# FUSION

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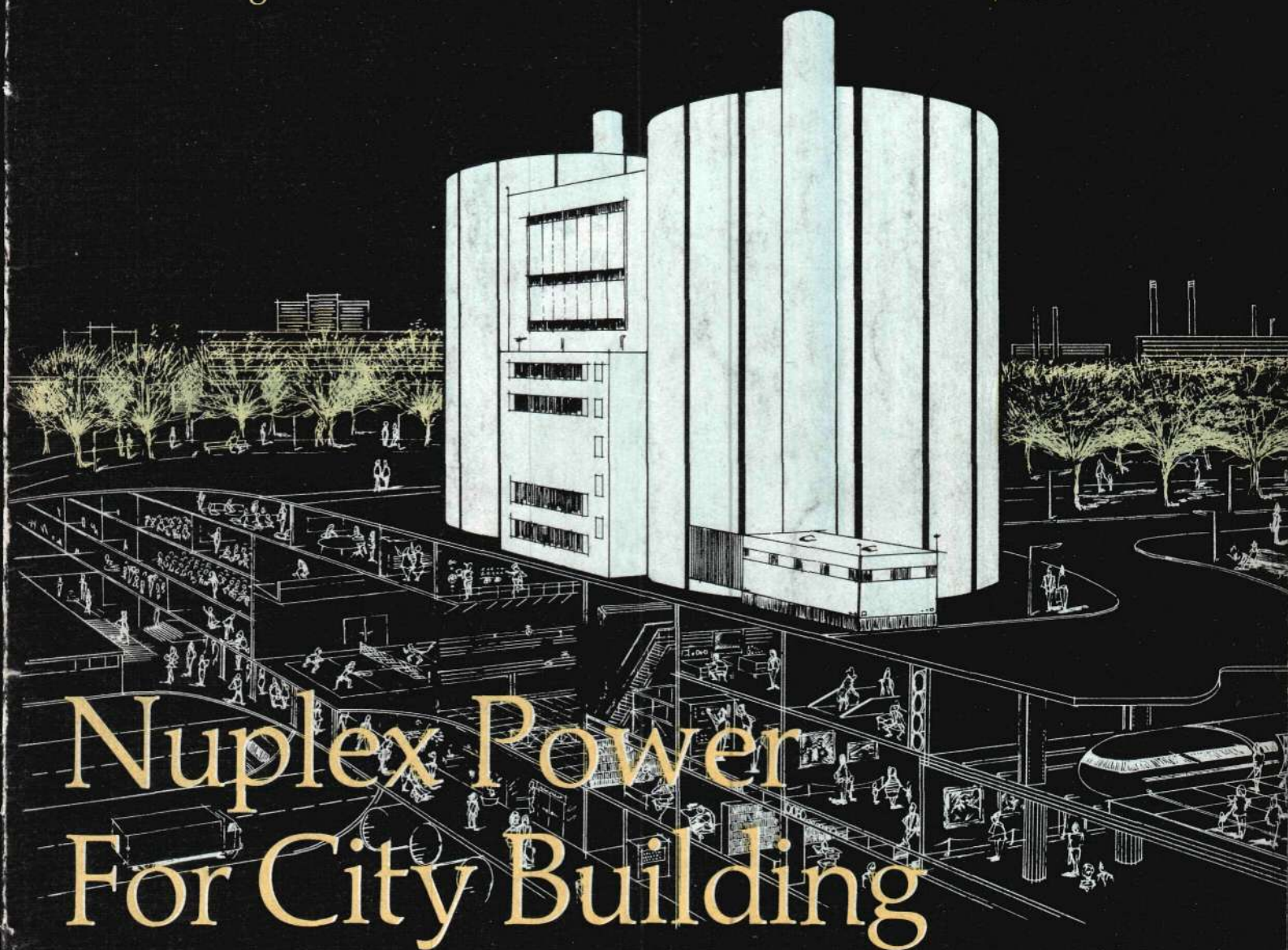

# Nuplex Power For City Building

- *There Is No Cancer Epidemic*
- *The Current Status of Fusion Research*

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# Features



# Special Report



# News



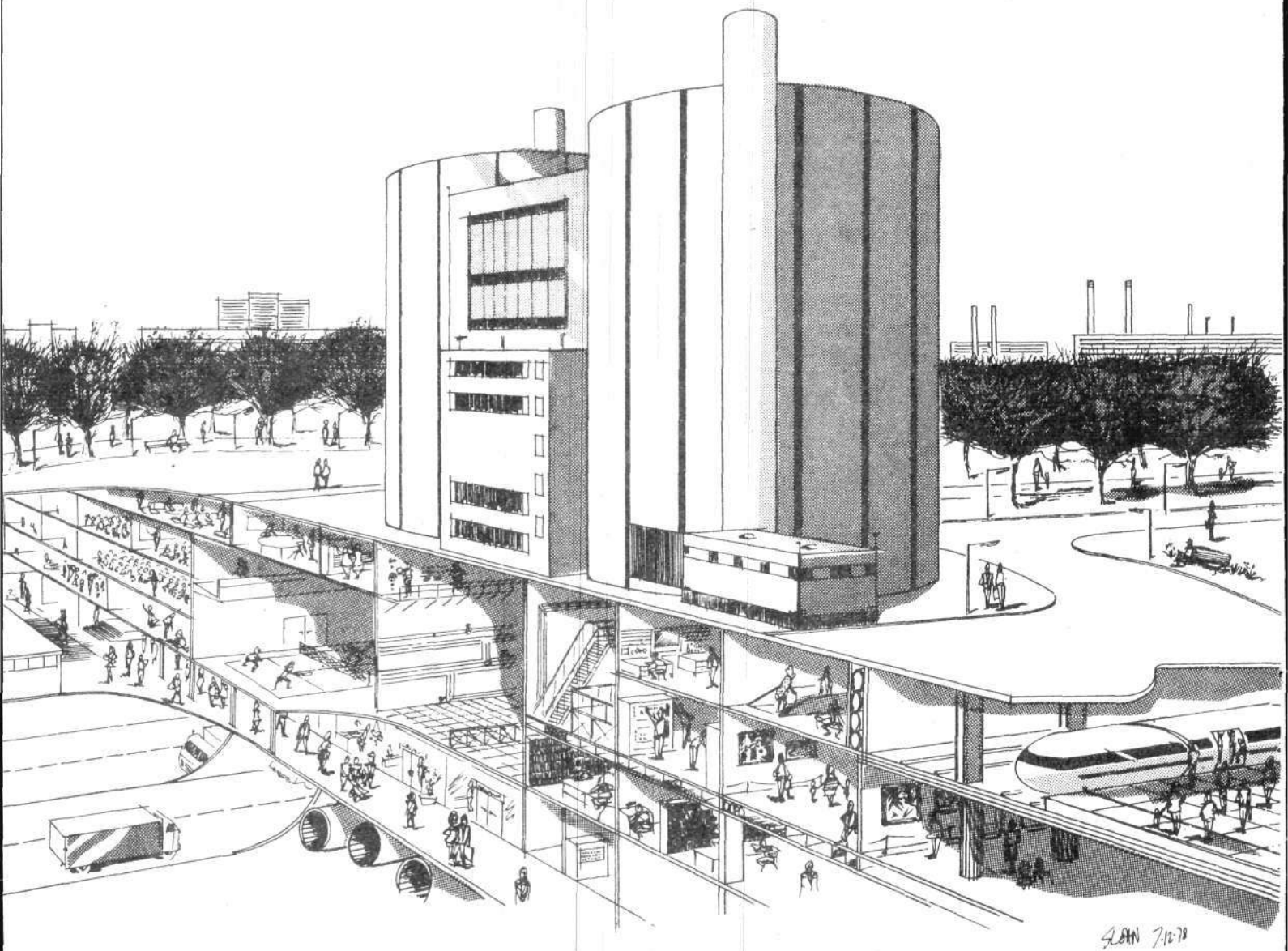
# Departments

# Editorial

# The Grand Design

Fortunately for the human race, there have been many periods of history when a humanist political faction forced peace on the world by pursuing a Grand Design—*a plan to guarantee prosperity by building cities, trade networks, and development projects and by encouraging the best possible science and technology.* These Grand Designs were inspired by a passion for human development, a passionate commitment to build the institutions that would ensure the best cultural and material conditions then and in the future.

Today's Grand Design is similarly inspired. The political forces, most notably the West Germans, the French, and the Japanese, are determined to force world peace by implementing the most massive global development program ever



conceived. There are plans to desalinate enough water to irrigate enough cropland to produce enough food to feed the entire world; plans to use high technology to extract and process the world's chemical and mineral resources to feed the light and heavy industries that will house and clothe the world; and, most important, plans to build cities as cultural centers to educate a population to the level where it can develop and carry out the Grand Designs of the future.

To change the face of the earth as these political leaders intend, to make the earth man's garden, requires the vast energy resources of nuclear power. That is why the building blocks for the Grand Design will be nuplexes, agroindustrial complexes that use the electrical grid and heat source provided by one or more nuclear plants. As the cover depicts, these nuplexes will be the core of the hundreds of cities the Grand Design will create throughout the world.

The far-reaching proposals worked out at the Bonn, West Germany meeting of Western heads of state this month and the commitments made by the Europeans and Japan at an economic summit meeting in Bremen, West Germany in June are the political and economic foundation for this Grand Design. Massive trade deals and technology transfers, a new monetary system that will safely cage the predatory World Bank and International Monetary System, and an unequivocal commitment to nuclear development to meet expanding energy needs are the beginning of the construction process. As for the future, West German Chancellor Helmut Schmidt summarized this spirit of progress in words not heard enough around here: "We have to look for new products, new inventions, new goods, new capacity, and, above all, new markets."

**The U.S. Move**

Not since the Atoms for Peace plans initiated by President Eisenhower in his memorable 1953 speech to the United Nations has the United States been in a position to guarantee its own prosperity and that of the world by becoming part of a Grand Design. In addition to the political developments pushed forward by such nations as Japan, West Germany, Mexico, every day there are new reports of technological and engineering breakthroughs at the frontiers of science—especially, fusion energy—that make the U.S. contribution to the Grand Design so critical. The United States has the technology and the manpower to perfect the nuplex, to mass produce it; and the United States desperately needs the resources proposed by countries like Japan to get the job done.

The greatest danger we face is that the Carter Administration will punt or fumble and not make the political commitment to go forward with the Grand Design. Unfortunately, the precedents for fumbling are all too many, especially in the case of nuclear fission and fusion.

Twenty-three years ago, the Indian theoretical physicist Dr. Homi Bhabha told the United Nations Conference on Peaceful Uses of Atomic Energy meeting in Geneva that one day the use of atomic energy released by the fission process might be regarded as a primitive form of energy. "It is well known that atomic energy can also be obtained by a fusion process, as in the H-bomb," Bhabha explained. "The technical problems are formidable....I venture to predict that a method will be found for liberating fusion energy in a controlled manner within the next two decades. When that happens, the energy problems of the world will truly have been solved forever, for the fuel will be as plentiful as the heavy hydrogen in the oceans."

Bhabha, like many others at the August 1955 conference, was inspired by President Eisenhower and his Atoms for Peace policy. Like Eisenhower, he understood how nuclear power developed to its fullest potential in a Grand Design could bring his nation and the rest of the world out of misery and into an almost unimaginable era of unlimited energy.

Yet, the United States fumbled. Although the nuclear industry developed to the point where mass production was possible, and although fusion research in this country managed with paltry funding to solve those formidable technological problems with fusion, the nation still has not carried through the Atoms for Peace promise of the 1950s to make the fruits of nuclear energy and fusion power a world reality.

This year it can and must.

# Calendar

**August**

1-10
International School
of Subnuclear Physics: The New Physics
Erice, Italy

7-11
6th International Conference
on Heat Transfer
ASME
Toronto, Canada

20-25
13th Intersociety Energy Conversion
Engineering Conference
ANS,ACS, ASME, IEEE, AIAA
San Diego, Calif.

20-25
17th Int'l Symposium on Combustion
Combustion InstitutePittsburgh
Leeds, University
Leeds, England

21-24
2nd World Hydrogen Energy Conference
International Association
for Hydrogen Energy
Zurich, Switzerland

23-30
7th Int'l Conference on Plasma Physics
and Controlled Nuclear Fusion Research
IAEA
Innsbruck, Austria

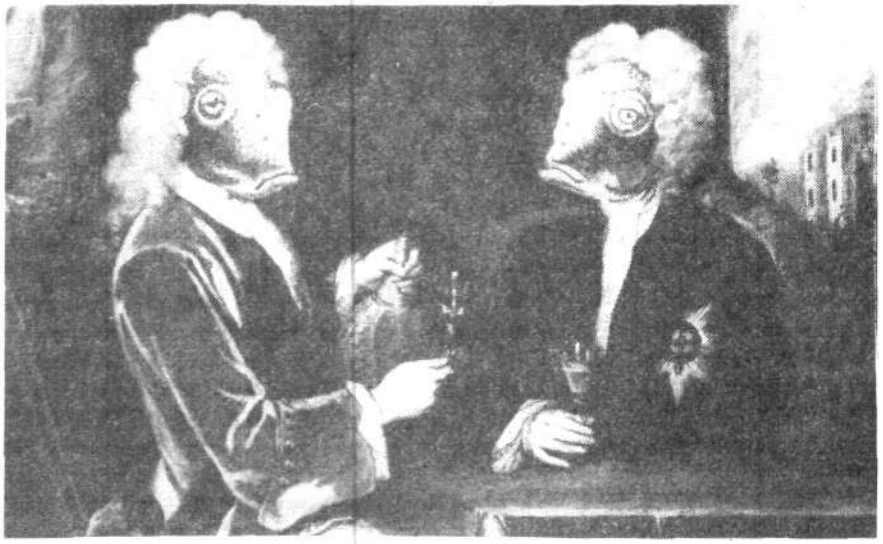
23-30
19th Int'l Conference
on High-Energy Physics
Tokyo, Japan

23-29
15th Int'l Conference
on Low Temperature Physics
Grenoble, France

24-30
8th Int'l Conference on Few Body
Systems and Nuclear Forces
Graz, Austria

Readers are invited to submit calendar events to Calendar, c/o *Fusion*, P.O. Box 1943, GPO, New York, N.Y. 10001.

# The Lightning Rod



My dear friends,

I fear you may think we turned into one of those dyspeptic public growlers who crowd the columns of our press disparaging all things current—and all hopes of man's improving them—so filled have my recent letters been with reports of foibles and asininities perpetrated by our nation's Government and people. To do so, I assure you, would be wrong and slanderous. Never have I imagined that mere recognition of the foolishness of others could make a man wise, wisdom being necessarily derived more from knowledge of the truth than a familiarity with falsity.

Nonetheless, our Reason is beseiged daily by circumstances whose only possible refrain is "The World Turned Upside Down," where men's actions seem guided by the sort of nursery daydreams that trumpet the steers' triumph over the butcher shop and the wily vegetables' defeat of the harvesters—for it is into this child's world that the environmentalists are marching us.

The case of the snail darter is exemplary. Here we are confronted with a 3-inch perch whose puny existence could not capture the imagination of an 11-year-old rod and reeler. Yet the judges of the nation's most elevated bench solemnly deliberate the fish's rights, judiciously balancing the snail darter's well-being against that of the interloping humans looking to replace him with a hydroelectric dam.

Nature gave to all her creatures instruments of protection. Talons and beak were evolved by the eagle, claws and sharp teeth by the lion, fangs by the snake; some say intellect by man. For the snail darter, Nature evolved the environmentalist movement, wisely anticipating the upcoming court battles.

### The Gene Pool

This unusual evolutionary history has made preservation of the snail darter species essential to the wretched European aristocracy, our former rulers who have spent centuries similarly colonizing and preserving populations of the human species—lest any unsightly industrial or agricultural inventions destroy their quaint, rustic environments. Representative of their concern is a recent eloquent sermon appearing on the *New York Times* editorial page which warns the following:

> Man should not lightly extinguish species that may one day yield products or information important to science and medicine and whose very presence enriches the world's pool of genes.

Although I consider unlikely the highly publicized reports that members of the English peerage are at this moment attempting to produce offspring from union with this small creature, these oligarchs have long taken responsibility for breeding the "world's gene pool." (The undoubted association in the rear of the minds of the *Times* editors, however, is with the brackish, still pool—backwater swamp, actually—that provided a home for this otherwise unneeded differentia in the first place.)

And given the evidence at hand, there can be no doubt but that the snail darter *is* busily enriching the world's genes—for why else would our Supreme Justices have decided this fish's dumb existence more important than the continued progress of man?

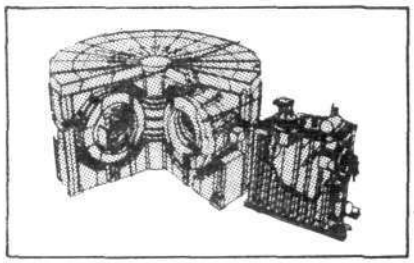
Our President has distinguished himself for his commitment to Human Rights throughout the world's nations. Am I wrong to spot the irony when our national policy sanctifies the fixed, imperfectible existence of insignificant flora and fauna over man's human right to develop and perfect his world for the betterment of all posterity? Is it not the same for the remaining victims of the oligarchs' colonial system? Do not their human rights begin with the right to industrial and agricultural development, advanced technologies and nuclear energy to effect the betterment of themselves and their nations?

The sanctity of human progress was certainly the spirit that moved us in establishing our Republic. It is immoral idiocy to dream of returning to the feudal bacchanal where the sheep and the shepherds comingle for the amusement of a few lords and ladies.

Yr. Obdt. srvt.,

*Benj. Franklin*

# News Briefs



*The Princeton PLT*

### IMPORTANT TOKAMAK BREAKTHROUGHS NEAR

Initial reports from the Alcator at the Massachusetts Institute of Technology, the Princeton Large Torus, and the fusion engineering group at the University of Wisconsin indicate that important fusion breakthroughs are near in several areas.

The Wisconsin research team, headed by Dr. Robert Conn, announced that simulated results from the latest in the series of UMAK tokamak conceptual studies, the NUMAK, show that fusion reactors can be built for capital costs about the same as those for conventional fission reactors. The NUMAK work has resolved most of the technological problems in tokamaks. In particular, the NUMAK research solved problems in remote maintenance and continuous energy output, and developed a system for modular construction.

Initial results on the Alcator indicate some success in lower hybrid microwave heating. Even better results are expected once a new power system is hooked up. The Alcator recently acquired a 7-megawatt microwave power supply from an old early warning radar system discarded by the U.S. Air Force.

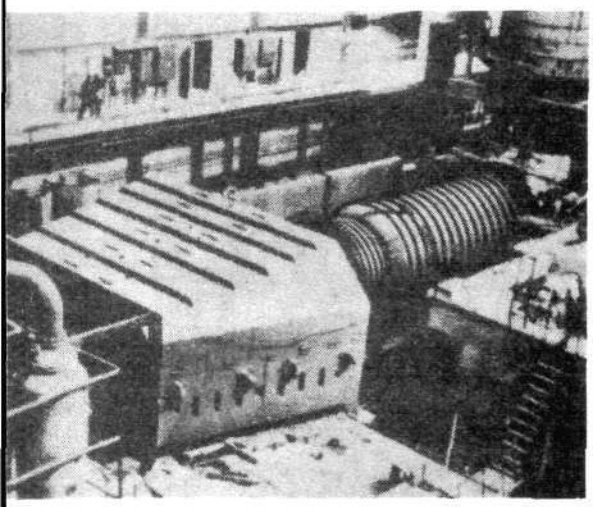
At Princeton, the PLT team reports good results with high power neutral beam heating after a short warm-up period to break in this new system.

### BONN SUMMIT SPURS NUCLEAR DEVELOPMENT

The final communique of the seven-nation Bonn summit meeting strongly endorses the development of nuclear power and stresses that the United States will not interrupt the supply of enriched uranium. Point 11 of the statement reads in part: "The further development of nuclear energy is indispensable, and the slippage in the execution of nuclear power programs must be reversed. . . . The [U.S.] president intends to use the full powers of his office to prevent any interruption of enriched uranium supply and to ensure that existing agreements will be respected."

In the wake of the Bonn push for development, Mexico has gone on the energy offensive. Mexican Foreign Minister Santiago Roel announced after a meeting of the country's ambassadors in Western Europe that the country is "preparing itself for a new international conjuncture" based on the transformations encouraged by Bonn and Mexico's vast uranium resources.

France, also moving quickly in the wake of the summit, has announced a proposal for selling a nuclear plant to Portugal as part of an overall economic and technological plan for the area.



*The Soviet U-25 MHD test facility, which uses a U.S.-made magnet.*

### SOVIETS PLAN COMMERCIAL MHD PLANTS BASED ON COAL

Soviet Academician Alexander Sheindlin announced in June that in the next 15 years the Soviet magnetohydrodynamics program will produce a series "of plants with a power of 1 million kilowatts, which would be operating on coal." These MHD generator plants would be commercial replacements for the less efficient fossil fuel steam turbine electric generating plants, Sheindlin said.

Sheindlin, who heads the Institute of High Temperatures where the Soviet MHD research is taking place, called this "a revolution in energy production," because the conversion efficiency for MHD is double that of conventional coal plants.

Sheindlin made the announcement just before the Moscow meeting of the joint U.S.-Soviet MHD cooperation group. U.S. scientists were particularly interested in the Soviet commitment to develop coal-based MHD, since the present Soviet work is in natural-gas-based systems, which are easier to engineer than coal systems. Dr. William Jackson of the U.S. Department of Energy's office of energy research, who is cochairman of the U.S.-Soviet cooperation effort, stressed after the Moscow meeting that the cooperative program was providing the United States with valuable data and saving the country the cost of building test facilities to replicate the Soviet work.

### SOVIETS MAKE INFORMAL OFFER TO INDIA FOR URANIUM

The Soviet Union reportedly has made an informal offer to supply enriched uranium to India. The offer comes at a time when India has expressed concern over future uranium supplies from the United States for its Taraput reactor. Congress and President Carter gave approval in mid-July for shipment of 7.6

tons of enriched uranium, but India views this as a one-shot tactic by the administration to pressure the country to sign the Nuclear Nonproliferation Treaty. The Indian government has refused to sign the treaty on the grounds that it favors the dominance of the present nuclear powers. India, which leads the developing nations in nuclear technology, told the United States that if further uranium supplies were refused, India would be forced to turn elsewhere for enriched fuel.

**IRAN-U.S. NUCLEAR AGREEMENT REPORTED NEAR**

Iran and the United States have come to an agreement on nuclear cooperation, according to Washington sources, and the text of the agreement should go to Congress for confirmation by early August. The sources report that part of the agreement includes giving Iran "most favored nation" trading status regarding the reprocessing of spent nuclear fuel—the same agreement the U.S. gives other nuclear nations.

The agreement was delayed for months by U.S. demands for proliferation safeguards, and it is unclear to what extent the delay has meant the loss of sales of U.S. nuclear reactor technology to Iran. Eight reactors from U.S. suppliers have been under discussion.

**SCHLESINGER'S 'GROWING RELATIONSHIP' OUT IN OPEN**

U.S. Secretary of Energy James Schlesinger, whom some diehards still identify as an advocate of nuclear power, recently presented the Department of Energy's first award for exceptional public service to Dennis Hayes, the chief organizer of the May 3 Sun Day celebration.

Hayes is a director of the Worldwatch Institute, a zero-growth thinktank, and the chairman of Solar Action, the group continuing the antinuclear campaign of Sun Day. Among his other qualifications, public service awardee Hayes told a Seattle environmentalist audience in April that if legal means failed to halt nuclear power, this might force environmentalists into such "drastic actions" as "detonating a nuclear bomb" in New York City.

In accepting the award, Hayes noted that the situation was "ironic" since Sun Day had been planned largely to protest that the Department of Energy and federal budgets did not devote enough emphasis to solar energy. Schlesinger replied that the award may not "be a symbol of love at first sight, but it may be the basis of a growing relationship."

Indeed.

*Denis Hayes: Exceptional public service?*

**TELLER ZAPS 'RADIATION SCARE'**

Speaking before the Texas Medical Society in San Antonio June 2, Dr. Edward Teller said that "radiation scare" was causing serious damage to the necessary development of nuclear power. Teller, director emeritus of the Lawrence Livermore Laboratory, said the publicity on radiation is also discouraging patients who have illnesses that could be treated with radiation from seeking help.

"You want to give the patient the best possible chance. The radiation scare is a very serious impediment to this. Unwarranted fears of cancer from important medical uses of radiation in diagnosis and in therapy have been created which have led many patients to reject such procedures and some physicians to be leery of suggesting them," Teller said.

**UMW JOURNAL WINS FEF'S 'LOUSEWORT LAURELS'**

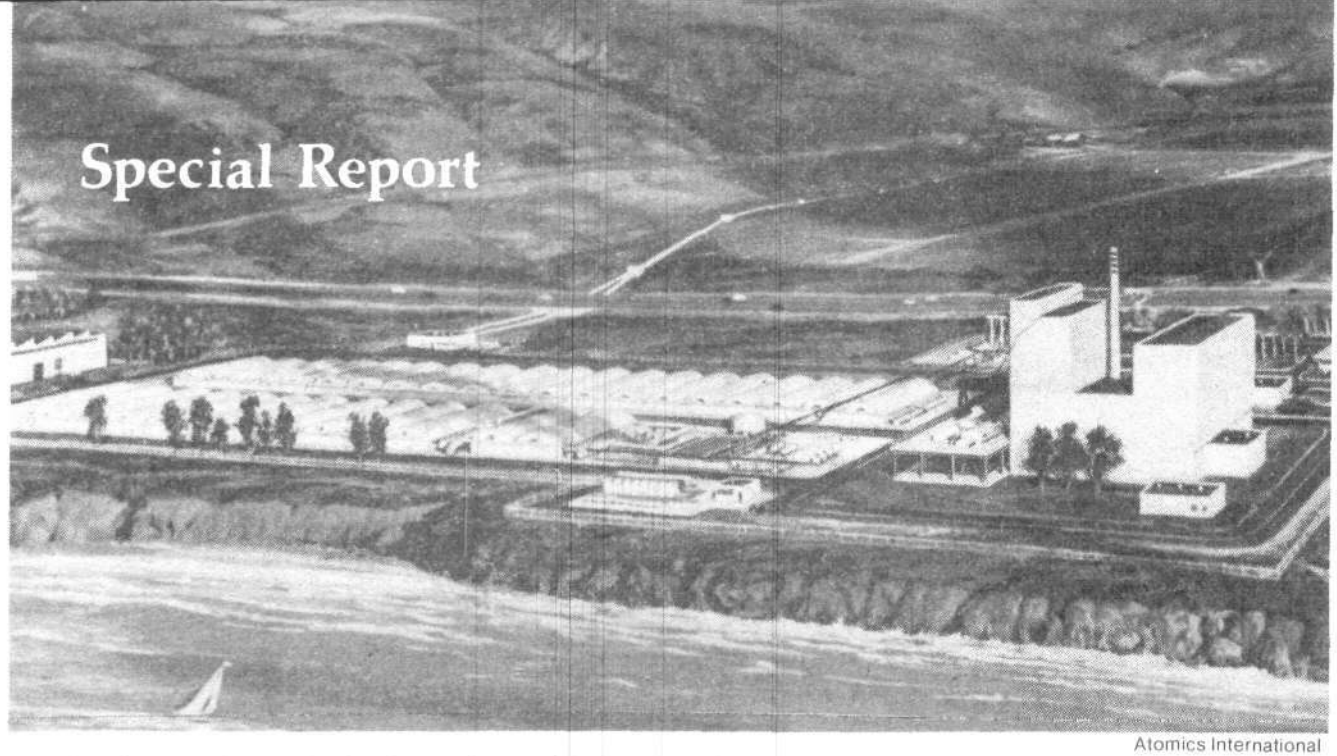
The June issue of the United Mineworkers monthly, *UMW Journal*, asserts that nuclear power development will put the union out of business.

Under headlines like "A Million Man Years of Mining Employment Already Has Been Zapped By Nuclear Power—What Lies Ahead," the *Journal* attempts to convince miners that nuclear power will cost them their jobs and income.

The Fusion Energy Foundation is awarding the *Journal* "lousewort laurels" of the month for its caveman logic.

Fortunately, most mineworkers are more advanced than their magazine editors. Rank and file miners and union leaders like former UMW vice president Mike Trbovich have strongly backed nuclear power development.

**Lousewort Laurels**




Atomics International

*Artist's drawing of a nuplex for the southern California coast that uses a sodium graphite reactor to produce electrical power [right] and desalinate water [left].*

## The Grand Design for World Development

# The Nuplex and U.S. Vital Interests

*The following statement by U. S. Labor Party presidential candidate Lyndon H. LaRouche, Jr. was issued June 26 under the title "New Profile for Oil Multinationals." LaRouche is the first major political figure to present a comprehensive program for nuclear energy to bring the world into the fusion age. The Fusion editors welcome the views of other candidates and elected officials on the subject.*

Evidence of the massive scope of petroleum reserves of Mexico prompts me to propose that U. S. (and other) multinational oil firms modernize their corporate policy profile. Specifically, the old petroleum-marketing cartel approach—and its offshoots—must be phased out, in favor of using the marketing of petroleum as a means for generating the cash flows required to recapitalize these firms as leading elements of an integrated approach to the production of nuplexes.

Mexico apparently rivals Saudi Arabia in extent of available reserves. The obstacle to proving and developing those resources has been twofold. Mexico proceeded with a shortage of qualified technicians (a shortage it has significantly corrected) and under arrangements between Pemex, its state-owned oil company, and multinationals, which in effect limited development of Mexican reserves according to multinational marketing strategies. This has been complicated—in multinationals' perceptions—by the fact that new Pemex developments will fall under the control of the national sector rather than multinational marketing controls.

Mexico is also one of the world's major holders of uranium reserves. These uranium reserves combined with Mexico's petroleum reserves create an extraordinary opportunity to the advantage of both Mexico and its trading partners.

We are approaching the end of the petroleum age. Although the magnitude of proven reserves is limited chiefly by the effort to discover and prove new, massive reserves, petroleum will have a diminishing *relative* importance during the closing decade of this century and the first decade of the next. So, from a corporate standpoint, major petroleum multinationals must shift, on balance, into appropriate new fields of *primary* activity during the quarter-century ahead.

The new field of energy production that will take over dominance during the remainder of this century is nuclear energy. We are now passing out of the prebreeder-only phase of nuclear fission-energy generation, and must emphasize breeder programs into the 1990s. During the 1980s, fusion energy will begin to come on line in a pilot form (at least). By the end of the 1990s, a shifting composition of ordinary nuclear-fission, fission-breeder, fission-fusion, and fusion energy will be the principal source of new energy supplies into the world's electrical grid-systems, and waste heat from nuclear production will be a major source of energy for industrial-process applications, desal-

ination, and related uses in the vicinity of nuclear-energy sites.

**The Nuplex Approach**

The most efficient approach to the use of nuclear energy in the developing sector generally is the creation of nuplexes.

