total funding commitment for heavy ion fusion is about $3.5 million, hardly enough to cover the cost of paper studies.

According to Dr. Dennis Keefe, head of the heavy ion fusion group at Lawrence Berkeley Laboratory, development would be relatively inexpensive to carry out. He estimated that an experiment demonstrating proof of principle could be done for a few tens of millions of dollars and that a precommercial test driver, not including implosion chambers and pellet design, could be built for $400 to $500 million.

A fairly detailed Brookhaven cost analysis estimated that the Brookhaven design would cost about $870 million to build as a commercial plant driver. Dr. Al Maschke, head of the Brookhaven heavy ion fusion group, carefully pointed out that we do not know enough at this time about pellet and boiler design to make an accurate estimate of the overall cost of a plant, but he indicated that the commercial viability of the heavy ion concept depends strongly on the fabrication cost of pellets and on the cost of boilers.

It is generally agreed in the field that heavy ion fusion plants initially would be treated as neutron factories rather than as power plants of the pure fusion type (Maschke 1978b). In this application, they would operate as hybrid fusion-fission fuel breeder reactors.

As with other areas of inertial confinement, heavy ion fusion in the West is largely in the U.S. domain because of the weapons design implications. At the third annual Workshop on Inertial Fusion Driven by Beams of Heavy Ions at GeV Energies, held September 19 to 26 at the Argonne Laboratory, most of the 158 participants were from U.S. laboratories, universities, and industry, with only a few European and Japanese representatives.

The West Germans have the right type of facility for heavy ion beam work at Darmstadt, but they are more interested in pursuing a joint European project at one of the Euratom joint facilities, such as CERN. However, nothing is expected to happen until the next five-year Euratom research period, about five years from now.

The Soviets also claim to have no plans at present for experimental work. Their two big accelerators at Dubna and Novosibirsk are reported to be scientifically overloaded now, compared with the half-dozen accelerators in the United States.

The Department of Energy is now committed to build a Heavy Ion Demonstration Experiment, HIDE, beginning in October 1981. The project will be based in part on one of the three major proposals described above. Considering the opinions of U.S. experts (see box), the expertise and capital already put into high-energy accelerators, and the potential fusion payoff, this planned investment to test ion beam fusion is quite minimal.

Morris Levitt is executive director of the Fusion Energy Foundation and John Schoonover is FEF director of nuclear research.

Footnote

(1) Earlier publications that have provided the basis for solution to these problems include: "The Secrets Known Only to the Inner Elites," by Lyndon LaRouche, Jr., in *The Campaigner*, May-June 1978 (see especially "The Physics of the Matter," p. 64); "The Concept of the Transfinite," by Uwe Parpart, in *The Campaigner*, January-February 1976; and *Energy Potential: Toward a New Electromagnetic Field Theory*, by Carol White (New York: University Editions, 1977).

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Making the U.S. Health System Healthy

By Ned Rosinsky, MD

From the standpoint of the patient or prospective patient, it is easy to find fault with the U.S. health care system. It is increasingly expensive both in dollar cost and in real social cost; there are no definitive treatments yet for the degenerative diseases like cancer, heart disease, and stroke, or for other aging processes; adequate health care remains inaccessible for large segments of the population; and the United States is besieged by an epidemic of illegal drug abuse, the number one public health problem today.

As I will show, however, the facts are that although medical costs have gone up in the past few years, costs per service have been in line with general inflation; that the bulk of hospital costs today are related to an increased intensity of medical care and advanced medical technology (not salaries); that the U.S. health-indicators, specifically infant mortality and life expectancy for 65 year olds, vastly improved under the two most recent medical programs that made health care accessible to the general population, Medicaid and Medicare.

Despite these facts, the advocates of cutbacks in health care have used two related myths to defend their position. First and foremost is the assumption that the nation has an inherently limited budget pie that must be sliced thinner and thinner and, therefore, that there must be a system of medical service "triage" — that is, some services must be sacrificed to save other services.

Apologists for this view, such as the *New York Times*, argue that the $28,000 spent annually to keep a renal dialysis patient alive would be better spent elsewhere in any number of good medical causes, such as a broad immunization

How the Health Bills Measure Up

Senator Edward Kennedy predicted when he introduced his national health insurance plan last year that "The next Congress will be known as the health insurance Congress." Ironically, most of the hundreds of health bills being readied for submission, and especially Kennedy's, would lower the current level of health care in America in the name of cost-cutting. Even the best of these bills fails explicitly to address the fact that the improvement of the U.S. health care system requires an expansion of what made U.S. medical science great—investment in general scientific and technological progress.

From the point of view of the public, the most important health care questions concern dollar medical costs and the accessibility of good medical care. More generally, these are two aspects of the basic concept of the efficiency, or productivity, of the health care system. Despite all the populist rhetoric about the greedy medical profession, the main determinant of increasing efficiency in health care is a rising rate of technological development and the realization of technological application, not the Kennedy-style cost-cutting approach. Specifically, this means high standards of medical personnel training as opposed to the barefoot doctor paraprofessional approach; the widespread use of the most advanced diagnostic equipment and treatment; and a heavy increase of investment into basic biomedical research and development.

The Kennedy Plan

The main questions involved can be seen in a brief review of Kennedy's health insurance plan and that of the American Medical Association, traditionally Kennedy's most vociferous opponent.

As Kennedy described his health plan in the *Congressional Record* Oct. 2, 1978:

> Immediately upon enactment, the legislation will impose overall revenue and expenditure limits on hospitals and revenue limits on physician services. Budget caps will be used to restrain current rates of increase in these services. . . . Future increases in health care costs will not be permitted to exceed rises in the costs of other goods and services. . . .

What this means is that Kennedy intends to reduce costs by cutting back on the quality and volume of services provided. The senator made this explicit in his hospital cost control bill in the last Congress, which would have put a 9 percent ceiling on the total spending of hospitals, resulting in a 3 to 5 percent cut in hospital services annually. As I shall show, health care costs *per service* are increasing in line with the general rate of inflation; the reason *total costs* are rising more rapidly is because of improvements in the quality and quantity of services provided. Furthermore, these im-

program for children, safeguards against industrial accidents in plants, and so forth.

The second myth is that past experience with advanced medical technology shows it to have at best only a marginal effect on the overall health or well-being of the population. This school, typified by Dr. John Knowles of Harvard University, generally admits that the 1938-1950 period of antibiotic (and other drug) development had a major, positive effect on the nation's health. However, this group maintains that subsequent technology has had very little effect on the population's overall health because it is not definitive or curative but "halfway"—for example, the sophisticated treatments for cancer, heart disease, arthritis, chronic kidney disease. At the current time, this group maintains, more of this technology would contribute virtually nothing, despite its huge cost.

To quote Knowles (*Daedalus*, Spring 1977):

> I will not berate the medical profession, its practitioners and professors—they reflect our culture, its values, beliefs, rites, and symbols. Central to the culture is faith in progress through science, technology, and industrial growth; increasingly peripheral to it is the idea, vis-á-vis health, that over 99 percent of us are born healthy and made sick as a result of personal misbehavior and environmental conditions. The solution to the problems of ill health in modern American society involves individual responsibility, in the first instance, and social responsibility through public legislative and private voluntary efforts, in the second instance. Alas, the medical profession isn't interested, because the intellectual, emotional, and financial rewards of the present system are too great and because there is no incentive and very little demand to change. But the problems of rising costs; the allocation of scarce national resources among competing claims for improving life; diminishing returns on health from the system of acute, curative, high-cost, hospital-based medicine; and increasing evidence that personal behavior, food, and the nature of the environment around us are the prime determinants of health and disease will present us with critical choices and will inevitably force change.

Another member of the Knowles group carries the "personal behavior" view of medicine even further, replacing science with humility. To quote Dr. Stanley Joel Reiser, codirector of the Kennedy Interfaculty Program in Medical Ethics at Harvard University (*Daedalus*, Spring 1977):

> Since the 1960s, the growing availability of technological aids such as artificial respirators and artificial kidneys has engendered in both physicians and laymen a searching examination of the moral principles that should guide medical decisions. This examination, whose depth and intensity is unparalleled in medical history, has had as one of its underlying themes the notion of limits. A humility has been urged upon medicine to match the considerable technological power it has created to overcome the

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provements correlate closely with significant declines in infant and overall mortality rates.

The Kennedy bill promises that "No other program to guarantee comprehensive benefits to all Americans will cost less than this proposal. . . ." The question here is what kind of services will be available to the insured population, given the service cutbacks Kennedy intends. Currently an inner-city Medicaid patient may have virtually unlimited access to an inner-city hospital, but the quality of the service is frequently extremely poor, as a result of the municipal cost-cutting of the sort that Kennedy is advocating on a national basis.

Here's how Kennedy says his program will work:

> Most Americans will be insured by a PA (federal Public Authority) certified and regulated insurer or HMO (health maintenance organization) which is a member of a consortium of first, insurance companies, second, nonprofit health service plans, or third, federally qualified health maintenance organization of their choice. . . . Since HMOs are expected to maintain their lower rates of hospitalization as compared with other types of insurers, the HMOs will be able to provide services beyond those mandated by the comprehensive benefits program and thus compete successfully with traditional forms of organization and delivery. . . . Financing will be effected through a combination of employer-employee contributions, and federal general revenue support for the poor and unemployed and for the improvement of the program. The self-employed and other individuals not covered by employer groups will purchase coverage at group rates through a certified insurer or qualifed HMO.

The issue here is whether increased funding for the already extremely inefficient third party insurers such as Blue Cross/Blue Shield will reduce costs at all. Also, setting third parties into competition with each other tends, as Kennedy is happy to point out, to induce the insurers themselves to cut back in services. Furthermore, a number of questions concerning the growing British domination of the reinsurance industry suggest that, if Kennedy is not immediately embracing the British medical system, he is nonetheless advocating putting U.S. health care heavily under the control of British finance.

The AMA's 'Medicredit' Bill

In contrast to the Kennedy approach, the American Medical Association's health bill, the Comprehensive Health Care Insurance Act, although far from optimal, makes clear at the outset that its goal is to maintain the high standards of U.S. health care. Representative Tim Lee Carter, who introduced the bill, stated in his introductory remarks (*Congressional Record*, Jan. 13, 1977) that the bill addresses the financial

Continued on page 40

natural forces that produce illness. These cautionary observations are similar to those of modern ecologists, who are urging us to act with humility in dealing with the natural world. The contemporary movement in medical ethics in part asks physicians who control a powerful technology store of therapy to consider, as the Ancient Greeks did, the limits imposed on therapeutic undertakings by the biological make-up of man, and the moral and therapeutic consequences of accepting these limits.

As is obvious, this school uses these types of arguments to advocate a sharp curtailment of hospital purchases and improvements in technology in order to counter the inflation of health care costs.

Advanced Health Care Works

Medicaid and Medicare provide an excellent test of the effects of introducing advanced medical technology into segments of the population. After Medicaid was enacted in 1965, infant mortality plunged (Figure 1), as a combined result of better prenatal care and neonatal facilities, including the development and widespread use of neonatal intensive care hospital units. Included in the drop in infant mortality is the remarkable drop in low-birth-weight mortality (Figure 2), which is directly correlated with the most advanced hospital technology, including monitoring equipment, incubators, and respirators.

Equally impressive is the fall in overall death rates of the aged population, which is associated with the enactment of the Medicare program in 1965. The increased health care expenditures for the over-65 population included a 47 percent increase in real hospital services from 1965 to 1975 (Table 1). Mortality data (Figure 3) show a significant drop-off in overall mortality between 1970 and 1975, 9.9 percent, which was greater than the total mortality decrease for the 15-year period from 1955-1970, 8.0 percent. However, for the aged category the changes in mortality are even more marked. The death rate for these people during 1965-1975 fell 11.2 percent, compared to only a 2.4 percent decrease during 1950-1965.

In addition, the life expectancy for 65-year-olds increased dramatically after Medicare. In 1900, the life expectancy of a 65-year-old was 12 years; in 1950, it was 14 years, an improvement of only 2 years over a 50-year period (which includes the development of antibiotics); by 1965, it had increased by .7 years to a total of 14.7; but in the 10 Medicare years, 1965-1975, it increased by 1.4 years to total 16.1. This last increase was more than 50 percent of the total increase during the entire period 1900-1965, a period that includes not only the development of antibiotics but also large-scale increases in general living standards.

A few examples should give the reader a qualitative sense of the kind of medical technologies that have been developed over the past 10 years. As mentioned above, neonatology (treatment of newborns) has been revolutionized. Continuous monitoring devices for impor-

Bills

Continued from page 39

problems of providing high-quality medical care for all Americans:

> While we can be proud of the outstanding technological advances and high quality of American medicine, we also know that not every American now has access to that system of care. Moreover, the onset of major illness or accident can bring the threat of financial disaster to virtually any family.... I believe this measure offers a workable approach to addressing these problems.

The summary of the bill begins:

> The basic concept of this proposal is full health care for all persons through private health insurance. For many who are now employed and have some insurance protection, it will mean a substantial increase in allowable benefits that will assure that their health care needs will be met. Equally comprehensive benefits will be available to the poor and the indigent, through federal participation in the cost of insurance. A special program of supplemental insurance will provide like protection for the Medicare population.

The bill goes on to require that employers pay 65 percent (or more if negotiated through labor contracts) of the insurance premium, the employee the rest; and that the self-employed and unemployed will also be covered. The services covered include all hospitalizations, physician visits, child dental care, and preventive health services.

There is no mention of top-down capping of expenditures or mandatory cuts in services, as in the Kennedy bill. However, the AMA bill sets up a coinsurance requirement, as follows:

> To keep costs down, and as a curb against overutilization, individuals will be subject to a payment of 20 percent (called "coinsurance") of health benefits derived. However, the total coinsurance which a family will have to pay in any year will be limited according to its income. The poor will pay no coinsurance, others will pay a maximum in any year of 10 percent of income reduced by a "coinsurance deduction" that will assure that the obligation for coinsurance will increase only gradually as income rises.

Payments are limited for a family of four to 10 percent of income over $4,200, with a maximum of $1,500 per person and $2,000 per family.

The bill provides that state agencies regulate the insurance and that the program is overseen by a 15-member Health Insurance Board, consisting of the secretary of the Department of Health, Education, and Welfare, the Commissioner of Internal Revenue Service, seven participating doctors, an osteopath, a dentist, and four members of the public.