A nuplex is a new agroindustrial city built around paired nuclear energy plants, each in the 0.5-gigawatt to 1.5-gigawatt range (by present standards). To economize on distribution costs, and to exploit the waste heat produced, industrial consumers of output will huddle around the plants, creating a new sort of "clean" industrial (and employment) center. With the growing importance of the "clean water" problem, and with the opportunity to replicate California's Imperial Valley in many parts of the world, desalination and other water-purification exploiting waste heat will make nuplexes key in meeting agricultural and population clean-water requirements.

A nuplex also has other natural features. Nuplexes can be established during a four-to-six-year construction period, during which period many engineering and other skills are employed on the site. In a developing nation (especially), construction phases are a blend of employed foreign specialists and indigenous employees. The construction period is a period of education and other training of a segment of the indigenous labor force. On-the-job training is not adequate. On-the-site training, including schools for technicians, workers and their families, cultural programs, and so forth, is indispensable.

So, to build an agroindustrial nuplex means to build an entire new city, to build structures and facilities to last as quality structures for a coming period of 50 to 100 years, and to build the core and basis of expansion of such a city over a four-to-six-year period of initial construction phases.

These nuplexes serve not only as self-contained concentrations of high technology, but as the hub of radiation of high-technology services to agricultural and other developments over areas of wide radius surrounding. A network of such nuplexes throughout continents such as Africa transforms the Sahara and Sahel into a vast new habitable and fruitful region, and establishes a continental grid-system of centers of high technology through which to transform the entire continent.

In the main, we have the proven technology to launch such projects. Looking for the moment solely at U. S. capabilities, our electrical utility industry, the major corporations which supply the utility industry, the oil multinationals, and firms specializing in large-scale construction have the capability to create an integrated package, mobilizing their vendors as part of the package.

Looking more broadly, our Japanese allies are masters of the integrated approach, and should be our partners throughout the Pacific and Indian Ocean regions most emphatically. French, West German, and Italian high-technology and construction industries have similar capabilities, especially when their capacities are integrated with U. S. potentials. The Soviet Union's Siberian development and related efforts have produced breakthroughs that make them the world's best for certain specific phases of a cooperative division-of-labor in nuplex creation in the developing sector.

Key petroleum multinationals have already developed their pilot capabilities for such diversification. The policy problem is that of upgrading qualitatively this aspect of their diversification. Corporate long-haul policy must be governed by the nuplex perspective, and orderly marketing of petroleum and related matters viewed as the economic lever for recapitalizing those corporations in the direction determined by long-haul policies. Petroleum and uranium serve as the universally needed primary commodities whose depletion pays for and otherwise aids the transformation of capital structures and marketing into agreement with the world of the turn of the century.

It is in the most vital interests of the United States that such a transformation, as part of an integrated approach, be encouraged and nurtured. In general, we must now build in such a way that the next 50 to 100 years of our nation's life is secured on all fronts. If we now build the world's hegemonic motion of development on a sound basis, a basis adequate to the coming century, we shall have created the foundation and means through which our posterity may then efficiently meet the new challenge of the further centuries yet to come.

**U. S. Vital Interests**

Any competent economist, or corporate executive perceptive of this side of the matter, will insist that existing U. S. fiscal and credit policies are not competently defined for the kinds of programs indicated. I not only concede that to be the fact, but I have already outlined the changes in fiscal and credit policies needed to correct the present errors. In the meantime, we can initiate such corporate policy shifts offshore, with nations such as France and Japan key to this effort. The benefits to the U. S. internal economy of such offshore-centered efforts will persuade the majority of the U.S. electorate of the need to make the required changes in fiscal and credit policies.

In the case of Mexico, it makes no proper difference to petroleum multinationals whether they are developing Mexican petroleum and uranium resources, or whether they are cooperating with Mexican-controlled entities. Mexico will be developing and exporting petroleum and uranium to secure high-technology capital for internal development. The petroleum multinational's concern is to provide a significant chunk of the high-technology capital Mexico purchases through petroleum and uranium sales, and to cooperate with Mexico in maintaining the orderly marketing conditions that process requires.

Our key, economic-strategic reference points for this policy are centered in Iran and Saudi Arabia among present OPEC nations and developing Mexican reserves. The proposal made by Japanese Premier Fukuda, for fusion-energy development cooperation with the United States, provides the point of tactical reference for mobilizing the needed shift in emphasis of policy at this time.

Fusion Energy Foundation Policy Statement

# World Development Requires the Most Advanced

*The Fusion Energy Foundation is circulating the following policy statement on development throughout the United States as a memorandum on U. S. policy for the upcoming United Nations Conference on Science and Technology.*

There are two general approaches in the current international debate over the transfer of science and technology from the advanced sector to the less developed countries and the policies necessary for development. One approach advocates the use of *appropriate technologies*—usually interpreted as labor-intensive techniques involving low rates of energy use, soft energy paths, and relatively primitive forms of technology. The alternative approach advocates the use of the most advanced and capital-intensive technologies available, linked with a policy of expanding the energy supply necessary for such technologies by rapid development of conventional nuclear energy, and the development of breeder technology and controlled thermonuclear fusion as long-term energy sources.

The first strategy has been endorsed by such prestigious institutions as the World Bank and the Brookings Institution and has generally come to dominate the debate at this point. Nonetheless, we shall argue here that the low-technology route cannot lead to a satisfactory solution of the development problem. On the contrary, such a route will at best preserve and probably aggravate the present backwardness of the developing sector.

### The Basis for Development

In order to situate the consideration of development policy in the proper scientific context, we must first define the goals of development and the process by which it takes place. The primary goal of development is to increase the standard of living and educational level of the population. The only possible way of increasing per capita consumption is to increase per capita production—the productivity of labor. In turn, the productivity of labor can be increased only by the application of new technologies that substitute inanimate energy and machinery for human labor. By increasing productivity, such new technology increases the standard of living directly. At the same time, by reducing the time the society as a whole must work to maintain the current level of consumption and the existing means of production, increased productivity generates a surplus that is available for expanding the economy as a whole. The combination of increased consumption levels and increased leisure time available for education makes possible the production of a more highly skilled workforce, which, in turn, allows the implementation of still more productive technologies, continuing the cycle of growth and development. Such is the process by which the most developed economies in the advanced and the developing sectors actually achieved their current success.

From this description of the goals and methods of development, it follows that the criterion for development strategy is the maximization of rate of development. Our aim must be to maximize the rate of increase of labor power or productivity, and thus the rate of increase of the overall social surplus.

From these very elementary considerations it can be seen that the strategy of appropriate technologies is not one that encourages development. The very basis of this approach is to maximize the labor intensiveness of the technologies employed in the developing countries; in other words, to minimize labor productivity. By attacking the very motive force of development—increases in labor productivity—such a strategy necessarily preserves existing backwardness.

Given the widespread credence awarded the low-technology approach, it is important briefly to review the arguments used by its advocates. Such reports as the Brookings Institution's November 1977 "Interim Report on U. S. Development Assistance Strategies," among others, argue that the low-technology development route is necessary because: (1) it makes possible the meeting of basic human needs by the poorest of the population; (2) it is more economical, utilizing abundant supplies of cheap labor found in the developing sector; and (3) it creates the large numbers of jobs necessary to overcome unemployment.

### The Failure of Appropriate Technology

Let us examine these arguments in light of the basic principles above. What, in fact, will be the consequences of widespread implementation of a policy of labor-intensive development? What is proposed is the mere extension of the present low levels of productivity to a wider proportion of the existing population—an increase in the intensiveness of labor by the population as a whole. At the very best such a process can result in only very modest increases in production in proportion to the additional labor employed, increases barely sufficient to cover the increased consumption necessitated by productive output. No added surplus is generated, and thus no basis for continued growth produced. In fact, the real situation is considerably worse, since any fixed level of technology tends to exhaust the resources available to it. For example, existing supplies of low-technology fuels such as firewood are already nearing exhaustion. Such limitations rapidly force upwards the cost of a fixed technology, leading to increasingly rapid declines in overall productivity and, therefore, in the standard of living. We conclude that even very modest "basic needs" cannot be met by the use of low-productivity technology

# Technologies

for any length of time. Furthermore, the extension of labor time at current wholly inadequate levels of productivity and consumption must lead to the actual destruction of present labor power on a large scale.

How, then, can such a policy appear to be economical in terms of the low cost of labor? It is clear that this argument is premised on the preservation of the very conditions of misery that development aims to alleviate. Only if the cost of labor is calculated at the present grossly depressed wage levels can labor-intensive methods compete with more productive, capital-intensive ones. But precisely these grossly depressed levels are the principal hindrance to development. By the accurate measure of the resulting growth rate, capital-intensive methods are far more economically effective than labor-intensive ones.

In other words, appropriate technologies are only appropriate to the existing level of backwardness; they are wholly inappropriate to the task of development.

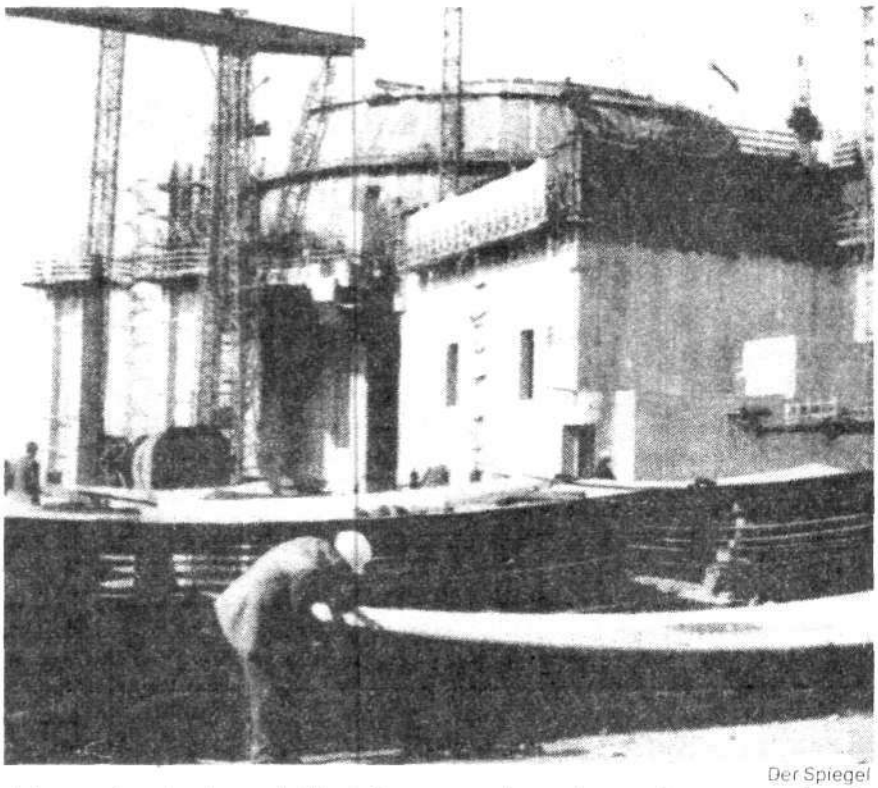
Nor can it be argued that inefficient modes of technology are essential to create jobs. This presumes that the problem is lack of work to be done, which is scarcely the case. The problem is lack of production of essential goods, and for that the highest level of productivity is needed.

**Capital-Intensive Development**

Even if such basic flaws of labor-intensive development are admitted, its advocates argue that there is no alternative, since capital-intensive development is impractical. The unskilled workforce of the developing sector cannot absorb advanced technologies, it is financially impossible for developing countries to import large amounts of capital goods, and the energy needed for capital-intensive development is not available. Such arguments ignore the history of development.

The two outstanding examples of agricultural countries that rapidly developed into first-class industrial powers, the United States and the Soviet Union, both utilized capital-intensive strategies. In both cases, the emphasis was put on using the most advanced technologies and the most rapid upgrading of the workforce to use these technologies.

In the case of the Soviet Union, the country began from an economic base comparable by all measures (per capita energy consumption, percentage of urbanization, productivity, education, and health) to current underdeveloped regions. Yet, in its transition to industrialization in the decade from 1928 to 1937, the Soviet Union achieved and maintained a growth rate of between 15 and 25 percent for energy production and the production of critical commodities such as steel and cement. At the same time, capital goods production increased by more than 40 percent a year in many categories. These examples of successful development, the United States and the Soviet Union, must serve as the models for development today.



Der Spiegel

*Advanced technology: A West German nuclear plant under construction in Iran.*

Capital-intensive development is premised today on two interrelated policies. First, to provide the energy supplies necessary to sustain development, we must accelerate the implementation of existing nuclear energy technologies and put the development of the breeder and of thermonuclear fusion on a priority basis. Second, in the developing sector regionwide centers of industrial development must be created to act as the focus for high-technology industrialization.

It is clear that without the development of nuclear energy, insufficient resources exist to power capital-intensive development for any length of time. However, existing fission technologies can sufficiently expand and supplement energy supplies to ensure adequate energy growth for the next decade and a half. By the end of that period, liquid metal breeders and fission-fusion hybrid reactors must be on-line, and controlled thermonuclear fusion reactors could begin to be introduced, assuring a virtually unlimited supply of cheap energy for the future. An international program

to develop fusion power within the next decade, a technically feasible objective, therefore, is a necessary aspect of any sound development strategy.

In the developing sector itself, capital-intensive industry must be introduced by a concentric-circles process that upgrades the entire workforce. The core of such a process will be regional industrial centers, using combinations of nuclear and fossil fuel and hydroelectric energy to drive advanced-technology heavy industry (for example, primary processing industries). These centers will utilize the available skilled workforces in parts of the developing sector. Surrounding these centers will be secondary centers of light industry, more closely linked to rural areas (such as food processing). Around these secondary urban hubs, in turn, must be regions of advanced agricultural development.

In this manner, a relatively low-skilled population can be progressively drawn into industries requiring a higher and higher level of skill. While each industry maintains the highest possible level of productivity and capital intensiveness, the combination of industries of relatively lower and higher skill levels provides the basis for a continuous upgrading of the total population.

The combination of nuclear energy development and regional industrialization can provide the basis for rapid rates of development in the developing sector, as similar policies led to the industrialization of the advanced sector. It should be noted that such a policy is ideally and uniquely suited to reenergize the currently depressed industries of the advanced sector (such as steel) and to generally achieve a high rate of exports from this sector to the lesser developed countries.

**Appropriate Financing**

Capital-intensive development is not only technically practical but also financially practical. The objection that large-scale importation of capital is impossible is based on the assumption of the current high-interest, short-term financing. Since capital-intensive development, although relatively rapid, begins to pay for itself only over a period of 15 to 20 years, such short-term financing precludes large-scale capital imports. If such financing is assumed, then indeed only technologies involving few imports—in other words, labor-intensive—are possible.

In fact, this is the real reasoning behind the appropriate technologies strategy—such technologies are those appropriate to existing financing schemes! Indeed, it was only in the early 1970s, when interest rates on loans to lesser developed countries rose rapidly and payment terms shortened, that the idea of appropriate technologies received widespread attention. However, if the primary aim is *rapid development*, then it is necessary to create *appropriate financing*—the provision of very long-term, very low-interest loans and credit arrangements that are suitable to capital-intensive development.

**The UN Conference Task**

Once the false assumption of maintaining existing financial arrangements is dropped, all rationale for labor-intensive strategies disappears. It must be the task of the United Nations Conference on Science and Technology to formulate the basic policy agreements that can lead to the initiation of large-scale, capital-intensive development in the immediate period ahead.

# The Sahel: Appropriate Technology Is a Disaster

The continuously declining situation in the eight drought-ravaged African countries of the Sahel region is a testimony to the failure of the internationally sponsored aid programs that have tried to help the area. These aid programs all have attacked the problem with the *appropriate technologies* approach, funding the lowest-level manual labor projects instead of capital-intensive development. The result is that by the end of summer 1978, 7 to 10 million people in the region will face starvation, according to the United Nations Food and Agriculture Organization.

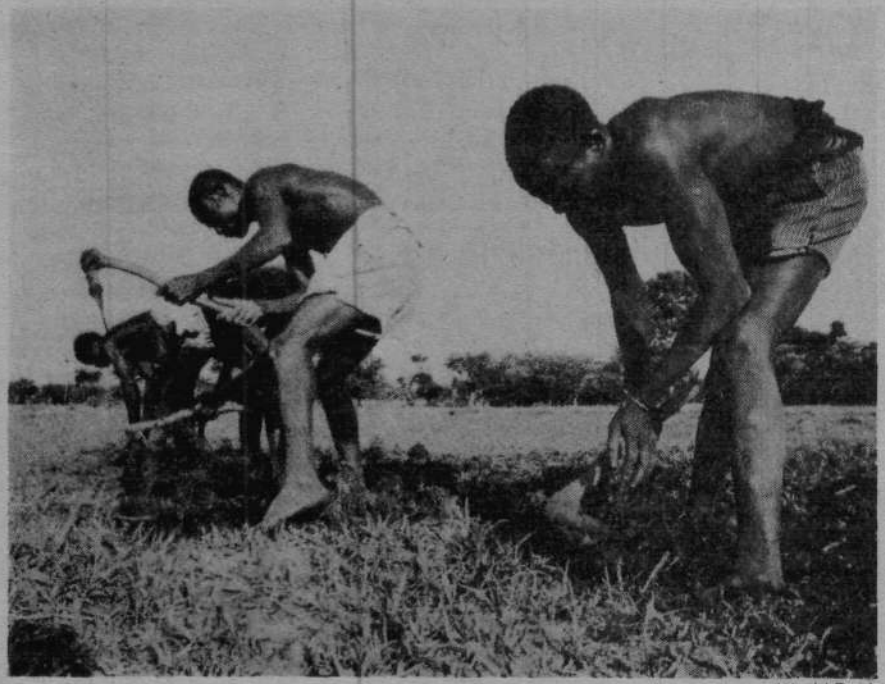
The starvation situation is exacerbated by the prediction that locusts will destroy the few crops that the drought leaves behind. Entomologists predict that locusts coming from east Africa will reach the area by the end of the summer, and that by January 1979 locust swarms will eat their way through Mauritania, Morocco, and Algeria, as well.

Even with an immediate international effort, there is little hope of dramatically changing the situation this year. The area already receives half of its food in aid, and existing port facilities and other infrastructure are at their limit in making these emergency supplies available.

The eight Sahel nations have been on food aid since their independence. Crop failures, not uncommon in the area, are devastating when they happen once, but successive failures over the last 10 years have left the region's population at starvation levels. Gambia, for instance, announced that 70 percent of last year's harvest had been lost by August 1977.

**Why the Failure?**

Why have the international aid programs been such a dismal failure? The latest Sahel report to Congress by the U. S. Agency for International Development indicates that the United Nations, the World Bank, AID, and the Club du Sahel (an umbrella organization that coordinates aid programs) all have plans for long-term development that call for keeping the populations at a primitive level. There are no plans for sending the Sahel tractors and other mechanized farming equipment, nor are there plans for investing in the kind of capital-intensive development, such as hydroelectric and irrigation projects, that would provide a basis for upgrading the local capability to deal with the crisis.



World Bank

*The World Bank's "appropriate technology" for Upper Volta.*

The problem of investment can be seen most clearly in the case of the World Bank. In the opinion of the Bank, the Sahel area has virtually no exploitable natural resources. The World Bank uses such resources as justification for investment. Therefore, instead of investing in development, the bank has funded a series of primitive, dead-end projects. One project expects the starving region to become a meat exporter to the rest of Africa, while another has women digging roads and wells by hand. These programs, all of which are labor intensive, are requirements in order for the countries involved to receive direct food aid. Although the World Bank policy is the most explicit, in its primitive approach, the other international agencies follow suit.

To take one example: after their livestock had died from starvation or thirst, Sahel herdsmen were forced to settle on tiny plots of lands to eke out enough to feed their families using primitive tools. But the slash-and-burn methods used to carve out the plots from the brush destroyed the vegetation holding the top soil in place. When the rains of 1975 and 1976 came, this top soil washed away, leaving the herdsmen even more desperate.

**There Is a Solution**

As the Fusion Energy Foundation has pointed out in its programs for the development of Africa and the Mideast, there is a way out of this increasingly self-destructive cycle through capital-intensive, high-technology development. Ironically, it is exactly this kind of development program that will also guarantee an economic future for the exporting donor nations.

*Cynthia Parsons, an FEF staff member, specializes in agricultural research.*

# International

# World Fusion Leaders Plan Test Tokamak

Leaders of the fusion energy programs of Europe, Japan, the Soviet Union, and the United States met in Vienna at the International Atomic Energy Agency headquarters June 27-28 to discuss plans for jointly building the first test fusion power tokamak. The project was proposed earlier this year by Soviet fusion scientist E. P. Velikhov, who had suggested that the nations work together under the aegis of the United Nations IAEA.

The meeting participants agreed that representatives of the four fusion programs involved would meet during the next year for extended periods to work out the details for the first fusion power plant prototype, to be constructed in the 1980s. By August, the fusion leaders expect to have the commitments from the governments involved to follow through with the project.

All but the U.S. commitment is assured. Edwin Kintner, director of the U.S. Department of Energy's fusion office, who represented the United States at the Vienna meeting, has proposed that Assistant Energy Secretary Robert Thorne okay the $150,000 to $200,000 necessary to finance U.S. participation in the design phase of the project. Energy Secretary James Schlesinger and Deputy Secretary John O'Leary, however, have been maneuvering for weeks to close out the U.S. fusion program.

Velikhov, vice president of the Soviet Academy of Science, had privately proposed the plan to build a fusion device based on the tokamak magnetic bottle system to U.S. fusion officials in Washington in April. Then he made a formal proposal in May to the U.S.-Soviet Joint Fusion Power Coordinating Committee meeting in Moscow.

The Velikhov proposal is geared toward realizing a full demonstration of fusion energy production by the early 1990s. Velikhov told U.S. fusion officials that the rapid world scientific progress on the tokamak had made the time ripe for beginning to demonstrate the engineering capabilities to make fusion practical as an energy source, and that such a demonstration could be realized most efficiently with an international effort.

Although the details of the Vienna project have not yet been worked out, it has been decided that the tokamak will burn deuterium and tritium with high energy gains, use superconducting magnets, and be designed to eventually produce electricity. The systems will represent both a conclusive scientific demonstration of the tokamak magnetic bottle approach to fusion and a technical demonstration of the engineering needed for power plants.

The meeting included Doctors Pease and Colombo from Euratom, the joint European organization for nuclear research, and Dr. Mori, the director of the Japanese fusion effort.

*Japanese Prime Minister Fukuda*

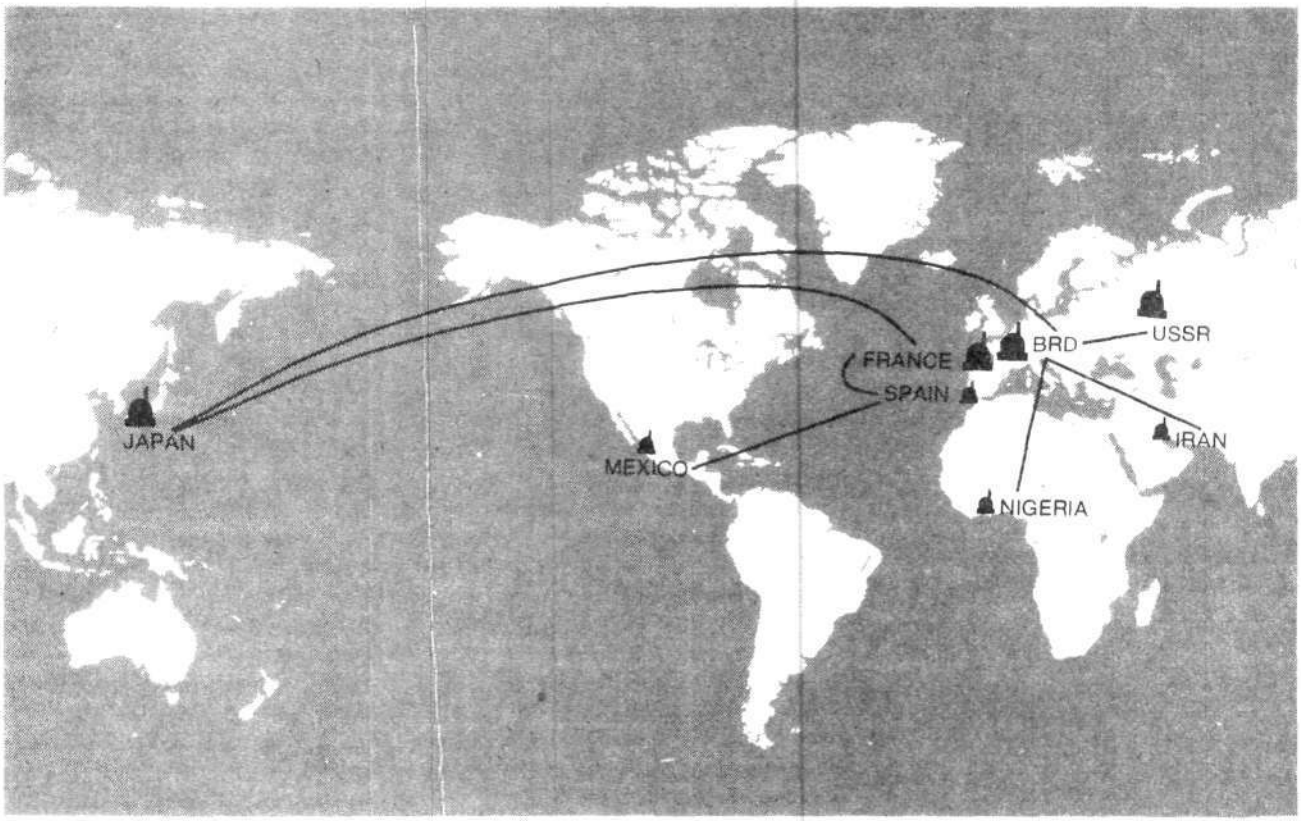
# Japan Goes All Out for Fusion Power

The Japanese government has launched an all-out effort to make its bold plan for the cooperative development of fusion power a reality. Prime Minister Takeo Fukuda, who proposed a joint $1 billion fusion development program to President Carter in May, will submit his fusion plan to the Bonn, West Germany summit meeting of Western governments July 16-17.

Although there has been no official U.S. response to the dramatic Japanese offer, teams of Japanese scientists and government officials have arrived in the United States in the past few weeks for tours of the major laboratories and industries involved in the fusion effort and to organize support in the U.S. fusion community. In addition to fusion research, Fukuda had proposed funding for advanced technology.

The English language edition of the *Mainichi Daily News*, Japan's third largest daily, reported July 2 that Fukuda's official spokesman, Chief Cabinet Secretary Shintare Abe, "...told reporters that the plan stands a good chance of winning support from other government leaders taking part in the Bonn summit and leading to an international cooperative effort."

The *Mainichi* reported that "in response to Fukuda's call, the government will next week set up a task force of experts from the Foreign Ministry, the Ministry of Industry, the Ministry of Finance, and the Science and




**NUCLEAR TECHNOLOGY TRANSFER**

*These nuclear technology transfer deals form the beginning of the Grand Design discussed at the Bonn summit in July.*

Technology Agency. . . .The team will be charged with the task of working out financial plans for a joint fund for the proposed committee and to promote contacts of scientists."

"At a summit meeting" in Washington during May, *Mainichi* said, "Carter reportedly agreed in principle on the Fukuda-advocated plan for a joint research and development program. But subsequent working-level talks on the plan to harness energy generated by nuclear fusion, solar energy, and other alternative energy sources have made little progress."

SEE WASHINGTON SECTION FOR THE DETAILS OF THE JAPANESE FUSION PROPOSAL

# International Nuclear Agreements Set Stage for 'Grand Design'

In the weeks leading to the mid-July Bonn economic summit of Western governments, West Germany, France, and Japan have negotiated a series of nuclear deals that can become the centerpiece for the expected Bonn agreement to accelerate nuclear power development in the Third World. In effect, these nuclear-linked agreements, involving Europe, the Soviet Union, the Mideast, Africa, Latin America, and Japan, are the seed crystal of what leading Japanese and European statesmen refer to as a Grand Design for global industrial development.

Most conspicuous about these preliminary agreements for nuclear technology transfer is the absence of the United States. The U.S. nuclear industry is constrained by an array of export legislation, such as the Nuclear Nonproliferation Act of 1978, which makes other countries extraordinarily hesitant to gamble billions of dollars in what they see as a politically uncertain U.S. situation. France, West Germany, and Japan, which are in the forefront of the nuclear deals, are the same countries that have been sharply critical of the Carter administration's nuclear energy policies and that have moved to stabilize the value of the dollar.

### The Deals

On June 22, France, West Germany, and Japan signed a technical cooperation accord on the development of sodium-cooled fast breeder reactors, covering exchange

of information on physics and plant safety. The Franco-German-Japanese collaborative effort in the field was initially decided during a meeting in July 1977 between French President Valery Giscard d'Estaing and West German Chancellor Helmut Schmidt. France, along with the Soviet Union, has the world's most advanced breeder development program.

During the same week, Deutsche Babcock, a leading West German engineering and generating equipment manufacturer, signed a potentially far-reaching agreement with the Soviet Union that provides for joint design and construction of power stations for the Soviet market and for sale to third countries. According to a Deutsche Babcock spokesman, the agreement was made from the standpoint of benefiting from Soviet access to Asian, African, and OPEC countries. The Iranian government holds a 25 percent interest in the German firm.

**The French Role**

French President Giscard was in Spain in late June for talks that open up Franco-Spanish nuclear industry cooperation as well as development deals for all of Latin America. Spanish banking networks are extensive throughout Latin America, and the Mexican press was quick to appreciate discussions by the Giscard delegation on Spain's functioning as a bridge for technology transfer to Latin America.

Also during this period France concluded several months of negotiations with Iran by agreeing to deliver four nuclear power reactors in return for the Iranian shipment of a dollar equivalent of oil to France. French Foreign Trade Minister Deniau announced the agreement in June after three days of talks in Teheran. At the same time, French Industry Minister Andre Giraud, former head of the Atomic Energy Commission, proposed a new policy, believed to have backing from President Giscard, to systematically link French industrial exports to crude oil imports.

Bringing Africa's largest oil producer into the trade deals, West German Helmut Schmidt concluded an unprecedented visit to Nigeria two weeks ago with the signing of a joint cooperation agreement with the Nigerian government on nuclear energy development. In a speech to the Nigerian nation, Schmidt said, "We want to help African states become strong economic partners with whom we can carry on mutually advantageous trade."

**Union Pressure**

There is strong pressure within West Germany for the expansion of nuclear technology exports. Klaus Barthelt, chairman of West Germany's leading nuclear manufacturer, KWU, stated in a recent interview in the West German daily *Die Welt*: "We now have a letter of intent with Iran for the construction of four nuclear power plants with an output of 1,300 megawatts each. But here at home in the Federal Republic, absolutely nothing is moving. It is only because of orders from abroad that the Federal Republic's nuclear industry—built up over a period of 20 years— has not died out."

Barthelt noted that the last domestic order for a nuclear plant was in 1975, and that more than $7 billion worth of plants are being held up by environmentalist legal action. Those plants alone, Barthelt said, could provide 70,000 new jobs.

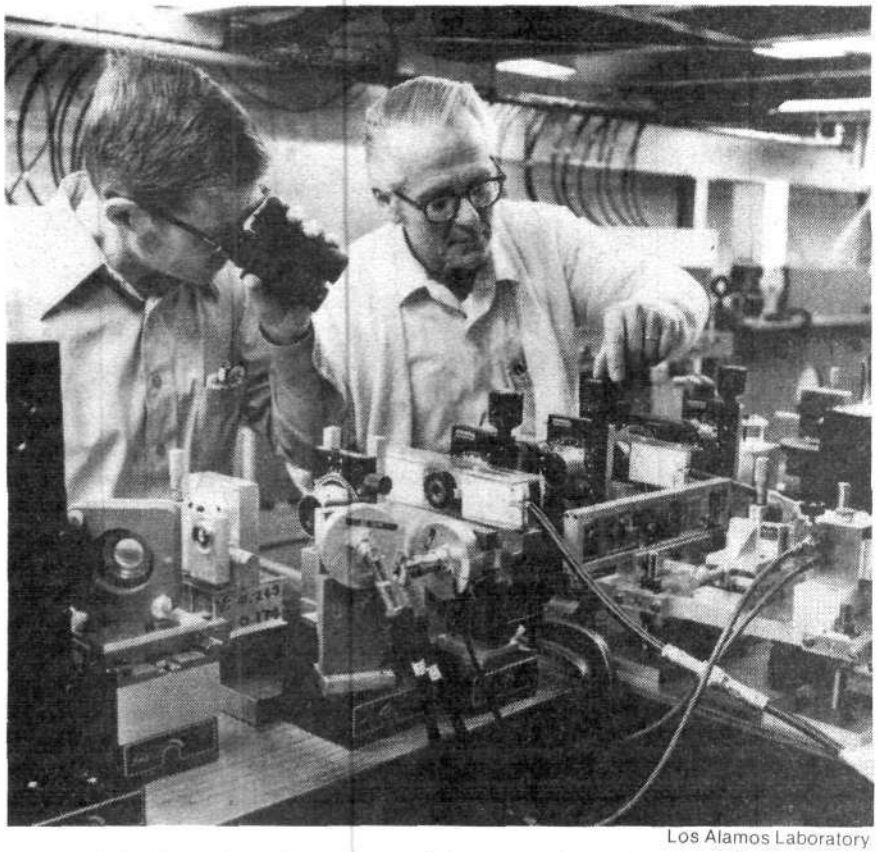
*—William Engdahl*

## Fukuda-Brezhnev Deal in Works?

The *Mainichi Daily News* reported July 20 that Soviet Vice Foreign Minister Yuri Brezhnev, the son of Soviet President Leonid Brezhnev, was in Japan to negotiate a vast program for economic cooperation. The Japanese daily quoted officials of the Ministry of International Trade and Industry, whose head was meeting with Brezhnev, as saying that "... the Soviet Union was considering an agreement comparable to the one signed with West Germany in May calling for a wide-range of economic cooperation including energy supply."

# Washington

# Good News For Fusion Budget



Los Alamos Laboratory

*Laser scientists at Los Alamos, one of the U.S. laboratories slated to take part in a joint U.S.-Japan fusion research effort.*

The fusion research budget for 1980 will not get the $350 million cutbacks threatened by Energy Secretary James Schlesinger and Deputy Secretary John O'Leary, according to the latest reports from sources in the Department of Energy. The sources said that the fusion budget for the next few years has been set at the minimal level necessary to support the crucial experiments ongoing and in construction, with $500 million scheduled for the year 1980 for the magnetic and inertial confinement programs.

That the fusion supporters won the battle against Schlesinger's axe was indicated in a July 17 *Washington Post* interview with the director of energy research for the department, John M. Deutch. Deutch, who predicted the first U.S. commercial fusion reactors by the year 2005, said, "I think there's a little doubt we will have a demonstration of the scientific feasibility of fusion by 1982." Schlesinger had told a June 5 Chicago press conference, "It is not feasible to develop fusion until late in the 21st century."

The budget holding action means that the world's largest tokamak, the Tokamak Fusion Test Reactor now under construction at Princeton University, will have sufficient funds to permit significant upgrading of this breakeven experiment. The TFTR has been singled out for attack by Schlesinger, O'Leary, and others in their campaign to cut what they called "unnecessary and wasteful" parts of the fusion budget.

**Japanese Proposal in Works**

Even better news for the fusion budget is in the works as the department's laser office and fusion office discuss a positive reply to the Japanese government's offer to fund a joint U.S.-Japan fusion research program to the tune of $1 billion. According to department sources, the Japanese Embassy forwarded a detailed memorandum to the department, and a meeting is scheduled for August to discuss policy and the scientific aspects of the collaboration.

The sources said that Japan proposed that the United States and Japan each put up $100 million for the first year to be used to immediately increase funding of existing projects and to develop new projects. The Japanese made a point of noting that their funds could directly go toward balancing the U.S. trade deficit.

The open-ended Japanese memorandum mentioned six areas of potential collaboration, as follows: (1) collaboration in basic plasma physics research; (2) provision of an upgraded power supply for General Atomic's Doublet III tokamak in San Diego; (3) investment in the chemical processing of tritium, now underway at the Los Alamos laboratory; (4) exchange of auxiliary equipment between the TFTR tokamak and Japan's JT 60; (5) investment in alternative fusion systems now dropped or inadequately funded in the United States, such as the Elmo bumpy torus, the toroidal mirror system, and stellarators; and (6) investment in research on inertial confinement, such as an upgrade of the Shiva-Nova laser at Lawrence Livermore and the carbon dioxide laser at Los Alamos.

As Washington sources noted, the ramifications of the Japanese proposal are far-reaching. The Japanese can strategically enhance the U.S.

program, speeding up promising lines of research and adding to programs that now have too low funding levels to be able to replicate results.

According to department sources, the Japanese understand that the U.S. has already developed major inertial confinement systems and that much of this work is classified. By funding the U.S. program, the Japanese will not have to replicate this basic work, and as leading U.S. scientists in the field have noted, the present classification serves no purpose, and will probably be removed in the future.

**DOE Budget in for Cuts**

Other Washington sources reported that the entire Department of Energy budget was on the Office of Management and Budget's chopping block. Reportedly, OMB head James McIntyre has sent a memo to Schlesinger specifying that the $12 billion department budget for 1979 must be cut to $8.4 billion in 1980 and $7.5 billion the following year, with Schlesinger's project for strategic oil reserves included in the cuts.

The sources said that the Office of Management and Budget was definitely against any of these reductions coming from the fusion budget.

# Court Upholds Price-Anderson

In a June 26 decision, the Supreme Court upheld the constitutionality of the Price-Anderson Act, which limits the liability of private power companies in the unlikely event of an accident at a commercial nuclear reactor. This was the court's second unanimous decision this term to uphold nuclear power.

The high court rejected the decision by Federal District Judge James B. McMillan of North Carolina, who declared the act unconstitutional in March 1977. McMillan had admitted in his decision that the risk of a nuclear accident was incredibly small. Nevertheless, he said, "the court is not a bookie," and he held that any restriction on the liability of power companies represented a denial of due process and unequal protection of the law to potential victims of a nuclear accident.

In the Supreme Court decision, three justices—Rehnquist, Stewart, and Stevens—stated that McMillan did not have jurisdiction over the case because it was not "ripe for controversy" and because the environmentalist plaintiffs did not have the legal right to bring suit. Chief Justice Burger, writing for all seven justices participating in the decision, rejected McMillan's contentions that the Price-Anderson Act violated due process and equal protection provisions of the U.S. Constitution. Burger said that the Act "bears a rational relationship to Congress's concern for stimulating the involvement of private enterprise in the production of electric energy through the use of atomic power."

# House Votes Full Funding for Clinch River Breeder Reactor

The House of Representatives voted July 14 to authorize $159 million to continue the Clinch River breeder reactor, despite the Carter administration's attempts to kill the project.

In the 187 to 142 vote, the House defeated the so-called Flowers Amendment, proposed by Alabama Democrat Walter Flowers, that called for a three-year study of an alternate breeder system with no commitment to build it. Spokesmen for the breeder had labeled the amendment "sure death" for the nation's only breeder program.

Representative Michael McCormack, a Washington Democrat who has led the pronuclear fight on Capitol Hill, told the House that the Flowers amendment would make the United States a "second-rate nuclear power," forcing the country to import needed breeder technology from France, Japan, and other nations now moving full speed ahead with breeder programs. The labor movement and the nuclear industry gave congressmen the same message in the days before the vote (see national section, this issue).

The vote came as part of House consideration of the $4.3 billion Department of Energy budget authorization for fiscal year 1979.

The Senate is expected to vote on the Clinch River funding in the next few weeks.

# Senate Approves Part of Energy Bill

The Senate voted July 18 to approve the so-called coal conversion portion of the five-part national energy bill. The vote, 92 to 6, had been delayed by a threatened filibuster from Senator Harrison Schmitt of New Mexico until the conclusion of the summit meeting in Bonn, West Germany of Western heads of state.

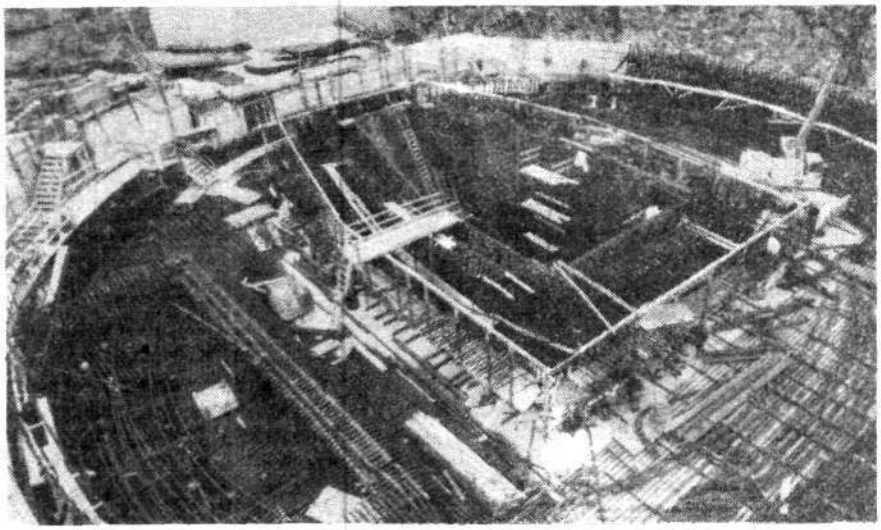
The coal conversion proposal is the least controversial portion of President Carter's original energy package and is no indication of a turn in support for the original Carter program.

Despite the formal vote on the coal conversion section, there is at this point no scheduled meeting of the Joint House-Senate Energy Conferees to act on other portions of the legislation. A number of congressmen, including Senate Majority Leader Robert Byrd, are pressing to complete action on four of the five sections before taking up the tax section, the most far-reaching and controversial part of the package.

A spokesman for Senator Russell Long, the Louisiana Democrat who chairs the Senate Finance Committee, commented off-the-record that the centerpiece of the president's overall bill, the Crude Oil Equalization Tax has no constituency and will not be passed in this election year, "short of a national emergency or war situation."

# National

# Seabrook Halt Spurs Pronuclear Mobilization



*The Seabrook site and its opposition.*

The U.S. Nuclear Regulatory Commission's 2 to 1 ruling June 30 to halt construction of the Seabrook, New Hampshire nuclear power plant could be the rallying point for a national campaign for nuclear power and a counteroffensive against the anti-nuclear movement.

Immediately after the commission's decision, New Hampshire Governor Meldrim Thomson opened what a spokesman termed a "national mobilization to defend nuclear power and the Seabrook nuclear facility." At an emergency energy conference in Concord, July 6, Thomson told the more than 400 delegates from New England industry, trade unions, and political organizations that the issue is not whether the Seabrook facility is built or whether "we can win battles here in New England. . . . The issue is whether this nation is committed to nuclear power. . . . Seabrook is a symbol of that national commitment, and it must go forward."

Lashing out at the commission for acting against the national interest in halting Seabrook, Thomson urged a return to the policies exemplified by President Eisenhower's 1953 Atoms for Peace proposal, and he read at length from Eisenhower's speech.

Thomson has asked the leadership of the unions affected by the Seabrook work stoppage to file an action to enjoin the commission. As a last resort, Thomson said, the state would sue the commission for $500 million in damages.

Thomson's call for a national battle to defend nuclear energy has met with support from key sections of the labor movement—especially the Building Trades, the Steelworkers, and the Teamsters—as well as from other progrowth leaders like Washington Governor Dixy Lee Ray, and American Association of Blacks in Energy head, Clarke Watson. Telegrams and messages of support from unionists and political and industry leaders reached the governor, as word of the mobilization spread throughout the country.

### The Seabrook Decision

The commission ruled that construction on the Seabrook nuclear plant, which is more than 10 percent completed, must stop as of July 21 for an "indefinite period." This halt is to enable the commission "to protect its freedom to decide on an alternative to the Seabrook site" in case the Environmental Protection Agency rules in the future to require all nuclear plants to have cooling towers, and bans "open cycle" cooling systems, like Seabrook's, that use pumped ocean water.

The decision, ostensibly based on a hypothetical EPA ruling, means that 1,800 of Seabrook's 2,200 workers will be laid off this month. The Public Service Company of New Hampshire estimated that it will lose $500,000 a day during the indefinite delay.

Voting against Seabrook were Commissioner Gulinski and Commissioner Peter Bradford, the latter a recent Carter appointee who is a former "Nader's Raider" and a known environmentalist. Commission Chairman Joseph Hendrie, who would have

been expected to vote with Commissioner Kennedy for Seabrook, thus incurring a tie vote, had disqualified himself from the decision, citing his earlier experience with Seabrook when he was on the Atomic Energy Commission.

Hendrie has been under attack from the antinuclear lobby, in particular James Cubie, a former paid lobbyist with Ralph Nader and now with the Union of Concerned Scientists and New Directions. Cubie's attack centers on a 1972 internal AEC memo Hendrie wrote that the antinuclear groups are now claiming proves Hendrie came to the regulatory commission with a "pronuclear bias." Informed Washington sources have noted that these public attacks on Hendrie and not his prior experience with Seabrook are what caused him to withdraw from the Seabrook case.

Governor Thomson has turned around this environmentalist attack by calling for the ouster of Commissioner Bradford for his "biased antinuclear stand."

**The Antinuclear Raiders**

On the same day the commission ruled against Seabrook, New Hampshire courts overturned the conviction of trespassing demonstrators who had attempted to occupy the Seabrook site in April 1977. The Clamshell Alliance, which led that demonstration as well as the recent ones, greeted the decisions with the announcement that "This will be the end of nuclear power in this country."

Clamshell Alliance leader Harvey Wasserman was quoted extensively in the *New York Times* June 26 on the possibility of violence at Seabrook. Wasserman made much over "the impromptu debate" going on among the various Clamshell groupings between peaceful protest and violent confrontation. "I can't be responsible for breakaways. We're at the stage in a movement's life when there are breakaways," he said.

One of the breakaway groups Wasserman referred to is a ragged band of anarchists called Edge of Night. Another grouping calling itself the Seabrook Natural Guard staged a march on the commission headquarters two days before their Seabrook decision.

# The Seabrook Supporters

*New Hampshire Governor Meldrim Thomson at the rally for Seabrook June 25:*

"Those people who oppose nuclear power and the breeder must be removed from office and replaced by our friends. . . . You must stand up for America on this issue like the founding fathers did."

*AFL-CIO Building Trades Department President Robert Georgine at the rally for Seabrook June 25:*

"People who oppose nuclear power are opposed to economic growth, period! . . . All productive jobs, jobs that contribute to the national welfare, jobs that give workers a human identity, require energy. . . Those who would have us spraying windex on solar panels in the desert don't understand today's workers. . . Our only viable fuel source is nuclear and we ought to admit it. . . . Even the oil rich Arabs want nuclear power development."

*Six West German union leaders in a June 22 telegram to the New England Council and the Voice of Energy, organizers of the pro-Seabrook rally:*

". . . We have received with enthusiasm the news of your initiative to organize in Manchester a demonstration in favor of nuclear energy and progress. . . . Your constitution, the American Constitution of the founding fathers, guarantees the right to technological progress. This idea has been shared by both German and American humanists, by Benjamin Franklin as well as by Gottfried Leibniz. We are proud of these common historical roots. . . . Helmut Schmidt himself has emphasized that the forced development of nuclear energy resources will be the most important motor in the task of freeing the developing countries from hunger, misery, and warfare."

*AFL-CIO Building Trades head Georgine: "People who oppose nuclear power are opposed to economic growth, period!"*

## Nuclear Power Assembly:

# Breeder Crucial

The Nuclear Power Assembly gathered 250 leaders of the nuclear and utility industries and labor unions for a Capitol Hill rally July 11 prior to the Assembly's lobbying effort for the Clinch River nuclear breeder. The Assembly is an umbrella grouping for the various U.S. organizations concerned with nuclear energy.

The spirit of the prelobbying meeting was summed up by AFL-CIO Building Trades Department President Robert Georgine: "The future of the nation" depends on a successful fight for the Clinch River Breeder.

Georgine assured the group that the AFL-CIO lobbyists would guarantee that Congress passed full funding for the breeder, although he shied away from committing his more than four million union members to a mobilization. In addition, James J. O'Connor, the head of Chicago's Commonwealth Edison, told the audience that he had a firm pledge from AFL-CIO President George Meany that the federation would fight for the breeder.

Georgine made it clear that his union's support for the breeder was not based simply on the jobs factor: "We got into this fight because it concerns the future of our country

# NAACP Reaffirms Energy Stand

# for U.S. Future

The energy panel at the annual convention of the National Association for the Advancement of Colored People, meeting in Portland Oregon the week of July 4, reaffirmed the association's strong stand for a U.S. policy of energy growth and announced the establishment of an NAACP energy office in Washington, D.C. The office, the panel said, will exert pressure on the administration and the Congressional Black Caucus for pro-growth energy policies.

"We are very familiar with the proposals of zero growth coming out of the Carter administration," Kenneth Guscott, a Boston businessman, told the convention, "and we are not going to accept zero growth for this country. . . Last week the Clamshell Alliance had a demonstration, and now the Seabrook reactor is shut down. It was a political, not a technical, decision. This is politics, and politics is what the NAACP knows very well."

Rufus McKinney, vice president of Southern California Gas, called the NAACP energy policy issued last January "the most significant thing done by the NAACP. . . . It has generated huge national debate. . . . We have received invitations to speak from Indonesia, Japan, and many European countries."

Panelist McKinney explained that the NAACP intervened in the energy issue because the Carter administration's "limits to growth" orientation and "no-growth energy and economic policy posed a danger to blacks who have just begun to advance their economic situation." That, declared McKinney, is the NAACP's answer to "the *New York Times* [which] ran an editorial in January suggesting that the NAACP has no business having a view of this issue."

In the panel's concluding remarks, Clarke Watson, head of the American Association of Blacks in Energy, blasted Malthusian liberalism: "It's July 4 and America's romance with liberals is over. The NAACP's alliance with liberals is over. . . . The environmentalists, liberals, intellectuals, socialists were with us in the past, but they've turned around on energy."

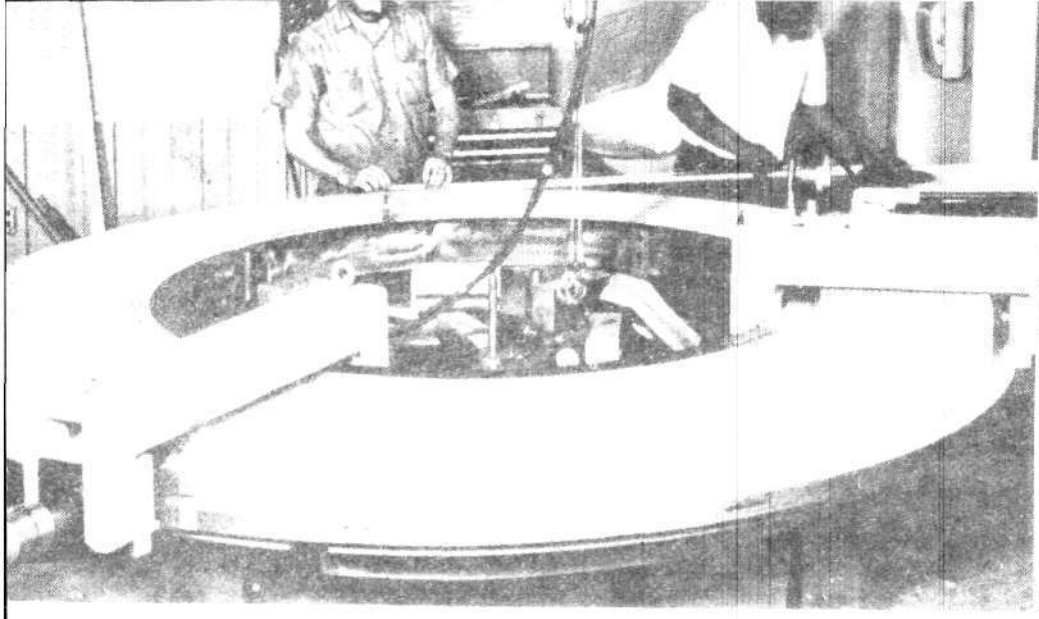
Backing up New Hampshire Governor Meldrim Thomson's emergency energy conference on the Seabrook ruling, which was being held as he spoke, Watson continued: "The Nuclear Regulatory Commission bent to the elitist environmentalists and canceled the Seabrook reactor. . . . If we tolerate further delays in the development of oil and nuclear energy they will be made up by further oil imports and price increases."

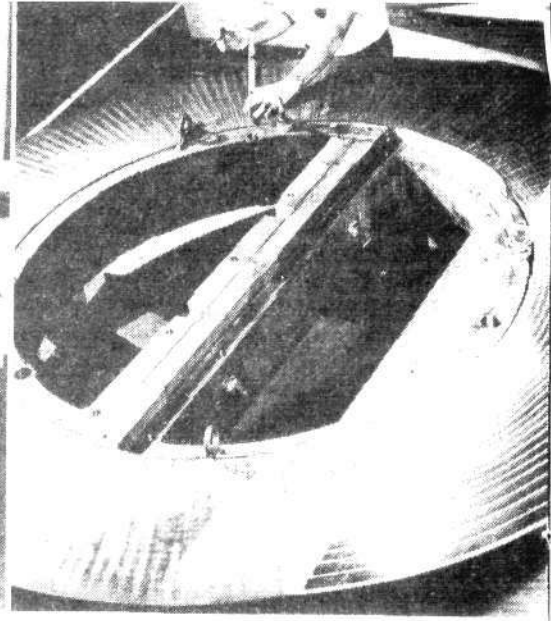
and it is now hanging in the balance."

"Tremendous pressure has come down from the Carter Administration and particularly James Schlesinger," Georgine said. "I have been leaned on very heavily to back away from this fight. But we won't. Too much is at stake. . . ."

Georgine's assessment of the importance of the breeder fight was seconded by Representative James Roe, a New Jersey Democrat, who addressed the rally: "The future of Western Civilization depends on the energy question. . . . The way to create jobs is to make our energy cheap. . . . The solution for both questions is nuclear energy. . . . Without it inflation will soar and the dollar will collapse."

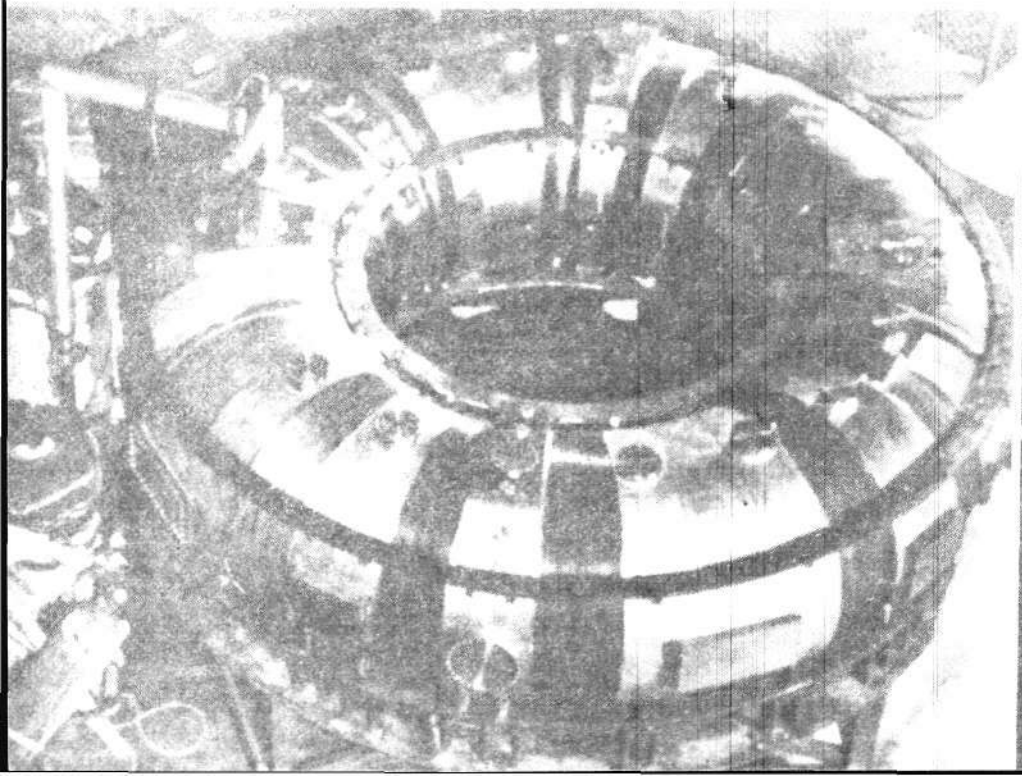
Senator Bennett Johnston, a Louisiana Democrat who is considered as a spokesman for oil and gas interests, urged nuclear energy advocates to organize strongly against the antinuclear lobby—the Council on Environmental Quality, the Mitre corporation, and the three major television networks— that is feeding the public misinformation about nuclear power, with government sanction. "The message of the pronuclear forces must get out," Johnston said. "The country is at a crossroads."

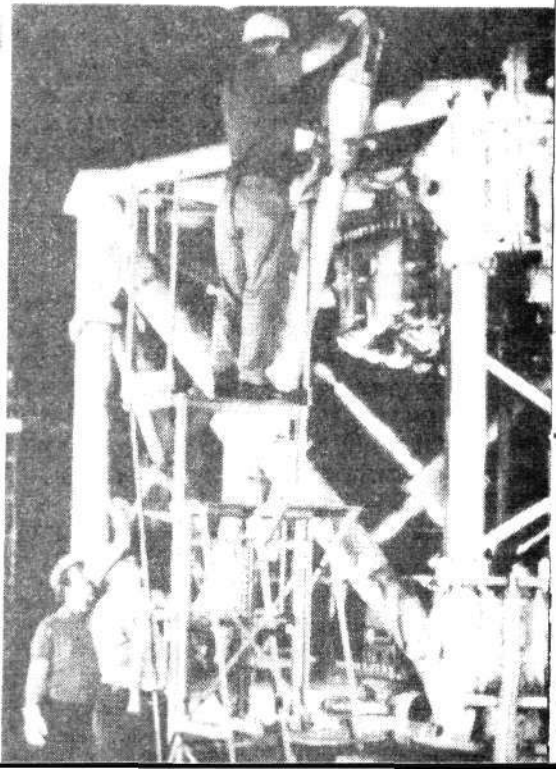


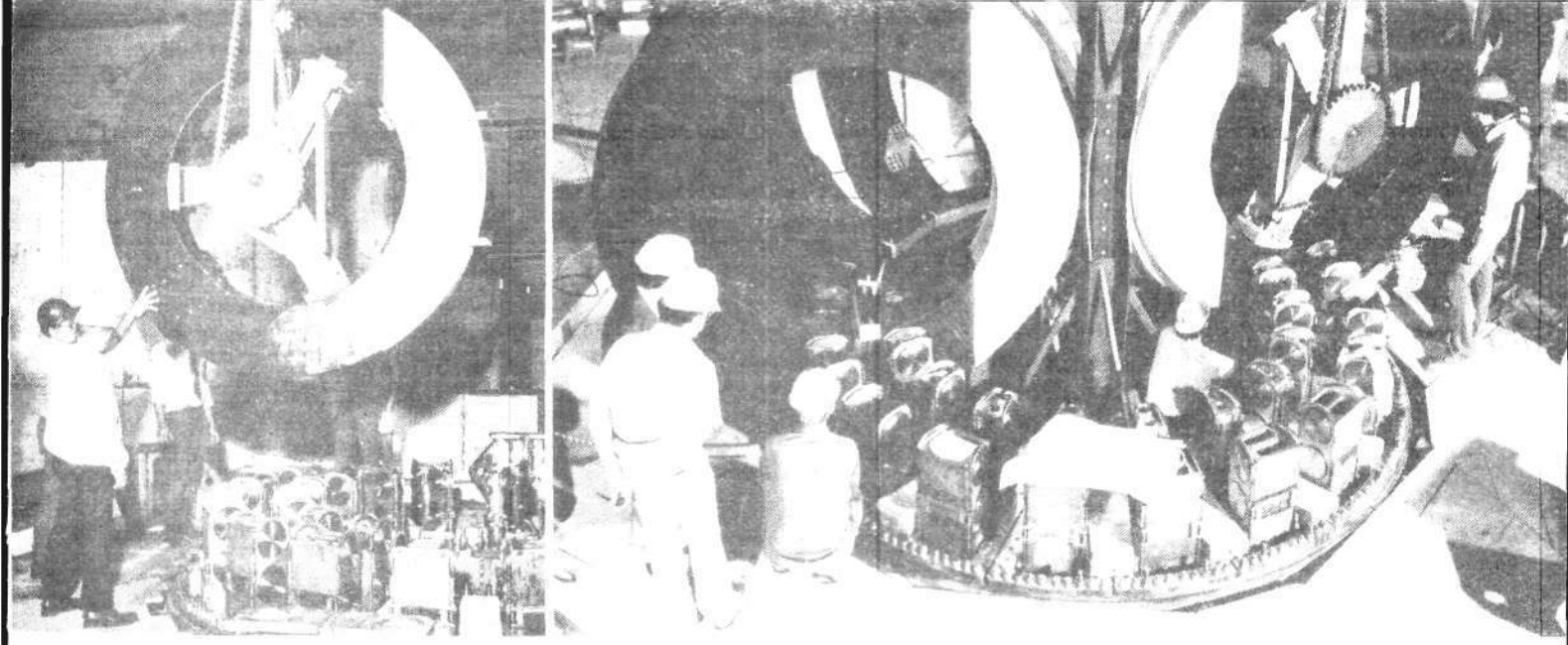


# The Current Status Of Fusion Technology And Research

by Charles B. Stevens







FOR THE FIRST TIME in history humanity possesses an endless supply of readily available, cheap energy that is of sufficient quality to secure the continued existence and development of human civilization. The known technologies of nuclear fusion and fission make this energy supply a reality. Furthermore, the rapid research progress on new types of fusion technology, despite the scarcity of research funding, guarantees that even more advanced energy systems are easily realizable. These more advanced systems will be more economical and more efficient and will have wider application for producing essential material resources.