Although the AMA bill allows for a

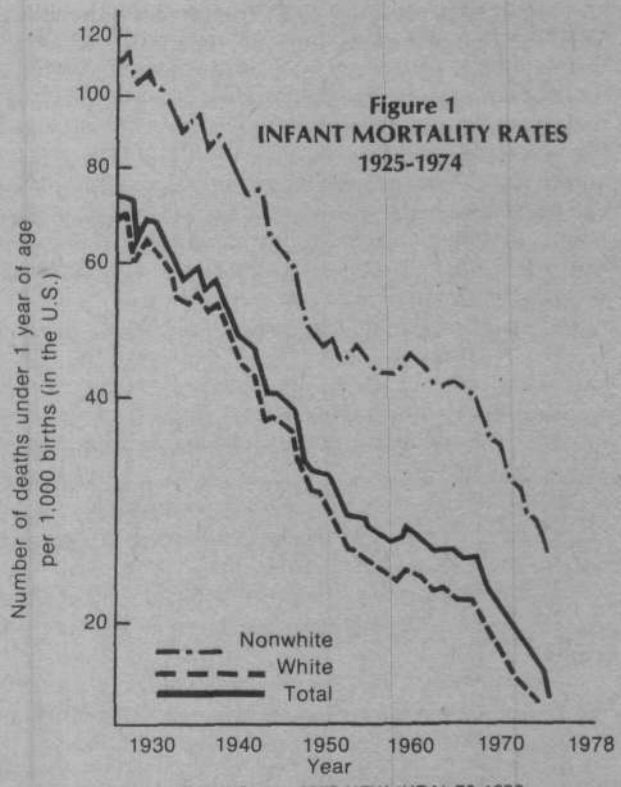

Figure 1
INFANT MORTALITY RATES 1925-1974

Source: *Health United States 1975* HEW (HRA) 76-1232.

Table 1
SHORT-TERM HOSPITAL STAY UTILIZATION BY THE OVER-65 AGE GROUP

Utilization factor	1965	1975	Percent discharge
Discharges*	264	359	36%
Patient days*	3,447	4,166	21%
Average length-of-stay per discharge	13.1 days	11.6 days	-13%

* Per 1,000 noninstitutionalized aged
Source: *Health, United States 1976-77*, HEW (HRA) 77-1232

The table documents the significant increase in hospital use following Medicare, which correlates with the fall in death rates, as well as with the increase in life expectancy at age 65.

There was an abrupt decline in the rate of infant mortality (the number of infant deaths below the age of one year per 1,000 live births) after the passage of Medicaid in 1965. The Department of Health, Education and Welfare ascribes the change to better prenatal care and more available infant care following Medicaid.

presumed continuation of strides in improved technology, manpower training, and other aspects of health care at the same time that it assures the population of more comprehensive medical insurance, it, like the scores of other health care bills before Congress, fails to address the main problem of the U.S. health care system—the effects on health care of the decline of the economy as a whole.

No 'Kool-Aid'

I quote from a recent statement of U.S. Labor Party chairman Lyndon H. LaRouche, Jr., critically reviewing the Kennedy health plan. As LaRouche correctly notes, the kind of medical cost-cutting Kennedy prescribes has a horrifying precedent:

> The model for this feature (cuts in medical assistance to senior citizens) of the Kennedy bill is the pilot project conducted at St. Christopher's Hospice in London. Yet, the more appropriate precedent is those features of Nazi Germany medical practices during the 1930s which became the subject of the postwar Nuremberg Tribunal proceedings. The Nazi precedent shows that it is but one step from "Brompton Mix," as a medical cost-cutting measure, to the "cost-benefit" dictum of quickly terminating the existence of "useless eaters." The relevant provisions of the Kennedy proposal represent the wedge-end for such Nazi-like practices. . . .

To combat what he called Kennedy's "Kool-Aid for the aging" approach to health insurance, LaRouche proposed the establishment of a "Blue Ribbon Commission":

> The primary focus of the commission's work should be the service of those ethical principles for which all honorable professionals stand in essential agreement, despite secondary divergences among them on the issue of financing the delivery of a quality of professional service on which all honorable professionals are generally agreed. . . .
>
> The issue to be emphasized at this moment must be made the issue of what is to be delivered. After the fight for the quality of health services is won, we can settle the issue of financing delivery properly. . . .
>
> The duty of the medical profession—and of national policy-makers—is to encourage the medical profession to promote high rates of expansion of services and high rates of improvement in basic research and in high-technology equipment. *It is the economy which is sick, not the medical profession.* With a return to emphasis on generalized scientific and technological progress, and emphasis on high-technology forms of employment in production of useful tangible goods, the economy will begin to be cured of its own disease, and with that development the burden of medical services will begin to evaporate. . . .

tant variables such as the blood's content of oxygen are now available in the form of a noninvasive skin monitor. Other devices monitor breathing, heart beat, blood pressure, and so on, and can trip an alarm warning the physician if there is any abnormal change. Similar devices are used now in adult intensive care units and cardiac care units and can be helpful in monitoring the fetus prior to birth.

Computer-aided diagnosis, as Figure 4 shows, can be enormously helpful in making decisions on difficult cases such as abdominal pain.

Visualization techniques have mushroomed during the past decade. The widely publicized CAT scanner, a computerized (multiple) X-ray, rapidly takes a large number of X-rays at different angles (using very small amounts of radiation) and then constructs a detailed image by computer analysis of the data. The technique is far superior to the usual X-ray. For example, it can be used to evaluate conditions that otherwise would require injecting a dye into the carotid (neck) artery (and tracing its circulation through the brain), a procedure with a high morbidity and mortality. Or it can be used to evaluate other conditions that would require the injection of air into the spinal canal, tilting the patient to allow the air to move up into the brain and following the air pattern by normal X-ray methods — again a procedure with a high morbidity. The CAT scanner is also an excellent example of how technology can increase the efficiency of medical manpower, allowing faster diagnosis with fewer tests.

The main impediment to further improvements on this scanner technology has been the health services agencies (structures similar to those proposed in the Kennedy health bill), set up by federal mandate in most states to monitor and reduce hospital purchases. These agencies

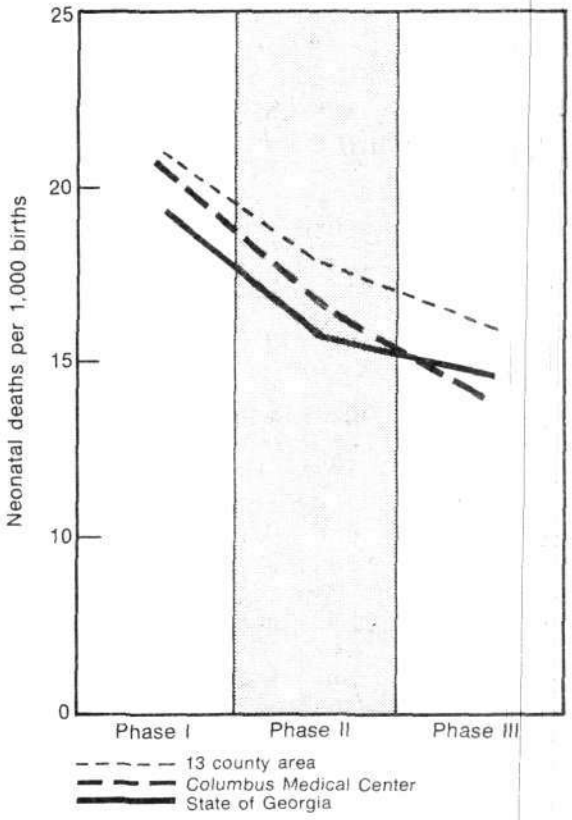

Figure 2
DECLINE IN LOW BIRTH WEIGHT MORTALITY

The mortality of infants born weighing under 1,500 grams has declined markedly over the past decade, primarily due to the development and widespread use of neonatal intensive care units with the most advanced technology. This graph shows the decline in infant mortality in Georgia during the phasing in of high-technology newborn intensive care wards in the state's hospitals during the 1969-1972 period.

Source: *Southern Medical Journal* 69:688 (1976).

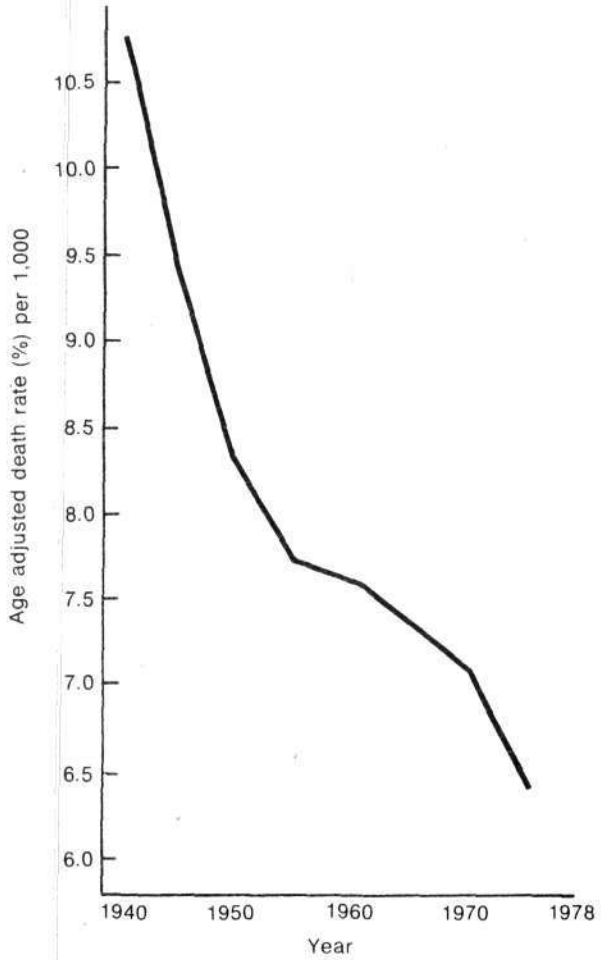

Figure 3
OVERALL U.S. DEATH RATES, AGE ADJUSTED

Note the large percentage drop in death rates in the period 1970 to 1975, nearly as large as the drops occurring during the period of antibiotic development in the 1940s and early 1950s.

Source: *Health, United States 1976-1977*, HEW (HRA) 77-1232.

(a) Admitting doctor's clinical diagnosis

	APPX	NSAP
APPX	1 **129**	3 **2**
NSAP	2 **170**	4 **43**

50% correct

(b) Senior clinician's diagnosis

	APPX	NSAP
APPX	1 **127**	3 **12**
NSAP	2 **42**	4 **231**

87% correct

(c) Computer diagnosis

	APPX	NSAP
APPX	1 **141**	3 **0**
NSAP	2 **8**	4 **262**

98% correct

Figure 4
COMPUTER AID IN DIAGNOSIS OF ABDOMINAL PAIN

These data compare the diagnosis made by a senior clinician with the diagnosis made by a computer that was fed information on patients with abdominal pain at the time of admission to the hospital, such as location of pain, type of pain, presence of nausea or vomiting, fever, previous abdominal surgery, and so forth. The data shown record only two categories of diagnosis, appendicitis and nonspecific abdominal pain (pain that would resolve by itself within several days and that did not require any specific therapy, such as mild gastroenteritis). In this series, the computer was more accurate in determining which patients should and should not be operated on.

It should be emphasized that the point is not to eliminate doctors, but to demonstrate that computers may be highly useful in conjunction with a skilled clinician in deciding difficult cases. As the data show, if the computer's advice had been followed in this series, 12 patients would not have had an unnecessary delay in their surgery, and 34 patients would not have had unnecessary surgery.

THE DATA

In (a), the admitting doctor's diagnosis is compared with the final diagnosis; that is, the final findings after hospitalization and treatment. Box (1) represents 129 patients whose admitting diagnosis was appendicitis (that is, the admitting doctor recommended surgery) and whose final diagnosis turned out to be appendicitis (that is, the admitting doctor was correct on these patients). Box (2) represents the 170 patients whose admitting diagnosis was appendicitis, but who turned out to have "nonspecieic abdominal pain." These are patients who, if the admitting doctor's advice had been followed, would have been operated on needlessly. Box (3) shows the two patients who were thought by the admitting doctor to have nonspecific abdominal pain but who eventually were operated on for appendicitis (that is, the initial diagnosis was wrong). Finally, box (4) shows the 43 patients admitted for nonspecific abdominal pain whose final diagnosis was the same, indicating that the admitting doctor was correct on these patients.

In sum, boxes 1 and 4 represent correct diagnoses and boxes 2 and 3 represent incorrect diagnoses.

In (b), the numbers represent the same total patient group as in (a), according to the diagnosis made by the senior clinical physician, the doctor who decides whether the patient will actually go to surgery. As the numbers indicate, the senior clinician's diagnoses agree much more closely with the final diagnosis than those of the admitting doctor; 87 percent are correct, compared to only 50 percent correct. In the actual final outcome of the patients, 12 were not operated on immediately who should have been (3), and 42 were unnecessarily operated on (2).

A computer's diagnoses of the same patients compared with the final diagnoses is shown in (c). The computer, which uses the data provided by the senior clinician, does even better than the senior clinician. If the computer's advice had been followed by the doctors, no patients who needed surgery would have had it delayed (3), and only 8 patients would have been operated on needlessly (this is a very small percentage of needless operations for suspected appendicitis, by any standard), resulting in an impressive total of 98 percent correct diagnoses.

Source: *Advances in Medical Computing—Proceedings of the Third International Symposium on Computers in Medicine*, J. Rose, ed. (New Churchill Livingstone, 1975).

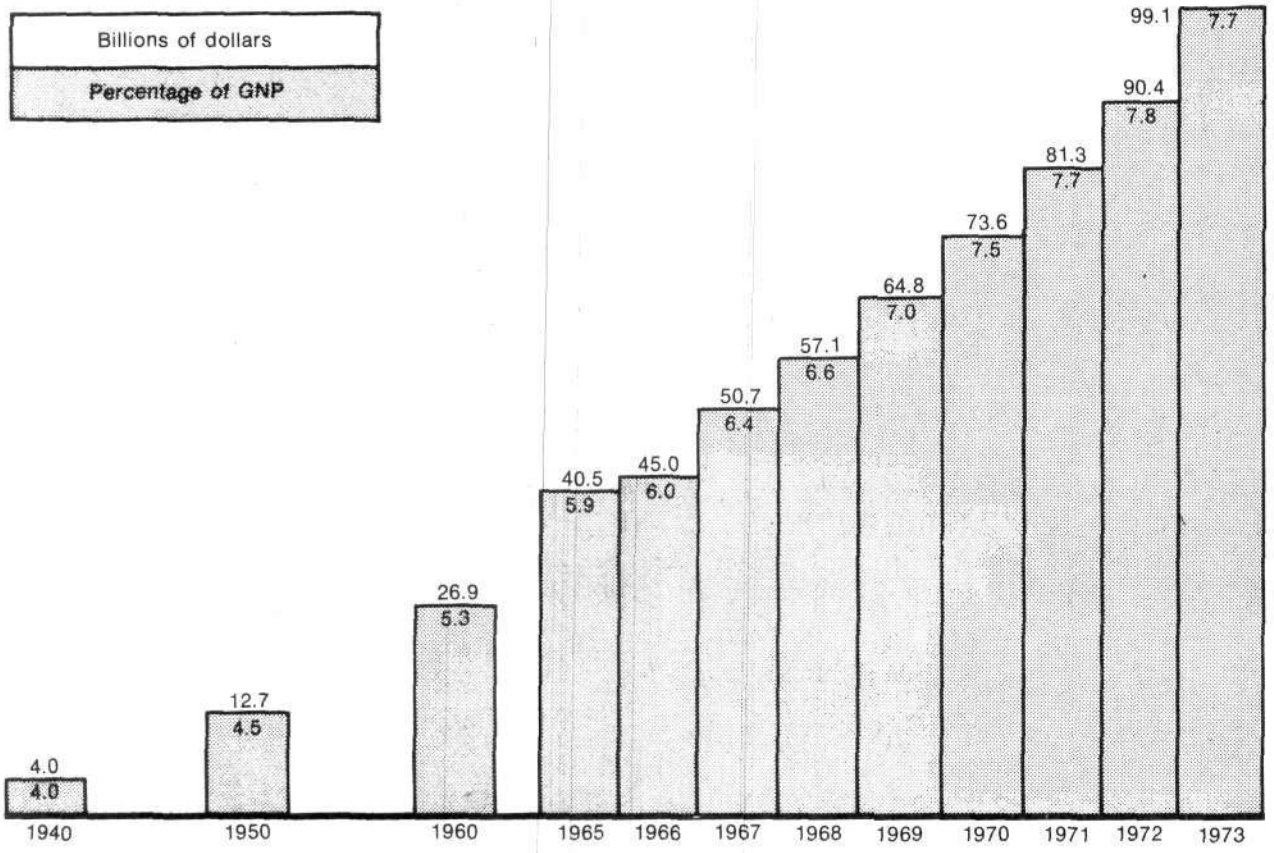

Figure 5
PERCENTAGE OF GNP SPENT ON HEALTH

Health care spending has been rising as a percentage of GNP, from approximately 4 percent in 1950 to more than 8 percent currently. Most recent estimates of spending indicate a figure close to $200 billion in 1979, approximately $850 per capita. The U.S. medical profession now totals approximately 370,000 doctors and approximately 7,000 hospitals.