In a word, world peace and prosperity are guaranteed once governments make the commitment for a full use of nuclear technologies and the development of thermonuclear fusion.

This report summarizes the current political, technical, and scientific status of fusion energy developments and reviews the essential facts to support the above assertions.

When nuclei of lighter elements like hydrogen fuse and form the nuclei of heavier elements like helium, there is a net energy gain because some of the end-product nuclei weigh less than the nuclei of the input fuel. The sun is continuously changing its hydrogen into helium through thermonuclear fusion reactions and releasing energy—sunshine—in the process.

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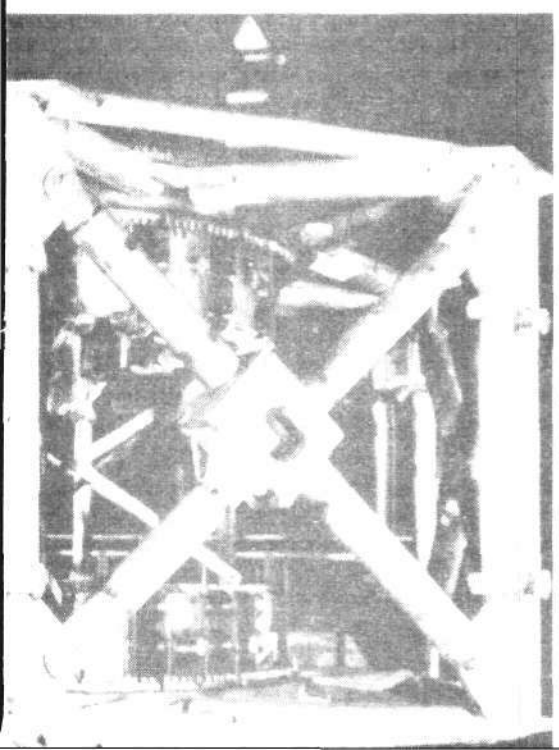
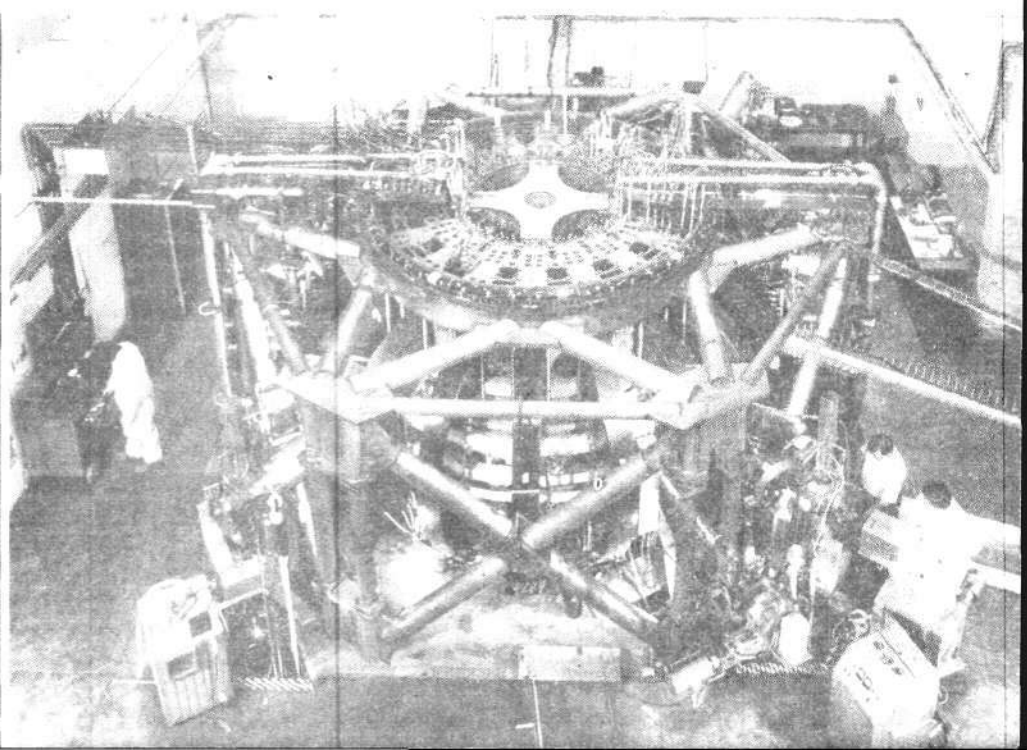
*The Princeton Large Torus, the largest U.S. tokamak, is shown here in various stages of assembly. In the pictures above [from left], the coils for the magnet are being wound and put into place. The pictures below [from left] show the testing of the vacuum chamber, the construction of the reactor frame, and the completely assembled PLT.*

Princeton Plasma Physics Laboratory





This fusion of atomic nuclei is the process by which all the heavier elements we know on earth and have observed throughout the universe were built up from the simpler, lighter elements. As such, it is the major energy source directly and indirectly in the evolution of the earth.

Although man first demonstrated the capability to harness fusion energy only three decades ago, commercial fusion power is recognized by the experts as a possibility within this century. The general consensus of the world scientific community holds:

(1) that fusion is the unique technology for resource creation;

(2) that energy-producing fusion systems, together with associated plasma physical processes, define the theoretical and experimental frontiers of contemporary physics; and

(3) that the immediate potential for realizing fusion energy has been demonstrated pragmatically; the only thing lacking is a commitment of the necessary funds and scientific manpower to make it happen.

The full scientific feasibility of man-produced fusion energy was first demonstrated in the early 1950s when both the United States and the Soviet Union detonated hydrogen bombs. Since that time, nuclear fusion triggered by an atom bomb has been developed as the most reliable military technology guaranteeing the national security of both nations. At the same time, fusion research and development for peaceful applications has become the basis for the most extensive international cooperative effort in history.

The scientific collaboration for fusion began in 1956, when the late I. V. Kurchatov and L. Artsimovitch unilaterally declassified Soviet magnetic fusion research in response to President Eisenhower's "Atoms for Peace" proposals. Kurchatov was the father of the Soviet nuclear fission and fusion research efforts, and Artsimovich was the scientist chiefly responsible for developing what is now the world's most researched approach to magnetic fusion energy, the tokamak.

During the Atoms for Peace period, the United Nations established the International Atomic Energy Agency and the IAEA's World Fusion Research Council played an increasing role in coordinating international fusion research. Most of the initial research cooperation involved the stellarator, tokamak, and pinch devices, but the U.S. role was limited by budget constraints and classification policy. It was Artsimovitch who got the U.S. fusion program off the ground. In 1969, his organizing trip to the United States led to the unprecedented U.S.-Soviet cooperation agreement on magnetic fusion research and a turnaround in U.S. funding of fusion research.

The fusion situation took another leap forward in 1972 when Edward Teller, the father of the U.S. fusion research effort, unilaterally declassified the most crucial scientific aspects of inertial fusion. In the same year, under the Nixon Administration, the U.S.-USSR Joint Fusion Power Cooperation Committee was set up.

The chief scientists involved in the worldwide cooperation on fusion energy research and development have given ample testimony on the feasibility of developing commercial fusion reactors and on the necessity for an aggressive, well-funded research program to bring this about. Two years ago, E. P. Velikhov and Edwin E. Kintner, the directors of the Soviet and U.S. fusion research effort, respectively, made the following joint statement:

> Those of us working in fusion energy research and development are more confident than at any time in the past that practical fusion power can be achieved by the end of this century... We have passed through the phase of concept demonstration, confirmation of main physical principles and establishing certain regularities, both theoretical and experimental, and now we are in the phase of attaining near-reactor parameters and elaborating the basic engineering means needed for reactor construction.*

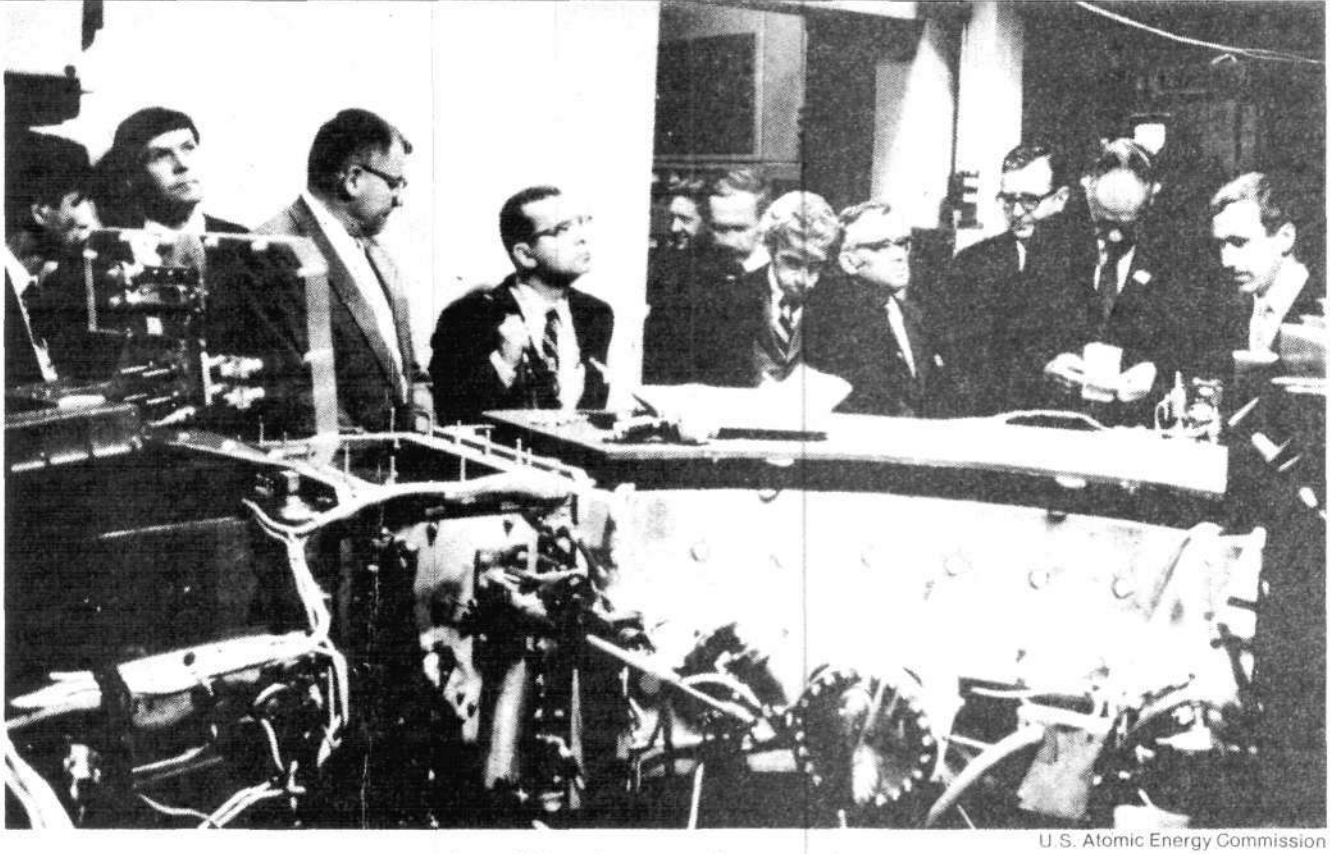
The Velikhov-Kintner statement was first presented in November 1976 at the joint American-European Nuclear Societies conference held in Washington, D.C. Edward Teller, the chairman of the session, endorsed the statement immediately after its presentation and noted that he was now convinced that a prototype fusion reactor generating electricity could be realized by 1985.**

At the same conference, Harold Furth, director of the theoretical division of the chief U.S. magnetic fusion research laboratory, made a similarly enthusiastic statement:

> Comparing fusion power with other long-range solutions to the energy problem, one may note two main features favorable to fusion: (a) the fusion approach is continuously perfectible from the economic and environmental points of view... (b) the extremely broad spectrum of possible technological approaches, while providing an element of complication in the planning of present-day research, constitutes a unique long-term asset. The *basic* physical constraints on the fusion process are remarkably lenient, and the technological constraints on *specific* approaches to fusion power will be overcome by appropriate selection in the light of progressing physical research.†

A year later, March 1977, Edwin Kintner told the U.S. Congress:

> Fusion could be considered the enduring solution to energy problems. Its potential for satisfying the need for energy can be sensed if one imagines the effect on world economic and military affairs if fusion were now developed and available on a competitive economic basis.... Within the fusion community, fusion is no longer looked on as a question of scientific feasibility, but only one of practicality and economics.¶



U.S. Atomic Energy Commission

*A U.S. scientific delegation viewing the colliding beam accelerator at the Institute of Nuclear Physics, Novosibirsk, Siberia in 1971.*

And finally, the IAEA World Fusion Research Council wrote in May 1977:

> In view of the great progress achieved in fusion since 1970, the Council is convinced that the time is ripe to urgently make a large and aggressive effort toward the practical demonstration of fusion power at the earliest possible date. ‡

**On the Governmental Level**

By May of this year, the above-stated consensus of the worldwide fusion research community had become the official policy of the Japanese and Soviet governments. Prime Minister Fukuda of Japan made this clear during his May visit to the United States when he called for a $1 billion joint U.S.-Japanese fund for fusion research and privately proposed to help rectify the U.S. balance of payments deficit with Japan by investing substantial funds in U.S. fusion research.

Japan, it should be noted, has increased its fusion research program 25-fold in the last several years and the Japanese program will overtake the U.S. effort within two years if the U.S. program continues to stagnate.

The Soviet Union's call for a worldwide crash fusion development program was part of the Soviet presentation to the United Nations disarmament conference in May. The official Soviet daily, *Pravda*, outlined the details of the plan in a full-page statement May 31 titled, "Practical Ways to Stop the Arms Race," which read in part: "We declared only recently our readiness to participate, together with the United States, the European countries, Japan, and other countries, on an international project on the 'tokamak' thermonuclear reactor."

Just a week before the proposal appeared in *Pravda*, E. P. Velikhov had presented this plan to the U.S.-USSR Joint Fusion Power Coordinating Committee meeting in Moscow. Velikhov, who was recently elected vice president of the Soviet Academy of Sciences, specifically proposed that the United States and the Soviet Union jointly build a prototype tokamak fusion electric power reactor in the 1980s, under the direction of the IAEA.

The Soviet fusion program at present is about twice the size of that of the United States.

Although the Carter Administration has not officially responded to either the Japanese or the Soviet fusion offers, a debate on fusion is raging within the Department of Energy. Adding to the pro-fusion arguments is the report of the fusion review committee initiated by John Deutch, assistant secretary of the Department of Energy for energy research and development. This panel of experts (known as the Foster Committee after its chairman, John Foster of

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* Joint American-European Nuclear Societies meeting, Washington, D.C., November 1976.

** Joint American-European Nuclear Societies meeting, Washington, D.C., November 1976.

† Transactions of the American Nuclear Societies meeting, the American Nuclear Society, November 1976.

¶ U.S. Department of Energy press release, March 22, 1977.

‡ Reprinted in *Fusion*, July-August 1977, Vol. I, No. 1.

Table 1 EXOTHERMIC FUSION REACTIONS

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

*Shown here are the reaction energy output, the threshold plasma temperature needed to ignite the reaction, and the maximum energy gain per fusion reaction of the most likely fusion reactions to be used in power reactors. MeV stands for 1 million electron volts; keV stands for 1,000 electron volts. Most chemical reactions involve energy releases much lower than 100 electron volts. D is deuterium, the heavy isotope of hydrogen which contains one proton and one neutron; T is tritium, the hydrogen isotope with two neutrons and one proton; He is helium; P is simple hydrogen with one proton; Li is lithium; B is boron; and N is neutron.*

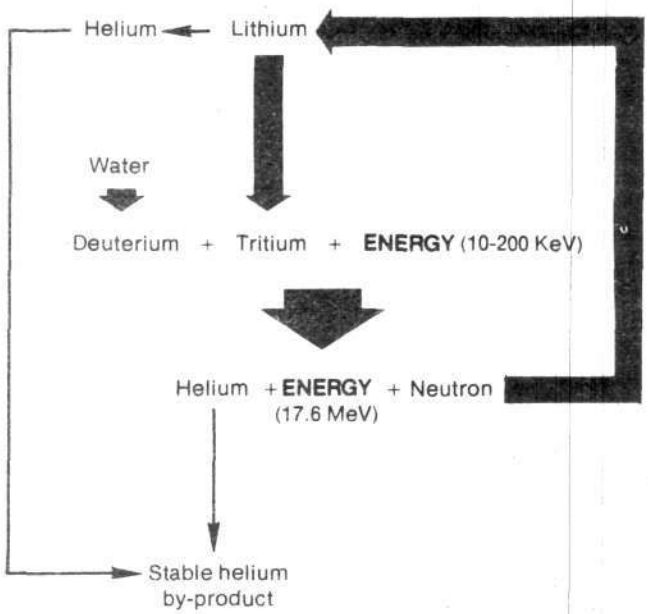



**Figure 1**
**FUSION FUEL CYCLE**

*Figure 1 gives the fuel cycle for the easiest fusion reaction to achieve, deuterium (D) and tritium (T) fusion. At temperatures greater than 10 keV [10,000 electron volts, which is approximately equal to 110 million degrees Celsius), deuterium and tritium form helium (He) and a high-energy neutron (n) with a total energy output of 17.6 MeV (million electron volts). Of this, 3.5 MeV is associated with the He nucleus, and 14.1 with the neutron. The 14.1-MeV neutron reacts with lithium to produce helium (He) and tritium (T). This allows for the maintenance of the tritium fusion fuel, since this hydrogen isotope does not occur naturally on a large scale and must be generated.*

TRW) submitted its findings in April; and although the report is not yet public, the major conclusions of the panel are known to support a full-speed-ahead U.S. research program.

## GENERAL SCIENTIFIC AND TECHNICAL STATUS

To ignite a fusion reaction, the appropriate fusion fuel must be raised to temperatures of hundreds of millions of degrees. In order to produce more fusion energy than the energy invested in raising the fuel to fusion temperatures (this is called breakeven), the fuel must be insulated from losing its high temperature; that is, it must be *confined* in some manner.

Since the rate at which the fusion reaction proceeds is a function of the density of the fusion fuel given in terms of number of reacting nuclei per cubic centimeter, the energy-producing confinement condition is expressed as the product of the density times the confinement time. This product is termed the *Lawson criterion* for energy breakeven in fusion reacting systems.

The most likely candidates as fuels to produce fusion reactions are listed in Table 1, along with their expected energy gains. The easiest fusion reaction to achieve and the one with the largest potential energy gain is the deuterium-tritium (D-T) reaction shown in Figure 1.

At temperatures of several thousand degrees, matter becomes *ionized*; that is, dominated by electromagnetic phenomena. The ionized state of matter is called the *plasma state*, and although it is rarely found on earth, plasma is the general condition of 98 percent of the universe.

To the uninformed it may appear impossible to obtain and insulate matter at such extreme conditions on earth. But one should remember that the picture of the ordinary color television set is generated by an electron beam with a "temperature" of 300 keV.*

In fact, contrary to the conventional notion of thermo-

* An eV is an electron volt, an energy unit roughly equal to 10,000 degrees Celsius; keV is 1,000 eV, and MeV equals 1 million eV.

**Figure 2**
**POTENTIAL USES OF FUSION ENERGY**

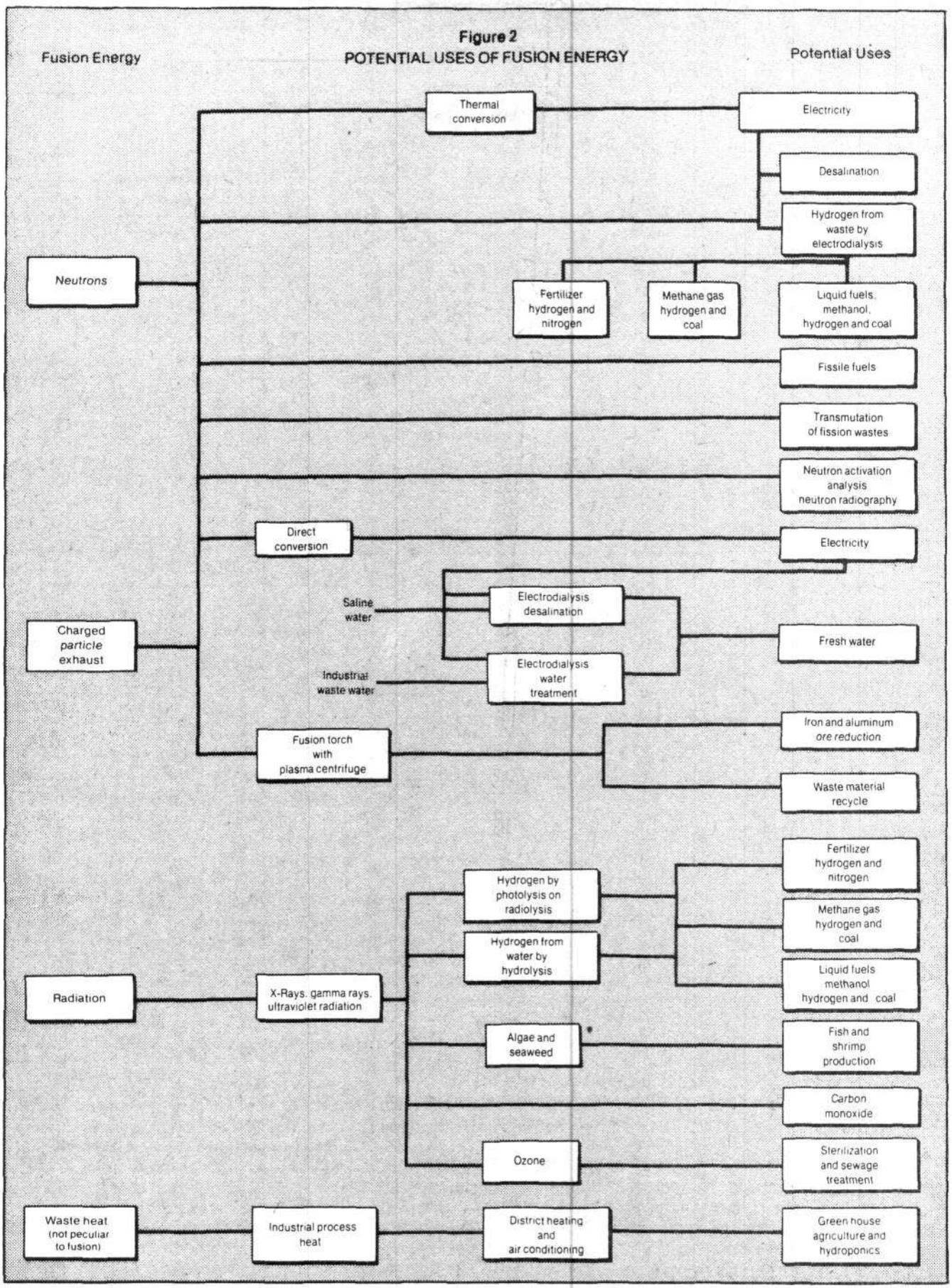
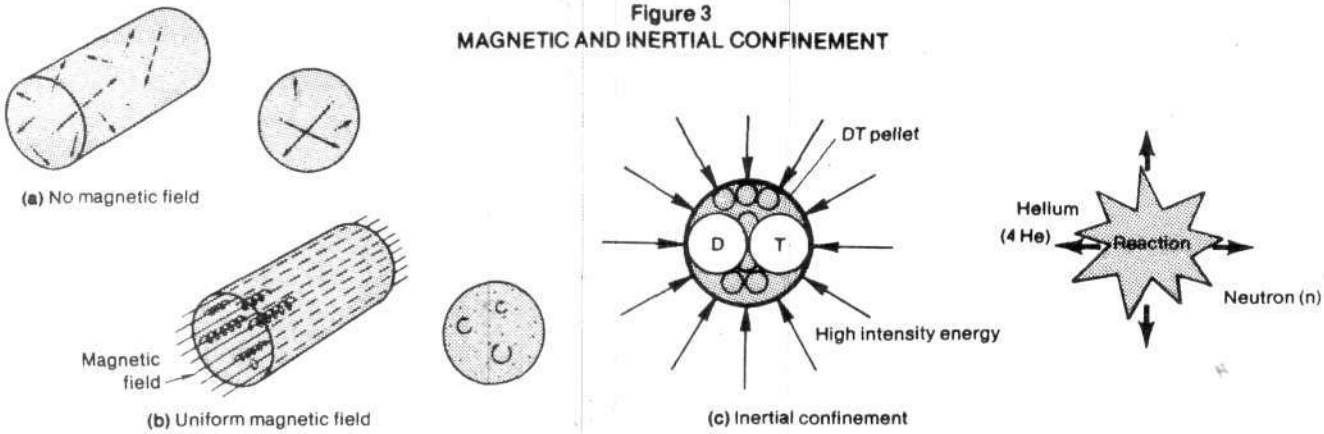


**Figure 3**
**MAGNETIC AND INERTIAL CONFINEMENT**




*In (a), arrows denote the random motion of an unconfined plasma in a cylindrical vessel. In (b), an axial magnetic field is applied to the plasma in the cylindrical vessel. The electrically charged electrons and nuclei are then trapped into spiral paths along the magnetic field lines. This type of magnetic confinement is incomplete, however. For complete plasma magnetic confinement, the ends of the cylinder would have to be closed off or brought together to form a torus (donut).*

*In (c), some form of intense energy (laser, electron, or ion beams) is being directed onto a spherical pellet containing deuterium-tritium fusion fuel (D-T). The surface of the pellet absorbs these intense energy beams and is quickly vaporized. This vaporized layer expands outward like the exhaust of a rocket. This produces an equal and opposite inwardly directed force that compresses and heats the remaining part of the pellet. The time it takes for a shock, traveling at the speed of sound, to travel the distance from the core to the surface of the compressed pellet is the time the fusion fuel is "confined." This is simply the time it takes for the explosive release of fusion energy to overcome the "inertia" of the fusion fuel itself; that is, the time for the pellet to blow up.*

dynamics that matter becomes more and more disorganized and unmanageable as its temperature is raised, plasmas demonstrate well-ordered, coherent behavior as their temperatures, or energy densities, are increased. It is precisely for this reason that fusion and associated plasma research, which is explained theoretically using 19th-century classical hydrodynamics and electromagnetism, has led to the development of new concepts that promise to resolve the most fundamental questions in quantum mechanics and elementary particle physics.

### The Soliton Conception

To be specific, the development of the self-organized plasma-field structures observed in fusion research, such as *solitons*, has led to conceptions that provide the theoretical basis for obtaining discreteness out of a continuous system. The collective interaction of plasma electrons and nuclei with internally and externally generated electric and magnetic fields—these provide the physical means for heating and confining fusion fuel—can be usefully theoretically described only as the interaction of *continuous* fields and fluids. Yet, as the plasma is increased in energy density, well-ordered and stable *discrete* structures such as solitons form. Theoretically, this nonlinear effect, the creation of solitons, provides new ways to approach the chief problem of quantum electrodynamics—explaining how one gets discreteness out of continuity—and explaining the stability of the electron.

This nonlinear aspect of fusion systems is directly related to the unique array of its potential applications, shown in Figure 2.

Because of the inherent high temperatures (high energy densities) and the wide variety of matter-field structures associated with fusion plasmas, fusion promises to provide the scientific-engineering base for a virtually endless expansion of new sources of economic and material resources at ever-increasing efficiencies. Although such general applications are far from fully demonstrated, one major study commissioned by the Electric Power Research Institute, "Enhanced Energy Utilization from a Controlled Thermonuclear Fusion Reactor," concluded that fusion was economical and practical as an alternative means of electric power production when used in combination with synthetic fuel production such as methanol or with the breeding of fissile fuel for use in nuclear fission reactors (the fusion-fission hybrid). The 1976 report gave 1988 as a target date for such a demonstration.*

Two other spinoffs from fusion-related plasma physics research demonstrate the fertility of fusion research. The first is *laser isotope separation*, which grew out of the laser fusion research and now is progressing in its own right toward the development of new technologies that promise to revolutionize the chemical and nuclear fission industries within a few years.

The second is the use of the inherent high energy density of plasma structures for generating intense electric fields for economic and efficient particle acceleration. Experiments this summer at Kirtland Air Force Base in New Mexico on one such method promise to provide the basis for a whole new technology that can immediately provide an economic means for accelerator breeding of fissile fuel and a new tool for fusion research.**

Table 2
MAGNETIC BOTTLE CONFINEMENT SCHEMES – Magnetic

| Magnetic Bottles | | | | | | | |
|---|---|---|---|---|---|---|---|
| Closed bottles | | | | Open bottles | | | |
| Axisymmetric | | Nonaxisymmetric | | Axisymmetric | | Nonaxisymmetric | |
| Steady | Pulsed | Steady | Pulsed | Steady | Pulsed | Steady | Pulsed |
| Straight z-pinch TC | Tokamak TC | Stellarator T | Toroidal theta-pinch aux. field TC | Mirror P | Straight theta-pinch PC | Mirror with loffe bars P | Polytron |
| Multipoles PI | Toroidal theta-pinch TC | Torsatron T | Pulsed bumpy torus TC | Consecutive Mirrors P | Mirror Compression P | Toroidal picket fence | |
| Astron P | Toroidal screw-pinch PTC | Helical heliotron T | | Cusp P | | Helical multipoles PTI | |
| | | Bumpy torus | | Straight picket fence P | | Baseball | |
| | | Poloidal heliotron PTI | | Multigap trap P | | | |

There are two distinct methods of producing fusion energy, magnetic confinement and inertial confinement (Figure 3). In *magnetic confinement*, the tendency of charged particles to be trapped in spiral orbits along a magnetic field line is used to confine fusion plasmas in a number of different magnetic field configurations. In *inertial confinement*, fusion fuel is compressed to high densities and then ignited so that the fuel undergoes substantial amounts of fusion before it simply blows up.

Table 2 lists some of the general approaches to fusion within these two general methods.

As the discussion above of the eruption of self-organizing structures in energy-dense plasmas indicates, plasma cannot be described simply as a fourth state of matter. In fact, energy-dense plasmas actually describe a continuous unfolding of new manifolds that contain infinite numbers of new states of matter.

Given this fact, the vast array of different approaches to fusion outlined in Table 2 in no way can be competently compared on the basis of a few parameters, such as the Lawson criterion for energy breakeven discussed above. Even within any one distinct approach, simple comparisons are misleading. It is for this reason that a successful fusion program must fund a wide variety of approaches, in addition to the ones that appear most immediately promising.

Table 2
MAGNETIC BOTTLE CONFINEMENT SCHEMES
Nonmagnetic

| Guided systems | Quasi-steady systems | Inertia systems |
|---|---|---|
| Electrostatic wells | Electrostatic wells | Plasma focus |
| Beam systems | Beam systems | Laser compression |
| | Microwave confinement | Electron beam compression |

* P and T denote poloidal and toroidal *main* field components; C indicates that a plasma current makes an important contribution to the magnetic field; and I indicates internal conductors.

* Bernard J. Eastlund, "Enhanced Energy Utilization from a Controlled Thermonuclear Fusion Reactor," Electric Power Research Institute Report, ER-248 (September 1976).

** M. Reiser, "On the Generation and Focusing of Intense Ion Beams for Pellet Fusion," *IEEE Trans. Nucl. Sci.* (June 1977).

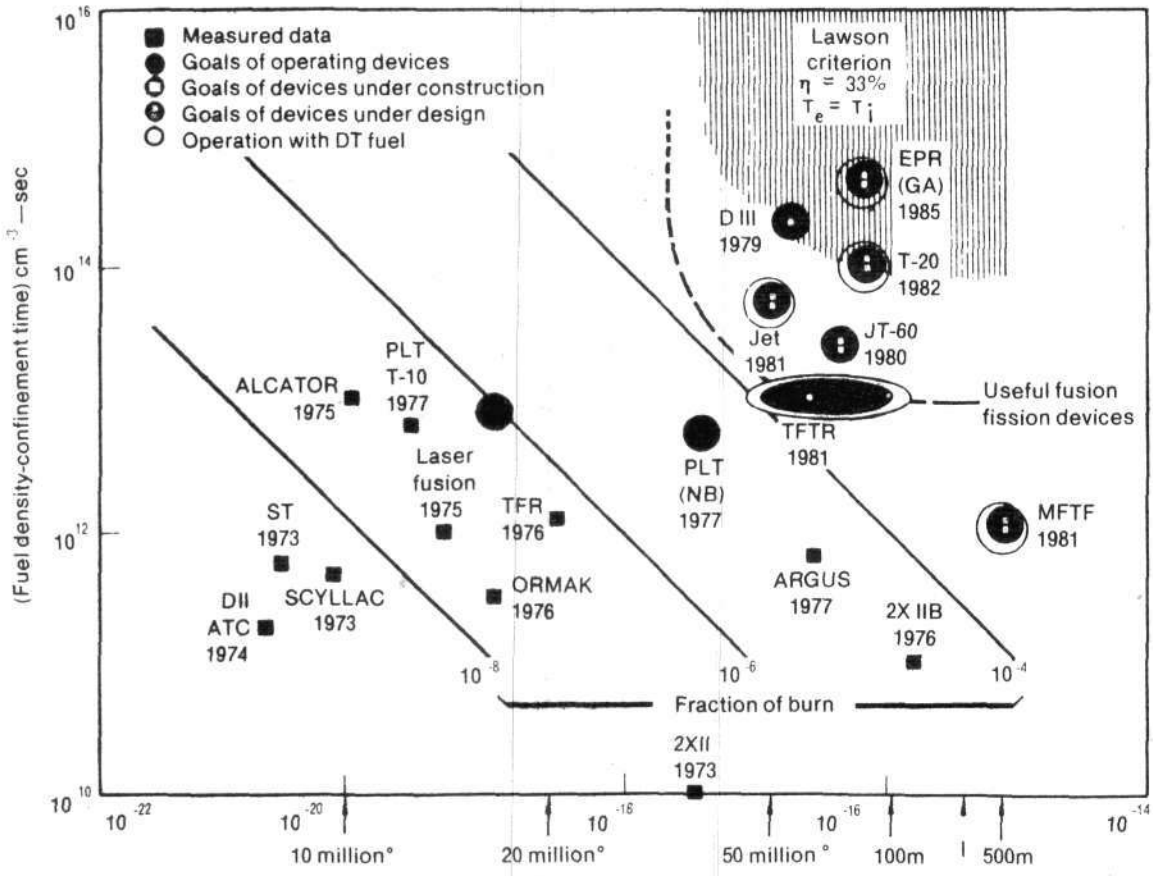
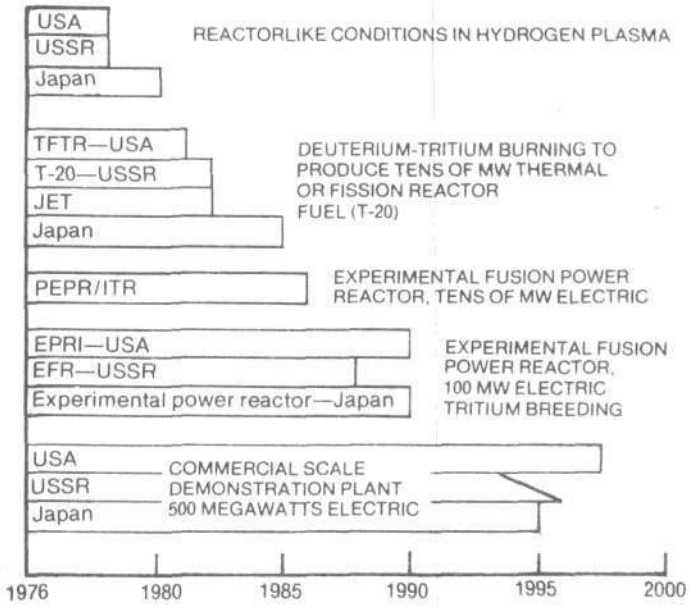



**Figure 4**
**RESEARCH PROGRESS IN FUSION POWER**

*The current state of fusion research is shown in Figure 4 in terms of already achieved results and projections for planned experiments under construction. Results from the various research projects are plotted logarithmically on both axes. The horizontal axis gives temperature in millions of degrees Celsius, and the vertical axis gives the density-confinement time product in number of nuclei per cubic centimeter-seconds. The hatched region in the upper right corner represents the area in which a pure fusion reactor must operate. The dashed line, also in the upper right, shows how these conditions are substantially lowered for fusion-fission hybrid reactors.*

*Below the names of the various experiments are the dates of measured results (boxes) or projected results (circles). A guide to the experiments follows: DII is the General Atomic noncircular tokamak, Doublet II, to which DIII is the followup. Doublet III, now on line, is expected to reach near-reactor conditions when neutral beams are added to the experiment in 1979. ST refers to the first U.S. tokamak, the converted Princeton ST stellarator, which duplicated the initial Soviet tokamak results. ATC was the second U.S. tokamak, also at Princeton, a small device that demonstrated the feasibility of neutral beam and plasma compression heating in tokamaks. Alcator is the Massachusetts Institute of Technology's high field, small tokamak, which, as seen, holds the record for density-confinement product. Ormak was the third U.S. tokamak to be built, and it demonstrated scaling both in terms of size and neutral beam heating. TFR, the French tokamak, also demonstrated neutral beam heating. PLT and T-10 are the large U.S. and Soviet tokamaks, respectively. PLT, the Princeton Large Torus, recently achieved temperatures of greater than 20 million degrees with neutral beam heating. TFTR is the Princeton tokamak fusion test reactor now under construction, which will be the first tokamak to burn D-T fusion fuel (all previous experiments used only simple hydrogen). EPR and T-20 are the General Atomic and USSR designs for Experimental Power Reactors, respectively. 2XII and 2XIIB represent the results from Livermore's open-ended mirror magnetic system. The Mirror Fusion Test Facility (MFTF) is a Livermore experiment that will demonstrate the feasibility of a number of different mirror approaches to fusion. Laser fusion refers to world results in inertial confinement. Argus was the prototype 2-beam system for the Livermore 20-beam Shiva system now in operation and projected to achieve results equal to the TFTR. Scyllac represents the results from toroidal theta-pinch research.*

Figure 5
FUSION POWER DEVELOPMENT PLANS




*The projections of various stages of developing commercial tokamak fusion power plants are shown here, based on the announced plans of the major countries involved. Note that the Soviet plan for commercial-scale reactors is indeterminate, although indications are that they plan to build such a plant by at least the early 1990s.*

The already achieved results and the projected results of a number of experiments that represent the various approaches to fusion are shown in Figure 4 in terms of the Lawson density-confinement time product and temperature.

The current projected time scales for reaching various stages on the road to demonstrating the commercial feasibility of tokamak electric power plants are shown in Figure 5, based on the announced fusion research plans of the leading countries involved. These dates could be substantially accelerated, given larger amounts of research funds.

The U.S. time scale for magnetic fusion is shown in Figure 6, from a 1976 U.S. Energy Research and Development Administration study giving the various costs and dates for a demonstration reactor. Similar studies for inertial confinement have come up with approximately the same time scales and costs.*

Figure 7 tabulates the key problem areas for developing power reactors in magnetic fusion and, in particular, the current and projected status with regard to the tokamak. Although not all of these problem areas are the same as those encountered in inertial confinement, many are similar. For example, development of the appropriate lasers and electron and ion beams should be substituted for categories VI and VII in Figure 7, and target gain (the amount of fusion energy generated divided by the energy

* Energy Research and Development Administration, *Fusion Power by Magnetic Confinement: Program Plan*, Vol. I-III, ERDA 76/110 (July 1976). Also C. M. Stickley, "Laser Fusion," *Physics Today* (May 1978).

Figure 6
THE U.S. TIME SCALE
FOR MAGNETIC FUSION

*In its July 1976 study, "Fusion Power by Magnetic Confinement," the U.S. Energy Research and Development Administration outlined time tables for achieving commercial fusion reactors based on different levels of funding allocated to magnetic confinement fusion research. The various funding paths in the study are labeled Logic I to Logic V in the figure, with Logic I as the lowest-level research budget. The horizontal axis gives time, and the vertical axis the budget dollars. The dots labeled with years indicate conservatively when fusion reactors would be achieved for each logic; the dashed curves at the point of intersection with each Logic represent "optimistic" (left) and "pessimistic" projections for the necessary scientific and technological progress required.*

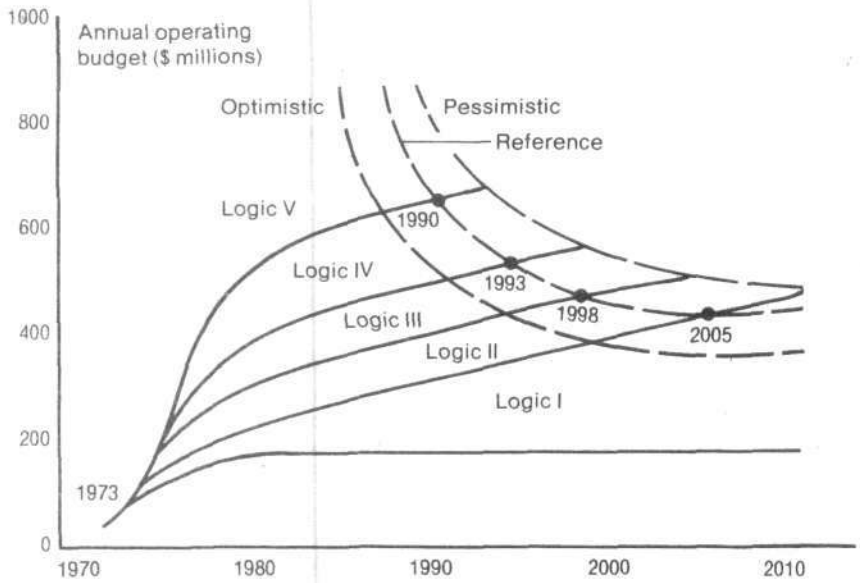
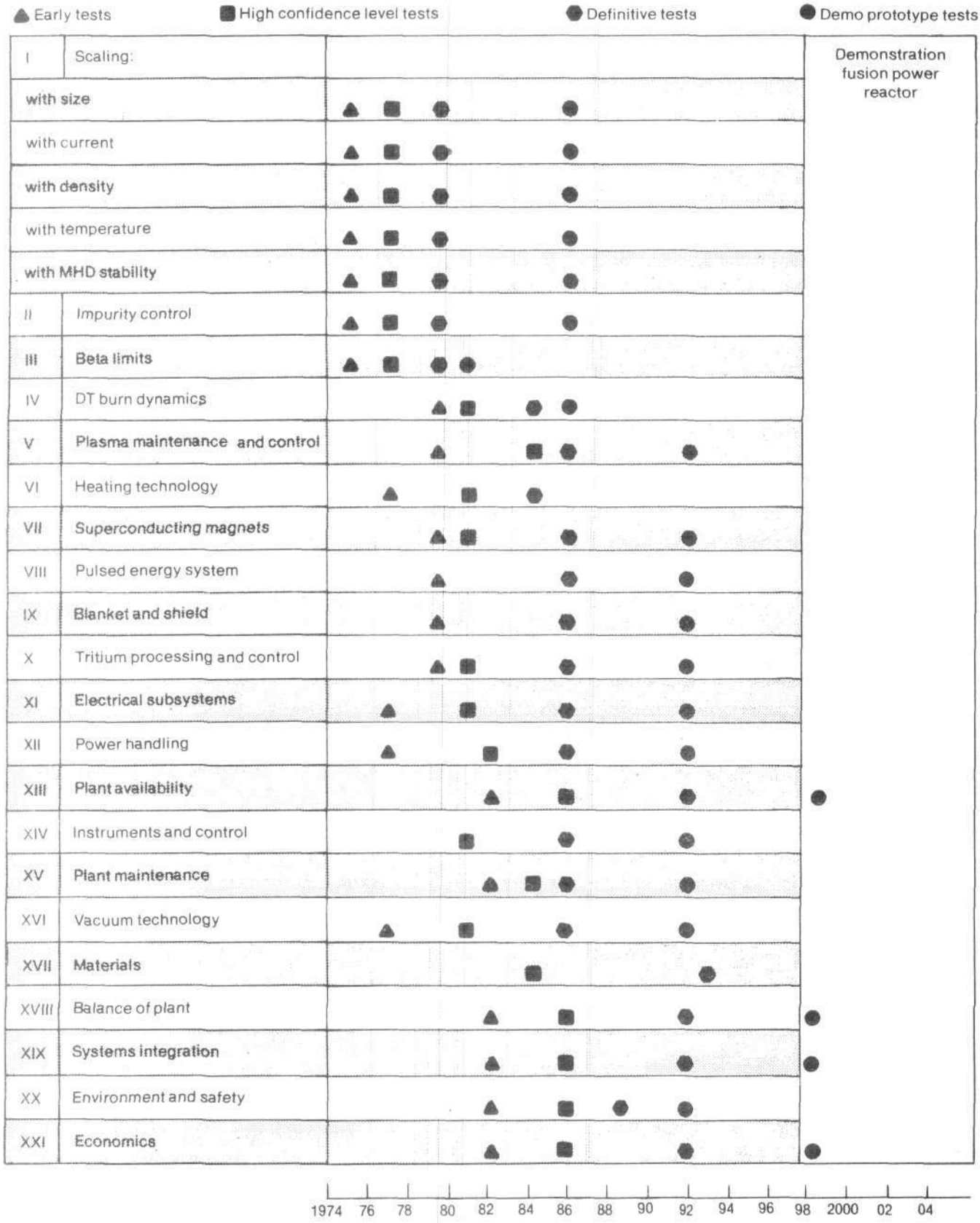


Figure 7
MAJOR PROGRAM ELEMENTS FLOW CHART
FOR THE TOKAMAK



invested in compressing and heating the fusion target) should be substituted for category I.

## THE STATUS OF MAINLINE MAGNETIC CONFINEMENT SYSTEMS

The chief mainline magnetic confinement approach is the Soviet-invented tokamak, a donut-shaped magnetic trap. Quickly catching up to the tokamak in terms of research results is the stellarator, another donut-shaped magnetic trap invented in the United States and researched mainly in the Soviet Union.

Other magnetic systems include the open-ended magnetic mirror trap, which continues to make major research strides. A number of recent experiments on the tandem mirror system, for example, have shown this to be the first type of mirror trap system that appears capable of being scaled up to use in an actual power plant. The tandem system was designed simultaneously by Dimov, a Soviet scientist working in Novosibirsk, and by Lawrence Livermore Laboratory in California.

In addition, there is the toroidal theta pinch device, which is also called a high-beta stellarator. The United States has all but abandoned its pinch device, the Scyllac, by not funding it, but the West Germans are planning a major experiment, the HBS II at the Max Planck Institute at Garching, their major fusion laboratory. The HBS II should bring the toroidal theta pinch back in as a mainline system.

### Tokamaks

Tokamak progress is reviewed here in some detail. Since there is a lot of overlap, other systems are discussed only briefly.

Although the physics of tokamak operation remains far from full comprehension, there is sufficient empirical information to confidently design minimally performing reactor prototypes with existing state-of-the-art technology. This is the chief conclusion of the joint Velikhov-Kintner statements cited above, as well as that of other experts. This perspective, however, is conservative in the extreme.

In fact, experimental results from a half dozen tokamak and stellarator experiments, but primarily from that small workhorse of the U.S. tokamak effort, the Massachusetts Institute of Technology Alcator, indicate both qualitatively and quantitatively that classical confinement of plasma (that which takes toroidal geometry effects into account) is being achieved.

In the Alcator results, several phenomena point to this classical confinement: the turnaround in confinement time as the central portion of the plasma proceeds from a plateau to a collisional regime, the asymmetrical distribution of oxygen impurities in impurity control experiments, and even the appearance of what appears to be the Ware pinch. It should be noted that the mirror and theta pinch devices have been getting what also appears to be classical confinement for some time now.

Even if these results are only partially true, the achievement of classical confinement is a stupendous breakthrough. Back in the early 1950s when the first large magnetic fusion research efforts were initiated, the classical theory of confining a 100-million-degree gas in a magnetic trap led many scientists to believe that the development of fusion reactors would be scientifically and technologically simple. This was before researchers encountered experimentally the host of plasma microinstabilities and MHD macroinstabilities.

Now, after 20 years of difficult research, plasmas are no longer unpredictable and anomalous creatures, but virtually can be created and confined to order. Classical confinement is hundreds, if not thousands of times better than the minimal confinement needed for economic power reactors. The achievement of the minimum breakeven confinement parameters by the Alcator in 1976 was no quirk.

From both a theoretical and engineering-technical standpoint, the startup of the Oak Ridge Laboratory ISX Impurities Studies Experimental tokamak in summer 1977 is most indicative of the speed with which progress can be made from this point. All previous tokamak experiments had taken between one and two years to tune up for successful experimental operation after construction: the Alactor took two years; the French TFR, two years; the Princeton PLT, more than a year; and the Soviet T-10 began operation on schedule but then burned out one of its coils and was down for more than a year; and so on. The Oak Ridge ISX, in contrast, began successful operation one day following completion of construction and achieved low impurity levels, relatively high betas and plasma currents.

In all the various tokamak devices (the PDX, Doublet III, Alcator C, and Princeton PLT), high-confidence-level tests of scaling of confinement times with size, current, density, temperature, and MHD stability have been accomplished and definitive tests will take place within the next year. Although classical (neoclassical) theory is by no means completely adequate, the behavior of toroidally confined hot plasmas is sufficiently known empirically to extrapolate several different types of plasma regimes needed for power reactor energy production.

### Complexity and Success

It should be noted that for each new problem or anomaly that has arisen experimentally in recent years, 10 or more new possibilities for better confinement have appeared. This inherent complexity of plasma physics in the long run guarantees success.

To take some examples: as little as a year ago, control of the influx of unwanted types of elements (impurities) into a hydrogen plasma, especially from the wall of the vacuum chamber, was the chief bugaboo of the magnetic fusion research program. The virtually impurity-free operation of the Alcator in 1976 remained a mystery.

Some researchers, such as Robert Taylor of the University of California at Los Angeles, believed that impurities

*Figure 7 shows the U.S. Energy Research and Development Administration's time estimates, from their 1976 study, for solving various problems along the way to a demonstration tokamak reactor. The assumed funding is Logic III.*

were the root cause for virtually all anomalous and unwanted behavior—such as the disruptive instability—in toroidally confined plasmas. Now, impurity control is rapidly approaching the point of definitive tests through the success of Taylor's important work at UCLA, the initial results of the ISX experiment, and the vast improvements in the PLT's operation with increasing temperature levels generated through neutral beam heating.

Taylor, who played a key role in getting the very successful MIT Alcator running, not only has made major progress in impurity control of tokamak plasmas but also has made tremendous strides in the design of tokamaks. His design improvements have made significant experiments sufficiently economical to bring them within the budgets of large universities. Since there is a great range of rich experimental areas opening up which the major fusion labs do not have time to explore (because of budgetary and time constraints on their tightly run programs), it is no exaggeration to say that Taylor's contributions may be the most significant advance for tokamak research in 1977.

Plasma beta limits—plasma beta is the ratio of the plasma gas pressure to the pressure exerted by the confining magnetic field—remain the weakest area of tokamak research. For power reactors, minimal betas of 4 percent appear to be certainly attainable. However, for really economic units, betas on the order of 10 percent are needed. Great progress has been made in this area through the work of the MHD team at the New York University Courant Mathematical Institute under the direction of Professor Harold Grad and through the work of theoreticians at Oak Ridge National Laboratory in Tennessee.*

Experimentally, the highest betas achieved by tokamaks are on the order of 1.5 percent. The usefulness of the Doublet device's figure-8 noncircular cross-section for attaining betas in excess of 4 percent will be tested definitively by the Doublet III, now in operation at General Atomic in San Diego.

At Oak Ridge, optimism is high that the concept of frozen magnetic flux will provide a sound basis for attaining betas in excess of 10 percent. However, failure to obtain funds for restarting the Oak Ridge tokamak, Ormak, will greatly retard the date at which this new concept can be definitively tested.

It is also possible that experiments with the Princeton PLT with further upgrading of neutral beam heating may provide the necessary data. In any case, although the low beta problem is by no means solved, several promising solutions are about to be tested and these will open up other solutions, even if they do not immediately succeed.

The dynamics of thermonuclear deuterium-tritium plasmas, D-T burn dynamics, is far from even initial exploration. One suggestion for greatly accelerating the time when actual D-T experiments are to be initiated (for example, the D-T startup of the Princeton Tokamak Fusion Test Reactor in 1982) is that of Bruno Coppi of MIT. Based on

* H. Grad, P.N. Hu, and D.C. Stevens, "Adiabatic Evolutions of Plasma Equilibrium," *Proceedings of the National Academy of Sciences*, 72: 3789 (1975).

# Fusion Is Practical

In a June 1978 article in the *Bulletin of Atomic Scientists*, Soviet physicist Andre Sakharov notes that nuclear fission technology is the safest and cleanest large-scale technology ever developed by man because of its recent origin and the scrutiny given to these questions during its development phase.

This is doubly true for fusion energy.

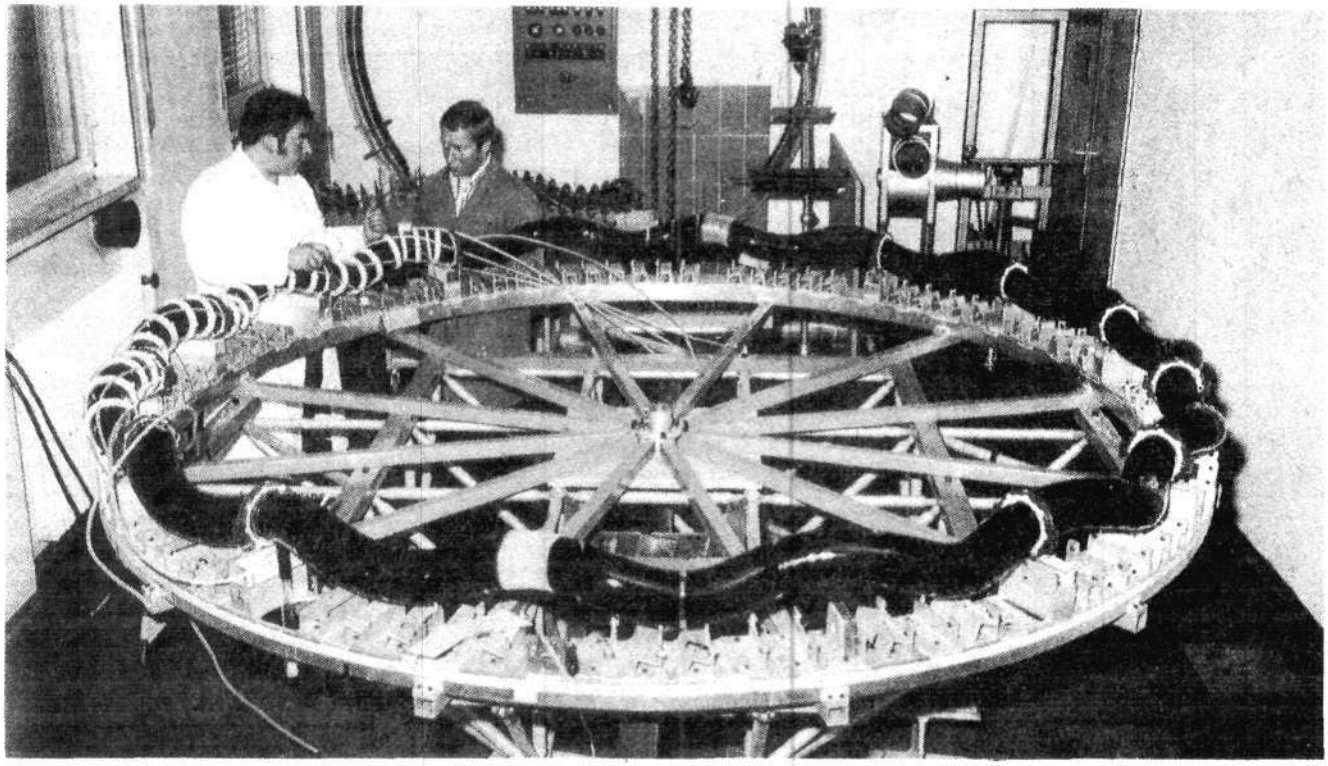
Fusion energy research is the subject of the most extensive international cooperation that has ever occurred. For this reason, the safety, environmental compatibility, and economic-technological feasibility of proposed fusion systems have received intensive analysis at every stage of their development. Since the community of scientists and engineers directly involved in this critical review process represent virtually every nation and political persuasion in the world, it is impossible that the conclusions reached in these cooperative studies would be critically influenced by some political motivation.

It is not surprising, therefore, that the Velikhov-Kintner conclusions with regard to the status of fusion represent the general consensus of the world scientific community. Outside of some unsubstantiated comments by U.S. Secretary of Energy James Schlesinger to the effect that fusion is "impractical" and will not be realized until "late in the 21st century," there have been only four articles in the world scientific literature in the past two years that attempt to contradict the Velikhov-Kintner prognosis. These articles are the following: A two-part series by W.D. Metz in *Science* (Vols. 192 and 193, pp. 1320 and 38, 1976); "The Prospect for Fusion" by David J. Rose and Michael Feirtag in the *MIT Technology Review* (December 1976, p. 20); and, most recently, "Engineering Limitations of Fusion Power Plants" by W.E. Parkins, director of research and technology at Atomics International in *Science* (Vol. 199, p. 1403, 1978).

First, it should be noted that none of these articles was subject to review before publication, as is customary in any substantial scientific journal report. In fact, when the Rose-Feirtag piece was submitted to one such journal, it was rejected. Since the first three articles mentioned have been refuted in the scientific literature in all their essential points, I will focus on the most recent article by Parkins, which utilizes the same fallacious method of analysis.

### The Parkins Argument

Parkins targets the front-running fusion system, the tokamak. He sum-



Max Planck Institute

*The HBS II, the West German toroidal theta pinch system at the Max Planck Institute.*

marizes his argument in terms of what he calls fundamental engineering problems:

> If conditions for a net power-producing thermonuclear reaction are ever demonstrated, difficult engineering problems must still be overcome. Two such obstacles to any practical application of fusion power are the magnitude of the plant capital cost and the limited lifetime of the reactor vessel. Among the factors contributing to the high initial cost is the constraint heat removal places on reactor size. The problem of limited reactor vessel operating life is inherent in the use of thermonuclear reactions, such as deuterium-tritium, which releases damaging energetic neutrons.

The tokamak reactor designs for which Parkins derives these conclusions are the University of Wisconsin's UMAK-I, II, III. These detailed studies were based almost exclusively on experimental results *prior to 1974*. Furthermore, they were oriented not toward developing a practical, economic tokamak fusion reactor design, but rather toward locating the key problems that would require major scientific-engineering progress in order to design such a reactor.

Although Parkins notes that there has been recent progress in materials research, he simply ignores all other experimental results and reactor designs based on this progress. Like the authors of the other anti-fusion analyses, Parkins generally assumes that scientific technological progress stops at some convenient date—in this case 1974.

As Dr. John Nuckolls of Livermore Laboratory noted in his presentation to the Atlanta plasma physics meeting in November 1977, where he refuted the David Rose critique of laser fusion, this is a particularly dangerous assumption in a rapidly advancing and fertile field like fusion.

Parkins proves Nuckolls's point by picking the one particular technical point to criticize that research since 1975 has demonstrated almost completely to be superfluous: the need for a magnetic divertor to remove impurities from tokamak reactors.

He develops a very well-documented, detailed case that because tokamaks require such magnetic divertors the tokamak reactor must be limited to some minimum size, many times larger than any existing power plant. This is because of the necessity to absorb directly the heat of the high-energy plasma particles diverted out of the fusion plasma onto some solid surface. In addition, Parkins says, this heat flux limitation limits the power density of the overall tokamak power plant.

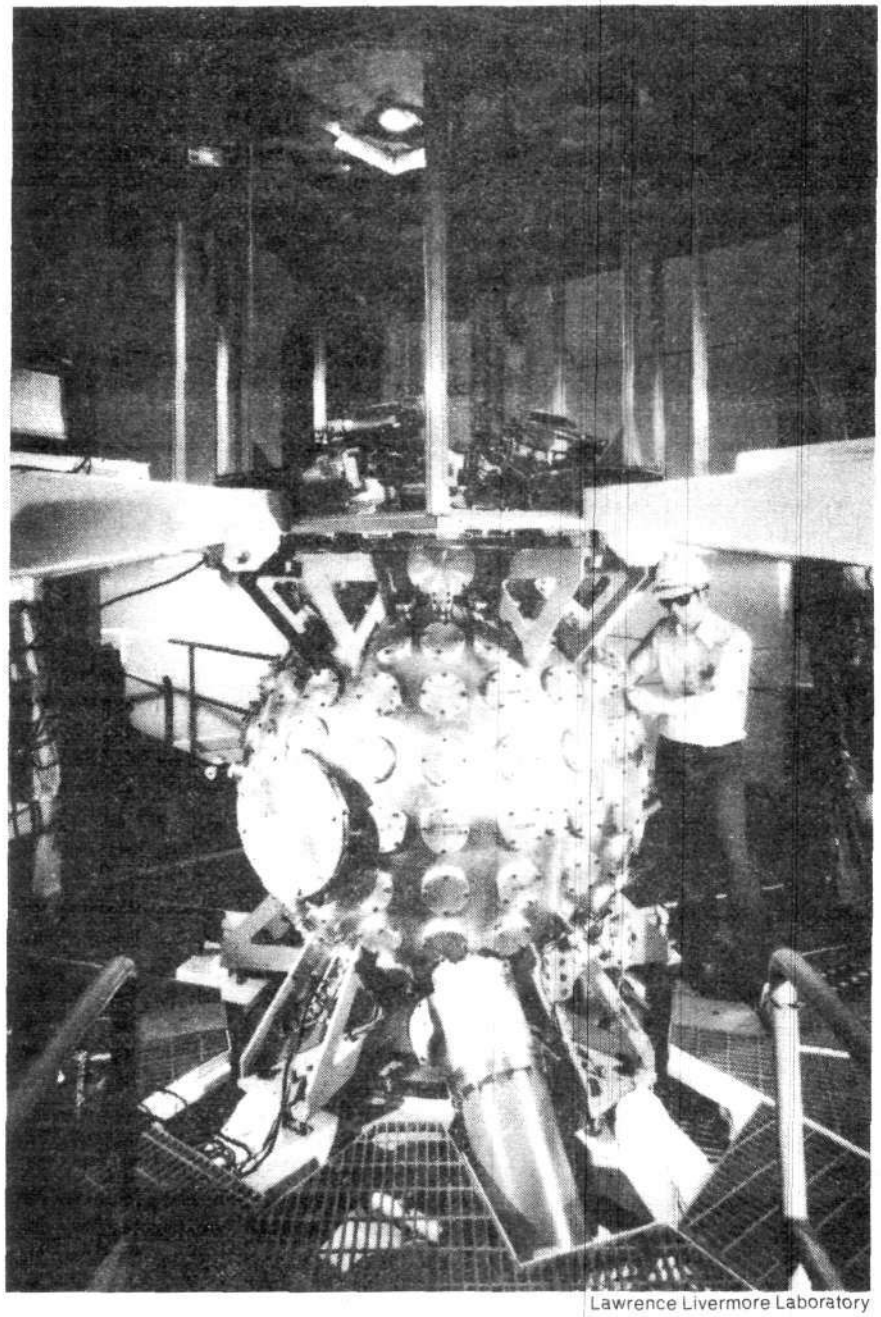
The problem, of course, with this analysis is that tokamak experimental research since 1974 has demonstrated that divertors most likely will not be needed, nor are they desirable.