Source: *Health United States 1975* HEW (HRA) 76-1232.

have blocked more than half of the CAT scanners ordered by hospitals, nearly bankrupting one of the country's major producers of the technology. Although the CAT scanner has gone through a remarkable four generations of improvement in the past 15 years, further R&D money which could improve the efficiency of the machines and medical manpower to an even greater extent—is getting increasingly scarse as sales plummet.

Even more distressing is the fact that one of the major producers of the CAT scanner has stopped funding an entirely new visualization technique, nuclear magnetic resonance, that can potentially take a picture of internal cancers of all the major types (lung, prostate, colon, breast, and so on.) This degree of ease and safety in early detection of cancer would doubtless revolutionize cancer management, yet because of losses in the CAT scanner, the work on nuclear magnetic resonance is stopped.

Another example of advanced medical technology is in the acute management of surgical patients. The main cause of death associated with surgery is not the surgery itself but indirect lung complications: pulmonary embolism (blood clot in the lungs), "shock lung" (lungs filling up with fluid in response to the bodily trauma of surgery), and other conditions. The key to treating these problems is early detection, and a new device, the swan-ganz catheter, is now currently used routinely in advanced hospitals to constantly monitor the internal state of the lungs.

Another major cause of death following surgery is the temporary inability to eat or digest food. During the past 10 years, predigested protein formulas and new forms of lipids for calories have been developed that can be given intravenously, to keep the patient alive until he recovers.

Why Is Health Care So Expensive?

Although the benefits of advanced health care have been enormous, it is also true that the prices of services, particularly hospital and laboratory services, have increased greatly over the past several decades. In 1950, 4.5 percent of the GNP was spent on health, while by 1977, this figure had increased to more than 8 percent (Figure 5). In recent years the annual increase in national health spending has grown by 12 to 15 percent, a good deal above

Table 2
AVERAGE ANNUAL INDEX FOR SOME CONSUMER PRICES (1967 = 100)

ITEM	1950	1955	1960	1965	1970	1971	1972	1973	1974	1975
Semiprivate room	30.3	42.3	57.3	75.9	145.4	163.1	173.9	182.1	201.5	239.0
Physicians fees	55.2	65.4	77.0	88.3	121.4	129.9	133.8	138.2	150.9	169.7
Tonsillectomy and adenoidectomy	60.7	69.0	80.3	91.0	117.1	125.2	129.9	132.3	144.2	165.5
Drugs/prescriptions	88.5	94.7	104.5	100.2	103.6	105.4	105.6	105.9	109.6	119.4
Medical care, total	53.7	64.8	79.1	89.5	120.6	128.4	132.5	137.7	150.5	169.8

Hospital room charges are increasing much more rapidly than other services; however, the services provided in the base hospital charge are increasing (see Figure 7).

Source: *Health United States 1975* HEW (HRA) 76-1232.

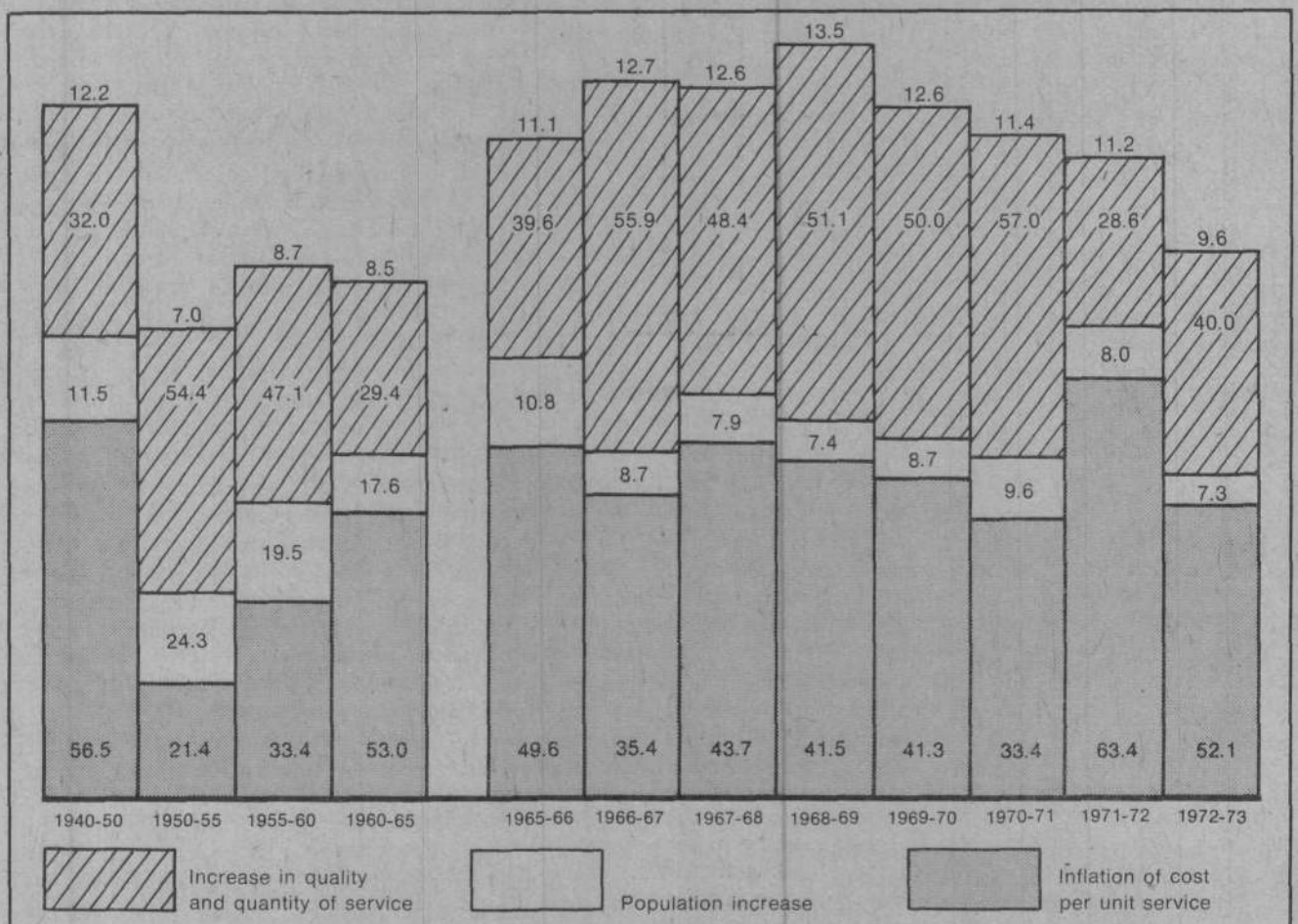

Figure 6

U.S. HEALTH CARE SPENDING: PERCENTAGE INCREASE ATTRIBUTABLE TO INFLATION, POPULATION INCREASE, AND INCREASED QUALITY AND QUANTITY OF SERVICES, 1940-1973

Increases in health care spending, analyzed by area, show that a major proportion of the increases goes for improvements in the quality and quantity of services; there is not simply an increased cost per unit of service. In fact, the increase in cost per unit service is climbing slower than the general rate of inflation for the economy as a whole. The number at the top of each bar is the total increase annually for the time period indicated. The numbers within the bar show the percentage of this increase attributable to the three categories.

Source: *Health United States 1975* HEW (HRA) 76-1232.

the calculated consumer price index of 9 to 10 percent.

Where is the money going? Nearly half of it is for improvements in the quality and quantity of services, not in so-called excess profits on the part of health care providers (Figure 6). In fact, the increase of health care costs as a result of price rises for the same services is actually *lower* than the general rate of inflation.

For example, consider hospital costs. If the cost per service is rising slowly, then why are the base daily rates for hospitalization climbing so quickly (Table 2)? The answer lies in the increased *intensity* of services provided for the patient by the hospitals as part of the base hospitalization day. The American Hospital Association calculates a Hospitalization Intensity Index (HII) that combines more than 40 aspects of hospital care, including number of doctors per hundred patients, number of nurses, number of lab personnel, quality of other services such as food, and so on, to produce an overall measure of intensity of services.

For example, between June 1977 and June 1978, daily hospital rates increased on average $22.42, or 12.2 percent. Of this increase, $12.89 (or 56 percent of the increase) was because of increased costs (inflation) of goods and services purchased by the hospitals, while $9.53 (44 percent of the increase) was because of the increase in intensity of services; that is, the quantity of services supplied to a patient during a typical patient day, extraneous of all special charges such as lab fees, drugs, and so on. The expense per patient day compared to the expense per real service Volume is shown in Figure 7. When adjusted by the HII factor, the price segment of the increase for 1969-1978 amounts to only 8.1 percent annually.

Why is this increasing intensity of care necessary? As pointed out above, medicine increasingly is faced with a growing elderly population (Figure 8) whose predominant illnesses, especially since the antibiotic discovery era of 1935-1950, have been the degenerative diseases: heart disease, cancer, stroke, chronic kidney disease, arthritis, diabetes, hypertension, and so on. At this point, there are no definitive cures or preventive measures for any of these conditions although there are many valuable, so-called halfway treatments. It is the task of basic biological and biomedical science to find cures for these diseases within the next two decades.

There is another major cost factor to be considered — bureaucratic overhead. During the past 10 years, the cost of added paperwork per patient-day in a hospital has increased by $50! This is 25 percent of the average base daily rate and is a result of the vast proliferation of forms required by Medicaid, Medicare, Blue Cross, various health maintenance organizations, and myriad governmental investigative and regulative agencies and committees. Doctors and other health personnel can spend up to half their time or more filling out forms, which adds a loss of manpower to the already outrageous cost.

Added to this nightmare of paper is the well-publicized increase in malpractice insurance (Table 3), which affects hospitals as well as practicing doctors. The absurdity of this branch of the so-called consumer movement, which helps price health services out of the consumer's reach, is that its biggest backers seem to be the same insurance industry so eager to see Congress pass a health bill like Kennedy's.

The Need for Continued Progress

Throughout man's history, technological revolutions always have been associated with necessary quantum leaps in the overall size of the population, as well as with its general standard of living. To name a few examples: the increase in food production with the neolithic revolution; the rise of towns and cities and the provision of public health measures such as running water, sewer systems, and disease quarantine measures; the conquering of infectious disease through Pasteur's discoveries, vaccines, and the development of antibiotics and other drugs associated with greater understanding of physiology; the rise of modern surgery with the development of anesthetics and infection control.

Now we face the next great challenge, curing and preventing the degenerative diseases, a challenge paralleled in physics by that of developing a new source of energy, fusion.

What is the current state of knowledge, and how can it be most rapidly advanced? First, the results of the past half-century of basic biological discoveries — from protein chemistry to the genetic code to three-dimensional enzyme structure — just now are slowly filtering into clinical practice, in such areas as inborn metabolic disease and in understanding how certain hormones and pharmaceuticals exert their effects.

On the other hand, this enormous development of physiology, molecular biology, and cell biology so far represents mere islands of knowledge in a sea of ignorance concerning basic biological processes. We have very little idea of how chromosomes function as entities. We do not know how differentiation takes place in the developing embryo. We have only the vaguest inkling of how the immune system operates overall.

We have few tools, then, for an in-depth exploration of cancer. Most generally, we can describe cancer as a progressive loss of differentiated cellular capacities (the cancer cell loses its special abilities, no matter what tissue — skin, muscle, and so forth — it originally comes from) as well as loss of coordination in growth.

Furthermore, we cannot fully interpret the observation of abnormal chromosome activities in cancer cells, nor the multiple roles the immune system seems to have in cancer. Similarly in atherosclerosis (hardening of the arteries, the main cause of heart attacks and stroke), there is an abnormal growth of cells lining the artery, as well as other degenerative changes. Similar uninterpretable events occur in the degeneration of the joints in arthritis, the degeneration of brain cells with age, and degenerative changes in the immune system, the eyes and ears, the skin, and virtually every other organ.

Unfortunately, the simpler solutions to cancer by now have been mostly ruled out. Cancer does not seem to be generally caused by a virus, nor by simply a carcinogen (though certain chemicals can induce cancer), nor by an inherited single "oncogene" (though a tendency for cancer can be inherited), nor by a specific immune deficiency

Table 3 MALPRACTICE INSURANCE RATES		
Year	General practice (excludes surgery)	Orthopedic surgery
1965	$137	$819
1970	443	5,258
1975	2,209	20,634
1978	3,370	27,737

Malpractice rates increased enormously during the late 1960s and early 1970s, adding to both doctor and hospital costs of production. Shown here are figures for New York State.