A detailed refutation of Parkins's article (although this is not its intention) appears in the same issue of *Science*: "The Tokamak: Model T Fusion Reactor" by D. Steiner and J.F. Clarke, two leading fusion researchers.

his experience with the Alcator and a large Alcator-type experiment about to come on line in Italy. Coppi has suggested the construction of small and inexpensive high-density, Alcator-type, D-T burning experiments within the next few years.*

One step along this path would be to upgrade the Alcator C with a neutral beam heating capability. Although difficult, such an experiment may very well point the way to relatively small power reactor designs along the lines that Coppi has suggested.

There are dramatic possibilities for greatly enhancing and accelerating the rate at which fusion can be developed as a versatile and cheap energy source by the full use of various strategies for fusion fuel burn dynamics. These possibilities are just beginning to be examined theoretically. A number of interesting studies by J.R. McNally of Oak Ridge demonstrate that with some hypothetical confinement systems utilizing advanced fusion fuels, other than D-T, fusion energy can be produced almost as pure electricity.** Other studies at the Princeton Plasma Physics Laboratory have shown that the existing types of temperature and density profiles produced experimentally would dramatically increase the rate of fusion reactions if they are projected to fusion reaction conditions.



Lawrence Livermore Laboratory

*Lawrence Livermore's Shiva, the world's most powerful laser.*

# Laser Fusion: U.S. Versus Soviet Ideas

One of the most spectacular fusion advances announced during the past 18 months was the claim by the director of the Soviet laser fusion effort, Nikolai Basov, that his laboratory had achieved a density times time factor of $5 \times 10^{14}$. Conventional wisdom indicates that breakeven for fusion requires a factor of $10^{14}$. Basov's announced result not only was well above the breakeven threshold but also indicated a laser-initiated compression of a factor of 50 better than any achieved in the United States.

Basov, who is a Nobel Prize winner for his work in lasers, made the announcement at a November 1977 meeting of the International Scientific Forum on an Acceptable Nuclear Energy Future in Fort Lauderdale, Florida.* The Basov presentation caused a tremendous stir throughout the U.S. laser fusion community. Many U.S. scientists initially said that they did not believe Basov and that it was inconceivable that such results would come from the relatively low-power, slow-pulsed Soviet lasers. Although several U.S. experimental teams are now trying to replicate Basov's results, perhaps the best characterization of the initial response was given by Edward Teller in a Chicago speech two months ago. Teller replied to a question about the

In particular, as a number of EPRI studies have discussed, if the next generation of tokamak experiments are successful, it may be possible to bypass the D-T fuel cycle and proceed directly to the D-D cycle, which necessitates much higher ignition temperatures.† This could greatly relax the overall engineering demands of a fusion power plant, since tritium would not have to be bred in a blanket surrounding the reactor chamber, and it would avoid the material damage due to the very high energy (14 MeV) of the D-T-produced neutron.

The United States, the Soviet Union, and Japan have recently initiated a new approach to magnetic mirror systems—open-ended magnetic bottles whose magnetic fields increase at the ends of the open bottle and "reflect" a significant number of the plasma particles back into the region of weaker magnetic field. The tandem mirror uses two conventional mirrors to plug the ends of a straight solenoid containing the fusion plasma.

The Livermore Mirror Fusion Test Facility in California,

* B. Coppi, "Compact Experiments for A-Particle Heating," *PRR, 76: 31 (December 1976).*

**J. Rand McNally, Jr., *Oak Ridge National Laboratory Reports*, ORNL-TM-3783 and ORNL-TM-3233.

† George H. Miley, Proceedings of the American Nuclear Society, 1976.

Basov results, "Nobody in the U.S. program understands what Basov is doing."

**Low Power Lasers and Large Targets**

The general parameters of the U.S. and Soviet laser fusion programs could hardly be more different. The U.S. program has devoted the preponderance of its effort to the development of high-power, short-pulse lasers. The U.S. program has emphasized small targets, with diameters smaller than a hair, that are bombarded by lasers of very high power. The current laser used for laser-fusion experimentation at the Livermore Laboratory delivers more energy to this microscopic target in an instant than the total energy consumed by the whole world!

The Soviet program has emphasized large targets, up to a half-inch in diameter, and low-power, long-pulse lasers. The relatively "crude" lasers that Basov used at the P.N. Lebedev Physical Institute in Moscow are made up for by a much more sophisticated pellet design, involving many layers of material and fuel. The gross differences between the two approaches are what prompted Teller's quizzical assessment.

What is not in dispute is the fact that the United States has consistently achieved higher *temperatures* in its experiments, while the Soviet Union has achieved higher *compressions*, most recently indicated by Basov's report. Researchers at Livermore were quick to point out that Basov's highly compressed pellet could not have been at more than 500 eV, compared with the necessary 5,000 eV, and that the U.S. approach had achieved temperatures approaching this higher figure.

More recently, the laser debate seems to be shifting in favor of the Soviet conception. There are three basic scientific considerations, listed below, that come into play in deciding on the best combination of pellet size, compression timing, and laser power. In each of these areas, the Soviet work is *now* being corroborated by U.S. work, and U.S. scientists are drawing the conclusion that perhaps Basov's big targets and little lasers are not so crazy after all.

(1) *Brillouin back-scattering*. A serious problem with the very high power U.S. lasers is the tendency for a plasma-laser interaction. This occurs only at high laser powers and it makes the pellet reflect the laser light rather than absorb its energy. Using lower energies, the Soviets have avoided the seriousness of this problem, but recent work at the U.S. Naval Research Laboratory indicates that it may be a nearly insurmountable problem given the present designs of U.S. lasers and pellets.**

(2) *Rayleigh-Taylor instability*. The intuitively obvious problem with trying to compress a spherical balloon containing fusion fuel is that the balloon will squish out of any holes and burst before it can be compressed uniformly (like trying to crush a balloon with your hands). The U.S. program has considered this a serious problem with present pellet designs. The Soviets, using much larger pellets which *should* be much more sensitive to the tendency to burst, have found that by suitably layering the pellet, it remained stable and that its larger size allowed the energy from the laser to be absorbed over a longer length of time. Recent work on layered targets reported by a group at the U.S. Naval Research Laboratory has replicated this general approach.†

(3) *Computer analysis*. The consistent U.S. response to the Soviet results has been that the complex U.S. computer programs designed to model the interaction of laser energy and the pellet fail to predict the Soviet results, even though the programs are impressively accurate for the U.S. experiments. New light on this discrepancy was shed at a plasma physics meeting in November 1977 where a new, more general computer analysis of the "parameter space" for laser fusion showed that a qualitatively different mode of laser-pellet interaction was possible if one used lower powers and larger targets.¶ These results demonstrated that present U.S. computer analysis tended to be constructed so that the regime the Soviets had found was missed entirely when optimization of pellet and laser design was performed. While not explicitly predicting that Basov's approach was better, the results indicated that the present U.S. approach was insufficient.

* Excerpts from the text of the Basov speech, "Prospects and Problems of Laser Thermonuclear Fusion for Future Energetics," and a report of the Fort Lauderdale meeting are in the December 1977-January 1978 issue of *Fusion*.

**U.S. Naval Research Laboratory *Plasma Physics Reports*, December 1977.

† J.P. Boris and J.H. Orens, "Rayleigh-Taylor Stability in the Pellet Ablation Layer." Paper presented at the Laser Fusion meeting in San Diego, California, March 1978.

¶ Ronald C. Kirkpatrick, "An Overview of Design Space for Small Fusion Targets." Paper presented at the American Physical Society meeting in Atlanta, Georgia, November 1977.

due to come on line in 1982, will demonstrate the feasibility of the end plugs for a tandem mirror reactor, and other experiments just beginning here, in the Soviet Union, and in Japan will explore the overall system to demonstrate its general scientific principles. Mirror research is also progressing toward the "reversed"-field mirror-type of configuration.

## THE STATUS OF INERTIAL CONFINEMENT SYSTEMS

In the last year, there have been a number of advances in the inertial confinement approach to fusion. Inertial confinement is based on the same general approach used in the H-bomb, except that an intense laser, electron, or ion beam (instead of an A-bomb) is used to compress and heat fusion fuel.

The major advances are listed here:

*Researchers at Lawrence Livermore and Los Alamos laboratories recently confirmed the empirical correctness of computer codes developed for designing H-bombs and modified for laser fusion.

*Los Alamos researchers achieved the ignition of fusion with the efficient carbon dioxide laser, and Sandia researchers did the same with electron beams. Previously, fusion had been accomplished only with very inefficient glass lasers.

* Soviet fusion laboratories developed a number of practical fusion reactor designs, based on existing laser and electron-beam technology, that could produce electricity cheaper than current technology does. Hybrid fission-fusion devices using these designs would significantly decrease the costs of energy.

* Under the leadership of N.G. Basov, the Soviets achieved the Lawson breakeven confinement product for the first time, using laser compression.

* Livermore Laboratory developed realistic fusion fuel target designs that will produce 100 to 1,000 times more fusion energy than the laser energy used to ignite them.

*Soviet experiments led by L. I. Rudakov and Japanese experiments have enhanced the deposition of electron beams in thin foil, making more efficient, high gain targets possible.

* Studies at Livermore Laboratory and the U.S. Naval Research Laboratory show that the Rayleigh-Taylor instability (like microinstabilities in magnetic confinement, this destroys inertial confinement by preventing uniform compression) can be overcome. This will permit the use of pellets with thinner shells that can achieve higher fusion energy outputs with lower power lasers, and electron and ion beams.

* Lawrence Livermore's Shiva glass laser system has put 26 trillion watts of energy on target. (The latest Shiva developments are described below.)

* The Los Alamos eight-beam carbon dioxide laser system put 22 trillion watts of energy on target and also demonstrated the prototype beam for the Antares carbon dioxide laser.

* The West Germans demonstrated a 1 percent efficient iodine laser system.

* Livermore Laboratory developed 1 percent efficient glass lasers with potentially high repetition rates (that is, not requiring long cooling times) that could be used in commercial laser fusion power plants with high gain pellets.

* Los Alamos developed new methods of increasing the efficiency of high power carbon dioxide lasers from the existing levels of 5 percent to as much as 20 to 40 percent by using multibeam throughput in a single amplifier.

* Sandia Laboratories in New Mexico demonstrated the electron beam technology needed for the 1980 Electron Beam Fusion Accelerator.

* Sandia demonstrated electron beam transport through a guide plasma to permit the standoff of the electron beam generator from target explosion in eventual reactor designs based on this approach.

* Sandia also achieved initial positive results showing that high repetition rate electron beams needed for reactors are technologically possible.

* Livermore Laboratory carried out the first experiments on laser pulse compression that would permit the rapid adaptation of very efficient high energy chemical lasers to laser fusion.

*Researchers at Sandia and Livermore developed an innovative electron beam target design that makes use of self-induced magnetic fields to enhance overall fusion burnup.

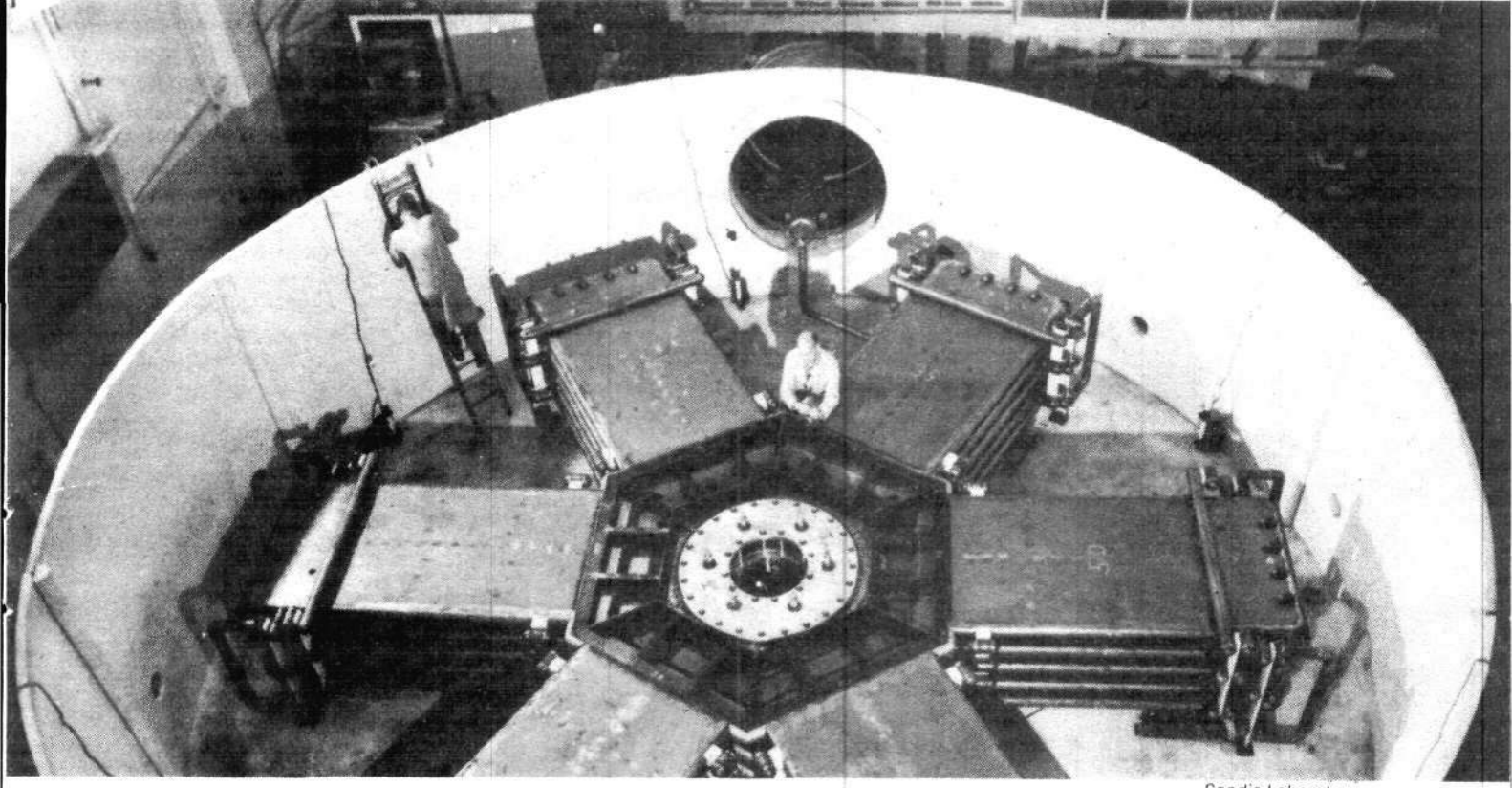
### The Shiva Breakthrough

The giant step in laser fusion is underway as this report is being written. In one of the greatest engineering and scientific achievements of the century, scientists at Lawrence Livermore Laboratory have completed construction of the world's most powerful laser—Shiva, a 26-trillion-watt, neodymium glass laser.

In a burst lasting less than a few billionths of a second, Shiva generates more energy than the total energy output of the entire world. This burst of powerful laser light will be used to compress matter to super-high densities like that at the center of stars, and, for the first time, will allow actual measurements of matter under these conditions. This achievement not only will guarantee the development of laser fusion, but also will have major implications for the frontiers of physical research in general.

One of the more interesting experiments to be carried out on Shiva, although one for which there is little public information, is the compression of fissile microspheres. This allows critical mass to be obtained with less than a gram of fissile material instead of the kilogram-plus necessary in conventional atom bombs. Furthermore, the microsize atom bomb generated would produce only an infinitesimal fraction of what is produced by the ordinary atom bomb, but the high density conditions would lead to almost complete fission burnup of the fissile fuel, possibly producing more energy than that of the laser beam. The output, mostly soft X-rays, from the microfissile explosion could then be used to compress fusion fuel.

It should be noted that when the Soviet electron beam researcher Leonid Rudakov reported to U.S. scientific audiences two years ago that he had used soft X-rays for compression of fusion fuel to generate the first electron-beam-induced fusion, the U.S. government classified his



*The Proto 1 electron beam accelerator at Sandia Laboratory in New Mexico.* Sandia Laboratory

presentation as top secret.* It is now apparent in the Shiva work that precisely the use of soft X-rays from an atom bomb explosion (70 percent of the initial energy output of an atom bomb is soft X-rays) makes possible the efficient compression of fusion fuel for almost pure fusion neutron bombs. Also, the type of asymmetrical, cone-shaped target that Rudakov used in electron beam fusion experiments would be used in a neutron bomb design.

In addition to crucial pure fusion experiments, Shiva also will carry out key experiments on the development of an X-ray laser.

Livermore researchers conservatively estimate that a prototype laser fusion reactor could be built by 1990, but in the past year the laser budget has been cut, a serious setback.

### Electron and Ion Beam Fusion

From a scientific standpoint, electron beam and ion beam fusion hold great promise in inertial confinement fusion. In the first place, the generation of high-energy, high-power electron beams and ion beams is more efficient than any comparable laser system. Second, although there are greater inherent difficulties in particle beam focusing (compared to laser light focusing), efficient beam deposition in the target surface seems to entail fewer problems, such as the Rayleigh-Taylor instability.

Since the initial Rudakov breakthrough in electron beam fusion in 1976, the major development was a new target design that led to the first U.S. electron-beam-induced thermonuclear fusion at Sandia Lab in late 1976 and early 1977. The new target design is based upon inducing a magnetic field in the interior of the pellet, which helps confine the compressed and heated fuel. Most significant, this design is inherently more efficient and apparently can be scaled to gains of greater than 10. It remains to be seen, however, whether it can be scaled to reactor levels.

Although no experiments exist as yet, ion beam pellet fusion holds great promise, since it has even better deposition properties than electron beams. The major question here is the development of beam generation technology. Two entirely different approaches to this question appear feasible: first, using existing high energy particle accelerator technology for producing large current beams of high energy heavy ions; and second, using collective acceleration in electron beam diodes. Three different systems using this latter approach are now being explored.

### SUMMARY

This brief review of the current status of fusion technology and research has touched on only a handful of the recent achievements and breakthroughs. As this report is being written, an independent government panel headed by Dr. John Foster, Vice President of TRW, is circulating its findings on the status of fusion within the Department of Energy. The chief conclusion of that study is essentially the same as this report: *practical fusion power can be developed within the next decade if we mobilize the necessary resources.*

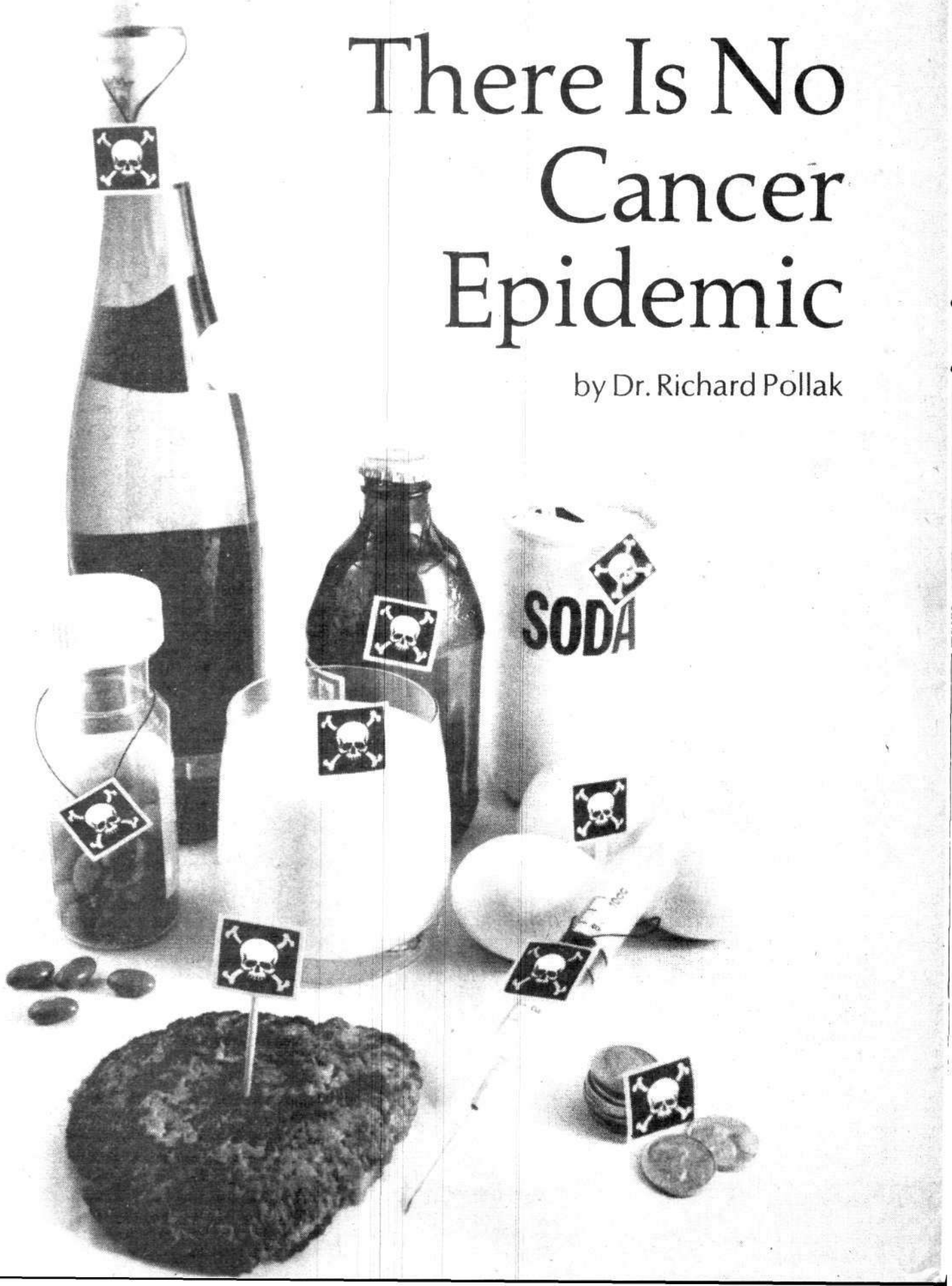
The international conditions exist for minimizing the risks and costs involved, and the scientific and technological capabilities plainly exist. The only missing ingredient is the national commitment here to do it. . . . *Let's do it.*

*Charles B. Stevens is the director of fusion engineering studies for the Fusion Energy Foundation and is well known internationally for his coverage of fusion developments.*

* For a review of the Rudakov case, see "How the U.S. Uses the Classification Weapon to Sabotage Fusion," *Fusion*, 1:54 (December 1977-January 1978).

# There Is No Cancer Epidemic

by Dr. Richard Pollak



ALMOST EVERY WEEK the national press reports that another commonly used substance causes cancer—everything from pan-fried hamburgers and diet soda to hair dye. The articles strike fear in a population that knows little or nothing about the value of the scientific methods used in the studies to determine what causes cancer. The overall impression created by the scare headlines is that cancer is on the increase because our society has become too complex and we use too many unnatural, artificial substances.

Cancer is not a disease of industrial society. *In fact, the unit number of cancers that occur throughout the population for any given age group has not changed since 1900*, with the single exception of lung cancer, whose increase is correlated directly with the increase in cigarette smoking.

A careful look at the myriad statistics quoted to prove that cancer has increased dramatically in the recent period actually shows just the opposite—once one takes into account the absolute increase in population and in the relative age distribution of that increased population. The oft-asserted increase in cancer cases and deaths simply reflects the fact that more people are alive today and that more people are living to an older age now than in 1900.

These statistics, in fact, indicate that the industrialization of society supports an increased population that is healthier than ever before and, therefore, that is able to have an increased lifespan. Cancer is more likely to occur in this older population; but again, the *relative number* of cancer victims in this advanced age group (that is, the number of cancer victims per 100,000 aged individuals) has remained unchanged since 1900. The *absolute* number of cancer victims (the total for the entire society) has increased, but only because more people live longer.

### The Cancer Test Fraud

Where do these cancer scares come from? The purported scientific evidence involves a long chain of so-called reasoning, each step of which involves long-shot guesswork, much of which flies directly in the face of current knowledge.

To begin with, the method most often used to categorize substances as carcinogens is the Ames test, named after its biochemist inventor, Bruce Ames.* The test involves treating a deliberately weakened type of bacteria to high doses of the chemical in question, and then checking for changes in the bacterial DNA—for genetic mutations. By Ames's own admission, there is no established causal link between bacterial mutations and the disease of cancer in the higher animals; there is only a statistical correlation.

This brings us to the second step, in which Ames correlates the bacterial mutation rate with animal cancers caused by high doses of the same chemical. This correlation has been hotly disputed on many counts. The first problem is that Ames takes the animal results from the published experimental results of other researchers, although he admits that the various investigators have many different criteria for deciding that an animal has cancer, such as using different pathological tests, allowing the animals to live until they die naturally or sacrificing them after a certain period of time, and so forth.

The next problem is the assumption that the effect of high doses of a chemical can be extrapolated to low doses; for example, if the dose is cut to one-hundredth of the original tested amount there will still be cancer cases, but at one-hundredth the rate. There is virtually no experimental evidence for such an assumption; and, in fact, the frequently used argument that low-dose radiation causes cancer in proportion to the dose is false.

Finally, even if the substance could be shown to cause cancer in low doses in animals, the extrapolation to humans is unwarranted because the human defense system is much more advanced than that of the usual test animals, rodents.

Since current reductionist-dominated biology has not yet produced an adequate theory of cancer, it is impossible to be absolutely certain that any given substance is not causing an extremely low rate of human cancer. For instance, it is impossible to be sure that vitamin C is not causing cancer in, say, 1 out of every 1 billion persons exposed, a rate which would have almost no impact on the population as a whole. Yet the environmentalists' tactic in such a case would be to put the vitamin manufacturers in a defensive position. The environmentalists would demand that the manufacturers *prove* that the substance has in fact absolutely *no* carcinogenic potential, even though by linear extrapolation the substance could not be causing more than one case of cancer out of the 1 billion persons exposed to it.

In addition to being bad science, this form of environmentalism raises the fundamental constitutional question of whether the demand for a completely risk-free environment (which is impossible to achieve) justifies the sacrifice of industry or other capital improvements necessary for the survival of the nation. The answer is an unequivocal no. The central policy question involved in the founding of the United States and its Constitution was support for domestic industry and internal improvements, as elaborated in Alexander Hamilton's defense of the National Bank. A number of recent landmark court decisions have upheld this principle of development, finding that a minimal risk situation may be necessary if the alternative is the significant harm of the interests of the nation as a whole (see box, page 45).

*Some of the everyday substances alleged by the environmentalists to cause cancer—with no scientific basis in fact. For example, a human being would have to drink 800 12-ounce diet sodas per day for life to ingest the amount of saccharin that produced cancer in rats.*

Photo by Ulanowsky

* Like many others in the field, Bruce Ames had been a decent basic science researcher in the area of biochemical genetics until the discovery of the so-called practical aspects of his work. The rationalization Ames used for his jump onto the popular and lucrative environmentalist bandwagon was that pure research must be justified by practical application. He would deny that his research is being used for political purposes.

To remove the question from the cancer scare arena, readers should contemplate the effect of outlawing driving. It would cause immeasurable harm to the country, yet the death rate associated with driving is much higher than anything associated with so-called industrial carcinogens.

### The Ames Test

The Ames test uses as its test organism a bacterial strain that has been genetically engineered to be very highly sensitive to the tested substances. The highly permeable membrane of the bacterium permits the introduction of normally excluded substances into the cytoplasm of the cell. Also, the cytoplasm of the bacterium does not have DNA repair enzymes, the enzymes normally present in cell material that repair any DNA damaged as a result of usual or induced environmental stress.

This bacterial culture is given a highly purified and concentrated dose of the agent in question, and then plated onto special agar growth plates where only those bacteria that have undergone certain mutations will grow. If a statistically significant number of bacterial colonies above the control number appears, then the substance is considered to be a mutagenic agent.

When a substance produces negative results after this process, it is often subjected to a liver-mash pretreatment, in which liver enzymes have an opportunity to transform the primary substance to a second, now perhaps mutagenic agent. This practice supposedly mimics the human physiological condition.

So far, it's a routine procedure. A substance is shown to be mutagenic when large amounts of it are put into a special test bacterium. What has this to do with cancer? The environmentalists assert that if a substance is mutagenic this means it is a predictor of carcinogenic hazard, and its use should be banned.

*The fact is that the Ames test has virtually nothing to do with human cancer!* Any categorization of a substance as a

# A Program to Bring Cancer Under Control

At the same time that the environmentalist carcinogen hoax shuts down industry, it is shutting down the very research that can find a cure and treatment for the disease. The false claim that cancer is an environmental disease has forced the gutting of basic biological research while funds are reallocated to so-called environmentalist sciences—the unproductive search for carcinogens in industry. Although it is difficult to get accurate figures on the shift from fundamental research to environmental research, it is estimated that environmentalists are now getting from 50 to 75 percent of all the funds earmarked for cancer research. In addition, the budget of the National Institutes of Health, which accounts for 60 percent of U. S. biological research, faces a projected funding cut of 9 percent for the 1979 budget.

These cuts in fundamental research come at a time when it is apparent that researchers are close to breakthroughs in the understanding, diagnosis, and cure of cancer. A program to bring cancer under control must fund a research program *in breadth*—a program that aims at understanding the biology of the disease state from the induction of the disease to the process of its cure.