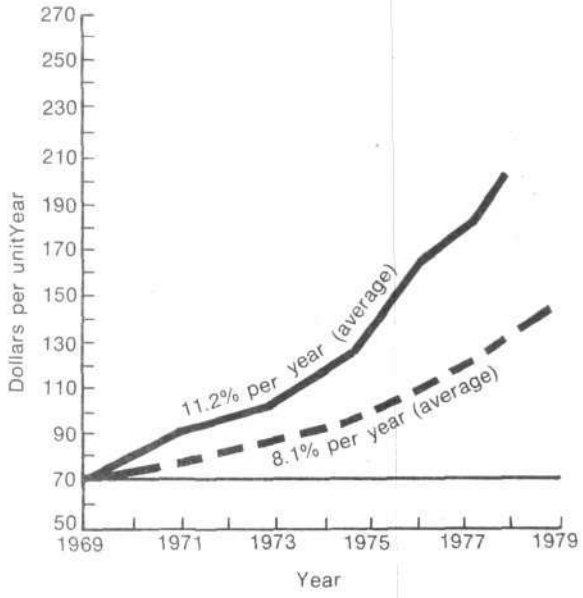

Figure 7
HOSPITAL INTENSITY INDEX: EXPENSE PER ADJUSTED PATIENT DAY AND EXPENSE PER REAL SERVICE VOLUME

The increasing cost of a hospital day per patient (solid line) is compared here with the increase in cost for the actual services received by the patient (dotted line). The American Hospital Association calculates the actual services rendered as a Hospital Intensity Index, based on more than 40 variables, such as number of patients per doctor, per nurse, and so on. This gives a picture of the actual quality of service given to each patient, exclusive of additional charges such as lab fees and drugs. As shown, when adjusted by the HII factor, the cost of a hospital day has been rising annually by 8.1 percent, which is less than the consumer price index.

Source: *Hospitals*, Oct. 1, 1978, p. 70.

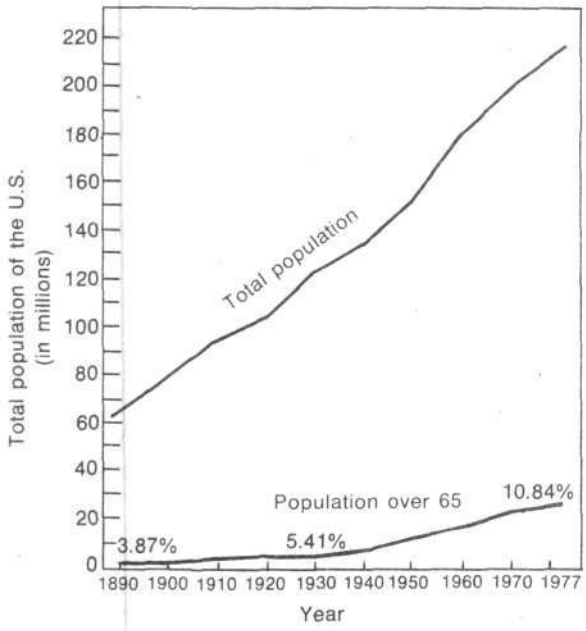

Figure 8
PROPORTION OF TOTAL POPULATION OVER 65

The proportion of the population over 65 is rising, as shown here. This segment of the population is most responsible for the increase in the proportion of deaths due to degenerative diseases. These diseases frequently require long term high-technology treatments because of a lack of definitive cures and preventive measures.

Source: HEW, Combined Sources

(or at least one that can now be measured). In all likelihood, an in-depth investigation of basic biological processes will be the fastest route to definitive cure and prevention of this and other degenerative diseases. (Of course, this approach must not displace the current screening of drugs and other measures as possible cures or interim partial treatments.)

Reformulating Biological Theory

What an in-depth understanding of these basic phenomena will require as a first step is a rigorous reformulation of theoretical approach to biology.

It is clear that the overriding tendency in the biosphere is away from entropic decay and toward higher-ordered self-development, an ever-increasing rate of negentropy. The key to understanding the basic functioning of genes, chromosomes, cells, and so forth is to identify their participation in creating negentropy.

An initial insight into this problem has been provided over the past several years by physics research in solitons, the self-organizing structures that spontaneously form in high-energy-dense gases (plasmas). This relation of high-energy density to self-development suggests that in other areas of critical negentropic leaps, the energies involved must be extremely high, even if this is not immediately apparent on first inspection.

For example, the ability of electrons to form collective stabilities with nuclei, resulting in atoms, should be approached as a case of a miniature plasma machine, in which the high energies represented by the mass involved ($E=mc^2$) are functionally related to ongoing activity within the atom. This high-energy notion stands in contrast to the much lower energies observed as lost or gained in chemical reactions among atoms.

The aim of such an approach would be to replace the ad hoc and incoherent assumptions of quantum mechanics with a causal and lawful conception of the atom as representing negentropic development in the universe.

This has direct relevance for biology. Macromolecules such as DNA and protein should be looked at as developing this high-energy-dense process and extending it into a wholly new and more powerful domain of negentropy formation, the biological domain. Several crucial experiments show the critical importance of this approach. For example, a number of biological molecules, including DNA, melanin pigment, and the steroid hormones, are known to be superconductors, indicating a highly ordered plasmalike state of the electrical charge content. (See Freeman W. Cope, *Physiol. Chem. & Physics* 10:233, 1978).

Another series of experiments, involving flax plants, shows the potentiality for rapid and large-scale changes in the overall gene content of the species, resulting in a heritible severalfold increase in size of the plant. This is not a simple chromosome doubling-type of change; it apparently involves changes within the chromosomes themselves, reorderings that are suggestive of high-energy states.

In the more advanced realm of neurophysiology, these high-energy effects should most obviously predominate. Neurophysiology immediately raises the question of how a more advanced kind of tissue, which represents an increase in negentropy, develops. For example, the continuing "differentiation" of the brain in its electrical and other activities after the period of embryological maturation represents a tremendous increase in negentropy. The high-energy state context for this activity and evolutionary development, at least in part, must be located in the im-

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The Cost-Cutting Approach to 3rd World Health

In the Third World, the cost-cutting approach to medical care advocated by Senator Edward Kennedy is euphemistically termed primary health care. Akin to the appropriate technology theory of development, primary health care assumes that there are no available resources to provide advanced medical care to 2 billion Third World people. Instead, this population must be helped to make do with the resources at hand, including witch doctors, no matter how many casualties result.

The policy guidelines issued by the World Health Organization and UNICEF at a conference on primary health care held in the Soviet Union in November 1978 are very specific.

"Conventional health care systems are becoming increasingly complex and costly and have doubtful social relevance. . . . It is out of the question for the developing countries to continue importing them. Other approaches have to be sought."

The following approaches, "in keeping with local culture" are prescribed.

(1) Decentralization of existing and new health care systems and distributing a fixed "allocation of resources according to an overall estimate of needs based on program objectives and common approaches for attaining them and using standard costs."

(2) Health care will be "appropriate and adequate in content and satisfy the essential needs"; "simplicity" is "always desirable."

(3) "It is an advantage if the equipment and drugs selected can be manufactured locally at low cost." The door is open here for inferior products, as well as "medicinal" coca leaves and marijuana.

(4) Health workers will include "people with limited education who have been given elementary training in health care, 'barefoot-doctors', medical assistants." Their training "has to be adapted to their degree of literacy." The people must learn how to administer self-help health care so that they need not accept "conventional solutions that are unsuitable but can improvise and innovate to find solutions that are more suitable."

mediate source of electrical activity, the cell membrane of the nerve cells.

A number of poorly understood but basic questions concerning membrane activity relate directly to the notion of high-energy content, such as active transport of substances across the membrane and the structure of the membrane itself. In neural cells the activity of the membrane becomes extremely differentiated and complex, a development that is related to the general high-energy content of membranes more generally.

To take a concrete instance, the findings of Eric Schwartz concerning the dynamics involved in the formation of the neural connection of the retina to the brain can be described using the mathematics of fluid flows (See "Neurophysiology and the Geometry of Vision," *Fusion* July 1978). However, there is no fluid flowing. Instead, a discrete bundle of nerve fibers is growing back from the eye to the brain and is behaving as if it were a fluid. This suggests that the membrane activity of the growing fibers is differentiated in such a way that it mimics various fluid dynamics, such as vortex turbulence.

The next question is, what is the energy source for the development of these membrane activities? This question could be approached along a number of lines, including the comparison of physiologies of developing visual systems with evolution (that is, among different species), in different parts of the brain, and so forth.

Finally, the study of membrane activity and other neural phenomena must be brought to bear on the question of human cognition, including the preconscious aspects of creative mentation, as an aspect of the high-energy context for the negentropic leap into the realm of social evolution.

The Question of Medical Technology

Theoretically, as society advances, the cost of technology should cheapen, since the society is becoming more productive. However, this is not the case during the current period because of a relative collapse in industrial R&D and a tapering off of investment in physics research. In the past, biology has relied heavily on physics for technology: X-rays; X-ray diffraction for crystallography to characterize biomolecules; the powerful electron microscope; computers for data analysis and experimental simulation; and materials research and microprocessors from industrial R&D and the space program, to name only a few areas.

The problem is that R&D for the country as a whole peaked in the mid-1960s and then plummeted. Basic biological and biomedical research held out longer, largely as a result of President Nixon's war on cancer, until the early to mid-1970s, but then it leveled out and now it is declining in real dollars.

Although the decline in physics and engineering affects all areas of biology, it is most detrimental in the area of instrumentation, because it either has increased costs or has made certain technologies completely unavailable. Some of the cases in which bioinstrument suppliers have had increasingly to go it alone include laser applications for studying photosynthesis and vision, X-ray diffraction used to study biochemistry, and the chemical research applications of nuclear magnetic resonance to biology.

In some cases, the technology supply houses are not producing at all. For example, the United States no longer produces electron microscopes, so purchasers must go to Japan; most NMR chemical analyers used here come from West Germany; another technology for analysing biomolecules, circular dichromism, is no longer produced in the United States.

"We get the feeling something is radically wrong," said a spokesman for the National Science Foundation concerning bioinstrumentation, "but the cutback in physics and industry is in so many areas, is so pervasive, that it would be difficult to trace it to any specific area. Now, of course, we are also starting to feel the crunch in our budget."

In summary, the lack of development of a rigorous theoretical framework, plus the more general collapse of scientific research and engineering, have reduced the productivity of biomedical research and thus increased the cost of medical care.

Health for the Future

A program for creating the kind of efficient and effective health care system necessary to make the United States a leader in the fight for progress must include the following two points:

First, in order to improve the coordination of present health services, existing infrastructure — including hospitals, clinics, and so forth — should be increasingly coordinated through referral systems and other publicly and privately funded measures to eventually produce integrated regional medical complexes (RMCs).

Each complex will serve a population of from .5 to 1 million persons, depending on local demographic conditions. The RMC will consist of a central medical school, research facility, and advanced ("tertiary") care hospital; coordinating outlying secondary care facilities; and subsidiary primary acute care hospitals, immunization stations, chronic care facilities, and other specialized institutions. Such a system would facilitate organized referral systems, proper planning of new facilities based on population patterns, and so on.

Second, an Apollo-style project must be launched in basic biology including such areas as genetics and chromosomes, other cellular organelles, embryology, the immune system, neurophysiology, as well as in-depth work on evolution. A similar effort must be launched in the area of degenerative diseases and aging generally.

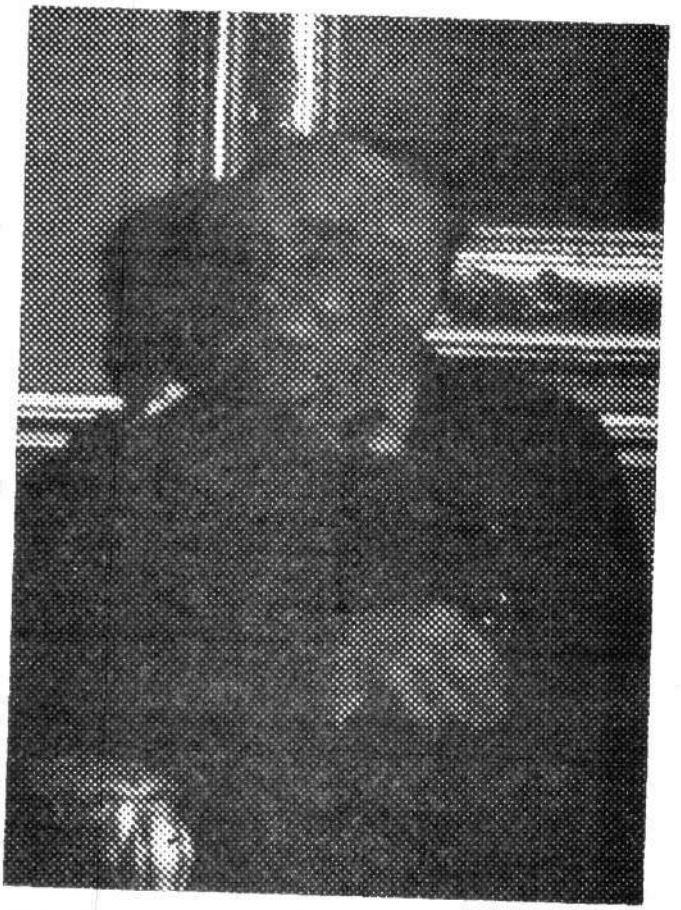
A minimal first approximation of the funds necessary is an immediate doubling of federal outlays for research, to be followed by further quantum jumps in funding over the next decade.

We have harnessed nuclear energy and put a man on the moon. With the same kind of commitment, we can find cures for the degenerative diseases.

Ned Rosinsky, a member of the Fusion Energy Foundation biological sciences staff, is a practicing physician in New York City.

Kapitza's 'Third Way' To Fusion

By Dr. Morris Levitt



Peter Kapitza at the Nobel ceremony Photo by Bardwell

SOVIET ACADEMICIAN PETER L. KAPITZA accepted his 1978 Nobel Prize for physics Dec. 8 in Stockholm in a most unconventional way. Although the Soviet physicist was being officially recognized for his pioneering research in the 1930s and 1940s on the phenomenon of superfluidity in supercold liquid helium, he told the audience at the Nobel Prize ceremony "I've forgotten all about" that long-ago work. Instead, he said he would rather discuss ongoing research on "plasmas and thermonuclear synthesis."

This was only the first of Kapitza's surprises. The remainder of his remarkable Nobel address—barely mentioned in the U.S. press—consisted of a candid assessment of the present state of fusion research and a review of his own unusual approach to controlled fusion. In a nutshell, Kapitza did not think that the present main approaches to fusion, the tokamak (magnetic confinement) and laser fusion (inertial confinement), could be developed technologically into economical reactors despite the impressive scientific advances recently made in these fields.

Instead Kapitza proposed a "third way," based on an amazing self-structuring phenomenon in high-pressure plasma discharges that is very similar to ball lightning.

Kapitza introduced his fusion subject by stressing that nuclear power and fusion are important because they represent cheap energy. By contrast, all the so-called renewable energy sources are very expensive; therefore, he said, cheap nuclear power is the only solution to the energy crisis. And for Kapitza, the only acceptable form of nuclear energy is fusion, since he is worried about the alleged dangers of weapons proliferation if enriched uranium or breeder-produced plutonium are widely disseminated. This arms control orientation, however, has not prevented Kapitza from working on many advanced science applications for the Soviet military.

Kapitza's Guiding Conception

For three decades, Kapitza's research in fusion has been guided by a special set of scientific conceptions. According to Kapitza, fusion occurs as the result of a two-stage plasma process. First, the fuel is heated and turned into an ionized plasma by electrical forces acting predominantly on the light electrons. The highly energized electrons then impart their energy to the much heavier positive ions, which undergo fusion if they become hot; that is, energetic, enough.

The problem of *economical* controlled fusion, then, is to come up with a geometrical configuration in which these two processes combine to produce a large amount of net energy before the plasma breaks up, and yet which is relatively small and simple.

Kapitza has built a machine that he thinks may do this better than any other. It is based on his hypothesis that the critical mechanism in ball lightning (the closed electrical

discharge that accounts for most so-called sightings of unidentified flying objects) is the interaction between microwave radiation and plasma.

That hypothesis emerged from research in 1950 on the production and propagation of highpower radar waves. Kapitza and his fellow researchers found at that time that the introduction of several kilowatts of 10-centimeter wavelength radiation into low-pressure mercury gas produced a discharge with a well-defined boundary. This led to Kapitza's famous conjecture that ball lightning represents a situation similar to that produced after high-frequency radiation is generated in clouds by normal lightning.

This research was followed in the 1950s and 1960s by the arduous development of higher power microwave generators and the testing of discharges in different mixtures of gases such as hydrogen, deuterium, and helium at various pressure. Remarkable results emerged. With gas pressures of 1 to several atmospheres, 10 kilowatts of 10,000 megaherz radiation absorbed in the gas produced a stable, free-floating plasma filament with electron temperatures of about 1 million degrees. As long as microwave radiation was beamed into the gas, part of it spontaneously ionized and formed itself into a closed circular filament that maintained its structure. The containment of the hot electrons was thought to be due to a special reflecting double layer of charge at the boundary of the ellipsoidal filament.

Controvery and Progress

According to U.S. scientists connected to Lawrence Livermore Laboratory in California who are familiar with Kapitza's work, these results generated great controversy in the Soviet Union. Kapitza challenged the leaders of the Soviet plasma and beam programs, including Budker and Artsimovich, to carry out detailed diagnostic analysis of his results. They accepted, and showed that Kapitza's results were even better than he had claimed.

This opened the way to full publication of the results of 10 years of research in Kapitza's 1970 article on "Free Plasma Filament in a High Frequency Field at High Pressure." Immediately afterward, an assessment of the potentialities of the phenomenon as the basis for a fusion reactor was also published in the main Soviet physics journal, *JETP*, of which Kapitza is chief editor.

At that time Kapitza concluded that a device of several meters diameter and length would constitute a "closed" breakeven system; that is, one in which a circulating energy of about 20 megawatts could be maintained without any outside input. Several basic questions remained, however. Could more microwave power be generated and absorbed? Would hotter electrons be produced and confined? And, the ultimate question: could an efficient mechanism for transferring energy to the ions be found?

On theoretical grounds, Kapitza identified the solution to the last question as being the production of *magneto-acoustic waves* to heat the ions. This involves producing an oscillation of the plasma and magnetic field lines around a strong uniform magnetic field that is also used to keep the free plasma filament in the center of the experimental chamber. Unlike a normal acoustic wave, which involves variations in the pressure and density of the gas or liquid it moves through, the magneto-acoustic wave is based on variations in the "pressure" of the magnetic field and the fact that plasma tends to be displaced along with motions of the embedded magnetic fields.

Although the ultimate issues are not yet settled, Kapitza's Nobel address presented striking progress in this approach. Several months ago, Kapitza reported, he obtained electron temperatures three times that of the sun, or about 50 million degrees (about the temperature required for fusion ignition) in a 30-kilowatt discharge through a 10-centimeter-long plasma at 30 atmospheres pressure. In conclusion, Kapitza noted that a prototype reactor would have to be only five times larger and that he is "very optimistic" about the prospects.

The Ellipsoidal Filament

Kapitza's results reflect a number of basic plasma processes that determine the stability of the plasma filament and its potentiality for generating fusion. The simplest physical analogy with the ellipsoidal filament, as Kapitza points out, is with the flame of a candle, which is a low-temperature, weakly ionized plasma. At low microwave power input, the prefilamentary plasma structure is, like a candle, a spheroid (Figure 1).

The basic determinant of the geometrical shape and stability in both cases is the balancing of the energy flow into the plasma and the losses from it. In the case of a candle, the input is supplied by the ignition of the fuel coming from the wick. For the high-frequency plasma discharge, the source of the driving energy is the rapidly oscillating electric field of the microwaves that transfers energy to the electrons in the plasma produced by the field. This field is not uniform in intensity in the discharge chamber, but has a geometrical pattern associated with the microwave wavelength and the size of the resonance cavity (Figure 2).

As the microwave power is increased, energy balance is maintained first by elongation of the filament—up to an upper limit of half the high-frequency wavelength, and then by an increase in its cross-section. At still higher power levels, the filament becomes unstable and breaks up into two pieces. As Kapitza notes, "...for a given frequency of the supply current apparently there exists not only a limiting length for the filamentary discharge but also a limiting diameter."

The other critical mechanism in maintaining the storage of energy in the filament (primarily in the form of the hot electrons) is the double reflecting layer of charge at its edges. The layered structure is set up by the fact that the escaping electrons penetrate more deeply into the gas surrounding the filament than do the heavy ions. (This phenomenon is commonly observed in the glass walls of discharge tubes, like neon signs.)

Experiments have shown that hydrogen gas has a natural tendency to set up these boundary conditions, especially compared with inert gases such as helium and argon. This property gives rise to a sharp difference (a discontinuity) in temperature between the hot plasma inside the filament and the cold diffuse cloud of gas immediately around it.

This well-defined surface plays a critical role in deter-

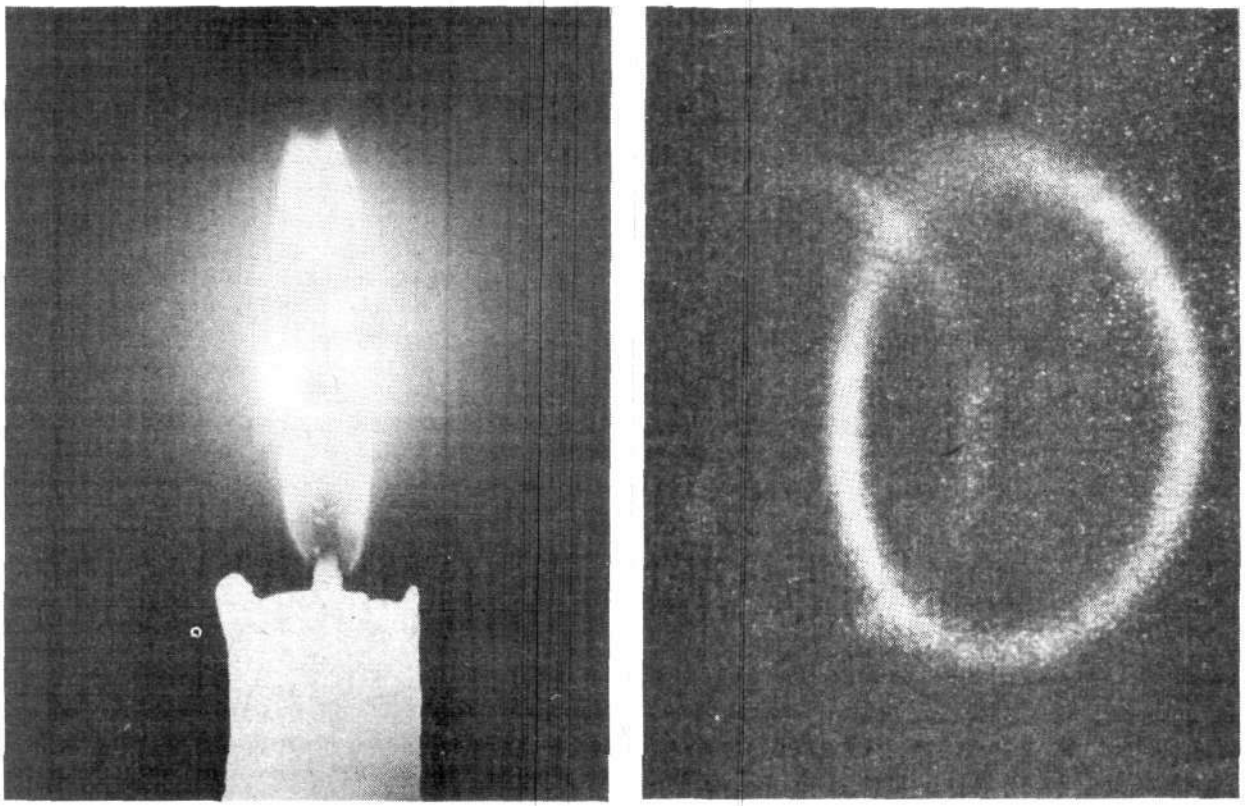


Figure 1
CANDLE AND FILAMENT
The flame of a candle and the plasma filament both have an approximately ellipsoidal shape as a result of the flow of energy into and out of the geometrical surface of the plasma region.

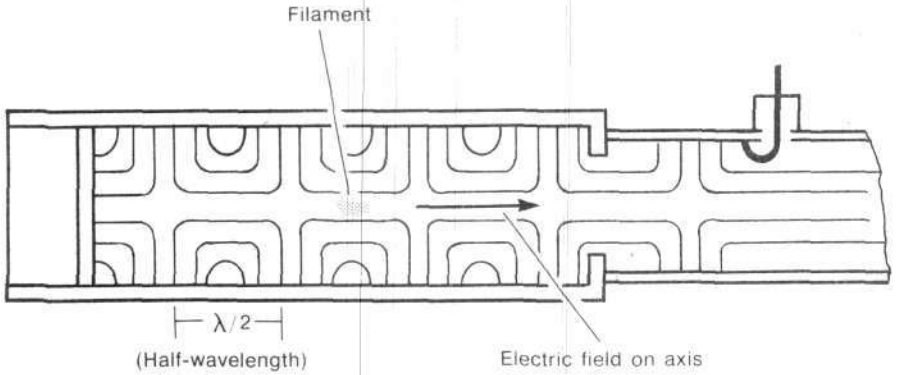


Figure 2
CAVITY AND FILAMENT
The electromagnetic energy from a high-frequency generator is stored in the cavity, with the maxima and minima in electric field strength shown. The size of the filament, as shown, is determined by the distance between peaks in field intensity, which is determined by the wavelength of the high-frequency field.

mining the geometry and stability of the filament. According to the basic equations of classical electrodynamics, all the current that flows in the plasma as a result of the driving force of the high-frequency electric field must flow in a thin "skin layer" at the surface of the plasma. At high frequency, the resistance of the layer exhibits anomalous behavior, increasing rather than decreasing with temperature, so that appreciable heating can take place in the surface region. (This is also a well-known phenomenon in the form of the anomalous high-frequency resistivity of metals.) If a fluctuation momentarily increases the filament cross-section, the density of surface current decreases and so does the heat energy deposited in the plasma. At the same time, more heat is able to leave the plasma through the temporarily enlarged surface area. Consequently, the plasma is cooled and the surface recontracts to its original size. The opposite set of processes occurs if the filament contracts, so that it is enlarged back to the equilibrium cross-section.

Finally, the size of the determined cross-section (the diameter of the filament) turns out to be the crucial quantity for the practicality of the filament phenomenon as a source of fusion energy. The theory that Kapitza and collaborators have developed for a controllable mechanism of ion heating (transferring energy from the electrons to the nuclei in the plasma via magnetoacoustic excitations) shows that the transfer of energy to the ions should increase with the square of the filament cross-section. (This heating thus goes up faster with size than does the cooling through the enlarged surface, which is only proportional to the filament radius.) Experiments so far have been with filaments too small to produce enough fusion neutrons to test this idea. In the work performed during the 1960s, for example, the filament radius was in the range 1.5 to 2.0 mm.

Is It Practical?

Kapitza thinks that this limitation can be overcome by scaling up the size of the experimental apparatus and the dimensions of filaments produced. In his 1970 reactor study, Kapitza found that the filament dimensions required for energy breakeven were a length of 650 cm and a radius of 65 cm. In a 1974 paper coauthored with L. P. Pitaevskii, "Plasma Heating by Magnetoacoustic Oscillations," Kapitza further calculated that a magnetic field oscillation with an amplitude of about 100 oersted (this is 1 percent of the strength of the static magnetic field) would be sufficient to provide a heating power adequate to balance the energy outflow and to maintain the heating of the ions.

At least two major theoretical questions remain about the practicality of the concept. First, what will be the final efficiency of heat transfer from the electrons to the ions via magnetoacoustic oscillations even under optimal conditions; that is, assuming large enough filaments can be produced in large, high pressure systems; and second, what other forms of complex collective interaction in the plasma will be effective for ion heating, and to what degree?

Kapitza's general outlook on this research was summarized in the conclusion to his 1970 paper: "The production and study of the thermonuclear process in the filament can, of course, also have a great practical significance for nuclear energy, but in addition to that a study of the filamentary discharge itself in which hot plasma exists continuously at exceptionally high temperatures and high pressures must lead to a deeper scientific understanding of a number of plasma processes."

The Methodological Issue

As for the more general implications of Kapitza's research, there are two positive features to his research method: First, the investigation of a series of basic plasma processes in order to solve the task-oriented problem of achieving controlled fusion; and second, the attempt to set up a succession of ordered states leading up to the conditions for sustained fusion ignition.