To take just two examples of promising cancer research: First is the use of nuclear magnetic resonance, NMR, which holds great promise precisely because it integrates diagnosis with new insights into the basic biological state of cancer cells. (See "FONAR: A Revolution in Cancer Treatment," by Carol Cleary in *Fusion*, December-January 1977-1978.) This technique relies on the fact that the water in cancer cells is less highly structured than the water in healthy cells, which allows for early detection of abnormal cells by NMR. NMR is more efficient than the usual procedure of biopsy, and it is completely harmless. Not only will NMR permit much earlier detection of cancers, therefore leading to greater rates of cure, but the technique will provide fundamental information about the physiology of the cancer state. Furthermore, it is hypothetically possible to integrate the cure and diagnosis of cancer.

Despite its obvious promise, the NMR technique is not getting the necessary funding to get the project off the ground.

A second promising area is the use of computer modeling in the evolution of a scientific basis of drug therapy. (See "Computer Helps Develop Cancer Drug," *Fusion*, May 1978, p. 58.) Computer modeling of the three-dimensional structures of drugs of known but limited efficacy in cancer treatment will allow the accelerated development of related classes of drugs. This has the potential to rapidly realize drugs of greater effectiveness and at the same time to provide the researcher with insights into the genetic makeup of cancer cells.

A successful program to control cancer would have to fund both these projects in addition to a wide range of similarly promising lines of research. This broad spectrum of research is critical for the following reason. Negentropy is the fundamental invariant of biology and its lawful tendency is manifest throughout the various subdisciplines of the field. Cancer can be thought of as representing an entropic deviation from this invariance. To achieve a fundamental solution to the disease, we must have research *in depth* that generates understanding of the lawfulness of biological processes as far ranging as embyology to evolution, immunology to mentation. The point is that only in the context of a general understanding of biological processes will the specific predicates of the outlaw cancer cell be exposed, understood, and controlled.

human carcinogen based on data from the Ames test is a fraud, and those making such a claim should be viewed with appropriate skepticism.

In the first place, the engineering of the bacterium to its hypersensitive state belies the very essence of life forms—the elaboration of structure and metabolism that renders it uniquely capable of rapid, intense energy throughputs and transformations. The interior of a cell is a controlled environment for these intense life processes, and breaking down the membrane barrier essential to this condition, as the Ames test does, in effect is a large step backwards in evolution toward a more primitive souplike state.

The physiological integrity guaranteed by the more normal semipermeable membrane is crucial to life's processes. To destroy that integrity is to create artificial, nonlife conditions.

Second, the use of a primitive organism like a bacterium removes the Ames test from the reality of the human condition. A bacterium lacks the internal membranes present in human and other advanced cells (eucaryotic cells), which serve to isolate genetic and other metabolic constituents from random undefined insults. The Ames bacteria also lack repair enzymes, which are implicated in certain severe human genetic disorders (for example, xeroderma pigmentosa). This abnormal condition belies *the validity of the test as a predictor even of mutagenicity* in humans, let alone carcinogenicity.

### The Threshold Effect

Even more damning is the question of the concentrations of the tested substances. The *threshold effect* is well known in biology, as well as in other physical sciences. It refers to the fact that a substance that is neutral, beneficial, or necessary in small amounts can become toxic in large doses. In other words, getting hit with one snowball 1,000 times in a lifetime is fairly harmless; getting hit with 1,000 snowballs at once can be disastrous.

To take some examples, calcium is an essential ingredient in diets; yet, just five times the normal amount of calcium will induce cancer in bulls. Estrogens are normal sex hormones; yet, excessive amounts will cause several diseases, including cancer.

The purification and concentration of the substances tested in the Ames test ignore this absolutely vital scientific fact. To compound the error, the hyperpermeability of the test organisms allows the introduction of great quantities of the substances in question into the interior of the test cells, even to the point of intimate contact with the DNA. This further exacerbates the violation of basic *human* genetics.

The most glaring evidence of the invalidity of the relationship of the Ames test to carcinogenesis is that the Ames test is not even a worthwhile predictor of carcinogenesis in animals tested using a similarly suspect methodology. The initial data indicated that, of the substances the Ames test found to be positive mutagenics, 85 percent yielded positive results for carcinogenesis in animal tests. Although strictly correlative (that is, not causal), the results did indicate that the Ames test had a certain predictive or screening value.


However, a spokesman for the American Cancer Society who is a trained statistician said that if all of Ames's published work and the animal studies he refers to are carefully scrutinized, the correlation between mutagenicity by the Ames test and carcinogenic activity in animals is only about 30 percent. Although such a correlation might still be marginally useful (for instance, if less than 30 percent of all chemicals gave positive results in high-dose animal experiments), it is still only a low-level screening tool whose implications for human cancer are nil.

This point is far from academic. At this moment the U. S. Department of Labor's Occupational Safety and Health Agency, OSHA, is holding hearings on proposed changes in regulations concerning the control of carcinogens. The OSHA proposals would define evidence of carcinogenesis so broadly that the Ames test and others like it could be used to bring chemicals under the category of "possible human carcinogens." This would increase the number of chemicals in this category that OSHA controls from the present 14 to more than 2,500, giving the agency the power to close down virtually any factory in the country.

Tests of potentially hazardous substances using

laboratory animals like rats, guinea pigs, and even chimps often are used by more serious researchers and environmental scientists. Basically such tests involve the exposure of the test animals to various substances by injection, inhalation, or dietary inclusion. These tests are far superior to the bacterial tests because they much more closely approximate the human condition—namely, mammalian organisms with a certain degree of physiological and anatomical correspondence to human beings. There is a hesitancy to use animals, however, for animal research is expensive and very time consuming, although adequate funding would greatly alleviate this drawback. A test on rodents, even the high-dose tests currently used that can "bring out the effects" with far fewer animals tested, costs from $250,000 to $500,000. A proper approach to the animal test question would include at least several trials in the 100,000-animal range, using low doses of several chemicals to determine if the extrapolation is at all valid.

The scientific findings generated from these studies must be treated with caution, for again the problem is one of linear extrapolation from large dosages to small, and from nonhumans to humans. The first extrapolation again involves the question of threshold levels: At what level of exposure to a particular substance does that substance assume a mode of action *qualitatively* different from its action at lower levels?

The snowball analogy is again appropriate. Most people are familiar with the saccharin studies, where rats were fed saccharin in amounts equivalent to 800 12-ounce cans of diet soft drinks per day for their lifetime. It is ridiculous to assume that such large amounts, which bear no relation to normal diet, would not assume a different mode of activity when ingested in greatly decreased amounts. The case of calcium, mentioned above, is an even more glaring example of the fallacy in reasoning that says since large doses are lethal, small amounts must be harmful. Calcium doses as low as five times normal dietary values have been shown to lead to cancer in bulls. By environmentalist standards, calcium is thus a proven carcinogen, and they might argue for banning milk, water supplies, chalk, and so on, all of which contain this highly potent carcinogen. (Interestingly the fact is that pure or distilled water is a great deal more deadly than "impure" water containing the carcinogen calcium, because it leeches vital ions, including calcium, from the body.)

Any study that uses substances in excessive amounts (because of time or the statistical pressures that occur under experimental conditions) and then extrapolates down to lower levels is absolutely unscientific and undoubtedly invalid. Such experiments imply a model that cannot be justified, as all known biochemical findings show.*

Another problem of a similar nature, albeit more subtle, is the extrapolation of animal data to humans. Here, the differences in anatomy and physiology between humans and animals define the problem: For instance, in inhalation studies, do the characteristics of lung retention of particulate matter show the same profile for rats and humans? In dietary studies, are the detoxifying biochemical profiles of the liver and other organs similar? Where bladder cancers are indicated, are the urinary constituents chemically the same, and are the voiding habits similar? And so on.

If basic physiological parameters like these are not demonstrated to be closely similar, extrapolations of demonstrated pathological effects from animals onto humans assume a high degree of uncertainty.

To limit or ban a substance, whatever the social cost, because a rat study is *claimed* to show human danger, is presumptuous, at best.

The extreme absurdity to which the environmentalist science has gone can be seen in the hair dye case. One well-publicized study tested hair dyes to determine their potential carcinogenity. Tested? The hair dye was *fed* to rats, and the increase in cancers noted was offered as proof of the dye's danger to the public. The fact is that a steady diet of hair dye is probably dangerous—but on this basis to ban dyes from external use is absurd.

One investigator in Colorado appreciated the absurdity of environmental science by proving that coins were carcinogenic. He implanted U.S. coins into the peritoneum of rats, and sure enough, the rats developed tumors. Now while this may be an ironic comment on the money supply, it is not cause enough to remove coins from the marketplace. The investigator who carried out the coin experiment to demonstrate the *lack* of scientific validity of this type of testing is now under attack. The environmentalists are attempting to have his funding cut off because they claim he has made a joke out of what they call serious science, and because he is cruel to animals.

### Epidemiological Studies

What can one look at to determine the carcinogenicity or other harmful health effects of various agents? The most valuable data have come from epidemiological studies, where the appearance of a significant number and grouping of afflicted individuals can be *correlated* with a unique array of conditions. I emphasize correlation, because these data in no way demonstrate *causation*; nonetheless, if generated, interpreted, and put to use in a correct manner, such studies can be of great value.

A good example of this dates back to the late 1700s and the use of the first systematic vaccination. Edward Jenner, a surgeon, noted that a certain sector of English rural society, milkmaids, did not succumb to smallpox. These epidemiological data allowed Jenner to correlate the exposure of these women to cowpox (which, unknown to him, was caused by the virus *vaccinia*). His observations led him to inoculate the population with cowpox, which is how the ultimately successful control of smallpox by vaccination was begun.

There are very practical drawbacks to this form of investigation, however. The most immediately apparent is time;

* For a fuller treatment of this subject, see J. Cornfield's article, "Carcinogenic Risk Assessment," in *Science*, 198: 693 (November 1977).

# The Environmentalist Campaign Against Industry

Despite the facts, the environmentalists have attacked the nation's industry and advanced technology as responsible for what they call a cancer epidemic. The proponents of these deliberate lies are not simply the antinuclear mob and zero-growth groups. Eula Bingham of the U.S. Department of Labor's Occupational Safety and Health Administration, OSHA, motivated an "emergency action" that recently prevented at least six companies from producing a vital ingredient for the manufacture of synthetic fibers: "Among the disheartening facts of our modern industrial society is the frightful increase in certain illnesses, cancer in particular. . . ."

### Regulated Antiscience

As of this writing, OSHA is holding hearings in Washington on its proposed industrial regulations for what it defines as carcinogens. The OSHA proposals could shut down any manufacturing plant in the country. The regulations call for the classification of substances into the various categories of danger determined by OSHA, with no safeguards written into the regulations to protect the public from the fraudulent scientific methodology described in this article. The OSHA proposal provides that bacterial tests like the Ames test would constitute positive evidence of a substance's carcinogenic danger, as would animal tests involving massive dosage of the suspected materials. Based on the results of such tests, OSHA would arbitrarily set levels of allowable exposure to the substances in question. No allowance is made for the necessity of the substance in the production process, nor the cost that the OSHA requirements might add on to the material being produced.

Five years ago, the U.S. Court of Appeals for the Third Circuit ruled that evidence of a substance causing cancer in animals was not sufficient for the Department of Labor to shut down a factory using the substance. The department would have to establish "sufficient probability of harm to man . . . more than some possibility that a substance may cause cancer in man." Furthermore, the court said that Congress had not meant for the department to have arbitrary powers outside of "the procedural safeguards of public comment and hearings. . . ."

The current OSHA hearings are an attempt to get around the question of scientific proof of cancer-causing substances with a charade of public participation in their proposed regulations.

That certain materials constitute a danger to workers and the public is not in question here. The proposed OSHA regulations, however, hand the environmentalists a carte blanche to continue their propaganda about the cancer epidemic and, at the same time, block the possibility of improving the technology of production. By forcing industry to satisfy arbitrary environmentalist demands, OSHA and other agencies either put certain industries out of business, because of the prohibitive cost of meeting the requirements, or divert funds from financing the actual solution to pollution and undesirable industrial by-products: the use of new technologies.

To take just one example: The steel industry has had to install smokestack "scrubbers" and other antipollution devices at a cost of $7 billion in the past few years. This same investment could have been used to modernize the industry using known technologies like the Jordan process. The Jordan process, which has been discussed for a decade, doubles steel output and eliminates pollution by turning the otherwise useless by-products of the steel-making process into socially necessary products like ammonia and methanol. The actual social cost of these minimally effective scrubbers has been to close down part of the steel industry and prevent the kind of economic, industrial and scientific advance that will make our society capable of controlling cancer.

it often takes as many as 30 years for adverse health effects to become apparent, during which time harmful conditions can spread and accumulate. In such situations, however, the effects are often very small or slow; when the effects are of a large magnitude, the lag time is usually shorter.

A second drawback, much more difficult to deal with, is the question of variables. How do you know that what you think you are looking at and blaming for the adverse effects, is really the agent of influence? Population studies have inherent problems such as mobility, health habits, dietary preferences, standards of living, jobs, drinking water supplies, and so on. To isolate the causative factors is a highly difficult task, and poorly designed or poorly interpreted studies will often obscure rather than enlighten.

For example: an environmental group recently claimed, based on a Swiss study, that diesel engines have been shown to cause cancer. The epidemiological study showed that in one town a group of people who lived near a major road had twice the incidence of lung cancer as had the rest of the town's population living in a more remote area. An entirely separate study pointed out that 80 percent of the vehicle traffic on the Swiss roads were diesel

# Cancer Deaths Have Decreased Since 1930

*To back up the fraudulent claim that an epidemic of cancer is sweeping through our industrial society, the environmentalists point to the fact that 118,000 people in the United States died from cancer in 1930, and by 1974 this had risen to more than 360,000. In order to examine the real significance of these data, it is necessary to look at how much of the increase in cancer deaths is due to the increase in the size of the population and to the increase in the proportion of older persons in the population—two steps the environmentalists always omit.*

*The three figures demonstrate that there is no epidemic of cancer in the United States. Once the increased number and increased longevity of the population are taken into account, along with the increased risk due to cigarette smoking, it is clear that there has been an actual decrease in the risk of death due to cancer since 1930, and, although not shown here, since 1900.*

*The growth of the population and the fact that the population enjoys the fruits of industrial society—a longer lifespan—are what account for the increase in the absolute number of cancer deaths. Since cancer is an age-related disease, the fact that people died younger meant that there were fewer age-related cancers. Also, a smaller population meant fewer cancer deaths in absolute numbers.*

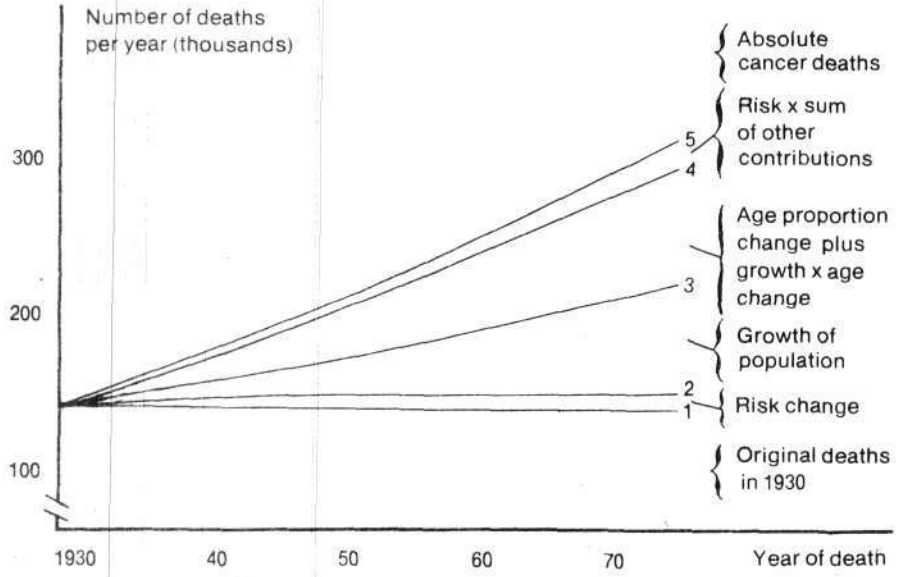



**Figure 1**
**TRENDS IN CANCER DEATHS, 1930-1970**

*Figure 1 shows the trends in yearly deaths due to cancer from 1930 to 1970 and the contribution of various factors to the noted increase. Line 1 represents the base number; that is, the number of cancer deaths that occurred in 1930. Line 5 represents the number of cancer deaths for the indicated year. The difference between line 5 and line 1 is the overall increase in the cancer deaths that occurred over this period. That number is the composite result of a variety of factors indicated by lines 2, 3, and 4.*

*The difference between line 2 and line 1 for any given year is the number of cancer deaths that result from the increased risk that any single individual will be stricken with the disease; this increased risk is closely correlated with an increase in cigarette smoking. If there were an epidemic of cancer due to industrialization line 2 would have to show a steep rise.*

*The difference between lines 3 and 2 is the increase in cancer deaths attributable to the increase in the U.S. population. The contribution due to the fact that the United States now has a greater number of older individuals is indicated by the difference between lines 4 and 3. Finally, the contribution due to the increased risk factored onto the population age and number changes is seen in the difference between lines 5 and 4.*

*As this figure shows, the major contribution to the increase in the number of U.S. cancer deaths is the increase in the size and longevity of the population. The increased incidence of cancer, that is, the increase in risk that an individual will get the disease, is small; and most authorities believe that is almost totally accounted for by the great increase in cigarette smoking over the last century.*

powered. The conclusion of the environmental group? Diesels cause cancer.

The study, needless to say, shows no such thing. For instance, what was the age distribution of the two distinct populations? If the population grouping further away from the main road were a young suburban generation, this could immediately and completely account for the discrepancy in the incidence of cancer for the two groups, since cancer incidence is absolutely age related.

Because no age breakdown was covered in the study, it is unclear, in fact, whether there was a *real* increase in cancer incidence at all. For the sake of argument, however, let's assume that there is a real difference in the disease incidence. Were the building materials of the two sections of the town the same? Or the water supply? Or the income and nutritional levels? Even with this information one would still have to determine the actual causative agent—perhaps the nondiesel vehicles were actually the crucial agent, or the road material, or some up-wind, air-carried agent.

Another case in point is the recent cluster of leukemia cases among children in a New Jersey town. The much publicized disease cluster has wrought terror among local residents and has exacerbated the antitechnology fears of

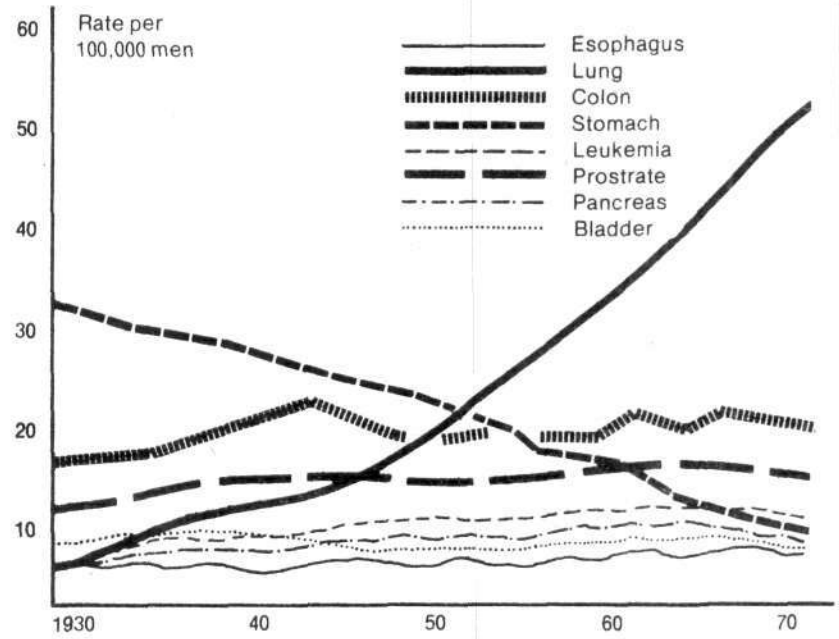



**Figure 2**
**AGE-ADJUSTED CANCER DEATH RATES IN THE UNITED STATES FOR MEN**

*Figure 2 depicts the relative number of deaths due to cancer of the various organs of the body. After a rise over a 10-year period, colon and prostate cancer deaths have not changed appreciably in the past 35 years. Leukemia and pancreatic cancers showed a steady increase until the early 1960s and then apparently leveled off. Bladder and esophageal cancers have not increased since 1930.*

*The two most startling rate changes are for stomach and lung cancers. Stomach cancer deaths have decreased about fivefold since 1930, while deaths due to lung cancer have increased almost tenfold. The reasons for the decrease in stomach cancers remain a mystery, despite much speculation. Epidemiological data strongly suggest that increased cigarette smoking accounts for the increase in lung cancers.*

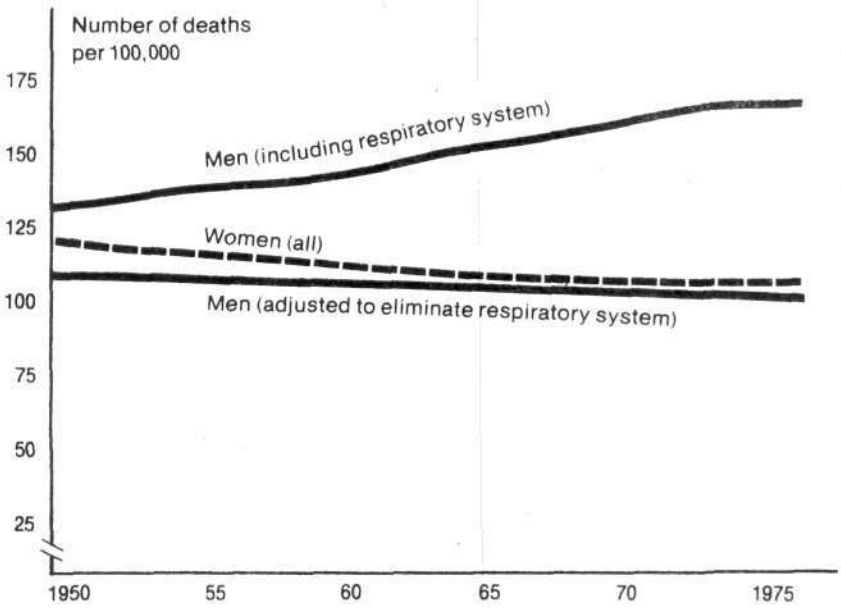



**Figure 3**
**AGE-ADJUSTED TOTAL CANCER DEATH RATES IN THE UNITED STATES FOR MEN AND WOMEN**

*Figure 3 depicts the age-adjusted cancer death rates for men and women in the United States since 1950. The data for males have been broken down further to illustrate the increasing role of respiratory-system cancers in the last 25 years. In fact, removing this component from the cancer death rates shows a decrease in the mortality due to cancers since 1950.*

*Women have, historically, smoked less, and it is believed that this accounts for their much smaller number of deaths due to cancer of the respiratory system. Some researchers anticipate that recent changes in women's smoking habits will lead to lung cancer rates comparable to those for men. One major factor in the decline in cancer death rates for women is the ability to diagnose and cure cervical cancers.*

the U.S. population, since the state is the most densely industrial in the nation. A more careful reading of the statistics away from the screaming headlines shows that the cluster is really not an unexpected statistical grouping when the data are viewed on a national basis. Although clusters like these are not commonplace, they are within the realm of what is predicatble, even when leukemias arise on a random basis. Thus, there is no *basis* to assume that the industrial plants nearby had anything at all to do with this situation. In fact, the nonindustrial District of Columbia, not New Jersey, has the highest cancer rate in the nation.

The point is that careless studies, aided and abetted by poor or even ill-intentioned interpretations, can prove anything and everything causes cancer.

Another important example of unscientific research is the question of cancers induced by the radioactivity associated with nuclear power plants. The frequently quoted study that purports to show an increase in cancers among nuclear industry workers is a Hanford, Washington study by Dr. Thomas Mancuso. A close look at the Mancuso study illustrates the fraudulence of the environmentalist position. First, the study as published shows no such increase in cancer, and, second, the study was conducted under dubious circumstances.

To elaborate on the first point: Although the study omits crucial factors such as age grouping, other statistical data show that there is a slight *decrease of cancers noted for* those Hanford workers with higher exposures to radioactivity, if they are compared to the general population. When these workers are compared to *low-exposure* workers at Hanford, they show an increase of cancers. Using the latter group as the baseline, and again not accounting for crucial variables, the authors of the study conclude that nuclear power plant workers are exposed to a significantly increased risk of cancer.

The environmentalists have extended these conclusions to assert that nuclear power plants generate health risks to anyone who lives, works, or even passes anywhere near the plant.

Is it correct to selectively compare the two Hanford groupings only? The answer is an emphatic "no," for the following reason. A comparison of the mortality rates for all the Hanford workers to the entire population gives a ratio of less than 1. In other words, a Hanford worker enjoys a lesser likelihood of dying than his counterpart in the general population.

This is not an unusual finding and is referred to in the literature as the "healthy worker" effect: Employed individuals tend to enjoy better health than individuals in society at large. However, if the incidence of cancer is relatively constant for a general cross-section of the population (that is, a population not affected by the healthy worker phenomenon), then the general decrease in mortality enjoyed by the working population will have the effect of raising the *proportion of deaths due to cancer* for a given age group *but not the absolute number of cancer deaths* for that age group.

Let's use hypothetical numbers to illustrate this point: If

**HOW DOES ENVIRONMENTAL CANCER RATE.?**

| CAUSE OF DEATH | RISK |
|---|---|
| Coal mining (black lung disease) | 10,000 in 100,000 |
| Motorcycle racing (accident) | 1,800 in 100,000 |
| Coal mining (accident) | 1,500 in 100,000 |
| Firefighting (accident) | 1,000 in 100,000 |
| Sun bathing (skin cancer) | 500 in 100,000 |
| Frequent airline travel (cancer from cosmic radiation) | 1.5 in 100,000 |
| Medical X-rays (cancer) | 1 in 100,000 |

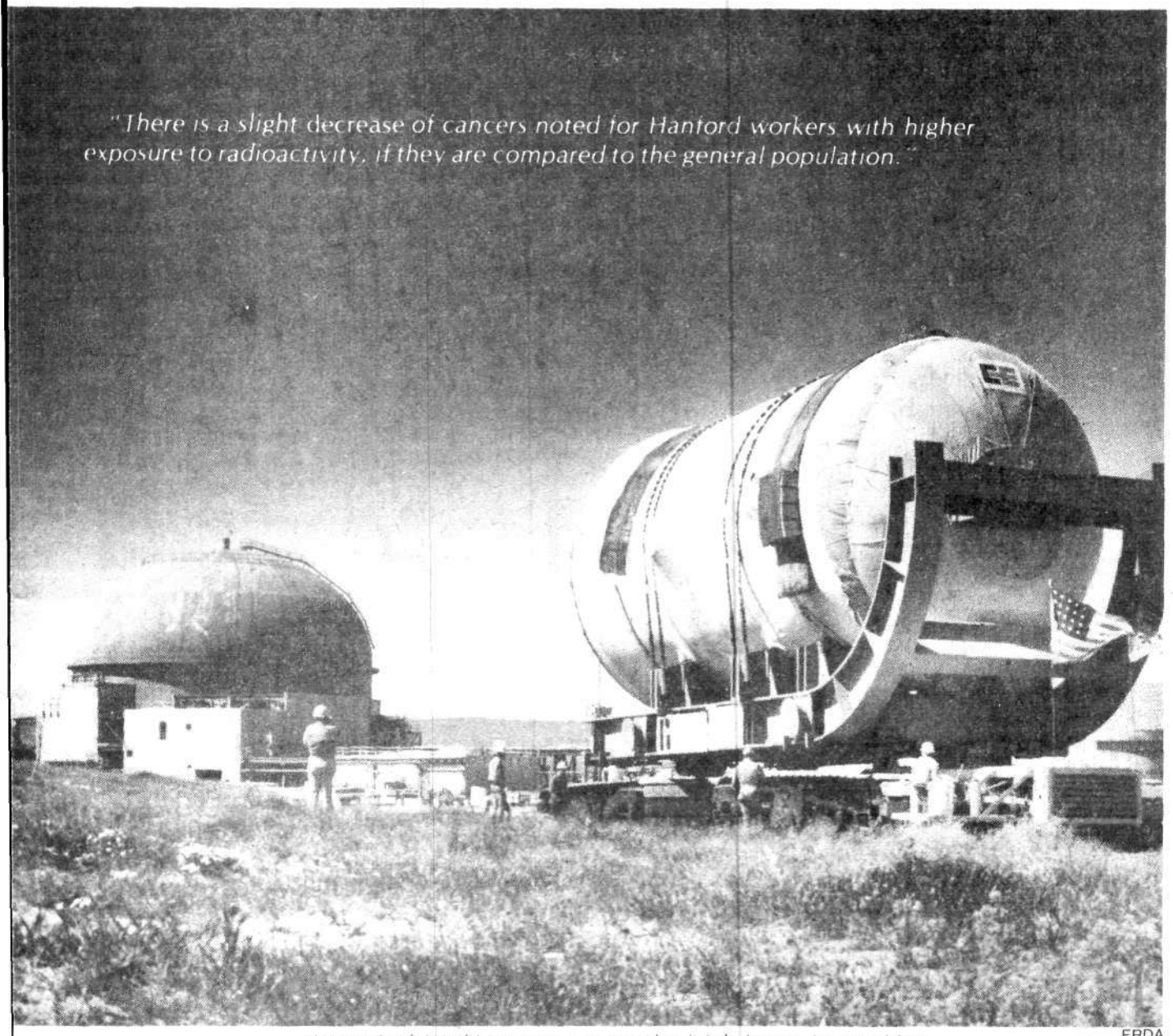
Source: American Industrial Health Council

100 individuals of a particular segment of the general population would be expected to die in a given period and 20 of these would die of cancer, we would say that 20 percent of the total deaths are due to cancer. However, if we look at 100 "healthy workers" (for example, the Hanford nuclear workers) in that population, only 50 would be expected to die during the same period, with perhaps 19 of the deaths due to cancer. We could analyze this situation in either of two ways. First, we could say there has been a slight *decrease* in the number of cancers for the healthy Hanford workers. Second, we could say that the number of deaths due to cancer for the Hanford workers rose from the expected 20 percent to 38 percent (19 out of 50), nearly double the expected rate in the general population. Therefore, environmentalist scientists would conclude, Hanford workers must be dying from cancer due to their work with nuclear power production.

Although this example used exaggerated numbers, it is a good demonstration of the fraudulent way the antinuclear environmentalists use statistics, and specifically of the fraudulent way they distort the oft-quoted Hanford study.

Now for the suspicious nature of the study. Although the Hanford study began in 1964, aside from a single oral presentation in 1971 by the chief investigator, Dr. Thomas Mancuso, the only published paper appeared in 1977. In 1971, Mancuso stated that the preliminary data indicated that no radiation effects were noticeable. His 1977 report, on the contrary, claimed that there was a significant health risk to Hanford workers, although the study lacked data on the crucial variables such as age that would determine the validity of such a claim.