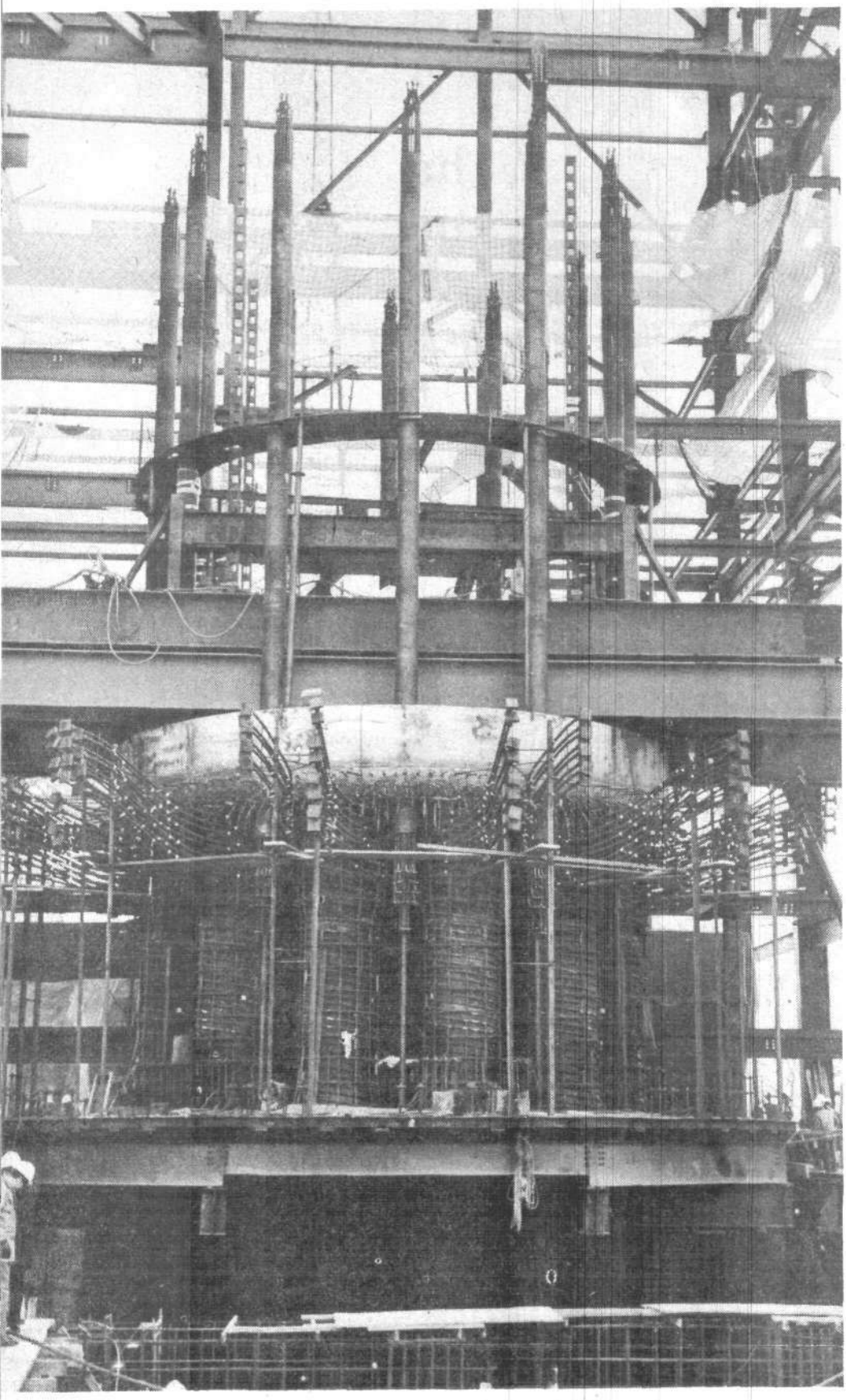
The problem is that Kapitza's conceptions have been limited to the inadequate models provided by kinetic and electrodynamic theory. Even these, however, point in the right direction—toward the study of the evolving organization of the plasma.

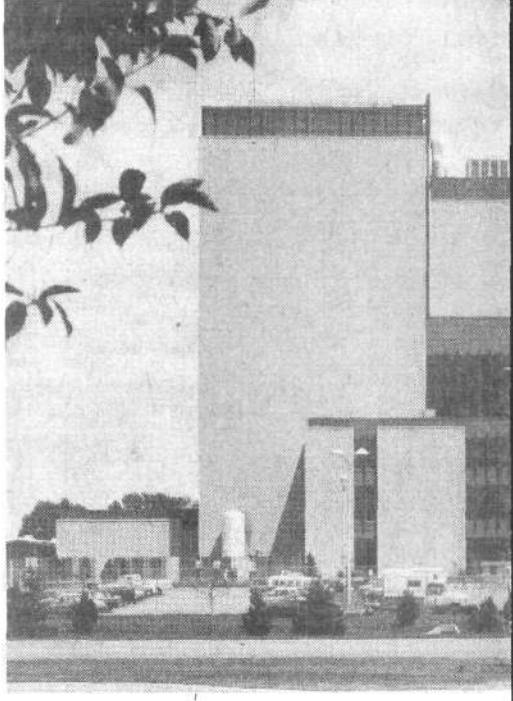
Kapitza is closest to this correct viewpoint when he takes the ostensible structure of the filament (density and temperature profile, and so forth), the variation of this structure with changes in the input microwave power and frequency, and the amplitude of the initial heating mechanism (magnetoacoustic oscillations) as parameters to be externally varied in order to then observe the effects of what he calls collective interactions in the plasma. If this is reconceptualized as the variation of certain "external" parameters in order to reconfigure the internal phase space geometry and organization of the plasma-as-a-whole, then one has the appropriate outlook for carrying through this research. This also can be thought of as defining a new minimal surface (a plasma geometry determined by the actual energy content), according to the "principle of least action," in the plasma phase space.

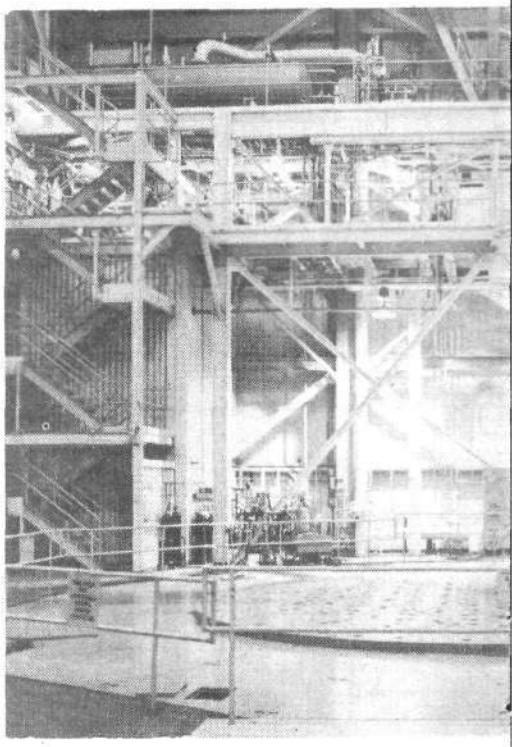
The idea is to search for that set of conditions or values of the indicated parameters that prepares the plasma for direct transition to a final configuration that is the desired ignition state. The beauty of Kapitza's research is that the parameters relevant to stimulating the desired kind of plasma transitions are so well-defined and directly subject to experimental variation and that the results can be observed with various types of diagnostics.

The Fusion Energy Foundation is inviting research groups in the United States who have access to the high-power microwave generators and other apparatus needed to pursue this research to consult with the FEF, with the aim of rapidly putting the United States in a leading position in this area of research. The pursuit of such a program would have two immediate benefits. Assimilation of the general methodological approach described above is indispensable to conducting any type of fusion research. Moreover, the specific phenomena under study in Kapitza's research undoubtedly are crucial elements of all other forms of inertial and magnetic confinement research.

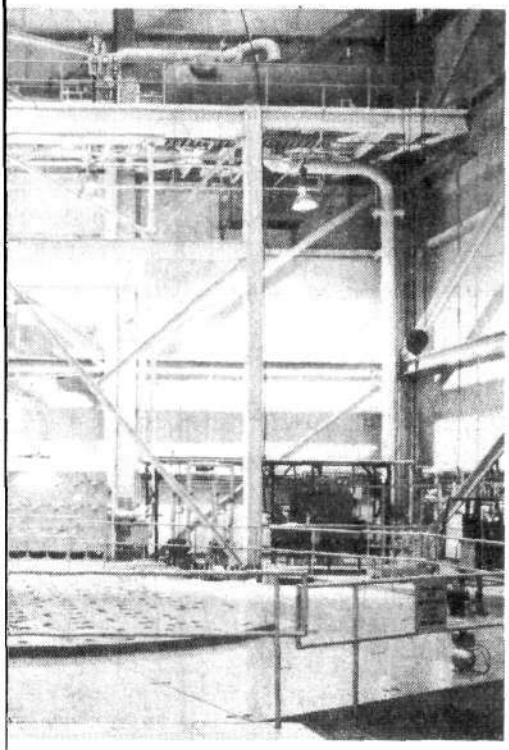
Morris Levitt is executive director of the Fusion Energy Foundation.

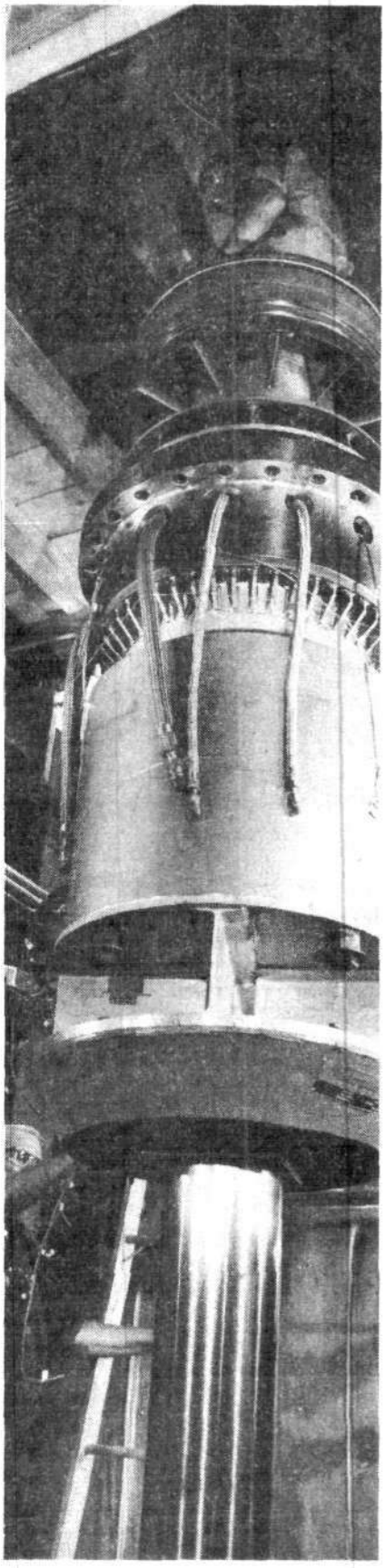






Left: The framework for the Fort St. Vrain steam generators and helium circulators. Center top: General view of Public Service Company of Colorado's Fort St. Vrain Nuclear Generating station near Plattesville, Colorado. Center bottom: Note the hexagonal seams that mark the edges of the fuel assemblies in this view of the





top of the HTGR reactor core. Right: The major new technology that had to be mastered for construction of the HTGR was the helium cooling gas recirculators and heat exchangers. This photo shows a hydraulic ram installing the helium recirculating mechanism.

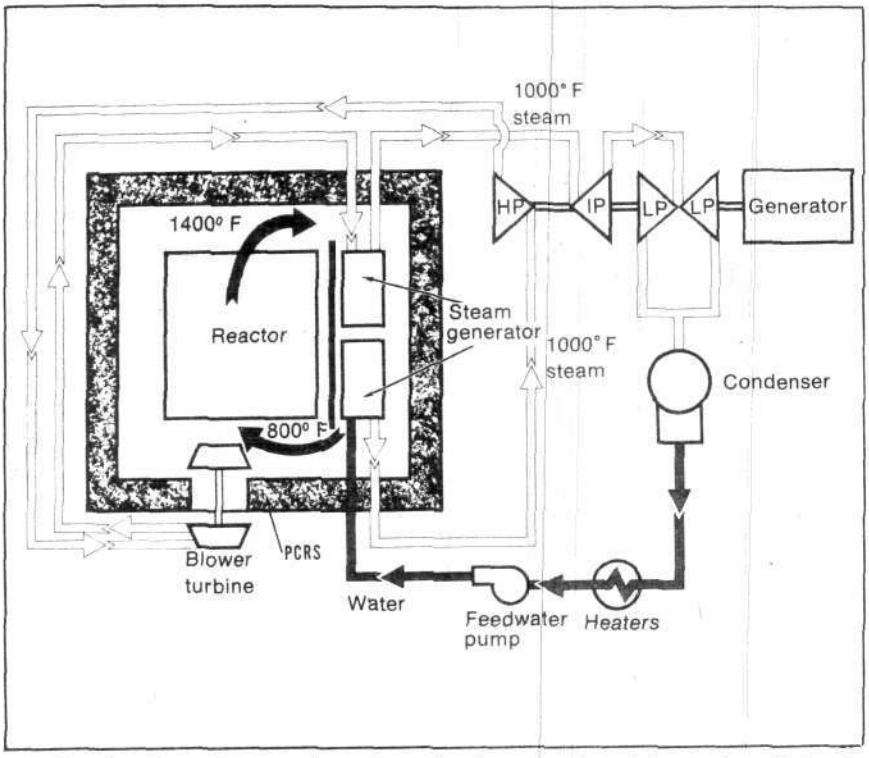
Photos by Public Service Company of Colorado

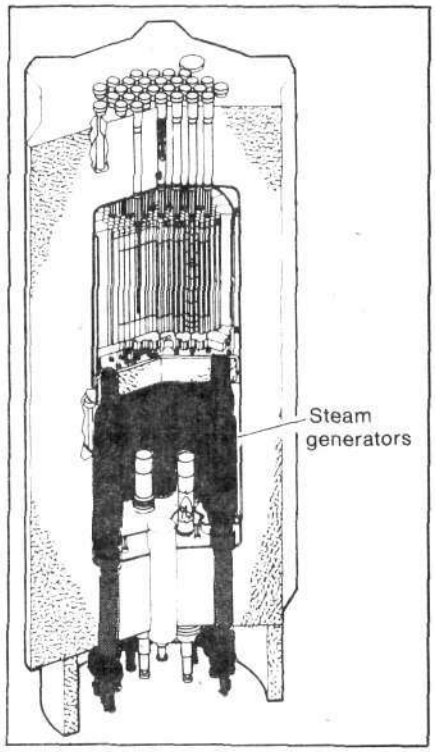
The HTGR: Today's Most Advanced Reactor

The first commercial-sized American high-temperature gas-cooled reactor (HTGR), the Fort St. Vrain Nuclear Generating Station in Colorado, may also have the distinction of being the nation's last HTGR. The projected elimination of funding for HTGRs in the fiscal 1980 budget by the U.S. Department of Energy means that the United States will not take this next crucial step in the development of nuclear technology. Prior to 1975, at least eight commercial-sized HTGRs were sold to U.S. utilities, but all these orders were later canceled. The Fort St. Vrain HTGR is thus the only commercial plant operating, producing 300 megawatts of electricity from high-temperature, steam-driven turbines.

The versatile HTGR, essential for nuclear steelmaking, has many advantages over conventional nuclear reactors:

- The thermal conversion efficiency for producing electricity is much higher for the HTGR than for conventional light water reactors—about 40 percent compared to 30 percent—since the HTGR operates at a much higher coolant temperature (up to 1,440 degrees Fahrenheit) and then uses chemically inert helium to transfer this heat to steam at 1,000 degrees. Since thermal efficiency is a measure of how much of the heat energy is converted to electricity, the HTGR can compete economically with the most advanced fossil fuel plants.
- Since more of the heat is used by the HTGR, it requires one-third less water to remove waste heat. In arid climates, such as that of Colorado, this smaller water requirement is critical to the





Left: This flow diagram shows how the heat produced by nuclear fission in the core of the HTGR is carried by helium gas at 1,400 degrees Fahrenheit to the steam generators, where steam is produced at 1,000 degrees. The steam then drives a turbine generator to produce electricity and the used steam returns to the steam generators for reheating. Right: This diagram shows the location of steam generators inside the prestressed reactor vessel of the HTGR.

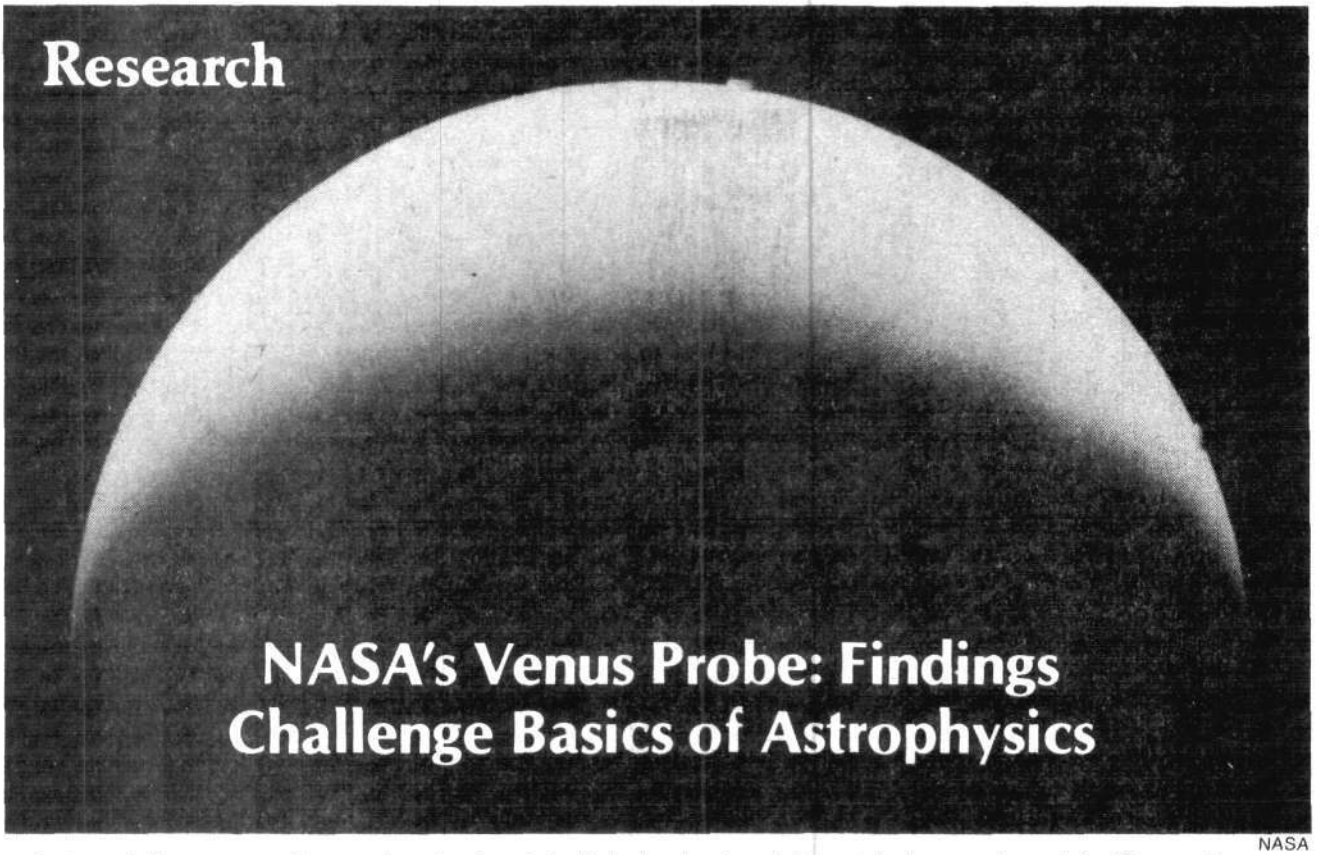
feasibility of nuclear energy. In other areas where cooling towers are used to dissipate waste heat, their size and thus capital construction costs are reduced by 30 percent for HTGRs, compared to equivalent light water reactors.

- The HTGR has less demanding fuel requirements than conventional nuclear reactors because it is able to convert more of the naturally occurring nonfissionable uranium into fissionable isotopes. In addition, the HTGR can also be used for efficient conversion of other fertile elements, like thorium, into nuclear fuel.
- Construction of portions of the HTGR is simpler in many respects than that of conventional nuclear reactors. Most notably, it uses reinforced, prestressed concrete reactor vessels.
- The HTGR is the most versatile fission reactor now on-line. Future versions will replace the steam cycle with a direct-cycle helium gas turbine, reducing capital costs by more than 10 percent. The HTGR will be essential in nuclear steelmaking because it can provide high-temperature process heat, high-temperature steam, electricity, or a combination of all three to any industrial process incorporated in the steelplex. Steel production, fertilizer production, synthetic fuel production, thermionic conversion of heat to electricity, and other technologies will all benefit from the HTGR's economical process heat.

Fort St. Vrain

The Fort St. Vrain HTGR, operated by the Public Service Company of Colorado, began construction in 1968 and generated its first electricity December 11, 1976. Since that time the plant has operated at 70 percent capacity, but has been impeded from tests at full power levels by rulings from the Nuclear Regulatory Commission. The commission refuses to allow the plant to be tested at higher power levels until certain unexplained temperature fluctuations in the reactor core upon start-up are explained. However, there is no evidence that these temperature fluctuations are dangerous.

The unique HTGR fuel assemblies use graphite hexagonal blocks that are filled with tiny pellets of a uranium-metal mixture that is essentially nonradioactive at loading time.



NASA's Venus Probe: Findings Challenge Basics of Astrophysics

NASA

A view of the crescent Venus taken in ultraviolet light by the cloud photopolarimeter aboard the Pioneer Venus orbiter Dec. 10, 1978.

In early December, the National Aeronautics and Space Administration began a series of precise technological maneuvers in an unknown territory—Venus. The results of the probes challenge the theoretical foundations of astrophysics.

The equipment aboard the Pioneer Venus orbiter and multiprobe spacecraft included an amazingly advanced display of precise miniaturized hardware: spectrometers, radiometers, temperature probes, a gas chromatograph, an interferometer to measure wind velocity, a nephelometer (cloud structure sensor), a gamma-ray burst detector, a magnometer, an electric field detector, an electron temperature probe, a retarded-potential analyzer for measuring plasma solar wind-ionosphere interactions, and a solar wind-plasma analyzer.

The advanced technology and findings of the Venus probes must serve not only as a reminder of the tremendous technological capacity used to create the U.S. space program, but also as a call-to-arms to save the program from being dismantled. (See the Washington section, this issue, for news of the administration plan to decorticate NASA.)

The Earth's Twin?

The space thrust of the late 1950s and early 1960s generated tremendous technological advances and totally revolutionized the scientific understanding of the character of Venus. Prior to a series of NASA Mariner fly-by measurements of Venus and a series of Soviet Venera probes of the Venusian surface and atmosphere, scientists had believed that Venus was much like Earth and called it Earth's twin. Superficially, by most Newtonian measures, the twin planets are remarkably similar. Venus is just slightly smaller in size, mass, density, and distance from the sun than Earth, and both planets are believed to have evolved at roughly the same time from a very similar composition of cosmic material.

Each successive space probe of Venus, however, made the planet more enigmatic. The combined Mariner and Venera series demonstrated that Venus is nothing like its habitable twin, Earth. The Venusian surface temperature is 900 degrees Fahrenheit (480 degrees Celsius), hot enough to melt zinc and to cause its surface to glow a dull red. Its atmosphere is 97 percent carbon dioxide and rather dense by Earth standards (90 atmospheres pressure). Circulating cloud patterns were demonstrated to be composed of sulfuric acid and sulfur particles.

In addition, even Venus's behavior as a Newtonian body was shown to be enigmatic: Venus lacks a substantial planetary magnetic field and rotates very slowly, retrograde: backwards from the rotation of other members in the solar system.

As space science generated an increased technological capacity to probe Venus directly, some scientists began to look at Venus as an oppor-

tunity, a sounding board to test the validity of many currently accepted theories. If Venus and Earth evolved at roughly the same time from a similar composition of cosmic material, their thinking was, such theories ought to be able to account causally for the immense difference in the outcome of the evolution of these two planets.

Shocking Discoveries

Preliminary analysis of the data from the current Pioneer Venus probes has confirmed and elaborated in detail many of the earlier, shocking discoveries of the Mariner and the Venera series that show Venus to be strikingly different from Earth. Furthermore, the current probes have tended to support the argument that this was not always the case.

For example, Pioneer Venus probes have resolved the question of whether Venus, like Earth, ever had any water. Results indicate that the Venusian atmosphere has 0.1 to 0.4 percent water vapor and 60 parts per million (.00006 percent) free oxygen, which supports the argument that Venus once had abundant water but lost it to ultraviolet photodissociation in the upper atmosphere.

Over a period of 4.5 billion years, this argument holds, the hydrogen split out of the water and escaped into space, and most of the oxygen combined with surface rocks (oxidizing them) and would now be found in Venus's crust. Both the preliminary Pioneer Venus radar mapping of the Venusian surface and earlier Soviet Venera 9 and 10 pictures of rocky Venusian terrains with different degrees of weathering support the thesis that Venus could have absorbed considerable free oxygen into its crust in the past 4.5 billion years.

In addition, the Pioneer Venus probe results indicate that the two twin planets have roughly the same amount of nitrogen in their atmospheres (taking into account density differences), and that Venus has the same amount of carbon dioxide in its atmosphere as Earth has tied up in its crust in the form of carbonated rocks.

The Pioneer Venus analysis of the Venusian atmosphere (98 percent carbon dioxide, 1 to 3 percent nitrogen, 0.00025 percent helium, 0.000025 to 0.00025 percent neon, 0.00002 to 0.0002 percent argon, 0.1 to 4 percent water vapor, 0.00024 percent sulfur dioxide and 0.00006 percent oxygen) appears to resolve the water question, but generates new problems. The Pioneer Venus probe found that Venus has 50 to 500 times as much primordial argon (argon-36, an isotope generated by fusion processes) and 2,700 times as much primordial (also fusion-generated) neon as Earth—a result that cannot be accounted for by currently accepted theories of planetary formation.

When the results were first transmitted back to NASA's Ames Research Center in California, Dr. David Black created an ad hoc variation in his recently completed thesis on solar system formation to account for the new data. Black now thinks that the inner planets—Mars, Earth, Venus, Mercury—may have been formed or at least partially formed before the sun ignited. This would allow these inner planets to trap varying quantities of inert gases, or allow the large rock masses that formed these planets to trap the inert gases.

It is assumed in this thesis that prior to the sun's ignition, the cloud of dust and gases differentiating into the solar system would have an even temperature gradient but more mass and gravitational forces toward the center. This, it is thought, would account for the observed differences between the quantities of primordial inert gases that exist on Venus, Earth, and Mars.

But the fluctuations between the gas chromatograph argon-36 reading and the three mass spectrometer argon-36 readings on different Pioneer Venus probes have left most scientists very uncomfortable over the Pioneer's argon-neon results.

Clues to Earth Meteorology

Since the Earth's meteorology is complicated by the Earth's axial tilt, rapid planetary rotation, mixing between continental and oceanic air masses and partial cloud covers, scientists are using Venus's lack of oceans, very slight axial tilt, and very slow rotation to test the validity of current meteorological theories.

This opportunity did not exist until the Venus probes, because the atmosphere of Mars, the subject of earlier probes, is too thin to develop complex weather patterns.

Thus far, the current meteorological theories are holding up rather well, generating a picture of Venusian weather circulation in which the atmosphere rises in the equatorial regions and redescends in a highly visible (through the changes in cloud layering) polar atmospheric vortex over both of the Venusian poles.

Smaller-scale convection cells in certain layers of the atmosphere are now under intense study, as are the 200 miles per hour globally circulating winds. These winds apparently keep the heat distributed evenly in Venus's upper atmosphere, despite the fact that it takes more than 58 Earth-days for a point passing out of the sunlit side of Venus to rotate through the night side and back into the sunlit side.

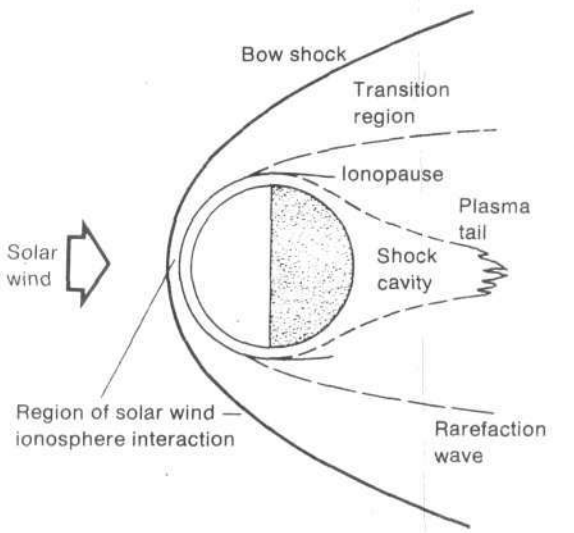
Solar-Wind Ionosphere Interactions

Equally intriguing, the Pioneer Venus found a far more powerful interaction between Venus's ionosphere, its ionized-plasma outer atmosphere, and the solar wind, a highly ordered beam of plasma emanating from the sun.

Venus, which has very slow retrograde rotation, has no apparent planetary magnetic field. Therefore, it has no magnetosphere to hold the solar wind back from direct interaction with the upper layers of the Venusian atmosphere. Pioneer Venus probes found that the region between the bow shock wave generated by the solar wind's impact against Venus and the top of the Venusian ionosphere (the ionopause) varies in width at the nose of the bow shock wave from 250 kilometers in periods of intense solar flare activity to 1,500 kilometers in quiet periods.

This is a more compact region than the comparable region on Earth, because the Earth's magnetosphere prevents its solar wind bow shock wave from interacting as closely with its atmosphere.

In the region where the solar wind bow shock wave interacts directly with the Venusian ionosphere, solar plasmas are exceedingly turbulent. Temperatures reach a million degrees, many times the comparable temperatures of corresponding interactions on Earth, and strong magnetic fields are



This sketch shows the bow shock where the solar wind is slowed down by the atmosphere of Venus. Behind the planet is a cavity and a plasma tail.

NASA

Orbiter photo of cloud circulation pattern on Venus.

generated at the top of the ionosphere.

There is an unanticipated, highly ordered boundary, called the ionopause, between the solar-wind plasmas and the Venusian ionosphere plasmas, for which Earth has no equivalent. By unknown mechanisms, energy from the solarwind plasmas penetrates below this ordered ionopause boundary, heating the atmosphere to what the Pioneer Venus probe measured as electron temperatures of 5,000 kelvins—a full 4,000 kelvins above the anticipated electron temperature for the upper ionosphere.

For unexplained reasons, the Venusian ionosphere is maintained in its ordered plasma form during the Venusian night, which lasts for 58 Earth days. In contrast, the Earth's ionosphere differentiates into a three-layered structure during the day and dedifferentiates during the night (increasing radio transmission).

Significance of the Venus Results

The crucial methodological flaw that dominates much of currently accepted astrophysical theory can be seen in the difficulty such theories have in explaining the fusion-generated argon (and the fusion-generated neon) results, in explaining the formation of the solar system from an ordered, differentiated cloud of plasma and cosmic dust, and in explaining the evidence of plasma ordering that reveals itself when solar-wind plasma structures interact with various planetary ionosphere plasma structures.