The plot thickens. Just prior to the publication of the 1977 report, funding sources gave notice of termination of the contract for the project. In the same period, two primary investigators left the project and were replaced by two British investigators, Dr. Alice Stewart and George Kneale. The two researchers who left are both highly critical of the study. One of them, Dr. Brodsky, has written a paper attacking the "many scientific absurdities" of the single published Hanford study report, and the other, Barkev Sanders, is writing a paper that concludes that no radiation effects can be detected at Hanford.




*The Hanford, Washington reactor vessel as it is being put into position.* ERDA

Equally revealing is the fact that Mancuso gave no indication about what data, old or new, had caused the shift from his verbally presented opinion in 1971—asserting no deleterious effects—to his published assertion six years later that work on the Hanford nuclear project was dangerous. Furthermore, although the notification of contract termination had been given prior to the publication of his report, Mancuso is now considered a hero by the environmentalists for his antinuclear stand. At the same time, the greenies have accused the government funding agencies of covering up the health dangers of nuclear power by terminating a contract in which Mancuso spent more than $6 million, yet published no scientific papers in a more than 10-year period.

The assumptions behind the entire cancer-scare phenomena are first, that the vast majority of cancers are due to *industrially produced* environmental factors; and second, that the proper commitment and vigilance can produce a society free of risks.

The first assumption is part of the environmentalist litany that 70 to 90 percent of cancers are environmentally induced. However, sunlight, smoking, and natural dietary foodstuffs are thought by some researchers to account for more than 80 percent of the so-called environmental cancers, with industrial sources accounting for only 1 to 5 percent, and only a very small number attributed to other societal activities. This is why, aside from the effect of the factors noted, *there has been virtually no increase in*

*the incidence of cancer, despite the substantial industrialization and use of chemicals that have occurred in the last century.**

The facts are that only the continued development and expanded use of new technologies in an industrial society can provide for the understanding, cure, and elimination of cancer from the human condition. It is true that industrial by-products often can produce deleterious health effects, but it is usually the case that the very development of these industries leads to a substantial improvement in the overall health of society.

For example, coal mining is a very unhealthful occupation. Besides the considerable risk of accidents, the conditions of the mines lead to serious health problems such as black lung disease and emphysema. The environmentalists claim that the introduction of gas- or diesel-powered machinery into the mines worsens these conditions and makes it even more likely that a miner will be stricken. This might appear plausible at first glance, but such a judgment discounts the major effect of that technological innovation: *increased labor power*. In other words, the rise in productivity per worker due to scientific and industrial practice invariably is sufficient to decrease the absolute number of miners and other workers who will suffer adverse effects in the mines and in other industrial sites. The history of American society is more than sufficient proof of this point.

Again, let's use exaggerated numbers for illustration. Suppose 100 miners produce 10 tons of coal by hand, and 50 of these miners are stricken by mine-induced diseases. Then introduce the so-called polluting machinery; now 10 miners can produce the 10 tons of coal, with 6 miners stricken by mine-induced diseases.

In this example, there is a marked decrease in the number of miners stricken, even though the percentage may have risen.

Beyond the fact that there is a decrease in the number of miners stricken and even more crucial in terms of the overall society is that this improved technology has freed 90 workers from the hell of a bestialized existence and provided society with an increase in free energy, represented by the minds of 90 human individuals. These individuals can make even more efficient mining equipment, can become doctors, and can become the scientific researchers who develop fusion power—or discover the basis and cure for cancer.

Let's look at the question of technological improvement in another way. Certain rat studies have concluded initially that subcutaneous injections of penicillin produce tumors in a few cases. Should we then ban penicillin supposedly to diminish the risk of cancers, or should we assume that this modern medicine technology is of immeasurably greater value for societal health than the benefit offered by banishing the drug?

It is possible to claim that the introduction of any new technology carries risks (although it must be emphasized that this claim is usually false—as the Hanford study shows). The fact is that the only risk-free situation is death.

It is a remarkable fact that instead of killing us all at younger ages, the rapid industrialization of the United States has extended our lifespan, decreased infant mortality, and, in general, improved the health and well-being of our population.

The fear-mongering environmentalists who would have us retreat to the rural bliss of preindustrial feudal life are actually prescribing a life truly fraught with risk; ecological holocaust, plague, starvation—these are the certainties of a feudal existence. In this the environmentalists are correct—if we succumb to their black propaganda about technology causing cancer and limit technology, there will be a decrease in cancer—for few will live long enough to get it.

*Dr. Richard Pollak, a frequent contributor to* Fusion *magazine, is a staff member of the biological sciences division of the Fusion Energy Foundation.*

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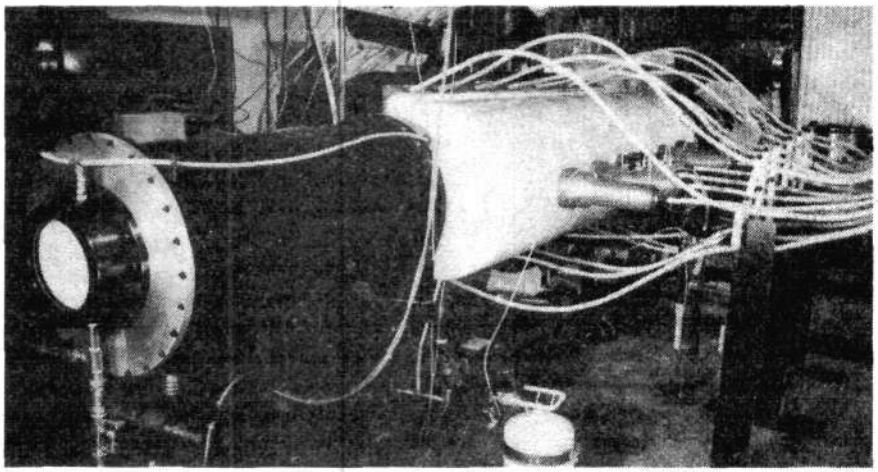
* There is no firm knowledge of exactly what causes cancer. Some researchers believe that 40 to 50 percent of cancer deaths in the United States are diet-induced. High fat and caloric intake, excessive alcohol consumption, mold-produced toxins that commonly contaminate grains and nuts, and chemicals naturally present in certain foods are thought to play the major role in the induction of these cancers. Food additives and agricultural chemicals are believed to be of relatively insignificant importance. It is currently hypothesized that the substances in the diet act as modifying or promoting factors; they do not directly cause cancer but, rather, set the stage for later development of the disease.

For cancers related to cigarette smoking, there is much more specific information. Of the estimated 390,000 people who will die of cancer this year, more than 100,000 deaths are believed to be directly due to smoking. According to the American Cancer Society, smokers have two times the risk of getting all forms of cancer as have nonsmokers, and the figures for lung cancer are far more frightening. Cigarette smokers have nine times the risk of getting lung cancer as have nonsmokers, and this risk increases with the amount of smoking involved. Those who smoke between one and two packs a day have 13 times the risk of getting lung cancer.

These data cut across all segments of society. Although epidemiological studies of the relation of smoking to cancer do not prove causation, the correlation is so great as to provide a sober warning to smokers. If the rising incidence of cancers associated with cigarette smoking were eliminated, the U.S. population would show no increase in cancers, after adjustment ofr age, for the last seventy-five years.

# Research

# Los Alamos Laser Reaches 20 Trillion Watts



Los Alamos Laboratory

*The Los Alamos carbon dioxide laser.*

Scientists at the Los Alamos Scientific Laboratory in New Mexico reported in June that they had obtained the most powerful bursts of laser light ever achieved with a gas laser. Over a period of several hours Los Alamos laser fusion researchers obtained pulses of 10,000 joules within a half-billionth second with their eight-beam carbon dioxide laser. This is equivalent to a power output of laser light of 20 trillion watts, more than twice the energy consumed by the entire world during that half-billionth second.

The 20 trillion watt output is double the original specification that the eight-beam system was designed to achieve. This puts the Los Alamos laser fusion program in the same ballpark as the Lawrence Livermore Laboratory group working with the neodymium glass laser system, Shiva, which recently achieved a 26 trillion watt output. Since gas lasers, like the Los Alamos device, do not have to be cooled down after high-power laser shots, the Los Alamos laser fusion group will be able to carry out 10 times the number of experiments of their Livermore colleagues.

Given their achievements, both the Shiva laser and the Los Alamos laser should be able to produce significant fusion burn in the small spherical targets containing fusion fuel that are compressed and heated by the powerful laser beams. Even more important, the Los Alamos success demonstrates that carbon dioxide lasers could go all the way to provide the minimum efficiencies and repetitive output needed for actual laser fusion electric power production.

# Is the Rigatron Case Rigged?

The June 12 issue of *Aviation Week*, the aerospace industry trade journal, featured a detailed report on what they called a new unrecognized concept in fusion research, the Rigatron. The magazine reported that the U.S. Department of Energy was canceling the Rigatron approach to tokamak fusion research because the more conservative fusion scientists working on the mainline tokamak at the Princeton Large Torus did not approve of it. A similar argument appeared in the June issue of *New Times* magazine.

**The 'Throwaway' Tokamak**

The Rigatron concept grew out of aerospace research and work with Alcator, the Massachusetts Institute of Technology's high-density, high-field tokamak. It would include a small "throwaway" tokamak core that would be used to produce energy for about three months and then be replaced. The main appeal of the system, according to *Aviation Week*, is that it would greatly accelerate the fusion effort, because Rigatrons are projected to reach fusion ignition with only ohmic heating (heat produced by resistance to the flow of electrical current) and to operate the most intense magnetic fields ever proposed for a tokamak.

The scientific community has disputed the Rigatron claims and called the reported controversy "overblown." The Rigatron idea has been kicking around for many months, sources say, and the only support for it comes from the U.S. Office of Management and Budget, which sees it as a short-term, cost-effective project, and from circles around Energy Secretary James Schlesinger, which see it as a way to denigrate the mainline fusion effort.

Leading fusion scientists are skeptical of the Rigatron because they think it won't work, and that the information gained from the effort would not feed into the body of fusion knowledge. The reason for this dead end is that the research and technologies that would go into the project are too narrow.

As a leading plasma researcher known for his independence put it: "We need a broad-based program of fusion research, but not at the expense of the mainline program—which is now completely justified by the last few years' theoretical and experimental results—and not when it actually undermines fusion research. There are many more promising unexplored areas that could be researched."

Several fusion scientists have mentioned that since the proposed funding for the Rigatron project would come out of the mainline fusion effort, they believe that the source of the recent Rigatron enthusiasm is Energy Secretary James Schlesinger, the fusion program's main enemy.

# Prigogine on Physics and the 3-Body Problem

I. Prigogine, the 1977 Nobel Prize winner in chemistry, has pointed out the devastating impact of the "three-body problem" on Newtonian mechanics in an article in the December 1977 issue of the Dutch journal, *Celestial Mechanics*.

Prigogine, whose major work is in the area of the statistical mechanics of structure formation and self-organizing phenomena in physical and biological systems, develops the thesis that classical mechanics is deterministic and causal only when it described two-body systems. As soon as more than two particles interact, the system develops certain irreducible statistical features that are intractible in traditional mechanics. In his conclusion Prigogine says:

> Thermodynamic considerations begin with the three-body problem. . . . It is fascinating to identify the limits to classical dynamics and the strictly deterministic scheme inside dynamics, when problems in the large are considered. The identification of dynamics with a strictly deterministic scheme is only valid for local problems [which he shows is impossible for systems with more than two particles], while the approach to thermodynamical equilibrium is obviously a global one.

**The Implications for Physics**

The conclusion that Prigogine and his collaborators at the Free University of Brussels have drawn is not that this inherent acausal implication of classical mechanics indicates a fundamental breakdown of classical mechanics. (This conclusion was elaborated in "Solving the Three-Body Problem," by Steven Bardwell in the June 1978 issue of *Fusion*.) Instead, Prigogine proposes that the *only* kind of physics is statistical physics. He points out that this would imply an importation into classical mechanics of a certain, and in principle unavoidable, indeterminacy in classical as well as quantum physics.

Prigogine develops a formalism for identifying the point at which the dynamical properties of a system imply qualitative change in the phase space appropriate for the evolution of the system. In fact, the same formalism illuminates the fundamental distinction that Poincare insisted on as the basis for understanding of classical mechanics: the difference between integrable and nonintegrable systems. The former have an irreducible statistical property due to a so-called disintegration of their phase space in the small, while the latter preserve a smoothness and simple continuity in the small and large which results in a deterministic, Newtonian causality.

Prigogine shows, in fact, that systems that are truly integrable cannot interact with the rest of the (nonintegrable) world, and hence. "Our very knowledge of the physical world, both in classical and in quantum mechanics, implies *both* dynamics and thermodynamics. If there would be only integrable systems we would have no way of knowing the world."

As one well-known physicist in the field remarked in response to Prigogine's article, the question is: "The uncertainty relations and the so-called irreducible indeterminacy of quantum mechanics are simply an indication that there is something else going on. I think the same is true of classical mechanics. There is more than Newtonian-type particle interaction going on."

# Montgomery: Making Use of

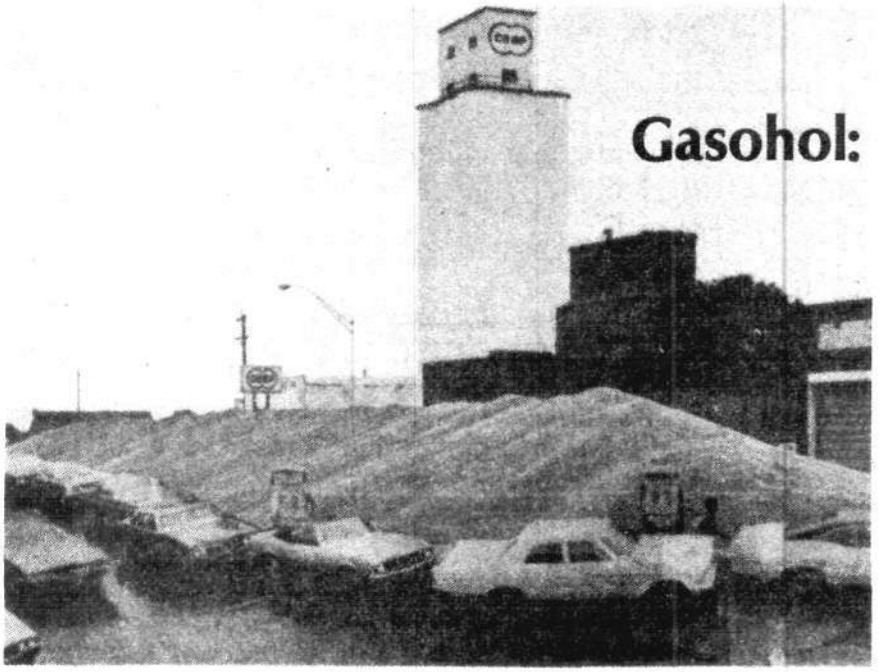
A long-standing critique of the major lines of approach to fusion research has been their reliance on the simplest, so-called equilibrium condition of a plasma, in spite of the fact that a plasma seems to be inherently dynamic or nonlinear. In fact, there is striking evidence that a plasma has no accessible equilibrium state.* It should be noted that the research based on the equilibrium connection of plasma, however, has produced extraordinary results, as indicated in this issue's review of fusion research.** Research into nonequilibrium plasma states defines the next phase of fusion development.

In the May issue of *Physics of Fluids*, David Montgomery reports on work done at the Los Alamos Scientific Laboratory that again raises the theoretical question of the global tendency of a plasma to form ordered, dynamic structures instead of a random, thermal, quiescent equilibrium.

Montgomery draws on a body of plasma physics dealing with the tendency of a plasma to form complex, but highly durable magnetic field structures that have the unique property of being force-free. These structures generate their own magnetic field that they use to stabilize their motion. However, unlike the usual magnetic fields generated by currents, these magnetic fields are *parallel* to the motion of the current and hence experience no self-force.

These structures, plasmoids and filaments, have been extensively studied both experimentally and theoretically by Dan Wells at Miami University, Winston Bostick at Stevens Institute, and others, but they seem to have been ignored by most plasma physicists.

Montgomery uses his results to show a striking, qualitative feature of the theoretical treatment he provides for this structure-forming tendency. In the most fertile areas of classical physics, extremal principles have been used very effectively to characterize global evolutionary tendencies of physical systems. The quantity usually minimized or maxi-



*Gasohol: Feeding cars instead of people.*

# Gasohol: Fuel for Famine?

The production of *gasohol*—fuel produced from grain—is an unlikely venture and could never be "feasible economically," according to an article in U.S. Department of Agriculture's June *Farm Index*. Gasohol is one of the energy schemes touted by the environmentalists for use in the Third World.

Estimates for the production of ethanol alcohol made from corn indicate that the energy balance for ethanol production is negative. "...Considering the applied fertilizer, the fuel used in planting and harvesting, pesticides applied, and all other imports, plus the energy needed for the alcohol production process, it takes 2 Btu's to produce 1 Btu of ethanol—more energy is used than produced," the USDA stated. The article is based upon a report prepared by the Budget Committee of the U.S. House of Representatives.

As the USDA article correctly points out, an increase in the highly inefficient grain ethanol would force the population to accept a massive decrease in food supply for the sake of a token increase in the fuel supply. "According to some studies, if grain alcohol is to replace 10 percent of the gasoline used for fuel, 40 percent of the total harvest must be diverted to ethanol production," the article stated.

The USDA article is slightly more optimistic about the economics of methanol—another form of alcohol produced from a wide variety of waste materials like coal, lignite, wood waste, and agricultural residue such as corn stalks. However, independent studies indicate that methanol production is cost effective only if the production process is highly concentrated—for example, if the methanol is produced as a by-product of steelmaking. If highly dispersed agricultural residue is used, the costs of collection would offset the energy balance negatively.

# the Nonlinearity of Plasma

mized was the free or available energy or the action. Montgomery shows, however, that the appropriate maximized quantity in the case of certain plasma geometries is force-free structure in the plasma. That is, the plasma evolves so as to maximize, at every point, the amount of coherent macroscopic structure.

Montgomery has identified a maximized quantity, magnetic helicity, that measures the large-scale, force-free structure in the plasma, and he has shown that the plasma evolves so that this quantity grows as large as possible.

The practical implications of this insight are characterized as follows in Montgomery's article.

> The likelihood seems great that it is as much the natural tendency of magnetofluids to be turbulent [and thus subject to a maximum magnetic helicity principle—ed.] for small enough resistivity (large enough magnetic Reynolds number) as it is for Navier-Stokes fluids to be turbulent for small enough viscosity (large enough Reynolds number). The search for the linearly stable configuration that has occupied so much of the energy of theoretical plasma physicists may come to seem as futile as a corresponding search for a stable high Reynolds number fluid-flow profile would be. Rather than avoiding, by assumption, the whole domain of turbulent plasmas, learning to manipulate and exploit their behavior may be the most challenging and useful task facing us.

One direct benefit of the research Montgomery suggests is in the development of smaller fusion devices.

* For a full discussion of this question, see Steven Bardwell's "The History of the Theory and Observation of Ordered Phenomena in Magnetized Plasmas," in the *FEF Newsletter*, September 1976.

** Even more advanced results, based on the Grad-Hogan theory, will be discussed in a future issue.

# Conferences

## Paris FEF Conference: Europe Needs Nuclear Energy

"Europe must rapidly opt for accelerated energy growth and abandon its present policy of energy savings in order to soon be able to reach the next great technological stage, the era of controlled thermonuclear fusion power." With these remarks, Hans Bandmann, the European director of the Fusion Energy Foundation, opened the organization's Paris conference June 13. The conference, titled "Nuclear-based industrial growth versus neo-Malthusianism," was held at the headquarters of the Society of Civilian Engineers.

In the audience were scientists, students, industrial representatives, officials from the principal French nuclear firms, Althom Atlantique, Novatome, and Framatome, and representatives from the Japanese and Soviet embassies.

Specific technologies always reach a point of saturation, Bandmann explained, but the reality of technological development is represented by an exponential curve reaching toward technologies of ever-higher energy density. The energy sectors of the economy "obey physical laws." Just as changing the direction of an automobile takes time and energy because of the principle of inertia, so to reach a fusion-based economy—which alone will be able to satisfy the energy needs of a growing world population—requires the most rapid development now of an ambitious policy of energy growth, Bandmann said.

Ralf Schauerhammer, an FEF staff member, next discussed the progress of current fusion research. Schauerhammer told the audience: "We have reached the point where reactors that are being developed or that are in construction can reach the breakeven stage. . . . Such is the case with the European JET, the American TFTR, the Japanese JT 60 and the Soviet T 20, all based on the Soviet Tokamak concept. However, diversification into other lines of fusion research is now also necessary, and the European fusion research program is committing the error of only timidly broaching other fusion options, such as laser and electron beam."

In the next presentation, Dr. Helmut Bottiger of the FEF staff discussed fusion technology. "A fusion reactor is not simply a more complicated kind of heating unit. . . . It offers the industry a large palette of different energies of vital interest for modern methods of production," Bottiger said. "As soon as fusion will permit man to use vast quantities of energy, a whole new era will open up for macromolecular chemistry."

Outlining the need for the steel and metallurgical industries to perfect materials resistant enough to confine plasma, Bottiger said "the success in the development of materials linked to an increasing mastery of nuclear energy—fission and fusion—has multiple and crucial applications notably in the space, chemical, and suboceanic technology industries."

### A Grand Energy Policy and Expanded Population

Dr. Emmanuel Tremblay, former head of the clinic at the Paris Medicine Faculty and professor of demography at the School of Higher Social Studies of Paris, opened the afternoon session. "The development of the energy at the disposal of mankind is necessary for the development of humanity on both economic and demographic levels," Tremblay said. "This development can take place only if man has sufficient energy at his disposal."

In order to implement a "grand energy policy," Tremblay said, we must put an end to the "intensely Malthusian demographic policy" that prevails today in the West. "Western demographic deterioration has taken on acute, unprecedented proportions, which in some European countries is now close to an irreparable point of no return." This would entail "the collapse of the economic power and investment capacity of the Western countries."

"The real measure of the demographic situation is the rate of birth and not longevity," Tremblay said. "We must massively increase the birth rate and proceed with an enormous investment and job creation effort, 5 to 8 times greater than that during the decade from 1960 to 1970." He concluded with a call for the governments "of Western Europe at least," to "radically change their orientations toward growth."

The noted demographer Alfred Sauvy spoke next, stressing the urgent need to reverse the reigning Malthusian policies, by launching a campaign against theories that call for slowing population growth to "resolve" the economic crisis. "All the pessimistic predictions concerning population growth have failed throughout history," he explained. "In 1781, the Abbe Raynal said of the United States, that if 10 million men ever found their existences ensured in these provinces, it would be a lot. . . . Today, the City of New York alone has a population larger than 10 million."

"When wood ran out as a source of fuel in the 18th century, man discovered coal," Sauvy said. "It is childish to look at the horizon and affirm that nothing exists beyond."

The next two speakers demonstrated the necessity of an increased use of energy in the medical and agricultural fields. Professor Andre Dodin, head of the cholera laboratory at the Pasteur Institute,* showed that to defeat the propagation of viruses that mutate and spread at high speed, we must create a high energy density environment, in terms of hygienic measures and advanced technical equipment.

Next, Marlene Goodwin, FEF specialist in agricultural questions, illustrated this concept in more detail based on the need for adequate nu-

*Continued on page 56*

# FEF News

### FEF ACCORDED TAX EXEMPT STATUS

The Internal Revenue Service notified the Fusion Energy Foundation July 19 that the foundation qualified for preliminary tax exempt status retroactive to April 1978 and extending until August 1980. Contributions to the foundation during this period are tax deductible.

In announcing the IRS determination, foundation executive director Dr. Morris Levitt said "the foundation will begin planning a massive fundraising campaign so that it can even more effectively play its unique educational and scientific role to promote the near-term onset of the fusion age."

### FEF TO TESTIFY FOR OREGON NUCLEAR PLANT SITE

The FEF will present testimony during July and August before the Oregon State Energy Facility Siting Council in favor of a site certificate for the proposed twin Pebble Springs nuclear power plants.

The case is an important one nationally in the battle against the environmentalists. Although the plants had received a site certificate after years of hearings, the Oregon Supreme Court overturned this decision in favor of a suit brought by an environmentalist. The antinuclear suit contended that the plants are not economically needed, that they are unsafe, and that there is no plan for waste disposal.

Testifying for the foundation on waste disposal, spent fuel handling, and safety issues is Dr. Bernard Spinrad, former director of the reactor engineering division of the Argonne National Laboratory in Illinois and former director of the division of nuclear power and reactors of the International Atomic Energy Agency.

Dr. Edward Reed, senior vice president of Oregon's U.S. National Bank, and Martin Simon, an FEF member, will testify on the need for electrical power and future economic trends. The foundation's research for the case shows that the annual electrical demand growth rate for the next 20 years will be almost twice the 2.8 percent projected by the state's Department of Energy.

### SUCCESSFUL FEF INTERNSHIP PROGRAM TO EXPAND IN FALL

"Probably the most serious and well-thought-out objection to a crash program for fusion—putting aside the crankish worries of 'it's impossible,' 'we can't progress that fast,' and the like—is the lack of skilled manpower. There is a frightful shortage not only of plasma physicists, but also of technicians, machinists, and nuclear engineers, all of whom are required for a successful crash program to develop fusion. That problem must be addressed now if we are to realistically talk about fusion by the year 2000."

With those words, the Fusion Energy Foundation Summer Internship Program was opened by Uwe Parpart, director of research for the foundation.

Parpart welcomed the six interns to two weeks of seminars by leading plasma physicists in the New York area that dealt with frontier areas in the physical sciences as defined from the perspective of plasma physics. The seminars dealt with the latest research in magnetohydrodynamics, tokamak stability theory, energy storage and compression, nonlinear field models, and computer simulation of plasmas. In each case, the physics and mathematics were discussed from the standpoint of identifying the areas in which contemporary science had reached an impasse.

The internship program will expand in the fall and summer 1979 to center around the foundation's comprehensive planning program and basic science project in fluid mechanics. Plasma physics, desalination, and meteorology—all central inputs for global development—require a fundamental understanding of fluid-mechanical approaches to the physical sciences.

Students interested in participating in the internship program should write the FEF indicating their qualifications and areas of interest.

*Uwe Parpart*

*Continued from page 54*

rition. Animal protein is essential for the complex needs of the human population, she explained, and in order to reduce the acreage of land set aside for the production of animal feed, we *must introduce new, higher-energy* industrial techniques to produce the proteins necessary for animals.

The neo-Malthusians use the failure of the so-called Green Revolution to pretend that advanced agricultural technologies do not work in the Third World context, Goodwin said. It is on the basis of the nuplex that the real development of the Third World must proceed. The nuplex idea, which evolved in 1956 for India, includes abundant energy sources from a nuclear plant to furnish electricity and heat to agricultural industries and other basic industries that permit vast regional development. "With the nuplex, Third World countries could quickly have access to the highest technological levels," she said.

**The Environment Issue**

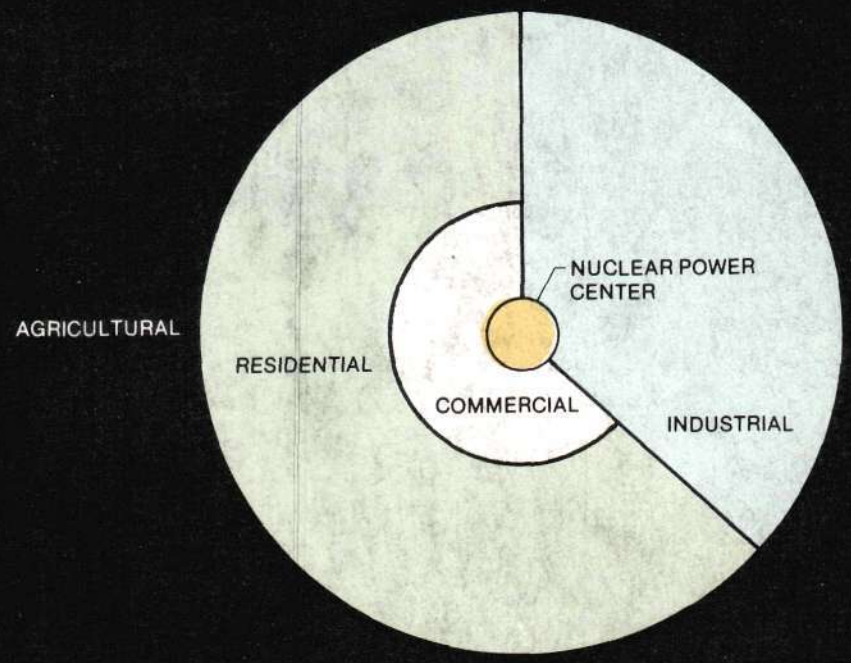
Taking up the question of nuclear energy from the angle of architecture, Claude Parent, a nuclear architect with Electricite de France, the state energy monopoly, showed how every landscape is the "work of man." To build a nuclear plant necessarily means modifying this landscape, which is not the same as destroying it, Parent said. Placing himself in the tradition of the humanist "city builders," Parent stressed that the industrial era is an ineluctable fact, and that to call for the construction of "villages" and to encourage "a return to the land" is to commit "a crime against one's mental development."

In the concluding presentation, Jacques Cheminade, an official of the Ministry of Economics and Finance,* showed how it will not be possible to finance the 3,000 gigawatts of nuclear energy the world will require by the year 2000 in the context of the existing economic order.

The credit necessary for this development must be based on the economic surplus created by new technologies. An effective credit policy, he said, is not based on existing fixed resources but on future surplus. This long-term credit at low interest rates must be based on a new international monetary system that would redirect liquidities now absorbed in speculative activities to production.

* Affiliations for identification purposes only.

AERIAL SCHEMATIC OF A NUPLEX




# Nuplex Power

Nuplexes are large industrial-agricultural complexes powered by one, two, or more nuclear plants like the one pictured on the front cover. The nuplex principle is to locate industries around a centralized nuclear energy source to make the most efficient use of the energy generated. For example, a desalination plant powered by the so-called waste heat of the nuclear plant would provide water for irrigating the regional farmlands, while an integrated steel-making complex using the Jordan process would make use of the steel plant by-products to produce fertilizer.

The nuplex idea is not new; nuplexes were on the drawing boards for India and Puerto Rico 10 years ago. Finally in 1978, the political forces have come into being that can make nuplexes the building blocks of the Grand Design. [See Special Report, inside.] Nuplexes will power new cities across the globe, cities that will produce the materials, technology, culture, and the educated human beings to take the world into the fusion age.

These new cities will be built from the bottom up, constructed in huge craters, with multilevel underground layers to take care of the sewer system, communications and power lines, subway transportation, and shipping that will keep the city and its people going for 100 years.

Most important, the people who build the cities and their families will live in these cities and grow with them, turning the nuplex cities into regional centers that will spread advanced technology, literacy, and human living standards throughout the developing sector. The nuclear plant, the core of these cities, will become the symbol of education, growth, and creativity.

By bringing the existing level of technology up to the current level of our theoretical science, we can rapidly put hundreds of nuplexes across the globe in the 1980s. And with a push forward in every area of science—from plasma physics to climatology—we can create the technology to produce thousands of fusion-powered nuplexes in the 21st century.

*Cover illustration and design by Christopher Sloan.*