Most of astrophysics approaches stellar and planetary evolution as if each planet or star were some oversized test tube, a chemical system dominated by certain radiation and temperature regimes and governed fundamentally by Newtonian mechanisms. This means that astrophysics looks at a universe that is known to be composed of more than 99.5 percent ordered plasma from the standpoint of the most superficial characteristics of the behavior of that 0.5 percent or less of matter on Earth that superficially appears most unplasmalike.

The problem is worse than examining the universe through the wrong end of a telescope. Why should 99.5 percent or more of matter in the universe be dominated by complex interactions of highly ordered evolving plasmas, and 0.5 percent or less matter be dominated by Newtonian mechanisms? Is the Earth effectively a separate universe with separate laws?

There is rigorous evidence indicating that although matter on Earth is highly differentiated into discrete geometries, its microphysics—its physics on the submolecular and subatomic level—is that of interacting highly ordered plasmas. Most of physics has remained blind to this lively negentropic quality that matter on Earth shares with all other cosmic organizations of matter; physics has focused on studying the more homogeneous, simple, fieldlike plasma states that laboratory experimentation can produce.

The Venus probe reminds science not only that present astrophysics is inadequate, but also that the entire approach to space and matter needs to be rethought rigorously from a more advanced standpoint. And that process and its technological fruits cannot be realized unless the fusion and space programs are continued and expanded.

—Carol Cleary, Tom Evans, and Wayne Evans

Korean Nuclear Sale

Continued from page 21

In that kind of exercise, you will find we will have to have something close to 40 nuclear power stations by the year 2000. Whenever we say 40 units, then people get really surprised and ask how you can afford 40 units. And my answer is if our economy demands 40 power stations, then certainly we will be able to afford 40. It pays for itself. It is a matter of the general economy leading and power supply following.

As you know, our projection is that the economy will probably grow at a rate of 10 percent for the next 10 years or so and then slightly less than that, but the forecast is that the economy will certainly maintain the momentum of growth for the next 15 to 20 years.

And if that is the case, certainly we will need a lot of power. And if we need a lot of power, we will have no choice but to rely on nuclear rather heavily. Our blueprint shows that perhaps something like 60 percent of power supply will have to be met by nuclear power, by the year 2000.

U.S. NUCLEAR POLICY

Question: Have you pretty much dropped the idea of obtaining fast-breeder technology, which you tried to obtain in 1973?

Right now our position is not so much to develop nuclear technology ourselves. We are thinking we will leave that and development of fancy technology to somebody who can afford it. We will just buy it as it is developed, as we have done. . . .

Question: Are you somewhat confused by the seeming lack of understanding in Washington that countries like yours have no choice but to move into nuclear power generation? U.S. policy does not seem to be in line with this.

I am neither confused nor bewildered by the American policy. But we certainly would like to present our position; namely that the United States, with all kinds of energy alternatives, can afford to neglect nuclear and go to coal or oil if it would like to. But in our case, as I said before, we don't have a choice.

Since energy is really the basis—well, the energy for industry and the economy as a whole—if you don't have sound and continuous supplies of energy resources, then you cannot very well plan your economy. When we say we have to have nuclear power stations, we really mean that.

But we think the kind of policy America is pursuing these days is thinking behind the implications—that is, once you go into nuclear technology, then one of these days you are bound to develop a nuclear weapons system. Well I don't know if this is actually the case, that one really follows the other. It seems to me it really doesn't have to.

You can take our position honestly, and right now you have very exact checking systems. As it is, we cannot move one bit of enriched uranium without being checked by your authorities. If you maintain this kind of checking system in the future, then I don't see why we should be so concerned about the technology being misused elsewhere. . . .

And there, we understand that the fast-breeder type reactor is very suitable. And if that is the case, then surely we are all for that. The world has always followed the latest and most up-to-date technology, and I don't see why we should have an exception in this field, particularly when it involves the very crucial energy problem.

Schlesinger Fuels Crisis

Continued from page 23

impact of the loss of some 5 million barrels per day of Iran export. Kuwait and Iraq have added an additional 1 million barrels to this.

Further, the official reported that the major oil companies had accumulated more than 100 million barrels in "excess floating stock," stored in tankers at sea in anticipation of a price hike by the Organization of Petroleum Exporting Countries. Companies stockpiled before the price rise by filling tanker fleets with the cheaper oil, shipping it at greatly reduced speed, and allowing it to be landed after the implementation of the Jan. 1 OPEC price rise.

In addition, the official said, the first quarter of the year is usually a low oil-buying season because stocks for the winter are built up by the previous quarter.

The United States gets only 5 percent of its total oil from Iran, a far smaller share than West Germany, Japan, or Israel, which get almost 60 percent of their oil from Iran. The crisis scenario revolves around the 19-nation oil-sharing agreement, created in the wake of the 1973-1974 oil embargo by then secretary of state Henry Kissinger. Under this agreement, which created the International Energy Agency, the United States will have to supply a major portion of other nations' oil shortfall in the event the emergency agreement is triggered by any member.

In his press conference on the Iranian situation, Schlesinger added that a strike by the 60,000 members of the national Oil, Chemical, and Atomic Workers union (OCAW), which is likely to occur when the national contract expires Jan. 7, could be "quite serious." The expected strike would affect the majority of the nation's oil refineries.

Oil company spokesmen cite President Carter's imposition of 7 percent wage hike ceilings as the major cause that might prevent a settlement. If a strike occurs, it will be the first such strike on a national basis. Although industry spokesmen have said that the impact of the strike will be negligible because of the ability of supervisory personnel to keep production at the plants going, press reports are bringing up the possibility of sabotage of facilities.

Although he has no direct role in these wage talks, Schlesinger has made an 11th hour move that can only aggravate the situation. The DOE called a press conference Jan. 5 to charge nine of the nation's largest oil companies with overcharging customers for natural gas liquids by $1 billion. One oil company spokesman, furious at the Schlesinger move, said that the press had been notified before the DOE informed the companies of the charges and gave them time to reply.

— William Engdahl

Sweden Conf.

Continued from page 14

one or more nuclear plants that would serve as educational and cultural centers for bringing agricultural populations into the nuclear age.

Mass Production of Nuclear Plants

"We must build at least 3,000 nuclear power plants by the year 2000 to raise the living standards of the world population," said Dr. Jonathan Tennenbaum of the FEF in the next presentation, "and that means assembly-line production." Tennenbaum proposed the revival of the old concept of *Örestad* — an integrated supercity encompassing the Danish city of Copenhagen and the Swedish city of Malmoe (which now face each other over a narrow body of water) — as an industrial center for the mass production of nuclear technology.

Floating nuclear plants produced in *Örestad* could then be sailed directly to coastal sites in the Third World to become the centerpieces of nuplex cities, Tennenbaum said. He pointed out that present attempts by environmentalists to destroy the nuclear industry in Sweden and elsewhere represent a mortal threat to the lives of millions in the developing sector, as well as to their descendants. "Without nuclear power, these people have no future," Tennenbaum said.

As for how this vast nuclear development will be financed, Clifford Gaddy, the Stockholm desk chief of the *Executive Intelligence Review*, explained that "just as the growth of the world economy requires new energy technologies such as fission and fusion, financing global economic development necessitates new technologies for financing. The present International Monetary Fund is obsolete, which is why the new European Monetary System is being introduced."

Gaddy stressed the importance of a scientific approach to the question of financing, and outlined how the EMS must be developed further into a gold-based, two-tier credit system that provides massive, long-term credits at low interest rates for development projects in the Third World.

The conference session on fission technologies included presentations by Dr. Jan Rydberg and Dr. J. O. Liljenzin, both of the Institute of Nuclear Chemistry at Chalmers Technical University in Gothenburg, Dr. Per Persson of the Institute for Reactor Technology at the Royal Technical University in Stockholm, and Steelan Hamrin of the FEF. The speakers detailed the full fission fuel cycle that must be developed on a world basis in the course of the next decade. This cycle would include the liquid-metal fast breeder, the high-temperature gas-cooled reactor (HTGR), and complete reprocessing and utilization of fission waste products.

On the much misrepresented question of nuclear waste, Liljenzin explained that most of the fission waste products can be converted into important raw materials for industry, and radioactive waste is potentially more valuable than many ores mined today: "If we bury our nuclear waste today, our children and grandchildren will be digging it up tomorrow."

The Rydberg presentation on "Why the World Needs Nuclear Power" then

opened up an extended discussion of the question of zero growth. Rydberg began by making a rigorous scientific presentation showing that the need for further development of nuclear energy is not a matter of opinion but of scientific certainty. As proof, Rydberg outlined the basic categories of consumption required for a population to have high living standards: food, shelter, health care, good working conditions, free time, travel, and so forth.

Using graphs, Rydberg then demonstrated how energy consumption would have to rise in order to bring the entire world up to this standard of living. This quantity of energy growth, Rydberg said, could be produced only by nuclear power. Furthermore, he said, the world would have a rapid exponential growth in consumption and population until the year 2050, at which point the curve on his graph (an "S" curve or "logistic" curve) would level out.

The Zero-Growth Question

At this point, Rydberg declared, "all reasonable material requirements of humanity would be fulfilled" and zero growth would be possible and necessary since "obviously exponential growth cannot continue indefinitely."

FEF representative Bandmann, among others, objected to this last point. "We must be very careful about scientific methodology," Bandmann said. "The 'S' curve you used is well known in the analysis of a single given technology; such technology is gradually developed, then used massively until it finally becomes obsolete. However, when we consider the world economy as a whole, we have to recognize that the basic process is technological development and the continual, accelerating supersession of old technologies by new technologies. Exponential growth arises by the succession of 'S' curves — a process that corresponds to the evolution of higher forms of life in the biosphere through the exponential growth of energy throughput."

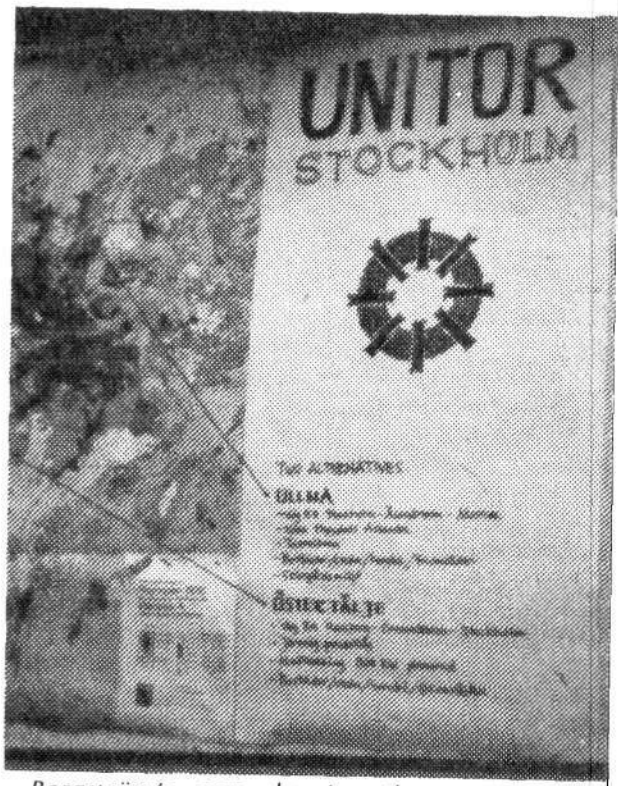
Another scientist countered Bandmann saying that technology growth "pulsates," using as an example of this ebbing and flowing the fermentation process in wine-making. To this FEF member Tennenbaum replied that unlike that wine, human society isn't confined to a bottle. "With fusion power we can colonize other planets and other galaxies; and if and when we populate all of the galaxies, we will make the universe larger to make room for human beings and further development."

There was further discussion of how the human mind must also grow to correspond to this expansion of human technological mastery of the universe. One trade unionist noted how the youth of today are losing the idea of progress under the influence of political zero-growth environmentalists.

An example of how to counter this zero-growth demoralization of youth, however, was constantly before the conference participants because of the presence of 13 members of the Organization for the Development of Nuclear Power, an active group including many high school and university students who had helped to organize the FEF conference.

Leading off the session on fusion research and development was the FEF's Ralf Schauerhammer, who gave an overview of the state of fusion research. Next, Jan Bergström, first research engineer of the Institute for Fusion Research at the Royal Technical University in Stockholm, and one of the top planners of the European fusion effort, gave an insider's view of the planning and construction of large fusion experiments such as the JET (Joint European Torus) experiment now being built in Culham, England as a joint fusion effort of the European community.

Stressing the unique potential of fusion technology for the development of industry, Bergström called for the construction of the proposed fusion prototype reactor, the Unitor, in Stockholm as a joint venture of the United States, Japan, the Soviet Union, and Western Europe. One industrialist present commented that Unitor, which is under the aegis of the United Nations International Atomic Energy Agency, should be located near industry and a large power grid such as Stockholm's so that the commercial application of the fusion energy generated could be immediately tested.



Bergström's map showing the proposed Stockholm site for the Unitor

The implications of fusion energy for the revolutionary development of science and industry were developed by Bergström and others in this session on fusion research and development.

The "Science of Fusion," a presentation by Dr. Steven Bardwell, director of plasma physics of the U.S. FEF, concluded the fusion session. "In plasma physics we have before us the most fundamental processes driving the universe," Bardwell said. Contrasting the false Newtonian view of the universe as an aggregate of "elementary particles" to the paradoxical self-organizing vortex phenomena of high-energy plasmas, Bardwell explained that the key to mastering fusion energy is the fundamental insight that the laws of the physical universe are developing according to the same invariant principle as the human mind.

The Bardwell presentation was followed by a wide-ranging debate among the conference participants on basic scientific method and the moral issues posed by the necessity of technological progress.

—Jonathan Tennenbaum

Two Fusion Exclusives

Fusion Energy Foundation representatives were on hand at two spectacular fusion events at the close of 1978—the provocative Nobel Prize lecture of Soviet fusion scientist Peter L. Kapitza in Stockholm and the startling Soviet proposal for international laser fusion collaboration at the 12th European laser fusion conference in Moscow.

Both exclusive stories are featured in this issue. Dr. Morris Levitt reports on the "third way" to fusion that Kapitza described in his Stockholm speech, reviews the Nobel Prize winner's theoretical and experimental work in fusion, and challenges U.S. fusion scientists to develop the important implications of Kaptiza's theory.

And Charles B. Stevens and Dr. Steven Bardwell give a first-hand report of how the Soviet Union's other Nobel Prize fusion scientist, Nikolai Basov, astounded the fusion community at the December fusion conference with a proposal for international collaboration on laser fusion. In a field dominated by military classification, political manipulation, and some of the most exciting scientific developments of the century, the Basov proposal is shaking up political and strategic perceptions internationally.

The cover: On the front cover is the beam alignment device for the Delphin laser at the Lebedev Physical Institute in Moscow; above is Kapitza (third from left) with other 1978 Nobel Prize winners in Stockholm, Dec. 8. Cover design is by Christopher Sloan. Both photographs are courtesy of Dr. Steven Bardwell.